The Atlanta Tornado of 1975

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ABSTRACT

Joint observations by radar and high-frequency sferics detectors at Georgia Institute of Technology provided unique data on the Atlanta tornado of 24 March 1975. The classic hook echo was detected by radar at a range of about 26 km, 15 min before the tornado touched down. While the tornado was on the ground the sferics burst rate was very low, despite very high values recorded immediately before and after this interval. This observation, together with visual reports of a strong cloud-to-ground discharge at the time of tornado touchdown, suggests an interaction of the tornado with the electric field of the storm.

1. Introduction

On the morning of 24 March 1975 a tornado crossed the northwest side of Atlanta, causing damage estimated at $56 million along a 19 km path. The tornado passed within 5 km of the Georgia Institute of Technology (Georgia Tech), where high-frequency sferics receivers and a radar were set up for detection of severe weather. The proximity of the storm to the sensors provided a unique set of data, which was supplemented by eyewitness reports and by an aerial survey of the damage area. The classic hook echo indicative of a tornado was observed by radar, and the sferics receivers revealed a near-cessation of electromagnetic signals while the tornado was on the ground. These observations illustrate the potential value of sferics and radar as severe weather warning techniques.

2. Synoptic situation and local weather

At 0700 EST[1] (1200 GMT) on 24 March 1975 a rapidly moving cold front, extending out of a deep closed low pressure system over Iowa, was moving into northwest Alabama (Fig. 1). A severe squall line ahead of the front was just entering the extreme northwest corner of Georgia and moving eastward about 65 km h^{-1}. A strong southerly flow of warm moist air at the surface was producing scattered thunderstorms over northern Georgia ahead of this line.

The thunderstorm that produced the Atlanta tornado moved toward Atlanta at an almost constant speed between 0500 and 0700, well ahead of a line of thunderstorms. The National Weather Service issued severe thunderstorm and tornado warnings for Atlanta at 0535 and 0615, respectively, based primarily on radar observations. The tornado touched down at 0630 west of town and moved toward the northeast at about 86 km h^{-1}, causing very heavy damage in northwest Atlanta along a 400 m wide path. About $1\frac{1}{2}$ h after the tornado, a squall line passed across the city with strong gusty winds and heavy rain.

3. Radar observations

The Georgia Tech weather radar is a 250 kW, 9.4 GHz (3.2 cm) noncoherent system with a beamwidth of 1.8°. The antenna is located on the roof of the eight-story Graduate Library on the campus (33°46′N, 84°24′W) and the transmitter and receiver are on the eighth floor. A plotting board, co-located with the displays on the seventh floor of the Library, facilitates tracking of thunderstorms. The radar configuration at the time of these observations provided a minimum detectable signal of −88 dBm, or 7.3 dBZ at 25 km range. On 24 March 1975 the radar was activated at 0200. Several lines of thunderstorms moving from southwest to northeast along an approximate heading of 30° were tracked before the storm that produced the Atlanta tornado was detected.

Fig. 2 shows the history of this thunderstorm, based on films from the National Weather Service radars at Centreville, Ala., and Athens, Ga. The storm formed in southern Alabama, 350 km southwest of Atlanta about 0300. The mature storm crossed into Georgia at a speed of ~90 km h^{-1} just after 0500. Two major cells topping 14 km with extremely heavy precipitation could be detected within the storm at this time. Convergence between these two cells began between 0500 and 0530.

The Georgia Tech radar operators first began tracking the thunderstorm at 0514 when the most easterly cell was near 90 km range on an azimuth of 238° from Georgia Tech. The ground track of cell location derived

[1] All times will be given in EST.

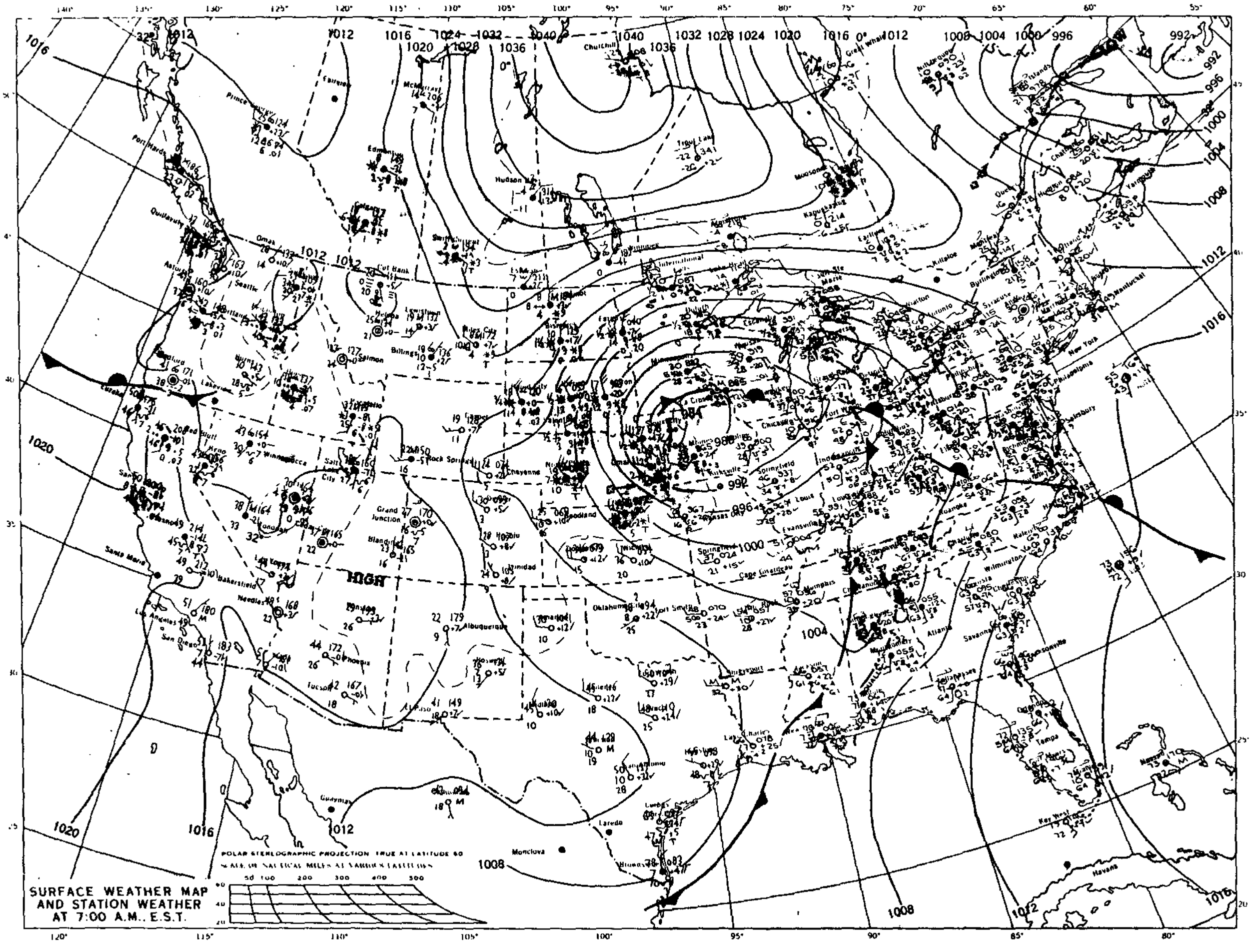

Fig. 1. Surface weather at 0700 EST 24 March 1975. Major squall line is just entering northwest Georgia about 30 min after the tornado occurrence at Atlanta.

from Georgia Tech radar data is shown in Fig. 3. The easternmost cell was topping 12 km at 0551 and was 40 km from the radar at 228°. The second cell, which was about 20 km WSW of the first at 0515 (Fig. 2), was topping 13 km and much closer to the other at 0555. The two cells had merged completely by 0559 so that they were no longer distinguishable as separate targets.

At 0610 the radar antenna was scanned at 2.0° elevation, corresponding to a beam height of 1 km at 28 km range. A wedge of extremely high reflectivity was observed to form on the PPI at this time at a range of about 28 km and an azimuth between 225° and 245°, within the storm echo near its southeast side. The sides of the wedge were no longer than 5 km and nearly straight, and the tip of the wedge was aligned with the direction of storm movement. This echo shape was probably due to attenuation in the high-precipitation core. Estimated two-way attenuation of 10–20 dB km^{-1} in the core implies rainfall of 150–250 mm h^{-1} but no quantitative reflectivity measurements are available to confirm this approximation.

The wedge was observed to form a hook at 0615 at a range of 26 km. At 3° beam elevation, corresponding to an altitude of 1.4 km at 26 km range, the hook apparently merged with the general precipitation echo within the thunderstorm, as it could not be discerned. At 1° beam elevation the hook was clearly defined and the vault area within the finger of the hook was no more than 4 km in diameter. The tip of the hook curved toward the main area of precipitation at 0620 forming a hole in the echo structure. The approximate diameter of the hole was 2 km at a range of 19 km with the antenna elevation angle about 1°. The hook was clearly discernible again by 0629 at a range of 7 km and azimuth of 260° and persisted until approximately 0633 when power was lost on the Georgia Tech campus. Auxiliary power was restored almost immediately but the high-voltage generator for the radar transmitter could not be restarted until 0648, at which time the hook was no longer visible and the main mass of the thunderstorm had moved north of the radar site.

The thunderstorm continued to move north-northeast on a heading of 38°. When the storm was approaching Buford, Ga., another hook echo was seen to form at 0704 at a range of 33 km and azimuth of 38°. No

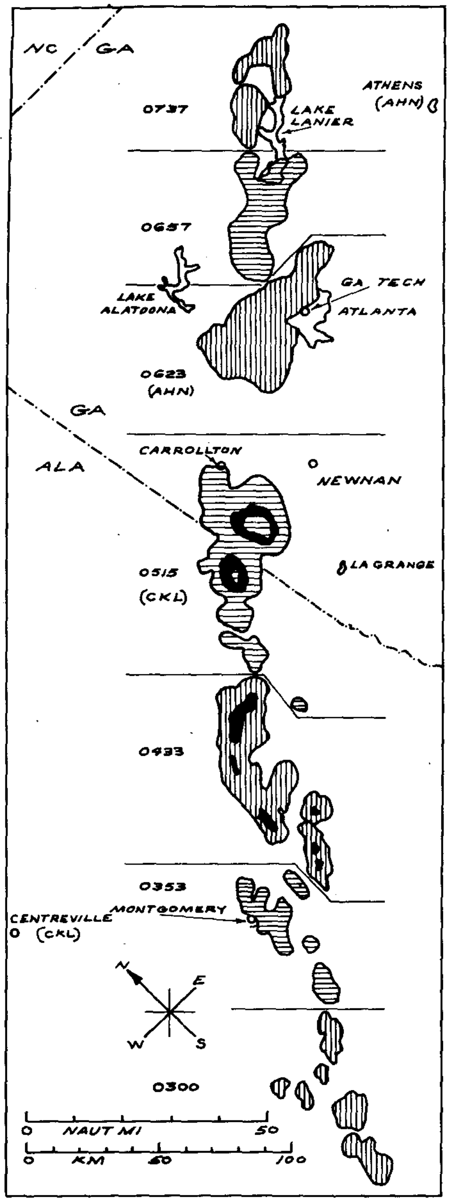

FIG. 2. Movement of Atlanta tornado thunderstorm as observed by NWS radars at Centreville, Ala. (CKL) and Athens, Ga. (AHN). Time shown is EST throughout. Quantitative display from CKL reveals multicellular structure. Display from AHN at 0623 shows indentation in southeast side of storm just ahead of location of hook echo detected by Georgia Tech radar.

further tornado activity occurred, however, and shortly thereafter the thunderstorm began to dissipate.

4. Sferics observations

Electromagnetic signals emanating from thunderstorms are strongest in the frequency range 1 to 100 kHz (VLF). Signals in this frequency range, however, are due mainly to cloud-to-ground discharges and the associated "ground waves" degrade the range discrimination of the receiver. Discharges within the cloud contribute more to the signals at higher frequencies. Studies by Taylor (1972, 1973b) have shown that tornado-producing thunderstorms have significantly more electrical activity than non-tornadic storms and that frequencies above 1 MHz (HF) are best for observing this enhancement. Sferics occur in bursts, each of which is associated with a single discharge. The individual pulses which constitute the burst have been counted at rates in excess of 10^5 s^{-1} for brief periods. The receivers used in this study were designed to integrate these pulses to form a burst count. For applications such as ours the burst rate is the more useful parameter, being easier to measure and to interpret.

On the morning of the Atlanta tornado four high-frequency sferics receivers were operating on the campus. One of these, built by Georgia Tech to operate at 2.8 MHz with a 6 dB bandwidth of 600 kHz, was used to count sferics bursts. A Racal receiver equipped with a Watson-Watt crossed-loop antenna and tuned to 2.8 MHz displayed angle of arrival for each burst. A military R-390 receiver was used to monitor sferics activity aurally in order to distinguish signals due to corona discharge. The Georgia Tech sferics burst counter has three registers, which record burst signals exceeding thresholds of -70, -60 and -50 dBm, respectively. Thus it is possible to derive a gross indication of range to the source by observing the register in which each burst count is displayed. The bursts are counted in intervals of 10 or 60 s (operator selectable). In addition, four 8-digit counters count the number of individual sferics pulses occurring in each quadrant. The direction-finding receiver displays each burst as an azimuth strobe on an X-Y display scope.

The fourth receiver was one designed by Taylor (1973a) and loaned to Georgia Tech in conjunction with a NASA-sponsored severe weather monitoring project. This NOAA sferics receiver operates at 3.0 MHz with a 6 dB bandwidth of 300 kHz. Burst rate thresholds are shown by four lights on the front panel: white ($\sim$3 min^{-1}), green ($\sim$10 min^{-1}), yellow ($\sim$20 min^{-1}) and red ($\sim$30 min^{-1}). The red light is supposed to indicate a high probability of tornadic activity. Differences in the techniques of computing the burst rate from the sferics pulses and differences in the amplitude thresholds of the NOAA and Georgia Tech receivers account for the quantitative differences in the data.

The burst rate data for the period 0515–0945 are shown in Fig. 4 for 6 min running averages, i.e., each 1 min data point is the burst rate averaged over a 6 min interval. Prior to 0515 the burst rate remained less than 50 counts min^{-1}. Sferics azimuth data showed that all the signals were arriving from the southwest quadrant at angles of 215° to 245° between 0500 and 0615. Thus we concluded that all the high-amplitude sferics signals recorded during this interval emanated from the isolated thunderstorm that produced the Atlanta

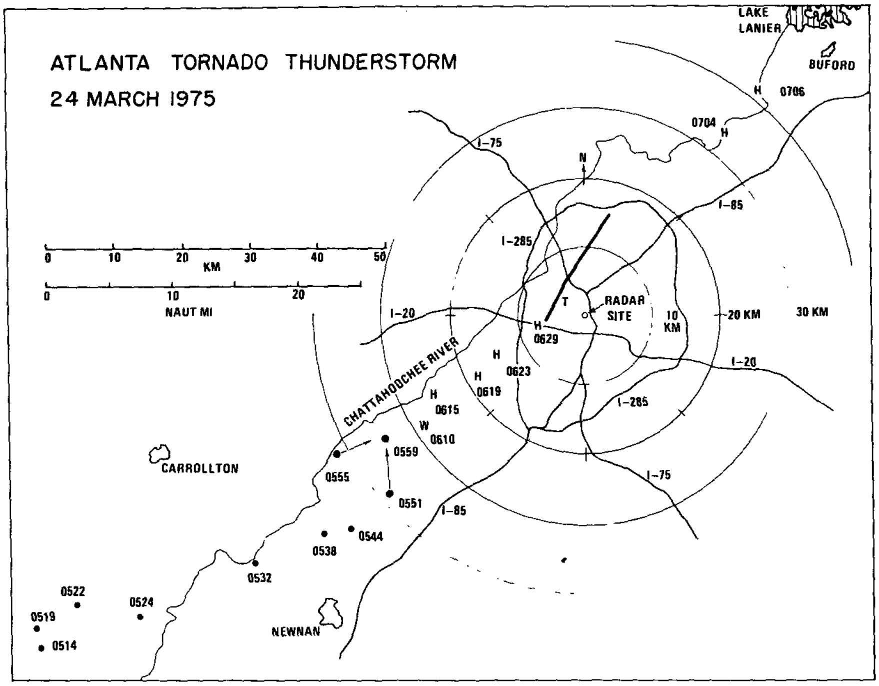

FIG. 3. Movement of storm cells and hook echo observed by Georgia Tech radar, and other storm features associated with Atlanta tornado. Time (EST) is noted for each location. Wedge and hook echo locations are denoted by W and H. T denotes tornado ground track. Interstate highways, Chattahoochee River and several towns are shown for geographical reference.

tornado. Fig. 5 shows the 1 min burst rate data and illustrates the rapid fluctuations in burst rate that occur at this time scale. The burst rate showed marked increases at 0525, 0545 and 0607, with significant minima between these times. During the period that the tornado was on the ground the burst rate dropped to a very low value.

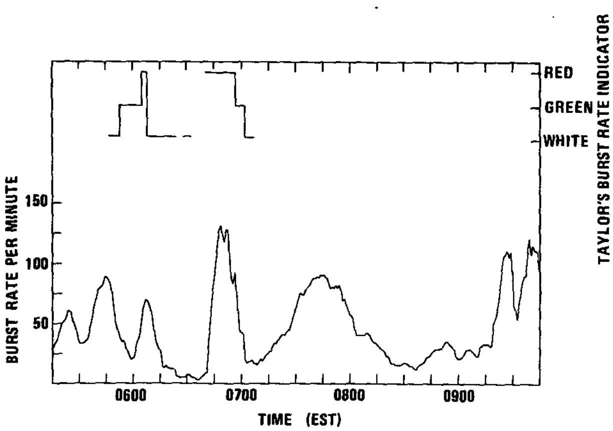

FIG. 4. Sferics burst rate record for 0515–0945 EST averaged over 6 min intervals. Three peaks are recorded as the storm approaches between 0515 and 0615. While the tornado is on the ground (0630–0645) the count is less than 10 min^{-1}; it increases rapidly to 130 min^{-1} as the tornado lifts. Peak burst rate at 0730–0800 is associated with squall line following the tornado. NOAA sferics receiver display shows qualitative agreement with Georga Tech sferics between 0600 and 0710.

The aural output of the R-390 receiver was consistent with the data recorded by the direction-finding equipment. Prior to tornado touchdown the operator noted a high-level aural output in the form of "static." At the time of touchdown when the burst rate dropped to a very low value the aural output from the communications receiver became "very quiet."

The indications of the NOAA receiver are shown with the Georgia Tech burst rate data in Fig. 4. (The "yellow" channel was not functioning properly on this day.) The instrument had been set to register signals

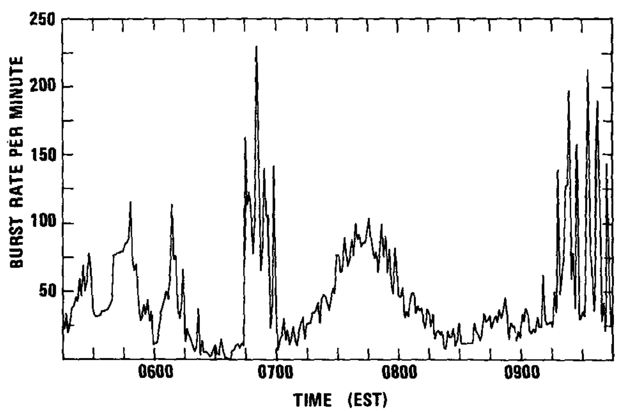

FIG. 5. Sferics burst rate record for 0515–0945 EST with values given at 60 s intervals. Major features correspond to those in Fig. 4, but shorter counting time reveals rapid fluctuations of count. Note particularly the very rapid increase from about 10 min^{-1} to over 150 min^{-1} at 0645 as the tornado lifts.

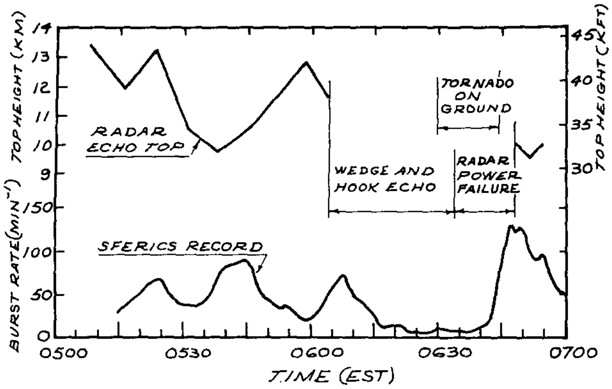

FIG. 6. Sferics burst rate and radar echo top height. The two parameters are partially correlated during the approach of the storm, prior to the tornado. Decrease of top height after 0600 suggests a collapse of the precipitation core.

out to its nominal 30 km range threshold, although a modified antenna permitted detection to about 40 km. The NOAA receiver began to indicate severe weather activity (white light) about 0545, about the time of the second burst rate increase indicated by the Georgia Tech receiver and when the major storm cell was about 46 km distant. The burst rate increased to medium (green light) at 0555 and continued at this level until 0608. During this time the burst rate indicated by the Georgia Tech receiver decreased significantly for a brief period. This lack of correlation in burst count is probably associated with the different amplitude sensitivities of the two instruments. It is also possible that a brief status change of the NOAA receiver may have gone unnoticed by the operator. (The sferics data from the Georgia Tech receiver were automatically recorded by a digital printer, whereas data from the NOAA receiver were recorded manually by the operator.) At 0608 the high burst rate indicator (red light) became active for approximately 2 min. This indication occurred about 20 min prior to confirmed touchdown of the tornado and simultaneously with the reported funnel cloud formation (see Section 5). At 0610 the NOAA receiver dropped from "red" to "white" status and continued to indicate either low burst rate or no counts (all lights out) until 0640. Beginning about 0640 the Georgia Tech sferics receiver indicated a marked increase in burst rate and the NOAA receiver again went to "red". This increase in burst rate occurred about the time the tornado reached the end of its ground track. Fig. 4 shows that between 0600 and 0705 a good qualitative correlation existed between the NOAA and Georgia Tech receivers. However, during the period 0705–0945 activity was indicated by the Georgia Tech receiver while no sferics activity was recorded by the NOAA receiver. It is not known whether this absence of counts after 0715 was due to the high-amplitude threshold of the NOAA receiver or to operator inattention following the occurrence of the tornado.

It is of interest to compare the sferics data with quantitative radar measurements of storm development. Fig. 6 shows the radar echo top heights and sferics burst rate for 0500–0700. The peaks of the sferics burst rate and the radar echo tops occurred together at 0525. However, the sferics maximum at 0545 led the radar echo top by approximately 15 min, while the sferics maximum at 0607 lagged the echo top by about 10 min. The decreasing echo top height after 0600 suggests the beginning of a collapse of the precipitation core, which several authors (e.g., Eskridge and Das, 1976) have associated with the formation of tornadoes.

5. Visual observation

The tornado was observed visually from the seventh floor roof of the Graduate Library. No precipitation fell before or during the tornado at the radar site. The hook had been visible on the radar display for about 10 min before the observer went to the door overlooking the roof at approximately 0625. He observed an unusually large cloud-to-ground discharge of lightning at an approximate azimuth of 250°. The discharge approximated a cylinder of angular diameter 0.7° (equivalent to a ball point pen held at arm's length). The 0626–0628 time of occurrence would have placed the discharge within 2 km of the location where the funnel first touched the ground. The lightning stroke was a very intense bluish color with no points of deviation from the vertical axis. Other witnesses from the community, calling on a radio talk show in the evening, commented on the intensity and unusual appearance of the stroke. This stroke was the only form of natural electrical activity observed from the Georgia Tech vantage point on the southeast side of the storm.

The tornado appeared as a dark cloud with an estimated angular diameter of 5° and was observed about 0627–0629 at an azimuth of approximately 250°. It extended to the ground from the cloud base of ~300 m. The sides of the dark cloud were vertical, but no characteristic funnel shape was observed at any time. Green flashes appeared within the vortex between 0628 and 0633. These flashes are thought to be due to broken power lines rather than to natural electrical phenomena as power to the Georgia Tech campus was disrupted about this time.

An attempt was made to visually correlate the tornado's actual location with the radar hook echo. The tornado vortex appeared to lead the hook by ~2 km, but no accurate optical angle measurements were available to confirm this finding.

The entire tornado track was photographed from the air. The flight extended 35 km beyond each end of the 19 km track to determine if the tornado had caused additional unreported damage. The first damage, on the southwest end of the track, occurred 2 km south-southwest of the Perry Homes subdivision and 6 km west of the center of the city. An eyewitness reported a funnel cloud between 0600 and 0615 approximately 25 km south-southwest of the point of touchdown. This location is in line with the observed ground track of the tornado but no damage was found southwest of the point of touchdown.

To the northeast there was evidence of sporadic damage beyond the official 19 km ground track. This damage took the form of trees uprooted from the ground in no specific pattern. A number of trees were uprooted in a wooded area southwest of Buford near where the second hook echo was observed at 0704. However, it could not be determined from the air whether these trees were felled by straight-line winds or by a tornado at tree-top level.

6. Summary

The Atlanta tornado was one of the best documented occurrences during the January–June 1975 Georgia tornado season. The isolated thunderstorm that generated this tornado was observed by NWS and Georgia Tech radars, and Georgia Tech sferics receiving equipment monitored its electrical activity. Eyewitness reports, radar observations, and analysis of aerial photographs place the locations of the hook radar echo and the funnel cloud within 2 km of each other. The vortex formed at the merging point of two cells within the storm, where a wedge-shaped radar echo with very high reflectivity was observed. The classic hook echo shape was observed about 15 min before the time of the first damage.

The sferics data indicate that as the funnel approached the ground the electromagnetic signals from the storm fell to an extremely low level. We suggest that this near-cessation of HF sferics activity occurred as a result of the funnel's acting as a short circuit between cloud and ground. The unusual cloud-to-ground electrical discharge observed at the moment of tornado touchdown supports this theory.

Taylor (private communication) described one similar observation made by an amateur radio operator who noticed a sharp reduction of static on his radio at the same time that he saw a tornado touch the ground. Observations of sferics signals by Taylor (1973b, 1975) which include ten cases of confirmed tornadoes within 10 km of the receiving equipment, have not shown any reduction in burst rate while the tornado was on the ground. The 3 min time constant of Taylor's receiver could smooth out a sharp reduction in burst rate in cases of short-lived tornadoes, but this factor does not apply to tornadoes that persist for longer periods of time.

Another possible reason for the lack of reports of the phenomenon we observed is that few sferics observations have been made as close as 7 km to a tornado in an isolated thunderstorm. If a line of thunderstorms contained ten electrically active cells and one of these produced a tornado, then the burst rate observed by an omnidirectional receiver would be reduced by only 10%. Such a decrease would be hard to detect with any certainty. The continuing improvement in sferics detection equipment, particularly in directional measurement at high frequencies, emphasizes the necessity for continued research in this area. Our observations illustrate the value of using both sferics detectors and radar in operational severe weather detection, as the data from each sensor tend to reduce the uncertainties or ambiguities of interpretation of data from the other.

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