THE MESOCYCLONE EVOLUTION OF THE WARREN, OKLAHOMA TORNADOES

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INTRODUCTION

The Texas Tech Tornado Chase Team had intercepted and filmed two tornadoes on April 12, l981 near the town of Warren in southwestern Oklahoma. The storm complex initially developed along a dry-line wave in north-central Texas and produced a series of mesocyclones during the next few hours. After the storm organized, it was observed that as the parent mesocyclone moved northeastward, it occluded into the rain area and a new mesocyclone began to develop further southeastward.

The mesoscale structure of the storm environ-merit will be presented which include mobile temperature and dewpoint measurements taken every five miles along the chase route. In addition, wind speed and direction measurements were taken within close proximity to the storm. These data are unique in that they crossect the dryline and sample the low-level environment of the storm prior to tornado formation on both meso-beta and meso-gamma scales.

STORM CHRONOLOGY AND OBSERVATIONS

On the morning of April 12, the chase team forecasted southwestern Oklahoma as the region most favorable for severe weather that afternoon. The decision was primarily based on hourly changes of dewpoint temperatures and surface pressure falls. The forecasted Lifted Index over the region was -9 degrees C which indicated strong convective instability. It was anticipated that severe weather was most likely to occur just ahead of the dryline bulge (Tegtmeier, 1974). The dryline had passed Lubbock at 1000 LST accompanied by a gradual windshift to the southwest. The chase team selected Quanah, TX as the initial destination and left Lubbock at 1300. The sky was relatively clear with the exception of a band of cirrus overhead extending to the northeast. The chase route is shown in Figure 1 which include the meso-beta mobile temperature and dewpoint measurements.

As the team headed eastward, dewpoint temperatures gradually increased and the highest temperature was reached just behind the dryline boundary. At 1410, cumulus began to develop toward the east and by 1500, an isolated congestus had formed about 30 miles to the northeast of our location. A line of smaller towers extended southward from what appeared to be the leading edge of the dry-line. Soon the top of the cloud began to glaciate and an anvil streamed eastward. At 1547, we had reached Quanah and turned northward toward the developing thunderstorm. As we passed under the line of towering cumulus, the wind direction shifted gradually from light southwest to a southeasterly direction. By 1630, the sky was overcast with light rain falling from the anvil. Two flanking lines could be seen to the north with well-defined rain-free bases. Cloud striations could be seen at the mid-levels of the storm which indicated the storm was rotating.

The paths of the mesocyclones and their evolution are shown in Figure 2 along with the meso-gamma scale observations. At 1648, a wall cloud began to develop on the southern flank of the storm. A small rope-like funnel immediately formed on the east side of the lowering and gradually moved northeastward. As the system crossed the road to our north, the surface winds veered to light westerly. It may be significant that this gust front was weak and that a rear flank downdraft was not apparent. The wall cloud never became organized and dissipated near 1716. During the lifecycle of the wall cloud, a second cumulonimbus flank persisted to the west and southwest and possibly inhibited the storm from organizing.

At 1716, a second wall cloud became evident under the new flank to the west. As the wall cloud approached, the surface winds backed to the southeast. The wall cloud began to rotate and rain curtains were observed moving around the lowering. At times, the wall cloud became obscured from the heavy precipitation. This rapid occluding sequence occurred several times during the hour and appeared to inhibit the updraft from organizing. At 1730, numerous funnels were seen forming and dissipating underneath the cloud base. The temperature of the inflow air remained fairly consistent throughout the lifecycle of the mesocyclone varying only between 77 and 80 F. Also, the wet bulb remained near 70UF. As the flanking line passed overhead, the surface winds gradually veered westward again and only a slight increase in temperature was noticed. We then continued eastward and crossed back into the inflow air.

By 1755, we reached our film site and noticed that the wall cloud (Figure 3a) had become organized as a clear region began to appear just west of the parent updraft. The flanking line suddenly began to accelerate eastward and strong subsidence was evident on the western edge of the cloud line. At 1800, the flanking line passed overhead and a sudden windshift occurred with only a slight increase in temperature. The clear region grew rapidly and appeared to have isolated the updraft within a few minutes. This rapid clearing sequence can be attributed to the development of the rear flank downdraft as described by Lemon and Doswell {l979).

At 1804, a tilted, laminar funnel formed and extended westward from the wall cloud toward the ground (Figure 3b). Note that the heavy precipitation had subsided near the wall cloud and that the clear slot is well defined. Rasmussen et al. {l981) has also observed the development of a tornado to be coincident with the eastward surge of a surface gust front at low-levels along with a clearing to the west and south of the wall cloud. The tornado lasted only a minute. Then a larger, more vertical and non-laminar funnel developed to the north (Figure 3c). The damage swath on the ground was a half-mile wide at this time. After ten minutes, the visible tornado shrank very rapidly and eventually only a non-rotating column of cloud material remained which was completely detached from the eroding updraft.

As the system occluded, a third wall cloud began to develop a few miles eastward ahead of the advancing gust front (Figure 3d). By 1835, a large funnel developed about a mile to the north of our location. As it crossed the road, the wind speed increased to 35 mph sustained and rain curtains were rotating around us. The funnel moved eastward and dissipated around 1900. The storm continued to produce mesocyclones after dusk but no further tornado activity was reported.

MESOSCALE SITUATION

The mesoscale situation is depicted at 1800 LST in Figure 4 just minutes prior to the first tornado. A surface low-pressure center was situated in northern Kansas with a stationary front extending southwestward into the Oklahoma panhandle. By early afternoon, the dryline had moved into western Oklahoma and a wave developed along it accompanied by a meso-low. As a result, moisture convergence was enhanced into the region. The dryline became stationary near 1800 and then retreated westward during the evening. Koch and McCarthy (l979) have studied the importance of dryline waves and mesolows as triggering mechanisms for severe weather.

TORNADOGENESIS: SIMILARITIES AND DIFFERENCES

A generalized schematic of the mesocyclone evolution of the Warren storm is presented in Figure 5. The diagram depicts the conditions near the time of the first tornado. Warm, unsaturated air descended rapidly behind the storm and is referenced to the rear flank downdraft as described by Lemon and Doswell (l979). However, it appeared that descending precipitation was not a factor behind the driving force of the downdraft in this case. Similarly, the downdraft appeared to isolate the parent updraft and accelerate the flanking line eastward. As a result, the inflow air was literally cut off from the updraft at the surface. The tornado appeared to have developed as surface vorticity had concentrated as a result of the downdraft occlusion. The occlusion of the parent updraft, as related to tornadogenesis, has been studied by Burgess (1977) and Brandes (l978) with Doppler radar. Similar observations by Moller et al. (1974), Brown and Knupp (l98O) and Rasmussen (l981) have supported the importance of the rear flank downdraft as a mechanism for tornado initiation. However, it should be emphasized that the Warren storm mesocyclone was on a much smaller scale than the cases just referenced. The tornadoes had developed from an updraft only a few miles wide. Also, the tornadoes began in the rope-stage, widened and decayed in the rope-stage. In contrast to Brown and Knupp's observations, the precipitation near the wall cloud had subsided as soon as the tornado developed. Also, it appeared that the surface meso-low was directly associated with the convective storm system.

Another feature observed was the organization of the surface inflow into the mesocyclone. The air was relatively cool and the strongest wind speeds were from the southeast. The coolness of this air might be attributed to the effect of evaporative cooling in the boundary layer. As the inflow accelerated northward, it converged along a wind shear line which later played a role in organizing a new updraft. The wind shear line coincides with the thunderstorm-scale surface stationary front in Lemon and Doswell's model. As the flanking line accelerated toward the east, it merged with the new updraft and the organization of the entire storm complex appeared to have taken a discrete "jump" southeastward.

CONCLUSIONS

With the advent of Doppler radar, chase teams have become more successful in photographing tornadoes at relatively close distances. However, the importance of documenting meteorological conditions and using proper filming procedures can yield more worthwhile results to the scientific community. In this case, the mobile temperature and dewpoint data as well as wind speed and direction measurements were valuable in sampling the low-level environment around the storm system. First, there was a gradual increase in temperature and dewpoint as the dryline boundary was approached from the west. Then after the boundary was crossed, the inflow air was cooler and more humid. Quantitative measurements of the rear flank downdraft air were minimal since psychrometer data were ceased as the tornadoes developed. However, this air seemed slightly warmer and as humid as the inflow air. The evolution of the mesocyclones had followed an organized lifecycle. It should be emphasized that the rear flank downdraft appeared instrumental for tornadogenesis and in the propagation of the storm system eastward.

ACKNOWLEDGEMENTS

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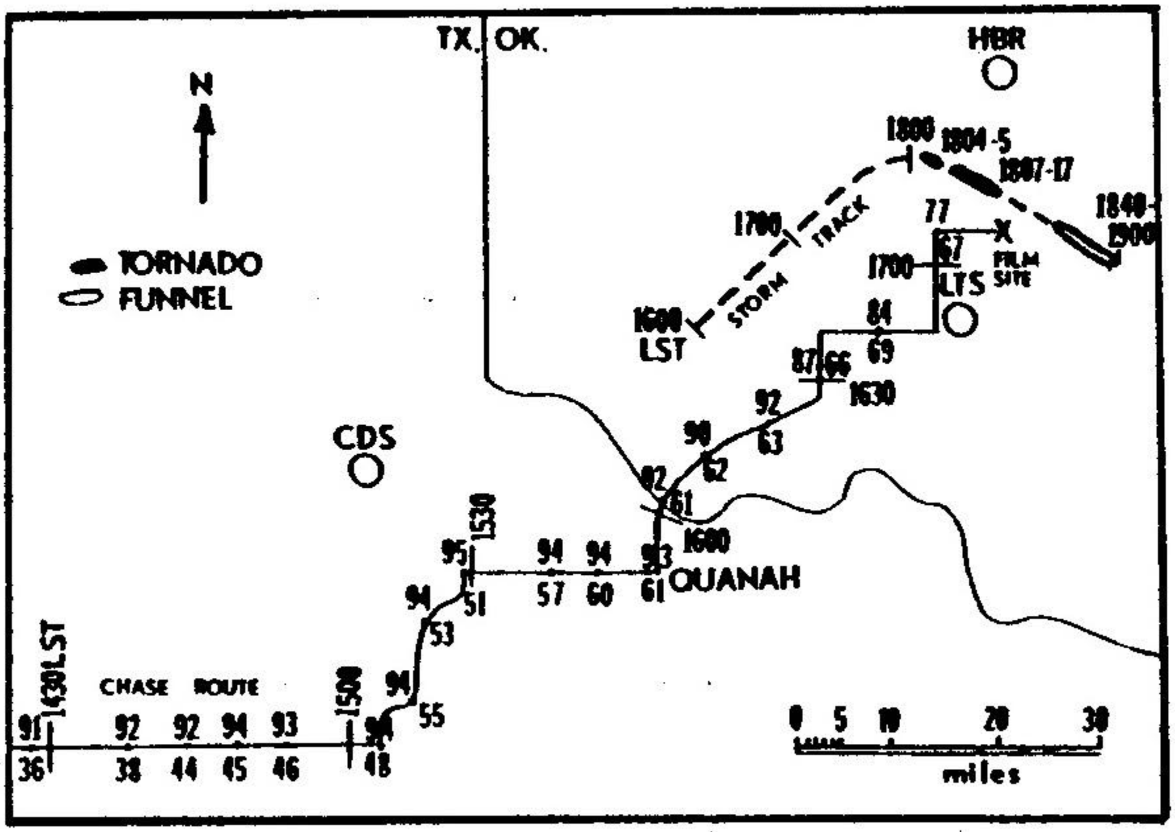

Figure 1. Temperature and dewpoint measurements In degrees F taken along the chase route (solid line). The approximate position of the storm track is Shown in the dashed line. Time is LST.

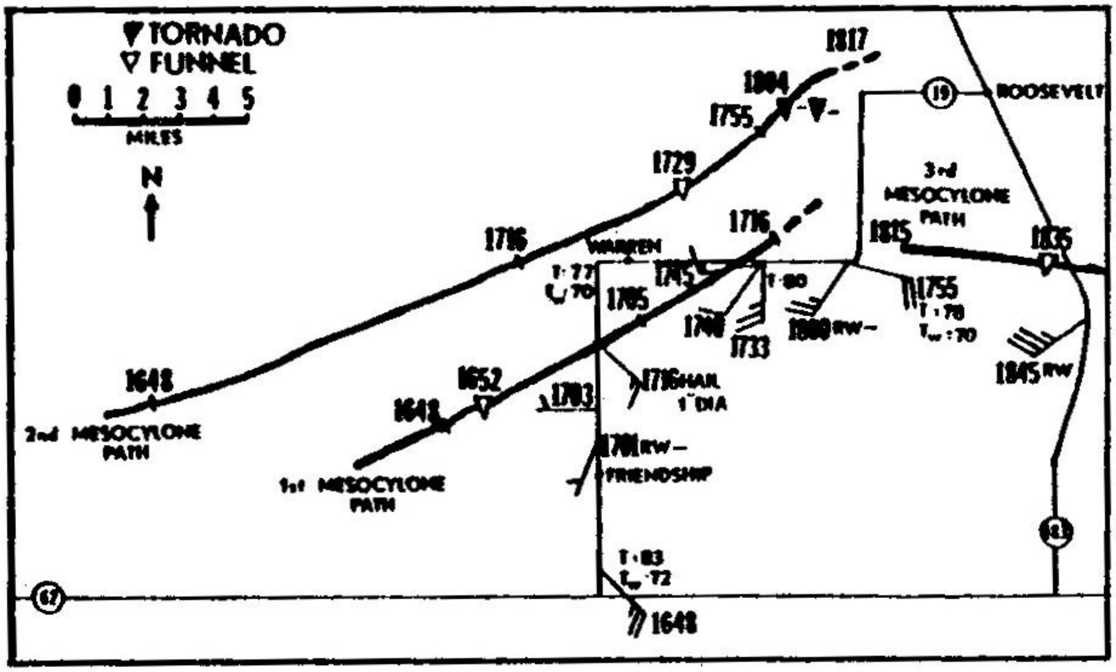

Figure 2. Postions of the chase team with respect To the mesocyclone tracks. Wind speeds are in m.p.h. and time is LST.

Figure 3. Life cycle of the Warren, OK Tornadoes

A)   Wall cloud

B)   Funnel cloud and clear slot

C) Initial rope stage

D) Mature stage

E) **Dissipating stage - rope stage #2 and new wall cloud.**

F) **New wall cloud to the southeast.**