THE LIMON, COLORADO TORNADO OF 6 JUNE 1990

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Abstract

On 6 June 1990, one of the strongest tornadoes to occur in the state of Colorado in recent history hit the small town of Limon, 75 miles southeast of Denver. Although no one was killed, several individuals were injured and the town was severely damaged. This paper investigates the development of the tornado and how an advanced meteorological workstation and Doppler radar, located at the National Weather Service Forecast Office in Denver, were used to aid the warning process. The coordination that occurred between National Weather Service offices and outside entities will be presented. In addition, the importance of NOAA Weather Radio, trained severe weather spotters and proper preparedness techniques will be discussed.

1. Introduction

During the afternoon and evening hours of 6 June 1990, severe thunderstorms developed over the plains of eastern Colorado and spawned several tornadoes. One of those tornadoes moved through the town of Limon. Limon, a town of 1800 people, is located 75 miles southeast of Denver and 60 miles northeast of Colorado Springs (Fig. 1). This tornado resulted in over $215,000 in damage and left the residents of Limon never to be the same. This F3 (Fujita 1981) tornado literally tore the downtown area apart and injured 14 people, but remarkably no one was killed. However, many other residents were affected in ways that no one will realize for years to come.

The reason for taking a second look at this event stems from the fact that tornadoes as large as the one that hit Limon are very rare in eastern Colorado. Also the new technology available at the National Weather Service Forecast Office (NWSFO) in Denver helped the forecasters to better analyze and forecast the mesoscale environment in which the storm developed. The warning dissemination process will also be discussed, as well as how this process may be improved as we head into the modernization era.

2. Synoptic Situation

On the morning of 6 June 1990, the day-shift forecaster was confronted by a weather pattern that is usually conducive to severe weather development in northeast Colorado. By afternoon, surface high pressure was building over western Nebraska in the wake of a weak frontal passage the previous day. This high pressure system centered over the Dakotas was providing eastern Colorado with an east to southeast flow (Fig. 2). At the same time a pool of moisture was located over western Kansas and southeastern Colorado. This can be seen as a ridge in the isodrosotherm pattern in Fig. 2 extending from southwest Kansas into eastern Colorado. This pattern for severe weather in the high plains has been addressed by Doswell (1980).

Morning upper air data showed a thermal trough at 500 mb over western Colorado. This thermal trough was forecast by the NWS National Meteorological Center's Nested Grid Model (NGM) and the Mesoscale Analysis and Prediction System model (MAPS, Benjamin et al. 1991) to move east and pass over eastern Colorado by 0000 UTC 7 June. The Denver 1200 UTC 6 June raob (Fig. 3) showed a Colorado ''loaded gun'' profile. Instability was high as shown by the large values of convective available potential energy (CAPE; Imy et al. 1992). This CAPE value (2161 Joules/kg) was likely an underestimate of what actually was present by the time the storm developed as it was based on a lower dewpoint than what was actually observed.

The 1500 UTC 6 June 1990 Convective Outlook issued by the NWS National Severe Storms Forecast Center (NSSFC) had eastern Colorado and eastern Wyoming under a slight risk based on the high CAPE, the forecast short wave, and the expected continuance of the moist low level southeast flow. A convective temperature of 85 degrees was calculated from the 1200 UTC 6 June sounding and with a high expected in the mid to upper 80s, the forecaster mentioned thunderstorms in the forecast. The possibility of a few thunderstorms reaching severe limits was also mentioned. The decision to mention severe was based on the expected development of the Denver cyclone (Szoke and Augustine 1990) and the models forecasting mid-level winds to increase, which would enhance the vertical wind shear.

3. Mesoscale Situation

The southeasterly surface flow that developed often leads to the formation of the Denver Convergence Vorticity Zone (DCVZ), known locally as the ''Denver cyclone'' (Szoke and Augustine 1990). Szoke (1991) has stated that the precise reason for the existence of this mesoscale feature is still uncertain. However, the interaction of the low level flow with the higher terrain to the south and west of Denver (Fig. 1) is a key ingredient. Many times the cyclone is just a wind shift line, but on occasion it develops into a well organized and easily identifiable cyclonic circulation. This was the case on 6 June.

As this southeasterly flow continued to intensify, it began tapping the moisture pool over southeast Colorado. In turn this increased the moisture advection first around the Palmer Divide, then in the vicinity of Denver. This can easily be seen by looking at the MAPS (Miller and Benjamin 1992) moisture convergence charts from 2100 UTC and 2200 UTC 6 June (Figs. 4 and 5). This moisture influx was intensified even more as the Denver cyclone intensified. By 0000 UTC 7 June, the

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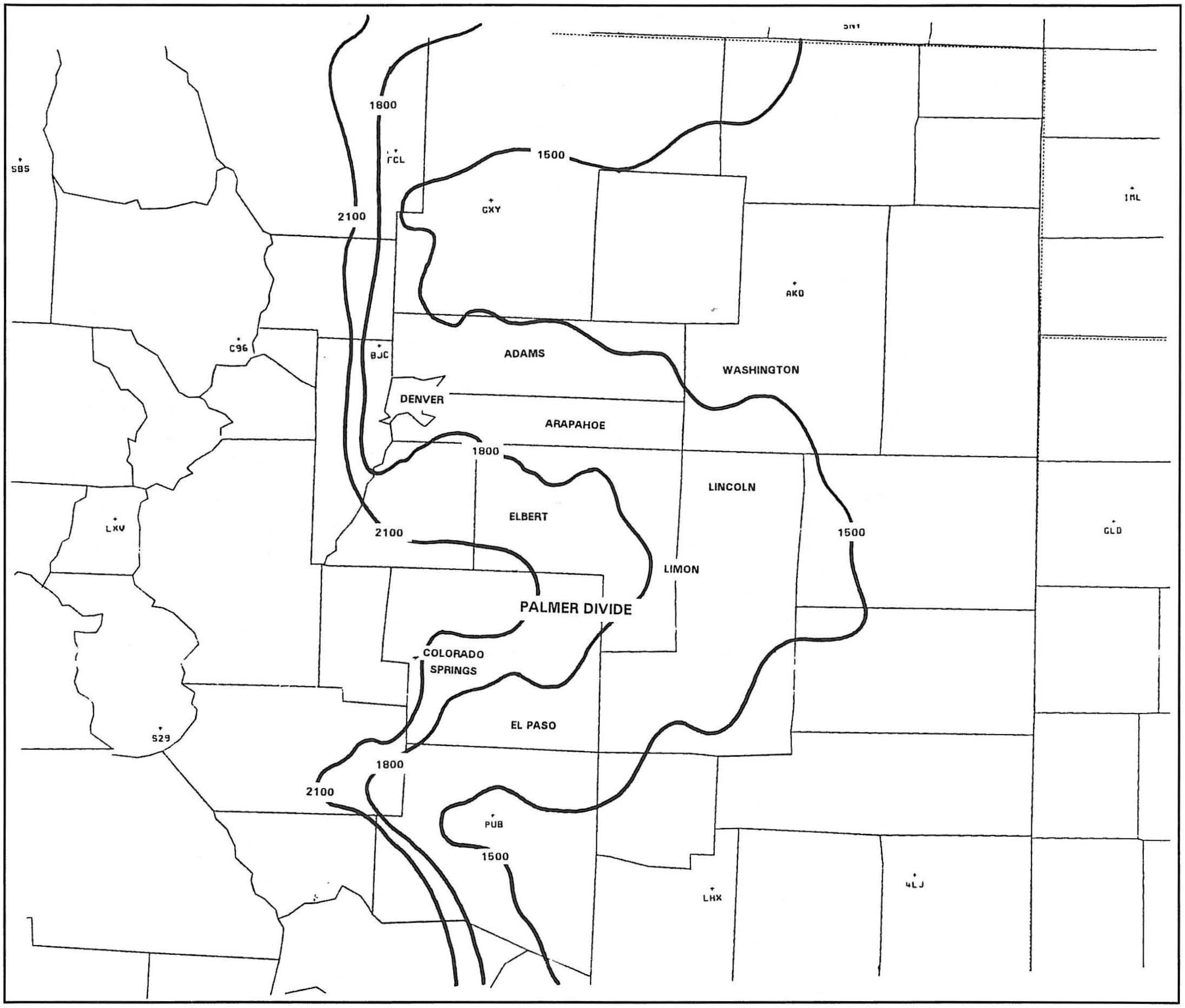

Fig.1. Map of northeast Colorado.

Denver cyclone was to the east of the Denver metropolitan area, and was continuing to strengthen. The Forecast Systems Laboratory (FSL) mesonet plot with associated streamline analysis (Fig. 6) and the MAPS surface relative vorticity chart (Fig. 7) easily denote the location of the cyclone.

Throughout the cyclone's intensification, moisture convergence increased and vorticity continued to spin up. By 0000 UTC 7 June (subtract 6 hours to get local time) moisture convergence was maximized as a 4.8 g/kg/hr bullseye was noted (Fig. 8). This was an increase of 1.2 g/kg/hr over a three hour period. The moisture convergence maximum remained in the same location throughout the afternoon and early evening hours. As Szoke et al. (1986) proposed, ''the deepening of the boundary layer moisture in the vicinity of the cyclone, due to a convergent wind flow, results in an environment which has a locally more favorable convective potential''. The spinning up of the vorticity in the vicinity of the cyclone has been shown by Szoke et al. (1986) to be critical in the formation of tornadic thunderstorms.

The vertical wind shear also became more favorable, as alluded to earlier by the NGM and MAPS forecasts, throughout the late afternoon and early evening. Both the Stapleton (70 miles northwest of Limon) and the Platteville (90 miles northwest of Limon) profilers (Figs. 9 and 10) showed directional and speed shear increasing after 2200 UTC. This type of wind shear has been shown to be favorable for the development of supercell thunderstorms (Doswell 1985), which are not as common in eastern Colorado when compared to the midwest.

In summary then, the synoptic situation on 6 June pointed toward an explosive situation. A short wave trough aloft was forecast to move over eastern Colorado and act on an airmass that was ripe for severe convection. Mesoscale analyses, most notably moisture convergence and mesonet streamlines, suggested that certain areas would be more favored for convective

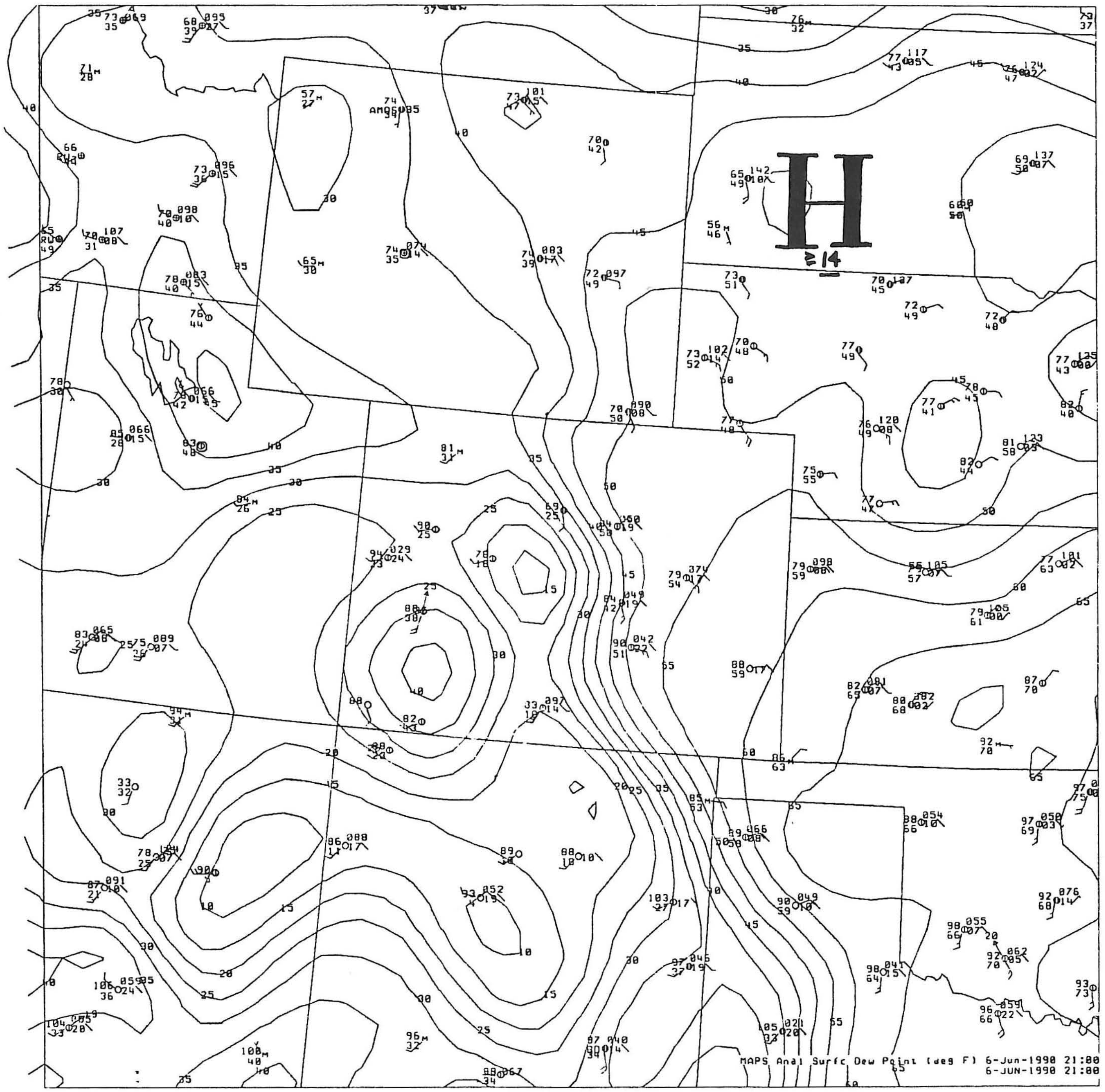

Fig. 2. Surface analysis at 2100 UTC 6 June 1990. Solid lines are isodrosotherms at 5 deg F increments.

development. This indeed is what happened as discussed in the next section.

4. Chronology of the Events

Early in the afternoon, thunderstorms began to develop in and along the foothills of northeast Colorado west of Fort Collins and in southeast Wyoming west of Cheyenne. The thunderstorms were expected to move into a "ripe" airmass favorable for the intensification of the storms. Special Weather Statements were issued by the NWSFO concerning the rapid thunderstorm development. With the expected intensification and development of other thunderstorms, the National Severe Storms Forecast Center (NSSFC) issued a tornado watch. At 1945 UTC, tornado watch number 400 was issued for parts of southeast Wyoming, much of northeast Colorado, and parts of the Nebraska panhandle until 0300 UTC. For the issuance of the watch, forecasters at NSSFC cited the increasing moisture, the steep lapse rates due to the approaching mid level trough, and the favorable vertical shear. By 2030 UTC, thunder-

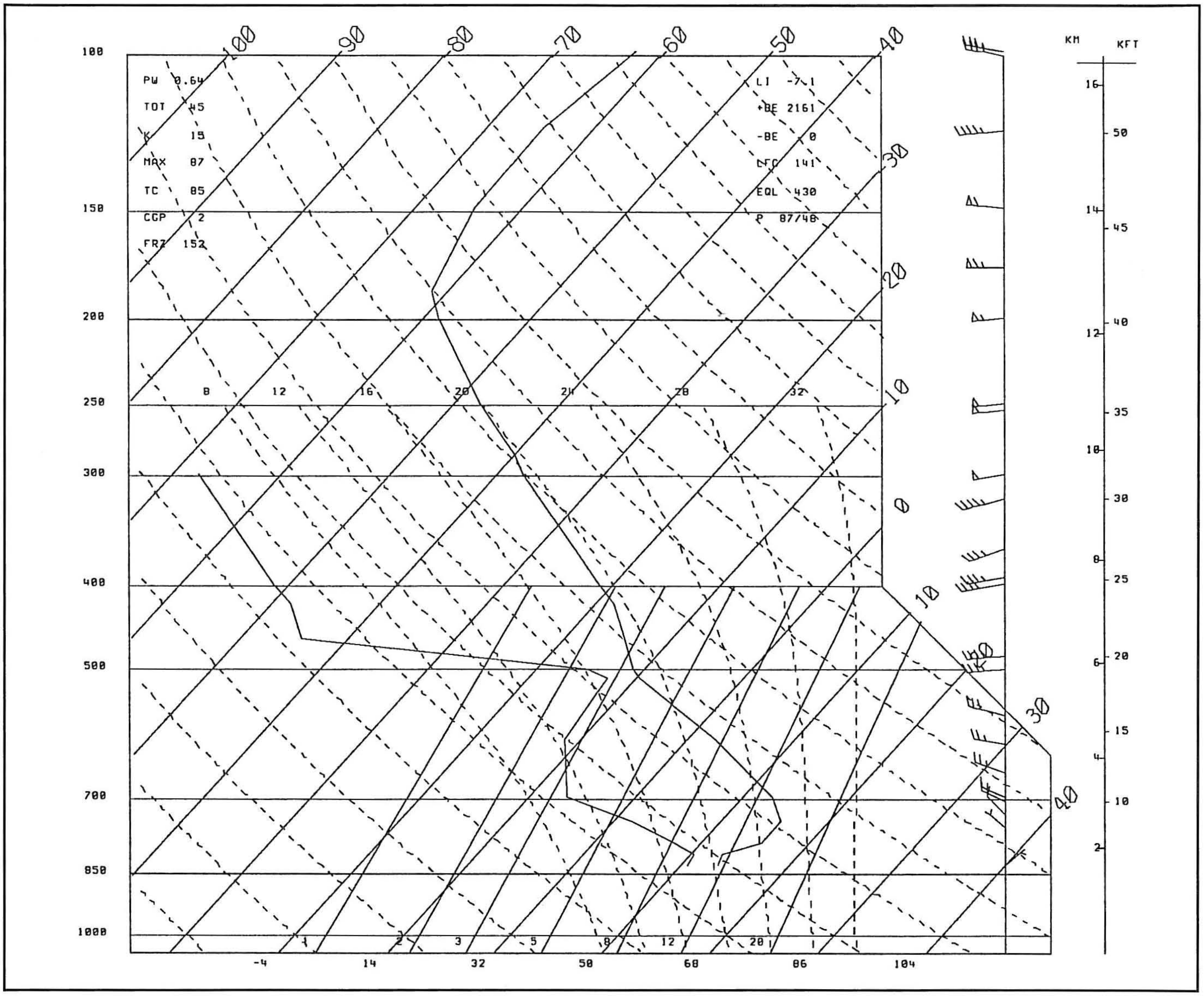

Fig. 3. 1200 UTC 6 June 1990 Denver rawinsonde.

storms were developing rapidly in the vicinity of the Denver cyclone, but no severe weather was reported by the public, nor suspected by the forecaster after review of the Doppler display. At 2145 UTC, the first tornado of the afternoon was sighted 27 miles northwest of Limon in eastern Arapahoe county. As the afternoon progressed, several Severe Thunderstorm and Tornado warnings were issued by the NWSFO and the National Weather Service Office at Colorado Springs (NWSO-COS). Coordination calls with the National Weather Service Meteorological Observatory (NWSMO) at Limon were made throughout the day by the NWSFO and NWSO-COS.

At 0107 UTC, National Center of Atmospheric Research (NCAR) chase teams reported a large tornado 15 to 16 miles southwest of Limon and moving northeast toward Limon. It later dissipated at 0117 UTC, 5 to 6 miles west of Limon. The report of this tornado was received by the NWSMO after it dissipated. At 0130 UTC, all significant weather in Elbert and Lincoln counties (Fig. 1) was inside the NWSMO's WSR-57's blanked out region, so the staff decided it was then a good time to switch to the back-up generator. This meant the radar would be down for 20 to 30 minutes. However, the NWSMO staff continued to brief the NWSFO, NWSO-COS, and the State Patrol in Limon based on visual observations. Due to the thunderstorms being too close to the WSR-57, the NWSFO briefed NWSO-COS on what the Mile-Hi Doppler radar was detecting. The Mile-Hi Doppler facility was located 16 miles northeast of downtown Denver. Based on radar and public reports, NWSO-Colorado Springs decided to issue a tornado warning at 0130 UTC for western Lincoln and eastern Elbert counties (Fig. 1), including the town of Limon. Ten minutes later Limon State Patrol called the NWSMO and notified them of a possible tornado three miles south and three miles west of Limon. The State Patrol was informed by the Official-in-Charge at Limon that a tornado warning had already been issued for the area.

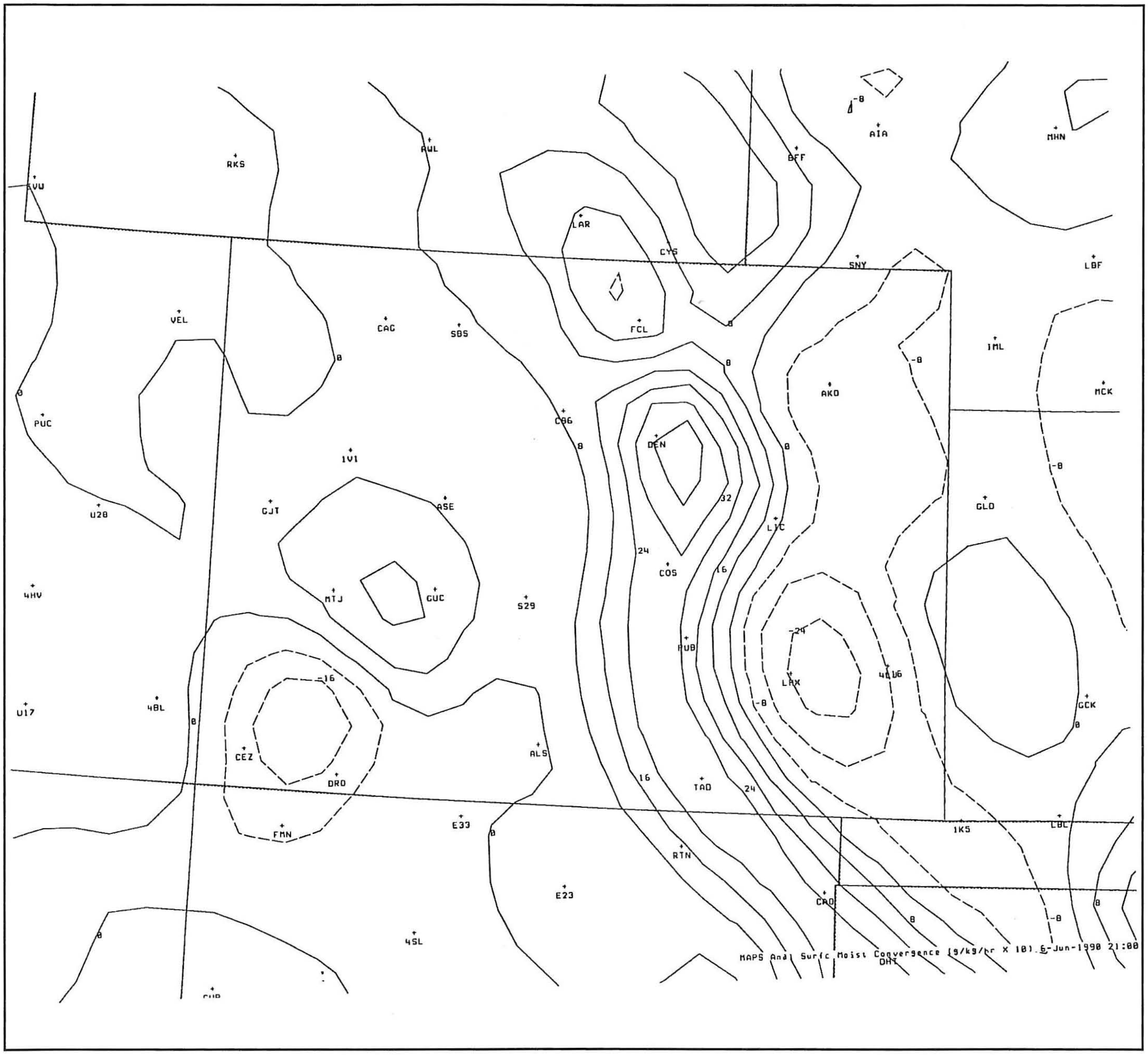

Fig. 4. MAPS analyzed surface moisture convergence at 2100 UTC 6 June 1990. Contours are g/kg/hr * 10.

The civil defense sirens were then activated for the town of Limon. The sirens sounded until power was lost at 0208 UTC.

The tornado, later classified as an F3 (Fujita 1981), hit Limon at 0208 UTC knocking out all communications and power in the town and surrounding areas. Its 10 mile destructive path went right through the heart of Limon devastating many businesses and homes, including those of NWS employees (Fig. 11). Even with the loss of communications, the NWSMO staff continued to monitor the radar not even knowing the status of their own homes and/or families. Due to the lack of communications with NWSMO-Limon, the NWSFO took over radar responsibility for NWSO-COS's county warning area. Continual briefings were given to NWSO-COS by the forecasters at Denver as well as by the NWSMO through an amateur radio operator. This continued until communications were restored at 0520 UTC. Communications with the NWSMO and the NWSFO were also done through the amateur radio network until normal communications were restored on 9 June.

5. Community Preparedness

Looking back at the evening of 6 June, one realizes that not much more could have been done to prepare the people of Limon for the horror they experienced in a period of seconds.

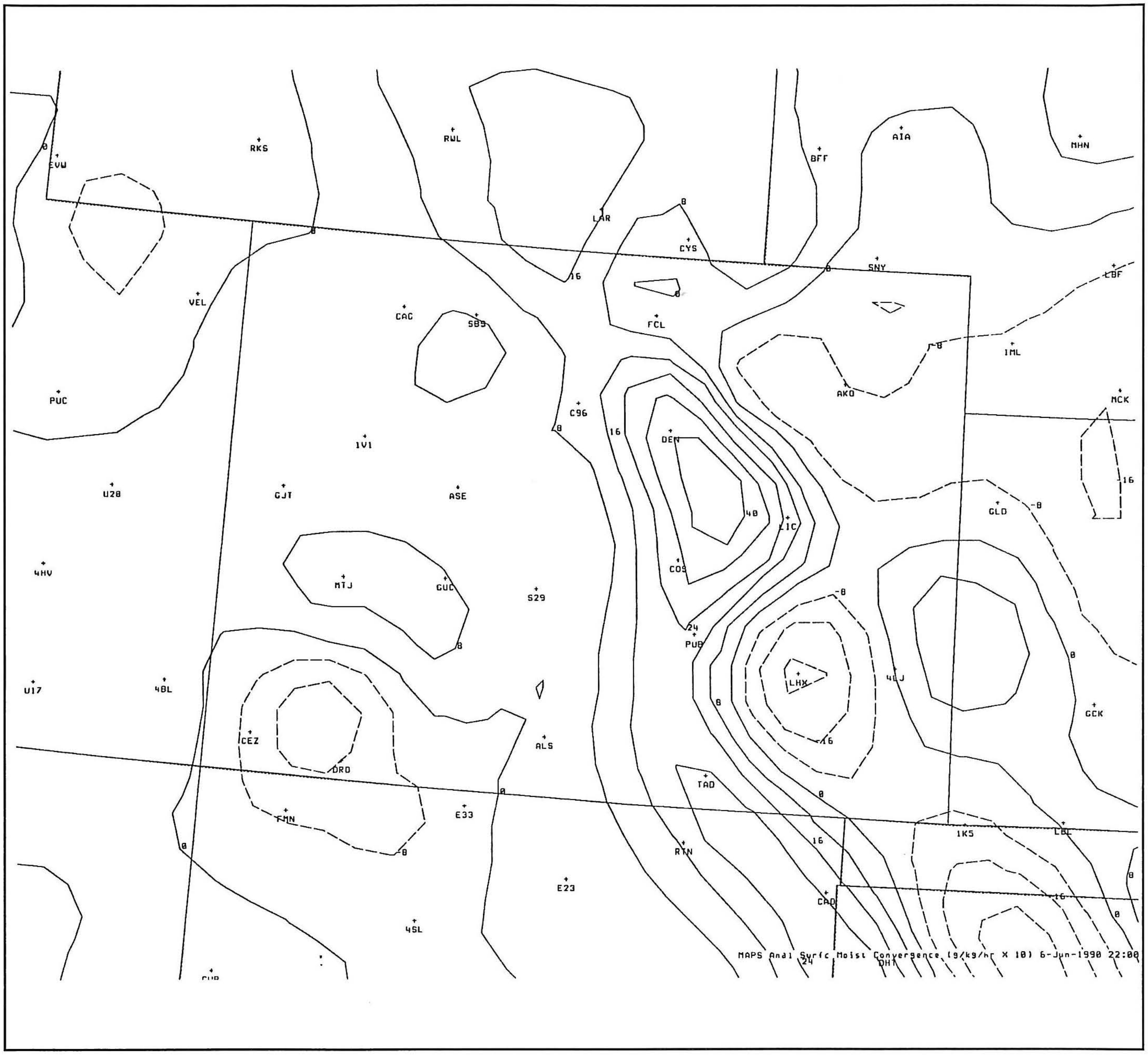

Fig. 5. MAPS analyzed surface moisture convergence at 2200 UTC 6 June 1990. Contours are g/kg/hr * 10.

Warning lead time was sufficient for the law enforcement agencies and emergency preparedness offices, as well as the residents themselves to take the appropriate and necessary action. Communication between the NWS offices and preparedness contacts was good, but internal dissemination within the emergency community had some breakdowns. This is evidenced by the State Patrol in Limon calling the NWSMO with the tornado report and asking if a warning would be issued. Even though NWSO-COS had already notified them of the warning via NAWAS (National Warning System), the people that needed the information did not receive it immediately. Once the warning was received, spotters were dispatched by Limon Patrol to locations around the town of Limon.

Many communities, not including Limon, do not have civil defense sirens or the sirens are in desperate need of repair or upgrading. Many of these sirens don't receive the needed care due to local budget constraints. The majority of Limon citizens received word of the impending tornado via the civil defense siren, which was electronically activated. However, some people could not hear the sirens due to large hail hitting metallic surfaces, such as those on mobile homes. Realizing that the sirens would not be sufficient, local police and other emergency

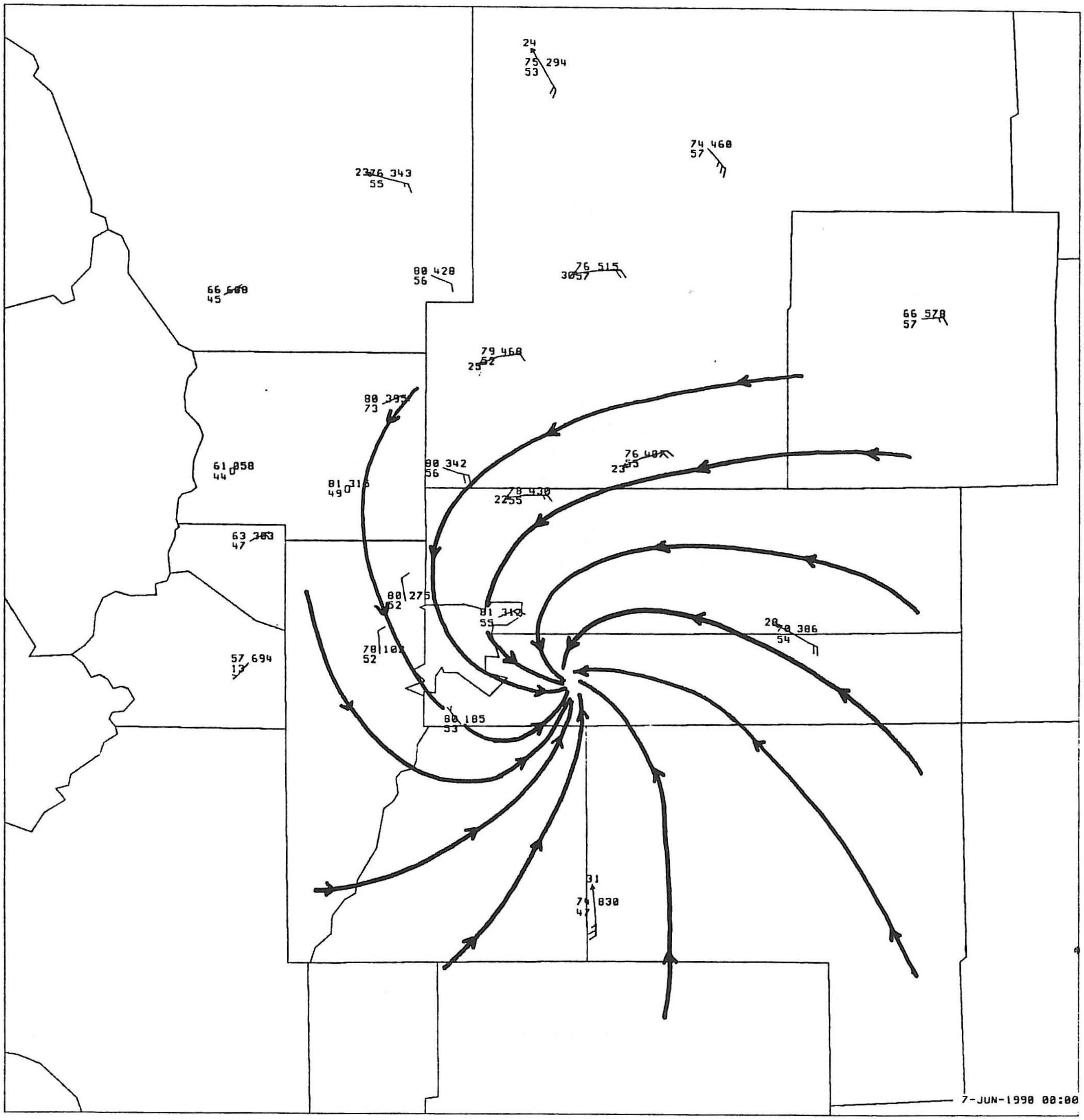

Fig. 6. FSL Mesonet data with associated streamlines at 0000 UTC 7 June 1990.

vehicles went through the neighborhoods with their lights flashing and announcing the warning over their speaker. It is hard to say what would have happened if the tornado that was spawned earlier in the evening southwest of Limon would have caused damage to phone or electrical lines servicing Limon and its outskirts. Would have the State Patrol in Limon received the warning? How many residents would have heard the warning? Instead of injuries, would there have been fatalities? We will never know.

The Amateur Radio/Spotter network was and still is well organized by the people themselves. The HAM severe weather network is an integral part in severe weather operations at NWSFO Denver, as well as other offices across the nation. The HAM network was fully activated at the time of the issuance of the watch and was in constant communication with the NWSMO and the NWSFO throughout the day. The evening of 6 June continued to show the value of the HAM network. Many questions across the nation have arisen concerning the need for volunteer spotters with the onset of the Doppler radar technology. This episode and many others give the answer to that question. Ground truth reports of the tornado added more confidence in what the radar was displaying. There are always

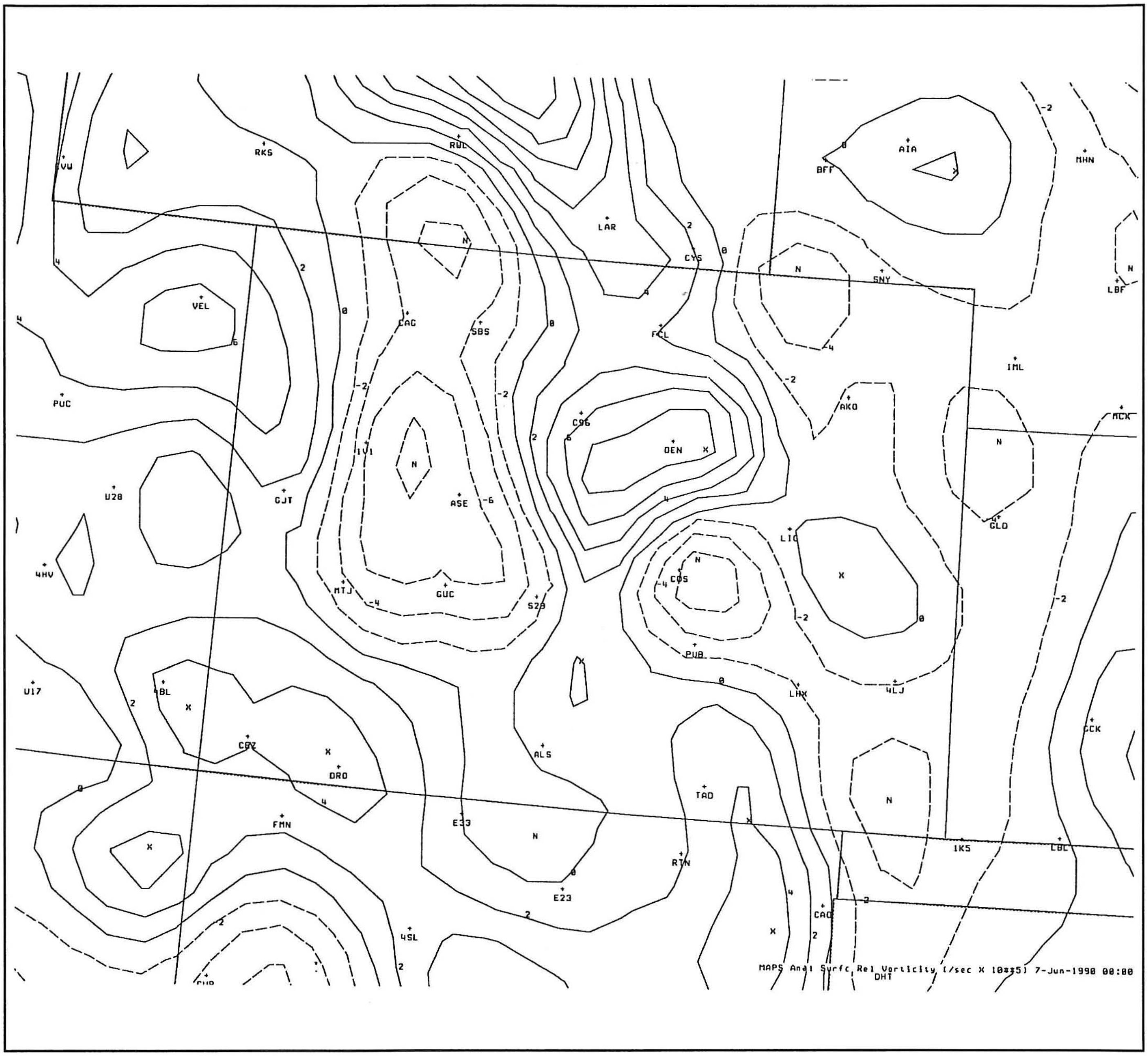

Fig. 7. MAPS analyzed surface relative vorticity at 0000 UTC 7 June 1990. Contours are 10^{-5} sec^{-1}.

going to be times when questions arise in the forecasters' minds of what is actually taking place at that moment. Doppler radar does and will continue to allow the forecasters to better utilize the spotter network by placing them in more precise locations. This task is a little more difficult when using conventional radar technology.

A correlation can be drawn from the proper preparedness procedures the residents of Limon practiced to the number of injuries or fatalities. Only 14 people were injured even though the tornado traversed through the heart of Limon. Many individuals sought refuge in their basements, while others improvised. People in a local tavern heard of the warning and went inside the beer cooler and waited for the storm to pass. Two men visiting from Oklahoma walked outside their hotel room and saw the tornado. They then grabbed a mattress off the bed and jumped in the bathtub, pulling the mattress over themselves. However, there were a few individuals that let curiosity get the best of them. They said they wanted to catch a glimpse of something they have never seen before. By nature, we as human beings are curious, especially of the unknown. If something is occurring that we have never seen before, we naturally want to see it. The good thing is that many of us overcome this

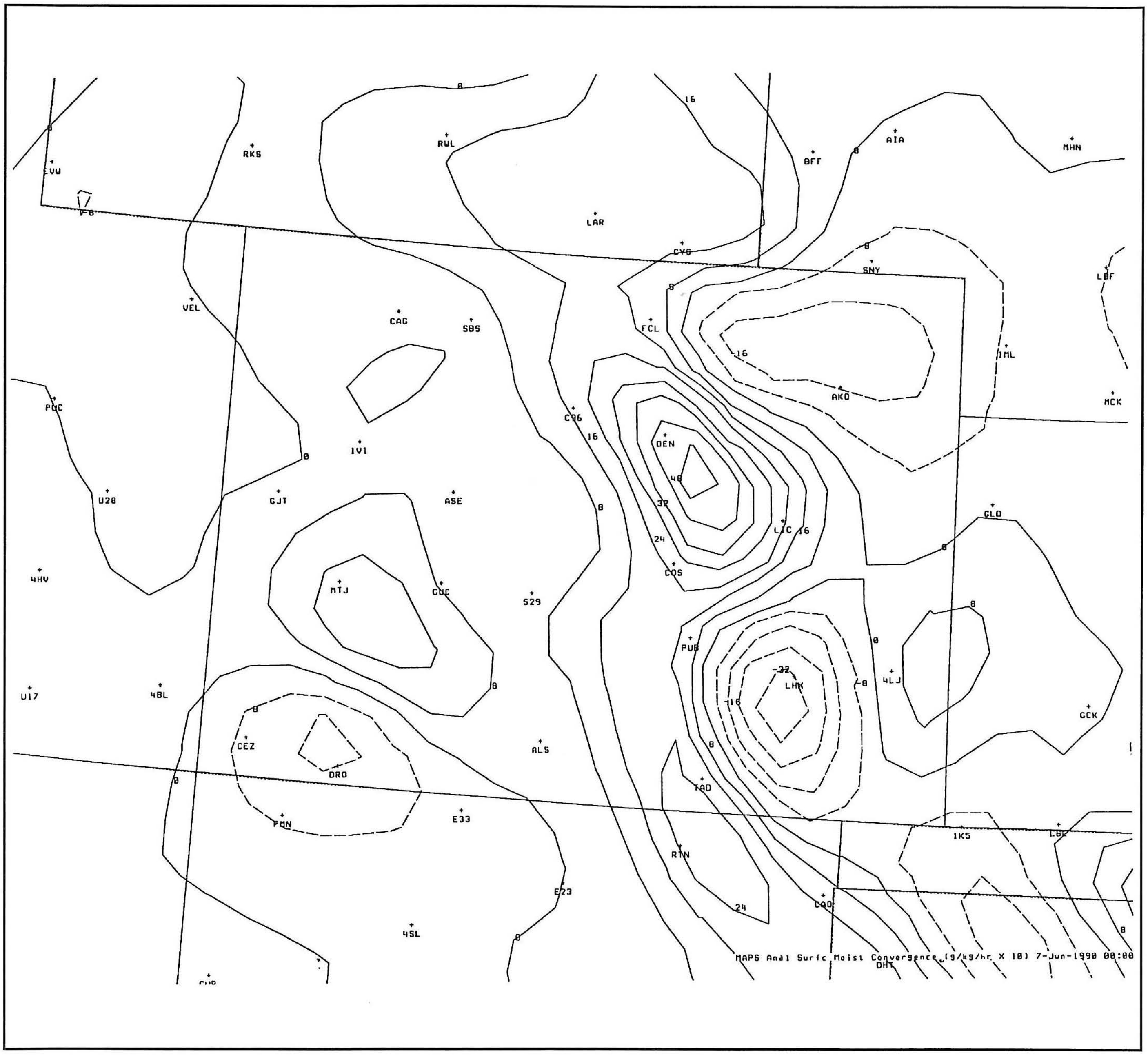

Fig. 8. MAPS analyzed surface moisture convergence at 0000 UTC 7 June 1990. Contours are g/kg/hr * 10.

feeling and seek protection, but there are always a few that never overcome it and are usually the ones that are injured or killed.

6. Conclusions

a. Strengths in the severe weather warning process

After the evening of 6 June 1990 many things were said about the performances of the National Weather Service offices and their radars. In my opinion, staff and equipment at each of the offices performed very well. The technology available to the forecasters at the NWSFO in Denver was very helpful in diagnosing and forecasting the mesoscale environment. The use of local analysis and prediction systems, such as profilers and the mesonet, allow the forecaster to better diagnose the mesoscale environment in which storms will form before they occur. The Doppler radar then provides a more comprehensive depiction of the storms after they form. Local law enforcement and emergency preparedness offices also performed very well in advance of the tornado as well as after the damage was done. Everyone was professional and accomplished what was expected of them.

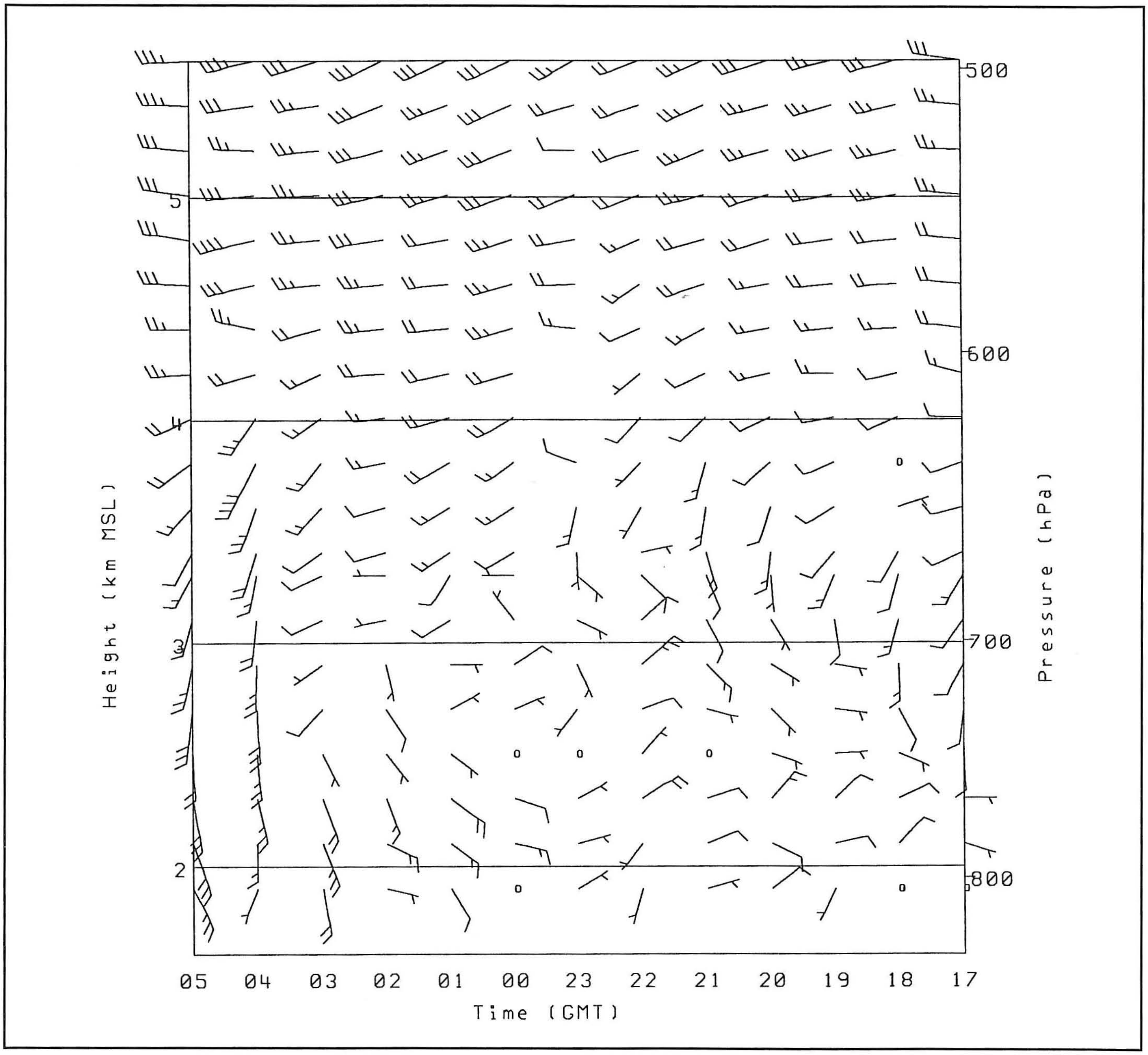

Fig. 9. Stapleton Wind Profiler. Time runs from right to left ending 0500Z 7 June 1990.

b. Weaknesses in the severe weather warning process

There are a few items that need to be addressed to better serve the public and emergency managers. Even with the new modernized equipment at the NWSFO, the warnings issued that evening or any other time are only as good as the means of disseminating the warnings. As the National Weather Service heads toward modernization, communication systems need to upgraded or improved. All the improved products will have little meaning if they are not reaching the users. Not counting the weather wire or NOAA Weather radio, most of the NWS offices rely on telephones, including NAWAS, to relay the warnings. Many times the person that is recording the information is the dispatcher, who may be overwhelmed with 911 calls and forced to make a decision as to which one is more important. This information needs to be in someone else's hands. An effort should be made to establish a computer link with the state crime information computer, which all local emergency preparedness offices and law enforcement agencies would be able to access.

NOAA weather radio areal coverage needs to be expanded by either using more radios or by repeaters. The need for this is immense. NOAA weather radio has been one piece of

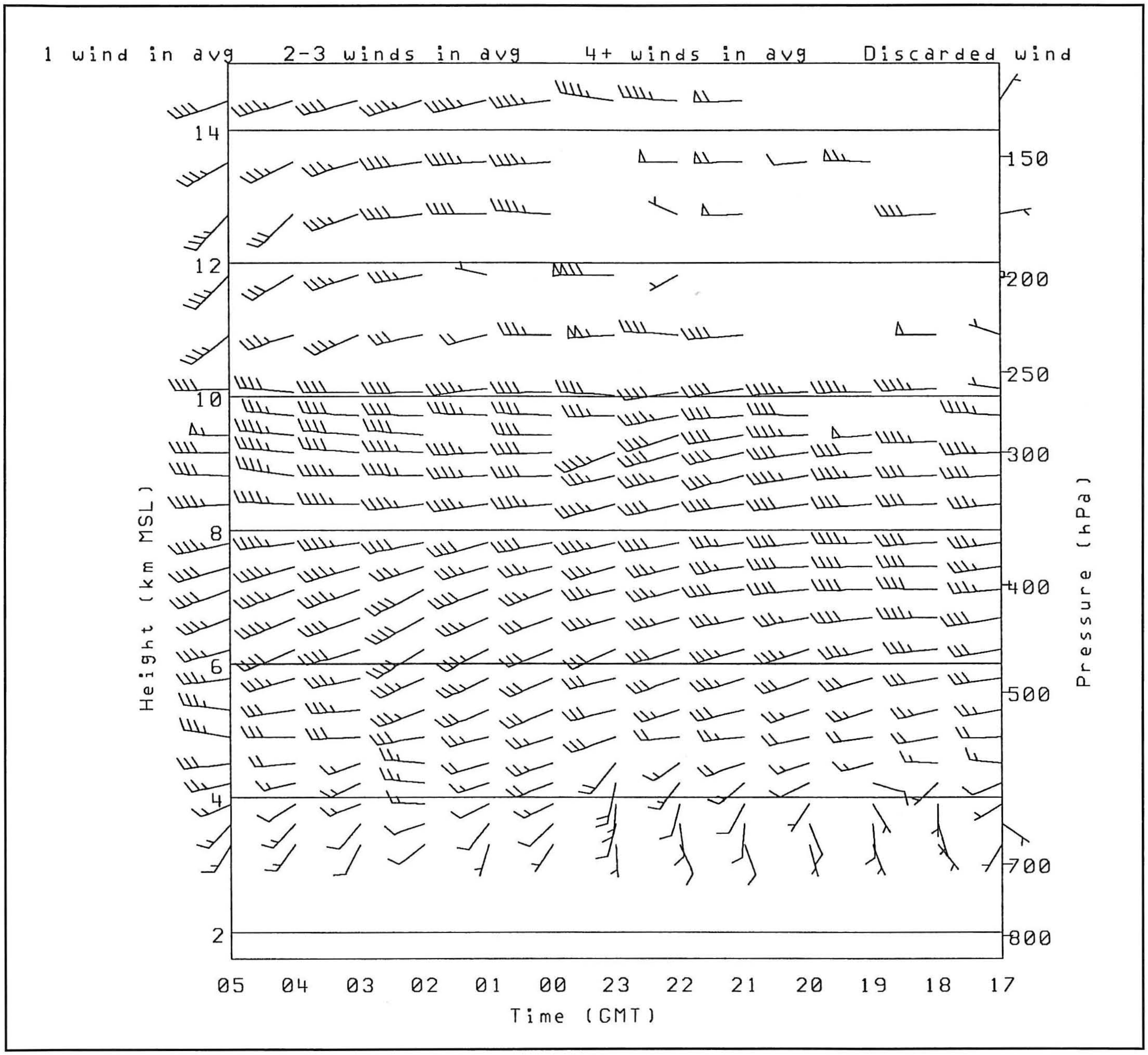

Fig. 10. Platteville Wind Profiler. Time runs from right to left ending 0500Z 7 June 1990.

equipment that has direct contact with the public and needs to be better utilized by the National Weather Service and local officials. Many areas across the nation are without any type of warning system. NOAA Weather Radio would fill that void. By using the Weather Radio Specific Area Message Encoder (WRSAME), the service of the alert tone would be of better service to the public. This system will also enhance the Emergency Broadcast System (EBS), which the Federal Communications Commission is currently in the process of upgrading. Many states, including Colorado, are helping with this endeavor. Other risk reduction programs, such as the Integrated Warning System should help bridge the gap of communications between the National Weather Service and the emergency preparedness officials.

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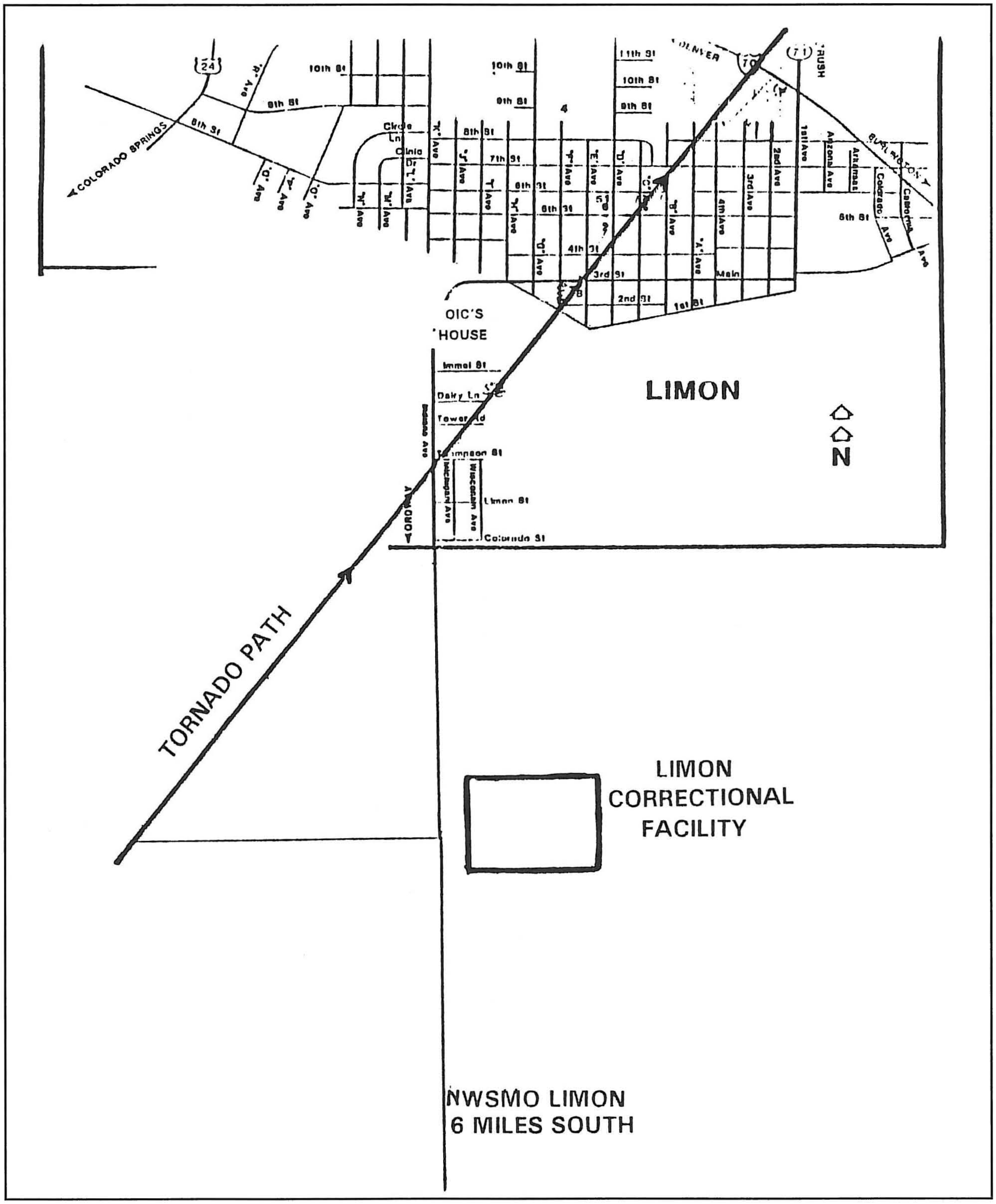

Fig. 11. Tornado Track.

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