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THE VIRGINIA CANYON FLASH FLOOD: TOPOGRAPHY AND THE MODERNIZED WEATHER FORECAST OFFICE

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1. Introduction

On 18 August 1991, a small, steep canyon feeding into Idaho Springs, Colorado received a storm total rainfall in excess of one inch, and as much as one inch in less than thirty minutes during the peak of the storm. This is a relatively substantial amount for the higher elevations of the semi-arid West. The rainfall resulted in a flash flood which put water and debris into some homes and damaged roadways, a bridge and a culvert. The meteorological setup that day was not very impressive with the only indicators of flash flood potential in northeast Colorado being precipitable water of 150 percent of normal, and moist, but weak upslope flow. The flash flood producing thunderstorm was typical of average, non-severe storms over the northeast Colorado plains. However, the complex terrain of the mountains proved to be a complicating factor.

This paper will describe this significant, life-threatening flash flood event in the Front Range of Colorado, west of Denver. While a few aspects of the meteorological environment were somewhat favorable for flash flooding, it was a rather modest rain-producing thunderstorm, based on Doppler radar observations. However, the storm interacted with the local physiographic environment to produce a significant flash flood. This combination of storm and topography indicates the necessity of combining WSR-88D radar data with sub-basin topography when assessing flash flood potential.

2. Background

A. Geography: Topography/Surface Characteristics

Idaho Springs lies along Clear Creek, 7600 ft (about 2300 m) above sea level. This historic mountain town, 30 mi (48 km) west of Denver, is a popular tourist spot. Virginia Canyon is a very steep and narrow drainage that opens into Clear Creek from the north on the east side of the city. The canyon begins 2¼ mi (3.6 km) northwest of Idaho Springs at 9450 ft (about 2880 m), and narrows significantly about ½ mi (0.8 km) before reaching town (Fig. 1). The creek bed just above its confluence with Clear Creek is about 6 ft (1.8 m) wide and 4 ft (1.2 m) deep. At one time, this drainage was very heavily mined and the result is quite visible today. Much of the 2 mi^2 (5.2 km^2) drainage is cluttered with old mine tailings which enhance debris flow and potential flooding. The 1980 USGS Clear Creek County topographic map (scale 1:50,000) identifies over 70 mine sites in the watershed. The part of the canyon not covered by tailings is mostly impermeable and sparsely vegetated.

B. Synoptic Setting

At 0000 UTC, 19 August 1991, a high pressure ridge at 500 hPa was centered over the Great Basin and Southwest U.S., resulting in northwest flow and 15 to 20 kt (8-10 m sec^{-1}) steering winds over Colorado (Fig. 2). At the surface at 0100 UTC, the Mesoscale Analysis and Prediction System (MAPS; Benjamin et al. 1991) indicated a weak trough over north-central Colorado and high pressure on the eastern plains, resulting in easterly low-level upslope flow (Fig. 3). The 0000 UTC Denver sounding (Fig. 4) indicated such from the surface to 680 hPa. This upslope flow into the foothills continued through 0300 UTC as shown by the Platteville profiler, located about 30 mi (48 km) north of Denver. While the lowest 5000 ft (about 1500 m) of the sounding was dry, moisture was quite evident just above 700 hPa. Since Idaho Springs is 2000 ft (about 600 m) higher in elevation than Denver, much of this drier air at low levels was of little consequence in the Idaho Springs environment. Precipitable water at Denver was around one inch, which was 150 percent of normal.

C. Radar Characteristics

The radar data available at the Weather Service Forecast Office (WSFO) in Denver for this study were provided by the Mile High Radar (MHR), a National Center for Atmospheric Research (NCAR) 10-cm Doppler radar similar to the WSR-88D. It is located about 15 mi (24 km) northeast of WSFO Denver, which is near Stapleton International Airport. Precipitation estimates are generated by the Precipitation Processing Subsystem (PPS) algorithms using the Z-R relationship of $Z = 500R^{1.5}$. According to Kelsch (Forecast Systems Lab, personal communication), this relationship is very similar to the WSR-88D Z-R relationship, $Z= 300R^{1.4}$, the latter having been found to be valid for Colorado warm season convective storms (Kelsch 1992).

Potential limitations of the algorithms in this case include the Z-R relationship, reflectivity contamination by hail, evaporation of rainfall below the lowest radar beam elevation, range of the storm from the radar, and terrain blocking. The Z-R relationship appeared valid for this environment and was not contaminated by hail since neither this nor any other storm that day contained hail. The 0000 UTC, 19 August 1991, DEN sounding indicated that the subcloud environment in the vicinity of Idaho Springs was rather moist, thus evaporation likely would not result in an overestimation of precipitation. The flash flood producing cell was approximately 40 mi (about 65 km) southwest of the radar site, close enough to limit overestimation of precipitation coverage.

Terrain, however, could have potentially posed a problem. The blockage correction within the PPS helps to minimize this problem as discussed in the Federal Meteorological Handbook No. 11, Part C (U.S. Department of Commerce, 1991). In this particular case, data from the 1.2° and 2.5° elevation scans were input into the PPS. Considering the beam height of these angles, approximately 12,000 ft (about 3660 m) and 16,000 ft (about 4880 m) above mean sea level at the location of the storm, it is apparent that these two angles were sufficient to adequately sample the storm and provide quality input for the PPS. Local terrain in the immediate area of the storm ranges in elevation from 7,500 ft (about 2290 m) to 10,000 ft (about 3050 m).

3. Discussion

A. The Event

The core of the flood-producing thunderstorm moved over the central part of Virginia Canyon shortly before 0230 UTC on 19 August 1991. Within a few minutes, excessive runoff had swept tons of mine tailings and other debris into Idaho Springs. One bridge and a large culvert were washed out by the combined forces of water and rock. When the bridge was dislodged from its embankment, a water main also broke and a gas pipeline became exposed to the flood debris. Several residents were evacuated because of the gas explosion threat. The Clear Creek County Sheriff's department reported some residential flooding on Clear Creek, downstream of the confluence with Virginia Canyon, which was 2 to 3 ft above bankfull shortly after 0230 UTC. The city's cost of the cleanup and rebuilding the roads and creek crossings was in excess of $25,000.

B. Radar Perspective

The 1.2° reflectivity image from the MHR Doppler radar at 0217 UTC on the 19th showed a line of rain showers with several embedded thunderstorms extending from east-central Boulder County through central Clear Creek County. A 40 dBZ storm was located in north-central Clear Creek County over the Mill Creek and upper Fall River basins. This was the storm that only minutes later produced the flash flood in Virginia Canyon. By 0226 UTC the storm had intensified to 50 dBZ. At this time, the radar placed the center of the rapidly developing thunderstorm in the Fall River drainage, immediately west of Virginia Canyon. By 0235 UTC, the maximum reflectivity core had increased to 60 dBZ and had dumped heavy rains into Virginia Canyon above Idaho Springs. Before the flash flood, thunderstorms were producing heavy rain in tributaries of Clear Creek upstream from Idaho Springs. Although these rains did not augment the problems in Virginia Canyon itself, the two events combined caused Clear Creek to rise out of its banks on the east side of Idaho Springs, downstream from the Virginia Canyon confluence.

The only rainfall report from this storm was an undocumented, post-event, second-hand 3 inch report in the Virginia Canyon basin. This report is suspected by the National Weather Service hydrologist as being excessive. Nevertheless, radar estimated rainfall totals at 0237 UTC indicated 0.5 to 1 inch of rain fell in the canyon within 20 minutes. NWS Flash Flood guidance for mountainous terrain is an inch or more in an hour or less (NWS, 1990). Based on radar estimated rainfall, the Virginia Canyon storm exceeded this guideline. However, if flash flood guidance were developed specifically for Virginia Canyon, we suspect it would certainly be even lower.

4. Summary

The Idaho Springs flash flood resulted in more than $25,000 of damage to roads and related structures and caused some damage to homes in Virginia Canyon and along Clear Creek. Meteorologically, this was an unimpressive event. Although the air mass was very moist and low level upslope flow was occurring, the synoptic setting was not quite that typical of those associated with flash flood events (Maddox et al. 1980). Based on observations of the stream channel and debris in this basin, this was a significant event--the likes of which had probably not occurred there for a few hundred years (Dr. Robert Jarrett, USGS, personal communication).

The areal extent of this storm was quite small compared to the typical plains storm, but it occurred in a geographic location favorable to produce significant runoff. If this event had occurred a mile or two from its actual location, it would no doubt have produced considerably less damage because of different topography and less population and infrastructure.

This event shows how critical it is to study topography and incorporate radar information with topography when considering flash flood statements and warnings. The storm that washed out the Virginia Canyon road was mostly a 45 to 50 dBZ storm with only a few minutes of 55 to 60 dBZ, though it was moving downstream. If on the plains, this short-lived storm would have been no different from any other typical non-severe northeast Colorado thunderstorm. In this case, the storm did not cause the event; the inseparable topography-storm interaction resulted in the flash flood.

While there is no substitute for visiting flash flood areas, NWS resources do not allow for most field staff to gain this critical knowledge first hand. However, warning forecasters can study county and smaller scale topographic maps to get an idea where problem areas are. In the pre-warning phase, a working knowledge of sub-basin scale topography should be a prerequisite, not an option.

With the deployment of AWIPS, there exists a great opportunity for using stream-scale basin maps to accomplish this purpose. This paper indicates that more accurate and timely flash flood warnings can result if WSR-88D data are combined with high resolution topographical data. In fact, this would be a necessity if complete utilization of WSR-88D data were desired.

5. References

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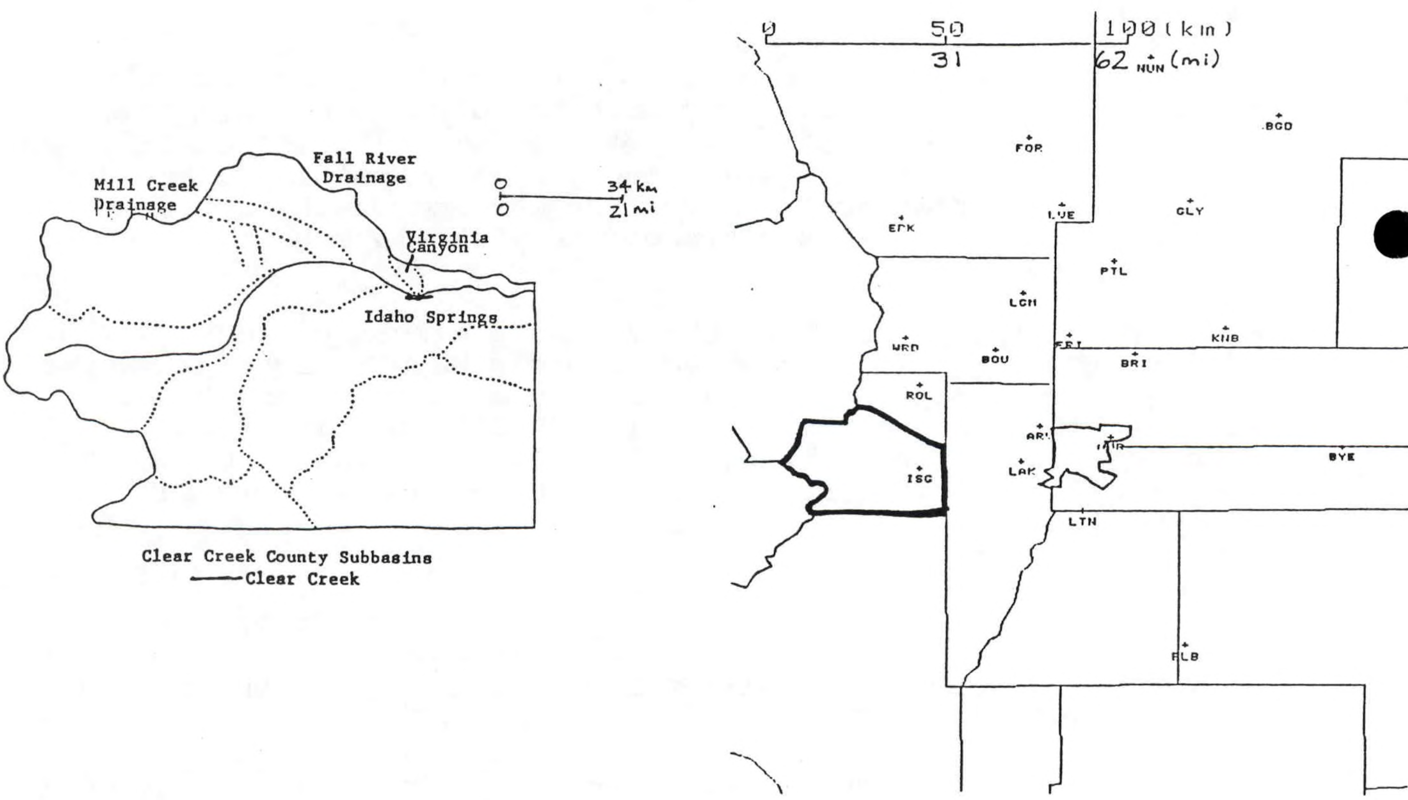

Figure 1. Regional county map and Clear Creek county inset.

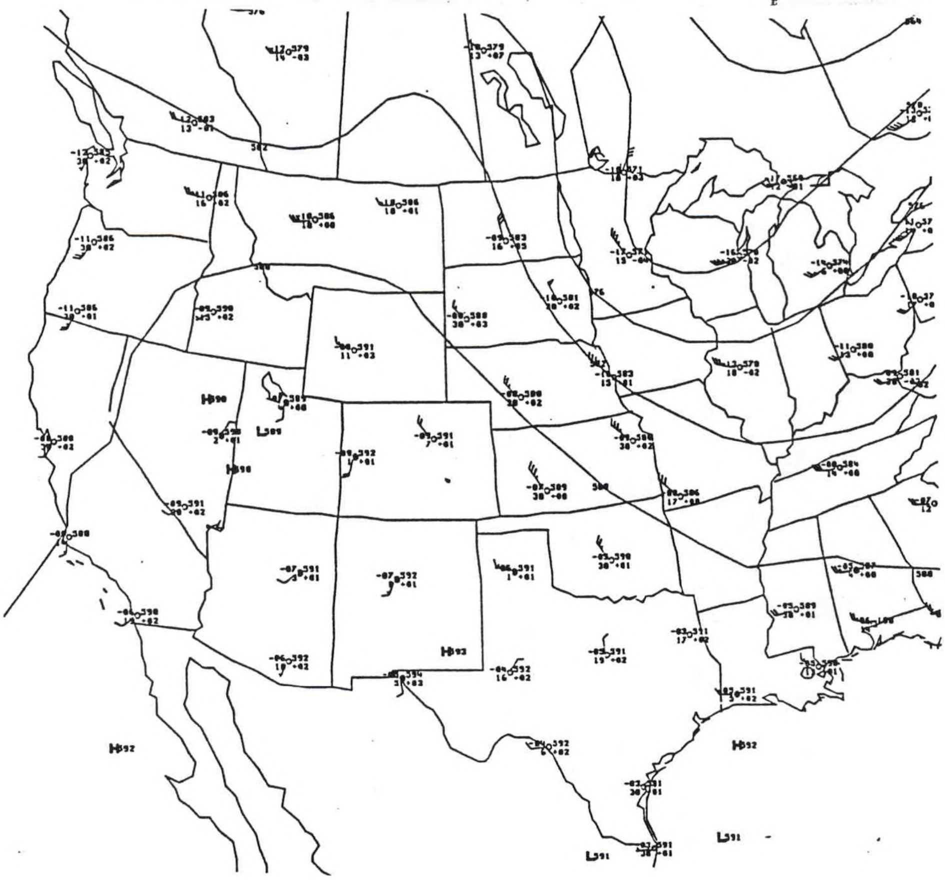

Figure 2. 0000 UTC 19, August 1991 500 hPa observations and NGM height analysis (gpm).

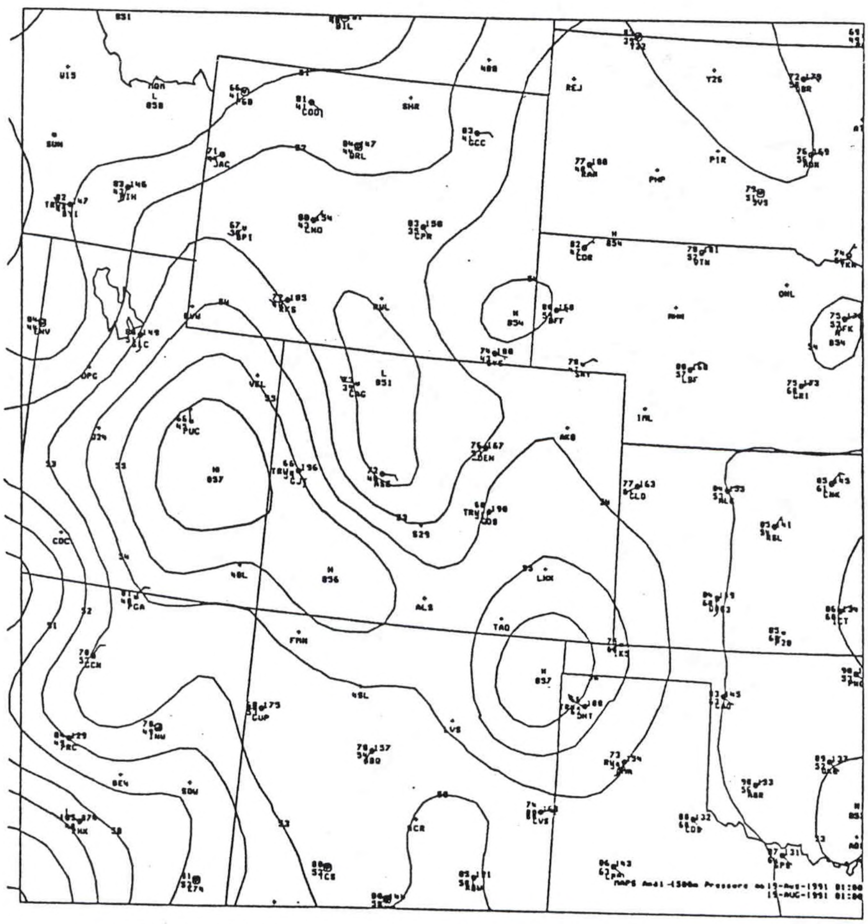

Figure 3. 0100 UTC, 19 August 1991, surface observations and MAPS 1500m pressure (hPa) (pressure reduced to 1500 m instead of sea level).

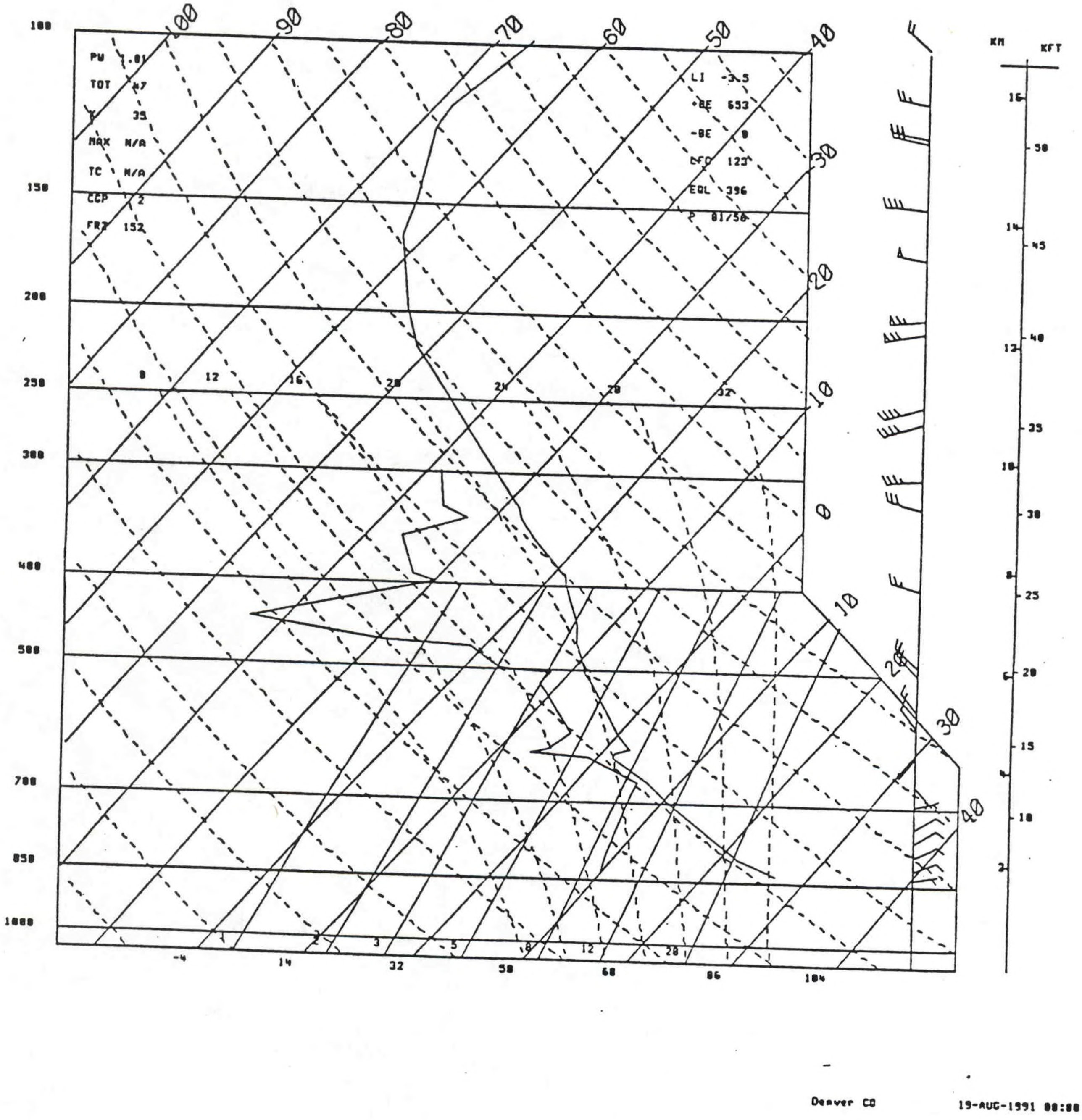

Figure 4. 0000 UTC, 19 August 1991 Denver, CO sounding.