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RHI Radar Observation of a Tornado

JOHN SCHUETZ AND GLENN E. STOUT [1]

ABSTRACT

Preceding the development of a tornado at the ground a fingerline projection developed on the PPI in the SW corner of an echo. This was also visible on the three-dimensional models constructed from RHI data. The parent echo extended to 37,500 feet and was the highest echo in the vicinity. Tornado occurrence was simultaneous with a new cell merging with the finger. Photographs of the tornado, the lower level echo tilt, and winds aloft data all indicate the same direction of shear.

1. Introduction

DURING the afternoon of 3 April 1956 the Illinois State Water Survey was operating an AN/CPS-9 (XE-2) and an AN/TPS-10 3-cm radar in routine data collection on a quantitative estimation of precipitation research project.[2] At 1554 CST a finger, which was later associated with a tornado, developed on the southwest corner of a large echo mass on the PPI. A few minutes later the finger appeared as a J-shaped, hooked echo. Constant elevation plots of the RHI data also showed a finger which developed into a J-shaped echo.

The present investigation was undertaken in order to present the three-dimensional echo structure in a tornado situation. A similar observation was reported in London [1].

2. Synoptic situation

In a detailed discussion of the synoptic conditions, Hanks and Neubrand [2] state that the movements of the jet maximum northeastward to Kansas City at 0900 CST on 3 April, coupled with the broad area of instability, was of prime importance in initiating the tornado activity which covered the Mississippi Valley from the Great Lakes to Mississippi. The)- further state that the vorticity equation and the upper-level charts suggest a strong vertical motion field over the area, which was another significant factor in the tornado formation. Referring to the Rantoul 1500 CST pibal (20 statute miles north-northeast of the radar station) and utilizing the thermal wind equation it can be seen that warm air advection is taking place below 9000 feet with little or no thermal advection above that level. This factor should further increase the instability.

3. Discussion of radar data

Fig. 1 consists of four photographs of the CPS-9 PPI taken at 1559 and 1604 CST on zero degree antenna tilt. Fig. la shows a north-northeast, south-southwest squall line with which the tornado was associated. This line moved from the west at 8 to 10 knots with individual echoes moving along the line from the southwest at 35 to 40 knots.

At 1559 CST a finger is evident at 276° /20 nautical miles. Subsequently, the tornado developed about three miles north-northeast of this finger. This suggests that the finger preceded the tornado at the ground which was also observed in the Illinois 1953 tornado [3]. Close inspection of fig. la shows a small secondary cell developing about one mile southwest of the finger. This cell appears to grow rapidly, particularly toward the north-northeast, and merges with the main finger to produce the J-shaped echo. This should not be interpreted as anticyclonic rotation. The tornado touched the ground apparently at the time the finger and secondary cell merged to form the pattern shown on fig. 1c. The tornado, location no. 1 in fig. 2, is located in the middle of the secondary cell which is now the western portion of the J-shaped echo. This secondary cell moved from the south-southwest at 55 knots. The tornado also moved from the south-southwest at an unknown speed. The main portion of the finger moved from the southwest at 35 to 40 knots. By 1611 CST the secondary cell had disappeared from the scope and this is probably the time of tornado dissipation. The divergent path of the main finger and secondary cell may be a factor in the dissipation of the tornado and the cell.

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[2] This project is sponsored by the Evans Signal Corps Laboratory, Belmar, New Jersey under Contract DA-36-039 SC-64723.

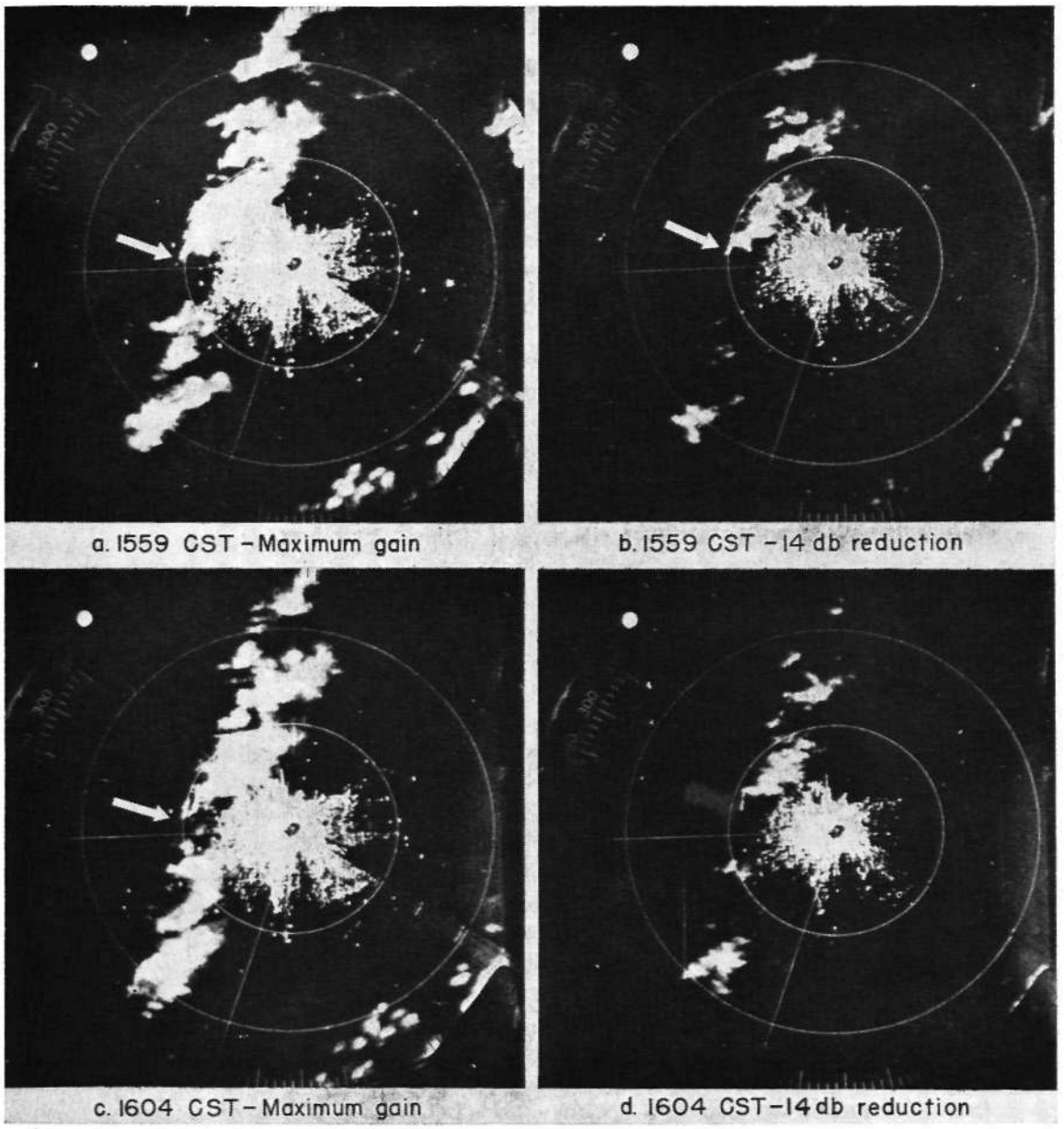

FIG. 1. Photographs of the PPI for 3 April 1956. The range marks are 20 nautical miles and north is at the top of the photograph.

Comparing figs. la and 1c on maximum gain with figs. lb and 1d, 14 decibels below maximum gain, one can see that the main finger is more readily detected on reduced gain. Thus, when using high-powered 3-cm radar sets much as the CPS-9, it seems advisable that reduced gain should be used in conjunction with maximum gain in the detection of severe weather producing echoes.

When constant level plots for each 5000-foot level of the TPS-10 RHI were made, the beginning of a finger at the surface was first noted at 1554 CST at 273° /23 nautical miles. This main finger generally moved from the southwest at 35 to 40 knots to the position indicated in fig. 2 at 1604 CST. A plot of the tornado damage path is also shown. The western portion of the J-shaped echo finger between 287° and 289° and at 20 nautical miles is the one believed to be associated with the tornado at the ground. Note that the tornado at the ground first developed in

this area. It is interesting to note that both the CPS-9 PPI at 1604 CST (fig. 1c) and the PPI constructed from TPS-10 RHI data (fig. 2) both show the J-shaped echo between 280° and 290° at a range of 18 to 20 nautical miles.

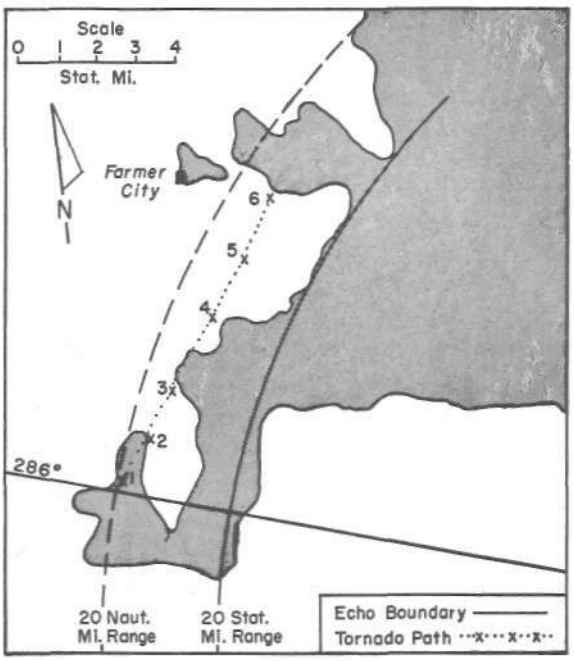

FIG. 2. PPI for the surface constructed from RHI data at 1604 CST and path of tornado.

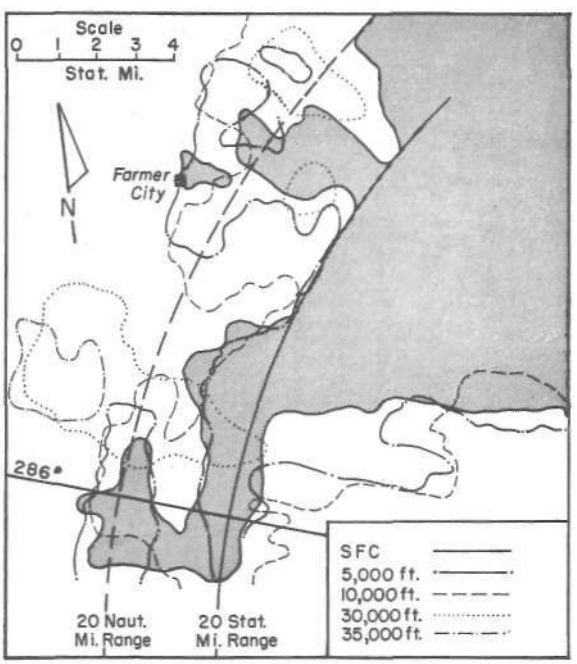

FIG. 3. Plots of echoes at various levels at 1604 CST.

The field survey indicated that the length of the damage path was about six or seven nautical miles and the tornado duration was probably less than fifteen minutes. The duration of the finger on the TPS-10 constant level plots was less than 16 minutes as determined by the absence of a finger on the 1551 CST and 1607 CST scans. In the Illinois 9 April 1953 tornado, the finger, which was referred to as an appendage, was visible as such on the APS-15 PPI for longer than a half hour [3]. However, this tornado had a much longer path and duration. It appears plausible there is a positive correlation between tornado and finger duration.

Fig. 3 is a plot of the echo appearance at various elevations. Plots at levels intermediate to those shown indicate that the J-shaped echo is a part of a larger echo mass overhead. Fig. 3 also shows that the western portion of the J-shaped echo leans toward north-northeast with height. Fig. 4, taken looking slightly south of east, shows the actual tornado leaning toward the north with height between the surface and 2000 feet in the plane of the photograph. Also the Rantoul pibal for 1500 CST shows northeasterly shear. Thus, it is noteworthy that the lower level echo tilt as indicated by the TPS-10, the shear indicated by the tornado, and the pibal are all oriented in approximately the same direction.

Fig. 5 shows an RHI profile along 286° azimuth (see fig. 2). The tornado at the ground appears to be associated with the echo at 23 statute miles. This particular echo extended to 37,500 feet between 290° and 295° and was the tallest echo in the vicinity. The appearance of echoes below the zero degree line is believed to be due to signals reflected from true echo to ground and then to the radar.

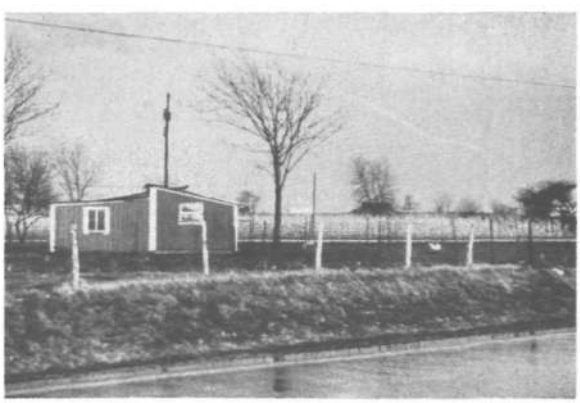

FIG. 4. Photograph of the tornado by David Fredrickson of Farmer City.

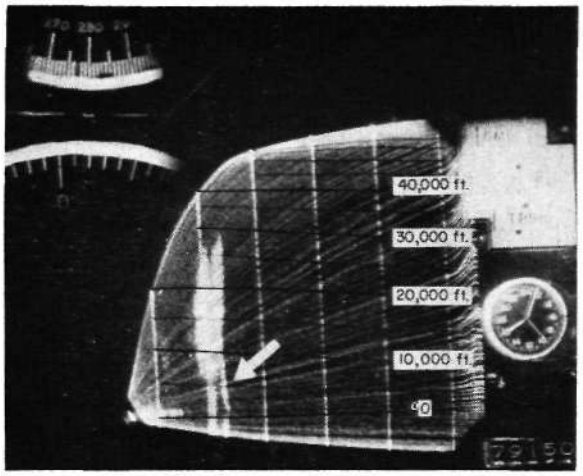

FIG. 5. Photograph of the RHI scope at 1604 CST on 3 April 1956. The dark horizontal lines are 5000-foot height intervals and the white vertical lines are 10 statute mile slant range marks.

Fig. 6 shows three photographs of two three-dimensional models of the echo mass associated with the tornado. Figs. 6a and 6b were taken from the western side at 1559 CST and 1604 CST. respectively. Fig. 6c is a view of the underside of the 1604 CST model taken at a 45 degree angle with the surface. Note the similarities between this view and the echo plots in fig. 3. These models were constructed by making PPI plots of the RHI data at intervals of 2500 feet. The PPI sections were then cut out and placed at the appropriate azimuth, range, and elevation, keeping the horizontal and vertical scales equal. The wind velocity, as determined from the 1500 CST Rantoul upper winds, is shown on the tags mounted at the appropriate elevations. These elevations are shown in thousands of feet as the first figure on the arrows. The white line represents the tornado path with the X's showing damage points (also shown in fig. 2).

Earlier plots in the region where the tornado finger formed show that the echo producing the finger grew down to the surface from aloft between 1549 CST and 1554 CST to form the pattern shown in the 1559 CST model. Between 1559 CST and 1604 CST the cell, labeled "new cell," with a base of 12.500 feet and top of 25,000 feet merged with the main echo mass. This merger was coupled with echo growth to 37,500 feet between 1559 CST and 1604 CST and the tornado development at the ground. Thus, the echo merger, vertical growth, and the tornado development at the ground occurred within a very short time of each other.

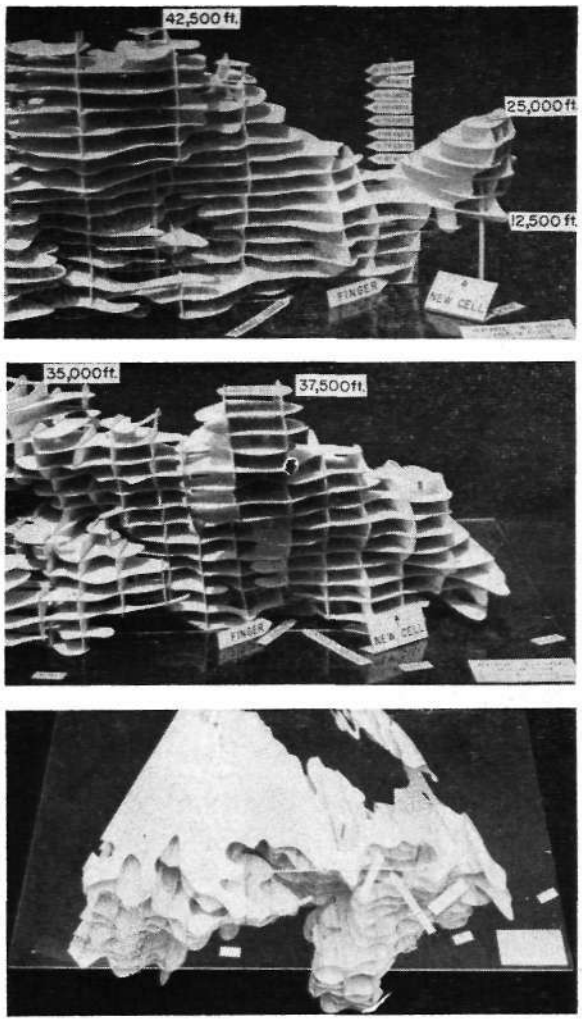

FIG. 6. Photographs of three-dimensional models of the echo mass associated with the tornadoes.

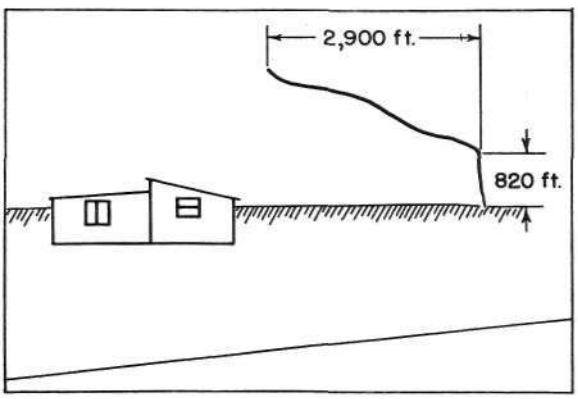

FIG. 7. Sketch reproduced from fig. 4 showing the important dimensions of the tornado.

4. Field survey

Fig. 7 is a drawing of the tornado showing important dimensions as reproduced from fig. 4. The tornado at the ground was present near location no. 6 on fig. 2 at the time of the photograph in fig. 4. The photographer reported that the tornado dissipated shortly after the photograph was taken. The most significant feature is the long tail which enters the base of the cloud 2900 feet north (in the plane of the photograph) of the tornado at the ground and the sharp bend at 820 feet above the surface.

A photograph, not reproduced here, shows a darkened area in the field where the tornado moved across and stripped the cut-corn stubble from the field at location no. 3 (see path on fig. 2). Circular markings were noticed in the field similar to those reported in the North Platte Valley tornado [4]. Debris scatter indicated that the rotation was cyclonic. The width of the path at this point, as well as throughout the tornado's history, was about 100 feet. A total of $30,000 damage was done at location nos. 2, 3, and 4.

Unfortunately, no electric clock stoppages occurred, so exact timing was impossible. The most reliable report was possibly that from a state policeman who saw the tornado at 1608 CST. All other witnesses gave "shortly after four o'clock" as the time of occurrence.

5. Conclusions

1. Reduced gain (15-20 decibels) should be used in conjunction with maximum gain as an aid in the detection of echoes suspected as tornadic on high powered sets such as the CPS-9.

2. The highest echo of 37,500 feet occurred within one statute mile of the tornado path.

3. A finger developed from the parent cloud and merged with a developing secondary cell in the region of tornado formation. This formed a "J" shaped echo which was visible on the PPI constructed from RHI data as well as on the CPS-9 PPI. The secondary cell appeared more closely associated with tornado development at the ground than the main finger.

4. The finger apparently precedes the tornado at the ground and the duration of the finger is positively correlated with the lifetime of the tornado.

5. Echo tilt and the shear indicated by the tornado and the pibal are oriented in approximately the same direction.

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