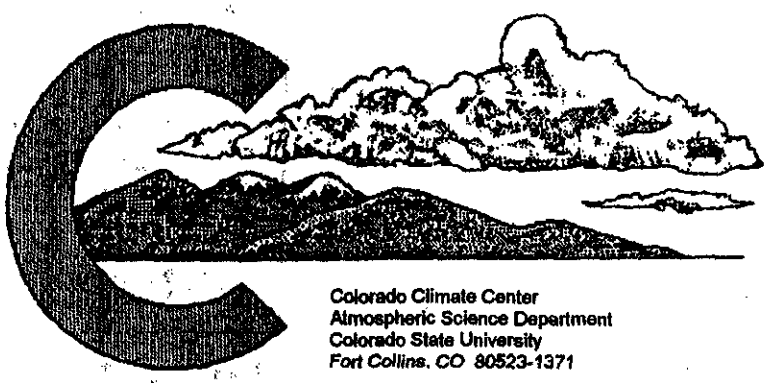

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COLORADO CLIMATE

AUGUST 1996 – JUNE 1999

Volume 19 Number 6

This report has been prepared each month since February 1977 with the support of the Colorado Agricultural Experiment Station and the College of Engineering

"Colorado Climate" Continues

In case you haven't noticed, you have not received a copy of "*Colorado Climate*" in a long time. To be precise, our last issue was Volume 19, No. 5, which covered the months of June-July 1996. Yikes – that's three years ago. Wow, has time flown by. I can make some excuses – like new projects, new research, increased work loads, etc. I'll say more about that later. I can also tell you what life has been like at our old rundown turn-of-the-last-century farm on the edge of the Fort Collins (trading a home office for an old barn has not helped my writing productivity). But instead of giving excuses, let me just apologize and then get back to business.

The good news is, WE'RE STILL ALIVE and REASONABLY WELL. More good news is that publishing "*Colorado Climate*," which slipped to our climatological "back burner," is now back to being the top priority of the Colorado Climate Center for the coming year. There is so much to tell you about. The climate is always interesting in a place like Colorado – even during normal times (if there is such a thing). But these past three years have been far from normal. El Nino, La Nina, monstrous mountain snows and Great Plains blizzards, floods, heatwaves, mudslides, drought – we've had it all. The weather always makes the news, but since 1997, CLIMATE – the big picture – has been front page news time after time. It is a great time to be a climatologist.

"Colorado Climate" is Changing

Wait!! This isn't what you think. I'm not talking about the climate changing – I'm talking about changes in the "*Colorado Climate*" publication. Before I start getting carried away telling you about everything that has happened here at the Colorado Climate Center and also in the climate here in Colorado, we need to take care of some important business. For years, we struggled with how to pay for mailing out hundreds of copies of "*Colorado Climate*" every month. Twice we asked if you would be willing to help cover distribution costs. Many of you said "yes." Others sent financial contributions that helped us get by. After so many years sending out a free publication – we resisted moving toward a paid subscription system.

Times have continued to change. Free publications are rarer. We could just post our information and research results on the internet like many organizations are doing, but if you are as busy as we all are, you'd rarely take the time to check. We feel there is still the need for a published report about Colorado's fascinating climate.

It is now my duty to announce that effective with the next issue, we will be initiating a paid subscription system for many of our readers. Some of you will be exempt, such as National Weather Service volunteer weather observers whose faithful service and quality data make it possible for us to monitor the climate of the entire state.

How much will it cost you? At this point we have no idea how many subscribers we will have. Undoubtedly some of you won't pay for this report – and I understand. Based on our best guess of the number who will subscribe this year, we will charge $15/year. In exchange for your assistance and support, we plan to improve the appearance and content of this report. You will start seeing a splash of color and better quality paper. More importantly, we are planning expanded content with more special features. For the 2000 Water Year, we will be publishing four issues of "*Colorado Climate*," one for each season. The first issue you receive will be our wrap up of the 1999 water year.

Please look over the subscription card and send it back as soon as possible. Our first issue of the new "Colorado Climate" will be completed in October and mailed in early November. If you have friends, co-workers, or know other weather and climate enthusiasts, please tell them about "*Colorado Climate*" or get them a gift subscription. This is all new to us, so hopefully it will go smoothly. We're actually quite excited about this change. As long as the

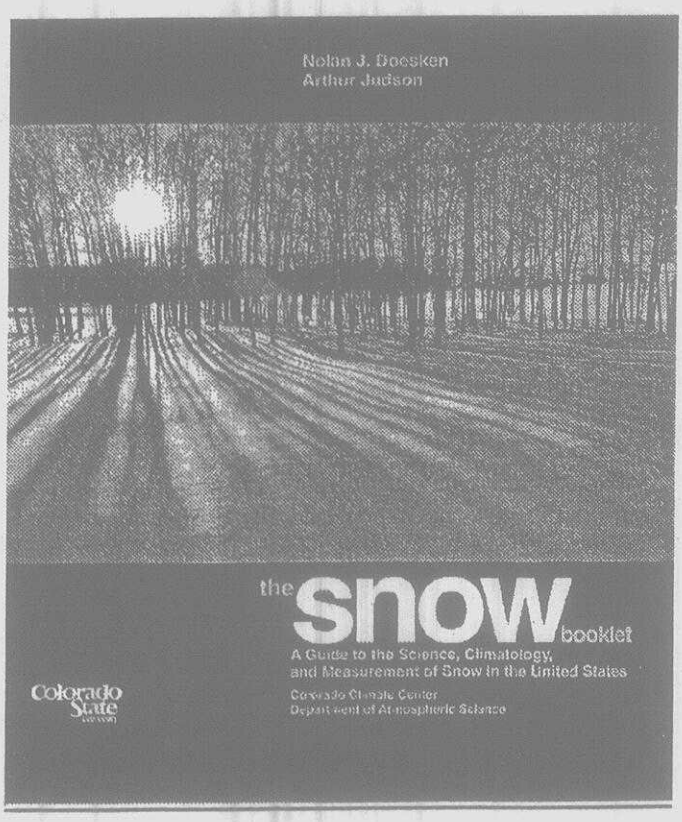
publication was free, we had to be terribly careful to make sure that only a limited number of people ever got copies. Otherwise, we would have gone broke. With a subscription system, the rules all change. At last we can tell people what we're doing. So wish us luck and SPREAD THE WORD. Extra subscription cards are enclosed.

Research Activities at the Colorado Climate Center since 1996

A lot has happened in three years. We don't have room here to go into a lot of detail, but here is a brief description of selected research projects that we have finished or started since we last wrote in 1996. Several projects have resulted in publications.

Date completed **Project**

June 1996 *"The Snow Booklet: A Guide to the Science, Climatology and Measurement of Snow in the United States"* by Nolan J. Doesken and Arthur Judson. This is the first actual book published by the Colorado Climate Center. If you like snow and want to learn more about it, you will enjoy this book. It is available here at the Colorado Climate Center for $15 plus $2.50 shipping and handling (new price effective 9/1/1999).



Sept 1996 The Colorado Climate Center co-hosted, along with the National Weather Service, a special workshop on measuring snow. As a result of this meeting, the National Weather Service prepared a small document, "*Snow Measurement Guidelines*" which took effect that winter for all National Weather Service professional and volunteer weather observers.

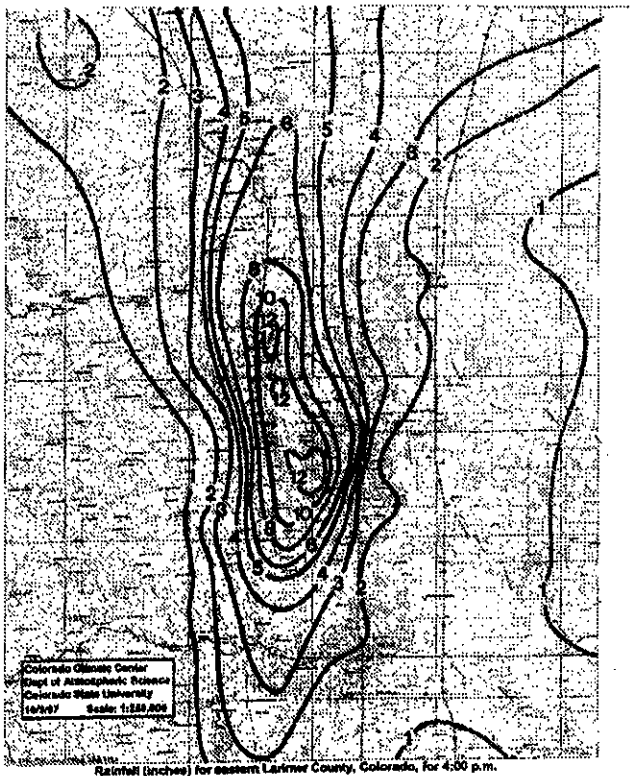
March 1997 *"An Evaluation of the Reported January 11-12, 1997, Montague, New York, 77-inch, 24-hour Lake-Effect Snowfall"* (main report out of print already). Nolan Doesken was selected to a small team of national experts invited to the Tug Hill Plateau in upstate New York to investigate this snowfall extreme. This was truly a remarkably heavy and highly localized snowfall, but after careful examination the report was deemed unofficial since it was based on summing a set of short-interval snowfall totals. The actual depth of snow on the ground increased by 51 inches. Thus, the previous record set at Silver Lake, Colorado, in April 1921 remained intact.

May 1997 "*Colorado Extreme Storm Precipitation Data Study*" by Thomas B. McKee and Nolan J. Doesken. 109 pages. Available for $5 plus postage and handling. The Colorado Climate Center completed a comprehensive study of the history of extreme rainfall events in Colorado. More than 300 storms were investigated since 1864 that had dropped excessive rainfalls and/or had produced significant flooding. The largest three dozen storms were identified as those that must be considered in any future study of extreme rainfall impacting high hazard dams and spillways in Colorado. The results of this 2-year study were presented to a committee of experts in Denver on July 17, 1997. It was recommended at that meeting that more might be learned by studying in great deal any future extreme rainfall events in Colorado rather than attempting to reconstruct rainfall patterns from past historic storms such as the extreme rainfall event of May 30-31, 1935. Little did we know that the opportunity was just around the corner.

1997 (July 28 and 29) The priorities and work load of the Colorado Climate Center changed abruptly on the evening of July 28 as more than 10 inches of rain fell in a few hours over portions of the City of Fort Collins. The resulting flood claimed 5 lives, remarkably low considering that this was the heaviest rainstorm ever recorded over an urbanized area of Colorado and was one of only about a dozen storms in Colorado's recorded history that dropped more than ten inches of rain in less than a day.

The very next night, July 29, an even larger storm produced incredible flows on the often-dry Pawnee Creek watershed as 10-13 inches of rain fell in a few hours in an area north of Stoneham that had also been hard hit by a similar flood back in June 1965. Flood waters washed out several bridges and then inundated the small town of Atwood before passing through Sterling, Colorado during the daylight hours of the 30th.

For the next three months, nearly all of the Climate Center's resources were directed towards assembling data on storm rainfall characteristics to help meteorologists, radar specialists, hydrologists, engineers, attorneys, insurance professionals and private citizens understand these potent storms and their impacts.



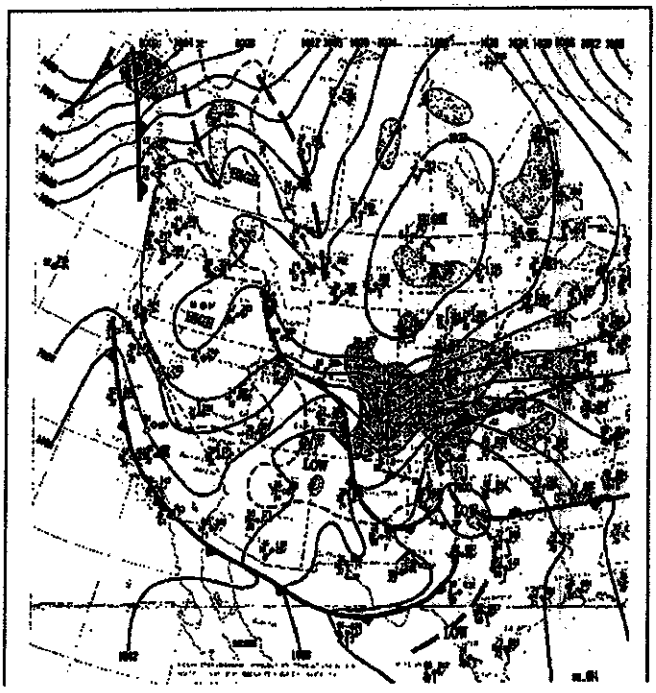
Rainfall (inches) for eastern Larimer County, Colorado, for 4:00 p.m. MDT July 27, 1997 through 11:00 p.m. MDT for July 28, 1997

Several reports have been written on these floods. Copies of *"An Analysis of Rainfall for the July 28, 1997 Flood in Fort Collins, Colorado"* are available for $5 plus postage and handling. A comprehensive meteorological and radar study of the storm was published in the February 1999 issue of the Bulletin of the American Meteorological Society. In 1998, a full year after the Pawnee Creek storm, the Climate Center was commissioned by the Colorado Water Conservation Board to do a post analysis of that remarkable storm. Limited copies of the report, *"A post-evaluation of rainfall reports associated with the Pawnee Creek flood of July 29-30, 1997 in eastern Weld County and western Logan County in northeast Colorado,"* may still be available.

October 1997 Nolan Doesken presented a special invited paper at the 1997 American Meteorological Society Applied Climatology Conference on the Fort Collins Flood. Special presentations were also given on the extreme rainfall event that hit northern Illinois during the summer of 1996. It was an interesting comparison as the Colorado extreme storm affected only a few tens of square miles. The Illinois storm, while similar in duration and intensity, covered thousands of square miles and produced flooding from south central Wisconsin all the way to northern Indiana.

October 1997 Nolan Doesken presented a paper at the American Meteorological Society Applied Climatology Conference on the infamous Front Range Snowstorm of April 14-15, 1921 which was responsible for the 76 inch 24-hour snowfall accumulation reported at Silver Lake, Colorado (Boulder Watershed). Copies of this paper are available on request.

Personal Anecdote: As the scientific conference where I presented these two papers came to an end on October 24, 1997, Tom McKee (State Climatologist) and I glanced at the weather forecast maps for that evening and the following morning. The maps looked remarkably similar to what had occurred back in April 1921. I considered delaying my flight but decided that the new airport could safely accommodate aircraft landings in severe winter weather. I knew driving conditions might be tough, but I just wanted to be home. My plane was late but did arrive at DIA that evening despite intense snowfall and increasing winds. Driving conditions, however, were horrendous. It took nearly four hours to get from the airport to just south of Longmont. As winds howled, windshield wipers froze solid and visibilities dropped to zero. We nearly lost our way more than once before we managed to pull off at a truck stop where we ended up spending that night in the car. I suppose we slept a little, but it certainly wasn't restful. Sometime after midnight the winds shifted slightly. The car shook with each wind gust and blowing snow made sounds like sand blasting the sides of the car. While the blizzard continued to rage across almost all of eastern Colorado, we managed to make it safely to Fort Collins by 8 a.m. Saturday morning. Only later did we come to realize that had we stayed at DIA only a few minutes longer, we would have been stranded on Pena Boulevard for 24 hours or longer. It was also a few days later when we learned of the tremendous event that



Surface Map of the Western U.S. for Oct 25, 1997

occurred that same night in Routt National Forest near Steamboat Springs. Millions of trees were blown down in a matter of minutes by powerful easterly winds cascading over the Park Range from North Park. Most likely, this rare event took place at the very time that the wind direction changed and the gusts increased which had woken us from our fitful sleep. While we had a frightening experience, it could have been so much worse. Several people lost their lives in that blizzard and thousands of cattle and other livestock were lost.

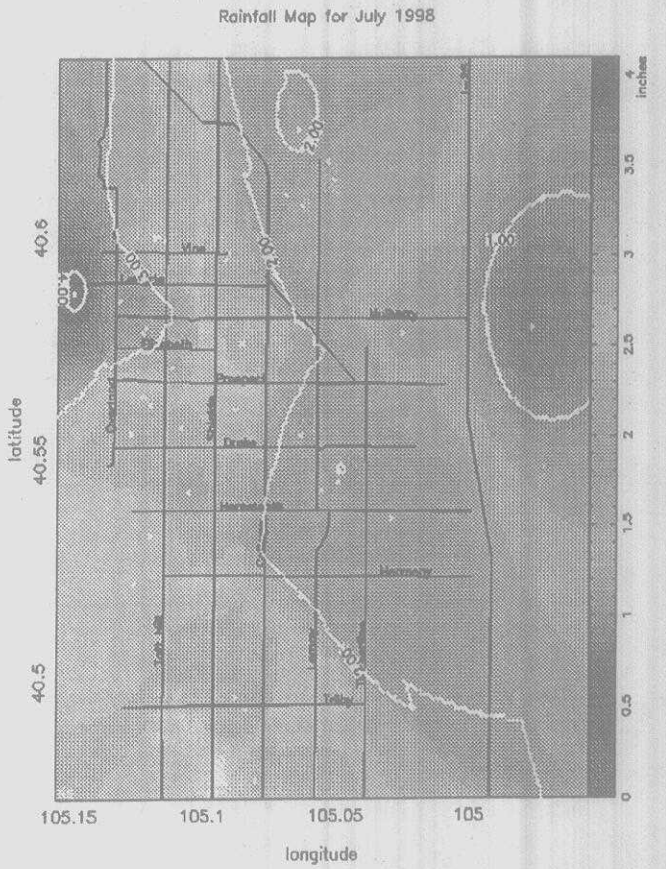
1996-1998 Tom McKee and Nolan Doesken of the Colorado Climate Center were both selected by the National Research Council to serve on the National Academy of Sciences special panel on climate record: Modernization of the Cooperative Observer Program. The Colorado Climate Center has been very active over the past 25 years in working closely with the National Weather Service to maintain and improve the important climate observing functions provided by volunteer weather observers across the country. The resulting report, *"Future of the National Weather Service Cooperative Observer Network,"* was published by the National Academy Press in 1998. It provides recommendations on what the National Weather Service can and should do to preserve the many wonderful attributes of a low-tech volunteer weather observing network while at the same time creating a viable program to serve the very high-tech needs of the 21st Century. Copies of this report are available from the National Academy Press at http://www.nap.edu.

1997-1999 *"Density of Freshly Fallen Snow in the Central Rocky Mountains"* by Arthur Judson and Nolan Doesken. As a follow on to *"The Snow Booklet,"* the U.S. Bureau of Reclamation provided funds to the Colorado Climate Center to complete investigations of variations in both time and space in the density (water content) of freshly fallen snow. Much of the data used in this report were collected and analyzed by Art Judson from his home in Steamboat Springs where he retired after working for many years in Fort Collins as an avalanche scientist for the U.S. Forest Service. This report documents the wide range of snow densities that characterize fresh snow in the Rockies, and proves that the age-old idea that ten inches of fresh snow contains one inch of water can be true but usually isn't. The majority of Rocky Mountain snows are less dense. The results of this study will appear soon in a scientific journal. Copies will be available on request.

1997-1998 El Nino (Warm phase)
1998-1999 La Nina (Cold phase of the Southern Oscillation). These climatic-oceanographic events seemed to send the whole world into an unprecedented climatological frenzy. From a scientific perspective, it was thrilling to observe modern global data collection and analysis in action. Remote sensing technology made it possible for us to watch on our computers, from the friendly confines of our offices, the rapid and expansive warming of the surface of the tropical Pacific Ocean during the summer of 1997 followed by dramatic cooling in 1998. Perhaps even more amazing was the media craze associated with what some will call climatologists' first true success story in predicting temperature and precipitation anomalies many months in advance. While you readers have endured two years of "El Nino, La Nina" mumbo jumbo on the evening news and in almost every newspaper and popular news magazine, we climatologists have tolerated hundreds of phone calls. First came the calls from prying news reporters who honestly believed we knew with certainty what the weather was going to be like for months in advance. We also heard from business analysts, utility engineers, long range planners, and even school children attempting to undertake unique science fair projects. Never have we received so many inquiries about a phenomenon taking place so far away. Never have we appreciated how the entire earth's atmosphere, oceans and land surface all work together to produce our remarkable climate.

While the long-range forecasts seemed accurate for many parts of the country, the success in Colorado was only marginal. Winter snow projections for the mountains were mostly wrong. However our first persistently windy winter in many years this past year may well have been accentuated by the cooler than average tropical Pacific sea surface temperatures.

1998–1999 CoCo RaHS is born, the Colorado Collaborative Rain and Hail Study. An extensive volunteer network geared for students, teachers, families and

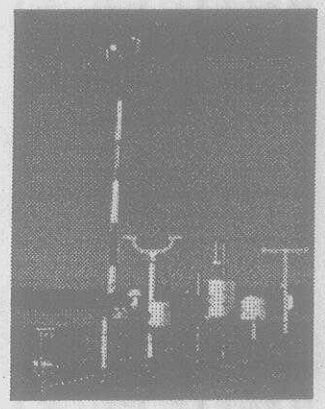


adults was initiated in 1998 as a means of collecting detailed local data on rain and hail patterns to help us study Colorado storms and to provide useful information to scientists, engineers, water managers and many more. After a very successful start in the Fort Collins area, spear-headed by three high school student interns, the project was expanded to Adams and Weld Counties in 1999 with the help of grants from the Colorado Water Conservation Board and the U.S. Department of Agriculture. This project will be expanding in Colorado in 2000 so we'll be telling you more about that later. Check out the CoCo RaHS website at http://ccc.atmos.colostate.edu/~hail/ for more information. Maps showing the detailed rainfall patterns for every day this year are shown. We hope your community will get involved soon. If you would like to become a volunteer rain and hail observer for CoCo RaHS, please contact us. Tell your friends.

1998-2000 The National Oceanic and Atmospheric Administration, NOAA, is concerned about the quality and consistency of climate data being collected in our country now and in the past. The Colorado Climate Center is currently being funded to study and document the impacts of rooftop weather station exposures on the accuracy and representativeness of climate data. Tom McKee is leading this study. We will begin to have results to report next year. As we've pointed out before in "*Colorado Climate*," it's easy to measure the temperature of a thermometer, but it's a lot harder to take accurate and representative measurements of the temperature of the air – and even harder to do this consistently year in and year out.

1998-2000 It has long been noted that the time of day selected for taking snowfall observations and the interval of time between snowfall observations has a direct bearing on the observed snowfall totals. In most circumstance, the more often snowfall measurements are taken, the greater the observed snowfall totals. Since not all stations take observations with the same frequency or at the same time, we may be introducing artificial differences in snowfall totals across the country. The Colorado Climate Center is currently supported conducting a national evaluation of the impact of the choice of time of observation and frequency of observation on measured snowfall totals, using data provided by cooperators in Colorado, Ohio, North Carolina, Virginia, New Jersey and New York. Results will be available in 2000.

1996-2000 NOAA Climate Data Continuity Study. Tom McKee and several graduate students in the CSU Department of Atmospheric Science have been actively involved for several years in an evaluation of changes to national climate data resulting from the deployment by the National Weather Service during the 1990s of the Automated Surface Observing System (ASOS) at airports across the country. Many reports have been written and presentations delivered at conferences and workshops across the country. Results to date show that the deployment of ASOS has resulted in systematically cooler temperatures at most airport locations across the country (approximately one degree F cooler, but with considerable variations among sites). ASOS does not measure snow, so urban locations have had to turn to local volunteer observers to provide snowfall data. The ASOS precipitation gauge initially deployed had serious problems and underreported precipitation at most locations. Subsequent changes have produced much better results with most stations now showing differences from the previous gauge of less than 10%. Unfortunately, the heated tipping bucket rain gauge used at all ASOS installations does not perform well in measuring the water content of snow at temperatures below the freezing point. A new all-weather gauge is under development, but in the meantime, there are now several years of questionable winter precipitation data in the national database for major weather stations across the country. Copies of these reports are available on request.



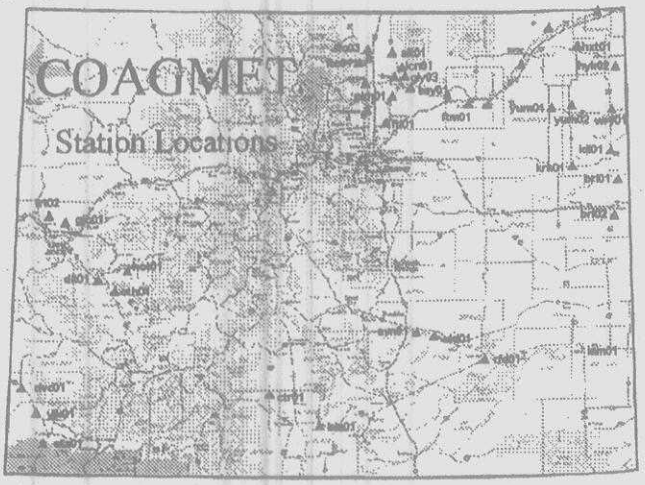
Automated surface observing system

1996-1999 "*Historical Dry and Wet Periods in Colorado*" by Thomas B. McKee, Nolan J. Doesken and John Kleist. This nearly 400 page report was completed during the summer of 1999 and is the culmination of years of research and development work using new types of drought indexes for monitoring precipitation, snowpack and streamflow. Results suggest that Colorado is currently enjoying a long period free of widespread multi-year droughts. From the 1930s through the 1970s, Colorado experienced several severe and widespread droughts separated by significant wet periods.

We will be providing a summary of the results of this research in the near future here in "*Colorado Climate*." For those of you with a good memory, this will be the long awaited "*Drought in Colorado, Part III*") that will finally complete the series of reports on drought that we began back in 1994.

1996-2000 CoAgMet – the Colorado Agricultural Meteorology Network, is a collaborative project of several departments at Colorado State University, the Agricultural Experiment Station, CSU Cooperative Extension, the U.S. Department of Agriculture, and other sponsors. Data are

received daily from remote weather stations throughout Colorado's agricultural areas, processed and made available to farmers, agribusinesses, researchers and any other interested parties by way of the Internet and the DTN commercial satellite communication company. The Colorado Climate Center is responsible for managing the incoming data, archiving and displaying data, and assessing data quality. This network has now been in existence for 10 years and has become an essential part of the state's pest management and crop disease assessment programs.



1996- present Climate Monitoring. In addition to the special research projects listed above, the Colorado Climate Center has continued to actively monitor statewide climate conditions, variations and extremes. We have continued to participate actively in the Colorado Water Availability Task Force which has been meeting routinely since 1981. Data tables that in the past appeared in "*Colorado Climate*" have routinely been posted on the Colorado Climate Center webpage under "*Data Access*" at http://ccc.atmos.colostate.edu

As more and more data sources become available on line, more and more opportunities are appearing for improving our climate monitoring capabilities. In future issues of "*Colorado Climate*" we plan to review the various sources of hydroclimatic information currently being collected in Colorado. We'll discuss how to access the data and how to interpret significant climate variations and extremes.

Fall 1999 Enough Already. Well, now I know why I haven't been keeping up with writing "Colorado Climate" reports. We just plain have a whole lot going on. At least we'll have no shortage of topics to write about as we begin our new publication format this fall.

Another Change at the Climate Center

Tom McKee, who has served faithfully for 25 years as the Colorado State Climatogist, has begun transitional retirement here at Colorado State University. Dr. McKee will still be involved in research, but is looking forward to spending more time with family, friends and fishing in the years ahead.

Dr. Roger Pielke, Sr., was appointed by the Department of Atmospheric Science to be the new State Climatologist effective in May 1999. Dr. Pielke has been at CSU since 1982 and brings with him a strong interest in climate and climate applications. His research has focused on modelling local and regional scale atmospheric processes and investigating land surface interactions. One of Dr. Pielke's top priority as State Climatologist is to bring new vigor to the publication, "*Colorado Climate*" and to make this report a primary outlet for climate monitoring and research results here in Colorado. Nolan Doesken and Odie Bliss, who have both been with the Center for more than 20 years, will continue their work. You'll be hearing more from Dr. Pielke in the months ahead, as he plans to contribute many features and research perspectives to this publication.

A Brief Review of Colorado Climate Conditions Since 1996

It is time to "catch up" on Colorado climate. On the next pages are summaries of the Water Years for 1996, 1997, 1998, and 1999. I'm sorry we aren't able to go into our normal detail, but here is a brief review of the climate events and anomalies (significant departures from average) which we've experienced in Colorado since the summer of 1996. More complete summaries have been publish in the annual proceedings of the American Geophysical Union, "Hydrology Days" conference proceedings. Copies are available.

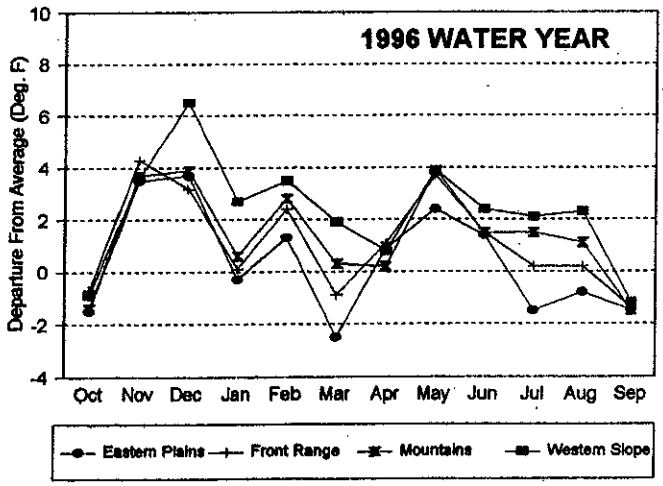
1996 Water Year

1996 Water Year Description. Previous issues of "*Colorado Climate*" included detailed summaries of monthly climatic conditions for the first ten months (October 1995 through July 1996). We will now wrap up the year to complete our documentation.

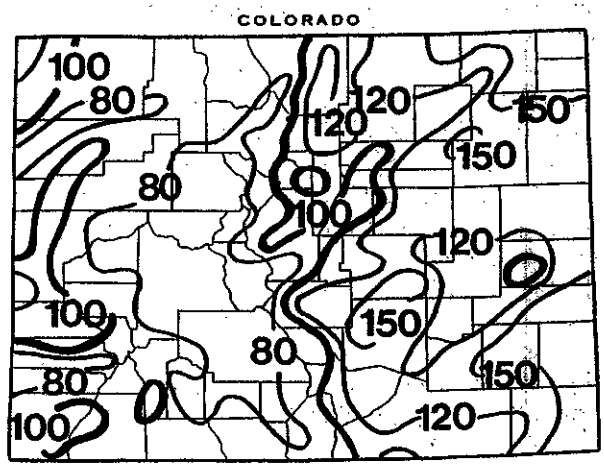
August was relatively cool, humid and stormy over eastern Colorado while the mountains and Western Slope were warm and dry. Hot weather persisted into early September, but then a dramatic change occurred. By September 7, a strong cold front crossed the state. Thereafter, a series of fallish storm systems brought cool temperatures and widespread precipitation.

Summer rainfall ended the emerging drought over southeastern Colorado (an extension of the severe drought in Texas and parts of New Mexico and Oklahoma). Precipitation totals ended up above average over Colorado's northern mountains and over much of the Eastern Plains. In the southwest, summer rains were unable to make up for the very dry winter and spring. Southwestern counties and portions of extreme western Colorado ended the year very dry. Stations near the 4-Corners area barely received 50% of average making this one of their driest years in recorded history. Temperatures for the year were warmer than average.

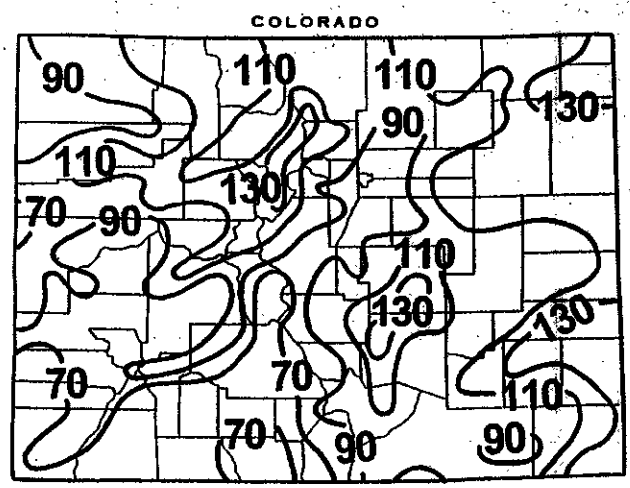
Temperatures. Colorado experienced a mild fall and early winter. A few bouts of winter cold struck from late December into early February, followed by 3 weeks of extremely mild February weather. March and April brought typical changeable weather followed by a very warm May and June. July and August were very hot over western Colorado while relatively cool and humid east of the mountains. The year ended with a cool September. Overall, 1996 water year temperatures ended up above average ranging from +0.4°F on the Eastern Plains to +2.3°F on the Western Slope.



Precipitation: With the exception of March, each month October-April saw plentiful snows in Colorado's northern and central mountains while the southwestern mountain and all of eastern Colorado were very dry. In southwestern Colorado, this was the driest winter since the famous drought of 1976-77. A late May storm improved conditions over eastern Colorado. June storms brought some relief to southwestern Colorado. July and August were each wet and stormy over eastern Colorado and dry to the west. September was wetter than average over most of Colorado. 1996 growing season precipitation ended up above average over nearly all of eastern Colorado while the mountains and Western Slope were dry.



May – Sept 96 (Summer) precip percent of average.

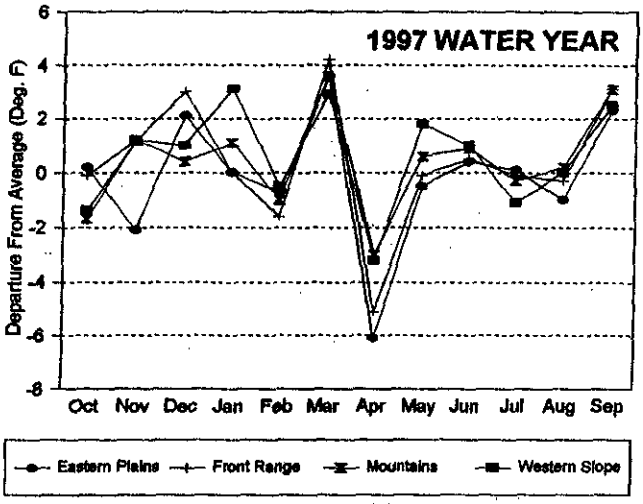


1996 Water Year precip as a percent of average.

1997 Water Year

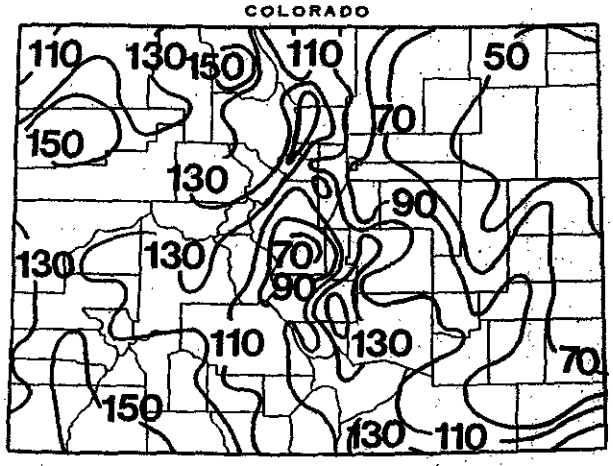
1997 Water Year Description. The 1997 water year brought above average precipitation to most of Colorado. Temperatures ended up close to the 1961-1990 averages. The dramatic onset of "El Nino" conditions in the Pacific region with very warm sea surface temperatures captured the interest and attention of the country and may have contributed to a wet summer in much of the state.

Temperatures. From October 1996 through February 1997, Colorado experienced a fairly typical range of temperature. Nighttime temperatures were above average in the mountains interrupted by a few brief but biting cold blasts. For example, Taylor Park had a high of –9°F and a low of –40° on December 15. Eastern Colorado's worst cold wave came January 10-14. March was unusually warm, but April compensated with monthly temperatures as much as 6°F colder than average. May-August temperatures were near average but the growing season was long. The water year ended with a very warm September. Some mountain communities escaped without frost.

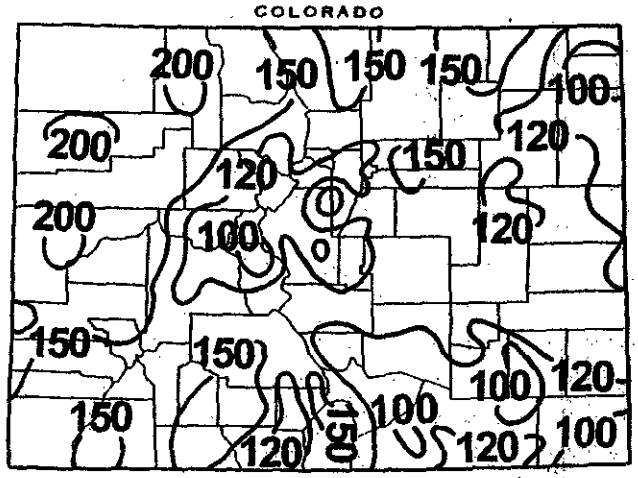


Precipitation. The first four months of the 1997 water year were wetter than average over the mountains and Western Slope, while eastern Colorado was dry. A series of modest storms whitened the plains in February. March was warm, dry and docile statewide. April made up for it with heavy precipitation except on the northeast plains. A late-month storm dumped two to four feet of snow in one day on the eastern foothills. Overall, October-April precipitation was 110% to 150% of average over the western Colorado, while northeast Colorado received less than 50% of average.

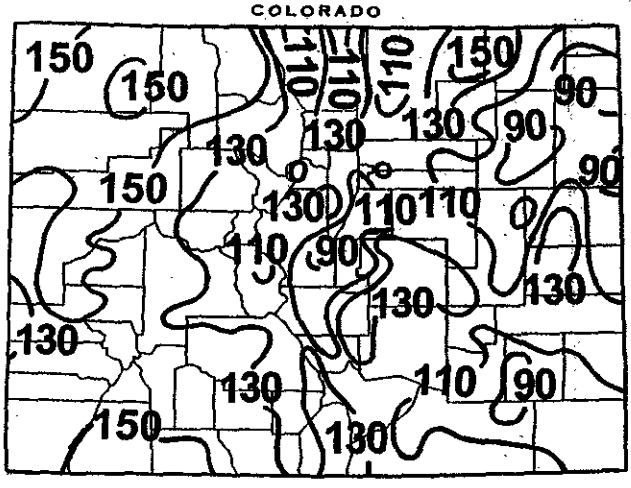
Growing season precipitation was highly variable mostly on the wet side nearly everywhere in the state. Dry weather from mid June into late July was followed by heavy storms with locally flooding rains from late July into August. Up to 14" of rain produced Severe flash floods in Fort Collins on July 28 and the Sterling area on the 29th and 30th. In September, moisture from a decayed hurricane helped produce record rainfall in an area from near Grand Junction northeastward to Walden. Buffalo Pass, near Steamboat Springs totaled a remarkable 8" of rain Sep. 18-21. In total, the 1997 water year was a wet one for Colorado with the majority of the state receiving more than 130% of the annual average.



Oct 96 – Apr 97 (Winter) precip percent of average.



May – Sep 97 (Summer) precip percent of average.

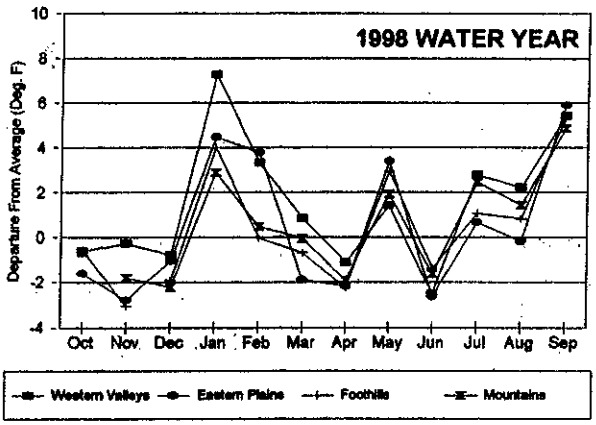


1997 Water Year precipitation as a percent of average.

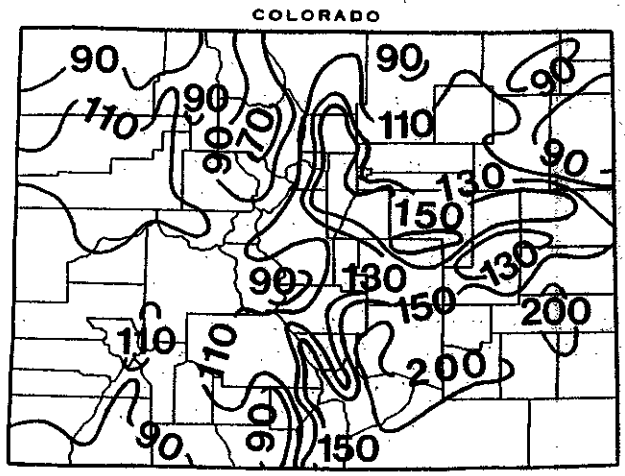
1998 Water Year

1998 Water Year Description. All eyes were on the skies as an "El Nino" frenzy grasped the whole country. The weather cooperated by delivering a terrible blizzard to Colorado October 24-26 – very possibly the worst October blizzard in Colorado's recorded history, and the first storm to totally paralyze the Denver International Airport since it opened. More heavy snows hit southern Colorado, but the remainder of the winter was unspectacular elsewhere. The summer was hot with variable precipitation. Temperatures statewide ended up above average for the 1998 water year while precipitation was below average over parts of the northeast and much of western Colorado. Southeastern Colorado was the exception with widespread much above average conditions for the year.

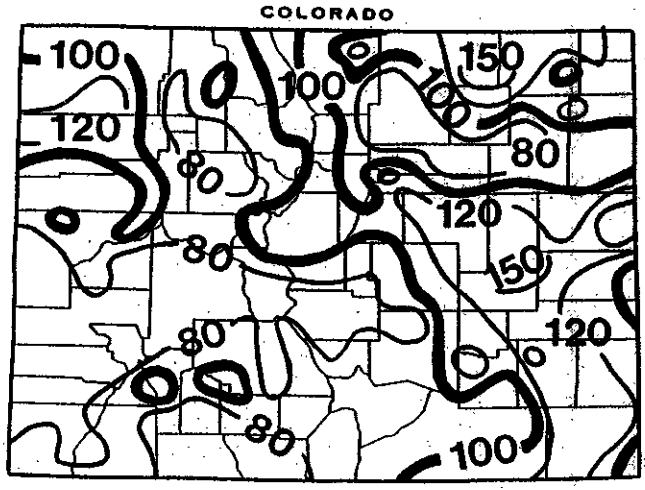
Temperatures. The water year got off to a chilly start October-December 1997, especially over southern Colorado. January and February were very mild, however, and eastern Colorado was spared subzero temperatures for one of the very few times in history. March temperatures returned to near average, and April was cooler than normal. The growing season got off to a slow start with some morning frosts in May and a cool June. Then the heat set in. July through September were significantly warmer than average. A severe heat wave July 18-21 sent temperatures soaring past the 100°F mark, and contributed to local power outages.



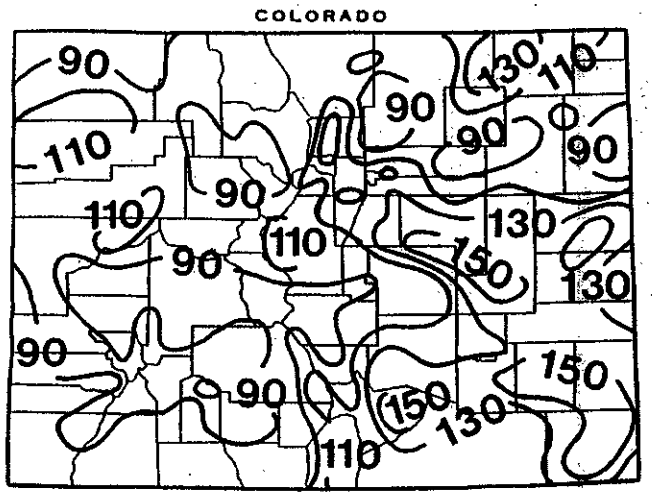
Precipitation. October precipitation was above average over most of Colorado. The big blizzard brought as much as 3 inches of liquid to eastern Colorado. November and December were drier than average in the mountains, but heavy snows fell each month over portions of southern and southeastern Colorado. January brought decent snowfall to the northern mountains but left eastern Colorado with almost nothing. February, March and April all had complex precipitation patterns with portions of the state wet while other areas were very dry. For the October-April winter season, precipitation totals were near to below average over western, central and northeast Colorado, while southeast Colorado experienced one of their wettest winters on record. May and June were unseasonably dry except for heavy rains over northwest Colorado in mid June. July was wet and stormy with numerous heavy downpours. Storms diminished in area and intensity in August and September. The 1998 growing season was drier than average in many areas, but much of eastern Colorado ended up with more rainfall than usual.



Oct 97 – Apr 98 (Winter) precip percent of average.



May – Sept 98 (Summer) precip percent of average.



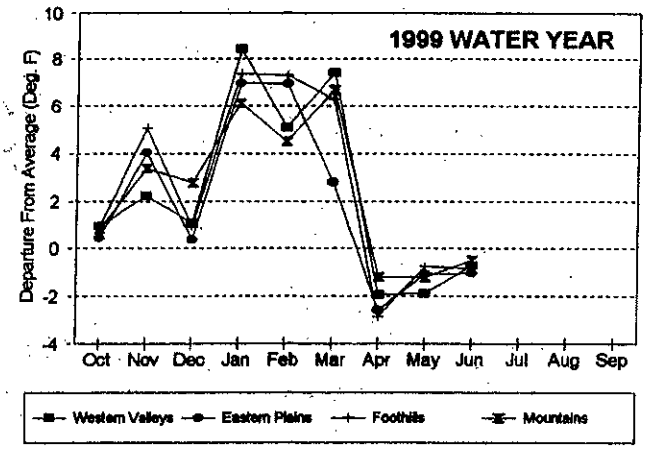
1998 Water Year precip as a percent of average.

Water Year 1999 (October 1998 – June 1999)

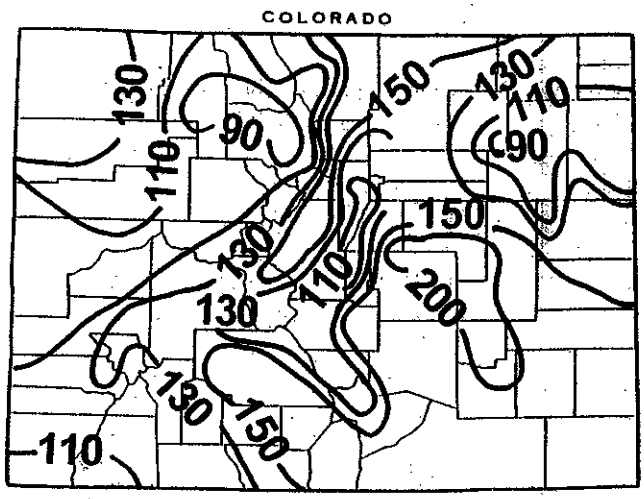
Status report, October 1998 through June 1999. In our next issue of "*Colorado Climate*" we will provide a complete wrap up of the 1999 water year. For now, we'll just touch on a few highlights and give a status of where we stand.

The words "La Nina" were as common in 1999 as "El Nino" had been the year before. Tropical sea surface temperatures dropped quickly during the summer of 1998, and as the autumn began, long-range forecasters were anticipating a dry winter for the southern Rockies and wet weather for the Pacific Northwest with a return of artic air masses over the Northern Plains (these had been largely absent the previous winter).

Temperatures. 1999 has been a warm water year so far. October and December were slightly above average, while November, January, February and March were all much warmer than average statewide. In fact, 10 out of 12 months, beginning with May 1998 were warmer than the 1961-1990 average for most of the state. This trend ended in April, and each of the past three months have been a bit cooler than average.



Precipitation. The 1999 water year got off to a wet and snowy start with a major storm in early October, and three more weeks of stormy weather in late October and early November. Skiers were excited, and the forecast for a dry winter in southern Colorado appeared to be a bust. The patterns quickly shifted, however, and from mid November to the end of December, snows were nearly non-existent anywhere in Colorado. The situation improved in January, as frequent snows fell in the Northern and Central Mountains, but February and March were again very dry over most of the state. Despite a tremendous start, statewide snowpack dropped to 89% of average by April 1 and was headed downward. Projections for a warm and dry spring made water officials even more edgy. Then, on April 21, one of Colorado's wettest two week periods in recent history began. By May 4, a statewide average of nearly four inches of precipitation fell in the form of cold rains and wet snows. Precipitation was especially heavy along the Front Range – see special feature on the spring floods of 1999. June rainfall was spotty, but the effect of the heavy spring precipitation in combination with the moisture that fell last fell, left Colorado with above average precipitation for the first 9 months of the 1999 water year everywhere but a small portion of the northern mountains and few spots on the northeastern plains. Nine-month totals exceeded 150% of average for nearly all of southeastern Colorado and much of the Front Range.



Oct 98 – Jun 99 precipitation as a percent of average.

Special Feature: The Spring of 1999 – A Closer Look at Heavy Rains in April

After a wet and stormy start, the winter of 1999 settled down to be dry and remarkably mild. A week of arctic cold just before Christmas caught our attention and deadened our car batteries. Many feared we were in for a long, cold winter after having almost no extreme cold the previous winter. (Actually, Colorado hasn't had a colder than average winter since 1993 – and that wasn't that bad. Are we overdue or what?) But the cold left as quickly as it arrived. January, February and March were so warm (second warmest on record in some areas, second only to the extremely mild winter of 1954 which preceded one of Colorado's most extreme spring and summer droughts) that what snow did fall melted quickly. Even in the mountains, drivers became accustomed to bare pavement.

From November 12, 1998 to April 14, 1999, Denver temperatures climbed above 50 on two thirds of the days and precipitation totaled barely two inches. From November 12 through March 31, only 14.4" of snowfall was recorded in Durango with a water content of 2.09".

Usually at least 50" of snow falls, and the average November-March precipitation total is about eight inches. It was dry!!

The mild and snow-free winter was pleasant in many ways (if you could ignore the downslope winds that buffeted the Front Range), but water officials became increasingly nervous. The mountain snowpack statistics didn't sound too bad – 89% of average on April 1. However, there was almost no snow on the ground at elevations below 9,000 feet, and south facing slopes were bare even higher. The Front Range foothills had remained free of snow for much of the winter. Where was all the water for spring and summer going to come from? Forecasts for a dry spring and summer by increasingly confident long-range forecasters at the NOAA Climate Prediction Center, created even more uneasiness.

We in the climate business have seen many dramatic "turn arounds" in the past with total flip-flops in the weather pattern – the onset of extremely dry weather just when it looks like we're all going to drown in mud or sink in snow, and sudden wet spells when we're at the very brink of drought. Springtime is particularly dynamic in this regard. Indeed, spring 1999 was far from over and Mother Nature had not yet spoken.

The change in weather pattern occurred already by March 31. We just hadn't realized it. Instead of dry, westerly winds whipping across the state, a deep trough of low pressure was developing over the Southwest and Colorado Plateau region. For the next 6 weeks, one storm system after another dropped down into the Southwest, and then moved slowly eastward across or just south of Colorado. The first of these storms was a 5-day snowstorm that brought greatly-appreciated moisture to SW Colorado. Wolf Creek Pass measured 88 inches of new snow with nearly 5" of water content April 1-5. Then came the first major thunderstorms of the season April 13th with locally heavy 1-inch rains at Denver, Burlington, and a few other areas of eastern Colorado and heavy, wet snows in and near the foothills followed by 3 days of on-and-off snow-showers with freezing, blustery northerly winds.

These early storms were helpful, but much more was still to come. On the 21st of April, rain showers spread eastward across western Colorado and turned to snow in the mountains. Rains developed east of the mountains during the evening and became widespread and steady. Nearly all of Colorado received some precipitation, but "upslope" winds from the east concentrated the heaviest precipitation in a north-south band along the Front Range. Rains changed to snow in many areas and continued all day on the 22nd and much of the 23rd. Rain and snow began again late on the 24th and ended gradually on the 25th with a few lingering showers on the 26th. Foothills locations ended up with two to four feet of sloppy wet snow. Much of the snow melted as it landed along the Front Range urban corrider, but 5-day precipitation totals were substantial. Examples included Pueblo, 1.49"; Colorado Springs, 1.76"; Denver, 2.27"; Greeley, 2.40"; Fort Collins, 3.42" and Boulder, 3.45".

Dry air usually returns to Colorado on the heels of passing storms, but as this slow-moving system drifted slowly eastward towards the Midwest, very moist air remained ready for the next storm. Already by the afternoon of the 27th, showers and thunderstorms began to develop, and southeasterly winds developed in advance of a rapidly developing low pressure area over Nevada, Arizona and southern California. With the ground already soaked along the Front Range, and with deep snows in place over the foothills, concerns over inadequate water supplies began to shift to "what are we going to do if we get any more rain?"

Well, we got more rain. Rains became widespread on the evening of the 28th, especially along the Front Range. Southeasterly winds increased. Thunder rumbled and localized heavy rains in the Colorado Springs area behaved much more like summer convective storms than springtime storm systems. A burst of heavy rain in the Colorado Springs area around midnight sent tributaries roaring towards Fountain Creek and on toward the Arkansas River.

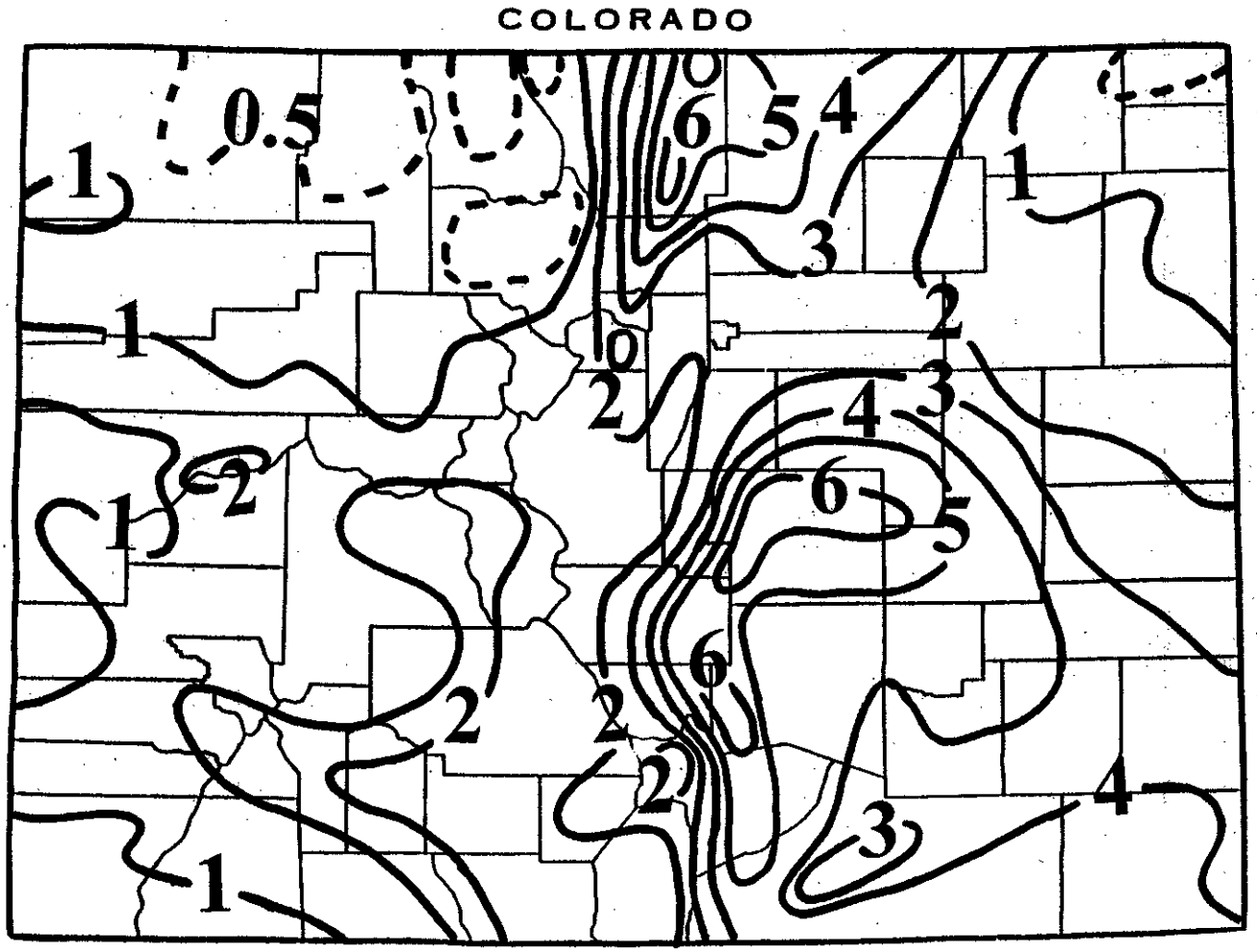
The center of the storm system remained nearly stationary over northern Arizona and southern Utah on the 29th and 30th. This allowed strong, steady southeasterly winds to continue to pump saturated air into eastern Colorado. Watersheds that drain towards the southeast were especially favored for heavy rains and flooding in this weather pattern. Two river basins separated by more than 100 miles proved to be most vulnerable. The Poudre River in northern Colorado and Fountain Creek in the Pikes Peak area both drain towards the southeast and both experienced particularly heavy rains and flooding although other tributaries such as the St. Charles River that flows from the Wet Mountains southwest of Pueblo to the Arkansas River also received excessive rainfall.

In northern Colorado, rainfall rates were moderate, peaking near 0.25" per hour for several consecutive hours on April 30th. Rainfall rates were somewhat higher at times in the Arkansas Valley closer to the storm's original moisture source, the Gulf of Mexico. Compared to summer storms with rainfall rates that can exceed three inches per hour, these rains seemed trivial. However, with rains simultaneously falling over hundreds of square miles "volume flooding" began to occur. "Volume flooding" is a term used by hydrologists that distinguishes the local "flash flood" that occurs when very high intensity rains fall over a relatively small area from the flooding that occurs on large river systems when moderate rains fall over a large area and over a long period of time. There was additional contribution to runoff from melting snows in the Front Range foothills that added to the high volumes. "Rain on snow," a common contributing factor for

flooding in California and the Pacific Northwest is rarely a problem in Colorado. However, some significant contribution from snowmelt may have been present in this storm. The 1999 floods were classic "volume floods," with flows on the Arkansas River, the Poudre and the South Platte far exceeding the high flows typically associated with snowmelt floods. Rains diminshed late in the day on the 30th in northern Colorado but continued in southern Colorado ending on May 1. The mountains and Western Slope received beneficial moisture and mountain snows. Those areas were not affected by flooding.

The following map shows total rainfall for the period April 28 through May 3, 1999 for National Weather Service official cooperative observing sites in Colorado. The majority of this rainfall accumulated between late evening on the 28th and midday May 1. The maximum rainfall was concentrated near the eastern base of the mountains and on the higher ground north and south of the Arkansas River. The Denver-Boulder area received moderate rains, but with southeasterly flow was partially shielded by the higher terrain of Monument Hill to the south. The maximum rainfall at any official National Weather Service stations was measured at Rye in the Wet Mountains southwest of Pueblo with nearly 8 inches of precipitation. This was just two inches less than fell during a two-day intense rain back in mid May of 1955; the highest documented rainfall of record for that area. Rainfall also exceeded seven inches immediately west and north of Colorado Springs with six-inch totals extended eastward into southern Elbert County. Local sources showed as much as 14 inches may have fallen over northwest portions of the city. A secondary rainfall maximum exceeding six inches occurred in the Larimer Couny foothills possibly extending into northwest Weld County. Local areas in the lower foothills west of Fort Collins may have received eight inches or more. Portions of Las Animas and Baca Counties also received very heavy rains.

Reports detailing the magnitudes, nature and extent of flooding in Colorado from this storm will be prepared in the coming months by the Colorado Water Conservation Board, Division of Water Resources, Colorado Department of Natural Resources. Overall, peak flows on the Arkansas River at La Junta may have been comparable to the 1965 floods. Downstream, flooding was not as severe as the June 1965 extreme events, but was sufficient to put huge volumes in storage at John Martin Reservoir. Flood damage on Fountain Creek, the Arkansas River, and the Poudre River as well as other tributaries were sufficient to produce a federal disaster declaration. This appears to be the greatest rainfall and flooding event to occur in April.



Precipitation amounts (inches) for April 28 through May 3, 1999 Storm.

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- History of Drought in Colorado
- Review of 1999 Water Year
- What is Average – What is Normal?
- Vegetation, Land Use and Climate
- CoCoRaHs (Colorado Collaborative Rain & Hail Study)

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If you have topics that you hope we can address in future issues, please bring them to our attention. We will focus on research we are actively involved in, but we will also try to answer questions from our readers as best we can.

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