Draft for NCADAC Meeting, April 4-6, 2011

Regional Climate Vulnerabilities and Trends—Midwest

Kenneth E. Kunkel
NOAA Cooperative Institute for Climate and Satellites
North Carolina State U. and National Climatic Data Center
Asheville, North Carolina

Disclaimer: This draft was prepared for the consideration by the NCADAC as a model that can be used by regional teams to understand the type of information that is desired in the regional climatologies. This draft has not been fully reviewed. The information is mostly from peer-reviewed sources or extensions of peer-reviewed analyses, but additional analyses and input are needed to insure that it is comprehensive and reflective of overall trends in the physical climate conditions of the Midwest region.

General Description

Midwest climate conditions are largely determined by the region's location, in the center of the North American continent. Far from the moderating effects of the oceans, the region experiences wide extremes of both temperature and precipitation that occur over days, weeks, months, and years. In the winter, the absence of significant mountain barriers to the north allows bitterly cold air masses from the Arctic to move southward into the region. The polar jet stream is often located near or over the region during the winter, with frequent storm systems bringing cloudy skies, windy conditions, and precipitation. In contrast, Midwest summers are characteristically hot and humid due to a semi-permanent high pressure system in the subtropical Atlantic that draws warm, humid ocean air into the area. Summer also tends to be the rainiest season, with short-lived rainfall and thunderstorms. Precipitation is generally abundant, but severe droughts occur from time to time. Some potentially dangerous storms occur in every season. Winter can bring major snowstorms, damaging ice storms, or both. Warmer months, typically March-October, have convective storms, including thunderstorms and lightning, flood-producing rainstorms, hail, and deadly tornadoes. All seasons have damaging high winds.

The average annual temperature varies by about 20°F across the region (Fig. 1) from less than 40°F in the far north to 58°F in the Missouri bootheel. Average annual precipitation varies widely across the region (Fig. 2) from about 20 inches in northwest Minnesota to 50 inches in the far southern regions. Average annual snowfall varies from less than 10 inches in the far south to more than 150 inches in the Michigan Upper Peninsula.
The Great Lakes have a large influence on the local climate. Nearshore locations are considerably warmer during the winter and cooler during the summer than locations some distance away from the shores. The moderate temperatures, combined with the many recreational activities, make the lake shore areas a popular summer vacation destination. A notable feature of the southern and eastern shorelines is the occurrence of "lake effect" snowfall. Water that evaporates from the lakes during outbreaks of cold Arctic air masses is

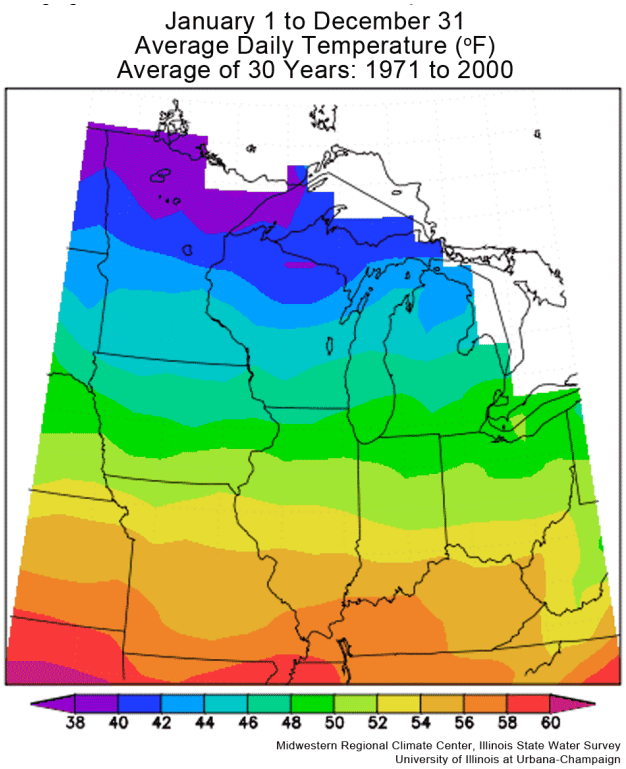

Figure 1.

weather. Rainfall, heat stress, pests, ozone levels, and extreme events such as heavy precipitation, flooding, or drought can seriously affect production. The risks for such events are often higher for smaller farmers and different types of crops and other food production.

The major urban centers in the region, which include Chicago, Cincinnati, Cleveland, Detroit, Des Moines, Indianapolis, Milwaukee, Minneapolis-St. Paul, and St. Louis, experience particular sensitivities that are unique to, or exacerbated by, the specific characteristics of the urban environment. Temperature extremes can have large impacts on human health, particularly in the urban core where the urban heat island effect raises summer temperatures. Severe storms, both winter and summer, result in major disruptions to deposited on the downwind shores as snow. Very large snowfall amounts can result. The areas regularly affected by lake effect snowfall have average amounts that are double that of non-affected areas.

The Midwest is the agricultural heartland of America, with one of the largest agricultural economies in the world. The region has over 400,000 farms and is the largest producer of corn (maize) and soybeans in the U.S. and several states contribute heavily to the production of wheat. The Midwest is also a major producer of fruits, vegetables and livestock especially dairy and beef cattle and pigs (Livestock makes up over 50% of the 200 billion dollars in agricultural market value.). Chickens, sheep, goats, and other animals are also grown in the region. Agricultural production in the Midwest is critically dependent on

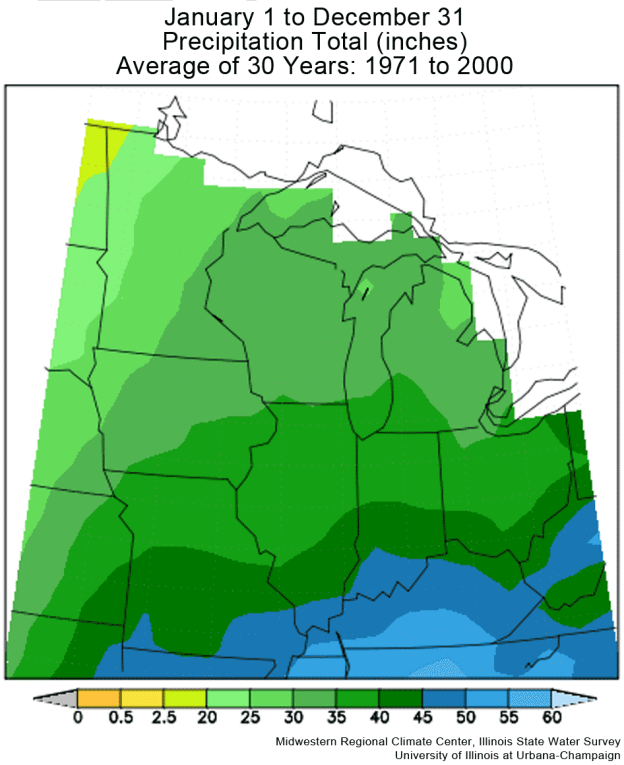

Figure 2.

DRAFT

surface and air transportation. Extreme rainfall causes a host of problems, including storm sewer overflow, flooding of homes and roadways, and contamination of municipal water supplies. Climate extremes combined with the urban pollution sources can create air quality conditions that are detrimental to human health.

The region serves as the nation's center for air and surface transportation; weather and climate extremes influence each form—commercial airlines, barges, trains, and trucks. Severe weather, including floods and winter storms, either stops or slows various forms of transportation for days and sometimes weeks. Urban sprawl contributes to traffic congestion which is exacerbated by severe storms. Both the Mississippi River and the Great Lakes are used intensively for barge transport; high and low water levels and ice cover, all determined largely by climate conditions, affect barge traffic.

Human health and safety are affected by climate conditions. Temperature extremes and storms have impacts on human health and safety, including loss of lives. Tornadoes, lightning, winter storms, and floods combined annually lead to many fatalities. The occurrence of vector-borne diseases is modulated by climate conditions.

Vulnerabilities

Major climate vulnerabilities include:

Floods. The 1993 Mississippi River flood was the 2nd costliest flood in modern times (after Katrina), with most of these losses occurring in the Midwest. A recent study ranked Iowa first, Missouri fourth, and Illinois sixth in state losses due to flooding (Changnon et al. 2001) for the period of 1955-1997. In addition to agricultural losses and direct damage to homes and infrastructure, floods can cause national disruptions to transportation because of the region's role as the center of the surface and riverine systems. In the 1993 flood, bridges, railroads, and the river were all shut down for periods of weeks to months. A flood event in 2008 was not as damaging overall, but massive flooding occurred in Cedar Rapids when the levels on the Cedar River exceeded the previous record by an incredible 11+ feet. In response, the city created an award-winning redevelopment plan that will mitigate against future floods.

Severe thunderstorms. Severe thunderstorms can be accompanied by tornadoes, hail, lightning, and strong straight-line winds, causing property and crop damage and human injuries and death. Non-tornadic thunderstorms are the most frequently-occurring weather catastrophe (as defined by the insurance industry) type based on insurance losses in this region (Changnon 2010).

Summer drought, heat, and flooding. Most agriculture in this region is not irrigated and thus vulnerable to summer drought. Major droughts can cause billions of dollars in losses. As the nation's and globe's "breadbasket", droughts can have substantial economic ramifications

both nationally and internationally. Disappointing yields in 2010 due to less-than-optimum conditions have contributed to a world-wide spike in commodity and food prices. These less-than-optimum conditions included moderate drought in some areas, but too much rain in others, as well as very high nighttime temperatures.

Heat waves. The 1995 heat wave, which lasted only 4 days, resulted in over 700 fatalities in Chicago, the most deadly U.S. heat wave in decades. Maximum daily temperatures were equal to or greater than 90°F for seven consecutive days, and greater than 100°F for two days at the peak of the heat wave. Even more importantly, there was no relief at night, as nighttime minimum temperatures were over 80°F during the hottest days. In this region, most days with temperatures in the 90s or soaring over 100°F would be considered hot by the region's residents. Examining data for the 9 urban centers of Chicago, Cincinnati, Cleveland, Detroit, Des Moines, Indianapolis, Milwaukee, Minneapolis-St. Paul, and St. Louis, these cities experience an average of 7 (Milwaukee) up to 36 (St. Louis) days over 90°F each year, while the number of days over 100°F range from one every two years up to an average of two per year. The factors that determine the region's climate favor occasional episodes of intense heat that are invariably accompanied by very high humidity. The heat index combines temperature and humidity to calculate how hot it actually feels. Currently, the southern Midwest states experience between 6 (Indiana and Iowa) and 18 (Missouri) days per year with a heat index over 95°F. Northern states and states that border the Great Lakes such as Michigan and Ohio experience less than 3 days per year. The episodic nature of these events contributes to vulnerability because the population does not become acclimated to the intense conditions. Heat waves also cause major power outages, contributing to health issues and also disrupting economic activities.

In response to the 1995 heat wave, the City of Chicago put together an extreme weather operations plan that included mitigation steps for the city to take during heat waves. These were implemented during a 1999 heat wave that was nearly as hot as the 1995 event, but fatalities were far less numerous. The city has also put together an ambitious Climate Action Plan that outlines both adaptation and mitigation strategies. One strategy is an aggressive "green roof" campaign, which has resulted in the installation of seven million square feet of green roofing; this should reduce the magnitude of the urban heat island.

Great Lakes water levels. The infrastructure on the shores of the Great Lakes is designed for a relatively narrow range of lake levels. Abnormally low or high levels cause impacts on hydropower generation, recreation and tourism, and shoreline structures, to name just a few. Low levels greatly restrict on-lake shipping.

Winter storms. Major winter snow and ice storms create many problems for surface and air transportation. These in turn create numerous other impacts on the full spectrum of economic activities. Winter storms were the second-most frequency-occurring weather catastrophe.

DRAFT

Trends

General

Precipitation (Fig. 3) has been near or above the long-term normal during the last 20 years. There have been occasional very wet summers, including the wettest in 1993 which was also the wettest year. The second wettest year occurred in 2008. Temperature (Fig. 3) has been quite variable but has tended to be warmer than normal on an annual basis. Summer temperatures have been about normal but include some very warm and very cool summers during the last 20 years. Very cool summers occurred in 1992, 2004, and 2009 and very warm summers in 1995, 2002, 2005, and 2010.

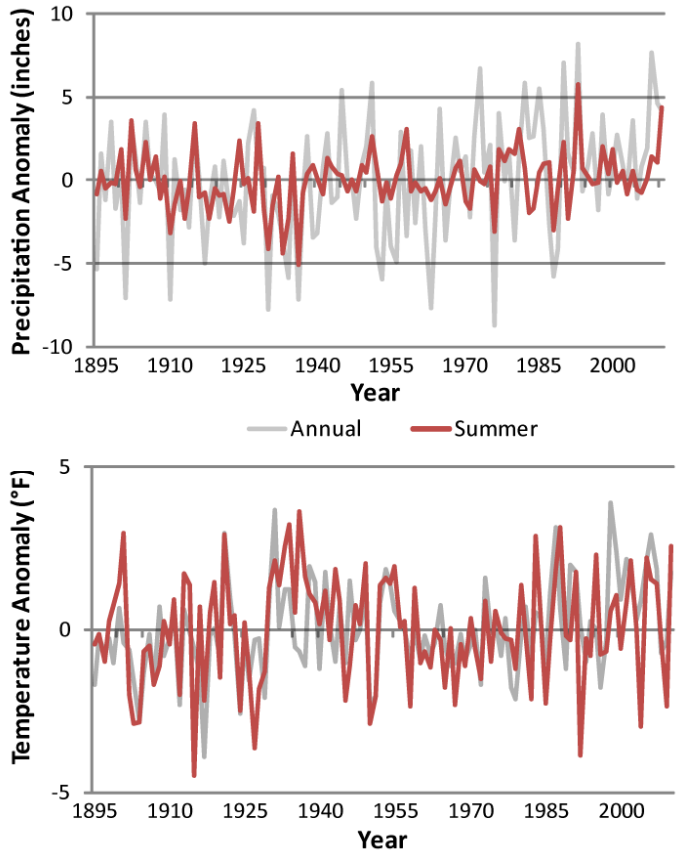

Figure 3. Summer temperature and precipitation for the summer (red) and whole year (gray) for the states of IL, IN, IA, MI, MN, MO, OH, and WI. Based on data from the National Climatic Data Center for the cooperative observer network.

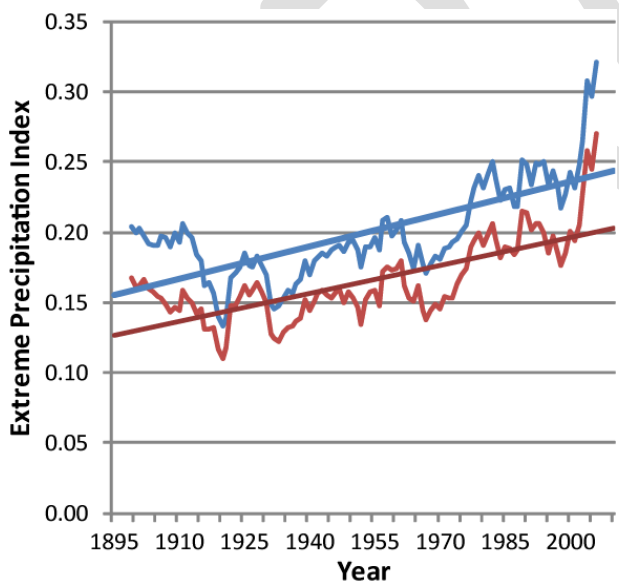

Figure 4. Time series of extreme precipitation index for the occurrence of 1-day, 1 in 5 year extreme precipitation events. The annual time series and linear trend (straight line) are shown in blue. A time series for the months of May through September is shown in red. Analysis is average for the states of IL, IN, IA, MI, MN, MO, OH, and WI. Based on data from the National Climatic Data Center for the cooperative observer network and updated from Kunkel et al. (2003).

Extreme Precipitation

The occurrence of extreme precipitation events has risen substantially. For example, the number of 1-day, once in 5-yr storms has increased by about 4% per decade since the beginning of the 20th Century (Fig. 4). About 85% of the events occur during the summer period of May through September. About 90% of the annual trend is due to increases during this warm season period.

Extreme Temperature

This region occasionally experiences episodes of intense cold. Intense cold waves tend to be quite episodic and when they occur they affect large areas. The

D

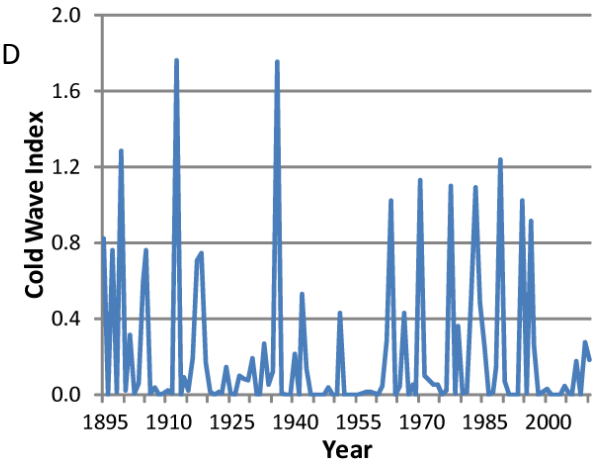

Figure 6. Time series of an index for the occurrence of cold waves defined as 4-day periods colder than the threshold for a 1 in 5 yr recurrence. Based on data from the National Climatic Data Center for the cooperative observer network and updated from Kunkel et al. (1999).

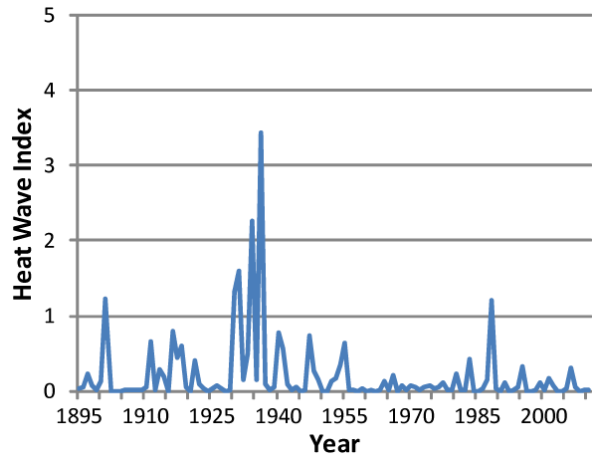

Figure 5. Time series of an index for the occurrence of heat waves defined as 4-day periods hotter than the threshold for a 1 in 5 yr recurrence. Based on data from the National Climatic Data Center for the cooperative observer network and updated from Kunkel et al. (1999).

frequency of intense cold waves has been very low since the mid-1990s (Fig. 5). Interestingly, the frequency of intense heat waves has not been particularly high (Fig. 6) in recent decades. In this region, the heat that occurred during the 1930s "Dust Bowl" era remains the most intense in the historical period of record. The 1930s heat waves were characterized by very high daytime temperatures and low humidity (by present-day Midwest standards). Recent heat waves, such as the 1995 event, have been accompanied by very humidity levels and high nighttime temperatures, but not quite as extreme daytime high temperatures.

Growing Season

The growing season length (Fig. 7) has increased gradually and now averages about a week longer than during the 1960s and 1970s. The last spring freeze has been occurring earlier and the first fall frost has been occurring later. The change in the timing of the last spring freeze has been somewhat greater than the timing change for the first fall frost.

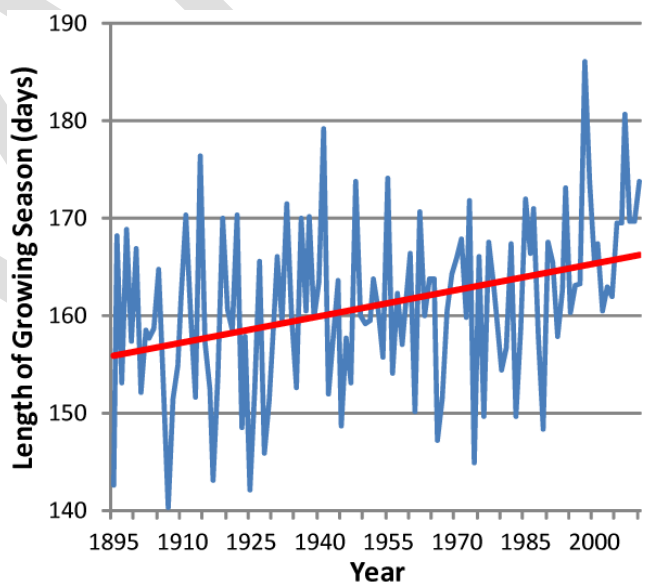

Figure 7. Length of the growing season, defined as the period between the last occurrence of 32°F in the spring and first occurrence of 32°F in the fall. Red line is a linear fit. Based on data from the National Climatic Data Center for the cooperative observer network and updated from Kunkel et al. (2004).

Storms

The occurrence of very high snowfall seasons has declined in central and southern regions, but increased in the far north, while the occurrence of very low snowfall seasons has shown the opposite behavior (decreases in the north, increases in the south. Lake

DRAFT

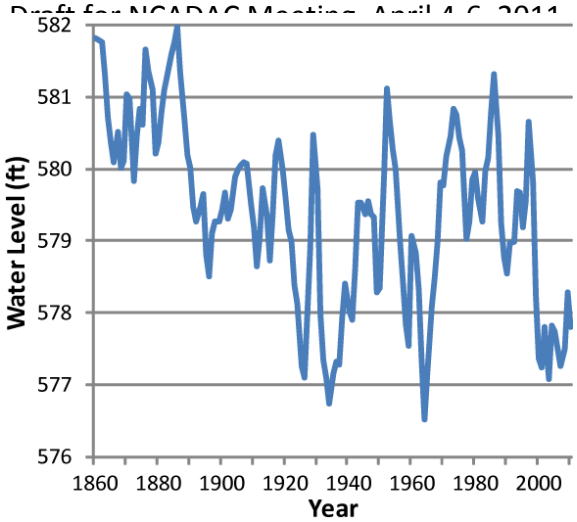

Figure 8. Time series of the water level of Lake Michigan-Huron. Data from the NOAA Great Lakes Environmental Research Laboratory.

effect snowfall has generally increased in the shoreline areas of Lakes Superior and Michigan, but not Erie.

Water Levels

Levels of Lakes Michigan-Huron (Fig. 8) have fluctuated over a range of close to 6 feet since the late 19th Century. Levels were notably high in the mid-late 19th Century, higher at times than during the entire 20th Century. Levels were also quite high during the early 1950s, as well as during the 1970s and 1980s. There was a rapid decline in levels during the late 1990s, and in recent years, levels have been very low, approaching the record low levels of the 1930s and early 1960s.

Ice Cover

Measurements of ice cover on the region's lakes indicate a decreasing trend in length of the period with ice cover or percentage of total ice cover. The total duration of ice cover on Lake Mendota in Madison, WI (Fig. 9) has decreased from about 120 days in the late 19th Century to less than 100 days in most years since 1990. The average ice cover on the Great Lakes (Fig. 10) has gradually declined since the 1970s. Average ice-out dates on Minnesota lakes (Fig. 11) show maximum values around the middle of the 20th Century and a tendency toward earlier ice-out dates since then.

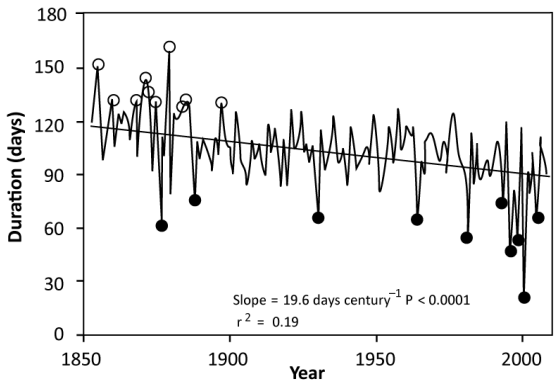

Figure 9. Long-term change in ice-cover duration for Lake Mendota, WI. The 10 cold (○) and 10 warm (●) extreme winters are indicated. From Magnuson (2010).

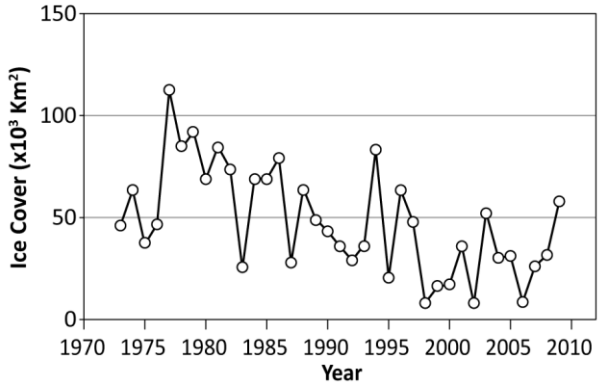

Figure 10. Time series of annual averaged ice area for the Great Lakes. From Wang et al. (2010).

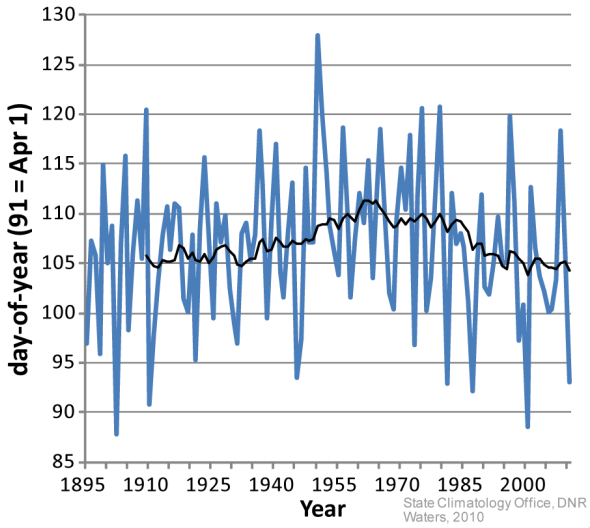

Figure 11. Average ice-out data for Minnesota lakes. The number of lakes varies from 7 in the early part of the record to over 60 lakes in recent times. All values were normalized by applying an iterative process to form an average bias for each lake from a theoretical average lake for its location. Courtesy of J. Zandlo, Minnesota State Climatologist.

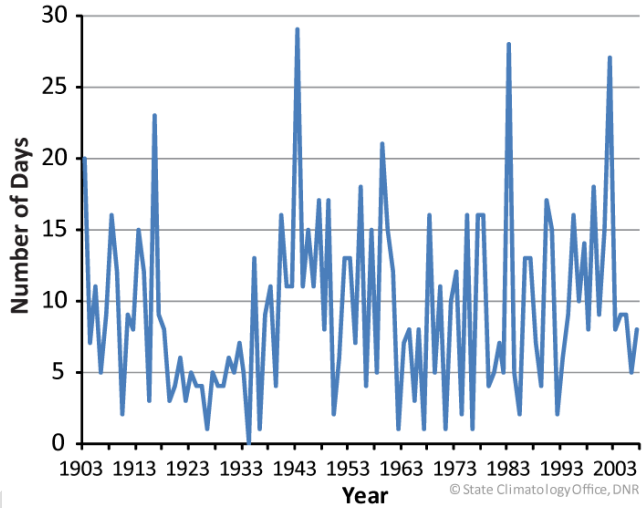

Figure 12. The number of days with late afternoon dewpoint equal to or exceeding 70°F at Minneapolis-St Paul. Courtesy of J. Zandlo, Minnesota State Climatologist.

Humidity

Measurements of the number of days with late afternoon summer dewpoint temperature exceeding 70°F at Minneapolis-St. Paul (Fig. 12) illustrate a characteristic of the 1920s-1930s drought and heat waves. The humidity levels during those summers were much lower than typical for the region with very days exceeding 70°F.

Frequently Asked Questions

To be filled in later.

Sources

Changnon, S.A., 2010: Temporal distribution of weather catastrophes in the USA. Climatic Change, doi 10.1007/s10584-010-9927-1.

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

Changnon, S. A., Angel J. R., K. E. Kunkel, and C. M. Lehmann, 2004. The Illinois Climate Atlas. Illinois State Water Survey Information/Education Material 2004-2, 309 pp.

DRAFT

Hayhoe, K., J. VanDorn, V. Naik, and D. Wuebbles, 2010: Climate Change in the Midwest Projections of Future Temperature and Precipitation. 28 pp.

Kunkel, K. E., D.R. Easterling, K. Redmond, and K. Hubbard, 2003: Temporal variations of extreme precipitation events in the United States: 1895–2000, *Geophys. Res. Lett.*, **30**, 1900, 10.1029/2003GL018052

Kunkel, K.E., R.A. Pielke, Jr., and S.A. Changnon, 1999: Temporal fluctuations in weather and climate extremes that cause economic and human health impacts: A review. *Bull. Amer. Meteor. Soc*., **80**, 1077-1098.

Magnuson, J.J., 2010: History and heroes: the thermal niche of fishes and long-term ice dynamics. Journal of Fish Biology, 77, 1731-1744, doi:10.1111/j.1095-8649.2010.02781.x.

Wang, J., X. Bai, G. Leshkevich, M. Colton, A .Cutes, and B. Lofgren, 2010: Severe ice cover on Great Lakes during winter 2008-2009. *Eos, Transactions, American Geophysical Union,* 91, 41-42

Wuebbles, D., K. Hayhoe, and B. Garrett, 2010: Potential Impacts of Climate Change on Agriculture in the Midwest. 10pp.

DRAFT