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Temporal Changes In The Climate Of Urbana-Champaign And Illinois

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INTRODUCTION

The Centennial of the Urbana (often labeled Morrow Plots) Weather Station on August 17, 1988, led to an assessment of the value of the data from this station, as well as that of other long-term weather stations in Illinois, to reveal how these unique records allow one to reconstruct and interpret the temporal fluctuations in the climate of Illinois over the past 50 to 150 years. An in-depth description of the temporal climate fluctuations during 1901-1980 across the state is available (Changnon, 1984). This paper addresses how the careful maintenance of long-term weather observations at Urbana and elsewhere by volunteer weather observers has allowed the study of climate change. Examples are presented to show how careful analysis of historical weather data at Urbana are essential to detecting important information. Information about the Urbana station, including station relocations and instrumentation since 1888, must be used since these factors affect the interpretation of the historical data and presumed climate fluctuations.

Ironically, on August 17, 1988, the date celebrating 100 years of 3,675 daily weather observations in Urbana, nature provided two record events: a record high temperature for August 17 of 101°F (breaking the record high established in 1913), and the date became the 58th day of the summer of 1988 with temperatures at or above 90°F, another new record for Urbana (and most of Illinois).

The commitment to collect weather data in Urbana and at over 240 other weather stations in Illinois is based largely on volunteer labor by "cooperative weather observers" of the National Weather Service. These observers have provided thousands of hours of effort to make weather observations, to record them, and to mail them to the National Archives. It is these data from Urbana and other comparable stations around Illinois (and the nation) that now provide us with the ability to describe and monitor the climate of Urbana, of Illinois, and of the United States. This capability has taken on new value as we enter an era where

scientists believe the future climate will change dramatically over the next 30 to 70 years throughout the world. Our ability to monitor, detect, and react to these presumed changes is no better than the quality of our climate data from this network of volunteer observers.

URBANA WEATHER STATION AND INDICATIONS OF CLIMATE FLUCTUATIONS

The first 75 years of the Urbana Weather Station had four eras relevant in the history of that station and its data quality (Changnon and Boyd, 1963). Each of these eras was marked by some form of station relocation within the campus of the University of Illinois and changes in weather shelters or instrumentation, all of which could effect certain forms of weather records.

During the first era (1888-1896), the station had begun as a part of the University's new Agricultural Experiment Station. The weather station was established to provide data for various agricultural experiments on the University farms (located close to the now existing Lincoln Hall). The second era (1897-1931) involved the relocation of the station to the famed Agronomy Plots called the "Morrow Plots." The station became a cooperative weather station with the U.S. Weather Bureau in 1902, and this act reflected a commitment of the College of Agriculture to the long-term operation of a weather station. In the ensuing years, the data from the station became a part of the local community.

Fortunately, the instrumentation bought in 1888, and maintained to present, has been of high quality and equivalent to "standard equipment." This has allowed comparison of the temperature and precipitation measurements with those at other stations of the Weather Bureau. However, the weather shelter during portions of the second era was located at an elevation higher than the "standard level" (4 feet), potentially causing the temperature values to be slightly lower than if they had been at the standard measured height.

The station's third era was from 1931-1948. It reflected decreased interest by University scientists in the Morrow Plots Station, but interest in a new weather station established on the "South Farm," 1.5 miles south of the Plots. By 1948 the College of Agriculture's interest in the station had seriously declined, and the Illinois State Water Survey (with a newly formed atmospheric sciences group) assumed station responsibility and maintained the station for the next 40 years after 60 years by the University of Illinois.

The fourth era (1949-1985) found the station maintained at the Morrow Plots location but with one minor move 100 feet south. The U.S. Weather Bureau identified it as a potential benchmark station in 1963 to help monitor climate change.

A fifth era (1985-present) began with the official relocation of the station 1.4 miles to the south campus where the Water Survey's facilities were located. Observations are maintained at the Morrow Plots Station to give data for a multi-year period for comparison of possible local differences.

The data emanating from the 100-year collection effort has allowed many research projects by University scientists interested in engineering, biology, agriculture, and water resources. Several publications have been generated by Water Survey scientists (Huff, 1949; Changnon, 1955, 1959). A few important

findings from the Urbana data are offered to illustrate applications of the data and how to interpret the findings.

Figure 1 presents the annual temperature values up through 1987. The possible effect of the taller shelter (causing slightly lower temperatures) from 1913-1931, exists. This was also a period of general climatic warming in Illinois (Changnon, 1985), and so it is difficult to isolate the effect of the shelter change in 1931 from the warming trend. As can be noted, the temperatures have declined slowly since about 1940.

The soil temperatures at 3 feet below the surface were measured during the period of 1888-1948 at Urbana. These values were used in conjunction with the air temperatures (see Fig. 1) to determine the amount of "urban effect," or heat island, developing in the Urbana temperatures (Changnon, 1964). The soil temperatures were measured at a rural site, whereas the Urbana station began in a University farm and generally rural setting in 1888, but by 1910 had become surrounded by university buildings and an enlarging community. The comparison of the deep soil temperature data and the air temperature data revealed that the mean annual air temperature between 1903 and 1947 increased 2.3°F, but that the soil temperatures increased only 1.2°F. Their difference, 1.1°F is a reflection of the growth in Champaign-Urbana and the effect of the urban "heat island." The remaining difference, 1.2°F, is due to general continental scale climatic warming during this period. Thereafter, and even though Champaign-Urbana continued to grow and the magnitude of the heat island certainly increased, the annual mean temperatures began a steady decline, as shown in Figure 1. The amount of decline presumably would have been greater had not the effect of the urban heat island continued to increase.

Figure 2 shows the annual snowfall values for Urbana from the initiation of measurements in 1903 through 1987. These reveal some interesting shifts in the winter storm climate of Urbana (and Illinois) over the past 84 years. A period of generally low snowfall values extends from about 1916 through 1950; thereafter, higher annual snowfalls occurred with peaks during the early 1960's and again during the late 1970's. The station relocations at Urbana cannot be responsible for any of the major differences found in the annual snowfall data. In all instances, exposure of the station (and where measurements were taken) was similar and susceptible to comparable conditions for snowfall measurements. Studies of Illinois winter storms (Changnon, 1969; Changnon et al., 1980) documented a very sizable increase in snowstorm frequencies across Illinois after 1960.

Table 1 presents a listing of the 20 years since 1888 having the greatest annual precipitation totals at Urbana. These values are ranked in the left column and listed chronologically in the right column. One of the important findings is that 9 of the 20 values occurred in the period from 1972-1985 (45% of the values in 14% of the years), revealing that this was a particularly wet period. In fact, only 1984 did not qualify in the 5-year period from 1981-1985, and in the 4-year period of 1972-1975, all years qualified. These 9 years were each typified by wet summers, a factor which played a major role in the locally high corn and soybean yields achieved during the 1970's and 1980's. The relatively recent increase in the number of wet years at Urbana is not related to station relocations or to a change in instruments used to measure precipitation. As will be shown in the discussions about temporal changes in the other part of Illinois in the next

section, the recent wet conditions at Urbana were found throughout Illinois (Changnon, 1984; 1985).

FLUCTUATIONS IN SELECTED CLIMATIC CONDITIONS ACROSS ILLINOIS

Several studies over the past 30 years have documented various aspects of the temporal changes in various climatic conditions across Illinois. Selected results are presented to illustrate some of the more significant fluctuations. Since most quality historical records at weather stations in Illinois began shortly before 1900, most results have focused on the climatic fluctuations during the 20th Century.

Temperature

The record of the statewide mean annual temperature from 1840 through 1985 is presented in Figure 3. The early data from 1840 through 1880 must be considered "suspect" because of relatively few weather stations and a lack of quality control of the data. Regardless, these data along with more reliable data from other parts of the East Coast suggest this was a cool period relative to what was to follow beginning in 1880.

The steady increase in Illinois temperatures from 1888 up through 1940 is shown. It's similar to that found in Urbana (Fig. 1). Thereafter, statewide temperatures systematically decreased up through 1985. Inspection of annual temperature changes for various parts of Illinois show that they occurred throughout the state (Changnon, 1985). Seasonally, the changes in temperatures since 1940 occurred in the winter (December-February) and summer (June-August) seasons (Changnon, 1984). Temporal changes in the spring and fall temperatures have been negligible; hence, the length of the Illinois growing season has not fluctuated in any systematic way during the 20th Century (Changnon, 1985).

One of the longer weather records in central Illinois is that from Peoria, with data beginning in 1856. The 10-year moving averages of January and July temperatures for Peoria up through 1980 are shown in Figure 4a and b. The January curve illustrates the relatively high temperatures of the 1930's and extreme low temperatures of the 1880's and early 1970's. The July curve shows peaks and high temperatures in the 1870's, 1930's and 1950's. Important on both graphs are the wide swings in values and the notable periods of 5 to 10 years duration with relatively high and/or low temperatures.

Precipitation

Figure 5 presents the statewide mean precipitation, based on 5-year values, for 1840-1985. This reveals the classic "see-saw" characteristic of historical precipitation records found in most continental climates like that in Illinois. Again, the early data for 1840-1880 must be considered suspect because of the paucity of stations compared to the number since that time. A wet regime across the state began in 1965 and is marked by the near-record high

values for 1981-1985. However, a drought began in 1988, and the statewide value for 1988 was 28.0 inches, the fifth lowest for the period of record.

An important measure of the temporal history of precipitation relates to growing season rainfall. Table 2 presents the frequency of wet and dry seasons per decade since 1900. Notably high frequencies of wet growing seasons are seen in the 1940's and 1970's with dry seasons frequent in 1910-19, 1930-39, and 1960-69.

The extremes of precipitation, wet and dry, have also revealed statewide fluctuations. Figure 6 is based on incidence of 12-month precipitation droughts across the state since 1905 (Changnon, 1985). To qualify as a 12-month drought, the statewide precipitation average was less than 80 percent, and at 20 percent of the weather stations in Illinois the period was rated among the five driest periods on record. This shows that the most severe droughts occurred in the 1930's and 1950's, and that since the 1950's, there have been few 12-month droughts. Further, those that have occurred were not as severe, as defined by the amount of departure of the precipitation and its areal extent across the state. Again, the tendency towards wetter conditions since 1940 are reflected in the lower incidence of droughts since that time.

Another key aspect of precipitation relates to heavy rains. The frequency of rainfall days in Illinois with 2 inches or more rain, and based on 59 stations (for 1911 through 1980) is shown in Figure 7. The curves for the warm season (April-October) and for July-August both show major fluctuations with major peaks in 2-inch rain events during 1971-80 (Huff and Changnon, 1987). The recent increase in the heavy rain events was closely related to the increases in the incidences of floods (Changnon, 1983).

The recent increases in precipitation across Illinois are illustrated by the annual values in Table 3. Here, for each crop reporting district, the annual precipitation values from 1981 to 1985 have been expressed as a percent of their normals for 1951-1980. All districts except one in one year (SE in 1981), experienced above normal values throughout this 5-year period, an unprecedented event. This extreme period of heavy precipitation was found to be related to the major increases in the levels of Lake Michigan (Changnon, 1987).

Many other aspects of the temporal nature of Illinois precipitation have been studied. For example, Changnon (1969a) analyzed growing season precipitation conditions (and temperatures) to develop models of 21 types of summer precipitation in Illinois. Then, their temporal frequency was examined. Lamb and Changnon (1982) inspected temporal distributions of seasonal precipitation in Illinois for periods ranging from 5 up to 30 years. This research attempted to determine what length of period best estimated the value in the following year. This revealed that the average of the most recent 5-year precipitation values most frequently were the best estimate of the value for the following year.

Severe Weather Conditions

Several climatological investigations have concerned the temporal variations in various severe weather conditions across Illinois. Changnon (1960)

investigated the temporal relationships between the number of warm season hail days in Illinois and the amount of crop loss due to hail. A strong relationship indicated that the frequency of hail days were a good predictor of crop loss. Problems related to historical tornado data affect their temporal distribution in Illinois (Changnon, 1982a). Temporal variations in high winds events (of a non-tornadic nature) were studied on a statewide basis. These showed periods of great incidence during the 1950's (Changnon, 1980b). The historical incidence of windblown duststorms was examined by Changnon (1982b). Peaks in windblown dust activity occurred in the droughts of the 1930's and 1950's, and then again in the spring of 1981. The incidence of severe weather conditions on calendar dates showed that certain dates, such as June 10-15, tend to have a higher likelihood of severe weather conditions than other adjacent dates (Changnon, 1962). The study of the temporal variations of severe weather events across the state also embraced severe winter storms (Changnon, 1969b; 1984). Severe winter storms peaked during the 1970's and early 1980's (Changnon, 1978; Changnon et al., 1980; and Changnon and Hilberg, 1983).

In general, the studies of various severe weather conditions, both those in the warm season (thunderstorms, hail, and tornadoes) and those in the winter season (snow and ice storms), show a large amount of temporal variability across Illinois. Many conditions had an increase in storm activity during the 1970's and 80's. This is in keeping with the cooler, cloudier, and wetter climatic conditions of recent decades.

SUMMARY

The temporal fluctuations and variations of various Illinois climatic conditions have been well documented. The continental type climate of Illinois, like that of the entire Midwest, is always in a state of fluctuation. Since the modern era of weather measurements began late in the 19th Century, Illinois has experienced two general periods. The first, from about 1890 to 1940 was one of increasing temperatures, decreasing rainfall, low incidence of storminess, and a high incidence of droughts. Since the 1940's, the Illinois climate has tended towards cooler, cloudier, and wetter conditions with increased storminess.

An oft-used description of the Illinois climate certainly applies; "Illinois has a continental climate typified by warm to hot summers with high humidity, cold and often severe winters, and with severe storms of various types in all seasons."

Knowledge of the temporal behavior of Illinois climate conditions is relevant for the design and operation of weather-sensitive systems. Growing national concern over the possibility of a future major change in global climate due to continuing atmospheric increases in CO_2 and other trace gases is of great concern to Illinois. Monitoring our climate so as to detect the onset and magnitude of this change is essential, and detecting shifts should be made easier by having documentation of the past temporal variations of the Illinois climate based on quality records.

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Table 1. The 20 largest annual precipitation totals at Urbana during 1888-1987.

Ranked Listing			Chronological Listing		
1	1927	55.64	4	1898	48.47
2	1983	50.26	9	1902	45.68
3	1973	49.37	6	1909	47.05
4	1898	48.47	18	1918	43.19
5	1945	48.01	16	1926	43.53
6	1909	47.05	1	1927	55.64
7	1981	46.00	13	1929	44.13
8	1975	45.79	5	1945	48.01
9	1902	45.68	11	1949	45.44
10	1985	45.54	19	1950	42.99
11	1949	45.44	12	1965	44.44
12	1965	44.44	17	1972	43.25
13	1929	44.13	3	1973	49.37
14	1982	43.76	15	1974	43.55
15	1974	43.55	8	1975	45.79
16	1926	43.53	20	1977	42.93
17	1972	43.25	7	1981	46.00
18	1918	43.19	14	1982	43.76
19	1950	42.99	2	1983	50.26
20	1977	42.93	10	1985	45.54

Table 2. Decadal Frequency of Wet and Dry Growing Seasons (May-August) in Illinois, 1900-1979.

	Number of Wet Seasons*	Number of Dry Seasons**
1900-1909	3	3
1910-1919	3	5
1920-1929	3	3
1930-1939	1	6
1940-1949	6	0
1950-1959	1	3
1960-1969	3	5
1970-1979	6	1

*Wet represents upper 1/3 of values.

**Dry represents lower 1/3 of values.

Table 3. Annual Precipitation Values in Illinois' Nine Crop Districts for 1 981 1985 Expressed as Percent of their 1951-1980 Average of Return Interval Values are Shown in Parenthesis.[1]

Districts	1981	1982	1983	1984	1985
NW	113 (4)	132 (10)	110 (3)	103	112 (4)
NE	105 (2)	135 (20)	131 (10)	103	115 (6)
W	116 (3)	115 (3)	107 (2)	111 (3)	124 (8)
C	127 (10)	133 (15)	109 (3)	108 (3)	119 (8)
E	121 (5)	137 (20)	115 (4)	100	125 (7)
WSW	123 (5)	134 (10)	103	121 (5)	122 (5)
ESE	107 (2)	135 (15)	116 (3)	116 (3)	126(10)
SW	103	117 (5)	110 (2)	118 (5)	124 (8)
SE	99	111 (3)	105 (2)	117 (5)	128 (12)

[1]A value of 10 means it is a value expected to occur once every 10 years.

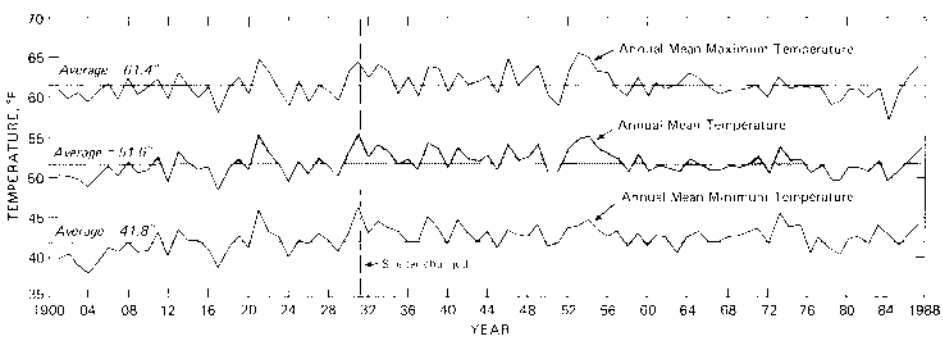

Figure 1. Annual mean temperatures (°F) at Urbana, Illinois, 1900-1987.

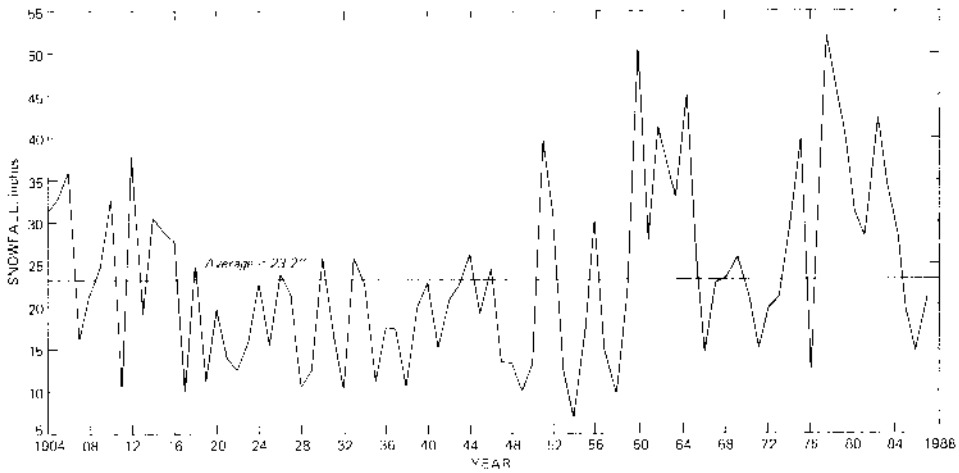

Figure 2. Annual snowfall values, in inches, at Urbana, Illinois, 1904-1987.

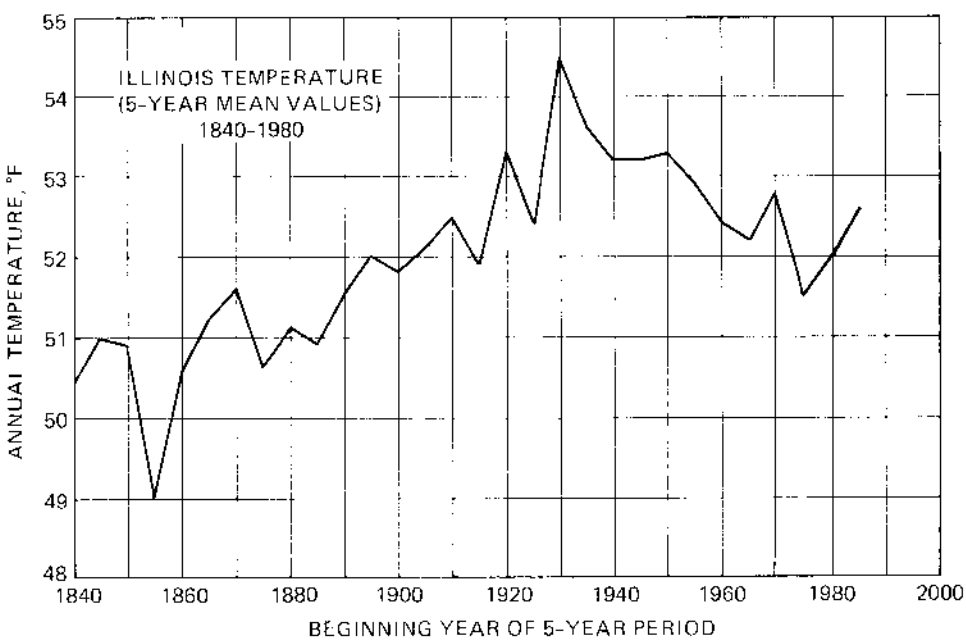

Figure 3. Illinois annual mean temperature (°F) for 5-year periods (1840-44, 1845-49, etc.) for 1840-1988.

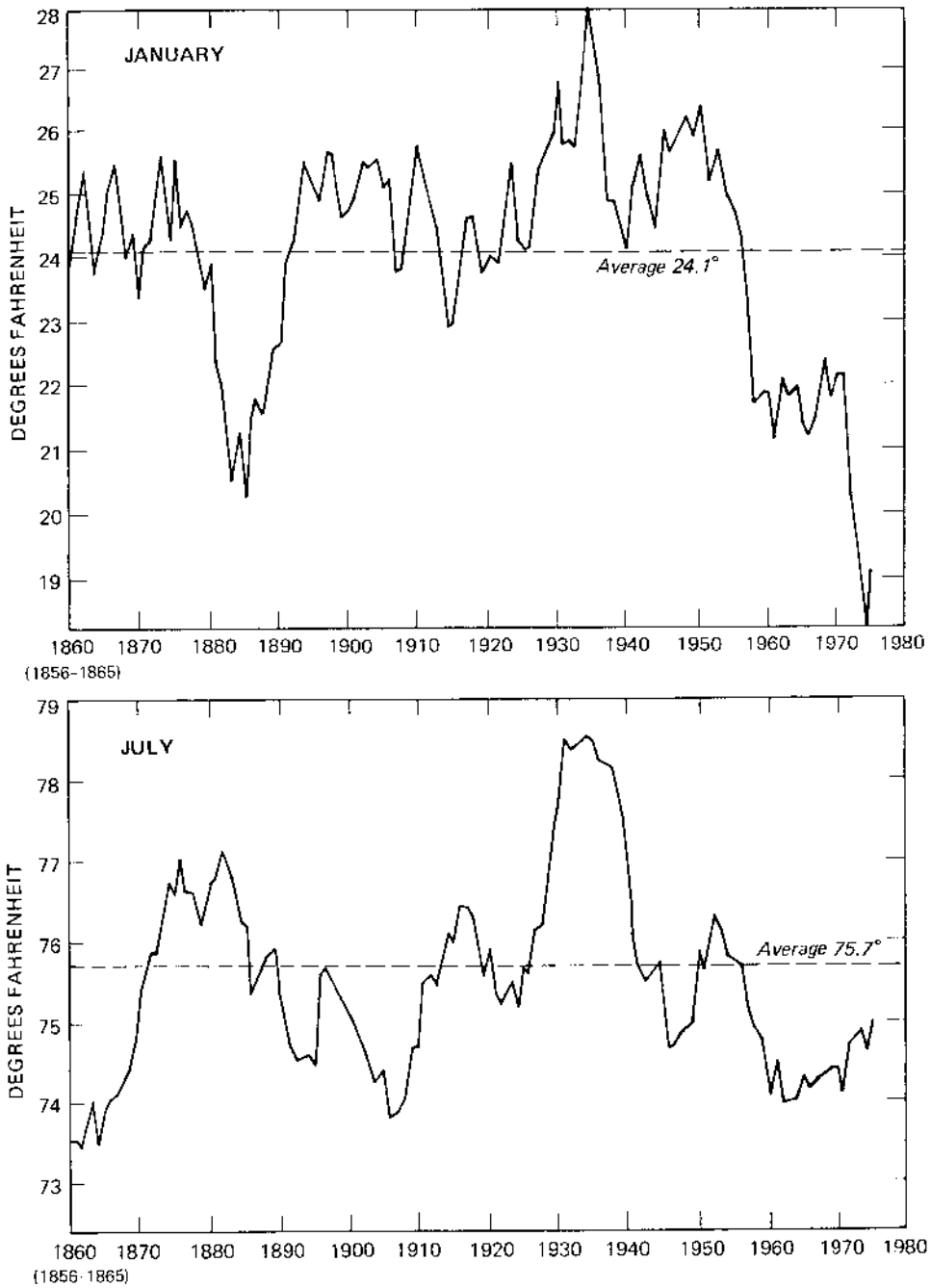

Figure 4. The 10-year moving averages of monthly mean temperatures (°F) at Peoria, 1856-1980.

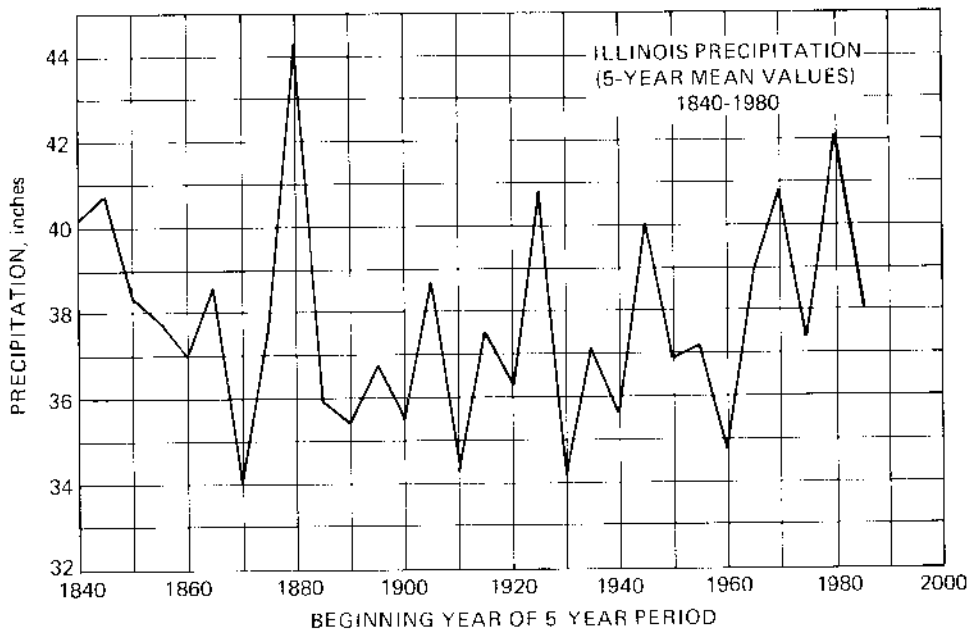

Figure 5. Illinois annual precipitation values, in inches, for 5-year periods (1840-44, 1845-49, etc.) for 1840-1988.

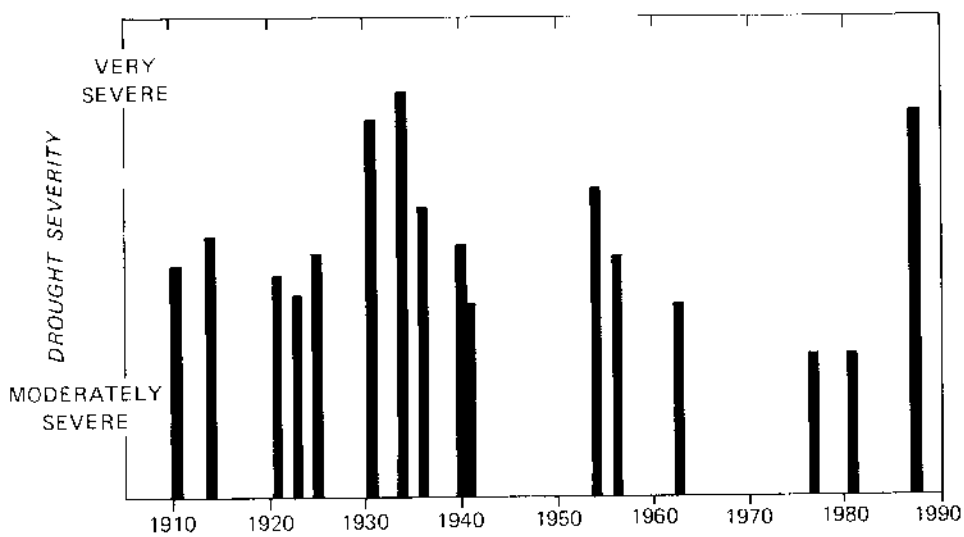

Figure 6. Severity of climatological droughts of 12-month duration in Illinois between 1905 and 1988.

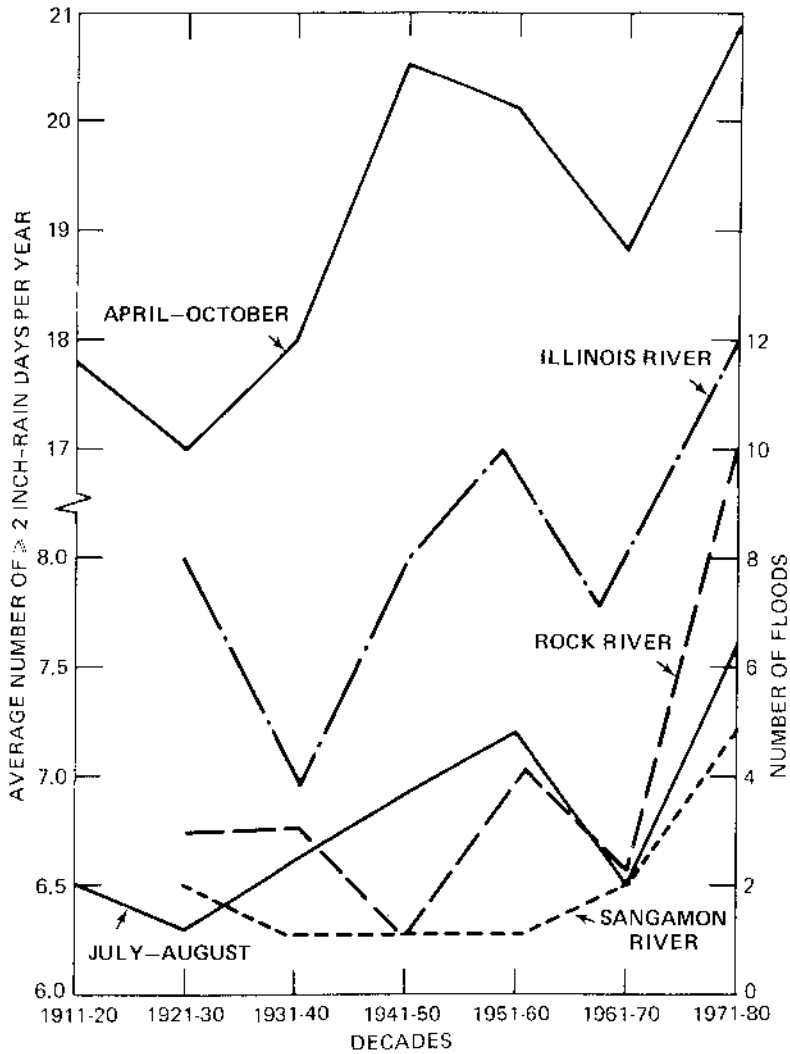

Figure 7. Decadal frequency of days with 2 or more inches of rain during April-October and July-August periods, and of floods on three rivers.