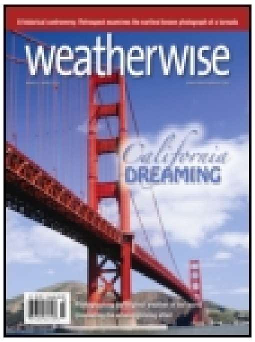

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A Note on the Successful Identification and Tracking of a Tornado by Radar

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ABOUT noon on 5 April 1956, a tornado forecast was issued by the U. S. Weather Bureau Forecast Center at Kansas City. The area of the forecast was in central and eastern Texas, extending 50 miles on either side of a line from 60 miles NW of Austin to Shreveport, Louisiana (fig. 1). College Station was located just to the south of this area. Because of the close proximity, the modified AN/APS-2F 10-cm radar located at Texas A. & M. College, installed just ten months previously and identical to those used in the Texas Tornado Warning Network, was operated during the afternoon to watch for any approaching weather. Photographs of the radarscope were made with a Polaroid Land camera. Mr. Billy Thomas, Weather Bureau meteorologist, assisted in recording data during the afternoon.

The radar was turned on at approximately 1340 CST. A particularly intense weather echo was located about 60 miles west when observations began. A picture of the scope was made as routine procedure at 1347 CST

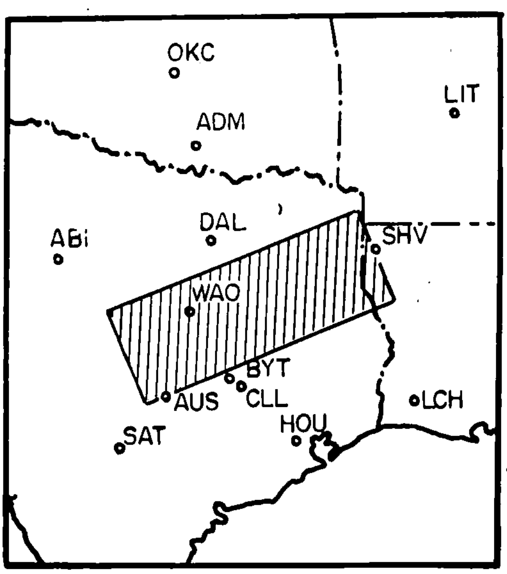

FIG. 1. Area of tornado forecast.

(fig. 2A) and a position check made to determine echo velocity. At approximately 1400 CST the movement was found to be from about 260°, at 35–40 knots. The echoes at this time were not sufficiently unusual to be considered menacing, although it was learned the next day that strong winds and hail had been reported just north of Taylor, Texas, which is located at azimuth 263°, 56 miles from the radar station. The wind and hail apparently occurred almost simultaneously to the time this picture was taken, since the echo appears directly over the Taylor location. The only reason for considering the echo as a producer of severe weather was its intensity and size in comparison to neighboring echoes. In several previous tornadoes, i.e., those at Worcester, Massachusetts; Blackwell, Oklahoma; and Urbana, Illinois; it had been observed that the tornado-producing echo was much more intense and also larger than other nearby ones.

The echoes continued to move eastward across the scope and by 1418 CST (fig. 2B) the prominent echo was located 30–35 miles west of the station and had developed a V-shape with the V opened towards the north. This echo shape had also occurred in the case of the Urbana, Illinois, tornado of 1953, but at a later stage in the tornado's development. Therefore, Dr. A. H. Glaser of the Department of Oceanography and Meteorology, who is conducting an investigation of the surface effects of tornadoes for the Weather Bureau, was notified of the situation. At 1422 CST, a height determination by antenna elevation angle measurement established the top of the radar echo at 40,000 feet. Between 1438 and 1442 CST (fig. 2C, D) the echo developed characteristics very similar to those of previously observed tornadoes which led to the virtual conclusion that a tornado must be on the ground or in an advanced stage of development. (The characteristic cyclonic hook on the SW side of the echo is somewhat

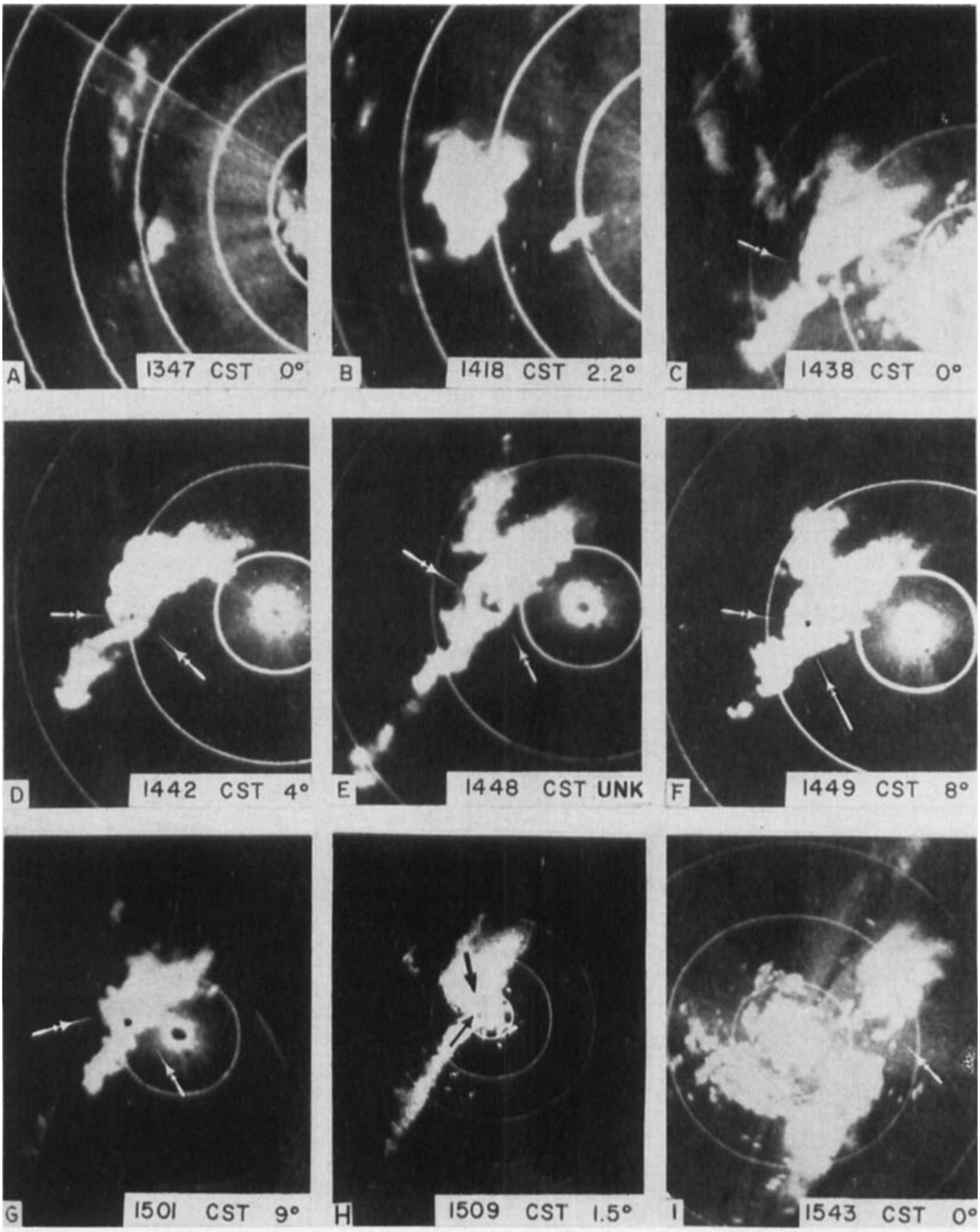

FIG. 2. Radarscope pictures of the tornado. Range mark interval between circular white lines: (A) 20 nautical miles; (B) through G, and I) 10 nautical miles; (H) 5 nautical miles.

masked by other close echoes in this picture; it was more readily identifiable on the 12″ viewing scope of the radar.)

Because of the significant nature of the observations, Dr. M. G. H. Ligda, director of the radar meteorology section, was called to the radar at this time to verify the diagnosis. Although no formal warning procedures had been established, the Bryan Police Department and the local radio station, KORA, were called by Dr. Ligda between 1445 and 1450 CST and were told that high winds and possibly a tornado would strike the area between 1510 and 1515 CST and would last approximately 30 minutes. Dr. D. F. Leipper, Head of the Department of Oceanography and Meteorology, telephoned the College Station Consolidated Schools and the College authorities and gave them the same information.

This was a very critical time because most of the local public schools are dismissed at about 1500 CST. The information was passed on immediately by the police and the schools were held in session until after the storm.

The hook continued to develop as the echo approached the two cities (fig. 2E, F), but then lost its identity except for a small hole in the center of the main echo, probably caused by the centrifugal force of the tornado circulation removing hydrometeors from the center of the circulation. The open V to the north is very well defined in these two pictures. Except for one report, described later, there was no evidence that a tornado, per se, existed during the early observations. This is the first known observation of a tornado in which the hook was completely developed before the tornado touched the ground. Although this hole was approaching Bryan rather than College Station, the possibility of a tornado in College Station was still

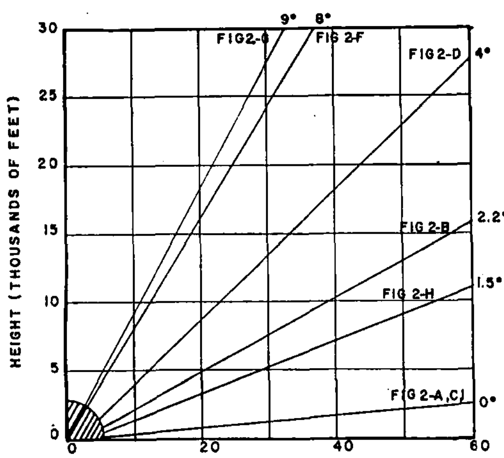

FIG. 3. Height of the center of the radar beam for pictures in Fig. 2. Beam thickness is indicated by the distance between the 0° line and the 4° line.

great, since a second funnel could have, and, as will be seen later, probably did, form to the south of Bryan.

The elevation angles of the antenna at the time of the pictures indicate that the circulation extended to rather high altitudes (fig. 3) and had very little, if any, slope. Two reasons reinforce this conclusion: (1) the location of the hole would be over the surface position of the damage path if the path were extrapolated backwards, and (2) since the radar integrates all signals over its beam width, the hole would not show if the slope within the beam width was greater than the diameter of the hole.

The apparent width of the hole at 1449 CST was approximately one mile, with some flatening of the edge on the sides normal to the radar beam axis. Assuming the beam width is accurately defined by the half power points, then the hole is approximately one-third of a mile wider on the axis normal to the beam than the pictures indicate. This would make the actual hole and circulation more nearly circular.

A single report of a tornado on the ground approximately 20 miles west of the station was checked several days later, but could not be confirmed either by visual inspection or through conversation with residents in the area. The hooked portion of the echo passed over the southern section of Bryan Air Force Base 10.5 miles west of the radar station without any funnels being reported. The maximum wind speed at the airbase weather station was 62 knots, and hail one inch in diameter was observed.

The storm struck the two cities at approximately 1509 CST with winds measured to 75 knots at the College Airport two and one-half miles southwest of the campus, and 55–60 knots on the campus itself. Hailstones with diameters up to one inch were also observed in both cities.

The tornado was located near the center of the echo as evidenced by a small circular hole at the tip of the arrow. The hole is not readily discernible in figure 2H, as a portion of the ground pattern is unfortunately located in the center of it, interfering with its observation. The hole, approximately five times larger than the width of the surface damage, coincides in position with that of the damage.

The picture in figure 2H was made at about the time of the first surface damage. Subsequent pictures taken at high and low elevation angles during the next several minutes did not show any indication of this hole. The pictures made at high elevation angles have some unusual shapes which must result at least partly from the sharply slanted beam.

It was not known until sometime later that a tornado had actually occurred because heavy rain reduced visibility in the direction of Bryan from observers at College Station.

A survey of the surface damage revealed two separate paths of destruction (fig. 4). The least destructive of the two circulations first dipped down one block north of Crockett Elementary School and caused minor damage to two rooftops. From the northward path of movement, it may have passed directly over the school. Its path later joined that of the other tornado, which first touched the ground just west of Bryan; then moved east-northeastward at about housetop level with a path about 400 yards wide, and passed within one block of Stephen F. Austin High School where students were huddled in the hallways.

Eyewitness accounts varied from one reporting five funnels aloft at the same time, to a more conservative witnessing of one large amorphous cloud mass. Several observers reported seeing a small, well-defined funnel and a large, low-hanging amorphous cloud at the same time. After reconciling the reports with the observed damage, it seems clear that the observation of two tornadoes is correct. The relative positions of the two indicate that the funnel cloud caused the north-south damage path, and the amorphous mass caused the east-west path. The radar pictures show one circulation only, that associated with the large cloud mass. Most of the other, but not all, radar observations of tornadoes in which the characteristic hooked echo shape has been seen were associated with either a very wide tornado (one-half to one mile) or a low-hanging mass without definition, similar to this one.

Several minutes later (fig. 2-I) with a low elevation angle setting, it was possible to identify what appeared to be a circulation pattern in the northernmost echo, with a cyclonically curved inflow at the north, and what appeared to be an anticyclonic shaped hook on the south. This was probably a result of an inflow into the storm rather than an outflow. There was no indication of any surface damage in this area; however, it is possible that the circulation was developed aloft and never reached the surface.

There were no casualties as a result of this tornado, but the exact effectiveness of the radar warning cannot be accurately assessed. The buildings which suffered the most extensive damage were unoccupied warehouses and residences, and heavy rain which occurred with the tornado kept most people off the streets and safe from flying debris. The radar warning did keep the school children sheltered in the schools and almost certainly did prevent injuries to them.

This is believed to be the first warning of a tornado based solely upon interpretation of the radarscope. In making this statement, the intention is not to take credit away from persons, particularly those in the Texas Tornado Warning Network, who have issued warnings based upon relayed visual observations and expected path of movement. Also, the value of the Kansas City forecast in locating the area of potentially severe weather must be given appropriate recognition.

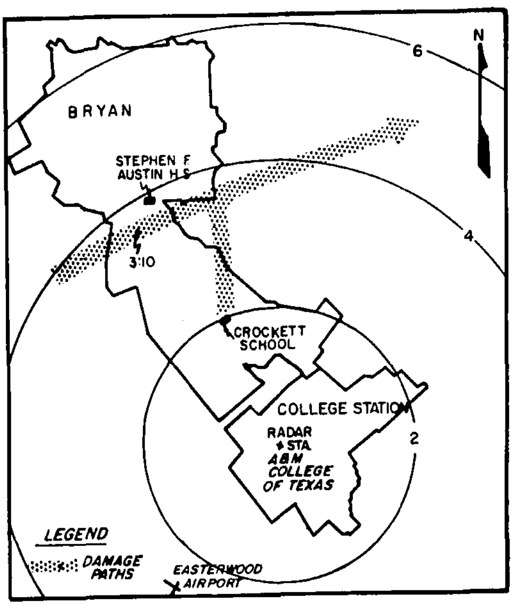

FIG. 4. Location of radar station and damage path through Bryan, Texas, as reported by Dr. A. H. Glaser.