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SUPEROUTBREAK TORNADOES OF APRIL 3, 1974 AS SEEN IN ATS PICTURES

T. Theodore Fujita and Gregory S. Forbes

The University of Chicago
Chicago, Illinois 60637

1. INTRODUCTION

Mother Nature has a tendency to produce tornadoes in the form of outbreaks. Most outbreaks are characterized by several tens of tornadoes occurring in several states in the Midwest.

In the U.S. history, however, there are cases of outbreaks involving extraordinary numbers of tornadoes over a wide-spread area. We may identify an outbreak involving more than 50 tornadoes within a 24-hour period as a "superoutbreak".

Ludlum (1974) pointed out the existence of the 1884 superoutbreak which occurred on 19 February 1884 in the states of Mississippi, Tennessee, Kentucky, and Indiana. Eight hundred people were killed by more than 60 separate tornadoes. So far as we know, no superoutbreak of such a magnitude occurred for a 90-year period.

The extraordinary outbreak of April 3-4 tornadoes is highly qualified as the "superoutbreak" of the century. For ease of memory, Fujita (1974) called the superoutbreak the Jumbo (747) outbreak, because the outbreak began in 1974 on the 3rd day of the 4th month of the year.

A total of 122 separate tornadoes were confirmed and mapped at the University of Chicago as of August 15, 1974. The statistics are subject to future revision. An extensive aerial survey was conducted for mapping the precise paths and characteristics of individual tornadoes.

Main objectives of the tornado survey are (1) to determine the life of individual tornadoes, (2) to assess the life of tornado-producing thunderstorms, (3) to investigate the variation of tornado intensity along the paths, and (4) to relate the variation with possible changes in the cloud tops seen by satellite.

2. INDIVIDUAL TORNADOES AND WARNING

A tornado warning is issued based mainly on the report of funnel-cloud sighting. Such a warning is effective only if a tornado stays on the ground much longer than the time required for transmitting warning to the public.

During the Jumbo Outbreak, more than 100 tornadoes were reported, thus initiating at least 100 warnings to nearby communities. The locations of reported tornadoes are presented in Fig. 1. 20 reports are in Indiana followed by 17 in Tennessee, 14 in Kentucky and also in Alabama. If a tornado on

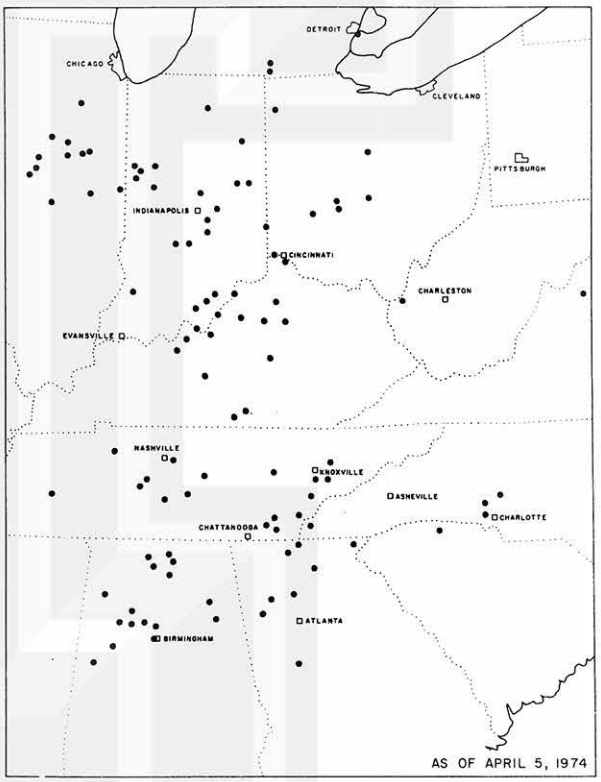


Fig. 1. Suspected location of tornadoes prior to the aerial survey. The dots represent tornado reports taken from SELS Log and Chicago newspapers. The University of Chicago survey team was assigned areas of responsibility based upon this map.

the ground is no more than a hit-and-run type of incident, issuance of a warning may not be fast enough for effective preparedness.

In an attempt to confirm the extent and the area of each tornado, an aerial survey team was organized at the University of Chicago. Up to five airplanes were used simultaneously for the purpose of mapping the damage paths which are to be found at or near the location of each black dot in Fig. 1 which was produced on April 5, the day after the end of the superoutbreak. Each member of the survey team was assigned to cover certain areas.

The tornado path map at the University of Chicago in 1:1,000,000 scale was improved each time when members of the aerial survey team returned to the base. The best possible tornado paths as of August 15, 1974 are shown in Fig. 2. The map shows regularity in the pattern of the paths, which was not evident at all prior to the aerial survey.

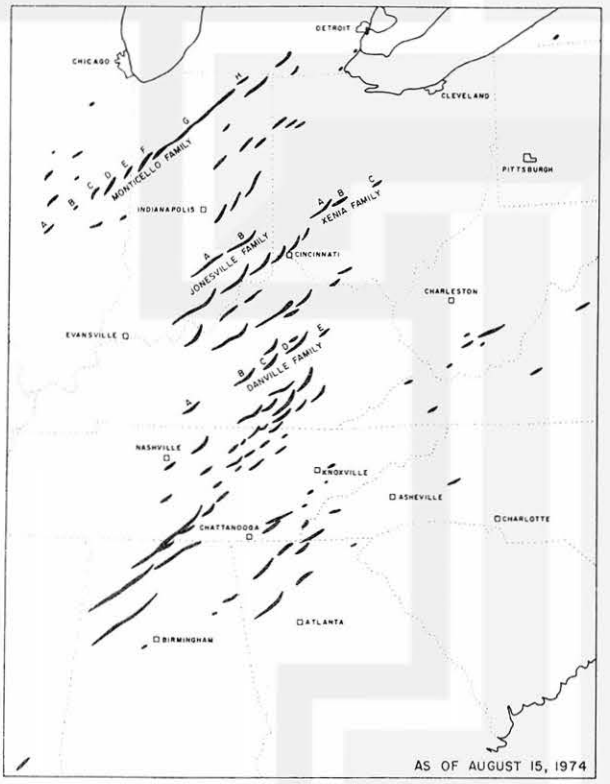


Fig. 2. Paths of tornadoes after the aerial survey. 122 tornadoes were confirmed as of August 15, 1974. Several tornado families are shown as examples - refer to Section 3 of the text for an explanation.

The life of individual tornado (Individual Life) was determined based on the path length and estimated translational speed of the tornado-producing thunderstorm. It turned out that the longest life was 125 min while the shortest one was one minute or less. As shown in the frequency distribution in Fig. 3, the most frequent life is between 10 and 20 min. The median life was 18 min and the mean was 21 min. 90% of the tornadoes had life less than 40 min. The frequency of tornadoes with life longer than 30 min decreases more or less exponentially. Although this tendency does not rule out a possibility of tornadoes which might live several hours, the maximum life was 2 hours and 5 minutes.

From the above statistics on individual life of tornadoes, one is forced to conclude that there is little chance of giving an effective tornado warning. By the time a warning is received by the public, the tornado may in many cases have lifted.

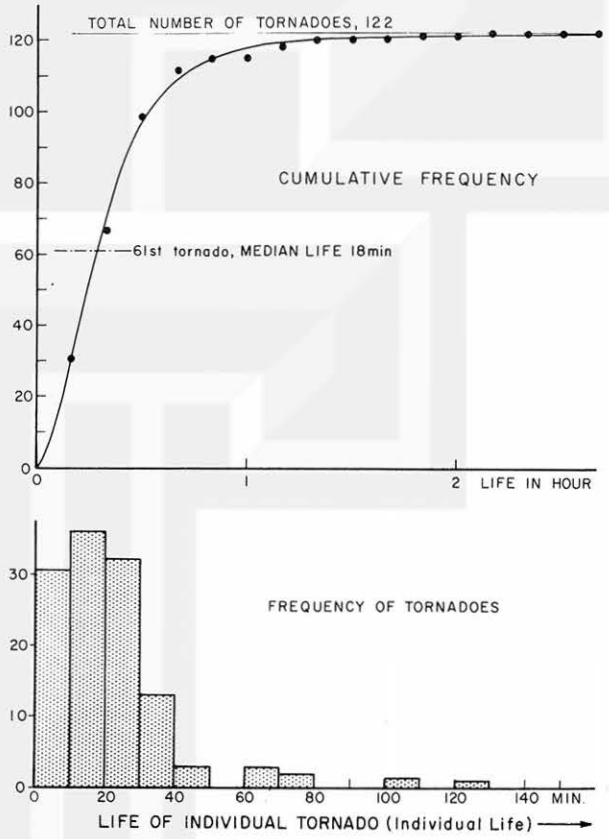


Fig. 3. Life of individual tornadoes. The frequency of tornadoes on April 3-4 with lives within 10-minute intervals is plotted in the lower graph. The upper graph shows the cumulative frequency.

3. TORNADO FAMILIES

It has been shown that tornado occurrences are not as random as indicated by Fig. 1. Accurate mapping of the paths of Jumbo tornadoes from aerial survey revealed that there are definite patterns of tornado occurrences. By visual inspection of Fig. 2 it is seen that tornado paths line up in many areas, giving an impression that the paths in a line were produced by a single thunderstorm.

We shall define a tornado family as a sequence of tornadoes spawned from a thunderstorm cell. For positive confirmation of family tornadoes, it is necessary to identify the time of occurrences as well as the existence of the parent thunderstorm. Four examples of tornado families are pointed out in Fig. 2. They are the Monticello, Jonesville, Xenia, and Danville families.

After careful examination of the data, thirty tornado families in Fig. 4 have been confirmed. A circle in the figure indicates the position within each damage path where the tornado intensity is estimated to be the highest. A box represents the section of a continuous path with complicated variations in intensity. An extremely long tornado path is regarded as that of family tornadoes which weakened in places without dissipating entirely. Two examples of long tornado paths are seen in Alabama and Tennessee. The congested pattern of tornado paths in Fig. 2 in the Kentucky - Tennessee area has been grouped into several tornado families.

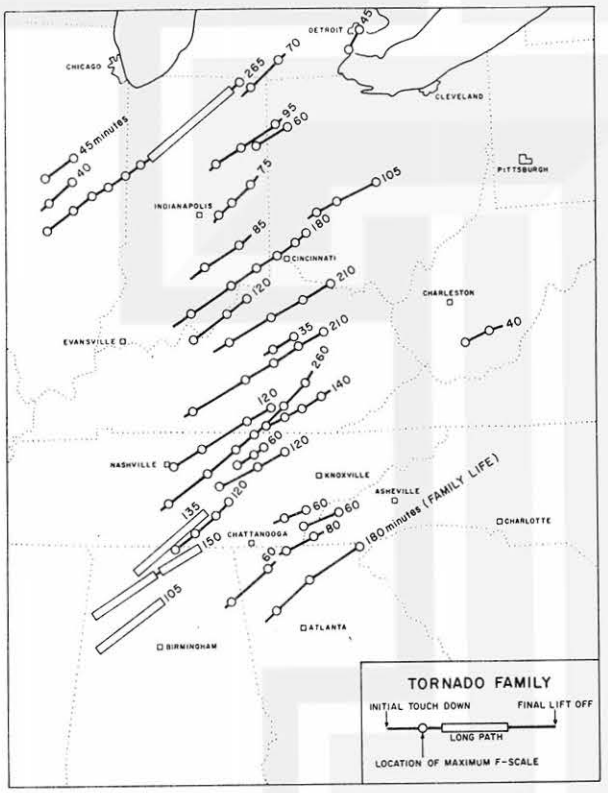


Fig. 4. Tornado families. 30 tornado families comprised 74% of the tornadoes on April 3-4. The life of each tornado family is shown beside the path. Circles indicate the location of maximum intensity of each tornado in the family and boxes indicate long tornadoes with complicated intensity variations.

90 of the 122 or 74% of the Jumbo tornadoes have been grouped into 30 tornado families. This fact is quite significant because it indicates that (a) only a limited number of thunderstorms are responsible for the production of most tornadoes and (b) forecasters may detect family-producing thunderstorms in order to predict the majority of tornadoes.

The life of tornado families may be called the "family life" and is the time between the initial tornado touchdown and the final tornado liftoff. The family life was calculated for each of the 30 tornado families in Fig. 4. The life of each tornado family is given in minutes, such as 45, 265, etc.

In an attempt to determine the distribution of the family life, the frequency of families falling into each 30-min category was computed. The frequency distribution in Fig. 5 reveals that no family had less than 30 min life. This is probably because a thunderstorm requires some time before producing the next tornado. The median family life is computed to be 105 min, while the mean family life was 111 min.

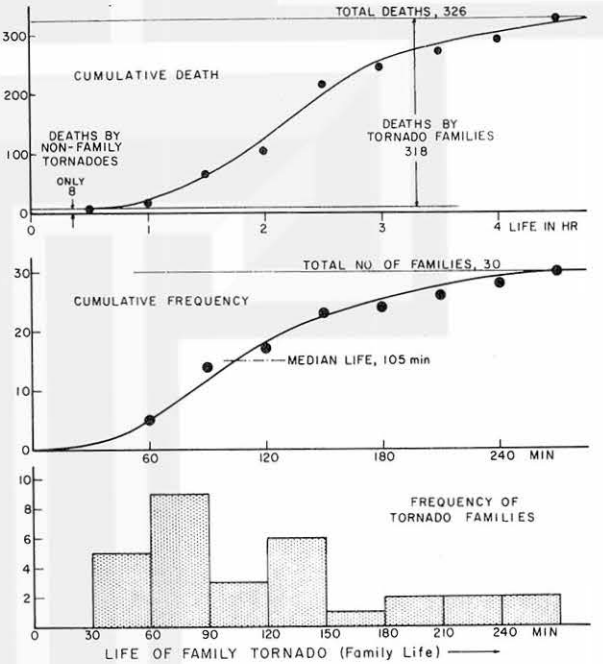


Fig. 5. Life of tornado families. The frequency of April 3-4 tornado families with lives within 30 min intervals is shown by the lower graph. The middle graph shows the cumulative frequency of deaths occurring with these tornado families.

It should be noted that the mean individual life was only 21 min, less than one-fifth of the family life. Therefore an individual tornado may not be effectively predicted, but there will be adequate time for predicting family tornadoes.

The most spectacular part of Fig. 5 concerns the deaths associated with tornado families. Whereas 74% of the tornadoes of Fig. 2 occurred in fami-

lies, 98% or 318 of the 326 deaths counted from Storm Data occurred with these families. Only 8 deaths were associated with the 32 non-family tornadoes

It is also important to find that 50% of the deaths were caused by the families with the life in excess of 2hr 15min.

4. RADAR SIGNATURES

The most generally accepted radar signature associated with a tornado is the hook echo. Ever since the initial studies by Stout and Huff (1953) and Huff et al. (1954) there have been numerous papers showing that hook echoes, indicative of rotating thunderstorms and tornado cyclones, often produce tornadoes. But the negative confirmation, hook echoes without tornadoes, has not received much attention. Thus it must be pointed out that there were numerous instances of hook echoes not producing tornadoes during the Jumbo outbreak period. One example is cited by Changnon and Morgan (1974) in eastern Illinois. Therefore tornado warnings based solely upon the existence of a hook echo could lead to "cries of wolf".

Among those hook echoes which produced the Jumbo tornadoes, the echoes had a hook-like appearance for a period in excess of the duration of the tornadoes. It can be seen in Fig. 6 that a hook echo existed prior to the touchdown of the Jonesville tornado. A study of Fig. 6 reveals that whereas one might expect a variation in echo shape or intensity as the tornado intensifies or weakens, the major changes in the echo prior to 1540 CDT are due to the decreasing range of the echo and a slight change in elevation angle. There does not appear to be a clear cut relationship between the tornado intensity and the characteristics of hook echoes.

The Monticello family, like the Jonesville family, shows considerable variation in the tornado intensity. In addition to rapid fluctuations with the period of up to 10 minutes, there appears to be a larger period of fluctuation with 30-60 min period (see Fig. 7).

So far, our research on PPI scope pictures indicates that not all tornadoes are produced by hook-echo cells. Moreover, a hook echo does not always produce a tornado during its active lifetime. Additional research on this subject is required.

5. SATELLITE AND TORNADOES

The Jumbo Outbreak was produced by three squall lines labelled A, B, C in the 1406 CDT satellite picture, each oriented approximately SW-NE. The locations of tornadoes at the time of the satellite picture are shown by dots. The direction of tornado movement before and after the satellite picture time is shown by arrows.

At 1406 CDT, each squall line is producing tornadoes. Line A is producing the Carlock and Lincoln tornadoes. Jonesville and Depauw tornadoes will shortly form from line B. Line C shows the Cleveland and Cherry Log tornadoes.

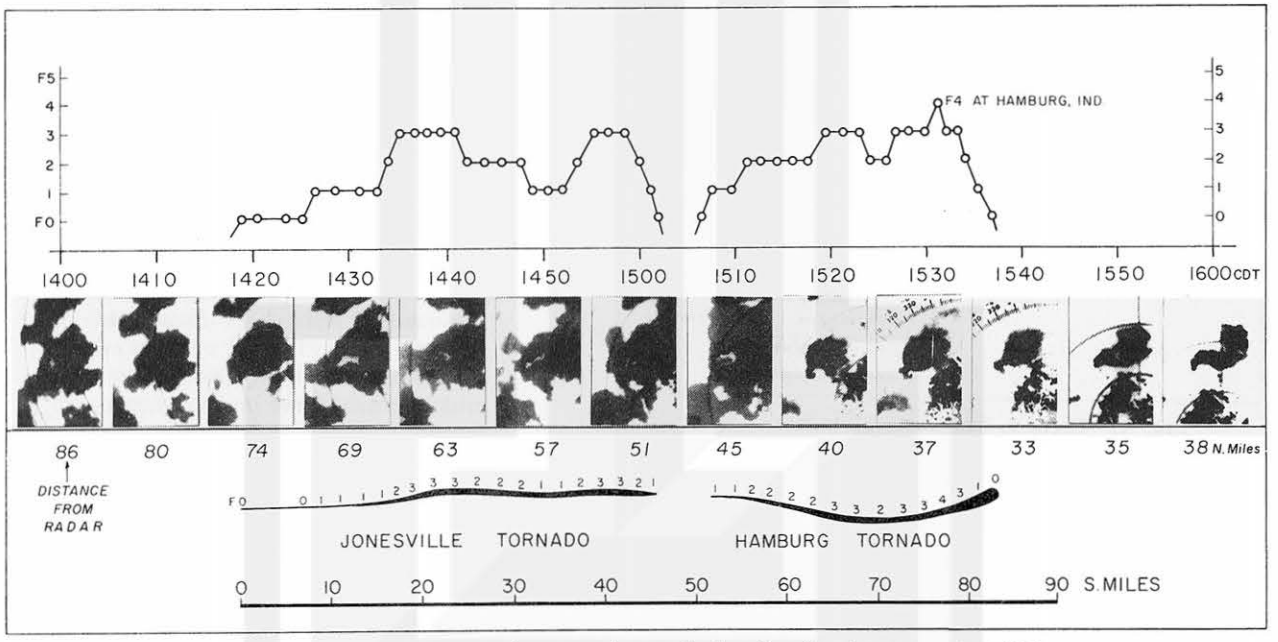


Fig. 6. Radar signature of a tornado-producing thunderstorm as revealed by CVG radar. There is no attenuation except: 15 db at 1520, 1540, 1550, 1600, and 6 db at 1530. The elevation angle was -0.4 degrees except: -0.1 at 1410, 1430, 1440; 0.0 at 1400; -0.2 at 1420, 1450; 1.8 at 1510. Tornado intensity in F-scale was determined by aerial survey.

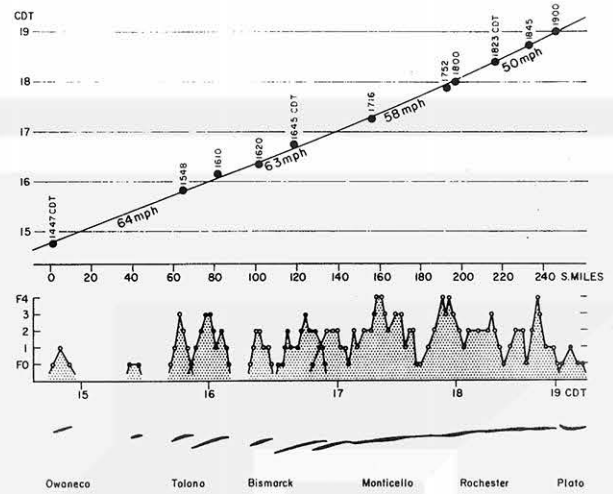
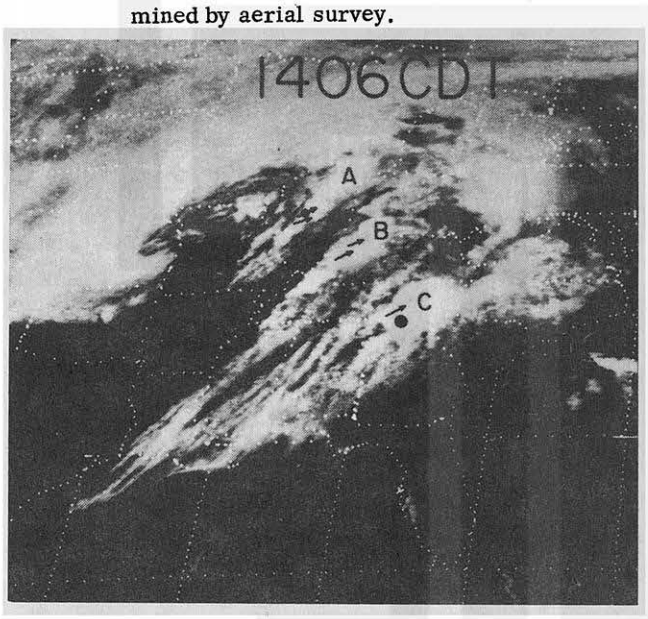


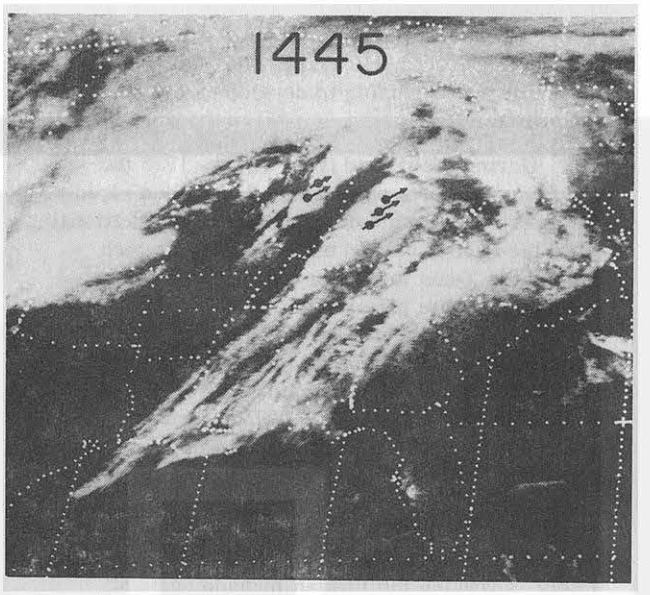
Fig. 7. Intensity variation of Monticello family. Eight tornadoes comprised the family. Several cities along the path are shown to indicate the locations of the tornado paths. The tornado intensity was determined by aerial survey.

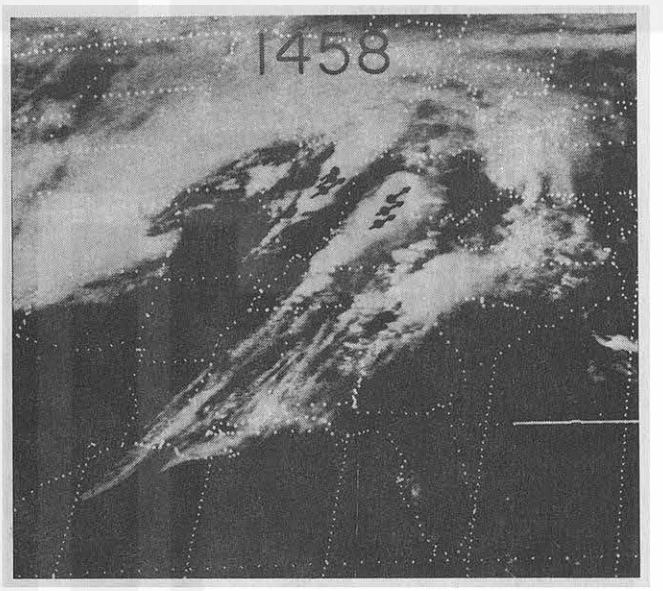


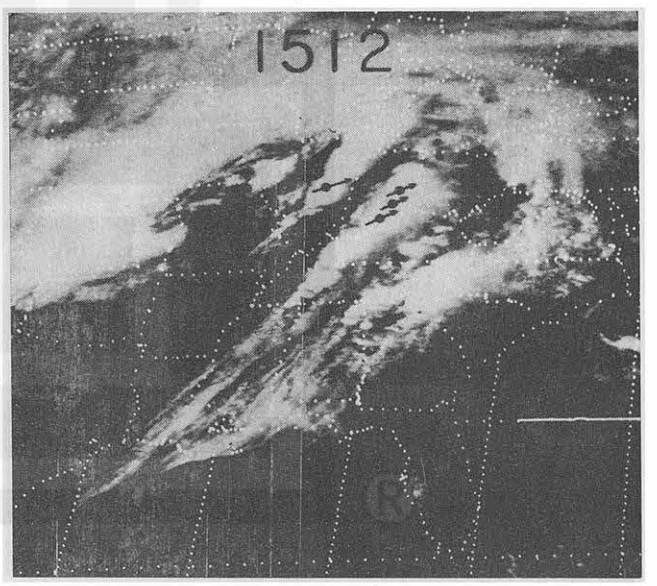
At 1445 the Anchor and Decatur tornadoes are being spawned from line A while the Fountaintown, Jonesville, and Depauw tornadoes have formed from line B. Line C is part way into an hour-long period free of major tornadoes.

At 1458 the southernmost cell on line A is very distinct. The Owaneco tornado, the first tornado of the Monticello family, occurred a few minutes earlier.

By 1512 only the Pierson tornado of the Monticello family is occurring within line A. This family had the longest life of all the tornado families of the Jumbo Outbreak. Line B is showing significant development of new cells on its south flank in Tennessee. No tornadoes are spawned from any of these new cells before 1630. A new cell is developing in line C on its southwest flank.







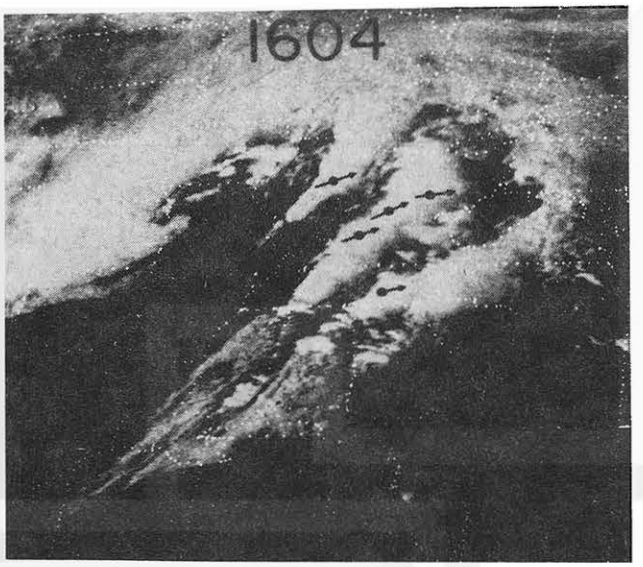
Forming in line B at 1525 are three intense tornadoes: Kennard, Hamburg, and Madison. Small cells are beginning to develop on the south flank of line A.

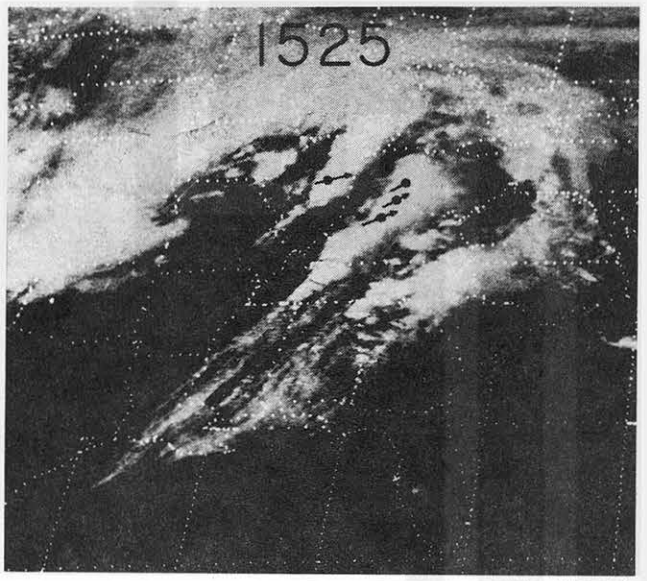
During the period from 1445 to 1525 the anvil from the north part of line B expanded rapidly. This may be due to the development of an additional cell to the east of the old but active line, which spawned the Xenia tornado a few minutes before 1538, the satellite picture time.

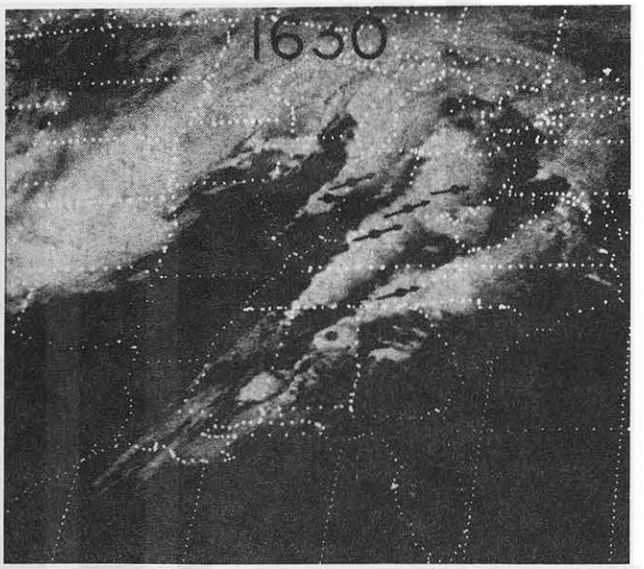
At this time line B is assaulting three states with the Xenia, Parker, Hamburg, Madison, and Brandenburg tornadoes. The Tolono tornado, the first killer tornado of the Monticello family, soon develops from line A.

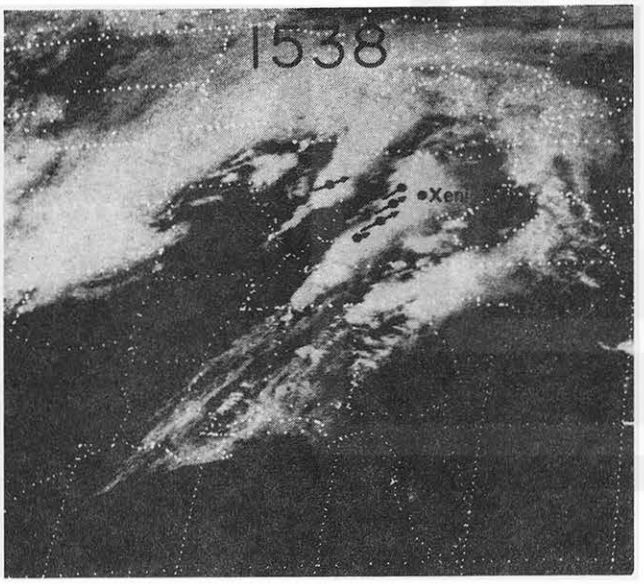
Between 1458 and 1538 the cell near the borders of Georgia, Alabama, and Tennessee grew rapidly, spawning the Etowah tornado by 1604. Forming at this time are new strong cells in Mississippi and Alabama.

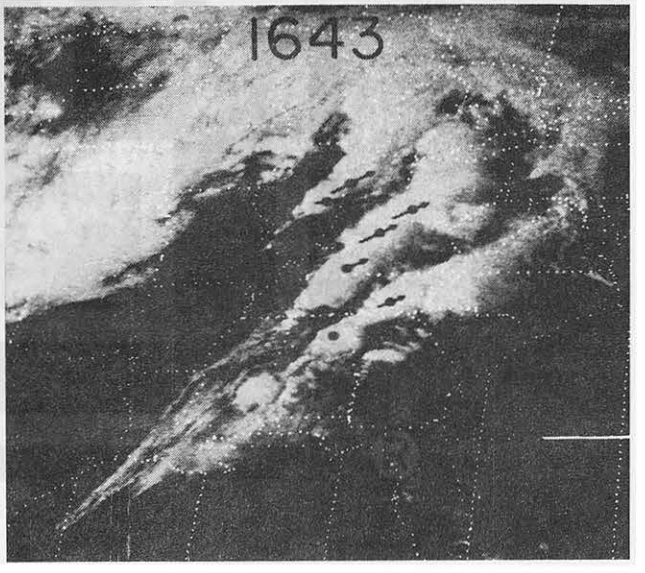
At 1630 the Charleston tornado has formed from the developing southernmost cell in line A. Line C appears to be re-forming southwestward from Tennessee to Mississippi.







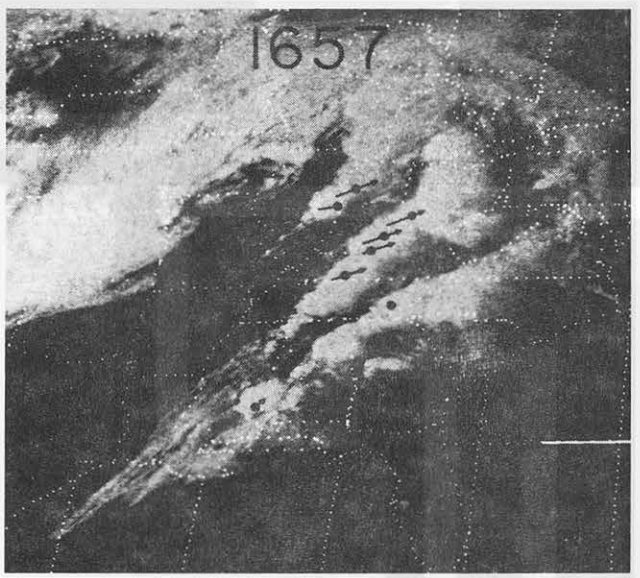


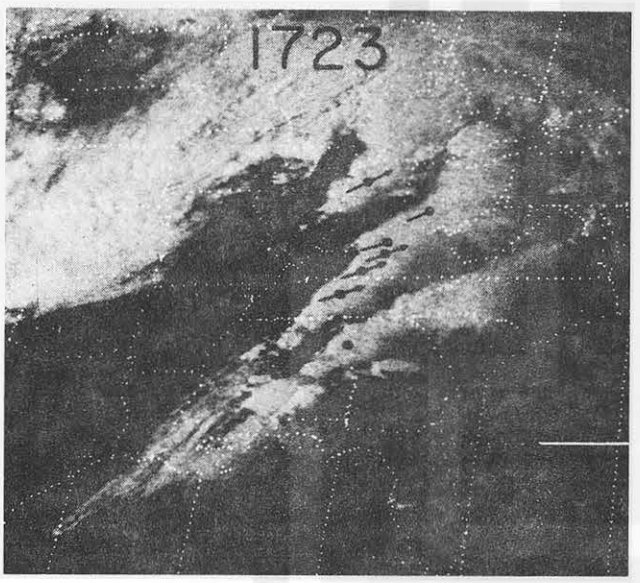


The tornado activity in line B is slowly shifting southward. The Franklin tornado of the Danville family touches down in southern Kentucky about 1643. The cell in Mississippi has become well defined.

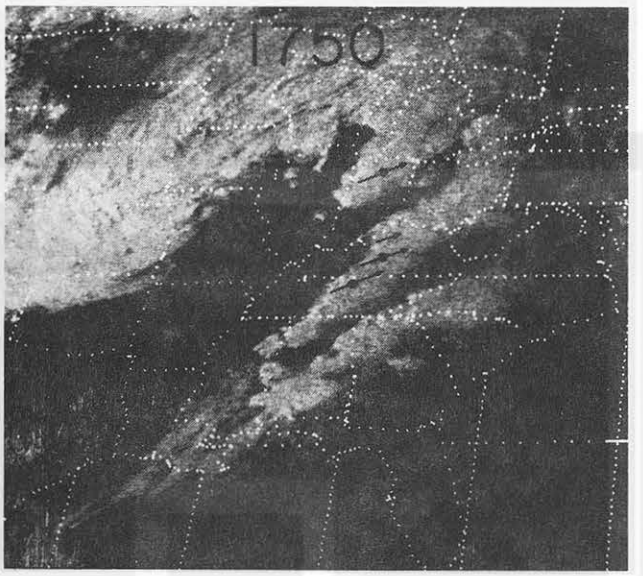
At 1657 the Laurel tornado touches down in Mississippi from line C. The Monticello tornado is occurring from line A and the Charleston tornado family is about to produce its last tornado, at Paris.

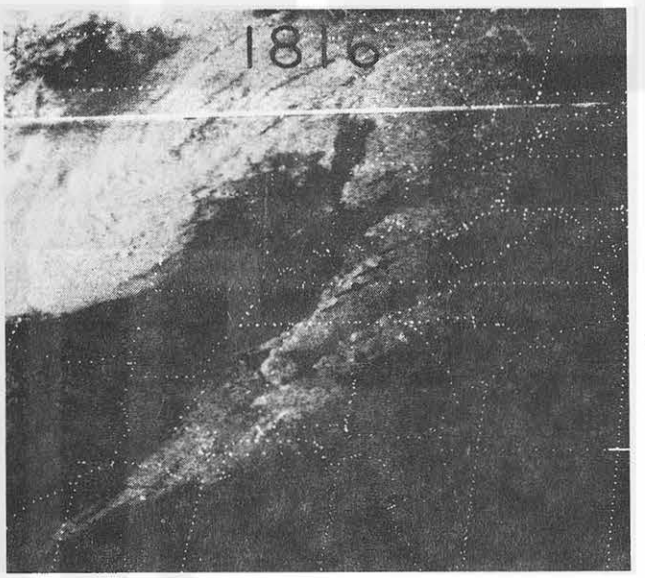
The Laurel tornado has ended by 1723, but the cell remains strong near the Mississippi-Alabama border for some time. No other tornadoes are known to have occurred from this cell however. Line B continues to develop southwestward extending into Mississippi.





At 1750 a cell can be seen growing on the Mississippi-Alabama border between lines B and C. This cell becomes a tornado producer around 1900.

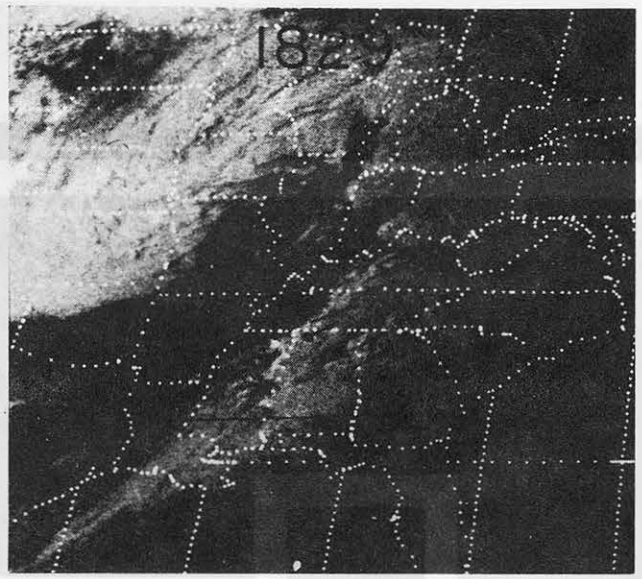




At 1816 the Monticello family is still in existence. It would be desirable to detect the changes in cloud top associated with this family. Unfortunately the ATS III pictures do not reveal these changes.

By 1829 significant numbers of tornadoes are forming in Alabama and Georgia. The Tullahoma tornado forms in NW Alabama in line B while the Resaca and Acworth tornadoes are occurring in line C. The southern cell of line A apparently produces the Swayzee tornado within a half-hour.

There has been much interest in obtaining a satellite signature of tornado-producing thunderstorms. One signature of severe thunderstorms is the appearance of thunderstorm supercells within a squall line, each supercell having a large anvil and a clear area behind its western edge. (See, for example, Purdom, 1971.) This type of thunderstorm was common on April 3, as shown in the satellite picture at 1630 for example.



Through this study it was confirmed that all tornadoes on April 3 and 4 occurred within the area of three distinct squall lines. It was also found that most tornadoes are located inside large active thunderstorm cells characterized by rapidly growing anvil and clear area to the west.

Unfortunately, however, we could not find specific features of clouds at the location of tornadoes. This is probably because the gray scale does not give enough contrast to detect small but important features of the bright thunderstorm top.

6. CONCLUSIONS

Based on the study of 122 confirmed tornadoes during the April 3-4 superoutbreak, the following conclusions have been reached.

(A) The life of the 122 individual tornadoes varied between 1 and 125 min with their mean life being 21 minutes.

(B) It was found that 74% of these tornadoes can be grouped together into 30 tornado families. In fact, 98% of the deaths were caused by these family tornadoes.

(C) The life of the 30 tornado families varied between 35 and 265 minutes with the mean life of 111 min. The mean family life is about 5 times the mean individual life.

(D) The identification of family-producing thunderstorms appears to be extremely useful in issuing a tornado alert and subsequent warning.

(E) Within the radar range of 50 miles, a tornado-producing thunderstorm often shows a hook echo on PPI scope. The PPI hook cannot be considered a fool-proof indicator of tornadoes, however.

(F) Successive formation of family tornadoes at 30 to 60 min interval implies a periodic variation of thunderstorm characteristics. It is suspected that the overshooting top of a family-producing thunderstorm varies with the intensity of tornadoes beneath the cloud.

(G) An infrared scanning from the geosynchronous altitude will be able to detect such variations if the sensor is able to detect

a. with 1.0-mile resolution

b. with one-degree NEΔT at 190 K.

Insignificant absorption above high tops of thunderstorms will permit us to use a spectral range much wider than the standard window channels.

ACKNOWLEDGMENT:-

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