RESULTS OF F P P CLASSIFICATION OF 1971 and 1972 TORNADOES

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1. INTRODUCTION

Tornado damage and visual indications have suggested that there are significant differences from one tornado to the next, but there has never been any systematic attempt to categorize tornadoes within the United States.

Seelye (1945) classified the intensity of New Zealand tornadoes from 0 to 5, with class 5 being defined as "demolishing well-constructed buildings". Clarke (1962) estimated maximum wind speeds for 62 Australian tornadoes and indicated that 50% of the tornadoes were accompanied by winds of 70 mph or less. For details refer to Fujita (1973).

As for the path lengths of U.S. tornadoes, Pearson (1971) tabulated a total of 7428 tornadoes between 1960-1970. Of these only 62% or 4627 gave path lengths in Storm Data. The rest, or 2801 storms had to be out of the statistics because their path lengths were not given despite their confirmation as tornadoes.

In order to perform subjective estimates of three basic tornado parameters, windspeed, path length, and path width, for "all tornadoes", authors devised the F P P tornado scale.

During the past two and one-half years, experimental estimates have been made first by NOAA state climatologists followed by NWS personnel. Practically all tornadoes were assessed with the F P P scale which is designed to be coarse enough to permit the estimates without additional effort such as special damage survey.

2. TABLES FOR WINDSPEED, PATH LENGTH, AND PATH WIDTH

The intensity scale was constructed initially by connecting Beaufort force 12 (73 mph) with the speed of sound, in 12 non-linear increments. F scale windspeeds may be computed from the formula

$$V_F = 14.1 (F+2)^{\frac{3}{2}} \quad \text{mph} \qquad (1)$$

Since it is believed that the maximum wind along a tornado path will vary, the maximum F scale anywhere within the tornado swath is regarded as the F scale for classifying the entire storm.

The path-length scale is computed from

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

where L is the path length corresponding to the P_L scale. When P_L equals 1 the path length is 1.0 mile. Each additional increment of one unit increases the path length by the factor of the square root of 10, or 3.162. The scale was designed to facilitate the estimates by NWS personnel, since experience had shown that it was highly unlikely that surveys would be made in more than 10% of storms.

The path-width scale is determined from the width of the tornado damage averaged over the entire path length, and is computed from the equation below. The scale was designed to facilitate estimates in the same manner as the P_L scale.

$$\bar{w} = 10^{\frac{1}{2}(P_W - 5)} \quad \text{miles} \qquad (3)$$

The values computed from these equations are given in Table I.

TABLE I. Ranges of windspeed, path length, and path width corresponding to F, P, P. Negative and 6 or larger scales may be used whenever necessary. *in miles

Scale	F (mph)	P_L (miles)	P_W (yds)
negative	less than 40	less than 0.3	less than 6
0	40-72	0.3-1.0	6-17
1	73-112	1.0-3.1	18-55
2	113-157	3.2-9.9	56-175
3	158-206	10-31	176-556
4	207-260	32-99	*0.3-0.9
5	261-318	100-315	*1.0-3.1
6	319-380	316-999	*3.2-9.9

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The preliminary tabulations of the 1972 tornadoes indicated that greater definition is needed for the short tracked tornadoes and this was accomplished by adding five additional increments.

TABLE II. Negative numbers for P scale to be used for short tracked tornadoes.

P_L scale	Path length (yds)
0	1760-557
-1	556-176
-2	175-56
-3	55-18
-4	17-6
-5	6-2

The damage area of a tornado swath can be obtained by

$$a = L \times \bar{w} \qquad (4)$$

where a is the damage area caused by a specific storm. By substituting L and $\bar{w}$ with Eqs. (2) and (3), respectively, we have

$$a = 10^{\frac{1}{2}(P_L + P_w) - 3} \text{ in sq.mi.} \qquad (5)$$

The logarithm of the damage area which may be called the area scale, "A", is expressed simply by

$$A = \log a = \tfrac{1}{2}(P_L + P_w) - 3. \qquad (6)$$

Table III. Tornado areas as a function of P_L and P_w .

$P_L + P_w$	a in sq.mi.	A
-2	0.0001	-4
0	0.001	-3
2	0.01	-2
4	0.1	-1
6	1	0
8	10	+1
10	100	+2

Equations (5) and (6) along with Table III indicate the simple relationship between P P and A scales, allowing an immediate computation of the tornado area.

3. STATISTICAL RESULTS

Because of an earlier effort by Fujita (1971) to classify tornadoes by area and intensity, no P_L P_w estimates are available prior to 1972 although work is underway by the authors to classify all tornadoes back to 1950. A partial classification of F-scale for three separate years and of A-scale for 1965 are shown in following Tables.

TABLE IV. F-scale tornado intensit in 1965 from Tecson (1972) and 1971 from Fujita (1972).

F scale	1965	1971	1972
0	33%	20%	23%
1	44	42	46
2	17	26	24
3	5	8	6
4	1	2.5	0.8
5	0.1	0.2	0.0
Total	893	888	740

TABLE V. A-scale tornado area in 1965 from Tecson (1972).

Area in sq.mi.	Frequency	A scale
0.0001	21%	-4
0.001	24	-3
0.01	29	-2
0.1	16	-1
1	9	0
10	1	1
100	0.1	2

1972 is the only year for which a complete tabulation of the FPP frequency is available.

TABLE VI. F P P distribution of 1972 tornadoes

Tornado Intensity		
F 0	169	23%
F 1	344	46%
F 2	174	24%
F 3	43	6%
F 4	11	0.8%
F 5	0	0%
Total	740	100%
Path Length		
P 0	389	52%
P 1	186	25%
P 2	97	13%
P 3	58	8%
P 4	10	1.4%
P 5	0	0%
Total	740	100%
Path Width		
P 0	201	27%
P 1	301	41%
P 2	148	20%
P 3	79	11%
P 4	9	1.2%
P 5	2	0.3%
Total	740	100%

All negative scales in Table I are included in 0 scale. For 1973 and beyond, however, negative scales are to be used by the NWS where the F P P classification is to be made.

Frequency distribution of tornadoes as a function of P P scale was obtained based on 740 tornadoes in 1972. Fig. 1 reveals, as expected, frequent occurrences of short and narrow tornadoes with P P scales 0 0 0 1 1 0 and 1 1. Their combined frequency was 443, just about 60% of the total frequency.

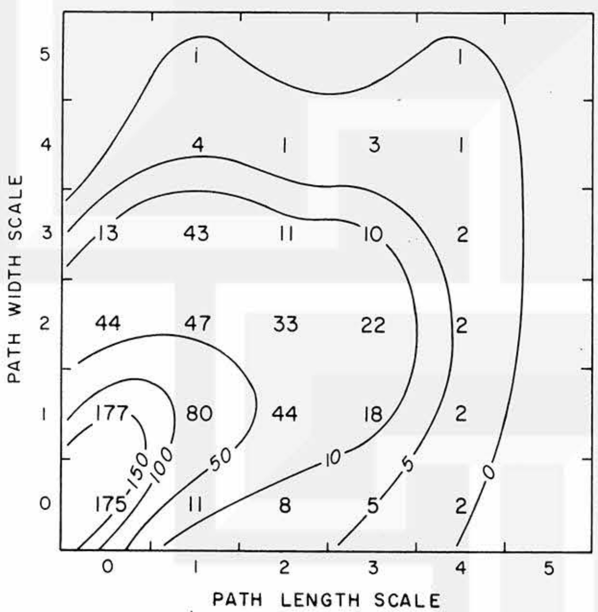

Fig. 1. Frequency vs. P P scale of U.S. tornadoes in 1972.

A similar statistical diagram of Fig. 2 was made by computing the mean F scale for each combination of P_L and P_W scales. In case only one tornado is available, the F scale for the storm was plotted in the figure without using a decimal number. F 2.8 is found where P P scales are 2 3 and 3 3. It is of extreme interest to find that the mean F scale of short and narrow tornadoes is very small.

When the maximum F scale was plotted against the P P scale, the center of the strongest tornadoes is seen where both P scales are between 2 and 3. Since 1972 was a year of weak tornadoes, this result may not be applicable to other years. Accumulation of more statistical evidence in future years will improve the F,P,P correlation.

For the purpose of computing tornado risk and probability, an estimate of tornado areas is often necessary. The P P distribution of tornado frequencies can readily be used for such an estimate.

The total tornado area can be obtained by adding individual tornado areas, thus

$$\sum_1^n a = n_1\bar{a}_1 + n_2\bar{a}_2 + \cdots \qquad (6)$$

where n is the total number of tornadoes with an individual area, a; n_1 the number of tornadoes with mean area a, etc.

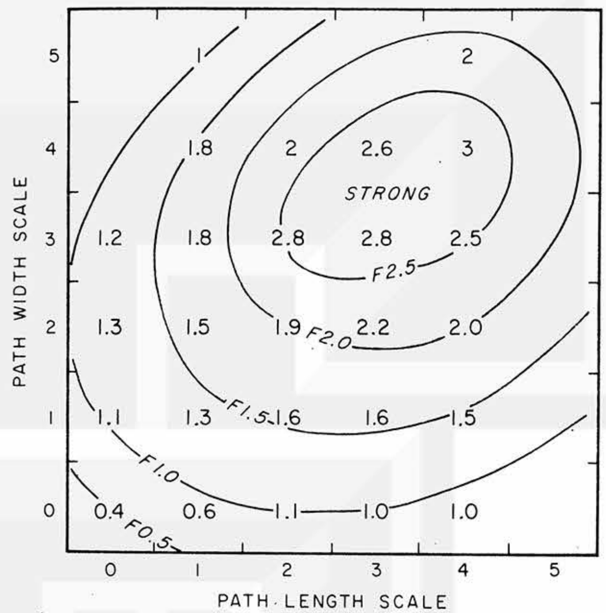

Fig. 2. Mean F scale vs. P P scale of U.S. tornadoes in 1972.

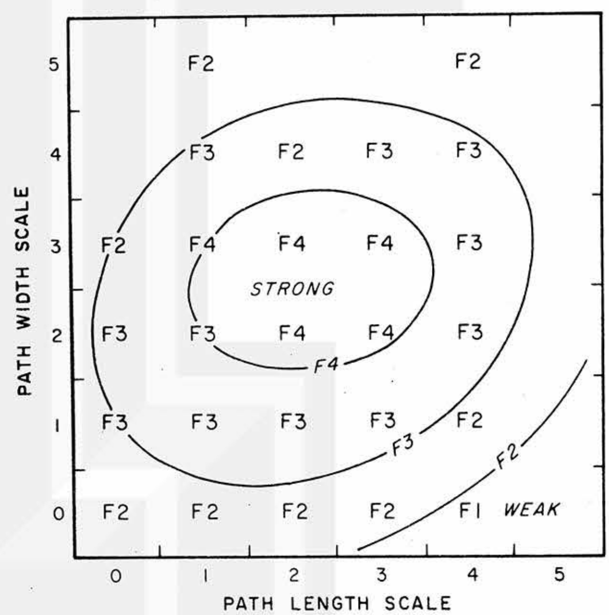

Fig. 3. Maximum F scale vs. P P scale of U.S. tornadoes in 1972.

Since the variance of tornado areas in each term on the right side of Eq.(6) must be small, isolines of A were drawn in Fig. 4 to select the proper values of a corresponding to the tornado number at each P P grid point. The figure shows that the individual tornado area increases 0.001 to 1000 sq. mi. from the lower left corner to the upper right corner of the square box in the figure.

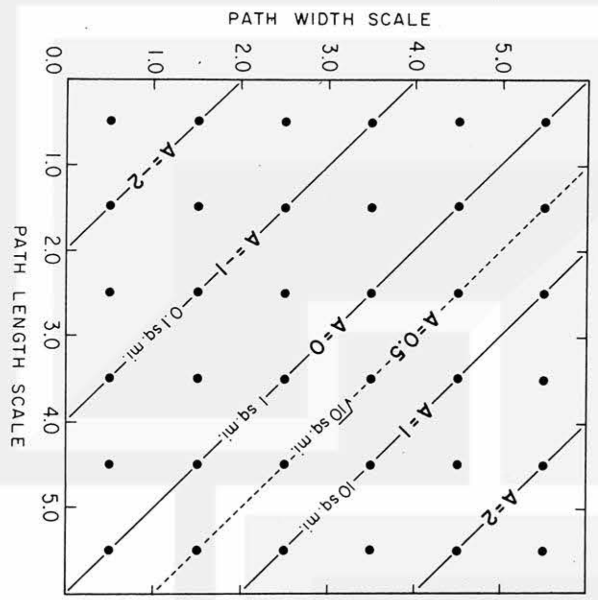

Fig. 4. Isolines of individual tornado area as a function of P P scales.

By superimposing Fig. 4 upon Fig. 1, each term on the right side of Eq. (6) was computed. The result in Fig. 5 reveals that storms of large P P contribute significantly to the total tornado area. It should be noted, for instance, that the 175 tornadoes with P P = 0 0 contribute significantly less than one tornado with large P P scales.

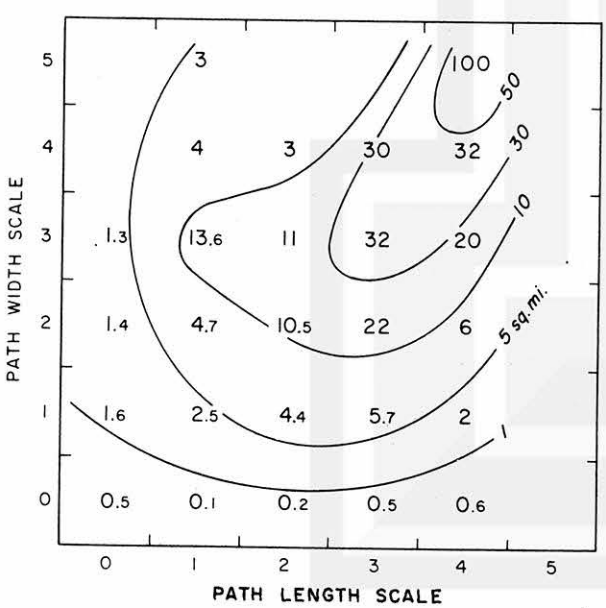

Fig. 5. Damage areas contributed by tornadoes with respective P P values.

SUMMARY AND CONCLUSIONS

Preliminary results of the F P P classification of tornadoes are presented in this paper. Results undoubtedly confirm that most storms called tornadoes are relatively weak in intensity, short in path length, and narrow in path width. Small number of strong and large tornadoes are of extreme importance in terms of damage and casualties. These tornadoes should be predicted as accurately as possible.

An attempt is being made to classify past tornadoes in the F P P scale. Meanwhile, future storms are to be assessed with reasonable accuracy so that the accumulation of F P P tornado data can be beneficial to those who are involved in various aspects of tornado research and prediction.

For further information on the method of the F P P classification refer to "Experimental Classification of Tornadoes in F P P Scale" by Fujita, distributed to National Weather Service Offices dated May 10, 1973.

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