TORNADOES IN NORTHEASTERN KANSAS, MAY 19, 1960

R. A. GARRETT
U.S. Weather Bureau, Topeka, Kans.
with collaboration of
VAUGHN D. ROCKNEY [1]
U.S. Weather Bureau, Washington, D.C.

[Manuscript received January 19, 1962; revised March 5, 1962]

ABSTRACT

The track of a complex series of tornadoes which occurred in the late afternoon and early evening of May 19, 1960, in northeastern Kansas is described in detail.

A very pronounced "hook-shaped" radar echo was observed with the storm. Time-lapse radar photographs taken from Topeka, Kans. on the WSR–3 radar, clearly reveal that the "hook" is the echo from targets spiralling counter-clockwise into a vortex and that the hook is located in the right rear quadrant (if one faces in the direction toward which the storm is moving) of the parent cloud. The inwardly-spiralling motion into an area near the pole is unmistakable when viewed by the time-lapse technique. The coincidence of a singular feature at the end of the "hook" echo, with the damage path on the ground, is shown.

1. INTRODUCTION

The tornadoes in northeastern Kansas in the evening of May 19, 1960 provided a rare opportunity for the observation of a major tornado complex. The tornadic action reported on here lasted for 3 hours and 19 minutes with an overall damage path 70 miles long that followed a mean direction of 14° north of east. The Weather Bureau Office at Topeka is located 7 miles south of the approximate midpoint of the tornado track. Although the funnel of the major tornado was never visible from Topeka, frequent eyewitness reports of its location and direction of movement were received from shortly after it touched down until it struck the town of Meriden. After that time, a lowering cloud deck, an increase of associated precipitation, and the onset of darkness (toward the end of the period) hampered or prevented visual observation.

The thunderstorms that spawned the tornadoes were under surveillance of the Topeka WSR–3 radar from the time of their inception until after they had passed eastward into Missouri. An exceptionally good series of photographs was obtained of the "hook" phenomenon that has previously been observed on radar and reported to be associated with tornadoes [1]. The unusually good radar photography prompted a detailed investigation of the damage area and collection of information that might be important to interpretation of the radar indications. This report is mainly concerned with a physical description of the tornado paths and their association with singular features of the radar echoes. (Note: Herein, all distances are in nautical miles.)

[1] Collaborated on section 4, "Radar Indications."

First indications of thunderstorm development on the afternoon of May 19 were detected by radar shortly before 1600 CST when a cell began developing rapidly in the vicinity of Junction City, Kans. At 1600 CST the cell was reported as of moderate and increasing intensity, 8 miles in diameter, (without correction for beam width) at 267°, 58 miles. The first of a series of frequent statements and warnings regarding this storm and the subsequent tornadoes was released at 1615 CST. During the following hour the initial cell moved northward with increasing intensity and size and at the same time a line of echoes developed eastward from it. The 1700 CST radar observation described the situation as a broken line of strong echoes from 281°, 20 miles to 284°, 60 miles with the top of the strongest echo measured at 45,000 feet at the western end of the line. Marble-sized hail fell in Junction City at 1630 CST and at about 1645 CST there was a public report of a funnel not touching the ground to the northeast of Fort Riley (approximately 271°, 53 miles from Topeka). See figure 1. The first positive tornado report, which was received by the Weather Bureau at 1730 CST, placed the location at approximately the 1728 CST time mark on figure 2.

The tornado damage path (fig. 2) began 36 miles directly west of Topeka at the Riley-Wabaunsee county line. It cut across five northeastern Kansas counties, extended slightly into a sixth county, and terminated at the city limits of Leavenworth, 36 miles east-northeast of Topeka. The *average* forward speed, neglecting irregularities and discontinuities of path, was 21 kt. Damaging windstorms and possible tornadoes were reported farther east in Missouri along a projection of the same general line later in the evening, but no attempt is made here to

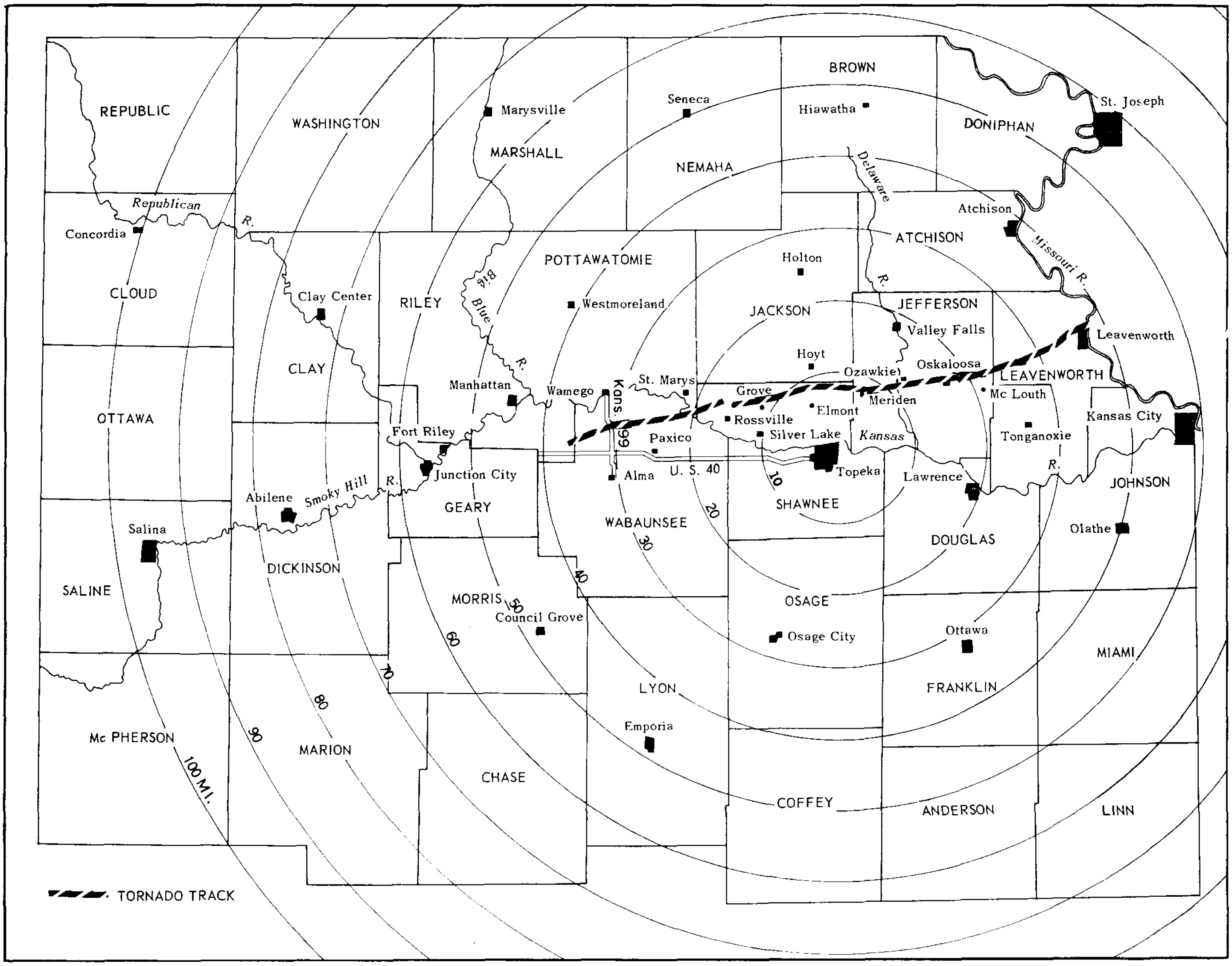


FIGURE 1.—Map of northeastern Kansas with general track of tornadoes of May 19, 1960 and range circles (10 n. mi.) from Weather Bureau radar at Topeka

link these with the Kansas occurrences. The path of major damage ranged from less than ¼ mile wide along a few segments to over 2 miles wide. It followed a general east-northeastward and eastward direction, and was discontinuous with several offsets, both to the north and the south. The areas of wider damage provide evidence of multiple or complex tornadic action.

The tornadoes began in the northeastern portion of the Flint Hills area, a hilly, mostly pastureland region, crossed the populous and intensively-farmed flatlands of the Kansas River, and then for the last two-thirds of their course traversed a rather hilly region of alternating cultivated fields and pastures generally at right angles to the major drainage features.

Complete destruction or major damage occurred along much of the 70-mile long swath. Much of the town of Meriden (pop. 405) was demolished and the northern portion of Oskaloosa (pop. 808) sustained general damage. Agricultural losses including homes, farm buildings, machinery, crops, and livestock have been estimated at $5,450,000. Urban loss estimates are about $1,500,000 which puts the total dollar loss from these storms in the neighborhood of $7,000,000. American Red Cross reports list 461 families suffering loss with 110 homes demolished, 111 sustaining major damage, and 239 minor damage.

Only one death is directly attributable to the tornadoes and this person, while aware of the approaching tornado, was attending to business matters instead of seeking shelter as the storm neared. Tornado injuries of a major nature numbered 25. Considering the magnitude of the destruction and the number of families affected, the small loss of life is a distinct tribute to the effectiveness of the warnings and the efficiency of community warning plans as well as to the efficacy of the educational programs on

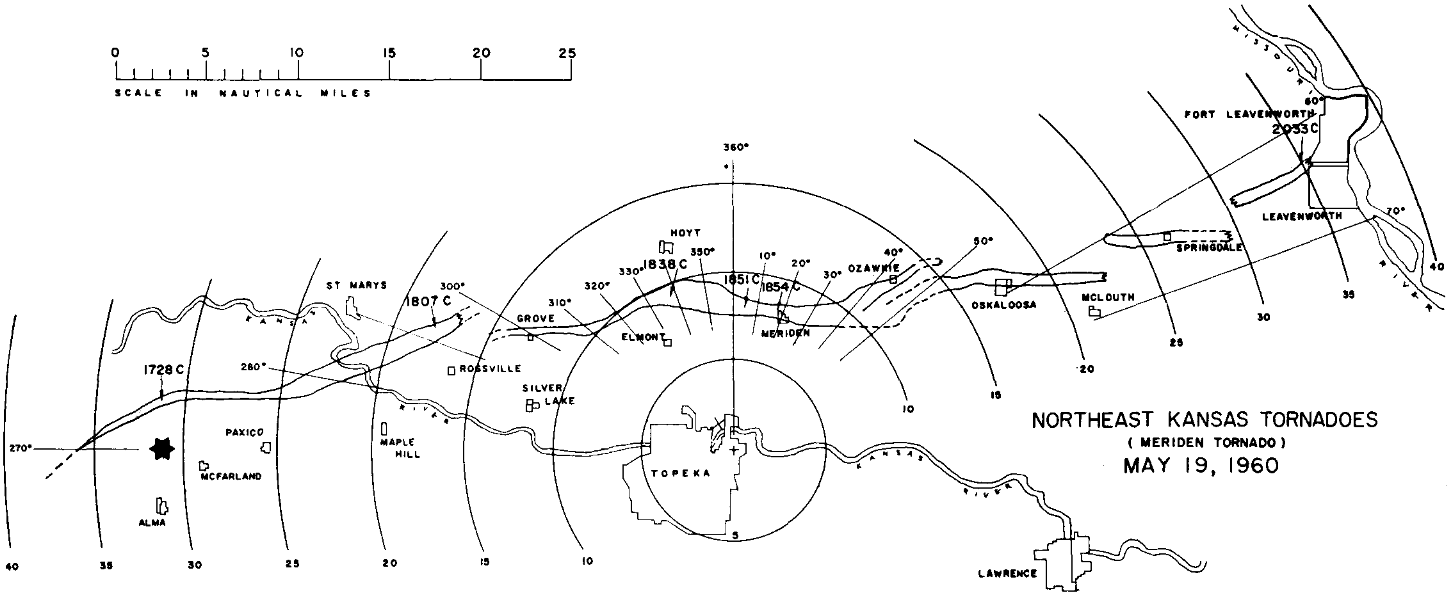


FIGURE 2.—Damage paths made by the tornadoes of May 19, 1960, shown against range circles (5 n. mi.) and azimuth markers centered on Topeka radar. Solid lines enclose areas of major damage; dashed lines, scattered or lesser damage. Times shown (in CST) are times of failure of electric transmission lines. X marks isolated tornado damage at edge of Topeka. Star is location from which pictures shown as figures 3a and 3b were taken.

tornado preparedness that have been carried on in these areas for the past seven or eight years. A number of agencies and groups including the Kansas Highway Patrol, radio and TV stations, local tornado warning committees, and a countless number of individuals assisted in distributing the warnings so that practically everyone was informed of the tornadoes before they struck.

2. DESCRIPTION OF TORNADOES AND DAMAGE FEATURES

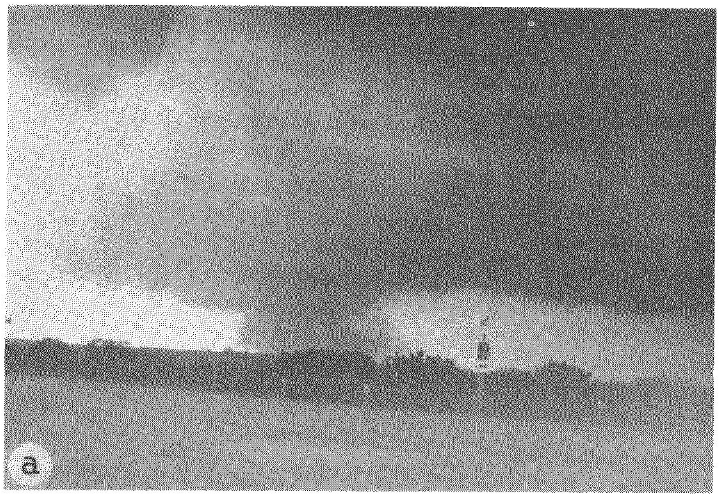
Figure 2 is a location map upon which range and azimuth markers with respect to the Topeka radar have been inserted. Cities and towns near the damage path are outlined for geographical reference. The principal tornado paths are indicated by solid or broken lines. The solid lines encompass areas of major damage; broken lines, areas of more selective damage or where the tornado path was less distinct. Damage of a selective and generally lesser nature also occurred beyond these lines. The "X" near the northeastern limits of Topeka at 330°, 1.7 miles, indicates the location at which a positively-identified satellite tornado dipped down.

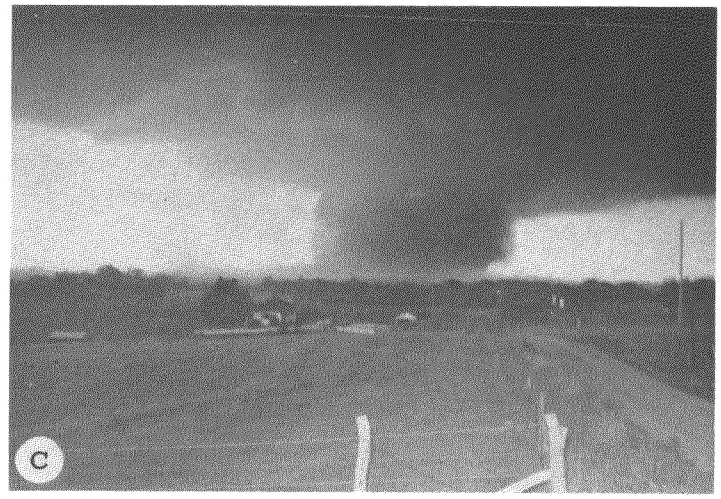
Exact times were generally difficult to establish with assurance. Those shown are times of failure of major electric transmission lines, and in all cases except at 340° azimuth the damage path cut across the transmission line at an angle of 70° or more.

Ground and air surveys have been made of the damage path with several members of the Topeka Weather Bureau staff and research personnel of the Kansas City District Meteorological Office participating. Nearly every section line road was surveyed along much of the path. A 5-mile wide strip along the damage path has been photographed by the Kansas Air National Guard, but these photographs have not been analyzed at the time of writing this report.

Three excellent photographs of the tornado are reproduced in figures 3a–c. A number of people have been interviewed who saw the tornado in its formative or early stages; most of them had some difficulty in recognizing it as a tornado. That is, it either did not resemble tornadoes that they had seen previously or it did not correspond to their conception of what a tornado should look like. Most described it as a rather shapeless and poorly defined very dark mass hanging down out of the clouds. Others described it as a black mass resembling a huge cone or ball bulging down from the clouds which, after it came to earth, seemed to resemble a truncated cone with the apex cut off at the ground and the lower portion obscured by the dust scarf which developed shortly after it hit the ground. Later it seemed to take on the appearance of a connection between the ground and the clouds such as a large pillar or column with its outlines greatly obscured by dust or cloud fragments. At Topeka there was a broken cloud deck at 4,000 feet which lowered to 2,000 feet between 1900 CST and 1930 CST, and this is perhaps representative of the general ceiling in the vicinity of the tornado.

The tornado first followed a northeasterly course for 5 miles with the damage path gradually widening from very narrow at the beginning to ½ mile wide (fig. 2). It then veered and followed a due east course for 6 miles and along this trajectory the damage path very gradually narrowed to less than ¼ mile. This eastward path fol-





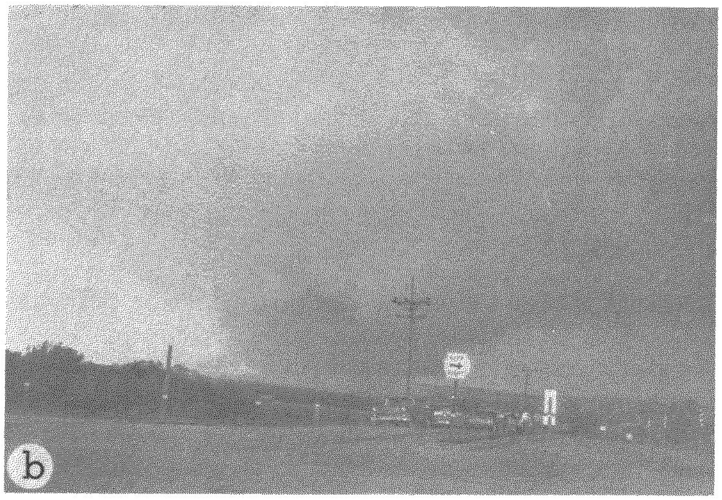


FIGURE 3.—Photos of the tornado made by Kansas Highway Patrol troopers. (a) Picture taken 3 miles north of Alma slightly east of the junction of routes US 40 and State route 99, facing northwest with tornado 3 miles distant. (b) Picture taken at junction of US 40 and State route 99, facing north-northwest with tornado 3 miles distant. (c) Picture taken near Rossville.

lowed a country road with mostly open pastures and very few buildings or trees on either side. Consequently, it was difficult to determine the exact width, but there were indications it was not much more than 200 yards wide by the time it had traveled about 6 miles due east. The tornado then made a sweeping curve to the east-northeast and again broadened out to $1\frac{1}{2}$ miles in width as it approached and crossed the Kansas River Valley bottoms between St. Marys and Rossville. As it moved into the hillier terrain to the north of Rossville it narrowed slightly and then appeared to have lifted rather abruptly. Major destruction and in most cases complete demolishment occurred along the 22-mile long path of this first of the tornado series. The tornado centerline could be readily established along much of this path from the position of debris and the direction in which trees were blown over. There was little evidence to support multiple tornado action along this first path, even where the damage was uncommonly wide. Secondary funnels were reported by a number of people but were apparently only pendants hanging out of the clouds surrounding the primary funnel. The rate of movement calculated from the two good time fixes along this segment of the path was 23 kt. Projecting this rate to the point of letdown gives 1714 CST as the time of beginning which is in close agreement with several eyewitness reports. There was no rain preceding and but little rain following this tornado.

Either following or nearly coincident with the lifting of the first tornado, another let down to the west of the Grove community, offset about 2 miles to the south and east of the lifting point of the initial tornado. This development coincides with a disturbance of the associated vortex on the radar display which will be discussed later. At first the damage was selective and minor but within a mile the tornado became very destructive and produced a damage path about $\frac{1}{4}$ mile wide. The tornado followed a nearly due east course for about 4 miles and then turned to the east-northeast. After another 4 miles the area of destruction widened out to between $1\frac{1}{2}$ and 2 miles.

This widened damage area is about 4 miles long and presented a more complex damage structure than where the path was narrow. Numerous multiple-funnel sightings were reported from this area. Well developed secondary funnels were seen both to the north and the south of the primary tornado. Rain and hail seem to have been associated with the secondary funnels and rain occurred both prior to and following the primary tornado in this area. Most of the multiple sightings were coincident with the primary tornado, but one creditable account describes one tornado following another separated by a 15- to 30-minute time interval and offset about ¼ mile to the south. The one observer providing this account lives near the south edge of the damage path and stated that the roar of the second tornado was much louder than from the first and could be heard for at least 15 minutes. The second tornado appeared to pass directly over his place without doing much damage.

The tornado then assumed a slightly south of east course as it advanced toward and passed Meriden, and the path again narrowed, giving the appearance of having retracted from the northern side. Rain and hail occurred in the Meriden area ahead of the tornado and intervening rain occasionally blocked off the view of the approaching tornado to Meriden residents.

Another unusually wide and complex damage area was found near Ozawkie. Destruction indictaed that a very intense tornado moved in from the west-southwest just south of the town and then gradually ceased about a mile east of the town. Selective and spotty damage, some of which could be classified as major, was found all through the area enclosed by the broken lines south of Ozawkie (fig. 2). Debris was strewn in an easterly direction through this area. About midway between Ozawkie and Oskaloosa the wide strip of selective damage consolidated into a definite tornado path that crossed the northern portion of Oskaloosa and remained well established for a distance of 8 miles until it ceased north of McLouth.

Two miles immediately north of this termination another tornado path segment began and ran eastward for 7 miles. Damage was mostly of an intermittent nature east of the Springdale community. The final tornado path in Kansas again had its inception offset 2 miles north of the termination of the previous path but it followed a northeasterly course. This last tornado of the series wrought heavy damage along its 5-mile long path as it traversed a populous farming and suburban area terminating near the northwestern corner of the City of Leavenworth.

3. SATELLITE TORNADOES

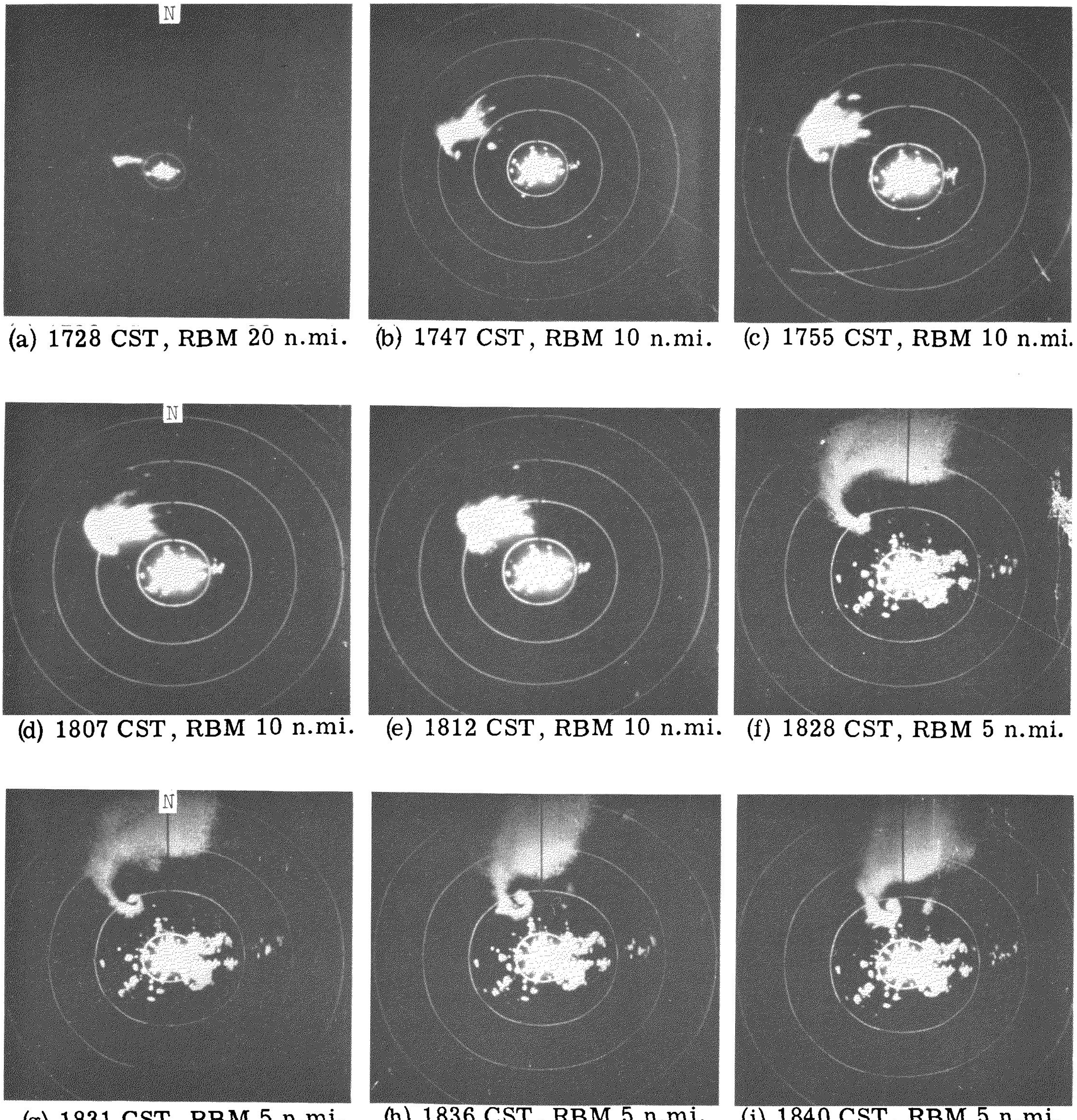
Several cases of spot damage occurred well to the south of the main damage path. One occurred to the southwest of Rossville, another south of Meriden, and a third near the northeastern limits of the city of Topeka. In the Topeka case, the only one of these investigated, the evidence definitely establishes it as tornadic. A number of witnesses report seeing a funnel and the Weather Bureau observer saw a whirl of dirt rising out of the river bottoms. Apparently the funnel only touched down momentarily with damaging vigor. A cement-block truck terminal was demolished at the point marked "X" in figure 2 (1.7 miles northwest of the radar site) and trucks in a nearby graveled area sustained major paint and glass damage from flying stones. Roofing material and other debris from the demolished buildings were carried up into the vortex circulation. Some debris was thrown out to the northeast and some to the southeast on the south side of the river. Buildings and trees on a hillside a mile east-northeast of the truck terminal were damaged and one witness who lives north of the terminal states the funnel swung around in an arc from the terminal to the hillside. Another witness from near the demolished terminal described the air as suddenly becoming noticeably hot, similar to a blast of heat from a stove. The damage occurred at approximately 1905 CST. The FAA tower controller noted the debris in the funnel circulation at 1907 CST and it had all disappeared or fallen out by 1912 CST. Radar indications of these satellite tornadoes will be discussed in the next section.

4. RADAR INDICATIONS

Radar photography was not good during the formative and early stages of the storm, but usable pictures were obtained after 1725 CST. In figure 4, photo (a) at 1728 CST, which coincides with the time of failure of the electric transmission line north of Alma, shows a protuberance on the southwestern part of the large thunderstorm cell. (Note that at a range of 35 miles, beam-width distortion limits the ability of the WSR-3 radar to discriminate small-scale storm details. The presentation would also have been enhanced if the radar had been operating on shorter range.)

Upon switching to shorter range, the radar operator positively identified the "hook" echo configuration as early as 1742 CST. In photo (b) the distinctive "hook-shaped" echo which has come to be known as "characteristic" of some tornadoes, is easily recognizable. The pronounced enlargement and brightening at the end of the "hook" is especially striking and noteworthy. (From study of radar pictures of this and other tornadoes and comparison with the damage track of this storm it appears that this feature represents the radar plan view of an approximately *a*nnualar *s*ection of the *c*ylinder (or cone) of the storm vortex. Herein this feature will be called "asc.")

Photo (b) at 1747 CST shows the asc on the end of the hook located over the widening damage path as the tornado approached the Kansas River. Photo (c) shows the evolution and growth of the hook as the tornado moved across the flatlands of the Kansas River Valley. Photo 4 (d) showing the asc moving close to the parent echo, corresponds to the time of failure of the electric transmission north of Rossville at 1807 CST. The "hook" persisted clearly until the period 1810–1812 CST when the



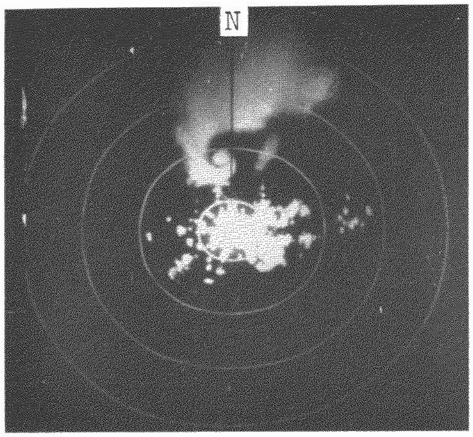
(a) 1728 CST, RBM 20 n.mi. (b) 1747 CST, RBM 10 n.mi. (c) 1755 CST, RBM 10 n.mi.

(d) 1807 CST, RBM 10 n.mi. (e) 1812 CST, RBM 10 n.mi. (f) 1828 CST, RBM 5 n.mi.

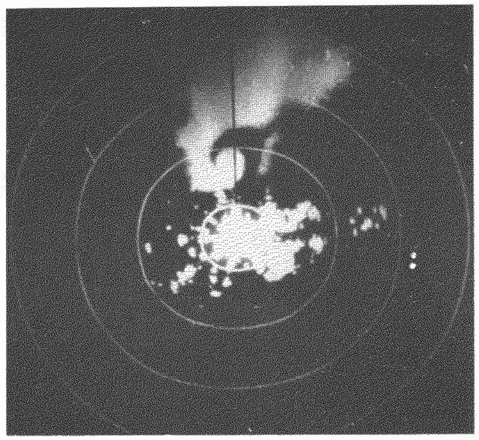
(g) 1831 CST, RBM 5 n.mi. (h) 1836 CST, RBM 5 n.mi. (i) 1840 CST, RBM 5 n.mi.

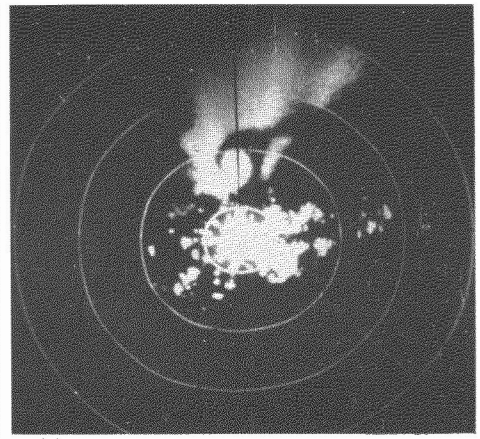
FIGURE 4.—Sequence of photographs of the PPI scope of WSR–3 radar at Topeka Weather Bureau Office during the tornadoes on May 19, 1960. The WSR–3 is an S-band radar, operating with a peak power output of 60 kw. and 4° conical beam (at the range of the hook, 7–15 miles, the beam was thus about 3,000-6,000 feet in diameter). During the time the pictures were taken the pulse length

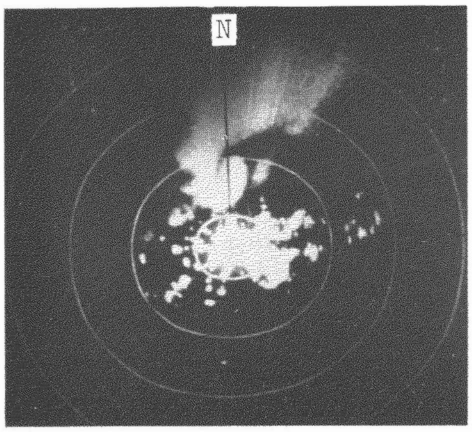
circulation appears from the radar pictures to become disturbed and the asc is not recognizable (fig, 4 (e)). At this time, a new protuberance can be detected growing southward out of the lower curved portion of the echo that had been the bend in the now nearly indistinguishable hook. The closing off of the hook corresponds quite closely in time and location (within the limits of time synchronization of the storm reports and the clock



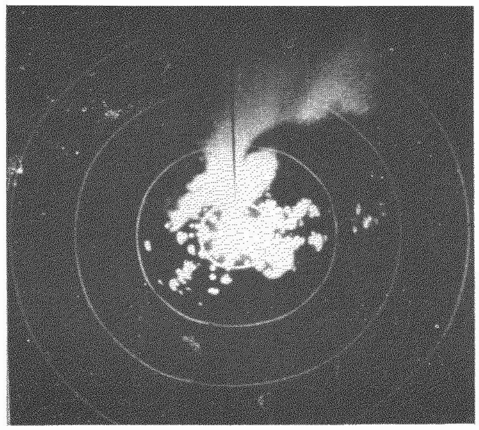
(j) 1842 CST, RBM 5 n.mi.

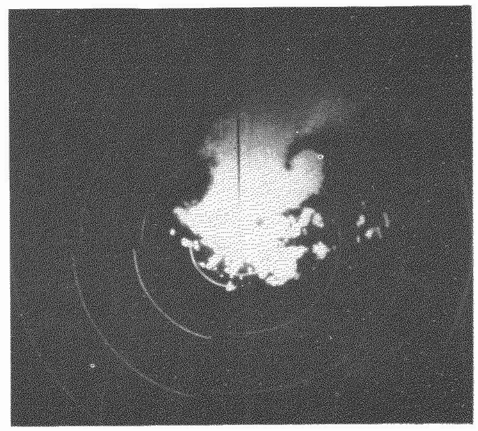

(k) 1843 CST, RBM 5 n.mi.

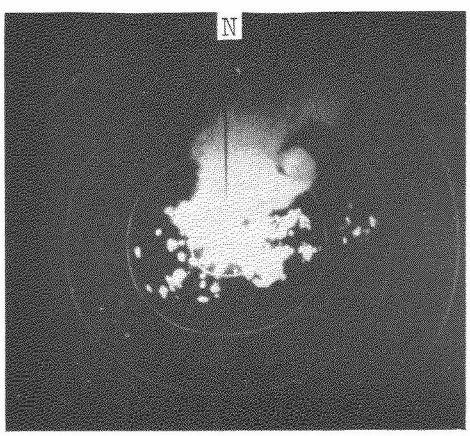

(l) 1844 CST, RBM 5 n.mi.



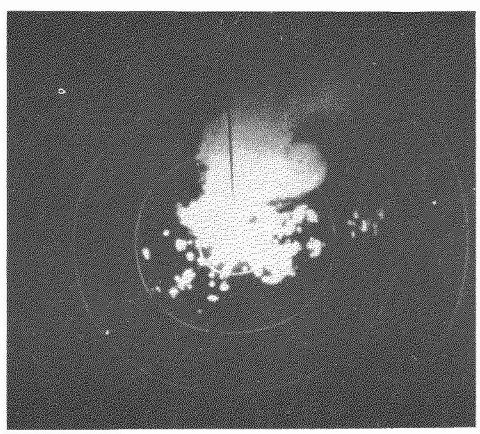
(m) 1846 CST, RBM 5 n.mi.

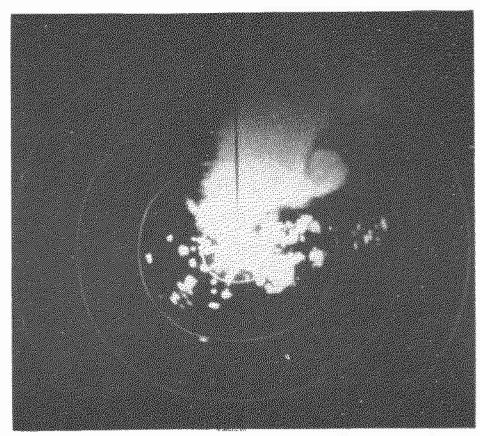

(n) 1852 CST, RBM 5 n.mi.


(o) 1902 CST, RBM 5 n.mi.



(p) 1903 CST, RBM 5 n.mi.


(q) 1904 CST, RBM 5 n.mi.


(r) 1907 CST, RBM 5 n.mi.

was 2 microseconds and the antenna was at 0° tilt. The radar was in correct azimuth orientation at the time of observation, and insofar as can be determined with the test equipment available, correctly calibrated in range. On the radar photographs, "RBM" indicates "range between markers." Note change to 10 n. mi. range in photo (c) and to 5 n. mi. range in photo (f).

in the radar camera) with the lifting of the first tornado and inception of the second in the area northeast of Rossville. Several frames of pictures were lost or spoiled at about this critical time during the course of taking a written observation for record. However, a faint picture (not reproduced) at 1816 CST with 5-mile range markers shows the asc of the new hook at about 295°, 15 miles. (See also fig. 6.)

Following about 1816 CST the tornado was on the ground and the hook was clearly evident. Figure 4(f) at 1828 CST is the first good picture with 5-mile range markers and the asc is located over the ¼ mile wide damage path. After this time the center of the asc appears to hug the northern edge of the widening damage path. The complex damage structure and multiple funnels in the wide damage area have already been described, but the report of the two tornadoes separated by an interval of 15 to 30 minutes warrants further examination of radar indications. The observation was made at a location 331°, 8.7 miles from the Topeka radar. The center of the asc would have passed to the north of this location at about 1831 CST, (fig. 4(g)) and the shank of the hook would have passed over the observer's location some 10 to 15 minutes later. Attention is now called to the horny protuberances on the west side of the shank of the hook as shown in photos (h) and (i). Since the receiver gain was not disturbed there is no way of positively determining the relative intensity of these protuberances, but they are strong echoes. It appears likely that the second tornado was associated with the passage of the shank of the hook or one of the spurs growing out of it (photos (j), (k), and (l)).

Photos (m)–(r) show the continuing evolution of the hook as the tornado passed eastward to the north of Topeka, across Meriden, and into the Ozawkie area. The lower portion of the hook first closed off, ((m) and (n)) leaving a very strong echo in the lower portion of the former hook location. Then a new protuberance developed out eastward from the upper portion of the former hook (photo (o)). The shank of the new hook never developed the amplitude or the classic definition of the previous hooks that projected southward from the mother echo, but the asc is of greater prominence.

The best estimate obtained for the time of the severe tornado that passed just south of Ozawkie is 1915 CST or a few minutes later. This would indicate that the primary Ozawkie tornado was associated with the hook, in figure 4(r), which was approaching that location at 1907 CST. In subsequent pictures, which are not reproduced, the outlines of this hook were attenuated by intervening precipitation but it was still faintly identifiable as late as 1914 CST with the asc centered slightly east of Ozawkie.

Radar echoes of developments associated with the satellite tornado that touched down briefly at 1905 CST about 1.7 miles northwest of the Topeka radar location were largely masked by heavy ground return, but a brief discussion might be of interest. A new weak development becoming evident at 300°, 7 miles at 1844 CST (fig. 4(l)) increased rapidly in intensity and by 1852 CST (fig. 4(n)) had become a solid short line intersecting the hard echo of the former hook at an angle of almost 90°. Further evolution of this configuration is obscured by the ground return, but the overall pattern appears to have drifted eastward in the next 15 minutes and a vortex may have formed at the intersection of the short line and the west side of the hook in the approximate location of the satellite tornado occurrence by 1905 CST.

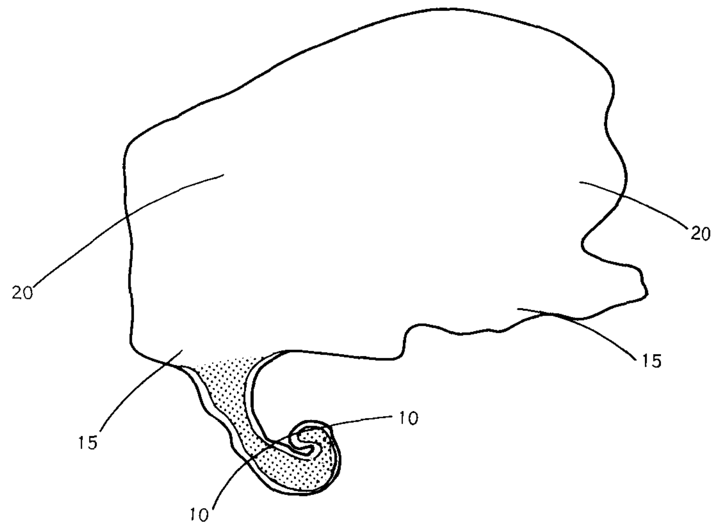


FIGURE 5.—Tracing of hook echo at 1831 CST (fig. 4(g)). Stippling shows dimensions of hook after corrections for beam-width and pulse-length distortions have been applied. Range arcs are labeled in nautical miles.

5. EVIDENCE OF POSSIBLE ATTENUATION

An interesting echo developed in the Meriden area in advance of the hook at about 1837 CST (022°, 10 miles). (See fig. 4(i).) It remained nearly stationary but varied in intensity and size for about 12 minutes (fig. 4(j)–(n)) until consolidating with the hook echo. When viewed in time-lapse, this echo rapidly changes in size and shape, and does not appear to have been reflected from a precipitation cell, suggesting that it may have derived from a shaft of falling hail whose dimensions in plan change rapidly in the sampled volume. Inquiries in the Meriden vicinity produced fairly definite information that variable showers of rain and hail were occurring at about the time this echo was prominent.

Figure 4(i)–(n) seem to indicate precipitation attenuation on the S-band radar. The display for 1844 CST (fig. 4(l)), with the radome dry, clearly shows a shadow north of the hook, and another shadow to the north-northeast of the suspected hail shaft echo area, with a bright sector between the two shadows. The "fading away" of the northern part of the parent cell is also possibly indicative of the precipitation attenuation. Large hail was observed with the parent cloud and the possibility that the attenuation may have been entirely owing to hail rather than rain should be considered. (Note that the absence of range markers in the northeast sector of pictures such as figure 4(g) is owing to the nature of the electronic circuitry of the radar repeater used for photography. The range mark and video signals are mixed in a single tube prior to display, and, unless the two inputs to the tube are in perfect balance, strong video signals may saturate the circuitry so that the range marks are suppressed. This characteristic does not affect the video signal in any way.)

6. DIMENSIONS OF RADAR FEATURES

A clear short-range picture of the "hook" such as figure 4(g) offers a unique opportunity to measure the dimensions of the hook and asc phenomena. Note that the radar echoes observed on the PPI scope with this radar are plan views, not of cloud cover, but of the areas of relatively large amounts of precipitation. The "plan" view of the echo such as in figure 4(c) is thus not necessarily the plan view of the cloudiness associated with the tornado situation. It is also of interest to note that this hooked echo was associated with a single, large, strong storm cell. It has been our experience that this is the circumstance when it is easiest to discriminate this feature.

Figure 5 is a tracing of the indicated hook shape at 1831 CST. Assuming that the reflective material in the target was not visible beyond the half-power points of the beam, the "corrected" tracing is shown by the stippling. The effects of beam-width and pulse-length distortion have been eliminated, thus giving the approximate true dimensions of the hook. Unfortunately, the exact shape of the inner part of the asc cannot be investigated from these pictures. It is interesting to speculate that at the center of the asc there was a target-free area (micro-Low) which marked the center of the circulation. If such a clear "eye" in the asc existed, its dimensions were so small that it could not be resolved by the radar owing to pulse-length and beam-width distortion. Using the WSR–3 radar with its beam width of 4°, a clear "eye" theoretically could not be seen in an asc of ½ mile diameter unless it were within 7 miles of the radar, and then, perhaps, only if the gain were substantially reduced so as to reduce the effect of strong side lobes at short range.

A clear space in the center of the asc has been observed by other workers [1] and it should best be observed by a radar having a very narrow beam and short pulse length, and at very close range when display distortions are at a minimum.

7. COINCIDENCE OF THE ASC AND DAMAGE PATH

In general, the diameter of the asc seems to be slightly less than the width of the damage path. The coincidence of the asc with the damage path (within the limits of time synchronization) and the spiral circulation into the asc, seem to indicate that it is the echo from the high-speed particles in the vortex. These particles are believed to be precipitation in some form, and, at least in low levels and to some degree, possibly debris. Thus, there is good reason to believe that in a non-complex case the asc and the damage path should be coincident, or nearly so, depending on the slope of the vortex. Figure 6 shows the superposition of the hook and the damage path at various times for this storm.

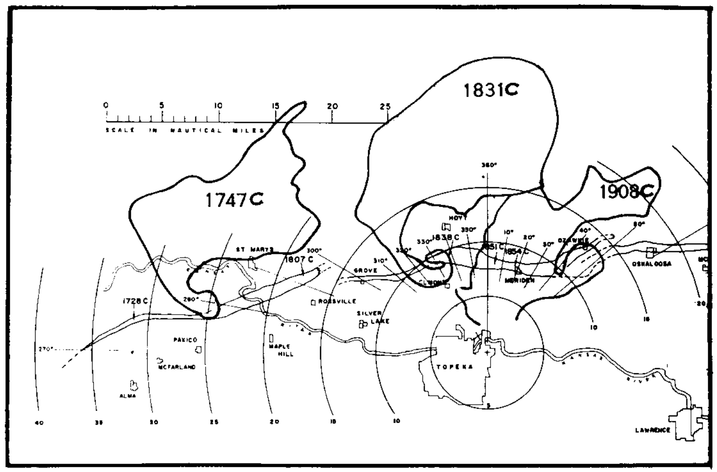


FIGURE 6.—Superposition of hook tracings on damage path map.

Careful study of the size and position of the asc as related to the damage path on the ground, clearly reveals the following:

(a) When the asc is large, the damage path is wide; when the asc is small, the damage path is narrow.

(b) Disruptions in the damage path on the ground are synchronous in time and space with disruptions in the symmetrical shape of the asc.

These radar data suggest a model for this tornado wherein, (a) as viewed in plan presentation, an inwardly spiralling band of precipitation terminates in an annular ring (the asc) surrounding the pole of the spiral; the funnel drops from the center or edge of the asc; and (b) from the motion of the radar echoes as viewed by the time-lapse photographic technique, the high speed in the asc appears to be at least partially the result of the conservation of angular momentum. No attempt has been made to calculate echo velocity in the asc (it is very difficult to find salient echoes whose identification with time can be preserved with certainty), either by direct measurement of echo velocity therein or through calculations involving measurement of echo speed in the inwardly spiralling precipitation mass. These possibilities should be examined in this or future storms for which proper radar data are obtained. The similarity in appearance, but not in scale, of this radar model to the spiral bands and wall cloud of a hurricane is striking.

ACKNOWLEDGMENTS

Credit is due numerous members of the Topeka Weather Bureau staff for their assistance in making damage surveys and their comments and suggestions during the preparation of this report. Mr. B. E. Hall was responsible for the radar watch as well as the usual surface observation program prior to 1800 CST. By that time off-duty

members of the staff had reported in and the radar watch was assumed by R. T. Tice with the assistance of Electronic Technician J. Z. Galeziewski. D. T. Williams, Weather Bureau, Kansas City, Mo., and Maj Albert Ehrlich of the U.S. Air Force, made the ground survey of the area east of Oskaloosa.

Appreciation is expressed to the Kansas Highway Patrol for permission to reproduce the excellent tornado photographs taken by their troopers.

Special appreciation is expressed to Mr. Hal Foster of the Radar Analysis and Development Unit, Kansas City, Mo., for helpful suggestions and advice and very active assistance in the preparation of this report.

REFERENCE

1. F. A. Huff, H. W. Hiser and S. G. Bigler, "Study of an Illinois Tornado Using Radar, Synoptic Weather and Field Survey Data," Illinois State Water Survey Division, *Report of Investigation* No. 22, 1954, 73 pp.

Recent Articles in Other Weather Bureau Periodicals

Weekly Weather and Crop Bulletin, National Summary, vol. XLIX:

No. 6, Feb. 5, 1962,
"Rainfall and Corn Yield," by A. R. Long, p. 8.

No. 7, Feb. 12, 1962,
"Agricultural Meteorology—History and Activities of Its International Commission: Part I—The World Meteorological Organization," by M. L. Blanc, pp. 7–8.

No. 9, Feb. 26, 1962,
"Agricultural Meteorology—History and Activities of Its International Commission: Part II—Commission for Agricultural Meteorology," by M. L. Blanc, pp. 7–8.

No. 13, Mar. 26, 1962,
"Great Atlantic Coast Storm, March 5–9, 1962," by A. I. Cooperman and H. E. Rosendal, pp. 7–8.

Mariners Weather Log:

vol. 6, No. 2, March 1962,
"Sea Conditions—North Atlantic Ocean," by M. D. Burkhardt, J. M. Kipper, and E. Joseph, pp. 35–43.
"Tropical Cyclones in the Eastern North Pacific Ocean," by M. W. Mull, pp. 44–46.

vol. 6, No. 3, May 1962,
"Great Atlantic Coast Storm, 1962", by A. I. Cooperman and H. E. Rosendal, pp. 79–85.
"Typhoons of the Western North Pacific, 1961," pp. 85–91.