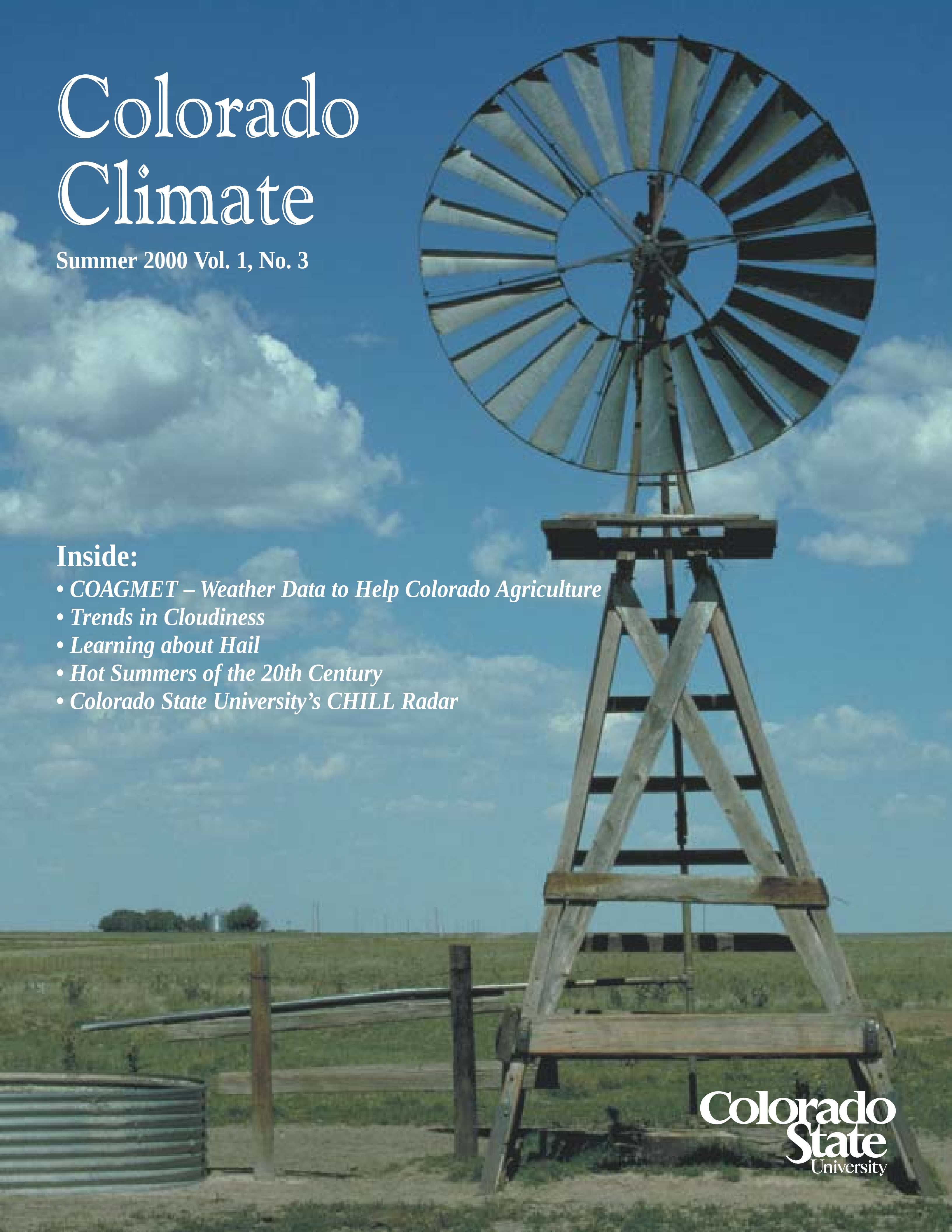

Colorado Climate

Summer 2000 Vol. 1, No. 3

Inside:

Colorado State University

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Colorado Climate

Summer 2000
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Cover Photo: *Windmill near Brush, Colorado. Photo taken by Professor Howard F. Schwartz, Bioagricultural Sciences and Pest Management Department, Colorado State University.*

If you have a photo 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://ccc.atmos.colostate.edu

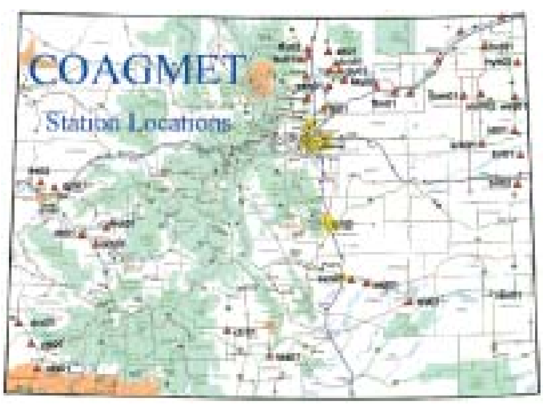
COAGMET – Weather Data to Help Colorado Agriculture

Nolan J. Doesken

COAGMET is an acronym that stands for COlorado AGricultural METeorological Network. That's a mouthful, but an important one. For a decade now, an informal but effective partnership has been established involving several departments at Colorado State University, the U.S. Department of Agriculture, the Northern Colorado Water Conservancy District, commodities groups and other individuals and organizations committed to Colorado agricultural. These groups are working together to collect and share weather data.

And why this effort? Weather affects almost every aspect of agriculture. It is easy to think that the only weather information that farmers need is an accurate forecast for the next day, the next week, or even the entire season. Yes, that would be nice, but it is also important to accurately document the weather conditions as they occur. Detailed, accurate and timely data on current and past weather conditions are very important for on-farm decision making and to support research leading towards a more profitable and sustainable agricultural economy.

COAGMET consists of a network of automated weather stations throughout Colorado, and the computer system for collecting, archiving, displaying and disseminating the data.



COAGMET remote electronic weather station site east of Holyoke, Colo. (Photo courtesy of Howard F. Schwartz.)

The basic elements observed by COAGMET weather stations include precipitation, temperature, humidity, wind speed, wind direction, solar radiation, and soil temperature. Barometric pressure, a standard element measured at most airports and weather stations needed for weather forecasting, is not measured at most agricultural weather stations. All measurements are done automatically using electronic sensors. Data are processed locally using sophisticated data loggers. Stations are powered by electricity generated by solar panels. Currently, most of these weather stations transmit data summaries for one-hour increments to the central processor at Colorado State University once daily just after midnight. Most stations are equipped with cellular phones programmed to turn on at assigned times. Daily updates meet most agricultural requirements at this time. However, the stations could be contacted much more frequently, if resources warranted.

COAGMET is a great example of what can be accomplished with the help of cooperation and collaboration. Back in the 1980s, Dr. Harold Duke and Mike Blue of the Water Management Unit of the

(continued on page 2)

COAGMET *(continued from page 1)*

COAGMET Daily Summary for August 29, 2000

Sta	Mon	Day	Tmax Temp degF	Tmin Temp degF	Vapor Press mb	Solar Rad Lngly	Prec in.	Wind Run mi.	Soil Temp degF	MinRH RH Pct	Grow DegDay F.
akr02	8	29	***** Missing *****								
alt01	8	29	83.5	54.7	17.81	544	0.00	90	69.0	45.0	2433
avn01	8	29	88.2	60.0	15.33	470	0.00	118	79.5	29.3	2761
bla01	8	29	78.8	50.0	10.69	529	0.00	173	69.6	23.5	2077
brl01	8	29	86.2	59.3	15.20	544	0.00	131	70.8	36.4	2679
brl02	8	29	86.4	58.7	15.42	558	0.00	147	71.4	37.3	2708
ctr01	8	29	77.1	47.3	12.64	469	0.00	101	63.5	34.7	1652
ctz01	8	29	79.1	53.0	13.80	434	0.17	92	65.8	34.1	2574
dlt01	8	29	88.1	59.3	16.25	421	0.00	61	68.6	31.4	2646
dvc01	8	29	79.9	53.0	13.75	446	0.37	128	64.8	35.9	2373
eac01	8	29	86.1	58.4	15.24	537	0.05	140	65.5	29.5	1002
frt02	8	29	90.9	56.2	17.06	410	0.25	64	96.9	32.0	2835
ftc01	8	29	79.8	55.4	16.43	415	0.02	113	55.5	40.7	2388
ftc03	8	29	81.6	54.3	15.80	482	0.00	138	63.1	36.7	2350
ftl01	8	29	83.2	60.4	20.23	306	0.04	106	68.3	51.4	2604
ftm01	8	29	87.1	60.0	19.75	520	0.08	190	67.7	36.8	2655
gjc01	8	29	87.4	57.9	15.87	359	0.33	65	75.0	18.1	2948
gly03	8	29	85.9	57.0	17.50	549	0.00	89	72.1	41.7	2560
hne01	8	29	87.9	52.2	13.40	508	0.00	65	66.3	24.0	2047
hot01	8	29	86.2	58.9	14.90	492	0.04	109	65.8	29.9	2648
hxt01	8	29	83.9	57.9	16.43	495	0.00	119	69.2	41.2	2529
hyk02	8	29	83.2	57.8	19.52	426	0.19	108	70.3	51.9	2657
idl01	8	29	84.1	58.2	19.36	513	0.00	87	70.9	49.3	2732
krk01	8	29	82.7	56.8	19.52	279	0.00	86	68.0	54.8	1542
ksy01	8	29	88.8	58.6	19.65	519	0.05	152	66.2	38.4	2575
lam01	8	29	95.9	60.9	1.12	277	0.00	174	81.2	0.2	2487
lcn01	8	29	85.6	56.4	18.23	505	0.00	95	68.6	46.1	2536
oth01	8	29	87.6	59.0	16.44	432	0.04	33	74.5	30.2	2551
pkh01	8	29	84.4	57.2	20.15	558	0.16	115	73.6	52.5	2547
rfd01	8	29	89.2	60.5	14.84	517	0.00	85	73.3	28.4	2939
san01	8	29	79.0	45.4	10.10	386	0.00	***	65.3	25.0	282
twc01	8	29	87.5	58.1	14.03	486	0.07	150	77.3	24.8	2831
vld01	8	29	88.5	57.6	18.39	527	0.00	55	69.2	36.5	2746
wry01	8	29	85.6	57.2	18.69	562	0.02	81	71.8	41.8	2649
yjk01	8	29	79.2	52.5	12.25	419	0.18	136	68.6	33.1	1880
yum02	8	29	80.7	58.0	17.40	551	0.02	121	71.1	49.4	2885

Ryan Younkin and Dale Heerman program irrigations for an automated center pivot sprinkler system near Wiggins, Colo. Photo courtesy Information Staff, USDA-Agricultural Research Service, Beltsville, Md.

USDA-Agricultural Research Service were setting up automated weather stations to aid research projects on water use efficiency. At the same time, Dr. Howard Schwartz and Mark McMillan with CSU's Department of BioAgricultural Science and Pest Management were setting up weather stations to help study insects and diseases affecting crops in Colorado. The two groups decided to work together and by 1989 the foundations for COAGMET were in place. The Colorado Climate Center joined the team during the 1990s. Cooperative Extension, the Colorado Agricultural Experiment Station, and several commodity groups are also a part of the team.

Weather data from COAGMET are currently being used in several ways, one of which is irrigation scheduling. According to Dr. Duke, "Meteorological data such as COAGMET, has allowed an estimated 10% of U.S. irrigators to reduce their water applications an estimated average of 10% per year, saving some 160 billion gallons of water each year."

Dr. Schwartz has demonstrated that careful monitoring of weather conditions can help producers anticipate insect and disease outbreaks and reduce the quantity and increase the effectiveness of pesticide application which can save tens of thousands of dollars for producers each year.

COAGMET is linked to Colorado State University's VegNet. VegNet, an outgrowth of years of work by Schwartz and McMillan, is an online resource maintained by CSU Agricultural Experiment Station and Cooperative Extension Service in concert with various commodity groups including dry bean, onion and potato growers. Crop and disease models can be run directly using COAGMET weather data.

All weather data from COAGMET, including summarized data up to midnight of the previous day for all stations are available via the Internet. Even most historic data back to the early 1990s can be accessed. The COAGMET website is:

http://ccc.atmos.colostate.edu/
then click on COAGMET.

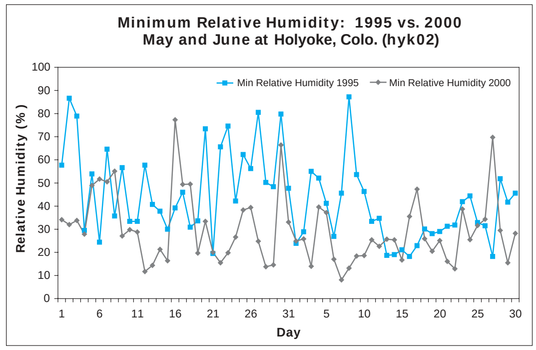
For more information on insect and disease hazards and to access various crop pest models, CSU's VegNet system is available at:

http://www.colostate.edu/Orgs/VegNet

Several COAGMET weather stations have been in operation for close to a decade. The longer the data records, the more opportunities appear for climatic research and applications. This is exciting for us at the Colorado Climate Center. For example, up until now, wind and solar energy data from agricultural areas of Colorado have been very limited. Similarly, data to evaluate year to year differences in humidity and evaporation rates have been hard to get. The graph (top of page 3) shows an example of how humidity varied from in northeast Colorado in recent springs. The contrast between the remarkably wet spring of 1995 versus the dry weather of 2000 had direct effects on crop and pest development.

In future issues, we will present more results from COAGMET and offer some suggestions on how teachers can utilize COAGMET data on the web to help students discover relationships between weather conditions, water use, pest development and plant growth.

If you would like more information about COAGMET, please contact us at the Colorado Climate Center.



Climate on the Web: The Urban Drainage and Flood Control District

http://www.udfcd.org

Nolan J. Doesken

As we have said before, there is no shortage of weather and climate data available to the web surfer willing to type a few keystrokes and click a few mouse buttons. During the summer, intense convective thunderstorms are an important part of Colorado's climate. An interesting web visit during the summer is the Urban Drainage and Flood Control District site. Their offices just west of I-25 near downtown Denver play host to an ever-expanding network of rain gauges and weather stations that serve to help monitor and predict flooding in and near the Denver metropolitan area caused by local heavy rains.

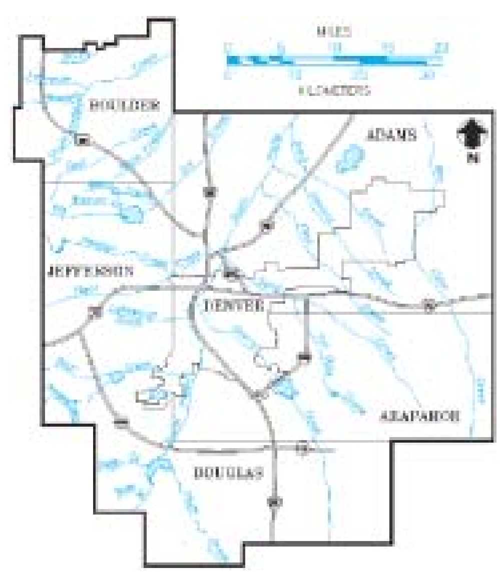
Urban areas tend to exacerbate flash flooding conditions. For this reason, the Urban Drainage and Flood Control District (UDFCD) has been very proactive both in designing and building structures to carry storm water safely through urban areas. UDFCD is also a leader in providing timely data to help warn the citizens of the area should floodwaters exceed the carrying capacity of these structures. They work closely with the National Weather Service, the media and local private meteorologists to assure the best information available reaches the public.

To learn more about the Urban Drainage and Flood Control District and their weather information system, visit:

http://www.udfcd.org and http://alert.udfcd.org

While you can link from these sites to many other weather and water-rich websites, the unique feature of this site is the access to both recent and historic precipitation data from Ward in Boulder County down to Elbert in Elbert County. Well over 100 rain gauges now communicate in real time to help the district track rain storms across the area that could produce flooding. There are also a growing number of complete weather stations reporting temperatures, humidity and wind conditions, so if you want to keep track of weather conditions in the Denver area and surrounding counties, this is a great place to go.

Note: If you have a favorite website for climate, weather, agriculture and water information pertinent to Colorado, let us know and we'll take a look.



The Urban Drainage and Flood Control District encompasses Denver, it's suburbs, and outlying areas in adjacent counties as shown here. There are currently 16 complete weather stations, dozens of stream gauges, and over 100 automated raingauges constantly monitoring the hydrology of the region.

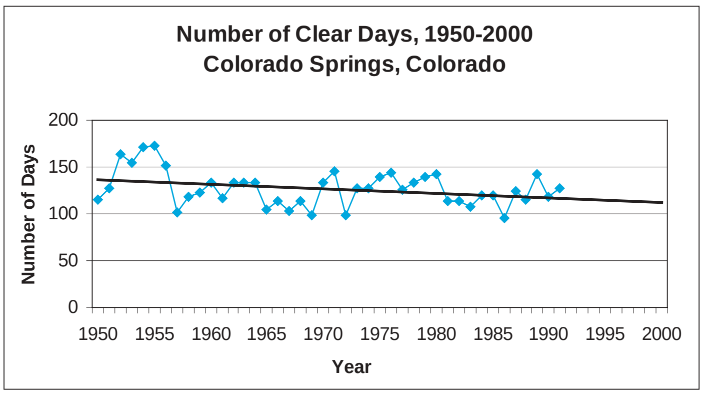
A Time for Time Series – Cloudiness

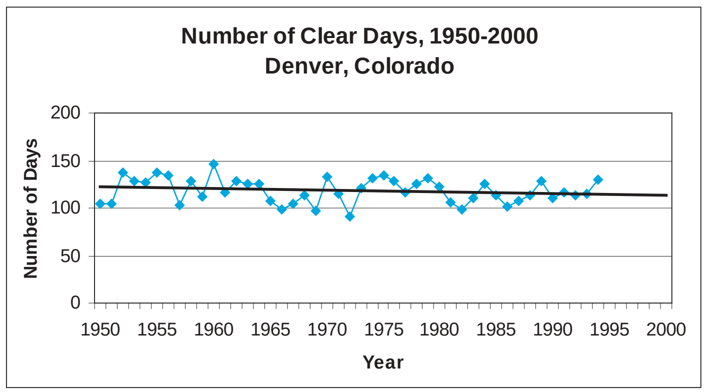
Nolan J. Doesken

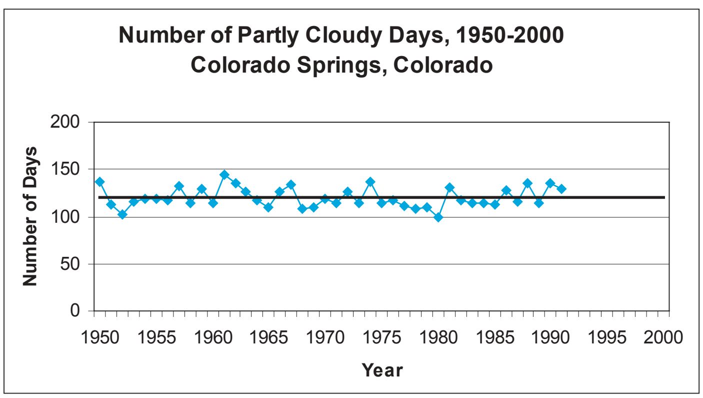
Several years ago, after a period of wet years in Colorado in the 1980s, we looked at cloudiness records from a few airport weather stations in Colorado and Wyoming. The data indicated a significant increase in cloudiness in Colorado over the previous few decades. In fact, the trend was so pronounced that it looked like we were on our way to being like Cleveland, Ohio, or Seattle, Washington, in just a few decades. Now that several more years have passed, has the trend continued, or has the recent dry weather aimed us back to the days of Colorado sunshine?

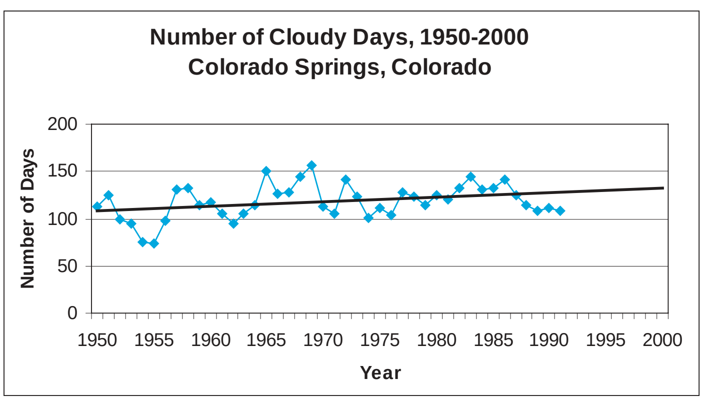
To try to answer this question, we pulled out monthly data for three Colorado airports: Denver, Colorado Springs and Grand Junction. For many years, airport weather observers have visually assessed sky conditions every hour and determined what fraction of the sky was covered by clouds. If, over the course of the day, the sky cover was 0 to 30%, the day was considered to be “Clear.” If sky cover was 80% or greater, averaged over the time from sunrise to sunset, the day was considered “Cloudy.” Anything in between was considered “Partly Cloudy.”

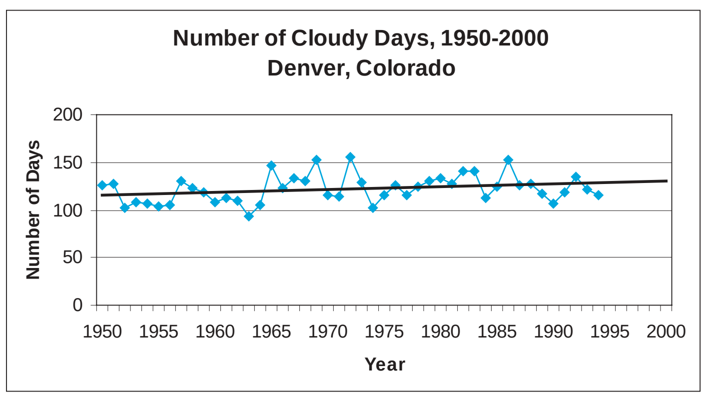
Going back through the records, we simply added









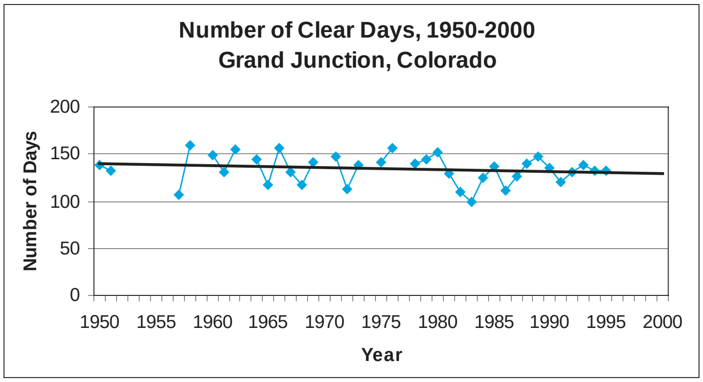


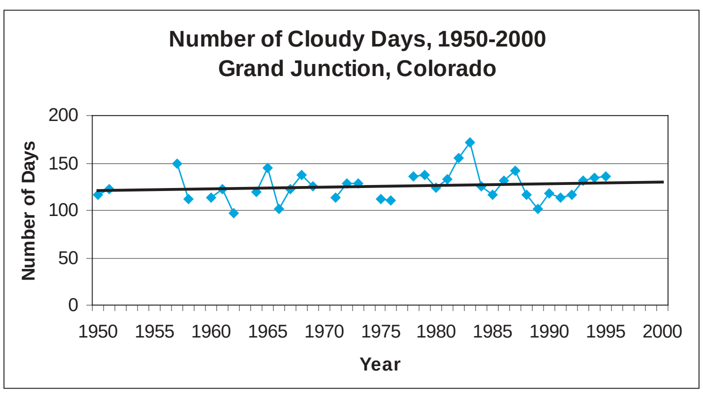
up the clear, partly cloudy and cloudy days each month and each year since these consistent records began around 1950. The results are shown here for Colorado Springs, Denver and Grand Junction.

Analysis suggests that there has been an upward trend in cloudy days and a downward trend in clear days at each of these weather stations since 1950. Partly cloudy days have varied from year to year but with no net trend. On closer examination, however, the severe drought of the early 1950s (1952-1956), and the generous sunshine that accompanied that drought especially along the Colorado Front Range, were responsible for most of the apparent trend. Remove those 5 years from the early part of the record, and no real trend remains. Recent years have been sunnier than the 1980s so the upward trends in cloudiness are not as dramatic as our 1980s analyses indicated.

But something isn't right about these graphs? Why aren't they complete through 1999? It turns out that a fundamental change took place in how airport weather observations are taken. Beginning in the 1990s, automation replaced visual human assessment of sky cover. Consistent historical records of sky cover ended and new procedures using ground-based laser technology and space-based satellite imagery took over. Eventually, these technologies may give us long-term time series, but for now, the record is temporarily broken and we cannot compare the most recent years with earlier records. That means we really can't answer our important questions about current cloudiness trends with the data we have. Bummer!!

But don't give up. We have some other tricks up our sleeves that may help us. Next issue, we'll look at trends in observed solar energy as measured by a network of pyranometers. The results should be interesting.





For Teachers – Learning About Hail

Nolan J. Doesken

Hail is one of those strange phenomenon that nature throws at us from time to it. On first glance, it doesn't really seem to have any good purpose, and can be incredibly devastating. When is the last time a hailstorm helped your garden or improved the appearance of your car?

If you've lived in Colorado all your life, particularly east of the mountains, you are accustomed to hail. Many storms are brief and harmless, but some get downright nasty. Practically every year we hear of areas of eastern Colorado pummeled by stones the size of baseballs or larger, and every year thousands of acres of crops are damaged or totally destroyed. Occasionally, livestock are killed. Throughout history, many people have been injured. Back in 1979, an infant was killed in Fort Collins when struck by a giant hailstone.

Some of us are so accustomed to hail that we scarcely notice that Colorado is near the center of the hail maximum of North America. Most locations in the U.S. rarely see more than 2 or 3 hailstorms per year, even in stormy places like the Southeast and Midwest. But in eastern Colorado, some areas average more than 7 days with hail per year. Some years bring many more. Why is Colorado so "lucky?" The combination of high altitude, the Rocky Mountain barrier, and the often-present boundary between very dry air from the desert Southwest and humid air to our east and southeast help makes Colorado an ideal hail storm generator.

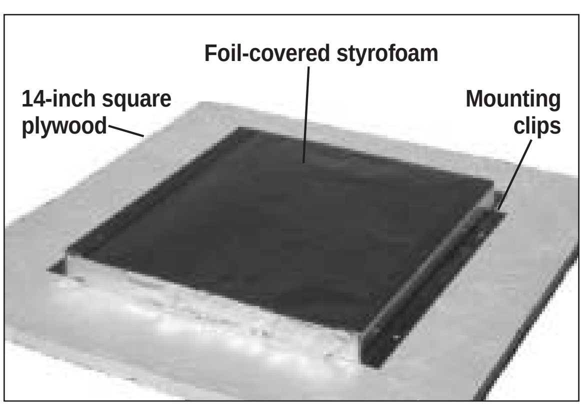
Instead of crying about it, we might as well take what we've got and make the best of it. Hail, believe it or not, is a great topic for school. Not only does the process that allows hailstones to grow layer by layer in artistic forms before crashing to the ground fascinate our children, it is also an exciting topic to draw students attention to other related fields. It's also a topic that can stir up lively conversation at home around the dinner table.

Ask any child from eastern Colorado if they've ever seen hail, and you better be ready to sit down and listen to their story. The impression that hail makes on the psyche of the young child is quite remarkable, so we might as well put it to use.

In an earlier issue, we mentioned our project, the Colorado Collaborative Rain and Hail Study (CoCoRaHS). Very low cost instruments (see caption and photo, bottom left) make an excellent scientific instrument for you and your class to study hail. You can make just enough to have a couple at your school, or you can make one or more for each of your students to take home. Once you're set up, it takes about two minutes to make each hail pad at a cost of about 75 cents.

When hail does come, and it almost always does (have another plan up your sleeve, just in case it doesn't), you will have a great opportunity to do a special project with your class. The hail pads allow you to count quite accurately the number and size of hailstones. If you are able to put out several hail pads in different locations, you will be able to examine how hail varied across your community. Almost always the hail stone characteristics are different from one part of town to another, even in small towns.

Low cost materials can be used to build a hail pad – a piece of open-core styrofoam from a craft store covered with extra-heavy-duty aluminum foil and mounted with clips on a 14-inch square piece of plywood.



A "used" hail pad showing indentations from hail stones. Wind direction is also evident from the marks from the stones.

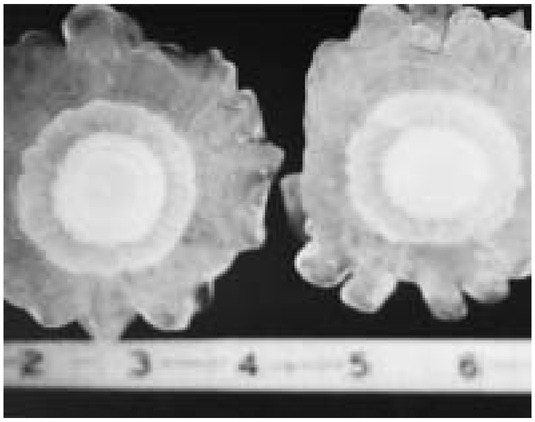
Have your students count the dents on each hail pad, and then make graphs together showing the number of stones in different size categories. Then look at the hail pads and talk about the process by which thunderstorms produce hail. It is so much easier to have their listening ears when your students have just helped measure and count the stones themselves. Also, if you can catch and save any stones in a freezer, it is fascinating to cut them in half and examine their growth pattern. Compare these to tree rings, if you wish.

If you have time, ask a local insurance agent or claims adjuster to come to your class and talk about hail damage in your area. You can show him or her your hail pads and discuss the different-sized stones and the types of damage they can do.

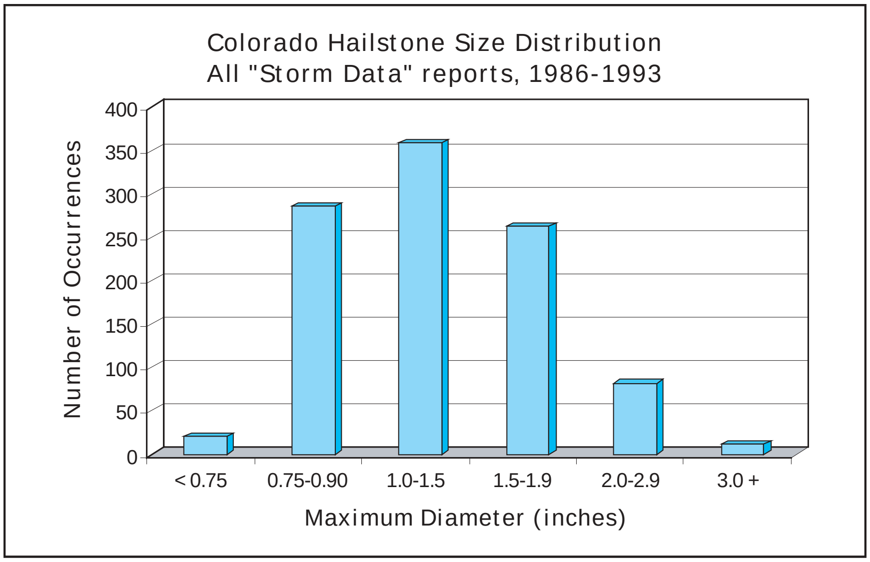
Finally, it is good to talk about what you can do about hail and the damage it can do. So far, we've been unable to get rid of hail, although some Colorado farmers are using a type of acoustic canon that shoots sound waves at approaching storms. Cloud seeding with silver iodide and other types of crystals has also been attempted with mixed success. Some farmers buy or lease land far away from their primary farm in order to spread the risk of hail. Finally, many of us just pay money for insurance so that if we do get wiped out, which happens from time to time, we will be reimbursed for a portion of our loses.

When should you do your studies? Fall and winter is not the time. Get set up in March or April and be ready when one of the storms hits in spring. Try to have as many of your students as possible equipped with hail pads so that when a storm hits you will have something to talk about, even if it doesn't happen during school hours. Have them bring in their hail pads, or have friends or relatives help. This is a good way to talk about maps, too, and a super opportunity to learn how to map and graph data. Write a report. And send it to us here at CCC. We would love to hear from you.

By the way, hail is not all bad. It does have an extremely important place in nature. Hail and other forms of ice in the tops of cumulonimbus clouds (thunderheads) are essential in the process of lightning production. And as scary as that is, what would the world be like without lightning? That's a topic for another day.



Cross section of Fort Collins hailstones, July 30, 1979.



Example distribution of maximum stone diameters from nearly 1,000 damaging storms that hit Colorado during the period 1986-1993.

Fort Collins Boy Scouts made and donated over 1,000 hail pads for Summer 2000 rain and hail project.

A Look at the Past – Hot Summers of the 20th Century

Nolan J. Doesken

The spring and summer of 2000 here in Colorado are proving to be toasty warm. It hasn't been the extreme, blistering, egg-on-the-pavement frying "I can't stand it another minute" type of heat. Instead, it has been the nagging, tiring, day after day heat that makes you look forward to autumn leaves, football games, early sunsets and that chilly Colorado evening air.

We've had our share of mild winters and warm springs in recent years. But at our high altitudes here in Colorado, there just aren't many people who complain about warm winters and springs. Summers are a different story. The difference between average summer temperatures and three degrees above average is equivalent to being warm but bearable in an un-airconditioned house or just plain miserable. For the most part, summers in recent years have been near average or even on the cool side. The tomatoes don't ripen, but we stay comfortable.

For the fun of it, we dug back into the record books and computer files here at the Colorado Climate Center to identify some of Colorado's hottest summers during the 20th Century. Here's what we found. Maybe this will bring back a few memories.

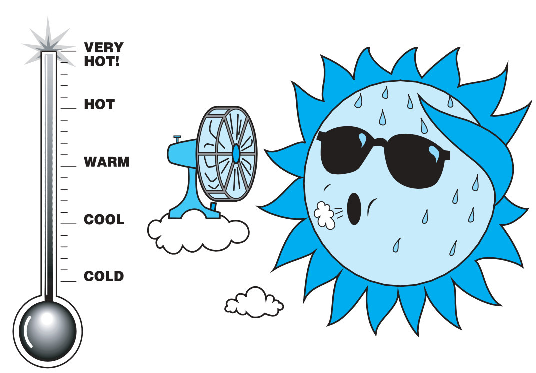
First of all, please know that temperatures in the summer are quite stable from year to year. While January monthly temperatures might be 8 degrees Fahrenheit above average one year, the next year they could just as easily be 8 degrees below average. For summer months, however, temperatures averaged over a month or longer are usually within about 3°F of the long-term average and often within just a degree or two. The difference between an unusually hot summer and a cool one is only a few degrees, but your body knows it.

Based on statewide average temperatures for the 3-month June through August time period, a few summers have stood out among the crowd for their heat here in Colorado. In chronological order, here are some of the warmest ones we found. Not surprisingly, the hottest summers tended to occur in years that were much drier than average over large portions of the state.

In the past two decades there have been some hot summer months here and there. June 1981 was very hot and August 1983 was miserable. June of 1990 was uncomfortably warm as was June 1994. August 1995 was about as hot as it gets for late summer, and July 1998 was also up there. But overall, sustained summer heat has not been a problem in Colorado since the summer of 1980.

Among all summers in the 20th Century, the summer of 1934 remains on top of the list of hot summers in Colorado. Even before that summer began, each of the preceding 12 months had been warmer than average across the state, and precipitation deficits were profound. June 1934 was plenty hot across Colorado, especially east of the mountains where most stations ended the month 4 to 6°F above their long-term average. July, however, was the killer. For 17 consecutive days in mid July, temperatures approached or exceeded the century mark on the plains. In southeastern Colorado, readings approached 110°F. Even in the higher mountains, the mercury soared into the upper 80s to mid 90s at locations such as Fraser, Dillon and Steamboat Springs. The only good news was the low humidity air that covered the region allowed nighttime temperatures to drop quickly, so there was some relief. The heat continued into August with seemingly endless days with temperatures of 100 degrees or higher out on the plains. Cheyenne Wells, for example, recorded 21 days in July 1934 with temperatures at or above 100°F with another 9 days during the first half of August. Imagine the rejoicing when the cold front arrived on the 20th of August which kept the mercury below 80 degrees for four days. People must have frozen on August 24th in eastern Colorado when temperatures stayed in the 60s all day.

The summer of 2000, as hot as it seems, will fall short of 1934 and several other summers of the 20th Century. For those of you who have been suffering, please know, it could be worse. And for those of you who have been comfortable due to air conditioning, please know that someone has had to pay a lot more this year than last to keep you cool.



Climate Data in Use – Cooling Degree Days

Nolan J. Doesken

Cooling degree days ???? What in the world is that? If I didn't already know, I'm sure I couldn't even make a good guess.

The concept of cooling degree days was developed several decades ago as a simple method for relating summer temperatures to energy requirements for operating air conditioning systems. This is how it works. For each and every day, the mean temperature is computed by taking the maximum for the day, the minimum temperature, adding them up and dividing by two.

For example if the high temperature on a warm summer day in Denver was 89°F and the low that morning was 57°F, the mean temperature is
(89 + 57) ÷ 2 = 146 ÷ 2 = 73°F.

The assumption was made long ago that if the mean temperature for a day exceeded 65 degrees F, some air conditioning would be required to maintain indoor temperatures at a uniform and comfortable level. Therefore, for each day with a mean daily temperature greater than 65 degrees F, the difference between the mean and 65 is the number of cooling degrees for that day.

In our example above,
73 - 65 (base temperature) = 8 cooling degrees

Now, depending on how a building is built, how well it is insulated and shaded, what goes on inside that building, and how cool the temperature needs to be maintained, the base temperature may vary from 65. Engineers familiar with the performance characteristic of a particular building may use a different base temperature. But for our examples here, we will stick to 65 degrees F.

Let's give two more examples:

On the same day that Denver had a mean daily temperature of 73°F, up in Breckenridge the high was only 73°F and the low was 45°F.

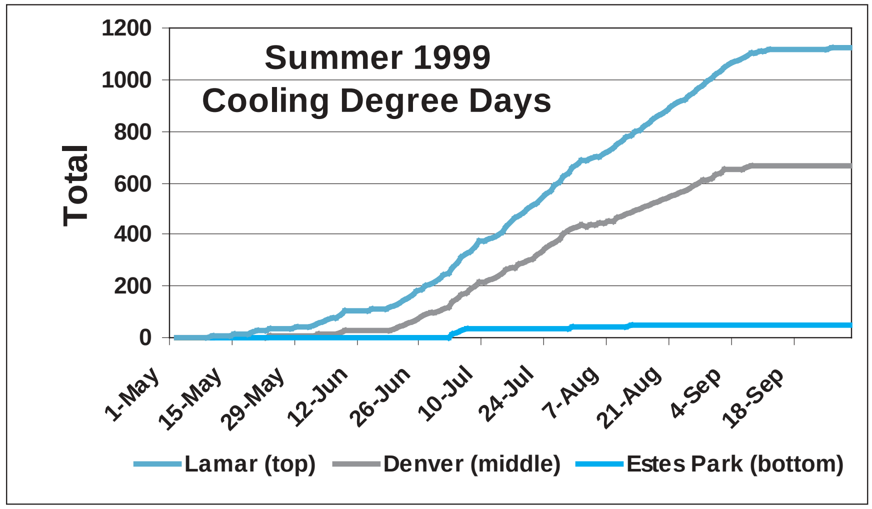
(73 + 45) ÷ 2 = 59 (mean daily temperature)

Since 59 degrees is less than the base temperature of 65 degrees, there would be NO cooling degrees for that day, and presumably, no need for air conditioning.

Meanwhile, down in Phoenix, Arizona on that same day the high was 107°F and the low was 83°F. Therefore, (107 + 83) ÷ 2 = 95 and 95 - 65 = 30. That means 30 cooling degrees for that day in Phoenix which is nearly 4 times greater than in Denver.

Cooling degrees are computed each day and then accumulated by week, month or season. Accumulated "cooling degree day" totals are then compared to energy consumption for air conditioning and ventilation costs. Relationships between cooling degree days and energy use are then developed.

Who pays attention to "Cooling Degree Days?" Until the last 15-20 years, only a few people here in Colorado had ever heard of them. Few homes were air conditioned, and the amount of energy used for cooling homes and businesses was small. This has changed. Now many of the newer homes and more older homes along the Front Range and at lower elevations throughout the state have air conditioning. A large number of businesses use air conditioning extensively, and the fraction of annual energy costs used for summer cooling continues to rise. Providers of electricity, for example, look at cooling degree days from past years to create models to estimate future energy demands. School districts, large businesses, and anyone interested in understanding and managing energy use and costs can make good use of cooling degree day data. When used in combination with weather forecasts, they can also be used to project future energy consumption. If energy costs continue to rise, more and more homeowners will also begin to look more closely at degree day data.

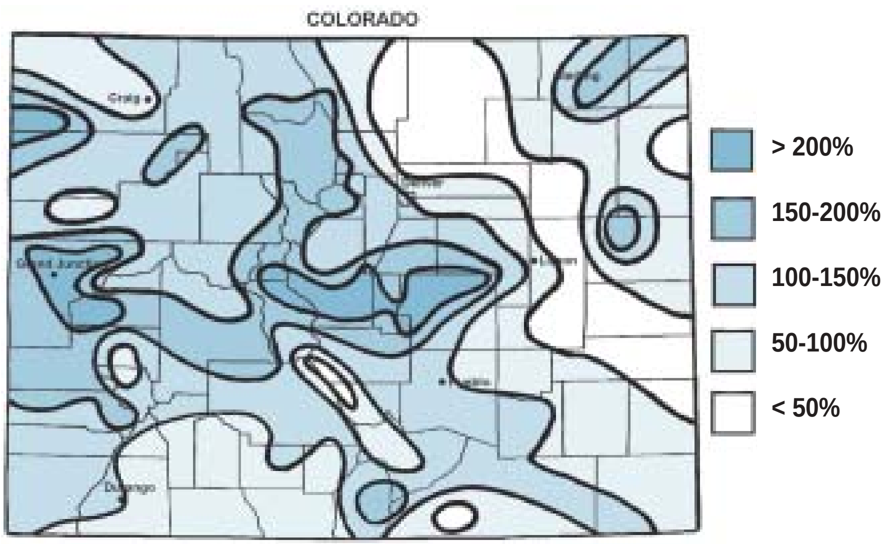


Let's look at a recent example for two locations in Colorado. Let's compare Denver and Evergreen for the summer of 1999 with the beginning of the summer of 2000. 1999 was relatively cool, while 2000 got off to a warmer start.

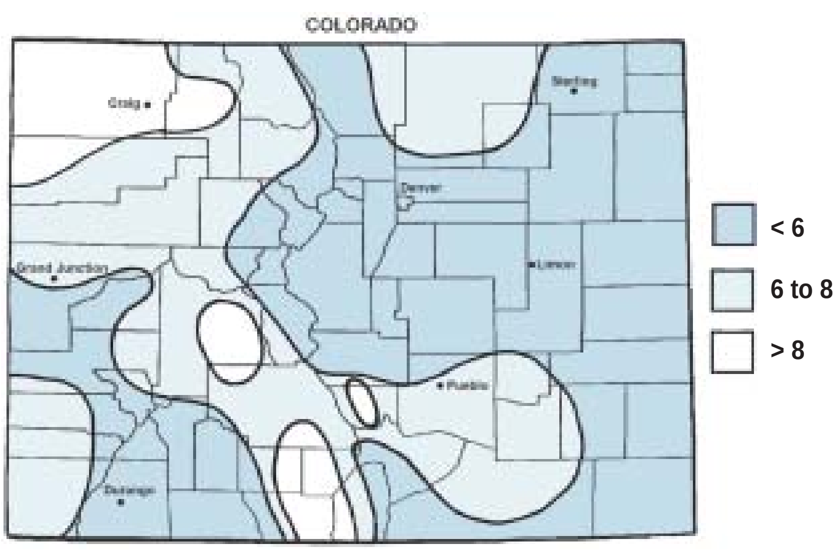
In addition to cooling degree days, other "Degree Day" computations are used for other applications. Heating degree days are computed in the winter season to help track energy consumption and costs for heating. A whole variety of definitions exist for growing degree days that relate observed daily high and low temperatures to units that can be added day by day to track crop growth and development. We won't get into these details now, but I bet you can now guess how these other types of degree days are computed. They are simple but effective.

Colorado Climate in Review

In each issue of Colorado Climate we provide maps, graphs and brief narratives describing the interesting and unique aspects of each month's climate. Since this is now a quarterly publication, it is inevitable that these monthly reviews will seem distant and out of date. As I describe January 2000 you may care less and be much more interested in January 2001. I understand, but keep in mind that these brief synopses are really intended to serve as historical documentation that we may turn to years from now when we need to recall past climate conditions and events.
Therefore, in this issue we will be including two extra months (January through May), and next issue we will include June through September. Thereafter, we won't seem quite so far behind.



January 2000 precipitation as a percent of 1961-1990 average.



January 2000 temperature departures from 1961-1990 average, degrees F.

January 2000

Climate in perspective

Unusually mild air from over the Pacific Ocean dominated January weather patterns in Colorado. Temperatures were consistently above average, and significant amounts of precipitation fell in the form of rain over western Colorado, all the way up to elevations of 8,000 feet. Continental polar air was a rarity, and most of eastern Colorado experienced no subzero temperatures all month. As an example, Grand Junction reported a high of 57°F and a low of 44 on January 17, a whopping 27 degrees above average for that day. That is more like a winter day in San Francisco than one in Colorado.

Precipitation

Several storm systems brought moisture to Colorado. Most of the northern and central mountains and western valleys were wetter than average for the month, but eastern and extreme southern Colorado remained dry. Portions of central Colorado received more than double the January average. The moisture was greatly appreciated, but the rain and wet snow was much different than Colorado's typical January fluffy powder.

Temperature

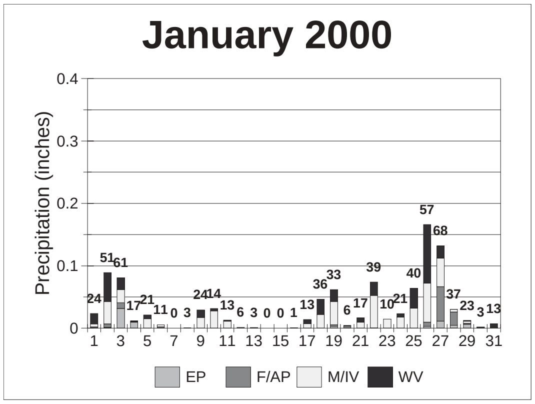
January temperature ended up much warmer than average statewide. Most areas were 5 to 8 degrees F above average but local valleys near Rangely, Gunnison and Westcliffe were more than nine degrees above the long-term mean.

January Daily Highlights

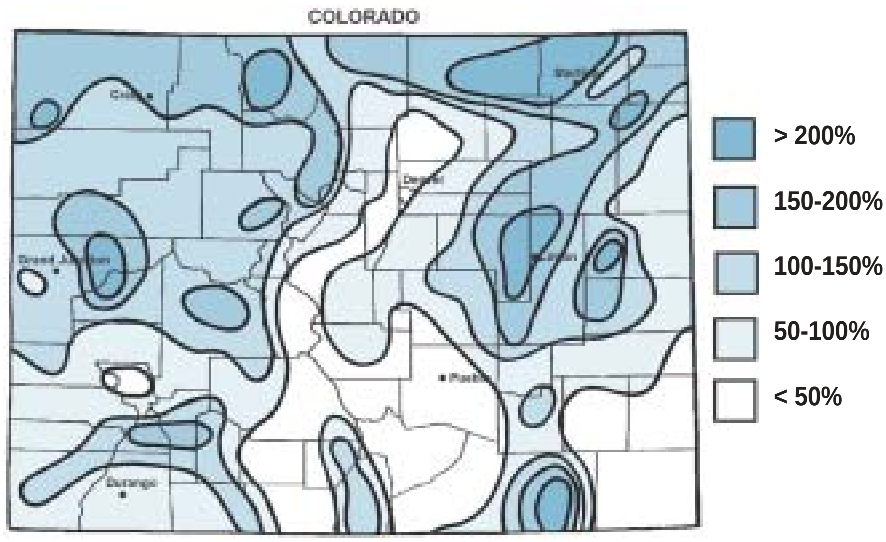
1-3 Mild temperatures gave way to cloudy, colder weather with widespread light to moderate snow. Cedaredge reported 11" of new snow, their greatest of the season. A skiff of snow made it to eastern Colorado on the 3rd. However, a very localized blizzard near Joes

January 2000 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Bonham Reservoir	1.30"	Jan. 3
Precipitation (total):	Crested Butte	3.76"	
	& Marvine Ranch	3.76"	
High Temperature:	Trinidad Airport	73°F	Jan. 16
Low Temperature:	Antero Reservoir	-38°F	Jan. 29



Statewide Average Daily Precipitation graph(s) (above and throughout this article) shows relative amounts of precipitation for each region. Label on each column inidcates percent of stations with measurable precipitation for each day.



February 2000 precipitation as a percent of 1961-1990 average.

February 2000 temperature departures from 1961-1900 average, degrees F.

dumped nearly a foot. Very cold temperatures gripped the mountains.

4-10 Chilly with periods of light snow in the mountains. Significant accumulations were reported 9-10th in the northern and central mountains.

11-15 Mostly dry and mild. Strong winds accompanied mountain snow showers on the 12th. Warm temperatures with readings in the 60s were common on the plains.

16-23 Mild, moist Pacific air continued to move into Colorado from the west with periods of mountain snows and valley rains. Dry east of the mountains. Remarkably warm mid January temperatures were observed 16-19th with a snow line of at least 8000 feet. One inch of rain fell near Steamboat Springs 17-19th. A bit cooler 20-23rd with mountain snows.

24-28 A major storm system developed beginning as mixed rain and snow 25-26th. Moderate snows fell along the Front Range on the 27th. Colorado Springs totaled 6 inches.

29-31 Mostly sunny and seasonably cold statewide. With clear skies, Antero Reservoir reported a low of -38°F on the 29th, the coldest in the state for the month.

February 2000 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Bonham Reservoir	1.90"	Feb. 15
Precipitation (total):	Wolf Creek Pass	5.62"	
High Temperature:	La Junta &	77°F	Feb. 9
	La Junta 20S	77°F	Feb. 9
Low Temperature:	Antero Reservoir	-30°F	Feb. 1

February 2000

Climate in Perspective

Arctic air was once again absent over Colorado. Mild Pacific air dominated February weather patterns. Prevailing westerly winds with embedded disturbances provided lots of cloud cover west of the Continental Divide. Meanwhile, the Front Range and eastern plains experienced mild temperatures with occasionally strong downslope winds. Thunderstorms, more reminiscent of April or May, rumbled across eastern Colorado in late February, and much of the February precipitation on the plains fell as rain.

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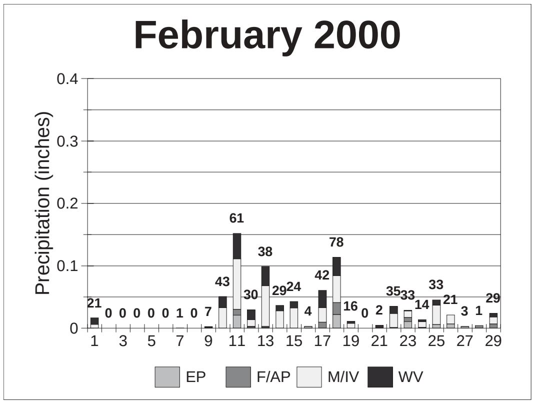


Precipitation

February precipitation totals were above average over most of western Colorado. Portions of northeastern and east central Colorado also ended up on the wet side with some areas near Limon, Walden and south of LaJunta reporting more than 200 percent of average. February averages are very low, of course, east of the mountains. The greatest accumulations were observed on the Grand Mesa east of Grand Junction. Bonham Reservoir, for example, totaled 5.55" of water content for the month. Meanwhile, little or no precipitation fell all month in the San Luis Valley and over extreme southeastern Colorado.

Temperature

February temperatures were again above average statewide with most areas 5-8°F above average for the month. Nighttime temperatures were especially mild. For example, at Greeley, the long-term average daily minimum temperature in February is 19.5°F. This year, the coldest temperature all month was 15 and only 5 days dropped below 20°F, Grand Junction's low for the month was only 19°F. Temperatures were colder in the mountains, but several areas went all month without dropping below zero.

February Daily Highlights

1-8 Sunny to partly cloudy and dry statewide with very warm temperatures. Pueblo hit 79°F on the 2nd and 74°F on the 8th. A cold front brought no precipitation but somewhat cooler temperatures 4-5th.

9-18 Pacific storm systems moved in one after another. Moderate to heavy precipitation fell on and off through the period, heaviest in the northwest quarter of the state and over the northern slopes of the Colorado's southwestern mountains. Hayden received over 2 inches of water from several days of mushy wet snows. Higher mountains got more than 4 inches of water content. Very little of the moisture crossed the mountains into eastern Colorado, but a few inches of snow accumulated on the 11th and again 17-18th from the eastern foothills out toward Kansas. Periods of strong winds were also observed.

19-21 Sunny on the 19th. Increasing clouds from the west 20-21st with high temperatures near 70°F east of the mountains.

22 Warm but unsettled. Thunderstorms with hail developed over northeastern Colorado prompting an unusual severe thunderstorm warning for this time of year in Weld County. Some snow fell in the mountains.

23-25 Warm temperatures continued. A deep low pressure area developed over eastern Colorado late on the 24th, followed by a burst of wind-driven snow early on the 25th in east-central Colorado. This storm brought sharply colder temperatures to the mountains and strong winds across all of eastern Colorado on the 25th.

26-29 Sunny on the 26th. Becoming partly cloudy with mountain snow showers developing on the 28th continuing on the 29th.

March 2000

Climate in perspective

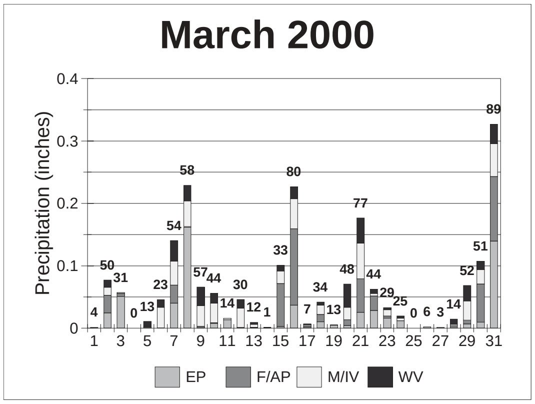
Weather patterns shifted in March. The trend toward warmer than average temperatures continued, but the storm track changed bringing more storms to southern Colorado and much-needed snow to the southwestern mountains. Storm motions slowed, as they often do in spring, resulting in more widespread and longer-lasting precipitation events. Five major storm systems brought significant moisture to the state, each about six days apart. Again, there was no sign of Arctic air masses in Colorado all month. While precipitation was abundant, much in the form of snow as one would expect in March, warm soil and air temperatures hastened snow melt. Travel conditions remained favorable, but low elevation snowpack accumulation was minimal.

Precipitation

Large portions of Colorado witnessed wet weather for the month of March. Practically all of the southeastern half of the state received more than 200% of the average for March, with local areas exceeding 3 or even 4 times the average. Del Norte, in the San Luis Valley measured precipitation on 13 days and totaled more than 3" for the month, 400% of average. Still,

March 2000 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Sedgwick 5S	1.81"	Mar. 8
Precipitation (total):	Wolf Creek Pass	6.99"	
High Temperature:	John Martin Dam	87°F	Mar. 28
Low Temperature:	Taylor Park	-19°F	Mar. 11



there were some dry areas including northwestern Colorado and north central areas near the Wyoming border. Northern Larimer County, for example, received barely half of average.

Temperature

With no outbreaks of polar air, all of the state ended up above average again for the 6th consecutive month. Northern Colorado and most of the mountain valleys were 2 to 6 degrees above average while lower elevation areas of southern Colorado were generally 1 to 3 degrees above. The lack of cold nighttime temperatures resulted in low heating bills for Colorado residents. The coldest temperature all month at the weather station remaining at Denver Stapleton was 24°F. By comparison, the average minimum temperature over the past several decades has been 20.5°F.

March Daily Highlights

1-2 March got off to a wet start with wet snow across southern and eastern Colorado. Some parts of the southeast Colorado got more than 0.50" of moisture.

3-8 Fog early on the 3rd gave way to sunshine and warm temperatures. Increasing clouds 5-6th as the next storm system approached. Rain and mountain snow began on the 5th and spread eastward. The majority of the moisture again fell over southern counties. Thunderstorms rumbled over eastern Colorado on the 7th with some reports of hail. Burlington picked up 2.42" of rain and hail. Strong winds developed as colder air moved in. Gusts exceeded 70 mph in the eastern foothills early on the 8th.

9-13 Partly cloudy, breezy and chilly with mountain snow showers, especially early on the 12th. A little more wet snow fell over southeastern Colorado on the 10th.

14-16 Increasing clouds. A major "upslope" spring snowstorm spread snow from eastern New Mexico to southern Wyoming on the 15th. 8 to 20 inches of wet snow were measured at many locations along the Front Range, although much of the snow melted as it landed. Canon City measured 1.13" of moisture, and Boulder recorded. 1.19". Precipitation totals on the eastern plains were much lower.

17-19 Generally sunny and seasonal. Dry, except for a few showers in southeast counties on the 18th.

20-23 Another storm moved into southwestern Colorado on the 20th. 1.70" of much-needed moisture fell at Durango. Again, the southern portion of the state took the brunt of the storm, with showers continuing near Lamar through the 23rd.

24-27 Dry and pleasant but with some springtime convective clouds and gusty winds.

28-31 Colder and unsettled with widespread cold rains and snow developing by the 30th continuing on the 31st. The heaviest precipitation from this

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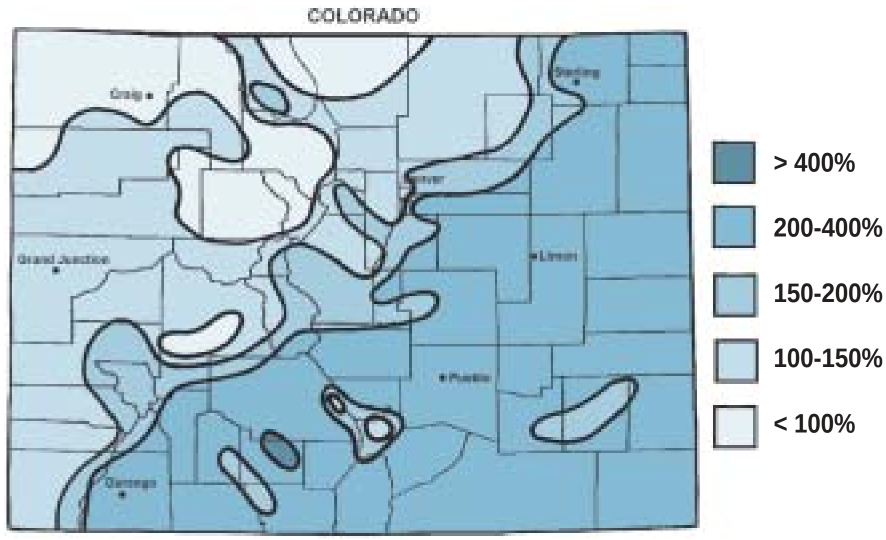
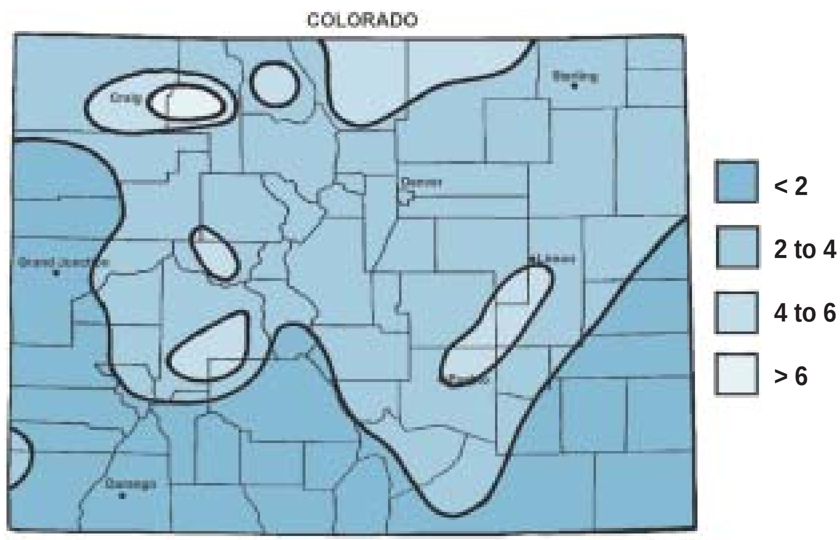
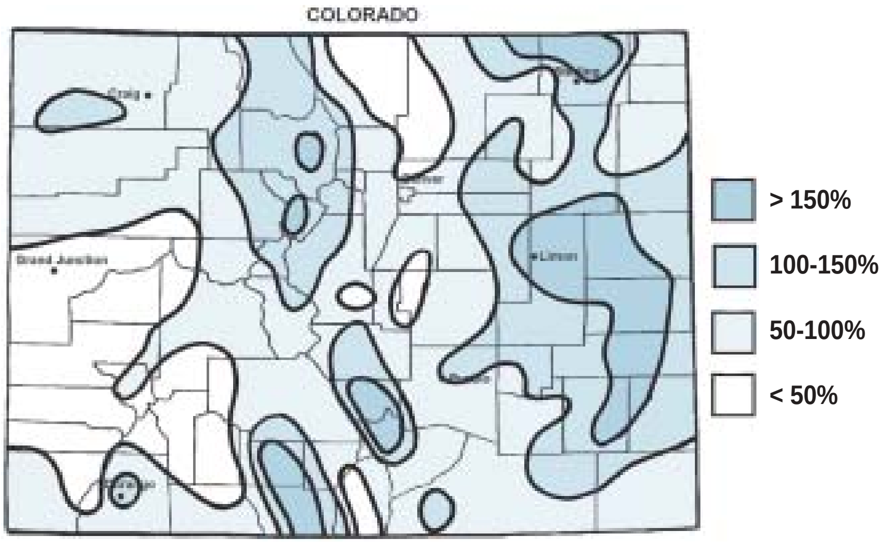


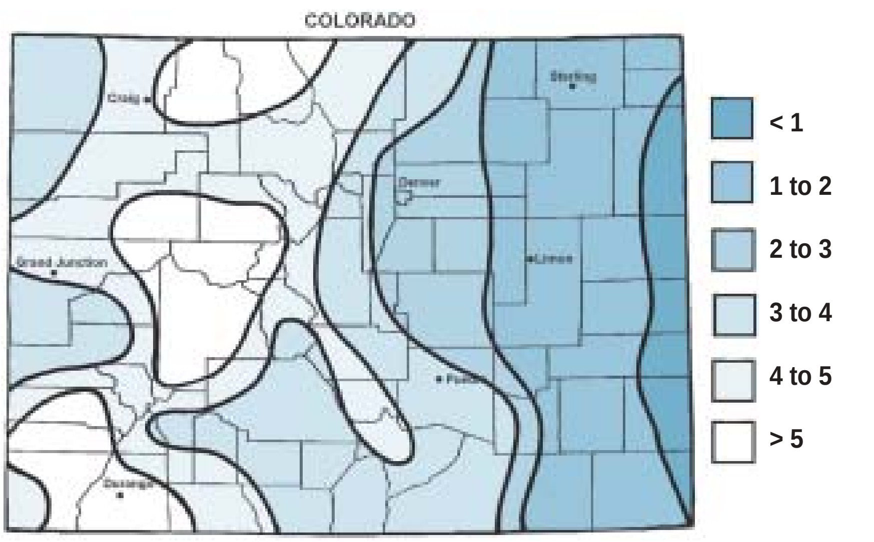
March 2000 precipitation as a percent of 1961-1990 average.



March 2000 temperature departures from 1961-1990 average, degrees F.



April 2000 precipitation as a percent of 1961-1990 average.



April 2000 temperature departures from 1961-1990 average, degrees F.

April 2000

Climate in Perspective

Several spring storms crossed the state, and some brought substantial precipitation to selected areas. Rain, snow, thunderstorms, hail, strong winds, and large temperature variations were all a part of April weather. While that sounds extreme, it was fairly typical spring weather. The unusual part of April was the persistent warm temperatures, especially in the mountains and western valleys. This resulted in an early start to the spring snowmelt in the high mountains.

Precipitation

Precipitation for the month as a whole was above average over much of east central Colorado, the San Luis Valley and significant portions of Colorado's northern and central mountains. Storms which ended on the 23rd and 30th were responsible for these wet areas. The remainder of the state was quite dry. Much of west central and southwest Colorado were extremely dry with locally less than 25% of average in some locations. Portions of Larimer, Weld and El Paso Counties along the Front Range also ended up very dry.

Temperature

It was another very warm month for Colorado with all areas of the state warmer than the 1961-1990 April average. Conditions for the month as a whole ranged from just one degree F above average near the Kansas border to as much as 5 to 7 degrees above average in western parts of the state.

Daily Highlights

1-3 Cold with scattered snow showers 1-2nd. Clearing on the 3rd.

4-9 Warm, dry and windy with some gusts over 60 mph on the 5th and 7th east of the Continental Divide. A few sprinkles east of the mountains 6-7th and turning cooler.

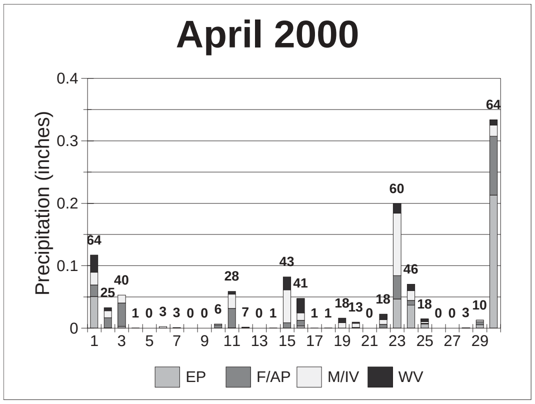
10-13 A period of cold rain and wet snow late on the 10th with most precipitation falling in central Colorado. Antero Reservoir, normally a dry location, received the most with 0.76" of moisture from 6.0 inches of snowfall. Warmer weather quickly returned after that with more melting snow in the mountains.

14-16 Windy and very warm east of the mountains on the 14th. Las Animas reached 90°F. Temperatures then dropped sharply late on the 14th, and snow developed in the mountains and along the Front Range on the 15th with high temperatures only in the 30s - the coldest day of the month

storm fell east of the mountains, with a few areas of southeastern Colorado reporting more than one inch. The snow melted quickly, and roads remained passable. This moisture was very beneficial to dryland farmers whose fields and rangeland had dried prematurely due to the very warm winter temperatures and minimal snow cover.

April 2000 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Vail	2.30"	Apr. 23
Precipitation (total):	Winter Park	3.82"	
High Temperature:	La Junta &	92°F	Apr.19
	Holly	92°F	Apr.19
Low Temperature:	Hohnholz Ranch	-3°F	Apr. 3



for eastern Colorado. Grand Lake reported 7" of new snow, while Boulder added 4". Clearing and warmer on the 16th.

17-19 Sunny, warm and pleasant on the 17th. Some convective clouds on the 18the and very warm with some low 90s reported in southeast Colorado. Windy and cooler on the 19th with a few showers over northwest Colorado.

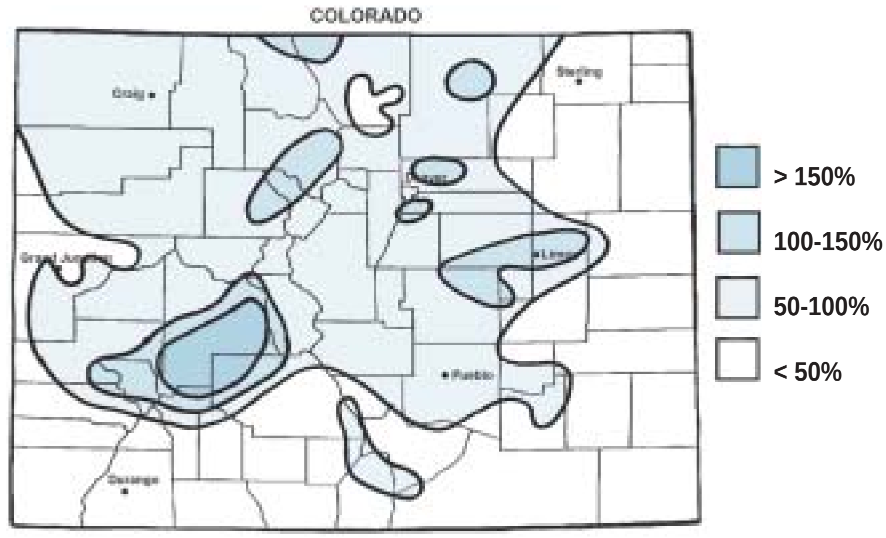
20-24 Sunny and pleasant on the 20th with diminishing winds. Warmer with increasing cloudiness on the 21st. Heavy snow began falling in the northern and central mountains on the 22nd and spilled over to the Front Range. Ten inches of wet snow were measured early on the 24th at Dillon, Breckenridge, Grand Lake. Vail reported 2.30"of moisture from the wet snow. Estes Park and Allenspark also reported substantial moisture. Thunderstorms with local hail developed east of the mountains 22-24th. More than one inch of rain fell at Lamar and north of New Raymer.

25-28 Sunny, dry and warm statewide. The mountain snowmelt accelerated, although temperatures in the mountains dropped below freezing at night.

29-30 Cloudy and cooler in western Colorado with a few scattered showers and mountains snows. Very warm and windy east of the mountains. Severe thunderstorms developed on the 29th with some large hail. Rains continued overnight and became widespread with many stations in eastern Colorado reporting at least an inch - the greatest rain of the spring. Chilly and windy on the 30th as the rains moved beyond Colorado.

May 2000 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Briggsdale	2.39"	May 17
Precipitation (total):	Genoa	4.31"	
High Temperature:	La Junta 20S	107°F	May 31
Low Temperature:	Climax	9°F	May 12
	Sargents	9°F	May 12



May 2000 precipitation as a percent of 1961-1990 average.

May 2000 temperature departure from 1961-1990 average, degrees F.

May 2000

Climate in Perspective

May is normally a month of storms and generous precipitation, especially for northern Colorado. This year, storms were few, and warm temperatures meant that mountain snows melted quickly and rivers were running high much of the month. Many locations set new records for the warmest temperatures ever recorded so early in the season.

Precipitation

A few areas in central and northern Colorado received near or slightly above average precipitation. Storms on May 8th and 17th were responsible for these

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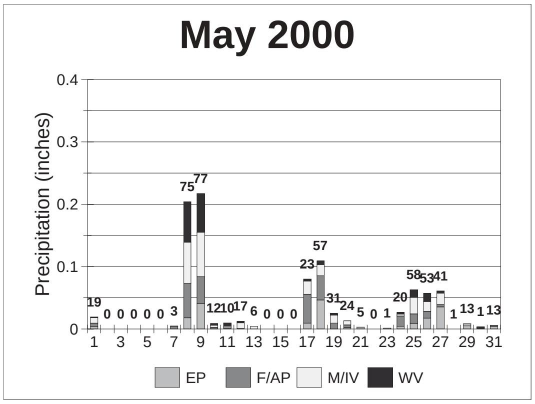


limited wet areas. More than 2.00 inches of rain fell in a short period on the 17th in portions of Adams and Weld counties. Otherwise, May was an unusually dry month with much of southern and eastern Colorado receiving less than half the average. It was one of the driest May's in history over extreme northeastern Colorado.

Temperature

For the 8th month in a row, all of Colorado experienced above average temperatures. There were some cool days, especially during the 2nd week of the month. However, very warm weather early and late in the month more than compensated. For the month as a whole, temperatures ranged form 2-4 degrees F above average east of the mountains to as much as 6-7 degrees above average in parts of western Colorado.

May Daily Highlights

1-6 Mostly sunny, dry and becoming very hot with rapid mountain snowmelt, especially 4-6th. Highs climbed into the 80s and 90s at low elevations with 60s and 70s in the mountains. Several record high temperatures were set 4th and 5th. Fort Collins hit 90°F on the 5th, the earliest 90-degree reading by several weeks.

7-9 Increasing clouds as a major storm system approached. Still quite warm on the 7th. Much cooler on the 8th with widespread precipitation, heaviest from Montrose and Gunnison eastward to Limon. Taylor Park reported nearly an inch of moisture, and several inches of snow fell at high elevations. Skies cleared and temperatures rebounded on the 9th.

10-13 Windy and warm on the 10th with some early morning showers over northern Colorado. Windy, much colder and unsettled 11-12th with some rain and snow showers, especially over the northern and central mountains. A hard freeze hit western Colorado on the 12th but without much damage to fruits. Eastern Colorado had a hard freeze the with temperatures as low as 21°F doing major and widespread damage, especially to winter wheat on the morning of the 13th.

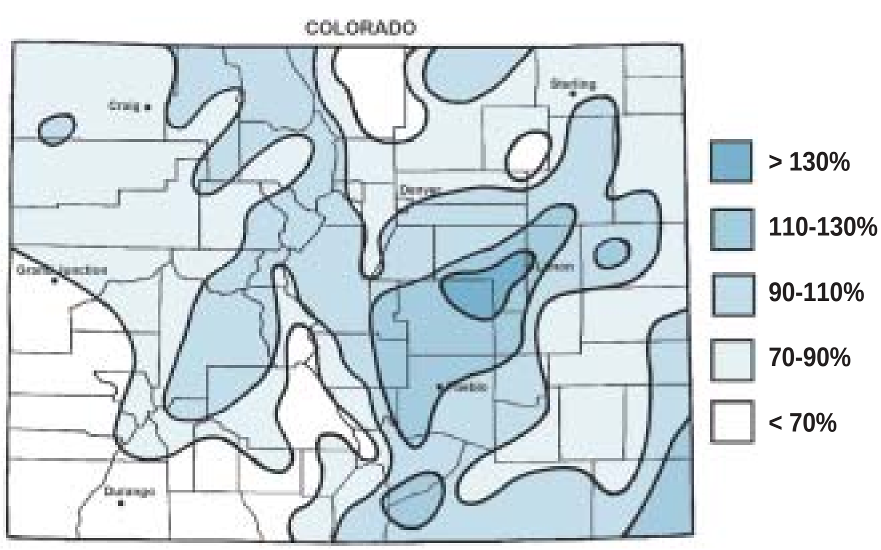
14-16 Partly cloudy, warm and dry with strong southwesterly winds developing on the 16th with some blowing dust in advance of a strong developing low pressure area.

17-18 A deep low pressure area crossed Colorado. Thunderstorms with hail developed early in the morning over northern Colorado and spread eastward during the day. Many funnel clouds were reported later in the day in Washington and Morgan counties. Heavy rains fell in an area from Fort Collins to east of Greeley and southward to east Denver. More than 2.50" fell in a few hours in portions of Weld County. Heavy snows fell near the Wyoming border. Hohnholz Ranch on the Laramie River measured a foot of new snow. The storm exited the state on the 18th, but temperatures remained cold.

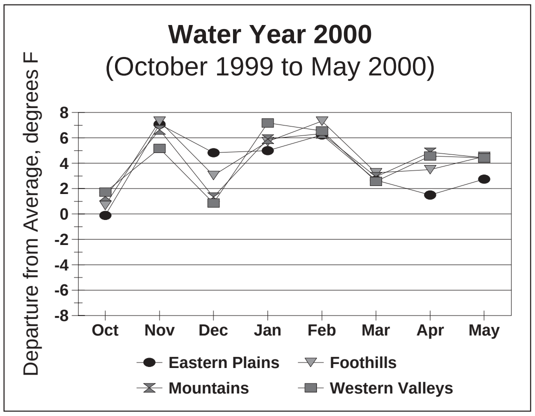
19-23 A few showers lingered on the 19th. Then a warming trend returned with summer-like temperatures by the 23rd. Many areas set new record highs with readings in the 90s. Pueblo hit 100°F on the 23rd.

24-27 Temperatures aloft cooled, and low-level humidity increased providing an opportunity for daily thundershowers to develop. Most showers were light, but some of the storms produced hail and moderate rains. Byers reported 0.84" on the 25th.

28-31 Dry weather with record heat to end the month. Northeastern Colorado experience temperatures in the mid to upper 90s 28-29th, the hottest ever for so early in the season. Southeastern Colorado saw the thermometer surpass the 100°F mark. La Junta reached 106°F on the afternoon of the 30th. Many locations, including



October 1999 through May 2000 Water Year precipitation as a percent of 1961-1990 average.



mountain communities, reported their highest temperatures in recorded history for the month of May. Aspen reached 84°F and Steamboat Springs hit 88 degrees.

Water Year in Review, October 1999 through May 2000

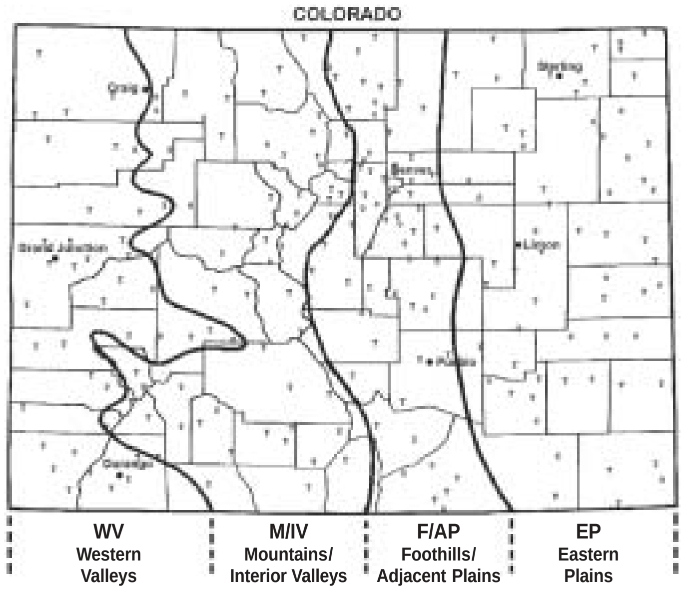
Each month, January through May 2000, has brought above average precipitation to parts of Colorado while leaving other areas dry. Above average temperature all winter and spring have contributed to more evaporation than usual and great demand for irrigation water. While overall precipitation has not been terribly low in most areas, it has seemed even drier due to the evaporation, strong winds, lack of snow cover and the early snowmelt. Precipitation totals as a percent of average for the 2000 water year to date are shown here.

Most of southwestern Colorado has received less than 70% of the average precipitation since October 1, 1999. Very dry conditions are also apparent over northern and extreme northeastern Colorado where spring 2000 has been much drier than average. The danger for fast spreading wildfires will be especially high in these areas. Precipitation totals have been very close to average near the Continental Divide from near Lake City and Gunnison northward to Wyoming. Above average precipitation totals for the first 8 months of the water year are limited to portions of eastern and southeastern Colorado. The wettest area is a band from Pueblo and Colorado Springs northeast to just past Limon where some areas have reported more than 130% of average.

A Look Ahead

Colorado's autumn climate is profoundly different than summer. As we move through September, the familiar cumulus and cumulonimbus clouds (thunderheads) become less and less common, and smaller in stature. The flashes of evening lightning that grab out attention in summer, become rare in the fall. If you see evening lightning, watch it, for you may not see it again until next year. On clear days, the sky is bluer

Colorado Weather Station Map



T = Temperature/Precipitation   0 = Precipitation site only

than in the summer, partly because there is less humidity in the air and, hopefully, less smoke from the western forest fires. Another reason for the bluer skies is the ever-lowering daytime sun angle.

With rapidly decreasing daylength in September and October, colder nights are inevitable. On clear days, the temperatures begin to plummet even before the sun goes down. It is common in valleys for temperatures to drop 20 degrees or more (F) in the first two hours after sunset. Frost comes soon, too. By early September, mountain valleys begin to see frost, and by late September or early October, most of the state has seen the first morning freeze. Of course, the trees remind us of the changing seasons as leaves change color and, before we are really ready, begin dropping to the ground.

Many days are totally clear. September and October traditionally are Colorado's clearest months. But cloudy days come and sometimes linger. While fall rains are infrequent, when storms do come they may last several days and cover most of the State. After our dry spring and summer this year, few would complain. Fallish weather holds on until mid November. After that, it really can't be called fall anymore as nighttime temperatures dip towards zero in the mountains, and snow becomes a common visitor.

Snow can show up anytime in Colorado. From Labor Day on, snow is possible. September snows can be rude and unwelcome, breaking trees whose leaves have not yet begun to show their fall colors. The amazing whiteness of the first autumn snows upon the Rockies make the blue skies appear even bluer. September snows don't stay, though. They visit and

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then return to liquid, moistening the dry soils left from summer. October snows are different.

In many years, early October brings day after day of deep blue skies and bright sunshine. With the intense heat of summer gone, it is a wonderful time to hike, or bike, or finally finish those outdoor projects. For suddenly your chances may be gone. Mid or late October often brings harsh storms. Hunters both welcome and curse these storms. They make tracking game possible, but the sloppy early snows can trap the unprepared and increase their labors. November snows are certain, and with them comes the beginning of the mountain snowpack - the last snow to melt next spring and summer. The 1980s and 90s have brought huge November snows. There have been recent years where November has been the snowiest month of the entire year. Perhaps now it will change back to what we were accustomed to – a big snow now and then, and almost always a snow near Thanksgiving, but otherwise irregular and unpredictable.

Halloween has a long tradition of playing tricks on our youngsters. Everyone remembers the times they nearly froze or had to stay home due to bad weather. In truth, most Halloweens are fine, and the snowy ones are far outnumbered by the pleasant ones. But we always remember the bad ones.

The winds of autumn are light and sweet - carrying the smell of leaves and river bottoms. But do not be caught off guard. Each fall, sometimes in September, often in October, and nearly always in November, storms will sweep in tearing off leaves and occasionally even knocking down trees. (this is generally limited to the downslope wind corridor of the Front Range). These winds announce the change of seasons and the strengthening jet stream. Take notice.

Whatever autumn brings this year, it will fit this pattern and yet it won't. Every year follows the cadence of the annual cycle, but also follows its own drummer. Every year there is something special and unique, yet every year there is something familiar. Make sure that this year you are there to notice. For each day may be the finest day left in the year. Don't miss it!

Some Folklore

Nolan J. Doesken

As summer again draws to a close, our attention begins to turn toward cooler weather and the winter ahead. What do we need to prepare for? Will this finally be a severely cold winter?

These same questions have been asked for generations – probably all the way back to the beginning of civilization and communication. So it should come as no surprise that there is an incredible wealth of weather folklore using all types of signs and signals to try to peek ahead toward the approaching winter.

Much weather folklore about the winter ahead originates in Europe and the eastern U.S. A favorite forecasting tool for Kentucky old timers was to count the number of fogs in August. The number of August fogs was believed to foretell the number of snow-storms in winter. We're not too certain of the origin of this bit of "wisdom," but I don't suggest using it here in Colorado. Some people in Kentucky swear by it. Here in Colorado, however, August fogs are rare. Also, for snowier parts of the state, there are many more days with snow, even in a dry winter, than there are days in August, even if it was foggy every day. So let's just tuck that one away for now.

There are some bits of winter forecast wisdom that do appear to have an origin in or near Colorado. Some folks look at the color and timing of the golden aspen to help look ahead to winter. The late summer habits of elk have also attracted the attention of observant lorists. My favorite is the Colorado skunk cabbage. The height to which skunk cabbage grows in the mountains is believed to be the depth to which the winter snowpack will accumulate. This bit of lore doesn't have the poetic cadence of some of the original European and New England folklore, but what the heck. It still sounds interesting.

Hopefully you have all assessed the height of the skunk cabbage now, if you can find any. Now sit back and get ready for winter.

CSU-CHILL Radar

Pat Kennedy and Margi Cech, Atmospheric Science Department

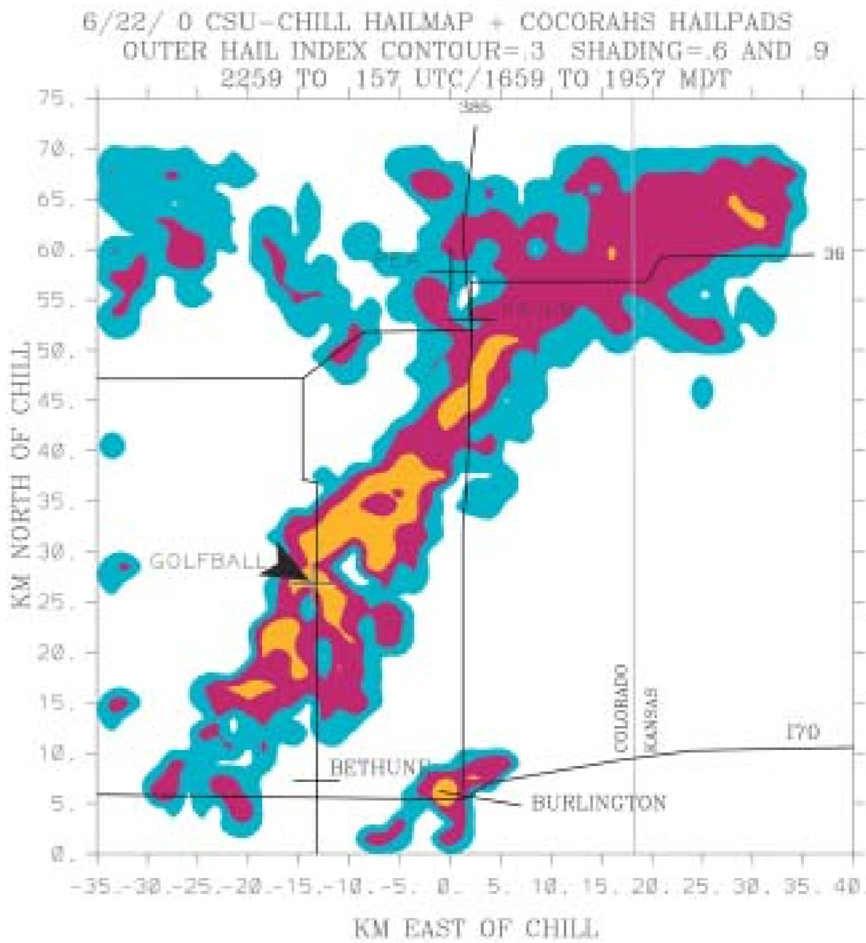
The Colorado State University (CSU) CHILL radar is a transportable, 11 cm wavelength research weather radar system operated by CSU's Departments of Atmospheric Science and Electrical and Computer Engineering. The National Science Foundation (NSF) provides funding for this research facility. The CHILL acronym was derived from the Universities of CHicago and ILLinois, where the radar was originally developed. In 1990 CSU assumed operation of the facility, and the radar was relocated from Illinois to a site outside of Greeley, Colorado. In 1998 the Pawnee radar was brought on-line to create a dual-Doppler observational network along the Front Range of Colorado, and further expand the research and educational opportunities in radar meteorology.

Scientists from local, national, and international research entities have enlisted the services of the CSU-CHILL Radar Facility. These activities have resulted in numerous publications in radar-related research journals, and many significant advances in the science of remote sensing. Research findings have led to improvements in precipitation measurement, detection of hydrometeor types in severe storms (rain, hail, snow, etc.), and severe storm detection (such as the Fort Collins flash flood of July 1997). Radar data provided by CHILL is used in undergraduate and graduate coursework conducted by both Atmospheric Science and Electrical and Computer Engineering. In addition, CHILL staff members conduct on-site tours, short courses, and participate in local science fairs to encourage the science education of junior and senior high school students, and the general public. Currently, CHILL researchers are developing methods for viewing real-time radar images via internet connection, and fine-tuning the radar's quick-scan and remote control capabilities.

This past summer the CHILL radar was deployed to Burlington, Colorado, in support of the STEPS (Severe Thunderstorm Electrification and Precipitation Study) Field Project (http://www.chill.colostate.edu/STEPS). This study, funded by the NSF, was launched to achieve a better understanding of the interactions between the kinematics, precipitation production, and electrification in severe thunderstorms on the High Plains. STEPS focused on supercell thunderstorms and associated lightning behavior occuring most commonly in eastern Colorado/western Kansas.

Volunteers participating in the Colorado Climate Center CoCo RaHS project (Colorado Collaborative Rain and Hail Study) are helping the CSU-CHILL research effort. Many CoCo RaHS volunteers participated in the STEPS project to

(continued on page 20)



Hail map constructed from CSU-CHILL polarimetric data during the STEPS project on 22 June 2000. The hail index values are based on a combination of hail differential reflectivity (HDR) and linear depolarization ratio (LDR) radar measurements. Significant hail should be associated with hail index values larger than approximately 0.6. (Note: the hail region depicted over the city of Burlington is an artifact due to radar ground clutter from buildings, etc.)

Photograph of Ms. Alvina Guy's hailpad that was struck by hailstones up to golfball size. This hailpad was located at the point marked "golfball" in above figure.

CSU-CHILL Radar *(continued from page 19)*

June 22, 2000 hail producing thunderstorm near the STEPS Operation Center, CSU-CHILL Radar Facility, south of Burlington, Colo. (Photo taken by Dave Brunkow.)

provide information that can be used to confirm various precipitation characteristics inferred from CSU-CHILL dual polarization radar data. During dual polarization operations, the polarization of the transmitted radar signal was alternated from pulse to pulse. Thus, in radar pulse 1 the electric field vibrations are in the horizontal plane, while in pulse 2 they are in the vertical plane, etc. When the precipitation particles are illuminated in this way, the signals that are backscattered to the radar contain information about the average shapes and orientations of the particles. For example, as large raindrops fall they are deformed into flat-bottomed "hamburger bun" shapes by the aerodynamic pressure on their lower surface. Therefore, on average, the raindrop diameters are larger in the horizontal direction than in the vertical. In contrast, falling hailstones seldom deform under aerodynamic pressure and they typically tumble, so the horizontal and vertical cross sections that they present to the radar pulses are approximately equal. These characteristic differences in particle shapes and orientations permit dual polarization radars like the CSU-CHILL system to distinguish between areas of rain and hail.

The figure (page 19) shows a hail map constructed from dual polarization radar data collected over a 3-hour period during the afternoon of 22 June 2000. The shaded regions depict areas where increasingly strong indications of hail were detected by the CSU-CHILL radar. The hail maximum size observations were supplied by CoCoRaHS observers. The largest stones were reported by Ms. Alvina Guy, occuring at the point marked "golfball" in the figure. A photograph (page 19) of Ms. Guy's hailpad shows the large dents, gouges, and small foil rip that verifies the occurrence of significant hail at this location. (Some of Ms. Guy's windows were broken during this hail event). This example demonstrates the crucial value of cooperative observer reports in verifying the polarimetric radar hail indications.

Fall Frost Dates

It has been a few years since we updated our frost dates for Colorado weather stations. Back in 1989 we published a large document entitled "Colorado Temperatures with Degree Day and Growing Season Data" by Doesken, Kleist, and McKee, Climatology Report Number 89-2. This was the "everything you ever wanted to know about Colorado temperatures but were afraid to ask" book. A lot of time has past since then, so let's take another look.

When we say "fall frost dates" what we are referring to is the first time each fall when the temperature falls to 32°F or below as measured at an official weather station. There may be days when frost is visible on your car, your roof, or your grass, but if the official temperature did not dip to at least 32°F, then it didn't count as an official freeze. The first autumn freeze brings to a close the growing season for many plants.

Let's look at some fall freeze dates for selected Colorado locations. The box and whisker graph shows the earliest, latest and most likely window when the first freeze of the autumn occurs. The table shows the same information but with more detail. As you can see, for mountain locations like Dillon, frosts can occur almost anytime. There is usually a short growing season at Dillon with the average first fall frost occurring on August 3rd. But some locations like Fraser (not shown) there really is no growing season.

At lower elevations in Colorado, the first freeze usually arrives in September or the first half of October. The average date of the first freeze for locations listed here for eastern Colorado ranges from as early as Sept 26 at Akron to as late as October 8 at Pueblo. Denver and Boulder, while farther north, have similar first freeze dates to location in southeast Colorado.

Probability first autumn frost (32 degrees F) will occur on or before this date

Station	Number of Years	Earliest	10%	20%	30%	40%	50%	60%	70%	80%	90%	Latest
AKRON	31	9/09/1929	Sep 14	Sep 18	Sep 21	Sep 24	Sep 26	Sep 28	Oct 1	Oct 4	Oct 8	10/11/1973
ALAMOSA	48	8/21/1964	Aug 29	Sep 3	Sep 6	Sep 9	Sep 11	Sep 14	Sep 17	Sep 20	Sep 25	10/04/1997
BOULDER	43	9/12/1974	Sep 19	Sep 25	Sep 29	Oct 3	Oct 6	Oct 9	Oct 12	Oct 17	Oct 22	10/31/1963
BUENA VISTA	28	8/27/1992	Sep 5	Sep 9	Sep 12	Sep 15	Sep 17	Sep 20	Sep 22	Sep 25	Sep 29	10/06/1981
BURLINGTON	42	9/06/1956	Sep 16	Sep 22	Sep 26	Sep 29	Oct 3	Oct 6	Oct 10	Oct 14	Oct 20	11/02/1974
CANON CITY	38	9/14/1993	Sep 21	Sep 27	Oct 1	Oct 4	Oct 7	Oct 10	Oct 14	Oct 18	Oct 23	11/05/1962
CO SPRINGS	48	9/03/1961	Sep 20	Sep 25	Sep 29	Oct 2	Oct 5	Oct 7	Oct 10	Oct 14	Oct 19	10/31/1963
CORTEZ	54	9/09/1941	Sep 15	Sep 20	Sep 24	Sep 27	Sep 30	Oct 3	Oct 6	Oct 9	Oct 14	10/23/1947
CRAIG	21	8/01/1962	Aug 23	Aug 30	Sep 3	Sep 7	Sep 11	Sep 14	Sep 18	Sep 23	Sep 29	10/04/1969
CRAIG 4SW	15	8/27/1992	Sep 4	Sep 8	Sep 12	Sep 15	Sep 18	Sep 21	Sep 24	Sep 28	Oct 02	10/08/1990
DENVER	49	9/08/1962	Sep 20	Sep 26	Sep 30	Oct 3	Oct 6	Oct 10	Oct 13	Oct 17	Oct 23	10/30/1974
DILLON	84	7/19/1915	Jul 14	Jul 21	Jul 26	Jul 31	Aug 3	Aug 7	Aug 12	Aug 17	Aug 23	9/25/1963
DURANGO	61	8/23/1900	Sep 7	Sep 12	Sep 15	Sep 18	Sep 21	Sep 23	Sep 26	Sep 30	Oct 04	10/15/1933
FORT COLLINS	100	8/25/1910	Sep 13	Sep 19	Sep 22	Sep 25	Sep 28	Oct 1	Oct 4	Oct 8	Oct 13	10/23/1972
FORT MORGAN	46	9/09/1962	Sep 19	Sep 24	Sep 28	Oct 1	Oct 4	Oct 6	Oct 9	Oct 13	Oct 18	11/01/1963
GRAND JUNCTION	93	9/18/1971	Oct 5	Oct 10	Oct 14	Oct 17	Oct 20	Oct 23	Oct 27	Oct 30	Nov 05	11/26/1965
GREELEY	33	9/12/1989	Sep 18	Sep 23	Sep 26	Sep 29	Oct 2	Oct 4	Oct 7	Oct 10	Oct 15	10/23/1972
GUNNISON	84	7/19/1945	Aug 2	Aug 9	Aug 15	Aug 19	Aug 23	Aug 27	Sep 1	Sep 6	Sep 14	9/24/1997
LAMAR	84	9/13/1945	Sep 23	Sep 28	Oct 1	Oct 4	Oct 7	Oct 10	Oct 12	Oct 16	Oct 20	11/01/1963
MONTROSE	81	9/09/1941	Sep 19	Sep 25	Sep 29	Oct 2	Oct 5	Oct 8	Oct 11	Oct 15	Oct 21	10/30/1974
PUEBLO	41	9/19/1971	Sep 23	Sep 28	Oct 2	Oct 5	Oct 8	Oct 11	Oct 15	Oct 19	Oct 24	11/01/1963
RIFLE	61	8/17/1960	Sep 8	Sep 13	Sep 16	Sep 20	Sep 22	Sep 25	Sep 28	Oct 2	Oct 7	10/24/1918
ROCKY FORD	88	9/09/1941	Sep 21	Sep 25	Sep 29	Oct 1	Oct 4	Oct 7	Oct 9	Oct 13	Oct 17	11/01/1963
STEAMBOAT SPR	83	7/19/1919	Jul 25	Aug 2	Aug 7	Aug 12	Aug 16	Aug 21	Aug 25	Aug 31	Sep 7	Sep 24/1997
STERLING	38	9/01/1956	Sep 14	Sep 19	Sep 23	Sep 26	Sep 29	Oct 2	Oct 6	Oct 10	Oct 15	10/28/1963
TRINIDAD	42	9/14/1993	Sep 21	Sep 26	Sep 29	Oct 2	Oct 5	Oct 8	Oct 11	Oct 15	Oct 20	10/24/1972

The date of the first freeze can very greatly from one year to the next – no big surprise there. Even at lower elevations, the first freeze can come already in early September or it can wait until well into October. Back in 1963, most locations didn't have their first autumn freeze until Halloween. But now and then look out. Back in August 1910, an incredible cold outbreak arrived already in August and some areas of northeastern Colorado had their first freeze on August 25. That would not have been a good year for all you avid tomato growers.

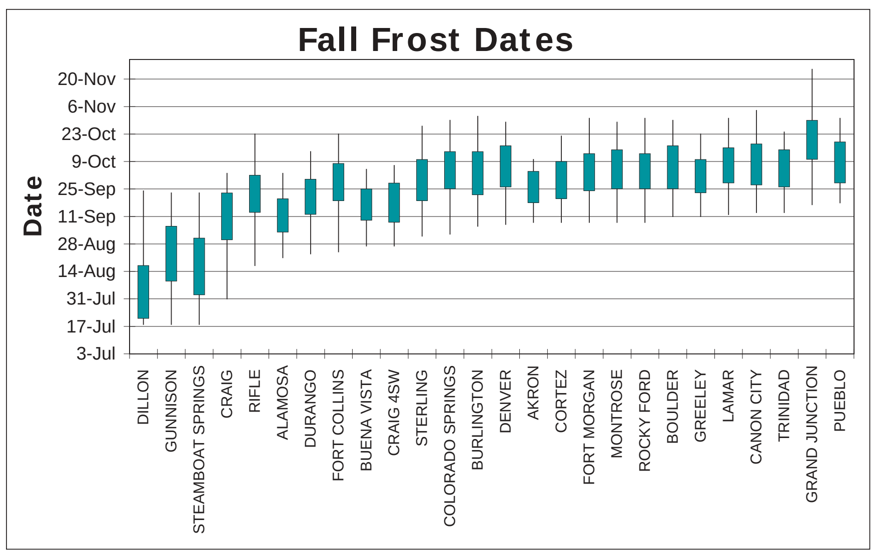
Frost dates and probabilities are available on the Web for any National Weather Service station archived by the Colorado Climate Center. To check frost dates, go to our web site at:

http://ccc.atmos.colostate.edu

Click on "Data Access" and select "Daily Data." A menu will allow you to select the location and years of record that you are interested in. Under the heading of "Select Process," highlight "10-Frost Dates." Click the "Submit" button. Data will be listed in text format.

In our spring 2001 issue, we will show similar statistics for the last frost date each spring and will look to see if any trends are evident towards earlier or later freezes.

Aspen leaves photo courtesy of Lynn Kral, Loveland, Colo.



Earliest, latest, and 20-80% probability range of first frost.

NDVI Greenness Images

Colorado NDVI (Normalized Difference Vegetation Index) greenness satellite images are shown here for March through May 2000. The increased greenness seen in these images shows the growth (increase) in vegetation over this time period.

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

March

April

May

Colorado State University

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Fort Collins, Colorado 80523-1371

Next Issue:

- Solar Energy Variation
- Historical Snowstorms and Blizzards
- Measuring Snow
- 2000 Water Year Review
- Megadrought