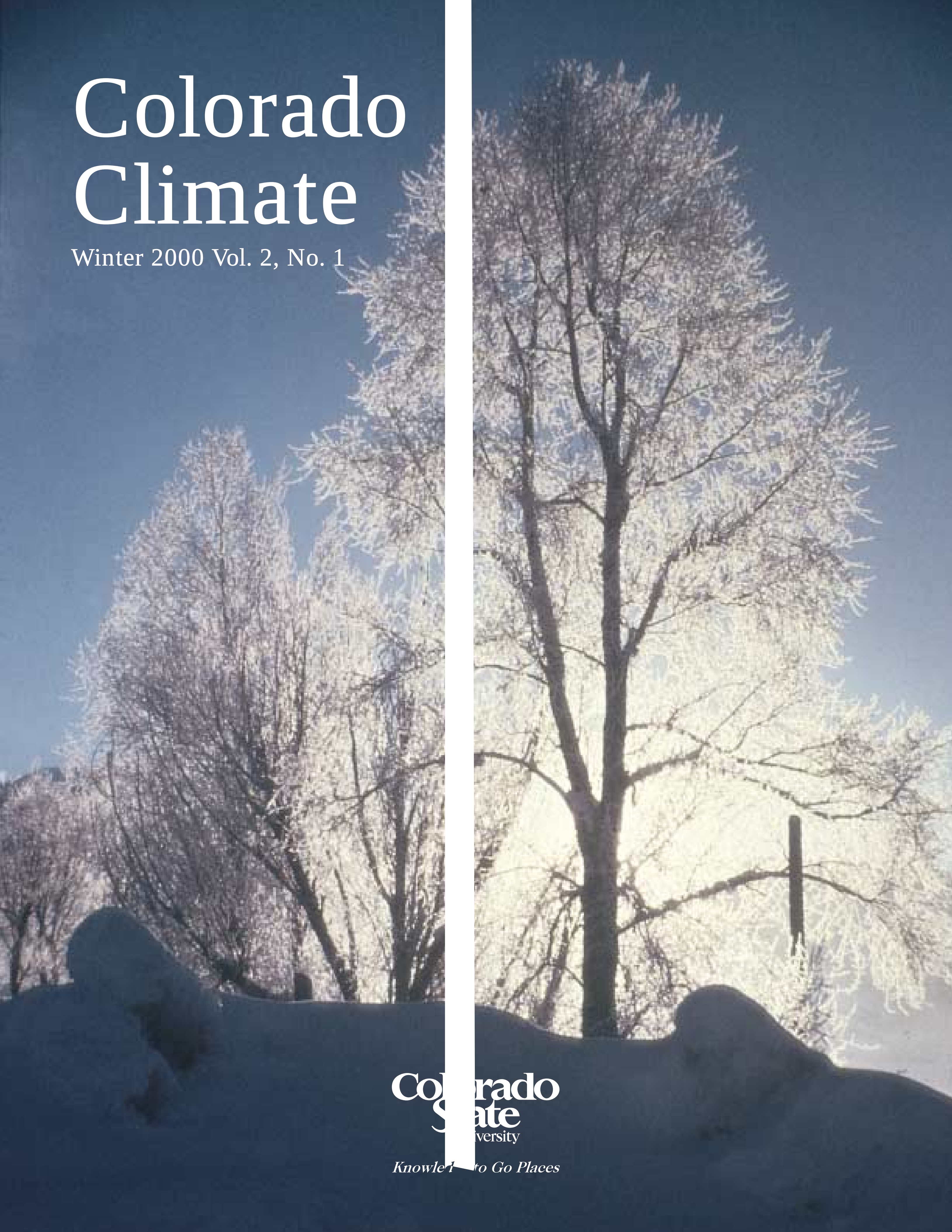
Colorado Climate

Winter 2000 Vol. 2, No. 1



Colorado State University

Knowle to Go Places

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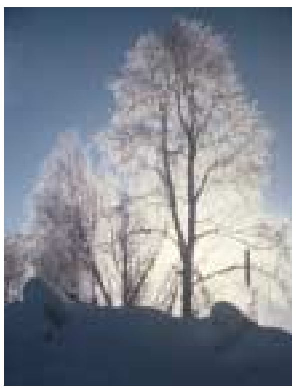

Cover Photo: *Early morning rim ice in a Colorado mountain valley. Photo by Nolan Doesken.*

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

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

The Winter Cloud of the Rockies

Altocumulus Standing Lenticular – the Mountain Wave Cloud. Photo by Nolan Doesken.

Nolan Doesken

Have you ever seen a cloud like this? The scientific name for this type of cloud is altocumulus standing lenticular or altocumulus lenticularis. This name refers to mid-level clouds with some vertical structure that are shaped like lenses. The meteorological abbreviation for this cloud type is ACSL. If you live within 50 miles of any of the various ranges of the Rocky Mountains the chances are that you have seen clouds like this. But have you really watched them and wondered why they are shaped the way they are?

ACSL are most likely seen upwind, downwind, or immediately over mountain ranges. They can occur most anywhere in the world, but are only common over or near mountains in the middle and upper latitudes. They are most often seen here in Colorado during the fall, winter, and spring and are least often seen during summer. They form when moderate or strong winds in the atmosphere encounter an obstacle such as a mountain range. As the air is deflected upward, the air cools by expansion (same principle that is used in your refrigerator). Depending on the temperature and profile of the atmosphere, a wave motion may be triggered, setting up a series of waves. In the portion of the wave where air is rising and cooling, condensation will occur if sufficient water vapor is present. As the air descends, evaporation occurs and the cloud eventually disappears.

When you see an ACSL what you are really looking at is the top half of one of these waves. Watch closely if you can. Unlike other clouds that move through the sky carried along by the winds aloft, the ACSL tends to stand still even though the winds aloft may be blowing very hard. Individual cloud elements within the larger wave cloud form on the upwind edge of the cloud and dissipate at the downwind edge. You can stand and watch those edges literally appear and disappear continuously before your eyes.

While the ACSL may be the most obvious demonstration of waves, the attentive observer will see many other examples appearing in clouds at any height. The atmosphere is a fluid, and waves are the primary means of transporting energy in fluids. Keep your eyes open and you are sure to see evidence of these waves. The picture below, sent to us by one of our readers, is a vivid demonstration that waves are alive and well up in the air. If you don't believe me, talk to a pilot. Even when you can't see them, the pilots feel the motions of those subtle but significant waves.

Have you seen spectacular wave formations in the sky? Have you photographed them? Send us your photograph and a description of where you were and what weather conditions were that day. We will periodically select photos for publication in Colorado Climate *based on the quality of the photograph and the nature of the clouds.*

Kelvin Helmholz wave clouds over Colorado Springs. This is a much rarer type of "wave" cloud. Photo by Tye Parzybok, Fort Collins, Colorado.

Climate on the Web – The NOAA Climate Prediction Center

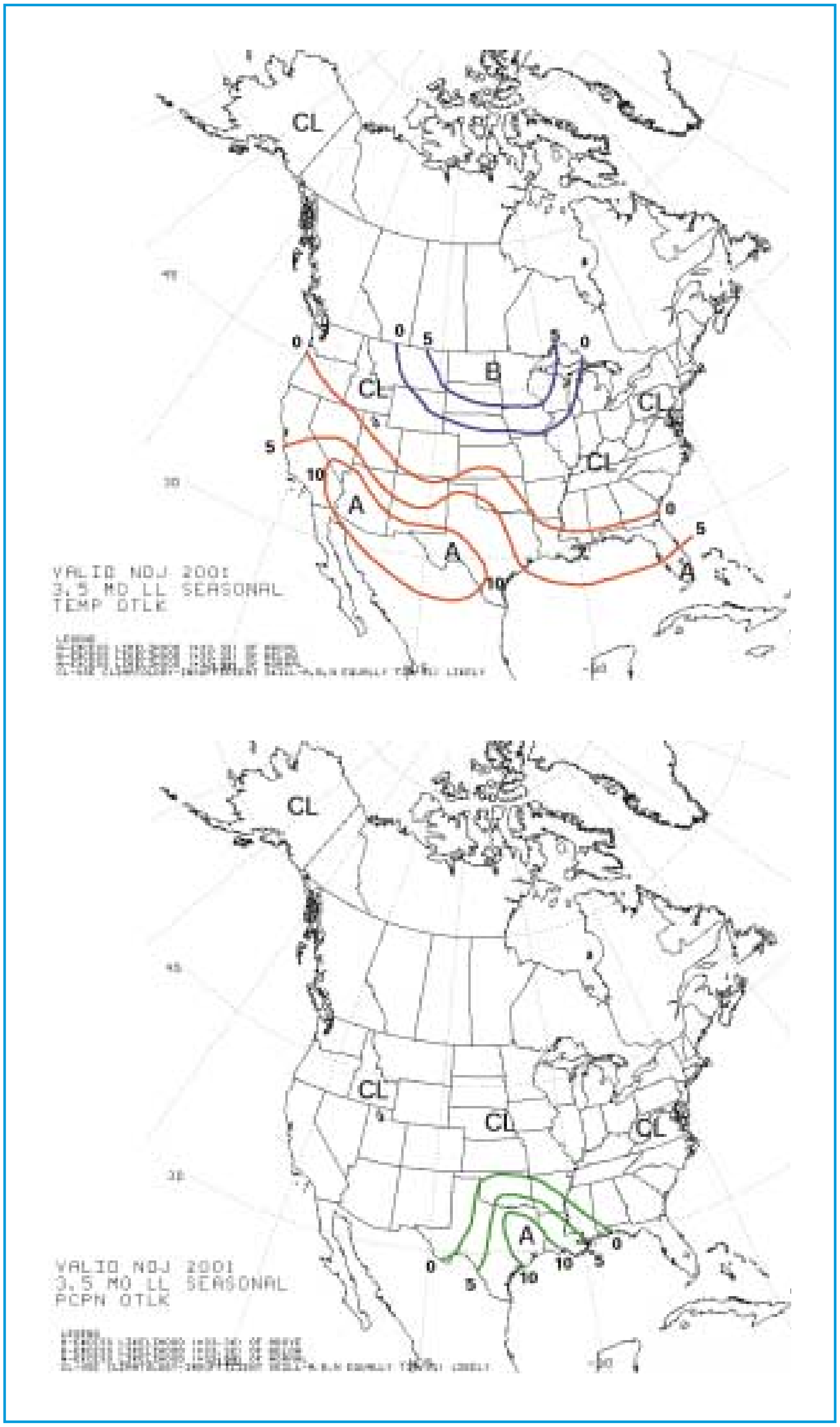
Nolan Doesken

Long-range forecasts (one to three months) have been issued by a special branch of the National Weather Service for many years. Many people across the country have viewed those forecasts but until recently few took them very seriously. With the help of years of research followed by some carefully monitored dramatic changes in sea surface temperatures, winds, and pressure patterns over the Pacific Ocean beginning in 1997, long-range seasonal climate forecasts have gone from being pooh-poohed to being in high demand. A better understanding of how oceanic conditions subsequently affect continental climate resulted in a new suite of long-range forecasts issued as much as 15 months in advance.

Did you know that anyone can check out the latest long-range forecast at any time? Like so many other things, they're right on the Web and they're updated every month. If you want to check out these forecasts plus a myriad of other climate information for the country and the world, take a quick journey to the National Oceanic and Atmospheric Administration's Climate Predication Center web page:

http://www.cpc.ncep.noaa.gov/

Not only can you find current forecasts, you can even check out forecasts from the past and how well they fared. Right now, what you're going to see in most of the seasonal forecasts for the next 15 months is the abbreviation "CL." What that really means is the forecast models and forecasting gurus don't have enough information to suspect that the chances of being hot or cold, wet or dry, will differ from "Climatology." Some people interpret "CL" to mean "Near Average," but what it really means is that no skill exists based on current information to lean one direction or another, and that pretty much anything can happen. That's not a bad forecast, but it certainly admits the uncertainty that is still very much a part of long-range forecasting. We have come along way, but if you think we've got it mastered, think again.



November, December, January 2001-02 seasonal forecast for temperature (top) and precipitation (bottom) taken from the Climate Prediction Center's web site.

Climate Memories: 25, 50, and 100 Years Ago in Colorado – 1976, 1951, and 1901

Nolan Doesken

We keep hearing so much about global warming and how we're having more extreme weather than ever before. I hear those stories and I listen with interest, but I have to admit that I'm always just a little skeptical. I have easy access to the historical weather records for Colorado and I often look at them. Extreme weather is nothing new to this state. We've always had wild weather. Every time we have a storm, media reports make it sound like something terrible and unprecedented. But in reality, we've had storms before, and we'll have them again.

Let's go back in time and see what interesting weather was going on in this fine state of ours.

25 Years Ago: 1976

In 1976, I still lived in Illinois and was just finishing graduate school. I had no idea I would soon be heading for Colorado. In fact, I was so busy finishing my thesis paper, I didn't pay much attention to anything. But I did hear about the Big Thompson Flood late on July 31 and it brought back thoughts of family vacations years earlier in the Rockies when we first drove up that canyon in 1959 – Illinois flatlanders gawking at the scenery and driving 15 mph, I'm sure.

I was less aware of the other Colorado memory from 1976 – drought! Despite some heavy summer rains, the fall turned dry and by Christmas 1976, with bare ground showing on ski slopes throughout all parts of Colorado, we were well on our way into the worst winter drought ever measured in Colorado.

50 Years Ago: 1951

Fewer of you will remember this year, but it also made its mark on the Colorado record books. On February 1st, extreme cold gripped the state with temperatures dropping below -40°F at many locations. Taylor Park Reservoir reported a new state record low of -60°F that morning. Fruit orchards were damaged or destroyed by the extreme cold. Fort Collins registered a low of -41°F. For many locations in Colorado, the records from that morning still stand.

In mid May of that year, a large storm system dropped heavy rains and hail. More than 7 inches of rain were reported in one day at a weather station in southeastern Colorado. Flood waters inundated parts of the town of Holly and at least one death was reported. Later that summer a round of heavy slow-moving thunderstorms in early August associated with the Southwest Monsoon dropped excessive rains. Severe flooding occurred in Denver, while up to 12 inches of rain fell in the foothills of Larimer County west of Fort Collins and Loveland. The campus of Colorado State University was flooded, and several lives were lost from flooding in the foothills.

One more bout of extreme weather occurred the last three days of 1951 (December 29-31). The "Pineapple Express" (a term coined many years later after the advent of weather satellites) carried a fast moving river of very moist Pacific air from the area of Hawaii towards Colorado. Extremely heavy and wet snows totally buried the Colorado mountains from Steamboat Springs to Durango and everywhere in between. Even the normally drier valleys like around Eagle and Montrose were covered by feet of snow. By the last day of December, the snow depth on the level in the town of Crested Butte was nearly 7 feet. Transportation in the mountains was totally blockaded for several days. To this very day, this storm remains the largest and most widespread snow blitz in the Colorado Rockies in recorded history. Heavier snows have fallen at individual locations, but this storm was remarkable for its north-south and elevational extent.

100 Years Ago: 1901

There just aren't a whole lot of people around today with personal memories of 1901. If you're one of them, let me know.

There were already more than 70 weather stations operating in Colorado then, and those records remain on file at the Colorado Climate Center. It wasn't an exceptional year and few events stand out as unique. However, there were all the variations and extremes that we are accustomed to.

Winter temperatures were fairly normal by today's standards but snow accumulation was quite meager, even in the mountains. March and April each brought some heavy, wet snows. May 1901 was extremely dry in eastern Colorado but very wet near the Front Range with 4 inches of rain at some stations. This spring moisture was greatly needed, as only limited reservoirs had yet been built to store water from the spring runoff.

June began with a very late freeze on the 6th damaging some crops in northeastern Colorado. On the 14th, widespread severe thunderstorms brought damaging hail, high winds, and locally flooding rains. Then the weather turned hot and dry from late June into early August. For July, Denver reported its warmest month on record up to that time since 1871.

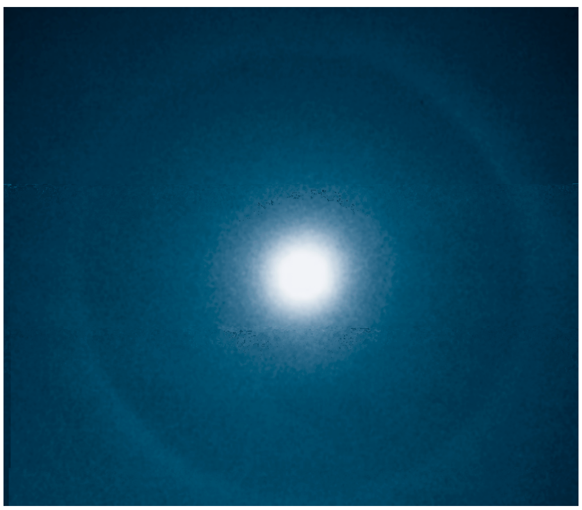
Following a warm but wet August, good moisture continued for the first two weeks of September. The weather then dried in time for harvest, and the state

(continued on page 4)

Folklore: Aunt Nervie Told Me to Watch the Moon

Nolan Doesken

When I was a child, Aunt Nervie used to point out interesting things to us neighborhood kids that she would observe. Aunt Nervie was not her real name and she wasn't my aunt. Her actual name was Minerva Putnam and she was my best friends' great aunt and part of their extended family. With her help, by the time I was 6 or 7 years old I was already well aware of lunar halos – those neat rings that you sometimes see around the moon at night. Aunt Nervie watched the moon like a fox watches chickens and whenever she saw one of those rings she would confidently announce that a storm was headed our way and to look out for snow (or rain) in about a day and a half.



At that time, Aunt Nervie was my idol, and it seemed that she knew things that others could not even fathom. Furthermore, she made great homemade bread that she shared with us kids. Well, anyway, she was the first weather forecaster I ever knew. With most of her teeth missing, she wouldn't have done too well on TV, but that didn't matter.

Years later, when as a professional climatologist I began investigating the truths and myths of weather folklore, I found that old-timers long looked for rings around the moon or sun to give early indications of coming storms.

"Circle around the moon, rain or snow soon."

Is there truth to this old halo wisdom? Yes, there actually is. In many parts of the country and, in fact, many parts of the world, particularly in the mid latitudes, a predictable progression of clouds precedes many storm systems, especially during fall, winter, and spring. High wispy cirrus clouds appear first, thickening and lowering gradually, followed later by thin mid level clouds (altostratus) which also gradually thicken until they block all view of the sun or moon. It is these first films of thin cloud that can produce the halo phenomenon that Aunt Nervie so aptly pointed out to us.

Unfortunately, here in Colorado, at least here at the eastern base of the Rocky Mountains, the cloud patterns are different. We sometimes do see halo phenomenon in advance of Pacific storm systems. These storms may bring moisture to our mountains, but on the lee side of the mountains, we are often skipped. When we do get snow, the cloud progressions here are much different than there. I don't see as many halos as I used to, and it certainly doesn't rain as much here as it did back in the Midwest. But then again, maybe I'm just not looking like I used to. Many of us in the midst of challenging professional lives and busy family schedules just don't take the time to look. Sad, but true.

Yes, Aunt Nervie knew what she was talking about, and those halos were good indicators. If your cable or satellite TV goes out on you, I recommend turning on "the nature channel" and heading outside. Actually, those halos are much more inspiring than any 3-D color graphics on the tube. Both you and I might do well to take a little more quiet time just watching – and wondering.

Climate Memories *(continued from page 3)*

enjoyed a mild and sunny autumn – the type we enjoy very much now. Topsy turvy weather waited for December 1901. Temperatures climbed briefly into the 60s at lower elevations early in the month but this was short lived as a cold wave with heavy snow moved in mid-month. Temperatures plummeted to -20° or below on December 14th over much of northeastern Colorado and some mountain valleys. But temperatures rebounded quickly and on the 21st and 23rd several low elevation stations east of the mountains reported temperatures in the 70s. The Trinidad weather station even reached 81°F. While there wasn't much winter recreation back in 1901, there was a hint of rejoicing after several heavy snowfalls. The monthly reports written back then focused on the "Snow in the Mountains." At least 80 reports of mountain snow conditions from all areas of the state were compiled each month not unlike the much more sophisticated snow pack readings gathered today by the Natural Resources Conservation Service.

Yes, there was weather in Colorado 100 years ago, not all that much different than today.

Colorado Climate in Review

October 2000

Climate in Perspective

October brought a variety of weather conditions to Colorado. Summer-like temperatures early in the month, periods of sunshine, morning frosts, periods of low clouds, fog and drizzle, thunderstorms, and mountain snows were all a part of the month. After a period of quiet weather in mid October, one storm system after another developed and marched across the state taking aim most directly on southern Colorado while skipping over northern Colorado leaving some areas bone dry.

Precipitation

Several major storm systems brought significant precipitation to Colorado in October, but each storm dumped most of its moisture over southern and eastern parts of the state and skipped over north central and northwestern counties. The majority of precipitation fell in the form of rain, but in the southern mountains above 10,000 feet snow accumulations were generous. Well over a foot of dense snow covered the ground by month's end. A widespread rain event deposited much-appreciated moisture over nearly all areas of the eastern plains 28-29th providing some relief to dry soil moisture conditions following the hot and dry winter, spring, and summer of 2000. Overall, October precipitation was much above average over southern and eastern Colorado with many areas reporting two to three times their average. Wolf Creek Pass totaled 7.96 inches of moisture for the month. Walsh reported 4.78 inches of rainfall, their wettest October in the 33-year history of their station. At the same time, north central Colorado was very dry. Hayden totaled just 0.30 inches (19% of average) while the Granby station only reported 0.05 inches (5% of average), their driest October in the 53-year history of that station.

Temperature

Western Colorado cooled gradually through October while temperatures were more variable east of the mountains. Overall, most of the state ended up near to slightly warmer than average for the month as a whole. The largest anomalies were found in central Colorado where several communities were 2 to 3 degrees Fahrenheit above average for the month.

October Daily Highlights

1-3 Hot weather was widespread on the 1st. Cooler air moved into northeastern Colorado 2-3 but warm conditions prevailed elsewhere. Many weather stations in southeastern Colorado reported highs in the 90s on the 3rd. A few showers and windy thunder sprinkles developed on the 3rd.

4-8 Much cooler over eastern Colorado and gradually cooler elsewhere. Fog, drizzle, and light rain developed over eastern Colorado on the 4th and continued 5-6th, changing to snow close to the foothills at times. A band of rain also crossed western Colorado on the 4th. Totals were generally light, but Cheyenne Wells picked up nearly a half inch of rainfall, and Boulder totaled 0.64 inches of rain and wet snow. Temperatures remained in the 30s and low 40s east of the mountains 5-7th. Clouds gradually broke up 7-8th and temperatures moderated.

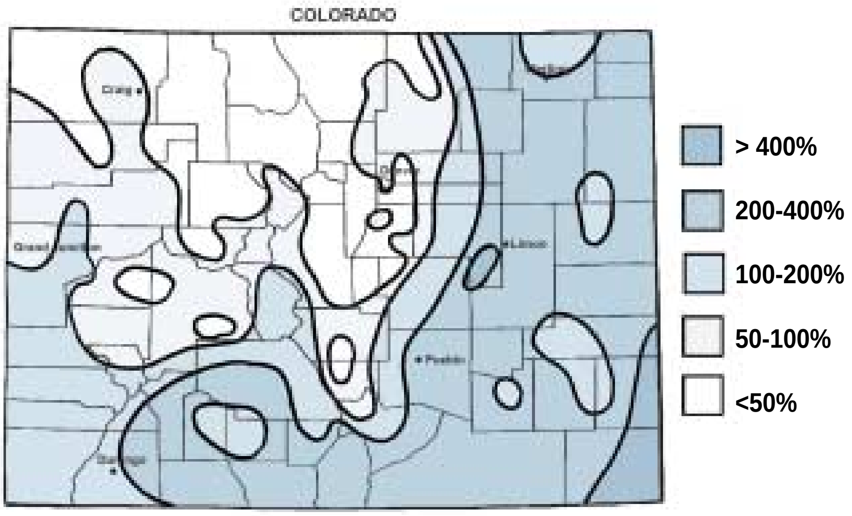
9-12 Eastern Colorado enjoyed pleasant autumn weather 9-12th. At the same time, an upper-level low pressure trough and Pacific cold front brought wet weather west of the mountains, particularly over southwestern Colorado. Wolf Creek Pass picked up nearly 3 inches of rain, ice pellets, and wet snow, mostly on the 11th and 12th. Strong winds accompanied the storm 10-11th. Only light showers fell over most western valleys, and little or no precipitation reached Colorado's northern and central mountains.

13-15 The upper level low pressure system moved northeastward late on the 12th bringing some late evening (12th) and early morning (13th) showers and thunder to parts of northeast Colorado. With clearing skies, nights were chilly. Grand Junction and surrounding areas had their first subfreezing temperatures of the season on the 14th.

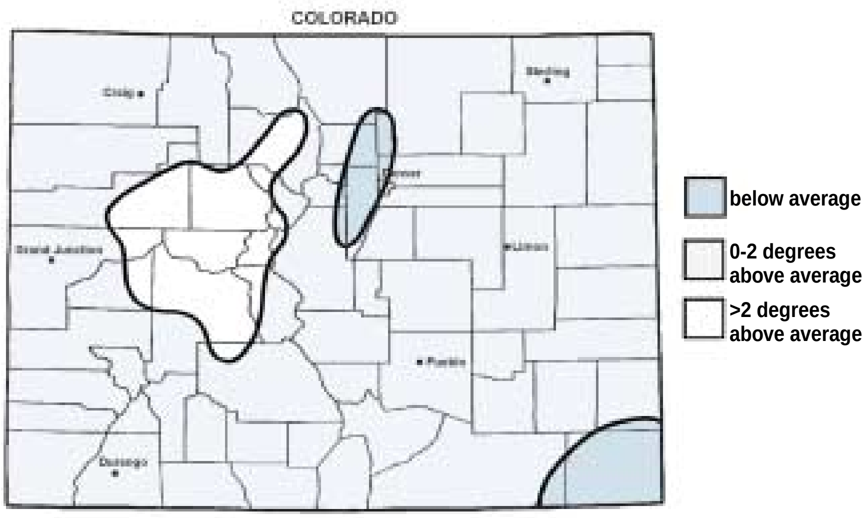
16-21 High pressure established itself over the region bringing sunshine and warming temperatures. Temperatures in the 70s were common at lower elevations. This would prove to be the last warm week for many months. Clouds, winds, and a few light showers spread into western Colorado on the 21st in advance of an approaching storm system.

22-24 A low pressure center developed over Arizona and moved northeastward spreading rain and mountain snows across most of Colorado. More than 1 inch of moisture fell over portions of southern Colorado including some areas on the eastern plains. Walsh, in extreme southeastern Colorado, measured 2.65 inches from the storm. Buena Vista, in the upper Arkansas Valley, recorded 0.90 inches. Unstable air triggered thunderstorms late into the evening of the 24th over northeast Colorado.

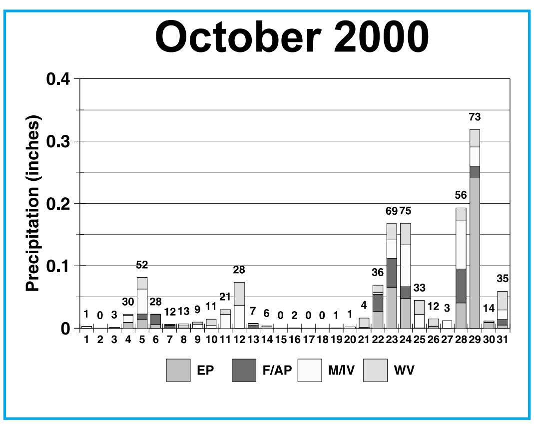
25-26 Mostly dry but unsettled with seasonally cool temperatures as one storm departed and a new one approached from the southwest.



October 2000 precipitation as a percent of 1961 to 1990 average.



October 2000 temperature departure from 1961-1990 average, degree F.



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

27-29 The next storm moved from southern California to southern Colorado 27-28th. Thundershowers developed late on the 27th over southwestern Colorado and turned into widespread low elevation rains and high-mountain snows on the 28th. Up to 2 inches of water content was observed over portions of the San Juan Mountains. Widespread rainfall developed over eastern Colorado on the 28th and ended from south to north on the 29th as the storm moved northeastward, but not before much of eastern Colorado received an inch of more of rain. Totals exceeded 2 inches at Wray, Holly, and Walsh.

30-31 As one storm moved out, yet another major storm moved in from the southwest. One half inch of rain fell at Grand Junction. East of the mountains, a heavy localized downpour dropped more than 1 inch of rain in a short period over northwest Fort Collins. Precipitation ended by evening so most Halloween trick-or-treaters had a chilly but fun evening.

October 2000 Monthly Extremes

Description	Station	Extreme	Date
Precipitation (day):	Holly	3.32"	10/29
Precipitation (total):	Wolf Creek Pass 1 E	7.96"	
High Temperature:	Campo 7S	98°F	10/4
	Arapahoe 14N	98°F	10/2
Low Temperature:	Fraser	12°F	10/8

November 2000

Climate in Perspective

After a full year with above average temperatures, November tried to make up for it all at once. Winter set in hard and fast with frequent mountain snows and persistent cold temperatures. Precipitation was not excessive, but with the cold temperatures mountain snows accumulated with little melting or settling. Winter outdoor recreationists were thrilled, but the timing coincided with skyrocketing energy costs shocking many homeowners and business managers with huge heating bills at the end of the month. In fact, this was the coldest November since 1972.

Precipitation

The storm track shifted from October to November. All the areas of southern and eastern Colorado that were very wet in October ended up drier than average for November. Many weather stations in southeast Colorado and the San Luis Valley received less than 0.20 inches of moisture for the month. Colorado's northern and central mountains took the brunt of the November storms with areas from Aspen to Grand Lake reporting above average precipitation in the form of light, powdery snows. Areas east and west of the mountains across northern Colorado were also near to above average for the month.

Temperature

November temperatures were much colder than average over all portions of Colorado. The areas hit hardest by the sudden onset of winter were found across northern Colorado particularly in the South Platte valley and the Yampa valley. At Hayden, for example, November temperatures ended the month 10.8 degrees F below the 1961-1990 average. Holyoke ended the month 9.7 degrees below average, their coldest November since 1952. The main feature of the cold was its persistence. Grand Junction, for example, reported that each of the first 26 days of November were below the long-term daily averages while nine days in a row from the 11th through the 19th were at least 11 degrees colder than average. Subzero readings were common in the mountains. Crested Butte temperatures dipped below zero Fahrenheit on 14 days during November.

November Daily Highlights

1-2 It was breezy and cold across Colorado with a few lingering mountain snow showers on the 1st behind the deep low pressure area that had crossed the state on Halloween. An upper air disturbance dropped down from the northwest on the 2nd bringing a round of light rain changing to snow along the Front Range from Fort Collins to Colorado Springs continuing into the early morning hours of the 3rd.

3-4 Cool and dry over most the state as high pressure perched briefly over northern Colorado. A little snow fell over extreme southwestern Colorado as an upper low just south of Tucson, AZ, spread some clouds as far north as the southernmost portion of the state. Temperatures climbed briefly into the 50s and 60s across eastern Colorado on the 4th – the warmest day of the month.

5 A complex storm system took shape over the Rockies early on the 5th as cold air aloft moved in rapidly from the northwest. Most of the mountains and western valleys picked up a little snow as the cold air moved in. Locally, snows were very heavy. Aspen measured over 16 inches of fresh, low-density snowfall. Rain and snow spilled across the mountains into eastern Colorado midday on the 5th. Some of the Denver area received as much as 5 inches of snow with substantial water content. Only an inch or two fell farther east on the plains

6-9 Dry in most areas but unseasonably cold across the state. A few snow showers in the mountains. Eight inches of snow fell at Rye with lesser amounts at other southern Colorado stations on the 6th as a storm center churned across southern New Mexico. High temperatures only reached the 20s in the mountains 6-7th with some subzero readings at night, the first of the season. Temperatures warmed a bit on the 9th in advance of the next push of cold air.

10-11 A strong surge of arctic air reached northeastern Colorado as a large, cold trough of low pressure approached Colorado from the west. Freezing drizzle and light snow began over northeastern Colorado and spread southward, while snow also developed in the mountains with southwesterly winds aloft. By late on the 11th, a few inches of snow covered broad areas of Colorado with 3-8 inches of new snow in many mountain locations. Daytime temperatures on the 11th were only in the 20s east of the mountains.

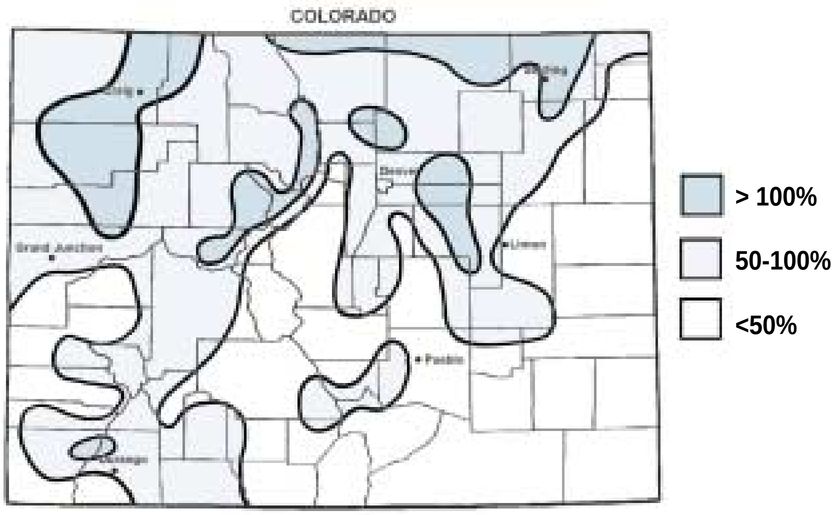
12-14 Clearing on the 12th and staying very cold. Lows dropped to near or below zero, even east of the mountains, on the 12th, and well below zero in many mountain locations 13-14th. Some flurries continued in the mountains.

15 Temperatures moderated briefly and winds picked up as a trough of low pressure aloft crossed the state from west to east kicking off a period of snow in the mountains.

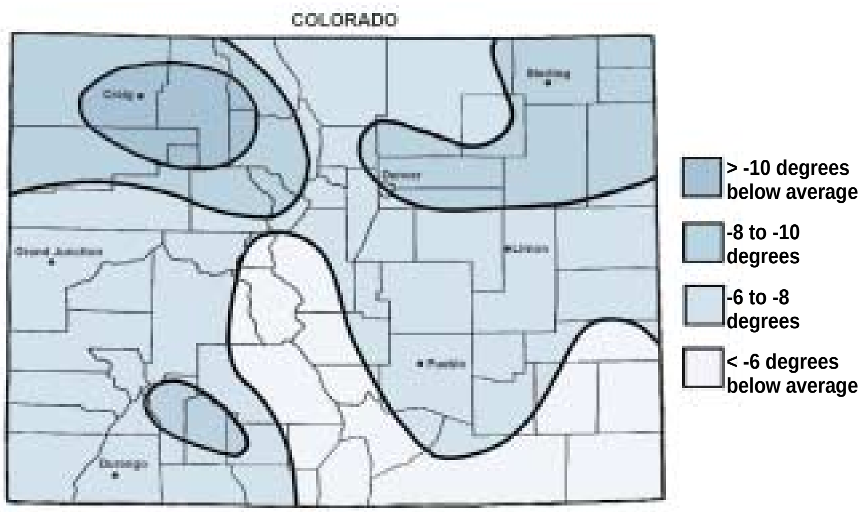
16-21 An extensive ridge of high pressure staked its claim on the western U.S. with strong northwesterly winds aloft over Colorado. Temperatures were very cold 17-18th in the mountains with widespread subzero readings. Walden recorded -19°F, Crested Butte -20°F, and Fraser -22°F on the morning of the 18th – very cold temperatures for so early in the season. Temperatures then began a gradual moderation but remained below average statewide.

22-25 Generally dry with temperatures near the seasonal average over much of Colorado. A small upper-level low pressure area spread clouds into the state on the 22nd and dropped a few flurries across extreme southern Colorado on the 23rd. Another minor storm brought a little snow to the northern mountains late on the 24th.

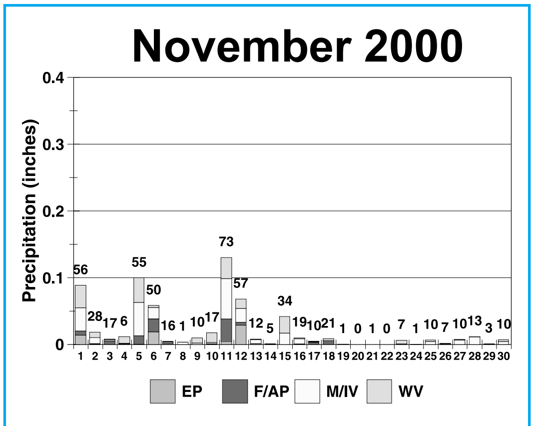
26-30 Mostly zonal (west to east) winds aloft over Colorado bringing milder temperatures at last. Temperatures in the low 50s east of the mountains felt remarkably warm to local residents. Pulses of Pacific moisture accompanied occasional upper air disturbances bringing periods of mostly light snow to the northern mountains. While most of the state remained dry, Steamboat Springs added small accumulations of new snow each day.



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



November 2000 temperature departure from 1961-1990 average, degree F.



November 2000 Monthly Extremes:

Description	Station	Extreme	Date
Precipitation (day):	Hermit 7 ESE	1.47"	11/11
Precipitation (total):	Wolf Creek Pass 1E	3.99"	
High Temperature:	John Martin Dam	73°F	11/1
Low Temperature:	Antero Reservoir	-23°F	11/18

December 2000

Climate in Perspective

The jet stream howled overhead above Colorado during much of December. At the same time, polar air lurked just northeast of the state occasionally nudging up against the Rockies. One after another, storm systems raced across the area, but storms moved so quickly they had little time to deposit much moisture. As each storm passed, strong winds shook exposed areas from the crest of the continental divide eastward across the plains. Wind gusts exceeded 50 miles per hour on at least 12 different days during the month in the eastern foothills, and gusts in excess of 80 miles per hour were reported on at least three days. Despite all the turmoil, temperatures ended up near average with most of the state drier than average. Most of the state was treated to a delightful Christmas Day snowfall – heavy enough to be beautiful yet light enough to scarcely affect travel.

Precipitation

Despite several good opportunities, December precipitation lagged behind average across most areas of Colorado. Snow fell on nearly half of the days of the month across the northern and central mountains, but most snowfall totals were light and snow water contents low. For the month as a whole, precipitation totals were less than half of average over southern, eastern, and portions of extreme western Colorado. Above average precipitation was limited to small areas of northwestern Colorado, central Weld County, and a band near the Continental Divide from Breckenridge to Cameron Pass. Enough snow fell in the mountains to provide more than enough raw materials for excellent winter recreation. Cold temperatures helped preserve this great resource.

Temperatures

December temperatures weren't far from average over Colorado's Western Slope with only minor changes from day to day. In the mountains and high valleys, periods of very cold temperatures occurred each time there were several days of clear weather to allow radiational cooling and cold air trapping. East of the mountains, December temperatures zipped up and dipped down like a yo-yo alternating between above average and below average at least eight times. When all the numbers were added up, temperatures for the month as a whole ranged from about 3 degrees F below average near the border with Nebraska and Kansas to more than 3 degrees above average out near the Utah border.

December Daily Highlights

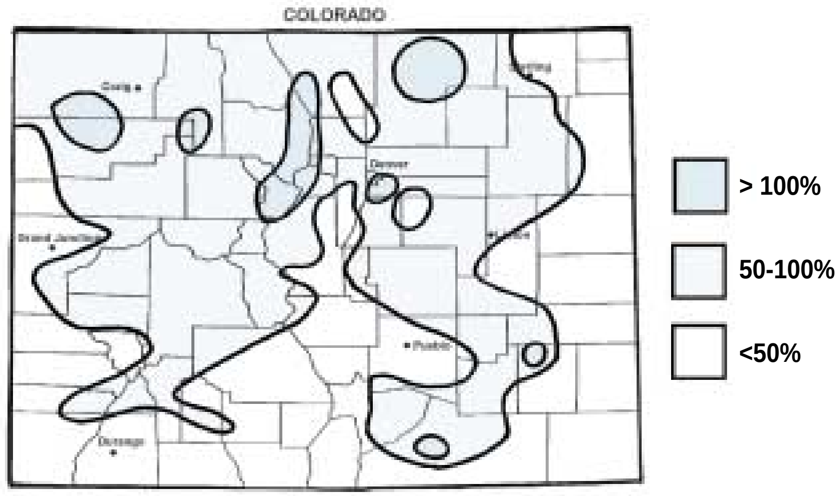
1-3 Mostly clear and dry as the jet stream slid northward for a few days. Quite cold in extreme eastern Colorado on the 2nd but warming nicely on the 3rd east of the mountains.

4-5 Gorgeous on the 4th with light winds and warm sunshine. A short wave trough dropped down from the north on the 5th accompanied by a period of light snow over the Front Range and eastern plains and a burst of strong winds. Before the cold arrived, Pueblo climbed to a toasty 66°F.

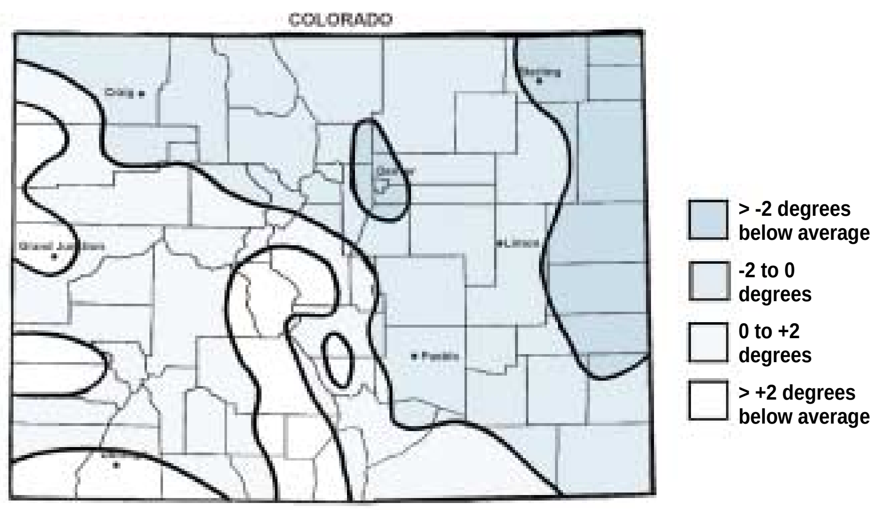
6-9 Winds diminished on the 6th, and mild and dry weather returned. Pacific moisture began moving into western Colorado on the 8th along with cooler temperatures. By the morning of the 9th, several inches of snow had fallen in the mountains.

10-13 The strongest shot of arctic air since December 1998 arrived in northeastern Colorado early on the 10th and quickly spread across all of eastern Colorado. An inch or two of snow marked the arrival of the arctic blast across most of eastern Colorado with 1 to 4 inches along the Front Range. High temperatures barely reached the teens 10-11th over northeastern Colorado, and low temperatures on the 11th and 12th dropped to near or below zero. Meanwhile, in the mountains and on the Western Slope, moist and mild Pacific air prevailed with valley rain showers and widespread locally heavy snows on the 10th and 11th with periods of snow and turning colder 12-13th. Crested Butte picked up 28 inches of new snow 9-13th while even heavier amounts fell higher in the mountains.

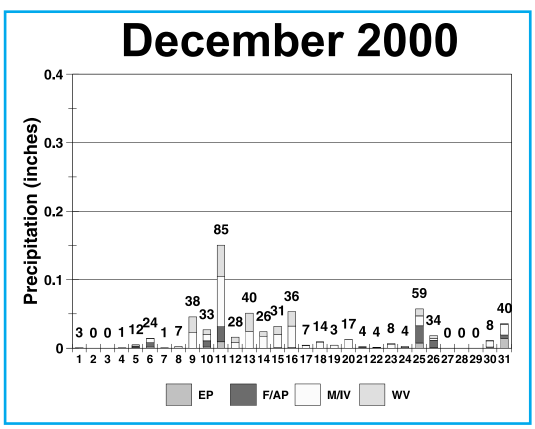
14-23 The pool of arctic air slipped eastward away from Colorado on the 14th. For the next 10 days, one disturbance after another raced across Colorado, each bringing bursts of snow to the mountains and blasts of strong, dry winds from the crest of the Rockies eastward across the plains. Gusts exceeded 60 miles per hour on several different occasions in wind-prone areas. East of the mountains temperatures bopped up and down like a super ball with temperatures mild on the 15th, cold on the 16th, very warm on the 17th (upper 60s over southeast Colorado), cold on the 18th, warm on the 19th, cold on the 21st, warm on the 22nd, and cooler again on the 23rd. Very little precipitation fell during this period east of the mountains, but each passing disturbance brought some snow to the mountains. Winter Park and Fraser each reported 8 inches of new snow on the 20th.

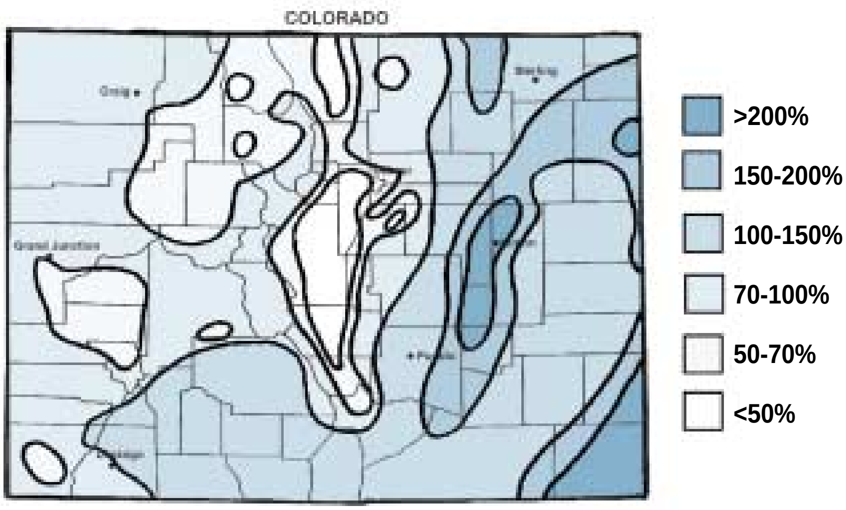


December 2000 precipitation as a percent of the 1961-1990 average.



December 2000 temperature departure from 1961-1990 average, degree F.





Water Year 2001 (October through December 2000) as a percent of the 1961-1990 average.

24-26 The progression of storm systems slowed down for the holidays. A low pressure area approached Colorado on the 24th and moved across New Mexico on the 25th. Light southeasterly "upslope" winds brought widespread light snows to the Front Range and portions of the eastern plains on Christmas Day. The heaviest snows fell in southern Colorado. Trinidad reported 5 inches of new snow. The mountains also received some snow. As skies cleared overnight, temperatures dropped over the surface of fresh snow. Many locations in the mountains awoke to temperatures near or below zero. The 26th was a great day with light winds, bright sun, and glistening snow.

27-29 With generally clear to partly cloudy skies and no precipitation statewide, cold air settled into Colorado's snow-covered mountain valleys with subzero temperatures each night. With the help of some downslope westerly breezes, temperatures warmed rapidly into the 50s east of the mountains on the 27th. Jet stream winds out of the northwest increased over Colorado on the 28-29th bringing dry but cooler air into eastern Colorado and strong winds to the high mountains and eastern foothills.

30-31 A shallow polar air mass from the Canadian prairies moved back into eastern Colorado with some fog and light snow, particularly over northeastern Colorado. The Akron weather station reported 2.5 inches of new snow. The winds aloft shifted to northerly on the 31st and brought a few inches of fresh snow to portions of the northern and central mountains. Southwestern Colorado was unaffected and remained mild and sunny.

December 2000 Monthly Extremes:

Description	Station	Extreme	Date
Precipitation (day):	Bonham Reservoir	1.00"	12/11
Precipitation (total):	Winter Park	3.16"	
High Temperature:	Campo 7S	71°F	12/1
Low Temperature:	Sargents	29°F	12/18

2001 Water Year to Date: October 2000 through December 2000.

Is Drought Still Hanging Around?

Early falls of powder snow brought broad smiles to the thousands of Coloradoans who either make a good chunk of their livings from winter recreation and tourism or who just plain love frolicking in the snow. While the mountains got the bulk of the early snow, cold temperatures with occasional snows at lower elevations also made for wintry landscapes – a rare sight after recent warm winters. However, what many failed to notice was that most of these early snows were light as a feather. Even in the high country, the deep snows contained relatively little water. When the actual water content of the snow was measured and compared, lo and behold, most areas remained well below average for the first three months of the new water year.

As the map here shows, precipitation for October through December was considerably below average from the Front Range westward to Utah. In fact, except for the southernmost Rockies, nearly all of the western U.S. got off to a dry start to the new water year. While we've seen much drier weather in the past, several stations such as Paonia, Glenwood Springs, Kremmling, Granby, and Steamboat Springs all reported less than 70 percent of the long-term average. The driest areas were found in a band from Westcliffe northward to Hartsel, Bailey, Evergreen, and Estes Park. In this foothill/mountain region, some stations reported less than one-fourth of the average October-December precipitation. While there is plenty of winter and spring ahead to catch up, this area will require close attention. Several of Colorado's worst forest fires last season exploded in the dry forests of this zone, and without heavy spring precipitation, this area will again be vulnerable to fast-spreading wild fires.

The picture is rosier out on Colorado's eastern Plains. The widespread and heavy October precipitation improved soil moisture conditions before the ground froze. While November and December have been quite dry, cold temperatures and occasional periods of shallow snow cover have helped to preserve the fall precipitation in the topsoil. Much more late winter and spring precipitation will be needed, however, to restore soil moisture to the levels that existed prior to the hot, dry 2000 Water Year.

Climate Data at Work – Heating Degree Days Are Back!

Nolan Doesken

When I was in college in the early 1970s, an energy crisis had all of us watching our fuel consumption carefully. This happened again in the late 1970s into the early 1980s. For several years a lot of our climate research was focused on how climate affects energy consumption and how renewable energy sources such as wind and solar energy can reduce our demand on fossil fuels. During that time, we published maps and tables of heating degree days and how they compared to average. Many individuals, businesses, and public organizations across the state subscribed to our reports in order to help track the effectiveness of energy conservation efforts.

Since the mid 1980s, the interest in energy conservation and renewable energy steadily faded. Many utilities have tried to maintain an energy conservation focus, but with low costs and many mild winters, most of us simply went about building bigger houses, driving bigger cars, and consuming more fuel – lots more.

Then along came 2000 and energy costs began creeping higher. Later in the year, the creeping changed to leaping, at the very time that much of North America had its coldest November-December in years. With the leaping prices came screaming customers shocked by the highest home gas and electric bills they had ever seen. And with that, suddenly the interest in climate and energy returned again.

With growing concern over high energy costs, residents and businesses were again studying their heating bills and comparing them to previous years. For the first time in nearly 20 years, people were again inquiring about heating degree days.

What are heating degree days (abbreviated HDD)? The concept is very simple and is nearly the same as the "cooling degree days" we wrote about a few months ago (Vol. 1, No. 3). For each day, you take the highest and lowest temperature, add them and divide by 2 to determine the mean daily temperature. Then, for each day when the mean temperature is below 65°F, subtract the mean from 65°F.

For example, if the high is 54 and the low is 30, the mean daily temperature is 42 degrees. Subtracting 42 from 65 yields 23 heating degrees for that day. Add each day's total together for a month or season, and you have the heating degree day total. The colder it is, the more heating degree days you accumulate.

(54 + 30) ÷ 2 = 42°F (mean daily temperature)
65 (°F base) - 42 = 23 (heating degrees for that day)

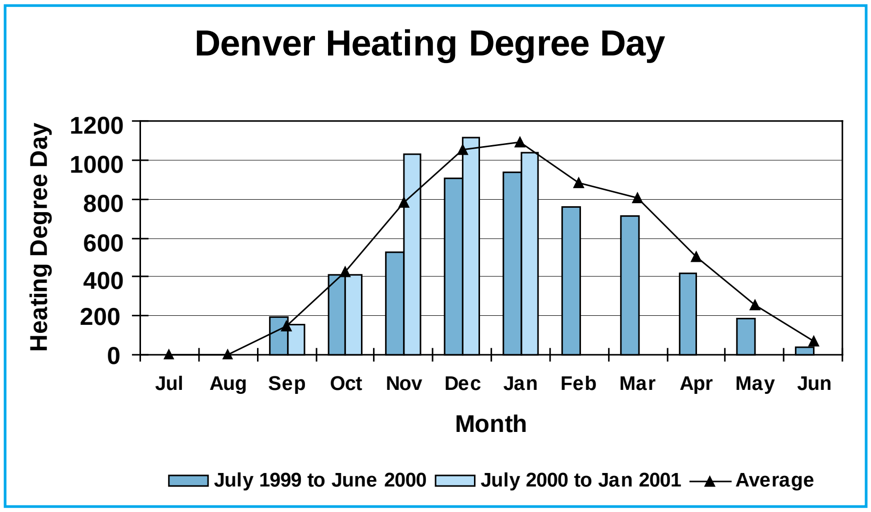
Heating degree day totals have been found to relate well to the amount of energy required to heat a building to comfortable indoor temperatures. Therefore, HDDs are an easy way to track potential energy costs and to evaluate the success of energy conservation measures. Since weather conditions are such a big factor in energy consumption, and since conditions change a lot from year to year, you can't just compare this year's bill to last year's to know if your new windows, the extra insulation you added, or the new high efficiency furnace you had installed is really saving energy. However, you can compute your energy consumption per degree day. If your consumption per degree day goes down significantly, you can be confident that your energy conservation efforts are paying off.

The graph below shows how different the past two seasons have been here in Colorado.

With our topography and high elevations, Colorado communities experience markedly different climatic conditions. This relates directly to differences in heating degree day totals and energy use. The table on the following page shows 1961-1990 average annual heating degree day totals for selected Colorado cities. These averages will be updated next year to the 1971-2000 period.

(continued on page 12)

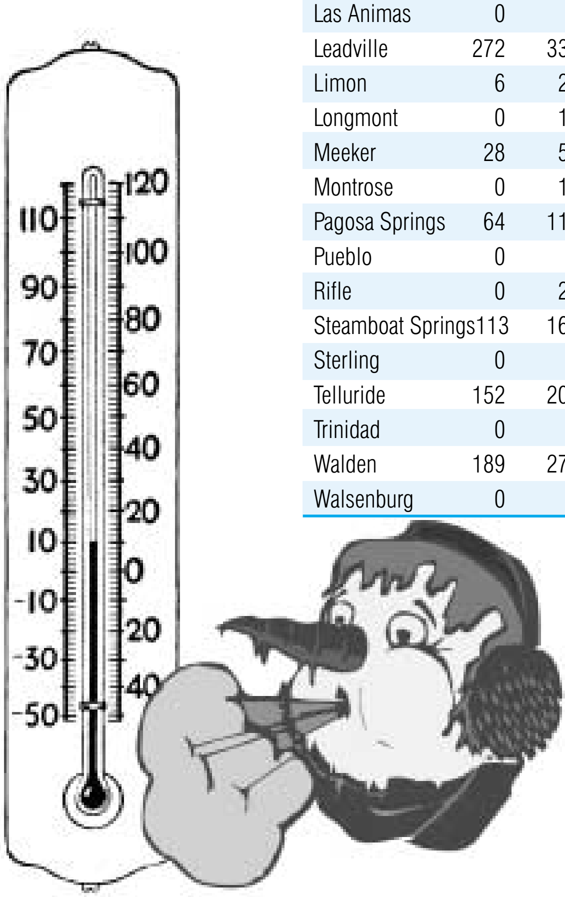
Comparison of heating degree day accumulations for Denver, Colorado, between the 1999-2000 winter season and 2000-2001.



Climate Data at Work *(continued from page 11)*

Monthly Heating Degree Day (1961-1990) for Selected Locations

Station	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual
Alamosa	42	98	306	667	1053	1473	1559	1193	1014	717	453	174	8749
Aspen	95	150	348	651	1029	1339	1376	1162	1116	798	524	262	8850
Boulder	0	7	136	387	726	973	1004	815	744	474	235	53	5554
Buena Vista	50	111	318	620	960	1243	1259	1047	992	729	477	197	8003
Burlington	0	9	138	432	822	1132	1175	946	859	519	254	34	6320
Canon City	0	11	91	325	645	896	933	756	688	408	193	41	4987
Colorado Springs	6	18	164	468	816	1091	1122	924	859	558	302	87	6415
Cortez	0	11	146	474	828	1163	1237	958	853	594	322	81	6667
Craig	32	58	275	608	996	1342	1479	1193	1094	687	419	193	8376
Delta	0	10	125	403	774	1128	1221	888	719	435	186	38	5927
Denver	0	0	144	429	780	1054	1094	885	806	504	253	71	6020
Dillon	282	341	555	856	1203	1504	1587	1355	1321	1008	747	459	11218
Durango	6	37	203	512	846	1172	1246	952	853	594	363	127	6911
Eagle	25	72	275	617	961	1376	1435	1106	958	675	422	184	8106
Evergreen	78	122	349	651	945	1194	1218	1039	1011	741	512	234	8094
Fort Collins	0	12	176	471	825	1113	1156	913	828	525	272	77	6368
Fort Morgan	0	8	144	445	840	1197	1277	963	831	492	222	41	6460
Grand Junction	0	0	55	332	738	1125	1240	854	670	389	132	13	5548
Grand Lake 6SSW	214	260	468	781	1113	1476	1600	1361	1283	945	660	381	10542
Greeley	0	7	158	446	831	1153	1206	924	806	492	231	52	6306
Gunnison	130	204	435	763	1143	1609	1786	1456	1237	867	580	306	10516
Las Animas	0	0	69	338	750	1088	1141	862	707	370	121	9	5455
Leadville	272	337	522	817	1173	1435	1473	1318	1320	1038	726	439	10870
Limon	6	21	189	521	879	1169	1218	991	924	603	344	96	6961
Longmont	0	10	171	468	834	1141	1190	941	840	525	253	70	6443
Meeker	28	56	261	564	927	1240	1345	1086	998	651	394	164	7714
Montrose	0	11	143	453	819	1159	1246	935	791	510	248	68	6383
Pagosa Springs	64	115	324	636	984	1330	1423	1131	1029	756	512	244	8548
Pueblo	0	0	62	357	735	1051	1091	837	722	396	152	10	5413
Rifle	0	23	184	502	858	1237	1330	980	825	549	298	95	6881
Steamboat Springs	113	166	396	725	1122	1525	1606	1316	1169	801	543	297	9779
Sterling	0	9	149	462	852	1200	1265	963	843	504	238	56	6541
Telluride	152	204	390	679	1005	1290	1336	1126	1101	819	574	310	8986
Trinidad	0	7	87	364	690	955	995	815	722	444	218	42	5339
Walden	189	273	498	825	1161	1457	1528	1296	1237	909	657	348	10378
Walsenburg	0	8	105	371	693	955	992	820	744	477	229	44	5438



For Teachers: Climatology – A Taste of Probability and Statistics. An Alternative to Flipping Coins

Nolan Doesken

Unless I'm really forgetting something, and that's always possible, I never was taught any statistics until well into college and then not all that much. I honestly don't recall doing linear regression or computing standard deviations until I started work.

Times have changed. Already in 6th grade our kids have been exposed to statistics. Last year in 8th grade, our daughter was solving standard deviations and correlations and trying to do linear regression. I don't believe she had any idea what she was doing or why, but she did as she was told and got most of the answers right. I guess they figure if they expose kids to statistics early they won't be so intimidated by them when they have to take statistics later in college.

While I didn't formally study statistics, I was fascinated with numbers and the characteristics of families of numbers (I know, I was weird.) Starting when I was in 6th or 7th grade, I spent a lot of time flipping coins. I knew that eventually you would get as many heads as tails, but I wanted to find out for myself. I also wanted to find out how many heads or tails I could flip in a row. I kept careful records of thousands of coin tosses. For years I kept my notebook with all my results. I also began keeping weather statistics early in life – calculating averages and extremes from the temperature and precipitation records that my father recorded in his journal. Yes, I was a little bit crazy, but I wasn't a total nerd. I also loved playing basketball and many other sports. In fact, I collected baseball trading cards. My mom, bless her heart, threw out hundreds of them when I was in college not realizing that those little pieces of cardboard with pictures of folks like Mickey Mantle, Yogi Berra, Stan Musial, Warren Spahn, Ernie Banks, and Hank Aaron, bought in packs of five for a nickel with my hard-earned paper route money, might actually be worth something. I also wonder if she ever realized how much I had learned about probabilities by studying the "statistics" on the back of each of those precious cards.

The fact is that probability and statistics are an important part of life and the more we learn about them, the better off we are. I guess it's OK if they want to teach it to our kids at an early age. After all, the best sports coaches know how to use probabilities to their advantage. If kids knew that, they might not dislike learning about them as much.

I really don't have a clue about how to teach statistics to kids, but I do know what would have gotten my attention – sports data or weather data. There are endless opportunities to use weather data in the classroom to teach some of the basic concepts of probability and statistics. Weather data are also easy to interpret, and work nicely in spreadsheet applications. The advantage of using weather statistics is that some of your kids will be able to relate to them. Even if the kids don't, there is a good chance (see, we're talking probabilities!) that their parents will get curious.

Where to find some data?

To get started, you need some interesting yet simple weather data. This is simple for me, since I work with it all the time, but it can be a bit intimidating if you've never done it before. There are many good sources of current and historic weather data on the Internet that you can get your hands on. If you are stressed for time, maybe your school librarian can help. Many librarians just love searching for things. So do some of your kids.

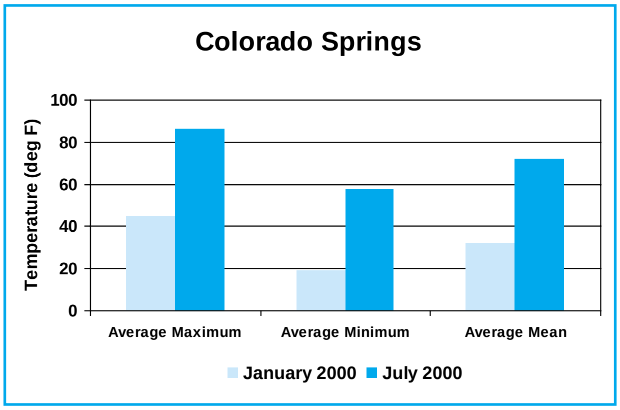
I won't send you in too many directions. To start with, why not use data from here in Colorado. The Colorado Climate Center web site provides access to current and historic temperature, precipitation, and snowfall data for more than 300 locations in Colorado. I would recommend starting with daily temperatures or precipitation. You can access this very easily via http://ccc.atmos.colostate.edu.

Click on "Data Access" and then click on "Daily Data" and you will see a menu of hundreds of weather stations. Choose the period of years you are interested in and the station that you want and then click on the "Submit" button and in seconds you will see lots of numbers. The daily data consists of the date, the high and low temperature (in degrees Fahrenheit), the precipitation for each day in hundredths of an inch, snowfall in tenths of an inch, and the total depth of snow on the ground in whole inches. You can either save the file to your computer or print it out. Beware, since there are 365 days in a year, that you will need several pages just to print out one year.

(Note: Depending on what you plan to do with your students, there are other interesting data sets including summarized monthly data for temperatures, precipitation, and snowfall (click on "Monthly Data"); data on wind, humidity, solar energy, and soil temperatures for agricultural weather stations (click on "COAGMET"); and maps and lists of daily precipitation and snowfall for many local weather stations in northern Colorado (click on "CoCo RaHS"). There are also web sites to acquire current weather information from locations all over the country and world.

(continued on page 14)

For Teachers: Climatology *(continued from page 13)*



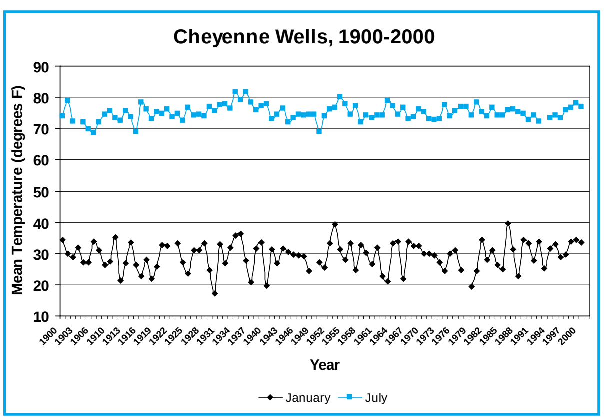
A simple graph of average high and low temperatures for Colorado Springs showing day-night and winter-summer differences.

Calculations

OK, what next? Now comes the fun part. You and your students can become climatologists while learning basic statistics at the same time.

Means, Medians, and Time Series

Let's start simply. You could take temperature data for a selected year (maybe the year when many of your students were born) for the weather station closest to your school. Select a winter month like January (usually the coldest month of the year) and a summer month like July (usually the hottest month). Divide your students into four groups. Let the first group calculate the average high temperature for January. All they have to do is add up the 31 daily high temperature readings to get the sum and then divide by 31 to get the average. Also have them sort the daily readings from lowest to highest and find the median value. This would be the 16th value with 15 higher and 15 lower. The other groups can do the same for January low temperatures, July high temperatures, and July low temperatures, respectively. Each student in each group can work separately and then compare answers with others in their group. Another approach would be to assign a separate month to each student so you have the entire year represented.



Mean January and July temperatures, 1900-2000, for Cheyenne Wells, Colorado.

When they're done, your class will have something to talk about. A good way to present and compare results is to make a graph. It is obvious that July is warmer than January, but go ahead and show it. Also see how close the median and the average are. Based on my experience, sometimes they are very similar and sometimes quite different depending on the weather patterns that particular month.

Another approach would be to compare the same month from one location to another or the same month from one year to the next. In fact, you could have your students compute the average temperature for every January, or every July (or both), for many years in a row. If you then plot the results on a graph you would have something we call "time series." Climatologists spend a lot of time looking at time series graphs as they investigate climate change. The graph on this page shows an example time series graph for a small town in eastern Colorado, Cheyenne Wells.

If your students do a project like this and do a good job, take it down to your local museum if you have one. Weather is a very important part of history, and your local historians will be very interested. More advanced students could also compute trends from the observations using linear regression.

Probabilities

Learning about probabilities and how to compute them from data is something well worth learning. Computing probabilities using real weather data will take a bit more work but it can be done and can be both interesting and informative. If you get lucky, you can even get your students thinking they're on a discovery adventure. Probabilities aren't just academic – something we have to do at school. Probabilities really help us make decisions. Probabilities of sporting events being rained out are a reality of school planning. Even the probability of having school cancelled due to snow is a situation that school administrators have to think about. In rural areas, farmers are all experts on probabilities, whether they realize it or not. Farming is an adventure in probabilities.

Let's solve a problem. Once you know how many years of data you have for your nearest weather station, you can begin posing countless probability questions. You could answer any question from what is the probability of the high temperature exceeding 70 degrees on the date of the Prom to the chances of having rain or snow for the first track meet or getting an inch of rain during County Fair. You can pose any question that you think some of your kids might identify with.

Let's say you are interested in knowing the chances for precipitation on April 5, your first track meet. Go back through the weather data and find April 5 for each year. Write down on a sheet of paper or enter into a spreadsheet the measured amount of precipitation for each year on that date. If the situation and time allows, let interested students help extract the historic data. That's part of the adventure, but I know not everyone would enjoy that task. How many years of data should you extract? That's a good statistical question all by itself. If you only look at the last couple of years, your results won't be very meaningful. Even 10 or 20 years could give much different results. The more years you look at, the more consistent your results will be, so use as many years as you can.

Precipitation Data for Alamosa, Colorado, from 1951-2000

Precipitation Data Totals for April 5th		Precipitation Ranked from Greatest to Least for April 5th		
Year	Amount	Rank	Year	Amount
1951	0.27	1	1951	0.27
1952	0	2	1990	0.23
1953	0.06	3	1963	0.12
1954	0	4	1961	0.11
1955	0.01	5	1987	0.11
1956	0	6	1994	0.11
1957	0	7	1953	0.06
1958	0	8	1976	0.06
1959	0	9	1996	0.05
1960	0	10	1955	0.01
1961	0.11	11	1965	T
1962	0	12	1978	T
1963	0.12	13	1993	T
1964	0	14	1952	0
1965	T	15	1954	0
1966	0	16	1956	0
1967	0	17	1957	0
1968	0	18	1958	0
1969	0	19	1959	0
1970	0	20	1960	0
1971	0	21	1962	0
1972	0	22	1964	0
1973	0	23	1966	0
1974	0	24	1967	0
1975	0	25	1968	0
1976	0.06	26	1969	0
1977	0	27	1970	0
1978	T	28	1971	0
1979	0	29	1972	0
1980	0	30	1973	0
1981	0	31	1974	0
1982	0	32	1975	0
1983	0	33	1977	0
1984	0	34	1979	0
1985	0	35	1980	0
1986	0	36	1981	0
1987	0.11	37	1982	0
1988	0	38	1983	0
1989	0	39	1984	0
1990	0.23	40	1985	0
1991	0	41	1986	0
1992	0	42	1988	0
1993	T	43	1989	0
1994	0.11	44	1991	0
1995	0	45	1992	0
1996	0.05	46	1995	0
1997	0	47	1997	0
1998	0	48	1998	0
1999	0	49	1999	0
2000	0	50	2000	0

After you finish the list of precipitation results for each April 5, sort them from largest to smallest. When it comes to precipitation, you will quickly find that in our climate, it usually doesn't rain. The majority of days will register "zero." The example at left should help explain the process.

Probability Calculations

Using the 50 years of data for Alamosa, solve these problems:

Probability of receiving no precipitation

(x÷n) where x = number with no precipitation and n = total number of years,

x = 37 so 37÷50 = 0.74 or 74%;

Probability of measurable precipitation (excluding traces),

(x÷n) where x = number of years with at least 0.01 inches,

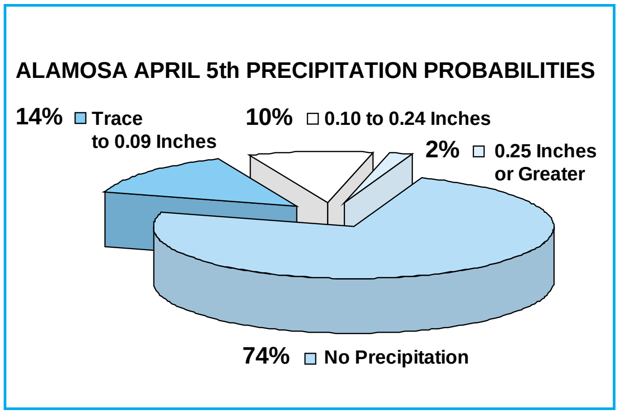
x = 10 so 10÷50 = 0.2 or 20% probability of receiving ≥ 0.01 inch;

Probability of receiving at least 0.10 inch,

x = 6 so 6÷50 = 0.12 or 12%

Once again, it is helpful to present results in the form of graphs. In this case, let's show the results in the form of a pie chart where all 50 years represent the entire sample. Suddenly that awkward column of numbers is simplified to clearly show the preponderance of dry weather and the rarity of heavy precipitation.

Precipitation probabilities are used a great deal in planning and decision making. As a result, our office has computed probabilities for many locations in Colorado. Probabilities for receiving precipitation on any given date are related to our weather patterns. As you can see from the examples on the following page comparing Durango to Fort Collins, probabilities vary a lot from one part of the state to another. One graph like this and you are on the way to an immediate understanding of weather patterns and differences here in Colorado.



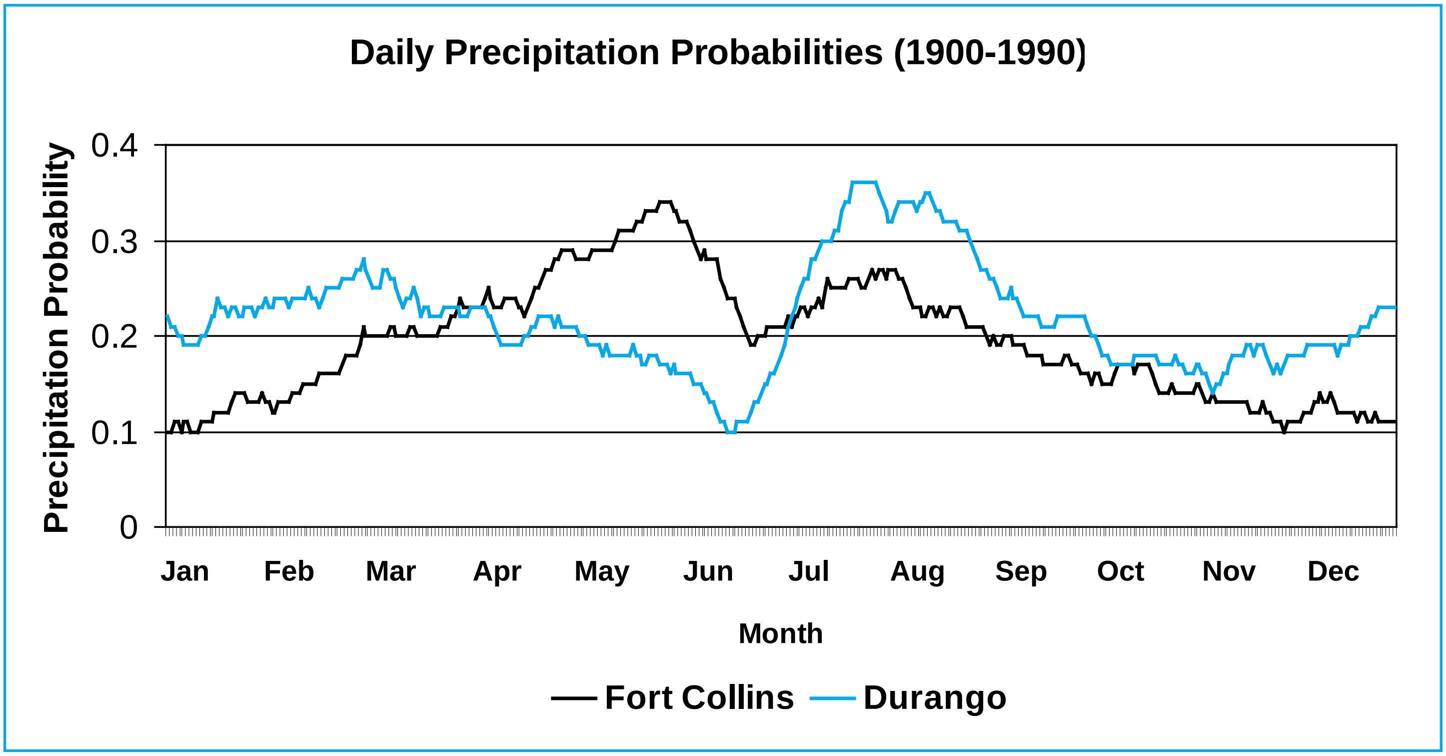
Pie chart showing the probability of receiving precipitation on April 5 in Alamosa in the specified categories.

Will We Learn Anything?

There is no guarantee that you'll have great success teaching probability and statistics using weather data, but it's worth a try. Your leadership as a teacher and your mix of kids will be the determining factors.

(continued on page 16)

For Teachers: Climatology *(continued from page 15)*

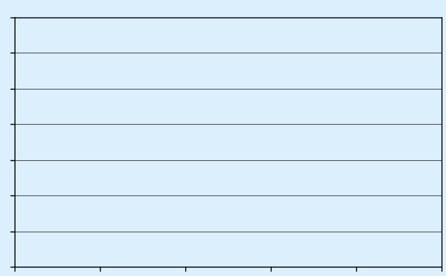


Comparison of smoothed daily probabilities of measurable (≥ 0.01 inches) precipitation at Fort Collins and Durango, Colorado, based on data from 1900 to 1990.

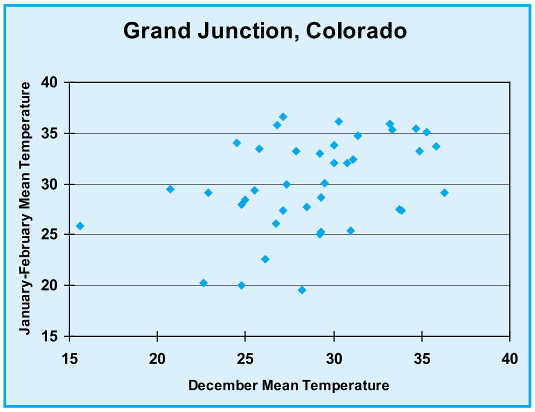
But if everything comes together, you could make a lot of headway with a few relatively simple lessons. Some of the things you could realistically accomplish are:

- Calculate and graph averages, medians, and extremes.
- Examine time series.
- Learn about probabilities and how to compute them from data.
- See how probabilities may be applied to real-world decision making.
- Perform applied mathematical basic computations.
- Learn about the climate of your area.
- Compare to climates of other areas.
- Investigate climate variations and changes over time (time series).
- Maybe engage a local history buff in a discussion of how weather has affected your community through history.
- Improve graphing capabilities.
- Use of spreadsheets (optional).
- Opportunity to engage parents in discussion of findings.

There is no reason to be afraid of statistics. There is nothing magical or complicated about probabilities. All you need is good data and some simple calculations, and a bit of motivation. Good luck. If you try this out, share your stories of success or failure with us.



A Time for Time Series *(continued from page 17)*



Scatter graph of December mean temperature (x-axis) versus mean January – February temperature (y-axis) for Grand Junction, Colorado.

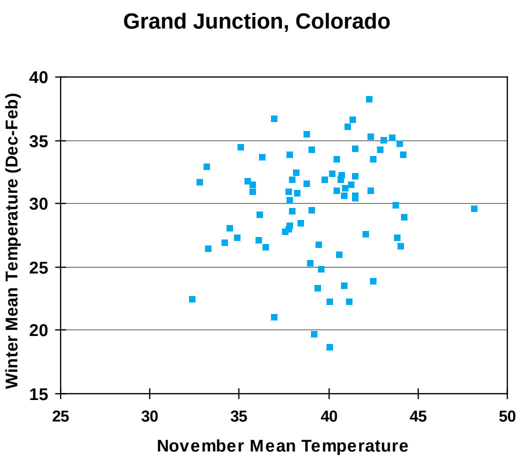
Snow that falls early in the winter tends to remain on the ground throughout the mid-winter months helping to retain persisting temperature anomalies. So if the winter begins cold and snowy, that snowcover will act to maintain colder than average air temperatures until it finally melts.

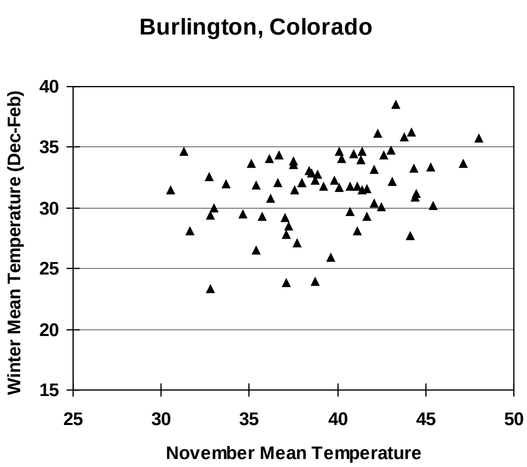
Precipitation Relationships

What about precipitation? History has shown us that wet weather is often associated with colder than average temperatures and dry weather goes along with hot temperatures. There are always exceptions, but this is a pretty good rule of thumb. So we also decided to look at winter precipitation and what has happened in the past following very cold Novembers. First of all, November 2000 was an exception itself. Despite the abnormally cold temperatures, much of the state was drier than average. Oh well. Actually, for mid winter months, extremely cold temperatures limit the amount of water in the atmosphere. Cold temperatures may indicate frequent winter precipitation, but not necessarily heavy amounts.

We then took December precipitation totals to see if they were at all correlated to November temperatures. For the most part, there was no relationship although a small negative correlation was noted at a few sites.

We did the same for winter (December-February) precipitation totals. Again, the results showed little association, with weak negative correlations noted at most locations. The relationships were a bit stronger at Steamboat Springs and Durango, suggesting that at those locations there is a better chance that cold Novembers will be followed by wet winters and that dry winters are more likely to follow warm Novembers. With correlations this weak, however, don't get too confident.





Scatter graphs showing the relationship between mean November temperatures (X-axis) and mean December through February temperatures (Y-axis).

Correlation statistics showing relationship between November mean temperature and precipitation for the following month (left) or the following three months, December-February (right). Values less than ± 0.20 suggest little or no correlation. Values of ± 0.20 to ± 0.40 indicate a very weak correlation

Station	Nov. mean temp. to Dec. precip.	Nov. mean temp. to Dec.-Feb. (winter) precip.
Burlington	-0.41	-0.14
Holyoke	-0.02	-0.09
Rocky Ford	-0.56	-0.10
Fort Collins	-0.28	-0.22
Dillon	+0.01	-0.13
Steamboat Springs	-0.04	-0.28
Montrose	-0.16	-0.13
Durango	-0.11	-0.24
Grand Junction	+0.03	-0.18

Conclusions

Have we learned anything from this exercise? Well, Alex learned that those stinking statistics they try to teach us in school actually serve some very useful purposes when you need to understand data. Secondly, we learned that there really are relationships – weak but non-zero – that connect late fall weather conditions with mid winter. It is hard to imagine that the large-scale atmospheric circulations of November over Colorado and North America tell us much about the atmospheric processes of the next three months. What is more logical is that cold Novembers result in more widespread snow cover just by keeping the snow that falls at lower elevations from melting. Snow cover, especially over the valleys of western Colorado, has a huge effect on temperatures. The article we wrote several years ago for *Weatherwise Magazine* (Doesken, 1992) showed that dramatically for Alamosa and the San Luis Valley. Anything that increases snowcover early in the winter will affect winter temperatures until that snow has melted. That's my bet. We don't have time to test that theory this time, but hopefully in the months ahead I can talk Alex into doing a few more statistics.

Doesken, Nolan J., 1992: "Alamosa's Amazing Anomalies." *Weatherwise Magazine*, Vol 45, No. 5, pp. 19-24.

Ode to Mud

Nolan Doesken

Those of you who are long-time subscribers to *Colorado Climate* know a little about my life. For you newcomers, I better fill you in – briefly. Six years ago, our family took the plunge and left our paved and sodded postage-stamp lot (actually, it was pie-shaped since we lived at the end of a cul-de-sac) and suburban neighborhood in west Fort Collins in search of a "richer" life – on a farm. It was not my idea, mind you. While I grew up in a tiny Illinois farm town surrounded by soybean and cornfields and have always loved agriculture and the lifestyle that goes with it, I still was content with my short commute to the Climate Center and a simple urban life. My wife, on the other hand, had a better idea. She had always dreamed of barns, horses, chickens, fruit trees, and hay. She felt confined by our neighborhood and wanted room to stretch out. She had a craving for soil, compost, and manure.

For many years our family had admired the old weathered barn that you could see out the kitchen window at "Grandma's house" (my mother-in-law) up on the north end of Fort Collins. Late in 1994, we got a call from the owner letting us know he planned to sell it. My wife and my mother-in-law were elated. I was – well, not as thrilled. It was a farm, all right – small, old, and rundown. But it was a farm, and it was nearby, and it seemed like a good idea in some strange sort of way. So in April 1995 we bought the farm (so to speak), and immediately the heavens opened and it rained without ceasing (or so it seemed) until summer. That was the beginning of my lesson in Colorado mud. I've learned more since then, but I certainly got an appreciation for words like "quagmire."

We only moved 2 miles, but in so many ways it felt like we moved at least 500 miles and, at the same time, back about 65 years in time. These last few years have been a great learning experience. Not a "great" experience, mind you, but a great "learning" experience. Cutting wood, loading hay, cleaning irrigation ditches, fixing fences, etc. I'm not at all sure I would wish it on just anyone, but more than likely you've already had your own comparable experiences sometime in life. We are NEVER bored.

With this introduction, let's move to the subject at hand – ***mud***. Somewhere in my childhood I was taught a lovely verse that went something like this:

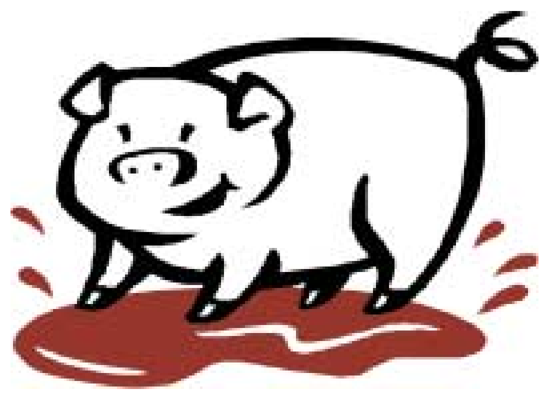
"Mud, mud, glorious mud!
Nothing quite like it for cooling the blood.
So follow me, follow,
Down to the hollow,
And there we shall wallow
In glorious mud!"

If you could hear the tune that goes with this, you would find it quite appealing. It makes mud sound almost romantic. Well, let me tell you the truth. It's not that way at all. Mud is awful.

I don't think I ever really knew mud before moving to this old farm. But I'm learning more all the time and one thing I've learned really well is **I DON'T LIKE IT**!! We've got corrals, we've got stalls, we've got paths, and when it's wet, **we've got mud**! We have no sidewalks and no covered walkways like folks in the city and suburbia.

Last winter and spring, mud was a hard thing to find. For those of us who work outside, the winter of 1999-2000 was a pleasure. We were in the midst of our remodeling effort and the dry weather was very convenient. With warm temperatures and little snow, the topsoil dried out quickly and what moisture did fall as rain or snow was quickly absorbed. All winter and spring there was no mud. It was wonderful. Summer came and it stayed hot and dry. We had some dust, but no mud. The wildfires and crop failures that ensued were not so wonderful. Dry weather is good, but only to a point. I didn't appreciate it at the time, but it was nice for all of us who work outside.

This fall and winter (2000-2001) has been a different beast altogether. Much of eastern Colorado received generous late October rainfall. We had a Halloween downpour that was great for our dry pastures, and also great for making mud. We even got a flow of fresh mud through a tiny crack and onto the floor of our basement. "Cool!" With the time of year being what it was and the cold November temperatures that followed, that rainfall did a great job of moistening the topsoil. The cold weather of November and the thin snow cover that came with it allowed the ground to freeze quickly and deeply. I didn't know it then, but we were headed down the path to mud like I had never seen before.



In December and January, many days were cold and the ground stayed frozen. But every time it warmed up just a little a thin layer of greasy mud appeared to greet me. I came to appreciate the cold more and more. Some days I would wait intentionally for an hour or two after sunset to let the cold settle in and the ground freeze before I went out to do the chores. I would much rather bundle up in my brown coveralls than to dress lighter but wear an inch of mud on my boots and up my ankles. Cold weather became

(continued on page 20)

Ode to Mud *(continued from page 19)*

my best friend. While others complained of the long winter, I gave thanks for each day where the ground remained hard and solid.

All good things must come to an end, and so time after time this winter the sun would greet us. While most in town delighted in the warm days, we on the little old farm at the edge of town were isolated by mud.

Oh, I didn't tell you. We've been remodeling the old farmhouse and we finally were able to move into the new addition at Christmas. Of course, that means our yard is a construction site – no sidewalks, no stone pathways, no grass, just dirt – wet dirt – **MUD.** It's been better since we put up gutters on the house. This weekend I spread wood chips to make paths. Maybe we'll make it.

Before I complete this ode to mud, let me bring in a little climatology. Mud is not all created equal. I've certainly learned that this winter. Soil type, of course, has a great deal to do with the character of mud, but the climate also has a major role. Please know that from a soil science perspective, I am ignorant. I know a little about clays, sand, loam, and all that stuff. I also know a tiny bit about soil structure, but only enough to be dangerous. What I do know is that our mud this winter has been more greasy and persistent than I've ever seen before. Back in Illinois, our soils were so loamy that they barely stuck to my boots. In other areas where sand is prevalent, moisture is quickly absorbed. That means no mud. But here we have clay – rich, heavy clay. The clay seems to seal itself when it rains hard. Much of the water just runs off. Soon afterwards, the ground is again hard and dry. It takes a slow, gentle rain to soak into heavy clay and make mud.

The moisture that soaks in the best is the water from melting snow. We've not had deep snows this winter but we've had frequent small snows. Every few days they melt only to be replaced by another inch or two. Precipitation has not been heavy, but the ground has stayed wet since October. We've had very few warm and windy days this winter to dry the surface. Evaporation rates have been very low. Finally, and perhaps most importantly, there is the matter of frozen soils. In case you haven't noticed, the 1990s were a decade of warm winters. Frost penetration in the ground has been intermittent and brief here east of the mountains and in some of Colorado's milder western valleys. Since we've moved to this old farm, frozen soil has not been a big issue. We've had a few bursts of very cold weather, but they all were accompanied by fresh fluffy snow that helped insulate the ground. This year was different. The ground was frozen before Thanksgiving and stayed frozen. Even when the air warmed up, the ground below was rocklike down almost 2 feet. No moisture from the surface could soak in. The result – slimy, greasy, persistently annoying mud.

Our winter (2000-2001) mud is now gone. Spring and summer warmth have greeted us. Spring mud can be deep and thick. It can gobble up small cars and send larger vehicles sliding uncontrollably. But spring mud means moisture for our crops and moisture for the people. It comes with sweet smells of blossoms and flowers – not just smells of manure. As long as there is mud, the drought can wait. And soon enough the high sun will dry it up. Spring mud is not the enemy for it will go away on its own. Summer mud is almost pleasant – an occasional cool interlude. It's the winter mud that lingers and clings. It doesn't wipe off when you wipe your feet. Even when you leave your boots outside, it somehow finds a way into the house – even upstairs – even in the bathroom.

P.S. We have a dog.

Snow Rollers Roll over Kansas and Eastern Colorado

Nolan Doesken

I've known about snow rollers ever since I was a kid. Everything about snow is amazing to me, and snow rollers are just one more thing that convinces me that the only thing more amazing than snow is the water that it's made from.

Just before Christmas, I got an e-mail from a long-lost cousin from Topeka, Kansas. He attached a newspaper article from a local paper describing rolls of snow tumbling across open fields in Kansas following an early winter snowfall. Then, a few weeks later, friends near Greeley, and other citizens of Weld County, Colorado, shared personal accounts of the identical phenomenon – snow rollers.

On January 29, 2001 following a modest snowfall over portions of northeastern Colorado, strong northerly winds developed. The sun came out and air temperatures climbed a few degrees above the freezing point. As winds gusted to over 30 mph, some of the snow on the ground began to move – the common phenomenon of drifting. Drifting, the movement and redeposition of snow that had previously accumulated on the ground, is very common. But what happened next was not. In a few locations, such as in the photos shown here, the snow stayed stuck together and under the force of strong winds formed small jelly-role like structures. I have never seen it happen in person, but it must be quite amazing to watch.

Indeed this was a rare event. Not unprecedented, but definitely rare. It takes just the right conditions of wind speed, gustiness, sunshine, temperature, humidity and snow structure to produce this phenomenon. There are written accounts by amazed onlookers that go back as far as 200 years and probably more. But this is the closest I ever came to seeing them forming in person. Thanks for bringing them to our attention.

I have seen similar snow rollers in the mountains formed by a much different process. Sometimes, especially in late winter and spring, a sunny, warm day will follow a fresh snowfall. Melting snow and thawing soils on the south facing side of steep slopes may result in small rockslides tumbling down the slopes. With wet sun-warmed snow on the surface, and colder, drier snow below, the impact of tumbling snow and pebbles from above will trigger snow rollers which tumble down steep slopes growing larger with each role. You may remember old cartoons showing huge snowballs rolling down mountain slopes. In reality, most of these gravity-caused snow rollers rarely grow to more than a few inches before they come to a stop due to their own weight and the soft snow beneath them. But they are fun to watch.

Snowrollers in cornfield south of the CSU CHILL radar site near Greeley, Colorado. Photos taken by Pat Kennedy, Atmospheric Science Department, Colorado State University.

Reminder: If you witness an unusual weather event similar to this, whether it be giant hailstones, white haze, or blue snow, take photos and then let us know.

Floods, Hail, Drought, Blizzards, Lightning, Tornadoes

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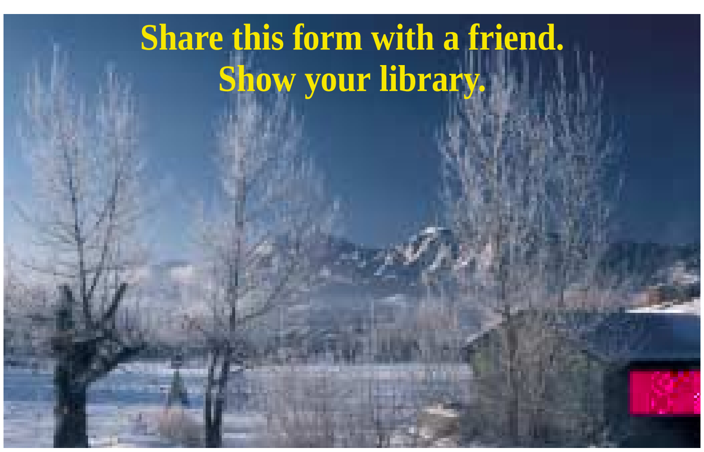

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Knowledge to Go Places