August 1991

Observed Variations in Great Plains Seasonal Temperatures during the Past Century

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OBSERVED VARIATIONS IN GREAT PLAINS SEASONAL TEMPERATURES DURING THE PAST CENTURY

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Abstract. *Time series of observed seasonal temperature data from selected locations on the American Great Plains contain a great deal of information on the nature and scales of climate variations over the past century. At four long-term stations in eastern Colorado, trends of increasing mean maximum and minimum temperatures occurred in all seasons except autumn; with most warming preceding 1940. Diurnal range has been decreasing considerably in recent decades, but long-term trends are not consistent at all locations. Interannual variability has also been changed but does not show a systematic trend.*

Time series similarities across the Great Plains decay rapidly over short distances in and near the Rocky Mountains, but are well correlated over longer distances in a north-south direction parallel to the mountains. The shared variance of mean seasonal temperatures decreased by 50% over a north-south distance of approximately 350 miles. Significant year-to-year differences in north-south and plains-mountains temperature gradients occur across the Great Plains. Changes in north-south winter temperature gradients appear to be related to Rocky Mountain precipitation patterns and other indicators of large scale atmospheric circulation patterns. Such connections offer explanations for variations that occur on an interdecadal time scale.

The American Great Plains is a region of special concern in the debate on potential global climatic change related to increased greenhouse gases. Interest in Great Plains climatic change arises from the very nature of the existing climate of this expansive region and its agricultural industry. A unique and complicated characteristic of Great Plains climate is the strong gradients of temperature and precipitation, which are nearly perpendicular to each other (US Department of Commerce 1968)—temperature increases from north to south while precipitation increases from west to east. Over sizeable portions of the Great Plains, just enough precipitation is received to support productive agriculture. Episodic cold

temperature extremes become an additional limiting factor for some agricultural activities from Nebraska northward, while high temperature extremes can also be a problem over much of the area in summer. The high elevation of the western Great Plains introduces additional challenges by accentuating the large day-night temperature differences of the interior continental climate. High winds and severe storms add vigor to the region's climate.

The average climate over the Great Plains supports a large and productive agricultural system, but the climate is characterized by considerable natural variability, on day-to-day (Landsberg 1966), seasonal, annual, interannual, and interdecadal scales. Natural variability of climate, apart from any systematic trends, already causes sporadic serious reductions in agricultural productivity across the region (Borchert 1971; President's Interagency Drought Policy Committee 1988). Indeed, the region's characteristic variability has raised the level of concern over climate change to its current high level. Although a small shift of the mean climate could go relatively unnoticed in a region of high variability, detectable climate change will likely involve a change in variability. Significant consequences become a distinct possibility. Likewise, changes in the seasonality of the climate may result in observable alterations in the ecosystem of the region (Kittel 1990).

Climate change is a natural ongoing process on a geological time scale. However, on a human time scale of a few decades, we typically assume climate to be stationary. Thus, many of us are reluctant to accept global climate model projections of a dramatic anthropogenic climate change within a few decades, and considerable controversy surrounds the subject (Reifsnyder 1989). The current controversy arises, in part, due to ambiguities in climatic records (Ellsaesser et al. 1986), problems with data used to evaluate climate trends (Karl et al. 1986, 1987, 1988), and the heavy reliance on projections based on computer model results that necessarily include many gross over-simplifications of the global climate system (Ellsaesser 1982). There are many avenues for exploring climate change and its possible impacts, but the burden of proof lies with the observed data.

In this paper, several aspects of observed temperature variability are described using data from selected locations on the Great Plains and in the adjacent Rocky Mountain region. Temperature is admittedly only one component of a very complex ecoclimatic system. By increasing our awareness in observed temperature characteristics and by improving our understanding of some of the time and space scales of temperature variations, we will be better equipped to interpret the temperature trends and variations that will be observed on the Great Plains in the years to come.

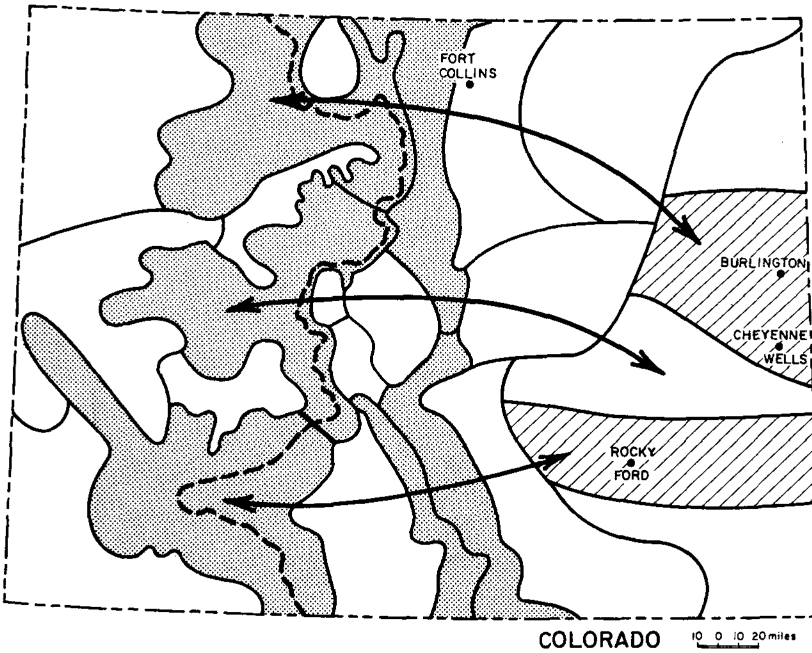

Figure 1. Colorado, climatic divisions and sites of long-term temperature records. Shaded areas are primarily mountainous. Arrows connect pairs of climate divisions used to identify plains-mountains temperature gradients. The continental divide is shown by the dashed line.

Temperature Analysis

Several different analyses were performed to describe features of Great Plains temperature variability as observed over the past century. Many investigators have selected mean annual temperatures for individual stations or combinations of stations to track climate fluctuations over the past. For example, apparent increases in Northern Hemisphere temperatures of about 1° F over the past century have been described by some as highly significant and indicative of an accelerating global change (Jones 1988). Unfortunately, the mean temperature for an entire year tells very little about the climate of that year and any impacts that may have been observed. Climate anomalies are easier and more reliably identified on shorter time scales. For that reason, the year has been broken down into four three-month seasons: summer (June-August), autumn (September-

November), winter (December-February), and spring (March-May). Temperatures were further separated into average maximum values, average minimums, and diurnal range (the difference between daily maximum and minimum temperatures). Winter and summer results will be emphasized.

Time Series of Seasonal Temperatures

Simple graphs of time series provide a good starting point for the analysis of long-term temperature characteristics. They display magnitudes, trends, and variations that will be expanded upon later. Four locations on the Great Plains in eastern Colorado were selected for this investigation. The sites of Burlington, Cheyenne Wells, Fort Collins, and Rocky Ford (Fig. 1) are a part of the National Weather Service's Cooperative Program and represent the best available long-term temperature records on the Colorado plains. The histories of each weather station are well documented, and these sites have had only minor station moves during their history. The Rocky Ford station is the only weather station in Colorado that has been unmoved in its 100-year history. These sites have all maintained late afternoon or early evening observation times throughout all or most of their history, so no time-of-observation corrections to the data were needed. The Rocky Ford and Cheyenne Wells stations are in rural environments. Burlington is a small-town environment. The environment surrounding the Fort Collins weather station has changed dramatically during this period. Originally it had a very open exposure, but buildings and vegetation increased during the twentieth century followed by large urban expansion in the general surroundings during the past three decades.

All four time series exhibit many similar characteristics (Fig. 2). Mean summer maximum temperatures fell from the end of the nineteenth century through the 1910s (note the extreme cold summer of 1915), rose abruptly in the 1930s, decreased again during the 1940s, again climbed abruptly beginning early in the 1950s, cooled again in the 1960s, and have since warmed somewhat and leveled off. All four locations have experienced an upward trend over the past century ranging from +0.8°F/100 years at Burlington to +4.0°F/100 years at Rocky Ford (Table 1).

Summer minimum temperatures show some of this same pattern but with less year to year variability (Fig. 2). The heat of the 1930s is apparent, but the 1950s did not stand out. Over the entire period of record, all stations again show an upward trend, and at Fort Collins the warming has been a remarkable +5.0°F/100 years (Table 1).

The long-term characteristics of mean summer diurnal temperature range reveal more complexities. Stations experienced larger daily ranges during the 1930s and especially during the 1950s. Since the early 1960s, a

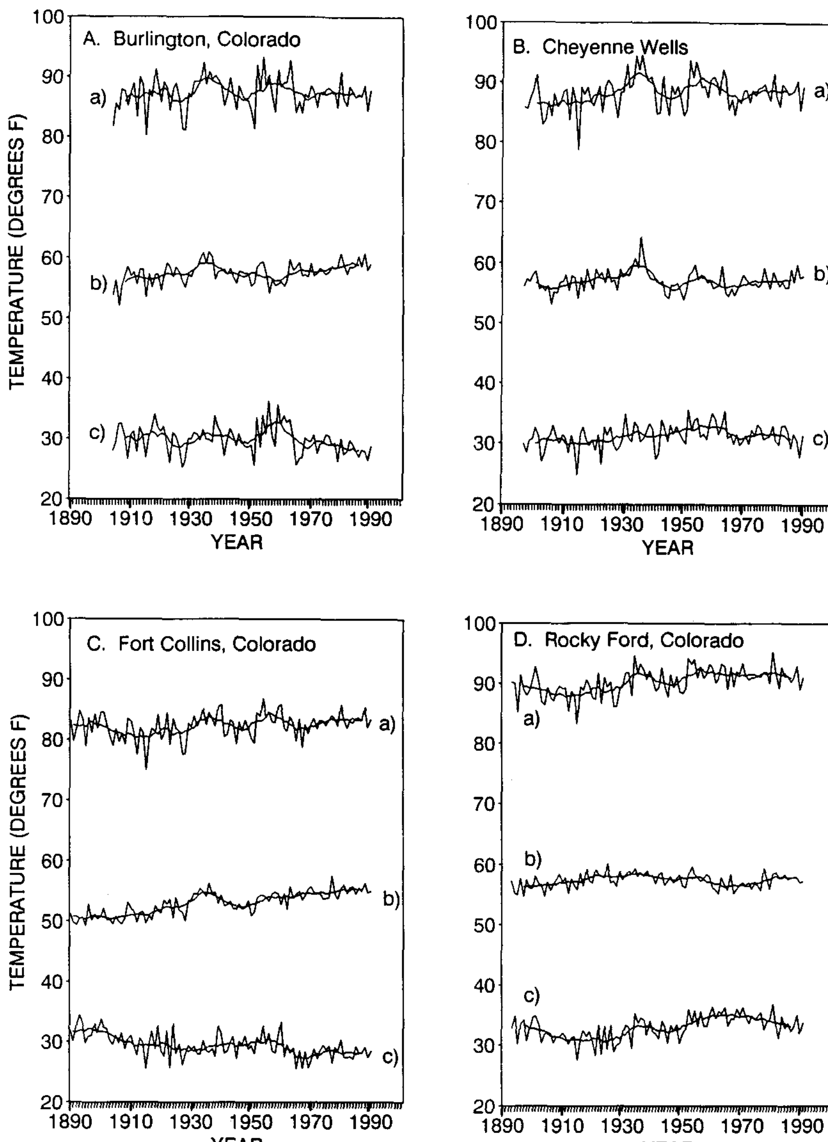

Figure 2. Summer (June-August) temperatures at four long-term stations in Colorado. The curves are mean maximum (a), mean minimum (b), and mean diurnal range (c). The smoothed curves are a centered nine-year running mean.

TABLE 1

Period of record trends in seasonal temperatures in eastern Colorado. All trends are expressed in degrees Fahrenheit per century.

	Winter (Dec-Feb)	Spring (Mar-May)	Summer (Jun-Aug)	Autumn (Sep-Nov)
		Burlington (1904-1990)		
Mean maximums	+2.7	+1.7	+0.8	-1.8
Mean	+3.1	+2.2	+1.7	-0.2
Mean minimums	+3.6	+2.7	+2.5	+1.4
Diurnal range	-0.8	-1.0	-1.7	-3.2
		Cheyenne Wells (1897-1990)		
Mean maximums	+2.4	+1.9	+2.2	-0.4
Mean	+2.2	+1.7	+1.2	-0.0
Mean minimums	+2.1	+1.4	+0.3	+0.7
Diurnal range	+0.3	+0.5	+1.9	-1.0
		Fort Collins (1887-1990)		
Mean maximums	+2.2	+1.9	+1.7	-0.7
Mean	+3.6	+2.6	+3.4	+1.7
Mean minimums	+4.9	+3.3	+5.0	+4.0
Diurnal range	-2.7	-1.4	-3.3	-4.7
		Rocky Ford (1893-1990)		
Mean maximums	+2.3	+3.4	+4.0	+1.5
Mean	+1.6	+1.8	+2.3	+0.8
Mean minimums	+0.8	+0.3	+0.6	-0.0
Diurnal range	+1.6	+3.2	+3.4	+1.6

downward trend in diurnal range is apparent at all four stations. Over the entire record, however, there is considerable divergence among the stations. Burlington and Fort Collins have each experienced decreasing diurnal range, while Cheyenne Wells and Rocky Ford have seen an

increase. This may be a result of some subtle changes in surrounding vegetation or local irrigation practices. It could also be indicative of local differences in temperature response to larger scale forcing.

Mean winter maximum temperatures were quite warm in the first decade of the twentieth century but dropped to their lowest levels during the 1910s (Fig. 3). Temperatures then climbed erratically to their peak in the 1950s and have since shown an irregular decline at three sites while remaining steady at Fort Collins. Despite the recent decline, an upward trend over the past century is observed at all sites averaging about 2.4°F per hundred years (Table 1). A notable feature of winter maximum temperatures is the large interannual variability. The standard deviation is approximately 4°F for these four stations compared to only about 2°F for the summer maximum temperatures. Apparent periodicities in the winter temperature time series with a time scale of two to three years were noted but not investigated in detail.

Winter minimum temperatures do not display as much year-to-year variability, and nine-year running means filter out much of the shorter term variations. The result is a fairly steady upward trend at these four sites averaging +2.8°F/100 years. Fort Collins again shows the greatest upward slope, +4.9°F per hundred years (Table 1).

The winter diurnal range time series indicate relatively large daily ranges in the first decade of the 1900s dropping off during the 1910-1920s. A small peak occurred during the 1930s followed by a more impressive one during the late 1940s and early 1950s. Since then there has been a general decrease in diurnal range consistent with observations over large portions of North America (Karl et al. 1986). This trend toward reduced diurnal range is consistent with observations of increased cloudiness over the western Great Plains (Doesken and Kleist 1988) since clouds reduce daytime temperatures but trap energy from escaping at night. However, in the most recent few years, this trend appears to be leveling off.

Time series have also been analyzed for spring and autumn, although the graphs are not included in this paper. The spring months (March-May) have also seen general upward trends for both maximum and minimum temperatures (Table 1). Autumn (September-November) is the only season that has not seen warming over the past century. Three of these four stations show a downward trend in autumn maximum temperatures. Autumn is also characterized by the greatest decline in average diurnal range with most of the decline occurring during the past two to three decades.

We place a large amount of confidence in these data due to the known reliability and consistency of these weather stations. Yet, distinct differences exist in these time series within the confines of a single state. In the case of Fort Collins, differences are not surprising since the

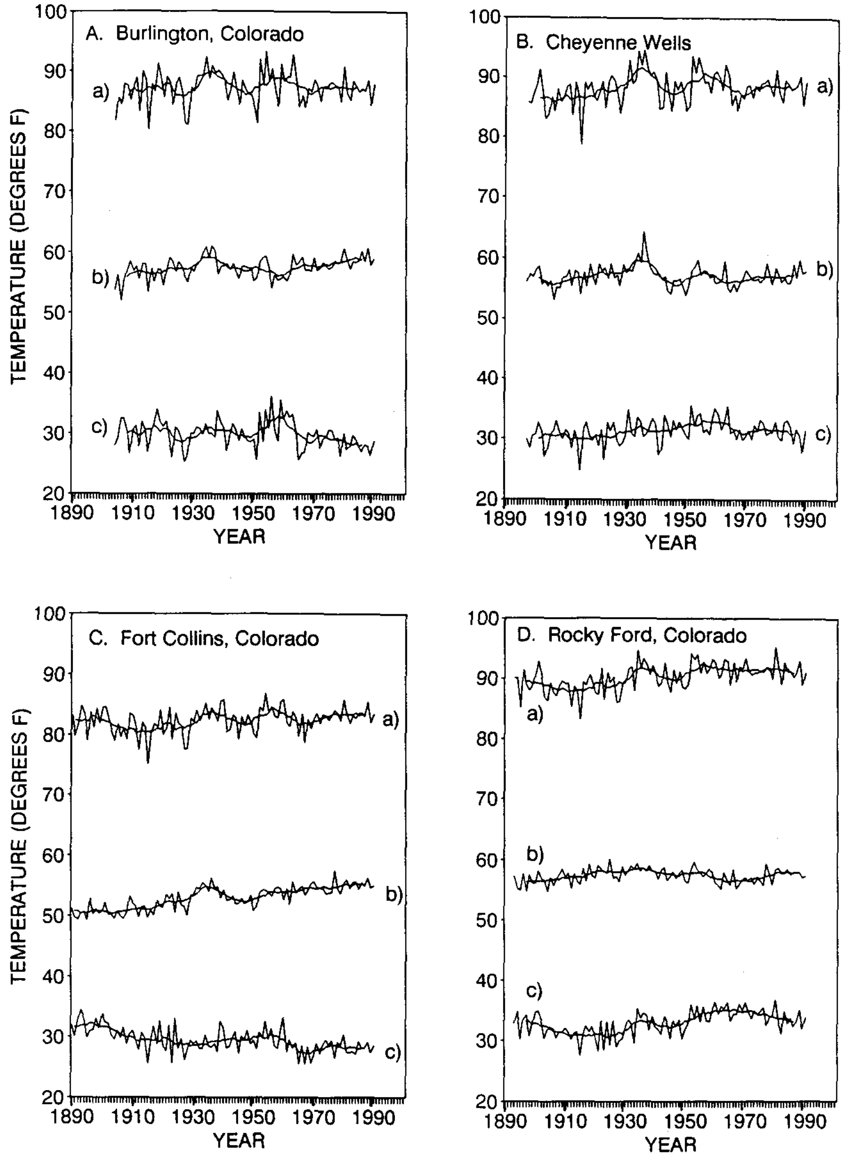

Figure 3. Winter (December-February) temperatures at four long-term stations in Colorado. The curves are mean maximum (a), mean minimum (b), and mean diurnal range (c). The smoothed curves are a centered nine-year running mean.

environment surrounding the weather station has changed with time, and strong evidence of an urban heat island appears.

Temporal Changes in Interannual Variability

The time series for four Colorado stations all displayed interannual variability that appeared to vary from decade to decade. A simple analysis was performed to demonstrate these apparent fluctuations. Standard deviations of season-averaged maximum and minimum temperatures were calculated for consecutive 21-year periods (the current year plus the 10 years before and after) at Rocky Ford. As expected, variability is greatest in winter and least in summer (Fig. 4). Some interesting time trends in variability have been occurring. Variability of winter maximum temperatures decreased quite dramatically early this century but has been increasing again recently. Variability of winter minimum temperatures has taken almost an opposite course, peaking in the 1920s and 1930s then decreasing and leveling off. A decrease in the variability of summer maximum temperatures has been evident since about 1930 reaching a minimum in the late 1960s. Summer minimum temperatures, the most stable of the temperature variables, have shown very little change.

The other Colorado stations show similar but not identical variability characteristics. For all sites, current variability appears to be within the natural limits established by the past century of weather data.

Representativeness of Seasonal Temperature Time Series

When using climate data from a particular station or set of stations, the question is often asked, "How representative is that data for other areas?" A similar question is, "How many long-term climate stations are needed for appropriately monitoring climate change?" There are no simple answers, but various statistical techniques can be applied.

To address the question of how representative the time series behavior of any one station or region is with respect to a larger area, 1950-1989 time series of mean winter and summer temperatures were compared for 25 climate divisions in Colorado (Fig. 1). These divisions were defined by similarity in elevation and climate seasonality (Doesken et al. 1983). Unlike divisional climate data produced by the National Climatic Data Center, which are simply the average of all station data available each month within a specific geographical area, Colorado divisional data are produced by combining the departures from individual station averages into a composite departure from average. The intent is to minimize the effect of missing data and station relocations in climatically and topographically diverse areas.

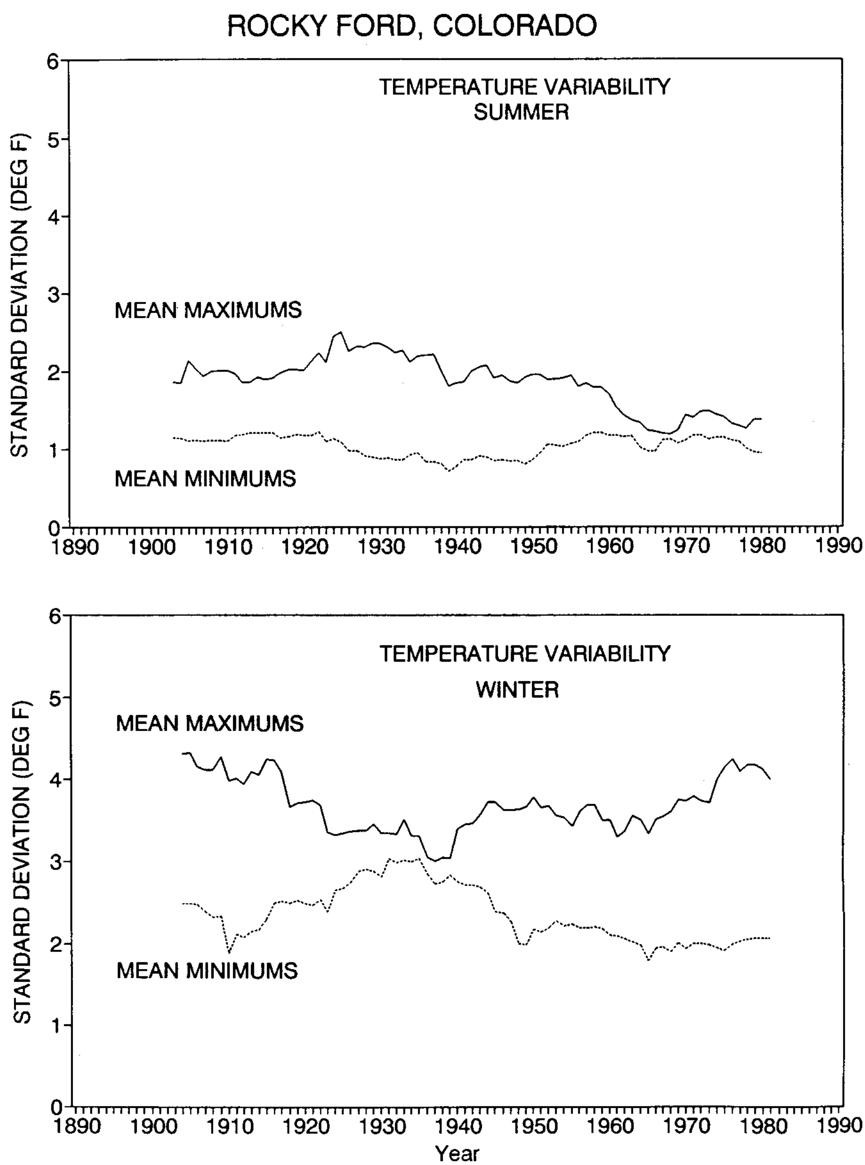

Figure 4. Time series of the standard deviation of mean seasonal temperatures for moving 21-year periods for Rocky Ford, CO. Top, summer (June-August); bottom, winter (December-February).

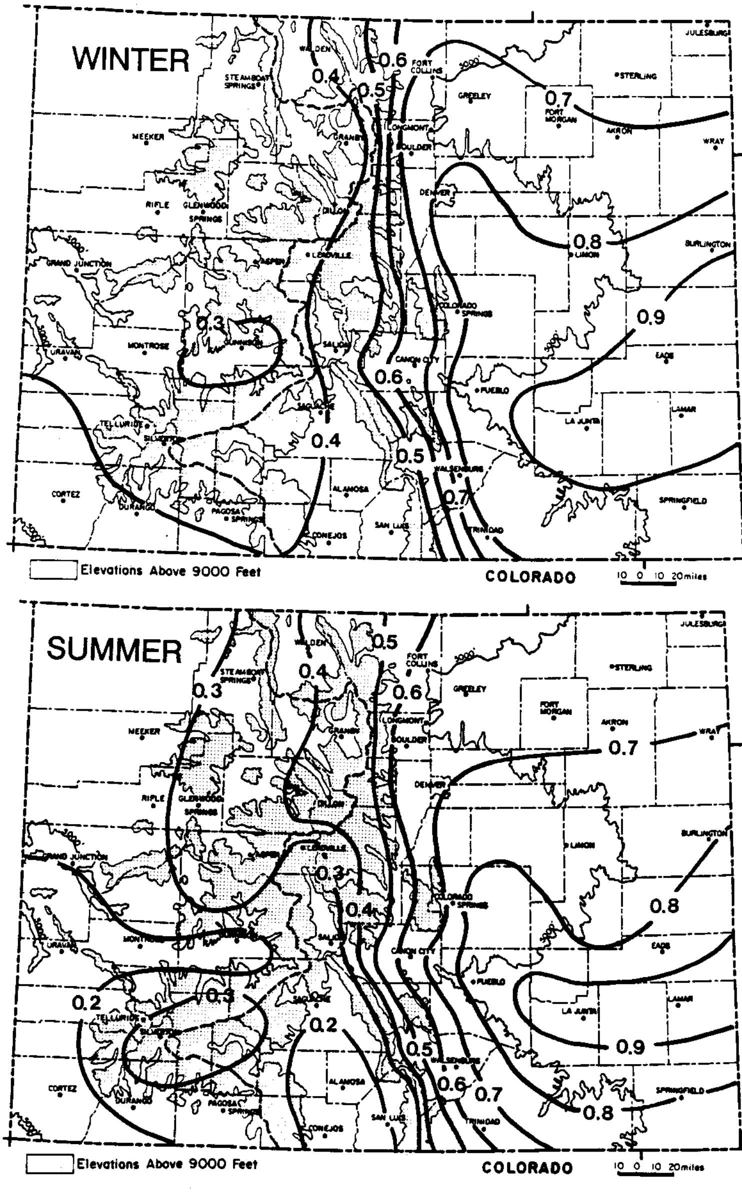

Figure 5. Coefficient of determination, interpolated from correlations of mean seasonal temperatures (1950-1989) in climatic divisions with those in the Lower Arkansas Valley division (Rockey Ford).

Each time series of mean seasonal temperature was regressed on each of the other 24 divisions. The coefficients of determination shows the amount of variance in common with a given climatic division. For the lower Arkansas Valley of southeastern Colorado, for example, similarities decay gradually with distance over the Colorado Great Plains, with all plains locations maintaining strong correlations both in winter and summer (Fig. 5). However, moving into the eastern foothills of the Rockies and crossing over the mountains, time series similarities decay dramatically. While there is a positive correlation throughout all parts of Colorado at all times of year, coefficients of determination less than 0.2 are observed between summer temperatures on the southeast plains of Colorado compared to southwestern Colorado. Plains-to-mountain winter correlations coefficient of determination 0.3 are a bit stronger due, for the most part, to the larger observed magnitude of variation during the winter. Spring correlation patterns are not shown, but they behave like winter with moderate correlations coefficient of determination 0.3 to 0.5). Region-to-region correlations show that the greatest relative similarity in time series between plains and mountain regions during the autumn months with coefficients of determination near 0.7.

The eastern plains of Colorado represent only a small portion of the total Great Plains area. An idea of how well correlated the seasonal temperature time series are across the entire region can be had from comparisons between a small number of other climatic divisions representing widespread areas of the Great Plains. Divisional climatic data from 10 areas on the Great Plains from North Dakota to Texas were used in this analysis. Historical temperature time series since 1895 have been compiled by the National Climatic Data Center. Divisional data are computed by combining the available individual station data within the division into a single divisional average for each month. Changes in the numbers and locations of stations within a division can affect the computed values, but this is considered to be a minor problem over climatically homogenous areas.

Comparative results are shown for four climate divisions outside of Colorado and two of Colorado's special climatic divisions (Fig. 6). These divisions include the cities of Bismarck, ND, Huron, SD, Grand Island, NE, Lubbock, TX, Burlington, CO, and Lamar, CO. For convenience, in the remainder of this discussion, the areas represented by the divisional data will be called by the name of these cities which they include.

Time series of mean winter and summer temperatures for each of these divisions were plotted for the period 1895-1988 (Fig. 7). These divisions are approximately equally spaced in the north-south direction to provide a cross-section of the region. The Colorado divisional data are only available since 1950. It is obvious from these graphs that north-south

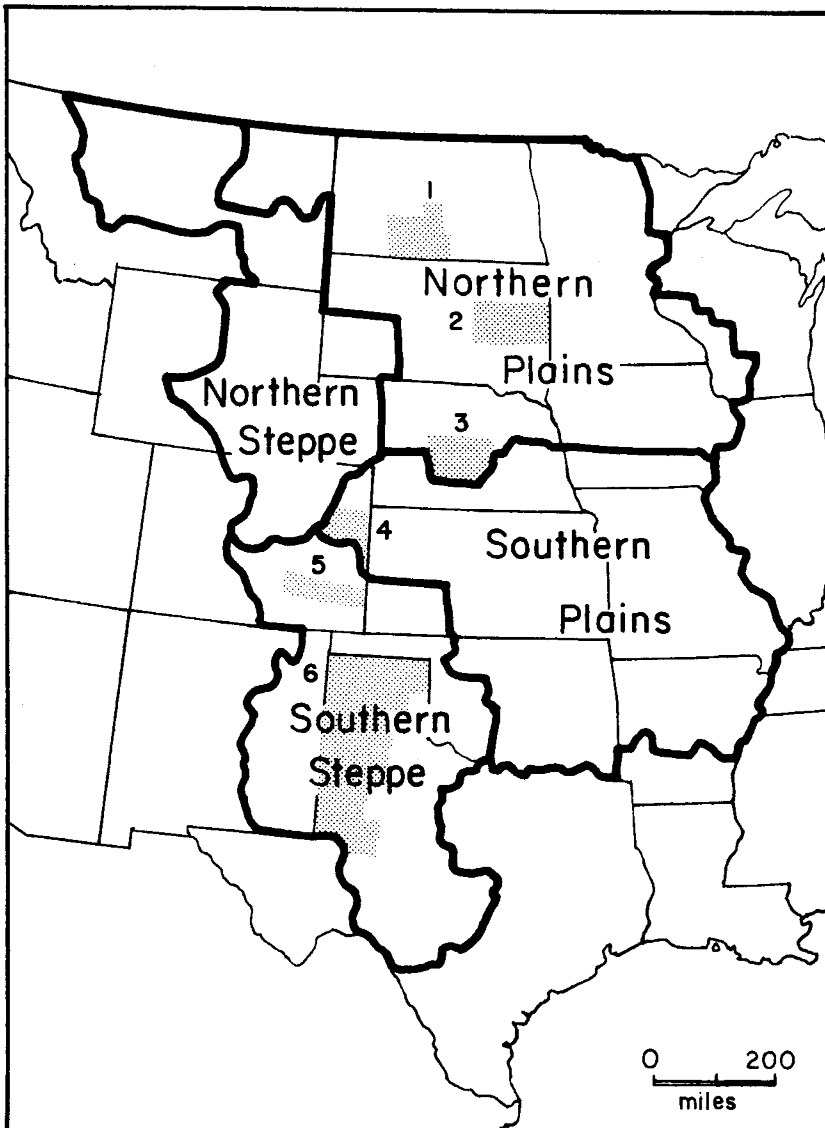

Figure 6. Great Plains climatic regions (Karl et al. 1989) and specific divisions used to compare time series similarities across the Great Plains. The regions identified by key cities are 1, Bismarck, ND; 2, Huron, SD; 3, Grand Island, NE; 4, Burlington, CO; 5, Lamar, CO; 6, Lubbock, TX.

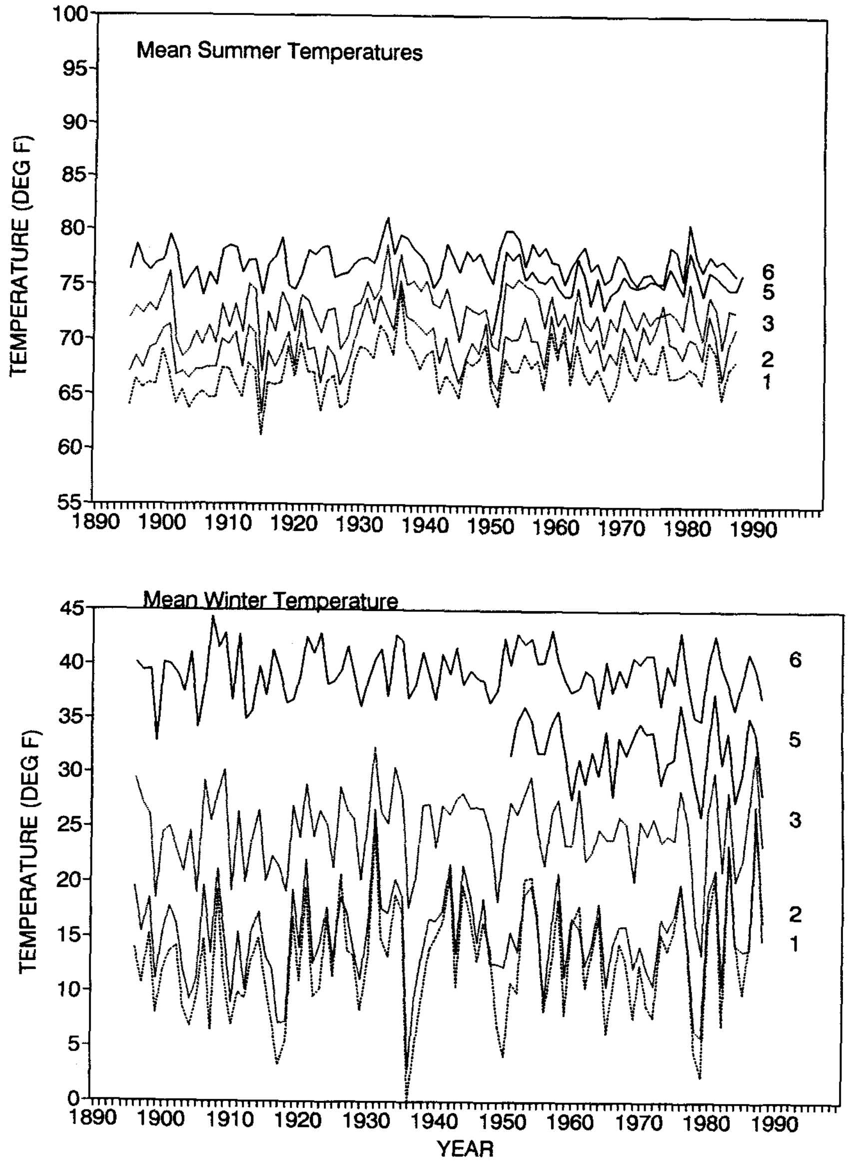

Figure 7. Comparative time series of mean seasonal temperatures for five of the climate divisions identified in Fig. 6.

TABLE 2

Coefficients of determination for winter (December-February) and summer (June-August) obtained from comparing each pair of 1950-1988 time series for climate divisions representing these selected Great Plains cities.

	Bismarck ND	Huron SD	Grand Island, NE	Burlington CO	Lamar CO	Lubbock TX
Distance south From Bismarck in miles	0.0	200.0	450.0	600.0	700.0	1000.0
			Winter			
Bismarck	1.00	0.87	0.57	0.23	0.14	0.02
Huron		1.00	0.67	0.28	0.18	0.06
Grand Island			1.00	0.67	0.50	0.33
Burlington				1.00	0.80	0.63
Lamar					1.00	0.73
Lubbock						1.00
			Summer			
Bismarck	1.00	0.69	0.40	0.22	0.14	0.00
Huron		1.00	0.57	0.38	0.30	0.00
Grand Island			1.00	0.78	0.64	0.27
Burlington				1.00	0.79	0.38
Lamar					1.00	0.53
Lubbock						1.00

temperature differences are much greater in winter than in summer. The magnitude of year-to-year variations is likewise much greater in winter than in summer. No outstanding long-term trends are apparent in these divisions, but many of the well-known features of recent Great Plains climate are evident, such as the extreme cold summer of 1915, the persistent summer heat of the 1930s, and the dramatic interannual winter temperature variations that began in the 1970s. The time series appear to go up and down together but with many exceptions.

To quantify these time series similarities, pairwise linear regression was used. Systematic decay in time series correlations with distance is

evident both in summer and winter (Table 2). Correlations are positive in all cases, but at a north-south separation of about 1000 miles (Lubbock to Bismarck) correlations drop to near zero in both winter and summer. North-south separation reduces the amount of variance in one time series explained by another by 50% over a distance of approximately 300-400 miles. Summer correlations decay at a uniform rate with distance. Winter temperatures maintain better correlation with distance over the northern plains and the southern steppe. However, correlations decay sharply with distance in between with the greatest change noted between the Nebraska and east central Colorado divisions. This transition zone, in fact, defines the typical southern boundary of the continental polar air masses that dominate northern plains winter weather but only episodically push farther south.

North-South Differences in Seasonal Temperatures

The previous analysis demonstrated the significant north-south temperature gradient that characterizes the Great Plains climate. This gradient is not constant. Temperature differences between locations across this gradient may carry significant supplemental information about climate that is closely related to atmospheric circulation characteristics. The difference between seasonal temperatures on the northern plains (Huron) and the southern steppe (Lubbock) shows year-to-year variability as the dominant feature, with winter variability far exceeding that of summer (Fig. 8). Winter temperatures in the Lubbock climate division average nearly 25°F warmer than the Huron area. The greatest seasonal difference occurred in the winter of 1936 with a 34° spread. In 1987 the difference was only 12.5°F. By comparison, in summer, mean temperatures in the Lubbock division average only 7.6°F warmer than the Huron area with differences ranging from 12.8°F for the summer of 1951 down to only 2°F in 1976.

North-south summer temperature differences showed little variation early this century but decreased during the 1930s. After peaking in the early 1950s, they have shown a gradual decrease into the mid-1970s followed by a return since 1977 to conditions more like that of the 1950s. The winter differences decreased through the 1920s to a low early in the 1930s followed several years later in that decade with very large north-south differences. More recent decades showed little systematic variations until about 1970 when differences have shown a marked decrease.

These north-south differences in winter temperatures over the Great Plains are consistent with documented north-south differences in mountain snowpack accumulation in the Rocky Mountains (Doesken et al. 1989). As the north-south gradient in mean winter temperature on the plains has

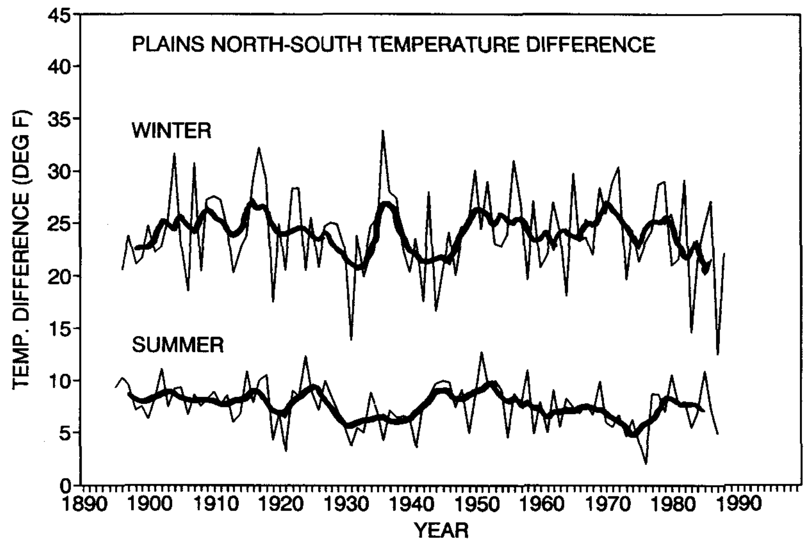

Figure 8. Time series of north-south seasonal temperature differences between climate divisions 5 (Lubbock, TX) and 2 (Huron, SD). The heavy lines indicate centered moving five-year running means.

shown a decrease since the early 1970s, so also has winter snow accumulation increased in the southern portion of the Rocky Mountains (southern Colorado and Utah) and decreased in the Northern Rockies (Montana and northern Idaho). This similarity is not a mere coincidence, nor is it convincing evidence of accelerating long-term climate change. Very similar changes have been observed in other North American climate time series (Trenberth 1990) that appear to be related to large scale fluctuations in atmospheric circulation that occur on interdecadal time scales.

Plains-Mountains Time Series Differences

An interesting companion analysis to the north-south differences in seasonal temperatures is the analysis of east-west differences. The Rocky Mountains form the western boundary for the Great Plains and contribute to many aspects of the Great Plains climate. It has already been shown that

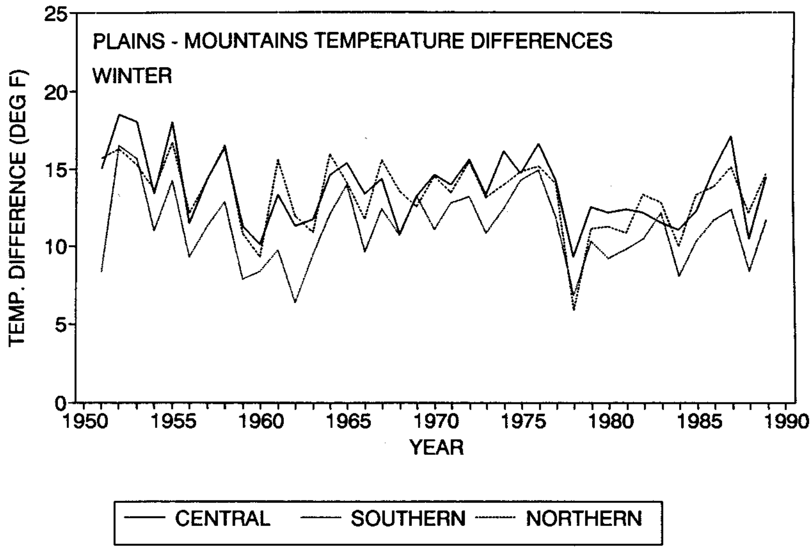

Figure 9. Time series of winter seasonal temperature differences between three pairs of Colorado plains-mountains climate divisions (as shown in Fig. 1).

seasonal temperatures do not correlate well between mountains and plains (Fig. 5), but the nature of plains-mountains temperature differences have not been previously investigated. Unlike the north-south differences, the plains-mountains differences are controlled by changes in the vertical distribution of temperature in the atmosphere. The atmosphere is thermodynamically more stable during the winter than the summer. This means that temperatures decrease more gradually with elevation in winter. The cooling with elevation is much more noticeable and consistent during the summer. Plains-mountains differences could be useful in evaluating changes in thermal stability that might have far-reaching climatic implications.

Plains-mountains differences were computed using seasonal temperature time series for three pairs of climate divisions shown in Fig. 1. All three pairs show very similar time series (Fig. 9). As expected, plains-mountains temperature differences are greatest during the summer and

least during winter (the reverse of north-south differences), but the winter season is still the time of greatest variability. During winter, plains-mountains differences decreased from the early 1950s until about 1960. A slight but steady increase then occurred up to 1976. The winter of 1978 was very unusual with persistently mild temperatures in the mountains but with fairly cold conditions on the plains. The resulting plains-mountains difference was the lowest on record since 1950. Since 1978, differences returned to values similar to the lower values of the late 1950s and early 1960s.

The time series of plains-mountains winter temperature differences do not appear to exhibit similar behavior to any of the other time series presented in this paper. They show a weak negative correlation (r = -0.16) with the time series of north-south temperature differences on the plains, suggesting a relationship controlled by differences in relative frequencies or strength of zonal (west to east) and meridional (north to south or south to north) flow in the atmosphere above the mountains and plains.

Conclusions

Utilizing monthly temperature data combined into three-month seasonal averages, we have examined the trends and variations in Great Plains temperatures over the past 90 to 100 years. There has been an upward trend in both maximum and minimum temperatures in winter, spring, and summer at four example long-term stations in Colorado. However, much of the increase occurred prior to 1940. The most dramatic recent trends in temperature are found in the diurnal range where significant reductions in average seasonal diurnal range have been observed over the past two to three decades. The nine-year running means of both winter and summer diurnal ranges were near or below there lowest values of the past century at some locations in eastern Colorado in the 1980s. All other Great Plains seasonal temperature data from the past few years continue to fall within the ranges that have been observed at other times during the past century. No clear evidence of accelerating greenhouse warming is apparent from these records, although Fort Collins temperature statistics show the impact of a local urban heat island as the city has grown up around the weather station.

The four long-term stations in Colorado that were analyzed as a part of this study all exhibited very similar interannual variations. Computed long-term trends, however, showed some disparities—especially the diurnal range time series. Diurnal range appears to be the most sensitive temperature element and may be reflecting changes in the environment immediately surrounding each weather station such as vegetation changes and irrigation. It may also suggest that local conditions are responding

differently to the same large scale climatic forcing.

Analysis of temporal changes in interannual variability also show interesting fluctuations but no unambiguous trends. Recent interannual variability has remained within the limits defined by the past century of observed seasonal temperatures.

Investigations into how similar the temperature time series are from one part of the Great Plains to another showed that time series of seasonal temperatures do retain similarity over considerable north-south distance but similarity decays rapidly in the east-west direction in and near the Rocky Mountains. Within the area from Texas to the Canadian border, a north-south distance of approximately 300 to 400 miles will result in a reduction of 50% of the amount of variance in one time series in common with the other. Time series of mountains and plains locations are correlated, but relative similarity decays quickly from plains to mountains. Limited analysis suggests that spatial seasonal temperature time series similarity is greatest during the autumn months.

Time series of temperature gradients (south-north and plains-mountains) showed that during the past century there have been surprisingly large differences of the temperatures in one area compared to another even averaged over a whole season. Interannual variations in these differences have been of the same magnitude as the variations at a point in temperature itself. The gradients also exhibit variations on an inter-decadal time scale consistent with other indicators of large scale atmospheric circulation patterns. Two recent winters, 1983 and 1987, produced unusually low south-north temperature differences.

These interesting time series of temperature gradients beg for more detailed analysis. They may offer considerable insight into the climate processes that contribute to the large natural variability on the Great Plains. These gradients may be the most informative temperature time series for evaluating future climate fluctuations and trends.

The analyses described here help define the expected range of variations in seasonal temperatures on the Great Plains. They suggest that our current excursions of seasonal temperatures are within the expected range of natural variability as defined by the past 100 years of observations. They also provide a foundation to which future Great Plains temperature patterns can be compared. But they offer only limited explanations for why variations occur, and they do not provide much basis for prediction of the future. Studies like this, while descriptively interesting, must be used in combination with research on the larger scale general circulation of our atmosphere. Knowledge of local and regional climatic response to larger scale forcing will eventually help explain the month to month, year to year, decade to decade and point to point fluctuations in our Great Plains climate that makes life on the plains so challenging—and so interesting.

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