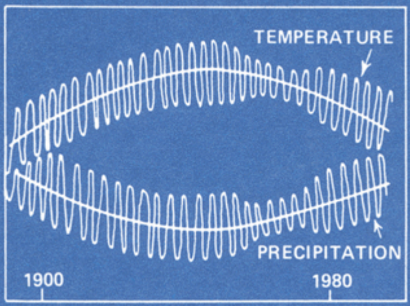
BULLETIN 68
STATE OF ILLINOIS
DEPARTMENT OF ENERGY AND NATURAL RESOURCES

Climate Fluctuations in Illinois 1901-1980

by STANLEY A. CHANGNON, Jr.



ILLINOIS STATE WATER SURVEY
CHAMPAIGN
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Indexing Terms: air quality, climate change, Illinois, precipitation, relative humidity, severe local storms, sky cover, sunshine, temperature, visibility, wind speed and direction.

STATE OF ILLINOIS
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Climate Fluctuations in Illinois, 1901-1980

by Stanley A. Changnon, Jr.

ABSTRACT

Changes in climate directly affect four areas of major activity and concern in Illinois – water, energy, agriculture, and transportation. This report presents selected Illinois records for 1901-1980 on a variety of atmospheric conditions that allow assessment of climate fluctuations, climate trends, variability around the trends, and impacts of these changes on the four areas of concern. Documented are changes in statewide and regional precipitation and temperature, plus selected point (station) data. Also presented are changes in other atmospheric conditions including relative humidity, sky cover and sunshine, visibility and related air quality (smoke/haze/dust), severe local storms, and wind speed and direction. The historical records are carefully evaluated as to quality.

Analyses of the data indicate changes in the more recent 20 years (1961-1980 compared with 1901-1960) to wetter and cooler conditions: more rain and snow and fewer droughts; decreases in temperatures especially in summer and winter, with fewer extremely warm days and many more extremely cold days; increases in cloudiness and decreases in sunshine and clear days especially in summer; and increases in wind speeds with more diverse wind directions. All trends are more marked in the extreme seasons of summer and winter than in the transition seasons of spring and fall, although somewhat warmer springs have produced a slightly longer growing season in the recent period. Mixed regional changes are noted in other atmospheric conditions, and no trend is apparent for relative humidity.

INTRODUCTION

Key Climate-Affected Issues Facing Illinois

The early 1970's brought widespread awareness of two major weather- and technology-related issues. These were the energy crisis and the world food crisis. After gaining a proper perspective on these crises over time, the two crises subsided. They became more correctly recognized as the first indicators of deep-seated, long-term global problems. Rational consideration of the foreseeable future, at least until the year 2000, indicates these two issues will re-appear as problems affecting Illinois and most of the world.

By 1980, water quality problems capable of creating future shortages of water and ensuing water-related conflicts were recognized (Illinois Water Plan Task Force, 1981). Water resources have emerged as a third broad resources problem that is significant in Illinois.

These water, food, and energy issues are multifaceted. They each consist of complex demand-supply-impact interactions that affect every citizen, endeavor, and industry in Illinois. The United States, with its present technologies and generally high standards of living 1) is incapable of furnishing the energy it consumes, 2) faces growing water shortages, and 3) is a great producer and consumer of expensive-to-produce agricultural products.

The United States, with Illinois as its third ranking agricultural producing state (Illinois produced 6.1% of all farm products in 1979, and generally leads the nation in corn and soybean production), will eventually seek to maximize its production of food, both to feed the U.S. at our current standards of living and to help feed many other nations, in many future years. In fact, food will continue to be the most important exportable product the U.S. and Illinois will generate during the foreseeable future.

In a similar vein, Illinois, with 15% of the nation's coal supply, will be a major national energy producer and consumer. Technological resolution of the sulphur-in-coal problem, certain to occur, will bring a rapid expansion in coal production and use in the future. Illinois, as the fifth most populous state, will remain a major consumer of the nation's energy in future years.

Thus, in both the food and energy issues, Illinois assumes an unusually important national role.

Illinois as both a major agricultural and industrial state, also uses vast quantities of water. Usage in Illinois is much greater than in any other midwestern state. Illinois diverts a sizable quantity of Lake Michigan water to serve the nation's second largest metropolitan area and the needs for water transportation on the Illinois River. For these reasons, Illinois assumes a near unique role in midwestern water resources. Coupling a large population with enormous agricultural and manufacturing endeavors leads to problems with waste disposal and ensuing concern over water quality.

Illinois with its central locale in the United States and large agricultural and industrial functions has become the nation's transportation hub. The nation's major north-south and west-east routes for railroads, highways, and airlines cross Illinois. Major lake and river traffic also exist in Illinois. These complex transportation systems converge in Illinois and must be maintained if Illinois is to retain its nationally unique role as a transportation center.

Influence of Climate on Major Activities and Key Resources

When and how these four resource and activity areas (agriculture, energy, water, and transportation) reach critical stages is considerably affected by the climate (Changnon, 1981). Climate must be viewed, like water and land, as a major natural resource of the state. Climate is not static and is always varying over time scales ranging from a few years, to decades, to centuries. Further, much of North America in the past 80 years has experienced a relatively warm period, when compared with temperatures experienced over the past several hundred years. Proper assessment of the current climate, including existing trends, changes in weather variability, and alterations in weather extremes, is integral to the water, energy, agricultural, and transportation issues.

Our agricultural technologies have become very sophisticated over the past 40 years to increase production. We depend on specialized field equipment and grain drying facilities; we have requirements for dry or wet periods to apply and get successful reactions of fertilizers, herbicides, and pesticides; and we possess a variety of plant types that can be chosen to optimize production in any one of a variety of growing seasons (dry, wet, hot, short season, etc.). In other words, we have finely tuned agricultural technologies. In some ways, the new technologies have reduced certain of the weather problems that used to limit production, but at the same time, they have made us more vulnerable to weather, especially to achieve high production to meet production costs. Knowledge of future weather events and awareness of climate trends, as best we can develop them, can and must be utilized to help maximize food production in Illinois.

Similarly, the rapid and all encompassing use of air conditioning, coupled with long recognized needs for structural heating, has made Illinois a major energy consumer, particularly during the two extreme seasons, winter and summer. These air conditioning/heating demands make the rate and amount of utilization of energy in Illinois very critical to supplies and suppliers. The frequency of extremely cold or hot periods (weeks, months, or seasons) in winter or in summer, is now a critical issue in meeting energy demands (Changnon et al, 1980).

Water, as the third climate-impacted area, is also intimately linked to the aforementioned agriculture and energy issues since both are great consumers of water. Climatic effects on Illinois' water resources is most easily visualized by the dramatic impacts of floods and droughts. A change to more of these, or to more severe extremes of wet and dry conditions, would be of singular consequence to the state's economy and its institutions. In a more gradual and complex way, available water resources are being impacted by ever poorer water quality. Soil erosion is a major unresolved problem aided or abetted by changes in high rainfall rates and high winds. Management of water pollution, including that resulting from industrial wastes, sewage, and disposal of hazardous wastes, is not resolved and is also related to the climate conditions. The water supply for northeastern Illinois, for example, is adequate to 2000 only if the deep tunnel and reservoir systems are completed to allow for local water treatment and flood control. Major potential future users of water in Illinois are apt to be irrigation and synfuel plants. Their water demands, and the availability of water for them, are directly linked to the climate.

Transportation networks in Illinois are complex, interrelated, and vital to the state's commerce. Most parts of this vital system are vulnerable to climate conditions. The massive surface highway network which serves the movement of private automobiles, intercity transport, trucking, and commuter movement in urban centers, is vulnerable to weather, to delay it or deter it in winter storms (Changnon et al., 1980), and to subject highways to destruction by severe winters and frequent freeze-thaw cycles. More adverse weather in any season limits commercial air traffic at Chicago, the world's busiest airport. Severe winter conditions ice up our rivers and Lake Michigan, either stopping or reducing freight movement.

The race to keep pace with these problems, and to seek their solutions, requires consideration of the current climatic conditions, and knowledge of shifts and trends that are developing. These trends to colder or wetter conditions are not always reflected in the average weather values of the past 30 to 40 years. Our energy, transportation, agricultural, and water systems are essentially designed or are operated in relation to many factors including the climate. The climate values used are based on data from discrete historical periods. These systems are vulnerable to climate conditions of today and the future.

For instance, a 32% reduction in corn yields occurred in Illinois in 1974 and a more than 50% reduction in 1983, and both were weather-related. However, the severity of the 1974 spring wetness, the 1974 mid-summer dryness, and the early frost of 1974 have all been collectively exceeded in previous years, 1892 and 1943 (Changnon, 1975). Important is the fact that corn yields in 1943 (1892 yield data are unavailable) were not as far below expectations as were those in 1974. Both of these early years occurred before we depended upon and used today's sophisticated farm technology.

An added example is another recent climate shift and its impacts. Since Illinois became a major user of air conditioning in the last 20 years, Illinois has not experienced long runs of high (> 100°F) daily temperatures such as those experienced in the 1910's, 1930's, and early 1950's. July 1980 was the first hot July in 26 years (with only three days of 100°F) and widespread power shortages occurred with curtailment of air conditioning. One question becomes, "Can we meet these extreme hot periods if they come again, and how often may they occur? Or, what can be said to suggest their occurrence and severity in the next 20 years?" The hot summer of 1983, with up to 19 days with temperatures over 100°F, raised these questions again.

Dealing with Climate Factors

The great influence of weather and its summation over time (the climate) on Illinois is clear (Changnon, 1981b). Wise decisions involving use of climatic data and information require awareness of the fluctuations in climate since climate is not stable.

This report does not attempt to "forecast" the Illinois climate for the next 10, 20, or 30 years. It does examine past climatic conditions that have a direct bearing on water, agriculture, energy, and transportation issues. The specific focus is on trends and fluctuations found in the entire period of record, generally since 1900. Inspection of current trends, frequency of extremes, and the variability of weather conditions offers guidance as to the type of climate Illinois may experience in the near future. We know that the best "normal" for estimating next year's average precipitation and temperature values is that based on the average of the past 5 years (Lamb and Changnon, 1982).

Prediction of the specific values of future climate conditions cannot be done. However, some statistical skill exists to predict the general classes of values (above normal, near, or below normal) or the trends of future climate for seasons ahead (Neill, 1981). Knowledge of conditions that control future weather is too meager to predict climate on the basis of physical understanding.

In the presence of trends to wetter, dryer, cloudier, warmer, or colder periods, we also have to consider two basic causes:

1) ***Natural fluctuations*** which are largely related to the sun but in such complex manners that they cannot be clearly understood, and/or
2) ***Man-made fluctuations*** caused by human activities that may alter our climate.

We know that the climate of Illinois has varied. A study of the geologic history of the state reveals that there were long periods when the area we know as Illinois was covered by tropical vegetation, and also thousands of years when glaciers covered large parts of the state.

Although the causes of climatic change or trends are not explicitly germane to this investigation, the basic causes for global climatic fluctuations should be noted. The sun is the engine that drives the atmosphere, and even minor changes in the sun's output could alter the atmospheric composition, temperature, or circulation. These changes, if persistent, could influence the long-term combination of the weather which we call climate. Present mathematical models of global climate suggest that a decrease as small as 1% in the total radiation output of the sun is enough to lower the global temperature average by 2 or 3°F, and hence to bring about a little ice age of the sort that gripped America 200-300 years ago. The same numerical simulations indicate that a change of only 0.1% in the solar flux, if sustained long enough, could bring about climatic changes of significant social and economic impact. A change of 10% in a negative direction would be globally disastrous inducing major glaciation and probably an ice-covered earth.

Another factor noted to have a significant influence on our climate is the orbit of the earth around the sun. We recognize that this orbit is not always uniform. The succession of day and night, the march of the seasons, and even the recurrence of the ice ages are all explained by the movements in the orientation of the earth alone with no need for any solar variability. Others have attempted to show that variations in volcanic activity could be another factor in climate change since volcanic dust could have a profound effect on incoming solar radiation. Indeed, some of the shorter variations in a few years may be explained by simple random variations.

The candidates for causing climate change in Illinois are solar variations, earth orbital variations, volcanic activity, and to a lesser extent random behavior of the atmospheric system. We know that climate changes, large and small, have occurred in Illinois.

The aim of this report is to statistically describe the changes of the past 80 years in a variety of atmospheric conditions. From this we can understand the potential impacts of the climatic regime we have experienced and may likely to continue to experience. On a long-term millenia scale, it appears that Illinois is in a relatively warm and wet portion of its climatic history. Quite likely, the climate of the past 80 years is the best immediate predictor of the range of events, up or down, wet or dry, that are apt to exist in the next 20 to 80 years. The simple fact that Illinois has been in a climatic regime that is relatively warm would suggest, when coupled with the known resonance in the climate system, a greater tendency towards cooling. This is in keeping with what has been experienced since 1940.

Scope of the Report

This report focuses on selected records of 1) precipitation, 2) temperature, and 3) other atmospheric conditions that directly relate to water availability and use, to agricultural and energy production and consumption, and to transportation problems. The focus is on two major questions related to past and potential future climates: the general trends, and the variability around the trends. These two issues are posed in figure 1 which schematically reveals the general climate of Illinois during the 1901–1980 period. Climate conditions are examined as to their trends, with clear recognition that with some conditions the records may be too short to provide anything more than a suggestion of an ongoing change that cannot be established as statistically significant. The report also presents information on changes in variability of several conditions because these also greatly affect agriculture and the other issue areas.

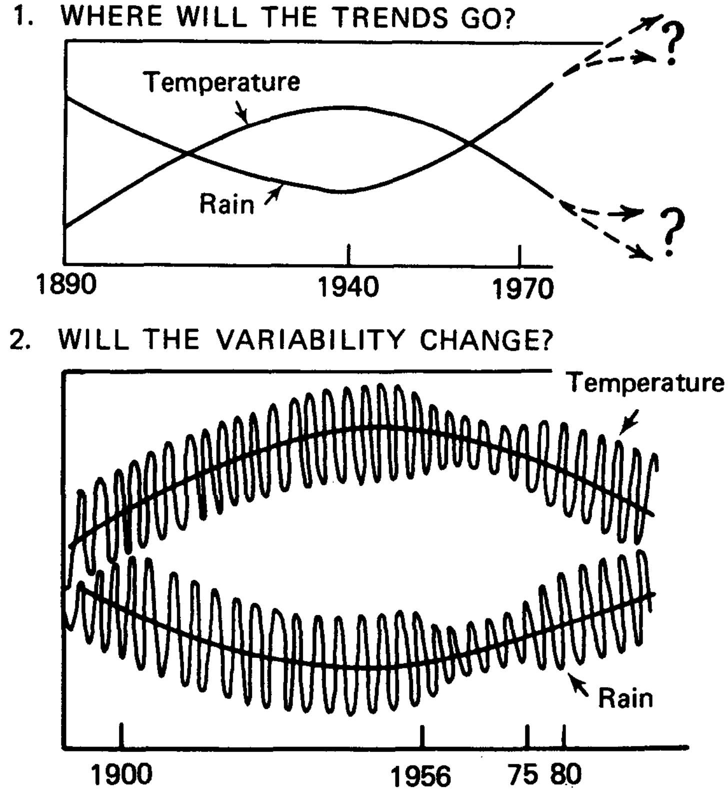


Figure 1. Two basic question about the past and future climate of Illinois

Data and results presented were aimed at known issues in the four major resource/-activity areas. For example, changes in cloud cover and sunshine were investigated because more desirable measures of solar energy (solar radiation) cannot be presented since long-term historical records just do not exist in Illinois. Among the elements selected for study relating to precipitation were thunderstorms which produce 50% of the rainfall in Illinois (Changnon, 1957), the growing season rainfall, the area1 extent of July-August dry periods within the state, and changing frequencies of excessive daily rainfalls that produce flash floods. Extremes of temperature on a monthly and seasonal basis, and the length of the growing season were investigated because they impact on all four issue areas. Frequencies of severe weather conditions including winter storms, hail, and tornadoes were studied because they impact on public health and safety, as well as on certain aspects of agriculture, transportation, and energy usage and supply.

DATA, ANALYSES, AND INFORMATION PRESENTED

Presentation of data and information on climate change, for use by widely diverse interests, is a difficult challenge. Space does not allow presentation of all possible graphical, tabular, or analytical solutions. Thus, the use of maps and graphs requires a choice of what to present. For example, there are hundreds of ways to present data on precipitation (by day, month, season, or year, and for the entire state, or regions, or for up to 200 points or weather stations).

Faced with this problem, we chose to present results in graphical and tabular forms. In the text certain temporal distributions are presented to illustrate the important changes in the climate of Illinois. The illustrations selected were also considered relevant to known needs of user groups. Obviously not all formats desired by some are presented. The data exist at the State Water Survey and can be obtained upon request.

Period of Study

The period of historical record presented varied largely on available data. Most data are based on the 1901–1980 period, or portions thereof, since most weather stations (temperature and precipitation only) were begun in Illinois during the 1890–1900 period. Efforts to reconstruct statewide annual values of temperature and precipitation yielded values back to 1840. Some data of interest, for example the number of rain days ≥0.5 inch, are readily available only for 1950–1981. In each section, the data used are documented as to source and time of record.

Data Quality

Another factor that can affect the correct or false interpretation of climate change is data quality. Many factors can produce an apparent shift in climate.

One factor is a shift in daily temperature measurements. A change from a late afternoon (5 to 7 p.m.) to early morning (6 to 8 a.m.) time of measurement can produce an apparent decrease in temperatures of about 1°F (Nelson et al., 1979). This could be a serious problem in the interpretation of trends in the 80-year temperature record of a single station. However, in presenting regional values based on 10 to 20 stations in a region, this problem is largely cancelled because of random nature of shifts of observation times at stations within a region.

Another critical data problem concerns possible changes in instruments or observational techniques. The U.S. Weather Bureau used comparable temperature, humidity, wind, and precipitation measuring equipment throughout the 1901–1980 period, while other data came from visual or audio observations by their weather observers. These included visibility (distance to known objects), the sky cover, and certain other weather conditions such as thunderstorms and tornadoes. These measurements are subject to certain vagaries, but because of constant and unchanging instructions to the trained observers, these subjective vargaries are not considered to have produced systematic shifts in these conditions which would falsely appear to be long-term climate shifts.

A third data quality concern relates to changes in exposure or siting of instruments, or location of observations. This is the most serious and difficult problem to deal with. For example, the shift of the instruments and observations at most first-order stations from in-city locales to rural airport locales, done largely during the 1935–1945 period, produced a notable shift in temperatures since cities produce a well known heat island. Such city-to-airport shifts produce an apparent climate shift of a decrease in temperatures (or increase in wind speeds). Hence, temperature trends were studied using data from carefully selected cooperative substations where station shifts or urban growth have been minimal.

Growth of trees near a raingage site can produce an apparent upward shift in precipitation. The sheltering increases the amount of precipitation caught. Again, knowledge of station locations was used in choosing stations for point precipitation analyses.

Other problems concern changes in heights (exposures) of wind instruments at the first-order stations. Again height or changes in surrounding obstacles can alter wind speed or direction values. Other reasons for possible false influences on data such as that for thunderstorms, tornadoes, and visibility are described in those respective sections of the text. Any changes in data collection considered possibly relevant to data quality are identified in the text.

Data Sources

For the above stated reasons, great care was used in the selection of cooperative substations for "point" analysis and presentations of point climate data. A few substations embracing the north-south extent of the state were often selected because the major spatial climatic variations in Illinois are due to latitudinal differences The substations selected were based on their high quality data and minimal changes in observation time or sites. Those chosen are shown on figure 2.

Six fist-order stations in and near Illinois were chosen to present those forms of climate data that are collected only at such stations. These include data on sunshine, visibility, humidity, winds, sky cover, and storms. These stations were Chicago, Moline, Peoria, Springfield, St. Louis, and Evansville (figure 2).

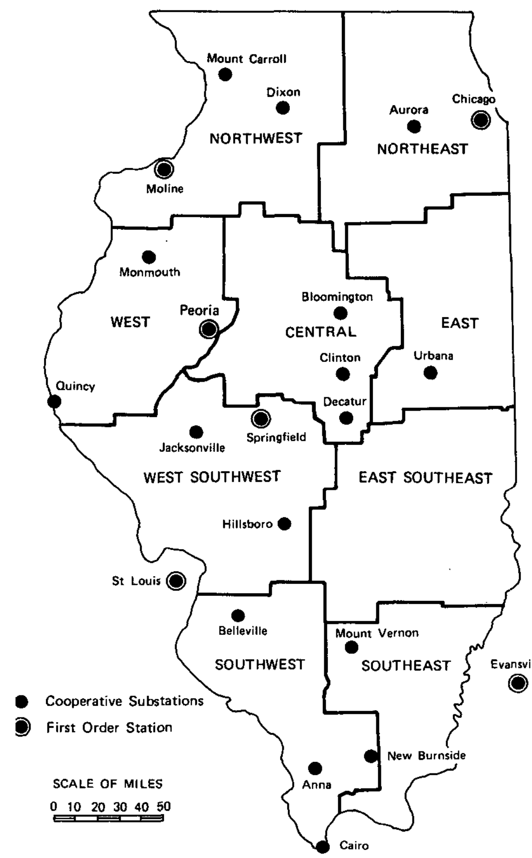


Figure 2. Data stations crop districts used in study

The regional analysis of climate conditions was based primarily on data from the nine crop reporting districts (figure 2). In each district, 8 to 12 substations provide the data to calculate the district mean values of temperature and precipitation. The same stations were used throughout the 1901–1980 period, although fewer substations were used when data were missing. This averaging process is believed to reduce or largely eliminate individual station problems such as exposure changes or shift in observation times. Regional data were used to examine temperature and precipitation values.

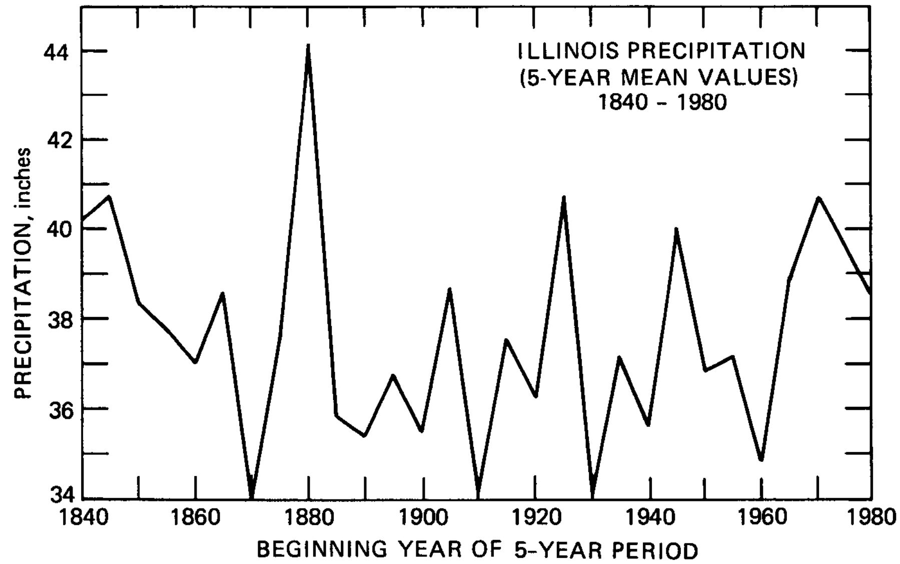


Figure 3. Statewide 5-year mean values of precipitation

PRECIPITATION CHANGES

Statewide

Precipitation has been measured in Illinois routinely and on a daily basis from 1840 to present. In the period of 1840–1890, precipitation (and temperature) was measured at only a few locales, typically 20 to 30. By 1900 the state had nearly 100 precipitation measuring stations, and by 1980 there were approximately 200.

Statewide Average Precipitation. Data from all available stations were used to determine in each year a statewide "average" precipitation value. Admittedly, the values from the 1840–1890 period when many fewer stations existed are probably less representative of the true statewide value than the values since the turn of the century. Nevertheless, and with this understanding, the statewide annual average values were used to develop the graph in figure 3. The statewide values were combined to form 5-year mean values. That is, the statewide mean value for the period of 1840–1844 was 40.2 inches, as shown in figure 3.

Two general features are indicated in the 140-year history of the state's precipitation. First is the erratic nature of precipitation with occasional very high and low 5-year values. There is a weak tendency for peaks about every 15 to 25 years. Note the highs in 1845, 1865, 1880, 1905, 1925, 1945, and 1970. However, this is not a strongtendency. The other feature of the distribution (figure 3) is the general-tendency for lower values in the 1910–1940 period, with higher values in the earlier years in the 19th Century and higher values in the more recent years (1960–1980). The three highest consecutive 5-year values in the 140-year period occur at the beginning (1840–1855) and in the most recent 15 years (1965–1979).

Heavy Rain Days. A network of 98 cooperative substations and first-order stations existing from 1916 through 1980 were used to compute the frequency of days when 2 or more inches of rain occurred in a l-day period in Illinois. If one or more stations had a ≥ 2-inch amount in a given calendar day, it was counted as an event. For example, there could

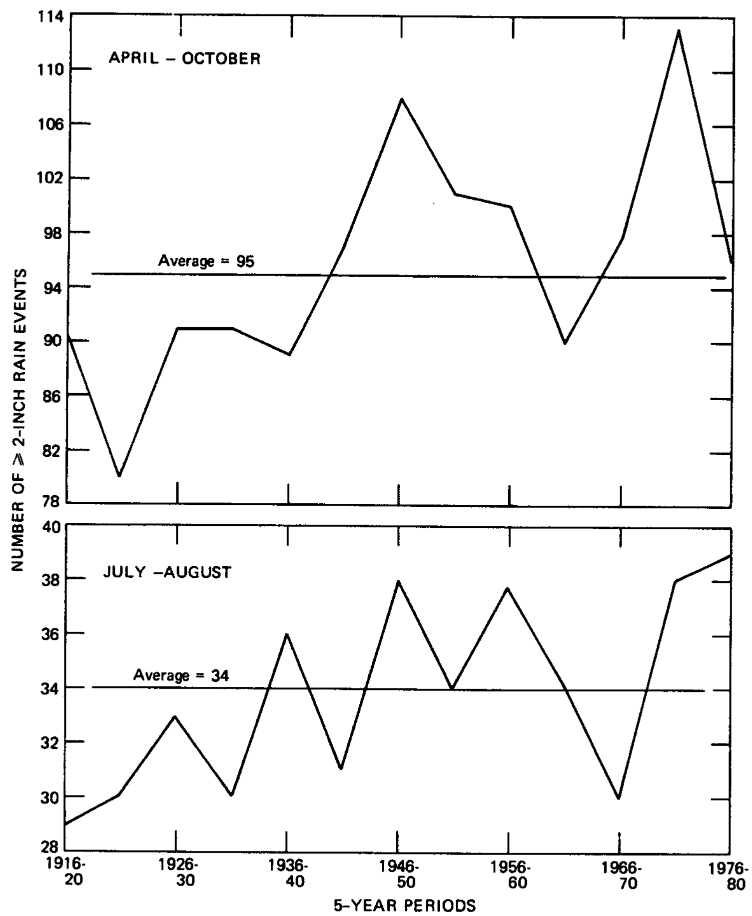


Figure 4. statewide frequency of 1-day rains of 2 inches or more

be up to 31 such events in the month of July if there had been a ≥2-inch rain on each of the 31 days. These heavy rain events, typically representing the once in 5-year l-day rainfall (Huff and Neill, 1959), were computed for two periods of interest. The first was April-October, the growing season and the period when most such events occur in Illinois. Heavier rain events are infrequent in the November-March period. The statewide values of 2-inch or heavier rain days were also calculated for the July-August period. This is a critical period of crop growth in which these flood-producing conditions greatly affect agricultural production.

The frequency of such events in both periods is presented in figure 4. The statewide average (April-October) over the 1916–1980 period is 95 per 5 years (or about 19 events per year). The values show a general increase from 1921–1925 up through 1945–1950, followed by a decrease through 1965, and then another increase in recent years. The overall trend from 1916–1980 is upwards with the highest values in the last few years. The distribution of these rain days in July-August also shows a general upward trend with a statewide average of 34 such days per 5-year period. The highest two values of the 65-year study period occurred in the last two periods, 1971–1975 and 1976–1980. These upward trends in heavy rain days in recent years are in agreement with the heavier statewide precipitation values shown in figure 3.

Areas of Deficient July-August Rainfall. Figure 5 presents bar graphs for the 1931–1980 period, based on the extent of areas that received 3 inches or less rainfall in July-August of each year. Three inches of rainfall for this 2-month period of critical crop growth is approximately 50% of the normal rainfall. This serves as an indication of the area of stress to corn and soybean growth in Illinois because these are the two months of greatest moisture demand by these crops (Changnon and Neill, 1967). Examination of figure 5 reveals the greater frequency of extensive dry areas in the 1930's and 1950's. The 1960's and 1970's had very small areas of deficient rainfall in July and August. These results are based on data for all available stations during this 50-year study period, approximately 200 stations.

Extremes of July-August Rainfall. Another expression of the important July-August rainfall conditions studied was the annual extremes within Illinois. Here, all available station data for the 1931–1981 period (approximately 200 raingage stations) were used. In each July-August period, the stations with the highest and lowest rainfall values were identified, and these extremes are plotted in figure 6. Reference lines are plotted at the 2-inch and 15-inch levels. Most of the values since the mid 1960's have been 15 inches or higher, whereas most of the maximum values during the 1930's and early 1940's were under 15 inches. A slight upward trend is suggested.

Examination of the curve based on the state's lowest July-August rainfall values in each year (figure 6) shows two general conditions. From 193 1 to 1953, many of the lowest values were 2 inches or less. Since 1954, most of the values (except in 1966,1974, and 1976) have been 2 inches or higher. A general upward trend is also revealed. Thus, as with the heavy rain events (figure 4), one sees a trend upward from the drier 1930's and 1940's into the wetter conditions of the 1960's and 1970's.

Droughts in Illinois. Prior studies of droughts (Huff and Changnon, 1963) described the frequency of droughts in Illinois, based on precipitation deficiencies for periods of varying duration ranging from 3 months to 60 months, for 1906–1955. These were updated to 1980, allowing inspection of the frequency and severity of precipitation droughts for the 1906–1981 period in Illinois. The distribution of these droughts is depicted in figure 7. The numbers for each drought indicate its rank, based on statewide severity. That is, rank 1 is the worst drought, meaning it had the greatest average departure from normal precipitation of any of the droughts of a given duration.

Inspection of the droughts' general distribution reveals that droughts of all durations were relatively frequent in Illinois from 1909 through 1941. Then after about 10 years with little drought activity, there were severe droughts in the early 1950's. Afterwards, Illinois has been relatively drought-free except for short duration droughts in 1961–1962, and in the late 1970's. Furthermore, these were low ranked droughts. In general, the drought distribution portrayal reveals what might be expected from figure 3. That is, that the relatively wetter recent period of the 1960's and 1970's has been a period of very few droughts in the state.

Severe Winter Storms. Another statewide expression of precipitation relates to severe winter storms. In a prior study, Changnon (1969) defined a severe winter storm as one that produced either 6 inches or more snowfall or widespread glaze over 5000 sq mi or more in a 60-hour period or less. The number of such severe winter storms was counted in each year, based on a network of 98 cooperative weather stations. The resulting annual frequencies, combined into 5-year values, appear in figure 8. The 5-year mean is 28 storms. In the earlier

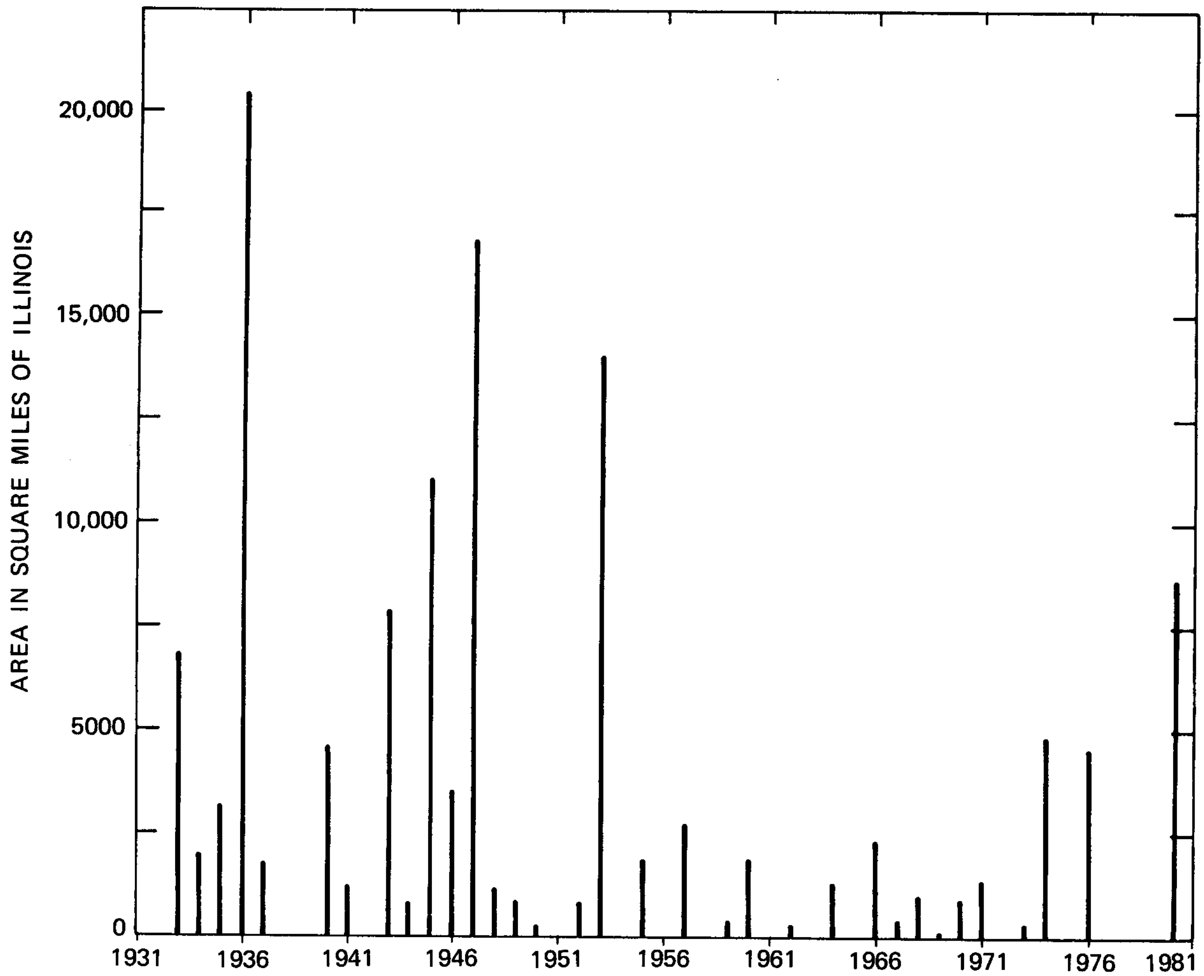


Figure 5. Areal extent of regions Illinois receiving less than 3 inches of rain (50% of normal) in July- August

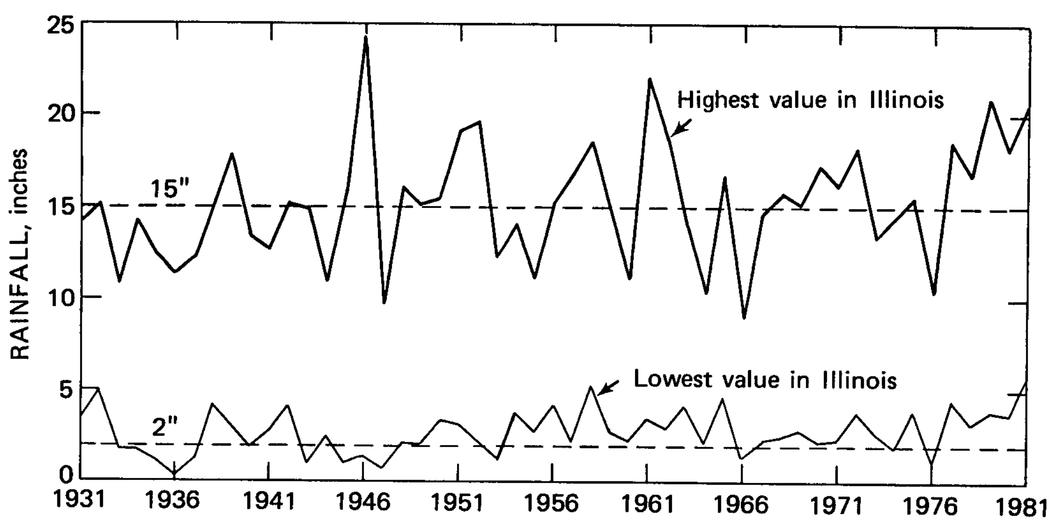


Figure 6. Illinois statewide extremes for July-August rainfall

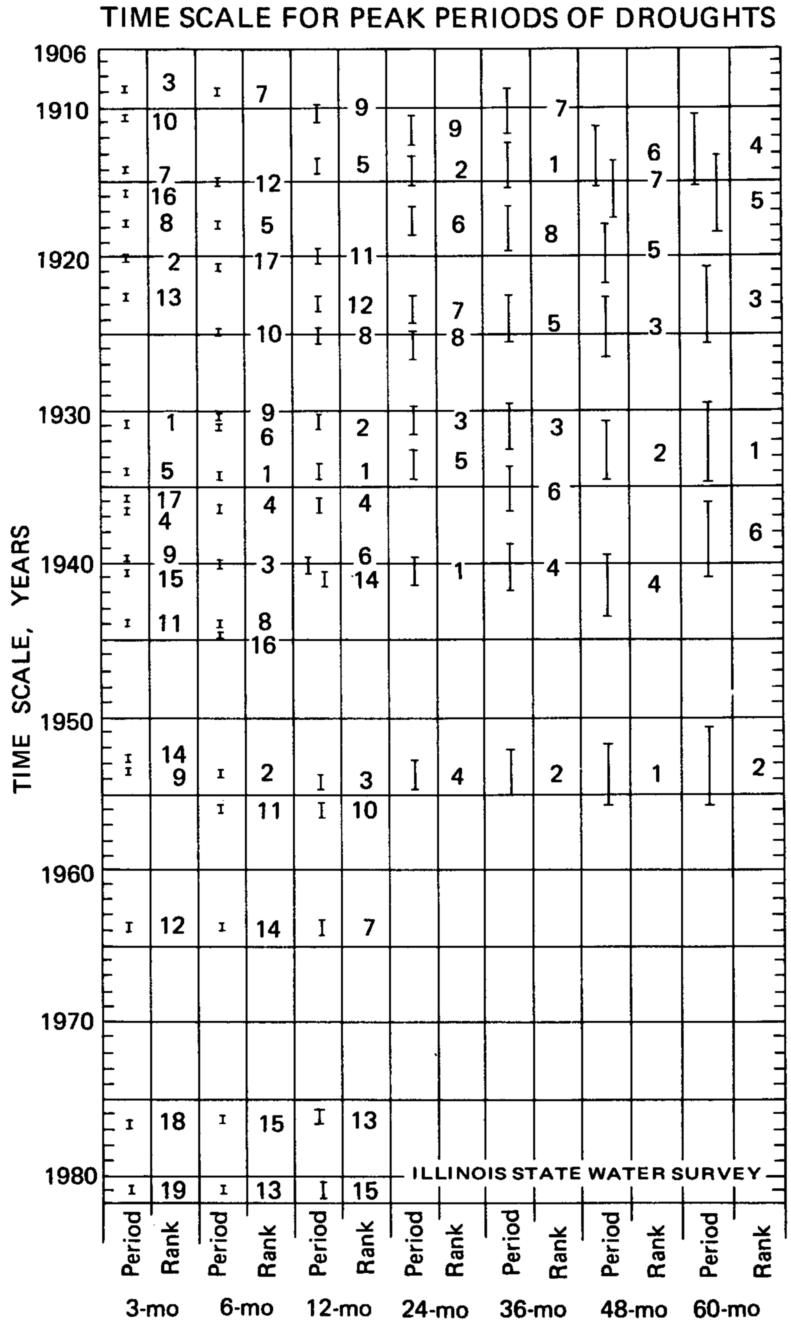


Figure 7. Droughts of varying durations in Illinois during 1906-1981, with their ranks

part of the century, 1901–1940, only two 5-year periods exceeded the mean, and values are generally low. Beginning in 1941, the frequency increased considerably with very high values achieved in 1971–1975 and 1976–1980. The general trend revealed is one of increase from early in the 20th Century to the present. The increase has been sizable in the last 10 years (Changnon et al., 1980), as Illinois has moved into a wetter and colder climatic regime.

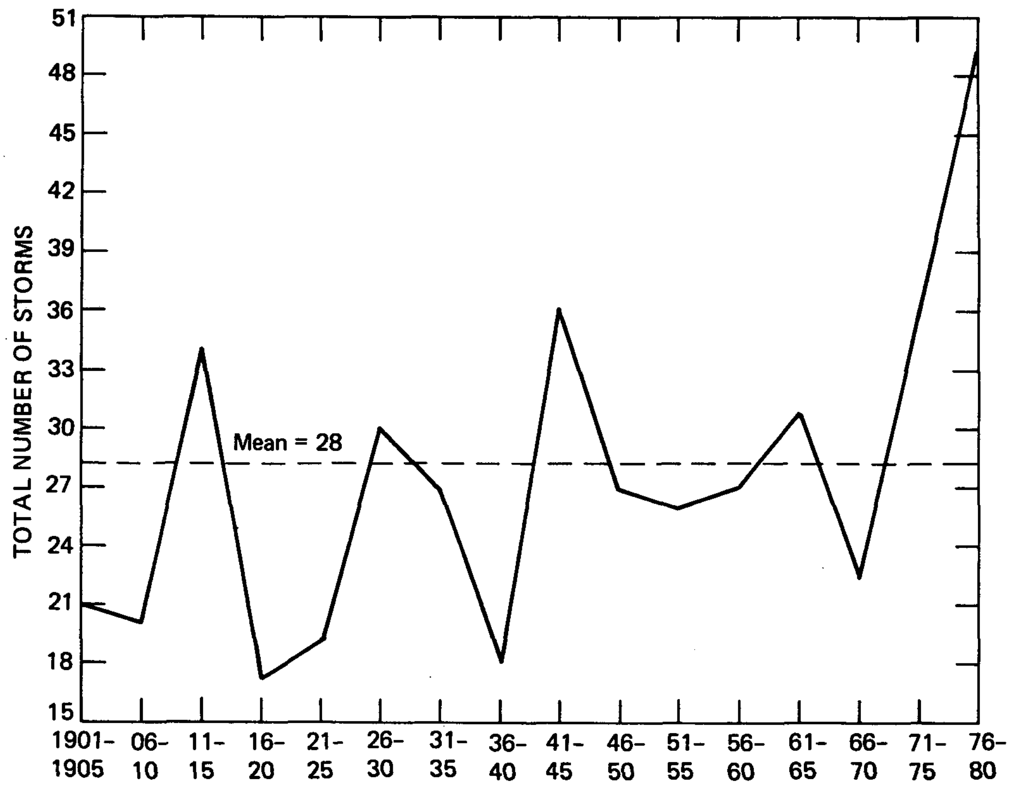


Figure 8: Number of severe winter storms in Illinois per 5-year period

Regional

Seasonal Precipitation. Figure 9 presents decadal average values for spring, summer, and fall based on three subdivisions of Illinois, and for Illinois as a whole. The area values are each based on three stations (Hillsboro, Mt. Vernon, and Anna = south; Quincy, Havana, and Urbana = central; Mt. Carroll, Dixon, and Aurora = north). The spring (April-May) curves (figure 9a) show a general increase from 1895 to 1974, then a decrease. The summer (July-August) rain curves reflect an early and late peak with minimums in the 1925–1944 period. The fall season (September-October) values show a peak in 1925–1934 and a minimum in 1955–1964. Note that all three seasons exhibit uptrends and/or high values in either or both of the last two periods (19651974, 19751982).

July-August Dry Periods in Selected Areas. Another expression of regional variations of precipitation over time in Illinois is revealed in figure 10. The distribution of dry periods in July and August for three areas of Illinois are presented, with areas defined on the basis of weather-crop yield relationships (Changnon and Neill, 1967). Dry is defined as the occurrence of areas of less than 3 inches of rainfall during July-August in a given year. Data for 193l–1980 from all stations in the three regions were used to develop annual maps of July-August rainfall. In some years, two separate dry (less than 3-inch) areas were found within each of these regions.

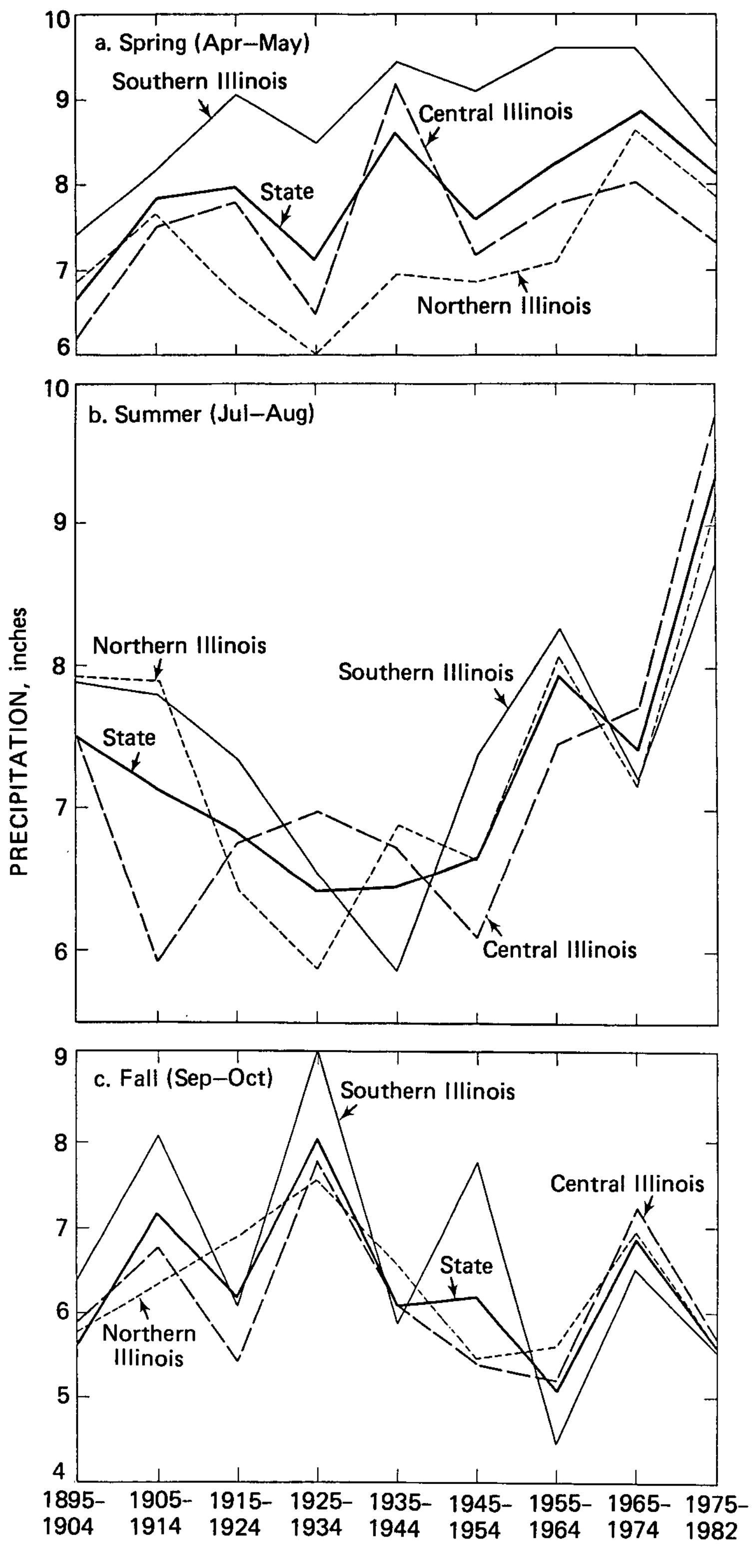


Figure 9. Decadal rainfall for 3 seasons in Illinois and 3 subdivisions

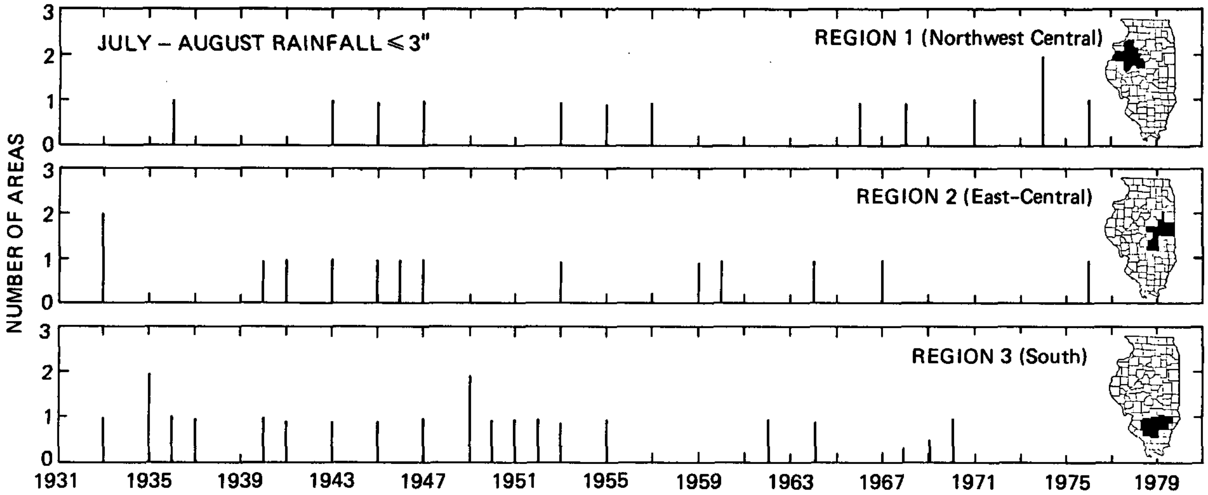


Figure 10. Temporal distribution of regions of 50% of normal (or less) July–August rainfall in 3 areas of Illinois

Figure 10 depicts the frequency of these dry areas in the three regions. One notes an occasional year such as 1949 in Region 3 when there were two dry areas in a region, but in most years, only one dry area occurred.

This graph allows two assessments. One is to compare the distribution of dry areas between regions within Illinois, and the other is to look at the general trends of dry area occurrences within a region over time. A rather even temporal distribution of dry areas occurs in Region 1 (northwest) with scattered occurrences during 1931–1980. Conversely, the temporal distribution in Region 2 shows a high frequency of dry July-August periods during the 1940–1952 period with only occasional ones thereafter, indicating a general decrease recently. Region 3 differs markedly from Regions 1 and 2. First, it has many more incidences of dry July-August areas. These occurred largely in the 1933–1955 period, with only two in the last 25 years. Thus, Regions 2 and 3 show a recent decrease in the frequency of July-August areas, whereas Region 1 shows an even distribution over the 50-year period.

Point (Station) Results for Groups of Stations

Growing Season Rainfall. The temporal distribution of growing season rainfall, defined as the totals for the April-September period, during the 1901–1980 period are presented in figure 11. These data are based on 5-year values of substations scattered along a north-south axis in Illinois. Growing season rainfall spatial variations in the state are moderately excessive, and are often due to a tendency for heavier April and May values in the southern section of the state. Singularly statewide low rain values are shown for 1936–1940 and 1951–1955. Statewide highs include 1906–1910, 1926–1930, 1941–1945, 1966–1970, and 1971–1975.

Monthly Rainfall. Data for 6 substations for 1895–1974 period were averaged by decade to derive figures 12a–e. The April curves show a general increase with time, although

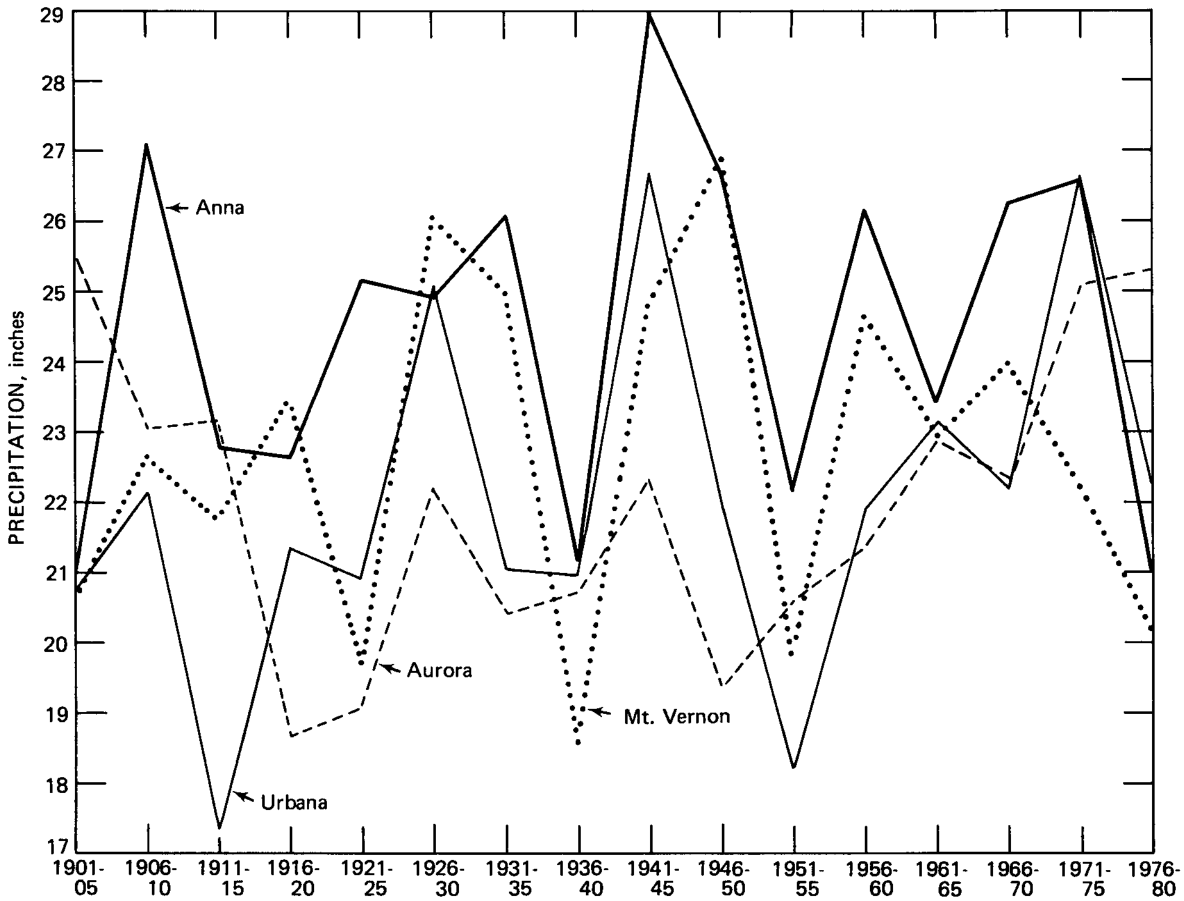


Figure 11. Growing season rainfall (5-year averages) for 4 stations

1905–1914 was the wettest decade at Anna. May values (figure 12b) show a up-down-up cyclical behavior, with maximums at the southern stations (Anna, Mt. Vernon, and Hillsboro) in the 1955–1964 decade. June values show an uptrend from 1905 to 1945–1954, followed by lesser values since 1954. The July curves (figure 12d) show a downtrend from 1895 to lows in the middle decade followed by a peak in 1955–1964. The August values (figure 12e) show no major trends with time.

Frequency of Rain Days. Data from 6 first-order stations (figure 2) were used to examine the temporal frequency of days of rain (midnight to midnight) equal to or greater than 0.01 inch, 0.5 inch, and 1.0 inch. Data from the first-order stations were used in this analysis to maintain temporal continuity (midnight to midnight) throughout the 81-year period (1901–1981), and because substation data on days with measurable low rainfall (at the 0.01 inch level) are often suspect.

The annual values for the 0.01 inch or higher values are summarized in figure 13. The annual totals are summed into 5-year values. For example, the 1901–1905 period value at Chicago was 620 days (an average of 124 per year) of measurable rain days. The curves for the three stations in the northern half of Illinois (figure 13a) show relatively uniform

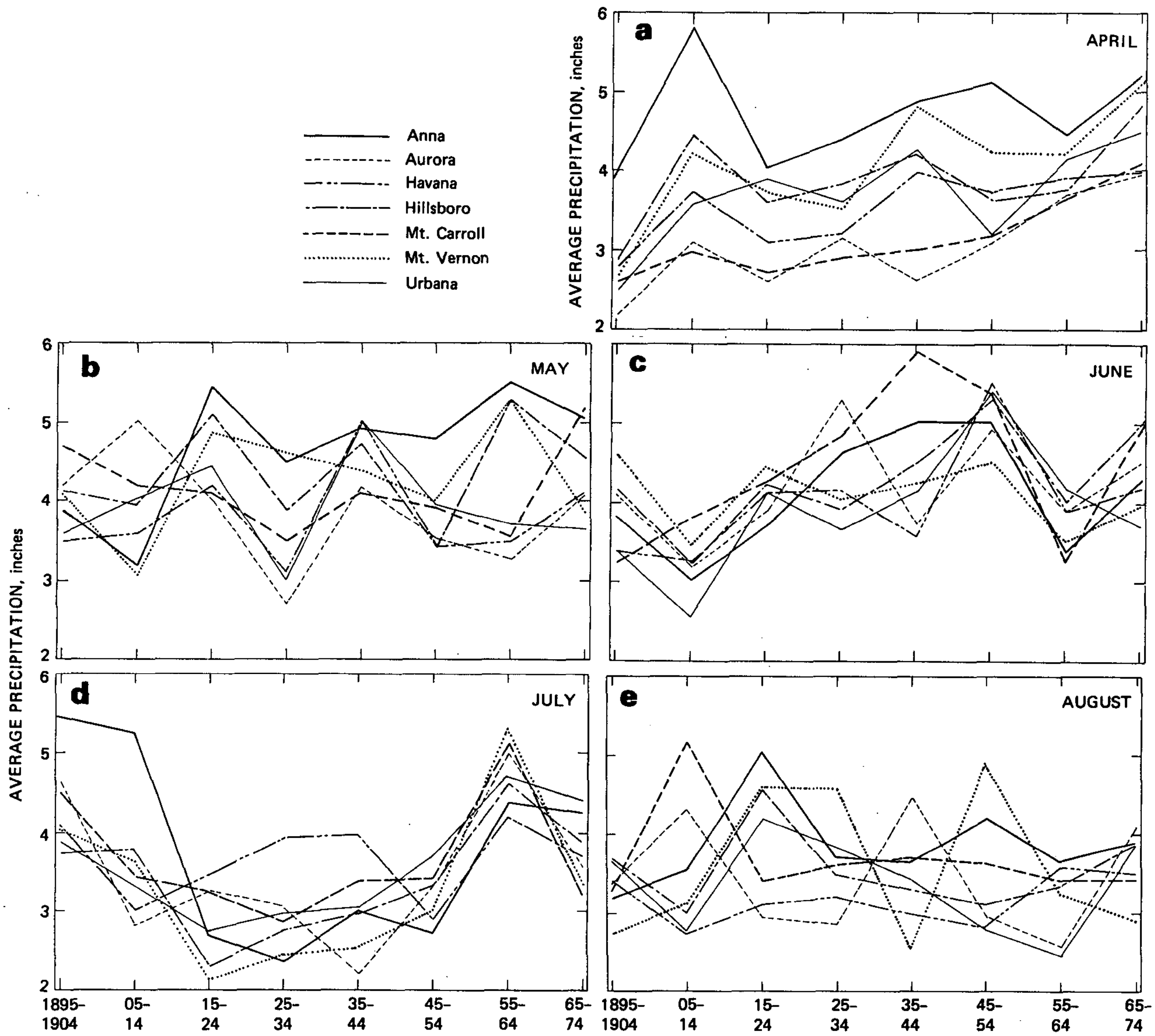


Figure 12. Decadal monthly values of rainfall for 6 stations

distributions during the 1901–1945 period, followed by a decrease during 1946–1965, and then an abrupt increase in measurable rain days to century peaks in 1971–1975. These curves do not show a major decrease in rain days during the droughts of the 30's, but they do suggest an upward trend, particularly during the last 15 years of the 80-year study period. Figure 13b presents the curves for the three stations in the southern half of Illinois. These are generally similar to the stations in the northern half of the state. They have relatively uniform distributions during the first 50 years of the century, followed by a decrease in measurable rain days during 1951–1965 and a major increase to the peak of the century during 1971–1975. In general, the measurable rain day frequencies support the trend to wetter conditions during the last 15 years.

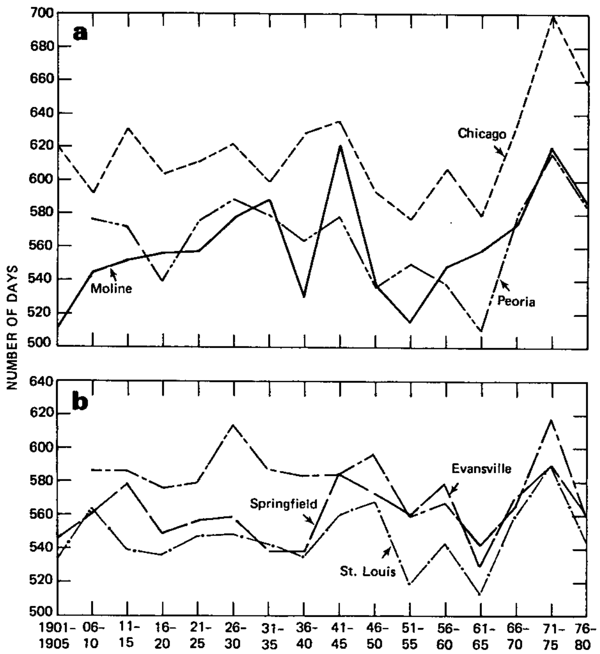


Figure 13. Number of days (5-year totals) with precipitation of 0.01 inch or more

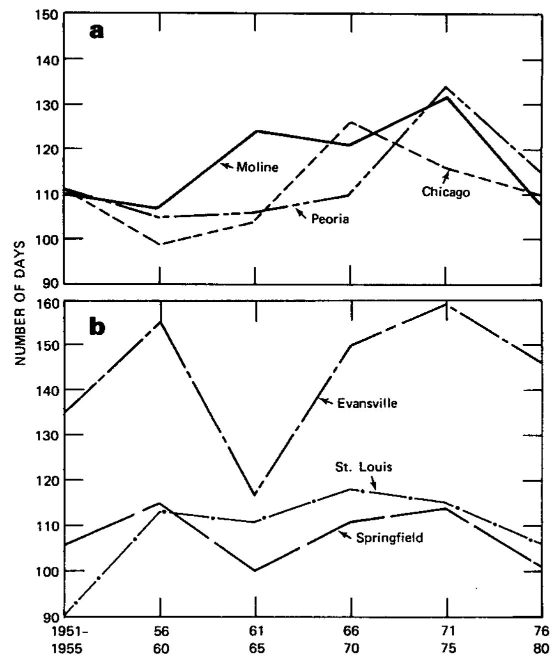


Figure 14. Number of days (5-year totals) with precipitation of 0.5 inch or more

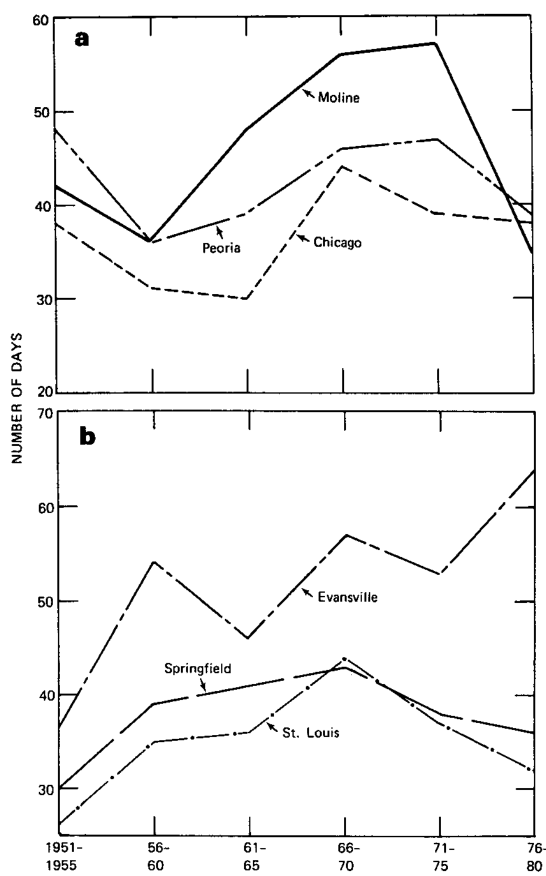


Figure 15. Number of days (5-year totals) with precipitation of 1.0 inch or more

Access to data for heavier rain levels over the 1901–1980 period is limited. Data on days with 0.5 inch and 1.0 inch or more were readily available for the 195l–1980 period. Hence, these were tabulated to form figure 14 for 0.5 inch or more and figure 15 for 1 inch or more. The 0.5-inch values for the three stations in the northern half of Illinois (figure 14a) show a general increase in frequency with time, reaching a peak at Moline and Peoria in 1971–1975. Clearly more 0.5-inch rain days occurred in the last 15 years at all stations. The data for the three stations in the southern half of Illinois (figure 14b) are not similar to those for the month. More even distributions are shown, although the frequency in 1951–1955 is low because of the extreme drought of 1953–1956 (Huff and Changnon, 1963, and figure 7). All stations show a marked low in 1961–1965. The peak in 1971–1975, so marked in the northern half of the state, is less pronounced in the southern section.

The 1-inch or heavier rain day frequencies are shown in figure 15. The northern Illinois-stations (figure 15a) show a decrease during 1956–1960 (as shown in the 0.01 inch rain day frequencies of figure 13) with a maximum achieved either during 1966–1970 or in 1971–1975. The first-order stations in the southern half of Illinois (figure 15b) also show upward trends in l-inch or heavier rain day events with time. At Evansville the peak is reached in 1976–1980, as opposed to 1966–1970 in St. Louis and Springfield. In general, the results for the l-inch daily frequencies are supportive of the other trends shown state-wide involving wetter conditions during the late 1960's and 1970's.

Seasonal Snowfall. The data on snowfall for the 4 substations (figure 2) were used to look at the temporal distribution. The 5-year totals for the four stations were calculated and an average used to compute figure 16. The Aurora distribution revealed a seesaw characteristic with a maximum in 195l–1955. In general, its values are higher during the 195l–1980 period than in the prior 50 years. The Urbana data show a decline from 1901 through 1925, then a flat distribution with an increase beginning in 1951–1955 (like Aurora), reaching the peak values of the 80-year study period during the last 20 years. The Mt. Vernon and Anna curves show very similar distributions with time with the lowest values during 1931–1935 and a generally increasing amount of snowfall beginning in 1951 (except for a low in 1971–1975). The marked peak occurred in the 1976–1980 period. Thus, the snowfall values across the state show an increase over the last 30 years reaching the 80-year peak during the most recent 5 years.

Maximum Snow Depths. The daily snow depth values (depth of snow on the ground) for 4 substations were examined for each year. The greatest daily depth recorded during each year was determined, regardless of date or month. These annual maximum values were used to choose the greatest depth in each 5-year period. That is, the 5 maximum annual values for 1901–1905 at Urbana were examined. It was found that 18 inches in 1903 was the greatest depth recorded, and this value appears in figure 17 for the 1901–1905 period. Data were unavailable for Anna prior to 1916. The general distribution of the values in figure 17 shows some moderately high values were recorded during the 1901–1920 period, followed by relatively low values, generally less than 10 inches at all stations, for 1921–1950. As noted in figure 16, this was also a period of generally low snowfall at most of these stations. Aurora had its peak value of 31 inches in snow depth during the 195l–1955 period, and the other stations peaked in the 1976–1980 period with snow depths between 16 and 20 inches. The maximum snow depth values at all four stations showed a sharp increase beginning with 1951 or 1956, with generally higher maximum depth values in the years

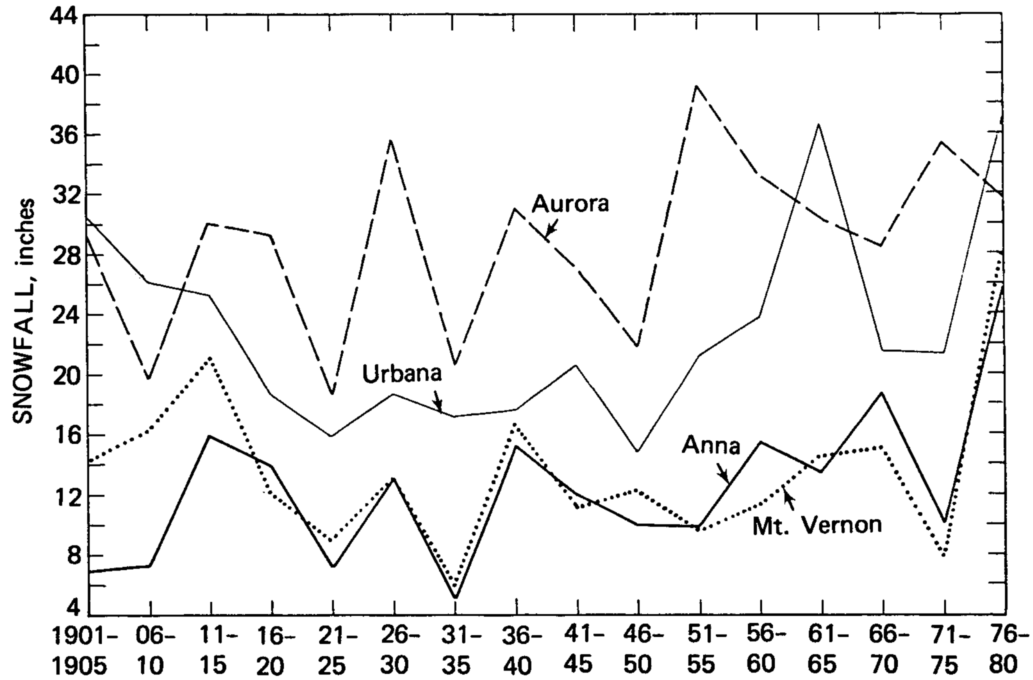


Figure 16. Snowfall (5-year means) for 4 substations

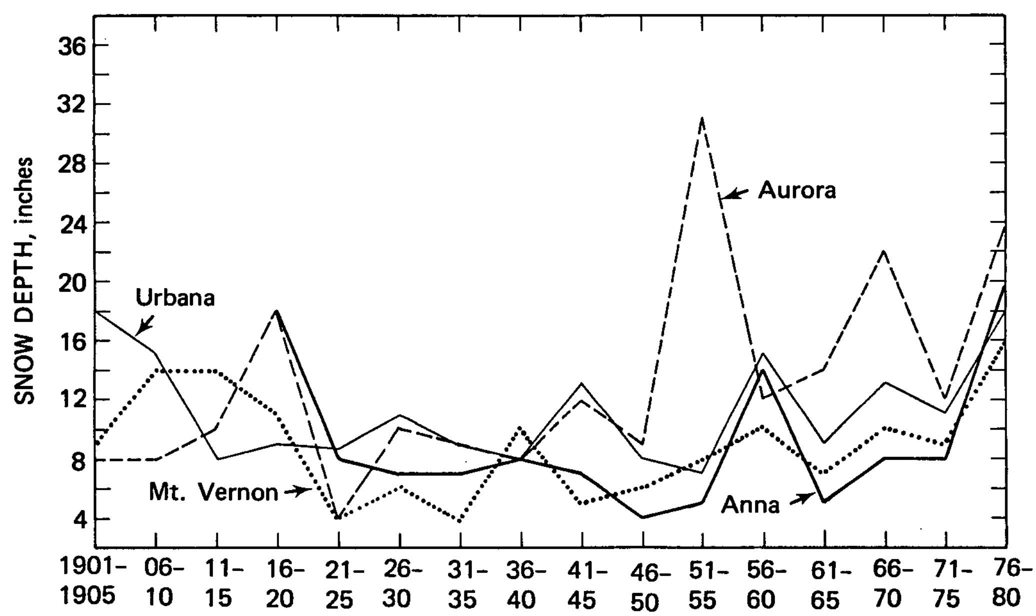


Figure 17. Snow depths (5-year maximums) for 4 substations

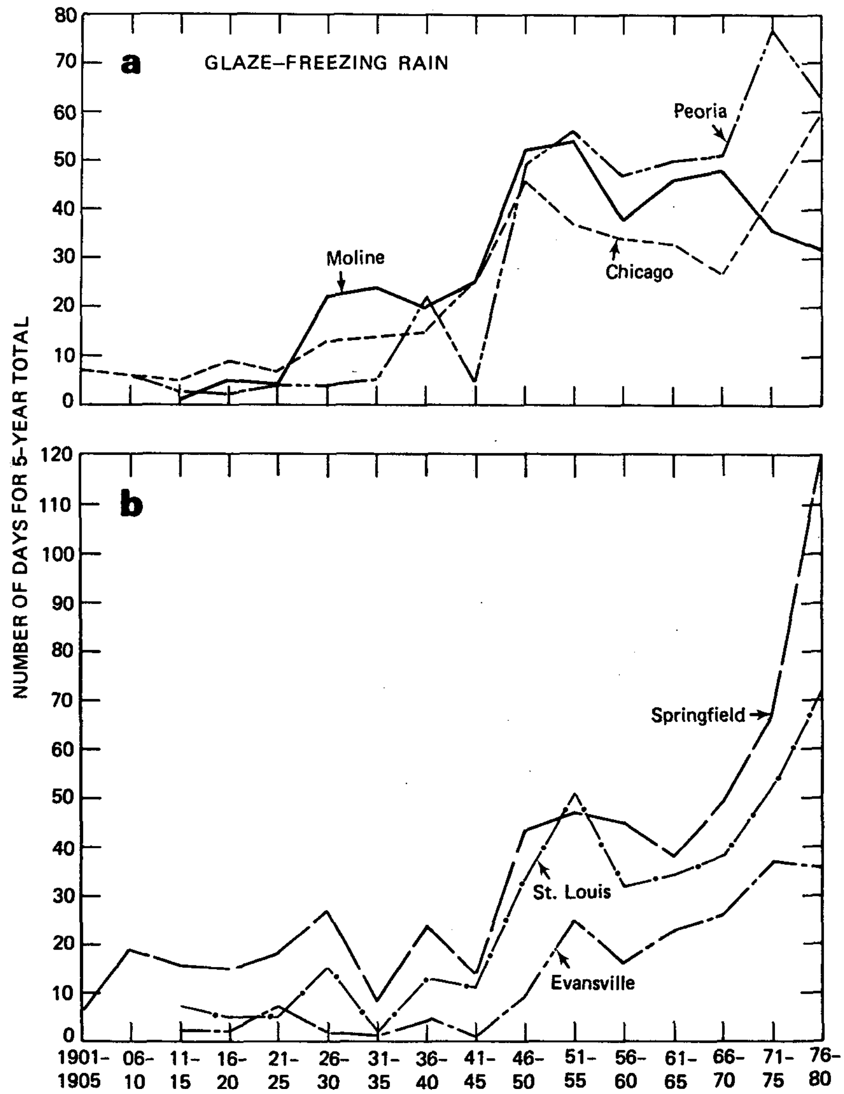


Figure 18. Number of days of freezing rain (5-year totals)

thereafter through 1980. Again, the snowfall values and the maximum snow depths reflect the previous stated conclusion of 1) increased precipitation in the last 20 years, and 2) decreased temperatures. These collectively lead to more snowfall and an opportunity for greater accumulation of snow on the ground during the winter season.

Freezing Rain Days. The data from the 6 first-order stations for the number of days with freezing rain were used to determine temporal variations. Figure 18a presents the 5-year values for freezing rain days for the stations in the northern half of Illinois. Their 5-year totals show low frequencies and relatively unchanging frequencies from 1901 through 1940. Thereafter, the frequencies increased dramatically through 1950, remained relatively stationary, and then increased again at Peoria and Chicago during the 1971–1980 period, reaching their 80-year peaks.

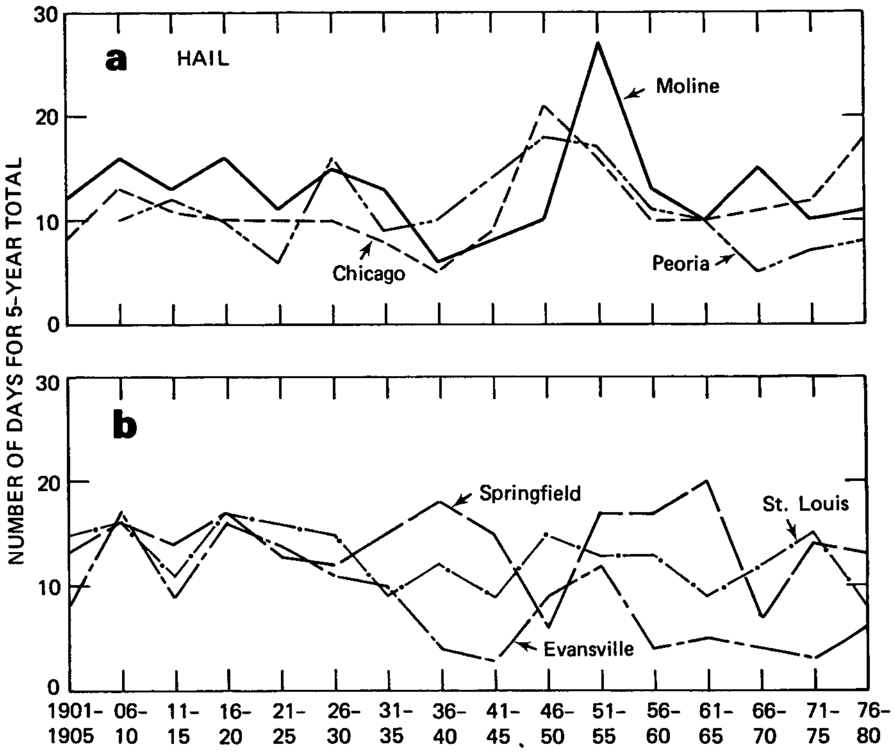


Figure 19. Number of days with hail (5-year totals)

The data for the stations in the southern half of the state are shown in figure 18b. They have similar temporal distributions with maximum increases during 1946–1955, then becoming fixed, and sharply increasing during the last 15 years. The frequency of freezing rain days across Illinois reflects two other conditions. The increase in number of rain days, as shown in figures 13a and b in the last 15 years, and the decrease in temperatures during the same period (see figure 25), collectively led to opportunities for more freezing rain in recent years. The recent increases in freezing rain days are extremely large.

Hail Days. The data on days with hail for the 6 first-order stations were examined for temporal changes. The temporal distribution for the stations in northern Illinois appears in figure 19a. Relatively uniform temporal distributions are shown for 1901–1945. Thereafter, increases occur during 1946–1955, similar to the increases in freezing rain days (figure 18a). Hail days then decrease and remain at frequencies similar to those of 1901–1945 for the remainder of the 80-year study period. Values for the first-order stations in the southern half of Illinois (figure 19b) are not similar. The frequency of hail days at Evansville shows a general decrease with time over the 80-year period. The St. Louis values are relatively stable with no marked up or down trends. The Springfield values show the greatest period-to-period variability with no distinct up or down trends during the 80-year study period.

Variations in Annual Precipitation at Adjacent Stations. Figure 11 presented the growing season rainfall values for 1901–1981 at four stations representative of the north-south variations of conditions in Illinois. Since precipitation can have considerable spatial variability in Illinois, annual precipitation data for four stations in central Illinois were used

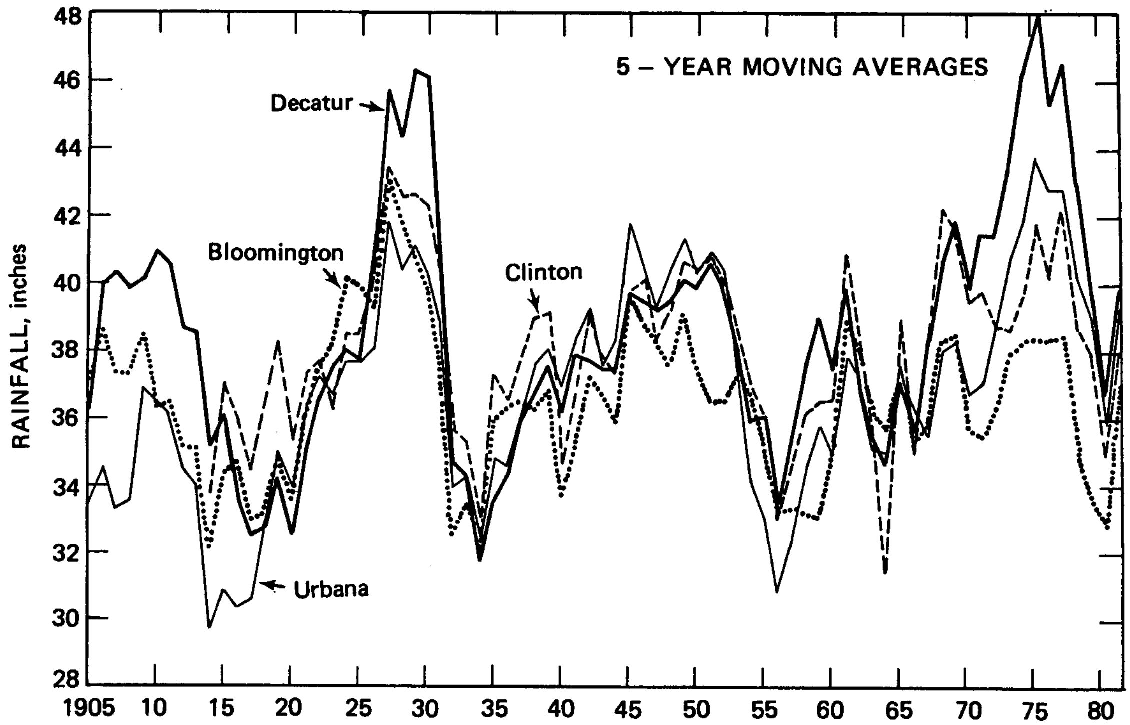


Figure 20. Variations in annual precipitation at adjacent stations

to calculate temporal distributions for 1901–1981. The annual values, plotted as 5-year moving averages, appear in figure 20. The four stations (Bloomington, Clinton, Decatur, and Urbana) are all located in a triangular area of about 50 miles on each leg of the triangle (figure 2).

The general shape of all four curves is similar. However, in many 5-year periods, there are some notable area1 differences. For example, in the early part of the century (1901–1910) the Urbana, Bloomington, and Decatur values were all quite different. During the late 1920's, the Decatur values were markedly higher than the others. The major droughts of the 1913–1918, 1932–1935, and 1953–1957 periods are all quite evident. The major wet period of the 80 years is that found during the 1970's, although there was a notable peak in the late 1920's.

Special Data Sets for Selected Points (Stations)

Certain available data sets and results from other studies relating to point data are presented in this section. An analysis (Vinzani, 1982) of the climate of Peoria provided the graph of summer rainfall shown in figure 21. The 5-year moving averages are plotted at the mid-year of their 5-year periods. The data at Peoria began in 1858, one of the earlier quality precipitation records in the state. These show the fluctuations with a general decline from 1858 to about 1900. Major peaks occurred in the 1900–1905, 1915–1920, 1925–1928, and in the early 1970's and 1980. The plots suggest greater year-to-year variability from 1900 through 1950. Lesser variability existed after the early 1950's.

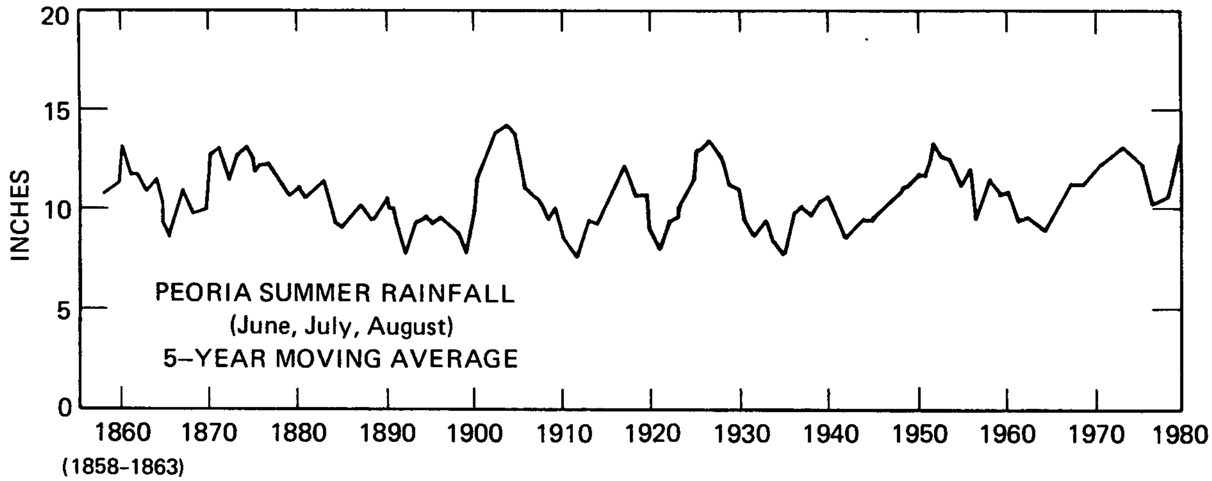


Figure 21. Fluctuations in summer rainfall at Peoria

The Urbana data, considered among the best long-term climate records in Illinois because of permanence at one site from 1888 through 1981 (Changnon and Boyd, 1963), were used to examine various precipitation frequencies. The annual and growing season precipitation values at Urbana for 1901–1981 are shown in figure 22. These allow examination of the year-to-year variability for both periods, as well as determination of major extremes such as that in 1927 when 56.1 inches of precipitation occurred and the record low of 24.8 inches in 1914. Since 1964, only two growing season values at Urbana have been below the long-term average, and only three annual values in this 17-year period were below the long-term average of 36.3 inches.

Another analysis of the quality Urbana precipitation records was based on the rainfall in the May-August period when rainfall is very critical for crop production. The 80 values of precipitation in each year used to determine the 25 wettest May-August periods, and the 25 driest May-August periods. The number of these in each decade appears in table 1. This shows a peak of wet seasons in the 1970's (6 out of 10 possibles), with no dry values in this decade. The 1940's was another period of generally wet summers and relatively few (only 1) dry May-August period. The 1960's was a period of extremes with three of the wettest May-August periods and six of the driest. The 1950's was a period of few extremes. There is a clear tendency to the wetter conditions, particularly of the last 15 years.

The interest in the wetter conditions of the 1970's was investigated in another study of the daily rainfall data at Urbana. The frequency of rain days in different class intervals was determined and compared with earlier frequencies. The data for 1971–1980 in various class intervals were determined and expressed as a percent of the total rain days in the decade. Similar calculations were done for the Urbana rain day data for 1903–1956. The percentage values for various class intervals are shown in table 2. Also shown are the differences between the two periods. This reveals that in the lighter rainfall categories, 0.01 to 0.6 inch, there were relatively fewer rainfall events in 1971–1980 than occurred in the 1903–1956 period. Conversely, the rain events during the 1970's produced relatively more in the category of 0.61 up to 2 inches. The value in the 1970's was 16.9% of the total rain events in this decade versus 11.9% in the earlier 54 years. These point data support the

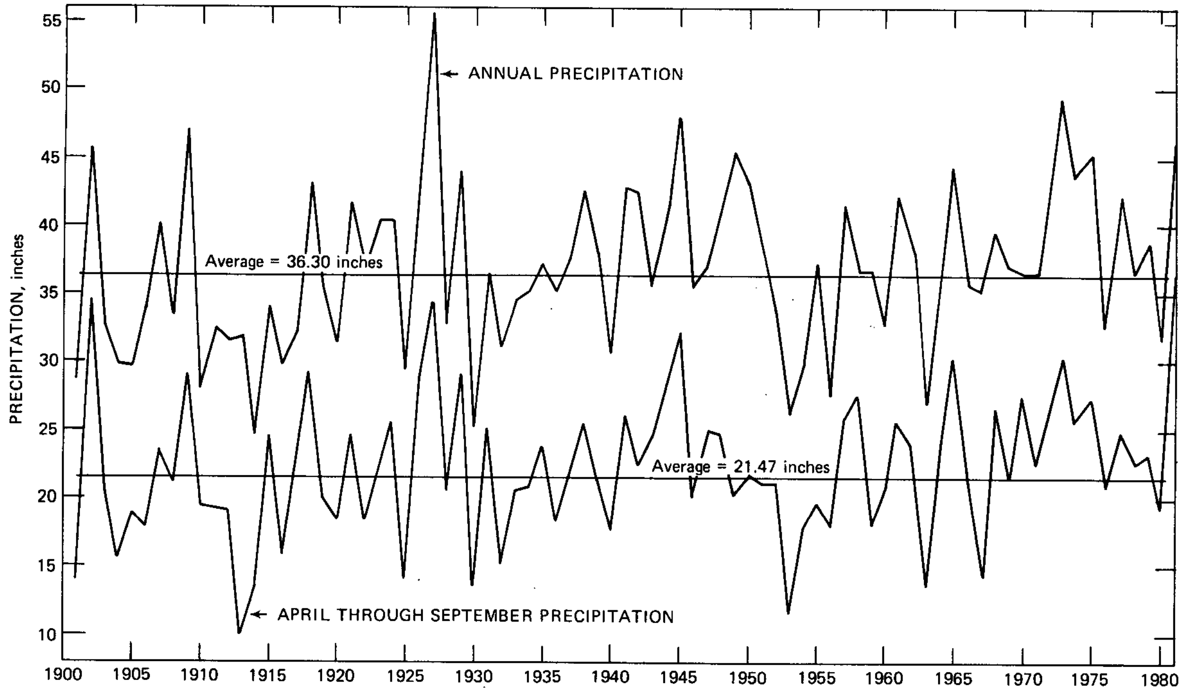


Figure 22. Annual and growing season precipitation at Urbana

Table 1. Number of Wet and Dry May-August Periods at Urbana, 1901-1980

	Wettest 25 Years	*Driest 25 Years*
1901-1910	3	2
1911-1920	3	6
1921-1930	3	3
1931-1940	1	5
1941-1950	5	1
1951-1960	1	2
1961-1970	3	6
1971-1980	6	0

Table 2. Comparative Analysis of Daily Rainfall Magnitudes at Urbana

Daily rain, inches	*Percent 1971-1980*	*Percent 1903-1956*	*(1971-1980) – (1903-1956) Percentages*
0.01-0.20	53.9	55.4	–1.5
0.21-0.40	18.8	19.1	–0.3
0.41-0.60	9.4	11.0	–1.6
0.61-0.80	4.7	3.6	+1.1
0.81-1.00	4.9	3.1	+1.8
1.01-2.00	7.3	5.2	+2.1
≥2.01	1.0	2.6	–1.6

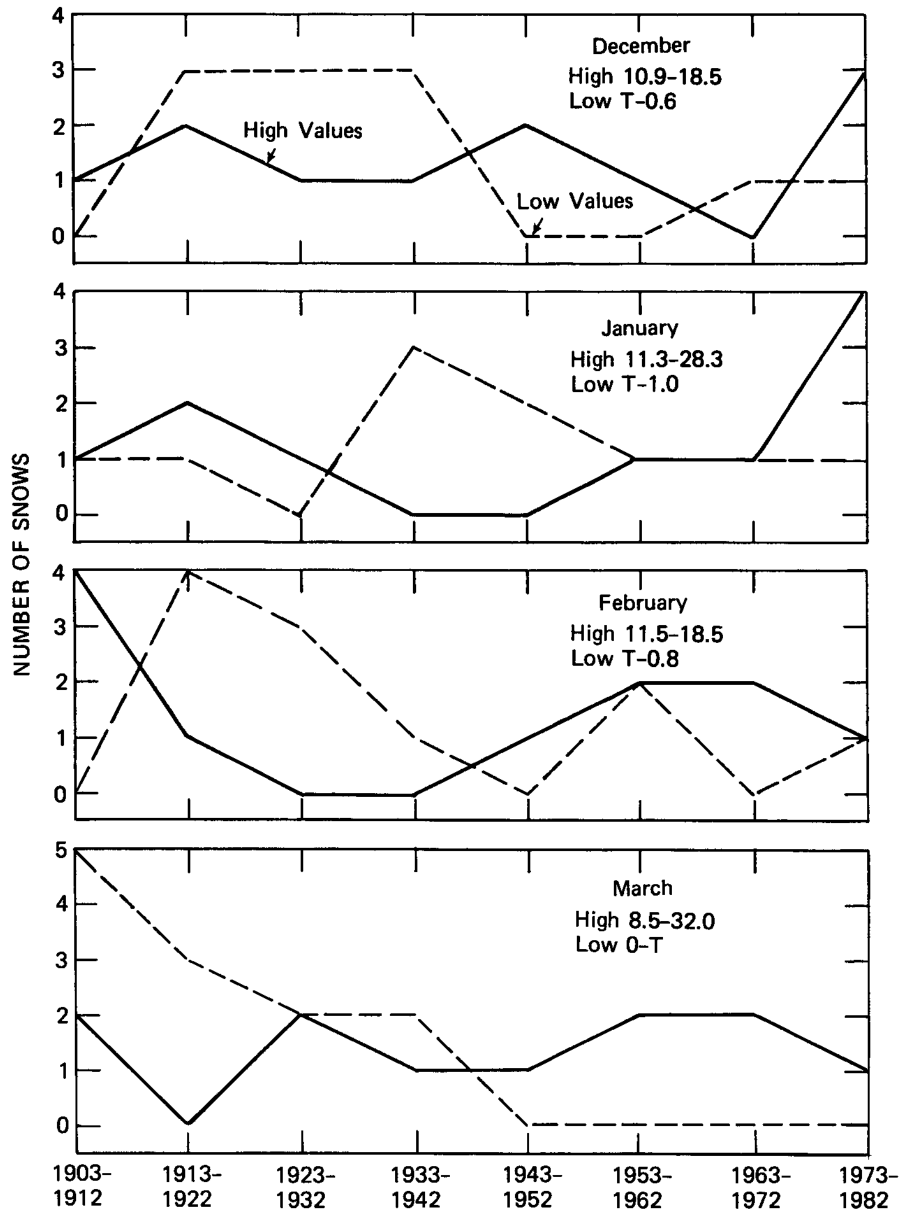


Figure 23. Number of snows at Urbana by decade based on the 10 highest and 10 lowest snowfall values in each month

statewide conclusions (figure 4) which show an increase in l-day rainfall values of ≥2 inch amounts with a peak in the 1970's.

Figure 23 presents the frequency of extreme monthly snow totals at Urbana. These are based on the 10 heaviest and 10 lightest snowfall values in each month. The high values peak in 1973–1982 for both December and January, with 1903–1912 the peak of values (4 of 10) for February. The greatest decadal frequency of lowest snow month values basically show peaks early in the 80-year study period, except in January (1933–1942). The greatest number of low January snow totals occurred in 1933–1942, in 1913–1922 for February, and in 1903–1912 for March.

TEMPERATURE CHANGES

Statewide

Data for temporal changes in the temperatures in Illinois are not as extensive, particularly as to the number of stations analyzed, as those for precipitation. This is basically because there is less areal variation in temperatures across the state in any given month, season, or year; hence fewer stations are needed to portray temporal changes. In fact, data from a single point (such as the long-term quality station in central Illinois, Urbana) can adequately portray many of the types of temporal changes found statewide in temperatures.

Furthermore, temperature measurements are potentially much more affected by their local environment than are precipitation data. For example, towns and cities with a population of more than a few thousand have measurable "heat islands." Thus, the temperature data collected in 1900 in a community with a few hundred persons that has grown to several thousand by 1980 could show a temperature increase that was related to the influences of the urban area growing around the station. Such measurements would not sample the natural change in the temperature over rural areas of Illinois. Hence, great care was taken in the selection of station temperature data for presentation. Also, fewer stations were needed because of the lack of areal variation mentioned earlier.

Temperatures have been measured in Illinois routinely and on a daily basis from somewhat before 1840 to the present. Many of the earlier, pre-1860 observations were not based on the daily maximum and minimum temperatures (they often lacked thermometers for this purpose), but were based on temperatures measured at 3 or 4 set times during the day such as 6 AM, noon, and 6 PM. These were then averaged to obtain daily and monthly averages. This method probably caused minimal difference in the calculation of the statewide annual temperatures, compared with the use of averages based on maximum and minimum temperatures.

Statewide Average Temperatures. Data from all available temperature stations in Illinois were used to determine in each year a statewide "average" temperature value. Admittedly, the values from the 1840–1890 period when many fewer stations existed are probably less representative of the true statewide value than those since the turn of the 20th Century. Available temperature data before 1890, generally from 20 to 30 locations scattered around the state, were used to calculate the annual mean temperatures. After 1890, the state had nearly 70 temperature measuring stations and by 1930 there were approximately 90 in the state where maximum and minimum daily temperatures were being measured.

The statewide annual average temperature values were used to develop the graph depicted in figure 24. The statewide values were combined to form 5-year means. That is, the statewide mean value for the period 1840–1844 was 50.8°F, as shown in figure 24.

Two general features are shown in the 140-year history of this state's temperatures. First is the general upward trend from 1840 through 1935. This 95-year period of warming caused the statewide temperatures to rise from around 50°F to 54.5°F. The lowest 5-year value occurred in 1855–1859 when the value was 49°F. The second major feature of the distribution is the cooling trend that has lasted since 1935. The 5-year value for 1975–1979 was 51.3°F, down 3°F from the peak in 1930–1934. This agrees with findings for Indiana (Agee, 1982).

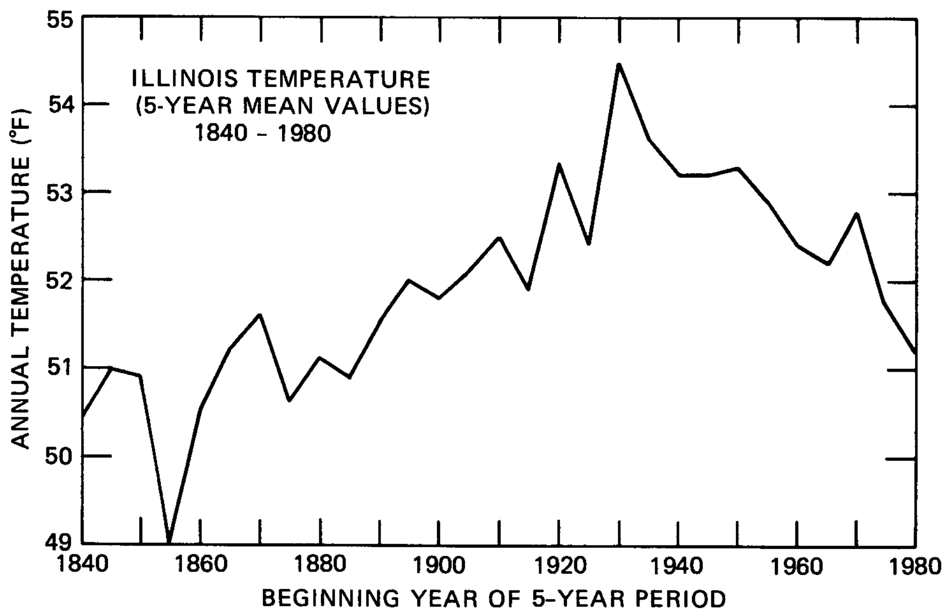


Figure 24. Five-year mean temperatures for Illinois

Regional

Seasonal. Seven stations distributed around Illinois were selected to reveal the regional variations in maximum and minimum temperatures for the 1895–1982 period. The seasonal maximum and minimum temperatures for these 7 stations were averaged to form decadal values. The last of the "decadal values" was actually based on 8 years, 1975–1982, and the first on 1895–1904. It should be noted that the 7 stations chosen for the seasonal analysis were selected largely to form a north-south axis since temperatures in most seasons show a latitudinal variation across the state, the variation being greater in the winter than in summer. Two of the stations in central Illinois, Urbana and Havana, are at nearly identical latitudes (figure 2), but they were chosen because east-west differences in temperatures across central Illinois are sufficient to seek a portrayal of the east-west differences, as well as those from north to south.

The winter season (December-February) values for 1905–1982 are shown in figures 25a and b. The maximum temperatures show a peak in 1925–1934 and in 1945–1954, with a general decline after 1954. The winter maximum temperatures (figure 25a), at all stations, show their minimum in the 1975–1982 period. Most stations show a peak in the winter minimum temperatures (figure 25b) in the 1945–1954 period, except for the two southern Illinois stations which peak in 1925–1934. The minimum winter distributions do differ from the maximums as to the time of occurrence of the lowest decadal values. Certain stations achieved their lowest decadal value of minimums in 1905–1914, and four achieved their lowest decadal value in 1955–1964.

The spring (defined here as April-May) seasonal maximum and minimum temperatures (figures 26a and b) show temporal distributions that differ greatly from those of the winter season. Basically, the maximum spring temperatures show a general uptrend with a peak achieved in 1955–1964. The lowest decadal maximum temperatures occurred either in

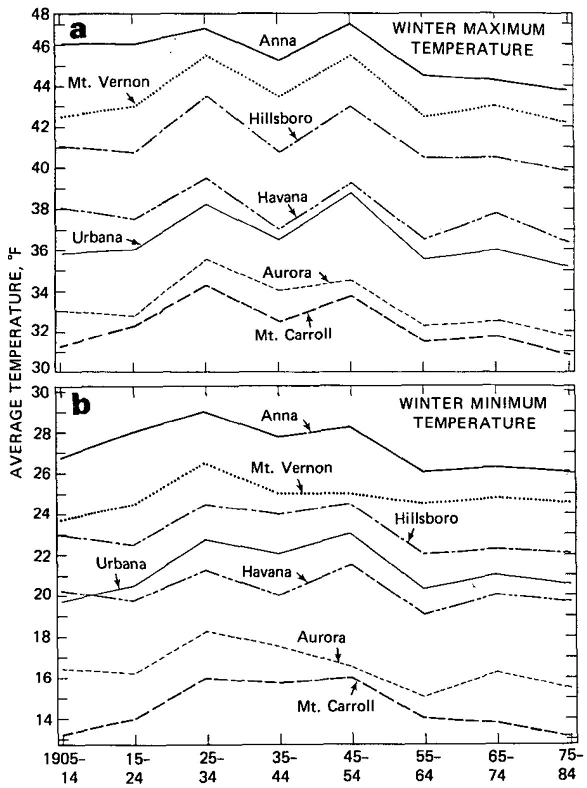


Figure 25. Decadal values of maximum and minimum temperatures in winter (December-February)

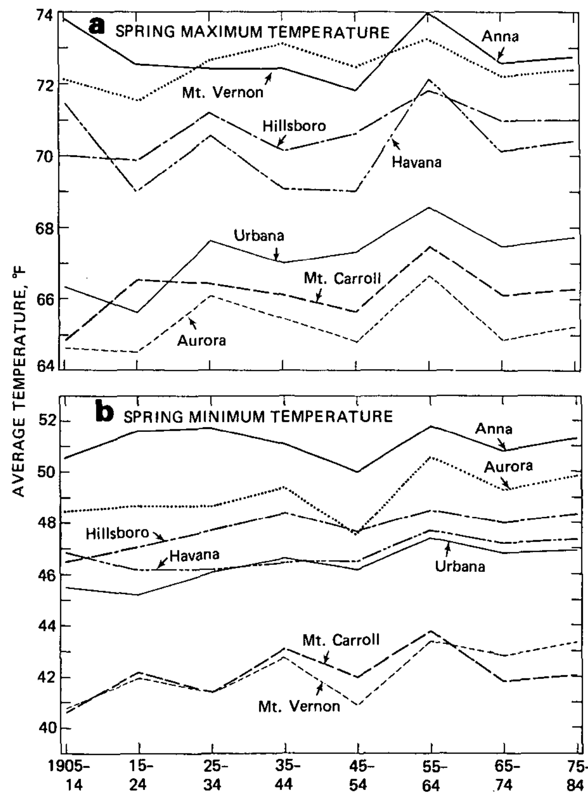


Figure 26. Decadal values of maximum and minimum temperatures in spring (April-May)

1905–1914 or 1915–1924. The minimum spring temperatures (figure 26b) also showed a general uptrend, peaking in 1955–1964, as did the spring maximums. Basically, the maximum and minimum spring temperature distributions are alike as to their highest and lowest decadal values.

The temperature data for the summer season (defined as only July-August) is shown in figure 27a and b. The data include values beginning in 1895 through 1982, although not all stations had data for the 1895–1904 decade. The average maximum summer temperatures (figure 27a) show a relatively flat distribution from 1895 to 1934 with a peak in 1935–1944, followed by a sharp decline thereafter. Certain stations like Anna and Hillsboro achieved their peak in maximum temperatures in 1925–1934. The statewide warm period of the 1930's (in figure 24) was largely determined by the peaking of both winter and summer temperatures during that decade, as shown in figures 25 and 27, and was less reflected in the spring temperatures.

The lower decadal values for the summer maximum temperatures are found during 1975–1982 except at Mt. Carroll which has its lowest value in 1955–1964. The summer minimum temperatures (figure 27b) reveal general trends upward from 1895 through 1944, and then a slight down trend. The peak values of the minimum summer temperatures occurred in 1935–1944 at four stations, and in 1955–1964 at three stations (Aurora, Havana, and Mt. Carroll). The lowest decadal values for the minimum summer temperatures occurred

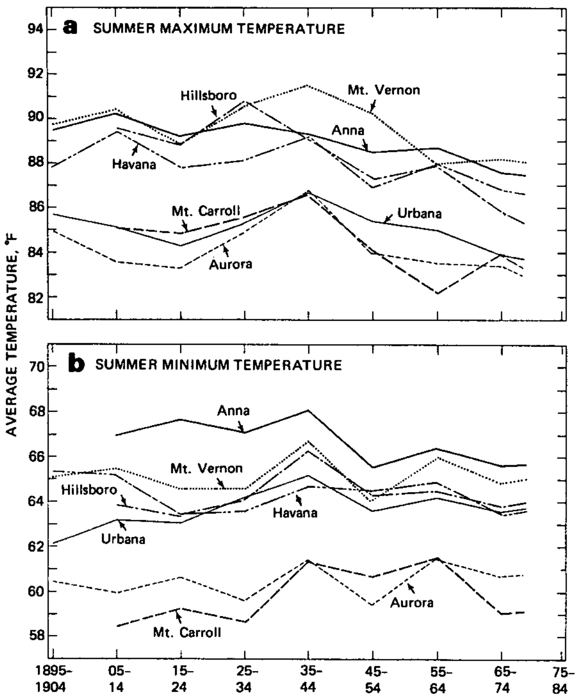


Figure 27. Decadal values of maximum and minimum temperatures in summer (July-August)

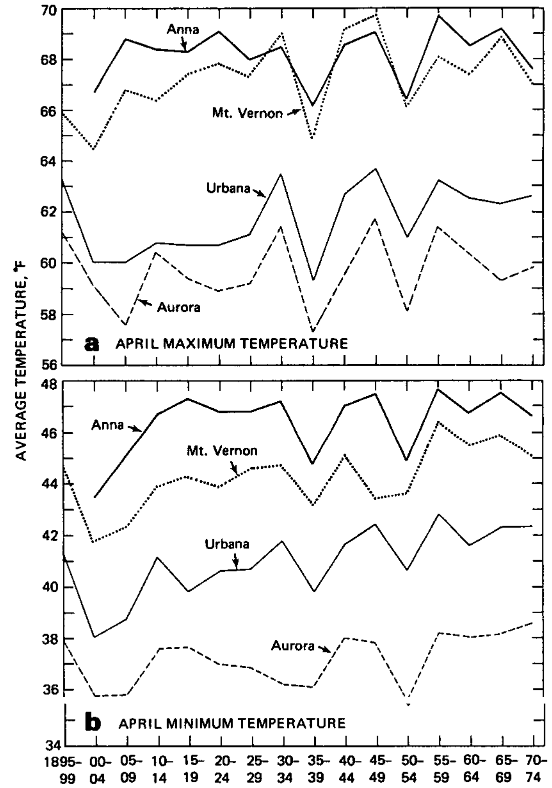


Figure 28. Five-year average maximum and minimum temperatures for April

in various decades. Mt. Carroll had its lowest value in 1905–1914, whereas Hillsboro and Havana had their lowest value in 1915–1924. The southern Illinois stations of Anna and Mt. Vernon had their minimums in 1945–1954.

Comparison of the summer maximum and minimum curves reveals that they were alike in their peak values, being achieved largely in 1935–1944, but the summer maximum and minimum temporal distributions were not alike particularly as to their low values:

Monthly Values. Monthly values of maximum and minimum temperatures are presented for four stations (Anna, Mt. Vernon, Urbana, and Aurora) for critical months in the growing season (April through August). The maximum and minimum temperature values in each year were averaged for 5-year periods. These four stations (figure 2) provide an estimate of regional variations along a north-south axis through Illinois.

The 5-year average maximum and minimum temperatures for Aprils of 1895–1974 appear in figures 28a and b. The maximum values illustrate frequent oscillations. Peaks occur in 1945–1949 at three stations, and in 1955–1959 at Anna. The lowest values occur in 1935–1939. The April minimum temperature curves all reflect a general upward trend with time, achieving a peak value in 1955–1959, except at Aurora which peaked in 1970–1974.

The May maximum and minimum temperatures appear in figures 29a and b. There are not general trends in the maximum or minimum temperature distributions. The maximum and minimum temperatures for May achieved their peaks in 1955–1959 except at Mt. Vernon,

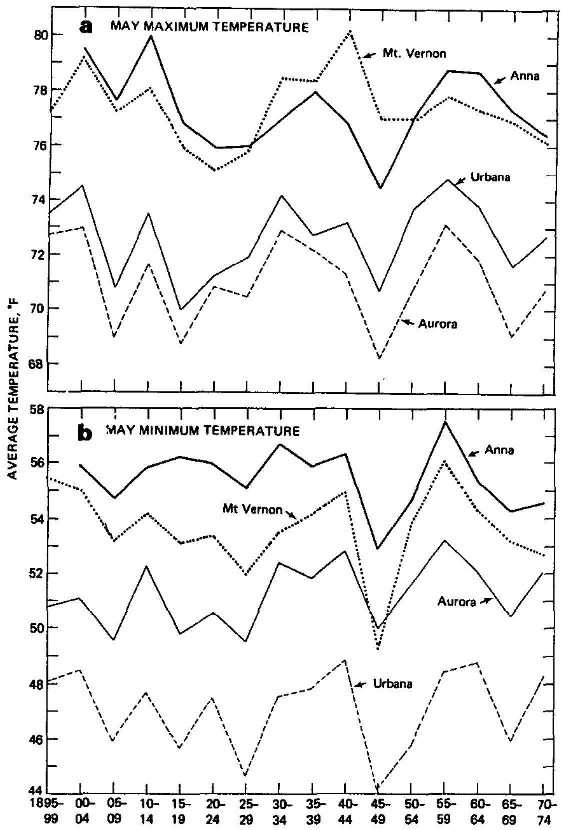


Figure 29. Five-year average maximum and minimum temperatures for May

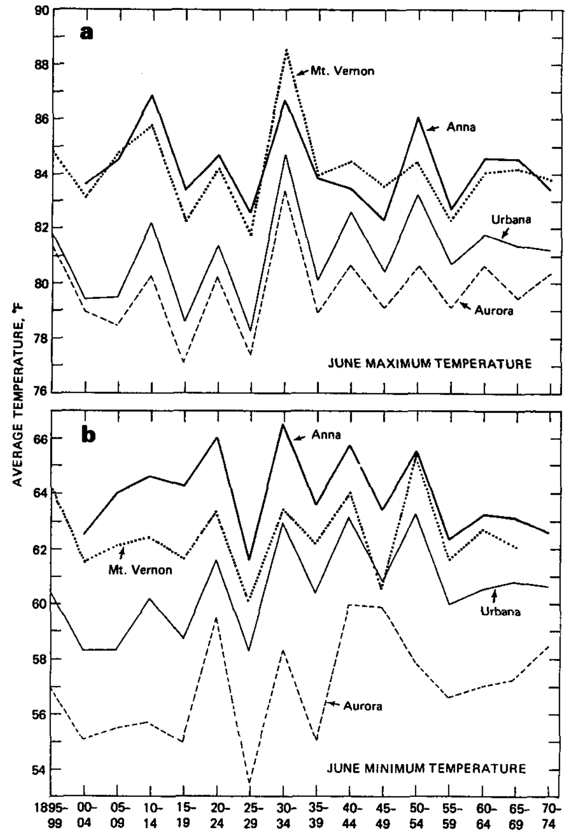


Figure 30. Five-year average maximum and minimum temperatures for June

and their lowest values generally in 1945–1949 (when peaks were occurring in the April temperatures).

The June maximum and minimum temperatures appear in figures 30a and b. The maximum temperatures suggest a 10-year cycle of peaks and valleys. Basically, the maximum June temperatures (figure 30a) do not show a marked up or down trend from 1895 to 1974. There is a major trough in temperatures in 1925–1929, followed by the peak of the study period in 1930–1934. The June minimum temperatures (figure 30b) suggest a general upward trend from 1900 to the 1940's and early 50's; then a downward trend. Thus, the trends and the peaks and lows of the maximum and minimum June temperatures are not alike. The upward trend in the minimum suggests a narrowing of the difference between the maximum and minimum temperatures for June over time.

The July average and minimum temperatures (figures 31a-b) show a seesaw characteristic. There is a flat trend in the maximum values from 1895 through 1929, then a major peak in the 1930's, followed by a general down trend thereafter in the maximum July temperatures. The peaks in the maximum July temperatures occurred either in 1930–1934 or 1935–1939. The lowest 5-year values in the July maximum temperatures occurred in 1905–1909 at Aurora and Urbana, but in 1945–1949 at Anna, and 1955–1959 at Mt. Vernon, suggesting north-south differences in July maximum temperatures. The minimum July tem-

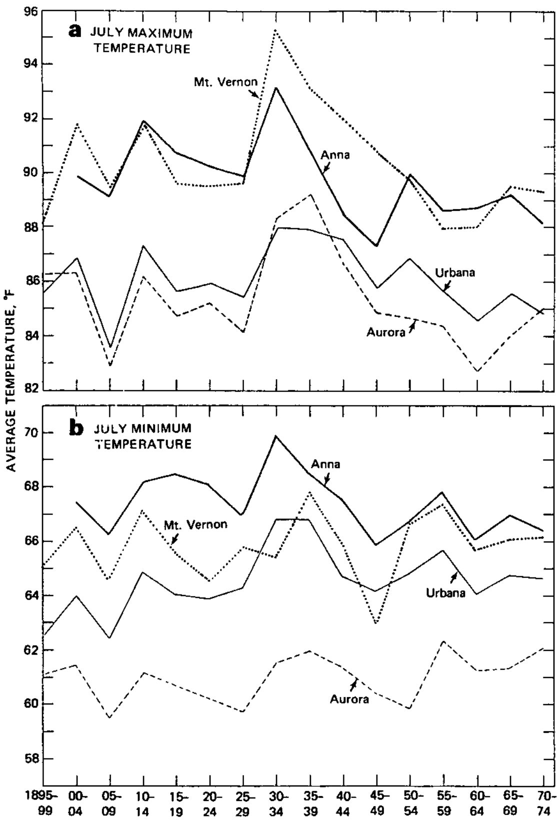


Figure 31. Five-year average maximum and minimum temperatures for July

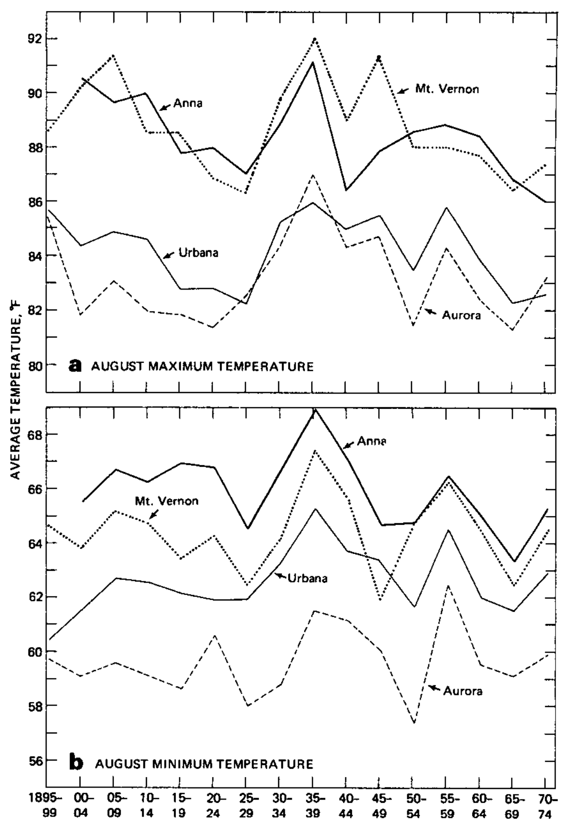


Figure 32. Five-year average maximum and minimum temperatures for August

peratures (figure 31b) show an up trend from 1895 to the 1930's, then a rapid decrease, becoming a flat distribution basically from 1945 until present. A moderate high in the minimum values also occurs in 1955–1959.

The August average maximum and minimum temperature distributions are shown in figures 32a and b. The August maximum temperature curves (figure 32a) show a peak of the study period in 1935–1939 just as was shown for June and July. Temperatures were greater in the early part of the century, dipping to lows during 1915–1929, and after the peaks of the 1930's, showed a general decline. However, a peak occurred in the 1955–1959 period which was also shown in the June and July (minimum) temperatures. The August minimum temperatures (figure 32b) also show a peak in 1935–1939.

Comparison of the August temperature curves with those for July and June shows certain common characteristics. These include 1) relatively lower values in the 1895–1925 period; 2) peaks in both maximum and minimum temperatures in the 1930's; and 3) lower values in the 1940–1974 period. Other similarities include a general upward trend in the minimum temperatures of all summer months. This trend is greater than the trends in the maximum monthly temperatures of the summer.

Differences in Seasonal Maximum and Minimum Temperatures. The temperature data for 5 stations (Anna, Mt. Vernon, Urbana, Havana, and Aurora) for the seasonal maxi-

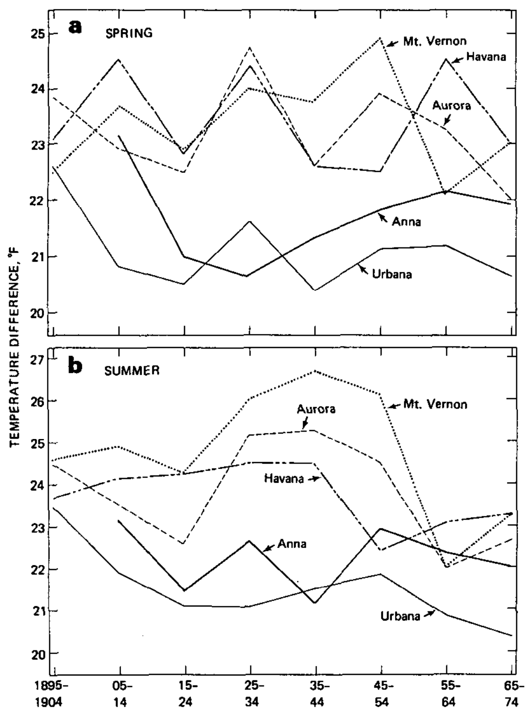


Figure 33. Differences (10-year averages) between mean maximum and minimum temperatures in spring and summer

mum and minimum temperatures were compared. The difference in the seasonal maximum and minimum temperatures was calculated for each year, and these seasonal differences were averaged for 10-year periods to help examine for trends in the amount of separation. The discussion of the summer monthly temperatures indicated a greater up trend in minimum than in maximum temperatures, which should provide a narrowing of the difference between maximum and minimum temperatures with tune.

The spring (April-May) differences for these 5 stations appear in figure 33a. The greatest difference in temperatures occurred at several stations in 1925–1934. Two stations, Aurora and Havana, show no tendency to trend up or down during the 80-year period. Three stations, Mt. Vernon, Urbana, and Anna, show a slight decrease in the differences in their spring temperatures, becoming generally less with time.

The summer season (July-August) differences between mean maximum and mean minimum temperatures appear in figure 33b. The temporal decreases at Urbana, Aurora, and Mt. Vernon are marked. For example, in 1895–1904 Aurora's difference was 24.5° but by 1965–1974 it had decreased to 22.7°F. There was a lesser decrease in the difference at Anna and Havana.

Length of Growing Season. Data from 9 substations scattered throughout the state were used to measure length of the growing season, defined as the period between the last spring temperature of 32°F (or lower) and the first fall temperature of 32°F (or lower). The stations chosen represented relatively stable stations such as Urbana, or those in small communities such as New Burnside, Dixon, Monmouth, and Hillsboro that are largely unaffected by urban growth. The distribution of the 9 stations across the state is uniform.

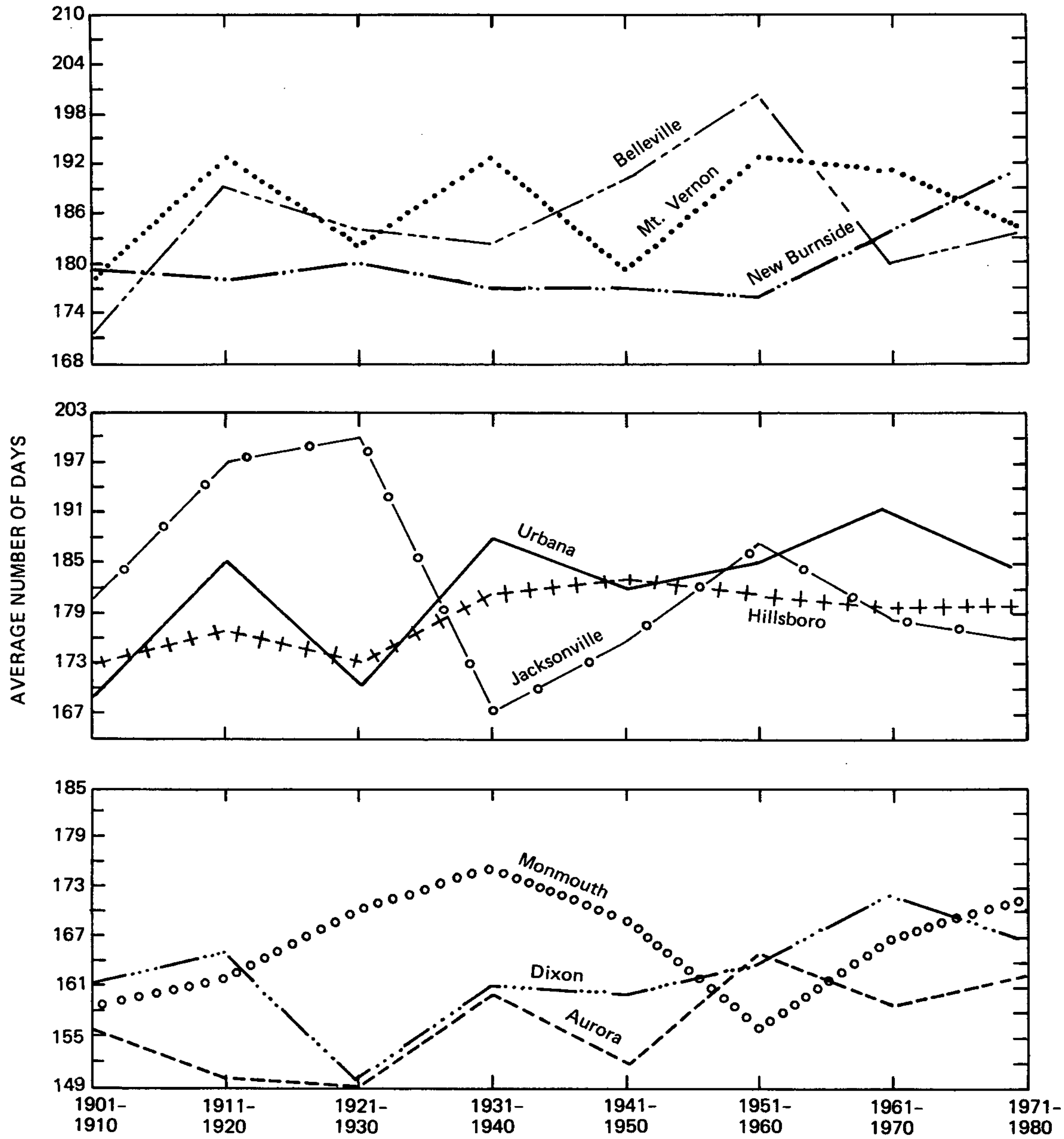


Figure 34. Decadal averages of the length of the growing season

The annual values of growing season were averaged to calculate decadal averages, and these are plotted in figure 34. Inspection of the curves suggests that most stations show some form of temporal increase, particularly during the most recent two decades. However, the values for Jacksonville and Monmouth show different temporal distributions with peaks (greater lengths) in earlier decades. The recent uptrend (increase in days) at Aurora could partially relate to the growth of the urban community. The record at New Burnside is in a very small community and should not be affected. In general, it could be concluded that ma moderate recent increase in the length of the growing seasons has occurred at most stations except for Jacksonville. As will be shown in the next two sections, this increase in growing season is largely a function of changes in the last date of spring freeze.

Last Spring Freeze Dates. Data from the same 9 stations were used to determine the date of the last spring temperature of 32°F or lower. These dates in each decade were used to get a decadal average value, and these are plotted in figure 35.

Inspection of the curves of figure 35 shows that all reflect a continuing shift with time to earlier dates during the 1901–1980 period. The downward (early) trends were interrupted by later dates in the 1921–1930 decade, followed by shifts to earlier dates in the last 50 years. For example, at Monmouth, the 1901–1910 average value was April 30, decreasing to April 22 for 1971–1980.

The 80-year shift to earlier dates increases with latitude across Illinois. In northern Illinois, the Aurora change was only 2 days and Dixon 6 days. In central Illinois the 80-year changes were 8 to 9 days, and the southern Illinois stations showed 10 days (Belleville and Mt. Vernon) and 12 days (New Burnside). The shift to earlier dates of the last spring freeze is indicative of a warming trend in spring and hence most of the curves in figure 35 support the spring warming trend (figure 26).

Date of First Fall Freezing Temperature. Data from the same 9 substations were also used to examine the temporal distributions of the date of first freezing temperature (≤ 32° F) in the fall season. The dates in each year were averaged per decade to get a decadal average, and these are plotted for the 9 stations in figure 36. In general, they show very little change over the 80-year period. Jacksonville and Hillsboro (both in SW Illinois) show a slight shift to earlier dates; Urbana and Aurora show a shift to later dates; and the other five stations show no change between 1901–1910 and 1971–1980. The upward shift in 1971–1980 at New Burnside is related to a shift in station location to Marion. Basically, no systematic change occurred during 1901–1980 in the timing of the first fall freeze.

Frequency of Months with Moderated Temperatures. In each month, the daily maximum and daily minimum temperature values were averaged and from these monthly values, long-term means were calculated for 4 stations (Aurora, Urbana, Mt. Vernon, and New Burnside). Using the long-term means of the hourly maximums and minimums, based on a 1901–1970 period, the departures of the maximum and minimum temperatures in each month from these means were calculated and compared. In most months when the maximum temperature is above the mean, the monthly minimum is also, or vice versa. A month with "moderated" temperature conditions is very unusual. It is defined as one that had 1) its average maximum temperature below the long-term mean, and 2) minimum monthly temperature (same month) above the long-term mean. In other words, the maximum and minimum temperatures were closer together than usual. The frequency of such months is not great.

The number at each station per decade was calculated and plotted as shown in figure 37. For example, at Aurora the number in the 1901–1910 decade was 12 out of 120 possible months (10 years x 12 months). The distribution of these months, as reflected in the 4 curves shown in figure 37, suggests an increase with time reaching decadal maximums at Aurora, Urbana, and Mt. Vernon during the last two decades. However, New Bumside in extreme southern Illinois (figure 2) does not show a comparable increase. Changnon (1981a)

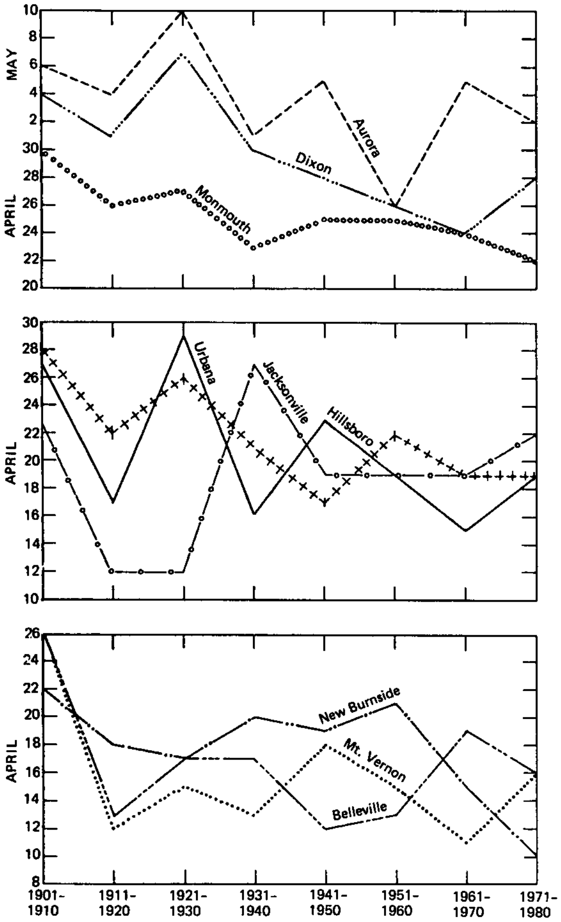


Figure 35. Average dates (decadal average) of last spring freeze

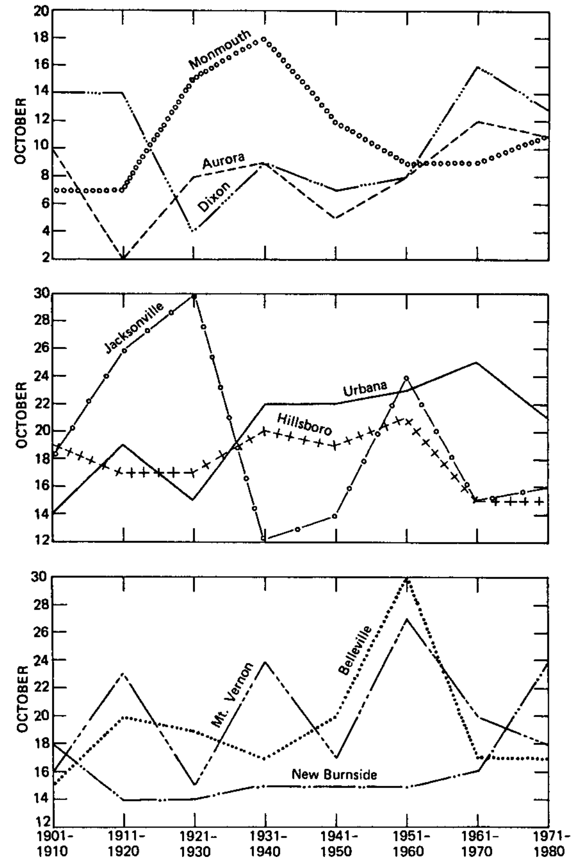


Figure 36. Average dates (decadal average) of first fall freeze

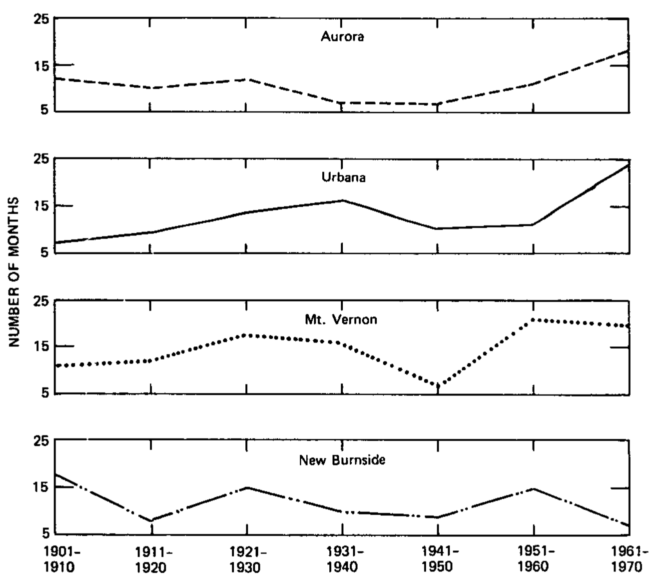


Figure 37. Frequency per decade of months with moderated temperatures

has speculated that the increase in months with moderated temperatures was caused by additional cloudiness and has occurred partially because of the additional cloudiness produced by contrails from jet aircraft activity.

Point (Station) Data

Frequency of Extremely High Temperatures. The temperature data from Urbana, which is one of the national benchmark stations because it has remained in a single location since its inception in 1888, are of very high quality. These data were used to calculate the number of days per decade when daily temperatures reached or exceeded 100°F. This arbitrary selection is for daily values that are not frequent and are extremely high. The tabulations of these per month and for the season, based on each decade, are shown in table 3. These show the maximum frequency during the 1930's, the warmest decade of the last 80 years, and moderately high numbers in the 1911–1920 and 1951–1960 decades which were also noted for their exceptional droughts (see figure 7). Only one day with temperatures of 100°F or higher occurred in the 1940's and the 1970's. The higher temperatures of the middle part of the century, as depicted in figure 24 and 27a, are reflected in the higher frequencies of extremely warm days from 1911 through 1960, with lower values in the decades before and after when summer temperatures were lower.

Frequency of Extremely Cold Days. The Urbana records were also used to express the frequency of extremely cold days per decade. Table 4 portrays two expressions of ocurrence of very cold days. Column 1 shows the number of days per decade with minimum temperatures that were –13°F or colder; column 2 shows the decadal number of days with daily mean temperatures that were –5°F or lower. These show greater frequency early in the century, and again in the most recent decade. Such cold days did not occur in the 1941–1960 period.

Occurrences of Record Daily Temperatures. The high quality temperature data at Urbana were used to count, per decade, the number of daily record maximum temperatures and number of daily record minimum temperatures. The number in each category could exceed 365 since a few records are shared between years. That is, the record for February 1 lowest temperature might be –15° F reached in two years in the 1890–1980 period.

The number of record maximum and record minimum temperatures in each decade are shown in table 5. One impression is that there is a clear tendency to record a large

Table 3. Number of Days with Temperature of 100° F or Higher at Urbana

Decades	*June*	*July*	*August*	*September*	*Total*
1891–1900	0	0	0	2	2
1901–1910	0	3	1	0	4
1911–1920	0	8	3	0	11
1921–1930	0	6	2	0	8
1931–1940	7	19	1	0	27
1941–1950	0	1	0	0	1
1951–1960	3	4	2	3	12
1961–1970	0	3	1	0	4
1971–1980	0	1	0	0	1

Table 4. Distribution of Extremely Low Daily Minimum Temperatures and Mean Temperatures at Urbana by Decade

Decade	*Number of days minimum temp of –13°F or lower*	*Number of days mean temp of –5°F or lower*
1901-1910	10	5
1911-1920	7	2
1921-1930	5	5
1931-1940	5	3
1941-1950	0	0
1951-1960	1	0
1961-1970	2	2
1971-1980	6	4

Table 5. Frequency of Record Daily Temperatures at Urbana

Decade	*Number of record maximums*	*Number of record minimums*	*Total*
1891-1900	34	85	119
1901-1910	33	64	97
1911-1920	42	47	89
1921-1930	47	43	90
1931-1940	72	21	93
1941-1950	42	22	64
1951-1960	62	29	81
1961-1970	37	28	65
1971-1980	29	36	65

number of records in the 1891–1900 and the 1901–1910 decades. Thereafter, the number of records reached in each decade have decreased, suggesting much greater extremes of high and low temperatures in the early 20 years of the record period. Although many of the temperature data show that recent years are getting colder, the number of record minimum temperatures set at Urbana has not increased markedly. The 36 dates when record low temperatures were reached in 1971–1980 period are more than those in the warmer decades of the 1930's and 1940's.

Temporal Distribution of Cold and Snowy Winters. The Urbana data of temperatures and winter snowfall, based on data for December-February in each year, were studied. The 10 winters that had the lowest temperatures were defined, as were the 10 winters that had the greatest total snowfall. The frequency of these extremes by decades is shown in table 6. This shows that the early and late parts of the 80-year study period had most of the cold winters, reflecting the general temperature distributions shown in figures 25 and 16. Most of the snowiest winters are in the last 20 years, with 6 of the 10.

Monthly Mean Temperatures at Urbana. Monthly temperatures at Urbana for 1891–1980 were used for the study of the temporal changes in the average monthly maximum temperatures, average monthly minimum temperatures, and average monthly temperatures (the average of the maximums and the minimums).

The data for the summer months, June through August, were combined for each decade. The summer season values per decade are shown in figure 38. The minimum summer temperatures showed an increase from 1891 up through 1931–1940, followed by a moderate

Table 6. Temporal Distribution of 10 Coldest and 10 Snowiest Winters at Urbana

Decade	*10 Coldest winters*	*10 Snowiest winters*
1901-1910	3	1
1911-1920	2	1
1921-1930	0	0
1931-1940	1	0
1941-1950	0	1
1951-1960	0	1
1961-1970	1	3
1971-1980	3	3

decrease. The distribution of maximum summer temperatures was not similar. The temperatures were constant from 1891 through 1940, followed by a decrease thereafter. The difference between the maximum and minimum also decreases, with temperatures being 24.7°F in 1891–1900 and decreasing to 20.7°F by 1971–1980. This reflects the findings on moderated temperatures (figure 37).

The winter season (December-February) average maximum and average minimum temperatures, per decade, are shown in figure 39. These show the rapid increase in temperatures particularly for the minimum values, followed by a rapid decline after 1960. Maximum winter temperatures also showed an increase but not as much as the minimums, but with a sharp decrease after 1960. As with the summer temperatures, the difference between maximum and minimum winter values decreased with time.

Figure 40 presents the seasonal average (mean) temperatures at Urbana for each decade from 1891 through 1980. The summer and winter trends reflect those shown in the maximum-minimum graphs of figures 38 and 39. The fall temperatures show less change with time, rising slowly from 1891 through 1940 and remaining generally stationary thereafter. The spring mean temperatures also show a slight increase with time peaking in 1941–1950, with no increase or decrease thereafter. Thus, comparison of the seasonal trends in figure 40 with those in figure 24 for Illinois, reveals that the warming trend from 1891 through 1931–1950 is apparent in all seasons but is relatively greatest in winter. Also, the decrease in temperature since the 1930's and 1940's has been greatest in winter.

Monthly Data for Peoria. Figure 41 is based on 10-year moving averages of the July average temperatures for Peoria for 1856–1980 (Vinzani, 1982). The 10-year values were plotted at the mid-year of the 10-year period. The July values show major oscillations with peaks in the 1880's and 1930's. A recent decrease in July temperatures is seen but has not exceeded the lows in 1905 and in the 1860's. Figure 42 shows the 10-year moving averages of the January average temperatures. This shows a general increase of temperatures from 1856 up to 193 5, followed by a rather rapid decline to the all-time low in the 1970's.

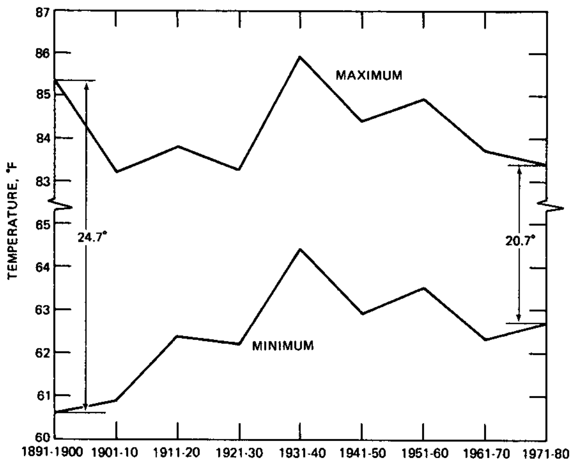


Figure 38. Summer mean maximum and minimum temperature per decade at Urbana

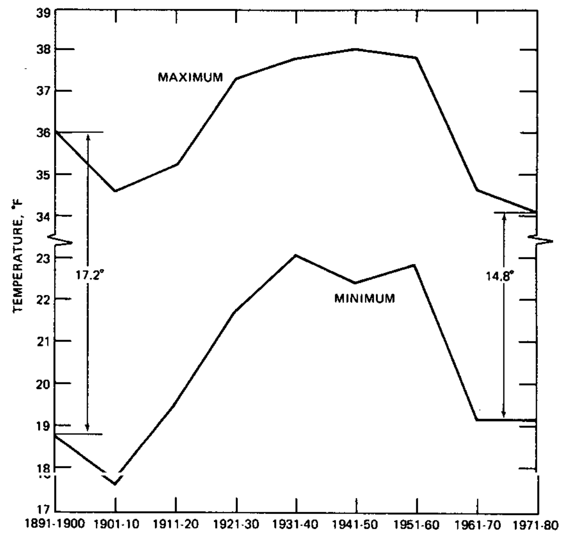


Figure 39. Winter mean maximum and minimum temperature per decade at Urbana

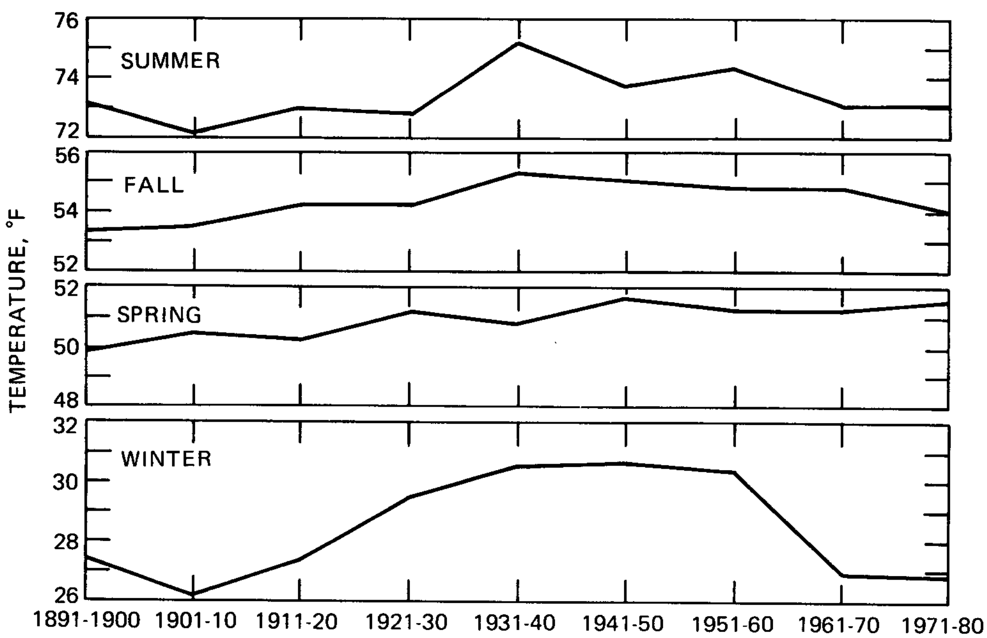


Figure 40. Seasonal average temperatures for Urbana by decade

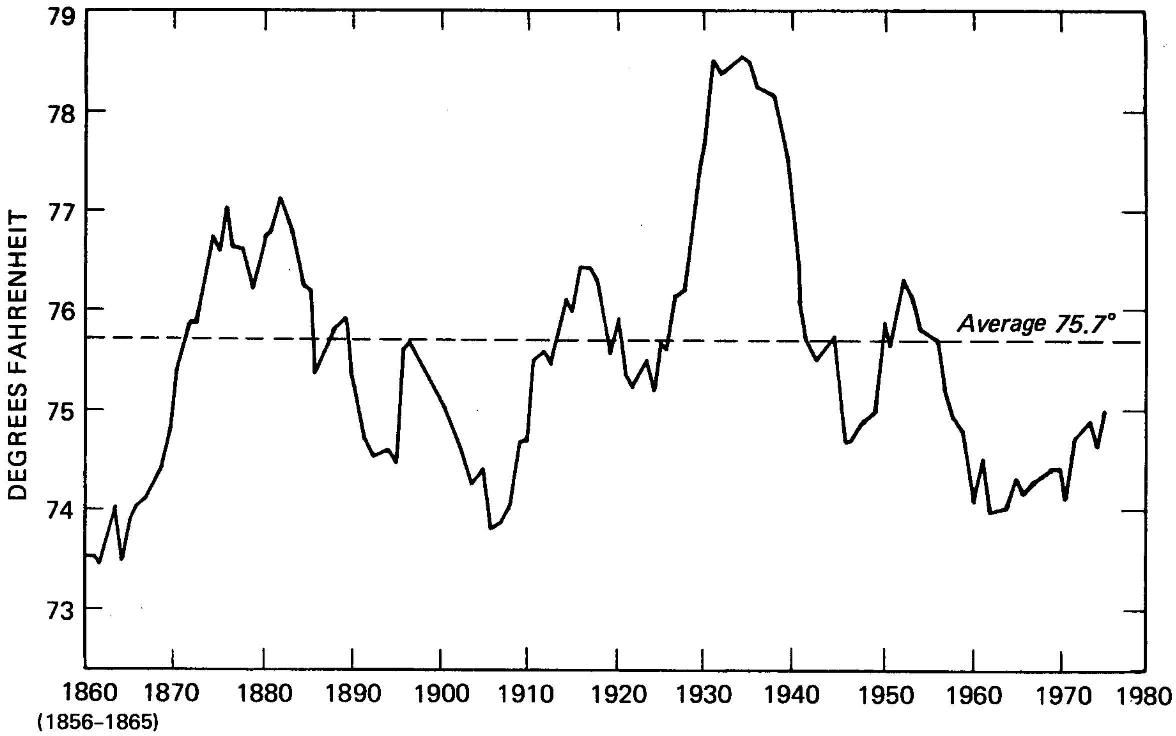


Figure 41. Ten-year moving average of July average temperature at Peoria

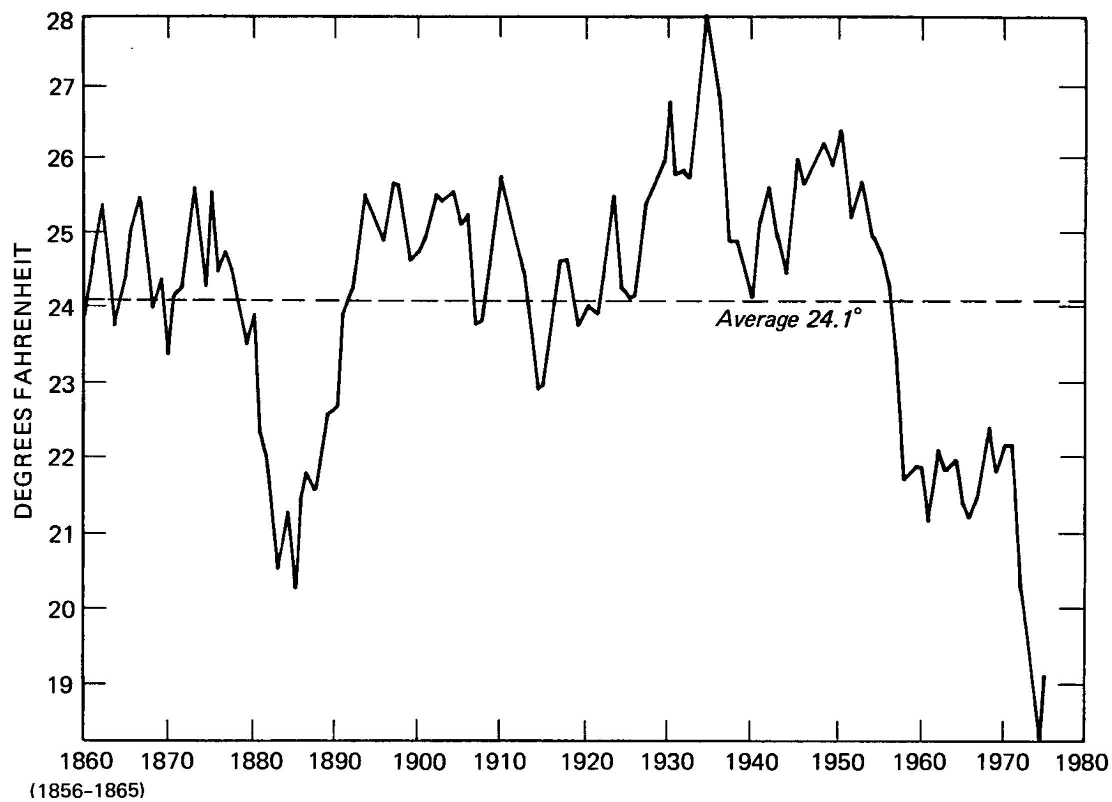


Figure 42. Ten-year moving average of January average temperature at Peoria

CHANGES IN OTHER ATMOSPHERIC CONDITIONS

Relative Humidity

The July relative humidity data for the 6 first-order stations (figure 2) were chosen to analyze for possible temporal changes. The July average relative humidity values for each year were averaged to obtain 5-year means. The resulting curves are shown in figure 43a for northern Illinois and in figure 43b for southern Illinois.

The temporal shifts all indicate a lowering of relative humidities from 1901 through 1940. This agrees with studies of most urban areas which have shown that relative humidity inside cities is lower than in rural areas due to urban effects (Landsberg, 1970). As these six cities grew, relative humidity decreased, probably as a function of the urban size.

Shifts upward occurred during the 1940's, when stations moved from the city centers to the rural airports as reflected in five of the station curves. They all reveal sudden increases in humidity as the stations were relocated to the rural airport sites. Note that the values of several stations, such as Moline and Peoria, for 1941–1950 agreed with those at these stations earlier in the 20th Century (when the cities were smaller). Only Chicago, which had station relocations to an airport but one well within the metropolitan area, shows no recovery in 1941–1950 period.

After the rural locations were established, the values since (1951–1980) show only minor temporal changes. They are largely not indicative of any marked temporal changes. St. Louis does show a continued rise in relative humidity with time after 1950, but the other stations show only slight changes up or down in the last 30 years. These data do not allow for an interpretation of major long-term shifts in any of these periods.

The 5-year values, however, do show some interesting short-term shifts in relative humidity. For example, low values were reached in the 1951–1955 period, one of generally hot and droughty conditions, particularly in the southern half of Illinois. Certainly, the hot and dry period of the 1930's would tend to produce low values as shown in figures 43a and b. At several stations, the 5-year period of 1961–1965 had relatively high recent humidities. Peaks are shown at Chicago, Moline, Peoria, and St. Louis. The 1906–1910 period was also one of high relative humidities.

Sky Cover and Sunshine

The single most important factor controlling the climate of Illinois is the amount of solar energy being received throughout the world. Unfortunately, there are no long-term records of solar radiation in Illinois that allow study of the 80-year temporal fluctuations. Data are available for the 28-year record at Argonne (Changnon, 1978).

At each of the 6 first-order stations studied, records are available for two important atmospheric conditions related to radiation: cloud cover and sunshine. These data were examined for historical fluctuations and trends. The amount of sunshine was investigated as sunshine is a useful indicator of solar radiation.

The amount of sky cover has a direct influence on the amount of solar radiation received and reflected back into space, and therefore sky cover affects the temperature of Illinois. Cloud cover limits incoming radiation which tends to produce cooling, and con-

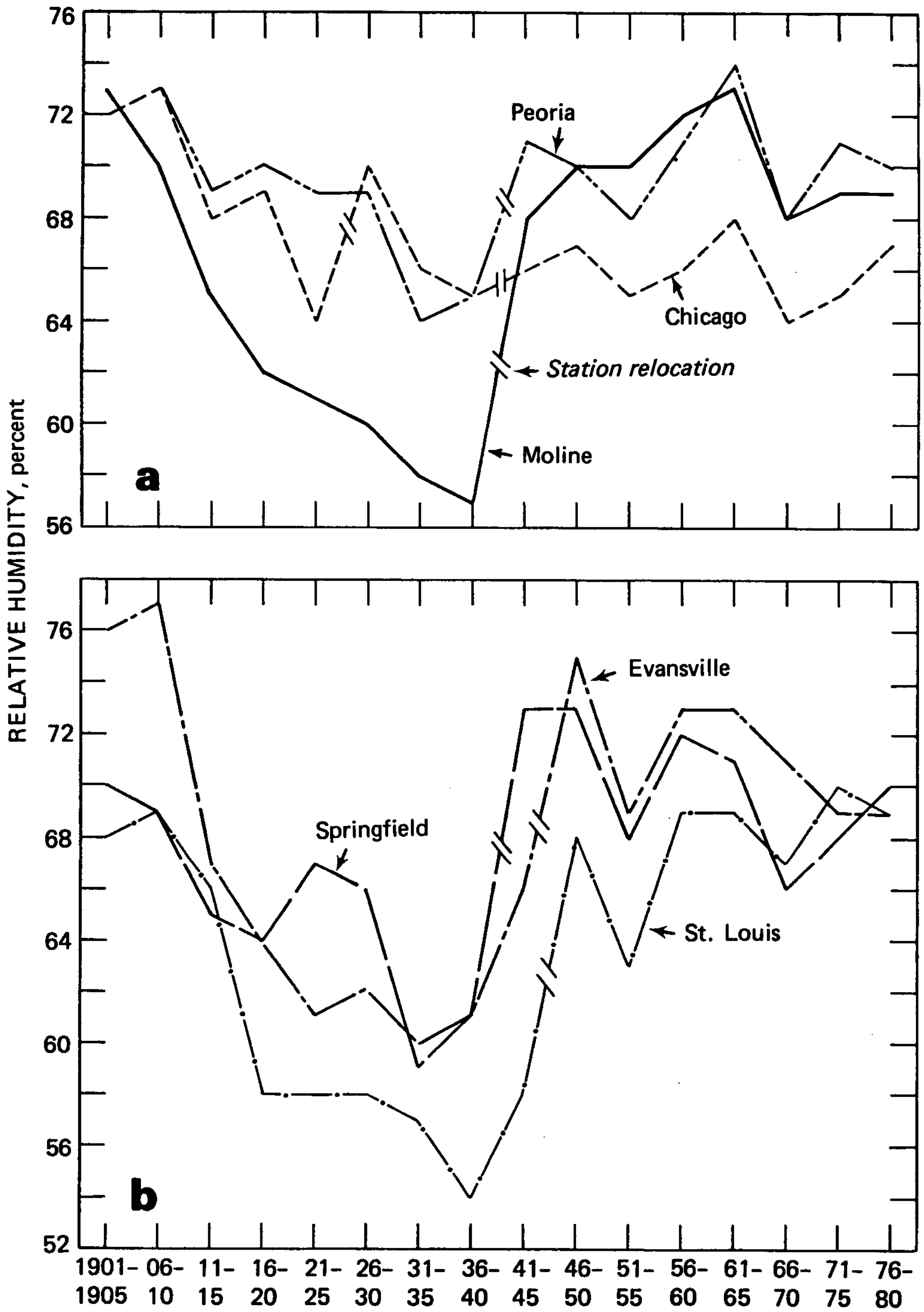


Figure 43. Five-year averages of relative humidity at first-order stations

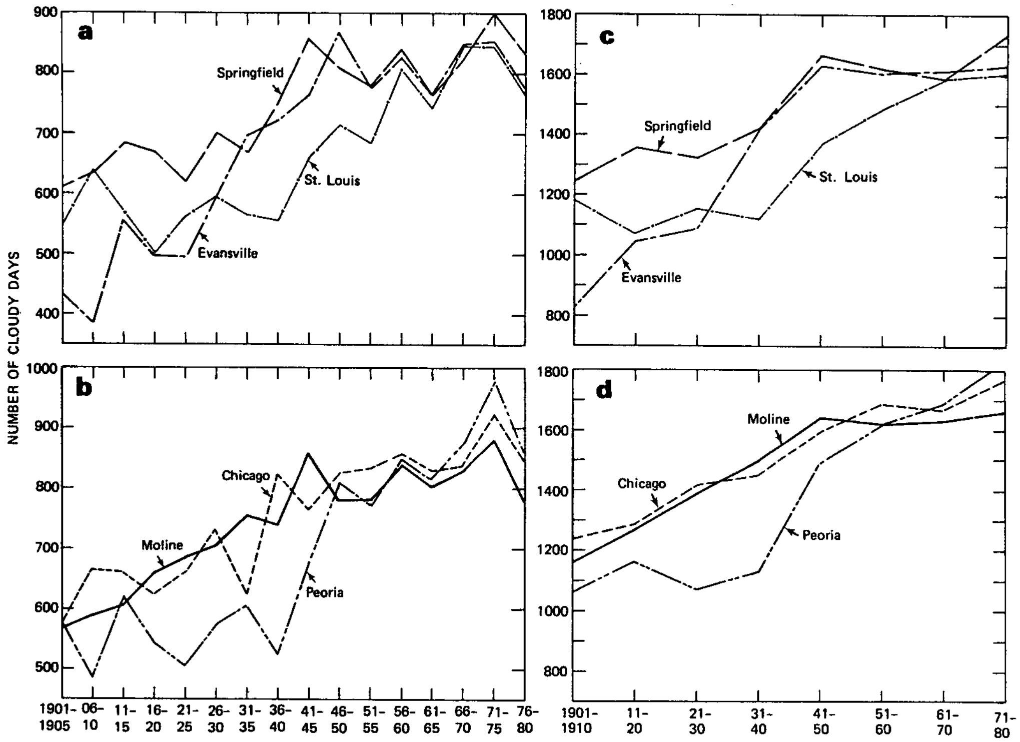


Figure 44. Cloudy days (5-year and 10-year totals) at first-order stations

versely, nocturnal cloud cover, when no solar energy is being received, restricts the terrestrial radiation being reflected out to the atmosphere. Hence, clouds at night generally lead to temperatures warmer than occur on nights with clear skies. Since low temperatures typically occur in the early morning, cloud cover at night can increase minimum temperatures, whereas cloud cover in the daytime tends to reduce or to lower maximum daily temperatures.

Cloud Cover. Figures 44a and b present annual totals for 5-year periods of the number of cloudy days (0.7 or more cloud cover for the day). Figures 44c and d show the 10-year values. The curves of the 6 first-order stations are typified by continuous increases over the 80-year period. However, the increase in cloudy days from 1901 through 1950 at most stations was a more rapid increase than the increase since 1950. Several stations showed a secondary major increase beginning with 1966. This latter increase has been a subject of investigation at the Illinois State Water Survey because of a possible relationship to recent jet-aircraft induced contrails (Changnon, 1981a). At all stations, the lowest decadal value of cloudy days was 1901-1910, and the highest was 1971-1980. Moline and Evansville show very slight increases in cloudy days after they peaked in 1941-1950, whereas Chicago, Peoria, St. Louis, and Springfield all show continued increases after 1950.

The 5-year and 10-year values of partly cloudy days (0.4–0.6 sky cover) are shown in figure 45 for the 6 first-order stations. In general, Moline and St. Louis showed little trend over time. The curves for the other first-order stations show a general decrease in partly cloudy days between 1901 and 1980. The Evansville values for 1901–1930 are much higher than those of the previous years, and the record may be suspect. Potentially, the great in-

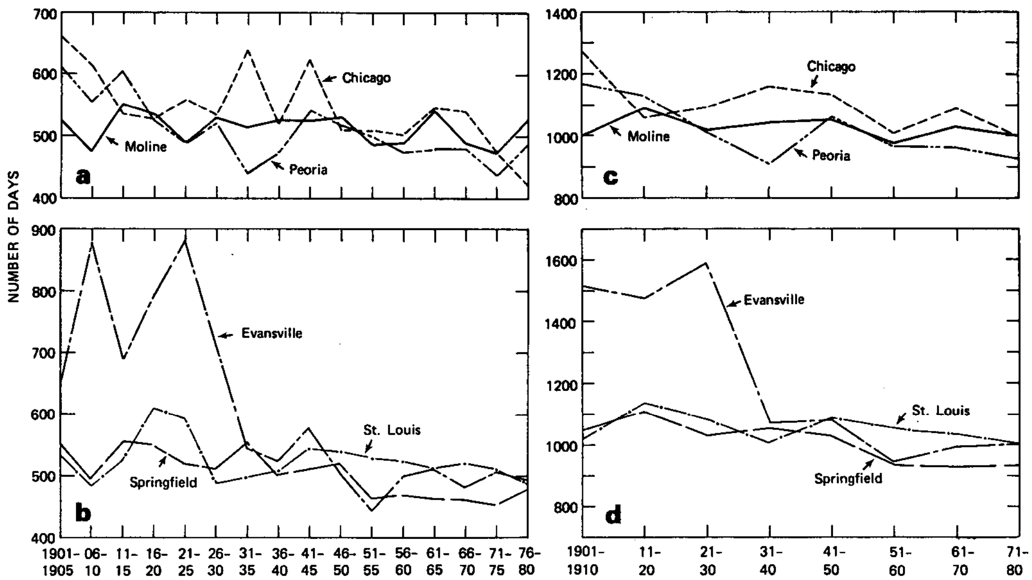


Figure 45. Partly cloudy days (5-year and 10-year totals) at first-order stations

crease shown in cloudy skies (figure 44) was related to only a slight loss in partly cloudy days.

Figure 46 shows the 5-year and 10-year totals for clear days (0 to 0.3 coverage). In many respects, these are the "reverse" of the cloudy day curves. They show erratic variations but a general decrease in the number of clear days for 1901–1945, followed by fluctuations in the 1941–1980 period and a lesser rate of decrease. The values in 1971–1975 were the lowest number of clear days at the Chicago and Peoria stations, whereas values in 1941–1945 or 1946–1950 were the lowest at Springfield, Evansville, and Moline. The annual values of sky cover thus show a major increase in cloudy days and a major decrease in clear days over the 80-year period.

The major shifts in cloud cover were examined further for conditions in the summer and winter seasons. Figures 47a and b present the 10-year values for number of cloudy days in summer. There is a general tendency for increase with time, but there are two other characteristics. The St. Louis, Peoria, and Springfield values show general unchanging frequencies for 1901–1940, followed by a sharp increase. The other three stations, located to the north and east, show a general increase during the 1901–1940 period. All show sharp increases in summer cloudy days during 1941–1950. Thereafter, the stations disagree and show one of two tendencies. The Evansville, Springfield, and Moline data show unchanging or slight decreases in cloudy days after the peak in 1941–1950, but St. Louis, Chicago, and Peoria show a continuing increase in cloudy days up through 1980.

Figures 48a and b show the summer clear day frequencies for 10-year periods. All stations reveal major decreases with time. However, the decade with the lowest values varies between stations. The 1941–1950 values are the lowest at Evansville and Springfield, whereas 1971–1980 are lowest at Peoria, St. Louis, Chicago, and Moline.

The decadal cloudy day values for winter days are shown for 6 first-order stations in figures 49a and b. In general, all stations show increases with time. Four stations including

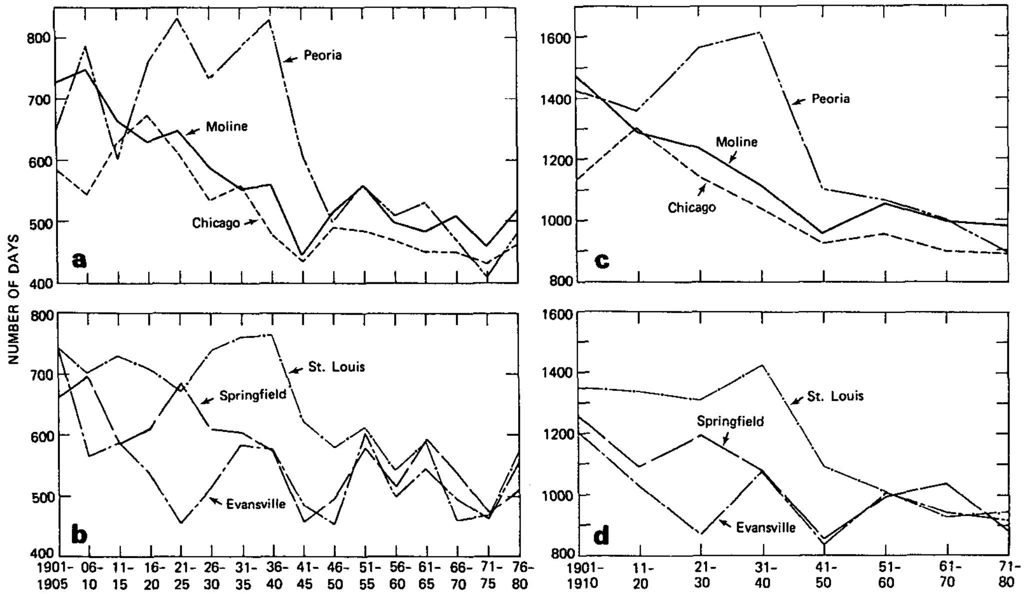


Figure 46. Clear days (5-year and 10-year totals) at first-order stations

Chicago, Moline, Peoria, and Evansville, reach their decadal maximum in 1971–1980; however, St. Louis and Springfield peaked in 1951–1960.

The frequency of clear days in winter (figures 50a and b) shows the general decrease with time. Peoria and Chicago achieved their lowest values in 1971–1980, but the other four stations have their lowest decadal values in 1951–1960 with little change thereafter. Thus, shifts in the annual numbers of cloudy and clear days, shown in figures 44 and 45, are related to increases in cloudy days in both the summer and winter seasons, and to decreases in clear days in these seasons.

Sunshine. Figure 51 presents the 5-year and 10-year values of possible sunshine. These are based on the annual values and averaging them for 5- and 10-year periods. In general, these support the findings from the cloud cover. That is, there has been, at most stations, a general decrease in percent of sunshine, particularly in the northern half of Illinois. There, the Chicago, Moline, and Peoria curves show a general decrease with time. The lowest decadal values achieved were in 1971–1980 at Moline, Peoria, and Springfield. The southern Illinois stations, however, did not show such a marked decrease in sunshine with time. Evansville and St. Louis values, although fluctuating over time, did not show a significant upward or downward trend.

Visibility and Related Air Quality Conditions

Visibility. Temporal changes in visibility and conditions that affect visibility (smoke, haze, and dust) were also examined for potential temporal changes. Visibility measurements at the 6 first-order stations were available from 1951 through 1980. The January average visibility values for 5-year periods are shown in figures 52a and b. The stations show varying

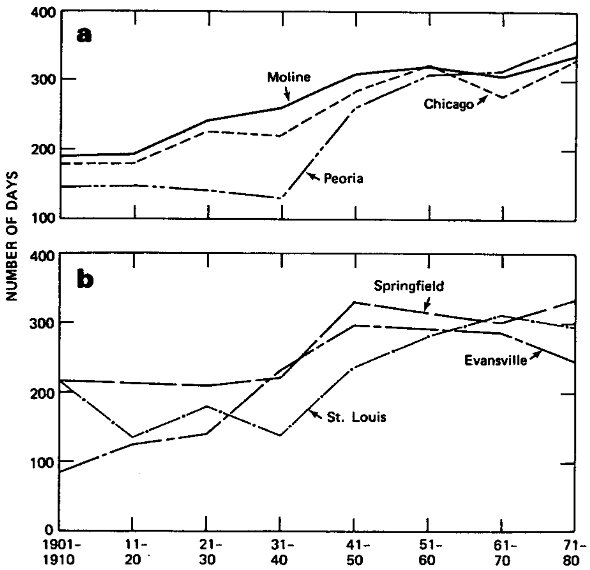


Figure 47. Cloudy days in summer (10-year totals)

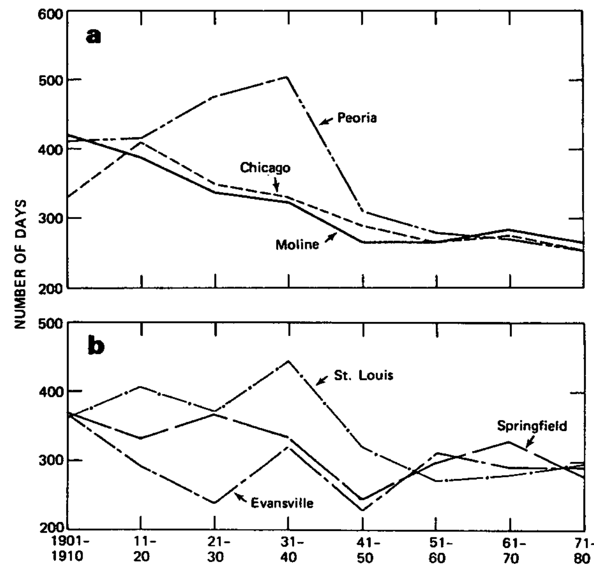


Figure 48. Clear days in summer (10-year totals)

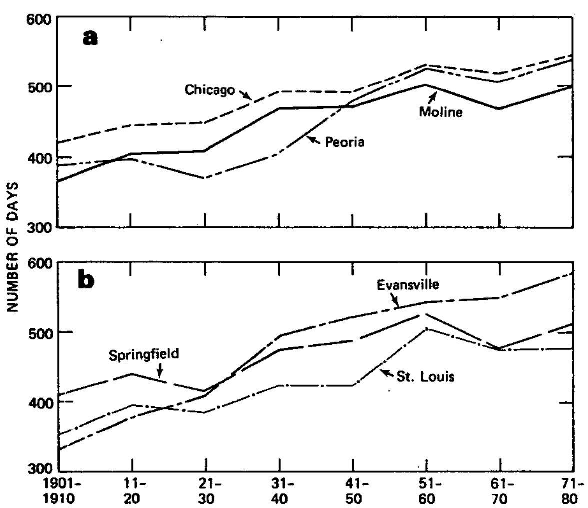


Figure 49. Cloudy days in winter (10-year totals)

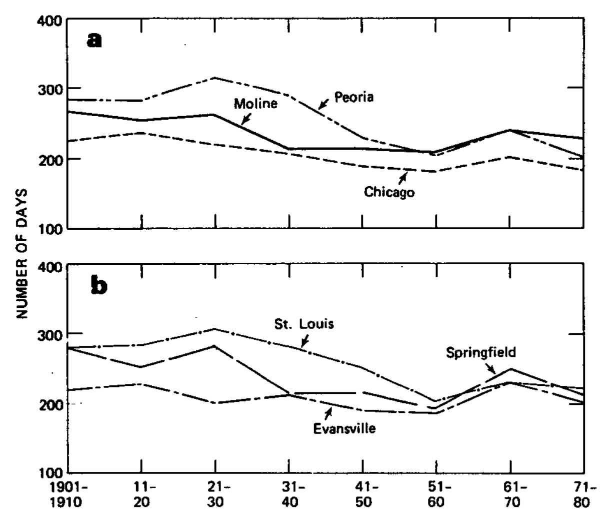


Figure 50. Clear days in winter (10-year totals)

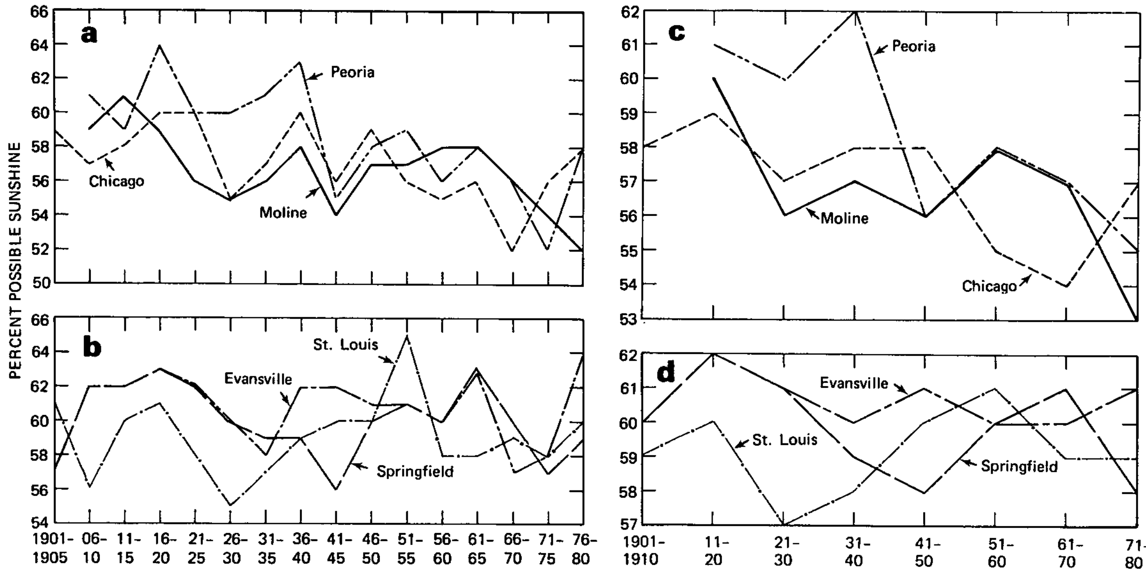


Figure 51. Five-year and 10-year averages of percent of possible sunshine at first-order stations

trends. Visibility generally improved over the 30-year period at Peoria and Chicago (increasing at Chicago from 7.5 miles in 1951–1955 to 8.9 miles in 1976–1980). The Moline and Evansville values do not show distinct upward or downward trends in visibility in January, whereas the St. Louis and Springfield visibility data for January suggest a decrease in visibility. For example, Springfield January values for 1951–1965 averaged around 10 miles, but decreased to less than 9 miles in the most recent 10 years.

Visibilities in July are shown in figures 53a and b. All stations except Chicago show a decrease in average visibilities from 1951 through 1980. Chicago values show a slight decrease with time, with a sudden increase in 1976–1980.

The visibility value for all seasons (annual value) were averaged for 5-year periods at the six first-order stations, and the values are shown in figures 54a and b. Chicago shows unchanging values, except for an increase in visibility in 1976–1980 of about 1 mile. The central Illinois stations including Moline, Peoria, and Springfield show a general decrease in visibility with time through 1975, followed by an increase in 1976–1980. The two southernmost stations, Evansville and St. Louis, show a general temporal decrease in annual visibility, reaching the lowest values in 1976–1980. Whether the shifts in visibility are related to climate or to local conditions is not certain.

Smoke/Haze Days. The frequency of days when smoke or haze were observed in the atmosphere were determined for the 6 first-order stations. The 5-year and 10-year values are shown in figure 55. Except for St. Louis, all stations show relatively low values from 1901 through 1930. Thereafter, and depending on station, sharp increases were shown at all the northern Illinois stations (figure 55a). Sudden increases occurred at Springfield and St. Louis in the 1941–1945 period, with major peaks achieved in 1946–1950 at both stations. Thereafter, general decreases are shown. Comparison of the smoke/haze day curves of the northern Illinois stations (figure 55a) with those for visibility (figure 54a) shows some agreement.

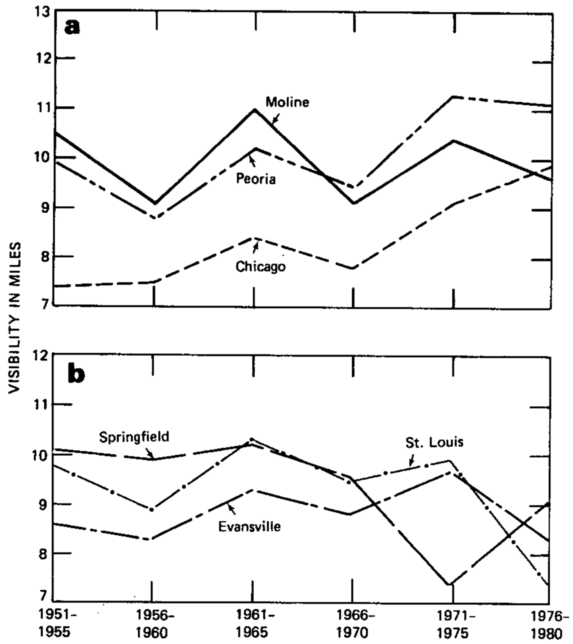


Figure 52. January average visibilities (5-year totals)

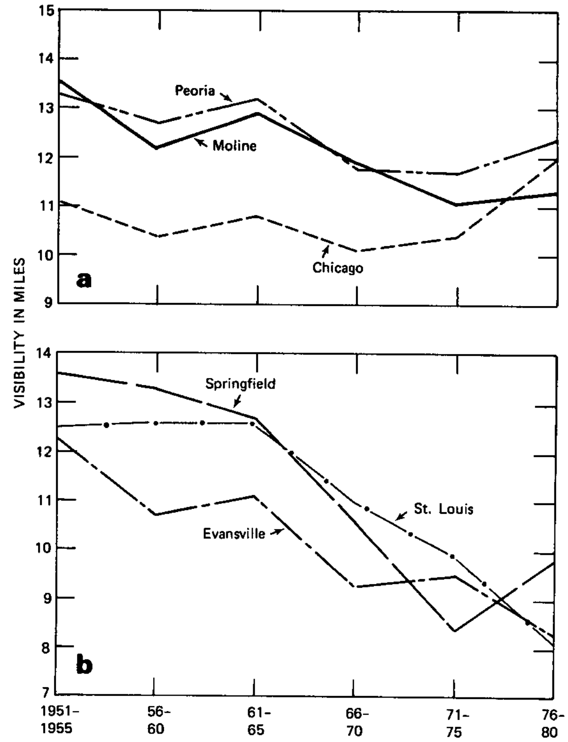


Figure 53. July average visibilities (5-year totals)

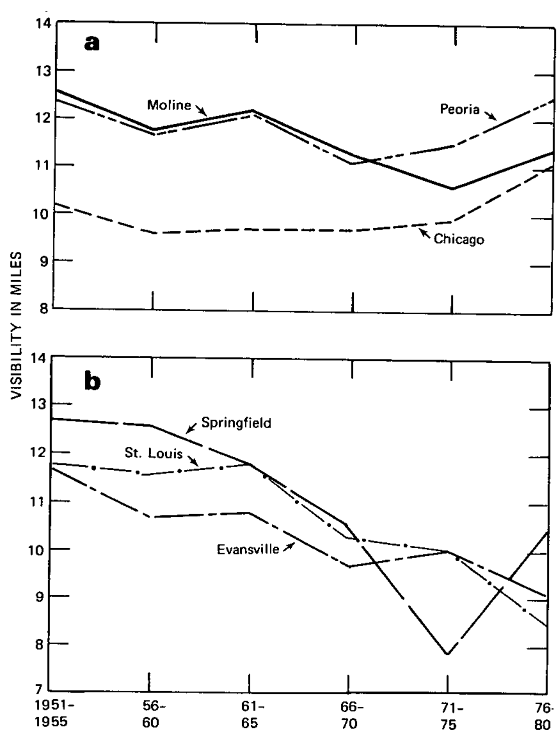


Figure 54. Average annual visibilities (5-year totals)

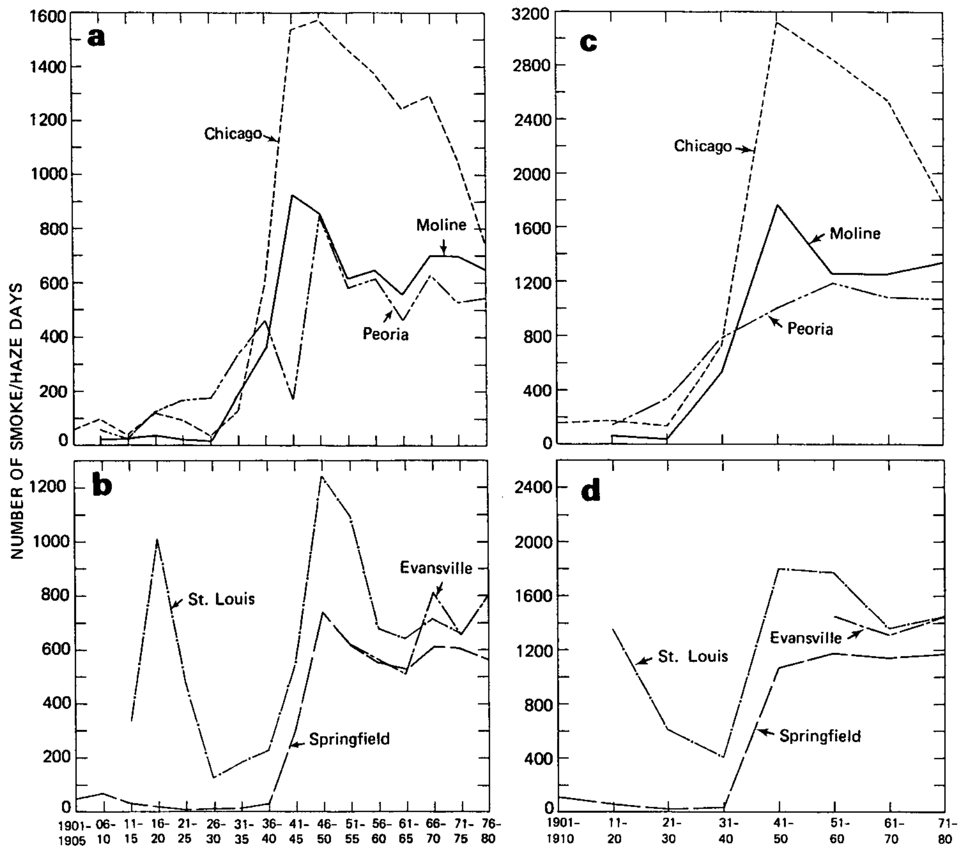


Figure 66. Frequency of days with smoke or haze (5-year and 10-year totals)

However, Chicago showed a major decrease in smoke/haze days during 1951–1980 period without a corresponding major increase in visibility until 1976–1980. A lesser recent decrease in smoke/haze days was evident at Moline and Peoria (figure 55a). Visibility at these two stations increased during 1951–1980.

The visibility of southern Illinois stations (figure 54b) decreased during 195l–1980. However, smoke/haze days for two of these stations (figure 55b) also showed decreases (Springfield and St. Louis). Hence, there was not an agreement; that is, visibility decreased but without an increase in smoke/haze days.

Dust Days. Another factor that can affect visibility and is indicative of certain climatic conditions (very dry and windy) are the number of days when dust is recorded in the atmosphere. The data for 5 first-order stations (Evansville was unavailable) are shown in figures 56a and b. Here, 5-year values are presented for the period of record with data. Dust days for 5-year periods were either 0 or very low in 1901–1930 period at all stations. The 10-year values appear in figures 56c and d. The highest values on record were obtained in the 1930's associated with the major drought of that time. St. Louis reflects high values during the drought period of 1951–1955. Fluctuations and trends found in days with dust in the atmosphere are not reflected in the visibility values shown in figure 54. In the recent 10 years, an uptrend is also exhibited at all stations except Peoria.

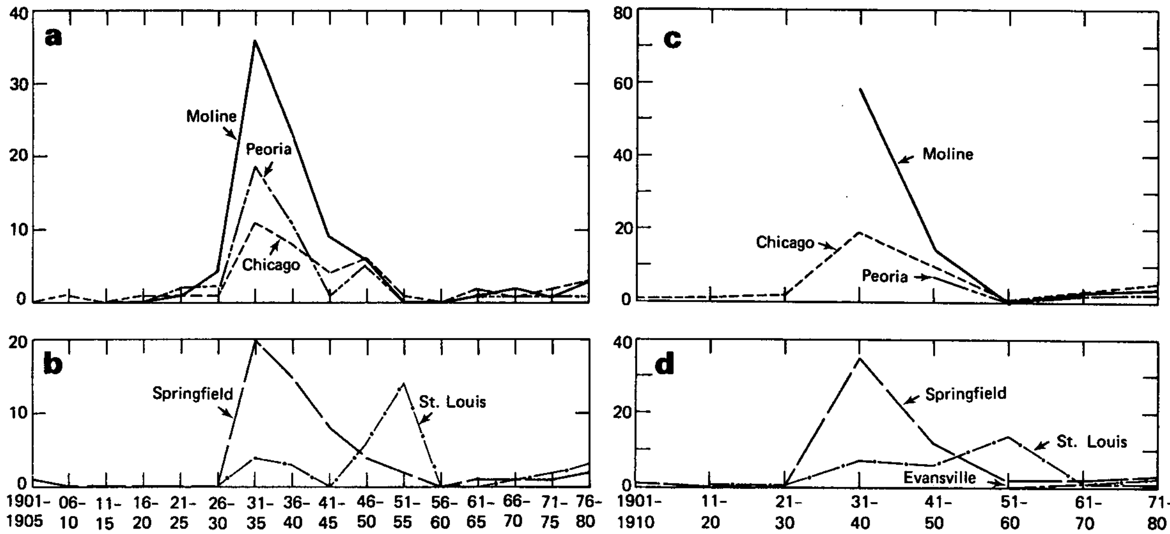


Figure 56. Number of days with dust (5-year and 10-year totals)

Severe Local Storm Conditions

Thunderstorm frequency, as measured by days when thunder occurred at the first-order stations, was also analyzed. The 5-year totals of thunder days at the 6 first-order stations are plotted in figures 57a and b. In general, Chicago and Peoria show little up or down trend for 80 years, but with a minimum beginning in 1946–1950, followed by an increase in thunderstorms beginning in 1966 through present. The Moline values show a general increase of thunderstorm frequency with time but also with the minimum in 1946–1950. There is little long-term trend revealed in the Springfield thunderstorm frequencies, but both Evansville and St. Louis (the two southernmost stations) show a general decrease with time. Basically, the northern Illinois stations exhibit slight upward trends in thunderstorms, whereas the southern stations show downward trends in thunderstorm day frequencies.

An earlier study (Changnon, 1981a) analyzed the frequency of days with high winds This is based on substation qualitative records made by observers of when damaging high winds, generally thought to be days with wind speed in excess of 45 mph, occurred. Quality data for certain substations allowed a reconstruction of statewide values for 1901–1948, and these values are shown in figure 58. In a general way, the statewide frequency of high wind days compares favorably with the thunderstorm data. That is, there is a decrease in the high wind daily frequencies into the late 1920's and early 1930's (see thunderstorm values in figure 57) with a sharp increase in the 1940–1945 period which agrees with the sharp thunderstorm increase at most staitons. Since high wind conditions are produced largely by thunderstorm activity, this agreement is expected.

Tornadoes are another form of severe local storm conditions which were studied for their temporal differences. Changnon (1982) made a study of the temporal fluctuations of tornadoes in Illinois. A major conclusion is that the frequency is highly dependent upon the observational conditions being employed by the National Weather Service. This is reflected (figures 59a and b) in the total number of tornadoes and number of tornado days.

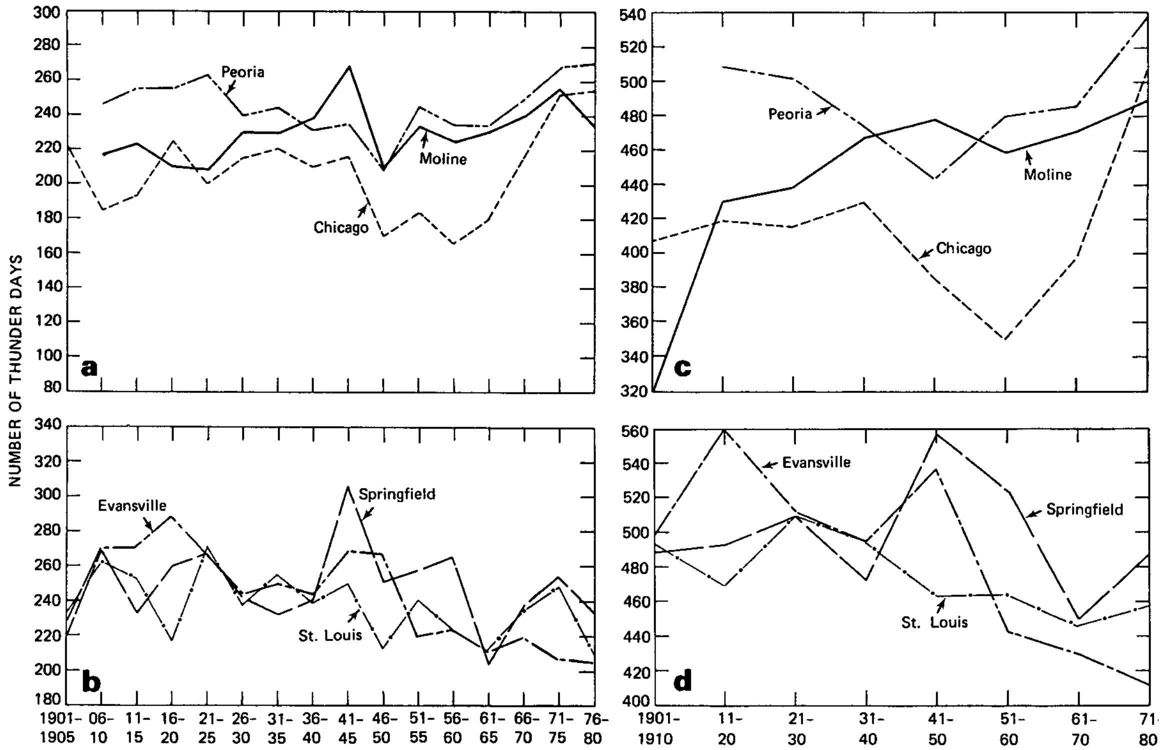


Figure 57. Frequency of thunderstorm days (5-year and 10-year totals)

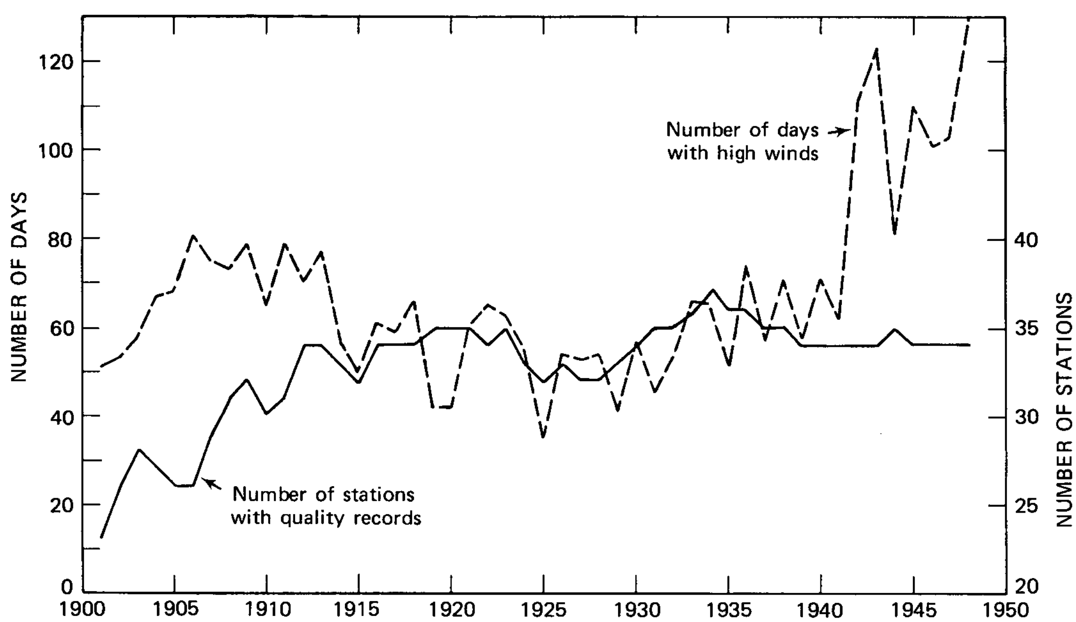


Figure 58. Frequency of days with wind speeds in excess of 45 mph

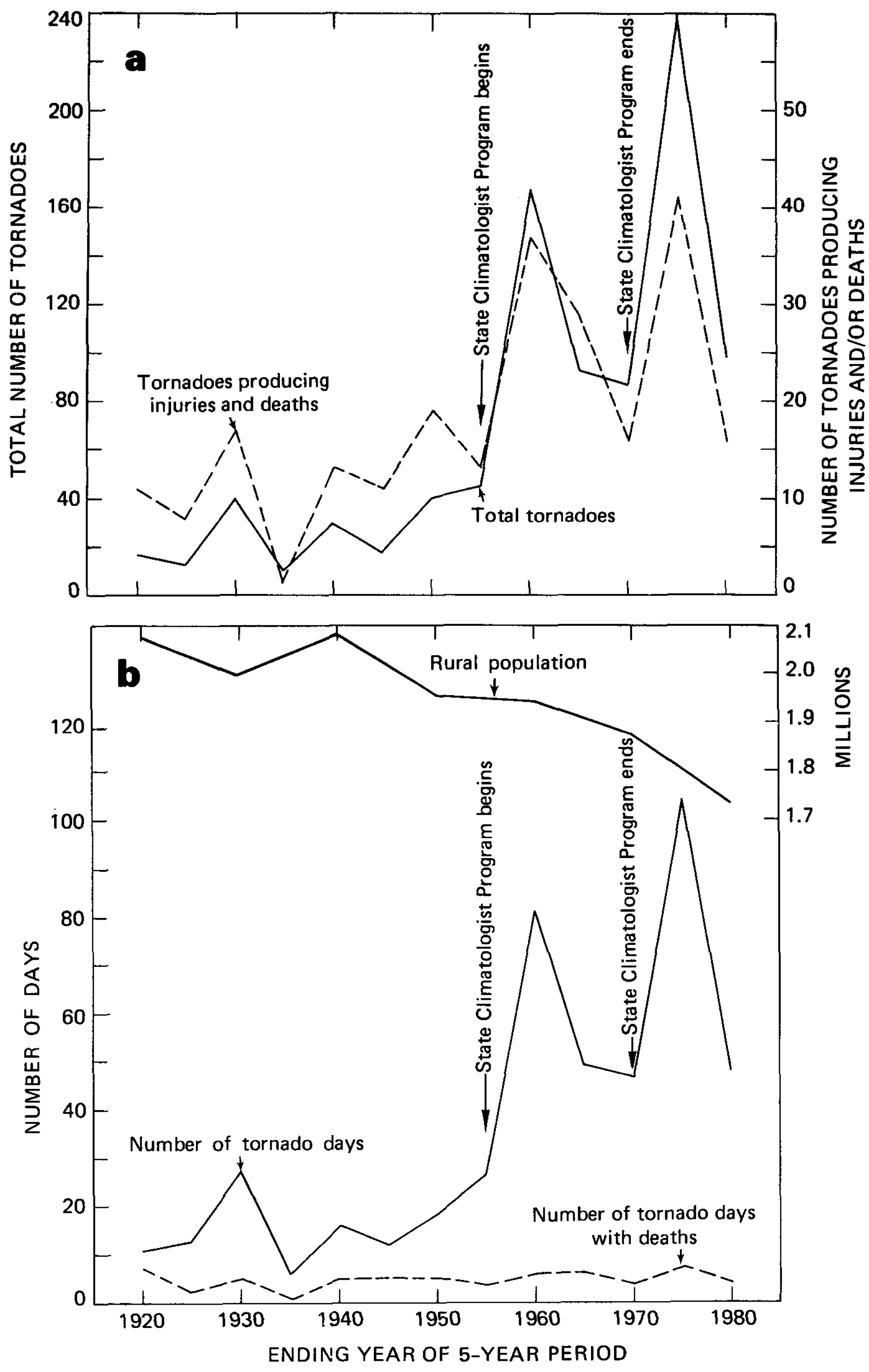


Figure 59. Five-year totals for Illinois of a) tornadoes and tornadoes producing injuries and/or deaths, and b) tornado days and rural population

These show marked increases after programmatic changes in recording procedures during the early 1950's and again in the 1970's. Of greatest importance is the frequency of tornado days when deaths occurred (figure 59b). This shows slight fluctuations but no general trend up or down with time. Slightly more deaths occurred in the 1970's than in any prior decade. However, the tornado statistics for Illinois are generally poor for many climatic studies including temporal trends. Many tornadoes in the early years were not recorded, and conversely, many conditions have been falsely recorded as tornadoes in the 1970's.

Wind Directions

Station relocations (city to airport) occurred at the six first-order stations generally in the 1940–1943 period. However, these are not considered to have produced marked differences in wind directions, except possibly at Chicago. There the lake has a great effect on direction, and winds were measured near the lake in 1901–1942 (1901–1926 in the Loop area, and 1927–1942 at the University of Chicago). Then from 1943-1980 the winds were measured at Midway Airport located 11 miles from the lake. The influence on prevailing directions if any, however, is not apparent except possibly in April (see later text).

January Directions. The prevailing wind direction in each January (1901–1980) was recorded. Their frequencies per decade were used to study possible temporal shifts in January wind directions. Because there are sharp latitudinal differences in Illinois in most winter climate conditions, studies of January wind shifts need to be in the context of statewide as well as point (station) tendencies.

Four directions predominate the 80-year January values at the 6 first-order stations studied. Their frequencies are shown in figure 60a. Westerly winds rank first at Chicago and Moline, second at Peoria, third at Springfield, and fourth at St. Louis and Evansville, revealing a systematic north-to-south shift in the prevalence of west winds in January. Northwest winds show a southwest-to-northeast gradation. They ranked first (most common) at St. Louis; second at Evansville, Springfield, and Moline; and third at Peoria and Chicago. South winds predominate in the south and central sections, ranking most frequent at Evansville, Springfield, and Peoria; second at St. Louis, and fourth at Chicago. Southwest winds rank third at St. Louis and Evansville, and second at Chicago.

If one plots, for each decade, the direction/s most frequent at each station on a map, an organized pattern of shifts is seen. The statewide synopsis of these decadal patterns is presented in table 7.

Table 7. Synopsis of Primary Wind Directions in Each Decade for January in Illinois

Decade	
1901-1910:	NW dominates northern 2/3; S prevails in southern 1/3.
1911-1920:	NW prevails in western 1/3; S is common in southern 2/3; W is common in northern 1/3.
1921-1930:	W prevails in northwest 1/2; S prevails in southeast 1/2 of Illinois.
1931-1940:	W prevails in northeast Illinois; S is common in southern 1/2; SW and NW tie in western Illinois.
1941-1950:	W prevails in northern 1/2; NW and S are common in southern half.
1951-1960:	NW prevails everywhere except at Peoria (S), with diverse other directions.
1961-1970:	WSW common in west 1/2; highly varied directions elsewhere.
1971-1980:	W prevails everywhere except at Evansville (NW), with highly diverse directions everywhere.

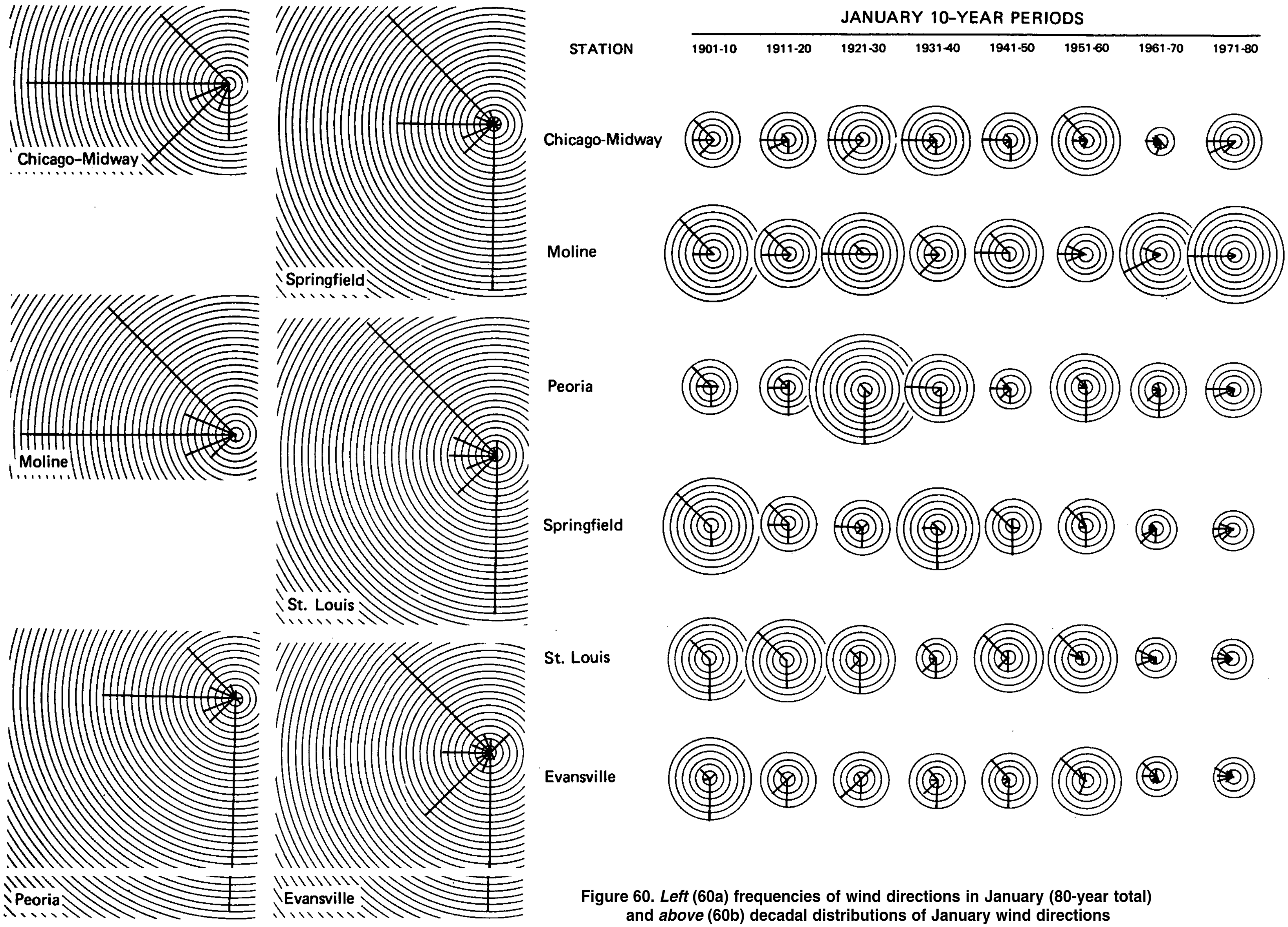


Figure 60. *Left* (60a) frequencies of wind directions in January (80-year total) and *above* (60b) decadal distributions of January wind directions

Review of the prevailing statewide wind conditions (table 7) shows that NW winds in January were particularly prevalent in 1901-1920; disappeared as common in 1921–1930, then reappeared as prevalent winds in western and southern Illinois in 1931–1950, prevailed over the entire state in 1951–1960, and finally disappeared as a common direction in Illinois during the last 20 years. Westerly winds were not a prevailing direction until 1911–1920 and then only in the northern third of Illinois. For three decades (1921–1950) W winds were prevalent in some parts of northern Illinois, disappeared as a common direction anywhere for two decades, then reappeared as prevalent direction most everywhere in 1971–1980. South wind directions prevailed over parts of the southern half or third of the state in each decade from 1901–1950. Thereafter south winds did not prevail. The fourth statewide finding is that January prevailing directions became less one-direction controlled in the last three decades (1951–1980) with much more diversity in wind directions shown, particularly in the 1961–1980 period, than in the 1901–1950 decades.

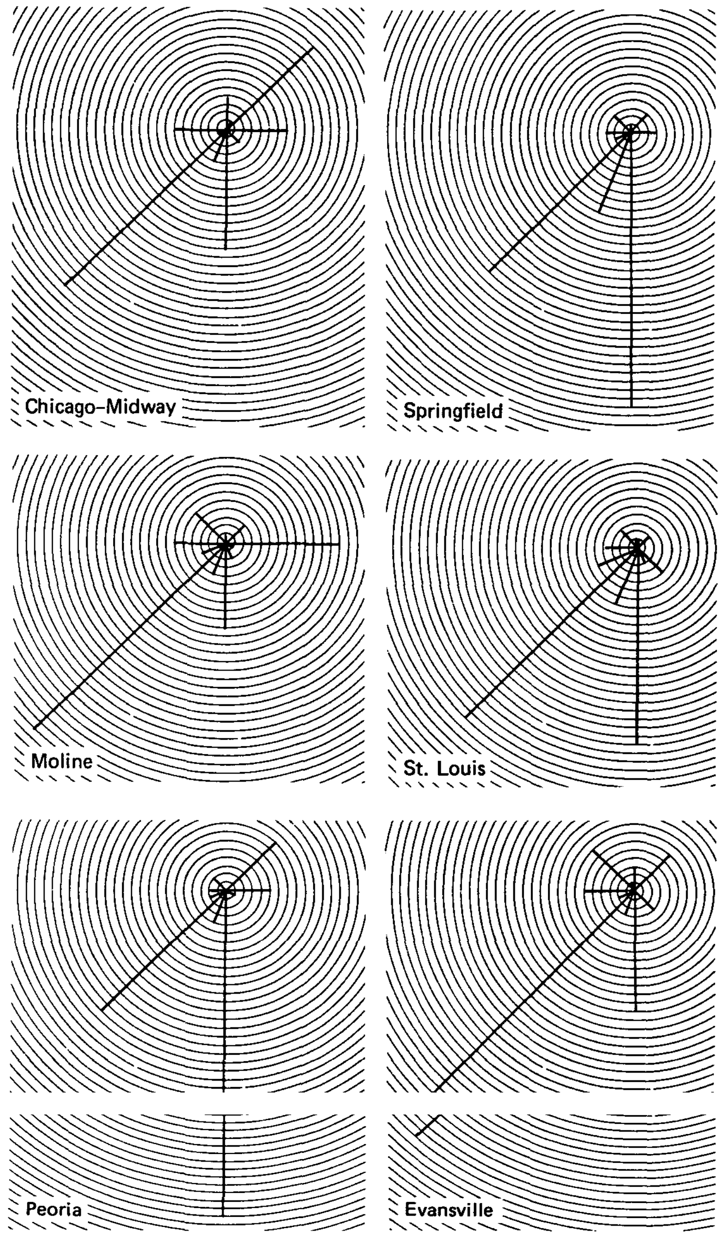
Figure 60b presents the decadal distributions of January wind directions for the six stations. A general summary of these follows. At Chicago NW prevailed for 1901–1940; then westerly for 40 years (until 1950); then NW from 1951–1960; then diverse with W and WSW in 1971–1980. Moline, also in northern Illinois, shows a different temporal pattern from Chicago, although over 80 years W is the most common prevailing direction at both. Northwest prevailed in 1901–1920; W in 1921–1930; then NW and SW tied for 1931–1940; and then westerly for the last 40 years.

Peoria also shows considerable changes with time in January prevailing winds. After being NW in 1901–1910, S winds prevailed in 1911–1930; then W winds prevailed for two decades, with S and other diverse directions in 195l–1980. Further south, Springfield shows a different but marked temporal sequence. After two decades with NW (1901–1920) and W for the 1921–1930 decade, S becomes prevalent for 30 years (1921–1950), with NW common in 1951–1960 and increasing diversity and SW winds in 1961–1980.

St. Louis was dominated by S winds for the first 40 years with NW showing a strong second. From 1941 to 1960 NW was prevalent, followed by a weak preference for W and diversity in directions in 1961–1980. Evansville data reveal that S winds dominated for 50 years, 1901–1950, with NW strong in 1941–1980 although directions are quite diverse in 1961–1980.

July Wind Directions. The prevailing monthly directions in the 80 Julys (1901–1980) for the six first-order stations were used to study temporal shifts. Since geographical differences can be important, the state patterns and frequencies were examined on a decadel basis. Figure 61a presents the 80-year wind frequencies for each station. Calculation of the July directional frequencies reveals that S winds ranked first in central Illinois (Peoria and Springfield), ranked second in the south, and third in the north. SW prevailing winds in July ranked first in both southern and northern Illinois, and second in central Illinois. Northeast winds ranked second or third in northeast Illinois; E winds ranked second at Moline and fourth elsewhere in the northern two-thirds of the state; and SSW July winds ranked third at St. Louis and Springfield.

The temporal shifts in prevailing July winds were examined on a statewide basis (figure 61b). In 1901–1910, SW winds prevailed in the northern two-thirds of Illinois, with S common in the south. In the next decade (1911–1920) a major shift occurred. SW prevailed in the southern third, S in central, and mixed or diverse directions in the northern



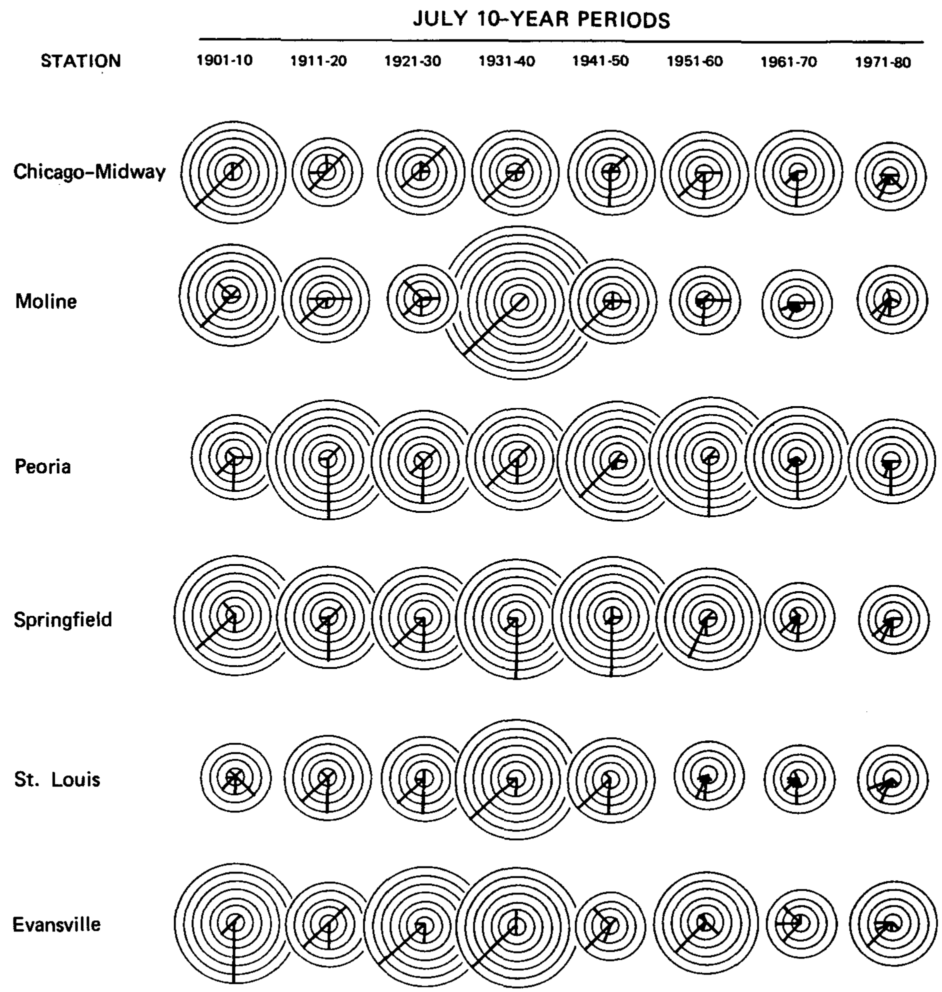


Figure 61. *Left* (61a) frequencies of wind directions in July (80-year total and above (61b) decadal distributions of July wind directions

third. The SW predominance then covered the southern half of the state in 1921–1930 with a diversity of directions to the north. During the next two decades (1931–1950), SW winds in July dominated Illinois with only Springfield showing S as prevailing. In the remaining three decade (1951–1980) July wind directions in southern Illinois became more diverse with a mixture of several southerly directions (SW, SSW, S, and SSE).

Shifts with time in July wind directions were also analyzed for each station. Although shifts between decades were not as major in July as in January, there were shifts with time, as well as spatial differences across the state in several decades, as noted in the above discussion. Chicago (figure 61b) had SW winds prevailing in 1901–1920, although NE winds tied in 1911–1920 and led in 1921–1930. SW winds prevailed again in 1931–1940; then S winds were most common for 30 years (1941–1970), with diverse directions in 1971–1980. Moline had SW winds predominating from 1901 to 1950 except for 1921–1930 when winds were diverse. In recent years (1961–1980) July winds at Moline have been from diverse directions.

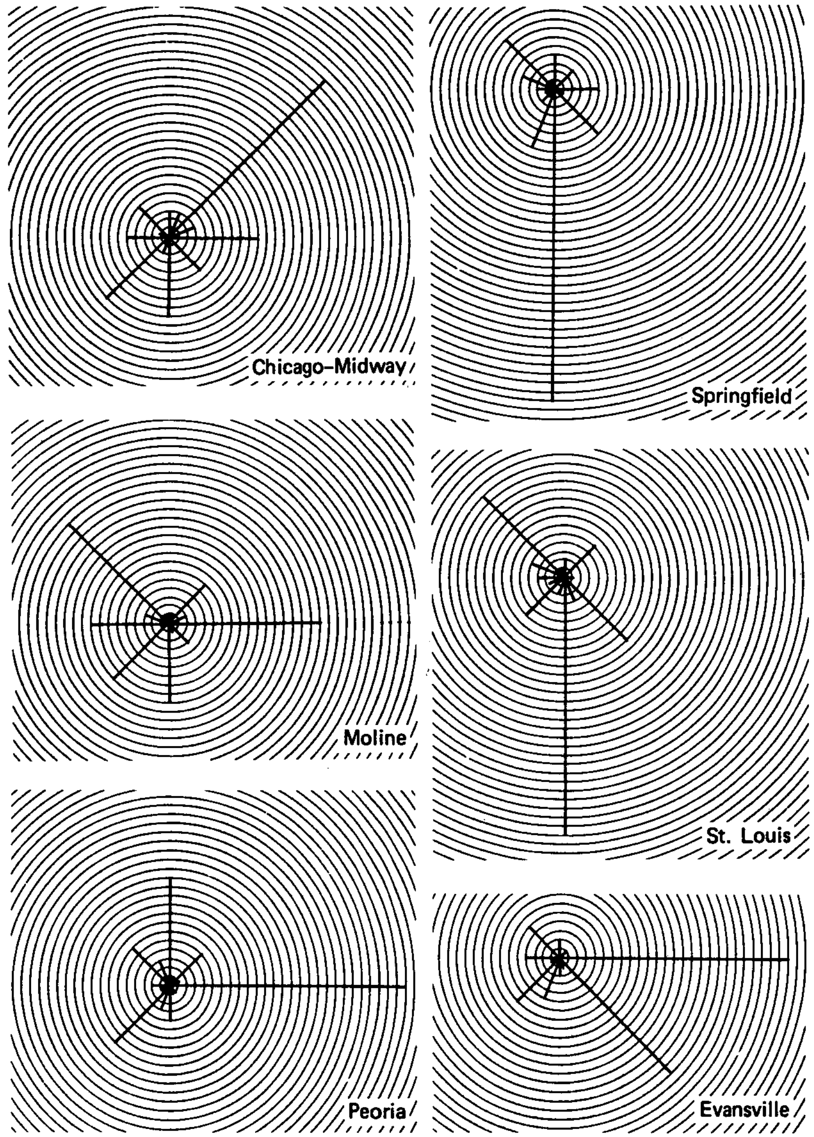
Peoria had S winds prevailing in Julys from 1901–1930, then SW prevailing for 1931–1950, and S prevailing for 1951–1980. Springfield had SW prevailing for one decade (1901–1910), then S for a decade, and SW again in 1921–1930. South prevailed for 20 years (1921–1950) and diverse southerly directions in the last 30 years.

St. Louis had SE prevailing in Julys of 1901–1910, then SW prevailed for 50 years, and diverse directions for the last 30 years. At Evansville, S winds prevailed in 1901–1910, with SW prevailing in the Julys of the last 70 years.

April Wind Directions. In similar fashion, the prevailing wind directions in April were analyzed on a decadal basis. Winds can be diverse across Illinois in April, a major month of climate transition. NW winds ranked second most frequent in the Aprils of 1901–1980 at Moline, Springfield, and St. Louis (figure 62a), and ranked fourth at Evansville. South winds were generally top ranked (most frequent) in the southern two-thirds of Illinois, but ranked only third at Moline and fourth at Chicago. NE winds ranked first in April at Chicago, based on 1901–1980, but are not frequent elsewhere in Illinois. East winds in April prevailed often in the northern half of Illinois (first at Moline and Peoria and second at Chicago). South-southwest winds achieved third rank at Springfield and Evansville, and SW winds ranked in the top four directions at Evansville (second), Chicago (third), and at Moline and St. Louis (fourth).

Temporal shifts in April prevailing directions are revealed in figure 62b. Temporal shifts were minor at the four southernmost stations. They all had S as a prevailing direction in April in most decades. However, there were a few exceptions such as SSW in 1951–1960 at Springfield and Evansville, and SSW (or SW) at these two stations plus Peoria in 1971–1980. The two northernmost stations exhibited greater temporal change. Chicago had NE as the prevailing direction for 1901–1950; then very diverse directions predominated in 1951–1960 and 1971–1980 with S leading in 1961–1970. This may have shifted with the change in location of stations in 1943. Moline also exhibited many directional shifts between decades. NW prevailed in the Aprils of 1901–1910, then E in 1911–1920, S in 1921–1930, and NE in 1931–1940. S and E tied as prevailing directions in 1941-1950, followed by two decades of very diverse directions.

October Wind Directions. The prevailing wind direction in each October was used to study temporal shifts from 1901 to 1980 at the same six stations (figures 63a and b).



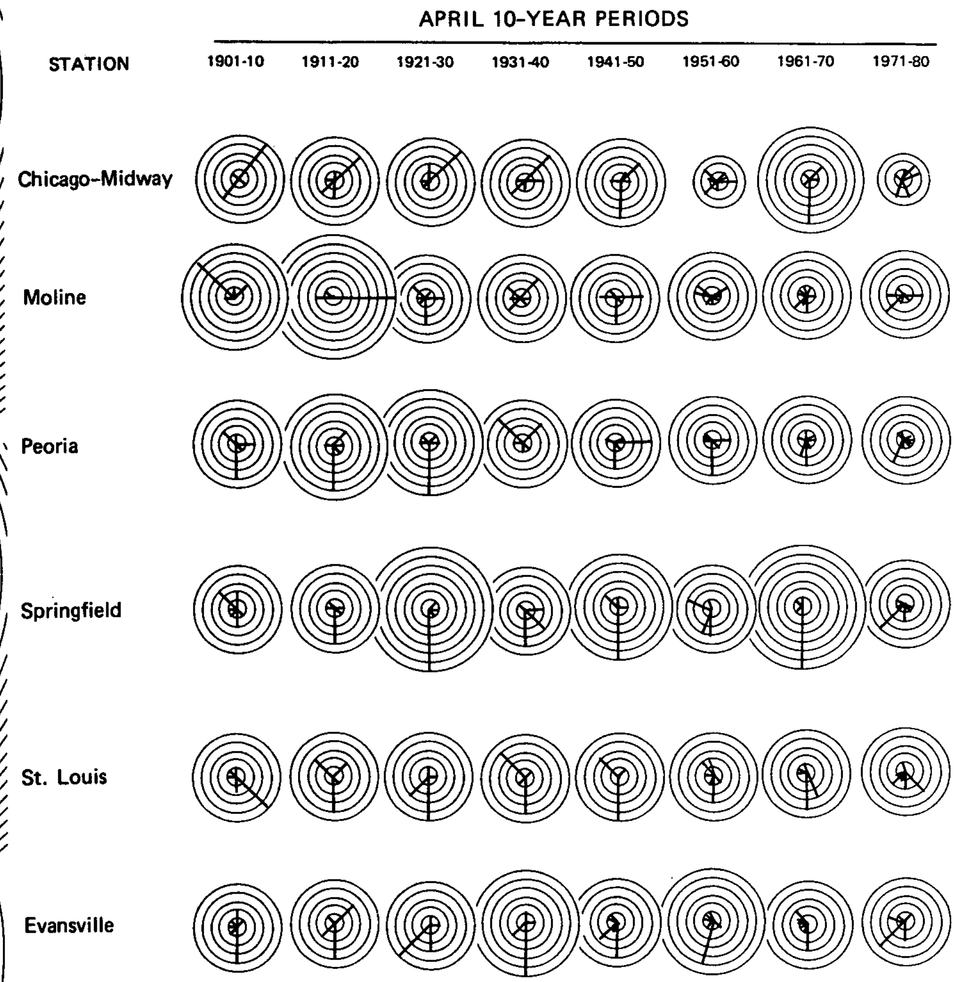
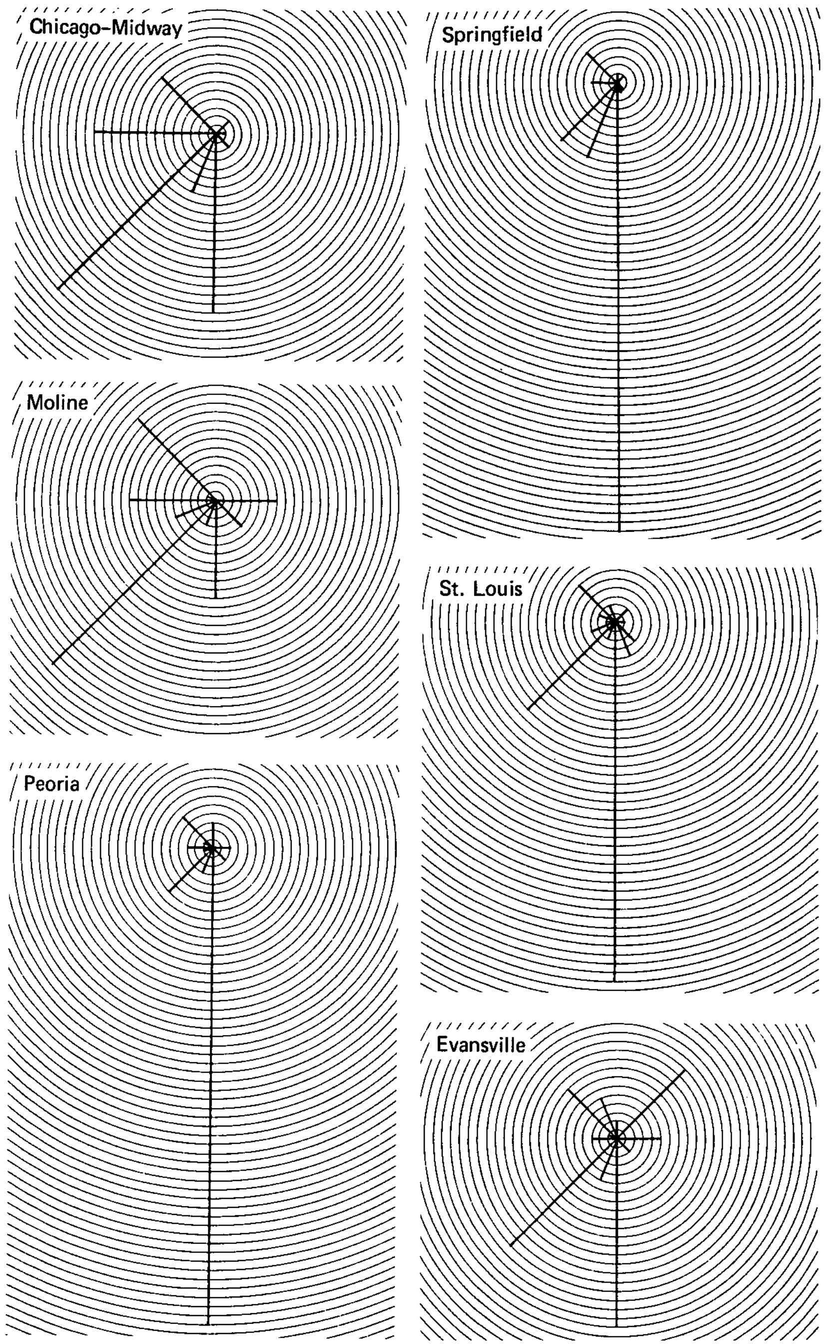


Figure 62. ***Left*** **(62a) frequencies of wind directions in April (80-year total) and above (62b) decadal distributions of April wind directions**



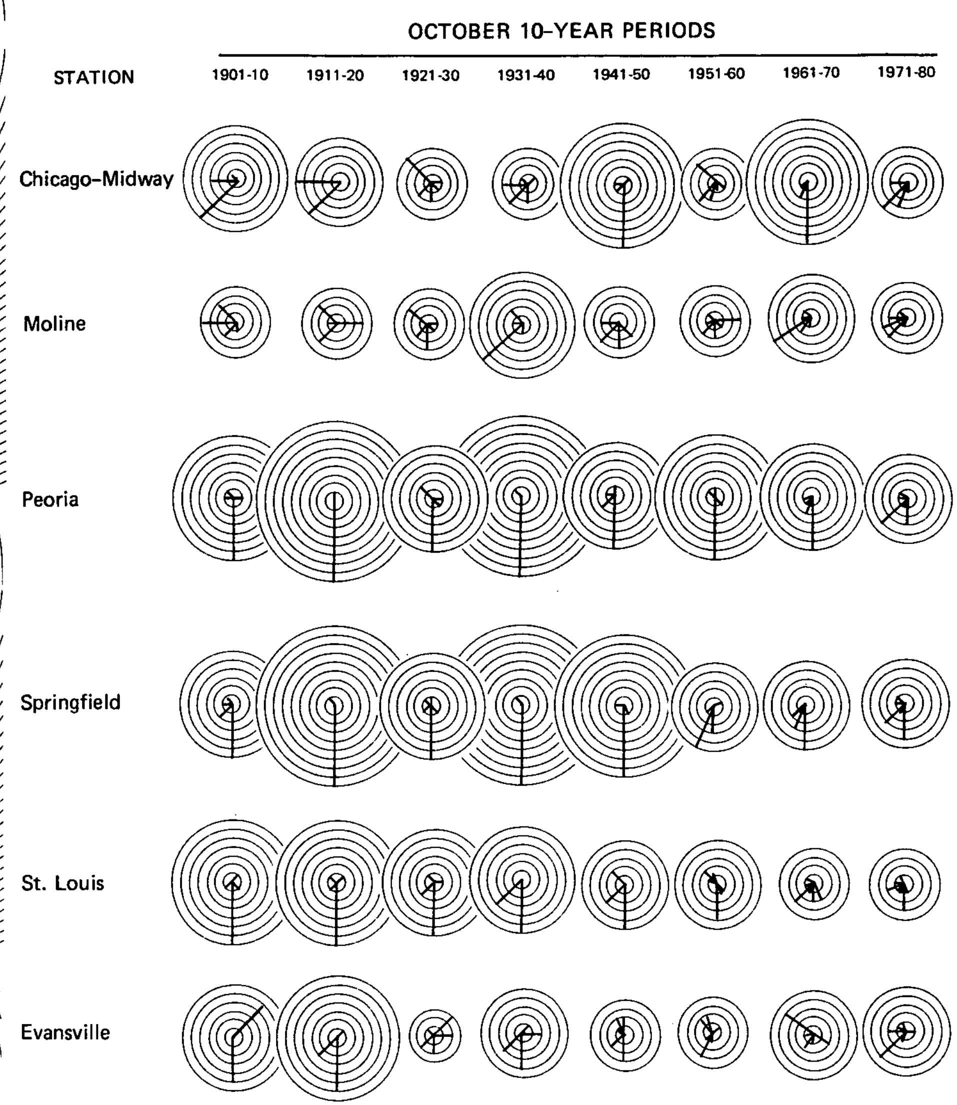


Figure 63. *Left* (63a) frequencies of wind directions in October (80-year total) and *above* (63b) decadal distributions of October wind directions

Prevailing winds in October across Illinois are southerly with SW predominant at Moline and Chicago, and S most frequent at the four more southern stations. Temporal change, as in the April transition season month, was not much at the four southernmost stations. S or SSW was most frequent in every decade at Peoria, Springfield, and St. Louis. At Evansville the only difference was that NE prevailed in 1901–1910 and 1921–1930; otherwise, all decades were S, SSW, or SW.

The two northernmost stations showed somewhat greater variation with time. At Chicago, SW dominated in 1901–1920; then NW in 1921–1930, W and SW in 1931–1940, S in 1941–1950, NW and SW in 1951–1960, S in 1961–1970, and SW in 1971–1980. Moline also showed these shifts that ranged clockwise from S around to NW. In 1901–1910 Moline's Octobers had primarily W directions; then in 1911–1920 a mix of NW, E, and SW, with NW and S equal in 1921–1930. In 1931–1950 SW prevailed in 7 Octobers, with SW and S leading in 1941–1950, diverse winds in 1951–1960, and SW predominant in 1961–1980. Thus, the dominance of NW and W winds occurred in the first 30 years (1901–1930) with S and SW winds dominant in the last 50 years of this century. Basically a similar situation occurred at Chicago.

Wind Speeds

Monthly average wind speeds for four months (January, April, July, and October – to represent the four seasons) were used to study temporal shifts in speeds. The monthly values of 6 first-order stations were averaged for decades.

Critical to this analysis were the sites and heights of the recording anemometers Sites of the stations from 1901 to their shifts to airport sites (done in the late 1930's or 1940's at most locales) were in city centers, and their heights varied between cities. After the moves to the airports, all sites (except Chicago) were rural and similar and remained at the same general heights (26 feet at Peoria, 50 feet at Springfield, Evansville, and Moline). The Chicago station was at 310 feet in the Loop (1901–1926), at 131 feet at the University of Chicago (1926–1942), and moved to Midway Airport in 1942 (36 feet), an airport site that was not rural. The shift from 310 to 131 feet elevations accounts for the major decrease in wind speeds between 1911–1920 and 1921–1930 found in the following graphs (figures 64–67). How these site and elevation shifts affected the various station values is assessed in the following text. Clearly, the shifts had major influences on the wind speeds; hence the analysis was divided into examination of trends during 1901–1930 (pre-shifts) and to 1941–1980 (post-shifts).

January Wind Speeds. The decadal average wind speeds of the 6 stations are shown in figures 64a and b and their dates of shift in station sites are marked.

Marked changes occurred at all stations; note how speeds increased considerably after shifts at Moline, Peoria, and Springfield. The shifts at Chicago (in 1926) and at St. Louis were from high anemometer elevations in city center to lower elevations at airports. The net result was a lowering of average speeds at both locales after 1940 with respect to 1901–1930.

The 1901–1930 January wind speeds at all stations (except St. Louis and Evansville) showed decreases with time. Chicago (figure 63a) went from 16.7 mph in 1901–1910 to 11.8 mph in 1921–1930 (a height-measurement effect), and Peoria from 9.9 to 7.3 mph. St.

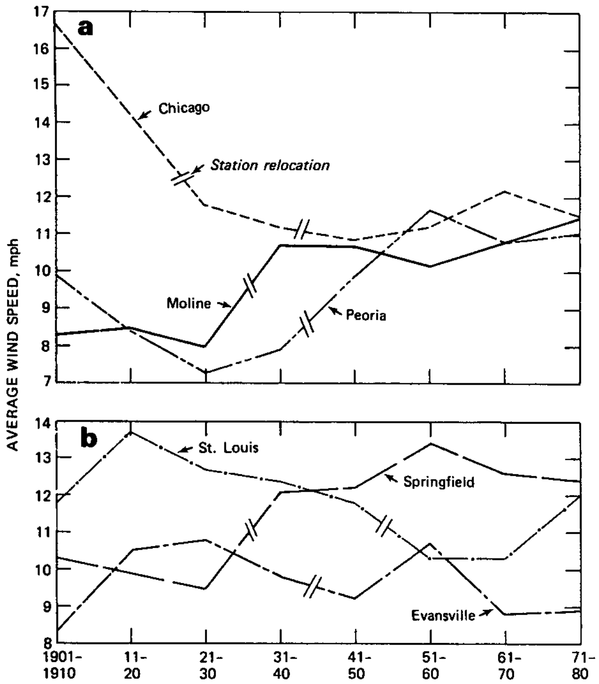


Figure 64. Average January wind speed (10-year totals)

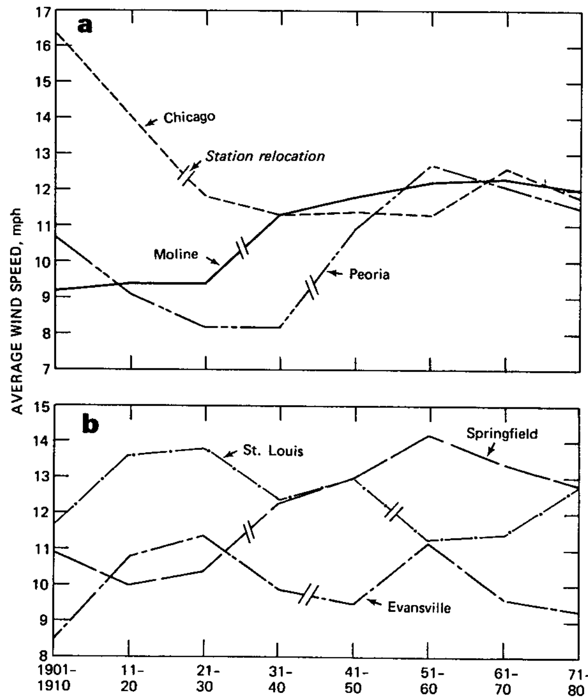


Figure 65. Average April wind speed (10-year totals)

Louis and Evansville, the two southernmost stations showed uptrends from 1901 to 1920, indicating a possible climatic difference. However, at Evansville, winds were measured at 82 feet in 1901–1910, but at 175 feet in 1916–1926, helping explain the increase there. Figure 60 reveals that in this 30-year period, January winds were most common from the south in southern Illinois, but were westerly or northwesterly in the northern two-thirds of Illinois.

The January wind speeds from 1941–1980 were different. The four northernmost stations showed slight uptrends (0.5 to 1.5 mph in 40 years), whereas Evansville and St. Louis showed no trends up or down. In this 40-year period, St. Louis and Evansville had prevailing NW winds for 1941–1960; then the directions were very diverse during 1961–1980. The more northerly stations showed different direction regimes (i.e., Moline showed westerly winds for these four decades), further suggesting a major climatic difference in January wind conditions between the southern third of the state and the northern two-thirds.

April Wind Speeds. The April wind speeds (figures 65a and b) revealed trends similar to those found in January. During the 1901–1930 period, Chicago, Peoria, and Springfield showed decreasing speeds, whereas Moline had a flat trend, and St. Louis and Evansville had uptrends. Figures 62 does not reveal marked directional changes during 1901–1930 at Chicago, Peoria, or Springfield, suggesting the speed decreases were a result of non-climatic conditions such as exposure changes in the business district sites.

In the 1941–1980 period, the data for the four northernmost stations (figure 65) show uptrends, as in January, and St. Louis and Evansville show flat trends. Interestingly, the northern stations revealed directional shifts in 1941–1980 and the southern stations did not. Basically, the northerly stations (Chicago, Moline, and Peoria) had E winds prevailing in

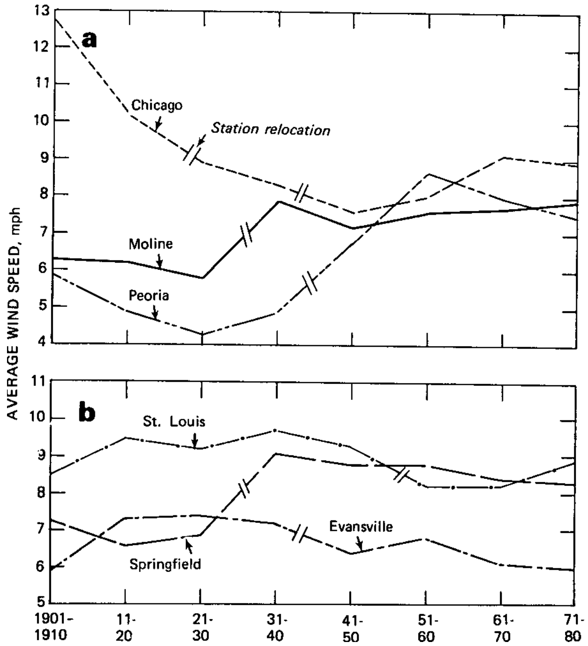


Figure 66. Average July wind speed (10-year totals)

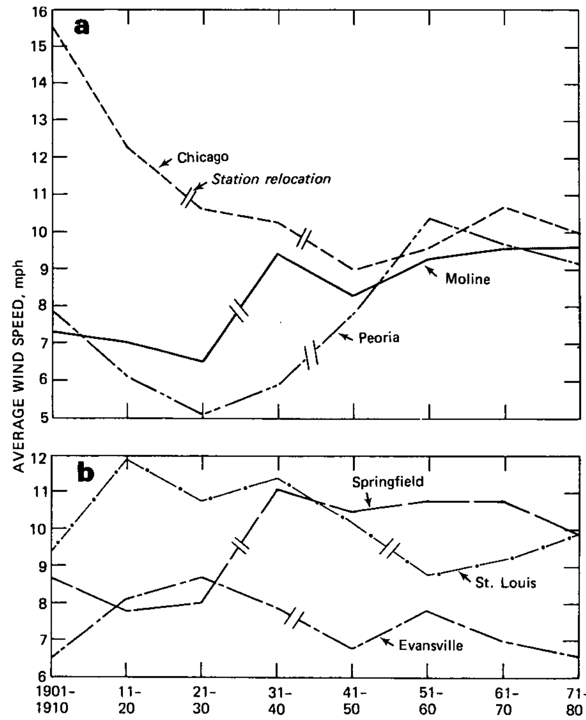


Figure 67. Average October wind speed (10-year totals)

the 1941–1950 period, becoming more frequently southerly later (1961–1980). This may substantiate the north-south difference of the wind elements in Illinois during the 1941–1980 period; that is, unchanging in southern Illinois (in speed or direction), but shifting from E to S and becoming windier in the northern two-thirds of the state.

July Wind Speeds. In certain respects, trends found in the July winds were similar to those found in the January and April winds. As shown in figures 66a and b the 1901–1930 period was characterized by sharp decreases in speed at the five northernmost stations (central and northern Illinois). Conversely, speeds at St. Louis and Evansville increased in this same period, suggesting a sharp north-south difference in wind conditions. At these two southern stations, directions had gone from S in 1901–1910 to SW for 1911–1930 (figure 61).

In the 1941–1980 period, July mean wind speeds at the three northernmost stations (figure 66a) all increased somewhat. In the southern half of Illinois, stations (figure 66b) all showed a decrease in July winds from 1941–1980. During this 40-year period, July wind directions became more diverse, in general, in the southern half of the state (figure 61), with prevailing winds being more southerly in the north.

October Wind Speeds. Wind speed characteristics for October were identical to those in July. In the 1901–1930 period, the four stations in central and northern Illinois (figures 67a and b) showed decreases in speed with time; whereas those in the southern half (St. Louis and Evansville) exhibited average speed increases of about 2 mph in 30 years. The decreases at Chicago (15.5 to 10.6 mph) and Peoria (8.0 to 5.1 mph) were sizable. Wind speeds in 1941–1980 also provided a north-south difference across Illinois. The south, (figure 67b) showed small downward trends over 50 years of about 0.5 mph. The northern stations showed uptrends of about 1 mph in 40 years.

RECENT CHANGES IN CLIMATE VARIABILITY IN ILLINOIS

Introduction

Recent years have had several extreme weather aberrations including the Sahelian droughts in 1971–1972 with subsequent severe droughts in Europe, the central United States, and California. Four record severe winters have occurred in Illinois during 1976–1982, and numerous other major weather anomalies have occurred since 1970.

Much discussion has centered on the question of whether the climate has shifted into a period of greater variability (figure 1). A correct answer to this question is extremely important in Illinois. Agricultural production, water usage, transportation systems, energy consumption, government services, and industrial-commercial activities are very extensive in Illinois and sensitive to climate extremes. Because of a need to furnish a variety of services in "all weather conditions," local and state agencies are among the groups most susceptible to the effects of weather extremes.

Deciding whether the climate has recently become more variable may depend upon the particular weather parameter being investigated. For example, one weather condition, say rainfall, may show little change in variability in a given 20-year period, whereas another condition, say winter temperatures, may show a systematic shift in the same time period. The data on statewide droughts and heavy rainstorms in Illinois (figures 4 and 7) indicate that their frequency and their severity have altered in the 1970's. The 1970's have been abnormal in the frequency of these precipitation aberrations, toward more heavy rain and fewer dry periods (see figures 3 and 4).

Other data define an increase in statewide cloudiness, particularly in summer and fall, since the 1960's. On an annual basis (figures 3 and 24), the 1970's have been relatively cool and wet years in Illinois when they are compared to those of the prior 130 years. Illinois experienced four of its worst winters in the last 100 years in a unique six-year sequence from 1976 through 1982. The summation of these findings suggests the climate of Illinois appears to be trending into a cooler regime than existed in the 1930–1960 period. Thus, certain activities sensitive to extreme cold season conditions, such as the energy and transportation systems, are being seriously affected.

To obtain another answer to the question of a possible change to more extreme weather conditions in Illinois, the monthly temperature and rain precipitation values of the 1970's (1971–1978) were studied. An arbitrary level of extreme events, based on the "outer" 10% of past values, was chosen to make this investigation.

Data and Analysis

Monthly mean temperatures and monthly precipitation values were selected for 21 weather stations evenly distributed across Illinois. Their monthly data for the 1901–1970 period were used to define the upper 10% and the lower 10% of the values achieved in each month and at each station. Thus, the values marking the upper and lower 10% levels were delineated. An example of these values at Mt. Vernon for the 70 June rain values was 6.9 inches for the upper 10% (7 June values were greater), and 1.6 inches for the lower 10% (7 June totals were lower).

The 1971–1978 monthly (temperature and precipitation) values were compared with the present 10% levels based on 1901–1970 experience. The number of times a monthly value exceeded the 10% level was counted for each station, month, and year. For example, in February 1976,15 of the 21 stations had monthly mean temperatures above their individual upper 10% extreme levels, and three stations had precipitation totals above their upper 10% levels.

Our major evaluation of these climatic excesses in the 1971–1978 period concerned the frequency of the station-month aberrations beyond (above or below) the 10% magnitude levels. These were counted on a monthly, seasonal, and annual basis. The number of monthly events above or below the 10% levels were labeled as "extreme events." The likely or expected number in 1971–1978 was determined as follows. In 1971–1978 (8 years) with 21 stations, there were 168 values (8 times 21), and one would expect that 10%, or about 17 values, would equal or exceed the 10% level.

Results

The number of extreme events in Illinois during each month of 1971–1978 is shown in figure 68. Shown in each graph is the average for the number of events in 1971–1978 and the expected extreme value for each month.

The results for extremely "warm" events, those monthly temperatures exceeding the upper 10% of the monthly mean temperatures (as shown in figure 68) indicate more excesses than expected in the spring months with up to 26 occurrences in April and also more in the fall (October-November). In general, however, the number of excesses was not greatly above the expected values. However, many fewer than expected occurred in the winter and summer months. The average based on the 12 monthly values was 16 events which nearly matched the 17 expected on the basis of past records.

A much different result for extremely cold events (months), or those lower than the 10% level, was found. The monthly frequencies (figure 68b) show exceptionally high frequencies of extremely cold monthly events in the July-November period (summer and fall) and in January. Near-expected values came in the February-June period and in December. The monthly average frequency for 1971–1978 was 30 cold events, a value much above the expected frequency of 17 per month. April and December were the only months to have fewer cold events than expected. July, September, October, and January had more than twice the expected number of extremely cold events.

On the precipitation side, we first examine the frequency of extremely dry events (figure 68c). Only April and August had more dry events than expected, and most months had totals much below the expected frequency of 17. Generally, the 1971–1978 period was not one of frequent extreme dry months.

Figure 68d presents the station-month frequency of extremely wet events (those months with totals greater than the upper 10% level). All months except January and the three fall months (September-November) exceeded the expected frequency, with many wet events (twice the expected frequency) in March, August, and December. The generally high frequency of wet extreme events is revealed in the monthly average which was 22, 5 above the expected value.

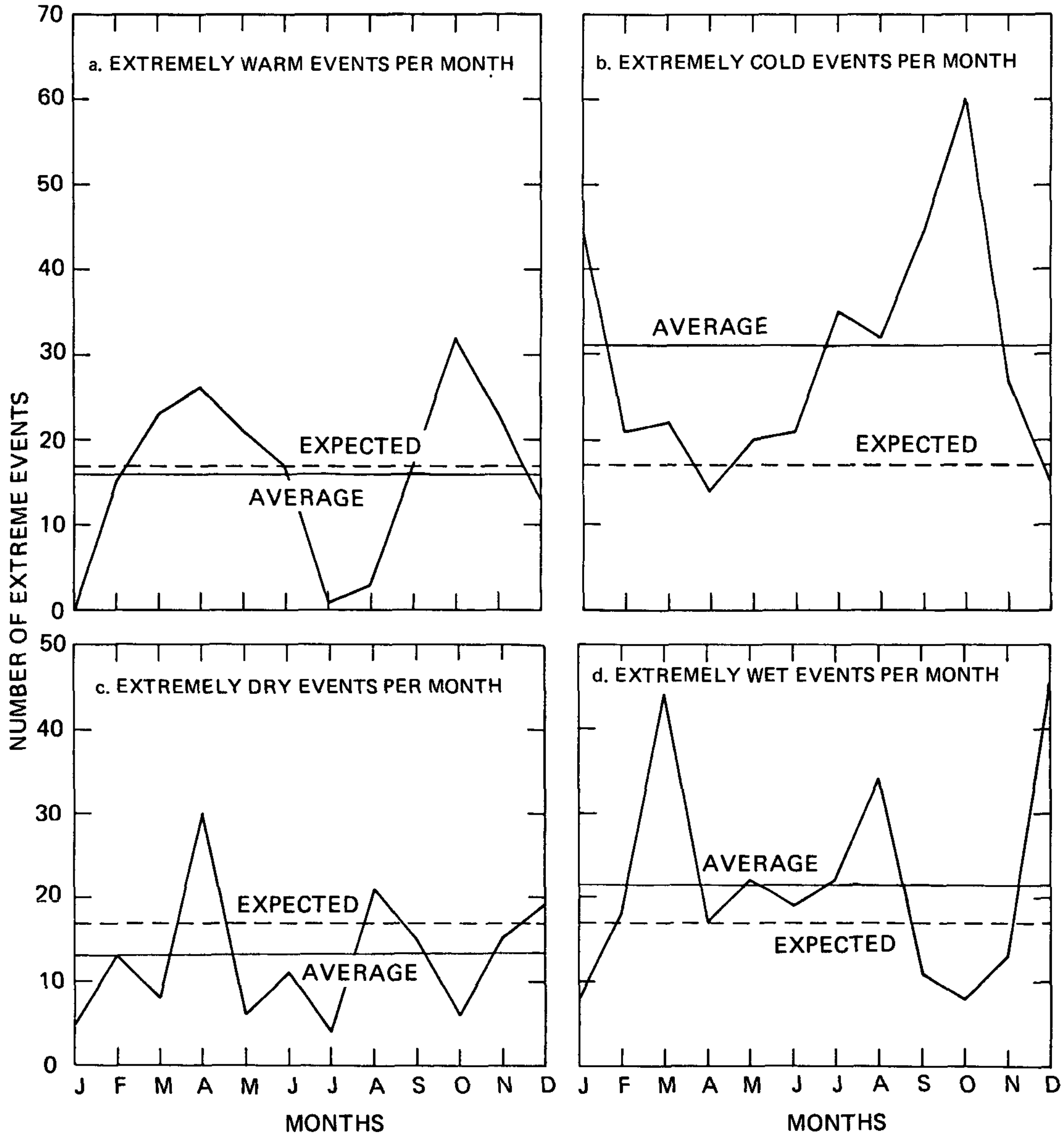


Figure 68. Number of extreme monthly temperature and precipitation events in Illinois during 1971-1978, by month

Table 8 presents the monthly totals including the totals of extremely cold, warm, wet, and dry values. The totals for the cold (+76%) and wet (+29%) extreme events show the tendency for the aberrations to be above expectations in 1971-1978, with near normal frequencies of extremely warm events (-5%) and much below numbers of dry events (-24%).

The previous discussion has pertained to the monthly distributions of the extreme temperature and precipitation station values during the 1971–1978 period. It is equally im-

Table 8. The Number of Extreme Station Monthly Values in Each Month, 1971-1978, at 21 Weather Stations in Illinois*

	Extremely cold	*Extremely warm*	*Extremely wet*	*Extremely dry*
January	45	0	8	5
February	21	15	18	13
March	22	23	44	8
April	14	26	17	30
May	20	21	22	6
June	21	17	19	11
July	35	1	22	4
August	32	3	34	21
September	44	17	11	15
October	60	32	8	6
November	27	23	13	15
December	15	13	45	19
Total	356	191	261	153
Expected	202	202	202	202

**There were 21 stations and 8 years in the study period. Hence, each month had a sample of 168 events (21 stations times 8 years = 168). If the normal number of extreme values occurred, each month in the table would have a value of 17.*

portant to look at temporal distributions of these months by year. Figure 69a presents the annual number of extremely warm events (station months) for each year. The expected number per year is 25. The distribution shown in figure 69 reveals that the expected and average values were nearly the same, suggesting normalcy based on warm events, in agreement with the findings in figure 68. Frequency in 1971, 1973, and 1977 were above expectations, but the other four years were below expectations.

Figure 69b presents the annual values for the number of cold events. The average of 45 per year is much above the expected yearly frequency of 25. The yearly values show an upward trend. All years except 1973, had more extremely cold events than expected based on historical values.

Figure 69c presents the annual values for extremely dry months. Only in 1971 and 1976 (1976 was a year with a moderately severe drought in Illinois) did exceptionally larger numbers of extremely dry months occur. In 1976, the 21 Illinois stations had 51, as opposed to the 25 expected. Most other years had totals that were much below the expected annual number.

Figure 69d presents the annual totals for the number of extremely wet events. This suggests a possible downward trend, but with above expected values in all years except 1976 and 1978.

Summary of Recent Changes

A review of the frequency of extreme monthly temperatures and precipitation in Illinois reveals that the 1971–1978 period was one with more than usual numbers of cold and wet months. All years except 1976 and 1978 had more exceptionally wet months than expected, and all years save 1973 had many more months of cold extremes than expected.

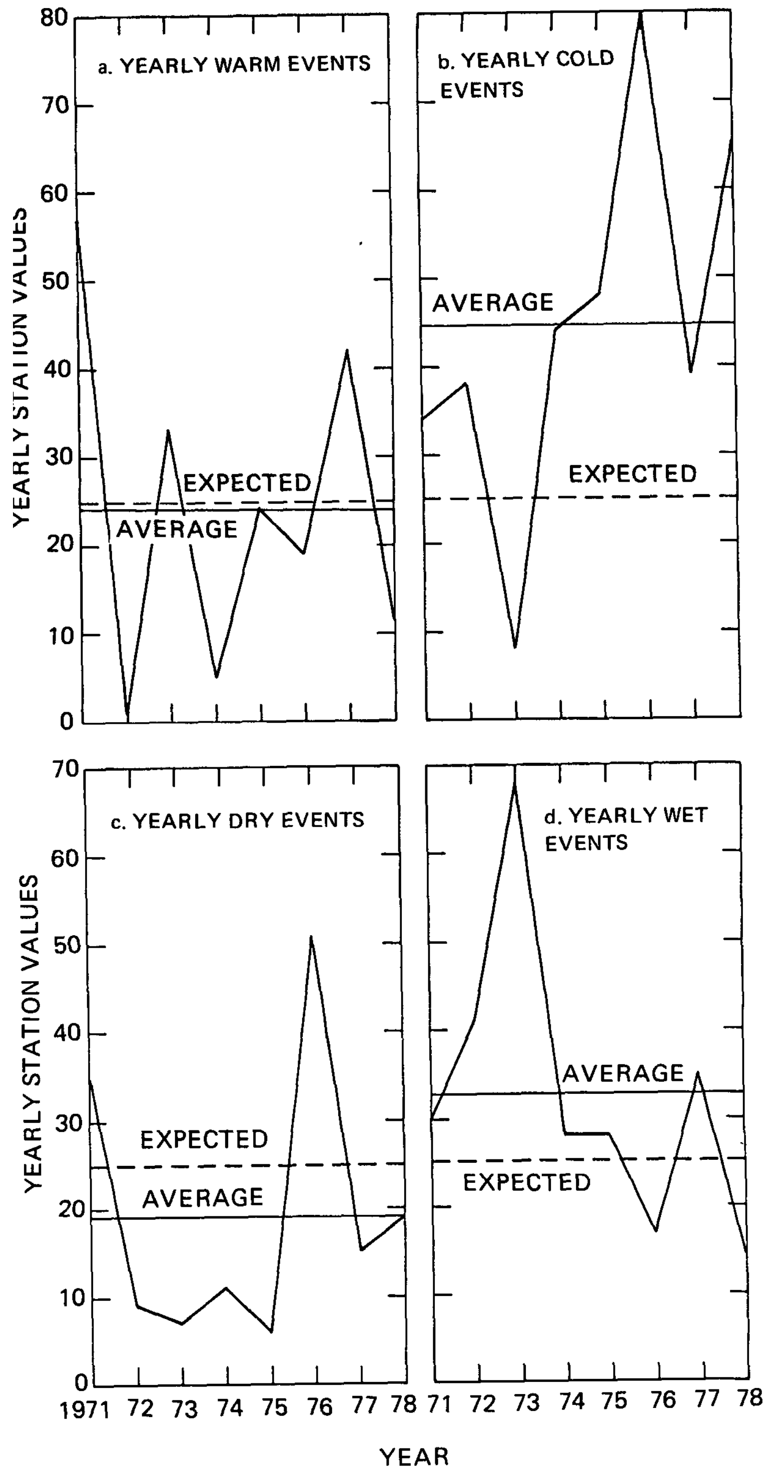


Figure 69. Number of extreme monthly events during each year of 1971-1978 period

However, the temporal distribution of these events suggested a decrease with time in the number of wet extremes, but an increase in the number of cold events with time.

Certain important seasonal characteristics appeared in the monthly distributions. The summers of the 8-year period experienced many extremely cold and wet events. This is fortunate for agriculture which is seriously hurt by hot and/or dry extremes in summer. This also means that demands on energy for air conditioning were not excessive.

The spring seasons were a mixture with slightly more extremely warm events than expected. Within the spring season, there was a great tendency for dry month extremes during April, as opposed to many wet months during March, with May generally normal in every respect. This situation was also generally favorable for agriculture.

The winter season did not reveal any consistency. December experienced many extremely wet events, whereas January had many cold extremes but with few precipitation extremes. The large number of cold Januarys, and increasing frequency of cold months (figure 69) have seriously impacted on heating requirements, on transportation, and on government related services.

Of interest is the fact that the high frequency of cold extremes occurred largely in the summer-fall months, a period when increased cloudiness has been noted in Illinois (see figure 47a). One Water Survey study noted the influence of jet-produced contrails as a cause of this additional cloudiness (Changnon, 1982). Illinois is now experiencing more clouds and less sunshine than at any other time since weather records began in 1900.

A primary question being asked in Illinois is whether the 1971–1978 period was one of greater temperature and precipitation extremes in Illinois. Basically, the answer is "yes" for temperatures, but "no" for precipitation.

During the 8-year study period, there were 547 extreme monthly temperature events measured at 21 Illinois weather stations. A normal 8-year period would have 404 events. This represents a 35% greater frequency of extreme temperature events. These excesses were largely due to extremely cold months since the extremely warm events totaled 191, 11 less than expected.

On the precipitation side, the 1971–1978 period was essentially near normal with regard to total number of monthly precipitation extremes. The total station-month extremes was 414, only 10 above the expected 404. There were, however, 29% more extremely wet months than expected, but 25 fewer extremely dry months. Other studies of droughts and extremely heavy rainstorms also suggest that the recent years were exceptionally wet, but not excessively dry.

SUMMARY

The data for most climatic conditions in Illinois during the 1901–1980 period reveal moderate to large fluctuations with time, and in many cases notable trends over part or the entire 80-year period. There can be no doubt that the climate of Illinois has fluctuated considerably over the past 80 years. This is not unexpected, but for the first time the results in this document provide a comprehensive description of the types and amounts of fluctuations in a diverse number of weather conditions. There has been no attempt herein to test statistically the significance of the shifts in variability or trends. The major purpose has been to display the historical records, to carefully evaluate them as to quality through selection of stations, and to allow the user to make an assessment of the changes and their importance. All the data portrayed in this report are located at the Illinois State Water Survey and can be obtained there for further studies.

Research at the Illinois State Water Survey (Lamb and Changnon, 1981; Neill, 1981) has shown that conditions in the most recent 5 to 20 years are the best estimate of conditions in the next few years, defined as 1 up to at least 5 years. Thus, the climatic conditions, including their trends, of the last 10 to 20 years are important as indicators of the climate conditions likely during the next few years. Therefore, the material summarized here focuses on conditions during the last 10 to 20 years (196l–1980). These are basically compared to conditions typical in the earlier 60 years of this 20th Century.

The recent precipitation data, in almost all respects, reveal a period of relatively wet conditions. The 196l–1980 period has had relatively heavy annual precipitation, more days of precipitation at all levels (ranging from 0.01 inch up to more than 2 inches, more snowfall and deeper snow depths, and more freezing rain days than earlier years. The tendency to a wetter climate was found in all four seasons. Other evidence of the wetter regime are the recent reduction in droughts and a lower number of relatively dry areas in Illinois in summer. Variability of monthly rainfall in recent years shows more wet months and fewer dry months than prior records would predict.

Temperatures in the last 20 years also show a marked trend, one toward colder conditions. We find recent and sharp downward trends in annual statewide temperatures, in winter temperatures, and in summer temperatures. The decrease in temperatures is more obvious in the maximum than in the minimum temperature values, and the colder regime is reflected in fewer extremely warm days and many more extremely cold days. The net effect of greater reduction in maximum temperatures than in minimum values is to narrow the difference. The average maximum and minimum temperatures have become closer together. An interesting aspect of the recent 20-year temperature conditions is the lack of much change from prior years in the spring and fall seasonal temperatures. The trend toward lower temperatures is found only in the extreme seasons, winter and summer. The slightly warmer springs in the last 25 years have made the average date of last freeze occur slightly earlier than before, producing a slight increase in the growing season length during the last 20 years.

The studies of cloud cover and sunshine support, in general, the temperature and precipitation shifts since 1960. This has been a period of increased cloudiness and decreased sunshine and clear days. These shifts have been particularly marked in the summer and winter seasons. The results agree with the cooler and wetter conditions.

There are no apparent changes in relative humidity in the last 20 years. Visibilities have generally decreased, particularly in the summer. The frequencies of days with smoke and haze have decreased, probably reflecting the national environmental protection controls, but the number of days with dust in the atmosphere has increased as a result of changing agricultural practices.

Investigations of severe local storms show mixed regional results. Thunderstorms have increased recently in the northern half of Illinois, but they have decreased in the southern half of the state. There is a slight increase in tornado frequencies in the last 20 years, but no apparent increase in hail days in the state. The differing regional trends in thunderstorms may explain a lack of statewide change in hail.

Analysis of wind conditions shows recent shifts in the wind directions during January and July, becoming more westerly in January and more southerly in July, and also with more diverse directions during the last 20 years. There has been little change in wind directions in April and October. Wind speeds have increased the last 20 years in all seasons in northern Illinois and have increased in all seasons in southern Illinois except fall.

In summary, there is a rather strong indication that the climate of the two extreme seasons, winter and summer, has changed most drastically in the last 20 years. This includes more precipitation with more rain and snowfall and fewer droughts; lower temperatures particularly in winter and reflected most in maximum temperatures in summer and winter; more cloudy days and less sunshine particularly in summer and winter; and notable shifts in wind directions and speed in winter and summer months. In contrast, the climate changes in the spring and fall, or transition seasons, have been much less. These two seasons have become slightly wetter, but have not experienced warmer or colder temperatures in contrast to earlier years. Very little change in wind directions or speeds have been noted in these two seasons.

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