A Small Updraft Producing a Fatal Lightning Flash

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ABSTRACT

Just prior to 1900 UTC 25 July 2000, an 18-year-old male was fatally wounded by a lightning flash on the summit of Pikes Peak, Colorado. This case is believed to be unique in that radar and satellite data indicated that the cell that produced the flash was quite shallow and exhibited marginal reflectivity characteristics typically associated with electrified storms. Additionally, the National Lightning Detection Network indicated that this was the first and only cloud-to-ground (CG) flash associated with this convective cell. It is believed the height and isolated nature of the Pikes Peak massif played a role in the initiation of this flash.

1. Introduction

Using radar, satellite, and upper air data, this paper will examine a shallow convective updraft that produced a −17.6-kA cloud-to-ground (CG) lightning flash that fatally wounded an 18-year-old male on the summit of Pikes Peak, Colorado (elevation 4.3 km MSL; Fig. 1). The young male, along with two other companions, were standing 10 m from each other in an exposed boulder field approximately 33 m from the summit of the mountain. The first companion, closest to the teen who was fatally struck, was knocked to the ground. The second teen was still standing after the flash. According to emergency personnel working at the summit, no thunder was heard prior to the fatal flash.

2. Data analysis

a. National Lightning Detection Network

In order to observe the spatial extent of CG lightning in and around the Pikes Peak region, the National Lightning Detection Network (NLDN) flash data (Cummins et al. 1998) between 1700 and 1930 UTC 25 July 2000 were reviewed. Analysis indicated that no flashes occurred between 1700 and 1800 UTC. Three flashes were identified between 1800 and 1900 UTC. The first flash occurred at 1837:34 UTC, 167 km to the west of Pikes Peak. The second flash occurred at 1856:54 UTC, striking the top of Pikes Peak. The third flash occurred at 1858:41 UTC, 114 km west-southwest of Pikes Peak (Fig. 2). Twelve additional flashes were noted between 1900 and 1930 UTC, but these occurred more than 75 km from Pikes Peak.

El Paso County Search and Rescue first received a report of a lightning strike victim on the top of Pikes Peak shortly after 1900 UTC. Based on this report, and analysis of the NLDN dataset, the flash that occurred on the summit of Pikes Peak at 1856:54 UTC was the flash that fatally wounded the young male.

b. Satellite analysis

Satellite data from *Geostationary Operational Environmental Satellite-11* (*GOES-11*) were available for examination for this study. Fortuitously, *GOES-11* was performing a Super Rapid Scan Observation (SRSO) science test during the morning and early afternoon on 25 July 2000. This test permitted examination of the data in high temporal resolution (∼1 min) over the Pikes Peak region. The SRSO science test ceased at 1853:17 UTC, a few minutes prior to the fatal flash.

Visible data from 1800:00 through 1853:17 UTC indicate that the storm over Pikes Peak was in the towering cumulus stage, with no anvil cloudiness noted. The

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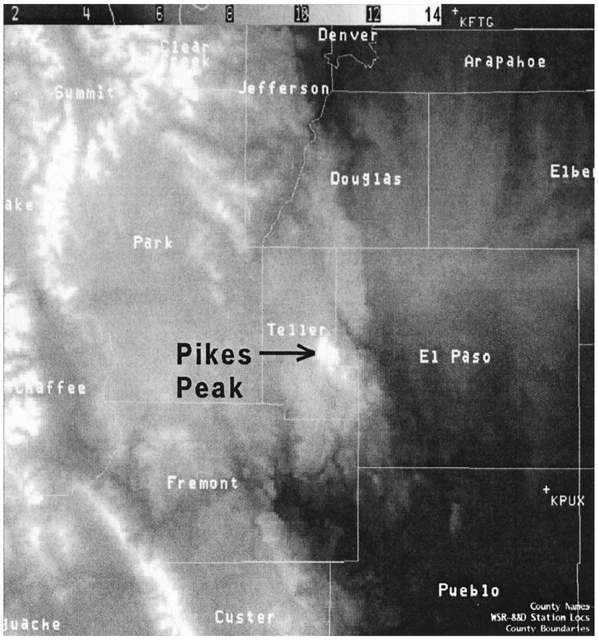

FIG. 1. Topographical map with counties labeled showing the Pikes Peak region. The summit of Pikes Peak is located in extreme west central El Paso County. KPUX (lower right) is the location of the radar used in this study. Elevation intervals (kft) are shaded as indicated at the top of the figure.

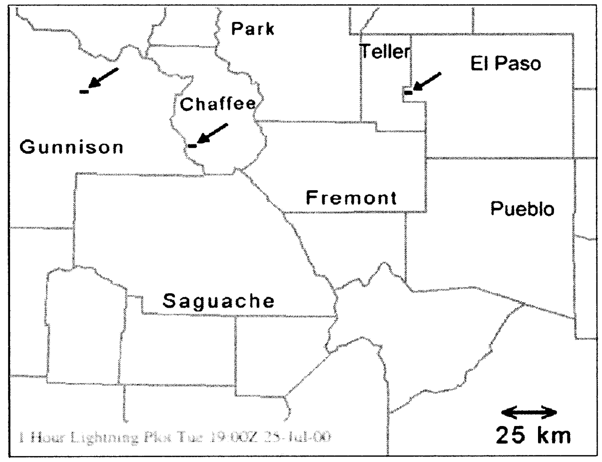

FIG. 2. One-hour lightning plot between 1800 and 1900 UTC 25 Jul 2000. Three flashes (arrows) occurred across the Pikes Peak region. The flash in extreme west central El Paso County is the location of the Pikes Peak massif.

1853:17 UTC image (Fig. 3) shows the convective tower to be rather small in horizontal extent (about 16 km in width). There was a small bright top in the visible image, composed of six to seven pixels, that was most likely associated with the updraft and therefore the highest cloud top. The two coldest associated pixels in the IR imagery from *GOES-11* were −13.5° and −12°C. By comparing the visible to the infrared imagery, we find that approximately 50% of the first IR pixel and 30% of the second were overlapped by the brightest pixels on the visible channel. Surrounding this area the cloud top measured about −8°C. By performing a weighted average, it is possible to estimate that the subpixel temperature for the ''updraft pixels'' was approximately −20°C (Reynolds and Vonder Haar 1977). Comparing these IR temperatures with the observed 1200 UTC sounding from Denver, Colorado (100 km north of Pikes Peak; Fig. 4), we find that the cloud top extended to as high as 7 km (23 kft MSL).

c. Radar analysis

Radar data from the KPUX (Pueblo, Colorado) Weather Surveillance Radar-1988 Doppler (WSR-88D), located 85 km east-southeast of Pikes Peak, were used to analyze the reflectivity characteristics of the cell that produced the fatal flash. Composite reflectivity 7 min prior to the flash (1851 UTC) indicated a small convective shower extending ~5 km in horizontal width over Pikes Peak (Fig. 5a). Interrogation of this cell using the National Severe Storms Laboratory (NSSL) WSR-88D Algorithm Testing and Display System (WATADS) software (McKibben 1996) indicated that the maximum reflectivity within the core was 31 dB*Z*. Cross-section analysis of this cell indicated that it was quite shallow, since precipitation extended only to a height of 7 km MSL (Fig. 5b). An elevated layer of maximum reflectivity was noted with this cell between 5 and 6 km MSL. This layer of higher dB*Z* values is likely to be an area of mixed-phase precipitation, since the Denver sounding indicated the height of the 0°C isotherm to be 4.6 km MSL (15 kft; Fig. 4).

Five minutes later, the 1856 UTC reflectivity volume scan (Figs. 5c,d) indicated no significant change in the intensity of the cell, as the maximum reflectivity value within the composite reflectivity image was 30 dB*Z*. However, the layering of higher dB*Z* values that was noted in Fig. 5b was no longer as evident, as the higher dB*Z* values were now extending toward the ground. It was during the beginning of this volume scan that the fatal flash occurred. After another 5 min, at 1901 UTC (Figs. 5e,f), the higher dB*Z* values were now located in the lower portion of the cell. No other CG lightning occurred as the cell moved slowly to the southeast away from the Pikes Peak massif.

Before continuing, it is necessary to briefly comment on the radar reflectivity data shown in Figs. 5a–f. Within the reflectivity cross section, especially Fig. 5f, dB*Z* values are displayed where terrain (in this case, Pikes Peak) is located. The reason for this is twofold. First, some of the dB*Z* values are likely associated with residual ground clutter left over from the KPUX WSR-88D clutter suppression algorithm. For the location of Pikes Peak, maximum clutter suppression is applied, and this value is typically 50 dB*Z* (National Weather Service 1995). If values of greater than 50 dB*Z* are measured by the WSR-88D, then the difference of these values

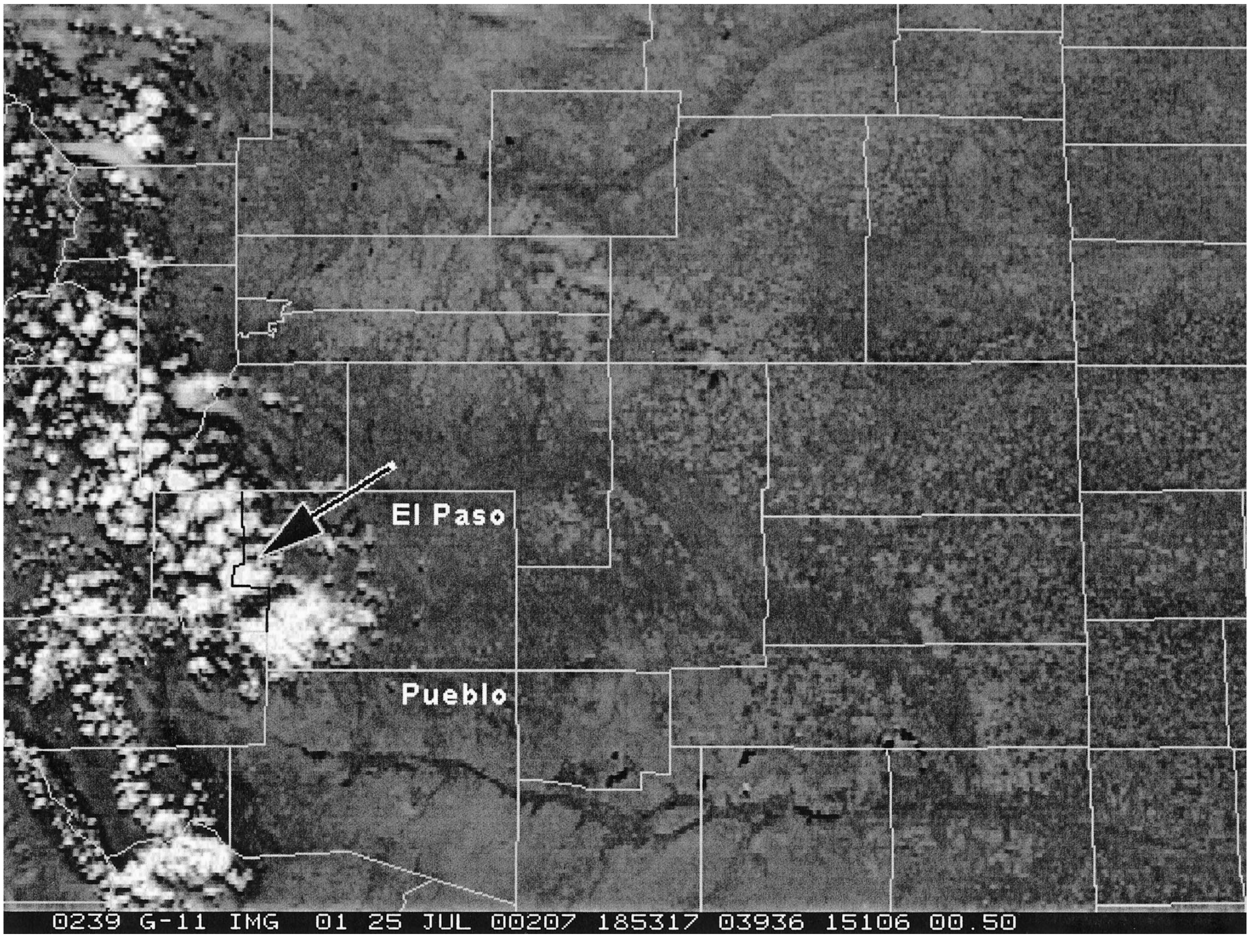

FIG. 3. *GOES-11* visible satellite imagery at 1853:17 UTC 25 Jul 2000. Arrow points to updraft over Pikes Peak. The county border between El Paso County and Teller County (not labeled) has been inverted for clarity. The map has been corrected for parallax so the top of the storm of interest lines up correctly with the county borders.

will be displayed in the radar display. It should be noted that, even on optically clear weather days, it is quite common to observe low-end reflectivity values at the location of Pikes Peak with the KPUX WSR-88D. The second reason may be an artifact of the WATADS software, which is not linked to any terrain database. If dB*Z* values (either true hydrometeors or residual ground clutter) are detected within the vicinity of the higher terrain, WATADS will interpolate these data vertically through that given radar bin. If higher terrain is located within this given bin, it will show dB*Z* values located where terrain is located (R. A. Maddox 2003, personal communication).

3. Discussion

The electrification process within a cumulonimbus cloud requires graupel. Radar studies of electrical storms have shown that high concentrations of graupel are associated with radar reflectivities greater than or equal to 35 dB*Z*; at temperatures less than or equal to −10°C (MacGorman and Rust 1998). The threshold of 35 dB*Z* and −10°C indicates a cloud with sufficient graupel to produce a CG flash. Sounding analysis in this case indicated the −10°C level to be located at 6.1 km MSL (20 kft; Fig. 4). Radar analysis of this cell indicated hydrometeors greater than 18 dB*Z* reaching above the height of the −10°C level; however, it did not show radar echoes greater than or equal to 35 dB*Z* reaching this height.

Satellite analysis of this cell did not support characteristics associated with electrified storms. Goodman and Meyer (1988) observed that cloud-top heights of convective updrafts prior to the onset of electrification are typically on the order of 10–11 km, with cloud-top temperatures of −30°C. They also observed cirrus blow off to occur ∼10 min prior to the first indications of electrification. Satellite-detected brightness temperatures of the convective updraft in this study were observed to be −13.5°C. Taking into account satellite sampling concerns, and including radar data, cloud-top temperatures at the time of the flash were on the order of

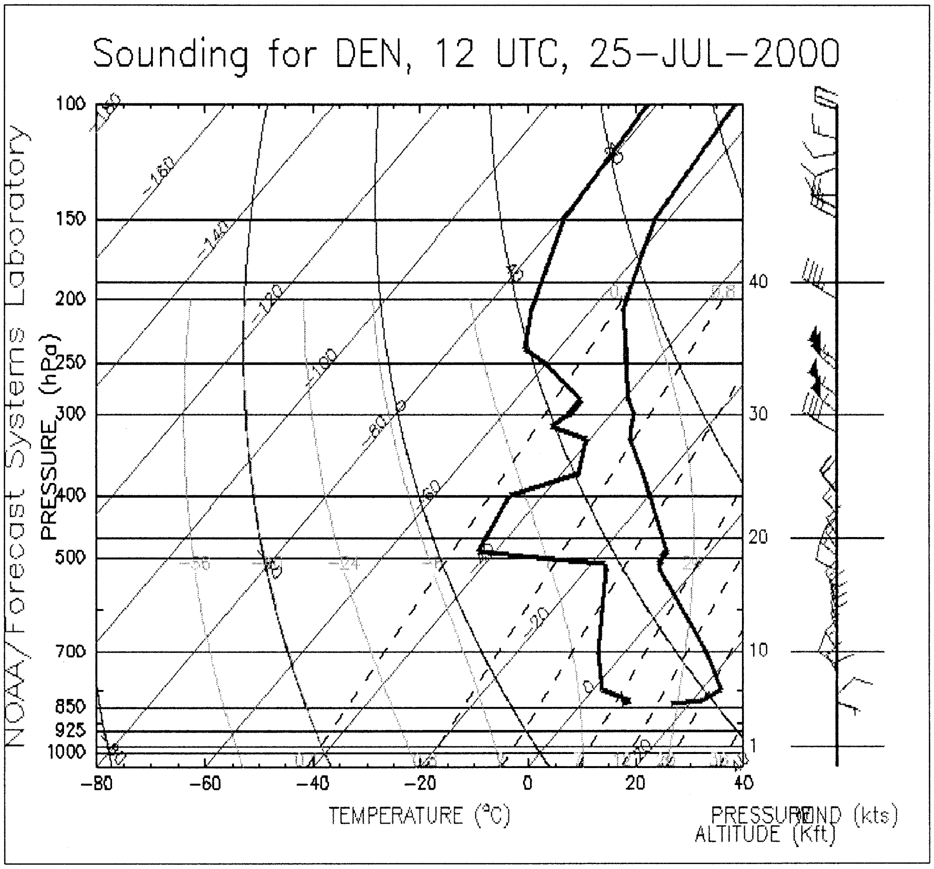

FIG. 4. The 1200 UTC 25 Jul 2000 sounding from Denver, CO; elevation (kft).

−20°C. This value, based on the 1200 UTC sounding, would indicate that the cell had a maximum cloud height of 7 km. No cirrus blow off was observed with this cell.

Why did this small convective cell without radar or satellite characteristics typically associated with electrified storms produce a CG flash? An explanation may be the combination of the geography of Pikes Peak and the location of the brightband layer above the mountain. It is well documented that lightning will typically strike the tallest object (Uman 1986), and very tall objects such as mountain peaks can initiate a flash (Uman 1984). Pikes Peak is a very tall and isolated mountain peak (Fig. 1). Radar analysis just prior to the flash did indicate a weak brightband layer between 5 and 6 km MSL, indicating that mixed-phase precipitation was likely occurring with the cell. More importantly, the distance between this mixed layer (~5.5 km MSL) and the top of Pikes Peak (4.3 km MSL) was only 1.2 km. Since this distance was relatively small, it would not take much charge separation to produce a flash capable of reaching the ground.

4. Conclusions

This paper documents a shallow convective updraft that produced a −17.6-kA CG lightning flash, fatally wounding a young male on top of Pikes Peak, Colorado. Radar and NLDN data indicate that this was the first flash of the day associated with this specific convective cell. Electrical characteristics of this cell did not follow either radar or satellite threshold guidelines, as the flash developed with lower radar reflectivities and warmer cloud tops than is documented in the literature. It is

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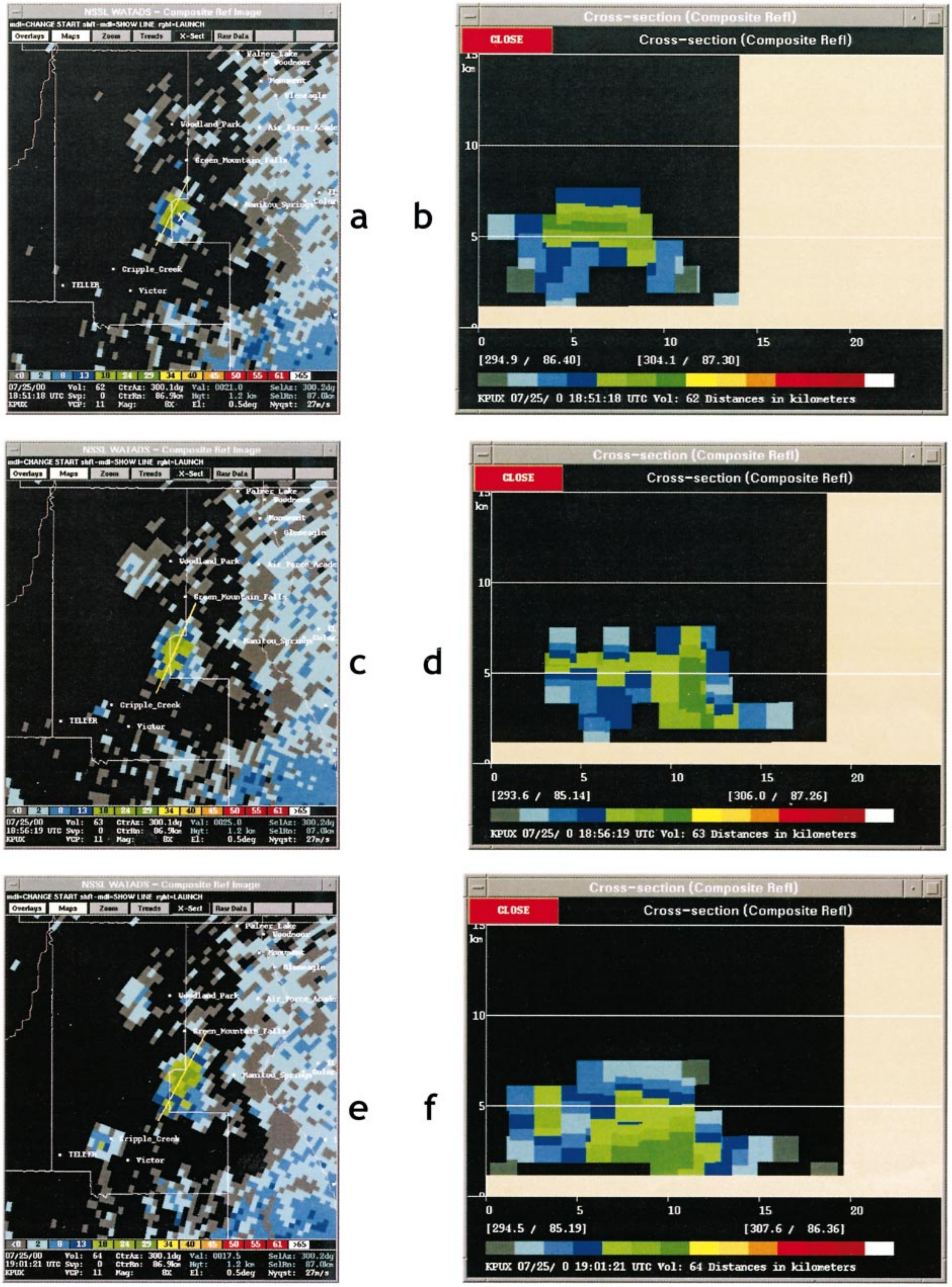
FIG. 5. KPUX composite reflectivity data at (a) 1851, (c) 1856, and (e) 1901 UTC. The white ''X'' in the center of the composite reflectivity in (a) marks the location of the top of Pikes Peak. The narrow yellow lines running southwest–northeast in (a), (c), and (e) denote the corresponding reflectivity cross sections shown in (b), (d), and (f), respectively. Height in radar cross sections is measured with respect to mean sea level (km). Reflectivity bin values are as follows: light green (18 dB*Z*) range from 16 to 22 dB*Z*; mid-green (24 dB*Z*) ranges from 22 to 27 dB*Z*; dark green (29 dB*Z*) ranges from 27 to 32 dB*Z*; and yellow (34 dB*Z*) ranges from 32 to 38 dB*Z*. The reflectivity scales in all six images are identical. The time stamp denotes when the volume scan began.


a
b
c
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Cross-section (Composite Refl)
CLOSE
[294.9 / 86.40]
[304.1 / 87.30]
KPUX 07/25/ 0 18:51:18 UTC Vol: 62 Distances in kilometers
[293.6 / 85.14]
[306.0 / 87.26]
KPUX 07/25/ 0 18:56:19 UTC Vol: 63 Distances in kilometers
[294.5 / 85.19]
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KPUX 07/25/ 0 19:01:21 UTC Vol: 64 Distances in kilometers
Woodland Park
Green Mountain Falls
Manitou Springs
Cripple Creek
Victor
TELLER

likely that the relative isolation and height of Pikes Peak played a role in the development of this flash.

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