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Illinois Tornadoes

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ABSTRACT

This report presents the climatology of Illinois tornadoes based on data from the 1916-1969 period, and offers a variety of general interest tornado facts. Illinois ranks eighth nationally in the number of tornadoes, but first in deaths and second in tornado damages. On the average, there are 10 tornadoes per year, occurring on five days. The annual average death rate from these storms is slightly over 19 with an injured average of 110 people. A majority (65 percent) of Illinois tornadoes occur during March through June, with 15-21 April being the prime 7-day period. Over 40 percent occur between 1500 and 1800 CST, and 65 percent take place from 1400-2000 CST. Five of the outstanding Illinois tornado days of the 1916-1969 period are discussed in detail, including the famed Tri-State tornado of 18 March 1925, the most devastating tornado in the United States since systematic collection of tornado data began in 1916.

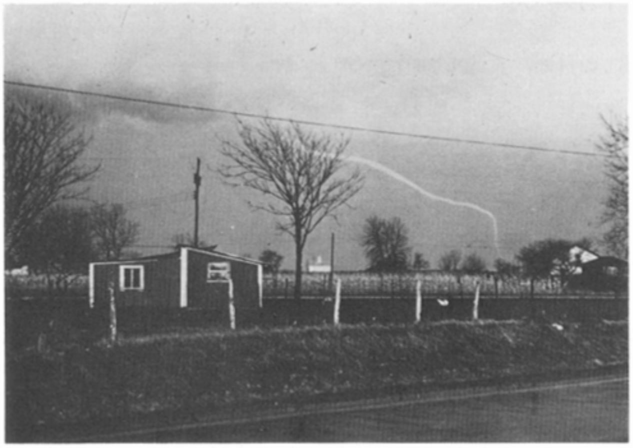
The general information includes, among other items, basic definitions pertinent to tornadoes, safety precautions, formulation of a tornado forecast, and methods for remote detection of tornadoes.

INTRODUCTION

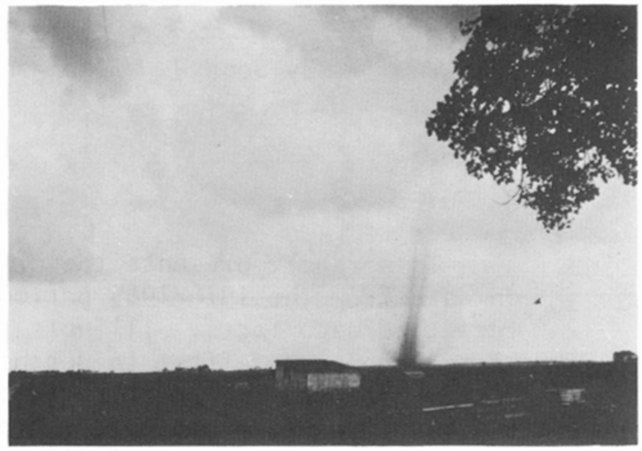
This report presents a series of scientific facts and public information items relating to tornadoes in Illinois. Continued public concern plus a need for a variety of tornado information, both general and specific to scientific interests, led to the preparation of this report. It serves to update the tornado data in an earlier Illinois study (Changnon and Stout, 1957), but also presents a variety of tornado information beyond the standard tornado climatology.

This study is based largely on tornado data for the 1916-1969 period. The U.S. Weather Bureau began the systematic collection of tornado data in 1916, and most of the data presented in this report were gleaned from various U.S. Weather Bureau (now National Weather Service) publications and reports. These include: ***Storm Data, U.S. Meteorological Yearbook, Report of the Chief of the U.S. Weather Bureau,*** and ***Climatic Data-National Summary.*** Additional data were secured from climatic records available on punch cards, old newspapers, and various published reports dealing specifically with certain major or unusual Illinois tornadoes. Some examples of tornadoes and tornado damages in Illinois are shown in figure 1.

The Illinois State Water Survey research mission is the scientific study of the water resources of Illinois, and in pursuing this topic as it relates to the atmosphere, the Survey frequently performs research concerning thunderstorms since they produce 40 to 50 percent of the total average annual precipitation (Changnon, 1957). Also, as the state's primary weather research agency, the Water Survey has investigated to some degree all severe weather phenomena related to thunderstorms and to significant precipitation production. Hail (Huff and Changnon, 1959), lightning (Changnon, 1964), snow and glaze storms (Changnon, 1969), and rainstorms



A rope-like tornado near Farmer City on 3 April 1956



A small tornado near Rantoul on 23 June 1958

Damage from tornadoes at Murphysboro on 18 December 1957

Figure 1. Examples of tornadoes and tornado damage in Illinois

(Stout and Huff, 1962) have all been investigated, at least from a climatological frequency basis. Early research on the use of radar to measure rainfall (Hudson et al., 1952) provided unique radar observations of a tornado (Huff et al., 1954), and the early development of a comprehensive program in climatology (Changnon, 1955) provided a wealth of background information on tornadoes and their related precipitation. Hence, the general public and scientific interests, the research background experiences, and the unusually large data bank of the Atmospheric Sciences Section of the Water Survey have provided the impetus to pursue tornado research, at least in a limited form, and to provide this report to answer common scientific and public questions relating to this unique and serious atmospheric phenomenon.

The first part of this report concerns the relative importance of tornadoes in Illinois as revealed by comparison with the national statistics for other states. The next part deals with various climatological aspects of Illinois tornadoes. First among these is a discussion of the spatial distribution of tornadoes based on county, area, and population frequencies. This is followed by a discussion of the temporal or time series distribution of tornadoes including the number of tornadoes, tornado days, and tornado deaths. The seasonal distribution of tornadoes, the daily-weekly distributions, and the hourly or diurnal distribution are then discussed with data being given for the state as a whole and for regional subdivisions. Also presented is information on tornado path characteristics including length, width, and tornado orientations.

The third part of the report deals with detailed discussions of selected major unusual tornadoes in Illinois. Five of the outstanding tornado days of the 54-year study period are discussed.

The final part of this report presents general tornado information of interest to the public. Included are definitions of terms such as tornado, funnel cloud, tornado watch, and tornado warning. Various safety precautions regarding tornadoes are discussed. The synoptic conditions and the formulation of a typical tornado forecast are described. Temporal variations in tornado likelihood of damage over the 54 years and probabilities for a tornado occurring at a point are presented. Means of remote detection of tornadoes and possible modification concepts are also treated. Data for the 542 Illinois tornadoes are given in the appendix.

This study was performed under the administrative supervision of Dr. William C. Ackermann, Chief of the Illinois State Water Survey. Appreciation is expressed to Daniel D. Watson for assistance in compiling and plotting tornado statistics. John W. Brother, Jr., prepared the illustrations, and Mrs. J. Loreena Ivens edited the manuscript.

NATIONAL EVALUATION OF ILLINOIS TORNADOES

State and National Ranking

The region of maximum tornado frequency in the world is the central United States (Bates, 1962). The factors which act to produce the high frequency of tornadoes in the central United States are: 1) the low-level tongue of moist air which penetrates into the heart of the continent, and 2) the incursions of the jet stream over this low-level warm, moist tongue which cause vertical motion fields that modify an air mass to make it conditionally unstable. The seasonal shifting of the area where these two factors coincide is considerable. The coincidence optimizes in spring and early summer in the central United States. In the winter the jet stream is strong but the air mass is unfavorable for tornadoes in Illinois, and in late summer and fall the air mass is often favorable but the jet stream is generally weak and displaced far to the north in the United States. Nowhere else in the world are the controls of the general circulation, geography, orography, and the jet stream more ideally interrelated for the production of tornadoes.

Because of the general climatic motions of these two basic tornado-producing factors, there is considerable seasonal movement of the center of maximum tornado frequency in the United States. The center of maximum activity moves northward from the Gulf states in late winter, to Iowa in the summer, and then returns southward in the fall (U.S. Weather Bureau, 1960). The greatest frequency in January is recorded in Louisiana, Alabama, and Mississippi. In February the center of activity begins to move northward with increased activity in Arkansas, followed in March by a rather widespread area of maximum tornado occurrences throughout Arkansas, Missouri, Alabama, Tennessee, Mississippi, and Illinois. During April and May the center of activity moves into Oklahoma, Kansas, Missouri, Iowa, and Texas. The center of maximum tornado activity begins to reverse its general northward motion during June and lies within the areas of Kansas, Nebraska, and Iowa.

The number of tornadoes occurring in the United States decreases dramatically during July, August, and September. In July and August, Kansas, Nebraska, and Texas are relatively frequent tornado states, and in September Kansas is the leading tornado state. It is interesting to note that although tornadoes are not frequent in Florida, they are more frequent there in September than in other months. This likely relates to tornadoes bred by hurricanes (Sadowski, 1966). In November and December tornadoes are generally infrequent in the United States, but occur most often in the Louisiana-Mississippi-Texas area.

The average annual numbers of tornadoes, based on occurrences for 1916-1964, were used to evaluate and compare state frequencies (ESSA, 1965). Figure 2 shows the state averages for all states that have an annual average of one or more tornadoes. This pattern clearly shows that Texas, Kansas, and Oklahoma are the leading states of tornado activity with reasonably high frequencies extending northward and eastward from these three states.

Tornado statistics used in these comparisons were based on available data from individual states and a fixed period. Court (1970) has delved into areal variations on national tornado maps to illustrate the variety of results obtainable with different base periods.

As shown in figure 2, Illinois, with an annual average of 9 tornadoes for the 1916-1964 period, ranks eighth in the United States. The seven states of greater frequency of tornadoes lie west and southwest of Illinois. The pattern shown by the averages on figure 2 indicates. that Illinois would be considered on the eastern edge of the 'tornado belt' of the central United States. Tornadoes have occurred in each of the 48 contiguous states.

Since states do not serve as ideal geographic units for comparison because they are of unequal size and shape, the averages (figure 2) were divided by the square miles of each state to get normalized values. When these were ranked, the order from high to low was: 1) Oklahoma, 2) Kansas, 3) Iowa, 4) Arkansas, 5) Indiana, 6) Missouri, 7) Illinois, and 8) Mississippi. The rank for Illinois did not materially change, but two high ranking states based on averages alone, Texas and Nebraska, achieved much lower normalized ranks, 14th and 10th respectively.

A more detailed expression of the national pattern and variability in tornado frequency appears in figure 3. Here the number of tornado initiations in each 1-degree square is portrayed for the 1916-1961 period. Values of 50 or more tornado initiations are found in squares in north-central Texas, and are common in most of Oklahoma and Kansas. However, east of these three states, only two squares with tornado values of 50 or more are found, one in Iowa and one in southwestern Illinois-eastern Missouri.

Evaluation by Tornado Deaths and Damages

Tornadoes in Illinois can also be evaluated by comparing statistics on deaths and damages with those of other states. Statistics for all states are available only for 1916-1950. In this 35-year period, Illinois had 914 deaths resulting from tornadoes (Flora, 1953). This value ranks Illinois first in the United States in the number of tornado deaths. For this same 35-year period, Illinois had tornado damages of $48.7 million which ranks it second only to Oklahoma. Thus, although Illinois ranks only seventh or eighth nationally in the occurrence of tornadoes, it ranks first in deaths and second in damages from tornadoes.

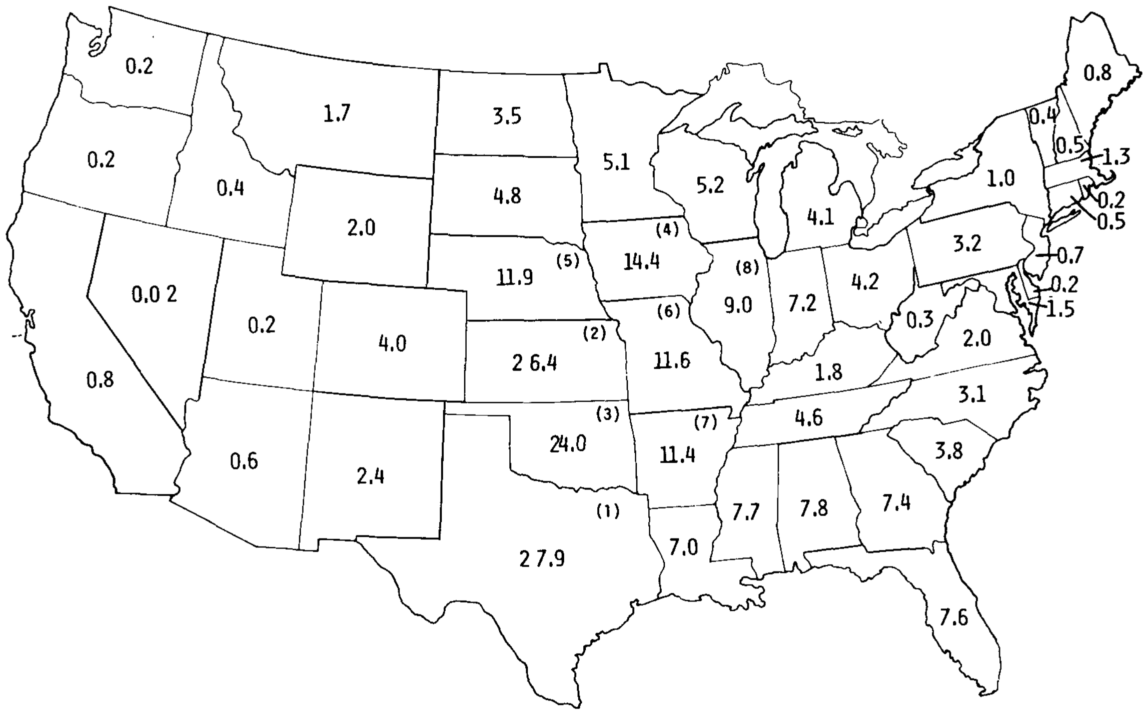


Figure 2. Average annual number of tornadoes, 1916-1964, and ranks for illinois and states with greater averages

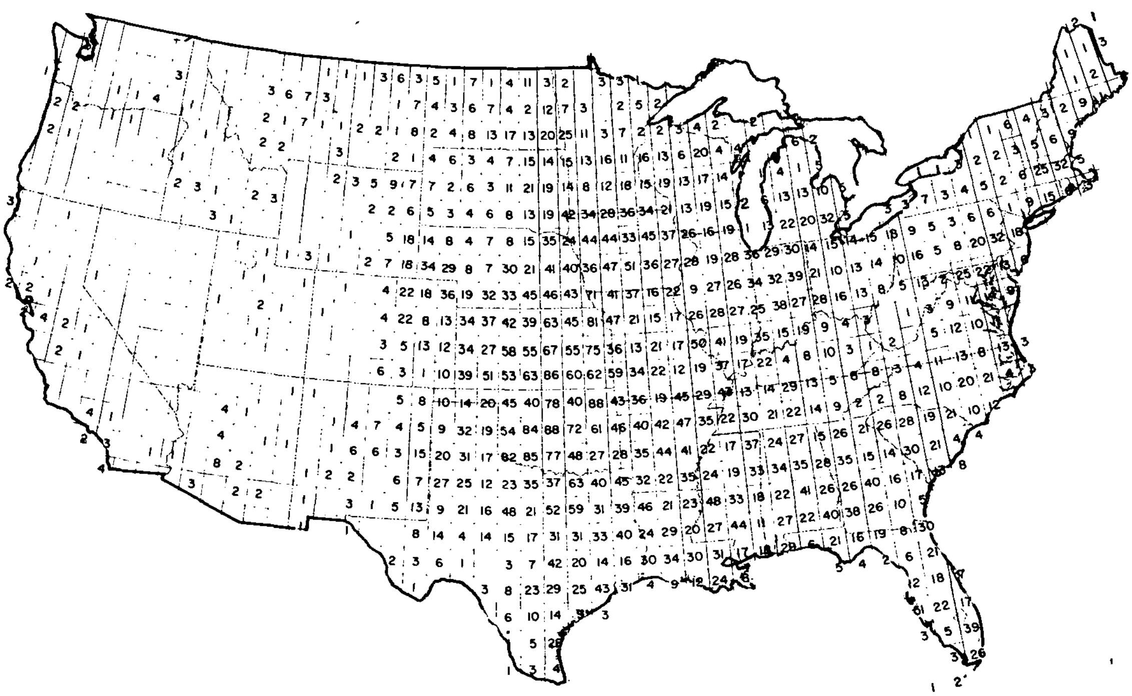


Figure 3. Number of reported tornadoes in the United States by 1-degree squares, 1916-1961, based on the first point of contact with ground of 11,053 tornadoes

These results signify the extreme seriousness of tornadoes in Illinois. The principal reasons for the high deaths and property damages are the relatively high densities of population and structures in Illinois. Illinois has the highest number of persons per square mile of all the states with higher ranking tornado frequencies (figure 2). This greater density of population certainly presents a higher probability of fatality and structural damage per tornado occurrence. Illinois has three times as many persons per square mile as any other state in the central tornado belt. Moreover, this high population ratio is not due to the population of the Chicago metropolitan area. After deleting the Chicago area population from the state total, Illinois still ranks first in the ratio per square mile in the tornado belt. Also, more than three-fourths of the Illinois population is classified as urban. Therefore, tornadoes occurring in Illinois where there are concentrated areas of population and high-value property are likely to be more damaging than those occurring in rural, sparsely populated regions having few small urban. concentrations.

Tornado Death Regions

In a study of tornado deaths, Linehan (1957) presents a map showing the centers of tornado deaths for each month in the United States, based on deaths in the 1916-1953 period. The center is located in central Iowa in July and August, but in the other 10 months of the year the center of tornado deaths is located along the Mississippi River Valley from southern Arkansas northward to central Illinois (where it is located in April and June). This positioning of tornado death centers 300 to 500 miles east of the states of maximum tornado frequency further indicates the importance of tornadoes in Illinois although they are less frequent than in several states to the west.

Linehan also presents regions of tornado deaths in the United States. Region 1, the region of most prevalent deaths, is in the south-central United States and includes the southern one-fourth of Illinois. His region 2, where deaths are less frequent by two-thirds, includes the remaining portion of Illinois. Thus, his analysis indicates that tornado deaths in Illinois are more apt to occur in the lower populated areas of extreme southern Illinois. However, this result may be due to the occurrence of one major tornado storm on 18 March 1925 which will be discussed later.

Frequency of Major Tornadoes

The U.S. Weather Bureau (1960) listed 173 'outstanding' tornadoes that occurred in the United States during the 1875-1958 period. Outstanding tornadoes were defined as those which resulted in the loss of more than one life and/or property damage of more than $100,000. Fourteen of these 173 tornadoes occurred within Illinois (over 8 percent), and only Missouri and Arkansas, each with 15, had a greater number of outstanding tornadoes during this period. The 14 outstanding Illinois tornadoes in this period are listed in table 1.

Table 1. Some Outstanding Illinois Tornadoes, 1875-1958

Date	Place	Deaths	Injured	Property damage ($)
6 May 1876	Chicago	0	0	250,000
4 Jun 1877	Mount Carmel	16	100	400,000
19 Feb 1888	Mount Vernon	18	54	400,000
18 May 1898	Northwestern Illinois*	47	Unknown	700,000
21 Apr 1912	Southern Illinois**	18	0	1,000,000
26 May 1917	Mattoon-Charleston	101	638	2,500,000
28 Mar 1920	Elgin-Wilmette-Clearing	28	300	3,000,000
17 Apr 1922	Eastern Illinois***	7	Unknown	295,000
18 Mar 1925	Southern Illinois	606	1430	13,303,000
14 Sep 1928	Rockford	14	0	1,200,000
25 Mar 1935	Massac County	1	34	300,000
19 Mar 1948	Gillespie-Bunker Hill	33	449	3,765,000
14 Jun 1957	Springfield	2	50	3,000,000
18 Dec 1957	Southern Illinois	13	259	2,000,000

**Crossed portions of Iowa, Illinois, and Wisconsin, deaths and property damages are totals for three states*

***Near Carbondale*

****Crossed portions of Illinois, Indiana, and Ohio*

Long-Track Tornadoes

The U.S. Weather Bureau (1960) also presented the tornado tracks of more than 9000 tornadoes occurring in the United States in the 1916-1958 period. The lengths of the longer tracks were measured and identified as to location and month of occurrence. A total of 25 tornado tracks with lengths of 150 miles or longer were found in the continental United States for this 43-year period. Five of these (20 percent) occurred in Illinois, and each extended into Indiana or Missouri.

Further investigation revealed that 14 of these 25 extremely long tornadoes developed and moved east of the Mississippi River, and 23 of the 25 occurred entirely east of a line connecting the eastern borders of Texas, Oklahoma, Kansas, Nebraska, and the Dakotas. This is of considerable interest because tornadoes are shown to be more frequent in three states west of this line. Hence, the very long-lived tornado, with its inherent greater probability of inflicting death and damages, is much more common in the eastern portion of the tornado belt including Illinois, Missouri, and Indiana, and in the southern states. This suggests that the steady-state storm capable of sustaining a tornado for several hours exists occasionally in the eastern portion of the tornado belt and not in the center of the tornado belt. Such a meteorological circumstance, along with the higher density of population in Illinois, is involved in the high ranking of Illinois in deaths and damages.

In summary, although tornado-producing conditions are more frequent in Texas, Oklahoma, and Kansas than elsewhere in the United States, the conditions that lead to long-lived violent tornadoes are much more prevalent east of these states. The state most frequently affected by the long-lived storms is Indiana, with seven such storms, followed by Illinois and Arkansas with five and three respectively. Thus, although these storms are infrequent, a considerable tendency to occur in the Illinois area makes them a unique feature of the Illinois tornado climatology, and one that deserves more study.

There were five tornadoes in Illinois during the 1916-1969 period with track lengths that equalled or exceeded 150 miles. These tornadoes were basically on the ground throughout their paths except for a few scattered skips of not more than 10 or 15 miles.

The first of these was on 26 May 1917 and is commonly called the Mattoon tornado. It began near Louisiana, Missouri, and in a 7.3-hour period traveled eastward across Illinois inflicting major damage at Mattoon and Charleston, then turned southeastward going almost across Indiana for a total track 293 miles long. There were skips totaling 12 miles in Illinois after which the tornado remained on the ground for 208 miles.

The next long-track tornado occurred on 16-17 April 1922. The storm began in Washington County at 2300 CST and, with a heading of 50 degrees (northeast), traveled 150 miles ending just inside Indiana. Five were killed, 47 injured, and the damages totaled $285,000.

The third long tornado occurred on the next afternoon, 17 April 1922. The storm began at 1530 CST at Ogden, Illinois, moved east-northeast across Indiana, and terminated at Oldan County in Ohio. It lasted 4.5 hours, ending at 2000 CST, and had a path length of 210 miles. Sixteen were killed and damages to property totaled $900,000.

The fourth of these storms was the famed Tri-State tornado of 18 March 1925. This national record storm began in Missouri, crossed Illinois, and ended in Indiana in 3.5 hours. Its funnel was on the ground for 219 miles, making it the longest continuous tornado on record, as well as the most deadly with 695 killed, 2027 injured, and $16,500,000 in damages.

The fifth major long-track tornado occurred on 19 April 1927. It began in Calvin County in Missouri (7 miles inside Missouri) just before 1200 CST. Its heading was 52 degrees with an average speed of 61 mph over a 171-mile track. Some minor skipping occurred, and the tornado ended near the Ford-Livingston County lines in central Illinois. There were 21 killed, 123 injured, and damages totaling $1,369,000.

Thus, the five 'long-track' tornadoes that have occurred at least partially in Illinois came in an 11-year period out of a 54-year study period.

ILLINOIS TORNADO CLIMATOLOGY

Spatial Distribution

Accurate analysis of the spatial distribution of tornadoes within a given area such as a state is difficult and somewhat biased. The primary method of tornado observation, the personal observation, is dependent upon people being in the area of a tornado when it occurs, or being able to determine by storm damage patterns the existence of a tornado. The nonhomogeneous distribution of population in Illinois compounds the problem, as the chances of a tornado being reported, especially if it causes little damage, are somewhat proportional to the population density, particularly in rural areas.

In the 1916-1969 period of study, Illinois recorded 542 tornadoes within its boundaries. Figure 4 shows the beginning and ending points of each tornado, and where the tornado was on the ground during its life. Of the 46 tornadoes to cross the state's boundaries, 3 have come from Iowa, 2 from Wisconsin, and 18 from Missouri, Three have traveled over Lake Michigan, 2 into Wisconsin, and 18 into Indiana.

Analysis of the tornado distribution within subregions of Illinois was done by counties, since they are units having readily available statistics of population and tornado occurrence. About 91 percent, or 496, of the tornadoes originated within the state's boundaries, and figure 5 shows the number which began in each county. Three counties, Bond, Edwards, and Scott, have reported no tornado originations, whereas two counties, Cook (urban) and Randolph (rural), have recorded more than 20.

Both the total number of tornadoes per county and the number per 100 square miles for each county appear in figure 6. Data from Wisconsin (Burley and Waite, 1965), Iowa (P. J. Waite, personal communication), Missouri (G. L. Darkow, personal communication), and Indiana (Agee, 1970) have been used to supplement the Illinois data. Figure 6a reveals a high degree of variability among counties in the number of tornadoes reported. Some of this variation is due to county size differences and some is due to differences in population among counties, with counties having higher population density usually exhibiting larger numbers of tornadoes. Chicago and St. Louis are evident as high occurrence areas.

The number of tornadoes per 100 square miles, based on county values, also shows variability (figure 6b). Highs are located in the southwestern portion of the state, around the Chicago area, and to a lesser degree in eastern Illinois. Western and southeastern Illinois and the five counties immediately south of the eastern Illinois high show relatively fewer tornadoes per unit area.

The problem of population bias in county data has been handled by Darkow (personal communication) and Agee (1970) by the creation of a tornado index. Their index is a nondimensional quantity defined as:

$$\text{tornado index} = \frac{\left(\dfrac{\text{tornadoes}}{\text{rural population}}\right)_{\textit{county}}}{\left(\dfrac{\text{tornadoes}}{\text{rural population}}\right)_{\textit{state}}}$$

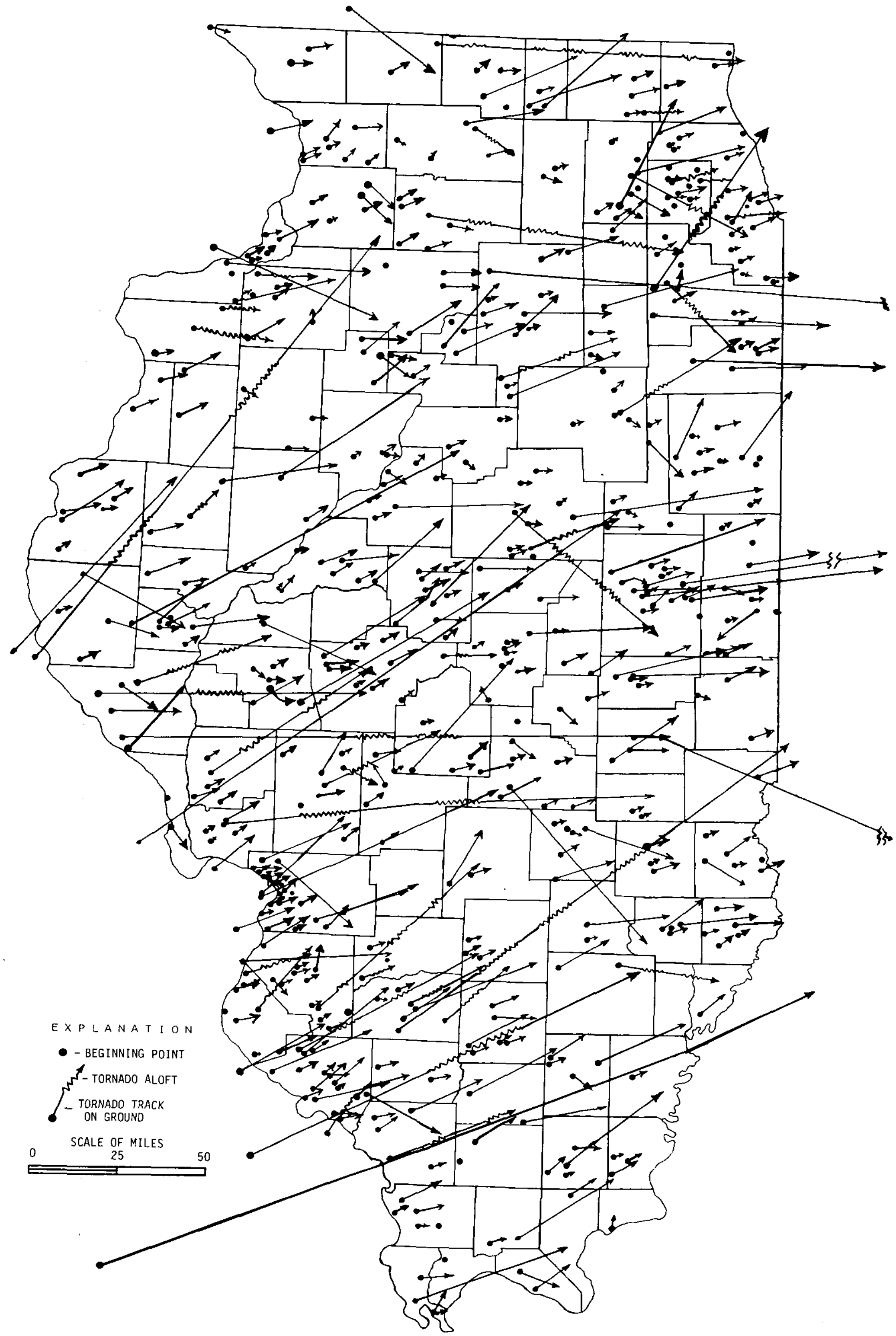


Figure 4. Paths of Illinois tornadoes, 1916-1969

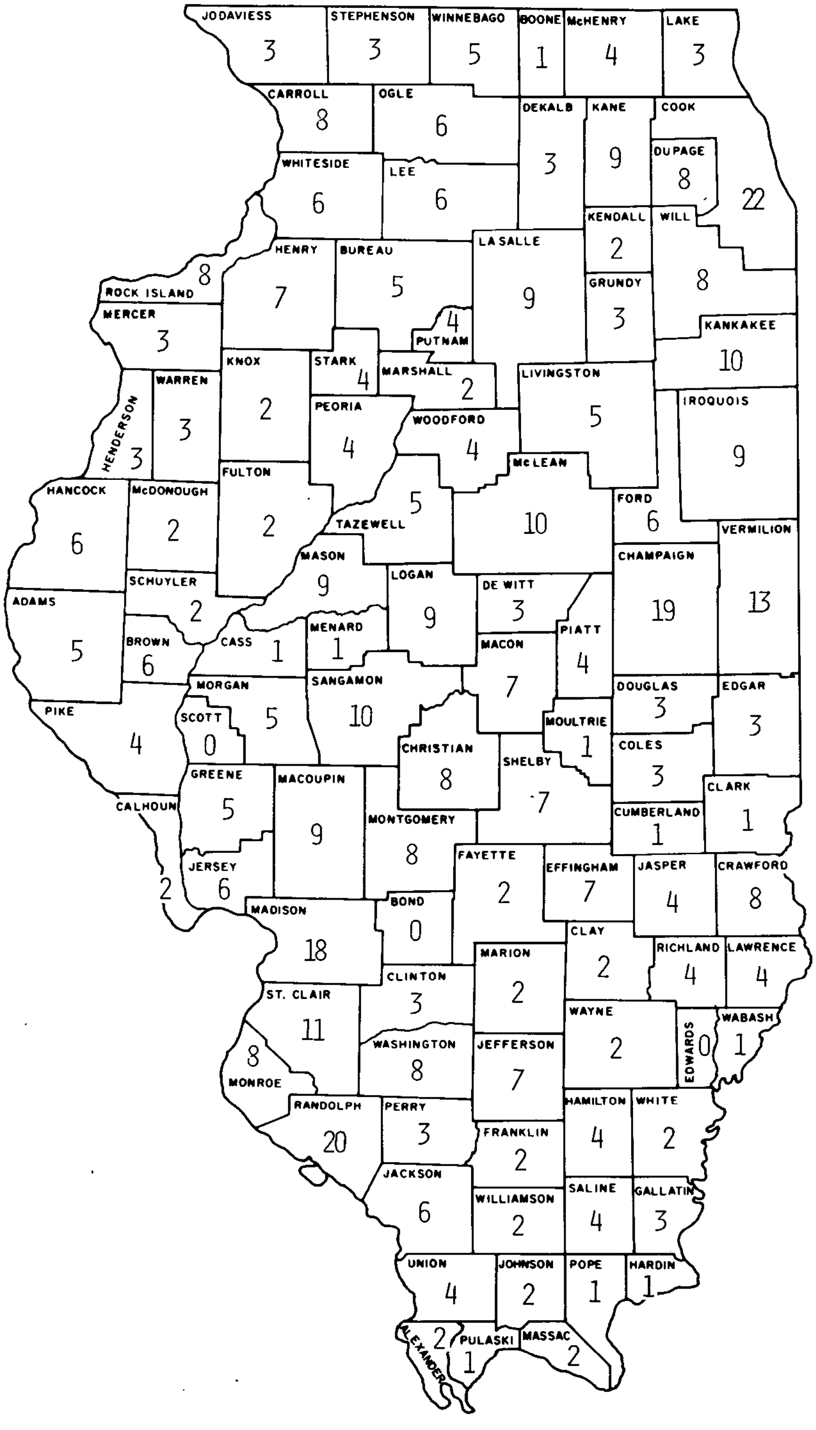


Figure 5. Number of tornadoes originating in each county, 1916-1969

Thus, the state average of 1.00 is the basis for comparison of county values. Rural rather than total population was used because of the theory that an area need be inhabited only to a certain extent for tornado observation, and the addition of more people in a given area will not improve the chance of observing a storm.

Figure 7 shows tornado indices for each county in Iowa, Missouri, Indiana, and Illinois. A consistent pattern of above-average values is present from north of

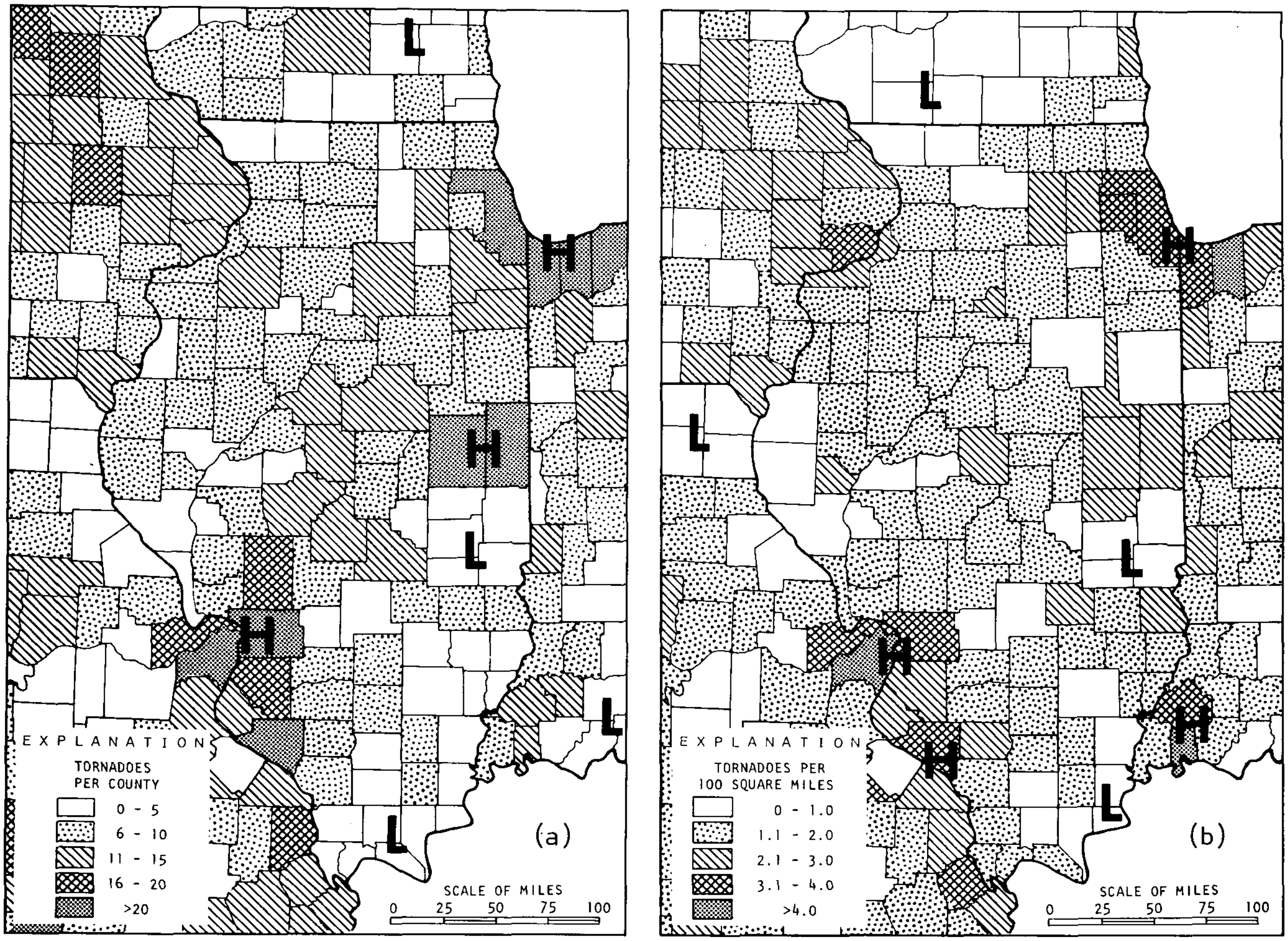


Figure 6. Total number of tornadoes per county (a), and number of tornadoes per 100 square miles (b) [Iowa, Missouri, and Illinois data for 1916-1969; Wisconsin, 1916-1964; and Indiana, 1916-1968]

St. Louis northeastward into central Illinois, and also in the west-northwest section of the state.

In the mid-1950s a large increase was seen in the annual number of tornadoes reported across the United States. Reasons relating to reporting procedures were responsible for this increase and are described in the next section of this report. Illinois statistics reflect the national change very well.

To test whether this, or any other factor, could have changed the areal distribution of tornadoes, maps of the 122 tornadoes in the 1916-1942 period and the 420 in the 1943-1969 period were prepared, and numbers per county are expressed as percentages of the state totals in figure 8. Changes in the patterns between the two periods are evident particularly in south-central Illinois where the percentages dropped sharply in the second period. During 1916-1942 only 12 counties, each reporting over 3 percent, accounted for almost 56 percent of the state's tornadoes, but from 1943-1969 only 6 counties each had more than 3 percent of the Illinois total. A similar percentage map for the total 54-year period is also presented in figure 8 for comparison with these maps. During the two periods the urban population of the state increased steadily and became more widely distributed, and the tornado figures reflect this.

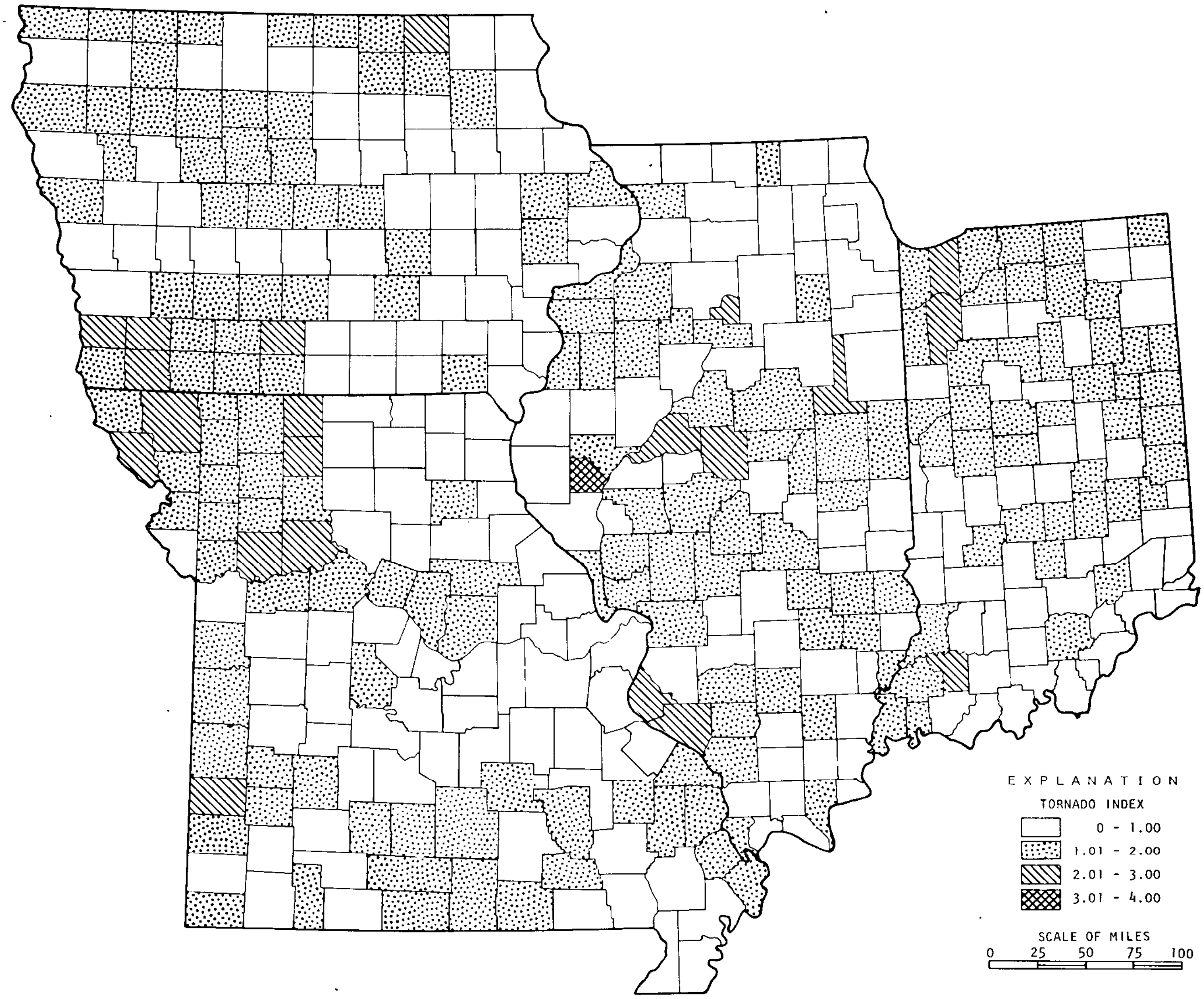


Figure 7. Tornado indices for each county in Iowa, Missouri, Illinois, and Indiana for periods of record given in figure 5

On the basis of the previous discussions, areas of Illinois which have continued to be preferred regions of tornado occurrence were delineated. The most favorable region for tornadoes extends from the southwestern to northeastern portions of the state (figure 9). Areas with low tornado incidence are found in western Illinois, in the eastern part of the state, and in the southeast corner. Most of northern and northwestern Illinois is characterized by moderate frequencies.

The climatological reality of the basic Illinois tornado pattern of figures 6, 7, and 8 and the primary high-low incidence areas (figure 9) is generally substantiated by an earlier tornado map (figure 10) prepared by Finley (1888). The Illinois tornadoes in this 53-year period of early settlement, 1835-1887, totaled 133, or 409 less than those in the 54-year period 1916-1969. However, the paths on figure 10 show a distinct preference to extend from southwestern Illinois northeastward into Champaign County, the northeast-southwest high noted in figure 9.

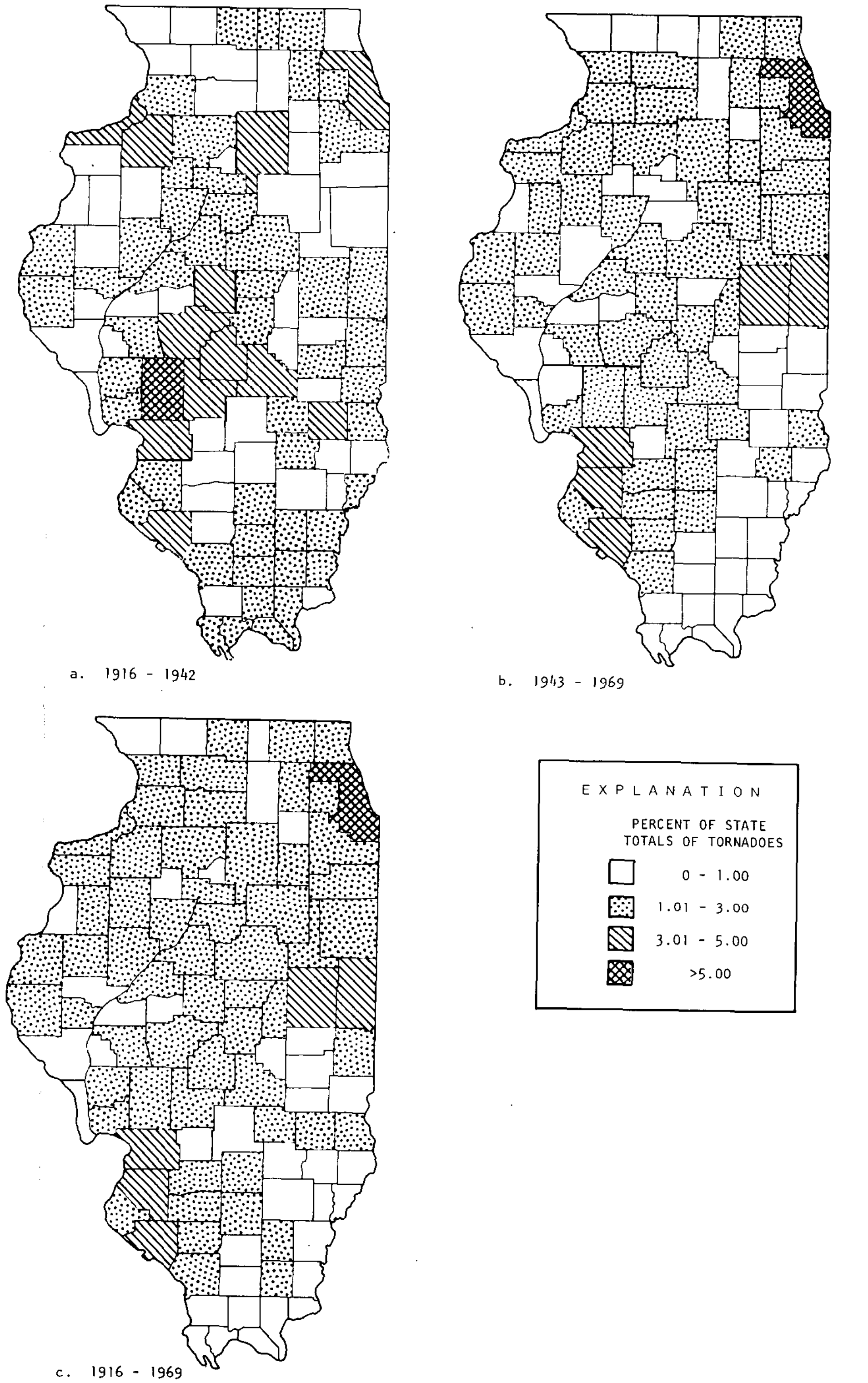


Figure 8. Percentages of state totals of tornadoes in each county for half periods and total period of record

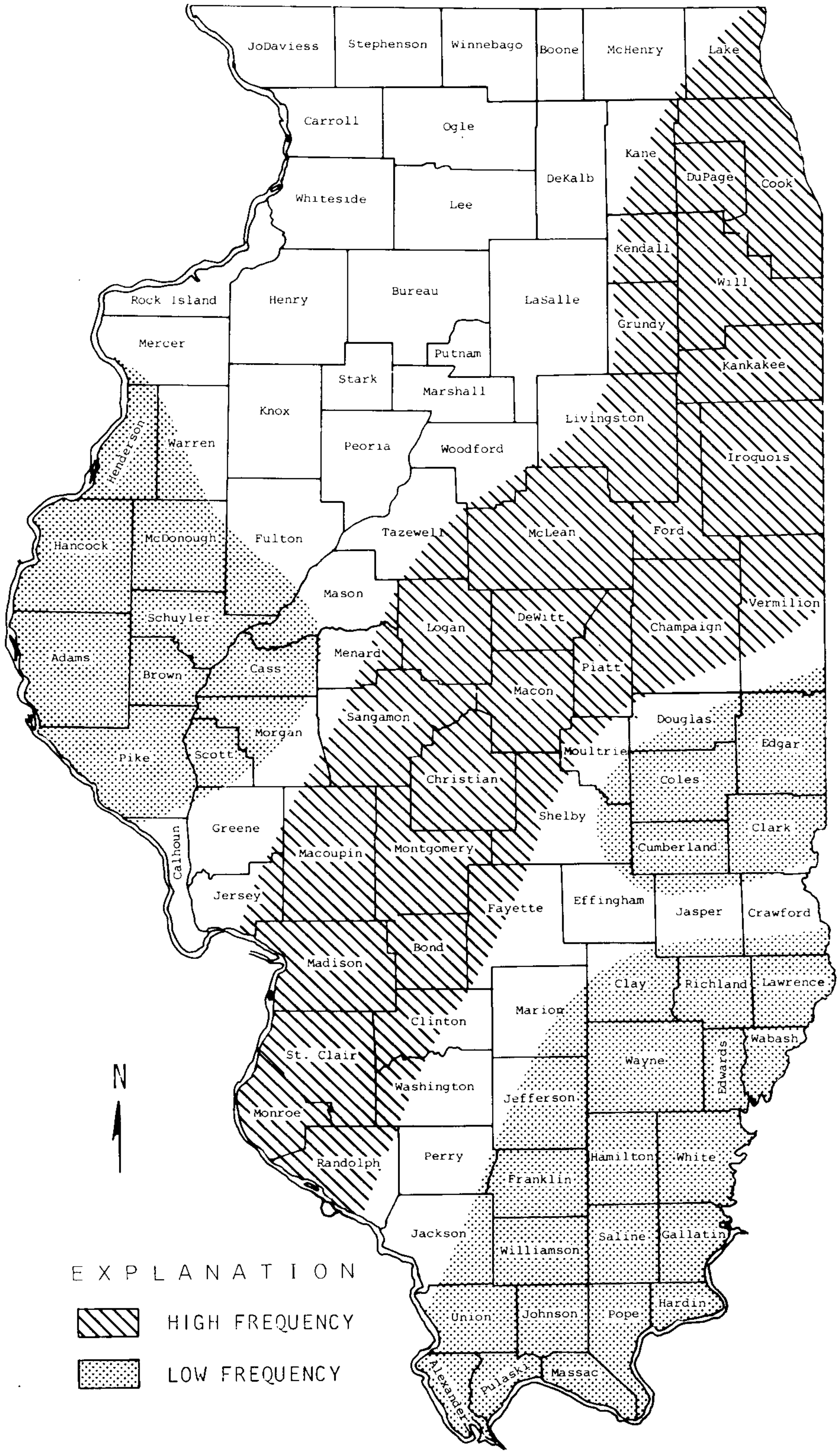


Figure 9. Areas of relative tornado frequency

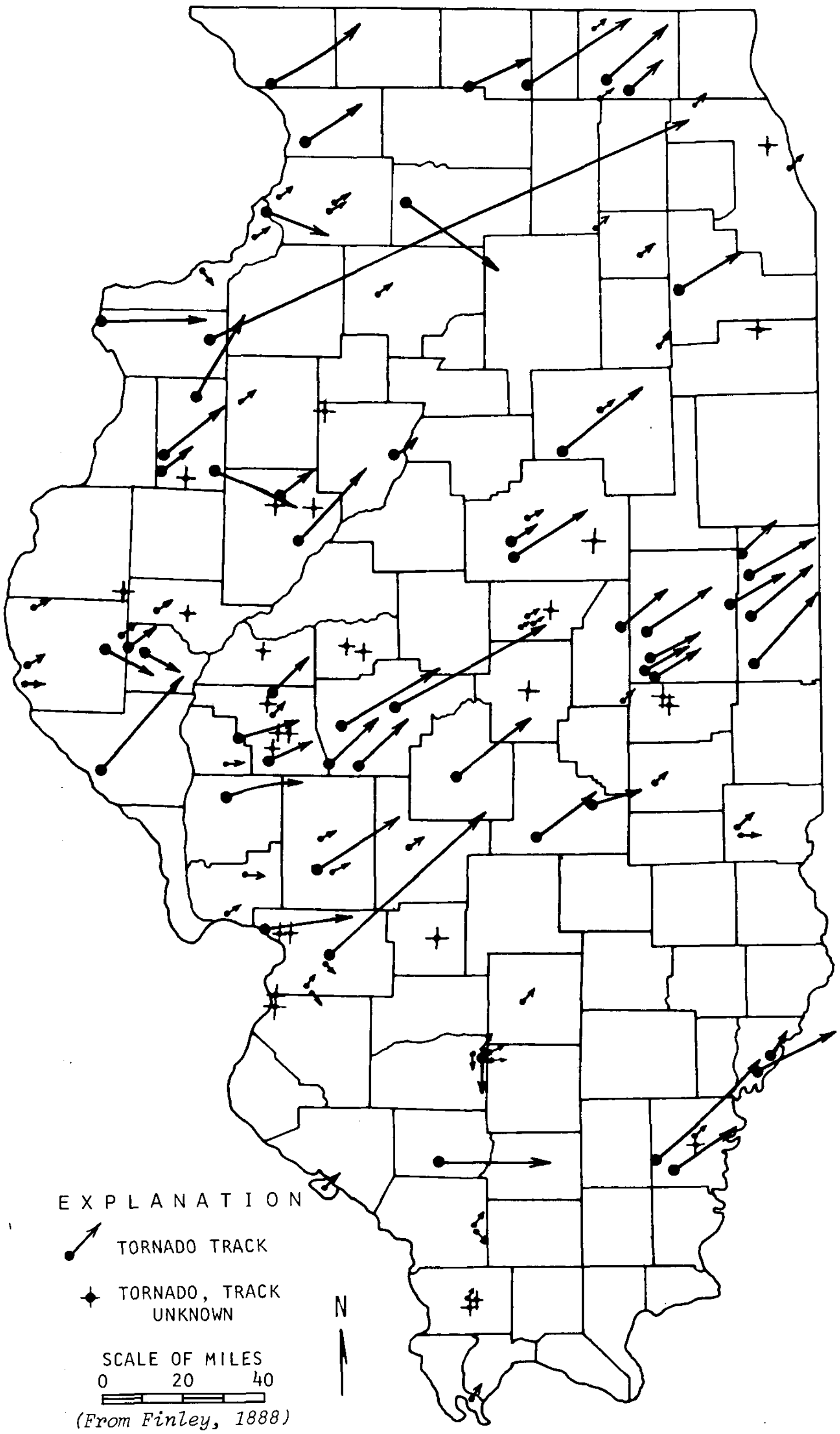


Figure 10. Paths of Illinois tornadoes, 1835-1887

Temporal Distribution

Quantitative comparison of tornadoes from one year to another also is difficult because observations are largely dependent upon having sufficient population to detect them or their subsequent damage paths. Since the population has increased greatly in Illinois since 1916 (rural −6 percent, urban +46 percent), temporal changes in reporting frequency can be expected. Also, telephone, radio, and television have advanced public communication greatly during this time, which in turn has made people more aware of tornadoes. Since 1950, reporting of tornadic storms either to meteorologists or to law enforcement officers has been encouraged in order that people in the path of an approaching storm could be warned and advised of safety precautions necessary for survival.

These things have progressed rather uniformly over the years, but in the early 1950s three events accounted for a substantial increase in public awareness of tornado information. One of these was a series of tornado disasters in 1953 in various parts of the country which killed 516 persons, more than twice the annual average of deaths until that time. The second occurrence was the increased use of television by the populace. From 1950 to 1955 over 28 million sets were put into use, compared with 3.6 million in use in 1949 (*Television Fact Book,* 1970). Widespread dissemination by television of pictures and eyewitness descriptions of tornadoes did much to make the public aware of the small but occasionally deadly storms. Finally, in 1955, the U.S. Weather Bureau began its National Severe Storms Project (U.S. Weather Bureau, 1961) to study all aspects of severe storms, including such things as the intensity and distribution of convective by-products (hail, tornadoes, lightning, icing, surface gusts, etc.). An outgrowth of this activity was better forecasting techniques for tornadoes.

At about this time a concerted effort was begun by the Weather Bureau to inform people of the dangers of tornadoes and the safety precautions to take if one should be sighted. A warning system was also established which would allow the Weather Bureau to inform persons in a particular area when conditions were right for tornado formation. Joos (1960) points out that an abrupt increase in tornado frequency in Illinois and four other states in the 1950s was due largely to three Weather Bureau changes: 1) changes in standards of classifying tornadoes; 2) use of newspaper clipping services to obtain added tornado information particularly from weekly newspapers; and 3) personnel shifts including the initiation of the State Climatologist position which provided for the first time a collection point for state tornado information.

Table 2 gives a summary of Illinois tornado statistics for each year, and figure 11 shows the number of tornado days in Illinois per year from 1916 through 1969. Through 1954 each year recorded eight or less days with tornadoes, but after 1954 every year but two had eight or more such days. The maximum number, 20, occurred in 1959, and no tornadoes were recorded in both 1919 and 1933. The annual average number of tornado days during 1916-1954 was 3.1, but the yearly average during 1955-1969 increased to 11.5 days.

The number of days per year when tornado deaths were recorded is also shown in figure 11. Interestingly, the trend is relatively stable during the entire 54-year period, averaging less than one (0.95) death day annually. The maximum number of annual tornado death days, three, occurred in three years, 1917, 1926, and 1940. This statistic suggests no change with time in tornadoes severe enough to result in deaths.

Table 2. Tornado Statistics by Year, 1916-1969

Year	Tornadoes	Tornado days	Deaths	Injured	Year	Tornadoes	Tornado days	Deaths	Injured
1916	1	1	2	3	1945	3	2	1	119
1917	4	3	106	674+	1946	1	1	1	10
1918	5	3	6	several	1947	3	2	0	7
1919	0	0	0	0	1948	20	5	37	503
1920	7	4	28	0	1949	6	3	9	68
1921	3	3	0	0	1950	10	7	3	31
1922	2	2	21	47	1951	5	3	2	60
1923	1	1	0	0	1952	4	3	0	1
1924	3	3	0	2	1953	6	4	1	13
1925	4	4	606	1430	1954	7	7	1	19
1926	1	1	0	0	1955	23	10	0	9
1927	19	8	36	294	1956	27	18	8	31
1928	9	8	14	101	1957	42	12	15	319
1929	4	4	2	2	1958	27	13	2	17
1930	7	6	0	20	1959	36	20	1	5
1931	1	1	0	0	1960	36	18	0	31
1932	4	2	0	0	1961	35	16	2	142
1933	0	0	0	0	1962	10	9	0	2
1934	3	1	0	3	1963	13	8	2	114
1935	2	2	1	34	1964	7	4	0	3
1936	1	1	0	0	1965	27	12	8	211
1937	1	1	0	2	1966	11	8	1	50
1938	17	7	24	162	1967	40	14	59	1061
1939	4	4	0	12	1968	8	3	8	135
1940	7	3	3	28	1969	10	8	0	4
1941	4	2	0	4					
1942	8	6	21	136	Total	542	293	1033	5934
1943	2	1	0	0					
1944	1	1	2	15	Avg	10.04	5.42	19.13	109.9

The temporal pattern of the annual number of tornadoes (figure 12) is somewhat similar to that of the tornado days in figure 11. The yearly average was 4.9 tornadoes prior to 1955, but jumped to 23.4 for 1955-1969. Except for 1927, 1938, and 1948, each year before 1955 had 10 or fewer tornadoes, whereas every year but two thereafter recorded 10 or more.

The annual number of tornadoes causing injury and/or death is also portrayed in figure 12. The trend does not increase as does that for the number of tornadoes, but there is a slight rise.

From 1916 through 1969 Illinois recorded 1033 deaths attributable to tornadoes, and figure 13 shows the distribution of these deaths by year. Over 100 deaths were reported in two years, 1917 with 106 killed and 1925 with 606. The famed Tri-State tornado of 18 March 1925 accounted for all 1925 deaths and 47 percent of the 1916-1969 Illinois total. A total of 22 of the 54 years included in the study recorded no deaths due to tornadoes.

In summary, it does not appear that the increased numbers of tornadoes noted after 1954 in Illinois is due to synoptic or other scales of weather conditions. It is probably due to a combination of factors, namely: 1) increased population to observe tornadoes; 2) increased alertness of the populace to the dangers of tornadoes,

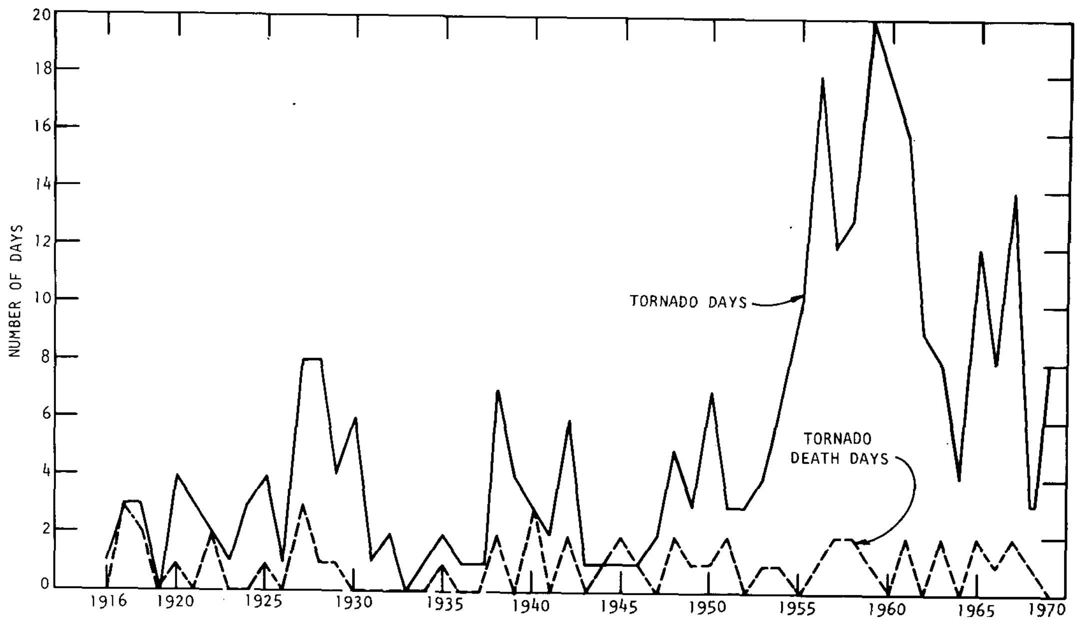


Figure 11. Tornado days and tornado death days, 1916-1969

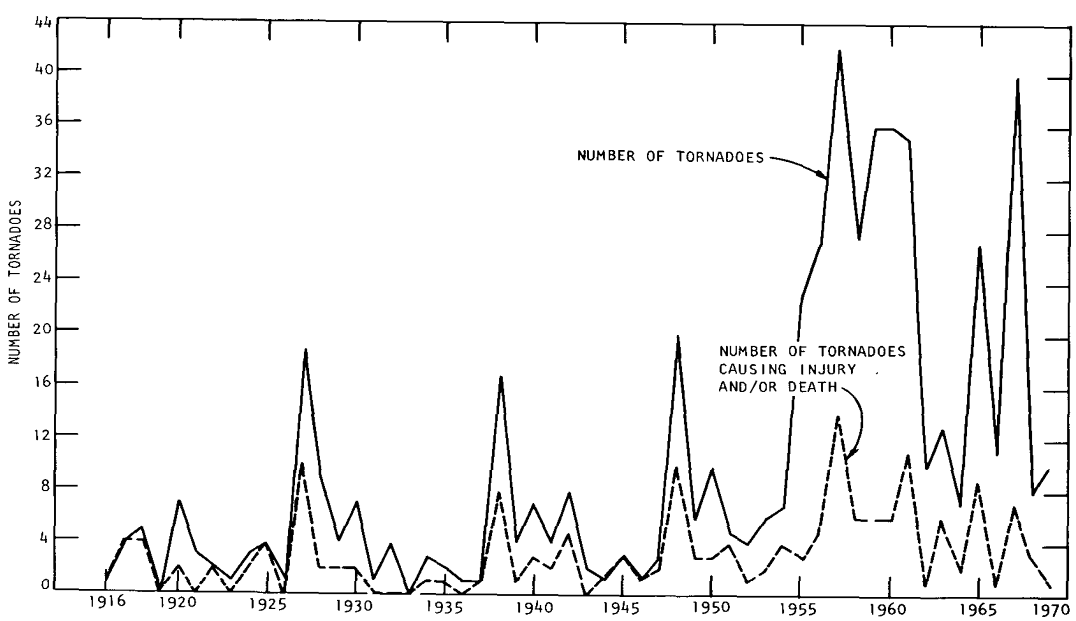


Figure 12. Tornadoes and tornadoes causing injury and/or death, 1916-1969

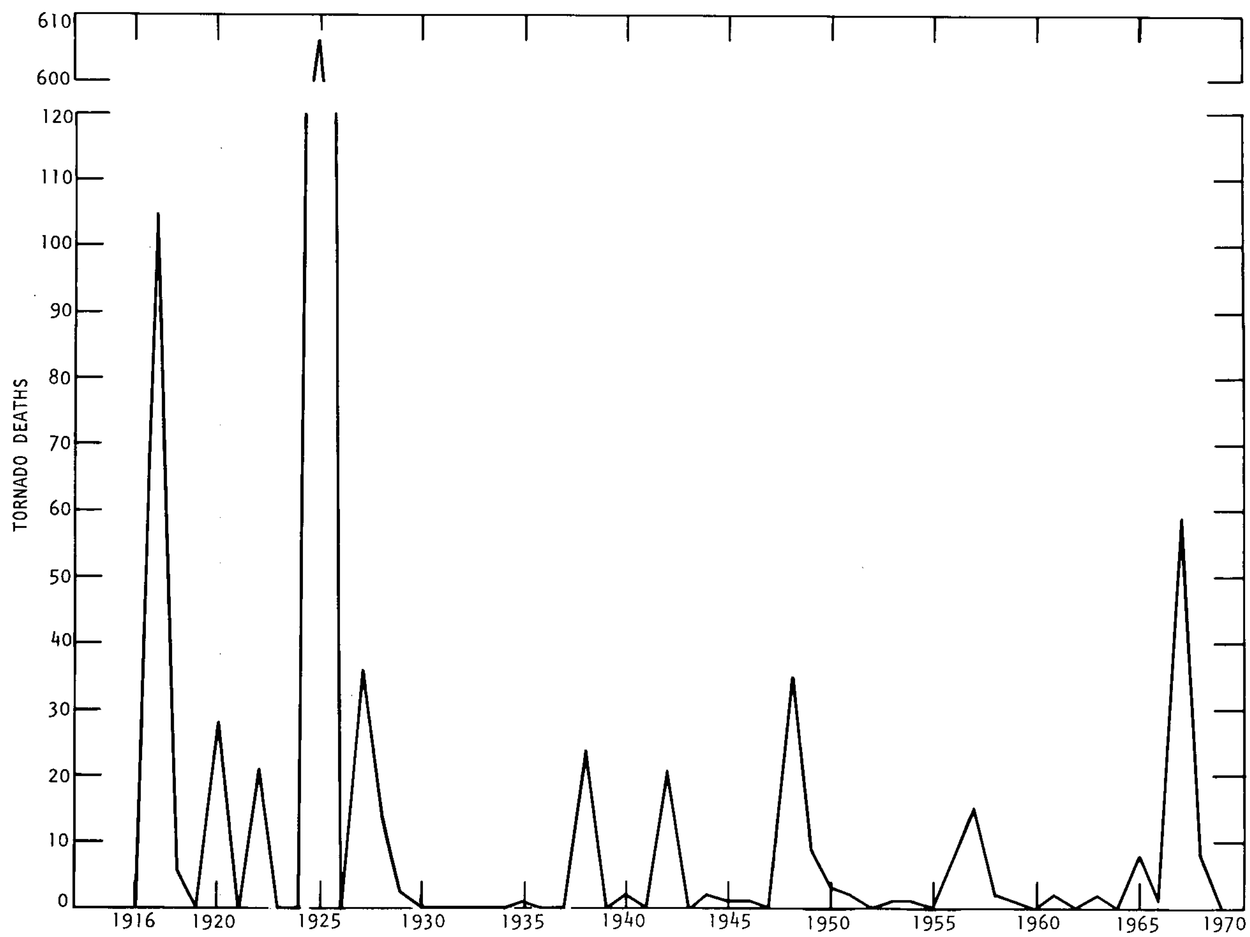


Figure 13. Number of tornado deaths per year, 1916-1969

made possible by U.S. Weather Bureau forecasts; 3) changes in Weather Bureau reporting procedures and data collection for tornadoes including state collections through initiation of the State Climatologist program; and 4) better communications for forecasting tornado alerts and for informing people (primarily through television) of approaching storms.

Monthly Distribution

As mentioned earlier in this report, the seasonal shifts of the jet stream and the variations of the low-level tongue of moist southerly air are the major factors responsible for a latitudinal shift of tornadic activity during the year. Thus, within any given state-sized region, there will be periods of increased and decreased activity as the area most favorable for tornadoes moves closer or farther away. This is particularly true for Illinois, as the national summer center of tornadic activity is in Iowa, adjacent to the western boundary of Illinois.

Table 3 compares the monthly frequencies for Illinois and the United States. Illinois data are given for the state as a whole and for the northern half and southern half of the state. Both tornadoes and tornado-day data have been considered, and percentages of the respective annual totals are shown.

Table 3. Tornadoes and Tornado Days in Illinois and the United States
(Percentages of annual totals)

	Tornadoes				Tornado days			
	Ill.	N. Ill.	S. Ill.	U.S.*	Ill.	N. Ill.	S. Ill.	U.S.*
Jan	2.2	2.7	1.6	2.7	1.4	1.4	1.6	3.0
Feb	1.5	0.0	3.3	3.0	1.4	0.0	2.1	3.5
Mar	14.6	9.5	20.8	11.8	12.1	7.2	13.5	8.8
Apr	20.1	24.0	15.5	16.7	17.3	25.2	14.5	13.8
May	17.2	16.6	17.9	20.7	18.6	20.9	17.6	17.8
Jun	12.9	15.9	9.4	18.0	17.3	13.7	18.7	17.4
Jul	5.3	6.1	4.5	8.3	7.9	7.2	8.3	12.2
Aug	6.5	8.5	4.1	5.3	10.0	7.2	10.4	8.1
Sep	7.4	8.8	5.7	5.4	6.2	6.5	6.2	6.4
Oct	3.0	2.0	4.1	2.7	3.4	4.3	3.1	3.4
Nov	3.5	4.4	2.4	3.3	2.1	2.9	2.1	3.4
Dec	5.9	1.7	11.0	2.1	2.4	3.6	2.1	2.2

**From Fawbush et al. (1951), based upon 1920-1949 data*

The national statistics show that the maximum 4-month number of tornadoes occurs in the spring (March through June), whereas the greatest 4-month number of tornado days lags by one month, extending from April through July. However, the national maximum occurrence of both tornadoes and tornado days is in May.

The Illinois distribution for these two parameters is somewhat different. April is the prime month of tornadoes, when 20.1 percent or 109 of the 542 reported storms occurred (table 3 and figure 14). The other spring months also have high frequencies, and those in March through June account for over 65 percent of the state's tornadoes. A secondary maximum is noted during late summer, and another high is evident during December. These last two features are absent from the national statistics. The number of tornado days is high in the spring, declines in July, and increases slightly in August and again in December (table 3). However, the December high is largely due to a high incidence (19 tornadoes) on one day, 18 December 1957, a daily record situation discussed in detail later.

Tornadoes causing personal injury and/or death are also most frequent in the spring (figure 14), with March through June accounting for 67.5 percent of the 174 such death-injury storms that occurred from 1916 through 1969. March has the highest percentage of personally harmful twisters; over 42 percent of the 78 tornadoes occurring in March have caused injury and/or death.

Illinois is a very large state from north to south, extending over 385 miles from the Wisconsin border to the southern tip. To test for separate monthly distributions in the northern and southern halves of the state, tornadoes originating on either side of a west-east line through the approximate geographic center of the state were grouped (table 3) and plotted (figure 14). Two different distributions are evident in the graphs. The northern half has more tornadoes in April, May, and June, while the south has the highest number in March. This is to be expected, as the northward-migrating center of tornado activity is closer to southern Illinois early in the spring. The number of tornado days reaches a peak in April in the north, but is highest in March farther south. The north had 296 tornadoes in the 54-year study period, compared with 246 in the south.

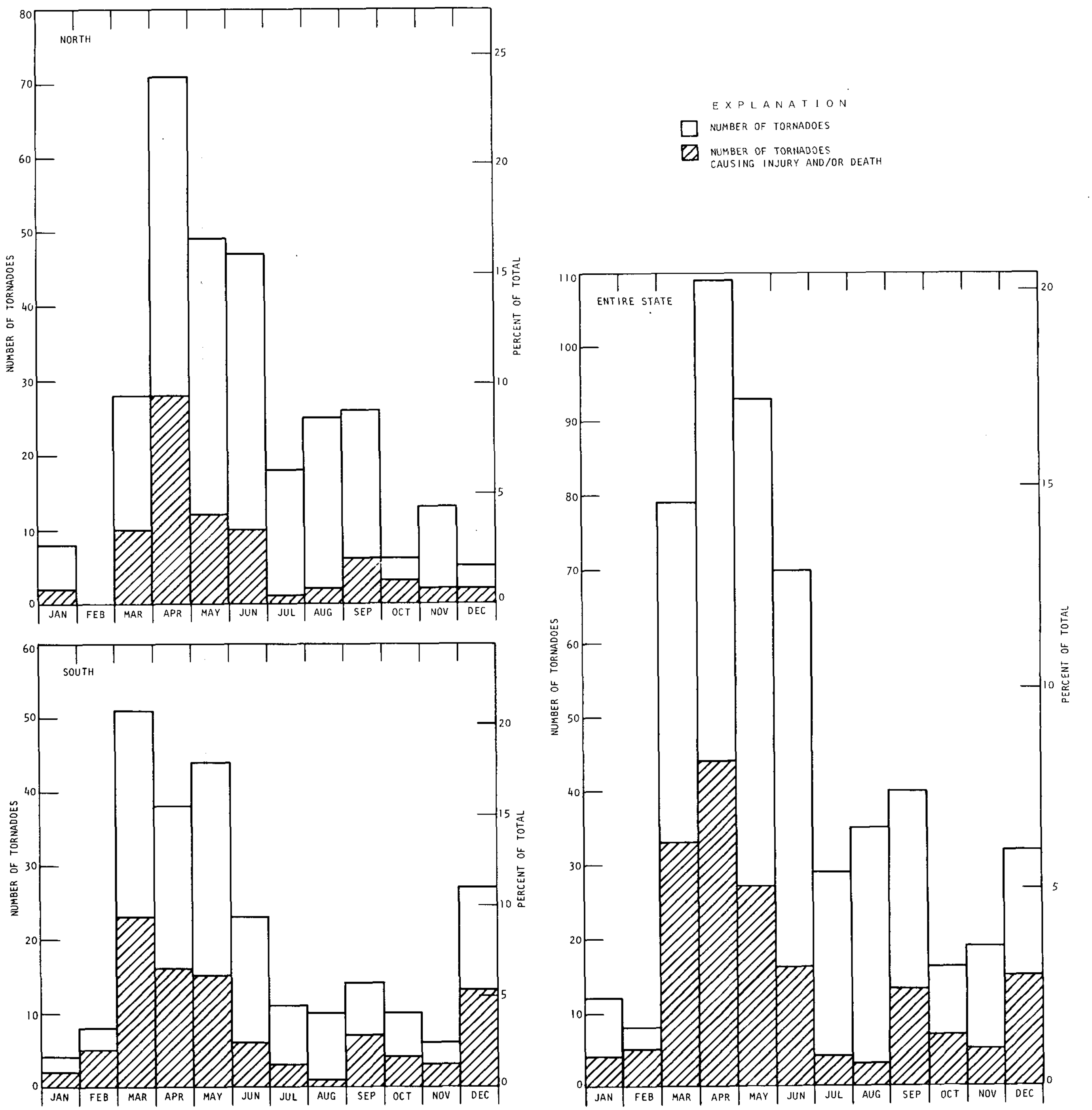


Figure 14. Number of tornadoes and number causing injury and/or death by month, 1916-1969

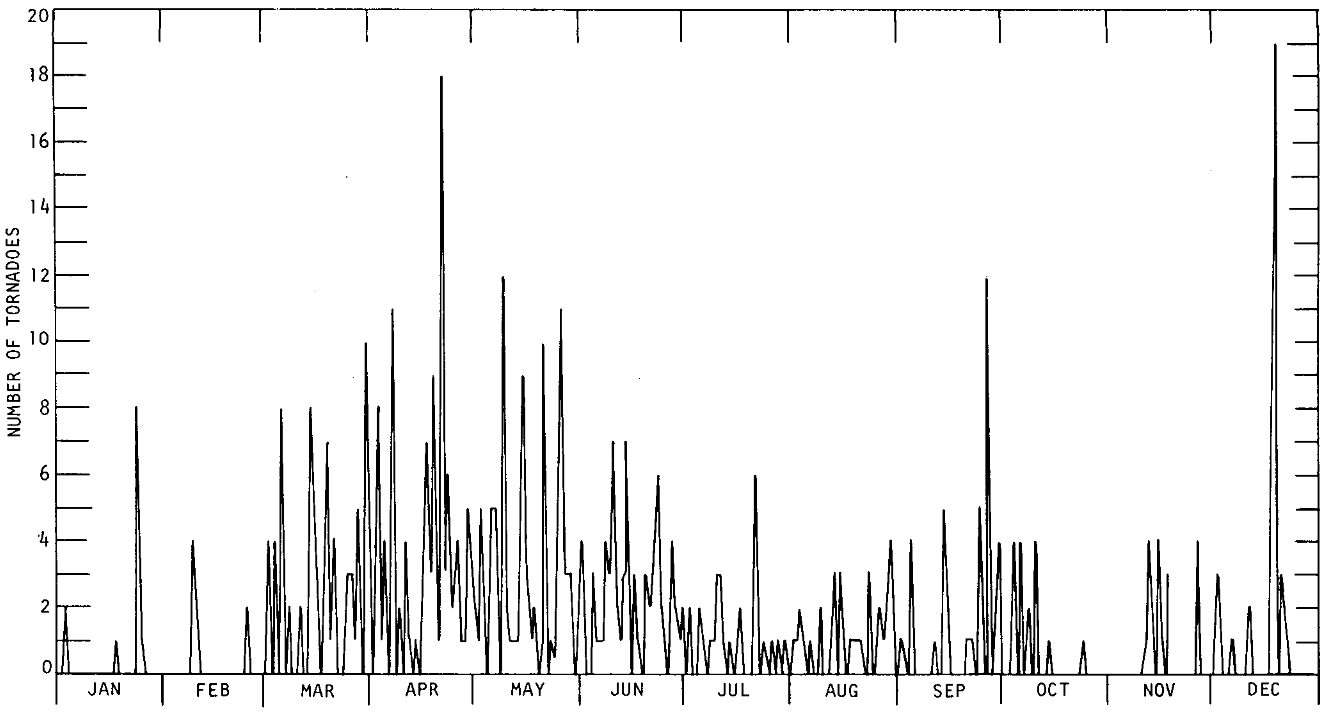


Figure 15. Number of tornadoes by date, 1916-1969

Daily-Weekly Distributions

Once the distribution of tornadoes by month is established, it is informative to look at smaller time scales for patterns in the daily and weekly statistics.

Figure 15 shows the total number of tornadoes (1916-1969) for each date. Considerable variability exists, but the spring maximum and autumn secondary maximum show up clearly. The large number of tornadoes evident on 18 December all occurred in one year.

Figure 16 shows the number of tornadoes and tornado days per week for the entire state, for northern Illinois, and for southern Illinois. The week of 15-21 April has experienced the greatest number of Illinois tornadoes, 42, and tornado days, 17. Interestingly, the week prior to that has recorded the least number of tornadoes and tornado days in the prime tornado months (March-June). The number of tornado days in Illinois drops sharply after 30 June, and is never over 9 per week from then until the week of 10-17 March. Late September and early October weeks have high numbers of tornadoes, but low numbers of tornado days. The same is true of the middle week in November and the third week in December.

Examination of the northern and southern Illinois graphs shows interesting distributions. The northern half of the state has had only two tornado days during January and February, but the number of such days increases unevenly after that until early May. During March and April there is generally a large difference between the number of tornadoes and the number of tornado days in northern Illinois. This is indicative of outbreaks of tornadoes containing several storms on one day, which is often the case during spring in the central United States. From late June through December, with two exceptions in late August and late September, both

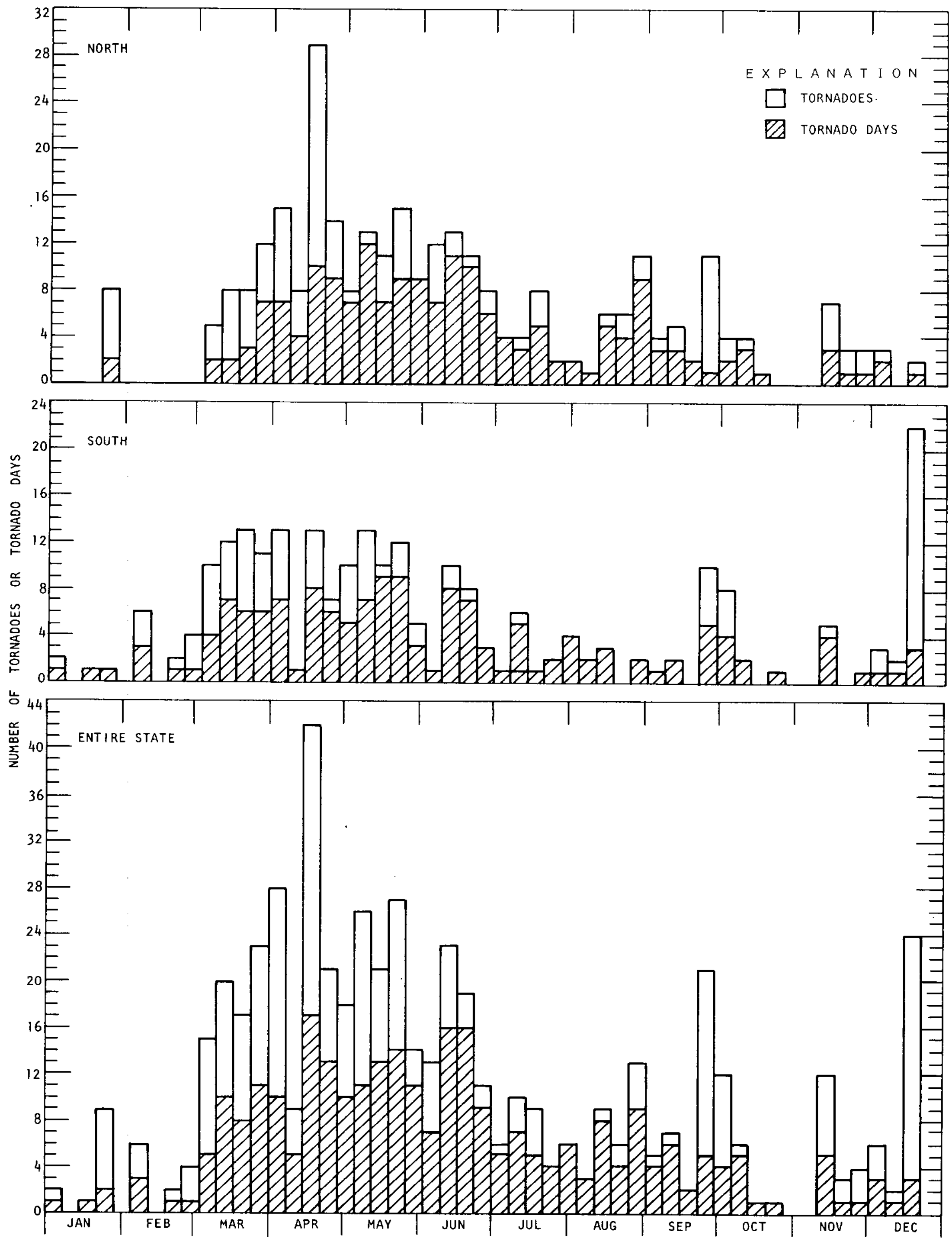


Figure 16. Number of tornadoes and tornado days by week, 1916-1969

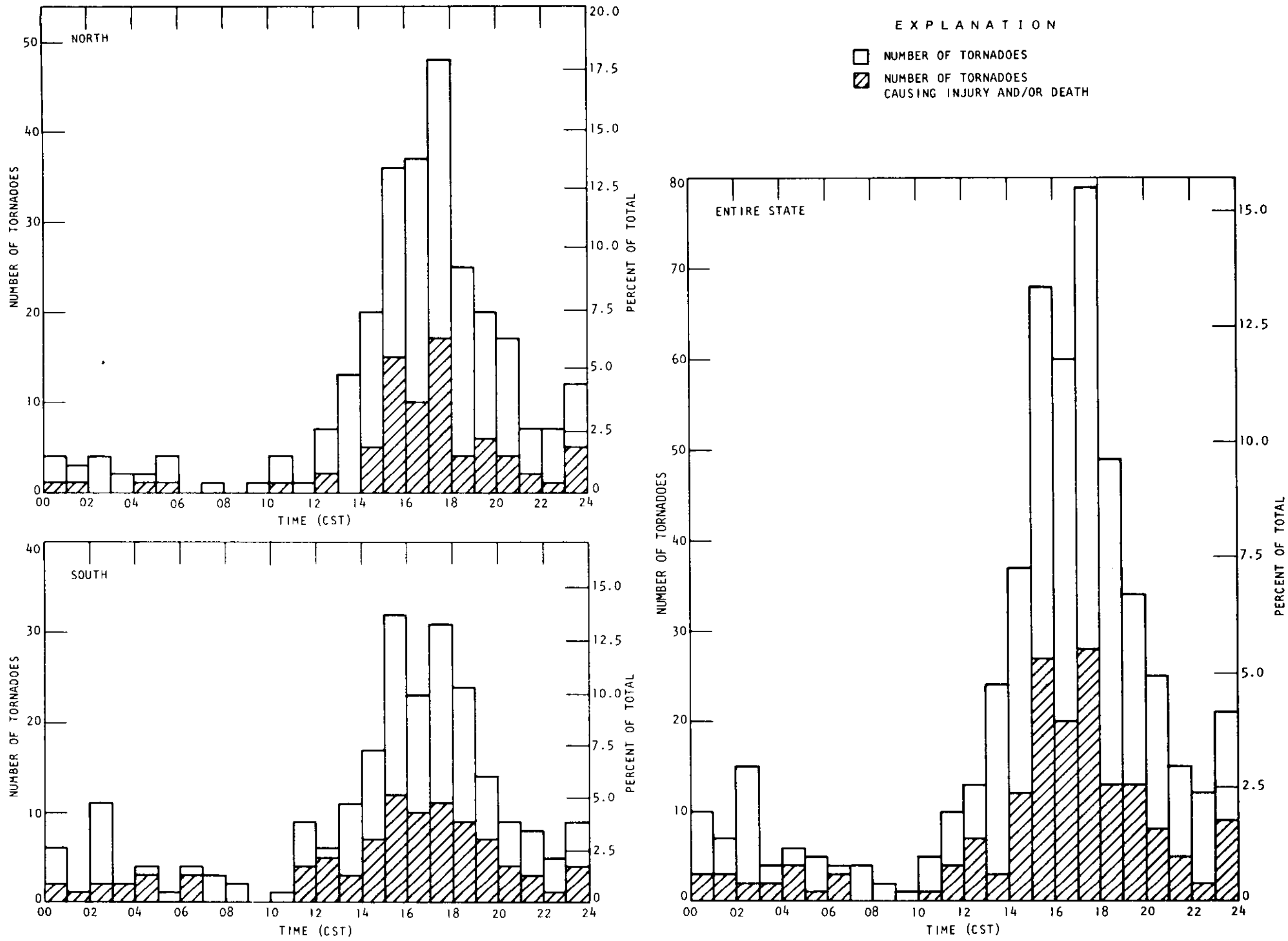


Figure 17. Hourly frequency of tornadoes

tornadoes and tornado days are low. Tornado outbreaks are less common during these months, and seldom does more than one tornado occur on a particular day.

Tornadoes in the southern part of the state are more evenly distributed in the spring weeks than are those in the north. They occur more frequently during the winter weeks in the south, and generally less often during the remainder of the year. There are substantially fewer tornadoes in southern Illinois in most weeks of July and August. The high number of tornadoes in the third week of December is a direct result of the 18 December 1957 storms mentioned previously.

Hourly Distribution

Tornadoes have occurred at all hours in Illinois, but they are most common during the afternoon and early evening hours. Figure 17 shows the distribution of Illinois tornadoes for each hour of the day. Although the graphs are as accurate as the data allow, they are not truly complete. This is because, for example, the time of a storm that traversed a large area may be reported in the data sources at 1400 CST, when in reality it occurred over more than one hour. However, this problem is not serious because of the short durations of most tornadoes, and should not affect interpretation of the results.

Table 4. Number of Tornadoes by Hour and Month, 1916-1969

Beginning hour (CST)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0000		1	2	2	1	3		1					10
0100			1	2		1	1	1	1				7
0200		2	1	4	1	1	1	3	1		1		15
0300			1	1	1	1							4
0400		1	3	1		1							6
0500				1	2	1		1					5
0600			3					1					4
0700			3	1									4
0800					1			1					2
0900					1								1
1000			2		1		1					1	5
1100	3			2	2	1			1			1	10
1200			3	3	3	1	1	1	1				13
1300			2		4	9		1	6		1	1	24
1400			5	8	3	5	2	5	2	1	4	2	37
1500		1	11	12	14	6	2	3	7	1	4	7	68
1600	1		7	16	13	5	2		4	4		8	60
1700	3		9	20	12	7	4	4	7	3	4	6	79
1800	3		10	10	7	3	5	4	1		2	4	49
1900			2	8	7	6	4	2	2	2	1		34
2000	1	1	2	2	6	5	2		3	3		1	25
2100		1	5	3	2	1		2				1	15
2200		1	1	3	2	1		2	1	1			12
2300			2	5	4	4	3	2		1			21
Unknown	1		4	5	6	8	1	1	3		2		31
Total	12	8	79	109	93	70	29	35	40	16	19	32	542

Table 4 is a list of all Illinois tornadoes by hour and month. It was used to construct the figures concerning the hourly distribution of Illinois storms.

From figure 17 it is evident that the peak 3-hour period for tornadoes in Illinois is from 1500 to 1800 CST. Over two-fifths (41 percent) of the 507 tornadoes for which time of occurrence was recorded happened during this period. Sixty-five percent of the storms took place in the 6-hour period from 1400-2000 CST. The least frequent 6-hour period for tornadoes is from 0300-0900 CST, when only 8 percent of the storms occurred.

Graphs of hourly tornado frequency for northern and southern Illinois (figure 17) show a similar pattern. In each half of the state the prime 3-hour period is from 1500 to 1800 CST, but the percentage of the storms in the north (44 percent) for this period is larger than that in the south (37 percent).

Although the number of tornadoes maximizes in the 1500-1800 period, the number of thunderstorms does not reach its peak until near 2000 CST in southern Illinois and near 2200 CST in the northern and central portions of the state (Changnon, 1968). The diurnal distribution of hail is much closer to the distribution of tornadoes, exhibiting its maximum in the 1400-1900 CST period (Changnon, 1968).

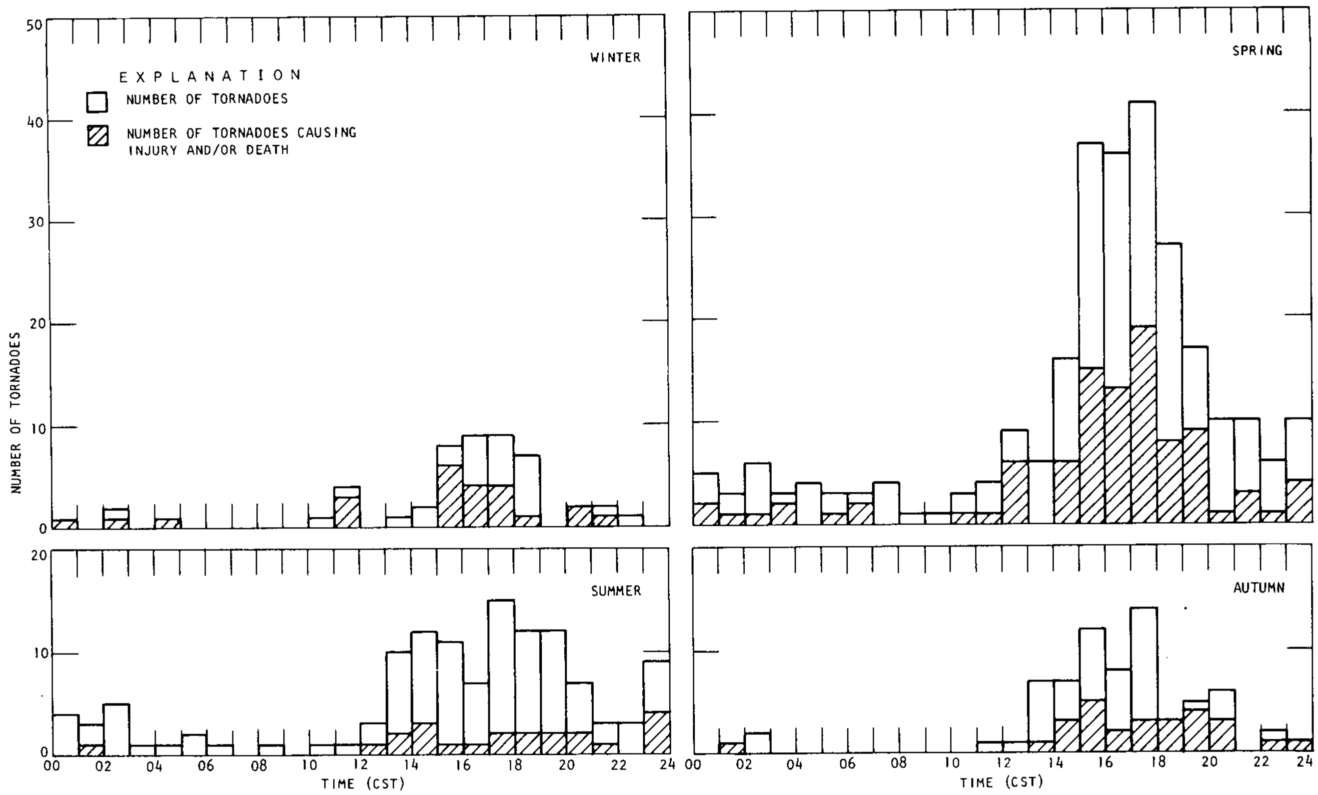


Figure 18. Hourly frequency of tornadoes for each season

The diurnal distribution of tornadoes changes slightly with the seasons, as shown in figure 18. During the winter months (December-February) most of the tornadoes occur in the 1500-1900 period, with very few taking place at night. The distribution of spring storms, which occur from March through May, is almost identical to the annual distribution. Summer tornadoes, during June, July, and August, occur fairly uniformly in the 1300-2000 CST hours, and occurrences from midnight to noon are rare. In the autumn months (September-November) the peak period is from 1500-1800 CST, with a moderate number of tornadoes in the 1300-1500 period.

Tornado Path Characteristics

The average path length of Illinois tornadoes is 13.8 miles, although 11 storms in the 1916-1969 period had paths of 100 or more miles. The greatest distance traveled by a single tornado inside the boundaries of Illinois was 188 miles. This storm took place on 26 May 1917 in the south-central portion of the state, and is discussed elsewhere in this report. A total of 56 tornadoes had path lengths less than 0.2 mile, accounting for 13.4 percent of the 418 storms for which path lengths were recorded.

The determination of tornado path width is sometimes difficult, because variations in the damage swath occur along the path of destruction. The average path width of Illinois tornadoes is 185 yards. Of the 424 storms for which path widths were reported, 12 had widths of 1000 or more yards, and 5 were at least 1 mile (1760 yards) wide. The widest tornado on record for Illinois occurred on 27 May 1930, and was 2200 yards wide.

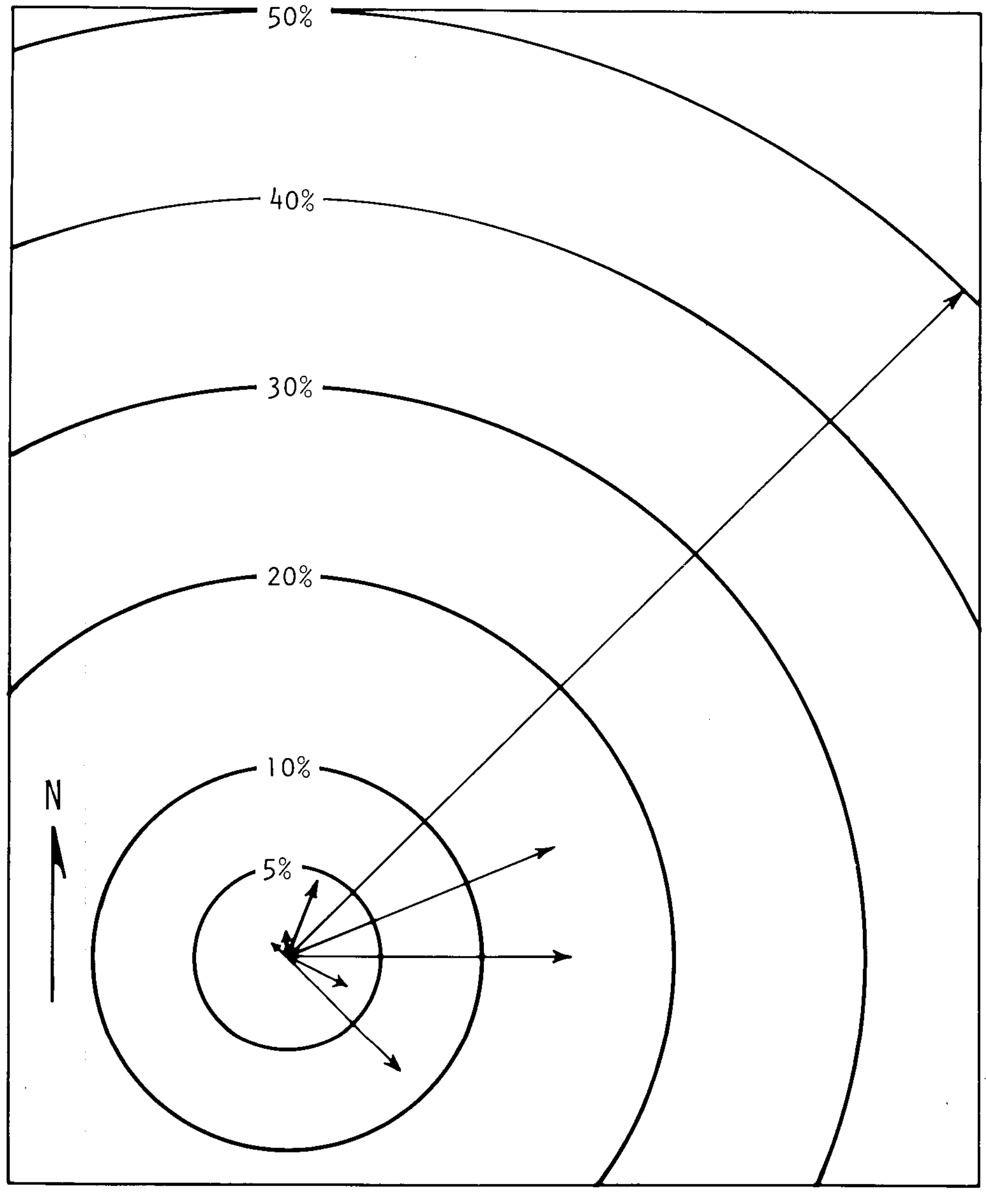


Figure 19. Direction of tornado movement, 1916-1969

Tornadoes in Illinois tend to move from southwest to northeast (figure 19). Fifty percent of the 448 storms for which a direction of movement was given moved toward the northeast, and slightly over 80 percent exhibited directions of movement toward the northeast through east. Less than 2 percent of the storms moved toward a direction with some westerly component.

Accurate tornado speed data are not available for a large number of Illinois tornadoes, and hence climatological averages are not too valid. Accurate speed data do indicate that tornadoes in Illinois have moved at speeds ranging from 4 to 67 mph.

MAJOR TORNADOES AND TORNADO DAYS IN ILLINOIS

Investigation of the 542 Illinois tornadoes in the 1916-1969 period indicates several interesting facts. One is that there are several types of tornadoes definable by any one of a number of physical and synoptic conditions. Some tornado investigators have attempted to define or model tornadoes by their genesis, structure, and mechanics of formation (Bates, 1962). However, two quantitative means of defining tornado types are by individual tornado size-duration values (length and width of path) or by frequency of tornado occurrences in a restricted area on a single day. Both such means of definition relate to the degree of instability in the storm-system dynamics. Use of these means of definition made it possible to delineate two classes of major tornado events in Illinois, along with two classes of lesser tornadic occurrences.

One major class is that of the extreme size-duration tornado which has a long-lasting, huge, violent vortex, with or without several other lesser tornadoes in Illinois or surrounding states. Two examples of this class are presented in this section. The other major class is that of the tornado day which involves relatively small areas (10,000 square miles or less) with a multiplicity of tornadoes (six or more) most of which have about average size-duration values and occur in a period of 6 hours or less. Three examples of this class are presented.

Of the lesser tornadic events, one class is that of the tornado day with a single tornado of average or smaller size, and this class is the most prevalent in Illinois. The other class is that of the tornado day with two to five tornadoes of small to average size.

The five examples of major tornadoes or tornado days in Illinois follow.

Tornadoes of 26 May 1917

The first remarkable tornado in Illinois of the 20th century occurred on 26 May 1917, and is known as the Mattoon tornado. It was extremely severe in places and of exceptional length. The total distance covered by its path was 293 miles (figure 20), and it crossed through most of Illinois and Indiana. The funnel of this tornado began near Louisiana, Missouri, before 1200 CST. It moved due east in a remarkably straight line toward Charleston, Illinois, and thereafter bore to the southeast across three-fourths of Indiana, terminating at North Vernon.

Root (1917) reports occasional lifting of the tornado, at least twice along its path in Illinois, although the skipping in each case was minor and for very short distances (figure 20). At various times along its path, the tornado was accompanied by severe hail, including stones with 3-inch diameters.

In Mattoon, an area 2.5 blocks wide by 2.5 miles long was completely devastated, 53 persons were killed, more than 400 were injured, 496 houses were completely demolished, 2500 persons were homeless, and damages totaled $1.2 million. Figure 21 presents scenes of desolation in north Mattoon. The storm was also very severe in Charleston, 11 miles east of Mattoon, where it passed through the business district with great damage to commercial interests. In Charleston, the storm killed 38 persons, injured 182, destroyed 221 homes, left 285 persons homeless, and caused property losses of $781,000. After passing through Charleston, the storm veered considerably to the east-southeast and crossed into Indiana, ending its 188-mile path across Illinois.

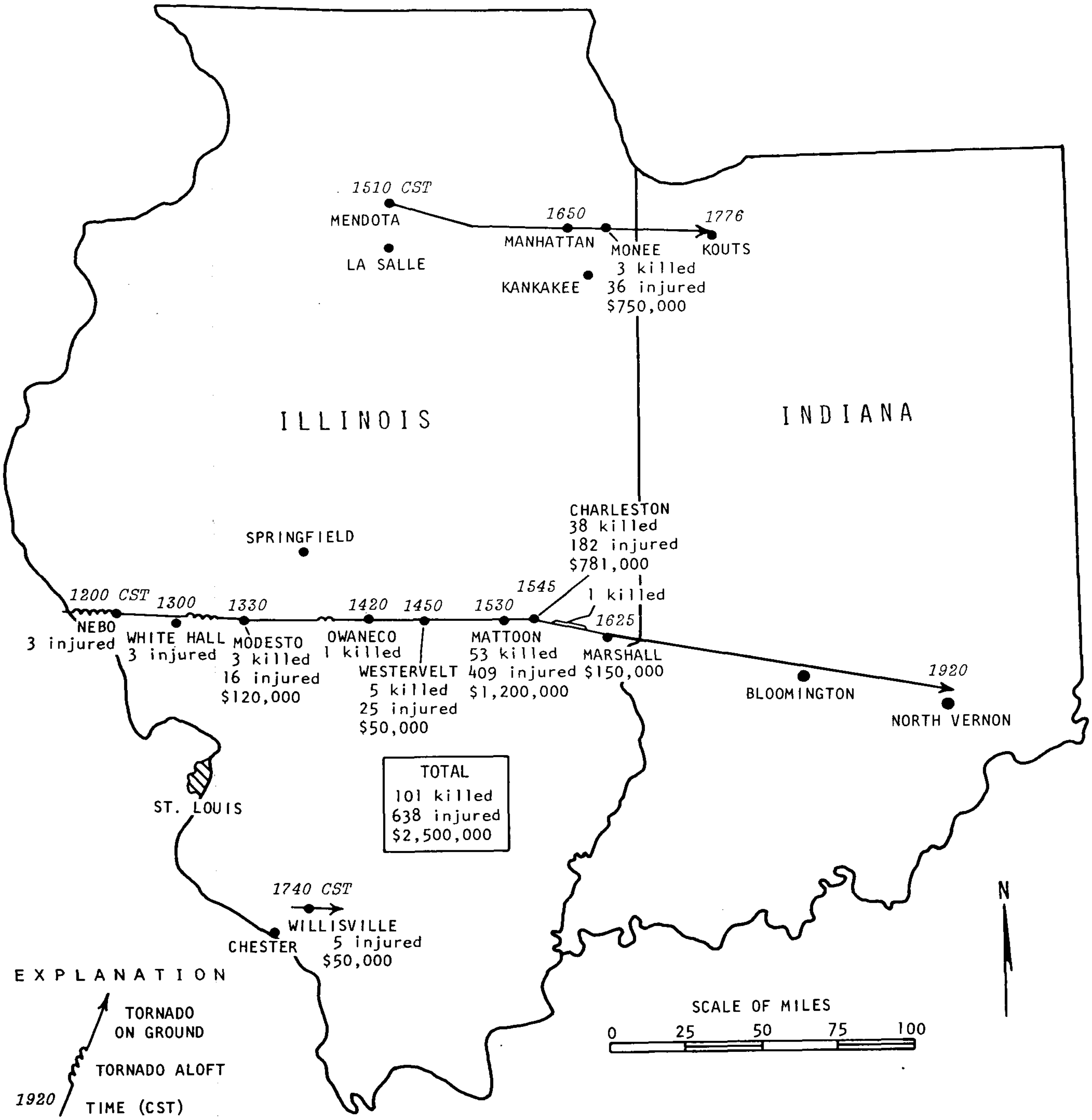


Figure 20. Paths of 26 May 1917 tornadoes

Figure 21. Damage scenes in Mattoon 26 May 1917

All witnesses from the Mississippi River eastward to near Mattoon agreed to seeing a funnel-shaped tornado cloud with a swinging tail, and east of Charleston the same type of storm was reported into Indiana. However, in the Mattoon-Charleston areas, where damages were excessive, no witnesses were able to describe the presence of a funnel-shaped storm.

The duration of the tornado was 7 hours and 20 minutes and it had an average speed of 40 mph. Although the path width varied considerably, it averaged nearly 0.5 mile (880 yards), with the major damage path being approximately 0.25 mile (440 yards) wide. Principal losses to lives and property in Illinois were those in Mattoon and Charleston, and a summing of the storm's losses in Illinois shows 101 dead, 638 injured, and property losses of $2.5 million. There were 2 deaths in Indiana.

On the same date another quite long (110-mile) tornado occurred in northern Illinois and Indiana (figure 20). It began at 1510 CST at Mendota, Illinois, and moved eastward at a similar speed, 40 mph. Its track was covered in 2 hours and 46 minutes. Three persons were killed and 36 injured with $750,000 in property damages. Another lesser tornado also occurred in southern Illinois.

The Mattoon tornado of 26 May occurred in the warm air zone southeast of a major low pressure center that moved rapidly eastward across central Iowa reaching northern Illinois by 1900 on the 26th.

Tri-State Tornado of 18 March 1925

One tornado among the more than 13,000 which have occurred in the United States since 1915 easily ranks above all others as the single most devastating storm of this type. Shortly after its occurrence on 18 March 1925, the famed Tri-State tornado was recognized as the worst on record, and it still ranks as the nation's greatest tornado disaster (Changnon and Semonin, 1966).

The tornado began in southeastern Missouri and remained on the ground for 219 miles in passing across southern Illinois and into southwestern Indiana (figure 22). The resulting losses included 695 dead, 2027 injured, and damages equal to $43 million in 1970 dollars. This represents the greatest death toll ever inflicted by a tornado and the second largest damage total.

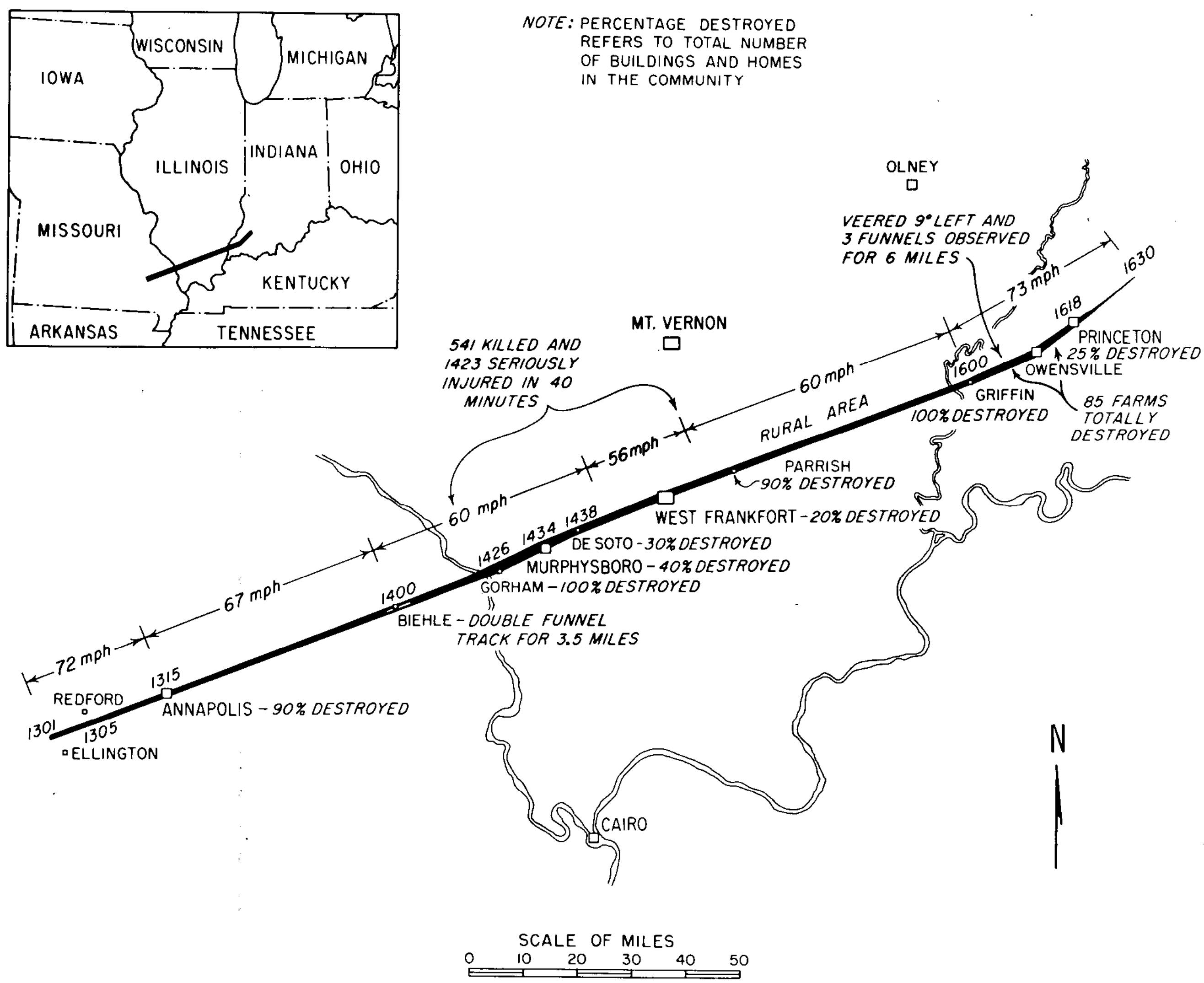


Figure 22. Path of Tri-State tornado on 18 March 1925

The significant meteorological aspects include the fact that this storm represents: 1) the longest continuous tornado track on record, 2) the third fastest speed of movement on record, 3) an unchanging exertion of extreme forces of damage throughout most of its life span, 4) a record long 3.5-hour duration on the ground, and 5) a design-tornado developing in the center of a deep low pressure center and being sustained by its unique juxtaposition with the low.

An exhaustive review of all known sources of information has permitted a very detailed reconstruction of many aspects of the tornado at and near the surface.

Path Size. The tornado path was unique from two considerations. The first was the extreme length of 219 miles with continuous presence at the surface. This is the longest continuous path on record. The second important aspect of the Tri-State tornado path was its extreme width. Throughout most of the 86-mile track in Missouri the path was 0.25-mile wide, but shortly after crossing into Illinois it widened to a mile and varied from 0.5 to 1.0 mile in width across Illinois and on to Princeton, Indiana, a distance of 121 miles. The path then narrowed to 0.25 mile until it dissipated. The total area of extreme damage amounted to 164 square miles across the 3-state area.

Movement. The tornado's movement also had two unique aspects. Its direction was exceptionally straight over much of the path. From its inception in Missouri until passing into Indiana, a distance of 183 miles, the tornado did not vary more than one degree in its heading of N 69 E degrees. A straight line best describes its direction of movement over the first 3 hours of lifetime. The tornado did begin to turn to the left near the end of the storm, so that in the final 16 miles of movement the heading was N 60 E degrees.

The extremely high speed of forward progress was the second unique aspect of the tornado's movement. The average speed over the 219-mile path was 62 mph which ranks as the third highest on record for a tornado. The highest is 65 mph for a Kansas tornado in 1917.

During its lifetime, the tornado's speed did not remain constant (figure 22). In the early and late stages the tornado was moving in excess of 70 mph with a high of 73 mph during the last 36 miles. In the middle of the storm's path its forward progress had diminished to 56 mph.

Funnel Appearance. Another of the many unique aspects, and a significant one as a cause of many deaths, was the inability to see a funnel over much of the path. In Missouri, a distinct funnel was visible from its inception near Ellington to Annapolis. But by the time the tornado reached Biehle, 1 hour after its beginning, no funnel was apparent although ground surveys in that area revealed a double track or two funnels over a 3.5-mile distance. No one in Illinois reported a visible funnel or typical 'twister,' but in the Griffin-Owensville area of Indiana several sighted three closely adjacent funnels. A few minutes later at Princeton, however, no funnel was visible.

Because of the enormous size of the vortex and the attendant debris and dust present after 1 hour of life, it might be expected that no funnel, as normally visually defined, would be seen. Investigators at that time suggested that the base of the storm cloud was so close to the ground that the funnel probably assumed a shape like an inverted truncated cone. The sky was nearly overcast in much of the storm zone, and to most viewers the storm simply appeared to be an approaching thunderstorm until it was very near since thunder did precede it by 5 minutes at most locations.

Damages. The tornado persisted for 3.5 hours, which is the longest duration on the ground on record and much longer than the average duration of tornadoes. This great persistence and the 164 square miles of area directly affected by the tornado led to the greatest loss of life ever produced by one tornado. Flora (1953) wrote: "This tornado still stands as the most destructive in life and property known in the United States." Although various reports list slightly different totals for the dead, injured, and property damage, the values selected were those reported by the field surveyors after adjustment by the Red Cross a year after the storm.

The total loss of lives, 695, is much greater than the second highest number killed by a single tornado which is 306. The number injured, 2027, is a large number, but has not been compared with similar statistics for other tornadoes because such data are often unavailable.

The property losses from the Tri-State tornado amounted to $16.5 million in 1925 dollars. Adjustment of this loss to 1970 Illinois values of materials and labor costs results in a present day evaluation of $43 million. Only the Worcester, Massachusetts, tornado of 9 June 1953 ($52 million in 1953 dollars) ranks higher in property losses.

A breakdown of deaths, injuries, and property losses by location is presented in tabular form in table 5. Also shown for the towns which were seriously affected is the percent of the total urban population killed and injured. The small towns of Gorham and Parrish, Illinois, and Griffin, Indiana, suffered the greatest percentage losses to their populations, 41, 30, and 60 percent, respectively. Murphysboro and West Frankfort were the two largest cities seriously damaged by the tornado; although the numbers of dead and injured were small in percentages, they were large in actual numbers. The toll of 234 persons killed in Murphysboro represents the second largest number killed in a single community by a modern tornado. The greatest number killed in a single urban area during the past century was 306 in St. Louis in 1896.

Figure 22 shows the percentages of all buildings, including homes, which were wholly or partially destroyed by the tornado in each town. The Gorham and Griffin communities suffered severe damage or total destruction to all buildings. In 90 seconds the small farming town of Griffin, comprising 375 persons and 90 buildings, experienced 227 killed or seriously injured, and all buildings leveled beyond repair. Building destruction in the cities of Murphysboro and West Frankfort was largely in their poorer residential sections.

The storm wreaked its maximum damage in a 40-minute period as it moved from Gorham to Parrish in Illinois. In a 47-mile distance it killed 541 persons, injured 1423, and produced $11.8 million (1925) in damages, which is 70 percent of the storm's total damage. The remainder of the tornado's path across Illinois passed over rural farmland, but the resulting losses in lives and property were still quite high. Shortly after passing into Indiana the tornado literally destroyed Griffin and in an 8-mile distance devastated 85 farms near Owensville.

Table 5. Summary of Losses in Tri-State Tornado

	Dead	Injured	Percent of population dead and injured	Property losses ($)
Missouri				
Redford	1	2	3	5,000
Annapolis	4	25	1	400,000
Cornwall	0	0	0	1,000
Biehle	4	11	15	45,000
Rural area	4	25		113,000
Illinois				
Gorham	37	170	41	150,000
Murphysboro	234	623	7	10,000,000
De Soto	69	105	19	400,000
Bush	7	37	3	212,000
Zeigler area	24	18		170,000
West Frankfort	148	410	3	800,000
Parrish	22	60	30	77,000
Rural area Parrish to Crossville	65	140		1,100,000
Indiana				
Griffin	25	202	60	375,000
Owensville area	6	47		600,000
Princeton	45	152	2	1,800,000

The storm then passed through the industrial section of Princeton, Indiana, resulting in a high loss of life as well as a very high property loss. No significant losses occurred after its passage through Princeton.

In its lifetime the storm moved over a wide range of topography including hills with 1400-foot elevations (msl) and over valley lowlands with 300-foot elevations. Topographic differences had no material effect on the damage capability of the tornado.

Many deaths and considerable property damage, aside from the usual collapse of buildings in a tornado, were caused by flying debris, often of exceptional size, which literally riddled structures all along the path. Martin (1961) has calculated that the rotational wind speeds on the south side of the damage path were 180 mph.

Causes of the Deaths and Damages. After studying this monstrous tornado, seven major causes for the excessive deaths and damages were identified:

1) Lack of Any Tornado Forecast. No routine forecasting for tornadoes existed in 1925, and hence no general alert could be issued.

2) Lack of Immediate Warning. Telephone lines in damaged areas were destroyed and the word could not be passed ahead that the storm had occurred. Further, the

lack of radio-type communications did not allow any 30-minute or 1-hour widespread. advance warnings to the public in Illinois and Indiana that a tornado in Missouri was heading in their general direction. Of course, neither warnings nor forecasts would have affected the amount of property damage.

3) Exceptionally High Speed. The 60- to 70-mph speeds caused many deaths since persons watching or hearing (first the thunder and later a roar) the storm's approach did not have sufficient time to seek adequate shelter even though they sometimes realized 2 or 3 minutes before it struck that an unusual storm was approaching.

4) Unusually Large Storm. The long track and wide path produced excessive damage over 164 square miles, and the areal size alone is a basic reason for extreme damage. The possibility of large-scale damage is evident when this is compared with the 3.5-square mile damage area produced by an average tornado. The immense size and prolonged lifetime resulted in an enormous amount of debris in the air at any given instant, and this was a major factor in the deaths of persons in unsheltered locations and in the property damage to exterior walls of structures.

5) Lack of Adequate Shelter. Many of the homes in the residential areas seriously damaged by the storm were without storm shelters and basements. Although many persons sought shelter in their homes and in ditches, the force of the storm swept away the dwellings and also often killed by flying and falling debris the people lying in shallow depressions.

6) Lack of Tornado Appearance. The fact that the storm did not look like a tornado and was preceded by thunder, combined to provide one of the major causes of deaths. Many people thought the approaching storm was just a thunderstorm. Because of the public's general inexperience with tornado conditons, the loud roar and whine audible 1 or 2 minutes before the tornado struck did not alert them to seek more adequate safety than their homes, whereas a visible funnel 3 to 5 minutes prior to incidence would have alerted people.

7) Poor Construction Techniques. Many of the residences which were destroyed or badly damaged were poorly constructed frame dwellings. An engineering investigation group also concluded that one of the basic causes for structural damage was inadequate anchorage of structures, particularly houses, to their foundations. These poorly constructed frame dwellings undoubtedly led to the great property damage and to many deaths.

Synoptic Situation. The low pressure system which eventually spawned the most destructive tornado in modern history was observed near Missoula, Montana, on the evening of 16 March with a central pressure of 1004.5 millibars (29.66 inches). During the ensuing 72 hours, the low moved southeastward to northern Texas where it recurved to the northeast passing through Missouri, southern Illinois, southern Indiana, and on to the St. Lawrence River Valley. Immediately upon recurving, the central pressure of the system decreased during its progress northeastward with the lowest pressure of 997.5 millibars (29.46 inches) near Toronto, Ontario, on the morning of the 19th.

From a careful analysis of the synoptic data near the time of the tornado and with the aid of a barograph trace near West Frankfort, Illinois, it is estimated that the central pressure reached a minimum of less than 982 millibars (29.00 inches) at the time of the cessation of the Tri-State tornado near Princeton, Indiana. The

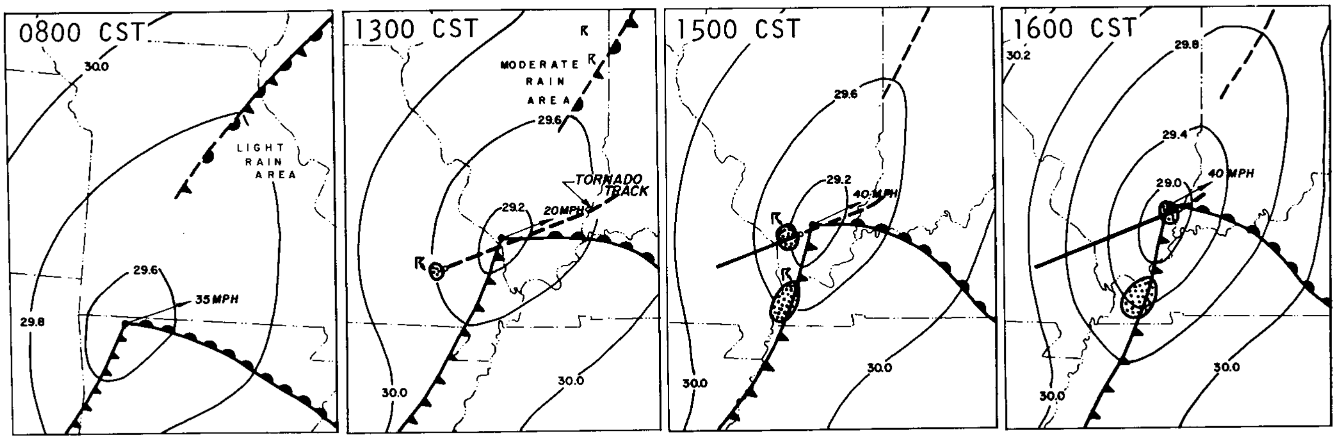


Figure 23. Surface weather maps for 18 March 1925

extreme deepening of the low was a direct result of the very close association of the tornado and the low pressure center.

The thunderstorm from which this devastating tornado developed originated in the cold air sector of the eastward-moving wave system. A strong cyclonic circulation provided the environment for the growth of the thunderstorm and the subsequent development of the tornado.

The low pressure center, now containing the tornado, was over the West Frankfort area at 1500 CST (figure 23). The tornado was moving parallel to the low center but with a greater speed. The upper winds as depicted by a kite sounding to an altitude of 665 millibars (approximately 11,600 feet) at Royal Center, Indiana, showed an increase of speed with height reaching a maximum of 67 mph at the top of the flight. The kite soundings prior to the tornado showed a Fawbush-Miller Type 1 distribution of temperature and moisture (Fawbush and Miller, 1954).

The tornado continued eastward at a more rapid rate than the low center. At the time of crossing into Indiana (1600 CST) the tornado had passed the center of the low, and it began to dissipate shortly thereafter (figure 23). The widest and most destructive portion of the funnel path occurred with the superpositioning of the maximum cyclonic curvature of the low pressure cell and the tornado-bearing cloud, the relationship which may have sustained the storm over the longest continuous path in tornado history.

Sufficiently detailed tornado-observer reports and surface weather reports in and near the tornado in the Illinois and Indiana areas facilitated the preparation of a model of the tornado-storm as it appeared at the surface during middle and late stages (figure 24). The detailed rainfall reports, as to amounts and duration, determined the storm system's width and approximate instantaneous isohyetal positions. The forward speed data and rain duration showed the depth of the storm cell, and the observed sequence of weather events gave the

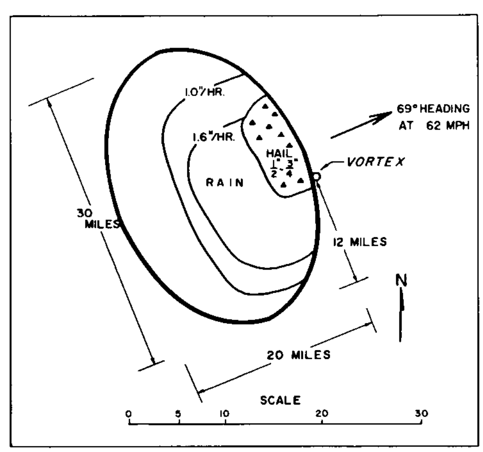


Figure 24. Model of tornado-storm at surface

Table 6. Average Tornado Characteristics and Those of the Tri-State Tornado

	National average	Tri-State tornado	National rank of Tri-State tornado values
Path length (*miles*)	16	219	Longest continuous on record
Path width (*yards*)	400	1320	No evaluation
Forward speed (*mph*)	40	62	Third fastest on record
Duration (*hours*)	0.4	3.5	Longest on record on ground
Number of deaths	1+	695	Greatest on record
Property losses (*dollars*) (unadjusted)	92,000	16,500,000	Third greatest (with adjustment) on record

location of the tornado and hail area. The position of the funnel path with respect to the storm's isohyetal pattern allowed calculation of the funnel position with respect to the width of the storm cell.

The model differs from others because of the position of the funnel at the front and near the center of the cell. Most storm-cell tornado models and radar observations locate the funnel along the southwest portions of the attendant thunderstorm.

Statistical Effects. The figures derived from the Tri-State tornado (table 6) have an enormous effect on the national and state tornado climatological statistics which are considered to be based on reliable data collected since 1915. The proper interpretation of this one tornado's statistics raises several questions in the already problem-filled area of tornado climatology.

On a national scale the 695 deaths from the Tri-State tornado represent almost 8 percent of all tornado deaths registered since 1915. The occurrence of a single tornado caused Linehan (1957) to include southern Illinois in his area of prime tornado death threat.

Illinois has a higher tornado-death total than any other state and ranks second in property loss. Of the 1033 people killed in Illinois by tornadoes since 1915, 606 were killed by the Tri-State tornado. Thus, a single hour out of 447,000 hours in the 1916-1969 period experienced enough deaths to make Illinois more than 40 years later still rank as the state with most tornado deaths. The Illinois damage produced by the Tri-State tornado represents 23 percent of the total unadjusted national losses in the 1916-1965 period. Again, a single tornado is a major reason for the high national position the state achieves in property damages. It is worthy of mention that another long-path Illinois tornado in 1917 produced 101 deaths and $2.5 million in losses, showing the extreme concentration of state losses during the early portion of this century.

In the 1916-1969 period Illinois has had 293 tornado days, and one of these, or 0.34 percent, produced 59 percent of the deaths and 23 percent of the property damages. The effect of this one storm on national and state tornado statistics reveals the 'skewness' caused by only one such sample in current climatological data.

Tornadoes of 18 December 1957

The single day with the greatest number of tornadoes in the 1916-1969 period was 18 December 1957 when 19 tornadoes occurred during a 5-hour period in southern Illinois. As an average, only 2 tornadoes occur in Illinois on each tornado day. This extreme event is made doubly unique by the fact that this day of widespread tornadoes occurred in December, one of the months of low tornado day frequency in Illinois (*see table 3*). The tornadoes were bred in warm, moist air flowing northward into southern Illinois from the Gulf of Mexico, ahead of a rapidly moving cold front that passed through the region during the early evening of 18 December.

The 19 tornadoes resulted in a total of 13 persons killed and 259 injured. Although exact property damages are not available, 4 of the tornadoes were classed as producing between $11,000 and $50,000 in damage, 5 were classed as producing between $50,000 and $500,000 in damage, and 2 were classed as producing between $500,000 and $5 million in damage. If one takes a minimum of these values the total for the 19 tornadoes is in excess of $2 million, and a better estimate is $8 million to $10 million.

Figure 25 shows that 14 of the 19 tornadoes occurred in a 10-county area from Chester in Randolph County northeastward to near Fairfield in Wayne County. The first tornado developed at 1430 CST near Chester and the last tornado developed at 1840 in east-central Illinois. It is interesting to note the repeated storm developments over a period of time in the tornado corridor from Chester to Fairfield. For instance, in the Chester area a tornado developed at 1430, another at 1500, another at 1615, and another at 1635. Similarly, 4 tornadoes developed in the Mt. Vernon area from 1545 to 1700. Radar observations (figure 26) on this day taken from Champaign, north of the tornado area, show a series of well-defined lines of echoes, many of which were extremely large thunderstorm echoes, as defined for warm season conditions. This multiple outbreak reflects the fact that tornado-producing conditions were often met in the several different thunderstorms in the area, a situation contrary to the normal one in which a solitary tornado occurs within a widespread thunderstorm area.

Other conditions related to this storm day are of consequence. First, the series of thunderstorms on 18 December produced reasonably heavy point rainfalls ranging from 0.5 to 2.5 inches across southern Illinois. At least 5 of the 19 tornadoes developed along the Mississippi River Valley in the Chester region which has been shown (figure 9) to be one of the high tornado incidence areas in Illinois.

Tornadoes of 21 April 1967

During a 2.3-hour period on 21 April 1967, 17 tornadoes occurred in northern Illinois, the second greatest number of tornadoes on any day in the 1916-1969 period. A line of severe prefrontal thunderstorms moved eastward across northern Illinois and produced the tornadoes, numerous severe hailstorms (Changnon et al., 1967), and further damages from straight-line winds.

The first tornado, a very short-track one, developed at 1530 CST in northwestern Illinois (figure 27), followed in the same area at 1535 by one of the longer track tornadoes of the day. The third tornado began at 1550 southwest of Belvidere, moved at 50 mph, and became one of the two most severe, killing 24 and injuring 450. Tornadoes, generally with short tracks, kept occurring throughout the afternoon. The last major tornado began at 1724 in Cook County and moved

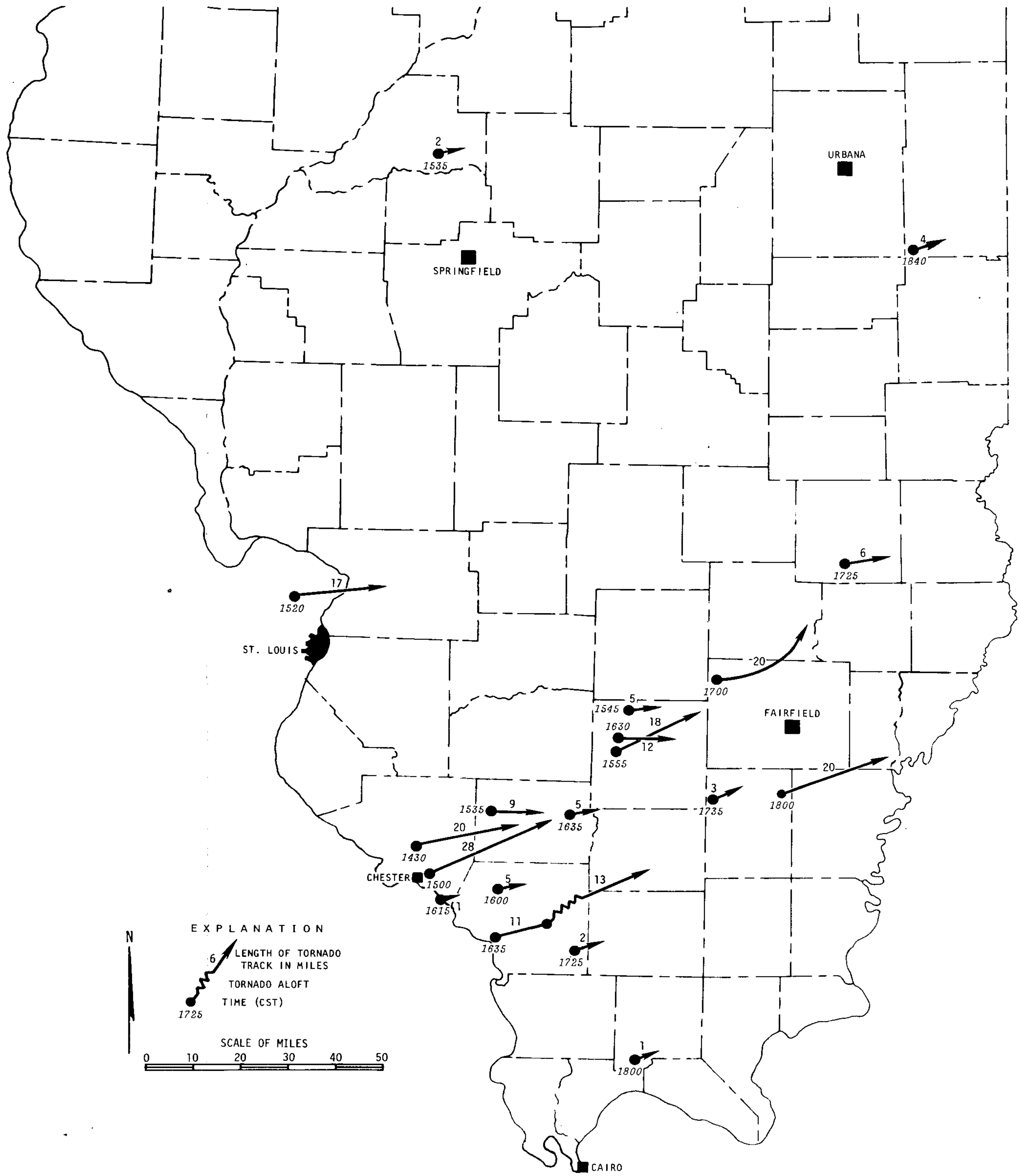


Figure 25. Paths of tornadoes on 18 December 1957

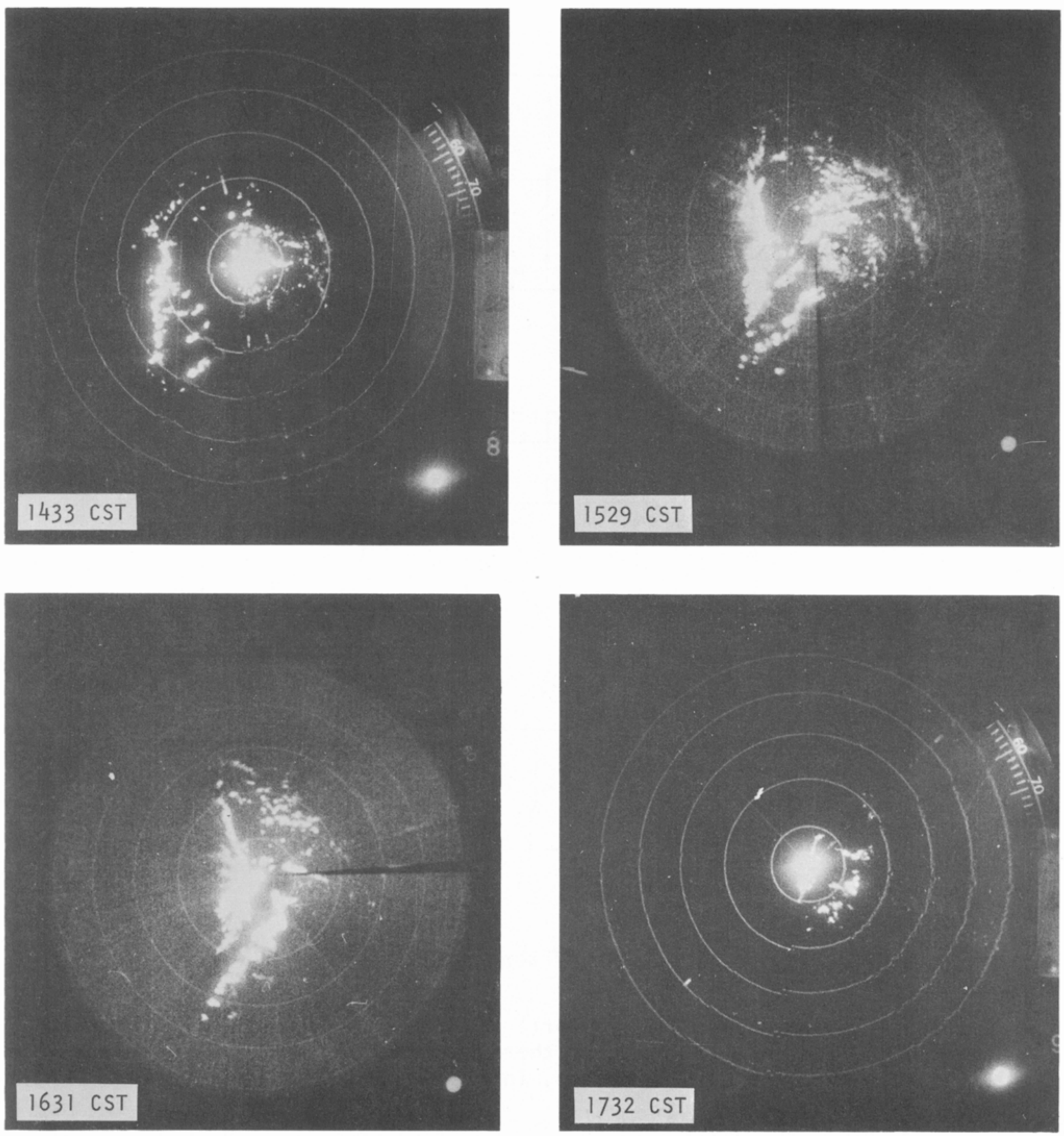


Figure 26. Radar echoes on 18 December 1957 near Champaign, north of the tornado area (Range circles are at 20-mile intervals)

16 miles at 60 mph. It was also a severe storm, killing 33 and injuring 500. A very minor tornado occurred farther south in Champaign and Vermilion Counties at 2000, but caused little damage and no personal injuries. All the tornadoes except a short one south of Oregon moved to the east-northeast at speeds varying between 40 and 60 mph. The total losses for the day in Illinois included 58 killed, 1051 injured, and $34 million in damages.

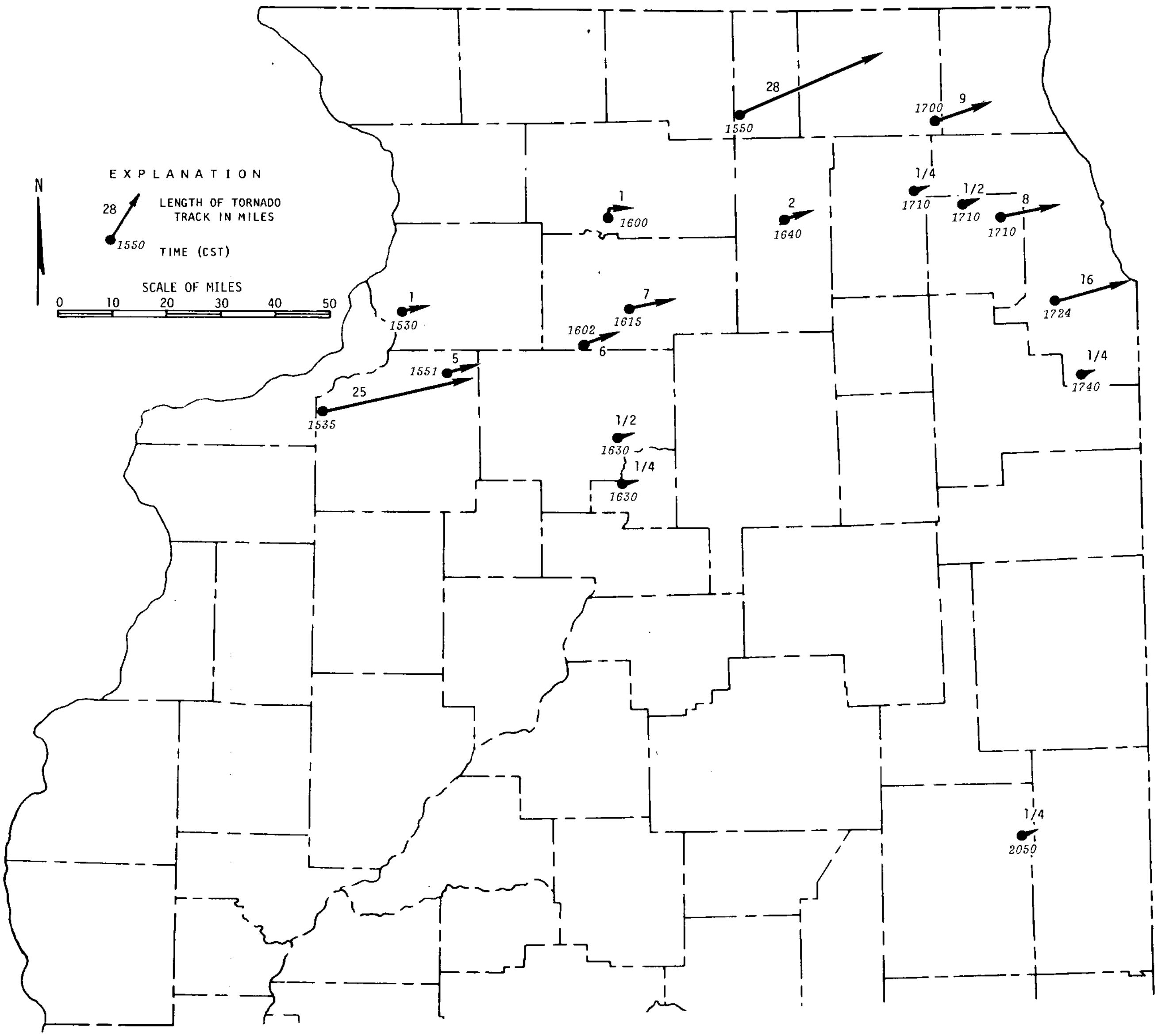


Figure 27. Paths of tornadoes on 21 April 1967

Tornadoes also occurred on 21 April in several other states including Iowa, Wisconsin, and Indiana. However, northern Illinois was the focus of the severe weather activity and resulting losses, in what was one of the more severe tornado days on record.

Tornadoes of 15 May 1968

A different form of the multiple tornado day class occurred on 15 May 1968. On this day six tornadoes took place within a relatively short time (55 minutes) and almost entirely within a 400-square-mile area in central Illinois. These tornadoes were part of a severe storm system which moved through central Illinois in a 14-hour period on 15 May; this system comprised four subsystems which also included 19 thunderstorms, point rainfalls exceeding 10 inches, and 113 hailstreaks which deposited hail over 1664 square miles. All four storm subsystems occurred and maximized within a 1765-square-mile meteorological measurement network operated by the Water Survey in central Illinois. A complete description of this storm day has been presented by Changnon and Wilson (1971), and only that portion relevant to the tornadoes is discussed here.

The field surveys to collect tornado information revealed the existence of six separate tornadoes within the network. Accurate delineation of these was difficult because of their close proximity in space and time and because there generally were no distinct 'damage-no damage' lines typical of most tornadoes. That is, funnels varying from 1/16 to 1/2 mile in diameter occurred at the surface, but the wind damage area for each was generally 1 to 2 miles across. Thus, it was impossible with available field data to define accurately the tracks of the funnels, but the areas (called envelopes) of wind damage related to each of the six tornadoes could be established accurately. No photographs of the tornadoes could be found, which is unfortunate since observer descriptions indicated a considerable variety of single and multi-funnel shapes and types.

The temporal analysis of the rain, hail, and tornado data revealed that three tornadoes formed in and remained with heavy rain cores, two were on the right flank of the storm and thus in a light rain area, and the position with respect to rain could not be established for one tornado, B. Five of the tornadoes also were occurring in heavy hail areas.

The proximity of the five tornadoes (envelopes A, B, C, D, and E) north of Clinton (figure 28) produced a nearly continuous damage area that was 4 to 6 miles wide and extended from Waynesville eastward to Farmer City, a distance of 26 miles. Almost every farm and town in this 100- to 150-square-mile area had some damage to buildings, fences, trees, and/or power lines. The major damage zone (figure 28) existed where tornado envelopes A, C, and D overlapped. Damage was extremely severe in the area extending eastward from 2 miles west of Wapella, through Wapella, and on to 8 miles east of Wapella. Four persons were killed and 56 injured at Wapella and Waynesville. The tornado damage was hard to ascertain because of the accompaning wind-hail-flood damages, but total storm damage for the affected county was estimated at $5 million.

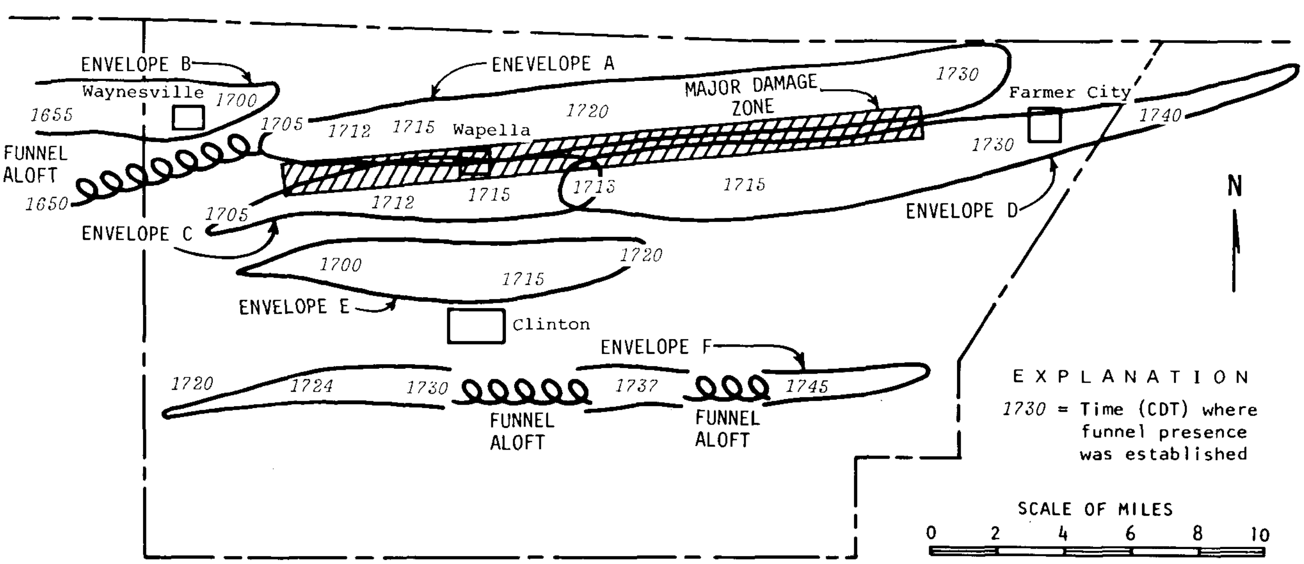


Figure 28. Envelopes of tornadoes in De Witt County on 15 May 1968

The complexity of this storm zone suggests a larger scale cyclone system such as the tornado cyclone (Brooks, 1949), where sudden pressure drops and high winds occur up to 5 miles distant from the tornado. The tornado cyclone is intermediate in size between the general parent low pressure system and the tornado funnel itself. With 40- to 50-mph winds out to 1 to 3 miles around the funnels there would be a tremendous contraction and a very large upward motion along with the release of great amounts of rainfall. Indeed, very heavy rain fell in and immediately to the rear of these tornadoes.

The tornadoes of 15 May 1968 also exemplify the difference in tornado verification criteria between the National Weather Service and the Water Survey. Extensive field surveying by Water Survey meteorologists during the eight days following 15 May revealed the existence of six distinct tornadoes, whereas the National Weather Service tornado records based on much less study and data indicate only one such storm in De Witt County.

On 15 May three other tornadoes occurred in Illinois, but they were in scattered locations and not related to the severe storm system discussed above.

GENERAL TORNADO INFORMATION

Definitions

A ***tornado*** has been defined in the ***Glossary of Meteorology*** (1959) as "a violently rotating column of air, pendant from a cumulonimbus cloud, and nearly always observable as a 'funnel cloud' ...." To qualify as a tornado, this column or 'funnel' must be in contact with the ground. The centrifugal force of the rotating column of air creates a partial vacuum in the center of the vortex, and condensation of water vapor around the vortex causes a pale cloud, usually in the shape of a funnel, to appear. This downward extension from the cumulonimbus cloud, or thunderstorm, can take other shapes, such as an elephant's trunk or a rope. The tornado may appear very dark as it lifts dirt and debris from the ground, and occasionally so much debris surrounds the vortex that it loses visual identity and appears as a dark cloud moving along the ground. It does not lose the sound characteristics of a tornado, however, which are described as the sound of many freight trains or jet planes.

A ***funnel cloud*** is normally distinguished from a tornado in that the funnel cloud does not reach the ground. Because funnel clouds do not cause damage at the surface, they are not included in the tornado statistics. The circular winds still rotate very rapidly, making funnel clouds a hazard to aircraft.

When a tornado moves over a body of water, it is termed a ***waterspout.*** Waterspouts are usually white, since they have no dirt around their vortices. Although more common in tropical and subtropical waters, waterspouts can occur elsewhere.

Tornado watches and warnings are the tools used by the National Weather Service to warn people of suspected or actual tornado activity, and it is important that careful distinction be made between the two terms.

A ***tornado watch*** is issued by the National Severe Storms Forecast Center at Kansas City, Missouri, when tornado formation is highly probable in a specified area for a given period of time. The purpose of the watch is to alert persons in the area of suspected tornado activity so they can be ready to take safety precautions if a tornado is sighted.

A ***tornado warning*** is issued only when a tornado has been sighted or indicated by radar. A warning indicates the probable direction of movement of the tornado, the area through which it should move, and the period of time when danger is present. Persons in the affected area should take immediate safety precautions when a tornado warning is issued. Radio and television stations, as well as Civil Defense disaster sirens, are used to disseminate tornado warnings.

Safety Precautions

Tornadoes are devastating storms, capable of very quick death and destruction, and the importance of following safety rules cannot be overemphasized. The safest place to be during a tornado warning is inside an underground storm cellar or sturdily constructed building. If a building is used as protection, several important rules should be followed:

1) Stay away from windows
2) Open several windows to help equalize pressure between the partial vacuum of the tornado and the inside of the building
3) Avoid rooms with large unsupported roofs such as gymnasiums and auditoriums, and stay in an interior hallway on a lower floor
4) In a home, move to the center of the basement or a lower floor, and stay away from outside walls (Contrary to past beliefs, debris collects near all outside walls if a house should collapse; the center of the house remains freer of such material.)
5) Get under a heavy piece of furniture such as a table or workbench
6) Avoid mobile homes, as they are easily tipped over by tornadoes -- seek other shelter if possible

If no buildings are available, move at right angles away from the tornado's path. If it becomes evident that escape is not possible, lie face down in a ditch or ravine.

In the event a severe thunderstorm or tornado is sighted, report it to the nearest National Weather Service office or law enforcement agency immediately. Collect telephone calls are authorized for this purpose, if the operator is told that the situation is an emergency. Be certain to include the following in each report:

1) Your name and address
2) Location of storm (in relation to highways, county roads, streets, or a commonly identifiable structure)
3) Type of storm (tornado or funnel cloud, heavy hail, destructive wind, or severe lightning)
4) Approximate speed and direction of movement (such as moving slowly from the south)
5) Intensity of the storm (moderate, severe, etc.)

Synoptic Conditions and the Tornado Forecast

There are generally three separate synoptic weather situations which tend to breed tornadoes in the United States (Fawbush and Miller, 1954); one is most common to the Great Plains, one to the Gulf of Mexico Coast area, and the third to the Pacific Coast.

The first, and by far the most common, synoptic tornado weather pattern is the squall line. It is a line of thunderstorms, some of which may be severe, which forms ahead of a surface cold front, along a surface or upper-air cold front, or in a low-pressure trough. Squall-line tornadoes frequently occur in families or groups, and move at an average speed of about 35 mph (U.S. Weather Bureau, 1960). They are more numerous during the afternoon, but may occur at any hour. Damage swaths from these storms are normally longer and wider than with tornadoes characteristic of other conditions. Violent windstorms and large hail occasionally accompany the squall line, and compound the tornado damage.

The second synoptic situation responsible for tornado generation is most common in warm moist air which travels northward from the Gulf of Mexico. Some Illinois tornadoes occur in this type of air mass, but most form in squall-line conditions mentioned above. Although many thunderstorms may be present in this air mass, only one normally will breed a tornado (or waterspout, if over water). If more than one tornado develops, they will usually be 100 or more miles from each other. These storms are slow moving, short lived, and produce short and narrow damage paths.

The third, and the least common, tornado-bearing situation is restricted to the Pacific Coast region where cold moist air prevails from the surface to great altitudes. Funnel clouds aloft are common, and those that reach the ground live for only a short time. Damage is normally confined to an area which is small in both length and width. These storms occur more often singly than in families, and are associated with isolated thunderstorms which are imbedded in scattered rainshowers.

When a forecaster at the National Severe Storms Forecast Center notes that any of the previous three synoptic situations, or a combination of them (usually the first and second types), exists at a particular location, he will make a tornado forecast for that area and issue a tornado watch. The forecast will be valid for only the area and time period when the conditions will be best for tornado formation; if the area is expected to move with time, other tornado forecasts will be issued to include the new areas.

When the forecaster receives a tornado or funnel cloud report, he has little time to decide whether or not to issue a tornado warning. Several reports of tornadoes and funnel clouds may be called in soon after the public has received a tornado watch forecast (Waldheuser and Hughes, 1969), and the forecaster must decide which are true funnel clouds or tornadoes and which are only peculiarly shaped clouds.

Once the forecaster has determined that a tornado is in progress, he will issue a tornado warning to persons in the area where he suspects the tornado to move. His selection of an area will be governed by the direction of movement of thunderstorms at the time the funnel was sighted, which in turn will come from either radar or the mean mid-tropospheric wind direction which steers the thunderstorms.

After the first tornado has been sighted, the forecaster will watch weather conditions in the area of its development closely for development of other storms. Experience has shown that additional tornadoes often form along a line perpendicular to the squall line or cold front and passing through the initiation point of a previous tornado (Waldheuser and Hughes, 1969). If the forecaster has radar on which he can watch the movement and shape of thunderstorm echoes in and ahead of the tornado area, he can watch for changes in the echoes which will give him clues to further development.

It is only after those conditions which bred the tornado-bearing thunderstorms have either diminished or moved out of a forecaster's area of responsibility that he can relax.

Temporal Changes in the Tornado Threat

The philosophy that there is less danger from tornadoes to life and to quickly movable property such as automobiles has been espoused by ESSA officials (Cressman, 1969), and has been indirectly or directly implied to the public by the Weather Bureau and ESSA (now NOAA) in their tornado publicity releases and forecasts during the 1956-1970 period. This philosophy has resulted largely from a general decrease in deaths with time (Cressman, 1969) and a realization that tornado forecasting and communication systems have both improved greatly in this period.

Unfortunately, the public may have been lulled into a false sense of security regarding the dangers of tornadoes. There is no doubt that the great loss of life in the Tri-State tornado of 1925 might have been reduced if highly developed communication networks had existed at that time. It is also argued by many that the threat has been diminished because structural methods, particularly as used in modern homes, are substantially better than those employed 30 or more years ago. Without doubt, forecasting technologies, communication systems (radio and TV), and remote detection of tornadoes (such as by radar) have improved greatly since 1950, and these should lead to the reduction of deaths and damages from tornadoes.

However, arguments can be advanced to illustrate why the tornado threat in Illinois is becoming greater with time. Primarily this is due to our rapidly growing population which provides an essentially greater target, assuming that all citizens cannot be warned or moved to safety. This is particularly true in our ever-expanding urban zones where the probability of deaths and damage, should a tornado occur, is exceptionally greater than in any rural area.

Although communication systems have improved tremendously in the past 25 years, the receipt of tornado forecasts or of warnings of existing tornadoes is dependent upon each person having an operational communication system or facility. This is especially a problem in major cities where at any given time large numbers of persons do not have ready access to radio or TV. Furthermore, tornado occurrences at night, after a large percentage of persons are asleep and communication systems are not activated, are just as much a problem in 1971 as they were in 1920 or 1810. Urban-wide audio warning systems would help alleviate this problem.

Average house construction methods may be better today than in 1920 or 1930, but a larger segment of our state population now resides in movable house trailers which are extremely vulnerable to tornadoes. These are often arrayed in trailer park areas that offer no safe refuge buildings or underground shelters for their residents. Therefore, the safer house construction methods of recent years may be canceled by the increasing use of trailer residences.

Of considerable importance in assessing the tornado threat in Illinois and its change with time is the fact that the long-track, fast-moving tornado is the really significant killer storm in Illinois. The five Illinois storms of 150-mile or longer length resulted in 749 deaths, or 73 percent of all Illinois tornado deaths in the 1916-1969 period. Interestingly, all five of these 'freak' events occurred in a single 11-year period (1917-1927), and the most recent occurred on 19 April 1927, or more than 40 years ago. There is little wonder that government officials have found downward trends in tornado deaths (Cressman, 1969), and have felt safe in proclaiming that tornado dangers were lessening as a result of forecast and communication systems.

The occurrence of similar fast-moving, massive long-track tornadoes in 1971, particularly through high density population areas in northeastern Illinois (and at night like the long-track storm of 16-17 April 1922), would certainly produce an immense loss of life and property. Hence, one cannot clearly say that the tornado threat to the citizens of Illinois has lessened with time. Many factors suggest that even with all the wonders of our modern technological age, the threat has actually increased because of our growing population, urban sprawl, and inability to communicate tornado warnings to all. We are still as vulnerable to the massive long-track tornado storm and widespread outbreaks of tornadoes as were the citizens of Illinois in 1916.

Probability of a Tornado at a Point

The relative infrequency of tornadoes (10 in Illinois per year) and their small areal size (3.5 square miles) indicates that on the average only 35 square miles, or 0.06 percent of the state, are affected. Hence the likelihood and hazard of a tornado occurrence at any point in Illinois appears to be very small. Furthermore, the general infrequency of tornadoes makes it difficult to determine meaningful point probabilities for them.

If one assumes no overlapping among the 542 tornadoes in Illinois during the 1916-1969 period (which is not entirely valid) and then multiplies the number by the average tornado path size (3.5 square miles), the result indicates that only 1897 square miles of Illinois (total of 56,400 square miles) have experienced tornadoes. Simple computations reveal that at this rate it would require 1587 years before every point in Illinois has had one or more tornadoes. Hence, the likelihood at a point is 1 chance in 1587 years, or a probability of 0.0006.

Thom (1963), using various statistical analyses, derived the point probability of tornadoes. His value for central Iowa was 0.0010 which is comparable to the Illinois figure. It indicates a point recurrence interval of 1000 years compared with one of 1587 years in Illinois. Certainly either estimate reflects on the exceptionally small likelihood of a tornado occurrence at any point in Illinois, and this is one of the reasons that so few people have ever seen a tornado.

Remote Detection of Tornadoes

The first means of remotely detecting tornadoes came from pioneering radar research conducted by the Illinois State Water Survey. The first radar observation of a tornado occurred on 3 April 1953. A hook-shaped echo, viewed on a 3-centimeter PPI radar, was associated with a confirmed sighting of a tornado in central Illinois (Huff et al., 1954). This unique observation provided the original impetus for the U.S. Weather Bureau to install a network of APS-2 radars in the Texas-Oklahoma area for severe storm warning. This eventually resulted in the present network of the National Weather Service, consisting of a number of WSR-57 radars and modified military equipment.

Another Illinois tornado in 1956 was detected by an RHI radar of the Water Survey (Schuetz and Stout, 1957). On 17 April 1963 two Water Survey radar meteorologists, who were observing the scope of the CPS-9 radar in Champaign, detected a developing tornado hook echo near Kankakee with sufficient time to alert Weather Bureau officials so they could issue a useful warning while the storm was still in progress.

However, it should be realized that the radar detection of tornadoes via the hooked echo (which essentially depicts the funnel) is highly dependent upon the position and range of the tornado from the radar. Further, the present radar network in Illinois should not be considered adequate for a ‘fail-safe’ system for uniquely identifying most tornadoes in the state. However, the hooked echo has remained to this time the only means of identifying tornadoes on an operational radar set, and is the criterion used by the military and the National Weather Service. Eventually, it is believed, a more positive identification of tornadoes should be possible by the use of a coherent doppler radar.

Since tornadoes are bred in moderate to severe thunderstorms, one would expect an abundance of lightning to be associated with them. On at least one reported occasion, a man looked into a tornado funnel, from which he gave this description: “There was a circular opening in the center of the funnel, about 50 or 100 feet in diameter, and extending straight upward for a distance of at least one-half mile.... The walls of this opening were of rotating clouds and the whole was made brilliantly visible by constant flashes of lightning which zig-zagged from side to side” (Justice, 1930). This excess of electrical activity in thunderstorms and tornadoes produces crackling and static in radio receivers, and is called sferics.

The use of sferics to detect thunderstorms is not new, but it was not until recently that its potential for tornado detection was proven. Jones (1965) noted that sferics occurring at 10 to 100 per second in the 150 kilohertz (KHz) region were indicative of tornado development. The center of this electrical activity is at an elevation of approximately 19,000 feet, inside of a tornado-breeding thunderstorm. It can be seen only at night, and then only rarely, as a small circular patch of pale blue light located high in the cloud. A direction-finding receiver tuned to 150 KHz can locate this tornado pulse generator if one is present in the thunderstorm. A 3-centimeter radar to find thunderstorms, when added to the direction finder, can complete the tornado tracking system.

The concept of the tornado pulse generator is important to the remote detection of tornadoes, but additional work is required to learn how often it is present in tornado-bearing thunderstorms, and how reliably it can be used as a warning aid.

Late in 1968, a new method of remote detection of tornadoes was announced. Called the Weller method, for its inventor Mr. Newton Weller, the new system uses an unmodified home television set as the receiver for tornado signals. Perfection of the method could give many communities several minutes of precious warning time in which to seek protection from an approaching tornado. However, research and testing of the Weller method has not progressed to the point where it can be used as the sole indicator of an imminent tornado; it must be used in conjunction with National Weather Service forecasts until tests prove its reliability.

The following rules and comments on tornado detection by the Weller method are reprinted from Biggs and Waite (1970):

"1. Warm up the television as for viewing, preferably with contrast control to maximum picture position.
2. Turn the dial to Channel 13 (or your highest numbered channel), then by adjusting the brightness control, reduce the picture (or blank screen) until the screen just reaches the threshold of black.
3. Next -- dial the channel selector to Channel 2. Do not reset the brightness after the initial adjustment.
4. Lightning appears on the screen as flashes. If the screen becomes bright or the darkened picture now becomes visible and remains continuously visible (or the blank screen light), this is the signal of a tornado within about 20 miles or less. With a positive signal you should be alerted to precautionary measures, particularly if there are other signs of a nearby storm.

"With practice you can easily recognize nearby lightning flashes of non-tornadic thunderstorms. An approaching tornado will brighten the screen, while a tornado moving away will dim the screen, even though the tornado may pass on either side of you. The Weller method works with color or black and white TV sets and with minimum inside antennas. You may leave the audio portion on while the screen is dimmed or use an auxiliary set (viewing any channel) or listen to a radio to follow the ESSA Weather Bureau warning or watches.

"The absence of a response by the Weller method cannot be guaranteed as a sign of safety; its presence calls for added precaution. It is noted that certain isolated TV sets will not indicate lightning flashes or tornadoes by the Weller method due to malfunction or defective components. Such sets are normally recognized by a very poor picture quality."

The physical reason for the apparent success of this method has been explained previously, i.e., sferics. A strong 54-60 megahertz (MHz) component of the sferic persistent enough to brighten a television screen for several minutes must accompany a tornado for the method to be effective. Changing channels from 13 down through 2 will cause the screen to become brighter in the presence of a tornado, since the energy of the sferics increases from channel 13 (200 MHz) to channel 2 (50 MHz) (Biggs and Waite, 1970).

It cannot be overemphasized that this system of tornado detection is still in the experimental stage, and that it must not be used as the primary means of receiving warning of an approaching tornado.

Tornado Modification Concepts

Tornadoes are extremely complex phenomena, and before scientists can hope to successfully dissipate the energy concentrated in the tornado vortex they must understand the causes and behavior of this energy. The Panel on Weather and Climate Modification stated in 1966 that "With respect to ...tornado modification, no practical success can be expected before the development of adequate theories of the genesis and behavior of these storms" (National Academy of Sciences, 1966). Progress is being made on dynamic modeling of tornadoes and the numerical modeling of mesoscale systems, as well as the interaction between the two. It will be some time, though, before a complete understanding of tornado behavior is attained.

Several methods of tornado modification have been proposed, but all await the results of modeling experiments before they are tried in the atmosphere. One suggestion has been to attempt suppression of the individual tornado-bearing cumulonimbus, since modification of cyclones and instability lines is presently impractical because of their large size (Gilman et al., 1965).

Another possibility is suppression of only the tornado vortex, not the convection which caused its formation. University of Oklahoma scientists have indicated that studies should be performed which attempt to destroy the rotation of the tornado, as this is the main energy source of the storm (National Science Foundation, 1968). Cloud seeding might possibly produce a number of weak vortices which would not develop into tornadoes, rather than one large tornado vortex. At present, however, such seeding is not practical because it must be conducted in a small area during a critical period of time, and upon short notice. It is also important to realize that to modify tornadoes or incipient tornado storms will require a highly sophisticated and accurate forecasting capability that is currently nonexistent.

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APPENDIX

For this study, data from all 542 tornadoes which occurred in Illinois from 1916 through 1969 were placed on punch cards to facilitate processing. For each tornado one card was generated, containing the following information (whenever recorded) about the storm: ***date and time of occurrence, path length, path width, number of persons injured, number of persons killed, property damage, crop damage, and counties affected by the tornado.*** The printouts from these cards are reproduced on the following pages.

In these tabulations, four parameters -- path length, property damage, crop damage, and counties -- are converted to codes. Path lengths have been multiplied by 10 and are therefore shown in 10ths of miles (first storm in 10ths was 80 or 8.0 miles long). In some cases, path length was reported as 'short' and path width as 'narrow,' for which values of 0.1 mile and 1 yard, respectively, have been coded.

Both property damages and crop damages are converted to category numbers as shown in the columns an the right, coded according to U. S. Weather Bureau (1963) procedures.

Category	Damage
1	Less than $50
2	$50 to $500
3	$500 to $5000
4	$5000 to $50,000
5	$50,000 to $500,000
6	$500,000 to $5,000,000
7	$5,000,000 to $50,000,000

Counties are converted to the following alphabetical-numerical list:

1	Adams	22	Du Page	43	Jo Daviess	63	Mason	83	Saline
2	Alexander	23	Edgar	44	Johnson	64	Massac	84	Sangamon
3	Bond	24	Edwards	45	Kane	65	Menard	85	Schuyler
4	Boone	25	Effingham	46	Kankakee	66	Mercer	86	Scott
5	Brown	26	Fayette	47	Kendall	67	Monroe	87	Shelby
6	Bureau	27	Ford	48	Knox	68	Montgomery	88	Stark
7	Calhoun	28	Franklin	49	Lake	69	Morgan	89	Stephenson
8	Carroll	29	Fulton	50	La Salle	70	Maultrie	90	Tazewell
9	Cass	30	Gallatin	51	Lawrence	71	Ogle	91	Union
10	Champaign	31	Greene	52	Lee	72	Peoria	92	Vermilion
11	Christian	32	Grundy	53	Livingston	73	Perry	93	Wabash
12	Clark	33	Hamilton	54	Logan	74	Piatt	94	Warren
13	Clay	34	Hancock	55	McDonough	75	Pike	95	Washington
14	Clinton	35	Hardin	56	McHenry	76	Pope	96	Wayne
15	Coles	36	Henderson	57	McLean	77	Pulaski	97	White
16	Cook	37	Henry	58	Macon	78	Putnam	98	Whiteside
17	Crawford	38	Iroquois	59	Macoupin	79	Randolph	99	Will
18	Cumberland	39	Jackson	60	Madison	80	Richland	100	Williamson
19	De Kalb	40	Jasper	61	Marion	81	Rock Island	101	Winnebago
20	De Witt	41	Jefferson	62	Marshall	82	St. Clair	102	Woodford
21	Douglas	42	Jersey						

In general, throughout the data tabulations, a zero indicates a report of 'none' and blanks indicate no report. However, in the time column, the zero indicates the hour from 0000 to 0100 (midnight to 1 a.m.). In a few cases, the time was reported in generalized terms such as AF for afternoon, EV for evening, etc. Injuries were sometimes given as S for several.

Example reading, first storm: This tornado was on June 20, 1916; started during the hour beginning at 2300 CST; had a path length of 8.0 miles and a path width of 68 yards; caused 2 deaths and 3 injuries; caused property damage between $5000 and $50,000 (category 4); had no crop damage reported; and occurred in Wabash County (93).

Data for Illinois Tornadoes

T = Time, CST
PL = Path length, 10ths of miles
PW = Path width, yards
D = Deaths reported
I = Injuries reported
P|C = Property | Crop damages, by category

Date	T	PL	PW	D	I	P|C	Counties							
62016	23	80	68	2	3	4	93							
52117	15			1		4	33	97						
52617	12	1880	440	101	638	6	75	86	69	84	11	87	15	12
52617	15	800	880	3	36	6	50	32	99					
52717	17			1	S	5	79	73	39					
50918	2	1300	150	2		5	68	87	25	13	80			
50918	EV			0		5	71	4						
50918	EV			3		4	88	6						
51218	12			1			76	83						
52118	19	1000	400	0	S	5	88	62	50	45				
32520		200		0		4	54							
32820		120		0		4	19							
32820	12	300		8		6	45	16	49					
32820	12	500		20		6	99	22	16					
32820	13	100		0		5	16							
60120		1	1	0			37							
62220	13	1	1	0			72							
32021		40	880	0	0	3	1							
62021		30		0	0	3	56							
90421	17			0			36							
41622	23	1400	200	5	47	5	95	41	61	13	25	40	12	
41722	15	350	100	16		4	10	92						
31123	21		300			4	30							
32824	21	15	100	0	1	5	60							
60524	PM	60	130			4	74							
111124			100		1	4	59							
31025	15	100	440		3	5	12	23						
31825	14	940	1300	606	1423	7	39	100	28	33	97			
61425			100		3	4	34							
91125	1	70	266		1	5	22							
51826	17	20	100			5	16							
31827	23	1	33			3	42							
40427	18	50	200			4	68							
41427		50					68							
41927		150	60		3	4	25							
41927		10	50				87							
41927	11	1700	60	21	123	6	7	31	59	84	54	20	57	27
50927	13	30	30				34							
50927	14	10				4	72							
50927	14	120	400	1	12	4	85							
50927	16	450	100	1	116	6	11	58						
50927	16	50	200			4	11							
50927	17	160	100		21	5	100	28						
50927	19	150	440	5	11	5	64							
51827	17	20	40			2	31							
52527	16	100	440			5	15							
52527	17	130	440		2	4	17							
92927	13	40	100	7		7	60							
92927	15	120	200	1	3	4	87							
92927	17	100	100		3	5	23	92						
61228	19	120	440	0	0	3	81	98						
72128	19	10	33				102							
81328	18	10	66	0	0	2	40							
82028	21	20	100	0	0	4	8							
82828	2	10		0	0	3	81							
82928	15	200	440				50	78						
91428	15	260	200	14	100	6	101	4	56					
100428	20	50	100		1	4	59							
100428	22	10	440				11							
11829	11	260	440	6			83	97						
40729	19	2		0	0	3	16							
51529	16	150	160		2	4	6							
81329	19	10	60			2	40							
41730	18	90	150	0		4	79							
50130	22	300	880	0		4	4	56						
50130	23	10	200	0		5	58							
50530	15	10	25	0		3	16							
52730	17	150	2200	0	8	5	50							
91430	22	15	320	0	12	6	41							
92430	11	25	20	0		4	91							
82831	2	30	30			5	79							
32132	15	60	16	0		4	83							
32132	17	10	25	0		4	17							
32132	17	70	100	0		3	40							
50632	18	20	440	0		4	62							
111834		10	50	0		3	81							
111834	17	20	167	0	3	3	37							
111834	18	10		0		4	52							
32535	15	100	100	1	34	5	64							
42635	16	150	880	0	0	4	59							
62936	15	10			0	0	98							
41437	18	10	440	0	2	5	57							
31538	15	30	170	0		4	79	67						
31538	16	50	170	10	65	6	82							
31538	17	300	100	0	12	5	79	67	82					
33038	15	1150	1760	13	67	6	1	5	85	29	63	90	102	
33038	17	1	47	0	0	3	84							
33038	18	10	67	0	1	3	11							
33038	18	300	440	0	11	5	60	59	68					
33038	18	65	587	1	3	5	60							
33038	19	10	352	0	2	4	10							
33038	19	40	440	0	0	3	58							
33038	20	50	170	0	0	4	79							
33038	23	120	200	0	1	4	93							
51538		30					67							
52838	15	20	55	0	0	2	37							
62438	18	30	133	0	0	3	99							

Date	T	PL	PW	D	I	P|C	Counties				
71138	16	100	100	0	0	44	87				
71238	18	60	100	0	0	44	70				
61039	15	250	450	0	12	53	38				
61939	13	110	250	0	0	43	63	90			
62139	15	30	400	0	0	43	101				
80239	15	70	200	0	0	32	59				
30240		150	150	1	8	5	44	76			
30240	12	30	100	0		4	30				
30240	15	40	150	0			59				
30240	15	35	35	0		5	60				
42940	15	240	74	1	20	5	63	54	90	57	53
43040		550	325	1			2	77	44	64	76
43040	17	100	650	0			2	77			
41941	12	5	50	0	1	3	42				
41941	12	5	100	0	3	4	84				
100441	16		22	0	0	3	54				
100441	16	20	40	0	0	3	84				
31642	10	600	150	11	50	5	10	92			
31642	16	600	400	7	70	6	29	48	72	62	
31642	17	50	400	2	2	4	54				
50242	19	650	300	1	12	5	69	84	54	20	
61942	14	100	200	0	0	4	17				
70542	23	500		0	2	4	81	37	6		
70642	2	30	440	0	0	3	69				
70842	1	10	1320	0	0	34	51				
51543	21	200	1760	0	0	4	34				
51543	22	3	35	0	0	3	8				
62244	20	180	1320	2	15	65	89				
41245	22	600	660	0	25	6	1	85	55		
62745	21	320	1760	1	48	66	81	37	6		
62745	23	250	1760	0	46	6	6	50			
51746	16	220	167	1	10	5	28	33	83		
42947	19	500	440	0	5	5	54	90	57		
42947	19	5	440	0	2	5	72				
60647	15	150	40	0	0	5	10				
31948	6	800	440	24	295	6	59				
31948	6	80	440	9	151	6	60				
31948	6		440	0	3	5	68				
31948	7		600			4	87				
31948	7		440	0	0	5	11				
31948	7	250	100	0	0	4	82				
31948	10			0	0	5	92				
32648	14			0	0	5	42				
32648	15	70	880	0	0	5	65				
40748	AF	50		0	0	4	32				
40748	16	160	50	0	2	5	10				
40748	17	20	70	0	1	4	16				
40748	17		440	0	0	6	16				
40748	17		400	0	0	4	39				
40748	17		100	0	20	5	46	99			
40748	17	160	100	3	25	54	46				
40748	17		200	1	0	5	46				
40748	17	200	100	0	1	5	92				
62848	14	70	100	0	0	44	10	92			
81748	17	100	1000	0	5	6	94	66			
33049	21	100	440	0	0	4	42	59			
52149	16	120	200	0		4	5				
52149	16		500	5	60	6	60				
52149	17	30	50	4	7	5	17				
121149	15		100	0	0	4	60				
121149	16	70	100	0	1	4	11	87			
10350	11		100	0	0	5	60				
10350	11	40	130	0	3	5	68				
12550	EV		100	0	0	5	46				
32750	16	30	50	0	0	3	10				
61350	3			0	0	4	8				
61450	13			0	0	0	10				
71650	20	10	33	0	0	4	53				
120250	15	250	50	1	3	42	60	59			
120250	16	220	200	2	25	6	60	3			
120250	17	110	50	0	0	4	79				
62751	19	80	300	1	35	56	54				
62751	20	150	200	0	15	66	54				
111351	13	500	50	0	0	44	63	90	57		
111351	14	60	250	0	9	52	39				
120651	18	250	150	1	1	54	78				
31852	18	30	10	0	1	4	31				
31852	18	40	100	0	0	5	79				
32452	17			0	0	43	82				
71752	17			0	0	32	66				
31453	20	450	200	0	0	5	95	41	61		
40953	16	60	30	0	3	4	54				
40953	17	380	150	1	10	6	10	92			
50753				0	0	0	17				
50753				0	0	0	17				
70553	EV			0	0	0	57				
31254	18	400		0	3	5	84	65	54		
40754	15	450	400	1	13	5	53	46			
52754	18	70	200	0	0	4	47				
52854	18	1	1	0	0	3	102				
53154	15	230	400	0	2	5	38				
71454	18	250	200	0	1	5	26				
101054	16	15	50	0	0	4	16				
30455	21	5	50	0	0	43	91				
41855	18	80	75	0	0	5	8				
41855	21	1	1	0	3	6	45	22	16		

Data for Illinois Tornadoes (Continued)

T = Time, CST
PL = Path length, 10ths of miles
PW = Path width, yards
D = Deaths reported
I = Injuries reported
P|G = Property|Crop damages, by category

Date	T	PL	PW	D	I	P|C	Counties				
42355	2	150		0	0	53	1	5			
42355	19	70	1	0	0	43	34				
52655	11	15	500	0	0	43	1				
52655	16	15	100	0	2	53	16				
52655	16	190	400	0	0	54	46	99			
82155	18	20	500	0	0	43	20				
82955	17	1	1	0	0	00	10				
82955	17	1	1	0	0	00	10				
82955	18	150	100	0	2	54	69				
100655	16	150	50	0	2	53	82	60			
100655	17			0	0	43	82				
100655	17		10	0	0	42	95				
100655	19	10				03	87				
111555	15	500					68	11	87	70	
111555	15						10				
111555	15	50	500			4	79				
111555	17	2	1			2	92				
111655	2	50	300	0	0	54	91				
120355	16	1550	100	0	0	42	5	9			
120355	20	500	1				50	53	32		
22556	0	400	500	6	20	61	82	14			
22556	2	200	450	0	2	61	80	51			
30656	16	30	200	0	0	41	57				
30656	17	80	500	0	6	51	38				
40256	1	20	10	0	0	51	16				
40356	14	30		0	0	41	51				
40356	16	100	40	0	0	41	20	74			
40356	16	20	50	0	0	41	27				
40356	17	50	100	0	0	41	11				
42656	19	120	500	0	0	51	6	50			
42656	21	350		0	0	51	37	6			
42756	19	40	900	0	0		5				
42856	23	50		2	0	41	68				
42956	0	30		0	0	41	58				
42956	1	250		0	0	41	95	61			
51656	17	40	80	0	0	41	43				
52156	21	20	70	0	0	41	38				
61756	5	20		0	0	43	8				
61956	20			0	0	4	75				
81256	22	130	30	0	0	4	27				
81356	1	50	25	0	0	41	90				
81856	8	300		0	0	41	80	17			
82356	14	450	40				45	16			
82356	14	450	40				45	16			
82356	14	450	40	0	3	51	45	16			
83056	23		15	0	0	31	52				
91556	2	10	400	0	0	4	82				
31457	14		100	0	0	4	63				
31457	14			0	0	4	85	29	72	62	
31457	15			0	0	4	54	57	27		
31457	16		30	0	0	4	74	10	92		
31457	17			0	0		99				
40357	14			0	2	51	2	77			
41857	14			0	0		67				
42557	2		300	0	0	41	67	82			
42557	5				2	41	10				
42657	14	250	30	0	0	41	57	27			
50957	19	40	200	0	0	3	34				
51357	11	1	1	0	0	2	84				
52157	15	250	150	0	0	5	67	82			
52157	17	40	150	0	0	4	80				
52157	18	90	200	0	0	55	39	91			
52157	19	100	120	0	0	5	55				
61057	22	500		0	0	4	75	69	9		
61457	13	30		0	5	5	69				
61457	13	230		0	1	5	75				
61457	14			2	50	6	84				
61457	15			0	0	4	46				
121857	14	200		0		4	79	73			
121857	14	180		0	0	5	79	73			
121857	15	30		0	1	5	73				
121857	15	180	250	1	45	6	41				
121857	15	10		0	1	4	60				
121857	15	1	1	0	1	4	63				
121857	15	50		0	2	4	41				
121857	16	50		0	0	4	39				
121857	16	120	200	0	0	4	41				
121857	16	50	200	1	0	5	73				
121857	16			0	0	4	79				
121857	16	300	300	11	200	6	39	100			
121857	17	200	200	0	1	5	96	13			
121857	17	20		0	5	4	39				
121857	17	30	150	0	3	5	33				
121857	17	60		0		4	40				
121857	18	1		0		4	44				
121857	18	40	60	0	0	4	92				
121857	18	200		0		5	97	24			
121957	17	10	65	0	0	4	41				
121957	21	5	100	0	0	4	83				
40558	14	750	100	1	7	5	82	14	61	26	
40558	15	50	100	0	0	4	79				
40558	16	50	80	0	0	3	27				
40558	16	200	100	0	6	5	39	73	28		
50358	13	700	100	0	0	4	79	82	95	14	61
50358	15	30	150	0	0	4	51				
50358	15	10	10	0	0	3	60				
50358	15	50	10	0	1	4	60				

Date	T	PL	PW	D	I	P|C	Counties					
50358	17	60		0	0		23					
53158	23	1	1	0	0		7					
53158	23	1	75	0	0	31	82					
60158	0	1	50	0	0	3	60					
60158	0	5	100	0	0	3	82					
60858	18	10	1	0	0	3	32					
60858	19	10	1	0	0	4	27					
60858	19	1	1	0	0	2	53					
61358	16	10	1	0	0	4	23					
62358	14	2	50	0	0	12	10					
71058	17	20	100	0	0	13	92					
71158	12	250	50	0	1	43	96	24	93			
71158	19	100	30	0	2	4	15					
80658	AF	20	70	0	0	5	71	19	45			
81558	2	750	100	0	0	5	52	19	47	99		
81558	5	170	30	0	0	31	92					
83058	19	1	1	0	0	41	101					
83058	22	10	70	0	0	41	16					
100858	23	800		1	0	6	89	101	4	56	49	
21059	2					5	60					
21059	4	1	1	0	0	40	17					
31459	21	50	120	0	1	4	79					
31459	22	70		0	0	40	95					
31559	0	20					25					
31559	0	20		0	2	40	95					
32659	13	40	200	0	0	40	5					
41759	14	20		0	0	4	89					
50959	EV					4	41					
51059	0	30	50			4	67					
51159	3	1	30			5	74					
52659	12	1	1			2	38					
52659	19	10	40			2	16					
61059	11	1	1			1	35					
71059	19	1	1			4	71					
71059	20	10	60			4	19					
73059	17					3	61					
80459	6	270	1			4	59	68				
81559	14	1	20			4	71					
82659	13	70	50			43	81					
92159	14	20	40	0	0	4	16					
92659	15	40	100	0		4	88					
92659	15	170		0		5	5					
92659	15	70	300	1		5	94					
92659	13	40	40	0		4	8					
92659	AF			0		5	37					
92659	16	40		0		4	50					
92659	16			0		4	52					
92659	17	100		0		5	16					
92659	17	40		0		4	47					
92659	17	30		0		4	101					
92659	19	2	130	0	0	3	73					
92659	EV	100		0		5	49					
92759	20	100	200	0	1	5	79					
100859	15	20	90	0	1	5	56					
101059	17	100	50	0	0	5	60	59	26	58	68	
20960	20	300		0	2	50	60	3				
20960	21	250	100	0	1	50	28					
20960	22	10	25	0	0	30	33					
41660	12	30	60	0	0	30	90					
41660	21			0	0	30	99					
41760	2	200	200	0	0	40	25					
41760	2			0	0	40	95					
41760	3	10	60	0	4	40	2					
42560	14	5	20	0	0	30	79					
43060	7	2	30	0	0	30	54					
50660	8	10	100	0	0	4	13					
50660	9	2	100	0	0	3	58					
50660	13	400	50	0	0	5	31	59	69	84		
50660	16	200	130	0	0	4	15					
51660	15						79					
51660	15			0	0	4	79					
51660	16			0	0	5	34	55	29	72	90	
52060	19	1	30	0	0	3	31					
52560	15			0	0	3	57					
52560	15			0	0	4	90					
60160	EV	1		0	0	2	57					
60460	13	1		0	0		26					
60460	18	1		0	0	2	50					
60460	23	550	20	0	1	5	57	20	74	10		
61660	AF			0	0	4	46					
61660	AF			0	0	3	60					
61660	AF			0	0	3	92					
62260	19			0	0	3	60					
62260	20			0	0	5	25					
62360	2	240		0	0	4	1	5				
62360	4	35	800	0	0	4	10					
62360	14	350	100	0	6	5	9	84				
62860	23	1		0	0	3	61					
63060	1	250		0	17	6	60					
70260	23	250	15	0	0	5	46	99				
80360	17	1	1	0	0	4	45					
30461	16	560	1	0	1	50	57	27	38			
30461	17	70	100	1	115	70	16					
30461	18	50	50	0	0	40	10					
30661	1	1200	75	0	3	50	42	59	68	26	25	18
30661	2	1050	1	0	0	60	79	73	41	96	24	
30661	3	50	100	0	2	50	83					

Data for Illinois Tornadoes (Concluded)

T	=	Time, CST	D	=	Deaths reported
PL	=	Path length, 10ths of miles	I	=	Injuries reported
PW	=	Path width, yards	P|C	=	Property|Crop damages, by category

Date	T	PL	PW	D	I	P|C	Counties						
30661	4	250	1	0	0	40	13	80					
30661	4	320	1	0	2	50	21	10	92				
30661	4	250	1	0	3	50	25	40					
42361	15	400	1	0	4	64	99						
42461	19	750	1	0	3	54	75	86	69				
51461	17	1400	150	0	8	63	1	85	55	29	48	72	88
51461	20	200	1	0	0	2	102						
51461	23	40	1	0	0	5	84						
60761	15			0	0	00	8						
61061	20	1		0	0	00	38						
61461	17	1		0	0	40	95						
72161	14	1600	1	0	0	55	1	34	55	94	48	37	6
72161	14	1	1	0	0	00	69						
72161	17	20	1	0	0	33	50						
72161	18	150	1	0	0	44	92						
72161	19	1	1	0	0	43	92						
72861	16			0	0	44	87						
80161	12	1	1	0	0	03	102						
81961	18	1	1	0	0	30	63						
90161	20	1	100	0	0	43	98						
92261	16	20	800	0	0	44	99						
92461	13	2	50	0	0	30	25						
92461	15	50					82						
92461	15	50		0	1	44	82						
92461	17	1		1	0	34	42						
93061	12	50	1	0	0	43	50						
93061	13	1	150	0	0	43	11						
93061	13	15	1	0	0	43	22						
93061	13	2	1	0	0	30	53						
31162	18			0	0	20	21						
43062	11	50	100	0		4	31						
50762	20	150	10				98	52					
50762	20	150	10	0		6	98	52					
52662	5	1		0	0	30	84						
52862	20	1		0	0	5	37						
52962	5	1		0	0	30	81						
60862	13	2	10	0	0	3	6						
62362	16	5	100	0	2	50	16						
70262	15	70	50	0	0	44	10	92					
31663	15	2	30	0	0	40	30						
41763	15	300	130	1	50	6	46						
41863	17			0	0	4	36	94	66	48	37		
41963	14	80	250	0	10	5	51						
41963	17	1	1	0	0	50	56						
42263	4			0	4	60	36	94	66	48			
42263	17	100	1	1	5	50	84	58					
42263	18	400	1600	0	40	60	21	23					
42263	18	350	200	0	5	50	74	10					
61063	16	20	30				58						
61063	16	20	30	0	0	4	58						
61363	17	2	200	0	0	30	18						
90263	20	100	10	0	0	4	71						
30864	18	40	50	0	0	40	14						
30864	18	35	20	0	0	30	67						
32564	15	110	75	0	2	40	33						
40264	18	2	10	0	0	20	58						
40264	18	60	100	0	0	40	84						
40264	19	55	20	0	1	40	68	11					
42164	15	140	20	0	0	40	55						
20965	15	40	10	0	0	50	97						
41165	15	105	400	6	75	60	56						
41165	16	3	150	0	0	50	45						
41165	16	57	200	0		50	49						
41165	16	1	250	0	0	50	49						
42365	23	5	100	0	0	40	66	37					
42365	23	25	100	0	1	50	66	37					
42365	23	2	100	0	0	40	81	37					
42465	0	70	200	0	1	40	62						
52665	15	5	1	0	0	40	67						
52665	19	155	70	0	5	50	22	16					
52665	20	10	50	0	0	40	16						
62365	17	1	1	0	0	30	22						
82665	23	20	70	0			16						
82765	0	4	55	0	0	2	38						
90465	19	15	100	0	0	30	67						
91465	14	50	200	0	30	6	72						
91465	16	120	75	0	2	5	27						
91465	18	10	50	0	2	4	38						

Date	T	PL	PW	D	I	P|C	Counties		
111265	14	10	20	0	0	40	22		
111265	14	360	120	2	90	7	32	99	16
111265	14	350	20	0	0	5	50	53	32
111265	17	2	10	0	0	30	92		
112665	15	80	500	0	0	5	78	50	
112665	17	2	10	0	0	40	57		
112665	18	2	10	0	0	50	27		
112665	19	5	20	0	5	40	80		
32166	14	1	30	0	0	40	98		
41966	22	5	50	0	0	50	22		
41966	22	5	100	0	0	30	45		
42066	17	50	75	0	0	40	41		
52366	18	20	100	0	0	5	29		
60966	17	1	1				16		
60966	17	1	1				16		
60966	17	1	1	1	30	60	16		
70966	23	30	400	0	0	50	43		
80966	21	2	100	0	0	24	59		
101466	20	10	100	0	20	60	5		
12467	16	70	75	0	0	40	36		
12467	17	70	75	0	0	50	8		
12467	17	50	30	0	0		63		
12467	17	10	80	1	3	40	63		
12467	18	25	75	0	0	40	57		
12467	18	25	100	0	0	50	59		
12467	18	35	75	0	0	30	90		
12467	20	100	50	0	5	40	10		
33167	16	65	100	0	0	40	48		
42167	15	280	1200	24	450	70	4	56	
42167	15	50	300	0	0	40	37		
42167	15	250	300	0	0	50	81	37	
42167	15	2	30	0	0	30	98		
42167	16	5	150	0	0	40	6		
42167	16	20	40	0	0	40	19		
42167	16	60	75	0	0	40	52		
42167	16	70	100	0	0	50	52		
42167	16	10	30	0	0	40	71		
42167	16	2	30	0	1	30	78		
42167	17	2	10	0	0	40	16		
42167	17	160	200	33	500	70	16		
42167	17	1	1	0	0	40	22		
42167	17	80	20	0	0	50	22	16	
42167	17	1	1	0	0	50	45		
42167	17	90	150	1	100	60	56	49	
42167	20	1	1	0	0	30	10	92	
50767	18	30	150	0	0	50	48		
51567	13	5	20	0	0	30	25		
51667	16	5	20	0	0	30	60		
61067	17	2	100	0	0	40	99		
61167	12	60	500	0	0	5	43		
61167	13	1	1	0	0	40	101		
62067	16	7	20	0	0	30	60		
62167	19	1	1	0	0	4	77		
72367	18	100	50	0	0	4	88	62	
80367	14	5	20	0	0	3	82		
102467	14	2	30	0	0	30	17		
122167	10	10	50	0	0	6	14		
122167	11	250	400	0	2	5	79	73	
122167	13	15	125	0	0	4	42		
40368	18	250	50	0	0	50	67	82	
40368	18	80	50	0	0	50	14		
40368	20	5	100	0	0	40	100		
51568	14	150	600	0	25	6	63	54	
51568	16	150	1000	4	50	6	20		
51568	17	60	400	0	0	50	38		
51568	20	20	200	4	60	60	82		
71768	18	40	125	0	0	23	94	48	
51069	10	1	10	0	0	10	92		
62469	13	1	1	0	0	30	87		
63069	0	1	1	0	0	50	99		
72469	10	2	50	0	0	4	92		
72669	15	50	35	0	0	40	21		
80969	15			0	0	30	91		
90469		1		0	0	4	53		
90469	17	250		0	0	4	46		
101069	19	2	100	0	4	4	7		
101069	20	10	200	0	0	50	90	102	

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