Transactions of the Illinois State Academy of Science
(2008), Volume 101, #3&4, pp. 205-216
received 4/21/08
accepted 9/1/08

The Development of Knowledge About the Climate of Illinois

Stanley A. Changnon
Illinois State Water Survey
2204 Griffith, Champaign, IL 61820
Email: schangno@uiuc.edu, Tel: (217) 5865691

ABSTRACT

Adequate understanding of all aspects of the climate of Illinois and its effects on humans and the environment has required data collection and research over the past 150 years. Meaningful climate studies were limited before about 1910 by the lack of an adequate network of weather stations to provide needed surface data. The evolution of a network of weather stations involved three eras of development that began in 1849 and included the Smithsonian Institute, U.S. Army, and the Department of Agriculture. In-depth studies of climate, given adequate upper air data that began being collected during the 1920s-1940s, were launched after 1950 . These have defined the considerable spatial variations in climate across the state, some caused by Lake Michigan and others by the hills of southern Illinois. The studies have also shown that considerable temporal fluctuations in temperatures and precipitation have occurred since 1850, but recent data do not suggest a change in Illinois' climate due to global warming. Studies have also defined the impacts of state's climate on human health and well being, on agriculture, transportation, business, and the environment.

INTRODUCTION

A long-term goal of climate scientists since the 18th Century has been to define and understand the climate of Illinois and other states. Scientists in the 19th Century struggled to collect sufficient weather data collected in Illinois to describe and then to understand the state's climate. These endeavors were motivated by awareness that the climate affected human health, crops, livestock, and human activities, but the relationships were not quantified. Thus, actions and adjustments to adapt wisely to climate conditions were not possible.

Initial measurements of climate were based on data from surface weather instruments, primarily thermometers and raingages. During the 19th Century instruments to measure other climate conditions, including clouds, winds, sunshine, humidity, soil moisture and temperatures, and evaporation, were developed and installed at a few locations in Illinois. A network of weather stations at a density adequate to define the climate's spatial variations across Illinois also had to be installed. The need to measure atmospheric conditions aloft led to use of kites by 1910 to carry instruments aloft, and this technique was improved in the 1930s by use of radiosondes, balloons that carried instruments aloft and

that radioed back the data. More recent measures of conditions aloft have come from radars and satellites.

In recent years the possibility of a change in climate due to human activities has become an issue facing Illinois and the rest of the world. Questions arise as to whether today's climate is different from that of the past. Answering this critical question relies on comparisons with historical climate conditions and how long adequate weather measurements have been made in Illinois. This article explores the history of weather and climate measurements and studies made in Illinois and presents historical data to show our past climate. The history of the efforts to define the state's climate and its impacts on society and the environment, reveals an interesting mixture of science and political activity in Washington, D.C. During the 19th Century there were three eras each involving different efforts to develop an adequate national weather network. In-depth climate research began in the 20th Century when adequate quality data had finally become available.

EARLY DATA COLLECTION

Measurements of certain weather conditions in the U.S. began during the 18th Century. A few individuals concerned with the climate like Benjamin Franklin established their own measurement station using a variety of early instruments. Thomas Jefferson was another famous person who was intrigued about the climate and how it affected crops. He established weather stations at his home, Monticello, Virginia, and over the years made assessments of how various climate conditions in nearby valleys and on hills affected his crops. The few scientists of the time were trying to figure out the mysteries about how the atmosphere circulates and the causes of storms. Early weather measurements were made in the settled East Coast where a few persons were interested in weather. Illinois was largely unsettled at this time and hence no data were collected here in the 18th Century.

The growing interest in weather phenomena and climate conditions led to the development of companies who began making weather instruments late in the 18th Century (Fleming, 1990). Their products included thermometers that identified the highest and lowest values since the last observation, usually done two or three times a day. They made cylinders designed to stand alone and serve as a raingage, and they also made wind vanes. Devices for recording rainfall over time were developed by mid-19th Century. The presence of such instruments allowed the measurements of Illinois weather and climate to begin early in the 19th century, and the subsequent evolution of weather measurements ultimately led to an understanding of the Illinois climate.

Army concerns about how the climate may have affected the health of soldiers during the War of 1812 led to the first organized effort to measure the weather (Fleming, 1990). The Army's Surgeon General, one Joseph Lovell, had a climate interest, and in 1814 he issued orders that medical staff at each army base of consequence would make weather measurements and record the data in a "weather diary". At this time, most military bases were in the east although Illinois had forts at three locations: Fort Armstrong (Rock Island), Fort Dearborn (Chicago), and Ft. Edwards (Peoria). Weather measurements began at these forts in 1820, the first organized weather measurement effort in the state (Whitnah, 1961).

EARLY CLIMATE QUESTIONS

Major debates among scientists about the local, regional, and national dimensions of the climate continued throughout the 19th Century. The possible cause of storms was a key question (Whitnah, 1961). Climate change and the influence of land clearing on climate were also questions of great concern. Many speculated about the influence of climate on agriculture and human health. Thomas Jefferson had offered various views of climate change, stating it was occurring. Others disagreed. Professor Elias Loomis, a well known scientist, stated in the 1860s that no climate change had occurred in past 2000 years. Today climate change has become a major scientific issue.

FIRST ERA OF A NATIONAL CLIMATE NETWORK

Professor Joseph Henry became head of the science-oriented Smithsonian Institute in 1846. He was intrigued with climate conditions, and in 1849 he started establishing a nationwide network of weather stations. Importantly, the Smithsonian Institute supplied standardized instruments to each station, plus standardized reporting forms, and set schedules as to when to make measurements. Some observers telegraphed reports but most kept only monthly reports. This ushered in the first era of an organized weather network in the nation. At each weather station a small wooden shelter was built to house the thermometers and shield them from direct sunlight. Measurements were typically made three times a day including 7-8 a.m., 2-3 p.m., and 8-9 p.m.

In Illinois, the Smithsonian program led to establishment of volunteer weather observers at 8 stations by 1856. Most were in the settled parts of the state in the north and at communities along or near major rivers. Some of the early stations were established at Galena, Marengo, Ottawa, and Augusta. The weather stations operating in 1860 are show in Figure 1.

The network grew and had 15 stations in Illinois by 1870, although several early stations lasted only a few years as observers died or lost interest. For example, a station began in Woodstock in 1857 and then ended in 1861. Only a few stations existed in central Illinois since settlement did not occur until the construction of several railroads through the area during 1851-1870. In 1852 Professor Henry began plotting monthly temperature and rainfall data on maps in an effort to define the climate across the nation. By 1860 the Smithsonian network had 50 stations, but the number was reduced by the Civil War.

SECOND ERA OF THE NATIONAL NETWORK

After the Civil War there was a desire to have a government-sponsored weather observer network, strongly urged by Issac Newton, Commissioner of Agriculture (Fleming, 1990). Certain members of Congress pressured for a national weather network to be led by the U.S. Army. Legislation to do this was passed and signed in 1870 by President Ulysses S. Grant who had learned to appreciate weather information during the Civil War (Fleming, 1990). Thus, a second era of a national weather network began in 1870 when the Army‘s Signal Corps was assigned the responsibility to operate a national network of stations, and to issue weather warnings based on data telegraphed to Washington D.C. from 25 stations, each manned by Army personnel.

The new network also included many non-military observers needed to handle the observations at the expanding number of weather stations. Several of the existing Smithsonian network's 283 stations were incorporated in the Army's network.

Individual state weather services designed to supplement the national network and to serve state needs became a widely accepted concept in the 1870s. This endeavor added many stations to the nation's network. Such a service was developed in Illinois in 1881, and created 8 stations including ones at Sycamore, Griggsville, Greenville, and Palestine (Page, 1949). A station at Urbana was established in 1888 to meet the local university's agricultural research needs (Changnon and Boyd, 1963).

DEVELOPMENT OF CLIMATE RESEARCH

The growing weather data base allowed climate research endeavors to be initiated. One research focus involved trying to understand the climate and its causes, and another on how the climate impacted human health, agriculture, and flooding (Page, 1949). By 1890 data in Illinois had become sufficient to allow definition of the major regional differences in the climate across the state, showing sizable spatial differences in the average rainfall and temperatures between northern and southern Illinois. These analyses also identified the presence of local climate differences due to the hills of southern Illinois and those in northeastern Illinois due to Lake Michigan (Page, 1949).

THIRD ERA OF THE NATIONAL NETWORK

Congressional concern about having the U.S. Weather Bureau housed within the Army grew. In 1887 the Chicago Board of Trade petitioned Congress to make the operations more efficient and public responsive. These issues led to debates in Congress about whether to have the Weather Bureau under civilian control. Weather and climate science and information had become of great interest and value to the nation's population and businesses.

Senator John Logan of Illinois became convinced of the need for an agency shift, and he introduced a bill in 1882 to transfer the service to the Department of Interior (Whitnah, 1961). This action and other problems led Secretary of War Robert Lincoln to support the detachment of the Weather Bureau from military control. However, no existing agency wanted the Weather Bureau at that time.

Meanwhile, agricultural interests in the nation were pushing for a federal agricultural department. A bill placing the Weather Bureau in the new agriculture agency was put forth in 1887. The Department of Agriculture was formed in 1889, and a law transferring the Weather Bureau to Agriculture was passed in 1891 (Whitnah, 1961). Thus, it became a civilian agency, the start of the third era of national weather measurements and one that is growing and changing to the present day.

Many existing weather stations in 1891 did not possess standard thermometers or raingages, and the new agency began replacing instruments during the 1893-1910 era. The expansion led in 1892 to 72 first order stations, those manned by trained observers,

including ones at Chicago, Peoria, Moline, and Springfield, Illinois. Illinois also had 29 stations manned by volunteers by 1891. The move of the Weather Bureau to the Agriculture Department in 1891 had also included the incorporation of the stations in the state networks into the national network.

Growth continued and by 1902 the nation's number of first order stations was 160. The cooperative observer network also underwent sizable growth. By 1900, 28 more stations had been established in Illinois, and the state now had 57 stations with temperature and precipitation records that had begun in 1891 or earlier. By 1913 Illinois had 81 weather stations and this grew to 109 stations by 1930 (Fig.2). Their data allowed the first meaningful studies of how the climate had shifted over time (Page, 1949).

Many new weather instruments were developed during the 1880-1920 period. This included the Triple Register, a battery-powered device that measured and then recorded the sunshine, precipitation, and wind speed and direction. Other instruments installed at a few stations included recording raingages, evaporation pans, and soil moisture probes. Devices to record the air pressure, temperature, and humidity were developed and installed around 1900 at a few stations manned by Weather Bureau personnel.

The advent of airplanes created pressure for data on the atmospheric conditions aloft and moving across the state. Since 1912, efforts to get data on upper air conditions had relied on use of kites carrying a few instruments, but they could not go high enough to get critical measurements aloft. In the 1930s a new device was developed, labeled the radiosonde. It was hauled aloft by a balloon and could radio transmit the atmospheric values back to launch site as it lifted aloft. It could go to great heights (50,000 feet), and had a parachute to bring the instruments safely back to earth after the balloon exploded. A radiosonde station was established in Peoria as part of a national network of radiosondes.

More major changes occurred. The pressures of commercial aviation for timely weather data led politicians to the shift of the Weather Bureau to the Department of Commerce in 1942. The Bureau was renamed in 1966 as the National Weather Service, and in 1970 it became part of a new sub-agency in Commerce, the National Oceanic and Atmospheric Administration.

Growing local interests in climate and concerns about flooding and its early detection, led to the installation of 78 more raingage stations in Illinois during 1910-1960. The development of radar during World War II led to its use to measure rainfall and storms across Illinois and other states, and the development of satellite-based measurements of clouds occurred. Today, Illinois has 212 weather stations, an average of 2 per county.

RECENT STUDIES OF ILLINOIS' CLIMATE

The post World War II era also saw the development of major weather and climate research. Scientists at the University of Chicago, Argonne National Laboratory, Northern Illinois University, and at the Illinois State Water Survey focused on the weather and climate of Illinois.

The debate over global warming and climate change has raised many questions including the extent of climate change since the mid 19th Century. Illinois' long-term trends in precipitation and temperature were developed for the years when sufficient quality data had become available in the mid 19th Century.

The statewide average temperature since 1840 exhibits several wide fluctuations (Fig. 3). Temperatures peaked in the 1920-1940 period when the nationwide severe droughts occurred in the 1930s. The lowest temperatures came in the 1850s. Statewide average precipitation has fluctuated during the 1861-2002 period (Fig.4). It was highest in the 1860-1890 period when temperatures were lowest. Precipitation was least, 95 percent of the 142 year average, in the 1928-1942 Dust Bowl period. Over the past 150 years the climate in Illinois has had several large fluctuations. Climate fluctuations are defined as variations lasting from 10 to 1,000 years (Landsberg, 1958).

The temporal distributions of weather and climate extremes in Illinois have also been well defined, but mainly for the 20th Century. The frequencies of thunderstorms and hailstorms have fluctuated but not exhibited long-term trends to more or less over time (Changnon, 2001). However, the incidence of tornadoes (Changnon, 1982) and heavy rain days (Changnon and Kunkel, 2006) have shown upward trends over time. Winter storms since 1900 have also fluctuated widely between years and have exhibited an upward trend over time (Changnon, 1969; Changnon, et al., 2008). Heat waves were frequent in the 1930s and again in the 1990s (Palecki et al., 2001).

The collection of adequate climate data since 1900, as well as the collection of data on conditions affected by the climate (crops, floods, etc.) allowed assessment since about 1950, of various impacts of climate. The climate's relationship to the state's water resources has been defined (Changnon and Demissie, 1996; Changnon, 2003), as have climate effects causing droughts (Huff and Changnon, 1963; Changnon and Easterling, 1989) and flooding (Changnon, et al., 2001). Climate impacts on agriculture are now well understood (Changnon, 1966a, 1975). Illinois climate also affects transportation and related businesses (Changnon, 1996), and the climate has diverse impacts on all major business sectors and thus on the state's economy (Changnon, 1985). The extremes of climate including severe local storms, have major economic and human impacts in Illinois, leading to 40 to 90 deaths each year (Kunkel et al., 1999; Changnon, 2002). Serious impacts on human health and well being result from longer-term climate events like cold winters (Changnon, 1979) and heat waves (Changnon, et al., 1996).

SUMMARY

The development of a national network of weather stations took several decades before reaching by about 1930 a level needed to provide data adequate for meaningful assessments of Illinois' climate. During these decades, numerous weather-measuring instruments were being developed allowing measurement of all conditions at the surface and aloft by 1940.

For 150+ years basic questions about the state's climate have existed. These included climate causes/controls, the climate's variability in time and space, whether the climate was changing, and how climate affected humans, the environment, and business. Since

1940 there have been extensive definitive studies of all aspects of the Illinois climate (Page, 1949; Changnon et al., 2004). These have included assessing severe storms across the state (Changnon and Kunkel, 2006); how Chicago and St. Louis have altered their climates (Changnon, 1973); and how the hills of southern Illinois influence their climate (Changnon et al., 1975). Furthermore, numerous studies have defined the influence of Lake Michigan on climate (Changnon, 1966b; Changnon, 1968), and numerous studies have addressed how the state's climate has affected the environment, human health, agriculture, and the economy of Illinois. The fluctuations in the state's temperatures since 1840 do not indicate an increasing trend in recent decades. The effects of global warming may not be evident in the data of all areas of the United States.

LITERATURE CITED

Changnon, S.A., 1966a: Relationship of Weather Factors and Crop Yields in Illinois. Crop-Hail Insurance Actuarial Association, Research Report 32, 28pp.

Changnon, S.A., 1966b: Effect of Lake Michigan on severe weather. Journal of Great Lakes Research, 15, 220-234.

Changnon, S.A., 1968: Precipitation Climatology of the Lake Michigan Basin. Bulletin 50, Illinois State Water Survey, Champaign, 46pp.

Changnon, S.A., 1969: Climatology of Severe Winter Storms in Illinois. Illinois State Water Survey, Bulletin 53, 45pp.

Changnon, S.A., 1973: Inadvertent weather modification by urbanization. Journal of Irrigation and Drainage Division, ASCE, 99, 27-42.

Changnon, S.A., 1975: Climate–is it changing? What will change mean to agriculture? Crops and Soils, 9-12.

Changnon, S.A., 1979: How a severe winter impacts on individuals. Bulletin American Meteorological Society, 60, 110-114.

Changnon, S.A., 1982: User beware: The upward trend in tornado frequencies. Weatherwise, 35, 64-69.

Changnon, S.A., 1985: Climate fluctuations and impacts: The Illinois case. Bulletin American Meteorological Society, 66, 142-151.

Changnon, S.A., 1996: Effects of precipitation on urban transportation. Climatic Change, 32, 481-494.

Changnon, S.A., 2001: Thunderstorms across the Nation: An Atlas of Storms, Hail, and their damages in the 20th Century. Changnon Climatologist, Mahomet, IL, 93pp.

Changnon, S.A., 2002 Increasing losses from weather extremes in Illinois: Their causes and future implications. Transactions Illinois Academy of Sciences, 95, 47-57.

Changnon, S.A., 2003: Effects of future rainfall increases on the hydrologic cycle of an Illinois basin. Transactions Illinois Academy of Sciences, 96, 4-19.

Changnon, S.A., and G. Boyd, 1963: History of the Urbana Weather Station: 1888-1963. Illinois State Water Survey, Circular 87, 19pp.

Changnon, S.A., Jones, D., and F.A. Huff, 1975: Precipitation increases in the hills of southern Illinois: Field investigation of the anomaly. Monthly Weather Review, 103, 830-836.

Changnon, S.A., and W. Easterling, 1989: Measuring drought impacts: The Illinois case. Water Resources Bulletin, 25, 27-42.

Changnon, S.A., and M. Demissie, 1996: Detection of changes in streamflow and floods resulting from climate fluctuations and land use changes. Climatic Change, 32, 411-421.

Changnon, S.A., Kunkel, K., and B. Reinke, 1996: Impacts and responses to the 1995 heat wave: A call to action. Bulletin American Meteorological Society, 77, 1497-1506.

Changnon, S.A., Kunkel, K., and K. Andsager, 2001: Causes for record high flood losses in the Midwest, Water International, 26, 223-230..

Changnon, S.A., Angel, J., Kunkel, K., and M. Lehman, 2004: Climate Atlas of Illinois. Illinois State Water Survey, 309pp.

Changnon, S.A., and K.E. Kunkel, 2006: Severe Storms in the Midwest. Information/Educational material 2006-06, Illinois State Water Survey, 74pp.

Changnon, S.A., Changnon, D., Karl, T.R. Karl, and T. Houston, 2008: Snowstorms Across the Nation: An Atlas About Storms and Their Damages. National Climatic Data Center, Asheville, NC, 96pp.

Fleming, J.R., 1990: Meteorology in America, 1800-1870. John Hopkins University Press, Baltimore, 264pp.

Huff, F.A. and S. A. Changnon, 1963: Drought Climatology of Illinois. Illinois State Water Survey, Bulletin 50, 80pp.

Kunkel, K.E., Pielke, R., and S.A. Changnon, 1999: Temporal fluctuations in weather and climate extremes that cause economic and human health impacts: A review. Bulletin American Meteorological Society, 80, 1077-1098.

Landsberg, H.E., 1958: Physical Climatology. Gray Publishing Co., DuBois, PA., 201pp.

Page, J.L., 1949: Climate of Illinois. Bulletin 532, Agricultural experiment Station, University of Illinois, Urbana, 364pp.

Palecki, M., Changnon, S.A., and K. Kunkel, 2001: The nature and impacts of the July 1999 heat wave in the Midwestern U.S.: Learning from the lessons of 1995. Bulletin American Meteorological Society, 82, 1925-1940.

Whitnah, D. R., 1961: A History of the U.S. Weather Bureau. University if Illinois Press, Urbana, 267pp.

Figure 1. The weather stations operating in Illinois during 1860.

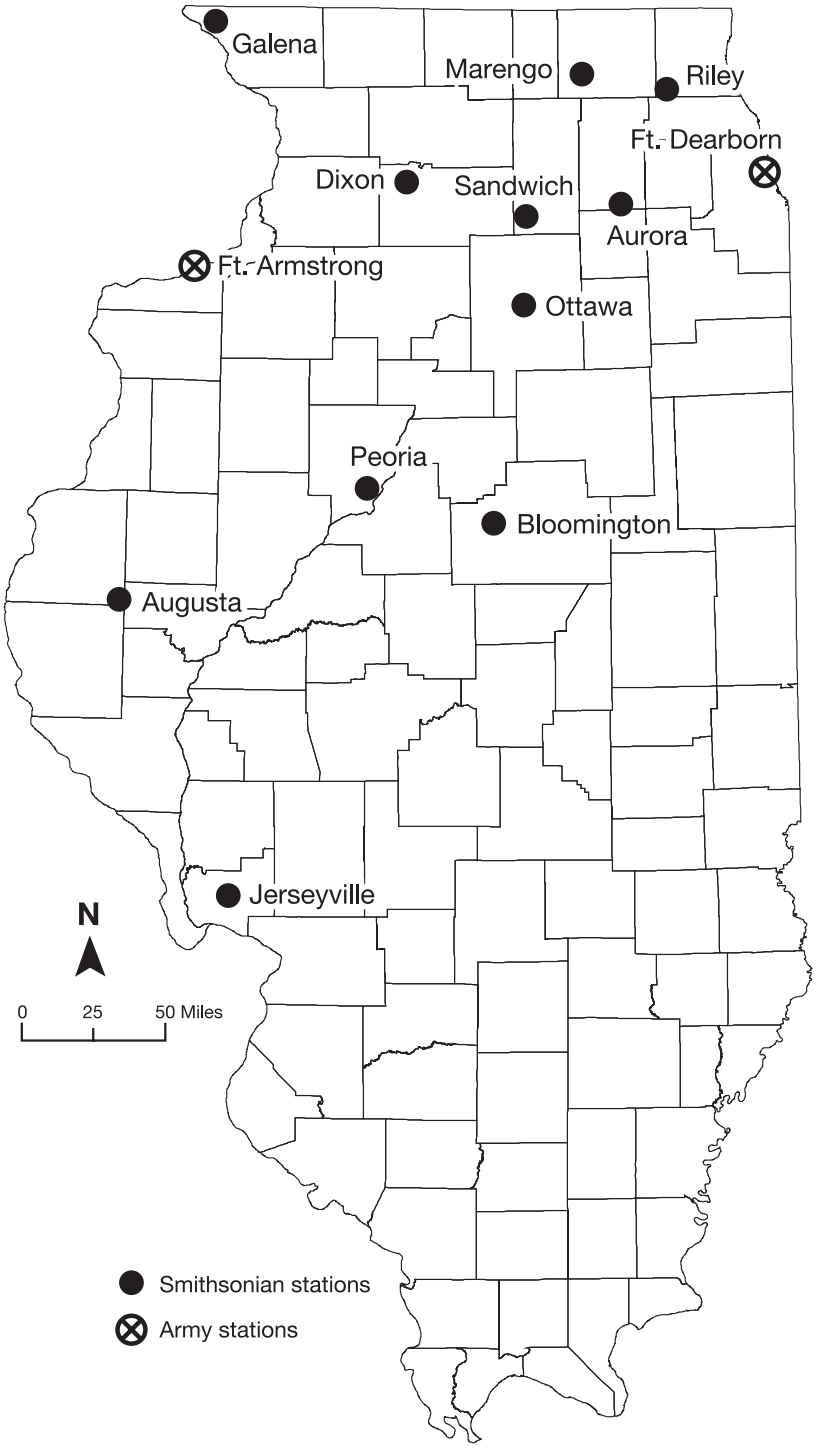

Figure 2. The weather stations operating in Illinois during 1930.

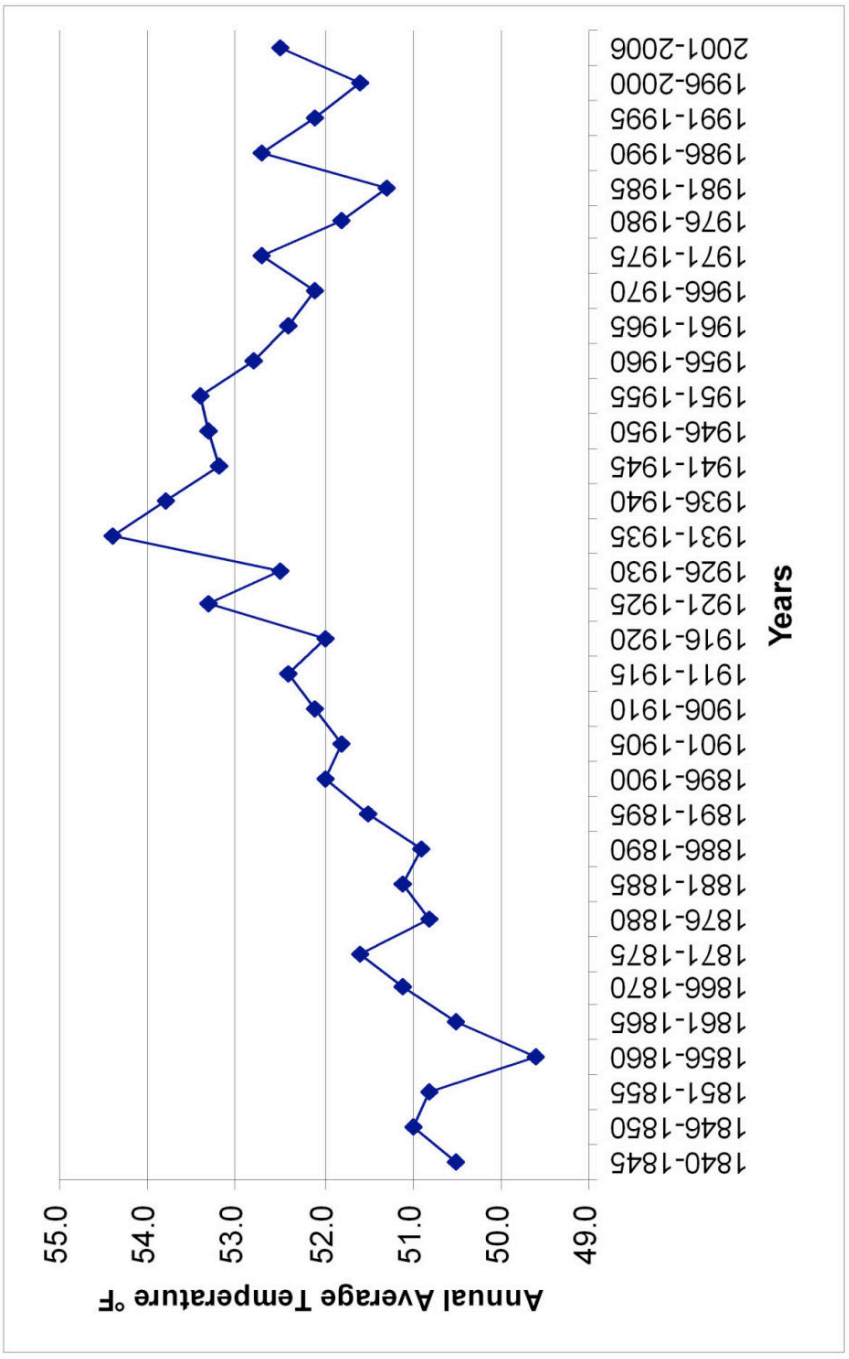

Figure 3. The annual average temperature for Illinois during 1840-2006.

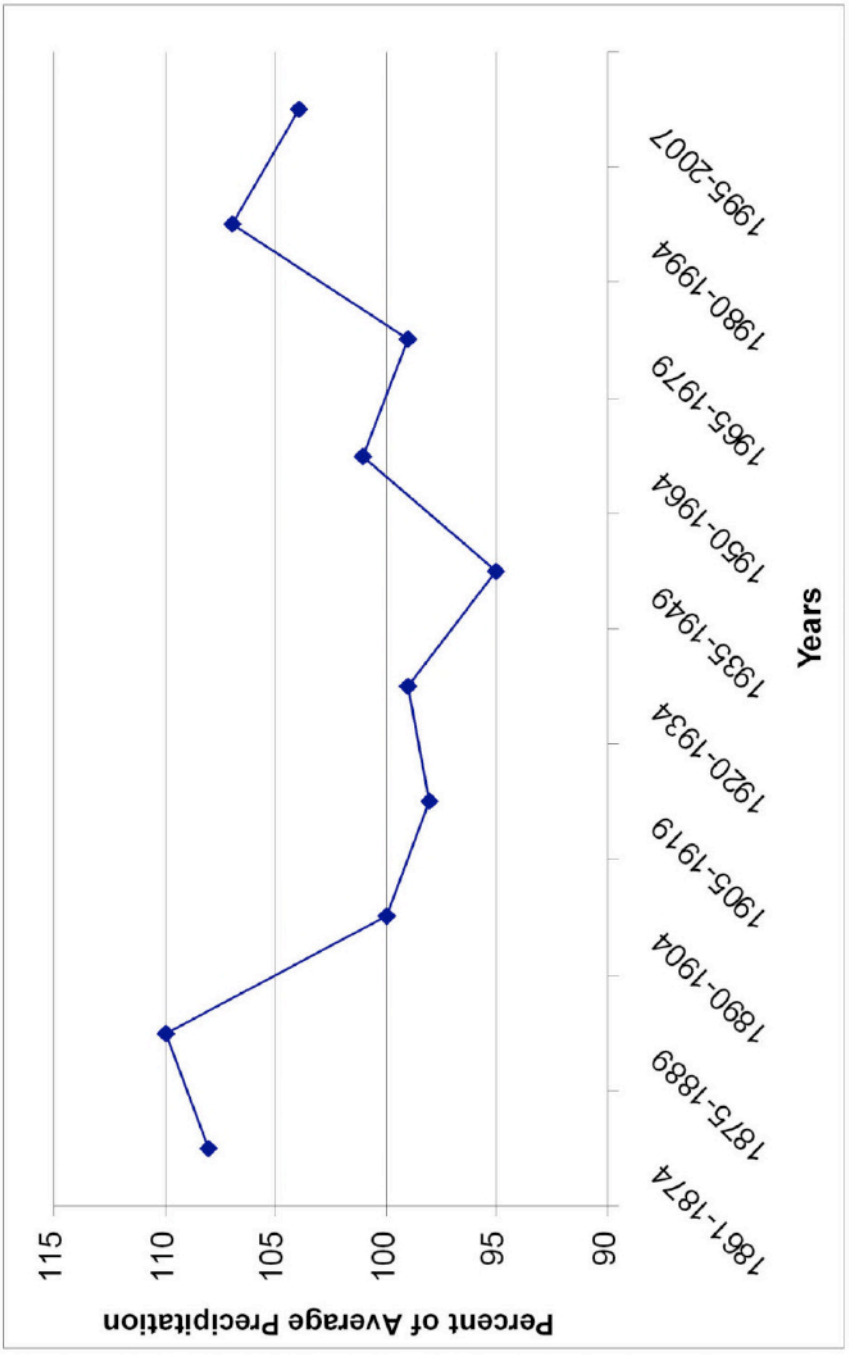

Figure 4. The average precipitation for Illinois during 1860-2007.