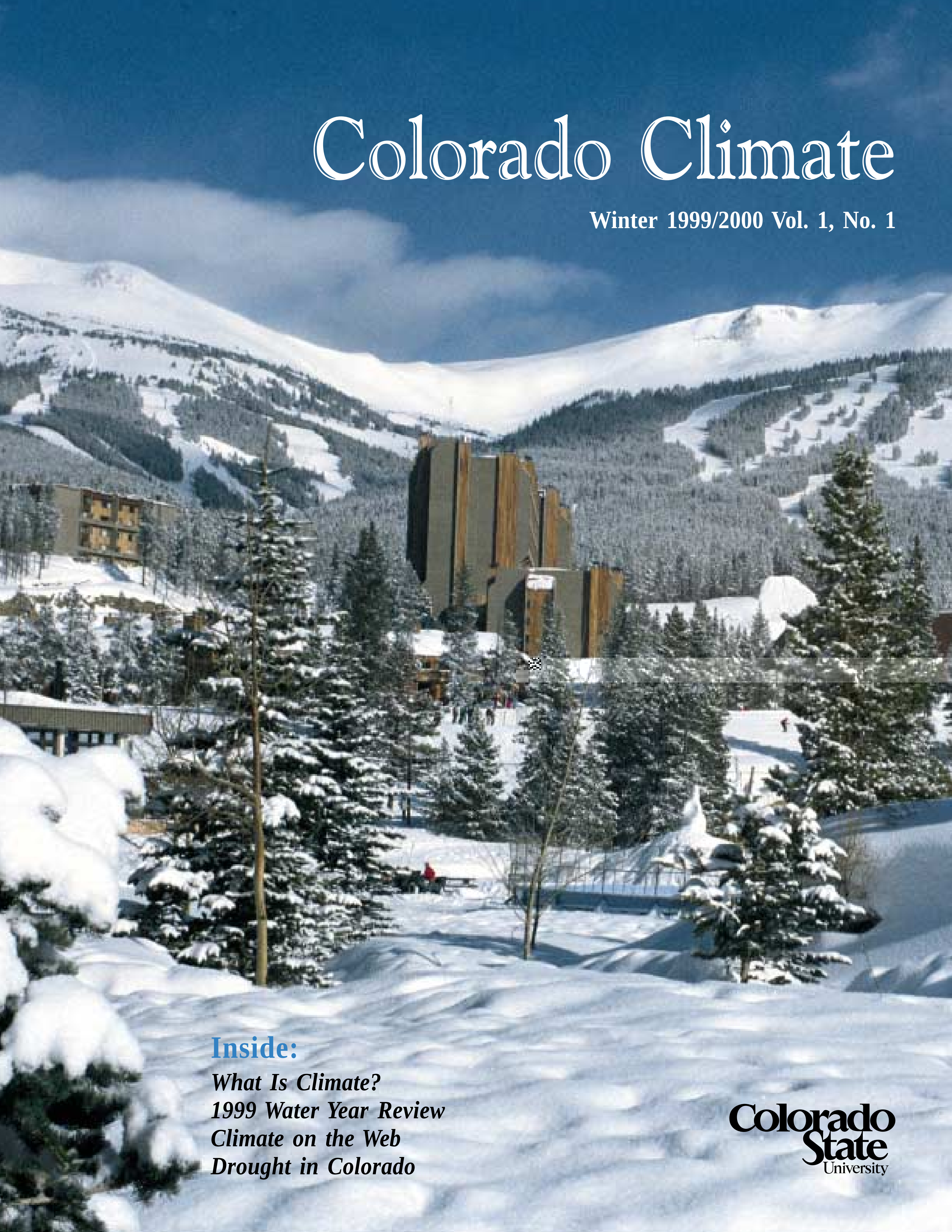
Colorado Climate

Winter 1999/2000 Vol. 1, No. 1



Inside:

Colorado State University

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An early publication with the same name, "Colorado Climate," was published monthly from 1977 through 1996 with the support of the Colorado Agricultural Experiment Station and the Colorado State University College of Engineering.

This is the first issue of the new quarterly publication, "Colorado Climate."

The Colorado Climate Center is supported by the Colorado Agricultural Experiment Station.

Subscription price is $15.00 for four issues. Single issue price is $7.50.

Cover Photo: The combination of fresh snow, steep mountains, rich evergreen forests, deep blue skies, and ever-changing cloud patterns is the unforgettable Colorado trademark that captures the essence of Colorado's climate. (Photo taken near Breckenridge, Colorado, by Nolan Doesken.)

If you have a photo that you would like us to consider for the cover of *Colorado Climate,* please submit it to:

Colorado Climate Center
Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523-1371

Enclose a note describing the contents and circumstances of the photo including the location and the date it was taken. Digital photographs can also be considered. Submit digital imagery via attached files to:

Odie@ccc.atmos.colostate.edu

Unless arranged in advance, photos will not be returned.

Welcome

As Colorado State Climatologist and Colorado Assistant State Climatologist, we welcome you to the first edition of the *Colorado Climate* summary! This new publication will appear four times per year. Our goal is to summarize recent Colorado weather, as well as discuss a wide variety of climate topics.

As you can see, we are working towards improving the appearance of *Colorado Climate*. No more 2-cent copies on the cheapest paper available. But color and the quality of paper don't guarantee success. We will strive to improve the content as well as the appearance.

In our first issue, we discuss what is normal Colorado weather. We often have particularly warm or cold days for the season, but are they normal? The term "climate" is defined. While it has been used to mean long-term weather statistics, at the Colorado Climate Center we adopt a more general definition, which includes land-surface processes, such as vegetation growth and soil moisture.

This issue also contains the completion of the three part series on drought that we started five years ago (what a relief). You will also find our traditional descriptions of monthly climate patterns and water-year wrap-ups.

In each issue we will address climate-related topics of interest to the citizens of Colorado. We already have a long list we want to write about. However, if you have suggestions for topics that you think are important, please let us know. We may be able to fit them in.

We look forward to providing you with climate information in this new format.

Dr. Roger A. Pielke, Sr.
Professor and State
Climatologist

Nolan J. Doesken
Assistant State
Climatologist

What Is Climate?

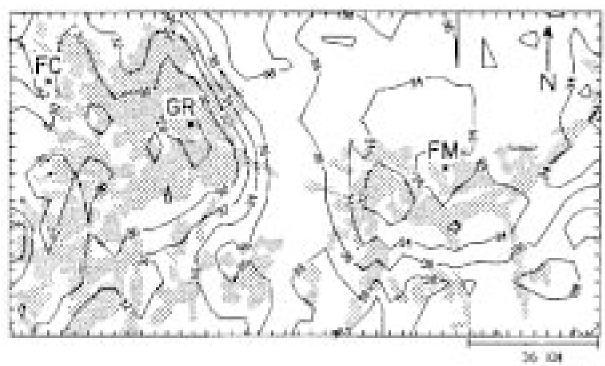
Roger A. Pielke, Sr.

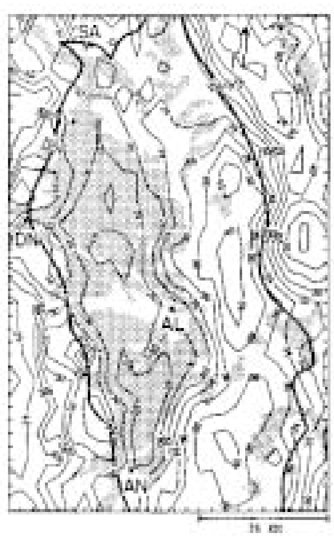
There is more than one definition of climate. One definition is that we average weather conditions over many years (say 30 years) to calculate the observed statistics of weather. The Colorado Climate Center (http://ccc.atmos.colostate.edu), the Western Regional Climate Center (http://www.wrcc.dri.edu), and the National Climatic Data Center (http://www.ncdc.noaa.gov) are examples of web sites that routinely provide this information.

However, there is a broader definition of climate in which earth surface conditions are as important as atmospheric conditions. This definition recognizes that the atmosphere and land surface interact with each other. Because of this, data must be collected for both the atmosphere and the land surface in order to adequately describe climate.

To illustrate this for a portion of Colorado, the figure on the following page shows the variation of the greenness of the ground in the central United States during the early growing season of 1988. The greenness means that photosynthesis is taking place and vegetation is actively transpiring water vapor into the air during the day. The greenness of the surface will directly affect the amount of water transpired to the atmosphere. Long-term weather data over eastern Colorado illustrate the large

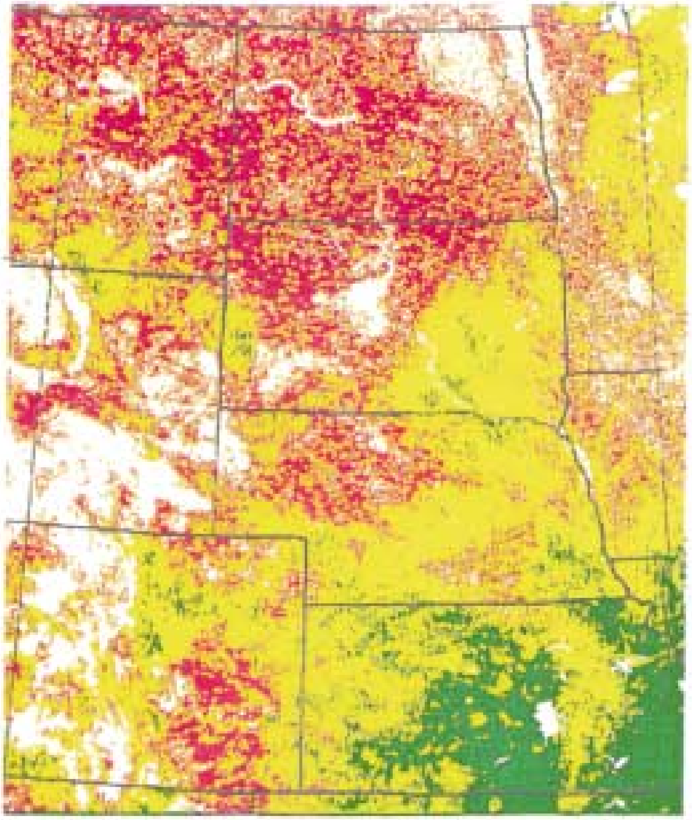
(continued on page 2)



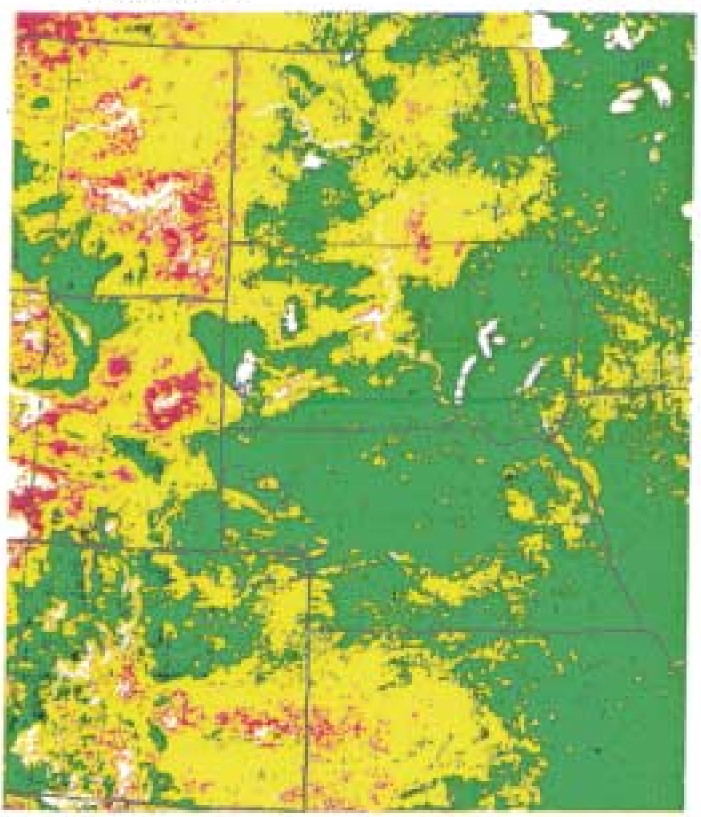


Composite of GOES derived surface temperature at 1300 LST for the period 1 August 1986 to 15 August 1986 for (a) northeast Colorado (FT = Fort Collins; FM = Fort Morgan; GR = Greeley) and (b) San Luis Valley in Colorado (AL = Alamosa; AN = Antonito; DN = Del Norte; SA = Saguache). The lower valley is outlined by a dark line separating it from significant elevated terrain. Irrigated areas are shaded. From M. Segal et al., 1988, "Evaluation of vegetation effects on the generation and modification of mesoscale circulations." J. Atmos. Sci., ***45****, pp 2287.*

What Is Climate? (continued from page 1)



April 26, 1988



June 2, 1988

variations in time and space between even close by locations.

We can telescope into Colorado to see how the greenness of the surface affects temperature. The figures on the previous page show the temperature of the surface of the earth at 1 p.m. in the afternoon averaged over two weeks in early August 1986. The stipled areas correspond to irrigated crops, while the white area corresponds to all other areas. The skin temperature is not the air temperature even a few feet above the surface, but it does show that the irrigated areas are decidedly cooler than other areas. This would also occur with the air temperature and, indeed, the cooling extends over a thousand feet above the surface!

There are additional variations in the skin temperatures in the two regimes shown in the figure. Recent research has shown that much of this variation is due to the specific landscape (such as a ponderosa forest in the foothills of the mountains versus a short grass prairie in the lower elevations), as well as where it rained most recently so that evaporation from the soils can cool the surface.

Since the landscape varies across the state of Colorado, it should therefore be expected that there are variations in weather and climate that results.

In future issues, we plan to start summarizing the variation of greenness across the state of Colorado.

Greenness in the central U.S. during 1988 growing season. Green corresponds to higher amounts of transpiring vegetation, with white corresponding to no transpiration. (Figure courtesy of the EROS Data Center, Sioux Falls, South Dakota, and Tim Kittel, NCAR, Boulder, Colorado.)

Is Our Weather Today “Normal”?

Roger A. Pielke, Sr.

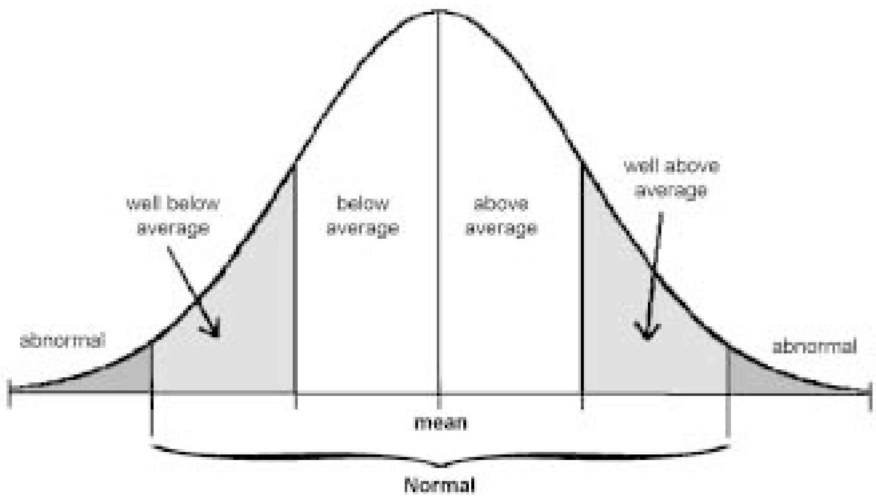
This question is often asked and commented on by TV and radio weather casters. If it is a warmer than average day, it is often stated that “the temperature today was above normal.” Is this really true?

This article suggests that we can have a day with above average temperatures, yet the warm weather is quite normal! Statisticians use the concept of standard deviation to express the range of data around a mean. If the distribution of temperature follows the so-called “bell curve,” there is an equal likelihood of values above and below the average value of the data. With a bell curve, 67 percent of the temperatures fall within one standard deviation of the mean.

We can use the bell curve to describe whether a day is warmer or colder than average, but is it still “normal” weather for the date. Only if the temperature were beyond the limits of most of the bell curve would a day be described as above or below normal. Such days are “abnormal.”

We can use weather data for Denver to illustrate cold and warm (but normal) days. The table presents the average maximum and minimum temperatures for January and July, along with the observed standard deviations. If the temperature reaches 63°F during the day in January, the day is warmer than average, but the temperature is not abnormal. Similarly, in July, a temperature of 100°F is hot, but is quite normal for Denver.

Standard Normal Distribution



Normal “bell-curve” statistical distribution

Maximum and Minimum Temperatures for Denver

	January (°F)	July (°F)
Daily average maximum temperature = $\overline{T}_{max}$	43.0	87.9
Daily average minimum temperature = $\overline{T}_{min}$	16.0	58.8
One standard deviation above $\overline{T}_{max}$	62.8	97.9
One standard deviation below $\overline{T}_{max}$	23.2	77.9
One standard deviation above $\overline{T}_{min}$	33.3	68.6
One standard deviation below $\overline{T}_{min}$	-1.3	49.0

Climate on the WEB

Nolan Doesken

Some of you have reached that stage in your life when you actually have time to contemplate the marvels of nature and time to surf the Net (younger than 26, older than 55, single, unemployed, etc.). There is more weather and climate stuff on the World Wide Web than you can shake the proverbial stick at. In this section we will bring to your attention some of the favorite websites of climatologists. I will not comment much about these sites, but just let you explore them for yourselves.

For a wide assortment of current and historic climatic information for the western United States, I highly recommend the Western Regional Climate Center’s website. WRCC is a part of the Desert Research Institute at the University of Nevada at Reno. Dr. Kelly Redmond is the Regional Climatologist for the WRCC and was largely responsible for developing this website. It will lead you to many and varied sources of valuable weather and climate data and information:

http://www.wrcc.dri.edu/

Also, feel free to visit the Colorado Climate Center website at:

http://ccc.atmos.colostate.edu

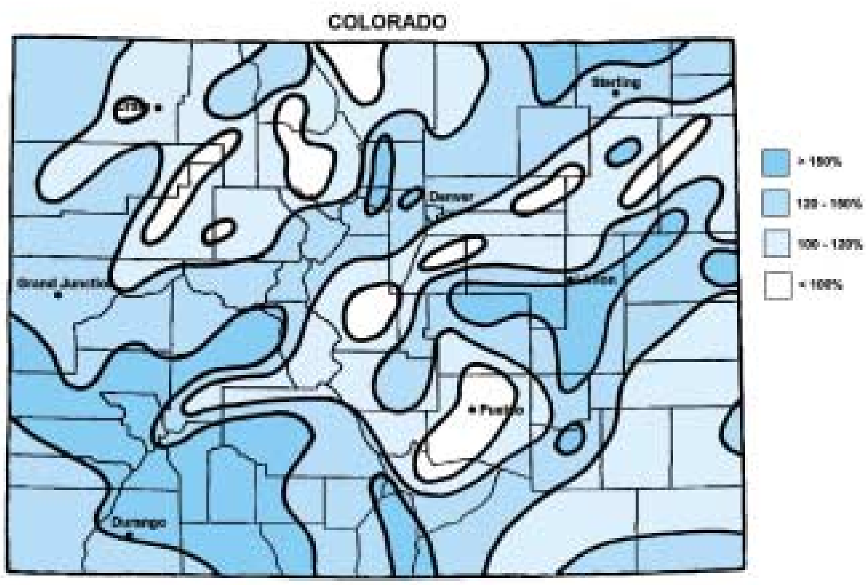
A Review of the 1999 Water Year

Significant Features

The 1999 water year in Colorado was another year of climate frenzy as La Nina conditions (colder than average sea surface temperatures in the tropical Pacific Ocean) led many climate forecasters across the U.S. to anticipate a dry winter in southern Colorado with more abundant snowfall in Colorado's northern mountains. Forecasters also anticipated a good chance that spring and early summer would be drier than average over eastern Colorado. Some of the La Nina forecast came true for the Western U.S. as the coastal Pacific Northwest experienced exceptional precipitation and record mountain snowfall while the Southwest was dry during winter and spring. For Colorado, however, which lies in the "gray area" between the more predictable Pacific Northwest and the Southwest, the forecast was less than stellar.

When it was all said and done, the 1999 water year ended up much wetter than average statewide. Stormy weather in October and early November 1998, flooding spring rains along the Front Range, and frequent and locally excessive summer storms more than made up for dry and exceptionally mild winter weather. Late April - early May flooding on the Poudre River, Arkansas River, Fountain Creek, and other tributaries did millions of dollars in structural damage and resulted in a Federal disaster declaration. Local flash floods were unusually numerous in the mountains in July and August.

Growing season (May-Sept. 1999) precipitation as a percent of the 1961-1990 average



1999 Winter Season

Winter got off to a quick start with heavy mountain snows in October and early November, especially over southwestern Colorado, and abundant low-elevation rains and wet snow. Then in mid November, the weather patterns shifted and dry weather became the rule. Finally, just before Christmas, a week-long blast of frigid sub-zero temperatures accompanied by several inches of snow renewed the winter spirit and again raised fears that we were in for a long, cold winter. Immediately, weather patterns shifted again. From Christmas Day through March, the entire state enjoyed unusually warm temperatures with no more blasts of arctic air. The storms that crashed continuously into the Pacific Northwest did nick Colorado and left our northern and central mountains with heavy snows in January and a few more storms in February. Eastern and southern Colorado remained very dry. The entire state was very dry and unusually warm in March.

A significant and annoying feature of the 1999 winter was wind. Strong westerly and northwesterly winds seemed to blow incessantly from late December into mid April. For Colorado's Front Range, it was the windiest winter in many years. February was particularly brutal with some Front Range foothills locations experiencing wind gust over 40 mph on at least 18 separate days in February. A ferocious windstorm April 8-10 was responsible for approximately $20 million in damages along the Front Range. Historically, strong winter and spring winds are a normal part of the climate from the crest of the Colorado mountains eastward to the plains. However, except for occasional episodes of very strong winds, the Colorado Front Range has been enjoying lighter winds since the mid 1980s. During the 1970s and as recently as 1982 windstorms were much more common and did considerable property damage.

By the end of March, precipitation totals for the first six months of the 1999 water year were near or below average over many parts of Colorado. Statewide snowpack was 89 percent of average on April 1, but conditions appeared much worse. The combination of strong winds and much above average temperatures had melted or evaporated much of the snows that had fallen earlier in the winter except in protected or north facing locations. Numerous wildfires were ignited and spread out of control in March. Concerns over an early forest fire season and reduced water supplies increased daily.

Then came the storms of late April (described in a special feature in the last issue of *Colorado*

Climate). In just a matter of days, the moisture deficits were wiped out and replaced by flood emergencies on the Arkansas River and several other rivers. This appears to have been one of the earliest major flooding events from widespread heavy rains in recorded history. Such events are most likely to occur in May or June. This was the beginning of what became a very wet growing season for most of Colorado.

1999 Growing Season

The 1999 growing season in Colorado was characterized by frequent and locally heavy precipitation, high humidity (not compared to the East, South, or Midwest, but compared to what we typically experience in Colorado), and comfortable temperatures. July and August were the only months that were warmer than average, but this was mostly the result of unusually warm nighttime temperatures. There were fewer days than average with temperatures above 90 degrees F, and only a handful of days with temperatures at or above the 100-degree mark, even in the normally sizzling valleys of southeastern and west central Colorado. Lush, green vegetation from the heavy spring and summer rains contributed to the warmer nights but cooler days.

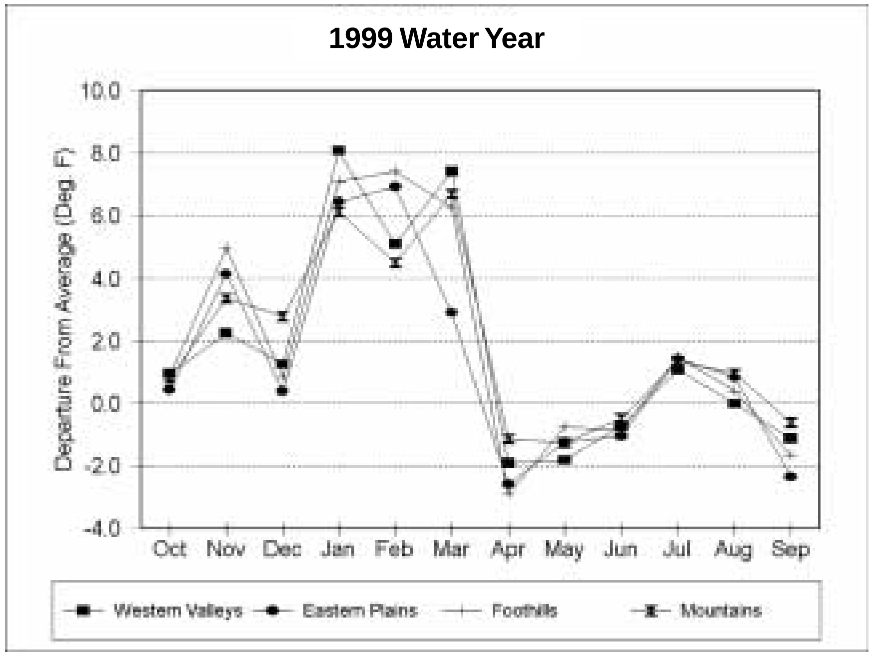
Summer-like weather continued well into September, with periodic active thunderstorms and warm temperatures. Humidity decreased dramatically, however, and the normal autumn deep blue skies appeared again. Before September ended, an early winter storm hit parts of the mountains and northeastern plains bringing wet snow, freezing temperatures, and ending the 1999 growing season slightly prematurely.

Growing season (May-September) precipitation totals were above average over almost all of Colorado (see map on page 4). Precipitation exceeded 150 percent of average over large areas of southwestern Colorado and over portions of the Eastern Plains. The majority of Colorado received between 100 and 150 percent of average for the growing season. A few local areas fell slightly short of average. For example, Kremmling measured 76 percent, Yuma received 82 percent, Castle Rock reported 93 percent, and Yampa ended up with 95 percent of the 1961-1990 average.

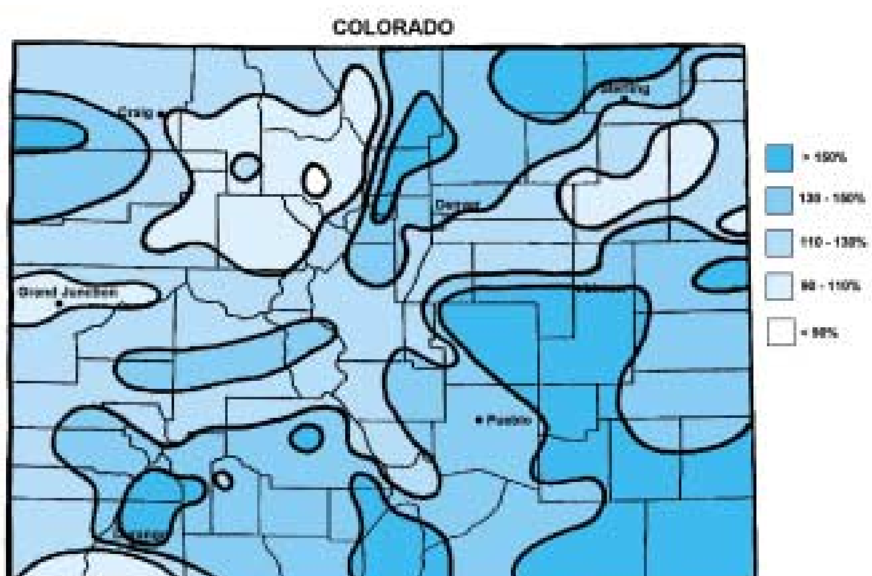
Temperature Summary

The key features of the 1999 water year were the exceptionally warm late winter months (January-March) and the remarkable consistency in departures from average throughout the year across all of Colorado. It is the exception, not the rule, for the entire state to be above average or below average at the same time, but this has been the case now since the spring of 1997. Colorado has not experienced a colder than average winter since 1992-93.

For the year as a whole, temperatures ended up about 1.4 deg. F warmer than average over the Eastern Plains increasing to 1.8 deg. F above average in the foothills and mountains. Over the course of the year there were few new record daily maximum temperatures and almost no new record low temperatures. However, there were many unusually warm nights. A number of new records for warmest overnight temperatures were established.



Regional temperature departures from 1961-1990 average for Oct.-Sept.

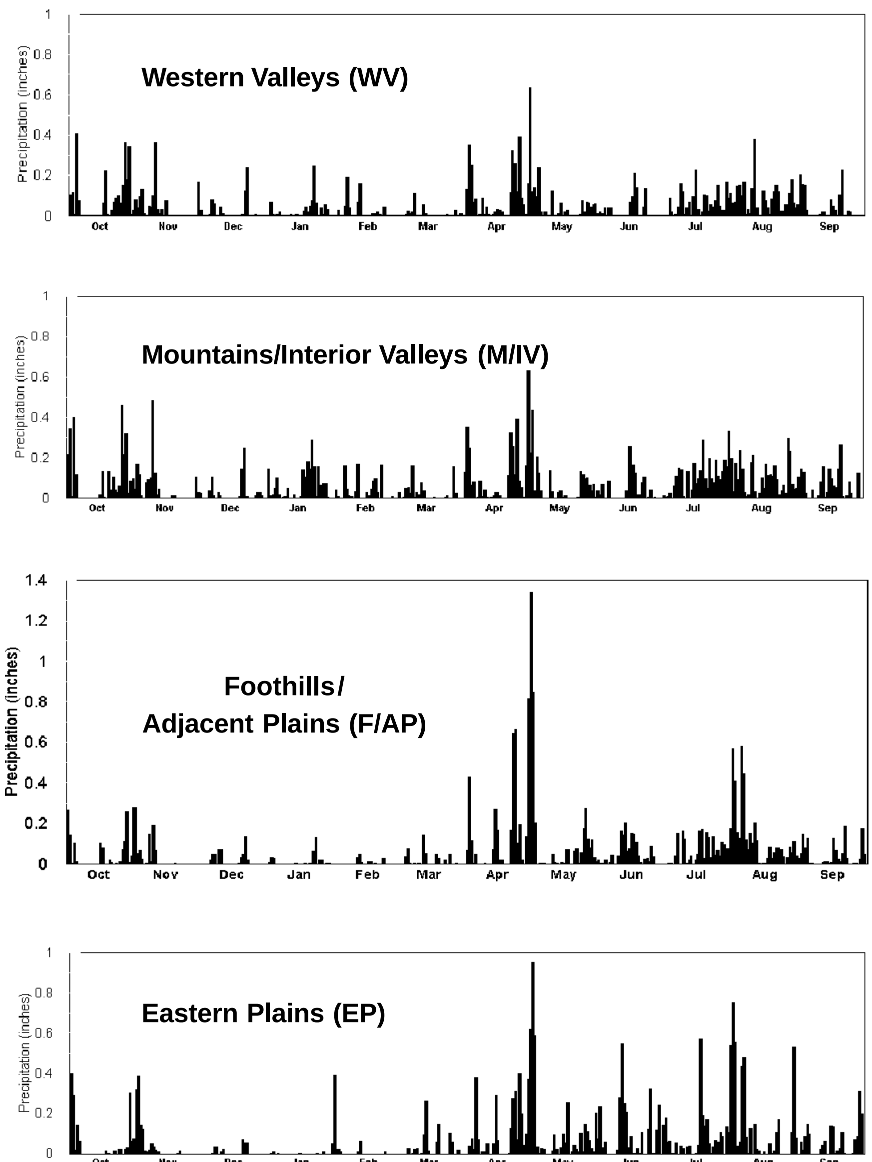


Water year precipitation as a percent of the 1961-1990 average

Precipitation Summary

Statewide precipitation for the 1999 water year (map on page 5) ended up 134 percent of the 1961-1990 average placing this in the top 12 wettest years on record for the state as a whole. The southeast quarter of Colorado was the wettest, with respect to average, with many areas receiving more than 150 percent of average. For some locations in southeastern Colorado, this was the wettest year in recorded history. Colorado Springs totaled 26.79" of precipitation for the water year, their wettest in recorded history exceeding such notable wet years as 1921, 1965, and 1995. Rocky Ford received 22.75" for the year, an amazing 209 percent of their average. This surpassed their previous record by nearly 2.50 inches.

Regional graphs of daily precipitation

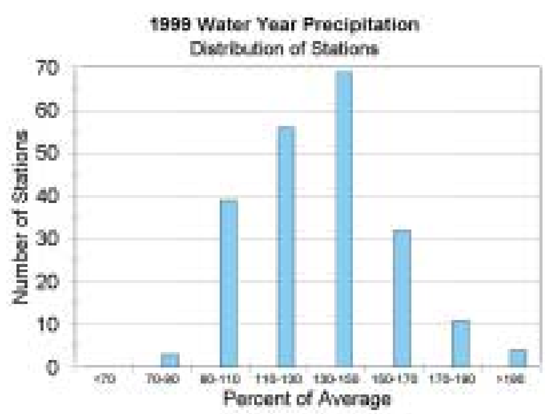


As usual, there were a few locations that missed out on the abundant precipitation. For example, the upper valley of the Colorado River near Kremmling received less precipitation than average. There were also a few locations in northeastern Colorado slightly drier than average for the year. Of the more than 200 National Weather Service cooperative weather stations with complete records for the year, only 3 stations received 90 percent or less of the annual average. A total of 12 stations (5 percent of all cooperative sites with complete data for the year) received less than 100 percent, and most of these were just slightly below average. More than half received in excess of 130 percent of average. All other reporting stations were above average for the year with 15 official weather stations reporting more than 170 percent of average for the year.

The regional graphs of daily precipitation (left) describe the year very well. The April - early May precipitation onslaught was largely responsible for the excessive annual totals. However, rains fell almost every day in July and August to contribute to the large annual totals. Winter precipitation was very sparse. Colorado's typical late June - early July dry spell was right on schedule over central and western portions of the state.

The Front Range rainfall at the end of April represented one of the heaviest widespread precipitation events in years with a regional average of nearly 3 inches over a 3-day period with 1.34" in a single day.

With another wet year, Colorado's wet spell, that has prevailed most years since 1982, continues. To put this in perspective please read this issue's special feature on Colorado's drought history beginning on page 13.



July 1999

Climate in Perspective:

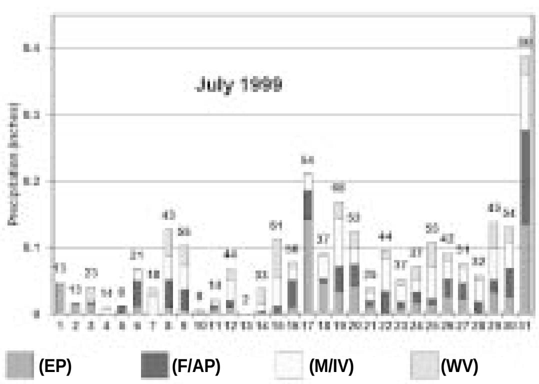
Colorado experienced hot summer weather in July with frequent thunderstorms. A steady flow of tropical moisture reached southwestern Colorado (a wind circulation known as the North American or Southwest monsoon) producing unusually heavy precipitation and several flash floods in the mountains.

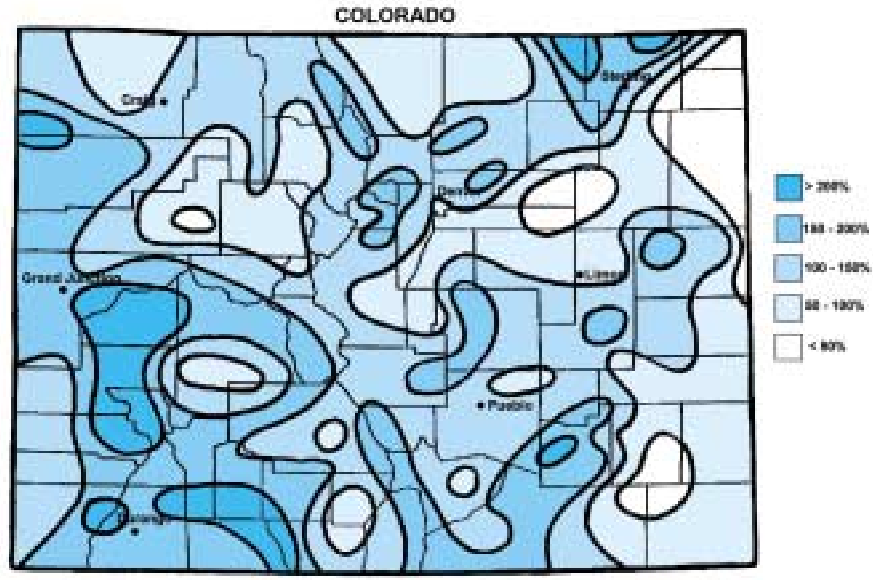
Precipitation:

July precipitation was highly variable ranging from over five inches at many locations in Colorado's southwestern mountains (7.84" was the state high at Wolf Creek Pass 1E) to less than 0.50" at a few stations in northeastern Colorado (just 0.44" at Holyoke for the entire month, compared to a July average of 2.75"). A few locations in eastern Colorado were also soaked. Rocky Ford 2SE totaled 6.79" for the month thanks to a 4.50" downpour on the night of July 16. Overall, most of Colorado was significantly wetter than average with many stations in southwestern Colorado over 200 percent of average. There were isolated dry spots statewide, but the driest area was extreme eastern Colorado plus some locations east and south of Denver. Some of these areas received less than 50 percent of the July average.

Temperatures:

Temperatures for the month as a whole were warmer than average over most of Colorado. Most locations ended the month about one degree Fahrenheit warmer than the 1961-1990 July average. North central Colorado was the warmest region of the state, compared to average, while portions of southern and west central Colorado were slightly below average. Daytime temperatures were actually a bit cooler than average over much of the state, but nighttime readings were quite warm.

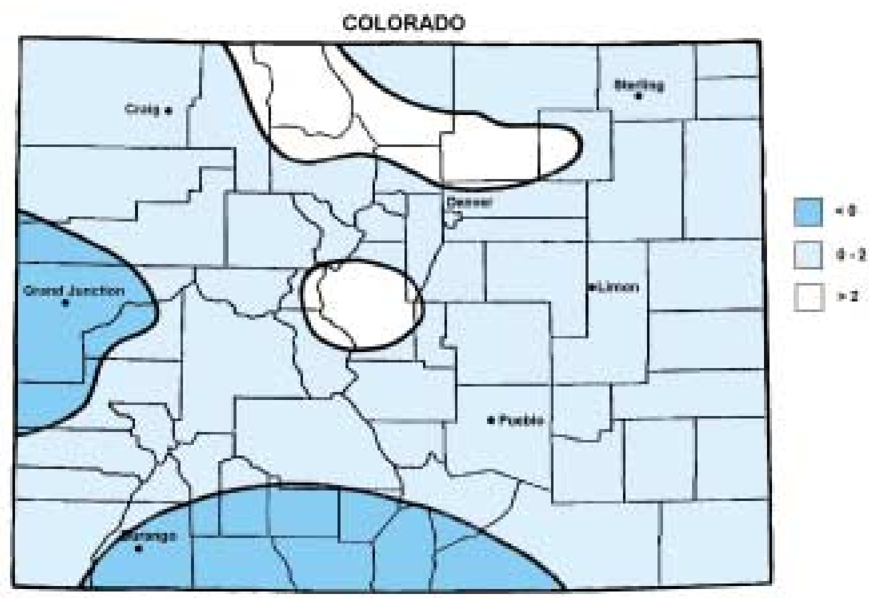




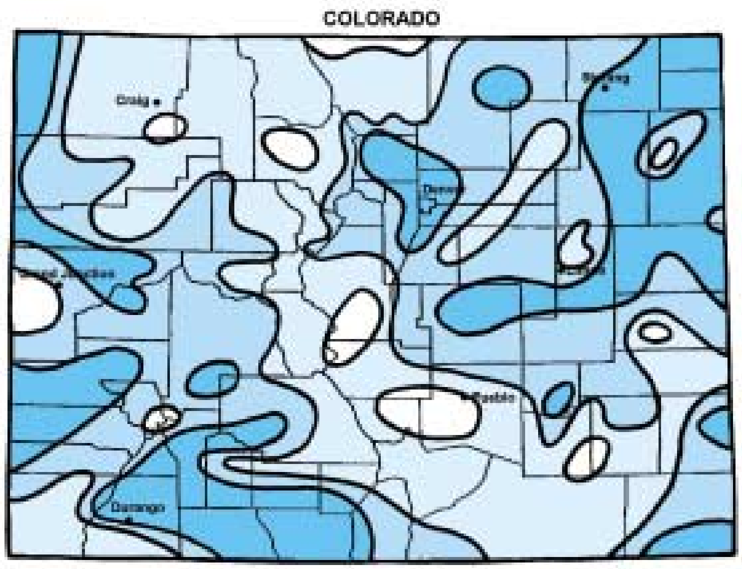
July 1999 precipitation as a percent of 1961-1990 average

Daily Highlights:

1-7 A modest heat wave. Some low elevation temperatures reaching the 100 degree mark. Las Animas hit 106 degrees on July 2nd, the warmest temperature of the year. Temperatures in the mountains reached close to 80 degrees. This was a dry period for northern Colorado with only a few isolated thundershowers. More storms developed in southern Colorado, however. Durango reported 0.66" on the 3rd. Blanca recorded 0.98" on the 6th. 2.10" of rain was measured at Trinidad on the 6th. The entire state enjoyed a seasonally hot but comfortably dry 4th of July.



July 1999 temperature departures from 1961-1990 average (°F)



August 1999 precipitation as a percent of 1961-1990 average

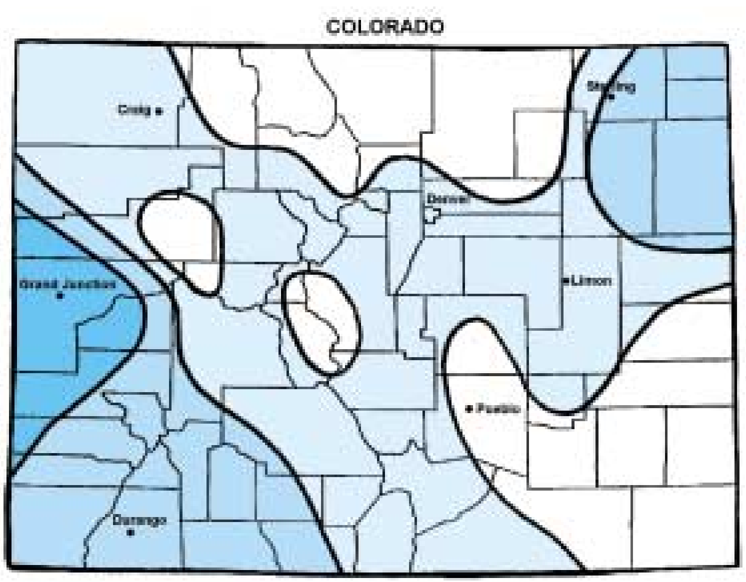
8-11 A disturbance crossed Colorado on the 8th with fairly numerous showers. Becoming sunny, cooler and very comfortable 9-10th, with increasing clouds but still comfortable on the 11th.

12-14 Quite hot and fairly humid with a few scattered thundershowers.

15-17 Cooler with increasing clouds and moisture. Numerous storms on the 16th especially east of the mountains, with locally heavy rains. 2.60" of rain reported at New Raymer 21N. 4.50" late on the 16th at Rocky Ford.

18-31 Stagnant weather pattern. Hot and humid (for Colorado) with thunderstorm development every day. Mountain clouds and storms each day as a steady flow of tropical moisture moved into Colorado from the southwest. Several locally heavy storms produced a series of high elevation flash floods and debris flows. For example, a localized but very heavy rain caused flooding on Saguache Creek and Middle Creek (south central Colorado) on July 26. On the 28th, high elevation downpours resulted in a huge debris flow west of Georgetown that closed I-70. On July 30-31, very heavy rain fell in southwest Colorado. Major flooding occurred on Dallas Creek. Placerville reported 3.13" of rain on the 30th. Brief heavy rains at high elevations are normal, but some of these rains at elevations above 8,000 feet represent some of the heavier rains of record in Colorado's mountains. Official National Weather Service rain gauges were not near the center of these storms. Exact rainfall is unknown, but is under investigation.

August 1999 temperature departures from 1961-1990 average (°F)



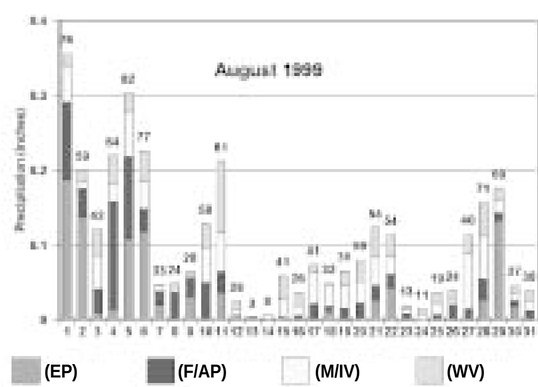
August 1999

Climate in Perspective:

The warm, humid and stormy weather pattern that began in July continued into August with thunderstorm development almost every day, especially in and near the mountains. With high humidity and frequent rains, there were few forest fire problems in Colorado. Rains and high humidity also helped dryland agriculture but led to increased diseases in irrigated crops in normally dry areas of Colorado such as the San Luis Valley.

Precipitation:

August was an exceptionally wet month in Colorado. Many locations in the state received well over double the average rainfall. Several weather stations in southwestern and eastern Colorado received in excess of seven inches of rainfall. Vallecito Dam measured in excess of 0.50" of rainfall on nine separate days, and their August



rainfall total was a remarkable 9.27". Runoff from August rains helped refill reservoirs in southwestern Colorado that are normally only filled with snowmelt runoff. Grasses grew tall and lush over eastern Colorado

Temperatures:

August temperatures ended up near to slightly above average statewide. Only southwestern and extreme northeastern Colorado were a bit below average. Daily maximum temperatures were substantially cooler than average due to cloud cover, frequent showers, and unusually green summer vegetation. The number of days with temperatures of 90° or above was much lower than usual. The nights made up for this, however. With unusually high humidity, temperatures did not cool off as much at night as usual.

Daily Highlights:

1-5 A cool, cloudy, and very wet start to the month. Widespread and locally heavy rains fell each day. Colorado Springs totaled 3.98" on the 4th, and a 3-day total of 6.01" 3-5th. Many locations had one-day rains during this period in excess of one inch. High temperatures each day only reached in the 60s and 70s in the mountains and across the eastern plains.

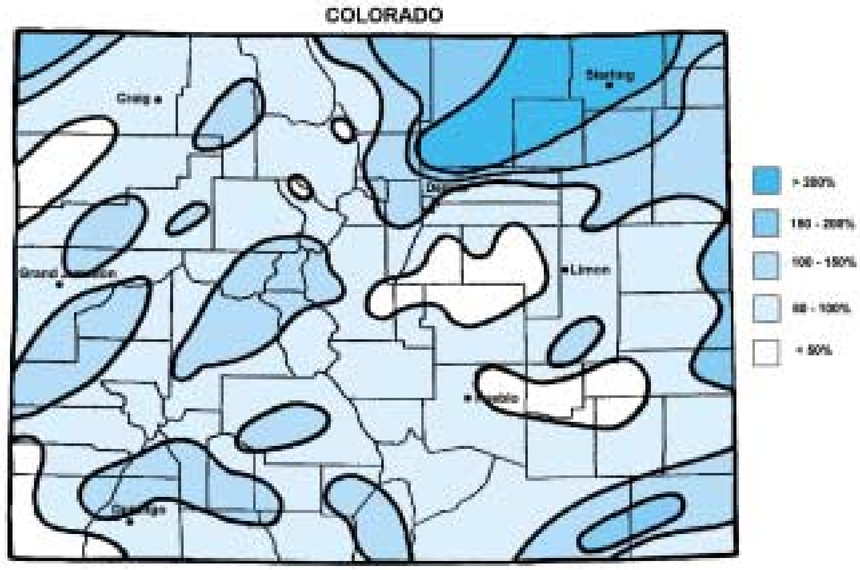
6-11 Warmer but still humid with scattered storms each day. Widespread and again locally heavy rains over western Colorado 10-11th. Grand Junction received 1.02" on the 10th.

12-14 Much drier air briefly moved into Colorado with lots of sunshine and with cool, crisp nights. Fraser reported a morning low temperature of 31°F on the 13th.

15-22 Warm and humid again with scattered storms each afternoon and evening, most numerous over western Colorado. A powerful storm brought hail and heavy rain to northeast Colorado on the evening of the 17th. A veteran observer, Layton Munson, 5 miles south of Sedgwick, recorded 3.43" of rain.

23-26 Hot and fairly dry. This was the only sustained period with low elevation temperatures in the 90s all month. Moisture moved back into southwestern Colorado on the 26th with increasing showers.

27-31 Summerlike weather continued with scattered afternoon thunderstorms.



September 1999 precipitation as a percent of 1961-1990 average

September 1999

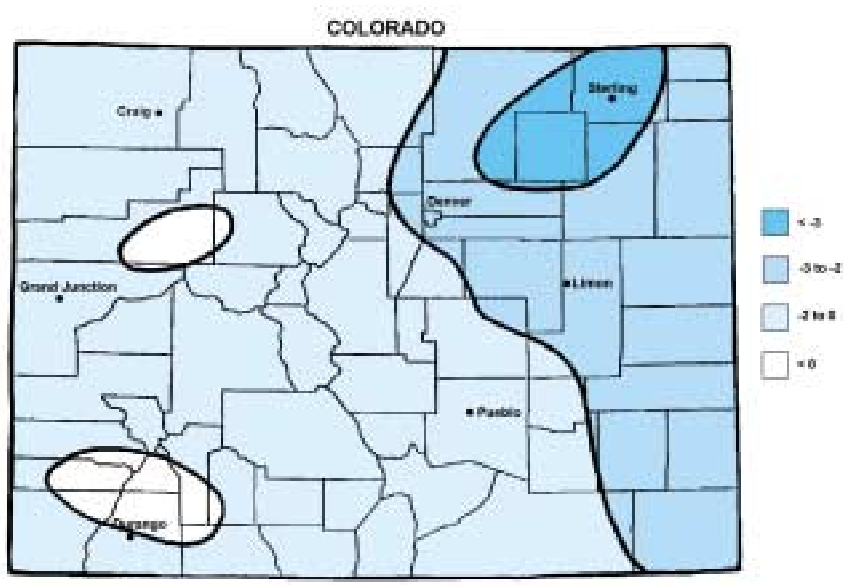
Climate in Perspective:

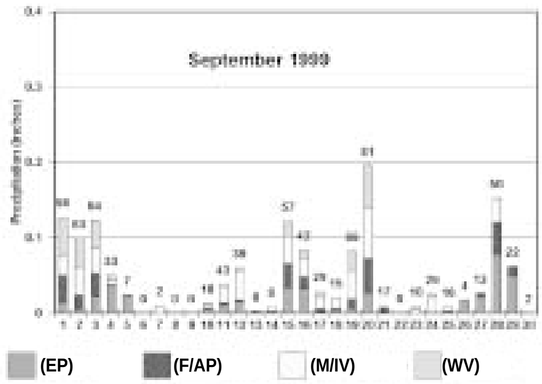
The stagnant weather patterns of summer gave way to more changeable weather in September. Tropical moisture still reached southwestern Colorado but retreated by the end of the month. By month's end, a lively early-winter storm brought the first snow and hard freeze of the fall to portions of northeastern Colorado.

Precipitation:

For the first time in several months, the majority of Colorado received less precipitation than average with a few areas of western and southeastern Colorado getting less than 50 percent of average. Scattered areas of the state were wetter

September 1999 temperature departures from 1961-1990 average (°F)





than average. Wolf Creek Pass was again remarkably wet with a monthly total of 7.72" bringing there July-September total to 24.45". Northeastern Colorado was also much wetter than average. New Raymer received 5.39" including 6.5" of September snow.

Temperatures:

September got off to a warm, summery, start. However, three strong cold fronts, each stronger than the next, progressively dropped temperatures each of the last three weeks of the month culminating in subfreezing temperatures in many areas late in the month. Fraser, for example, dipped to 11°F on the 29th and 30th. As a result, September temperatures ended up below average statewide. In parts of northeastern Colorado where snow fell, temperatures were as much as three degrees below average for the month.

Daily Highlights:

1-4 Warm weather with very lively thunderstorms each day moving up from the southwest. Storms were most numerous over the mountains and northeastern plains of Colorado. Severe weather with some damaging hail in the Fort Collins, Greeley, and Longmont areas 1-3rd. Fort Morgan received 1.50" of rain on the 3rd.

5-10 The first period with widespread dry weather in many weeks. Hot 6-7 and 9-10. Some showers on the 10th in advance of an approaching cold front.

11-12 The first strong cold front of the season crossed Colorado accompanied by scattered thundershowers. High temperatures only climbed into the 50s over portions of eastern Colorado on the 12th.

13-18 Pleasant temperatures statewide. Tropical moisture lingered over southern Colorado with daily shower activity.

19-21 Another strong cold front crossed Colorado with an early dose of snow for the mountains above 9,000 ft. Significant rains fell over parts of central and northeastern Colorado with local patches of fog. Crested Butte totaled 1.25" of rain. Skies cleared on the 21st and temperatures dropped to the lowest levels so far this fall.

22-25 Lovely, warm fall weather but with a few scattered showers in southwestern Colorado.

26-28 Two storms in rapid succession brought cooler weather statewide and significant precipitation and the first snow of the season to portions of northeastern Colorado. Boulder recorded 1.21" of precipitation on the 28th. New Raymer had a 3-day total of 1.78" of water including 6.5" of heavy, wet snow.

29-30 Clear – cool days with very chilly nights. Fraser temperatures dipped to +11°F.

What Lies Ahead?

Nolan Doesken

Years ago, we used to write a brief description of what to expect for the coming month. It was very popular among readers. In fact, many people thought we were bold and successful weather forecasters with a crystal ball that allowed us to see the future. Little did they know that all we were doing was studying the climate of the past and describing what usually happens. This isn't too hard to do, since climatologists love to study climate data from the past to determine things like average temperatures, record snowfalls, or probabilities of precipitation. It's fun – at least for some of us.

Now that our publication comes out quarterly (every three months), that old format won't work. But let's try something similar. Beginning with this issue, we will outline a few highlights of the coming months. It is not a forecast in the true sense. It is simply a description of what we have found to be the typical seasonal progression of Colorado climate. Some years we will be way off, but most of the time, we'll offer some useful insights to help you plan ahead.

(continued on page 11)

Colorado Climate, January-March

January is Colorado's coldest month of the year with the greatest likelihood of experiencing subzero (Fahrenheit) temperatures. Storm systems tend to zip across Colorado every few days with episodes of light to moderate mountain snows most numerous in the northern and central mountains. Little of this Pacific moisture ever falls east of the mountains. There is usually one major multi-day storm during the month that brings moisture into Colorado from the southwest and drops very heavy snows in the mountains of southwestern Colorado. These storms can sometimes bring snow east of the mountains. Rain in January is traditionally rare except at the lowest elevations of western Colorado where some of the Pacific storms begin as rain before changing to snow. Colorado can also expect a siege of several days in a row with strong northwesterly winds aloft and heavy snow accumulations on the upwind side of the exposed mountain barriers. Large snow accumulations in January are common near Steamboat Springs and other similar exposures. East of the mountains, January normally brings dry, lip-chapping weather with cold nights but many sunny days. There is usually at least one burst of bone-chilling arctic air out on the plains that drops temperatures well below zero. These cold fronts may bring a few inches of dry, fluffy snow that are eventually whipped into drifts when the winds inevitably pick up during or after the storm passes. For the eastern foothills, January is also a month of strong winds. With the jet stream often overhead, many days of strong winds should be expected from the crest of the mountains eastward to the base of the Front Range foothills. Winds may reach 100 mph in local wind-prone locations.

February is much like January except that the day length begins to become noticeably longer. Very cold weather is still possible, especially early in the month. Some of Colorado's coldest temperatures of all time, including the record low of –61°F at Maybell, have occurred in early February. There are often several consecutive days in February with bright sunshine. Despite occasional strong winds and doses of snow, February has gained the reputation for providing "the best spring weather of the year" east of the mountains.

The frequency of Pacific storm systems reaching Colorado decreases in March. However, as temperatures begin to warm a bit, more water vapor is available. More storms form and linger in the Great Basin area before moving eastward, so there is more time for Gulf of Mexico moisture to move north and westward into eastern Colorado. As a result, March has a reputation for heavy snows both in and east of the mountains. For some of the Front Range and central mountains, March is often the snowiest month of the year. There is always a threat of dangerous blizzards on the high plains, so travelers must be cautious. March is also a month for dramatic changes. Weather conditions rarely stay the same for long. Temperatures can climb into the 70s quite easily at lower elevations, but they can easily drop 40-50 degrees when a strong cold front arrives. Mountain top winds begin to diminish a bit, while winds out on the eastern plains grow stronger. As the sun appears higher in the sky each day, it warms the air quickly near the ground. This air then rises and mixes with the faster-moving winds aloft which easily sweep down to ground level. By comparison, there are many days in mid winter with strong winds at mountain top level but with nearly calm stable air in the mountain valleys and across the plains.

The months of January, February, and March represent critical months in Colorado's high country for snow accumulation. By the end of March, the majority of the snowpack is normally in place that provides the runoff to fill streams, reservoirs and irrigation canals throughout the spring and summer. Water resource managers don't care when it snows so long as a deep snowpack is in place by April. It may be beneficial, in fact, for most of the snow to fall in late winter and spring when storms are more widespread and when there is less opportunity for the snow to melt or evaporate before the spring snowmelt. Skiers, on the other hand, appreciate frequent snows spread out throughout the winter. In reality, the timing and quantity of snow varies greatly from one year to the next and remains difficult to forecast accurately well in advance.

Loveland, Colo., March 6-7, 1990. Photo by Joel Radtke, Loveland Reporter Herald, from the Snow Booklet.

Folklore Anyone?

Nolan Doesken

Long before anyone knew what a meteorologist or climatologist was – long before thermometers or rain gauges were invented – long before anyone knew of the New World, weather wisdom and folklore were alive and well and passing on from generation to generation. European settlers brought their home country folklore to the New World, for better or worse. The Native Americans already had their own refined and cherished weather wisdom.

The last 50 years have been hard on folklore. Dispersion of families after World War II and mass exodus from farms to cities has taken a toll on the wealth of weather wisdom. Much of the Native American folklore was not written down. Meteorological technology and verifiable improvements in weather forecasting as a science, not an art, has placed weather folklore in the closet.

Some might argue that a scientific publication is no place for folklore. Science, afterall, should rise above the lore and myths of common Man, should it not? For many centuries, however, weather folklore was the science. The wise lorists who applied their trade (usually to farming, hunting, or sailing) were respected by all.

In future issues we will present tidbits of weather folklore that have made their way to Colorado or developed here over time and observation. We will not pass harsh judgement on these bits of folklore but will attempt to keep alive for at least one more generation some of the wisdom that helped early settlers prepare for and survive the challenges that a variable climate provides.

If you have favorite folklore that you would like to share, please submit it in writing (mail or e-mail) to me at the Colorado Climate Center, e-mail address: Nolan@ccc.atmos.colostate.edu. I have been collecting Colorado weather lore for nearly 20 years, but there is much that has remained ungathered.

Climate Memories

Nolan Doesken

This section is dedicated to all the Colorado weather watchers of the past who have helped measure and record weather conditions each and every day. Without these dedicated people, we climatologists wouldn't have much to write about.

100 Years Ago – January 1900

The views from the high ground near Limon southwest towards Pikes Peak and northwest towards Denver are little changed today from what they were 100 years ago. But for many parts of Colorado, particularly the transportation corridors through the mountains, the river valleys, and, of course, the Front Range, old-timers from the last turn of the century would scarcely recognize our state. Yet with so many changes, the climate keeps marching along – always dynamic and dramatic yet always familiar and recognizable to the careful onlooker.

Back in January 1900, Colorado was in the throws of drought. Snowpack in the mountains was marginal, at best. South-facing slopes were bare as were most of the areas above tree line. Precipitation totals were below average statewide, with the mountains particularly dry when compared to average. Breckenridge totaled just 0.35 inches of snow water content for the month. At most locations, only two storm systems dropped measurable precipitation all month. Sunshine and warm temperatures were the rule. January 1900 temperatures were above average all across the state. Of approximately 50 official weather stations operating that year, most ended the month 5-6 degrees above their average. In the San Luis Valley, temperatures soared to nearly 10 degrees warmer than the average that had been established from weather records dating back just a few years. There were no subzero arctic airmasses east of the mountains all month until a brief cold spell hit late in the month dropping nighttime temperatures just below zero. More than likely, few complained about the warm, dry weather. That meant less firewood to carry and less coal to shovel. But residents also knew that the bare mountains could spell trouble for the coming summer water supplies.

Drought in Colorado

Nolan Doesken and Tom McKee

At long last, here is the conclusion to our 3-part story on drought that we started back in 1994. (Refer to February and March 1994 issues of *Colorado Climate* for Parts I and II)

Introductory Comments

Let's begin by refreshing our memory on what we mean by drought. Five years ago we wrote about the difficulty of defining drought. That is still the case today. There is no single quantitative definition that satisfies everyone. One can simply think of drought as periods when water supplies fall short of the demand. Another way to look at it is with respect to historical averages. Drought occurs when precipitation, snow pack, soil moisture, stream flow, reservoir levels, or other measures of water supply drop below the expected average far enough and stay below long enough to cause problems or pose a threat to "normal activities" (whatever that may mean).

Each day without rain or snow may mean another great day for work, recreation, or travel. It may also mean the beginning or continuation of a drought. As such, drought may well be one of the toughest natural disasters that we face. Other disasters like tornadoes, hail storms, earth quakes, and floods strike swiftly. They damage our possessions, interrupt communication, and destroy infrastructure. They leave a trail of ruin that emergency managers and response teams are trained and capable to deal with. We have learned to mobilize swift and focused reactions and response. Drought, on the other hand, is a non-event. It does not destroy structures or interrupt communications. It is more about what isn't happening and what isn't growing or flowing. It is a non-event. It creeps up on us, disguised as a long period of fine weather. Then it nags us with inconvenience or screams at us by way of frustration and lost revenue. We don't know exactly when it began and we're not sure when it's over. Even when we do recognize it, it often only affects certain sectors of a community. One person's drought is another's good weather. But eventually, if it lasts long enough and spreads far enough, many share in the misery of not having enough water to meet all needs.

For the past several years, we have continued to analyze historical data. We have looked at precipitation patterns. We have studied snow accumulation. Stream flow records have been examined. We have continued to develop and test different indexes and analysis tools in hopes of finding a simple, descriptive, and consistent way to display and discuss drought. After five more years of study, we have made great progress but we have not figured everything out. The hydrologic cycle that delivers and removes water is remarkably simple and yet so complex. The variables that we measure – precipitation, snow pack, and stream flow – don't always tell the same story. We'll never understand everything, but here are some of the things we have learned.

What We Have Learned about Drought in Colorado

Climate factors

1) Colorado, due to its interior continental location, is far removed from sources of atmospheric moisture. There are three sources of moisture that are responsible for most of Colorado's precipitation (as shown on map on page 14):

• Winter storm systems with strong westerly winds aloft bring Pacific moisture into western Colorado and usually drop significant snow on Colorado's mountains.

• Spring storms originate in the Pacific Ocean or form in the Western U.S. Some are large and strong enough and slow moving such that moisture from the Gulf of Mexico is drawn northwestward. These storms can bring widespread and heavy precipitation from Colorado's Front Range eastward across the high plains.

• During mid and late summer, tropical moisture drifts slowly and episodically northward

(continued on page 14)

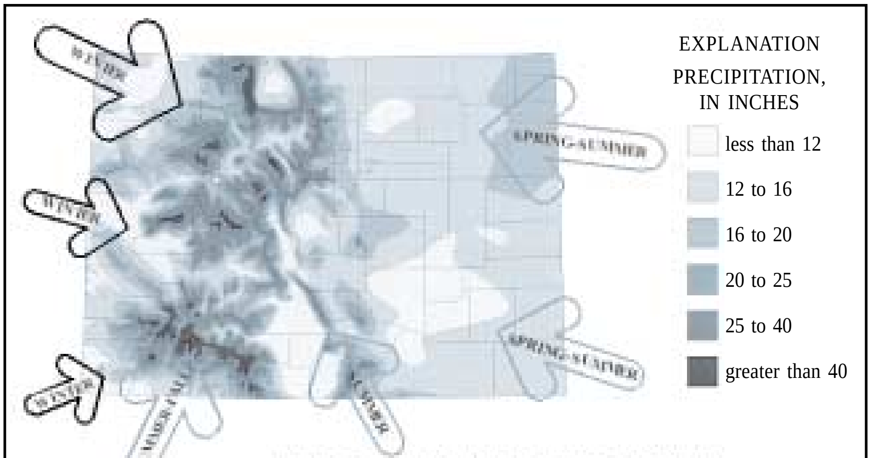
Horsetooth Reservoir near Fort Collins, Colo., December 1977 (photo by Nolan Doesken). Many of Colorado's large reservoirs have not been drawn down to such low levels since the late 1970s.

Drought in Colorado (continued from page 13)

into Colorado by way of Mexico. This moisture fuels the afternoon and evening thunderstorms that characterize the summer climate in the mountains. In September and early October, tropical moisture can also reach Colorado from dissipated Pacific hurricanes.

2) The combination of storm systems and topography result in precipitation magnitudes that vary greatly from one part of the state to another. Weather patterns that are favorable to precipitation for one part of the state are often unfavorable for other areas. Highly variable precipitation patterns are not unusual – they are the norm. The time of year (seasonality) of precipitation also differs greatly from one part of Colorado to another.

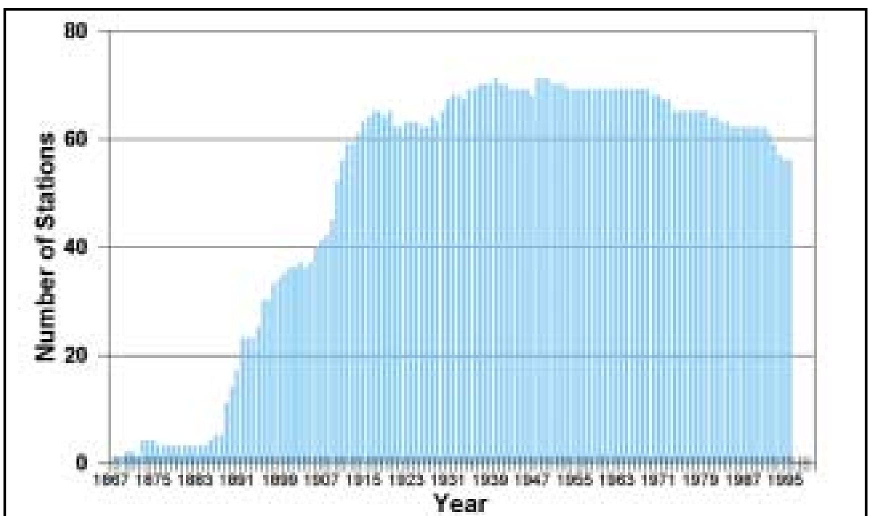
3) Much of Colorado is semi-arid. In semi-arid climates a small number of storm systems contribute a large fraction of the precipitation each year. As a result, the presence or absence of just a handful of stormy days during the year may be the difference between drought and generous moisture.



Average Annual Precipitation, 1951-80

Colorado average annual precipitation and moisture sources

Number of historical weather stations used in drought study



4) Precipitation is more likely to contribute to soil moisture recharge and runoff at certain times of year. Most summer precipitation is quickly evaporated. Winter precipitation in the mountains is most often converted to stream flow. Spring storms, and a few autumn storms, provide the most beneficial moisture contributing to both soil moisture and runoff. These storms tend to be large in area, long in duration, and light to moderate in intensity accompanied by cool temperatures and high humidity. As a result, they contribute very effectively to water supplies.

5) Statistically, precipitation is not "normally" distributed. Since it is zero-bounded, and since non-precipitation days outnumber precipitation days, precipitation distributions are skewed. A few large events tend to make "average" precipitation for a day, week, or month higher than the median (midpoint of the distribution) value. This means we are drier than average more often than we are wetter than average.

6) The large variations in dry and wet seasons in different areas of Colorado, the large variations in elevation, the effects of elevation on the quantity and seasonality of precipitation, and the fact that the fraction of precipitation that falls as snow varies dramatically with elevation (not to mention large differences in how much precipitation evaporates, sinks into the ground or runs off into river) results in a remarkable picture in which measurements of precipitation, high elevation snowpack, and full-basin streamflow don't always tell a consistent story. You can't just look at one element to understand drought.

Drought Analysis

1) Some of the most common questions about drought come in the following forms:

- How dry is it now (percent of average, magnitude of precipitation deficit)?
- How large are the areas affected?
- When is the last time we were this dry?
- How often does it get this dry – what are the probabilities?
- What are our chances of getting better? Worse?
- What is the driest we have ever been?
- How long can we stay that dry?
- What are the chances of having two or more very dry years in a row?
- Are there predictable drought cycles?

2) Precipitation and snowpack analysis with

respect to historic averages and probabilities provides excellent insight into Colorado's drought history.

3) The Standardized Precipitation Index (SPI), developed at Colorado State University in the early 1990s, appears to us to be the simplest yet most robust index for describing drought patterns. Index values relate directly to precipitation departures from average, but also show precipitation probabilities accurately. The SPI is particularly flexible for adapting to different time scales. While other indexes may have inherent time scales, the SPI can be set to accommodate one or a combination of time scales.

4) Historic data are critical to the successful determination and interpretation of drought. We must continue basic and routine measurements of precipitation, temperature, snow accumulation, and streamflow that remain consistent with historical measurements of the past.

Colorado Drought Patterns

Here are a few facts and figures that we have learned about drought in Colorado. This information is based on actual observations of precipitation here in Colorado dating back to 1890. Some areas of the state do not have much data prior to 1920.

1) Drought is a very frequent visitor to Colorado.

• Single season droughts with precipitation of 75 percent or less of average for one to three months in a row occur nearly every year in Colorado.

• Based on the Standardized Precipitation Index, 3-month droughts with an index value of –1 or lower (equivalent to a moderate precipitation deficit with a probability of occurrence of no more than 16 percent for any consecutive 3-month period), occurs approximately 90 time in 100 years

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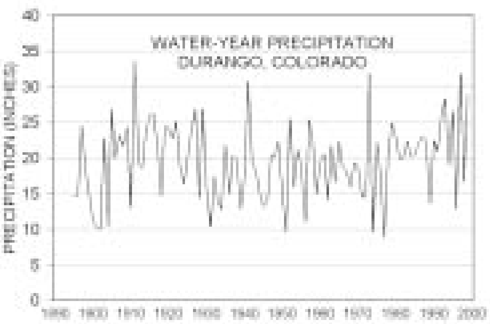
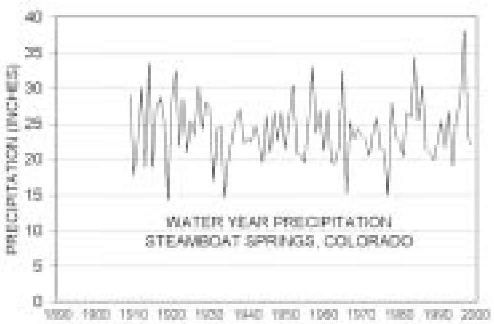
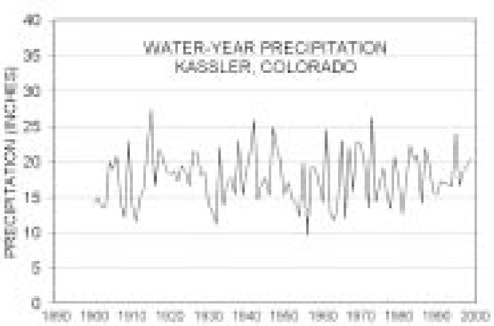
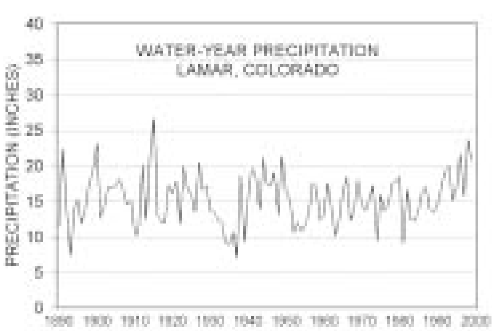
Drought in Colorado – (continued from page 15)









months (April 1900, May 1935, September 1938) were embedded in long-duration drought episodes.

5) Spatial patterns of drought.

• There appears to be no such thing as a "typical" drought pattern.

• Each of the largest and most severe droughts have had their own unique formation and spatial patterns.

• Each region of the state has its own unique drought history which may be similar or totally different from other regions of the state. Northern Colorado is sometimes wet when southern Colorado is dry and vice versa. The same is true for east versus west.

• It is rare for the entire state to exhibit similar precipitation patterns for more than a few months in a row. During the winter of 1995-1996, five consecutive months brought above average precipitation to Colorado's northern and central mountains while southern and eastern Colorado remained much drier than average. Such persisting patterns are very unusual.

6) Drought severity – how dry can it get?

• Many areas of Colorado have gone without any measurable precipitation for up to 60 consecutive days. Long dry periods like this are most likely in the fall and early winter. For a six-month winter season, 25-40 percent of the average accumulated precipitation represents an extremely dry winter (October-March). For an entire year, 50-60 percent of average represents an extreme drought year. Two to four months in a row with less precipitation than average is common. Five or more consecutive months with below average precipitation are very rare. Some weather stations have never had six or more consecutive dry months.

• The following set of contour maps (page 18 A-C) shows what the least measured precipitation has been, expressed as a percent of the 1961-1990 average, for A) winter (October-March), B) growing season (April-September), and C) the entire water year (October-September). A set of maps (D-F) is also shown for the 10 percent probability level (10th percentile). Ninety percent of all years can be expected to have more precipitation.

• Another way of looking at drought is by determining "accumulated deficits." For example, if your average annual precipitation is 16 inches, but you only received 12 inches, your accumulated deficit would be 4 inches for that year. When you accumulate deficits and surpluses year after year, you find that Colorado's worst droughts reach a deficit of about two full years of average precipitation. In Colorado's northern mountains, and other areas with more reliable precipitation, accumulated deficits only reach about 1.2 years of average precipitation. For example, if Durango averages 20 inches of precipitation per year, a very severe multi-year drought might result in an accumulated deficit of more than 20 inches over a few years time before above average precipitation reduces those deficits. (Refer to graph on page 19.)

7) Timing of drought – When does it start? When does it end?

• Short duration droughts can begin and end in any season.

• Major droughts with durations of one year or longer tend to begin in and end in the season that is locally the wet season. This varies from place to place in the state. For example:

• Major droughts in the mountains tend to begin or end during the winter or spring months. In extreme southwestern Colorado, significant droughts have both begun and ended in the fall. The more dramatic the seasonal precipitation cycle is, the more difficult it is to end a major drought during the time of year that is the climatological dry season. For example, over eastern Colorado, the months of December, January, and February are a very dry time of year. The three months combined produce, on average, less than 10 percent of the annual precipitation. Rarely does enough precipitation fall during this time of year to significantly alleviate longer-term moisture deficits. However, a week or two of very wet weather during late spring east of the mountains can bring a major drought to an end. For example, the spring of 1995 and the last few days of April 1999 delivered enough precipitation to compensate for large deficits.

• Droughts may end abruptly with widespread heavy rains. For example, the severe drought of 1952-1956 was followed by Colorado's wettest year on record, 1957. But not all droughts end completely and abruptly.

8) Does a dry winter foretell a wet summer?

There is endless folklore concerning drought. Even before “El Nino” found its way into climatological jargon, people have talked about drought and drought indicators. Does the climate of one season foretell the next? Much folklore would suggest that. Our analyses, however, did not bear that out. We looked at a number of combinations. What happens after a very dry winter in the mountains? What happens after a very dry autumn at lower elevations (such as fall 1999 in Colorado)? We didn’t get fancy and divide years into different groupings based on the phase of tropical circulations. We just dumped all the data into a pot and let the numbers fall where they lay. What came out looked like a bunch of shotgun blasts. In all, less than 10 percent of the variance was explained by the precipitation from the preceding season. Sometimes dry winters in the mountains were followed by wet summers (like 1999), but other years were different. Sometimes dry springs along the Front Range were followed by hot dry summers (like 1954), but other years they weren’t. All in all, the picture was pretty much clear as mud. Without a lot more sorting and analyzing, it is not obvious at all that one season helps foretell the next here in Colorado.

9) Colorado’s droughts and prominent wet periods, 1890-1999. The entire precipitation history of Colorado can be summarized into well-defined dry and wet periods. The table is a summary of Colorado’s drought history since 1890 (see page 20).

10) Are there drought cycles?

People don’t ask us if there are drought cycles in Colorado. Most people are positive that there are. Some say there is a 3 year cycle, while others claim 7. The sunspot cycle of 11 years has caught some people’s attention, while many strongly believe that a 22 year drought cycle (double sunspot cycle) controls Colorado’s drought patterns.

We examined our rainfall records in Colorado in search of drought cycles, and all I can say is – well, I don’t know. There is some evidence of a two to three year cycle over portions of southern and eastern Colorado. The dry periods in the 1890s, 1930s, 1950s, and again in the 1970s convinced some observers that the double sunspot cycle really does affect drought patterns in Colorado. That theory doesn’t explain why the 1910s were so wet, why parts of the 1960s were very dry, and why we have been wet for the better part of 18 years in a row, but many still believe it. As for a seven or eleven-year cycle, there isn’t much supporting evidence for that. It is true that dry periods are followed by wet, and wet followed by dry? That makes a cycle, doesn’t it? The problem is that those cycles just aren’t very reliable. As such, they don’t

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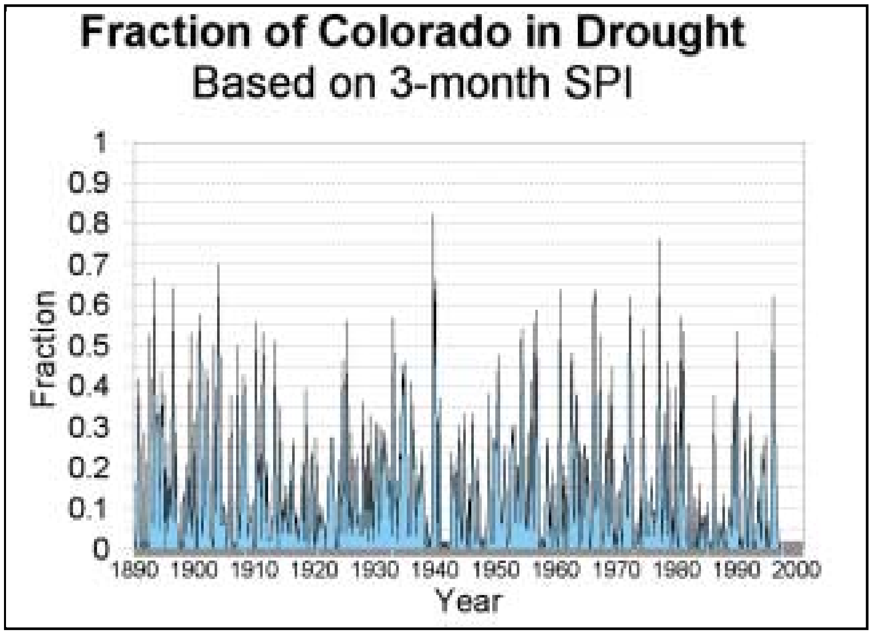
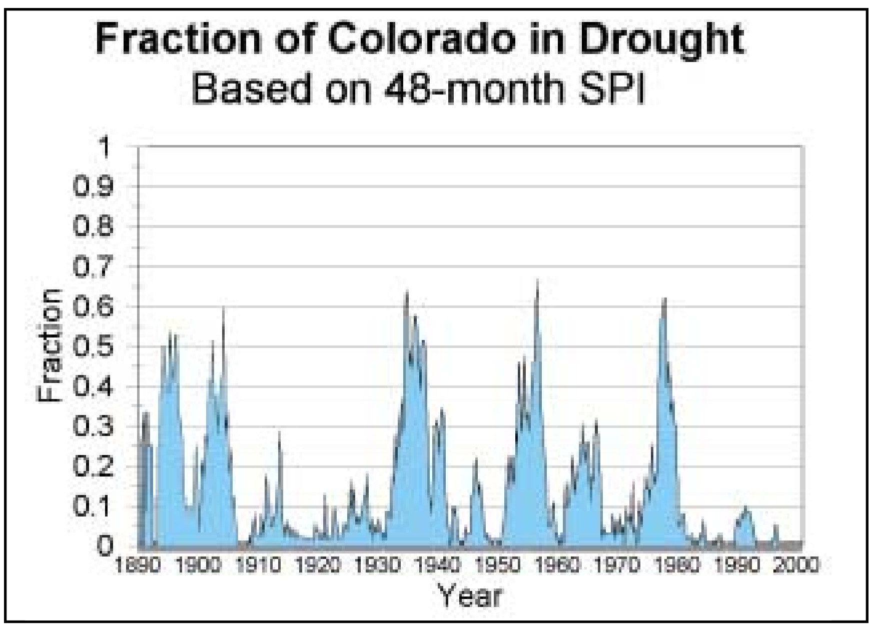


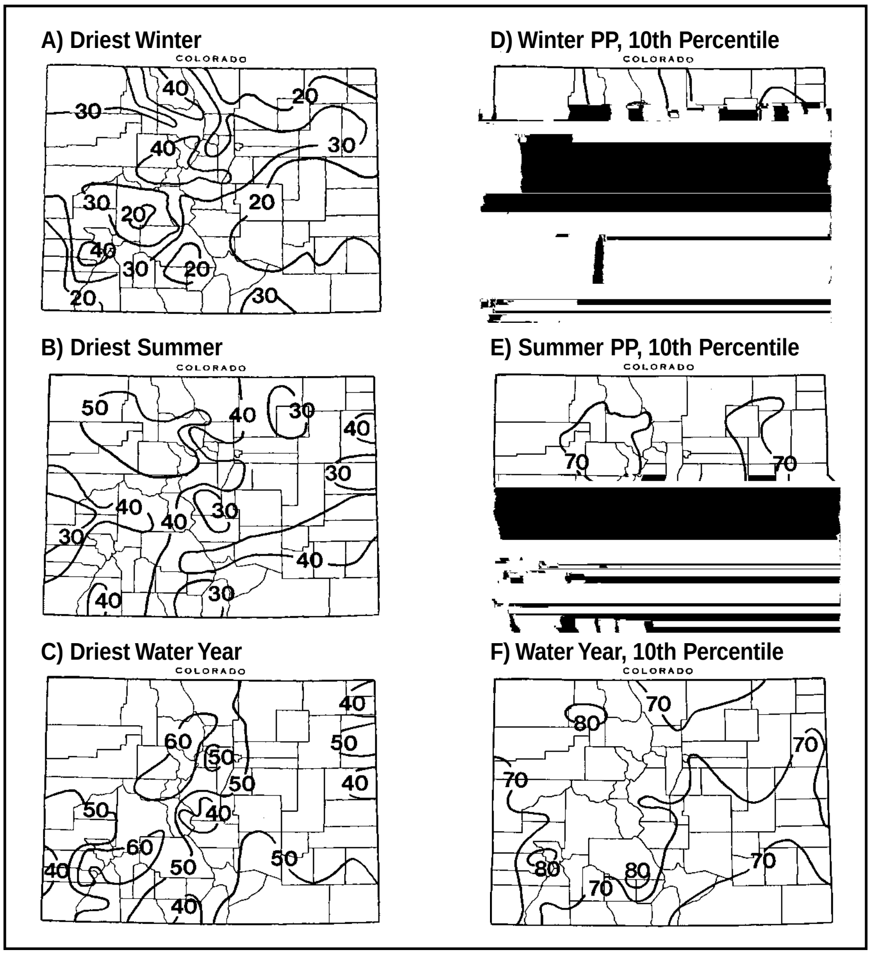
Fraction of Colorado in drought, based on 3-month SPI



Fraction of Colorado in drought, based on 48-month SPI

Drought in Colorado – (continued from page 17)

help us much if at all in predicting what will happen next year or the year after that. Even throwing in the irregular cycle of the El Nino Southern Oscillation, we are still left with a great deal of unexplained variability in our precipitation.



Precipitation as a percent of average

Will Colorado See Drought Again?

We all know the answer to that question. Yes, drought will return. But when? Where? What will it be like?

We don't know exactly, but what we have learned from the past does provide some wisdom to help us prepare for the future. Tree ring studies and other paleohydroclimatic investigations by a variety of scientists (sand dune movements, glacial retreats and advances, pollens, lake levels, sediments, etc.) all add to the picture.

Colorado has come a long way since the dust bowl years. We manage our crop and grasslands with soil and water conservation in mind. We store large volumes of water from wet years for use in dry years, and from wet seasons for use in dry seasons. We divert water from areas with lower demands to areas with more population and farmable lands. Still we know, history has a way of repeating itself.

Our study of past droughts has shown that the worst droughts are multi-year droughts. Vegetation dries up, soils blow, stored water reserves are gradually depleted, shallow wells go dry. What begins as a minor inconvenience can, for some people, mean economic hardship and eventually the loss of property and livelihoods.

Sometime and somewhere in Colorado a climatological scenario may unfold that goes something like this. For two to four years, winter and spring precipitation in Colorado's mountains will fall far short of the average. Winter precipitation totals of 60 to 70 percent of average in the high country will be followed by hot, dry summers on the Eastern Plains and Western Slope. The combination of diminished supplies along with

Correlation of summer precipitation (April-September SPI) to previous winter snow (April 1 snowpack) for selected Colorado watersheds from McKee et al, 1999.

April 1 Snowpack	April-September SPI: Yampa	White	Colorado	Gunnison	San Juan Animas Dolores	Rio Grande	North Platte	Cache La Poudre	Big Thompson	South Platte	Arkansas
Yampa/White	-0.05	0.05	-0.06	0.14	0.09	0.09	0.00	-0.11	-0.12	0.14	0.09
Colorado	0.03	0.09	-0.01	0.17	0.09	0.11	0.08	-0.02	-0.08	0.15	0.10
Gunnison	0.09	0.14	0.01	0.10	0.05	0.08	0.09	0.03	-0.02	0.07	0.06
San Juan/Animas	0.12	0.09	-0.09	-0.03	-0.14	-0.05	0.04	-0.09	-0.08	0.01	-0.06
Rio Grande	-0.02	0.14	-0.06	0.04	0.00	-0.01	0.01	-0.05	-0.16	-0.07	0.03
Upper South Platte	0.17	0.21	0.13	0.34	0.36	0.26	0.14	0.11	-0.03	0.30	0.29
Lower South Platte	-0.03	0.09	-0.05	0.12	0.14	0.21	0.03	-0.05	-0.08	0.06	0.09
Upper Arkansas	0.02	0.15	-0.01	0.12	0.07	0.02	0.02	-0.08	-0.13	0.13	0.00
Lower Arkansas	0.11	0.20	-0.01	0.17	0.20	0.18	0.06	0.00	-0.09	0.12	0.11

heavy use of irrigation water will gradually deplete surface reserves and make ground water pumping more expensive. The Ogallala aquifer will again show signs of rapid depletion like it first did in the 1960s and 1970s. Dryland vegetation will grow short and sparse. Bare patches will appear on sandy soils. Plant residue on unirrigated crop land will decrease each year. Despite efforts to retain soil moisture, crops will suffer and more topsoil will blow. Disputes between water users will increase. Then along will come a winter like the winter of 1976-77 with snowpack accumulations less than 50 percent of average over most of the Colorado mountains. Spring will not bring its normal series of widespread rain and snow storms to the Front Range and Eastern Plains. A few storms will tease and appease us, but only a few. For the months of April through June, only about half of the average moisture will fall. Strong westerly and southwesterly winds will blow frequently, kicking up more and more dust as agriculture production falters. Finally, with reservoirs already very low, a long, hot summer will bring frequent temperatures near or above the 100 degree mark at lower elevations. Forest fires will race through thousands of acres of dry timber, and clouds of smoke will turn sunsets on the Front Range a deep blood red.

Do you believe this? Will you be ready if it really does happen? Colorado's water planners think long and hard about drought. They know it is a part of life in the semiarid west. But most of us never give it a thought. Frankly, we haven't had too. The last multiyear drought in Colorado ended in the late 1970s, and the last severe and widespread year-long drought Colorado ended in 1981. Oh yes, there have been local droughts since then, some quite severe like we saw over southwestern Colorado in 1989-1990 and again from the late summer of 1995 to early 1996. But droughts of that duration are not uncommon. Overall, since 1982, Colorado has enjoyed the longest spell of wet (compared to historic averages) weather statewide since the favorably cool and wet period from 1905 through 1929 when so much of Colorado was settled and farmed. For portions of southeastern Colorado, the decade of the 1990s is the wettest decade since weather observations began in the late 19th century.

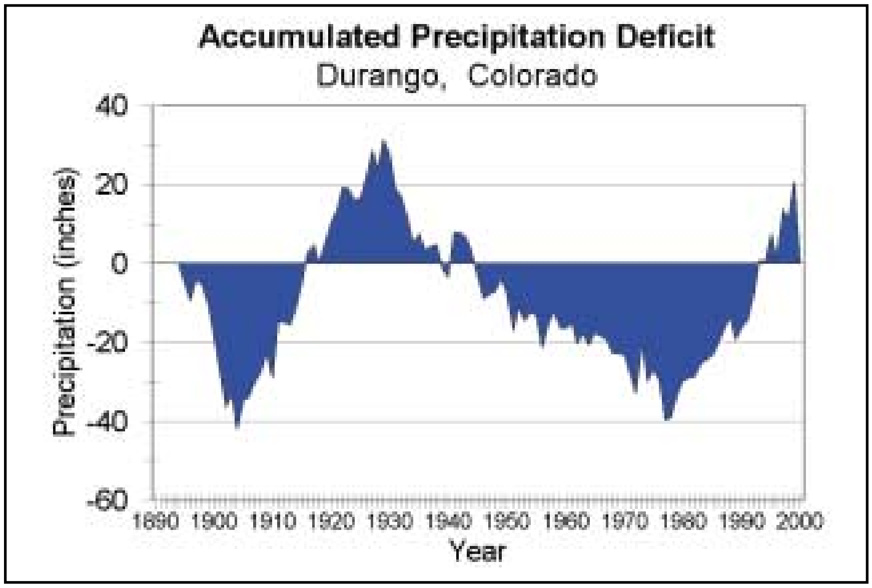
The population of Colorado has grown dramatically since 1982. Water is now needed for endangered fish populations, mountain snow making, and eager river and reservoir recreationists as well as for farmers, for hydropower generation and for rapidly growing cities. So far, we have done a fairly good job meeting these diverse demands while still delivering the water to downstream states prescribed by interstate compacts. We have met these demands by making changes in water management, but most importantly by the abundance of water that we have enjoyed. When drought returns, and surely it will, how far will we be able to stretch our water resources?

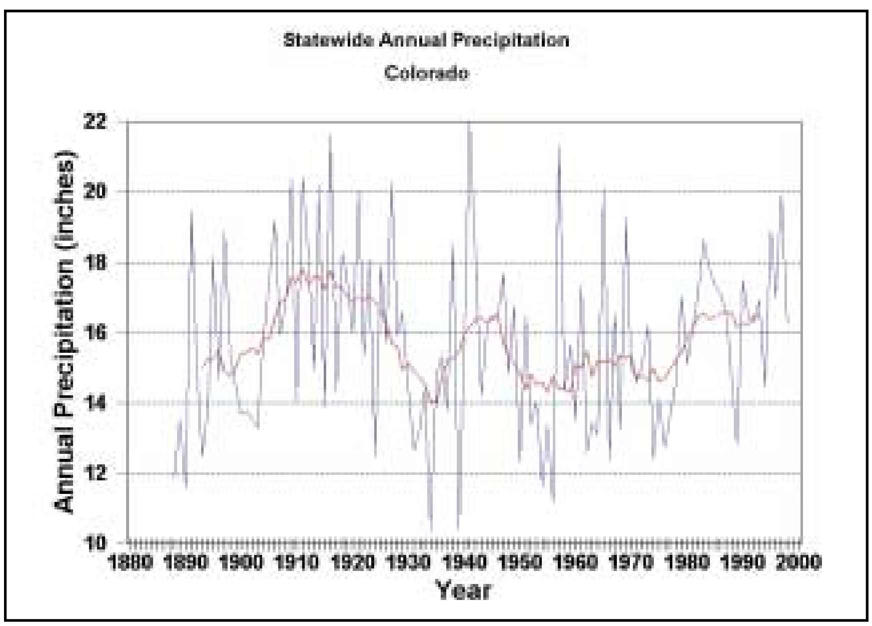
How to Get More Information

Beginning with the next issue of *Colorado Climate* there will be new regular section entitled "Drought Watch." There we will track the area, duration and severity of drought conditions in Colorado in comparison with known droughts of the past. We will also work towards a special set of

(continued on page 20)

Accumulated precipitation deficit for Durango, CO





Average line (in red) is 9-year running mean

Drought in Colorado – (continued from page 19)

pages on the Colorado Climate Center Website to keep track of drought.

If we haven't totally overwhelmed you, and you still want to learn more about drought in Colorado, a comprehensive volume entitled "Historical Dry and Wet Periods In Colorado" by Dr. Thomas McKee, Nolan Doesken, and John Kleist is now available. It consists of two parts: A) Technical Report (121 pages), and B) Appendices (containing many graphs and tables of drought and water supply information for all regions of Colorado – 280 pages). The two-volume set is available from the Colorado Climate Center for $18 plus shipping.

For those who prefer lighter reading, a new issue of *Water in the Balance* entitled ***Drought in Colorado – What Can We Learn?*** has just been published by the Colorado Water Resources Research Institute here at Colorado State University. This report also contains a set up publications and websites to obtain more information on drought. Call (970) 491-6308 or visit the CWRRI website at: http://cwrri.colostate.edu

On December 2-3, 1999 the Colorado Governor Bill Owens will convene a special conference on flood and drought preparedness. We will give you a brief summary of that conference in our next edition of *Colorado Climate.*

Colorado's droughts and prominent wet periods, 1890-1999

1890-1894	DRY	Severe but brief drought in 1890, particularly east of mountains, followed by a very wet 1891. Dry 1893 with severe drought 1894, again most pronounced over eastern Colorado.
1898-1904	DRY	Sustained and very severe drought over southwestern Colorado. Worst drought on record in Durango area. Some dry years elsewhere in Colorado, but not as severe or sustained. Very wet 1900 for northeast Colorado.
1905-1929	WET	Longest recorded wet period in Colorado history with greatest areal extent in 1905-1906, 1914-15, 1921, 1923, and 1927. Significant but brief droughts did occur during this period, most notably 1910-11, and 1924-25.
1930-1940	DRY	Most widespread and longest lasting (and most famous) drought in Colorado recorded history. Severe drought developed 1931 and peaked in 1934 and early 1935. Drought was interrupted by heavy rains in the spring of 1935 and more widespread heavy rains in 1938. The 1930s drought culminated with one more extremely dry year in 1939 when several stations along the Front Range recorded their driest individual year in history. Buena Vista only recorded 1.69 inches of precipitation for the entire year, the least annual precipitation ever reported at any Colorado weather station.
1941-1949	WET	Widespread wet weather, especially 1941-42, 1947, and 1949. Wet period interrupted with dry mountain winters – 1944-45 and 1945-46 with very low snowpack accumulation.
1950-1956	DRY	Extremely dry period statewide except for one very snowy mountain winter 1951-52. Most of state was affected, and this drought was more severe than the 1930s in some areas such as the immediate Front Range.
1957-1958	WET	1957 brought persistent widespread drought-breaking precipitation across nearly all of Colorado – wettest year in recorded history.
1959-1973	DRY/WET	Interesting roller coaster ride with alternating very wet and fairly dry periods and large spatial variations. Local drought was prevalent in 1959, 1960, 1962, 1963, 1964, 1966, and 1972. Very wet weather was reported in 1961, 1965, 1969, 1970, and 1973 with episodes of flooding.
1974-1978	DRY	Colorado's most recent period of sustained multi-year drought culminating in the record-breaking winter drought of 1976-1977, the driest winter in recorded history for much of Colorado's high country and Western Slope.
1979-1980	WET	Brief but pronounced wet period with heavy winter snows helping replenish reservoirs.
1981	DRY	An extreme but brief drought period from the fall of 1980 into the summer of 1981. This drought again took aim at the Colorado high country and ski industry and initiated a huge investment in snow making equipment. It also stimulated the writing of the "Colorado Drought Response Plan" and the formation of the "Water Availability Task Force" which has been meeting several times each year since 1981.
1982-1999	WET	Colorado's second longest sustained wet period in recorded history and the most drought-free period since 1890. Extremely abundant snowpack and surface water supplies 1982-1987 – largest annual streamflow volumes this century on several rivers. Interesting period, 1987-1994 with only modest snow pack accumulation and consistently below average streamflows, but with low elevation precipitation above average reducing demand for surface water. Significant but brief drought in 1989 to early 1990 in southwest Colorado. A brief growing season drought in 1994 in northeast Colorado, and another localized drought over SW Colorado from late 1995 into 1996. Very wet statewide in 1995, 1997, and 1999. The decade of the 1990s have been the wettest in recorded history over much of southeastern Colorado.

For Teachers

CoCo RaHS Is Coming to Town

Nolan Doesken

We are delighted to introduce this new feature to *Colorado Climate.* Over the years, many teachers throughout Colorado have had the opportunity to glance at our reports. But never have we had the time to package our climate information in a manner that teachers could easily use as a resource or in their class-rooms. This is new to us, so it may be a little shaky at first.

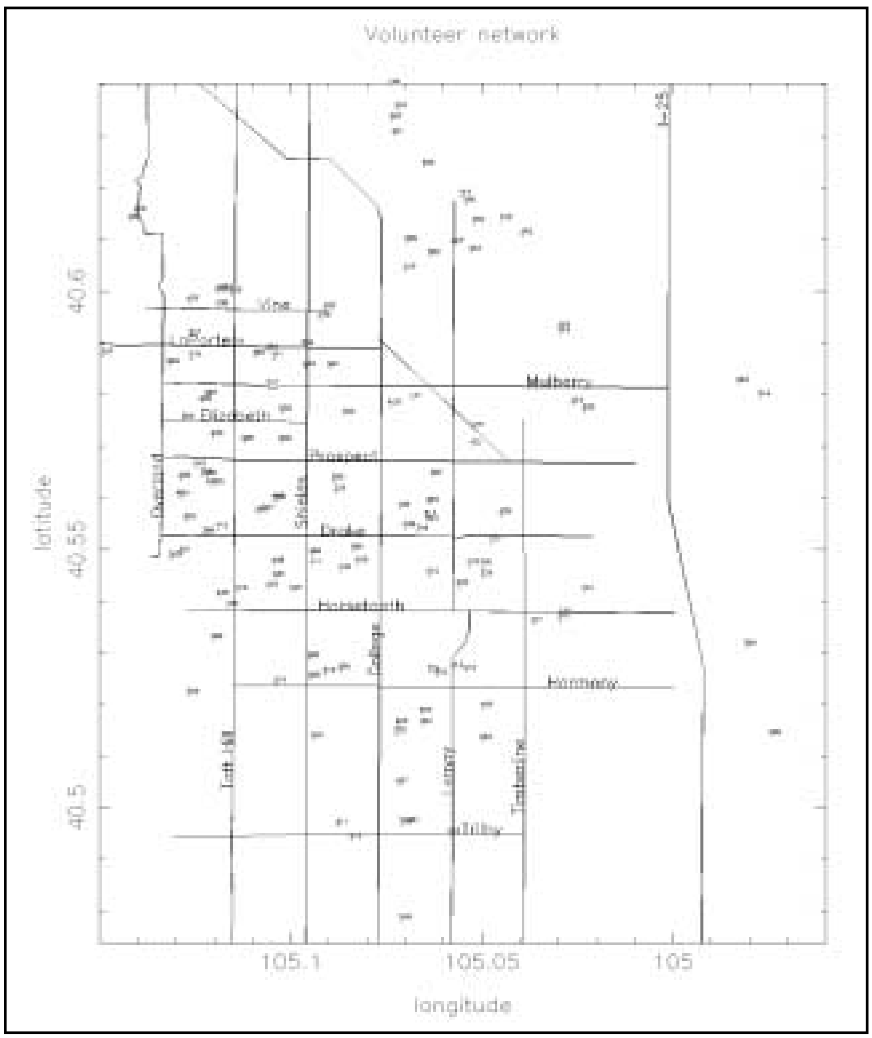
Last issue we described the little project we started in northern Colorado in 1998 called the Colorado Collaborative Rain and Hail Study (CoCo RaHS). What began as a local community project to get kids involved helping the Colorado Climate Center study local rainfall and hail patterns is quickly growing into a major research and science education project for all ages. Volunteers are currently being recruited to help gather rain and hail data during the spring and summer of 2000.

Several science teachers have been helping the Colorado Climate Center with this project. By the spring of 2000, we will have several lesson plans written geared primarily for middle school/junior high school earth science classes available for teachers. Topics will include:

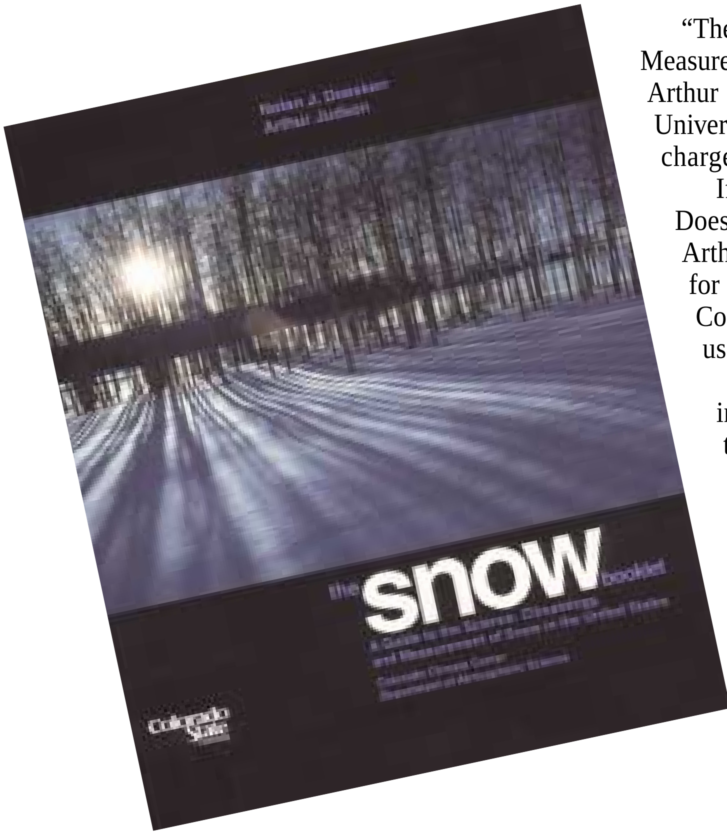
1) The importance of rain.
2) The history of rain gauges.
3) How to make and test your own rain gauge.
4) Rainfall patterns – how to map rainfall.
5) What do the clouds tell us?
6) Hail from the sky – demonstrating hail damage.
7) Drought – what happens when it doesn't rain enough?
8) Floods – what happens when it rains too much?
9) Storm patterns – what CoCo RaHS data tell us about our weather?

We are currently planning training workshops for teachers interested in learning about the importance of rain and hail in Colorado's fascinat-ing climate. Dates and locations have not yet been determined, but sessions will likely be held in eastern Colorado in February, March, and April 2000. If you are interested in attending or know of teachers who may want to participate, please contact Nolan Doesken at the Colorado Climate Center.

For more information, call (970) 491-8545 or visit the CoCo RaHS website at http://ccc.atmos.colostate.edu/~hail/



CoCo RaHS 1999 volunteer rain and hail abservers in Fort Collins. Many more volunteers from other parts of Colorado will be



"The SNOW Booklet: A Guide to the Science, Climatology, and Measurement of Snow in the United States" by Nolan J. Doesken and Arthur Judson, January 1997, ISBN # 0-9651056-2-8, Colorado State University, $17.50 per booklet (includes shipping and handling charges).

If you like snow, you'll like "The SNOW Booklet." Nolan Doesken, Colorado's Assistant State Climatologist, teamed up with Arthur Judson, long-time avalanche forecaster and snow scientist for the U.S. Forest Service (now retired in Steamboat Springs, Colorado), to compile an extensive but concise assortment of useful information about snow.

This is a handy and colorful reference for anyone interested in snow – weather watchers, skiers, students, science teachers, travelers. If you would like a copy mailed to you, send $17.50 (check or money order made out to Colorado State University) to:

Colorado Climate Center
Department of Atmospheric Science
Colorado State University
Fort Collins, CO 80523-1371

To order by phone, call Odie Bliss at (970) 491-8545.

Are you a National Weather Service Cooperative Weather Observer who would like a copy of this book? Contact your National Weather Service representative.

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Next Issue:

- Where do our climate data come from?
- Growing season trends across Eastern Colorado
- Summary of Governor Owens' Flood and Drought Preparedness Conference
- Urban Heat Islands – Do they exist in Colorado?
- Can We Predict Colorado Climate in the 21st Century?
- Plus our regular features, and more.