Relationship of Tornado Deaths to Severe Weather Watch Areas

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ABSTRACT

The National Severe Storms Forecast Center (NSSFC) has compiled statistics on tornado occurrences for the period 1950–1973 which not only include date, time, and location, but a variety of information such as deaths, injuries, damage class, and other descriptive features on each event. This study relates tornado deaths to the severe weather watches issued by the Severe Local Storms Forecast Unit (SELS) from the inception of the Unit in March 1952 through 1973. Some 14 600 tornadoes occurred during this period, but only 497 of the total caused fatalities. The total tornado-related deaths were 2575. The percentage of the tornadoes which caused deaths within the time and space of a watch is presented by year, as is the overall correctness (56%) for the entire period. Of the total tornado deaths, the percentage within valid watch areas is shown for each year together with the overall percentage for the period (66%). Statistics were computed on two lead times. One starts with the issuance time of a watch and the other starts with the valid time of the watch (both of which are indicated on the watch message), while both lead times end with the occurrence of a tornado producing death(s). The average lead times in hours and minutes were 3:16 and 2:33 respectively. Likewise, an investigation was made as to tornado deaths outside watch areas with respect to time of day and geographical location. While there appeared to be no relationship between these deaths and time of day, six southeastern states accounted for 48% of the total. An interesting corollary presented reveals that 235 of the 497 death producing tornadoes caused only a single fatality, while 26 tornadoes accounted for 1180 deaths. The statistics presented on tornado deaths and severe weather watches imply a comparatively high skill in forecasting severe weather. This is true in the area of major tornado outbreaks as compared to the isolated tornado occurrence. Two-thirds of all deaths from tornadoes in the period of study occurred with major outbreaks and 77% of these deaths were within watch areas.

1. Introduction

The National Severe Storms Forecast Center (NSSFC) has completed a project on statistical data describing tornadoes and tornado occurrences that have been listed in the U. S. Department of Commerce publication Storm Data since 1950. Storm Data not only lists date, time, and location of all tornadoes, but also their path length and width, fatalities, injuries, damage class, counties affected, and several other descriptive attributes, where known. While the data were compiled by the Staff at NSSFC, they were sent to the individual State Climatologists of the National Weather Service Climatological Program for correction and corroboration. As Storm Data is an unedited publication, various errors had crept into the data; while some of these were obvious to the Staff at NSSFC, others had to be confirmed from the original reports, newspaper clippings, and other records of the State Climatologists. The bulk of the work in collecting and reviewing these tornado data was completed prior to the abolishment of the State Climatological Program early in 1973. Minor adjustments of the data continued through the summer of 1973, and by the fall of 1973 the acquired information was placed on magnetic tape for computer processing. Since this is a continuing project, data for 1973 became available early in 1974. The total data set has been accepted at NSSFC as the most complete and accurate information on tornadoes for the period 1950–1973.

2. Data investigation

The avenues for studying these statistical data on tornadoes are legion. The Severe Local Storms Forecast Unit (SELS) of NSSFC, which issues tornado and severe thunderstorm watches for the conterminous United States, has been recognized for its timely and accurate issuances of tornado watches for the Palm Sunday tornadoes of 11 April 1965; the Topeka, Kans., tornado of 8 June 1966; the Mississippi tornadoes of 21 February 1971; and the Fargo, N. Dak. tornado of 20 June 1957. The death toll from these four tornado outbreaks was heavy; they account for about 15% of the total tornado deaths since the inception of tornado forecasting by the National Weather Service in 1952. Thus, one avenue of investigation available was to assess the tornado-related deaths and the existence or nonexistence of severe weather watches for the period 1952–1973. However, for any resulting figures to be meaningful, a knowledge of the lead time, that is, the amount of time between public dissemination of the

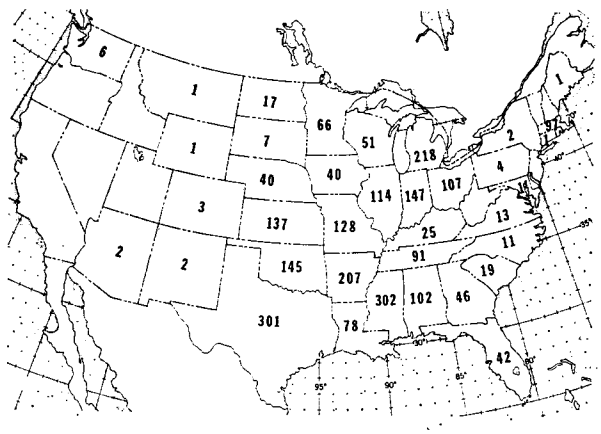

FIG. 1. Distribution of tornado deaths by state.

watch and the occurrence of the tornado which resulted in fatalities would have to be incorporated into the findings. While the foregoing assessment is the primary purpose of this paper, additional interesting information became available and is included as a corollary.

3. Tornado deaths and severe weather watches

The first tornado watch for public dissemination was issued on 17 March 1952. From that date through 31 December 1973, 2575 persons in the United States are known to have lost their lives owing to tornadoes. Figure 1 shows the distribution of deaths by state. A computer listing of tornadoes that caused these fatalities during this period was obtained from the data bank described in the Introduction. While some 14 600 tornadoes occurred between the middle of March 1952 through 1973, only 497 or 3.4% of the total caused fatalities.

Plots are on file at SELS of all the watches issued since its inception, along with their lead times. Thus, a simple comparison could be made as to whether the tornado fatalities occurred in an existing watch area or not. However, before proceeding with the investigation of the data, three decisions had to be resolved. The first involved lead time, which can be taken from either the issue time of the watch, defined as the time the SELS forecaster releases the watch for dissemination, or the valid time, which is the time the forecaster expects the onset of the severe activity. For example, a watch may be issued at 1700 GMT and becomes valid at 2100 GMT, some 4 h after issue time. It was decided to compare the time of tornado fatalities against both issue and valid times of the watch.

The second decision involved tornado deaths "close" to the defined boundaries of the watch area. National Weather Service Offices are required to disseminate the watch area to those radio and television stations located within 100 statute miles of the watch area as well as those within the watch area. The primary purpose of this policy is to alert the public on the periphery of the watch area. For purposes of this study, the 100 mi figure was judged excessive. Only fatalities which occurred within 25 mi of a watch area were considered as being within the area—the assumption here being that persons within the 25 mi limit could be aware of the watch from the mass news media both from within the watch area and its periphery.

The third decision was to combine tornado-related deaths within a severe thunderstorm watch area with those that occurred in tornado watch areas. A combination seemed resonable, since less than 7% of the total deaths occurred within severe thunderstorm watch areas and a separate breakdown did not appear warranted. Table 1 shows the number of tornado deaths within tornado and severe thunderstorm watch areas plus those that occurred outside or beyond a watch area as previously defined or when there was no watch in effect. The number of fatal tornadoes is also shown.

The first step in the examination of the 497 tornadoes producing fatalities was to determine the number correctly forecast within the time and space of a watch area. Figure 2 depicts the percentage of these tornadoes correctly forecast by year and the overall correctness for the period (56% or 280 of the 497 fatal tornadoes). Next, a computation was made of the percentage of deaths that occurred with these 280 tornadoes. This is shown in Fig. 3 with percentage by year and overall percentage for the period of 66%. Thus, about two-thirds of tornado-related deaths occurred in watch areas. The full impact of Figs. 2 and 3 becomes apparent when the lead time of the watches in which fatalities occurred is introduced. Figure 4 is the average lead time broken down into both issue and valid times of the watch areas. Lead time in this figure refers to the difference between

TABLE 1. Tornado deaths and severe weather watches.

	Tornadoes	Watches: Severe thunderstorms	None
No. fatal tornadoes	233	47	217
No. fatalities	1527	167	881

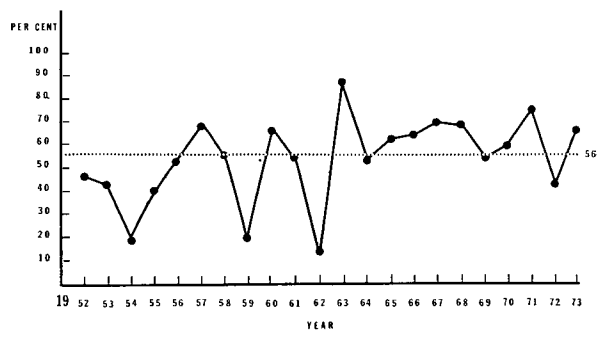

FIG. 2. Percentage of tornadoes forecast that produced fatalities.

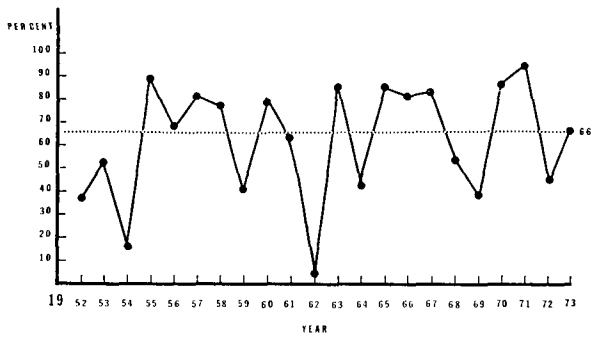

FIG. 3. Percentage of tornado deaths within valid severe weather watches.

the time the watch was issued (solid line) or the time it became valid (dashed line) and the time of occurrence of the tornado which resulted in deaths. The averages for the issue and valid times in hours and minutes are 3:16 and 2:33 respectively.

4. Tornado deaths outside severe weather watches

But what of the remaining 217 tornadoes which caused 881 fatalities? Questions that were raised, answers for which were obtainable from the data, were:

a) Did the deaths occur during the time of day climatologically least expected for tornado formation, that is, late at night or early morning hours?
b) Did the majority of deaths occur in a specific geographic location of the country?
c) Would catergorizing into death groups for each of the tornadoes provide some insight?

The time of day theory would appear to be the most acceptable and logical in accounting for the 881 deaths. Wolford (1960) and Pautz (1969) have shown in their studies that the majority of all tornado occurrences were between the hours of 1400 and 2100 LST (62.9% and 63.3% respectively). The 881 tornado deaths out-

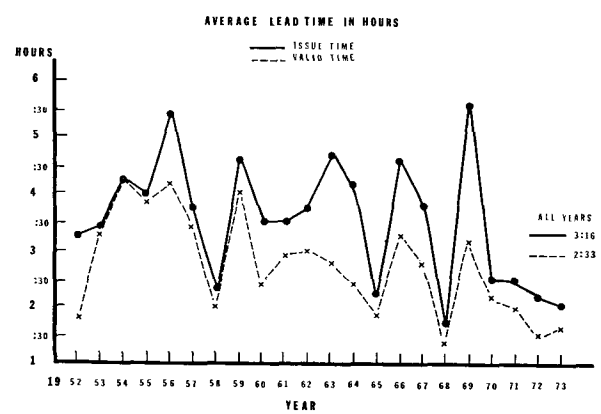

FIG. 4. Average lead time in hours.

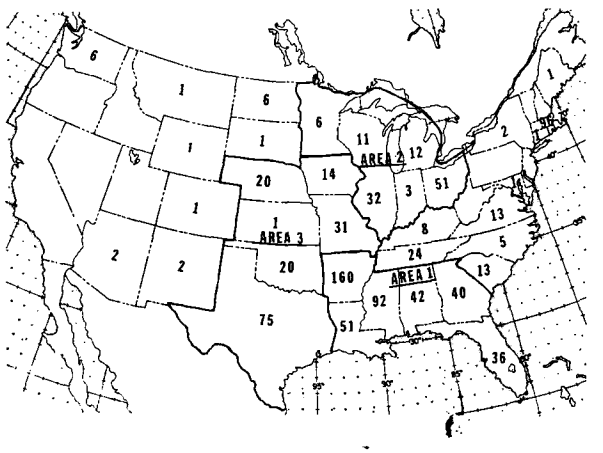

FIG. 5. Distribution of deaths outside watch areas.

side watch areas were readily available by time of day and a tabulation showed that 576 of the 881 deaths, or 65%, were within the normal (1400–2100 LST) times of maximum tornado occurrence. Also, 124 of the 217 tornadoes (about 57%) that caused these deaths occurred during this period. For comparison, the period 0200–0900 LST was examined. For this period, Wolford's and Pautz's studies indicate a minimum tornado occurrence of 9.6% (Wolford) and 8.2% (Pautz) of the total. One hundred and thirty-one of the 881 deaths (14.9%) and 26 of the 217 tornadoes (12.0%) fell within this time period. Thus, from the diurnal distribution, there appears to be no relationship between deaths outside watch areas and the time of day when tornadoes are least expected. However, from the forecast point of view, the 131 deaths represent 83% of the total number of deaths which occurred in the 0200–0900 LST period, i.e., a very large percentage of deaths in this period were not in areas under a watch.

The geographic distribution of deaths outside watch areas was next considered (Fig. 5). A plot of these deaths by state clearly defined one area that predominated in this unfortunate statistic. The six-state area (Area 1 in Table 2) of Arkansas, Louisiana, Mississippi, Alabama, Georgia, and Florida incurred 48% of the 881 deaths outside watches. A comparison was made with two other six-state areas that had comparable total deaths (within and outside watches) and in addi-

TABLE 2. Tornado deaths for selected areas.

	Total deaths		Deaths outside watches	
	No.	%	No.	%
Area 1	777	30	421	48
Area 2	703	27	115	13
Area 3	791	31	161	18
Totals	2271	88	697	79

TABLE 3. Number of tornadoes and deaths by category.

Death category	Number of tornadoes by death category					Number of deaths by death category*			
	1	2–5	6–9	10–19	≥20	2–5	6–9	10–19	≥20
1973	14	16	4	0	0	47	26	0	0
1972	7	4	1	0	0	14	6	0	0
1971	15	4	2	2	2	10	13	24	94
1970	13	5	0	1	1	17	0	16	26
1969	5	6	0	1	1	17	0	12	32
1968	8	11	3	2	1	38	23	27	35
1967	14	13	1	0	2	37	6	0	57
1966	6	1	1	2	1	2	6	27	57
1965	12	13	3	3	4	39	18	47	181
1964	7	6	1	2	1	16	7	21	22
1963	9	8	0	0	0	22	0	0	0
1962	5	2	0	1	0	6	0	17	0
1961	13	5	1	1	0	14	8	16	0
1960	9	7	0	1	0	22	0	16	0
1959	10	1	2	1	1	3	13	11	21
1958	11	4	1	2	0	15	7	34	0
1957	19	19	3	4	2	51	22	41	58
1956	6	8	2	1	1	21	13	18	25
1955	13	5	0	0	2	13	0	0	100
1954	14	6	1	0	0	16	6	0	0
1953	14	15	4	5	4	41	28	74	358
1952	11	12	4	2	3	36	33	27	114
Totals	235	171	34	31	26	497	235	428	1180
% Tornadoes	47.3	34.4	6.9	6.2	5.2				
% Deaths	9.1					19.4	9.1	16.6	45.8

1952–1973 Totals: All tornadoes—14 600. Fatal tornadoes—497. Tornado deaths—2 575.
* Category 1 is not reproduced since it is numerically the same as Category 1 under number of tornadoes.

tion some type of geographical relationship. One group selected (Area 2) all border on the Great Lakes and have a relatively high frequency of tornado occurrence. Area 2 is comprised of Minnesota, Wisconsin, Illinois, Indiana, Ohio, and Michigan. The third area (Area 3) is comprised of the states with the highest tornado incidence and geographically lie within the Central and Southern Plains. These are Texas, Oklahoma, Kansas, Nebraska, Iowa, and Missouri. For each of these areas, Table 2 depicts the total number and percentage of tornado deaths during the period studied, and also the number and percentage of deaths outside watch areas. The three areas combined suffered 88% of the total deaths but Area 1 had the misfortune to incur almost half the deaths outside watch areas.

5. Tornadoes and deaths by category

As a corollary to tornado deaths and severe weather watches, the number of people killed by each of the 497 tornadoes that produced fatalities was determined. A term, "death category," defined as the number of people killed by a single tornado, was devised to simplify the dual relationship between the number of tornadoes and the number of deaths. Five categories, (1, 2–5, 6–9, 10–19 and ≥20) were subjectively selected as a test. The results, which were quite surprising, are presented in Table 3.

The left-hand portion of Table 3 lists the number of tornadoes in each death category for each year while the right hand portion is the total number of deaths in each category. Totals and percentages are also included. For example, in 1971 there were 15 tornadoes that caused a single fatality, four that resulted in 2 to 5 deaths, etc. The total number of deaths in category 1 was, of course, also 15; the total in the 2 to 5 category was 10, in the 6 to 9 category, 13, etc. An inspection of the totals and percentages for the period under study is most revealing. There were 235 tornadoes that caused a single fatality each, or 47% of the total tornadoes that produced fatalities. These accounted for 9% of the deaths. At the other end of the scale, 26 tornadoes resulted in 46% of the total deaths. In combining the two lower categories, it is found that 82% of the tornadoes caused a little more than 28% of the total deaths. On the other hand, combining the two higher categories reveals that 56 tornadoes, or about 11%, caused almost two-thirds of the total deaths. The significance of such a small number of tornadoes stands out even more when one considers that the total number of tornadoes involved is 14 600.

6. Tornado deaths and tornado outbreaks

The statistics presented on tornado deaths and severe weather watches imply a comparatively high degree of

skill in forecasting severe weather. This is true in the area of major tornado outbreaks as compared to the isolated tornado occurrence. A major tornado outbreak, or "family outbreak," has been defined as five or more tornadoes associated with a weather system on a given day (Pautz, 1969). The definition has been modified to cover only such occurrences over a relatively small area at the lower end of the scale and expanded at the upper end to include portions of five or six states when 40 or 50 tornadoes occur on a given day. The definition of family outbreak in this investigation includes the categories small (6 to 9 tornadoes), moderate (10 to 19 tornadoes), and large (20 or more tornadoes). This differs slightly from the original definition—based upon the refined spatial distribution explained above—which was neglected in the original.

Table 4 lists the number of family outbreaks in which deaths occurred by category and the number of deaths within and outside watch areas. Other family outbreaks not involving deaths are excluded. The 1728 deaths represents over two-thirds of all deaths from tornadoes in the period of study and the 1331 within watch areas is 77%. By comparison, of the 847 deaths caused by less than six tornadoes, 363 deaths (43%) occurred within watch areas. These percentages give a definite indication of the SELS unit's ability in forecasting the larger severe weather outbreaks.

TABLE 4. Tornado outbreaks and deaths.

Category	No.	Deaths within watches	Deaths outside watches	Total deaths
Small (6–9)	72	339	126	465
Moderate (10–19)	45	454	37	491
Large (≥20)	21	538	234	772
Totals	138	1331	397	1728

7. Conclusion

The percentage (66%) of all tornado deaths which occurred in watch areas combined with an average lead time of between two and three hours implies some degree of skill in the forecasting of severe local storms. This becomes evident when major or "family" outbreaks are considered since 77% of the deaths related to these outbreaks occurred in watch areas. These statistics present a definite indication that in forecasting the major severe weather outbreaks there exists a better than average ability by the SELS unit.

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