Municipal Climate Adaptation: A Report for McCook, Nebraska

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Climate Change and Cities

1.1 Introduction

The Midwest and Great Plains are no strangers to extreme weather and climate events. Each year, events such as thunderstorms, tornadoes, and blizzards impact the local economy, infrastructure, and the safety and well-being of the people living in affected communities. Recent events, such as the back-to-back flooding and drought years of 2011 and 2012 or the recent increase in urban flash flooding due to extreme rainfall events, have left communities in a position of responding to the immediate needs of public safety, while rebuilding infrastructure - often with an eye to the future.

In light of these events, city leaders are increasingly considering climate data and information as a guide for their comprehensive plans. Changes to temperature, precipitation, and the frequency of extreme events in this region are already apparent; however, many of the impacts due to the changing climate are yet to be realized as the rate of future changes generally exceeds that of historical trends. Pinpointing and understanding how municipal-specific climate thresholds have changed historically and how these may change in the future is an important part of the process of preparing and planning for urban life under a changing climate.

"The nation's economy, security, and culture all depend on the resilience of urban infrastructure systems." - Urban Systems, Infrastructure, and Vulnerability NCA Report, 2014

1.2 Project Goals

This preliminary report is part of a larger effort to increase the capacity for municipal climate adaptation planning in the lower Missouri River Basin states (Iowa, Kansas, Missouri, and Nebraska). The goal of this project is to develop a process for incorporating climate information into long-term municipal planning strategies. By utilizing a combination of physical and social science approaches, the project aims to accomplish three objectives: 1) document thresholds associated with climate extremes in the municipal water resources sector; 2) develop municipal-specific climate information for use in planning; and 3) develop a methodology by which this information may be shared and replicated across multiple sectors. This effort builds on previous work with the Heartland Sustainability Directors Network, which is a regional subgroup of the Urban Sustainability Directors Network (http://usdn.org/uploads/cms/documents/climate_in_the_heartland_report.pdf).

Project partners include the High Plains Regional Climate Center, the Nebraska State Climate Office, the University of Nebraska Public Policy Center, the University of Nebraska-Lincoln Community and Regional Planning Program, and the City of Lincoln.

Funding is provided by the National Oceanic and Atmospheric Administration's Sectoral Applications Research Program (NA16OAR4310123).

HPRCC NEBRASKA STATE CLIMATE OFFICE UNIVERSITY OF Nebraska PUBLIC POLICY CENTER CITY OF LINCOLN NEBRASKA

Methods

2.1 Data Sources

All historical climate data used in this report originated from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NCEI). Although this report is intended to be used on the local level, statewide and regional data analyses were included to help to put local trends into context.

For each individual location, the last 50 years (1967-2016) worth of data were used in the analyses to allow for quick comparisons between cities. The only exceptions were Kansas City, MO and Lincoln, NE, which used 44 years (1973-2016). These data are a part of NCEI's Global Historical Climatology Network - Daily (GHCN-D) dataset and were obtained from the Applied Climate Information System (ACIS). Any season with greater than 9 missing days and any year with greater than 36 missing days were not used in the analyses.

For statewide and regional data, the entire period of record (1895-2016) was used. These data were obtained from NCEI's Climate at a Glance tool. Future projections of climate conditions were summarized from the multi-agency sponsored National Climate Assessment. Links to all climate data used in the report, along with other available resources, are located on page 12.

2.2 Climate Thresholds

The following thresholds were used to generate the contents of this report. The table was modeled after Anderson et al. 2015, which was co-developed by sustainability directors and climatologists during a pilot project funded by the Urban Sustainability Directors Network.

Municipal Concern	Climate Thresholds	Climate Condition
General climate conditions	Average, maximum, and minimum temperatures	Annual and Seasonal Temperature
General climate conditions	Average rainfall	Annual and Seasonal Precipitation
General climate conditions	Average snowfall	Annual and Seasonal Snowfall
Parks and recreation; employees working outdoors; insect vectors	Dates when minimum temperature is less than 32°F	Last Spring and First Fall Frosts
Energy demand; public health	Average heating degree days and cooling degree days	Annual and Seasonal Heating Degree Days and Cooling Degree Days
Energy demand; public health	Temperatures over the hottest and coldest 3-day times period each year	Heat Waves and Cold Waves
Stormwater management; floodplain planning; emergency response; infrastructure design	Days with rainfall ≥ 1.25 inches Days with rainfall ≥ 4.00 inches Amount of rainfall in wettest day Amount of rainfall in wettest 5-day period Amount of rainfall in wettest 15-day period	Heavy Rainfall
Snow and ice management; public safety; electricity and phone service outages	Days with snowfall ≥ 3.0 inches Days with snowfall ≥ 6.0 inches Days with snowfall ≥ 12.0 inches Amount of snowfall in heaviest 3-day period	Snowstorms

Historical Climate Trends - Statewide

3.1 Nebraska Temperature Trends

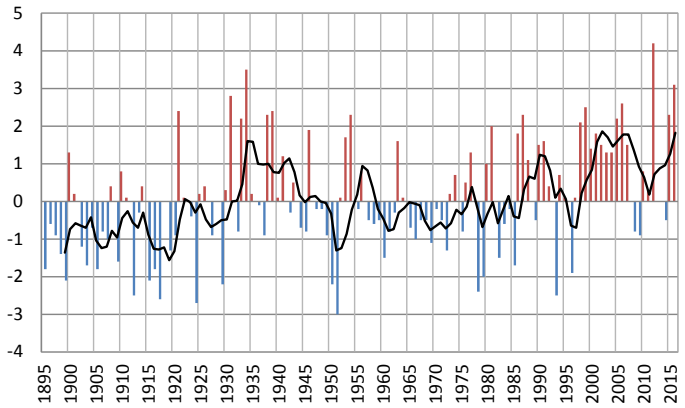
Statewide temperature records for Nebraska date back to 1895, resulting in well over 100 years worth of observations. A wide annual temperature range is a feature of Nebraska's climate, with hot summers and cold winters. There is generally a north to south temperature gradient across the state, with the warmest weather occurring in southeastern areas and the coolest weather occurring in the northwest.

The trend in average annual temperature for Nebraska shows an increase of 1.8°F over the 122-year period. There is high year-to-year variability, with significant warmth during the 1930's Dust Bowl era, and generally warm conditions since the mid-1980s. 2012 was the warmest year on record, followed closely by 1934 and then 2016. Four of the top ten warmest years on record have occurred since 2005.

The annual warming trend is greater for minimum temperatures (2.5°F) than for maximum temperatures (1.2°F), and this pattern holds true for the region, and much of the world. An increase in atmospheric moisture is one explanation for this difference, as this can impact nighttime low temperatures much more than daytime high temperatures.

On a seasonal basis, winter trends indicate the strongest warming with a 3.2°F increase, while summer and autumn trends show the least, with a 1.0°F increase during each season. This pattern is consistent with regional trends, as well.

Nebraska's Average Annual Temperature Departure (°F)



Average annual temperature departure (°F) from the 122-year long-term average for the state of Nebraska, along with the 5-year running average. Data courtesy NCEI.

Regional Temperature Trends

The average temperature trend for the four-state region encompassing Iowa, Kansas, Missouri, and Nebraska shows a 1.3°F increase over the 122-year period. This trend is not uniform across the region, however, as warming has been strongest in Nebraska (1.8°F) and weakest in Missouri (0.8°F). Just like each state in the region, minimum temperatures have increased at a higher rate (2.0°F) than maximum temperatures (0.7°F) region wide.

When broken down by season, the warming trend for the region is strongest in the winter (2.4°F) and weakest in the summer and autumn seasons (0.5°F and 0.6°F). Variability in seasonal trends at the regional level is also observed at the global scale.

Statewide Average Temperature Change by Season (1895-2016)
Temperature in degrees F

State	Spring	Summer	Autumn	Winter
Iowa	1.5	0.1	0.8	2.1
Kansas	1.8	0.9	0.7	2.6
Missouri	1.3	0.0	0.0	1.6
Nebraska	**2.1**	**1.0**	**1.0**	**3.2**
Four-state Average	1.7	0.5	0.6	2.4

Historical Climate Trends - Statewide

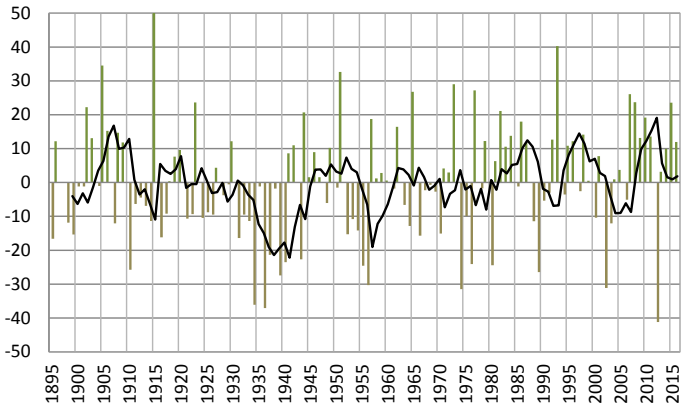
3.2 Nebraska Precipitation Trends

Statewide precipitation records for Nebraska also date back to 1895, resulting in over 100 years worth of observations. Precipitation varies seasonally, with a maximum in summer and a minimum in winter. Generally, precipitation decreases across the state from east to west. This precipitation gradient is a defining climatic feature of the state, with southeastern areas receiving about 40 inches of precipitation each year on average and areas of the panhandle receiving less than 20 inches.

Over the 122-year time period, average annual precipitation has increased by about 6% in Nebraska, which is the smallest increase in the four-state region. There is variability in the precipitation record, with drought periods of the 1930s and 1950s standing out, as well as the extremely dry single years of 2002 and 2012. Despite these recent two extremely dry years, the past 10 years have been one of the wettest periods in Nebraska's record. With the exception of 2012, the driest year on record for Nebraska, each of the past 10 years have been above average. Additionally, the back-to-back years of 2007 and 2008 both ranked in the top 10 wettest years on record for the state.

Seasonal trends in precipitation show variation. Substantial increases have occurred in the spring (14%) and autumn (12%), while precipitation has decreased in the winter (10%). Nebraska's winter precipitation is generally light and only constitutes about 10% of the annual total, so this seemingly large decrease is, in effect, negligible. Meanwhile, little change was evident in the summer months.

Nebraska's Annual Precipitation Departure (%)



Annual precipitation departure (%) from the 122-year average for the state of Nebraska, along with the 5-year running average. Data courtesy NCEI.

Regional Precipitation Trends

A distinguishing feature of the region is the east-west precipitation gradient in which annual average precipitation totals range from 50 inches in southeastern Missouri to less than 20 inches in the panhandle of Nebraska.

There tends to be high year-to-year variability in precipitation for much of the region; however, over the 122-year period, there has been a 10% increase in average annual precipitation. This increase varies across the region, with a low of 6% in Nebraska to a high of 15% in Iowa. On a seasonal basis, there is variability from state to state, with both increases and decreases in precipitation. On the whole, the strongest trends were in spring (16% increase), while the weakest trends were in winter (4% increase).

Statewide Annual Climate Trends (1895-2016)
Temperature in degrees F, Precipitation in percent

State	Average Temperature	Maximum Temperature	Minimum Temperature	Precipitation
Iowa	1.2	0.2	2.1	15%
Kansas	1.5	1.2	1.8	10%
Missouri	0.8	0.1	1.4	7%
Nebraska	**1.8**	**1.2**	**2.5**	**6%**
Four-state Average	1.3	0.7	2.0	10%

Historical Climate Trends - Local

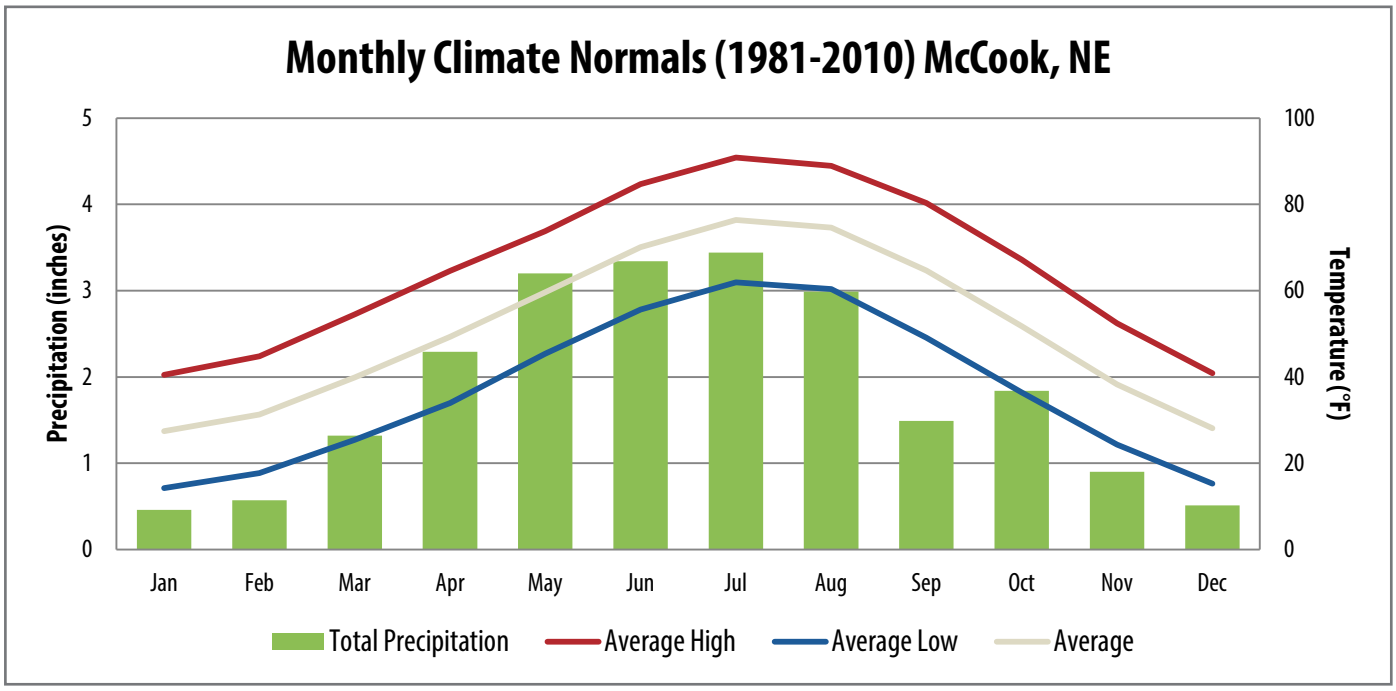
4.1 General Climate of McCook

Culbertson: 40.2333, -100.8300
GHCN ID: USC00252065, Map Data: Google

The weather station at Culbertson, located approximately 12 miles to the west-northwest of McCook, was selected for this report due to its over 100-year record. Daily measurements of temperature, precipitation, and snowfall have been taken at this location since June 1, 1889.

McCook's climate is considered to be humid continental with hot summers, which is characterized by large differences in temperatures throughout the year due to its interior location far from the moderating effects of the oceans. The city experiences all four seasons and there can be high variability in temperature and precipitation. McCook is also near the transition to an arid, steppe climate, experienced by its neighbors just to the west. The hottest time of the year is July, when average high temperatures peak at 91°F, while the coldest time of the year occurs in January with average low temperatures dipping to 14°F. The wettest time of the year is the summer (June, July, August), with precipitation totals averaging 9.77 inches, while the driest time of the year is the winter (December, January, February) with only 1.54 inches (liquid equivalent*). Much of the precipitation in the winter falls as snow, with an average of 15.1 inches. McCook's winds are predominantly from the north/northwest during winter and the south/southeast during summer. Winds from the north bring cold, dry air, while winds from the south bring warm, moist air. McCook's location between these contrasting air masses puts it at risk for severe thunderstorms, which can produce tornadoes, high winds, hail, and flooding. The graph below shows the average climate conditions for McCook.

*Winter precipitation in McCook is a combination of rain and the liquid equivalent precipitation of snow, i.e. the amount of liquid that would have fallen had the precipitation been rain instead of snow.



4.2 McCook Temperature Trends

Temperature Trends Vary by Season
McCook's average annual temperature has increased by 3.2°F over the past 50 years. Each season shows a warming trend, with autumn exhibiting the largest increase (4.0°F). Overall, both maximum and minimum temperatures have increased; however increases in minimums have outpaced maximums. For summer, this is important because fewer cooler nights can have serious public health implications, as heat is the leading cause of weather-related deaths in the U.S. (Peterson et al. 2013).

Heat Waves and Cold Waves
A look at multi-day heat and cold wave events shows that there has been an increase in the severity of heat waves and a decrease in the severity of cold waves. Interestingly, the increased severity of heat waves has been driven by minimum temperatures. Overall, the hottest 3-day period of each year has increased by nearly 3°F, while the coldest 3-day period of each year has increased by about 4°F.

Future projections already correspond to recent observed changes in temperature and these trends are expected to continue and accelerate.

McCook's Changing Seasons

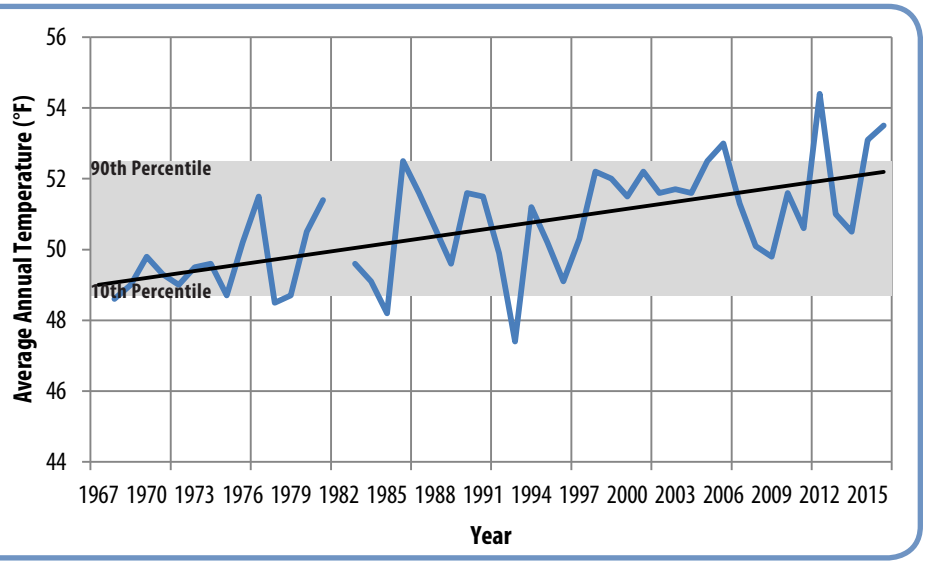
Spring	Summer
3.0°F ↑	3.1°F ↑
Autumn	**Winter**
4.0°F ↑	3.8°F ↑

Changes to Energy Needs

Heating and cooling degree days can be an indication of energy demand, and rising temperatures in McCook are leading to changes in energy needs. Trends in cooling degree days show a 29% increase overall, with the largest increase, by percentage, in the spring (63%).

Trends in heating degree days, however, show a 15% decrease, annually. This is not only due to warmer average temperatures in the winter, but also to significantly warmer cold waves, leading to lower peak energy demand.

Over the past 50 years, McCook's average annual temperature has increased by 3.2°F. Five of the past fifteen years has met or exceeded the 90th percentile.



4.3 McCook Precipitation Trends

Precipitation Trends Vary by Season
Overall, there has been a 9% increase in the annual precipitation in McCook, with noteworthy seasonal differences. Over the past 50 years, summer and autumn precipitation has increased15% and 10%, respectively. Unlike many locations around the region that show increases in winter precipitation, McCook's has decreased by 7%. A small decrease was also observed in the spring.

Mixed Trends in Heavy Rainfall Events
Unlike areas to the east, McCook has had little change in the frequency of heavy rainfall events* over the past 50 years. But, the intensity of single-day events has decreased, while the amount of rain in 5-day events has increased. This could signal a potential for flooding events because once soils are saturated from initial rains, subsequent rainfall will run off into ditches, streams, and rivers. Agricultural land management practices upstream can also have an impact on the quantity and quality of the water flowing through the watershed (Hatfield et al. 2014). *Heavy rainfall events are defined as days receiving at least 1.25 inches of rain.

Future projections indicate that winter and spring precipitation may increase, while summer precipitation may begin to decline.

McCook's Changing Seasons

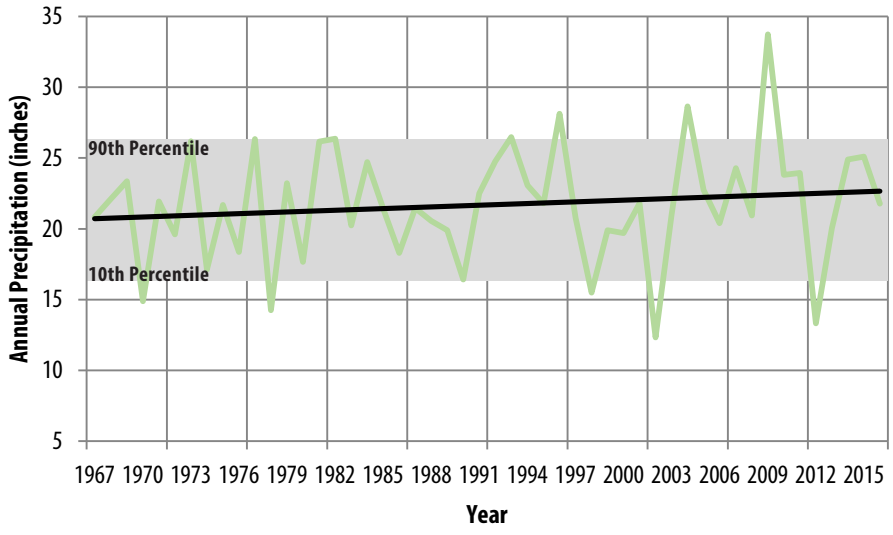
Spring	Summer
2% ↓	15% ↑
Autumn	**Winter**
10% ↑	7% ↓

Changes Within Snow Season

A snow season is defined as the period between July 1 and June 30. Overall, there has been a 17% decrease in snowfall totals with significant changes within the snow season.

Trends show that less snow is falling in the spring and autumn, with steep declines in snowfall totals over the past 50 years. Conversely, there has been a 17% increase in wintertime snowfall totals. The snowiest winter in recent years occurred in 2013-2014, which ranked as the 12th highest total on record.

Over the past 50 years, McCook's annual precipitation has increased by 9%. Recent years have been extreme, ranking in the top ten wettest or driest years on record.



Historical Climate Trends - Local

4.4 McCook Climate Extremes

Highest Temperature:

113°F, Jul 24, 1940

Lowest Temperature:

-38°F, Feb 12, 1899

Highest Precipitation:

4.45in, May 16, 1891

Highest Snowfall:

16.0in, Jan 23, 1965

Average temperature and total precipitation are helpful for understanding general conditions; however, these do not demonstrate the wide range of conditions that can be experienced at a location. This range of conditions is especially important for a place like McCook because 1) extremes are common in the continental type of climate experienced there and 2) extremes are impactful to people and infrastructure. Extremes in both temperature and precipitation are becoming more common in McCook, and those occurring in succession can make responding to and preparing for these events quite difficult. Extremes data presented here span the entire period of record for McCook, starting in 1889.

Temperature Extremes

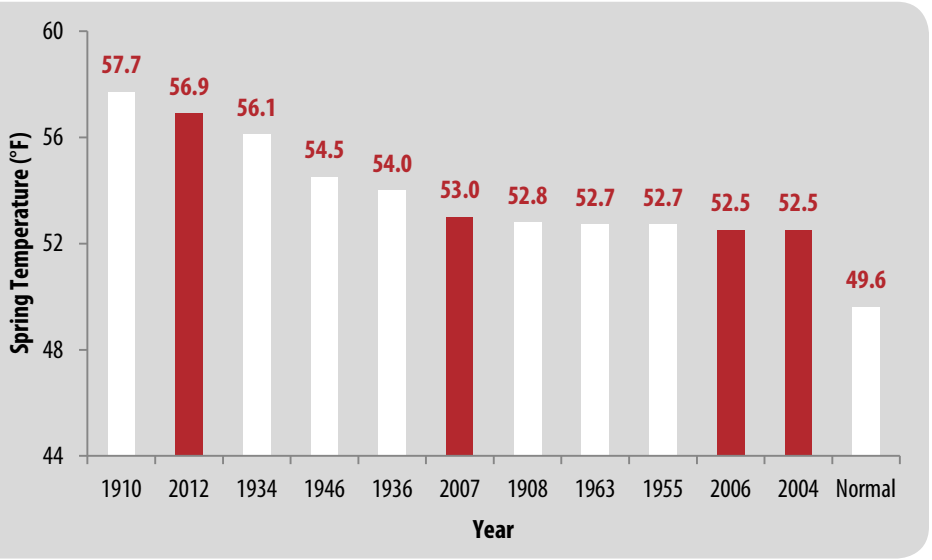
Two of the top ten warmest years on record in McCook occurred recently, including 2012 (2nd warmest) and 2016 (9th warmest). No recent year has broken into the top ten coolest years, however. A look at the daily temperature data shows that extreme high temperatures are increasing in frequency and occurring slightly earlier in the year. Over the past 50 years, the number of days reaching at least 100°F has increased by nearly 8 days, while the average date of the first 100°F+ day has moved from late to mid-June.

Precipitation Extremes

It has been a roller coaster ride over the past several years in McCook, with precipitation extremes on both ends of the spectrum. Two of the wettest years (2004 and 2009) and two of the driest years (2002 and 2012) on record all occurred in the past fifteen years. 2009 ranked as the second wettest year with 33.73 inches, while 2002 ranked as the 6th driest year with 12.32 inches. McCook's location near the Republican River has made it vulnerable to heavy rainfall events upstream, like those that triggered the historic flood of 1935 (Pearson 2017), but mitigation efforts have reduced this risk.

Recent Extremes - Top 10 Warmest Springs on Record

Four of the top ten warmest spring seasons in McCook have occurred in the past fifteen years. None of the past fifteen years have broken into the top ten coolest list.



4.5 Summary Tables

For quick reference, the following tables show a summary of recent changes in seasonal climate conditions and damaging events in McCook. All trends cover the last 50-year time period of 1967-2016.

Seasons are defined as follows: Spring (March, April, May), Summer (June, July August), Autumn (September, October, November), and Winter (December, January, February).

Season	Recent Changes in Seasonal Weather
Spring	Warmer springs Earlier last frosts
Summer	Warmer, Wetter summers Warmer nights; More Cooling Degree Days
Autumn	Warmer, Wetter autumns Later first frosts
Winter	Warmer, Snowier winters Fewer Heating Degree Days

Damaging Event	Recent Changes in Damaging Events
Heat Waves	Increased intensity of heat waves 3-day: Higher average and minimum temperatures Lower maximum temperature
Cold Waves	Decreased intensity of cold waves 3-day: Higher average, maximum, and minimum temperatures
Heavy Rainfall	Daily: 15% decrease in wettest 1-day period per year 5-day: 13% increase in wettest 5-day period per year 15-day: Little change in wettest 15-day period per year
Snow Storms	Little change in the frequency of snow storms 8% increase in snowiest 3-day period per year Snowier winters; Less snowy transition seasons (spring/autumn)
Late/Early Freeze	Growing season lengthened by nearly one month Earlier frosts in spring; Later frosts in autumn
Tornado, Wind, Hail	Inconsistencies in reporting exceed trend

Future Climate Projections

Over the past century, Nebraska's climate has become increasingly warmer and wetter. Seasonal differences in these overall trends highlight times of the year that have been impacted the most and future projections indicate that many of these trends could continue into the future. Projections in this section originated from the third National Climate Assessment (NCA) and associated sustained activities (Melillo et al. 2014; Frankson et al. 2017a; Kunkel et al. 2017). The fourth NCA is currently under development and is expected to be released in 2018.

Temperature

Temperatures have increased across Nebraska, predominantly in the winter and spring. Projections indicate that temperatures will continue to rise; however, the amount of future warming is largely dependent upon increases or decreases in greenhouse gas emissions. This means a range of conditions is possible and, depending on the scenario, a 4-9°F increase in average annual temperature could occur for McCook (Walsh et al. 2014). Like current trends, cold waves are expected to become less intense and heat waves are expected to continue to become more intense. Even a modest increase in summertime temperature could lead to more extremes. These trends could have serious implications for communities like Grand Island, as increases in cooling demands could put a strain on utilities and more intense heat waves could impact vulnerable populations, like the young, the elderly, and the poor.

"Communities that are already the most vulnerable to weather and climate extremes will be stressed even further by more frequent extreme events occurring within an already highly variable climate system." - Great Plains NCA Report, 2014

Precipitation

Western Nebraska, October 2009
Photo courtesy: Ken Dewey

Like current trends, projections indicate seasonal differences in future precipitation across Nebraska. Increases in precipitation are expected in the winter and spring seasons, and for McCook, this could mean a greater than 15% increase in winter and a 10-15% increase in spring (Walsh et al. 2014). Because extreme precipitation events are also expected to increase, this could potentially lead to an increase in the frequency and intensity of floods, both in terms of flash flooding and longer-term events. Although not yet apparent in the regional and local trends, summer precipitation is expected to decrease across all of Nebraska by 2050. For McCook, this could be a decrease of up to 5-10% (Walsh et al. 2014). While this decrease may not seem dramatic, in combination with significant increases in summertime temperatures it may cause an increase in the intensity of droughts, which are a recurring feature of Nebraska's climate.

Water Supplies

Much of Nebraska is dependent upon the Platte River system that flows across the state. Mountain snowpack in Colorado and Wyoming feeds the system, making it sensitive to changes experienced at these higher elevations. The Republican River, however, rises from the eastern plains of Colorado and is dependent upon tributaries and underground water to fill its banks. Increased water use for irrigation is already putting a strain on the Ogallala Aquifer and can reduce river flows. Future demands for water under a warmer climate will only stress the system further.

Implications

Hazards originating from extremes in weather and climate conditions impact municipalities in multiple ways, from infrastructure to utilities to human health. While many locations in the Great Plains already experience a wide range of weather and climate conditions, this range has increased over time in McCook, making the city more prone to weather and climate hazards. Recent and future changes in McCook that could have implications for municipal operations include:

Changes to energy needs

Recent

- An increase in winter temperatures coupled with a decrease in the severity of cold waves has led to a decrease in heating demands.
- An increase in temperatures in the spring, summer, and autumn seasons has led to an increase in cooling demands.

Future

- A continued increase in temperatures could further decrease energy needs in the winter.
- More intense heat waves in the summer could impact utilities during peak delivery times.

Strains to water resource management

Recent

- An increase in the intensity of multi-day (5-day) heavy rainfall events has increased the potential for longer-term flooding events.

Future

- Increases in single- and multi-day heavy rainfall events could increase the potential for more intense and frequent flooding episodes, which could lead to soil erosion as well as decreased water quality.
- Projected decreases in summer precipitation could increase the intensity of droughts, potentially putting strains on the quality and quantity of available water.

Human health impacted by extremes in temperature and precipitation

Recent

- Warmer winters could decrease cold weather-related impacts, while warmer nights in the summer could impact vulnerable populations, potentially increasing the need for cooling shelters.
- A longer frost-free season could signal a longer vector-borne disease season.

Future

- More intense heat waves in the summer could negatively impact vulnerable populations.
- Continued increases in winter temperatures could lead to the overwintering of pests.
- More intense and frequent flooding events can lead to short-term concerns, such as injury and death, and long-term concerns, such as a potential increase in water-borne disease and indoor air quality issues due to mold and mildew (Luber et al. 2014).

Other

Recent

- Declines in spring/autumn snowfall coupled with increases in winter snowfall could impact the timing and frequency of snow removal operations.

Resources

Historical Climate Data and Information

Historical Temperature and Precipitation Data
- Applied Climate Information System: http://scacis.rcc-acis.org/

Historical Drought Information
- Drought Risk Atlas: http://droughtatlas.unl.edu/

Temperature and Precipitation Trends at National, State, and Climate Division scales
- NCEI's Climate at a Glance: https://www.ncdc.noaa.gov/cag/

Local Trends in Midwest and Great Plains
- Corn Belt Climate Trends (1980-2013): http://www.hprcc.unl.edu/climatetrends.php

Recent and Current Climate Monitoring

Midwest and Great Plains Monthly Climate and Drought Webinar
- To sign up for future webinars: https://www.drought.gov/drought/calendar/webinars
- For archive: http://www.hprcc.unl.edu/webinars.php

High Plains Quarterly and Monthly Climate Summaries
- Quarterly Climate Impacts and Outlook: https://www.drought.gov/drought/resources/reports
- Monthly Climate Overviews: http://www.hprcc.unl.edu/climatesummaries.php

Temperature and Precipitation Maps
- HPRCC ACIS Climate Maps: http://www.hprcc.unl.edu/maps.php?map=ACISClimateMaps

Drought Monitoring
- U.S. Drought Monitor: http://droughtmonitor.unl.edu/

Streamflow Conditions
- USGS WaterWatch: http://waterwatch.usgs.gov/index.php

Future Climate Data and Information

National Climate Assessment
- Reports by region and sector: http://nca2014.globalchange.gov/

Climate Change Impacts by State
- EPA: https://www.epa.gov/climate-impacts/climate-change-impacts-state

State Climate Summaries
- NCEI: https://statesummaries.ncics.org/

Climate Change Implications for Nebraska
- University of Nebraska-Lincoln: https://go.unl.edu/climatechange

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