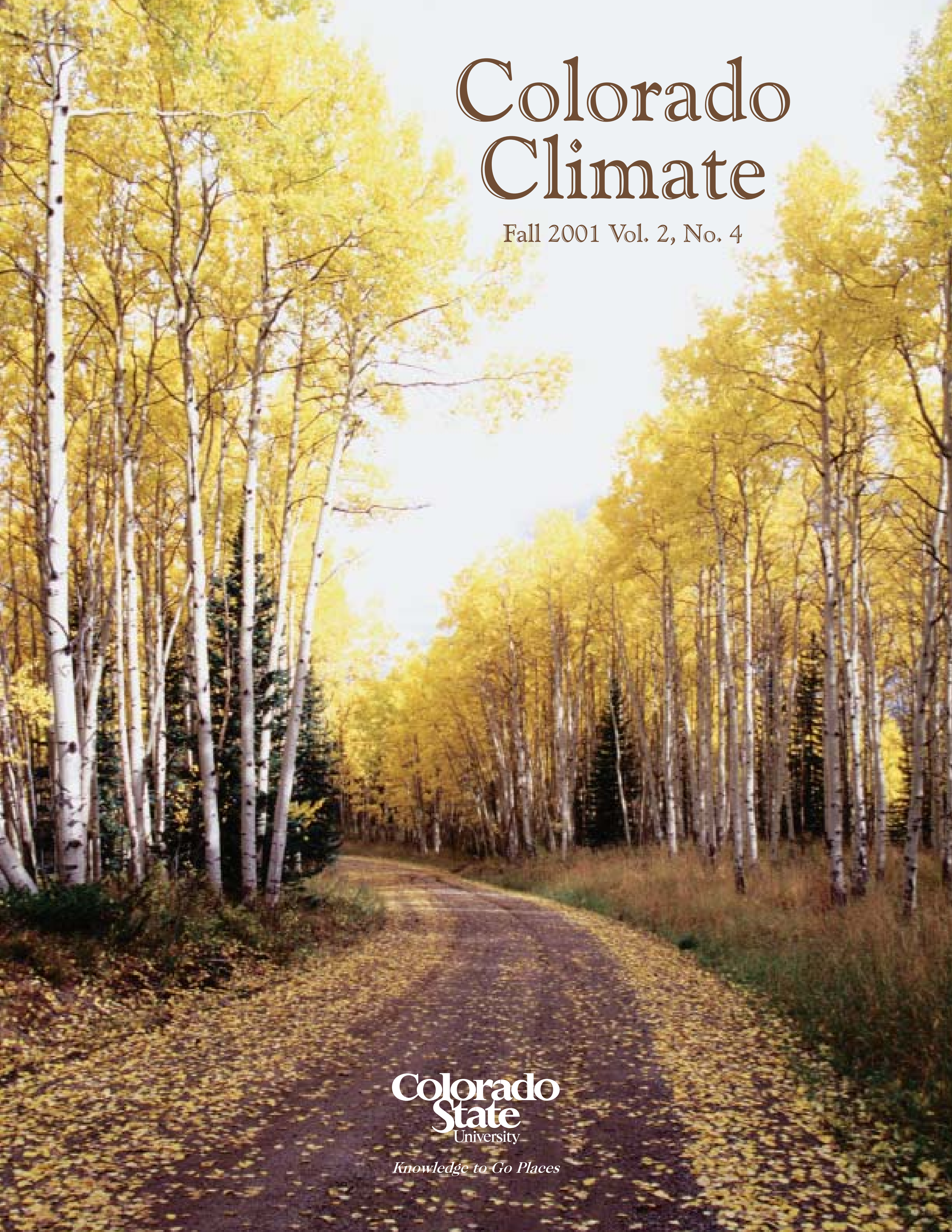

Colorado Climate

Fall 2001 Vol. 2, No. 4

Colorado State University

Knowledge to Go Places

Colorado Climate

Fall 2001
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Cover Photo: Aspen trees in their fall glory line the road near Dunkley Pass southwest of Steamboat Springs. Photo by Ian Wittmeyer.

If you have a photo or slide that you would like considered for the cover of *Colorado Climate,* please submit it to the address at right. Enclose a note describing the contents and circumstances including location and date it was taken. Digital photographs can also be considered. Submit digital imagery via attached files to: odie@atmos.colostate.edu. Unless otherwise arranged in advanced, photos cannot be returned.

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Web: http://climate.atmos.colostate.edu

On Being a Small-Town Weather Observer

Bill Wilson, NWS Cooperative Volunteer Weather Observer, Georgetown, Colorado

"How much snow will we get tonight?" a passerby asks.

"I don't know," is my stock answer, said with a grin. "I'll let you know tomorrow!"

The above exchange and variations of it ("Will it be a wet spring?" "I don't know. I'll let you know next summer!") were common when I first started being a volunteer weather observer in 1994, and my response always elicited a chuckle. But by now most of my friends and fellow townspeople know that I am a weather *observer*, not a weather*man* or weather *forecaster*. Nonetheless, some still hold me "responsible" for the type of weather that our town experiences. When friends jokingly harangue me about bad weather or (rarely) thank me for good weather, I remind them of my motto: "Always take credit, never take blame!"

As a newcomer to Georgetown (pop. 1,100), taking on the role of weather observer gave me an immediate notoriety and status. Perhaps that was in part because I viewed the role as an opportunity to contribute to the community, and to get the community involved in weather-related activities. The contributions and involvement have taken various forms – regular contributions to the local newspaper and Visitor Center, researching and publishing the history of weather observations in Georgetown, setting up anemometers to monitor Georgetown's notorious winds, and organizing a "sunshine" contest. This essay describes these activities in the context of Georgetown's distinctive weather and setting, in order to illustrate some ways that a volunteer weather observer and his local community can interact.

Georgetown has a long history of weather observers. Formal observations began in 1878 and have continued, albeit with numerous interruptions, to the present time. The first observer was Dr. W.R. Bradley, who was succeeded after 10 months by Dr. W.A. Jayne. Dr. Jayne had more than a casual interest in the weather – he was an active member of the Colorado Meteorological Association, and he submitted regular weekly weather summaries to the *Georgetown Courier*. Numerous observers have followed in the footsteps of these two pioneers. Some served for only a few months, and some, like employees at the local hydroelectric plant, served for many years. Unfortunately, there were also many breaks, the longest being nearly 26 years (1922-48). My tenure began in March 1994, after an interruption in observations of about 13 years.

I chronicled the history of the Georgetown weather station in an article that was published first by our local historical society, Historic Georgetown, Inc.

(continued on page 2)

The author and his assistant (seated) at the Georgetown Weather Station.

The Weather Report

Temperature and precipitation observations are made each day at about 8 a.m. at the Georgetown Weather Station by Bill Wilson and Saxon, National Weather Service volunteer observers. Wind observations are made each morning at a residence at the south end of Georgetown (by Bill Wilson) and at Georgetown Lake (by Howard Kimbrel, Joel Philips, and Bill Wilson). All temperature, precipitation, and wind values reflect conditions during the preceding 24 hours. "Total Precipitation" is inches of rainfall plus melted snow. "Snowfall" is inches of snow that accumulated during the preceding 24 hours. "Normal for the week" is average temperature and precipitation from the period of record for which statistical data have been compiled (about 26 years within the period 1948-2000). "Peak Wind" is daily maximum wind velocity in miles per hour; wind values are unofficial and are not a part of National Weather Service records. T = Trace; NR = Not Reported. Any temperature records noted are based on a comparison with data from the period of record.

Day and date of observation (2001)	Temperature (ºF)			Precipitation (inches)		Peak Wind (mph)	
	Max	Min	Mean	Total	Snowfall	South end	Lake
Tuesday, 7/3	86	53**	70	0.00	0.0	23	37
Wednesday, 7/4	87*	54**	70	0.00	0.0	21	42
Thursday, 7/5	86*	55**	70	0.00	0.0	21	NR
Friday, 7/6	87*	55#	71	T	0.0	32	33
Saturday, 7/7	85	52	68	0.47	0.0	20	46
Sunday, 7/8	82	51	66	0.10	0.0	22	46
Monday, 7/9	82	50	66	1.20	0.0	20	46
Week's avg or total	85.0	52.8	68.9	1.77	0.0	22.7	41.7
One year ago	82.4	49.8	66.1	0.06	0.0	21.4	
Normal for the week	78.3	47.7	63.0	0.24	0.0		

* Record high temperature for the date.
** Record high minimum temperature for the date
\# Ties record high minimum temperature for the date

Small-Town Weather Observer *(continued from page 1)*

View of Georgetown, looking north, showing its narrow north-south valley situation, bounded by steep mountainsides. Interstate 70 on the left; Georgetown Lake at the lower end of the valley. The Georgetown Station is near the lower left corner of the photograph.

(Wilson, 1995), and later by the Colorado Historical Society (Wilson, 1997). The article also includes accounts of early weather observations in Colorado by explorers, settlers, and residents; a description of the development of organized observations in the state; a discussion of Georgetown's climate; and a description of some notable weather events in the town. Information on the station history was obtained from the Colorado Climate Center and the National Weather Service. Much of the other information was obtained from research at the Denver Public Library, Western History Section; and from books, documents, and old newspaper accounts. This type of information would be available to any weather observer interested in doing research about his own area.

Local newspapers always seem to be interested in publishing weather-related features. I have made contributions to our county's weekly newspaper, the *Clear Creek Courant*, on such topics as El Niño and its effect on our local weather, and on the problems of getting a forecast that is specific to Georgetown. I have also resumed the practice of Dr. Jayne by sending regular weather reports to the *Courant*. These reports include a table that summarizes the week's weather (daily temperatures, precipitation, and peak wind velocity at two sites) and compares the temperature and precipitation information with data from the same week of the previous year and with the long-term averages for that week. An example of this table is shown on page 1. I also provide the *Courant* with a monthly table and summary description of the month's weather, and the same at the end of the year. "Georgetown Weather Data for the Month of July" is an example of the monthly table. In addition to reporting my daily readings to the National Weather Service, I telephone the values to the local Visitor Center each day, and they are posted for the benefit of all travelers who stop.

In the introductory paragraph of "The Weather Report" for the *Courant*, note that I have a co-observer, my dog Saxon, who faithfully accompanies me on my daily three-block trek to the weather station. I once was asked by a new reporter at the newspaper who this "Saxon" was, and shouldn't we be publishing his full name? I had to confess the truth, but I strongly maintained that Saxon is indeed a "volunteer observer" – he comes with me quite willingly, receives no pay, and is a keen observer of his environment. It's just that his reporting skills are somewhat lacking!

Although Georgetown weather observations date back to 1878, only the records of 1948-2000 have been compiled and analyzed statistically. For my data tables, I use the statistical records compiled by the Nevada Desert Research Institute. Their records for Colorado stations are on the web at www.wrcc.dri.edu/summary/climsmco.html. Included are daily climate summaries for whatever period of record was used to compile the data for each station.

I suppose every observer believes that his station is situated at a unique site where distinctive weather conditions prevail. This seems to be particularly true of Georgetown, whose geographic setting results in unusual weather features. In broad terms, the town has a mountain climate and is affected in rather predictable fashion by major frontal systems and storms. But in detail, the setting has some local-scale features that strongly affect day-to-day weather. Among these features are the town's position on the floor of a narrow valley that trends north-northeast; adjoining steep mountain walls with substantial topographic relief (about 3,000 feet within 1-1.5 miles); and Georgetown's surprisingly low elevation (about 8,500 feet) considering its proximity to the Continental Divide (about 7 miles both to the southwest and to the north). The Divide tends to protect the town from storms moving in from the west, and the town's interior position affords some protection from upslope snowfalls that periodically affect the Denver area and nearby foothills. The net effect is that Georgetown has a milder and drier climate than might be expected on the basis of its locale. Other effects are that the south winds tend to whistle down the valley rather briskly, and hours of direct sunshine are a bit on the short side, especially in winter.

Because the wind is such a prominent feature of Georgetown's weather, I early on installed an anemometer on my chimney at home and began recording daily peak wind velocities. I now have 8 years of record. However, my house is at the upper, more protected end of town, and residents down the valley, toward Georgetown Lake, would complain (or boast!) to me that my readings didn't reflect conditions at their end of town. Certainly we all believed that the winds were stronger near the lake, but no one had any data to prove it or quantify it. Thus, it was time for a town project! In September 2000, the local bank agreed to sponsor the purchase of a Davis Weather Wizard III instrument (the same type that I use at home), which includes an anemometer. The town crew installed the instrument at the warming hut alongside Georgetown Lake. Since then the crew has made weekday readings of the daily peak wind velocity, and I have made the readings on weekends and holidays. These are the values that are reported weekly in the *Courant*.

After one year of operation at the lake, the results are intriguing. The maximum peak wind gust in that first year was 112 mph, recorded on December 17, 2000. It is not uncommon for daily peak wind gusts at the lake to exceed 75 mph, the minimum velocity (if sustained) for hurricane winds. Weekly and monthly averages of daily peak wind velocities at the lake site are consistently about double those recorded at my home. For example, in July 2001, the average daily peak velocity at the lake was 39.8 mph; at my home, it was 20.9 mph (see monthly table at right).

Now arguments can be settled, residents at the lower end of town can be assured that the wind blows harder in their neighborhoods, and the town and others have useful data for planning, design, and other purposes.

Direct sunshine in wintertime is certainly a premium commodity in Georgetown. Of course, for everyone at these latitudes, the hours of potential sunlight are at their annual minimum in the days around the winter solstice. But in Georgetown, the supply of direct sunlight in the winter is particularly limited, because of the valley's narrowness, its north-south orientation, and the steep, high mountains that flank it on either side.

Isabella Bird, that intrepid English lady who traveled in Colorado in 1873, was particularly struck by the paucity of daylight hours during her November visit to Georgetown. She wrote, "But truly, seated in that deep hollow in the cold and darkness, it is in a terrible situation, with the alpine heights towering round it. I arrived at 3, but its sun had set, and it lay in deep shadow. In fact, twilight seemed coming on. The sun does not rise in Georgetown until 11 now; I doubt if it rises at all in the winter!"

Isabella Bird exaggerated only slightly. At my house, on the day of the winter solstice, the sun rises at 9:52 a.m. and sets at 1:15 p.m., giving us a little more than three hours of direct sunlight. But the times of sunrise and sunset and the number of hours of direct sunlight vary greatly in the town, depending on one's particular location. *Ah, ha!* Time for another project! In December 2000, we held the "Great Isabella Bird Georgetown Sunshine Contest." The idea was for contestants to observe and record the time of sunrise and/or sunset at their homes or properties on the day of the winter solstice. Gag prizes were awarded for the earliest and latest sunrise, earliest and latest sunset, and the most and least amount of potential sunshine. Rules were specific and somewhat complicated: they covered the definition of sunrise and sunset, how to calibrate timepieces, where to make the observations, what to do if it were cloudy, etc. Although the number of entries was disappointingly small, the contest provided a fun topic of conversation during our days of greatest sunshine deprivation!

With a little imagination, a bit of research, and some extra time, this small-town weather observer has had a great time contributing to the community and involving the community in weather-related activities. But for how much longer? I know that some observers are faithful contributors for decades, but this retiree probably won't hang in there long enough to earn his 30-year award. But who knows? Georgetown's most notable weather event was the blizzard of December 4-5, 1913, when Georgetown took the prize among all reporting stations for the greatest total snowfall: 86 inches, with 63 inches coming in one 24-hour period. My goal is to be the observer when a weather event of similar magnitude finds its way to Georgetown. Will I be the one to make the observations? I don't know. I'll let you know in a few decades!

Georgetown Weather Data for the Month of July

Parameter			2001	2000	Period of record (1948-00)
Temperature (degrees F)	Mean daily maximum		80.2	79.9	77.9
	Maximum		88	89	92
	Mean daily minimum		50.2	48.2	48.4
	Minimum		42	42	31
	Monthly mean		65.2	64.1	63.3
Precipitation (inches)	Total (rain, melted snow)	Month	4.70	3.22	2.13[1]
		Year-to-date	12.65	12.32	10.09
		Avg. annual	–	–	16.62[2]
	Snowfall	Month	0.0	0.0	0.0[1]
		Year-to-date	66.9	55.4	67.8
		Avg. annual	–	–	106.0[2]
Wind (mph)	Mean daily peak velocity	Upper Georgetown	20.9	22.6	22.2[3]
		Georgetown Lake	39.8	–	–[4]

[1] The average precipitation for the period of record is based on the data for all Julys during 1948-2000 that have no more than five days of missing record during the month. For total precipitation (rainfall plus melted snow), this includes 36 Julys; for snowfall, this includes 37 Julys.

[2] The average annual precipitation for the period of record is based on the data for all years during 1948-00 in which every month of the year has no more than 5 days of missing record. For total precipitation, 26 years meet this criterion; for snowfall, 16 years meet this criterion. For consistency, the year-to-date values for the period of record are based on the same sets of data. Note that one reason for missing data is that the weather station was not active, e.g., no station was active in Georgetown during December 1980 to March 1994.

[3] Based on 6 years of record (1996-2001).

[4] Insufficient length of record to calculate mean daily peak velocity for the month.

References

Wilson, W.E., 1995: Georgetown Weather Observations – A Historical Perspective. *The Georgetown/Silver Plume National Historic Landmark District Journal*. V. 1, No. 3, 26p.

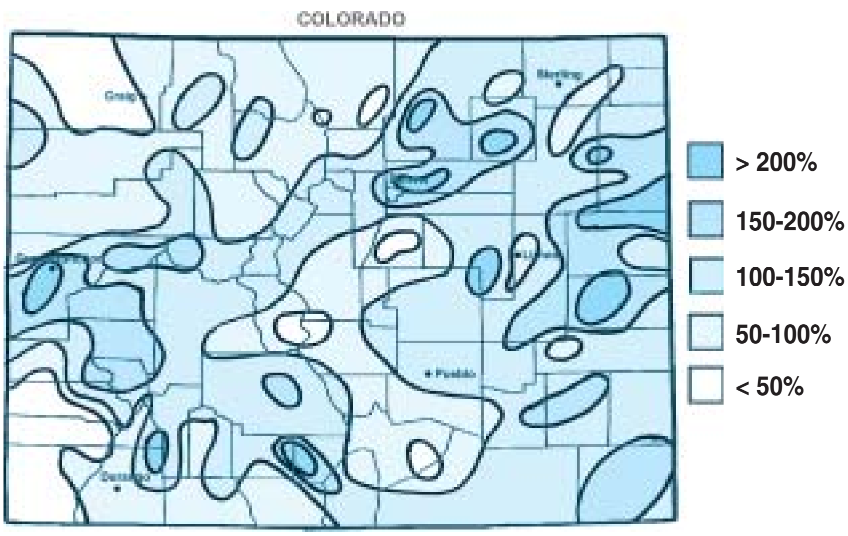
Wilson, W.E., 1997: Georgetown Weather Observations – A Historical Perspective. *Colorado Historical Society*, Colorado History. No. 1, p. 107-146.

Colorado Climate in Review

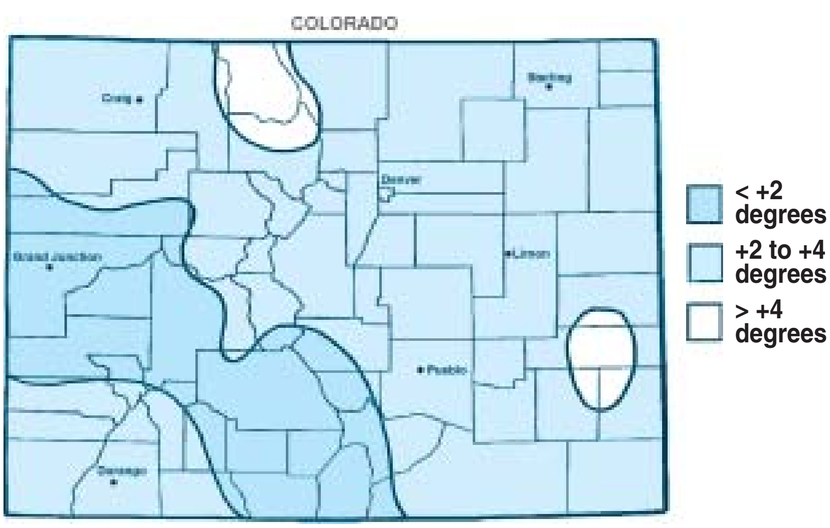
July 2001

Climate in Perspective

July 2001 was characterized by persisting heat and an early onset of the Southwest Monsoon. While wildfires raged over many western states, rainfall and high humidity in Colorado helped suppress wildfires. Thunderstorms developed almost every day. Some mostly minor hail and flash flood damage occurred during the month. Hardest hit was the Greeley area pounded by hail and flash flooding from a series of three separate storms in the same week.

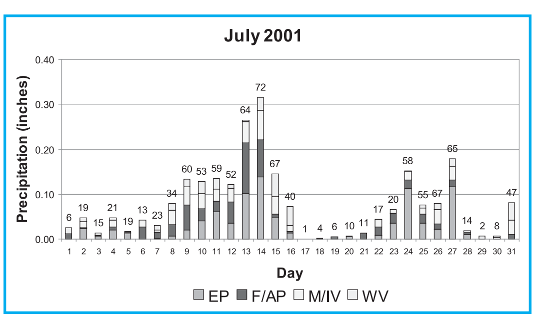


July 2001 precipitation as a percent of the 1961-1990 average.



July 2001 temperature departure from the 1961-1990 average, degree F.

Statewide average daily precipitation graph(s) (right and throughout this article) shows relative amounts of precipitation for each region. Label on each column indicates percent of stations with measurable precipitation for each day.



Precipitation

Much of Colorado enjoyed a wetter than average July with local areas receiving double or more their average. Greeley and nearby areas of central Weld County were especially hard hit as was the area along Highway 36 from Cope to the Kansas state line where over six inches of rain and locally ten or more inches were measured. But as is so often the case, not all areas benefited. Both northwestern and southwestern Colorado were extremely dry as was central Colorado from near Gunnison and Salida to Castle Rock. The Loveland-Fort Collins-Wellington area was also very dry with less than 50% of the July average.

Temperature

Historically, the majority of summer months with above average precipitation also have below average temperatures, but that was not the situation this year. Temperatures for the month as a whole ended up two to four degrees F above average over most of the state. It was a little cooler, from Alamosa and Gunnison northwestward to Grand Junction where temperatures were only about one degree F above average.

July Daily Highlights

1-5 Very hot and mostly dry with highs each day in the 90s and 100s at low elevations. A few isolated severe storms each day, especially over northeastern Colorado.

6-15 A high pressure ridge over the Southwest shifted eastward allowing warm, humid air to drift northward into Colorado from the southwest (a seasonal wind pattern often referred to as the Southwest Monsoon). Temperatures remained quite hot, but storms developed daily, especially near the mountains. Greeley and vicinity was hit by a series of storms including a severe wind-driven hailstorm on the 10th and a deluge of over 3 inches of rain in two hours on the 13th. The combination of storms was responsible for several million dollars of property damage. Very heavy rains with localized flash flooding took place near Bonny Lake in eastern Colorado on the 14th. The Bonny Dam 2 NE weather station measured 4.26” of rain the morning of the 15th. Cooler temperatures arrived 13-15th with highs mostly in the

80s with 70s in the mountains. Grand Junction, known for its summer heat, had a high of just 77 on the 14th, by far their coolest temperature of the month.

16-19 Mostly dry with a return of seasonally warm temperatures.

20-22 Hot, with gradually increasing humidity again and widely scattered storm in and near the mountains. Antero Reservoir received over an inch of rain from a stray storm on the 21st.

23-27 Another round of widespread daily thunderstorm activity, mostly concentrated from the mountains eastward and with the heaviest rains over southern and central Colorado. Heavy rains again drenched the area near Bonny Dam.

28-31 Hot again, with highs in the mid to upper 90s and low 100s over eastern Colorado. Dry over much of the state but with numerous showers on the 30th over southern and western Colorado.

July 2001 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Greeley UNC	3.48”	7/13
Precipitation (total):	Joes 2 SE	7.56”	
High Temperature:	John Martin Dam	110°F	7/7
Low Temperature:	Florissant Fossil Bed	28°F	7/26

August 2001

Climate in Perspective

Areas of Colorado in and near the mountains enjoyed a damp and stormy month, while Colorado’s eastern plains were mostly hot and dry. Measurable rain fell 15-24 days during the month at most mountain stations keeping wildfire problems to a minimum. Summer rains helped make up for below average winter precipitation over the northern and central mountains and added to the already above-average water year totals observed in the Rio Grande basin.

Precipitation

August brought frequent and plentiful shower activity to the mountains and western slope while areas east of the mountains were generally drier than average. August precipitation in western Colorado ranged from below average at Yampa and Kremmling to substantially above average at Grand Lake, Leadville, Grand Junction and Durango. The 3.22” total measured at Alamosa was 288% of average and nearly half of their annual accumulation. Much of eastern Colorado had a very dry month with less than 50% of average precipitation. Burlington only received 0.07 inches. A few widely scattered storms did drop significant rainfall. Campo, for example, in extreme southeastern Colorado, totaled over six inches of rain for the month.

Temperature

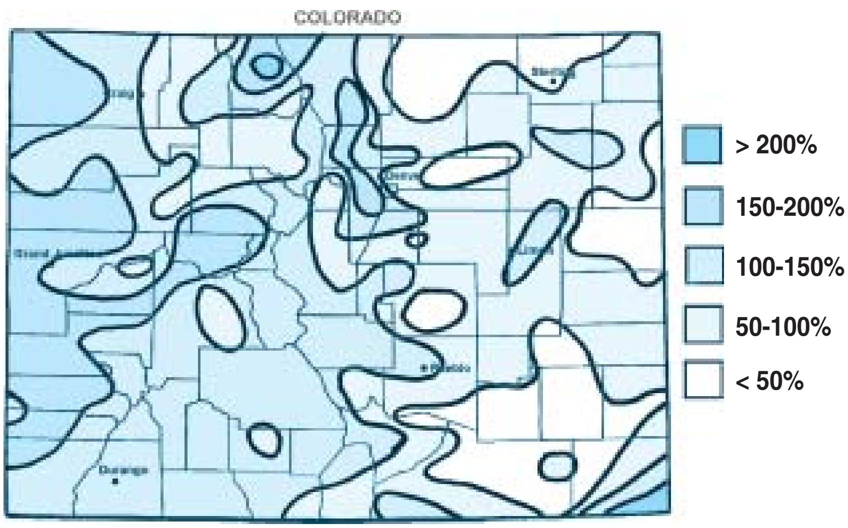
August temperatures were near or above average across the state. The warmest areas with respect to average were found over northern and eastern portions of Colorado where temperatures were as much as 3 to 3.5 degrees above average. Southwestern Colorado ended the month with near-average temperatures. This was the 6th month in a row with above average temperatures over most of the state.

August Daily Highlights

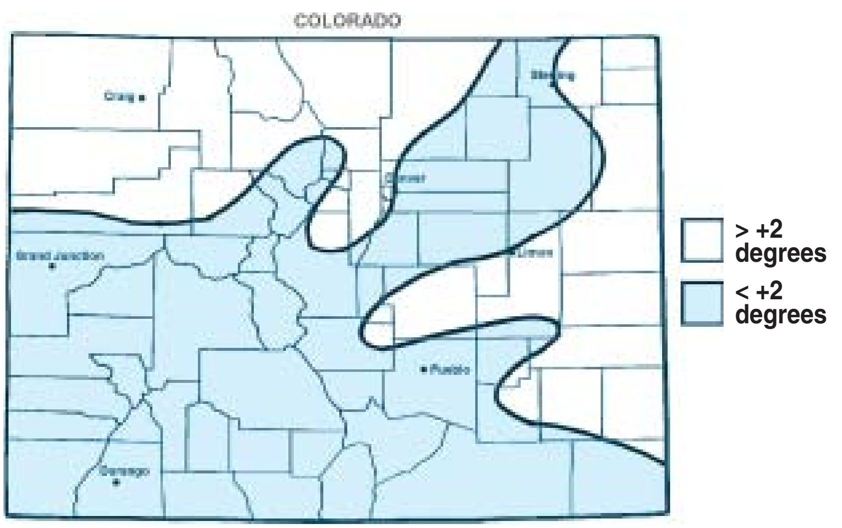
1-8 Numerous showers and thunderstorms on the 1st, some of them accompanied by heavy rains and large hail. Genoa measured 2.13”, Yuma reported 1.85” of rain, Antero Reservoir picked up 1.55”, and areas near downtown Denver also got more than an inch of rain. High pressure then shifted westward over Colorado with hotter temperatures and fewer afternoon clouds and showers except over southwestern counties. High temperatures climbed into the 90s at lower elevations. Shower activity increased again 5-8th, especially in and near the mountains. With light winds aloft, some slow-moving storms dropped locally heavy rains. Canon City got more than an inch of rain late on the 5th. Localized flooding was reported in the mountains each day 6-8th with the greatest damage reported between Telluride and Placerville on the 8th.

9-11 A Canadian cold front that reached northeastern Colorado late on the 8th brought a welcome break from the summer heat with high temperatures mostly in the 70s at lower elevations east of the mountains on the 9-10th and 80s on the 11th. Widespread cloudiness on the 9th with precipitation from the Front Range westward to Utah, some locally heavy. Portions of Boulder County received more than an inch of rain on the 9th. Thunderstorms developed again on the 10th and 11th but were less numerous, especially by the 11th. Campo, in extreme southeastern Colorado, totaled 4” of rain for the period.

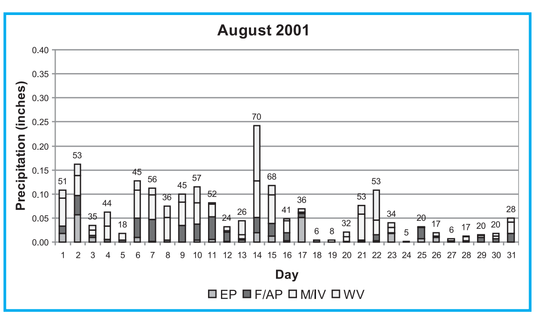
12-16 Hot on the 12th with highs mostly in the upper 80s and 90s at lower elevations. Continued quite wet and stormy, especially over the mountains 13-14th and over the eastern plains on the 16th as an upper level disturbance helped trigger strong storms with daily highs mostly in the comfortable 80s with cool 60s in the mountains. Eads received 1.10” from one of the storms, Walsh totaled 1.18”, and some wind



August 2001 precipitation as a percent of the 1961-1990 average.



August 2001 temperature departure from the 1961-1990 average, degree F.



damage and hail struck other areas of eastern Colorado.

17-19 Hot, dry with only a few isolated storms over southern Colorado, mostly on the 19th.

20-23 A weak upper-level low pressure trough moved across the state triggering more showers and thunderstorms. Gusty winds caused local damage near Denver on the 20th. Storms were widespread on the Western Slope and in the mountains 20-21st with locally heavy rains. Silverton measured 1.06” early on the 21st.

24-29 Hot and mostly dry. A few widely scattered storms from the mountains eastward. One storm managed to drop over an inch of rain and moderate hail at the Pueblo airport on the 25th. Daily highs still in the 90s at lower elevations most days, but nighttime temperatures beginning to cool down.

30-31 Cooler, humid air slipped across eastern Colorado. More thunderstorms developed with some localized heavy rains and hail. Washington and El Paso Counties both experienced hail and high water in a few places.

August 2001 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Campo 7 S	2.16”	8/11
Precipitation (total):	Placerville	6.20”	
High Temperature:	Holly	106°F	8/6
Low Temperature:	Climax	22°F	8/23

September 2001

Climate in Perspective

An unusually early winter-like storm brought heavy snow to the northern and central mountains of Colorado and cold rains to northeastern counties. This was followed by an early frost in some areas. Other than that one abrupt and notable exception September 7-9, and a few humid days mid-month with lively thunderstorms, September was very warm and dry with many days of bright sunshine.

Precipitation

Most of Colorado was very dry in September with monthly totals less than half of average over southern and western portions of the state. Alamosa, for example, totaled just 0.11” of precipitation for the month, 12% of average. With the help of an early snow storm, a few portions of the northern mountains and Front Range ended up near or slightly wetter than average. The only part of the state that was considerably wetter than average was northeastern Colorado which benefited from cold rains early in the month and several cloudy, wet and thundery days in mid September. This moisture helped Colorado’s winter wheat crop very much.

Temperatures

Except for very cold weather September 7-9th, most of the rest of the month was consistently mild. At Pueblo, the high temperature reached 90 degrees F or higher on 13 days during the month. Temperatures for the month as a whole ended up two to five degrees above average state wide completing the 2002 growing season with the seventh consecutive warmer than average month.

September Daily Highlights

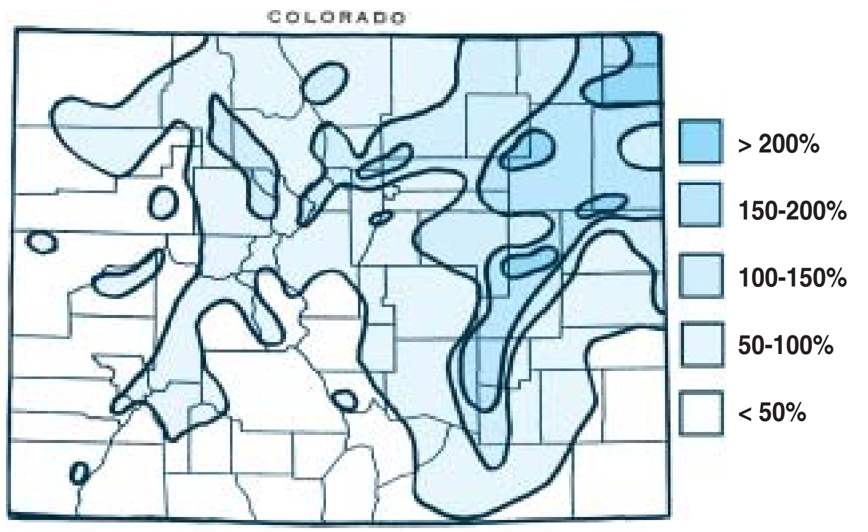
1-5 Continued summer-like with hot days and just a few afternoon thundershowers. High temperatures were mostly in the upper 80s and low 90s each day, but cooler in the mountains.

6-9 A profound change in the weather marked the approach of autumn. Very hot over eastern Colorado on the 6th in advance of a strong cold front. Highs climbed into the upper 90s in some spots. A few strong thunderstorms developed along the front. Temperatures on the 7th were twenty or more degrees cooler as a deep, cold low pressure trough dropped over Colorado. Cold rain changed to wet snows over the northern and central mountains late on the 7th and spread to lower elevations. Along the Front Range, the snow line dipped to around 6,000 feet early on the 8th, and up to an inch of rain soaked the northeastern plains. By the morning of the 8th, a foot of snow had accumulated in places near Allenspark and Nederland. The Coal Creek Canyon weather station southwest of Boulder measured 12.1 inches of snow with 1.46” of water content. Southern Colorado got only a few showers. Unusually cold 8th and 9th with subfreezing temperatures in many locations in and near the mountains. Boulder and Fort Collins each escaped hard freezes with lows of 33°F on the 9th, but many tender garden plants were damaged.

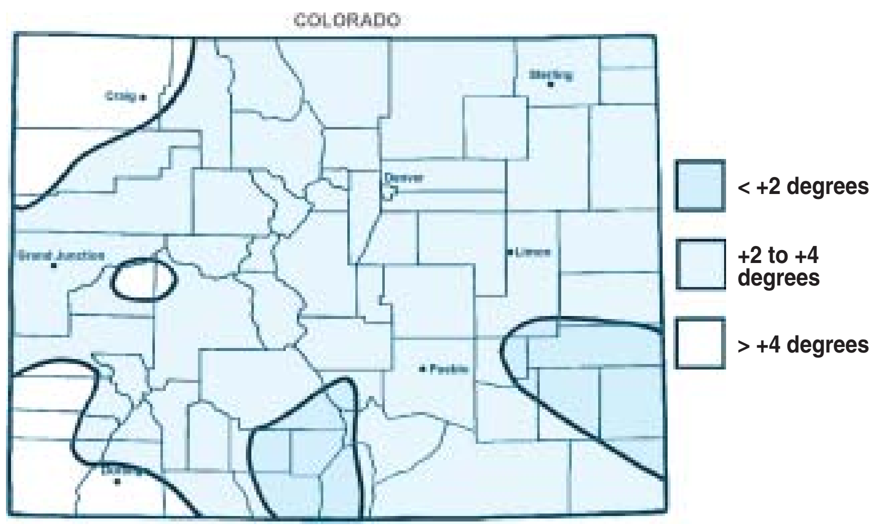
10-12 Sunny, dry and much warmer with a return to summer-like temperatures. Colorado was enjoying a lovely late summer day when we learned of the World Trade Center and Pentagon disasters on 9/11.

13-18 Humid, unsettled weather across the state. Scattered thundershowers, primarily over western Colorado on the 13th with locally heavy rains near Grand Junction. Stormy weather spread statewide 15-17th. Large hail fell in El Paso County on the 15th. Nearly 1,500 pelicans were killed by hail on Holbrook Reservoir in Otero County on the 17th. Holyoke, in northeastern Colorado received 2.45” of rain that same day.

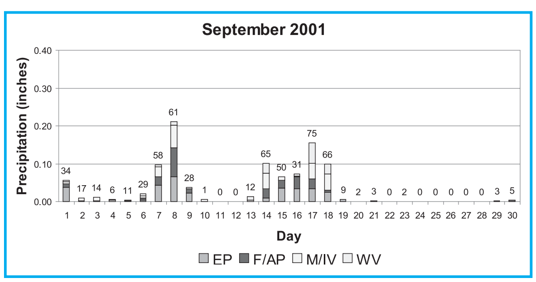
19-30 The drought of 2002 got its start during the last two weeks of September. Sunny, dry weather persisted with hot days and cool nights. In the mountains, many days saw high temperatures reach into the 70s while nighttime readings fell into the 20s. The only interruptions to the clear and dry weather came from some high-based convection with a few sprinkles on the 21st and 26th and a few very light thundershowers on the 30th.



September 2001 precipitation as a percent of the 1961-1990 average.



September 2001 temperature departure from the 1961-1990 average, degree F.



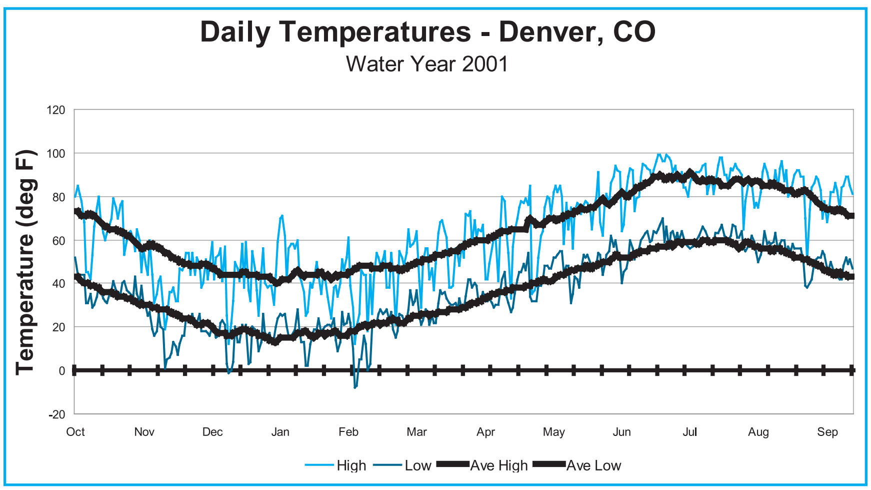
September 2001 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Holyoke	2.45”	9/1
Precipitation (total):	Holyoke	4.38”	
High Temperature:	Walsh 1W	100°F	9/7
Low Temperature:	Sargents	10°F	9/8

A Review of the 2001 Water Year in Colorado

Nolan J. Doesken and Michael A Gillespie (Snow Survey Division, Natural Resources Conservation Service)

Abstract. The 2001 water year was the fourth year in a row with below average snowpack statewide as of April 1 and the second year in a row with below average precipitation and very warm temperatures. There were wide variations in precipitation each month and for the year as a whole, but precipitation ended up 95% of average statewide. The driest portion of Colorado was the northern and central mountains and western valleys. Snowpack was below average in all areas except over south central Colorado where the Rio Grande basin experienced a very snowy winter. With warm spring and summer temperatures, the snows melted quickly and streamflow peaked earlier than average. Except for southern Colorado, 2001 streamflow volumes were below average and were only 60-80% of average on many of the larger rivers and streams. The trend toward reduced reservoir storage that began in 2000 continued. Statewide reservoir storage dropped to 93% of average by the end of September 2001, the lowest level in several years.



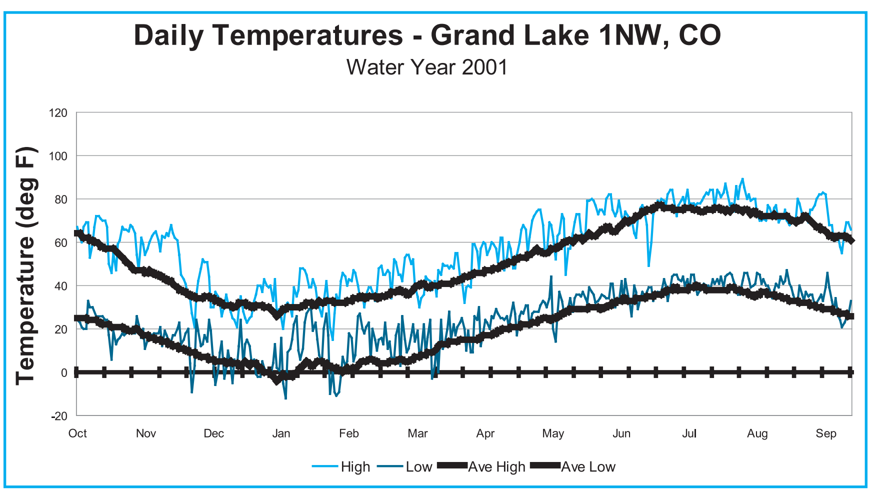


Figure 1. Daily maximum and minimum temperatures, 1 Oct 2000 through 30 September 2001, superimposed on 1961-1990 smoothed daily averages, for Denver (top) and Grand Lake (bottom).

Introduction

This report is a brief overview of the key aspects of the 2001 water year. More detailed information can be found in a variety of reports and on-line products available through the Colorado Climate Center at Colorado State University, the Natural Resources Conservation Service, the U.S. Geological Survey, the U.S. Bureau of Reclamation, the National Climatic Data Center, the Western Regional Climate Center, and the Colorado Division of Water Resources.

Meteorological Description of the 2001 Water Year

The water year is defined as the period beginning October 1, 2000 and ending September 30, 2001. It encompasses the accumulation-depletion cycle beginning with the winter snow accumulation season and ending at the end of the summer growing season. The 2001 water year followed on the heels of a very warm and dry 2000 in Colorado – a year with an exceptionally warm winter. The critical spring to early summer months were one of the driest on record for the state bringing drought concerns to the forefront, particular over northern and northeastern Colorado. Late summer brought more generous shower activity and locally above average precipitation. However, with continued very warm temperatures, summer precipitation contributed very little to surface water supplies, and reservoirs were rapidly being depleted as the 2000 water year came to an end.

The 2001 water year began with weak La Nina conditions in the tropical Pacific (cooler than average sea surface temperatures) and an apparent tendency towards warming (onset of El Nino). This warming never materialized, however. Long-range forecasters were stymied as the wet weather over the Pacific Northwest that sometimes accompanies La Nina conditions never came to pass. In fact, the Pacific Northwest experienced an extremely dry year more similar to what scientists believe should be more likely under warm eastern Pacific sea surface temperature regimes. For Colorado, relationships between tropical Pacific pressure and temperature patterns are not well defined, particularly during near neutral (neither a clear El Nino or La Nino pattern) conditions. As a result, long-range forecasts for the 2001 water year did not have much to go on and did not lean towards either better odds of wet or dry weather.

Temperature Patterns During the 2001 Water Year

Snow melt, evaporation rates, and urban and agricultural water demands, are affected by temperatures. Temperatures are much less variable from year to year than precipitation, but their anomalies are still important for water resource applications. Daily temperatures for the 2001 water year are shown for Denver and Grand Lake (in the mountains northwest of Denver) (Figure 1).

Regionally averaged temperature departures by month are shown for Water Year 2001 in Figure 2. The water year began with a much cooler start than the previous year, and for a time it looked like Colorado was headed for a miserably cold winter. November was one of the coldest late-autumn months on record with temperatures ending up 6-10 degrees F below average statewide. December, January and February were also quite chilly, in sharp contrast to the exceptional warmth of the previous year. However, weather patterns soon turned warm again beginning in late winter, and persistent above average temperatures were the rule for the rest of spring and summer. This was the second year in a row with a long hot summer. Some areas approached a record number of days with temperature of 90 degrees or above. Despite predominantly warm weather, three bouts of cold and snow created problems for Colorado agriculture and even affected the food supply in the mountains for bears and other animals. Severe cold waves May 20-22, June 13-15 and one in early September damaged gardens, reduced wheat yields and cut down on berries and other food sources in the mountains.

Precipitation

Each month during the 2001 water year brought complex precipitation patterns to the state with parts of the state enjoying wetter than average conditions while other areas were dry. October storms brought heavy precipitation to southeastern Colorado. Frequent snows from late October through mid November got the water year off to a good start, especially in Colorado's southern mountains. From mid November through January storms were less frequent and there were no widespread heavy snow events. Most of the state was unusually dry in December except parts of the northern mountains. January was also dry with few major storms. Storms favored southern Colorado in February and March, particularly the San Luis Valley and the Rio Grande River basin and portions of east central Colorado. Colorado's northern and central mountains were drier than average for much of this period. Most April precipitation was concentrated into two very strong and widespread storms that brought good moisture to much of the state but left southeastern Colorado very dry and windy. Twice, blizzards whipped parts of the northeastern Colorado knocking out power and blocking travel.

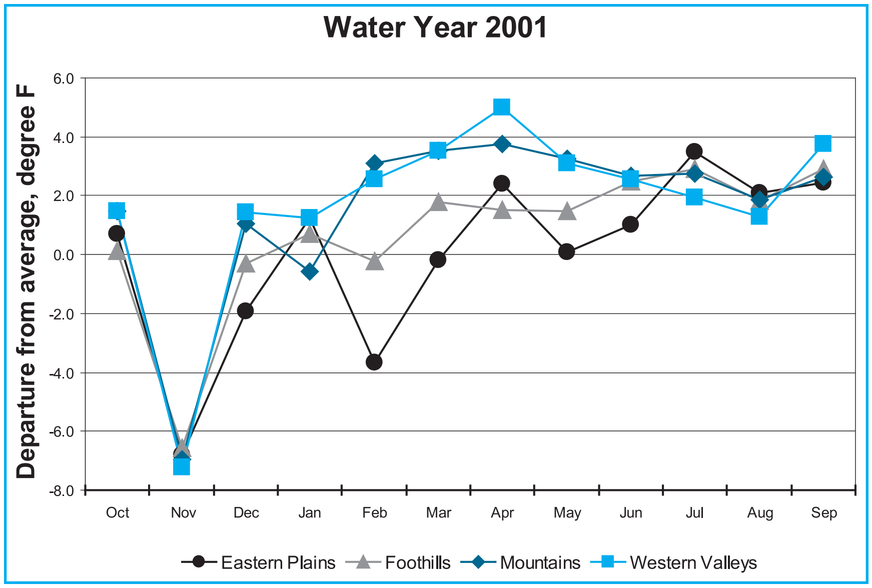


Figure 2. Regionally averaged monthly temperature departures from the 1961-1990 averages, October 2000 through September 2001, for Colorado's Eastern Plains, the Front Range foothills and adjacent plains corridor, the Colorado mountainous region, and the western valleys and plateau region (Western Slope).

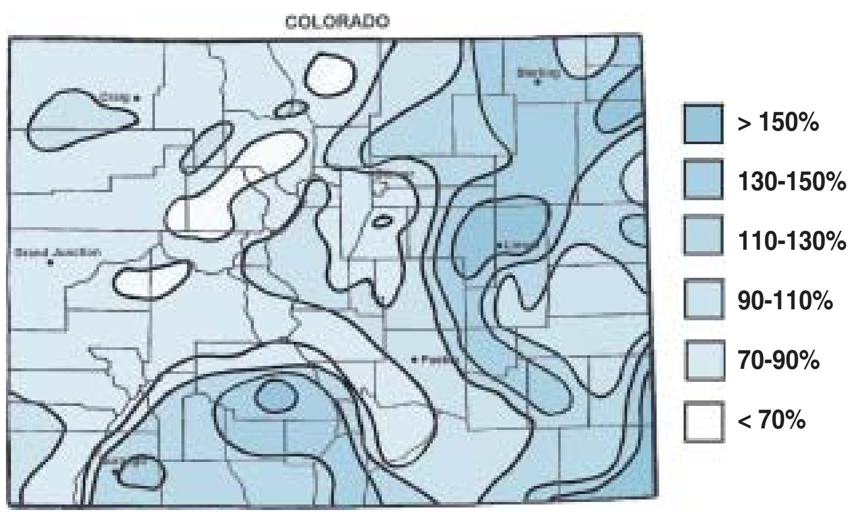


Figure 3. Accumulated precipitation for Winter season, October 2000 through April 2001, as a percent of the 1961-1990 average.

Winter (October through April) precipitation ended up well above average over the eastern 1/3 of Colorado and over south central areas from Silverton and Durango eastward to the Sangre de Cristo Mountains (see Figure 3). The 7-month cool season precipitation totals over eastern and south central Colorado were as much as 110 to locally 190 percent of average. Areas near Holyoke, Limon, Saguache and Walsh showed the greatest departures from average. But at the same time, much of Colorado's high country from Telluride north to Wyoming and essentially all of the western valleys and Front Range foothills were

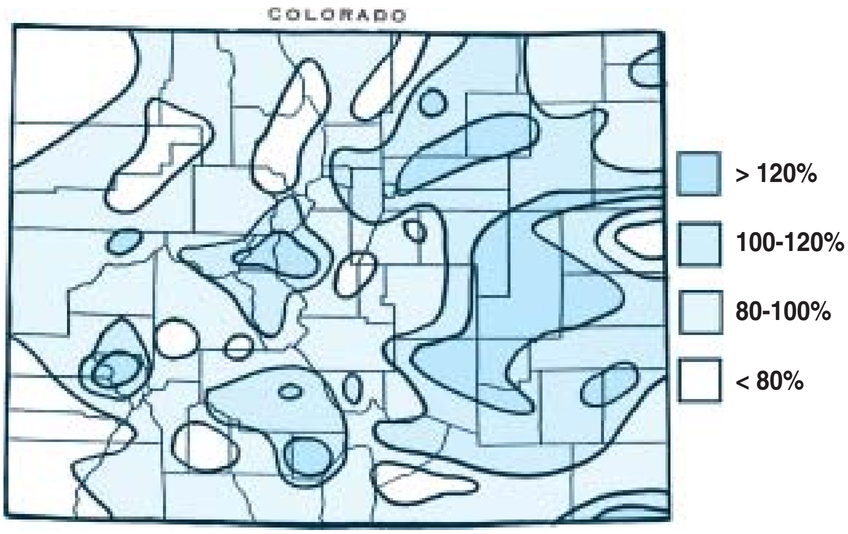


Figure 4. May through September 2001 growing season precipitation totals as a percent of the 1961-1990 average.

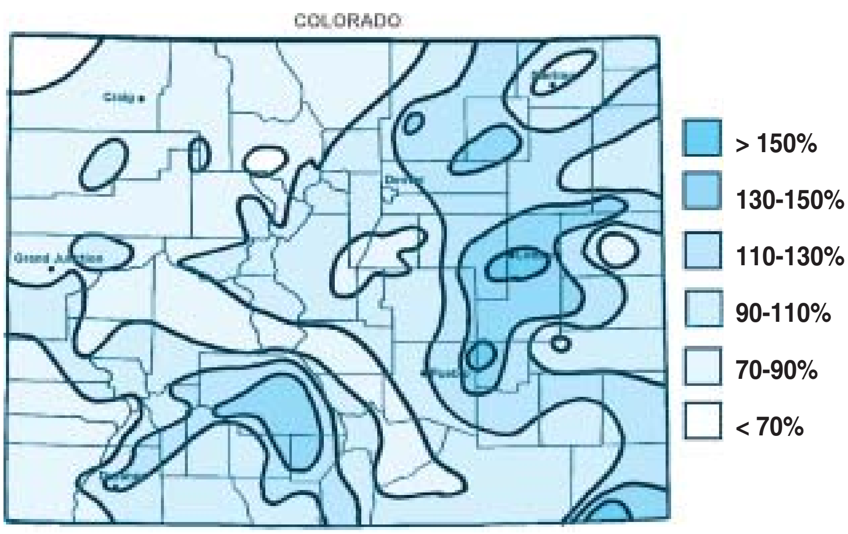


Figure 5. Water-year precipitation, October 2000 through September 2001, as a percent of the 1961 – 1990 average.

drier than average (approximate 80% of the 1961-1990 average) with a few sites such as Kremmling and Cedaredge at less than 60% of the long-term average.

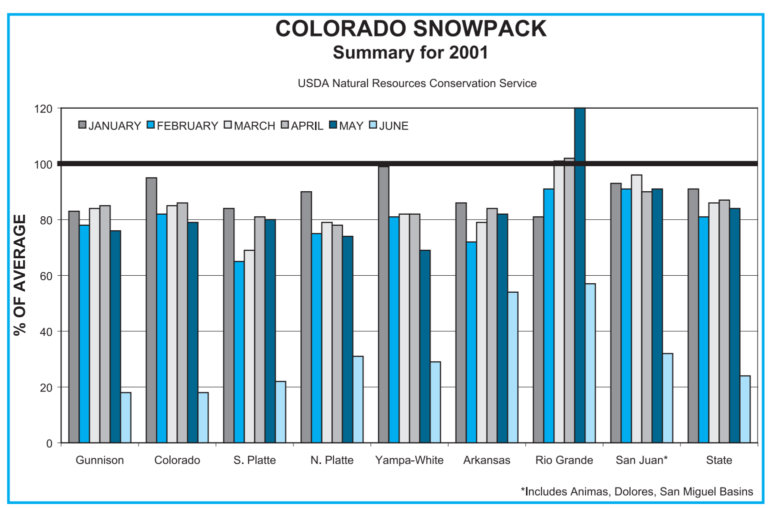
May brought very beneficial moisture to the state, mostly from one slow moving storm early in the month. Salida was buried under several feet of wet snow from this spring storm. Southeastern Colorado received some good rains later in May. There were localized heavy showers in June but no widespread heavy precipitation and most areas ended the month drier than average. July precipitation was also spotty and highly variable. August was very dry across the eastern plains but dropped wide areas of above average rainfall in the mountains and western valleys that helped bring an end to the main wildfire season. The water year ended with a dry September for most of the mountains but a very wet month for parts of the northeastern plains. For the May through September growing season as a whole (Figure 4), the majority of the state was drier than average with parts of northern and western Colorado receiving less than 80% of the long-term 30-year average. On the Eastern Plains there were both dry and wet areas, but above average precipitation prevailed with localized areas near Limon much above average.

For the year as a whole, statewide precipitation was approximately 95% of average and the second consecutive drier than average year (Figure 5). Almost all of the mountains and western valleys were drier than average while the San Luis Valley and much of the Eastern Plains were on the positive side.

Snowpack Accumulation

The winter of 2000-2001 was Colorado's fourth consecutive winter with below average snowpack. However, for southern Colorado it was a much better year than the previous winter. Heavy early-season snows fell over southern Colorado in late October and early November. December brought good snows to the Northern Mountains. By January 1, statewide snowpack stood at 91% of average. Except for the

Figure 6. 2001 monthly progression of snowpack for major watersheds in Colorado as a percent of the 1961-1990 averages.



Rio Grande basin, January was drier and sunnier than usual and by February 1, statewide snowpack decreased to 81% of average (Figure 6). February and March were fairly typical late winter months in the Rockies, and by April 1, statewide snowpack figures climbed to 87% of average. Despite near to above average April precipitation, warm temperatures began to reduce snowpack more rapidly than normal and statewide snowpack fell slightly to 84% of average. The wettest area of the state was the Rio Grande basin at 120% of average. One last blast of heavy snow in early May added to the years pack, but then warmer and drier weather prevailed resulting in an earlier than average melt.

A more detailed day-by-day accounting of precipitation and snowpack accumulation and melt are shown in graphs (Figure 7) for selected stations in northern, central and southern Colorado. These graphs are extremely valuable for describing the progression of events through the year. Marked differences in snowpack and precipitation accumulation patterns are shown here. The Slumgullion SNOTEL site was one of the snowiest in the state compared to average and, despite a lull in moisture in December and January, tracked well above average most of the season. Mesa Lakes on the Grand Mesa in western Colorado was totally different with very dry conditions throughout the winter followed by a nice recovery in April and early May to near average conditions before a very rapid snowmelt removed the pack in May. Joe Wright Reservoir in northern Colorado showed a more steady but below average accumulation throughout the winter and spring.

Runoff and Streamflow

Streamflow represents the integration of each year's complex and unique combinations of temperature, precipitation, snow accumulation, evaporation and sublimation. Daily discharges are shown for water year 2001 for selected basins in northern, central and southern Colorado (see Figure 8). The Poudre and Colorado River each showed a near normal early snowmelt in May but with much less runoff than average during June and July. Wet weather in August did bring slight improvements to late-season water supplies. The Animas River was dramatically different showing several large surges in early runoff greatly exceeding the average. But even with their above average snowpack, by July the streamflows had fallen to below average. There too, a late season increase was noted associated with a period of generous monsoonal rains. For most rivers in Colorado, their peak flows occurred a week or two earlier than average and were lower in volume than in many years.

Seasonal streamflow volumes for selected watersheds and comparison to average are shown in Figure 9. In southern Colorado, streamflow volumes were

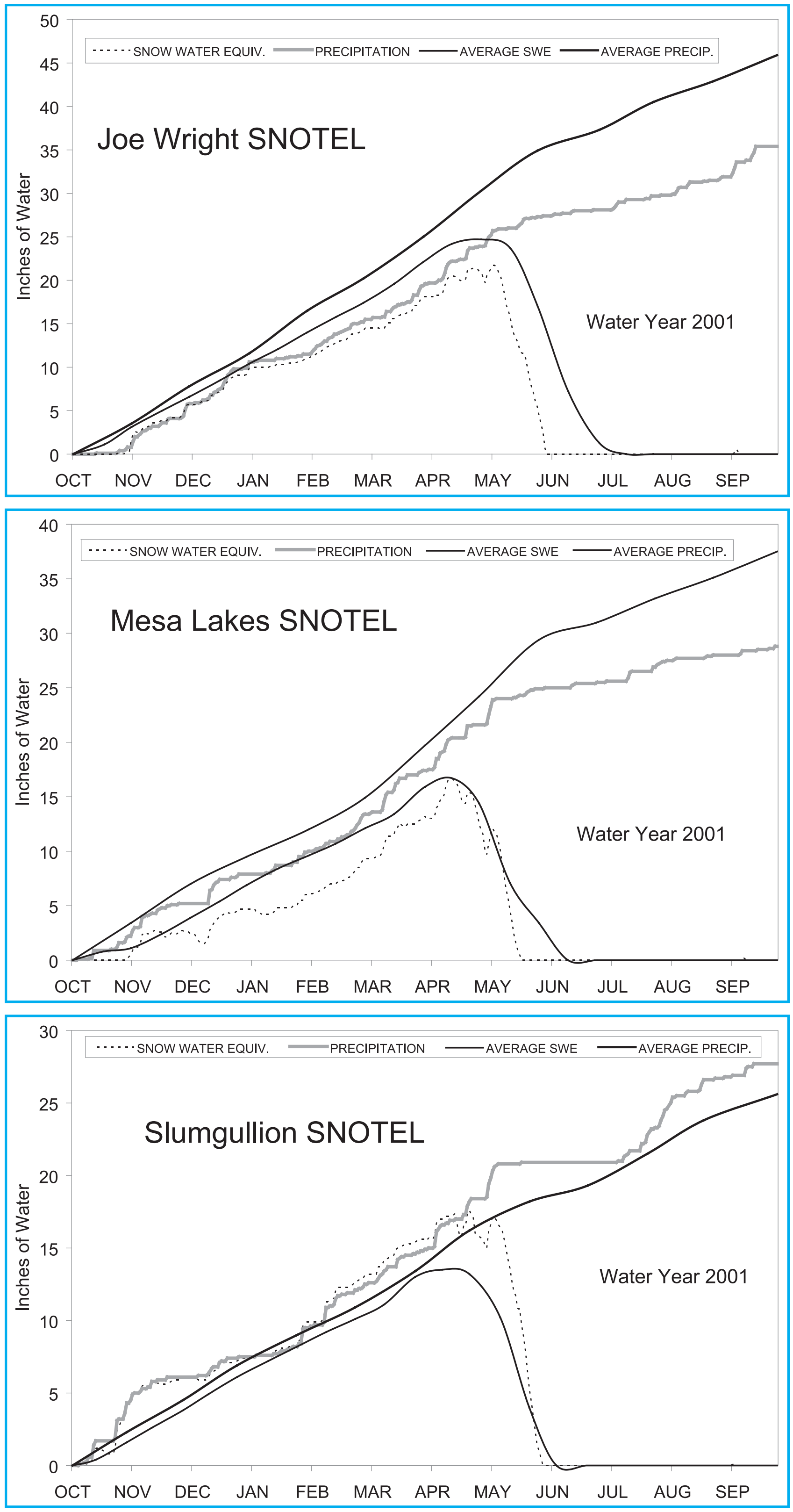


Figure 7. Daily accumulated precipitation (solid line) and Snowpack Water Equivalent (dotted line) for the 2001 water year and comparisons to average (black lines) for Joe Wright SNOTEL (north), Mesa Lakes SNOTEL (central), and Slumgullion SNOTEL (south).

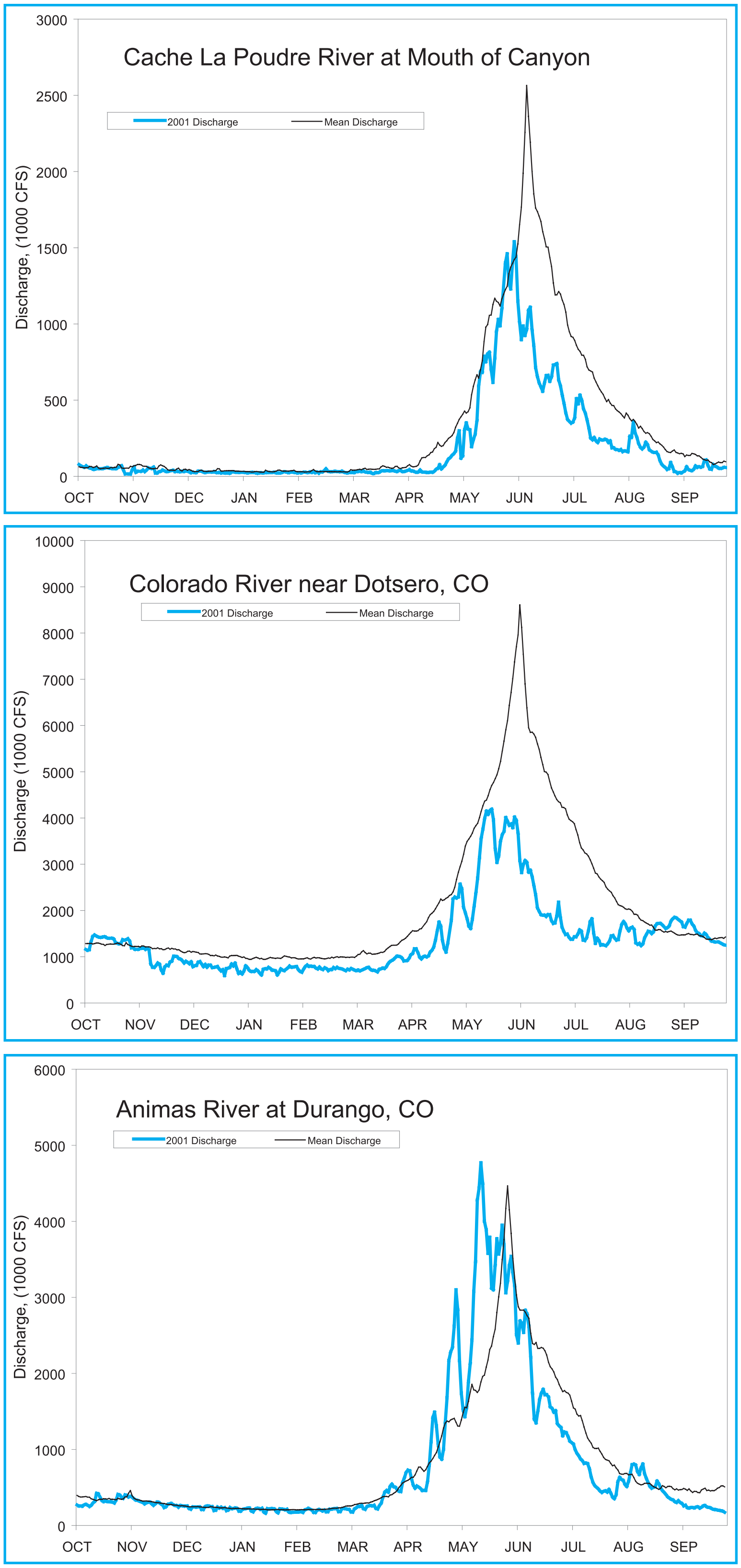


Figure 8. Daily streamflow discharge in cubic feet per second during the 2001 water year and period of record averages from USGS gauging stations on the Cache La Poudre River, the Colorado River near Dotsero and the Animas River at Durango.

near or above average – a very welcome change from the extreme low flows of 2000. But for the remainder of the state, it was not a great year for water with typically just 60-80% of average volumes. The Colorado River flow was only 65% of average while the Poudre River in northern Colorado was only 52% of average. This was the second year in a row with low flows in many basins.

Water Supplies and Reservoir Storage

Colorado began the 2001 water year with statewide reservoir storage on October 1, 2000 at exactly 100% of average. While this sounds good, there had been a very large decline in reservoir storage during 2000. This trend continued in 2001. With an earlier than average snowmelt, reservoir levels climbed to 115% of average by June 1st. However, as irrigation demand increased, persistently hot temperatures developed, and snowmelt runoff diminished quickly, reservoirs were drawn down and by September 30, 2001 were at 93% of average – the lowest in the state in more than a decade and more than 232,000 acre feet below average. Those basins with the lowest percents of average were the South Platte, followed by the San Juan, Animas and Dolores Basins, which were still suffering from the poor snow season the previous year (Figure 10).

Conclusions and Historical Perspective

Statewide precipitation for the 2001 water year was only slightly below average. However, the deficits were greatest in the northern and central mountains where much of the state's surface water supplies originate. Also, water year 2001, with the exception of a very cold November (2000), was another very warm year, and temperatures were particularly hot during the spring and summer months. The result was an early snowmelt, increased summer evapotranspiration and reduced streamflows. Fortunately, precipitation throughout the year was near or above average at many lower elevation locations where much of the mountain runoff is utilized. Also, it is fortunate that August rains were quite heavy in the mountains contributing at least a little to improved late season runoff and reservoir levels. While streamflows were well below average for the year in most basins, reservoir levels only dropped 7% from the same time one year ago now standing at 93% of the longterm average.

The graph of April 1 snowpack (Figure 11) shows some alarming information. 2001 was the fourth consecutive winter with below average winter snowfall. Since 1986 there have only been 4 years with above average April 1 snowpack. As we write this article in 2002 we are well on our way to our 5th consecutive low snowpack year. While we have been fortunate to have several years since the late 1980s with above average late spring or summer moisture, this cannot be expected every year. Dry summers like 2000 may occur again. With ever decreasing reserves in our reservoirs, the challenge that our water managers and planners face is getting tougher every year.

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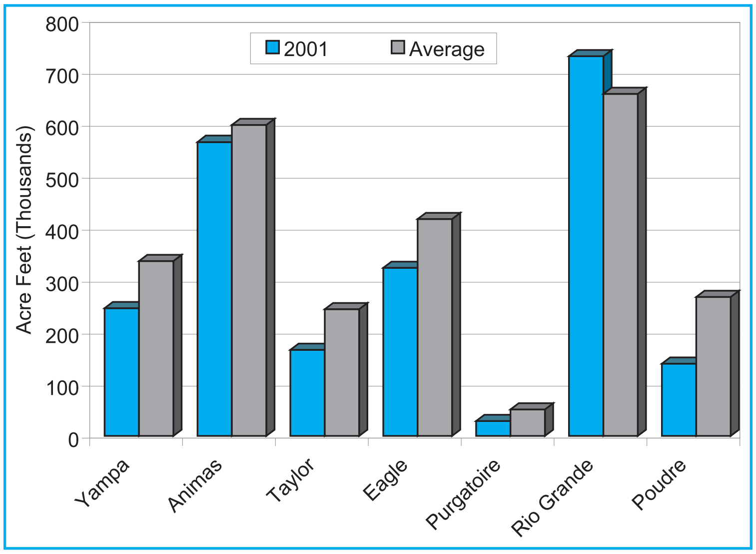

Figure 9. Water year 2001 streamflow volumes in thousands of acre-feet compared to period-of-record averages for selected rivers in Colorado.

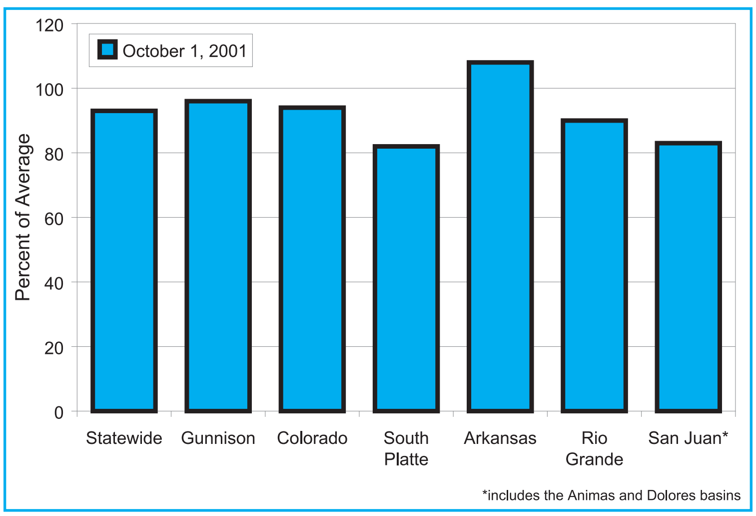

Figure 10. Reservoir storage at the end of the 2001 water year as a percent of average for each major watershed in Colorado.

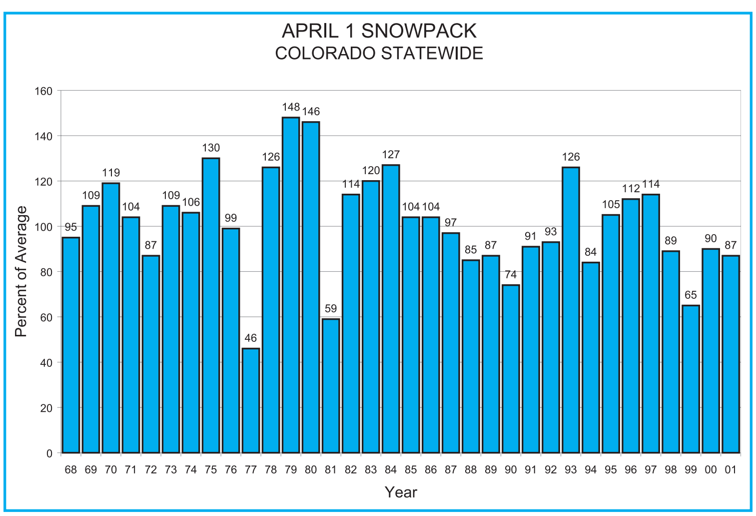

Figure 11. Time series for the period 1968 through 2001 of statewide snowpack on April 1 as a percent of the 1961-1990 average.

Are Temperatures Going Through the Roof? – Differences Between Rooftop And Standard Ground-Based Temperatures

Christopher Davey[1], Nolan Doesken, Robert Leffler[2], and Roger Pielke, Sr.
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If I may, I'm going to ask you to think about the weather segment on your local evening news for a second. I'm sure you know the general drill by now. Usually, the weatherman will start off by praising or belittling the weather for the day, after which he or she gives the current conditions from one of the big airports near the big cities, or perhaps the conditions from the news studio. Then they go to the forecast for the next few days. That's a pretty common thing to do on these shows. But something has changed in the past few years: we're getting live conditions from more and more places. I'll bet that sometimes you never have heard of some of these places before! Isn't it a pleasure nowadays to watch the weather segment on the local news and get live weather conditions from pretty much any town or community, big or small, within the region? Look how far our local weather news has come! It is only during the past few years that we have had the ability to check in on live weather from Anytown, U.S.A.! For those readers who live in bigger urban areas, Denver for example, these new locations of weather observations can really help show what is going on live throughout the metropolitan area, not just at the airport or downtown.

The rapid growth of local weather observing networks in recent years has greatly increased the geographic coverage and availability of near-real-time, non-airport weather observations. This tremendous expansion (Meyer and Hubbard, 1992) is a positive step toward the availability of meteorological data for a variety of applications.

Rooftop weather station at an Elementary School in Longmont, Colo.

So, where are these new weather observations coming from? Most of these sites are at local grade schools, which has proven to be very useful to the media and the general public for both educational purposes and for accessible real-time weather data, both for short-term weather monitoring and planning activities (Giannola, 1998). In fact, there are bigger consequences of the growth of such weather station networks. The National Weather Service (NWS) is becoming more interested in using these observations since they may provide the timely localized data needed to initialize local forecast models and provide helpful data for forecast verification.

So far, it probably really seems like the sky's the limit regarding these new weather stations. And for the most part, you're right! There's a lot of potential for new and exciting uses of these stations. But, there's a catch! Especially if these data ever start getting used to augment existing long-term climate records for local communities! The catch is that thousands of these new stations have non-standard, rooftop exposures. It is understandable why sites such as these are common. There are often a myriad of practical and security-related reasons for placing the weather stations on roofs versus down on the ground somewhere. But rooftops come in all shapes and sizes. It is not uncommon to find temperature sensors that are located on towers tens of feet above ground level, on metal, black asphalt, or stone-covered rooftops, or at other non-standard, unrepresentative locations. Sensors located in such exposures have been shown to exhibit temperature biases (Laskowski, 1936). Exposures such as these may by no means be representative of surface air temperatures measured at standard ground level (Landsberg, 1941), especially during certain seasons and weather situations.

Rooftop temperature measurements have been known to contain biases but the variables and magnitudes associated with these biases are largely undocumented. Thus, use of these data without knowledge of their environmental exposure can lead users to erroneous conclusions about local ground temperature conditions, especially in the context of historical or other standard ground-based real-time data.

Historically, the majority of temperature data used in climate studies, forecasting, and other applications has come from ground-based observations. One of the primary networks of ground-based weather stations is run by the NWS. The vast majority of the NWS airport and non-airport temperature observations are taken at a standard exposure height of 5 feet (1.5 meters) above a ground surface representative of the surrounding environment.

Two "official" national networks are operated by the NWS. The primary official network is composed of about 1,000 airport stations (some are operated by the Federal Aviation Administration) that take and transmit real-time hourly observations. The secondary network is part of the cooperative observer program. It consists of about 5,000 non-airport temperature sites that take daily observations. Most of these observations are not readily available to users.

Official stations are basically NWS-supervised sites whose observations and data are collected under defined standards with routine maintenance and supervision. Unfortunately, there are some official stations with non-standard exposures on and off rooftops, which exhibit non-representative observations (Foster and Leffler, 1981).

As far as temperature measurements are concerned, the official NWS networks have several types of temperature sensors. The primary network is comprised of radiation-shielded, aspirated electric thermistors that measure hourly temperature as a function of electrical resistance. The cooperative observer stations are equipped with radiation-shielded non-aspirated liquid-in-glass thermometers or thermistors that must be read manually.

Now that we have discussed NWS weather stations, let's return to the school-based weather stations to see how the two networks compare. Most include equipment to measure the basic parameters of daily precipitation and daily maximum and minimum temperatures.

Some of the school sites use homogeneous state-of-the-art sensors that record hourly temperature, pressure, wind speed and direction, precipitation amounts and rates of fall, and other elements. It is relatively easy to see that such sites adhere more easily to accepted standards for weather station exposure. Thus, the data from these particular sites may be easily combined with NWS data. On the other hand, there are many sites that contain a hodgepodge of much less sophisticated sensors. The lack of adherence to exposure standards with these latter sites makes it much more difficult to include their data with NWS data.

Data from the various federal, state, local, and private meteorological networks show that there are discontinuities between these databases. As we've already illustrated, one reason is the lack of comparability among weather data collected by different organizations and even within organizations. Many of these deficiencies are caused by differences in sensors, their siting and exposure, and non-standard processing algorithms.

So why are we emphasizing this idea of "exposure standards" so strongly? Is it really that big of a deal? To answer that question, just think about numerous bank signs you may have seen. Don't those temperature readings often look suspicious? You can often bet that some kind of exposure standard is being violated (being placed over asphalt, for example). The purpose of exposure standards is to assure greater comparability and usability, or continuity, of meteorological data among the user community. Standards exist in varying degrees in the international (World Meteorological Organization), federal, and non-federal communities. Some are specific to certain areas like airports. These standards then in turn are used by federal agencies for a basis for developing and implementing specific regulatory or technical documents. Many of these standards are also applicable to other data systems, but not all. For instance, different users want data from different heights or want the data to be averaged over varying time periods. It makes a difference whether you are an aviation user, a climatologist, a building engineer, a fire-weather forecaster, a mariner, or a utility company worker.

Even with these different requirements, there is far more agreement than there are differences among data providers and users. In creating standards, people with different interests come together and resolve differences by compromise. These compromises result in a standard that serves the interests of all involved.

So with that, let's now ask the obvious question: How do rooftop temperature observations compare to those of nearby official ground level stations? Do biases vary with time of year, type of roof, location on the roof, different weather conditions, etc? Is there a simple correction factor that one can apply to rooftop temperatures to make them consistent with ground-based readings? The following work will address these questions and hopefully find some useful answers.

Rooftop weather station at a Middle School in Boulder, Colo.

Background

Recent research (Griffith and McKee, 2000; Griffith et al., 2000; Doesken et al., 2001) indicates that warm rooftop temperature biases (relative to the ground) are most common for buildings whose roofs are comprised largely of low-albedo materials (e.g., asphalt), have limited sky view, have low surface moisture retention, and are well insulated. Warm biases are also regularly observed with wall-mounted sensors due to higher solar radiation absorbed and re-radiated by these walls. This interaction appears to create localized warm rising air pockets. Wall effects are most common on south- and west-facing walls during the winter, when lower sun angles allow incoming radiation to strike the walls at angles more conducive to maximum heating.

Rooftop Weather Station at an Elementary School in Highlands Ranch, Colo.

Lakewood South Elementary School.

Our studies indicate that warm biases are generally largest during the nighttime hours of days with clear and calm weather conditions. Smaller biases are observed for roofs constructed with materials having both high albedo and low emissivity. Also, warm rooftop biases tend to decrease or even disappear during cloudy and/or windy weather (Leffler and Schiesl, 1994; Griffith and McKee, 2000).

Rooftop temperature biases are not explained fully by surface effects alone. These biases will also vary as a function of seasonal and synoptic weather variations and likely vary as a function of the building height. These variables complicate the job of accurately determining the representativeness of rooftop temperatures.

How Data Was Obtained

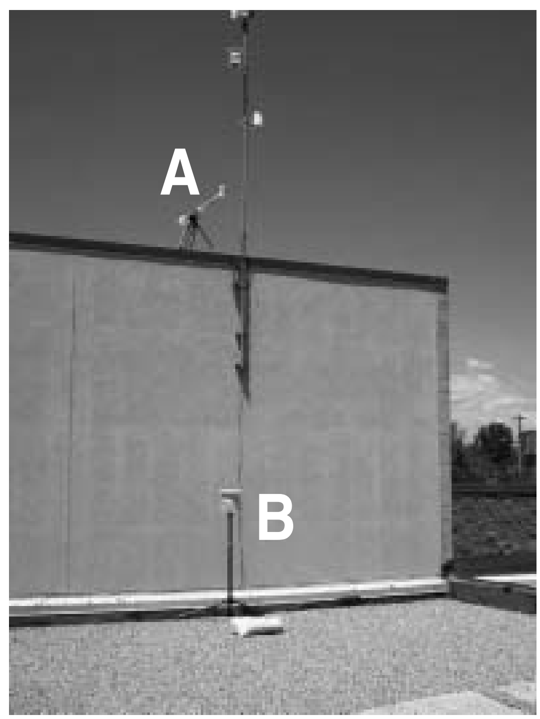
This study addresses the rooftop temperature bias issue using three basic approaches. In our individual case studies, several approaches are taken to quantify roof-ground temperature differences. First, the surface energy balance was examined in order to better understand how incoming sunlight energy gets distributed (reflected, absorbed, etc.) over the ground surface (Griffith and McKee, 2000). Second, observations from a number of rooftop sites with different types of roofs, orientations, and heights above the ground have been examined. Observations were taken as part of the study at different times of year and in different parts of the country to look for differences and similarities in roof-ground relationships.

Air temperatures were sampled at selected rooftop and ground-level locations at the standard height of 5 feet (1.5 meters) above the local surface using a set of lightweight portable temperature sensors. Both RM Young (RMY) platinum resistance thermometers and Environmental Sensors USA Inc. (ESI) sensors were used (see Doesken et al., 2001). The RMY instruments are accurate to within 0.018°F (0.01°C), while the ESI sensors have an accuracy of 0.9°F (0.5°C). The accuracy of the actual temperature sensors is only half the battle, however. Effective solar radiation shielding is critical in measuring accurate air temperatures. For this reason, the RMY sensors are mounted in aspirated radiation shields. The ESI sensors were installed in NWS Maximum-Minimum temperature system (MMTS) radiation shields – the shield used at thousands of NWS cooperative non-airport weather stations across the country. The MMTS radiation shield has been shown to perform very favorably with respect to the RMY reference (Doesken, 1995).

Two Case Studies

Measurements were taken at individual schools in the greater Denver, CO area during the summer of 2001. First, air temperature measurements were taken at South Lakewood Elementary School in Lakewood, CO, from June 21-July 5, 2001, during the summer solstice. High sun angles may accentuate daytime rooftop warm biases, so this data collection was timed to test that theory. Secondly, we visited Peakview Elementary School in Aurora, CO, from August 20-26, 2001. This school has been noted for warm rooftop temperature readings by the local media (Nelson, 2001).

Clear skies and calm winds dominated for almost the entire period of the Lakewood case study, thus providing an excellent data source of rooftop air temperatures during weather conditions that are suspected of being associated with warm rooftop temperature biases. The roof surface at Lakewood is a layer of coarse, tan-colored gravel up to 2 inches (5 centimeters) thick, which overlies black rubber fabric. The existing rooftop sensor at Lakewood is situated on the east wall of an elevated structure on the west side of the complex. Portable temperature sensors were placed on the school rooftop near the permanent sensor. One of these sensors was co-located with the



Lakewood South Elementary School rooftop weather station mounted to the side of the building. This east wall exposure exhibits warm morning biases under clear/calm conditions. Lake-A site is on top of the roof. Lake-B site is directly below the automated site.

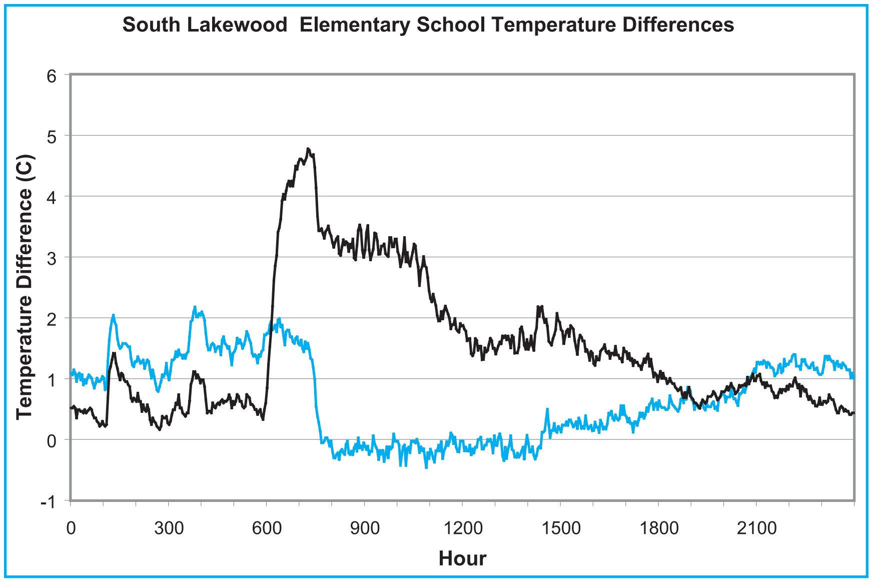
Portable temperature sensor at ground level for Lakewood South Elementary School (Lake-G site).

school weather station (Lake-A), to check the accuracy of its thermometers. Another (Lake-B) was placed below the school weather station at the foot of the east wall mentioned above. The last reference rooftop sensor (Lake-C) was placed in the middle of a level roof section about 50 feet (15 meters) southwest of the permanent sensor. One portable sensor was used as a ground reference station (Lake-G) and was located in a grassy area on the grounds at the northwest corner of the school building.

Results for the measurements collected at Lakewood are shown in the graphs in Figure 1. Due to the location of the school weather station on an east-facing wall, it is suspected that it experiences a marked wall effect (warm bias) during the morning hours. Indeed, the largest temperature differences between the school station and the ground surface occur in the morning.

Initially, due to our interest in the effects of high sun angle, the period from late morning through late afternoon was of primary concern. During this time, a comparison of our portable rooftop and ground sites reveals only a small rooftop warm temperature bias, although the readings taken from the school weather station at these same times indicated that a much larger bias was indeed present. With the exception of mornings, our results tend to match previous findings (Doesken et al., 2001) that larger roof-ground temperature differences occur at night rather than during the day.

Peakview Elementary School in Aurora was considered to be an excellent candidate for experiencing significant warm daytime temperature biases. First, the school weather station is located near the center of a large roof with dark brown vertical wind breaks (approximately 10 feet or 3 meters tall), erected about the perimeter of the roof. The windbreaks thus reduce airflow around the sensor and radiative heating effects are more likely to dominate the sensor's environment.



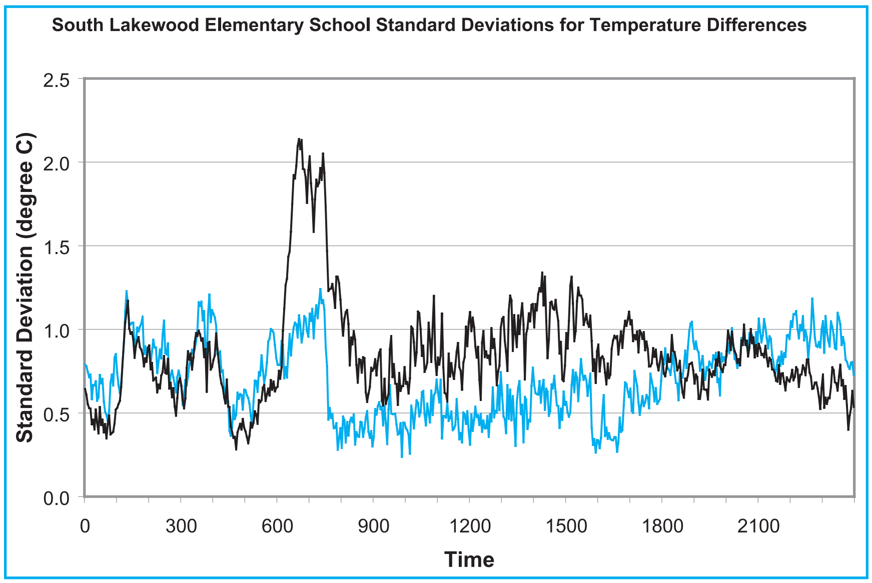


Figure 1. Two-week average and standard deviation of the daily cycle of roof-to-ground temperature differences from the Lakewood South Elementary School field study, June 21-July 5, 2001. The difference between Lake-B and Lake-G is shown as the black line while the difference between Lake-C and Lake-G is the gold line.

A second concern is that the school weather station is located within 16 feet (5 meters) of a large air-conditioning unit that is a possible artificial source of heat during the cooling season. The main rooftop surface is similar to Lakewood in that it is mostly level and consists of a 1 to 2 inches (3 to 5 centimeter) layer of course tan-colored gravel overlying black rubber fabric. To investigate rooftop temperatures at this site, we put up our own portable temperature sensors 1) next to the school weather station, Peak-A, and 2) 65 feet (20 meters) south of the permanent sensor on a section of level roof outside of the wind break perimeter (Peak-B). A ground sensor (Peak-G) was placed on an un-irrigated grassy section 50 feet (15 meters) to the east of the school building.

Measurements during clear/calm conditions from the portable sensors installed at Aurora gave mixed

Peakview Elementary School in Aurora.

Peakview Elementary School rooftop weather station looking west. Note the proximity to air-conditioning unit. Windbreaks, like this one behind the AC unit, are also present to the north and south (Peak-A site located next to automated site).

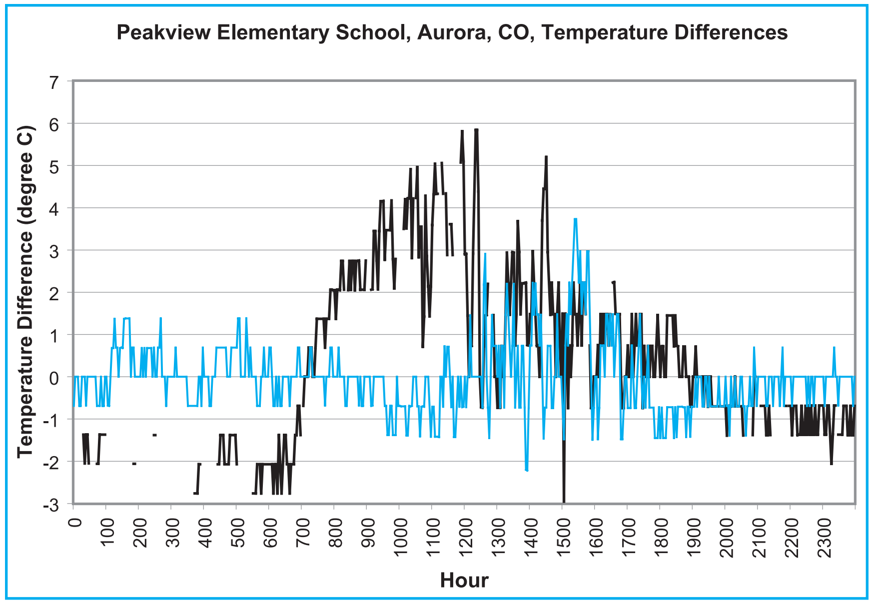


Figure 2. Peakview Elementary School temperature differences on 8/26/01 for Peak-A vs. Peak-G (black line) and Peak-B vs. Peak-G (gold line).

results. Under clear conditions (Figure 2), Peak-A indicated a significant daytime warm bias of 7-9°F (4-5°C) compared to Peak-G. At the same time, however, Peak-B indicated no significant warm bias compared to Peak-G. There were no significant nighttime roof biases observed. We concluded that a daytime rooftop warm bias is likely, but its actual magnitude remains uncertain because the biases indicated by Peak-B were still several degrees (Celsius) less than those indicated by school weather station.

Summary

The majority of the findings from this study have indicated that larger roof-to-ground temperature differences occur at night rather than during the day. Warm roof biases are observed in some cases with wall-mounted sensors as well as sensors placed in areas that are efficient at trapping infrared radiation.

Uncertainties still remain concerning what fraction of the suspected warm biases at these roof sites can be explained by instrument bias and the type of radiation shields used, rather than strictly physical rooftop-ground effects.

Ground temperature sensor at Peakview Elementary School in Aurora, (Peak-G site).

All photos in article provided by Christopher Davey

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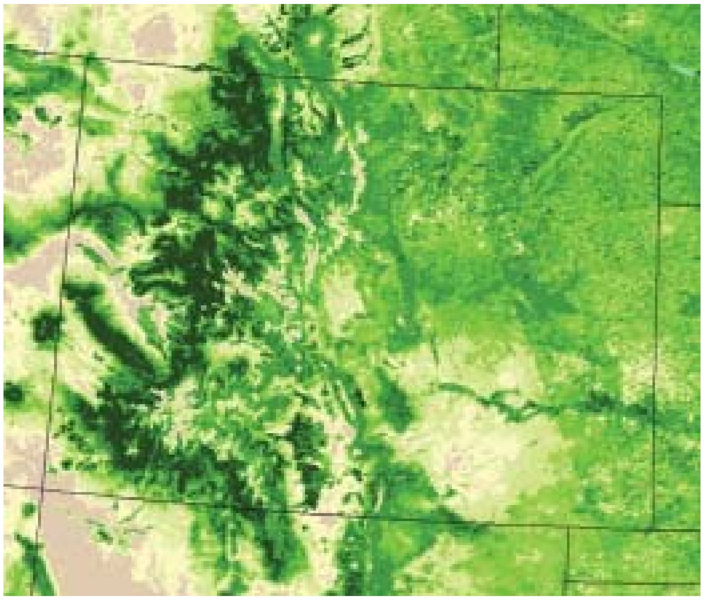
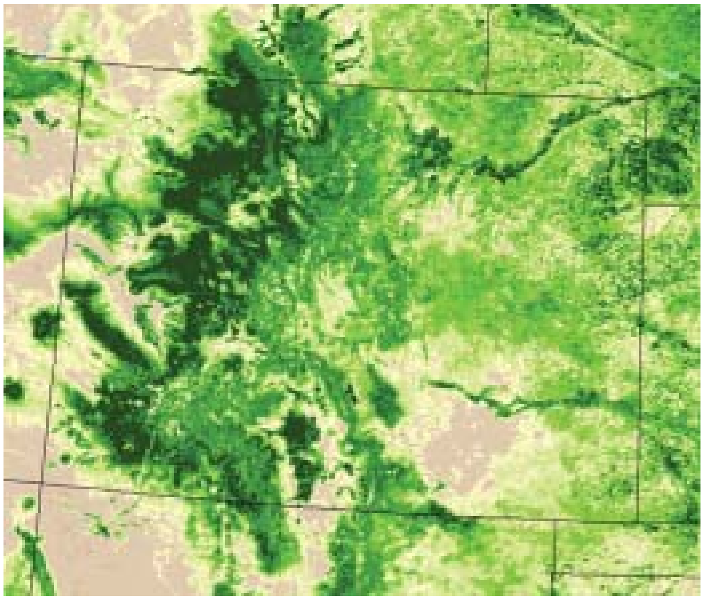
Colorado NDVI Greenness Images

Colorado NDVI (Normalized Difference Vegetation Index) greenness satellite images are shown here for June through September 2001. The decreased greenness seen in these images shows the drying up of vegetation or harvesting of crops over this time period.

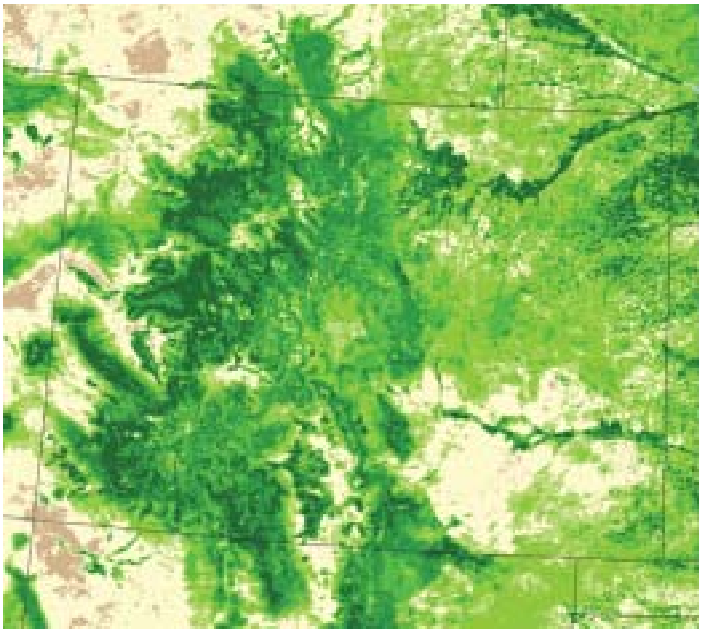
June 2001



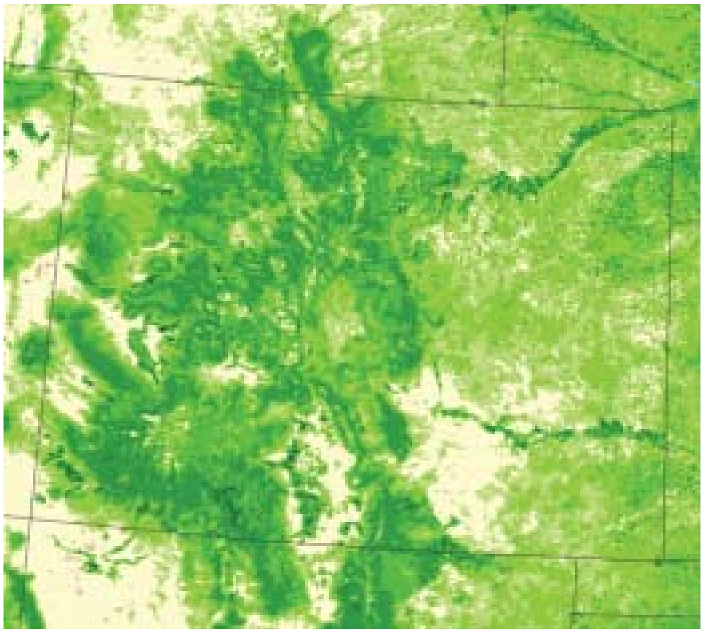
July 2001



August 2001

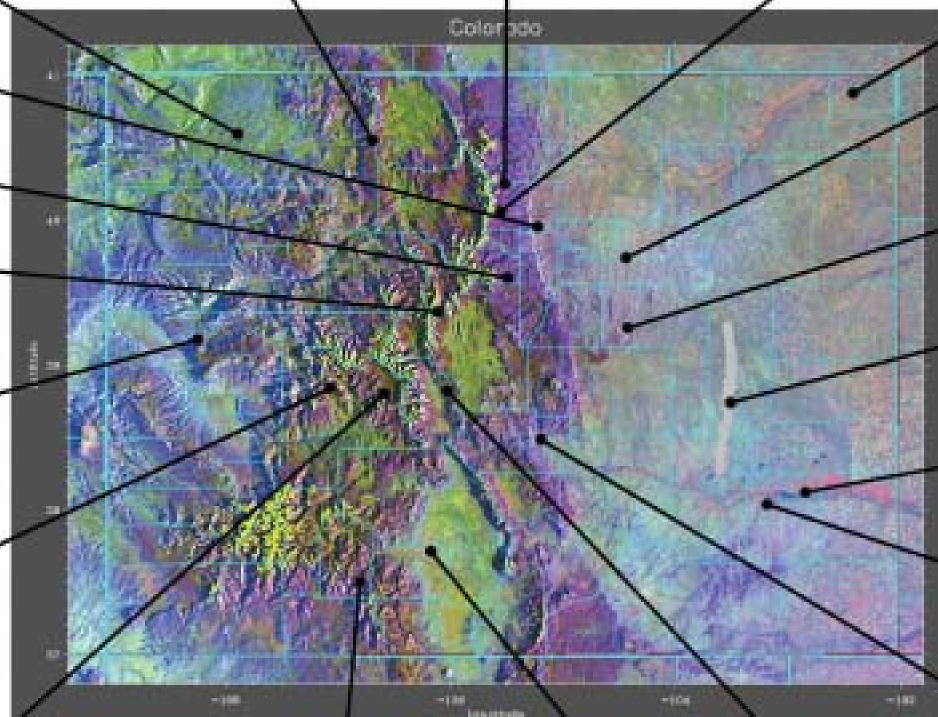


September 2001



Images courtesy of U.S. Geological Survey EROS Data Center, Sioux Falls, SD.

Extremes of Colorado Weather and Climate



Prepared by Colorado Climate Center, Colorado State University

Colorado's Coldest Temperatures

February 1st, 1985
Maybell, -61 deg F
State's coldest.
Also Berthoud Pass's
coldest, -34 deg F.

Nearly all of Colorado's
coldest temperatures are
preceded by fresh, dry snowfall.

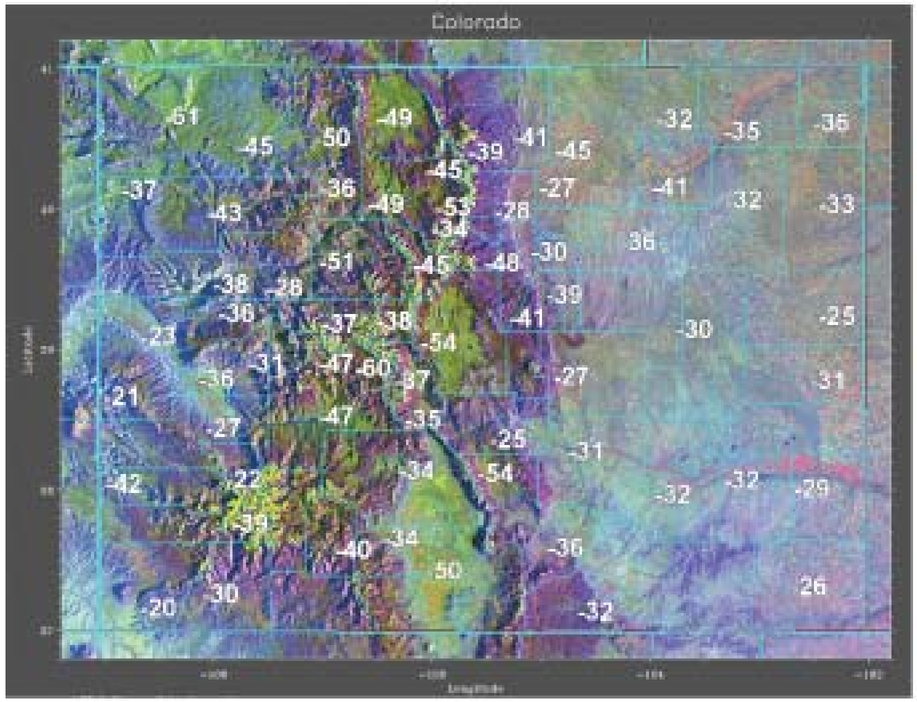
February 1st, 1951
Extreme cold statewide.
-60 deg F at Taylor Park,
-41 deg F at Fort Collins.
Cherry orchards killed.

January 12th, 1963
Western Colorado's coldest
morning! Grand Junction,
-23 deg F. Extreme damage
to orchards.

1978-79
Colorado's coldest winter
(Dec. - Feb.) this century.

Taylor Park
Most subzero days
on average -- 90 days.

Mesa Verde
Colorado's least extreme
temperature.



January 1937
Colorado's coldest month.
Persistant cold, 27 nights with
subzero temperatures in
Greeley and Sterling.

February 8th, 1936
Denver's coldest,
-30 deg F.

February 12th, 1899
-45 deg F in Greeley.
-32 deg F in Rocky Ford.

February 1st - 12th, 1899
Subzero all the way to Florida.
Eastern Colorado's coldest ever.

February 1st - 7th, 1989
"Alaska Blaster"
Snow accompainied extreme cold.
Denver's high on Feb. 4th, -9 deg F.
Craig's highest Feb. 4th - 6th, -14 deg F.

1991-1992
Localized extreme winter in
San Luis Valley. 79 days below
zero, 65 days dense fog.
The cause?
Deep early snowcover.

October 1991
Early coldwave damaged
countless trees in
Eastern Colorado.

December 20th - 25th, 1983
Longest subzero episode!
112 hours below 0 deg F over
much of NE Colorado.

Photo by Thomas McKee, Duststorm.

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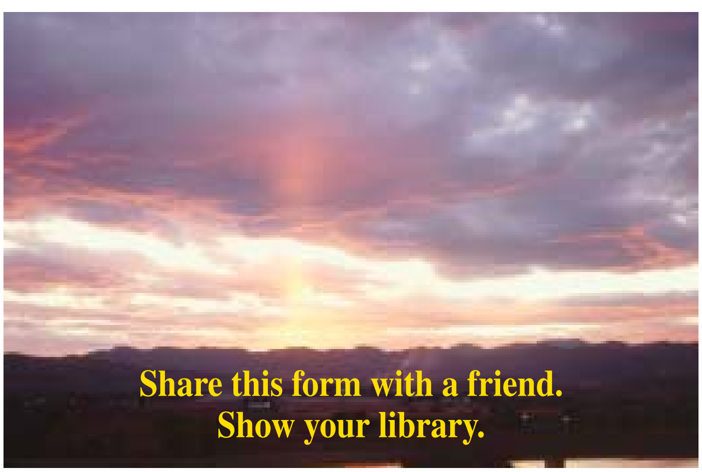

Photo by Thomas McKee, Sunset.

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