17.1 THE MARCH 2003 SNOWSTORM OVER SOUTHERN COLORADO

Paul Wolyn *
NOAA/NWS Pueblo, Colorado

1. INTRODUCTION

From 16-19 March 2003 a heavy precipitation event struck most of eastern Colorado. In the southern half of Colorado, some storm total precipitation amounts exceeded 150 mm (about 6 inches) with some snowfall amounts over 1.15 m (about 4 feet). This storm brought a significant reprieve from a long term drought for portions of eastern Colorado.

This brief discussion will highlight the storm in southeast Colorado. First, the precipitation patterns and topography of the area will be discussed. The topography of southeast Colorado can lead to a complex precipitation pattern with cold season storms. Next, the synoptic scale evolution of the storm will be discussed. Then, a discussion of the mesoscale aspects of the storm will highlight the interactions of the larger scale flow with the complex terrain. This section will discuss many of the features commonly seen with deep northeast upslope snowstorms, and it will also highlight what features of this storm made it an extreme event for this region. The final section will discuss some of the operational challenges with this event.

2. TOPOGRAPHY AND PRECIPITATION

Figure 1 shows the topography for the area with each color representing an elevation interval of 0.33 km. The topography is characterized by the eastern plains gradually rising to the base of mountains to the west. Two west-east ridges are significant topographic features, which influence precipitation patterns in southeast Colorado. The Palmer Divide is north of Colorado Springs with a crest over 2.25km MSL. Along the Colorado and New Mexico border, the Raton Ridge rises to elevations over 2.5km MSL.

The “eastern” mountains of southern Colorado are much more complex than the Front Range of northern Colorado. The northern Sangre de Cristo Mountains and Wet Mountains are orientated southeast to northwest. The Spanish Peaks are a significant topographic feature which extends northeast from the southern Sangre de Cristo Mountains. The Pikes Peak/Rampart Range is a fairly isolated mountain barrier which can have favorable orographic precipitation patterns for several wind directions.

Selected precipitation totals for the event (figure 2), which are only from NWS COOP observers, show amounts approaching 120 mm over the Wet Mountains and amounts approaching 150 mm over the Pike Peaks area. Near the crest of the Palmer Divide, amounts in excess of 60 mm were observed while amounts were half or less just 20 km to the south. Some locations close to the mountains also had large precipitation totals, such as 115 mm in Walsenburg (just south of Rye). The precipitation totals on the plains ranged from 15 mm to over 60 mm in some areas.

3. SYNOPTIC EVOLUTION

The snowstorm was characterized by a strong cutoff low which provided deep east to northeast flow to much of Colorado. Four different shortwaves were involved in the development of the strong upper low and its slow movement. Figure 3a-d shows the 50 hPa (500mb) height field and IR image for various times during this event. Figure 3a (0000 UTC 18 March 2003) shows the upper low centered over the four corners. The coolest cloud tops over Colorado were along the northern Front Range of Colorado, basically from Denver northward to the Wyoming border. This IR image shows 3 distinct shortwaves associated with the cutoff low at this time. One shortwave extended eastward over eastern Colorado; another extended northwest over Utah; and the third extended southwest over Arizona.

Twelve hours later (Figure 3b), the three shortwaves continued rotating around the upper low, with the 50 hPa circulation centered over the Colorado and New Mexico border. Cold cloud tops were along the eastern mountains of the northern two thirds of Colorado.

By 0000 UTC 19 March 2003 (figure 3c), the upper low had an elongated shape. The shortwave on the southeast portion of the low was the disturbance which was over Arizona 24 hours earlier. Cold cloud tops were in a band on the north and east portions of the upper low.

At 1500 UTC 19 March 2003 (figure 3d), the upper low had taken a northeast to southwest elongated shape. The disturbance on the northeast side of the disturbance was the shortwave which swung around the south side of the upper low. The shortwave on the southwest side of the cutoff low was a combination of a disturbance rotating around the upper low and another disturbance which moved onshore from the Pacific.

The 70 hPa (700mb) winds show the winds near the tops of the mountain ranges in southeast Colorado. Figure 4a shows the 70 hPa winds and sea level pressure for 1800 UTC on 18 March 2003. At this time,

* Corresponding author address: Paul Wolyn, National Weather Service, 3 Eaton Way, Pueblo, CO 81001. email: paul.wolyn@noaa.gov

the upper low was near the Colorado and New Mexico border. There was deep east to northeast flow at 70 hPa with surface low pressure developing over northeast New Mexico. The 70 hPa and sea level pressure pattern indicate deep easterly flow was over southeast Colorado at this time. By 1500 UTC 19 March 2003 (figure 4b), the flow at 70 hPa became northeast at speeds approaching 20ms^{-1} (40 knots). The sea level pressure pattern shows a low pressure center over Oklahoma with a surface trough extending westward across northern New Mexico. The surface trough and low caused generally northeast to north surface winds on the plains at this time. The surface trough was moving southward at this time resulting in an ageostrophic component producing northerly (towards the south) acceleration of the surface winds.

4. MESOSCALE ASPECTS OF THE STORM

The storm was an interaction between 4 different shortwaves which influenced the pattern of precipitation and location of the upper level low center. This analysis of the storm will divide the event into two phases. In both phases significant precipitation was occurring over portions of southern Colorado.

The first phase of the storm is dominated by deep, moist and unstable easterly flow which impinged on the high mountains. This phase began after 0000 UTC 18 March 2003. Figure 5 shows a radar image, METAR and 15 minute lightning for 0526 UTC on 18 March. At this time, the center of the circulation was near Pueblo. Most of the stronger radar echoes were north of Colorado Springs. Echoes from the north of Colorado Springs were moving southwest striking the Pikes Peak area, northern part of the Sangre de Cristo Mountains and nearby areas. To the south and east of Pueblo, the echoes were remnants of a convective band which moved south earlier in the evening. The surface observations show northerly winds at Colorado Springs and Pueblo which suggest a blocked layer had developed along the mountains.

Figure 6 shows 1836 UTC 18 March 2003 radar, METAR and lightning data. This is a later time in the first phase of the storm. The surface observations show easterly flow on the eastern plains advecting moist air westward. Dew points on the plains were in excess of 5ºC. Near the mountains, northerly flow gusting to 12-15 ms^{-1} (25 to 30 knots) at Pueblo and Colorado Springs is indicative of a blocked layer just to the east of the mountains.

During this part of the storm, bands of convection were moving westward into eastern Colorado. The radar and satellite images indicate these bands strengthened as they moved westward and intensified further as they reach the blocked layer. Figure 6 shows a time when the convection, especially south and southwest of Pueblo, was strong. These convective elements moved westward, striking the higher terrain of the Wet Mountains and nearby plains. The snow level was around 1.8 km MSL at this time, and thunderstorms with heavy snow were observed over the Wet Mountains and nearby plains. The reflectivities approaching 50 dBz near Rye suggest some graupel or ice pellets fell along with the heavy snow.

The storm transitioned to the second phase of the event in southeast Colorado starting around 0000 UTC 19 March. During this phase, the upper low began to move eastward. Moist and deep northeast flow developed over the region. In this phase, precipitation patterns had many similarities to other deep northeast upslope snowstorms experienced in southeast Colorado.

Figure 7 is similar to figure 5 except it is for 1500 UTC 19 March. Deep northeast flow is observed on the plains. The flow at Colorado Springs and Pueblo are from the northwest suggesting a blocked layer near the mountains. No lightning was observed during this phase of the storm, especially after the deep northeast upslope flow became established. The radar reflectivity shows an area of enhanced precipitation to the south and southwest of Pueblo. South of Pueblo, the terrain rises over 300m in a distance of 40-50km, and this ascent enhances precipitation south of Pueblo for deep north to northeast flow. Over the east slopes of the Wet Mountains, there is a much more rapid rise in elevation of roughly 1.5km over a distance of less than 10 km. This rapid rise in topography makes Rye and other communities on the east slopes of the Wet Mountains prone to heavy snowfall for deep northeast flow.

Significant precipitation is also occurring over the higher terrain to the north through northwest of Colorado Springs. Deep northerly flow rises up the northern side of the Palmer Divide, with heavy precipitation along the north slope and the crest of the Palmer Divide. Portions of Pikes Peak are also favored for heavy snowfall with deep northeast flow, and figure 7 shows radar echoes over this region.

From just north of the Colorado Springs observing site to Pueblo, there are no radar returns. The lack of precipitation on the south side of the Palmer Divide results from the strong orographic descent of northerly flow down the Palmer Divide. This feature is often seen with the deep north to northeast upslope events. Often, there is a fairly sharp gradient in precipitation totals between the crest of the Palmer Divide and the Colorado Springs observing site.

Although not discussed in detail, the north slopes of the Raton Ridge can also receive substantial precipitation with deep northeast upslope flow. In this event the convection from phase 1 did not reach this far south and the development of deep northeast upslope was delayed in this region. As a result only “modest” amounts of precipitation were observed in this region.

5. FORECAST CHALLENGES

Major storms can present many forecasting challenges especially in complex terrain. For this event, the first challenge was believing that a major precipitation event would occur. The evolution and movement of the cutoff low was an interaction between 4 distinct shortwaves. A significant error in the initialization and/or movement of one of these shortwaves could affect the magnitude of the event. Overall, the model handles the system well and they predicted substantial precipitation amounts for this storm.

Once we believed the models had a reasonable handle on the situation, there were some difficult and not so difficult decisions to make. With the deep east and northeast upslope, heavy snow would be likely along the eastern mountains as well as near the crest of the Palmer Divide. Watches were issued well in advance for these regions highlighting a major snowfall event.

Deep upslope events (similar to this event), which have instability, strong synoptic forcing, or a band of heavy precipitation, can bring significant precipitation in the upper Arkansas River Valley. Figure 2 shows precipitation totals from 20 to 40 mm in the valley bottom of the Upper Arkansas River Valley, which are significant precipitation totals for these dry locations.

A difficult forecast problem with deep north to northeast flow is snowfall amounts in Colorado Springs and Pueblo. In this storm, we were confident that areas north of Colorado Springs and south of Pueblo would receive major snowfall accumulations as well as the nearby mountains. The forecast for the areas close to Colorado Springs and Pueblo, however, was more difficult. This is further complicated when considering these areas have a total population around 500,000 which is about 60% of the people in NWS Pueblo's forecast area. As discussed earlier, the deep northerly flow is strongly downslope over this region which would tend to limit snowfall amounts. However, significant snowfall can occur with deep northerly flow, as in the 24 October 1997 blizzard. Blizzard conditions could develop the morning of March 19, even with modest snowfall amounts, because of the gusty north winds.

Another related problem was snow level. The March 2003 storm was relatively warm; however, a blocked layer near the barrier did form. This blocked layer can cause the snow level to lower with an isothermal layer developing in the blocked layer. Marwitz and Toth (1993) studied a blocking layer resulting in a lowering of the snow level over Fort Collins.

For this event, blizzard conditions did not materialize over the cities of Colorado Springs and Pueblo. Precipitation fell during the night of 18-19 March, but it fell as rain or wet snow. By morning (about 1300 UTC 19 March) the strong northerly winds dominated any other synoptic or mesoscale forcing to end the precipitation on the south slope of the Palmer Divide. If the weather was colder during the night, then the precipitation which fell during the night could have been a drier snow. In this case, there could have been significant blowing of the existing snow on the ground.

However, heavy snowfall along with strong winds was not too far from the legal boundaries of these cities. Heavy snow fell north of Colorado Springs along the Palmer Divide and fell south of Pueblo. People traveling along interstate 25 north of Colorado Springs or south of Pueblo would have driven into heavy snow. (The mountains around Colorado Springs and Pueblo also received heavy snow).

Over the Palmer Divide and Raton Ridge, blizzard conditions did not quite materialize. Heavy snow and strong winds did occur, but the snow was too wet to be blown significantly.

Finally, what made this storm a major precipitation event? In my opinion, the presence of the two phases made this a major event. Phase two of this event has many similarities to deep northeast upslope snowstorms which occur several times a winter. The stronger of the deep northeast upslope storms can bring precipitation totals of about 25 to 50 mm to the orographically favored areas with snowfall of around 30 to 60 cm. In the March 2003 storm the first phase of the storm, which had deep easterly flow, also brought significant precipitation and snowfall to the region. The occurrence of the first phase along with the second phase made this a major precipitation and snowfall event.

6. REFERENCES

Marwitz, J. and J. Toth, 1993: The Front Range blizzard of 1990. Part I: synoptic and mesoscale structure. *Monthly Weather Review*: **121**, 402–415.

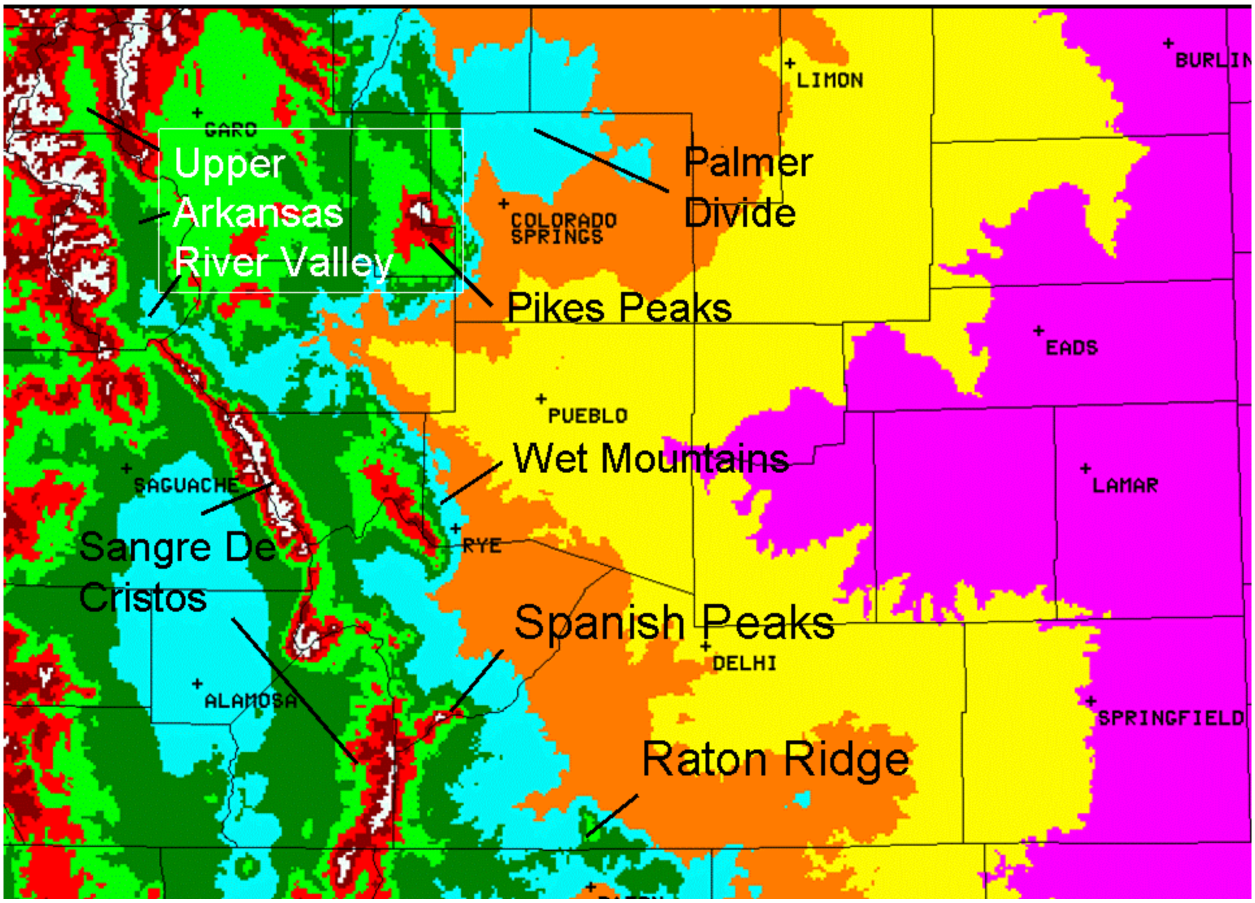

Figure 1. Topography with major cities and topographic features listed. Purple/yellow border is at 1.33km, orange/light blue boundary is 2.0km, light green to red is 3km, and white is higher than 3.66 km.

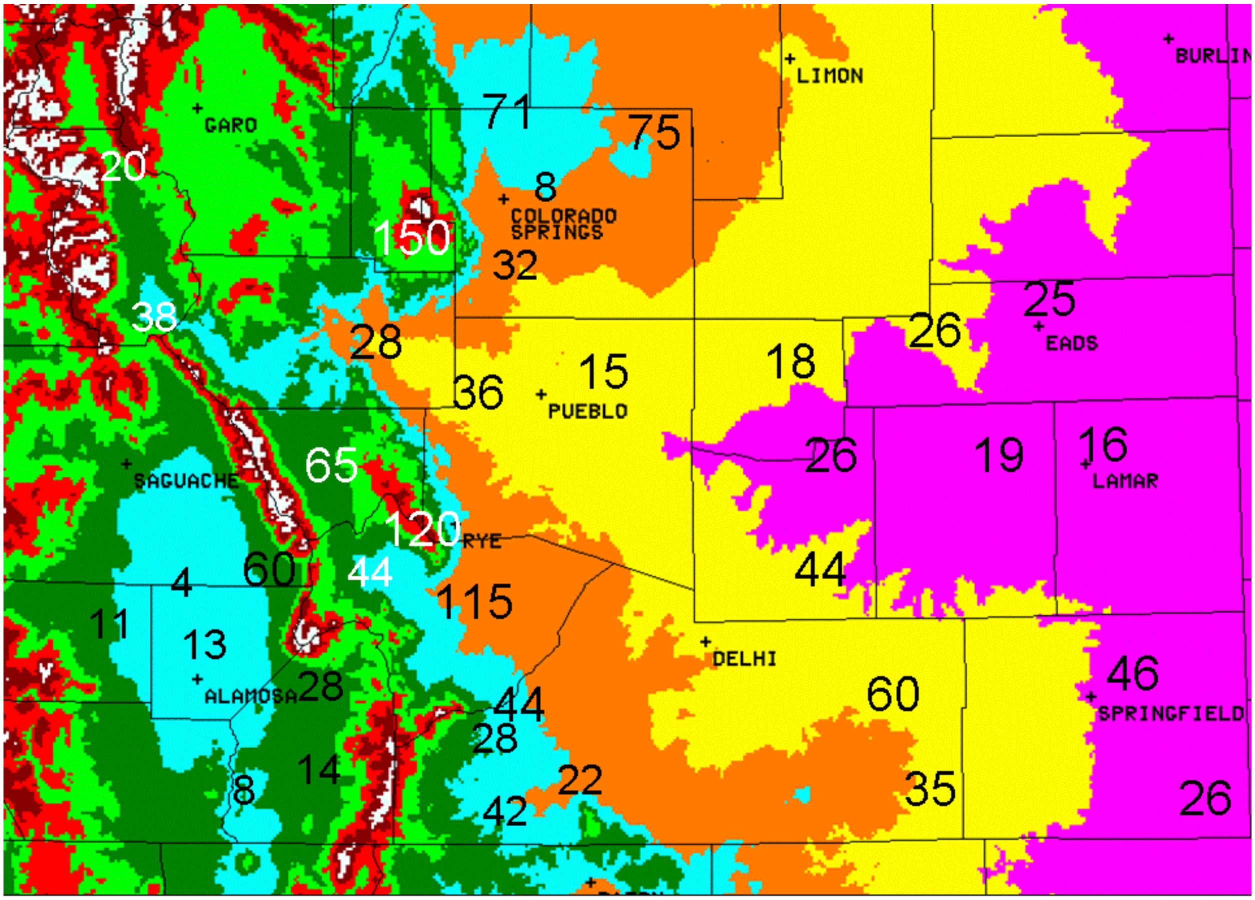

Figure 2. Topography and precipitation totals (mm). Color changes every .33km of elevation.

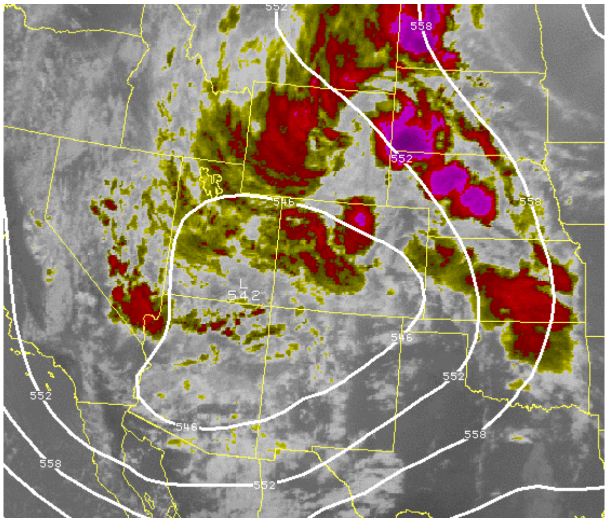

Figure 3a. IR image and 50 hPa heights (60 m interval) at 0000 UTC 18 March 2003.

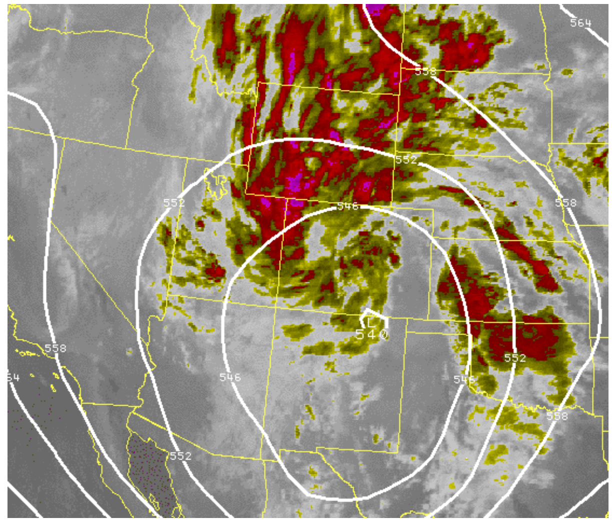

Figure 3b. Same as figure 3a but for 1200 UTC 18 March 2003.

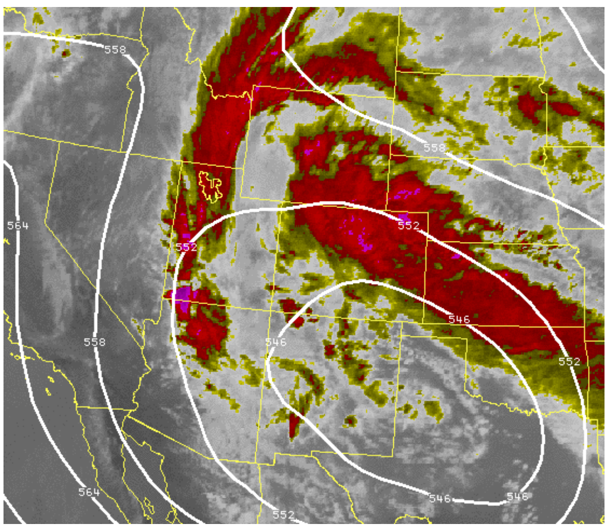

Figure 3c. Same as figure 3a but for 0000 UTC 19 March 2003.

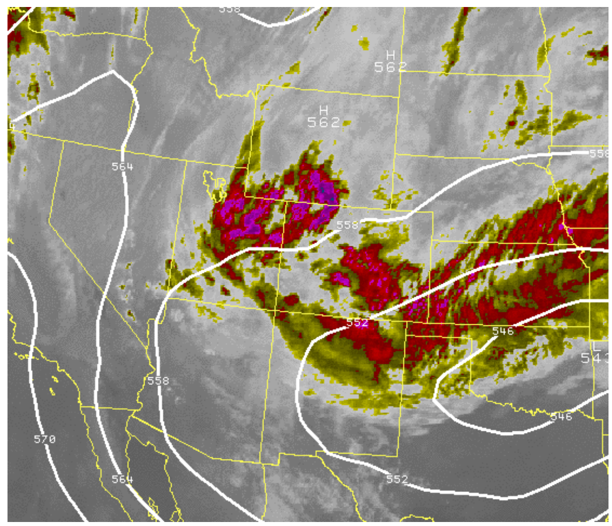

Figure 3d. Same as figure 3a but for 1500 UTC 19 March 2003.

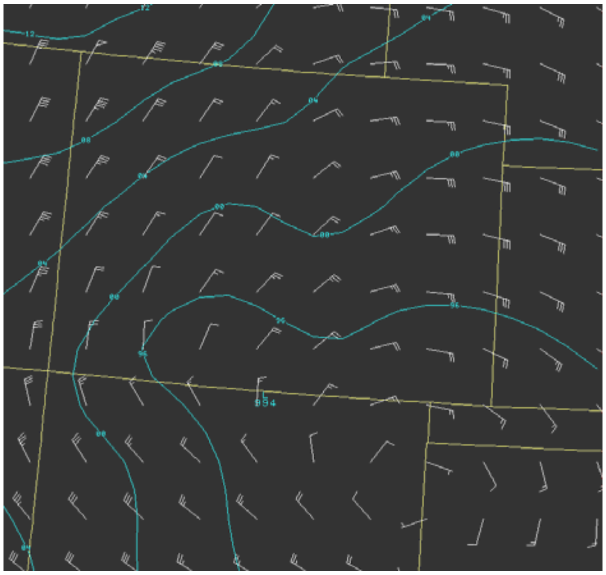

Figure 4a. 70 hPa winds and sea level pressure at 1800 UTC 18 March 2003. Sea level pressure interval is 4 mb. For winds, a full barb is 5ms^{-1} (10 knots) and half barb is 2.5ms^{-1} (5 knots).

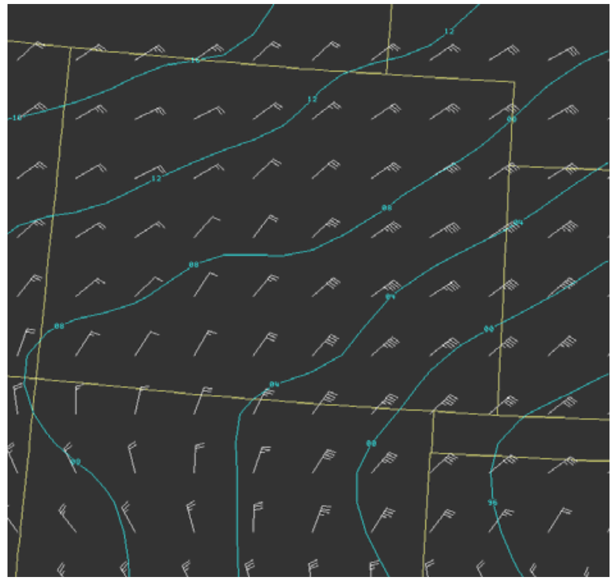

Figure 4b. Same as Figure 4a but for 1500 UTC 19 March 2003.

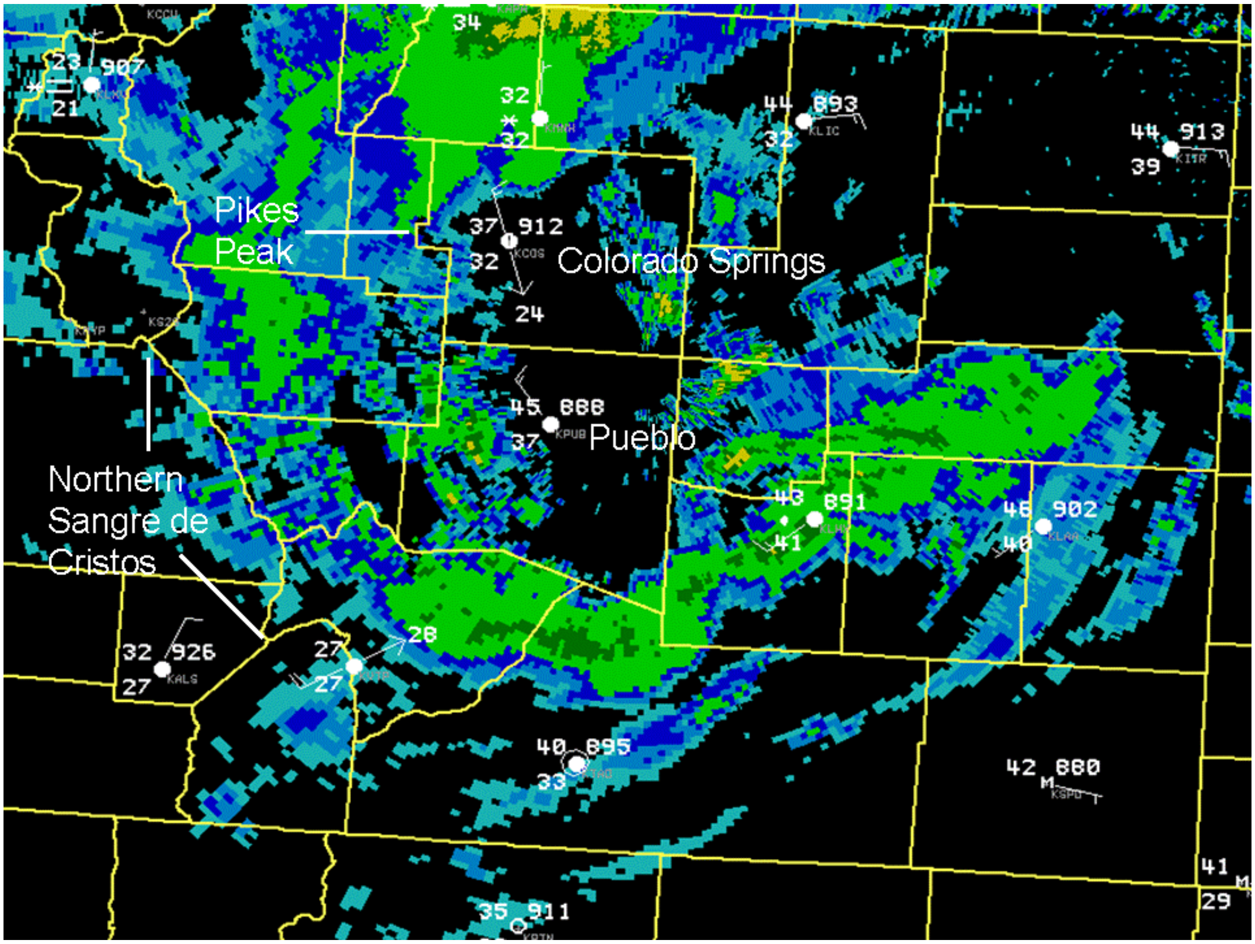

Figure 5. Radar, METAR and 15 minute lightning for 0524 UTC 18 March 2003. For METAR data, temperature and dew point are in ºF. For winds, a full barb is 5ms^{-1} (10 knots) and half barb is 2.5ms^{-1} (5 knots).

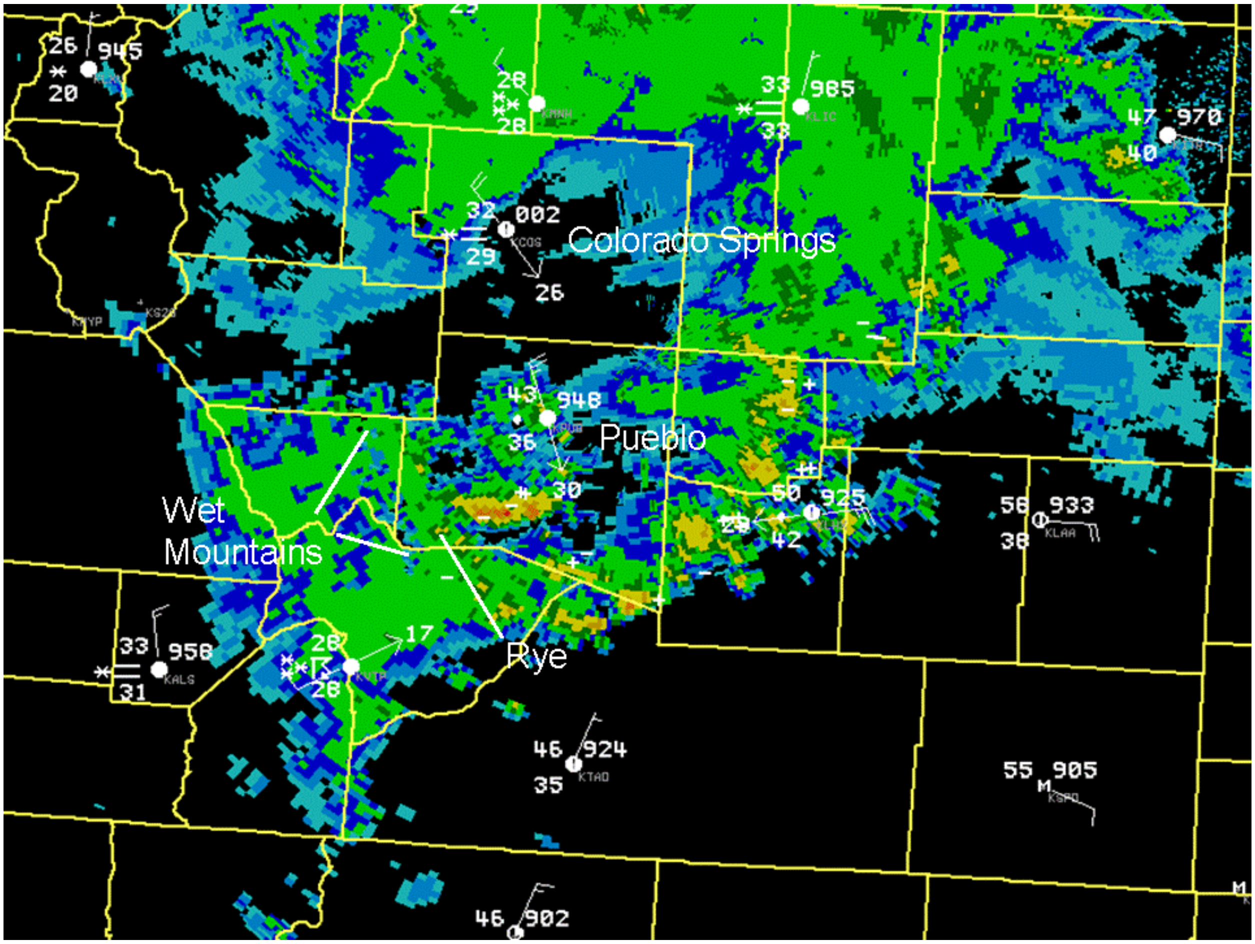

Figure 6. Same a figure 5 but for 1836 UTC 18 March 2003.

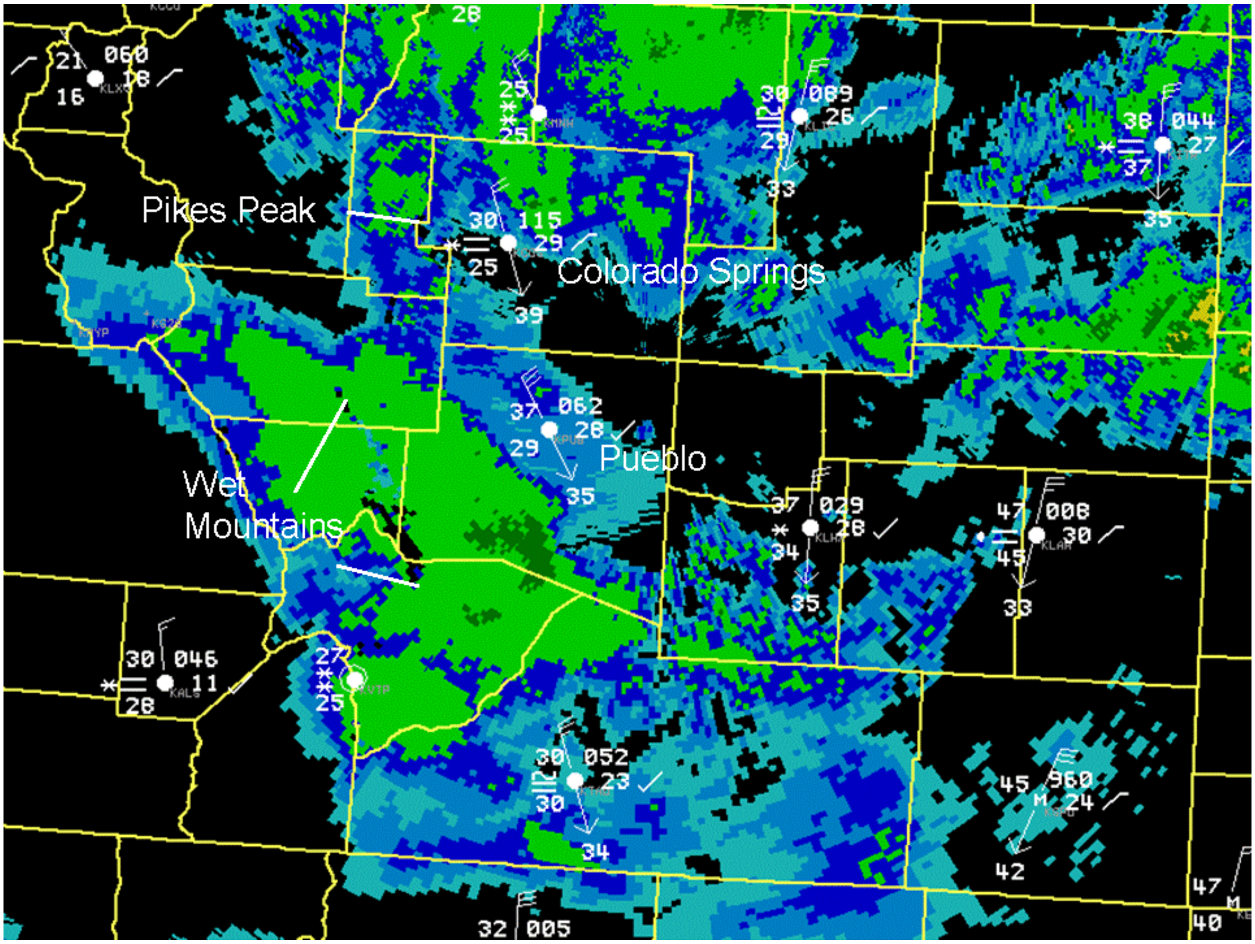

Figure 7. Same a figure 5 but for 1500 UTC 19 March 2003.