Colorado Climate

Summer 2002 Vol. 3, No. 3

Colorado State University

Knowledge to Go Places

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Cover Photo: Nymph Lake located in Rocky Mountain National Park in August. Photo by Brian McNoldy.

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Roger A. Pielke, Sr.
Professor and State Climatologist

Nolan J. Doesken
Research Associate

Colorado State University
Knowledge to Go Places

Colorado Climate Center
Department of Atmospheric Science
Fort Collins, CO 80523-1371
Phone: (970) 491-8545
Fax: (970) 491-3314

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What Records Have We Been Breaking?

by John Bartholow and Bob Milhous, U.S. Geological Survey

"Today was another record-breaking day," the evening radio or television declares. High temperatures, low temperatures, floods, drought – take your choice. But how can we put these pronouncements in perspective? What do they really mean?

We present two types of information in this article: 1) an analysis of daily air temperature and precipitation for Fort Collins and 2) an analysis of annual precipitation for Fort Collins. Each analysis provides a different meaning to the statement about a record-breaking day or year.

Fort Collins Daily Temperature and Precipitation

We conducted a simple investigation of daily maximum and minimum air temperature data downloaded from the Fort Collins weather station's web site (http://ccc.atmos.colostate.edu/). We used the meteorological data beginning with the first full year of available data, 1889, through the last full year, 2002. For each year, beginning in 1890, we calculated how many days in that year (omitting all 29-February leap days) broke the daily record that had been established in previous years.

We looked at four categories of records, two of which are commonly used and two of which may be just as relevant but are less often mentioned. The common metrics are 1) the maximum of the daily maximum and 2) the minimum of the daily minimum. The less common metrics are 3) the minimum of the daily maximum and 4) the maximum of the daily minimum. The first two metrics are the absolute highs and lows for the day and tell us something about how absolutely extreme the weather has become; by contrast, the last two metrics tell us something about how cool the days stay or how warm the nights are.

Our results for air temperature are shown in Figure 1. As you can imagine, broken records were common during the first several years at the beginning of meteorological data collection, so we begin these daily temperature graphs with calendar year 1900. The graphs appear to indicate that within the last few decades, Fort Collins continues to break daily air temperature records at a fairly high rate for both the maximum of the daily maximum and the maximum of the daily minimum temperatures. The minimum of the daily maximum and the minimum of the daily minimum records are being broken at a relatively low rate. Another way to think of this is that it is getting hotter all day, and all night, long.

We also wondered how these record-breaking events would look compared to a theoretical curve describing the number of records we expect to be broken based solely on random fluctuations in our daily weather. For example, in the second complete year of data collection

Fort Collins historic weather station on the campus of Colorado State University. (Photo by James E. Bliss)

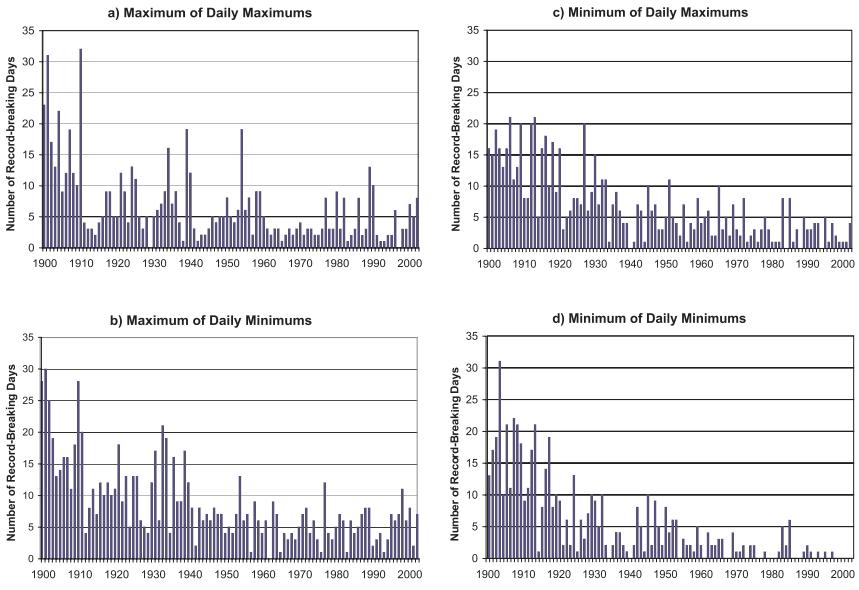

Figure 1. The number of days each year that broke the air temperature record for previous years for (a) maximum of the daily maximum, (b) maximum of the daily minimum, (c) minimum of the daily maximum, and (d) minimum of the daily minimum. The data represent full calendar years beginning in 1889 for Fort Collins, Colorado, but shown since 1900 only.

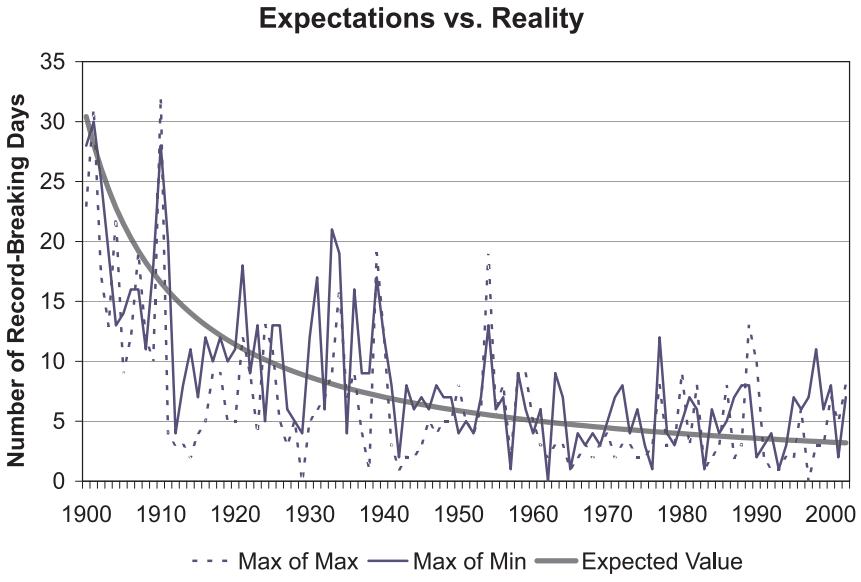

Figure 2. Number of record-breaking days for maximum of the daily maximum (max of max) and maximum of the daily minimum (max of min) compared with a theoretical curve describing a uniformly random process (expected value). The data represent full calendar years beginning in 1889 for Fort Collins, Colorado, but shown since 1900 only.

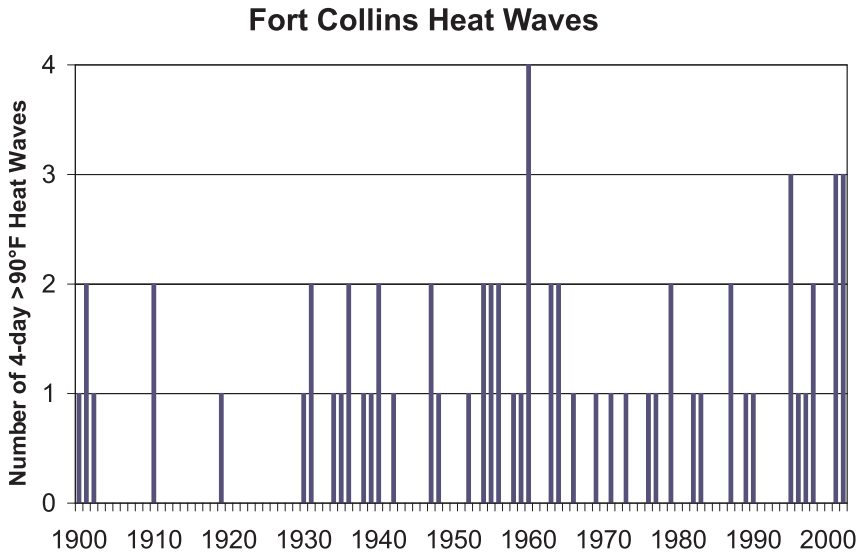

Figure 3. Annual number of "heat waves" in Fort Collins, Colorado, defined as non-overlapping 4-day periods when the maximum daily air temperature exceeded 90°F. The data represent full calendar years beginning in 1889 for Fort Collins, Colorado, but shown since 1900 only.

(1890), we would expect the record to be broken on one-half of the days, or 365/2 = 182.5. The next year we would expect 365/3 = 121.6 records to be broken, and so on. Figure 2 compares two of the metrics we looked at in Figure 1 with this expected value. The theoretical expectation predicts that we would break a total of about 82 records in the period 1980-2002. History confirms that we broke the maximum of the maximums record 102 times and the maximum of the minimums record a whopping 124 times in that time period. By contrast, we only broke the minimum of the maximums 61 times and the minimum of the minimums a mere 21 times, a good reason to believe things are heating up rather than cooling down.

This takes us to heat waves. Perhaps looking at single days is not the best way to characterize the brow-mopping heat we occasionally experience. Figure 3 illustrates the number of non-overlapping 4-day events each year when the maximum daily air temperature exceeded 90°F each day. Though it is not entirely clear from Figure 3, heat waves seem to be coming with a greater frequency in the later portion of the period.

Using the same techniques already applied, we examined the daily record for precipitation. Unlike air temperature, we looked only at the single measured daily value, ignoring all "trace" quantities. The results are shown in Figure 4 and appear to support that we have been staying well under the number of broken records we would expect from a purely random process. In addition, there appears to be some visual evidence for a recurring pattern illustrated by periodic especially low values.

Fort Collins Annual Temperature and Precipitation Records

We also examined how some records would look from an annual perspective. We first looked at the change in annual maximum temperatures for the period 1 July – 15 August (the hot part of the year in Fort Collins). Our objective was to see how the maximum annual temperature has changed over the 113 years of temperature record by looking at the change in the range of these maximum 4-day temperatures. Results are presented in Figure 5. The dashed colored line in the figure is the maximum 4-day temperature in each year; the black solid lines represent the annual maximum and minimum temperature records and when they changed. For example, 1889 begins the record with a maximum 4-day temperature of 92.5°F. In 1892, the maximum 4-day temperature set a new record at 97.5°F; in 1939 the record value rose to 98.3°F and then again to 101.3°F in 1954 setting our present record. There is about a 1% chance the 101.3°F record will be equaled or exceeded this year or next. Like Figure 5, Figure 6 looks at the variation of the 4-day minimum (usually night) temperatures for the same time period. This diagram indicates that nighttime temperatures have increased markedly, a conclusion similar to that seen from the daily analysis.

We performed a parallel analysis for annual water year precipitation data for Fort Collins. (A water year is from 1 October – 30 September and is used for water accounting purposes.) Results are presented in Figure 7. Changes in the limits of annual precipitation are of interest to many people because they tell us what conditions have existed and, to a certain extent, what we might face in the future. The concept illustrated here has been described as the Noah (rainy) and Joseph (drought) effect because the range of maximum-of-maximum and minimum-of-minimum water year precipitation becomes larger as our record becomes longer. In other words, we start out with whatever we observe as the maximum and minimum precipitation and this changes as the record length expands just like we saw for annual air temperature records.

We are very concerned about droughts in Fort Collins because of recent low precipitation. It is interesting that the last time the minimum-of-minimum record decreased was in 1966 where the record water year minimum was established as 7.40 inches, down from the 7.54-inch minimum established in 1954. The 2002 water year precipitation in Fort Collins was 8.39 inches – we still have a ways to go to break the earlier water year record.

We all tend to remember only the last few years of our weather and the land becomes parched if the precipitation is low for more than one year. In an attempt to illustrate longer-range effects, we have calculated an index to multi-year precipitation that is the sum of the present year, ¾ of the last year, ½ of two years ago, and ¼ of the year before that divided by 2.5 (1 + ¾ + ½ + ¼). This is not a perfect way of looking at long term "runs" in the precipitation data, but we found the results (Figure 8) interesting. This figure shows that we had a Noah (rainy) period in the late 1990s that established a new maximum multi-year precipitation record. Since then, we have moved rapidly toward a Joseph (drought) episode.

Discussion

Our results are relatively simple-minded ways to look at the widely acknowledged warming that many of us are experiencing. Warming could be the result of urbanization or it could be more global in nature. We have made no attempt to be rigorous here – we recognize that data collection methods have changed through time, and many skilled meteorologists have explored the detection of climatic trends far more than we (Pielke et al. 2000; Pielke et al. 2002). Simply tallying record-breakers or looking at yearly summer temperatures and water year precipitation does not fully describe the magnitude of the temperature and precipitation changes we have been experiencing, or whether they are biologically or culturally significant, like looking at the dates of first and last frost. But we do feel that the graphs we have presented can help put Fort Collins record-breaking in perspective.

Life would be boring if we broke no records. If our meteorological processes were completely stationary,

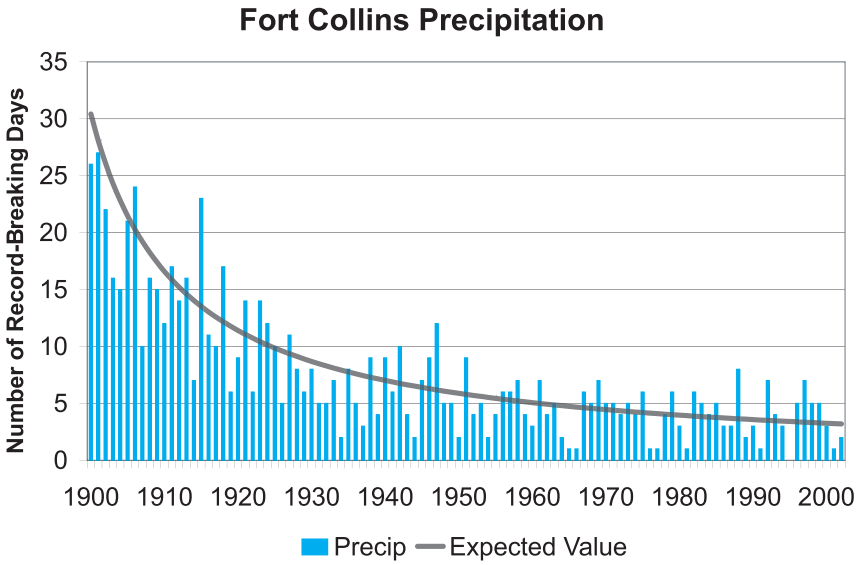

Figure 4. The number of days each year that broke the daily precipitation record for previous years. The data represent full calendar years beginning in 1889 for Fort Collins, Colorado, but shown since 1900 only. The solid black line represents an expected average value.

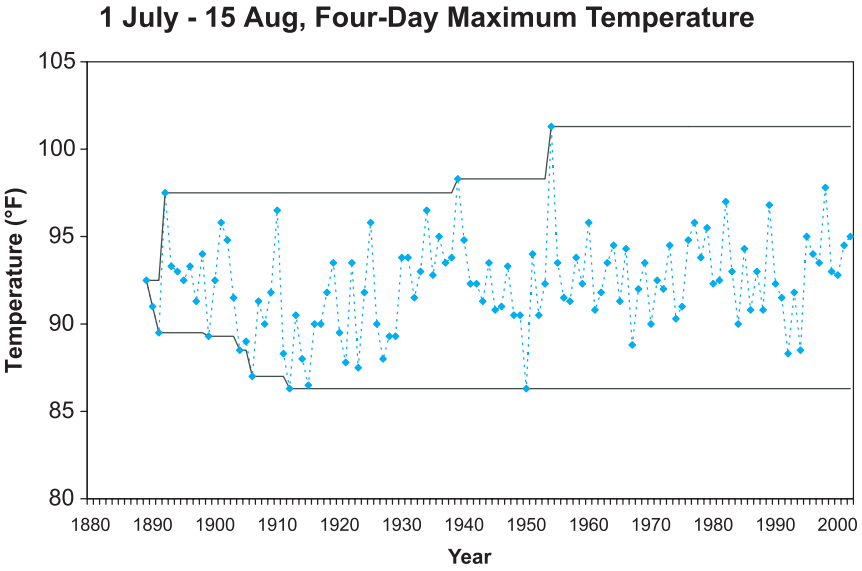

Figure 5. Variation in 4-day maximum air temperature in Fort Collins during the summer (1 July-15 August) along with the increase in maximum of the maximum 4-day temperature and decrease in minimum of the maximum 4-day temperature.

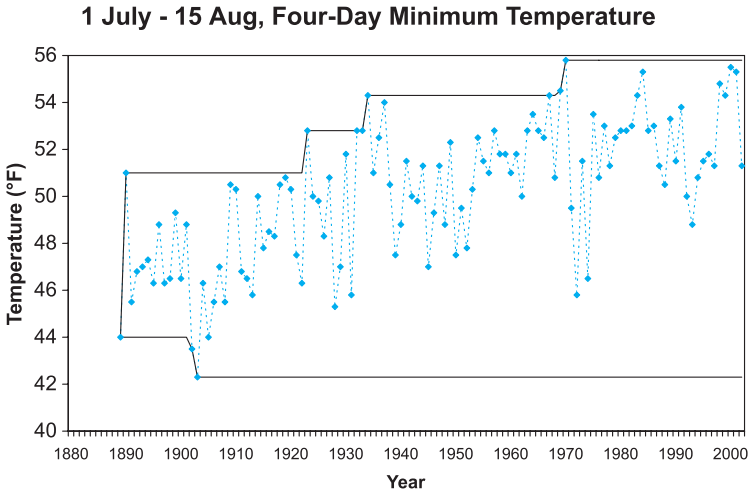

Figure 6. Variation in 4-day minimum air temperature in Fort Collins during the summer (1 July-15 August) along with the increase in maximum of the minimum 4-day temperature and decrease in minimum of the minimum 4-day temperature.

and we had no changing climate, we might expect to break only one air temperature record by the time the year 2254 rolls around. (But then we suppose that breaking no records would itself be a record-breaking experience!) Local, or more global, changes in our weather may make our historical records much easier to break, adding spice to our lives.

How many new records will we break in the next year?

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Pielke, R.A. Sr., T. Stohlgren, L. Schell, W. Parton, N. Doesken, K. Redmond, J. Money, T. McKee, and T.G.F. Kittel. 2002. Problems in evaluating regional and local trends in temperature: An example from Eastern Colorado, USA. *International Journal of Climatology*, **22**:421-434.

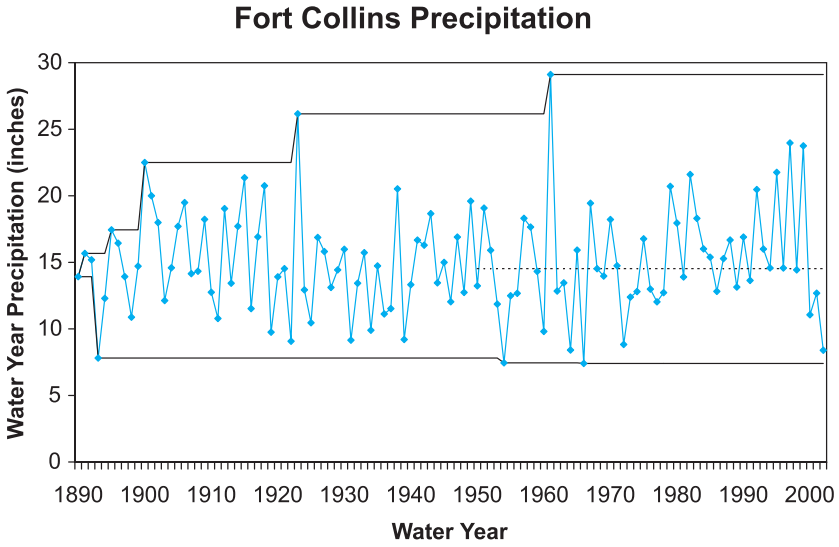

Figure 7. Water year precipitation records along with the ever-expanding maximum and minimum annual precipitation record. The dashed line in the center right is the median precipitation for the period of record.

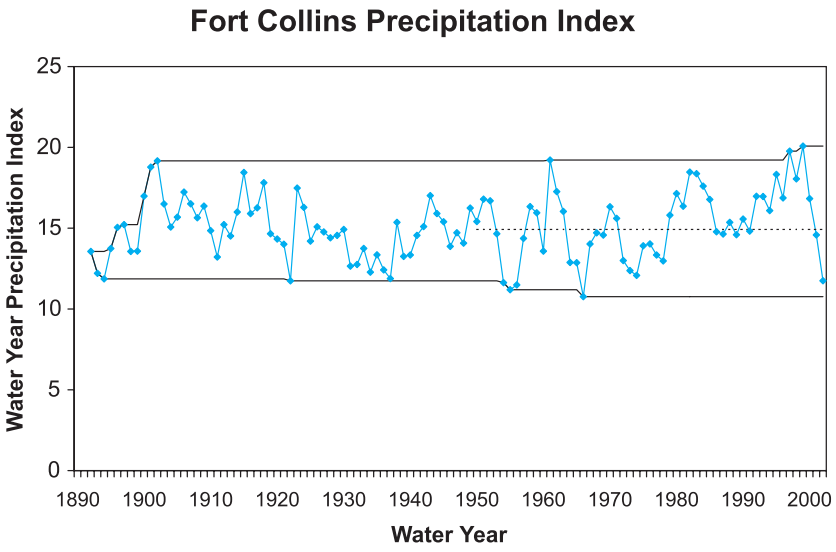

Figure 8. Index to the weighted 4-year run in precipitation in Fort Collins along with the ever-expanding maximum and minimum run record. See text for a description of the run index. The dashed line in the center right is the median index to precipitation for the period of record.

About the Authors: John Bartholow and Bob Milhous are employees of U.S. Geological Survey in Fort Collins, Colo., and budding climatologists!