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BOW-ECHO INDUCED TORNADO AT MINNEAPOLIS ON 26 APRIL 1984

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1. INTRODUCTION

For many years, meteorologists have used radar echo shape in determining the possibility of severe weather and tornadoes. The hook echo is widely known to be associated with tornadoes. Nolan (1959) identified the line echo wave pattern (LEWP) and Hamilton (1970) identified the concave-shaped echo to be associated with severe weather. Recently, Fujita (1978, 1981) and Forbes and Wakimoto (1983) have identified the bow-echo to be associated with downbursts and tornadoes. Przybylinski (1983) documented cases of severe weather occurrence and bow-echoes in Indiana and showed their importance to the forecaster.

This paper shows a case study of a tornado induced by a bow-echo. Infrared satellite temperatures from the storm shows and interesting correlation between the radar echoes and the contours of cloud-top temperatures.

2. TORNADO TRACK

On April 26, 1984 an outbreak of 47 tornadoes occurred throughout the plains and the midwest. One of these tornadoes was an F3 tornado in St. Anthony, Minnesota, located three miles north of downtown Minneapolis. The tornado was 5.5 miles long and 900 feet wide. A total of 288 homes were damaged by this tornado. The track of this tornado is shown in figure 1. This tornado started at 2033CST and ended at 2041CST. An enlarged section showing the F3 damage area is in figure 2. Notice the cyclonic circulation is quite evident from the damage. This indicates that the storm was slow enough to allow the backside flow. Based on the track its speed of propagation was 37 kts (18.4 m/s). However this speed may vary dependent on the time the storm reports were sent in.

One person was killed and 52 were injured in the storm. Figure 3 shows the damage in the F3 area including where the one person was killed. Figure 4 shows F2 damage sustained by an apartment complex in New Brighton. Extensive damage was also evident at the Apache Plaza shopping center and to many automobiles.

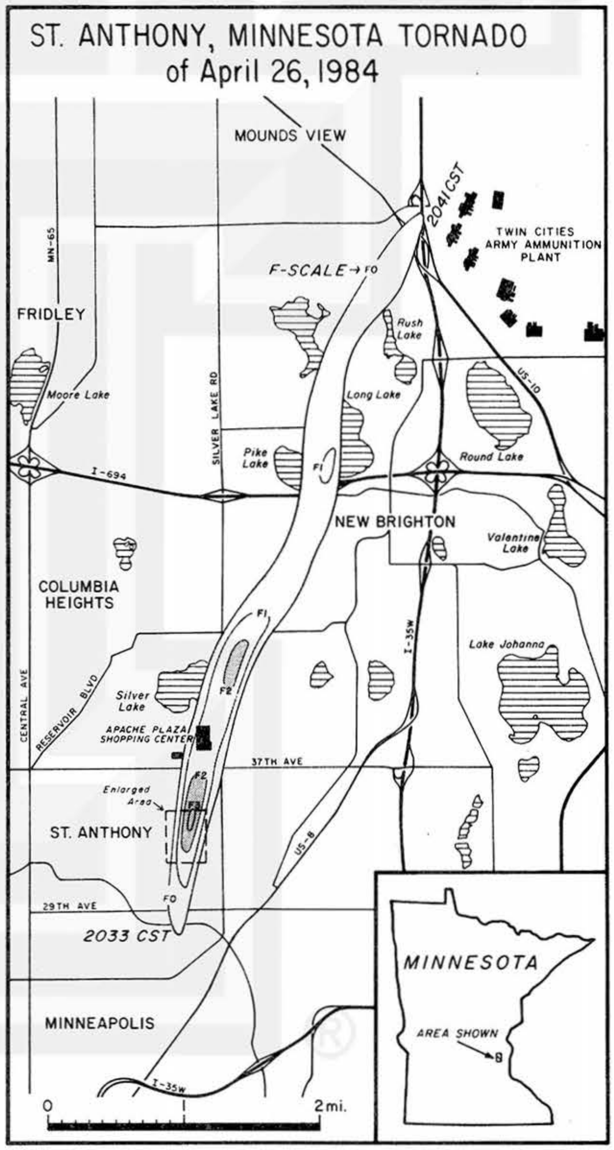


Fig. 1 Damage track of the St. Anthony tornado with isopleths of F-scale. Damage survey and mapping by the University of Chicago.

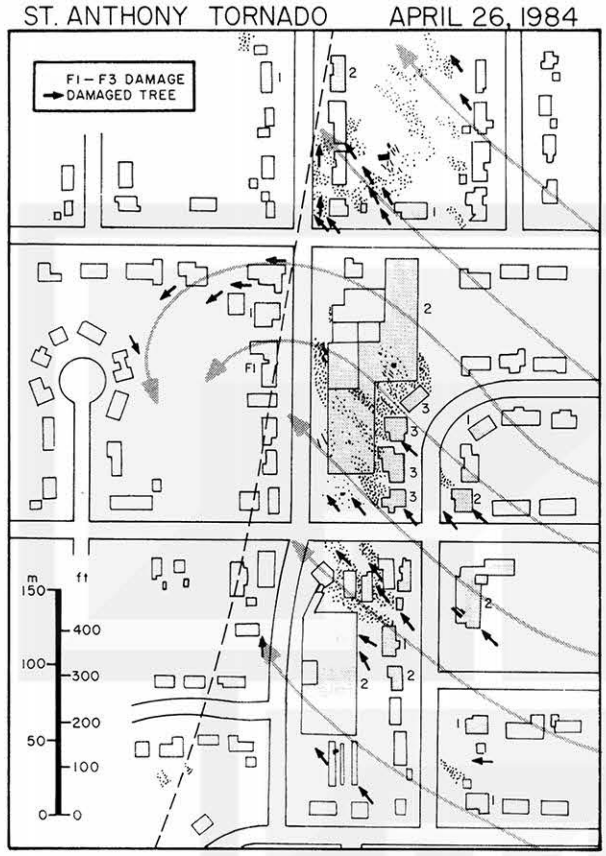


Fig. 2 Detailed analysis of a residential area of St. Anthony, MN. Notice the back-side circulation that is evident from this tornado. F-scales are indicated next to the damaged buildings. Mapping by Steve Lazarus, Florida State University and Brian Smith, University of Chicago.

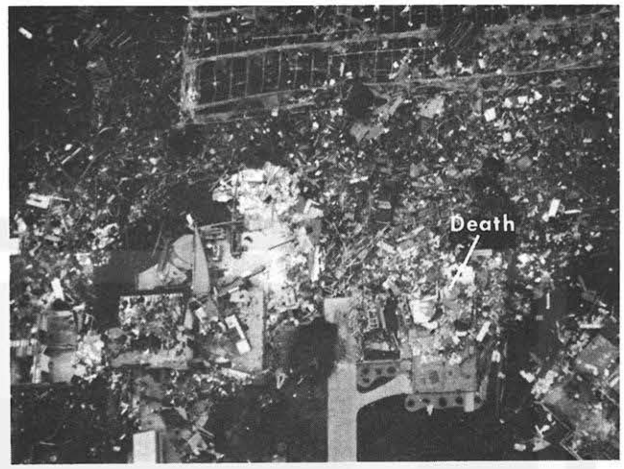


Fig. 3 Aerial damage photo of the F-3 damage area mapped in the preceeding figure. One death occured in the house that is marked.

Fig. 4 Damage photo of the Silver Lake Estates Apartment complex in New Brighton.

3. RADAR ANALYSIS

A sequence of radar photos taken by the Minneapolis National Weather Service Forecast Office from 2016CST to 2105CST are shown in figure 5. The southernmost echo is a bow-echo. The area of storms moved east-norteastward at 35 knots and had tops to 42,000 feet. The tornado was located north of the radar site. Although the ground clutter obscures it, the bow echo extends into the echoes north of the radar. Higher elvation scans show this. The tornado is located at the connection of the bow-echo and the northern echo area. From Fujita's model of a bow echo shown in figure 6, it is believed that the tornado had occurred in the rotating head region (north portion) of the bow where a mesocyclone circulation is present. It is likely that this circulation induced the development of the tornado.

Damaging winds did occur further south of the tornado nearer to the center of the bow. At 2100 CST wind damage was reported near Canon Falls, Minnesota (26 nautical miles SSE of MSP) where trees were uprooted and outbuildings were blown down. No severe weather was reported south of the bow region.

The northern radar echo was also active in producing severe weather between 1930 to 2150 CST. Damage to trees and power lines was reported 75 nautical miles north of the radar. It is interesting to note that this damage occurs near a bulge in the northern echo, indicating this may be a weak downburst from a less well defined bow-echo.

4. SATELLITE ANALYSIS

A satellite infrared temperature analysis is superimposed on the radar echoes for the time period 2033CST to 2041CST in figure 7. This day was set as a Research Rapid-Scan Day (RRSD) where 3-minute satellite data was available. The 2026CST analysis in figure 7 is seven minutes prior to tornado touchdown. Two areas with temperatures below -60°C are present corresponding to the bow-echo to the south and the other echo further north. Within this region are cold tops of -64°C.

The isotherms allign themselves with the highest radar reflectivity cores of the storms (VIP levels ≥ 3). The isotherms in the sourthern storm actually form the shape of a bow. This fea-

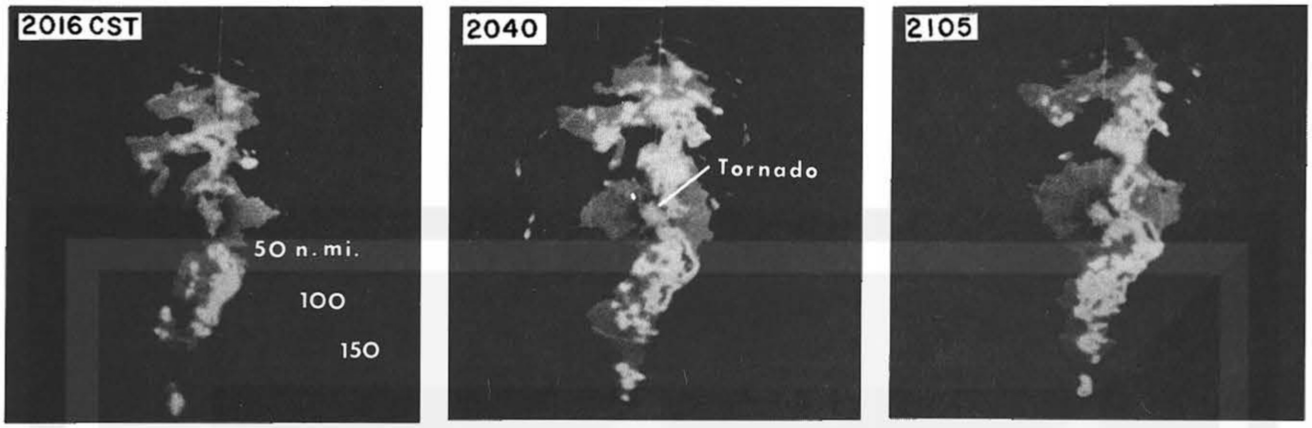


Fig. 5 Photo sequence taken from Minneapolis radar. Notice the bow-echo south of the radar. Range markings are fifty nautical miles.

ture shows up in the 2030CST analysis and to a lesser extent in the 2041CST analysis. Notice also that behind the bow shape is a notch or "tongue" of warmer temperatures. This possibly may represent sinking or subsidence of air that Fujita (1978) hypothesized occurs in a bow-echo storm. The tornado itself occcurs in the region between the two cold cloud tops within a trench of warmer temperatures.

The northern cloud area in 2026CST and 2030CST analyses shows a cold core of -64°C with a warm core of temperatures >-60°C just west of it. This is in the general vicinity of where damaging winds were reported. Again, as in the bow echo a warm spot is in the vicinity of where damaging winds occurred. The significance of the warm spot in the upper left of the 2026CST and 2030CST analyses is not known.

5. CONCLUSIONS

The analysis of the St. Anthony, MN tornado on 26 April 1984 revealed a cyclonic tornado that had back-side circulation visible from the debris and damage patterns. Radar analysis revealed a bow-echo may have been responsible in inducing the circulation of the tornado. From Fujita's bow-echo model, it is likely the tornado formed in the "rotating head" mesocyclone in the bow-echo.

Satellite analysis of infrared temperatures show that a bow feature in the isotherm field corresponds to the the radar bow-echo. Behind the bow area of cold temperatures is a trench of warmer temperatures indicating that high speed tropospheric air may be sinking to initiate the downburst and bow-echo, this eventually leads to a mesocyclone on the north side of the bow which in turn may induce tornado formation.

Future studies should be made in determining the usefulness of satellite infrared shapes and their relationship to severe weather. Rapid-scan data may be able to tell if such a "bow-cloud" feature occurs frequently in downburst/tornado producing bow-echo storms and ultimately would lead to a better understanding of the mechanisms involved in bow-echo formation.

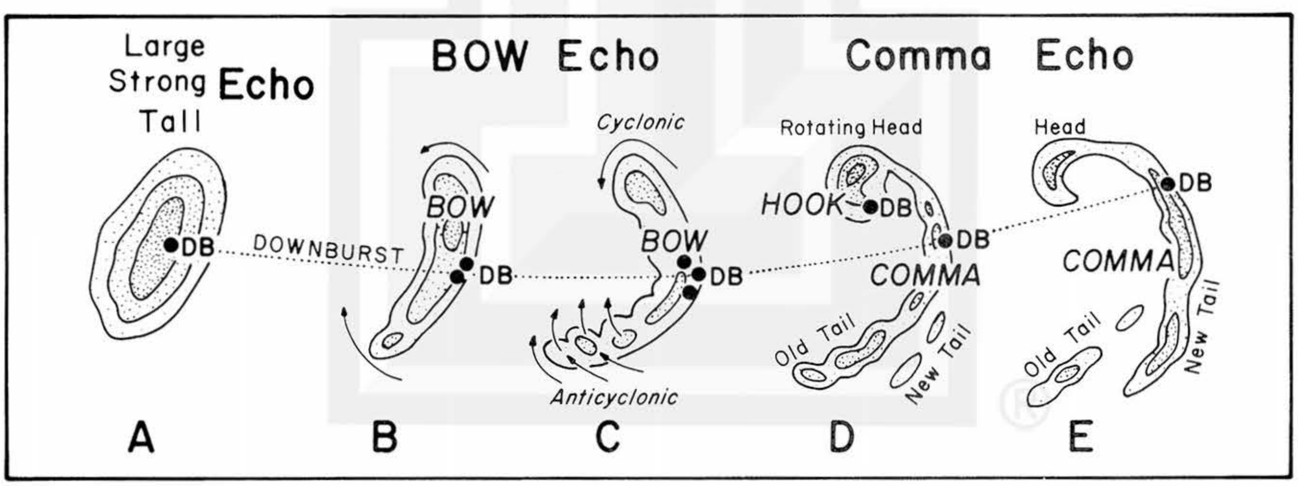
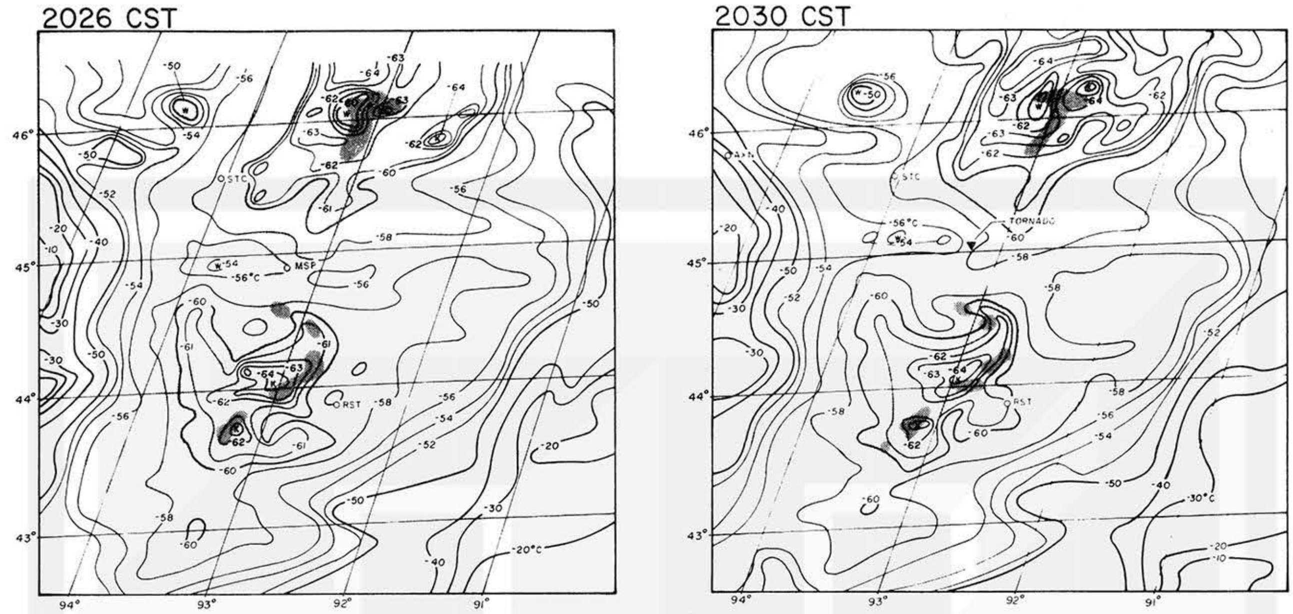


Fig. 6 Evolution of a bow-echo as modelled by Fujita. It is beleived that the tornado formed on the north side of the bow-echo in the area which is the rotating head. From Fujita (1978).



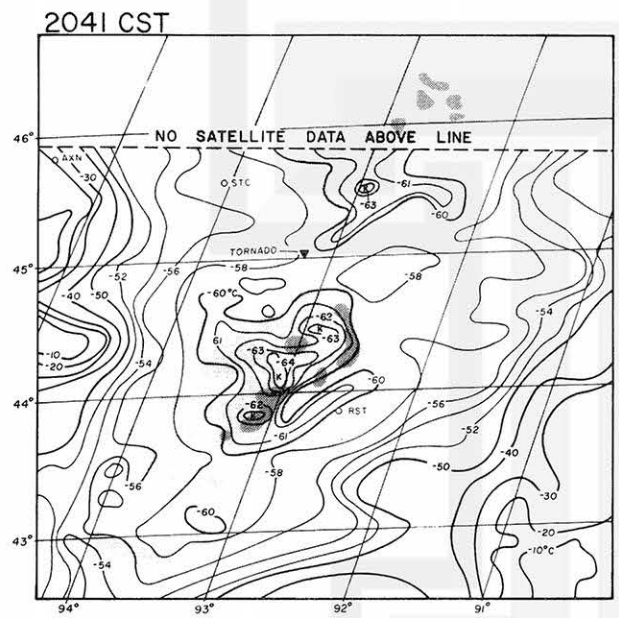


Fig. 7 Sequence showing isotherm analysis of equivalent blackbody temperatures superimposed upon radar echoes. Analysis is 10°C interval for temperatures >-50°C, 2°C interval from -50°C to -60°C, and 1°C interval <-60°C. "k" indicates cold tops, "w" warm tops. Radar reflectivity is light gray for VIP level 2 and dark gray for VIP>3. Tornado location is marked by triangle.

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