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UNUSUAL FEATURES OBSERVED WITHIN A SERIES OF TORNADO PICTURES

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ABSTRACT

A 1969 Minnesota tornado was photographed by a number of observers at various points along its track. The pictures show an unusual combination of features that might possibly lend visual evidence to theoretical tornado models and such related phenomena as fire whirlwinds.

During an investigation of western Minnesota storm damage, the authors found that local residents had taken a series of photographs of a tornado situation containing a number of unusual features. Pictures were taken from a number of observation points, thus providing a varied perspective of the phenomena. Some of the more interesting photographs are shown here.

The tornado occurred about 1800 CST on Sept. 5, 1969, west of Elbow Lake, Minn. At least five observers took photographs of the system at distances of 1.75 to 18.5 mi. The photographs were taken at the locations and distances shown in figure 1. The tornado traveled about 4 mi between points 2 and 6 at a forward speed of about 20 mi/hr, moving to the east-southeast. Heavy rain showers fell approximately 1.5 mi to the north of the track; but negligible, if any, precipitation was reported to the south.

The pictures show a curious combination of phenomena. One can clearly see a fully developed tornado with well-defined features. However, there are also other turbulent vortexes evident as well as a following arcus (roll) cloud or possible shelf cloud. We believe that the last picture shows the roll cloud associated with the cold air outflow moving into the downstream entities, perhaps destroying them by mechanical or thermal action, or a combination of these two mechanisms.

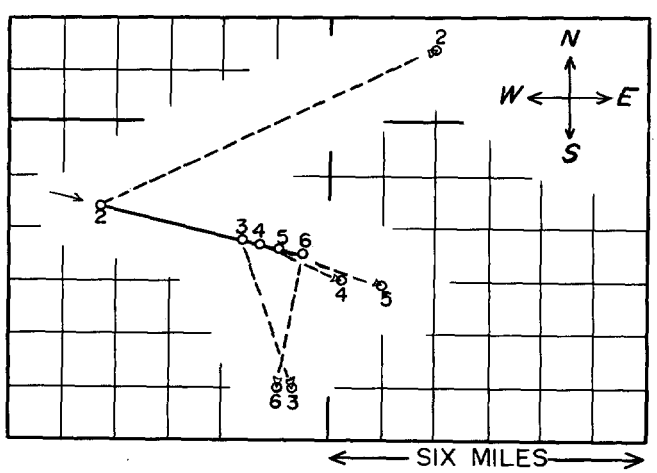

FIGURE 1.—Tornado track (solid line) and the position of the observers when they photographed the system. The numbers correspond to figure captions.

The first photograph (fig. 2) was taken northeast of the tornado track, with the system moving toward the left. A sharply defined funnel is visible in the left center along with a turbulent funnel-shaped cloud to its right and a roll cloud following this.

The leading funnel shows an interesting bulging deformation on the top part of the vortex core, a feature that Ward (1970) observed in his laboratory model experiments. It often indicates a forthcoming structural change; and in this case, another picture (not included) taken a minute or so later shows the funnel cloud decisively elongated as the bulb disappeared. Another photograph, taken from a different angle, shows that the arcus cloud is completely detached from the parent cumulonimbus. This same photograph reveals that the center feature, the turbulent funnel-shaped vortex, really consists of twin turbulent cells moving ahead of the roll cloud.

The next photograph (fig. 3), a closeup of the tornado, was taken while it was passing over a plowed field. The photographer was southeast of the track; therefore, the system is moving to the right in this picture. The tornado at this point was picking up fine sandy loam comprised of 15 to 20 percent of clay and about 4 percent of organic material (U.S. Department of Agriculture 1971). The topsoil is quite evident within the tornado cascadelike area; and topsoil dust is obvious in the lower portion of the funnel rim, which has a diameter of about 100 ft at a point directly above the sharply outlined cascade region. The angle between the surface and the base of the cascade region is very low in the forward cascade area and steep to the rear, perhaps the result of translational movement of the system.

The third photograph (fig. 4) presents many of the features of the last, but with some interesting differences. We now see the sides of the cascade region rather than the front and back; and here, although the shape is still outlined by topsoil dust, the angle is now not well defined. It is evident that dust is being thrown and/or falling out of this rapidly whirling region.

Above the cascade region, the air is clear through a large section of the vortex; and this raises an interesting

FIGURE 2.—First of the photographs in the series showing (from left to right) the principal funnel, a turbulent funnel cloud, and the arcus (roll) cloud.

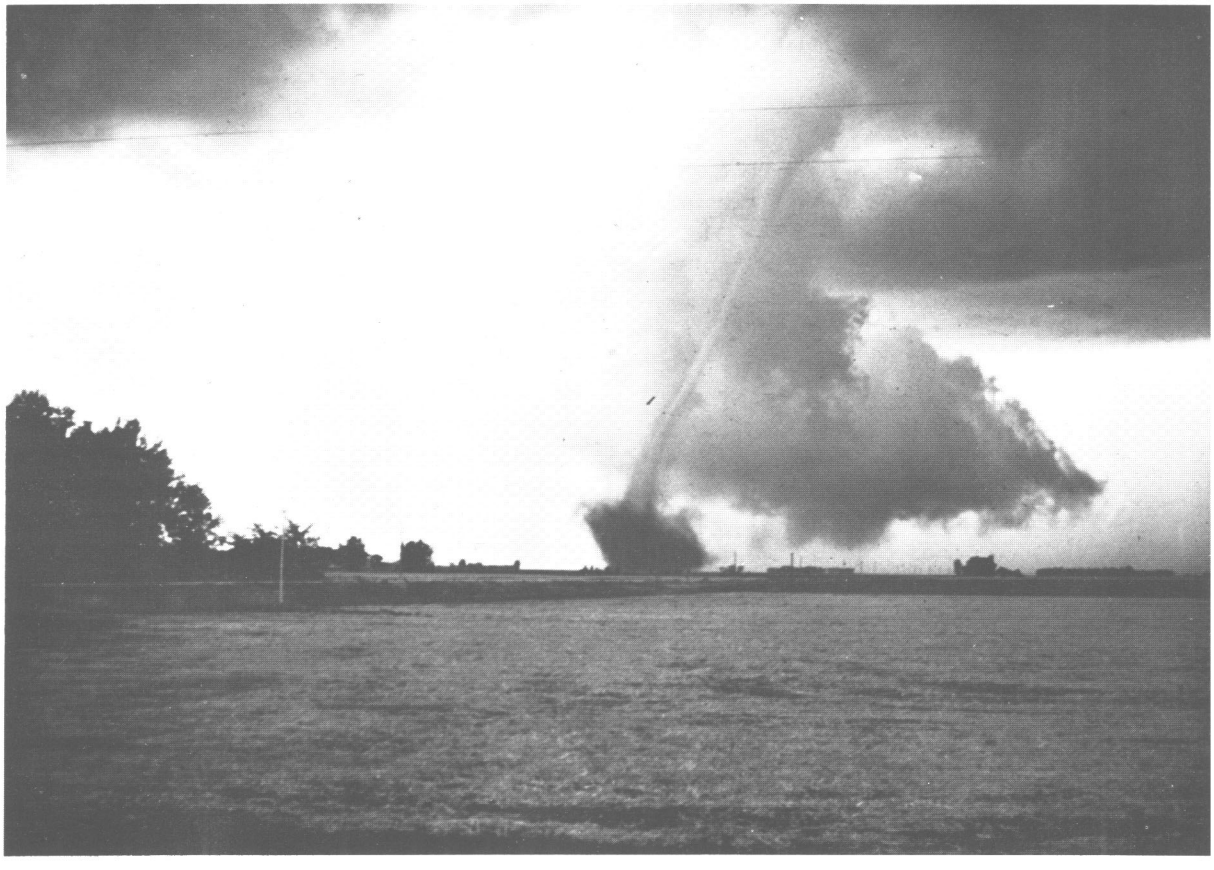

FIGURE 3.—Closeup of the Minnesota tornado.

FIGURE 4.—Another closeup of the tornado with one of the twin turbulent funnel clouds immediately behind it.

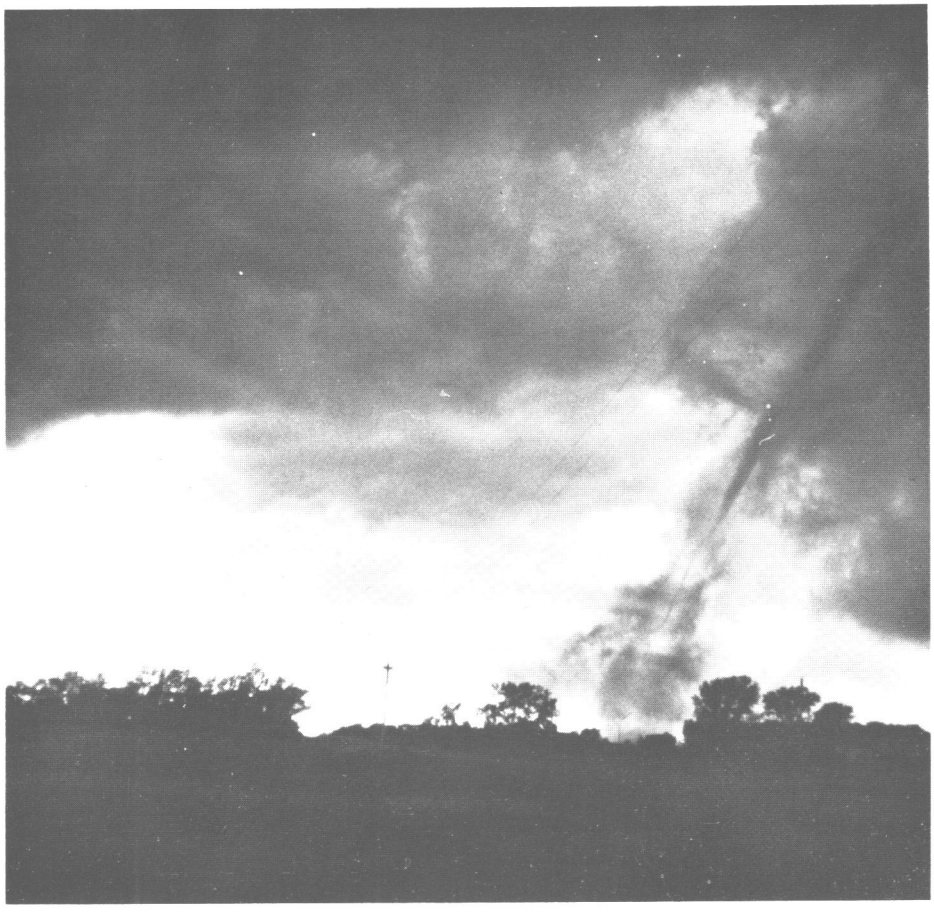

FIGURE 5.—Minnesota tornado picking up less dust as it has now moved beyond the plowed areas.

FIGURE 6.—The tornado and funnel clouds are destroyed as the roll cloud apparently moves into their circulation pattern.

point. If air were rising in the center of the vortex, then dust should be evident through the core region. Because it is not, we might conclude (at least in this particular case) that the air inside either has no vertical motion or motion downward.

There is, of course, nothing new in the concept of downward motion inside the tornado funnel or in the idea of upward motion around the funnel (at least upward through the cascade region). Rossmann (1960), Devine (1965), and Kuo (1966) among others have proposed this type of core flow. Serrin (1970) has recently suggested that three types of inner funnel motions are mathematically possible:

1. The radial velocity component is directed inward along the surface with an upward component along the axis of the vortex resulting in turbulent flow.
2. There is downward motion on the central axis with a radial velocity component directed outward near the surface.
3. The radial velocity component is directed inward along the surface with a downward component on the axis and a compensating outflow at an intermediate angle.

It appears that the third possibility may well apply to this tornado, at least at the point in time during which the picture was taken.

The next photograph (fig. 5) was taken while the tornado was passing over terrain containing less loose topsoil; consequently, less dust is seen within the tornado structure at this point. Again, the central core appears clear. The dust, nevertheless, does outline another important feature—turbulent banding in the outer shell. This banding is not nearly as well marked or extensive as some other documentation has shown (e.g., Dye 1968), but it is obvious from this picture that there is banding (whirling around the rim), and the dust within the banding appears to be spiraling upward at approximately a 15° angle.

In the final picture (fig. 6), it appears that the roll cloud has moved through the twin funnel clouds and may be the cause of dissipation. Large quantities of dust are still concentrated in the lower 200 ft, and it appears that some vortex action is still helping to keep it suspended.

We will not hazard an explanation for the two limbs protruding through the arcus cloud or the cause of the formation of a whirlwind dust cloud 500 ft in diameter. The dust cloud developed briefly before the tornado disintegrated.

ACKNOWLEDGMENTS

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PICTURE OF THE MONTH

A Fast-Moving Cold Front as Seen by ATS 3

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The kind of weather surveillance possible with geostationary satellites is illustrated by this example. A cold frontal system moving rapidly across Florida on Mar. 3, 1971, was photographed by ATS (applications technology satellite) 3 at 1931 GMT (fig. 1). The picture shows the front and a sharply defined prefrontal line of showers and thunderstorms. Figure 2 is the picture taken at 1227 GMT on March 4. This early morning (0727 EST) view shows the front after passing over Miami. The prefrontal line is exceptionally well defined over almost the entire length of the front. The definition of the prefrontal line is sharper in figure 2 than in figure 1 because of the differences in solar elevation. In the early morning picture (fig. 2), the line of convective clouds casts shadows westward, thus emphasizing the cloud line. In figure 1, the picture was taken near noon, so the sun was nearly overhead; and the prefrontal line clouds did not cast shadows that would be visible from overhead.

The morning forecasts issued on March 3 by the National Hurricane Center called for a cold front passage at Miami after 0000 EST on March 4. By noon of March 3, a time-lapse motion picture loop made from ATS 3 pictures taken that morning showed the rapid movement of the front across the Gulf of Mexico. Measurements made from the film loop showed the front to be moving southeastward at 32 kt over the northeastern part of the Gulf of Mexico and at 25 kt across the Yucatan Peninsula. On the basis of these measurements, the later forecast called for frontal passage at Miami at 2100 EST on March 3. Passage was recorded at the Miami Airport at 2048 EST. The intensity of the prefrontal line of thunderstorms evident in the ATS 3 pictures, the speed of movement of the front, and reported surface winds also led to a special warning to the shrimp fleet fishing off Dry Tortugas. This revised forecast called for more severe weather to arrive over the area earlier than did the previously issued forecast.

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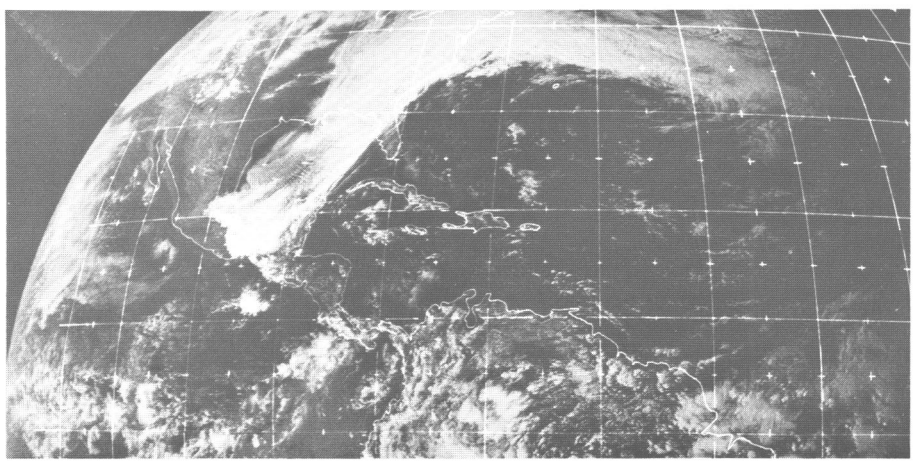

FIGURE 1.—ATS 3 view at 1931 GMT on Mar. 3, 1971.

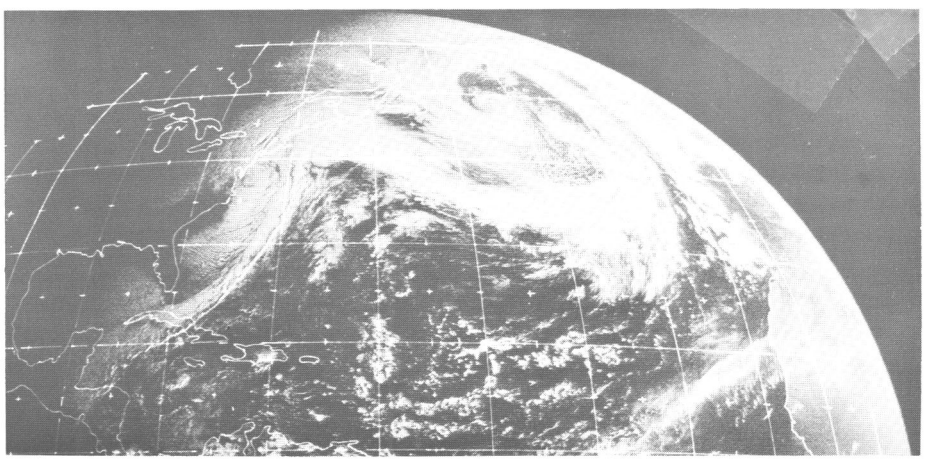

FIGURE 2.—ATS 3 view at 1227 GMT on Mar. 4, 1971.