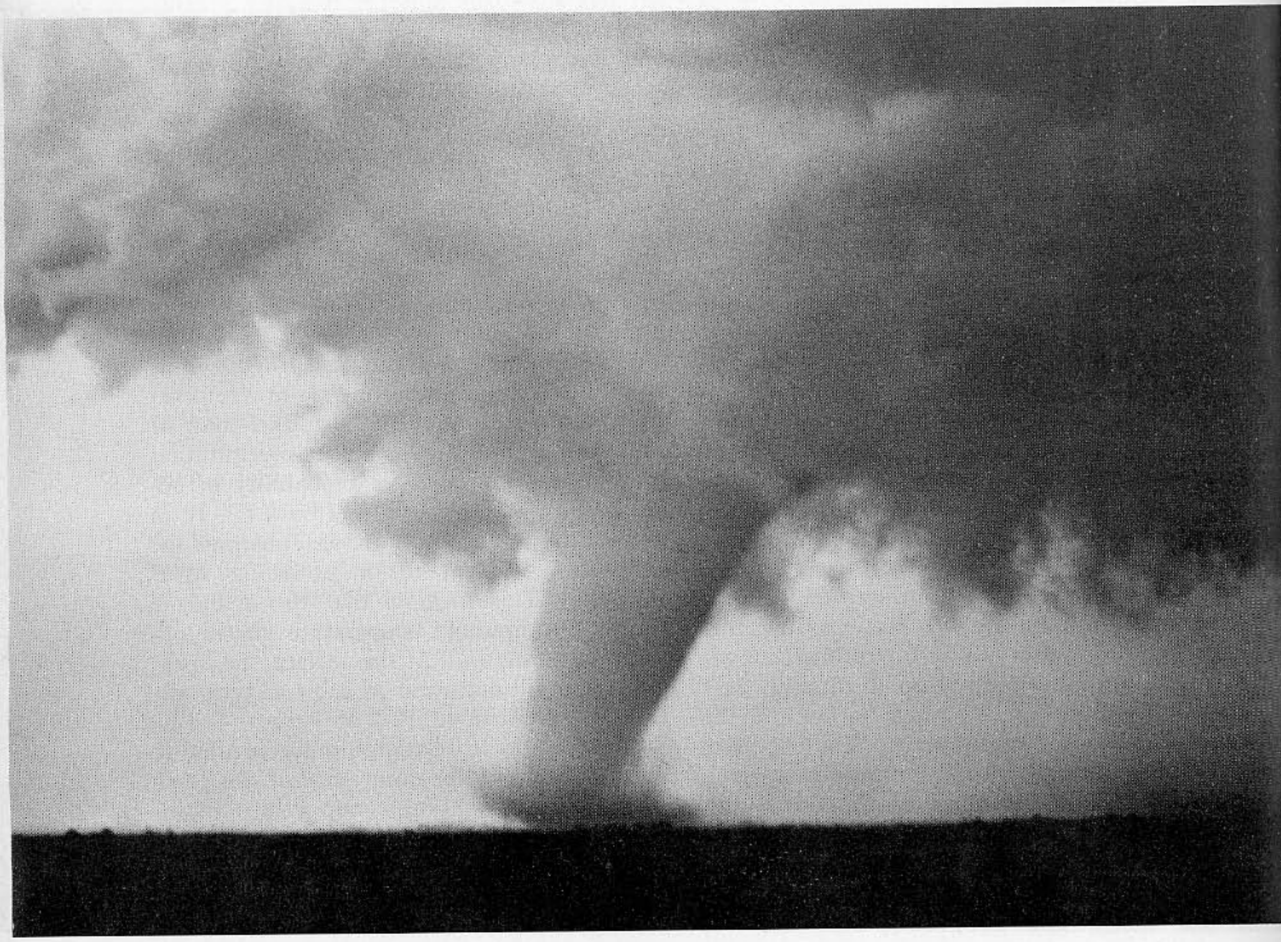


The Union City Tornado in rounded bottom stage.

Field Observations of the Union City Tornado in Oklahoma

Joe a. McG

ALAN MOLLER, CHARLES DOSWELL, JOHN McGINLEY, STEVE TEGTMEIER, AND RANDY ZIPSER, *Graduate Students, University of Oklahoma, Norman*

1973 was "the Year of the Tornado." Verification of this undesirable distinction came in December when the total number of tornadoes during the year exceeded 1,100. This discussion deals with observations of a particularly savage storm at Union City, Oklahoma, on 24 May, which commenced a four-day onslaught of 190 tornadoes across the United States during the Memorial Day weekend.

For the previous two years Oklahoma University graduate students have received partial support from several grants to photograph severe thunderstorms and tornadoes. During this period the students coordinated their efforts with those of the National Severe Storms Laboratories (NSSL) to intercept, track, and photograph tornadoes and associated severe weather phenomena in Oklahoma (Golden and Morgan, 1972). Interest has been remarkably high. A number of students have spent considerable time and money outside the normal NSSL tornado intercept limits in pursuing the elusive storms.

Although many fruitless trips have been made, students have had the good fortune to intercept and photograph 11 tornadic mesosystems and seven tornadoes in the last two years. The Union City tornado must be considered the case with the greatest significance. The primary factors were:

1) The NSSL vehicle and two student cars observed the long-lived tornado from different viewpoints. Excellent camera work by these groups and the local residents made a photographic study feasible.

2. The storm occurred in the NSSL mesonetwork. The available surface data, along with Doppler and conventional radar trackings of the parent storm, will allow a detailed examination of the tornado and its parent thunderstorm.

Synoptic Situation—24 May

On the morning of the 24th, a vigorous short wave trough aloft was moving southeastward from Colorado into Kansas and Oklahoma. Associated with this system was a marked thermal trough, as seen on the 500mb chart at 0600 CST. The positions of the jet streams were unusual for an Oklahoma tornado day, the mid-latitude jet being far to the north in Nebraska, while the subtropical jet was deep in southern Texas. A moderate 500mb wind maximum extended from Colorado into central Oklahoma. The strongest wind speed at Oklahoma City was 74 knots at 200mb. Weak horizontal wind shears and negligible difluence aloft did little to suggest severe local storms over Oklahoma.

Conditions from the surface to 700mb gave a stronger suggestion of severe thunderstorm potential. Although there was not a pronounced low-level jet over Oklahoma, the morning surface and 850mb charts indicated warm moist advection would occur in Oklahoma during the day. The lower and upper advection patterns implied that the already

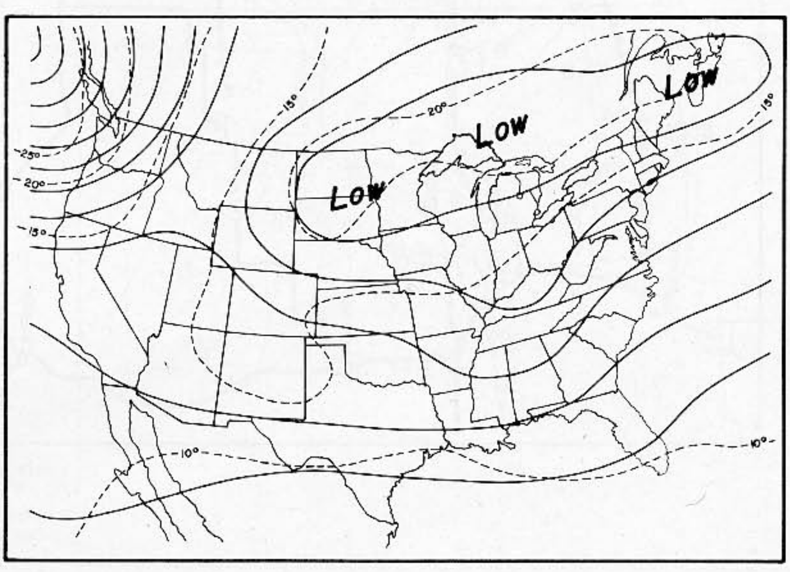


Fig. 1. Upper-air chart at 500 mb contour level, 0600 CST, 24 May 1973.

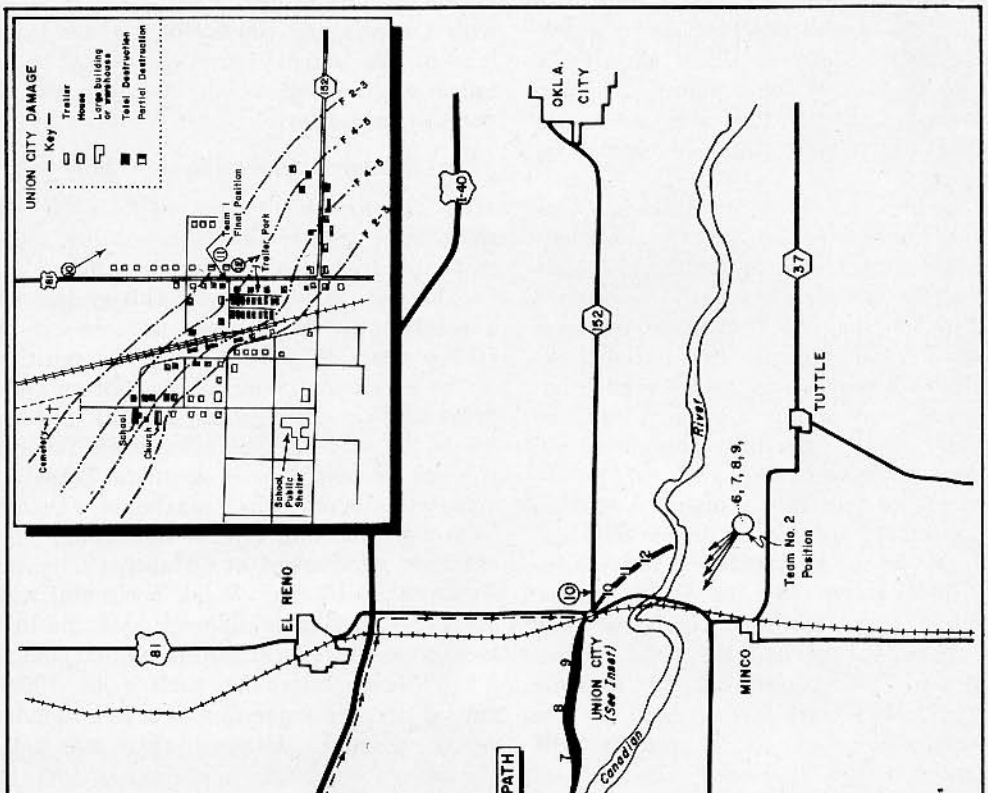


Fig. 2. Map of tornado path and position of photographers during Union City Tornado on 24 May 1973. By Eldon Cox.

conditionally unstable atmosphere in the area would undergo further destabilization. In addition to this, a surface cold front extended from a deep low in the Dakotas southwestward into the Texas Panhandle. During the morning, strong moisture convergence was discernable along the frontal zone as it drifted toward central Oklahoma.

Even though surface to 700mb speed shear was minimal, strong directional wind shear was apparent in the low levels. Southeast surface winds veered to the southwest at 850mb which gave way to dry northwest winds at the 700mb level. Such directional shear is deemed favorable for development of severe storms of the supercell variety.

Finally, the most favorable factor for the ensuing tornadic activity was the formation of a subsynoptic low pressure system in west-central Oklahoma around 1100. The low tracked toward the east-southeast during the afternoon until 1600 when it was located approximately 50 miles southwest of Oklahoma City. During the later half of the afternoon the Union City tornado and other severe weather broke out in the northeastern quadrant of this subsynoptic system. The activity shifted discontinuously to the southeast, roughly paralleling the movement of the low center.

In analyzing other potential severe weather days, University of Oklahoma storm chasers have noted similar results, with tornadoes in Oklahoma often occurring northeast of a minor low pressure system.

Observations

The thunderstorm which bred the tornado was over one hour old when the funnel descended at 1545. Student Team #1 had an excellent opportunity to witness the growth of the storm. In doing so, they documented several important events prior to the tornado.

At 1415, Team #1 observed the Union City thunderstorm to be developing rapidly

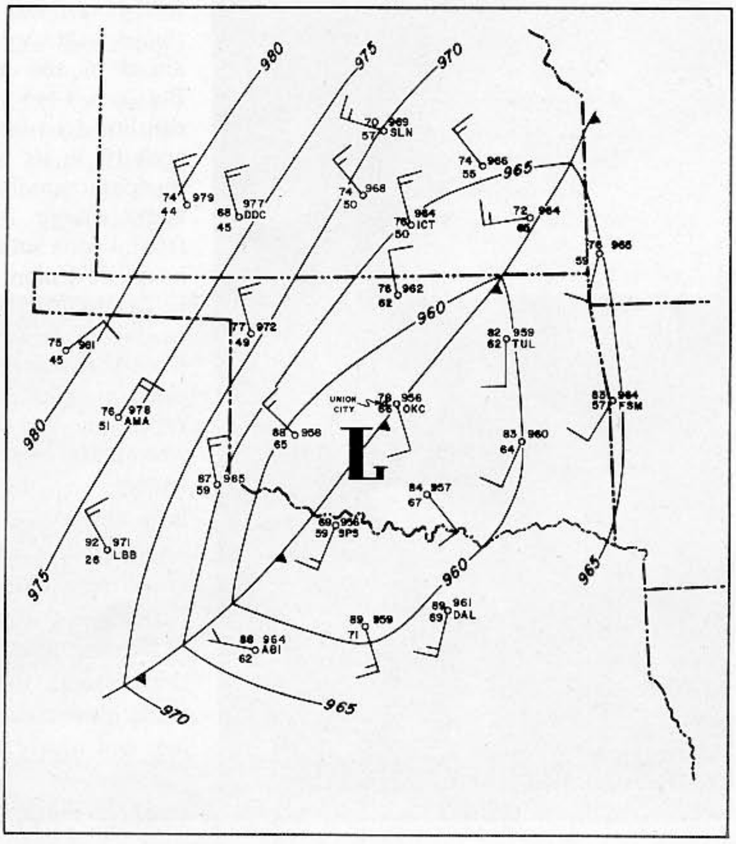


Fig. 3. Sectional surface weather chart, 1600 CST, 24 May 1973. Indicated pressures are altimeter settings, 960 = 29.60 inches.

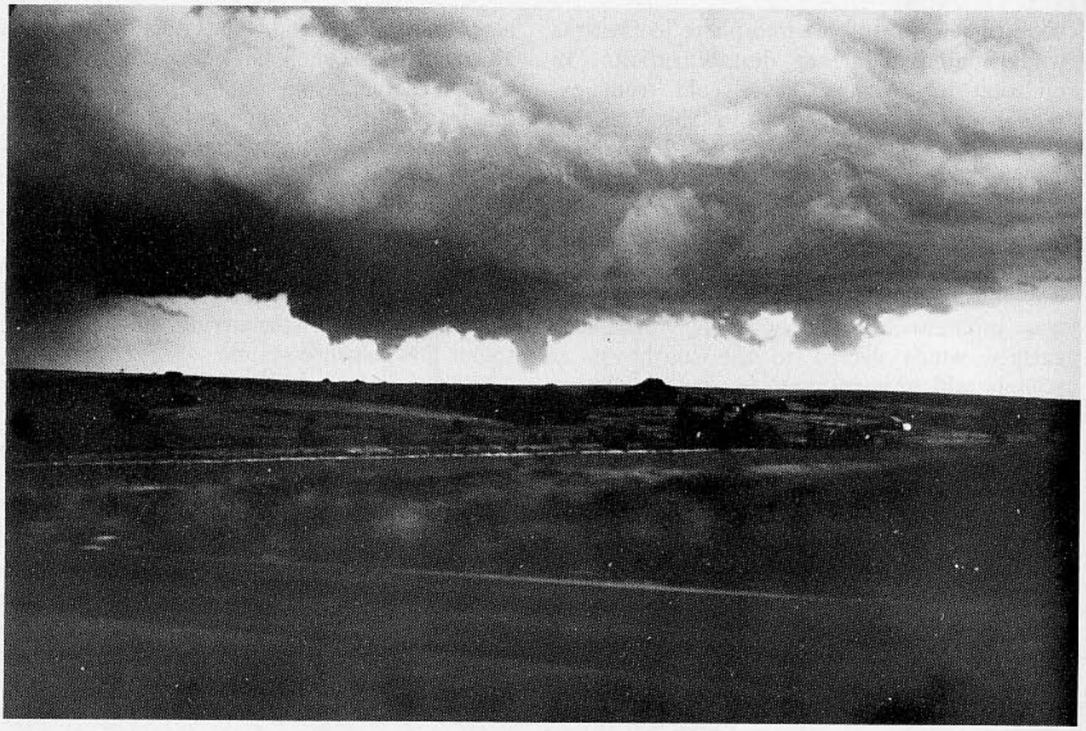


Photo 4

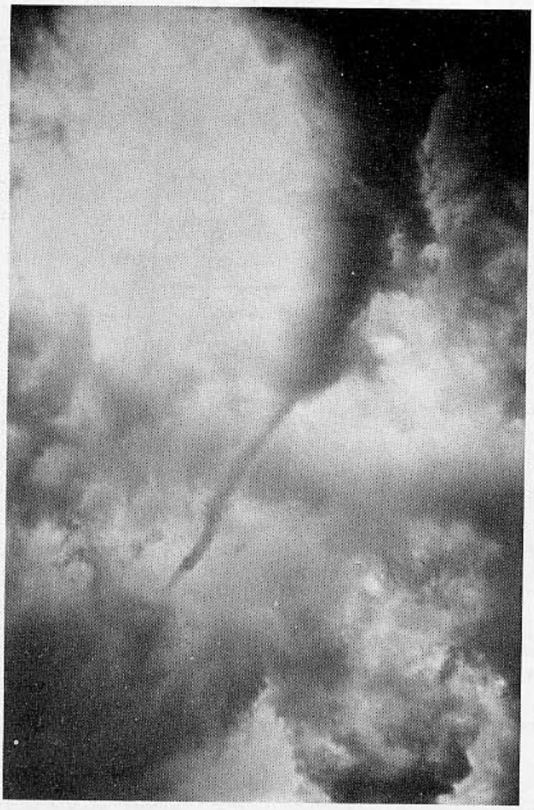


Photo 5

to the west and southwest of El Reno. The thunderstorm was forming 20 to 30 miles ahead of the main line of frontal storms. Between 1445 and 1515, this cell complex continued to intensify as the line of frontal activity to its west and northwest began to dissipate rapidly. It appeared that the primary energy influx had shifted from the frontal zone southeastward to the area of the incipient Union City storm.

Team #1 considered this occurrence to be favorable for possible tornadic activity, since the new thunderstorm was isolated instead of situated in an extensive line. Past experience has shown that isolated Oklahoma storms are most likely to produce large tornadoes. Solid lines of thunderstorms have been observed in many cases to produce only small funnels, probably induced by the two-dimensional shear along the long and continuous gust front.

Driving west on I-40, Team #1 scanned the northern flank of the storm cell. They made observations concerning the thick, boiling, and nearly cumuliform anvil, along with the birth of a "splitting" storm cell on the northern flank. An important consideration was that the cloud slope of the new cumulus on the parent storm's north and west flanks was toward the southeast. This fit well with the morning soundings showing northwest winds at 700mb and above.

Direct communication with NSSL radar operators at 1450 indicated the formation of a hook echo on the southwest flank. Team #1 at Geary began to photograph the history of this area of the thunderstorm. The positions and directions in which the accompanying photographs of the funnel were taken are shown on the map.

Photo 4 was taken at 1527 looking south-southeast from I-40. The incipient tornado-producing mesostructure consisted of a line of dark, flat-based cumulus extending in a southwest-northeast line. A low-hanging wall cloud structure similar to that in the 1957 Fargo storm (Fujita, 1960) extends below the higher cumulus bases. Two turbulent funnels or protuberances are visible below the wall cloud which were exhibiting rapid transformations in shape. Strong vertical motion was evident in this cloud system. Two lightning discharges were the only electrical phenomena observed, and both hit the ground after coming out of the larger protuberance.

Driving eastward to stay with the mesosystem, Team #1 nearly missed the formation of two funnels overhead, one of which is shown in photo 5. Both funnels had substantial, ten-minute lifetimes while rotating cyclonically. It is thought the twin funnels were not linked to the mesoscale system which was centered eight miles to the southeast. There is the possibility that the two west flank funnels were either products of local horizontal shear or were wake vortices left behind the southeastward-moving thunderstorm.

After photographing the two funnels, Team #1 entered the shaft of heavy precipitation of the parent storm at 1640. Visibility dropped sufficiently to obstruct their observations of the southwest flank.

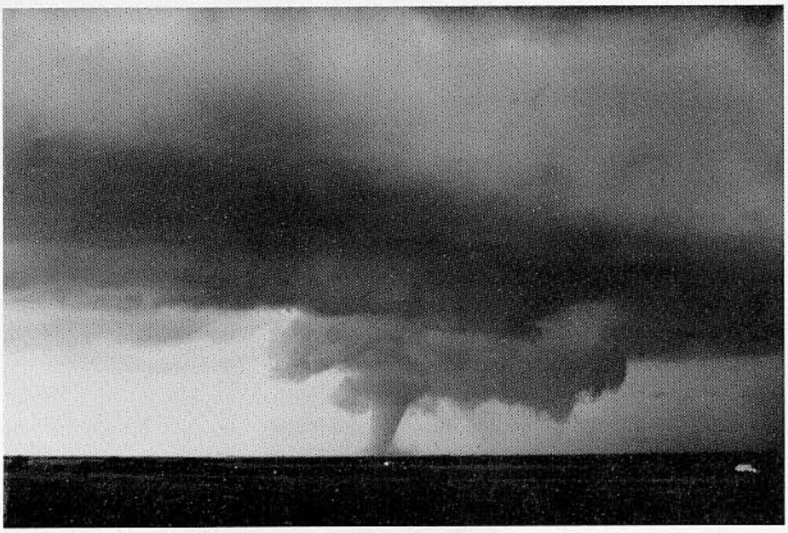
Fortunately, Team #2 captured a series of high quality slides of the mesosystem and its tornado. Photo 6, taken at 1545, shows the descent of the funnel. Notice the ragged wall cloud structure above the funnel, and the heavy precipitation northeast and north of the wall cloud in the right of the photo.

Photo 7, taken several minutes after photo 6, shows the tornado on the ground for the final time following a series of bounces. Damage became continuous and the path of destruction reached a width of approximately 1,300 feet when photo 8 was snapped. This pictures the tornado at its maximum size, a truly terrifying spectacle. Photo 9 was taken a moment before the tornado churned through Union City. The conical condensation funnel has decreased in size, the shrinking phenomenon continuing until the funnel dissipated.

Photo 6

Photo 7

Photo 8



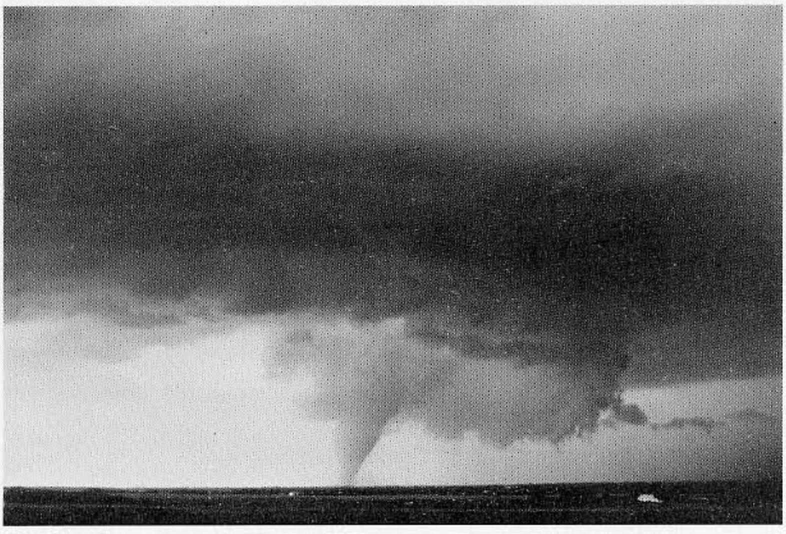


Photo 9

The sequence of photographs by Team #2 depict the highlights of the first half of the lifetime of the Union City tornado which extended over 25 minutes. Among the interesting features seen is what appears to be a dry intrusion into the mesoscale tornado circulation. This is visible in the lower left center of photo 6, advancing cyclonically around the southeast side of the tornado, or from left to right in photos 6–9. The cloud deck in this area was apparently evaporated by the dry air, a phenomenon that can possibly be likened to the dry intrusion observed to move into a mature synoptic scale low-pressure system, clearing out middle level clouds in the process.

Immediately ahead of the dry surge, Team #2's photographs show a small shelf cloud structure "wrapping" cyclonically in toward the wall cloud. This poorly developed shelf is suggestive of a wind shift demarcation. Team #2 reported southeast inflow winds throughout this period, and it is believed the shelf cloud separates the warm moist inflow from air of a denser nature. The gust front and dry air surge is well in advance of the tornado. This may suggest that inflow to the tornado is wrapping in cyclonically from the funnel's northeast, immediately ahead of the dry surge of air from the southwest.

After taking several more photographs, Team #2 noticed the tornado, which had moved from their left to right (or eastward) previously, was bearing down on them. A curtain of precipitation began to fall between them and the tornado, masking the funnel. Considering themselves in danger, Team #2 wisely elected to retreat to the southeast.

Team #1 during this period was driving east on I-40, then south on Highway 81. In the precipitation shaft north of the tornado, Team #1 observed a definite sorting of hail by size from north to south along Highway 81. In seven miles, the hail went from marble-size at El Reno, to golf ball-size one to two miles north of Union City. This phenomenon agreed with the theory of hail separation espoused by Browning (1965), who suggested the tilt of the high speed updraft in the vault region could lead to hail separation underneath the updraft.

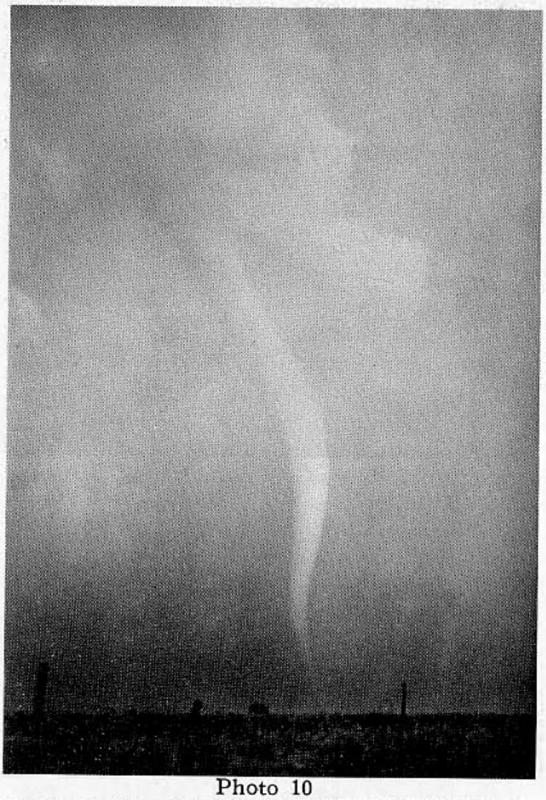


Photo 10

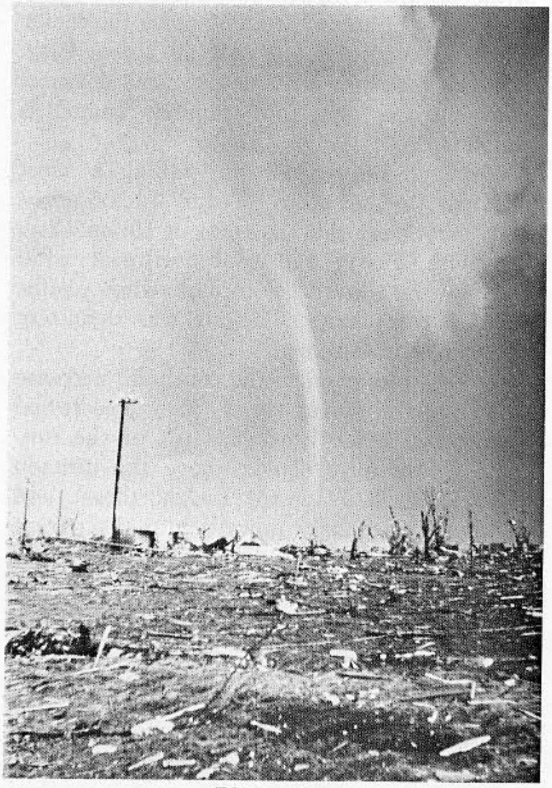


Photo 11

Photo 12

At 1600, Team #1 broke out of the hail zone one mile north of Union City. The students were greeted with the ominous sight of the tornado leaving Union City. In its wake was an eighth-mile-wide path of total destruction. The team exposed a steady succession of slides and one reel of super-eight movie film of the tornado accelerating southeastward. Photos 10–12 depict stages of the last half of the funnel's existence. Notice photos 11 and 12 training down the center of the extreme damage path in Union City. The contrast between the extensive devastation and the now thin, laminar funnel is startling.

Although heavy hail was falling a short distance to the north, Team #1 observed only very light rain at 1600 in Union City. A strong, gusty, and cool northwest wind was blowing toward the tornado when photos 10–12 were taken. The air was definitely thunderstorm outflow.

These slides confirm the continual decrease in size of the vortex core. They also reveal an increasing northeastward tilt of the funnel. Cumuliform clouds above the tornado were also tilted toward the northeast and spiraled cyclonically upward into the parent thunderstorm. Such updraft slope confirms the observations of the late F. C. Bates, who utilized them in his tornado model (Bates, 1967).

The storm interceptors were intrigued by this updraft slope, as earlier cumulus had exhibited cloud tilt into the southeast. We can conclude that some mesoscale forces were at work, creating the differential vertical cloud tilt around the Union City thunderstorm.

Shortly after photo 12 was taken, the tornado lifted and dissipated. The rope stage of the vortex marked the beginning of its demise, as it did in Fujita's study of the Fargo tornadoes (Fujita, 1960). The entire evolution of the Union City tornado exhibited similar characteristics to the three major tornadoes of the Fargo storm. Fujita summarized each as having four distinct stages: a) Dropping stage, b) Rounded bottom or conical stage, c) Shrinking stage, and d) Rope stage.

The one major structure of the Fargo storm lacking in the Union City tornado system was a so-called tail cloud. The Oklahoma students have described tail clouds in several other tornadic storms. When this structure is observed, it is visual evidence of a mesoscale inflow jet feeding the tornadic mesosystem.

An interesting observation was recorded by NSSL radar operators. A mesoscale hook observed in the cloud formation disappeared before the formation of the tornado, although a notch-shaped echo was reflected on the screen during the tornado's lifetime. It is possible that this represented a transfer of vorticity from the mesoscale to the microscale, or from the tornado cyclone to the tornado itself.

Damage Survey

On the morning following the storm the students and NSSL personnel conducted a damage survey. It was found that the width was greatest where the condensation funnel was largest, though the most severe damage was not necessarily linked with increasing funnel size. It was apparent, in fact, that the storm's intensity increased as the vortex diameter decreased. The tornado was narrowing rapidly as it entered Union City, and destruction became complete. An eighth-mile-wide path of F4-F5 damage (on the Fujita scale) occurred in the city. Photo 13 graphically illustrates what was left of a 17-trailer mobile home park in Union City. Only twisted trailer frames remained in the immediate area.

As the vortex accelerated southeastward from Union City, the damage path decreased to a width of 50–100 yards. F5 damage continued, with a large farm house being completely swept off its foundation at the approximate time photo 12 was taken. A zone of debris deposition accompanied the rope stage of the tornado whose path appeared to be an area of extreme convergence near the tornado's center. It consisted of dirt and small items vaccumed into a path paralleling the tornado's movement.

Fujita, Bradbury, and van Thullenar (1970) first suggested the term suction swath for such a deposition zone. In their study of the Palm Sunday 1965 tornadoes from the air, they noted cycloidal marks in fields and suggested that these narrow bands of debris marked areas of extreme pressure reduction and convergence rotating around the tornado itself. This would imply the deposition zone was characterized by a sink, rotation, and translation movement. The Union City deposition path differed in that rotation around a vortex core was absent. It would appear that angular momentum was being conserved as the vortex core shrank, resulting in the development of one intense suction swath.

Owing to the timely warnings by the television and radio media, along with the early visual sightings, the tornado caused only one death and eight injuries. The public was alerted by the quick warning system employed by the news media. Even though millions of dollars of damage may be caused by a tornado, the extra few minutes gained from warnings can save countless lives.

Conclusions

University of Oklahoma students and NSSL scientists believe that the intercept program is an invaluable tool. Documentation of the times of occurrence of various phenomena and simultaneous photography of cloud structure are very helpful in analyzing conventional and Doppler radar data. Their data have assisted in describing the synoptic and subsynoptic patterns attending the severe storms of the Great Plains. With the exceptions of the late F. C. Bates and the late N. B. Ward, direct observational field work by trained observers has not been utilized in the quest for knowledge of these storms. The authors believe we have demonstrated that such studies are feasible and will help immensely in understanding these awesome creations of Nature.

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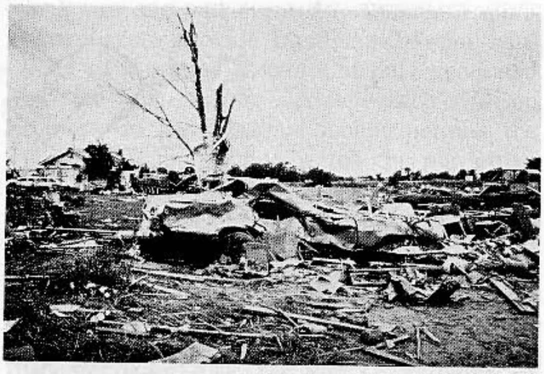

Photo 13