EC715

Climate Change Impact on Air Temperature, Daily Temperature Range, Growing Degree Days, and Spring and Fall Frost Dates In Nebraska

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This UNL Extension Circular provides data and quantitative analyses, discussion, and interpretation of impacts of change in air temperature as a result of climate change on some of the basic temperature-related indices related to agricultural practices and their potential implications on agricultural practices.

Adapting agricultural practices to a changing climate can help to sustain and even increase productivity. While we notice and hear stories about the climate changes going on around us, such as seeing robins and lilacs blooming earlier in the spring, it is important to know the numbers behind the observations and what they mean. Also, while global climate change is making headlines, local conditions and climate changes need to be quantified and interpreted.

Even within a given region (i.e., Nebraska), the impact(s) of climate change can vary substantially depending on the gradients in interactions between land surface characteristics versus atmosphere. Thus, the climate change impacts in even one state should be quantified locally. Better preparations and management decisions can be made by combining relevant climate trend information with up-to-date forecasts.

To quantify the trends in air temperature across Nebraska, five locations with long historical records were chosen. From west to east, the locations are Alliance (Box Butte County), Culbertson (Hitchcock County), Hastings (Adams County), Central City (Merrick County), and Fremont (Dodge County). The available data dated from 2012 back to 1897 at Fremont; back to 1901 at Alliance, 1904 at Culbertson, 1908 at Hastings, and 1918 at Central City. Trends are based on annual frost dates, daily high and low (maximum and minimum) air temperatures, average air temperature, daily temperature range (high minus low temperature), accumulated growing degree days, and temperature distribution.

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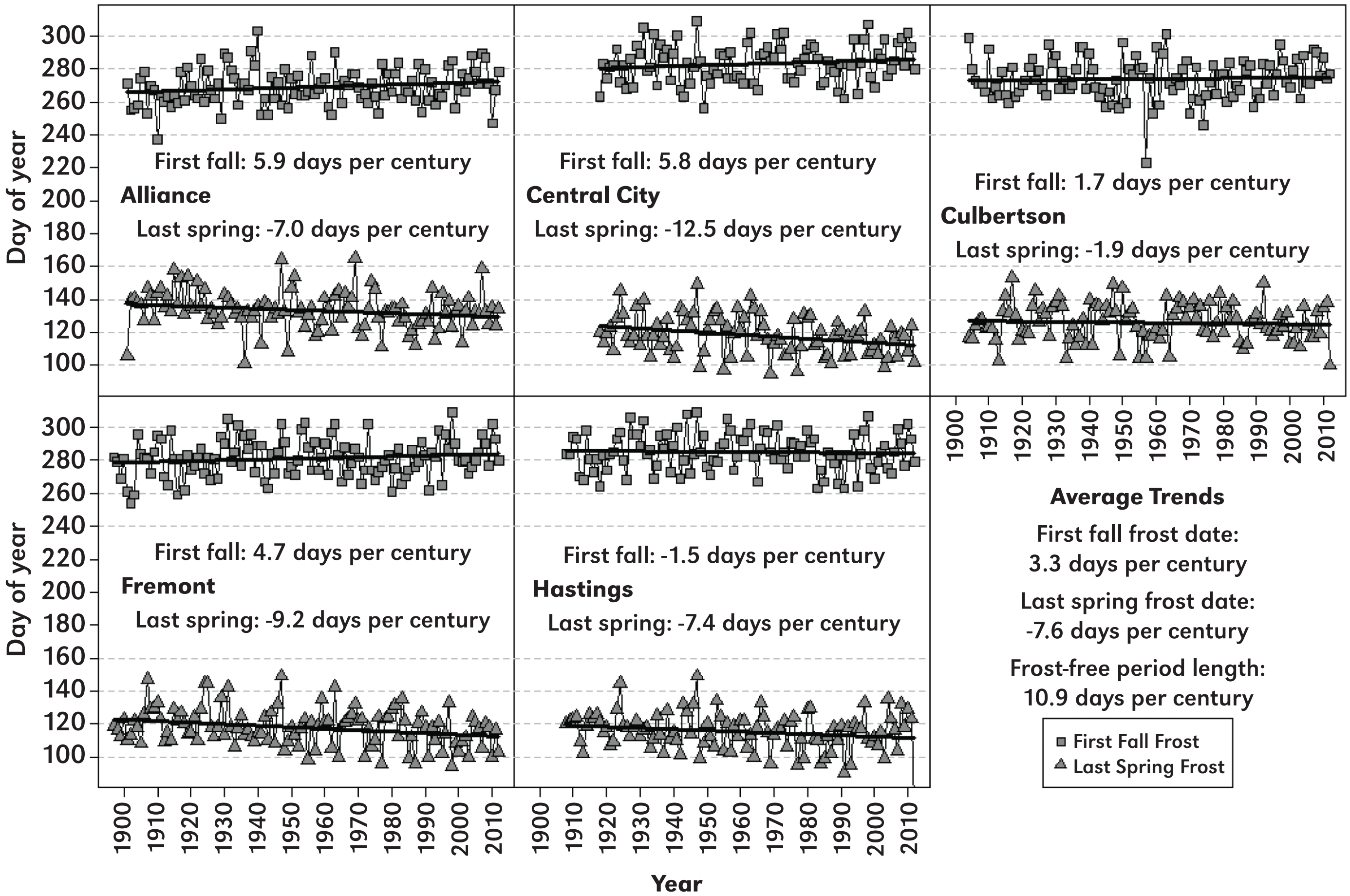

Figure 1. Time series of last spring frost and first fall frost and their linear trends for Alliance (period of record: 1901-2012), Central City (1918-2012), Culbertson (1904-2012), Fremont (1897-2012), and Hastings (1908-2012). Positive numbers for the first fall and last spring frost days represent frosts occurring later in the respective season, and negative numbers represent earlier frosts in the respective season.

Trends in Frost Date

This analysis presents the linear trends of the last date in the spring that the temperature drops below 32°F (last spring frost), the first date in the fall that the temperature drops below 32°F (first fall frost), and the length between these two dates (frost-free period or climatological growing season). *Figure 1* presents the time series and trends of the frost dates for the five locations.

The greatest trends in frost dates occurred at the northern locations — Central City, Fremont, and Alliance. All of these locations had significant trends toward earlier last spring frost dates (7-12 days earlier per century) and slight trends toward later first fall frosts (5-6 days later per century). These trends resulted in much longer frost-free periods, indicating longer growing seasons — 13 days longer per century for Alliance, 14 days longer for Fremont, and 18 days longer for Central City. Hastings had a trend toward slightly earlier last spring frost (7.5 days per century), yet a trend of slightly earlier first fall frost (1.5 days per century), which led to only a 6 day per century increase in frost-free period. Culbertson had only a 3.5 day increase in the frost-free period, with a 2 day earlier per century trend in the last spring frost and 1.5 days later first fall frost.

Trends in Daily High, Low, and Average Temperature

The largest changes in daytime high temperatures occurred for the locations in the more south-central part of Nebraska during the summer and fall. Monthly average daytime high temperature **decreased** year-round, with the greatest monthly average decreases over 2°F per century occurring in April and the fall months at Culbertson. At Hastings, the daytime high temperature **decreased** by almost 4°F per century in July and August, and around 2°F per century in September and October. Central City had a **decrease** in the daytime high temperature of 4.7°F in July and 4.0°F in August, but also had **increases** in daytime highs from November through June with over 4°F increases from January through April.

There were very little changes in monthly average daytime high temperatures for the most northern locations, Alliance and Fremont.

The most northern locations — Alliance, Central City, and Fremont — had **year-round increases** in monthly average nighttime low temperature. Alliance averaged a 1.5°F per century **increase** in low temperature. Central City averaged a 3.1°F **increase** in low temperature with increase of over 3°F per century occurring from January through June and November. At Fremont, there was an average of almost 2°F per century **increase** in low temperature with the greatest increases occurring in February (4.0°F per century) and a more than 2°F per century increase May through August. At Hastings, low temperatures increased during the first half of the year with an up to 2.2°F per century increase in July. Low temperatures decreased during the second half with a maximum decrease of 2.1°F per century in September. There were only slight changes in the average nighttime low for Culbertson.

The top rows of *Figures 2-6* present the time series and trends of seasonal average air temperature. Central City and Fremont had the greatest increases in average temperature. Increases occurred from winter through spring for Central City, which had an average monthly increase from November through May of 4.0°F per century. At Fremont, increases in average air temperature were concentrated from late winter to mid-summer with the greatest increases occurring in February at 3.5°F per century and June at 2.0°F per century. Alliance also experienced slight increases during spring and summer with the most significant increase occurring in July at 1.7°F per century.

At Hastings and Culbertson, late summer and fall decreases dominated the average temperature trends. At Culbertson, decreases of more than 1.5°F per century were sustained from September through November. At Hastings, average air temperature decreases of over 2°F per century occurred during August and September.

Trends in Daily Temperature Range

The middle row of *Figures 2-6* presents the time series and trends of the daily temperature range (DTR) for the five locations. Daily temperature range is the daily high temperature minus the low temperature. DTR is

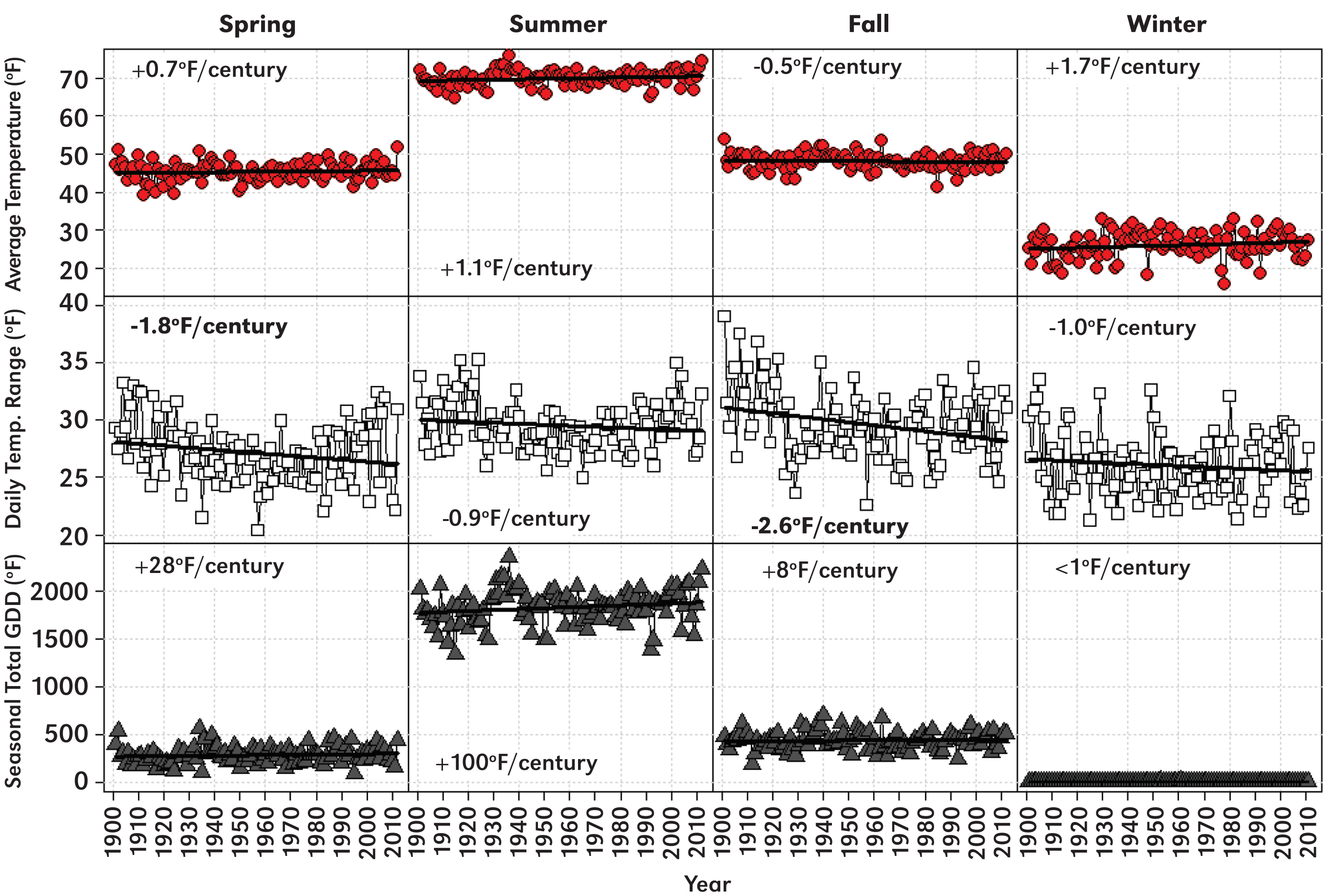

Figure 2. Time series and trends in seasonal average air temperature, seasonal average daily temperature range, and seasonal total growing degree days (GDD) for Alliance, Neb., from 1901-2012.

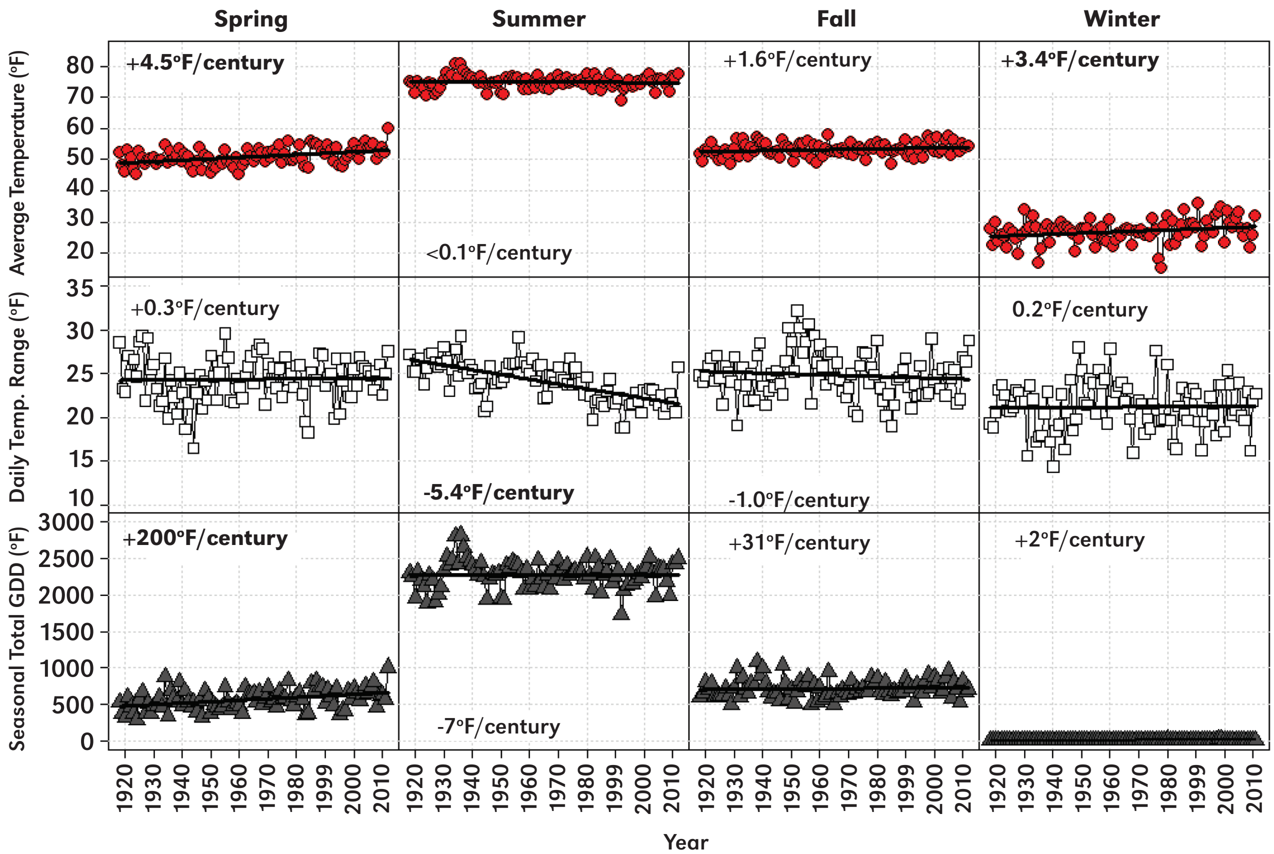

Figure 3. Time series and trends in seasonal average air temperature, seasonal average daily temperature range, and seasonal total growing degree days (GDD) for Central City, Neb., from 1918-2012.

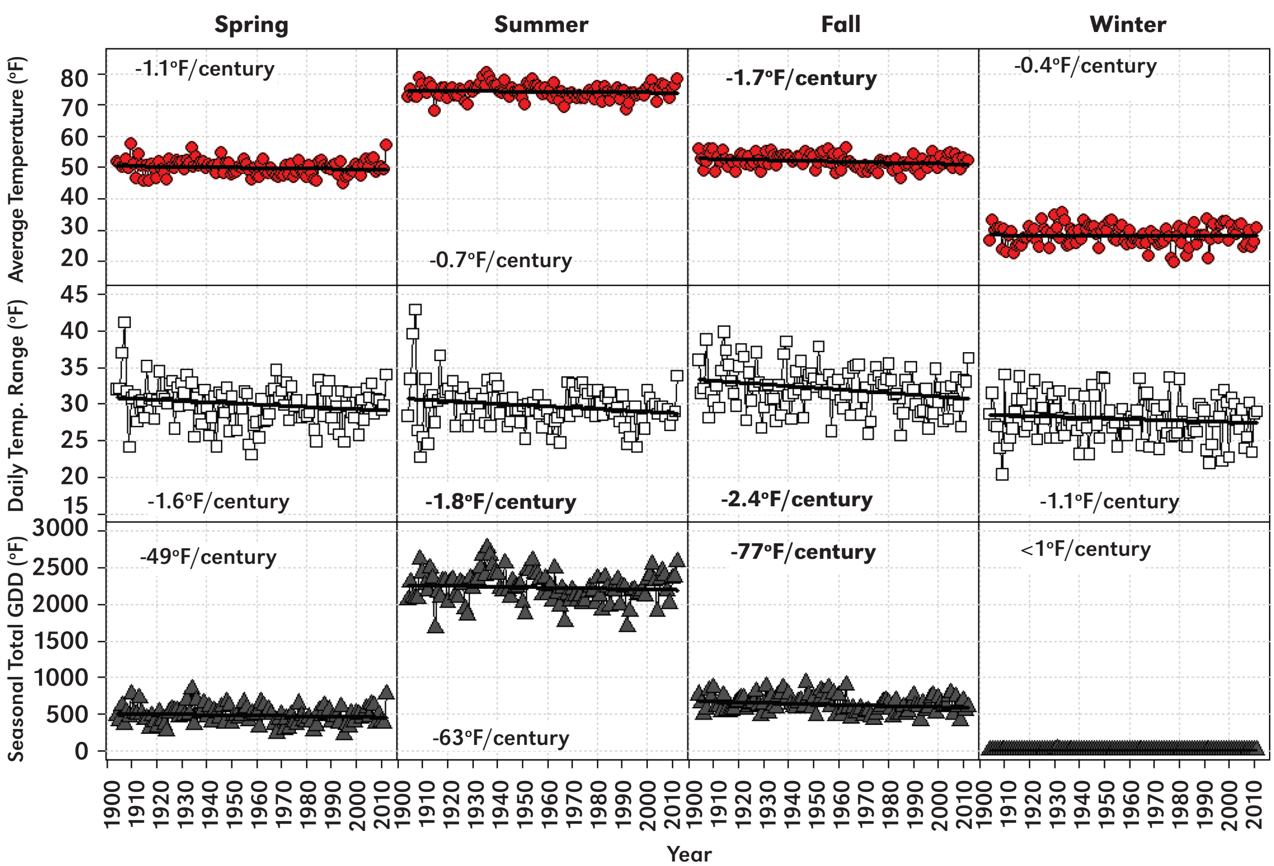

Figure 4. Time series and trends in seasonal average air temperature, seasonal average daily temperature range, and seasonal total growing degree days (GDD) for Culbertson, Neb., from 1904-2012.

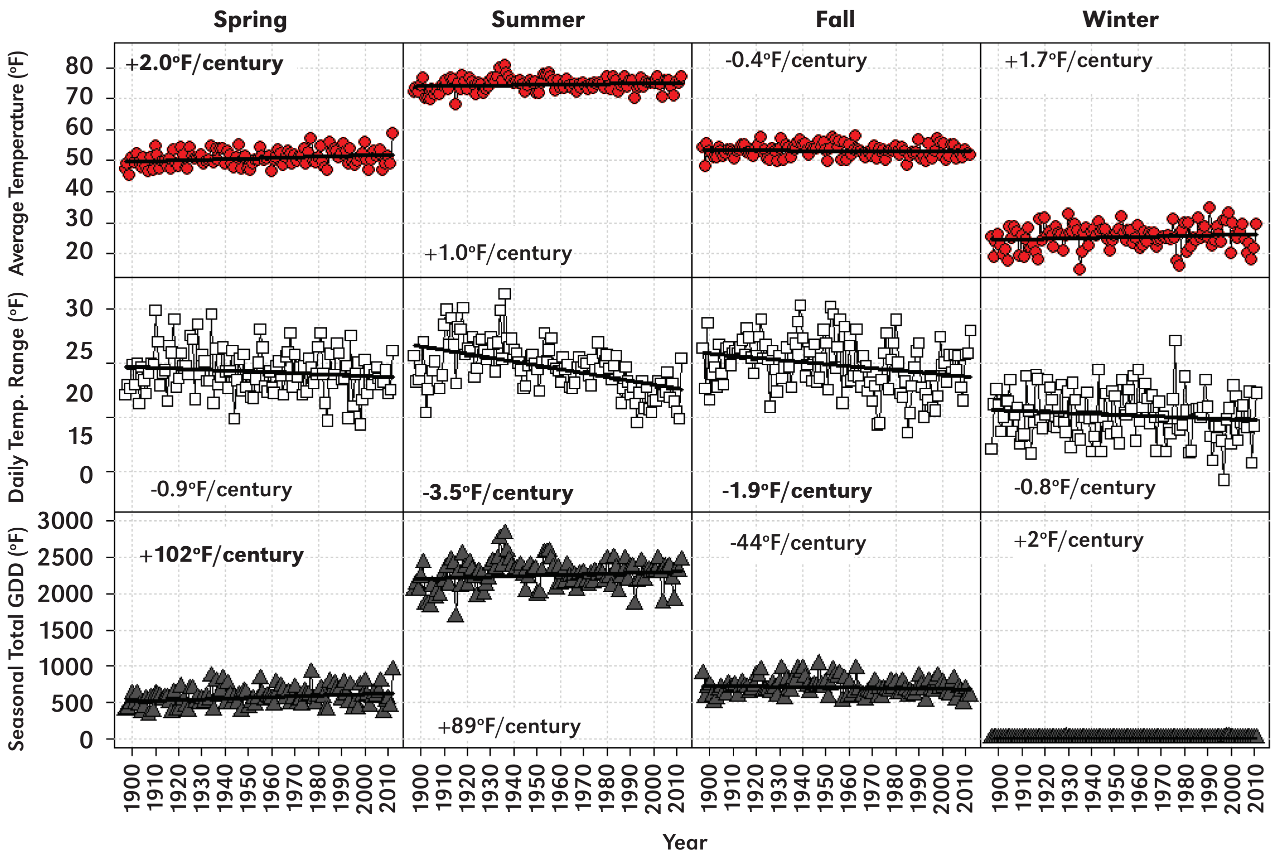

Figure 5. Time series and trends in seasonal average air temperature, seasonal average daily temperature range, and seasonal total growing degree days (GDD) for Fremont, Neb., from 1897-2012.

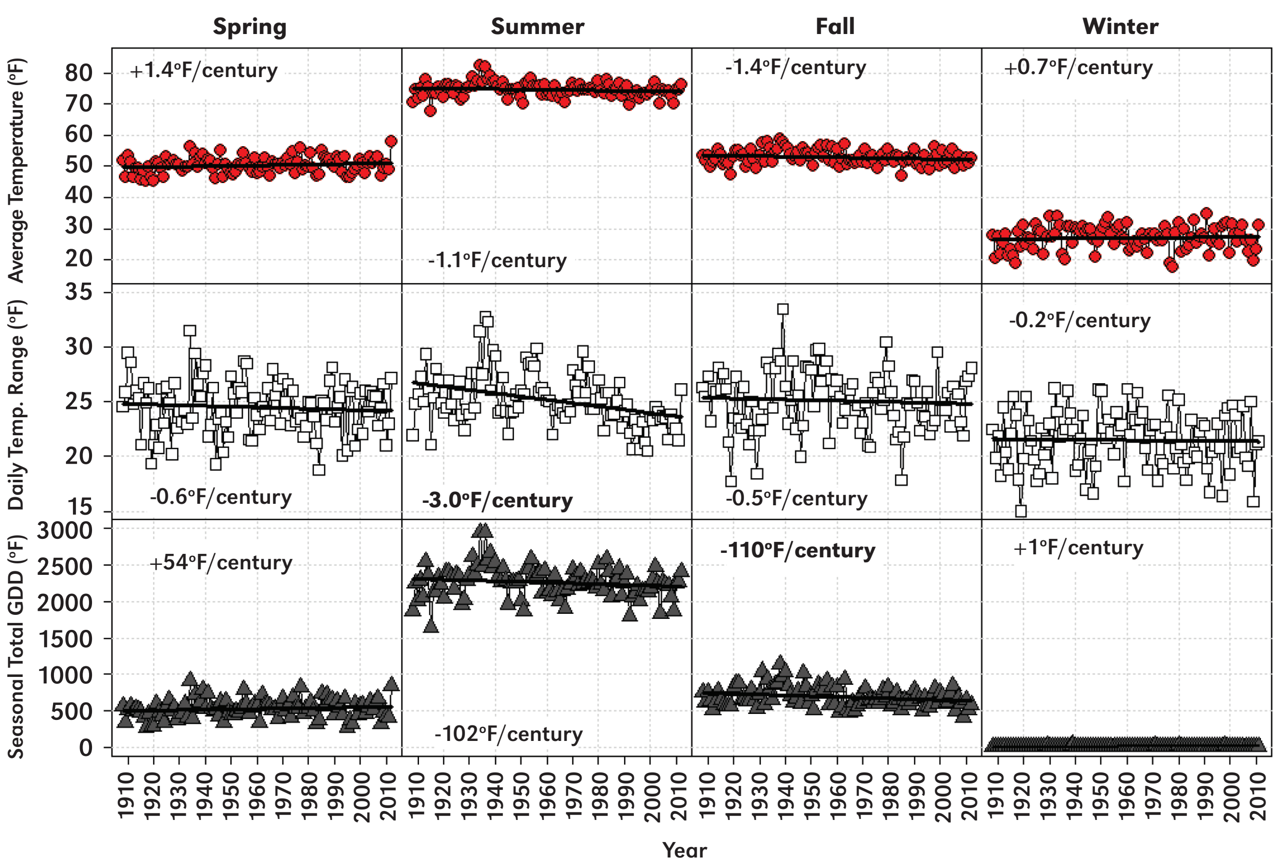

Figure 6. Time series and trends in seasonal average air temperature, seasonal average daily temperature range, and seasonal total growing degree days (GDD) for Hastings, Neb., from 1908-2012.

typically between 23 and 35°F in the drier, western part of the state, including Alliance and Culbertson. DTR is between 17 and 29°F in the central and eastern parts of the state, including Hastings, Central City, and Fremont. DTR is usually greatest in the fall and the least during the winter and summer.

Daily temperature range has been decreasing in many parts of the world, including the United States, and especially the High Plains and Midwest. The locations in this study were no different. The greatest trends in air temperature were in the daily temperature range.

DTR **decreased** at annual average rates of 1-2°F per century across all locations. DTR **decreased** year-round at Alliance, Fremont, and Culbertson, and during most months at Central City and Hastings. The greatest decreases occurred during July and August for Culbertson, Hastings, Central City, and Fremont with a monthly average decrease of up to 7.6°F per century for July at Central City. The greatest decreases in DTR occurred during spring and fall for Alliance with the greatest decrease of 3.6°F per century occurring for the month of November.

Decreases in DTR are often associated with increases in atmospheric moisture and increased cloud cover. Increased cloud cover reduces daytime heating by blocking radiation from the sun and reduces nighttime cooling by absorbing the radiation emitted by the earth and reemitting it. Changes in weather patterns and increases in irrigation development have been noted as causes for increases in atmospheric moisture.

Trends in Growing Degree Days

Growing degree days are the number of heat (thermal) units usable for crop growth. It is quantified as temperature accumulation above a base temperature, which is the minimum temperature at which a given crop can perform its physiological functions. The base temperature for soybean and corn often used is 50°F. In this research, the growing degree days were calculated as the average temperature minus 50°F. For each month and over the growing season, the number of growing degree days was calculated as an accumulation of growing degree days.

On average, the southeastern tip of Nebraska accumulates greater than 3600°F GDD each year, which decreases northwestward to 2000°F GDD in the Panhandle. On average, corn generally requires an accumulated 2700°F GDD to reach physiological maturity for the longer-season hybrids grown in the southeast and 2000°F GDD for physiological maturity for the shorter-season hybrids grown in the northwest.

Farmers who have an increase in GDD throughout the growing season may want to plant longer-season, higher-yielding hybrids/varieties to take advantage of the increase in thermal units. Earlier planting may be an option for those who have had an increase in spring and early summer GDD if it is coupled with early last spring frosts. While longer-season hybrids have greater yields than shorter-season hybrids, the crop water use (evapotranspiration) is also greater for the longer-season hybrids. More research is needed to evaluate the dynamics involved with the long- and short-season hybrids, crop water use, yield, and productivity relationships, and also their implications to the water resources availability/allocation in a given location to determine best practices for maximum crop water productivity.

The bottom rows of *Figures 2-6* present the time series and trends in seasonal accumulated growing degree days (GDD) for the five locations. In general, GDD **increased** for more northern locations, while the southern locations of Culbertson and Hastings had **decreases** in accumulated growing degree days associated with decreases in daily high temperature.

Hastings had its greatest **decreases** in GDD occurring in the late summer and early fall with an annual accumulation decrease at a rate of 156°F per century. At Culbertson, small monthly decreases in GDD from April through October led to a **decrease** in annual accumulated GDD of 188°F per century.

Moving northward to Central City, there were large **increases** in spring growing degree days with a total of a 200°F per century increase for March through May. At Central City, there were also **slight decreases** in late summer GDD, similar to those observed at the more southern locations. The largest change at Fremont was an **increase** in GDD of 60°F per century in June. There were also slight increases during spring and the rest of the summer with slight decreases (around 20°F monthly per century) during September and October for Fremont. An increase of 52°F per century during July occurred for Alliance with slight increases in GDD for most of the rest of the year, resulting in an annual total increase at a rate of 136°F per century.

Shifts in Temperature Distribution during The Growing Season

Since plant growth, plant response to environmental factors, crop stress, and, ultimately, yield and crop water productivity show varying degrees of sensitivity to different ranges of air temperature, the decadal shifts in the distributions of the daily recorded high and low temper-

High Temp. Range (°F)	Alliance	Fremont	Central City	Hastings	Culbertson
<40	+				
40-50	+	-		---	-
50-60	+	-	-	-	+++
60-70	-	-	-	0	+
70-80	-	+	+++	+++	+
80-90	---	+++	+++	+++	+
90-100	+++	-	---	---	---
>100	+	-	---	---	-

High Temp. Range (°F)	Alliance	Fremont	Central City	Hastings	Culbertson
<32	-	---	---	-	0
32-40	---	---	---	---	-
40-48	0	---	---	-	+
48-56	-	-	-	+	-
56-64	+	-	+	0	+
64-72	+	+++	+++	0	-
>72		+	+	-	-

Figure 7. Trends in ranges of high and low temperatures for the locations north to south: Alliance, Fremont, Central City, Hastings, and Culbertson. Green negative signs indicate that the frequency of high or low temperatures in that range is decreasing. The graphic on the top presents the decadal trends in daily high temperature, while the bottom graphic presents the trends in low temperature. Blue positive signs indicate that the frequency of high or low temperatures in that range is increasing. Three plus (+++) and minus (---) signs and darker shading indicate statistically significant trends.

atures were determined. The bottom graphic in *Figure 7* presents the trends for daily low temperatures.

At Alliance, Fremont, and Central City, daily low temperatures had a general shift from temperatures less than 56°F toward temperatures greater than 56°F, with a very distinguished increase in low temperatures in the 64-72°F range and a decrease in low temperatures less than 48°F. The average increase in nighttime low temperatures observed at these locations, as mentioned previously, occurred due to this shift in temperatures. The shift was less pronounced at Hastings, though there was a decrease in the frequency of low temperatures less than 40°F. There were no consistent shifts in low temperature at Alliance.

The top graphic in *Figure 7* presents the trends in daily high temperatures. At Fremont, Central City, and Hastings, daily high temperatures less than 70°F and greater than 90°F became less frequent, while highs between 70°F and 90°F became more frequent. From these shifts, it seems that the decreases in daytime temperature observed during much of the growing season at these locations were not due to an increase in the coldest temperatures, rather due to a general mildening of high temperatures. There was also a pronounced shift from temperatures greater than 90°F to cooler temperatures.

At Alliance, the high temperature shift was opposite of that at the other locations. The high temperature extremes — both the coolest and warmest (less than 60°F and greater than 90°F) — increased in frequency, while high temperatures between 60°F and 90°F decreased in frequency.

Table 1. Potential crop production practices that can be impacted by different temperature variables.

Temperature variable	Agricultural activities that can be impacted
Last spring frost	Planting date; crop emergence; cover crop determination
First fall frost	Freeze potential; cover crop determination; second crop viability
Growing season length	Hybrid/variety determination; and factors listed above
Daytime high temperature	Plant heat and water stress potential
Nighttime low temperature	Respiration and dry matter accumulation; crop water productivity
Daily temperature range	Plant water and heat stress potential; cloud cover; radiation interception; transpiration; crop water productivity
Total growing degree days	Growth rates; developmental/maturity period length; hybrid/variety determination
Changes in certain temperature ranges	All of the above

With some locations experiencing earlier last spring frosts and longer frost-free periods, some farmers should consider earlier planting of longer-season hybrids/varieties. It is especially important to look at long-term precipitation outlooks for the coming growing season when making the decision to use longer-season hybrids/varieties that typically require more water, as previously mentioned.

Longer-season hybrids/varieties could make the best use of air temperature and solar radiation in a longer growing season with normal or above normal rainfall. However, some locations experienced decreases in late summer-early fall growing degree day accumulation. Earlier spring planting with the use of the current hybrid/variety season length may be needed to offset the later season deficit in growing degree days to reach maturity before the first fall frost.

Table 1 summarizes the potential crop production practices that can be impacted by different temperature variables studied in this Extension Circular. How plans can be impacted by these various temperature variables will not be described in this Circular.

Resources

In making agricultural management decisions in relation to climatic conditions and to learn more quantification of changes in climatic characteristics and changes in soil temperature, please see the following additional resources:

- Some weekly to seasonal temperature and precipitation outlooks are available online, such as *www.cpc.ncep.noaa.gov*, and daily forecasts are available from many sources, including the National Weather Service at *www.weather.gov.*
- UNL general cropping systems information: *http://cropwatch.unl.edu.*
- For additional information on drought and available resources for potential mitigations, check the UNL Drought Resources website at: *http://droughtresources.unl.edu/* and soil temperature across the state of Nebraska in NebGuide G2122, *Soil Temperature: A Guide for Planting Agronomic and Horticulture Crops in Nebraska*, where shifts toward earlier soil warming have been observed.
- High Plains Regional Climate Center monthly climate summaries and updates of frost statistics are found at *www.hprcc.unl.edu*.

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