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OLD AND NEW CONCEPT OF TORNADOES

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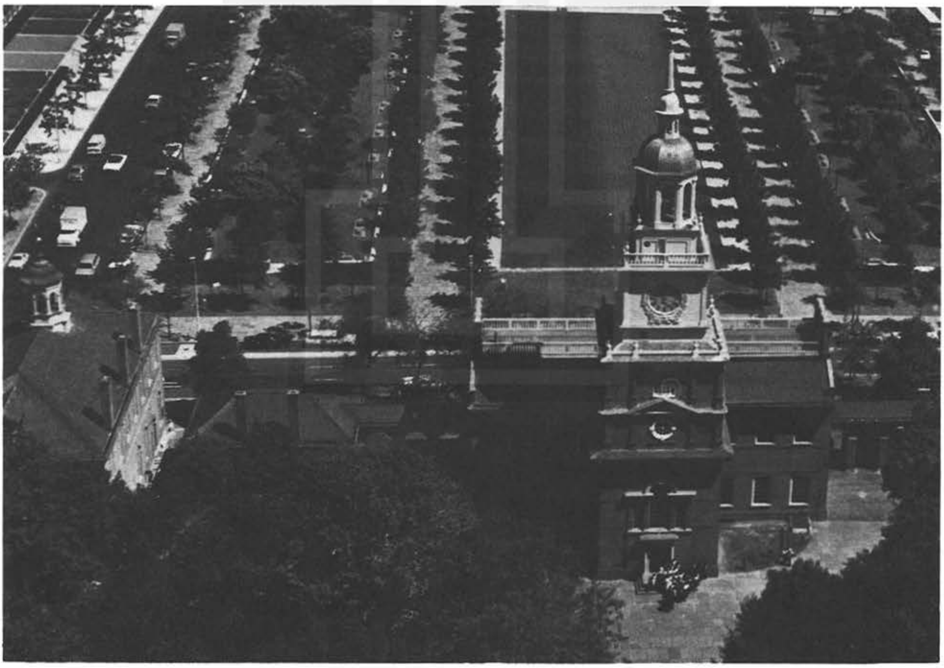

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OLD AND NEW CONCEPT OF TORNADOES[2]

by

T. Theodore Fujita[1]

INTRODUCTION

The United States is the worst country in the entire world in terms of tornado activities. Storms have been watched, followed, and studied during the past 200 years. In spite of our efforts for a better understanding of the nature of tornadoes, we still do not know exactly how they form, behave, and die. In recent years, to meet the requirements of the nuclear industry, new evidence on tornadoes has become evident.

1. The activity center in the U. S. is not at Oklahoma, it moves around.
2. Maximum tornado windspeeds are likely to be about 300 mph, while the median windspeed of all tornadoes is only 77 mph.
3. Large tornadoes are accompanied by suction vortices which produce severe damage while looping around the cores of the tornadoes.

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TORNADO RISK OF THE UNITED STATES

Summary: Since the days of the Wizard of Oz, Kansas and Oklahoma have been identified as the states with the highest tornado risk. Recent studies by Fujita, Pearson, and Ludlum (1975) revealed, however, that tornado activities move around in the Midwest. A 45-year fluctuation was cited, although we still do not know the physical relationship between the 11-year (sunspot), 22-year (draught), 45-year (tornado) and 90-year (climatic) vatiations.

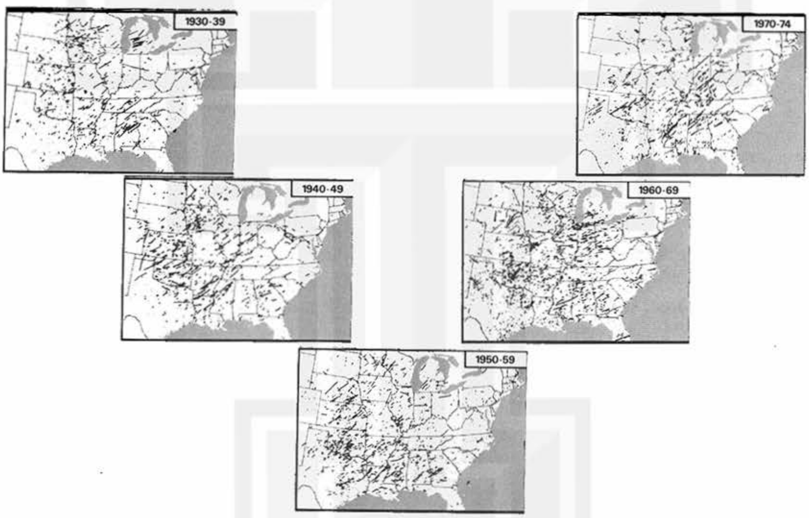

Fig. 1. Paths of tornadoes during each decade since 1930.

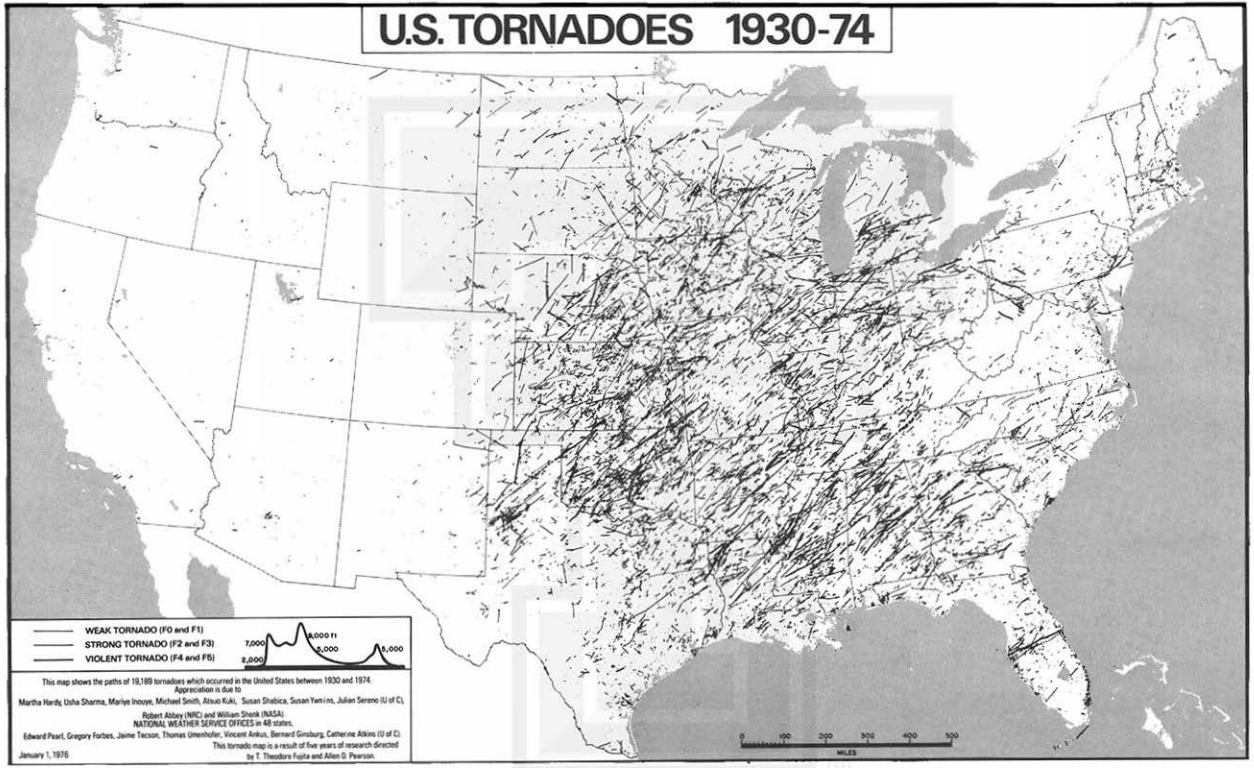

Fig. 2. Paths of the 19,189 tornadoes confirmed in the United States during the 45-year period, 1930-74. (A copy of the original color map may be obtained from the author.)

MAXIMUM WIND SPEEDS OF TORNADOES

Summary: An estimate of the maximum wind speed is dependent upon the individual's background. Some think it is as low as 70 mph while others believe that it must be over 600 mph. Recent estimates through engineering and photogrammetric analyses suggest that the maximum speeds are lower than we had been thinking (see Fig. 3). Some meteorologists estimate the maximum speed to be as low as 180 mph while others do not rule out a possible 360-mph speed. The evidence collected by the author shows the maximum wind speeds to be about 300 mph.

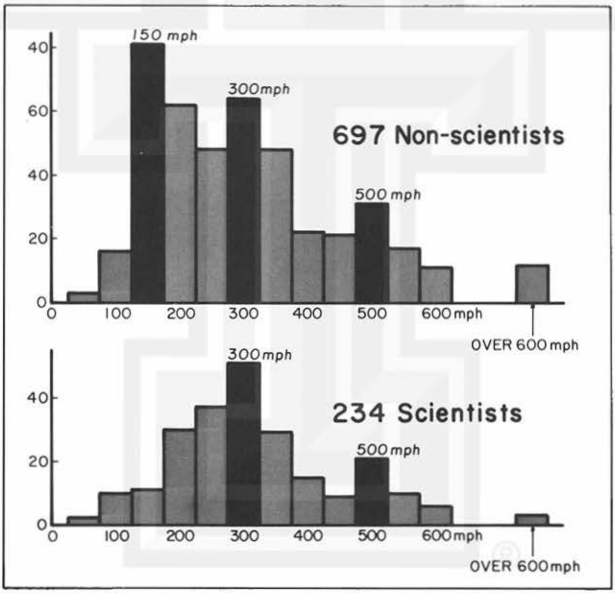

Fig. 3. The maximum wind speeds voted by both scientists and non-scientists.

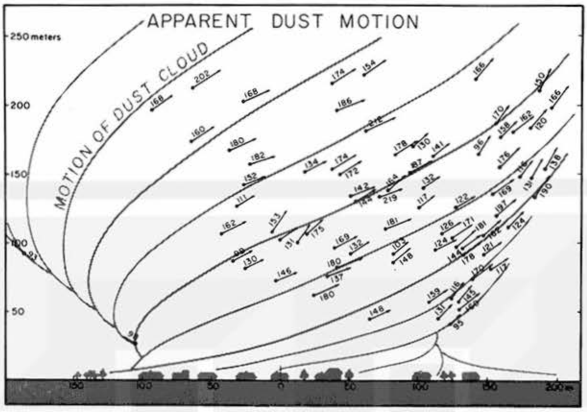

Fig. 4. Apparent motion of dust cloud in the Xenia tornado of April 3, 1974 (motion relative to the tornado center). After Fujita (1975).

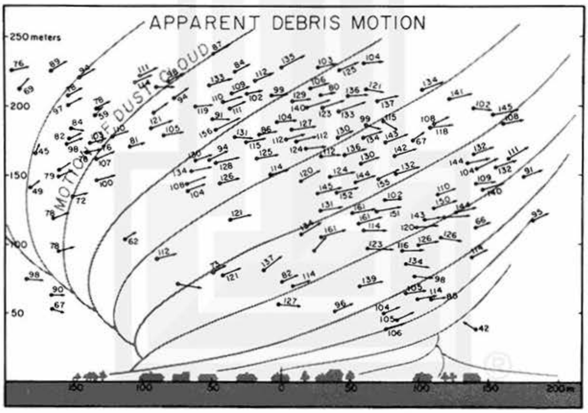

Fig. 5. Apparent motion of debris in the Xenia tornado of April 3, 1974 (motion relative to the tornado center).

AVERAGE AND EXTREME TORNADOES

Summary: The variation of tornado characteristics is extremely large. Fujita and Pearson attempted to obtain statistical distribution of tornadoes by intensity (F scale), path length (first P scale), and path width (second P scale). Their latest tornado statistics in the Fujita - Pearson scale (FPP scale) are

F scale	Speed	P scale	Length	P scale	Width
F5	rare	P5	rare	P5	rare
F4	2%	P4	4%	P4	4%
F3	8%	P3	13%	P3	16%
F2	24%	P2	15%	P2	21%
F1	42%	P1	23%	P1	45%
F0	24%	P0	45%	P0	14%

The F scale wind speeds are computed from

$$V = 14.1\ (F+2)^{\frac{3}{2}} \quad \text{mph.}$$

The dynamic pressure can, therefore, be written as

$$\frac{1}{2}\rho V^2 \cong 100\,\rho (F+2)^3 \qquad mph^2(\rho).$$

The P scale length and width are expressed by

$$L = 10^{\frac{1}{2}(P-1)} \text{ miles}$$

and

$$W = 10^{\frac{1}{2}(P-5)} \text{ miles.}$$

The median FPP scale of all tornadoes is rather small, indicating that one-half of the confirmed tornadoes are weaker than 77 mph, shorter than 0.71 mile, and narrower than 22 yds.

	F scale	P scale Length	P scale Width
Median scale	F1.1	P0.7	P1.2
Corresponding value	77 mph	0.71 mile	22 yds

Tornadoes with their FPP scale equal to or larger than 442 (207 mph, 32 mile long, 56 yd wide) are called MAXI TORNADOES. The ones with FPP no larger than 001 (73 mph, 1 mile long, 55 yd wide) are called MINI TORNADOES.

LARGE CORE TORNADOES AND SUBVORTICES

Summary: Large core tornadoes are more common than people had thought. The Dallas tornado of April, 1953, analyzed by Hoecker (1960) and being used widely for engineering purposes, had a core diameter of 200 to 300 ft. Looping marks, as shown in Fig. 6, left behind by tornadoes are now used in determining the core diameter. Recent statistics show that the median core diameters of F4 and F5 tornadoes are 500 ft to 1000 ft.

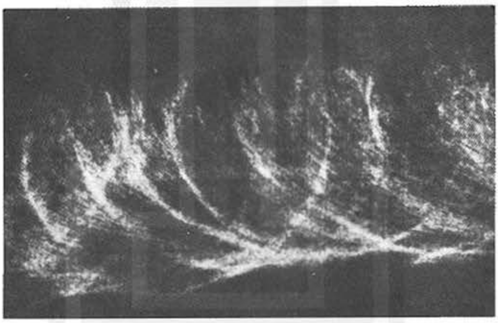

Fig. 6. The looping marks in an open field near Magnet, Nebraska left behind by the May 6, 1975 tornado.

When the core diameter increases, a tornado can no longer maintain its axial symmetric circulation. The edge of the core breaks up into several subvortices. These vortices often orbit around the tornado center, causing severe damage along their paths. The F scale mapping of the damage area shows a number of curved swaths (see Fig. 7).

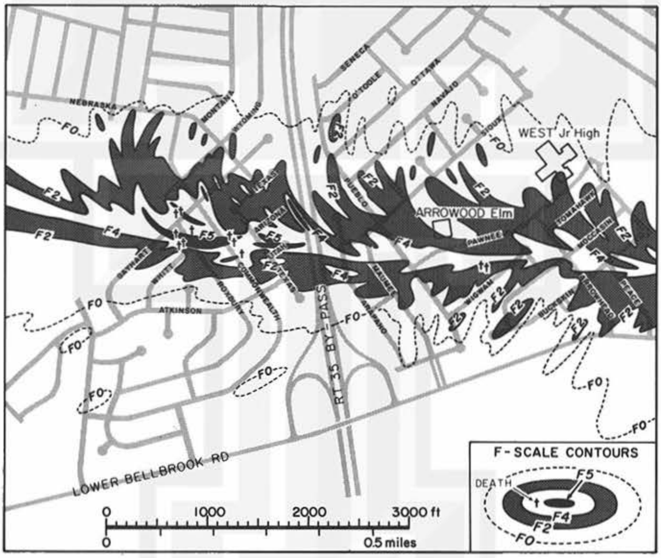

Fig. 7. The F scale contour of damage in the western part of Xenia, caused by the April 3, 1974 tornado.

SUCTION VORTICES

Summary: When the vertical acceleration acting upon the air at the vortex center near the surface is estimated to be greater than g, the gravitational acceleration, the vortex is called the SUCTION VORTEX. Most subvortices inside a tornado induce acceleration in excess of g, being qualified to be called SUCTION VORTICES.

A suction vortex consists of two vortex parts: inflow vortex and helical vortex. Inflow air spirals in and ascends violently inside the inflow vortex. Upon entering the base of the helical vortex, the air moves up along the helical paths (see Fig. 8).

As shown in Fig. 9, a suction vortex in an open field removes light objects and weak vegetation and gathers it near the vortex center. Since the vortex cannot pick up everything it has collected, a line of deposit is usually left behind its path.

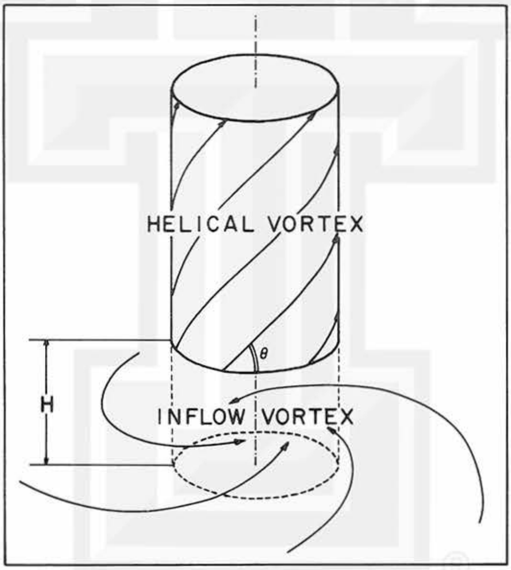

Fig. 8. Schematical view of a suction vortex including the inflow vortex and the helical vortex.

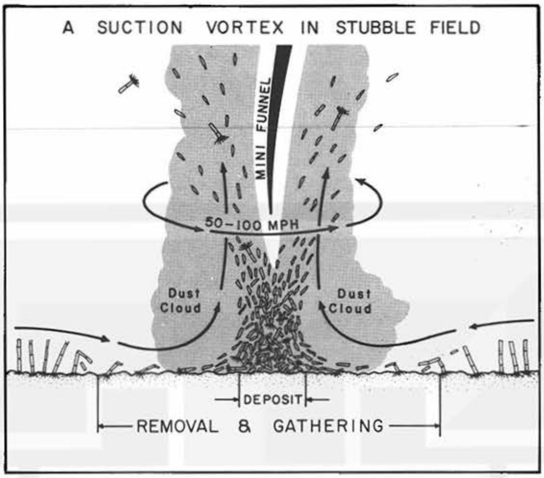

Fig. 9. A model of a suction vortex in an open field.

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