Spiral Cloud Band Associated with a Tornado

Abstract. The radarscope photographic sequence, by far the best example on record, reveals a spirally banded structure about 10 miles in diameter which is similar to spiral bands of hurricanes ranging as far as 250 miles and to the banded cloud structure of well-developed storms of 1000 miles as photographed by Tiros I.

On 19 May 1960, the radar at the U.S. Weather Bureau Office, Topeka, Kansas, tracked a devastating tornado that cut a path over 100 miles long across northeastern Kansas, where the town of Meriden suffered the greatest destruction. Two scientifically noteworthy features of the radar observations were: (i) indications on the range-height-indicator scope that the top of the tornado's parent cloud was above an altitude of 70,000 feet and (ii) pictures of the plan-position-indicator scope that show the best example yet recorded of a cyclonically spiraling hook-shaped echo associated with a tornado.

The first observation of a radar hook echo associated with a tornado was reported in 1953 by Stout and Huff (*1*) and was later carefully analyzed by Fujita (*2*). Fujita found that the spiraling of the hook echo cyclonically inward was produced by a small cyclone approximately 30 miles in diameter and "resembling a miniature hurricane in many respects." Figure 1 shows Fujita's outline of the radar echo of the parent cloud and its hook-shaped appendage. A sequence of pictures of this original observation showed that the hook formed in about 13 minutes on the right rear quadrant (relative to direction of movement) of the large echo of the parent cloud and curled cyclonically inward.

Although many radar observations of this phenomenon have been recorded (see *3*) since the original observation by Stout and Huff, the observation of the spiraling hook associated with the Meriden tornado is noteworthy because it is by far the best example on record. Time-lapse photographs of the plan-position-indicator scope show conclusively that the hook formed in

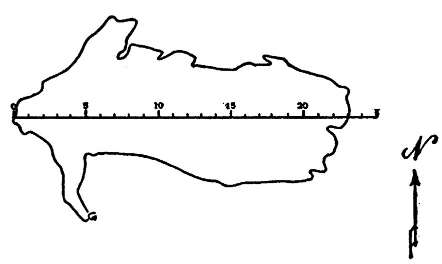

Fig. 1 (above). Outline of radar echo of parent cloud and the hook (lower left) associated with a tornado at Champaign, Ill., 9 Apr. 1953. The tornado was located near the tip of the hook, which was curling cyclonically as indicated by the arrow. [After Fujita (*2*)]

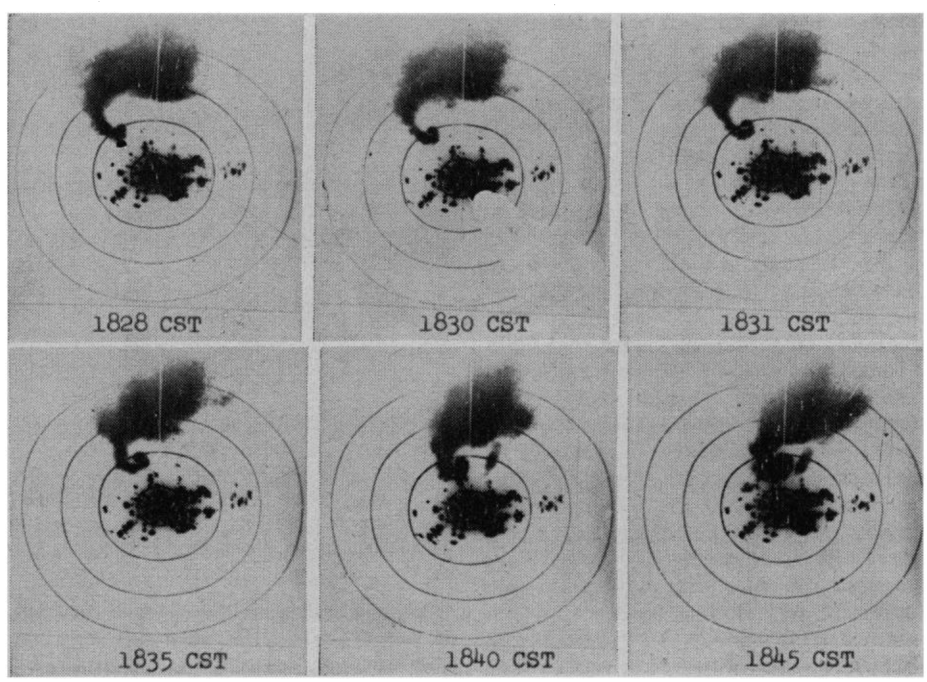

Fig. 2 (right). Sequence of photographs of the Topeka, Kan., plan-position-indicator radar scope, showing the cyclonic inward-spiraling hook echo associated with the Meriden tornado, 19 May 1960. The hook protrudes from the right rear (lower left) quadrant of the parent cloud. The scale is indicated by the circular markers at 10-nautical-mile intervals.

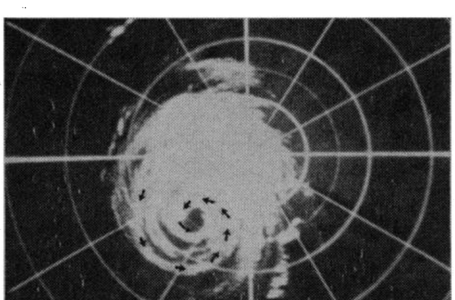

Fig. 3. Picture of radar scope at Weather Bureau Office, Cape Hatteras, N.C., showing hurricane Helene at 1705 EST, 27 Sept. 1958. Note the cloud bands spiraling inward to a closed "wall cloud" surrounding the hurricane "eye." The circular markers are at 50-nautical-mile intervals with an intermediate marker through the eye at the 72-nautical-mile radius. [After Sadowski (*7*)]

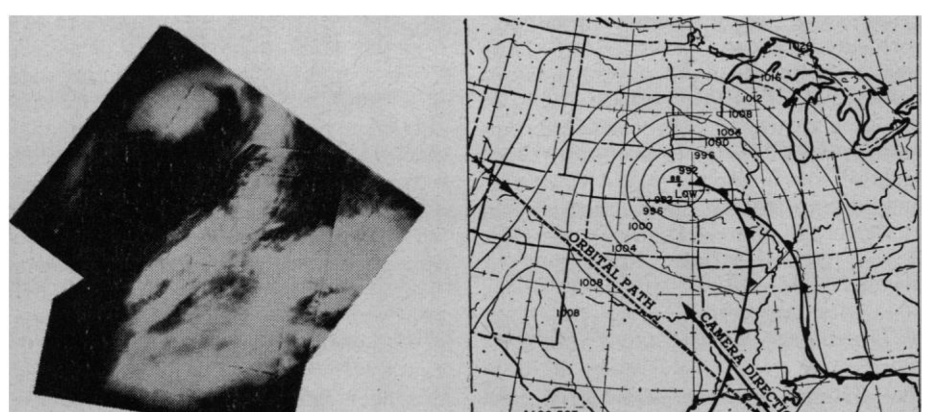

Fig. 4. Picture by Tiros satellite (left) shows clouds associated with storm centered over southeastern Nebraska, as shown on the weather map (right). The large *X* at the bottom of the map marks the position from which the photograph was taken as Tiros traveled from northwest to southeast at an altitude of about 450 miles. [After Fritz and Wexler (*9*)]

a cyclonic flow. The photographic sequence reproduced in Fig. 2 reveals the spiral motion of the well-defined hook echo as it curled cyclonically inward to a center in the right rear quadrant of the parent cloud.

The dimensions of the small cyclone (mesoscale low) that apparently curled the hook into a tight spiral have not been determined from analysis of the weather observations, but the curvature of the hook and of spiral streamers imbedded in the parent cloud suggests a diameter of the same order of magnitude (10 miles) as that of the "tornado cyclone" discovered by Brooks (*4*) in 1949.

These radarscope photographs come at an opportune time, when meteorologists are becoming keenly interested in the spirally banded structure of weather phenomena at all scales. The spiral bands of hurricanes observed on radar, as shown in Fig. 3, are well known (*5–7*). These spiral bands extend in length up to 250 miles (*6*).

Recently Tiros I (experimental weather satellite) revealed that spiral cloud bands also exist around well-developed storms located outside of the tropics (*8*, *9*). In these storms the bands, separated by clear areas, range in width from several miles to a few hundred miles, and in length they range to about 1000 miles. Such a spiral band is shown in Fig. 4 in a photograph taken by Tiros of a well-developed storm centered over Nebraska at 3:30 P.M. EST, 1 April 1960. The center of the storm was marked by a circular cloud mass in the upper part of the photograph, with an extension of the spiral along a cold front trailing from the storm center to the south and southwest, as shown on the surface weather map of Fig. 4.

Striking similarities can be seen in these observations (Figs. 1–4) of cyclonically spiral bands associated with atmospheric vortices ranging in size from the small scale of a 10-mile hook echo of a tornado, through the medium scale of the 250-mile-long spiral band of a hurricane, to the large scale of the 1000-mile-long frontal system of an extratropical storm. The atmospheric processes which produce these bands are believed to be different at each scale, but the similarity of appearances may reflect some similarity of kinematics. To the extent that this may prove to be true, there is hope that increased understanding of any one of the phenomena will contribute to our progress in understanding the others (*10*).

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References and Notes

1. G. E. Stout and F. A. Huff, *Bull. Am. Meteorol. Soc.* **34**, 281 (1953).
2. T. Fujita, *Meteorology* **15**, 288 (1958); *Univ. Chicago Dept. Meteorology Tech. Rept. to U.S. Weather Bureau* (1956).
3. A. Sadowski, *Monthly Weather Rev.* **86**, 405 (1958).
4. E. M. Brooks, *Weatherwise* **2**, 32 (1949); *Compendium Meteorol.* **1951**, 673 (1951).
5. H. Wexler, *Ann. N.Y. Acad. Sci.* **48**, 821 (1947); V. Rockney, *Proc. Tropical Cyclone Symposium, Brisbane, Australia* (1956).
6. H. V. Senn and H. W. Hiser, final report on work done under U.S. Weather Bureau contract No. Cwb-9174 (1958).
7. A. Sadowski, *J. Geophys. Research* **64**, 1277 (1959).
8. H. Wexler and S. Fritz, *Science* **131**, 1708 (1960).
9. S. Fritz and H. Wexler, *Monthly Weather Rev.* **88**, 79 (1960).
10. Grateful acknowledgment is made to R. Tice and J. Z. Galeziewski, whose excellent and timely radar observations provided the basis for this report.

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Electrical Responses of the Retinal Nerve and Optic Ganglion of the Squid

Abstract. Recordings were obtained from the retinal nerves and optic ganglia of intact squid, which were maintained in good condition by perfusing their mantles with sea water. Only "on" discharges were found in the nerves, whereas "on" and "off" discharges as well as spontaneous activity and tactile responses were obtained from the ganglia.

Several highly competent investigators (*1*), as well as one of us (E. F. M.), have repeatedly tried without success to record impulses from the retinal nerve fibers of cephalopod mollusks. There appeared to be two possible reasons for this lack of success: (i) impulses are not discharged in this nerve; (ii) the retinal nerve may be unusually sensitive to injury or ischemia produced after interruption of the circulation.

It has been suggested (*2*) that impulse propagation is unnecessary in short axons only a few space constants in length. It is entirely conceivable that the large electrical changes known since the time of Fröhlich (*3*) to take place in the receptors could be conducted decrementally in the optic nerve fibers, which are the axons of these cells, and retain sufficient amplitude to cause excitation in the optic ganglion.

Evidence of this mode of transmission in the squid's retinal nerve would furnish a concrete example of an important phenomenon which has long been postulated but has never been established by direct experiment.

It occurred to one of us (W. E. L.), in the course of bleeding squid to obtain hemocyanin for x-ray crystallographic studies, that it should be possible to maintain the squid in good condition by perfusing the gills with sea water while probing the retinal nerve with a microelectrode, and thus to determine whether conduction in this nerve takes place by the discharge of impulses or by electrotonic spread. A similar technique has been used for studying the giant axon in vivo (*4*).

In our experiments the squid (*Loligo pealii*) were placed on their backs, and their mantles were wrapped in a jacket of sheet lead. Two plastic tubes were inserted into the mantle through the valve on either side of the head. Sea water at 17°C flowed into these tubes and out the siphon, which could be deflected to one side by means of a lead hook to uncover the region over the optic nerve and ganglion. The tentacles were immobilized with a lead strap. An animal in good condition exhibited regular breathing movements and ejected a jet of water violently when stimulated.

Potentials were recorded between a glass-coated metal microelectrode (*5*), inserted into the head of the animal, and the lead jacket. A capacitance-coupled amplifier, dual-channel oscilloscope, and camera were used for recording, and an audio amplifier and loud-speaker were used for monitoring the experiment.

A stimulator comprising a tungsten lamp, electromagnetic shutter, neutral density wedge, and lens system was used to project a spot of light on the eye. A photoelectric cell was used in conjunction with one trace of the oscilloscope to indicate the duration of the stimulus.

Under suitable illumination the retinal nerves and optic ganglia could be seen through the transparent, cartilaginous "skull." A strong, steeply tapered electrode could be inserted manually through the skull, which then held it in place. Under these conditions impulse discharges from several units were recorded simultaneously. It was not possible to manipulate the electrode with sufficient precision to record from single units in isolation. It was also possible to punch holes in the skull with an 18-gauge hypodermic needle to permit the insertion of more fragile microelectrodes and still maintain the squid in good condition for an indefinite period.

To make certain of the exact location of the tip of the microelectrode in some experiments, the cartilage and muscle overlying the retinal nerve and ganglion were dissected completely away before insertion of the electrode. Results were identical to those obtained with an intact skull, except that survival time was only a few minutes.

As shown in the top trace of Fig. 1,