Spatial Representativeness of Temperature Measurements from a Single Site

Abstract

This paper discusses the spatial distribution of the early spring minimum temperature and the length of the growing season in eastern Colorado. It is shown that even in the relatively homogeneous landscape, there are significant differences in long-term trends of these data. The authors conclude that the direction and magnitude of regional climate trends cannot be reliably inferred from single-site records, even over relatively homogeneous terrain.

1. Introduction

It is common practice to use single-station weather data to characterize the climate over a region. Examples include Alward et al. (1999), Williams et al. (1996), and Singer et al. (1998). In this correspondence, we report on the representativeness of a single weather station within a region of reasonable uniform vegetation and topography. Such a region should provide one of the better locations to evaluate the representation of weather data from one location.

Warming has been documented at the Central Plains Experimental Range (CPER) site in northeast Colorado. There is a concern with respect to the consequent potential effects on the short grass steppe of Colorado associated with an increase in average minimum temperature for this region (Kittel 1990; Alward et al. 1999). An inference of the Alward et al. (1999) paper was that the density of *Bouteloua gracilis*, a dominant native grass of the region, would decrease as a result of only a few degrees increase in the average spring minimum temperature, while the density of exotic grasses and forbs would increase. Melillo (1999) amplified on the results of Alward et al. (1999) to emphasize the significance of an increase in minimum temperature as an example of the relation between climate change and the earth's ecosystem.

The conclusions of the Alward et al. study, however, are based on weather data from only one location. The question of the spatial representativeness of the CPER weather data remains unanswered. We used other available sites in eastern Colorado for the years for which CPER climate data are available to investigate this question (Tables 1 and 2 and Figs. 1 and 2 show the stations used).[1]

2. Analysis

We analyzed the trends for the period of early spring (15 March–30 April) for the years 1970–96, since the temperatures at the beginning of the growing season would have the most effect on the growth of cool-season grasses. We also included length of the growing season to provide another perspective on this subject. We analyzed two periods of records corresponding to the first year when CPER climate data became available and the first year used in the Alward et al. (1999) study. The values of the trends and their statistical significance of average minimum temperature and the length of growing season[2] for the two periods of record for each of the stations are shown for eastern Colorado. The longer period of temperature record is shown graphically in Figs. 1 and 2, in order to show how the shorter period of record relates to the weather data collected earlier in this century.

The average minimum temperature for early spring for the period 1948–96 has a mixed signal, although most stations show a slight increase in average minimum temperatures. The statistically significant trends ($p \leq 0.2$; this value of p is used to define significance since the sample size was relatively small) are for Fort

[1]These include sites used in the National Climatic Data Center U.S. Historical Climatology Network [Cheyenne Wells, Eads 2S (2 mi south of Eads), Fort Collins, Fort Morgan, Holly, Lamar, Las Animas, Rocky Ford 2SE (2 mi southeast of Rocky Ford), and Wray, Colorado] and one other [Akron 4E (4 mi east of Akron), Colorado]. The number of years for which data are available at each site is also presented. There are, unfortunately, changes in the time of observation (Karl et al. 1986) and the type of thermometer used (Quayle et al. 1991) at several of the stations. A change from an afternoon daily observation to a morning observation, for example, causes a cool bias in minimum temperatures. The conversion of thermometers to the new electronic maximum–minimum temperature system produces less than 0.5°C differences in the minimum temperature with the older system, although their tendency to be placed closer to buildings to minimize the amount of electrical cable that needs to be buried would tend to produce warmer temperatures. Each of these effects, of course, confounds further the interpretation of trends from just one site.

[2]The growing season is defined as the number of days between the last and first 0°C date during a year. This definition, of course, is actually the number of days without a freezing temperature at the height of the thermometer at the weather observation site.

TABLE 1. Trends in spring daily mean minimum temperature in degrees Celcius per year (15 Mar–30 Apr 1948–96) and number of growing season days per year (1940–96) for weather stations in eastern Colorado. Here, *n* = years of data. Values of *n* less than 49 indicate data for one or more years were missing.

Spring daily mean minimum temperature				Number of growing season days			
Station	**Slope**	***p* <**	***n***	**Station**	**Slope**	***p* <**	***n***
CPER	0.06	0.1	49	CPER	0.75	0.001	57
Fort Collins	0.10	0.001	49	Fort Collins	0.42	0.002	57
Fort Morgan*	0.06	0.02	48	Fort Morgan*	0.07	0.5	43
Akron 4E	0.01	0.5	49	Akron 4E	–0.03	0.5	57
Wray	0.02	0.5	44	Wray	0.37	0.05	37
Cheyenne Wells	0.07	0.01	48	Cheyenne Wells**	0.12	0.5	40
Eads 2S	0.00	0.5	45	Eads 2S	0.08	0.5	41
Holly*	–0.03	0.5	47	Holly*	0.11	0.5	41
Lamar	0.01	0.5	47	Lamar	0.09	0.5	51
Las Animas	0.06	0.01	47	Las Animas	0.24	0.2	45
Rocky Ford 2SE	0.03	0.5	49	Rocky Ford 2SE	–0.04	0.5	56

*from 1949 to 1996
**from 1941 to 1995

TABLE 2. Trends in spring daily mean minimum temperature in degrees Celcius per year (15 Mar–30 Apr 1948–96) and number of growing season days per year (1970–96) for weather stations in eastern Colorado. Here, *n* = years of data. Values of *n* less than 27 indicate data for one or more years were missing.

Spring daily mean minimum temperature				Number of growing season days			
Station	**Slope**	***p* <**	***n***	**Station**	**Slope**	***p* <**	***n***
CPER	0.09	0.5	27	CPER	0.84	0.1	27
Fort Collins	0.12	0.1	27	Fort Collins	0.47	0.5	27
Fort Morgan	0.03	0.5	27	Fort Morgan	0.51	0.2	22
Akron 4E	0.01	0.5	27	Akron 4E	–0.03	0.5	27
Wray	0.01	0.5	24	Wray	0.39	0.5	17
Cheyenne Wells	0.09	0.2	26	Cheyenne Wells	0.21	0.5	20
Eads 2S	0.06	0.5	27	Eads 2S	–0.20	0.5	15
Holly	–0.02	0.5	26	Holly	0.44	0.5	24
Lamar	–0.13	0.1	27	Lamar	–0.25	0.5	24
Las Animas	0.07	0.5	26	Las Animas	0.48	0.2	21
Rocky Ford 2SE	0.06	0.5	27	Rocky Ford 2SE	0.04	0.5	26

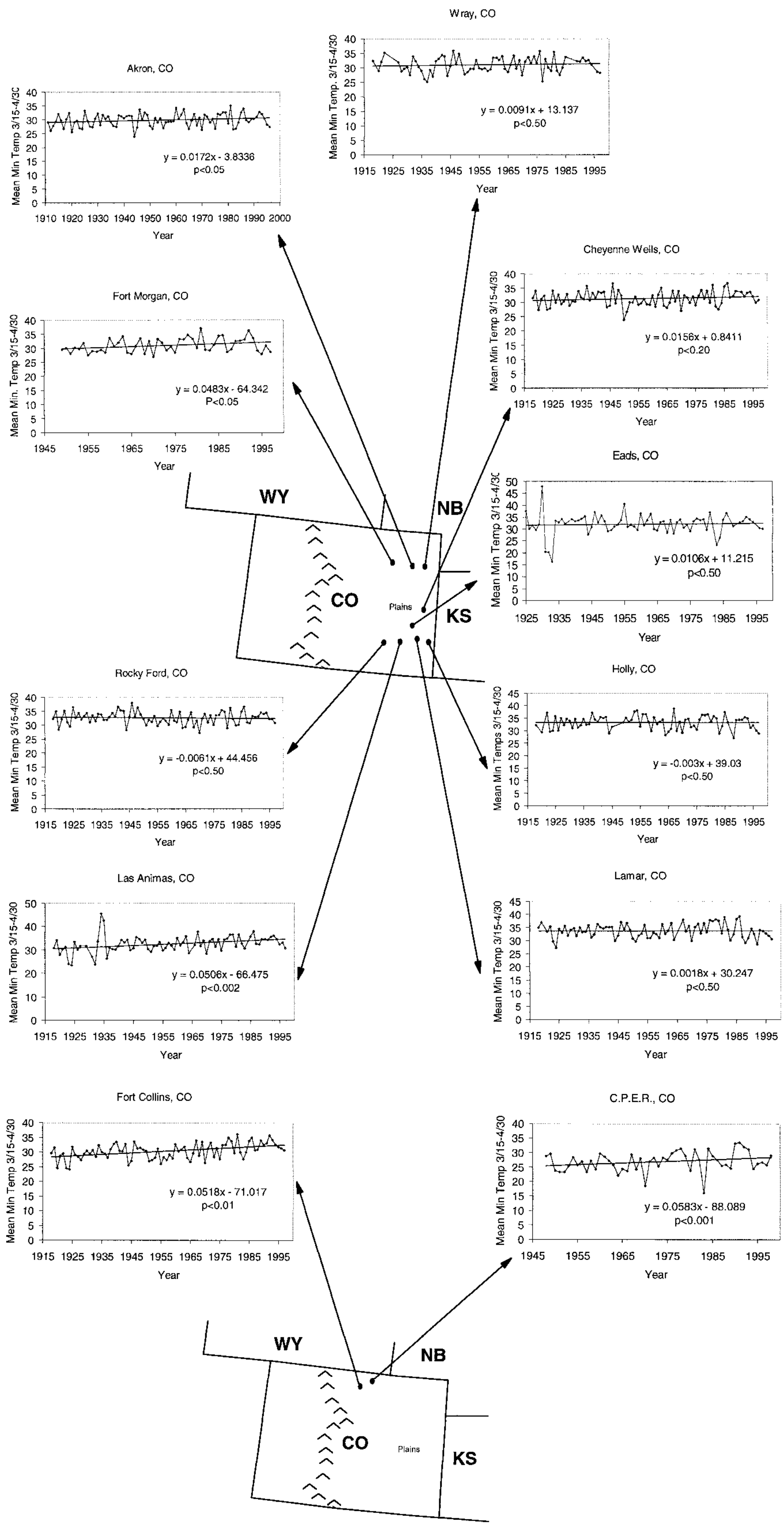

FIG. 1. Spring mean minimum temperatures (°F) for 15 Mar–30 Apr for eastern Colorado locations.

Collins, Cheyenne Wells, Fort Morgan, and Las Animas, Colorado, as well as at CPER. The remaining six sites have statistically insignificant trends. Based on the regression, the CPER has warmed by 3.0°C (Fort Collins by 4.8°C), while Holly, Colorado, cooled by 1.4°C since the late 1940s. Fort Collins's minimum temperature trends are atypical in the magnitude of change as the slope is almost three times as great as the average slopes at the other sites. Holly can be viewed as atypical in the direction of change (i.e., the only site with a negative slope in minimum springtime temperature).

CPER, Fort Collins, Las Animas and Wray, Colorado, show a statistically significant ($p \leq 0.2$) lengthening of the growing season during the period 1940–96, although five of the remaining seven sites had positive slopes. Based on the regression line slopes, the growing season at CPER has lengthened by 43 days, while it has shortened at Rocky Ford, Colorado, by 2 days. The increase of growing season length at CPER was about 2.5 times the average of the other sites; at Rocky Ford and Akron 4E, Colorado, the growing season had shrunk.

Table 1 shows that 9 of the 22 trends are statistically significant ($p \leq 0.2$). Fort Collins is a large, rapidly growing city and is presumably showing an urban heat island effect. Excluding

Fort Collins, 7 of the 20 trends in the rural and small-town portions of eastern Colorado show statistically significant warming of which CPER is the most pronounced.

Shorter-term trends were also spatially variable. For the period 1970–96 (Table 2), only Fort Collins, Cheyenne Wells, and Lamar, Colorado, have statistically significant trends ($p \le 0.2$) in early spring minimum temperature. Fort Collins and Cheyenne Wells have increases in early spring minimum temperature, while Lamar has a cooling. The changes over the 27 years, based on the trend analysis, range from +3.1°C at Fort Collins to –3.6°C at Lamar. The length of growing season trends for the period 1970–96 show a statistically significant ($p \le 0.2$) lengthening of 23 days for CPER, 13 days for Fort Collins, and 10 days for Las Animas. Of the 22 trends, 6 are statistically significant at $p \le 0.2$, with 5 showing a warming and 1 a cooling trend. Excluding the urbanized Fort Collins site, 5 of the remaining 20 trends are statistically significant.

This analysis leads to several conclusions. Only about one-third of the nonurban sites exhibit significant positive slopes for minimum early spring temperature and growing season duration. Also, since 1970, the CPER site has an atypical trend in the weather data analyzed.

Regional averages constructed from such point mea-

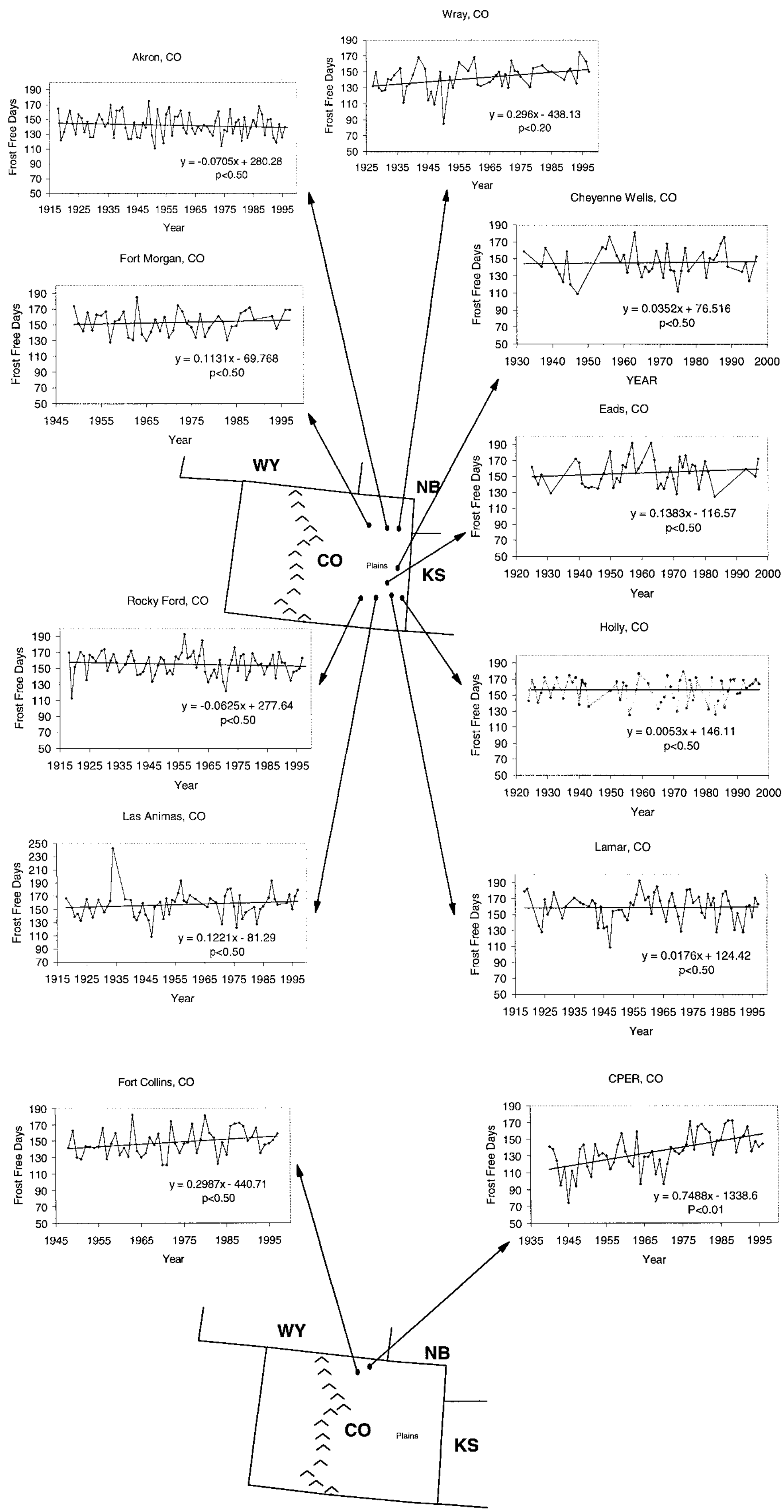

FIG. 2. Growing season days for eastern Colorado locations.

surements can, therefore, be misleading. The lack of regional consistency in early spring temperature trends at nonurban sites in eastern Colorado supports caution in drawing inferences about temporal change in regional grassland vegetation from individual localized measurements of climatic and ecological state variables.

3. Conclusions

As a general conclusion, the spatial variations in climate variables indicate that the direction and magnitude of regional climate trends *cannot be inferred from single-site records, even over relatively homogeneous terrain.*

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R. A. Pielke Sr.
Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado

T. Stohlgren
Midcontinent Ecological Science Center
United States Geographical Survey
and
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado

W. Parton
Rangeland Ecosystem Science
and
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado

N. Doesken
Colorado Climate Center
Colorado State University
Fort Collins, Colorado

J. Moeny
Canyonlands Headquarters
Moab, Utah

L. Schell
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado

K. Redmond
Atmospheric Sciences Center
Desert Research Institute
Reno, Nevada