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A TORNADO AND SEVERE WINDSTORM CLIMATOLOGY FOR ILLINOIS: 1955-1986

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ABSTRACT

The Illinois tornado and severe windstorm record from 1955 to 1986 is presented and compared with earlier data. Illinois experiences about 28 tornadoes per year on the average, although the actual annual frequencies vary from as few as 7 (1964) to as many as 107 (1974). Total tornado frequency is shown by county, as well as weighted by area. In addition, an index is presented wherein equal area tornado frequencies are adjusted by a rural and total population function, thus minimizing biases introduced by population density.

Whereas several earlier studies have shown mean monthly Illinois tornado frequency to maximize in April, these data show maximum frequency in June, closely followed by April and May, with the tornado "season" essentially delimited by March and September, though tornadoes have occurred in all months of the year in Illinois. In the mean, tornadoes are most frequent in the (1) northeastern, (2) west central, (3) central, and (4) southern sections of the state.

1. Introduction

Although the average annual wind speed in Illinois varies from about 8 to 12 mph, strong, damaging winds occur during all months of the year. Spring storms are either caused by intense cyclones (storm centers), or by thunderstorms and tornadoes. Those during late spring and summer are most likely associated with convection in the form of thunderstorms or tornadoes, whereas those during the colder months of the year are associated with intense cyclones and cold fronts. Thunderstorms exhibit stornger winds and are of shorter duration than the winds

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due to cyclones. They may exceed 60 mph (tornadoes exceeding 200 mph) and may continue for a few tens of minutes. Winter winds are generally less than about 100 mph, but may persist for several hours or more than one day.

The down-rushing air from thunderstorms moves out in all directions from under the thunderstorm cloud as the air nears the earth's surface, often reaching speeds of 60 mph or more. This outflow may extend for several tens of miles outside the outer edge of the thunderstorm cloud. It is impossible to specify the extreme speed of these winds because anemometers are only located at about 25 sites in Illinois. Since severe thunderstorms and tornadoes are less than a few miles in diameter, the wind speeds of most of these phenomena are never observed with the existing network of meteorological sites.

2. Quality of Tornado Data

Observations of tornadoes and the archiving of these observations has improved since the turn of the century. As recent as the early 1950s however, records of tornado occurrences were incomplete because no concerted effort was being made to archive that information on a continuing basis. Although the U.S. Weather Bureau (now the National Weather Service) began to actively gather (as opposed to only *receive*) tornado observations in the mid-1950s, even observations from the most recent years are somewhat suspect.

First, not all tornado observations are necessarily reported to the National Weather Service. Second, if the tornado, itself, is not seen, but only the damage is investigated, the possibility exists that the damage due to a tornado may be categorized as that due to straight line winds, or vice versa. Even professionals disagree as to the cause of any specific damage pattern. Therefore, individual tornado data must be suspect. The quality of tornado data since 1973 was further questioned by Changnon (1982). Prior to that year, U.S. Weather Bureau and/or Environmental Scientific Services Administration State Climatologists visited tornado sites and verified occurrence and damage. After 1973, when the federal State Climatologist program was terminated, site verification was much reduced, and the numbers of tornadoes may be overstated due to the observer attributing damage to tornadoes as opposed to strong straight-line winds. When average frequencies are constructed however, we believe that erroneous data are largely filtered from the results. The material of this paper are composed of such averages.

3. Intensity of tornadic winds

Limited observation, experience and research suggest that although tornadoes generally move forward at relatively slow speeds of 10 to 50 mph, the wind speeds *around* the tornado may exceed 250 mph. Illinois tornadoes have been categorized by intensity since 1970. Eighty-seven percent of the 530 observed tornadoes in Illinois during that time exhibited wind speeds less than about 160 mph.

Though not the state with the highest tornado frequency, nor located in the heart of "tornado alley," Illinois experiences about 28 tornadoes each year (1955-1986 average). The loss of life with any one event is a function of the size and movement of the tornado, the effectiveness of the communications alert system, and is strongly dependent upon the trajectory of the tornado, i.e., whether it moves through a major population center. Illinois is located on the northern periphery of

"tornado alley" (roughly Texas, north-northeastward to Illinois), a favored location for tornado occurrence in the United States, and, indeed, in the world.

4. Early Tornado Reports in Illinois

Tornado statistics for Illinois from 1916 through 1969 were presented by Changnon (1971) and are not repeated here. Instead, this discussion will focus on 1955-1986 data, the most recent 32 years. Pre-1916 tornado occurrences in Illinois are summarized below, recognizing that the list is incomplete. The record is incomplete because not all tornado occurrences were seen nor were they recorded, and written records from the 19th century may have been lost. For example, only 27 tornadoes were recorded in Illinois from the early 1800s through 1870 according to Ludlum (1970) and the U.S. Weather Bureau (listed in Table 1). The 1805 event represents the first surviving record of a tornado in Illinois. The event reported for April 1852 may have included several tornadoes. Four lives were reported lost in the Pana tornado of June 1857, 19 at Ellison (May 1858), and 26 in the Camanche tornado (June 1860). During the 30 years from 1870 to 1899, 81 tornado reports in Illinois survive. The tornado of 21 April 1912 must have been phenomenal in strength, and the magnitude of damage suggests that it occurred over a heavily populated area.

5. The Illinois Tornado Record since 1955

Total number of tornadoes, tornado days, deaths, and injuries from 1955 to 1986 are shown in Table 2. The data of Table 2 are comparable to those presented by Changnon (1971: Table 2) using tornado data from 1916 to 1969. Although Changnon summarized 54 years of data, and the data of this study encompass 32 years, the mean number of tornadoes per year in Illinois increased from 10 to 28 from his study to this one, and the number of days per year with tornadoes increased from 5 to 12. While each of these tornado frequencies increased by a factor of 2 to 3, the average annual number of tornado-caused deaths decreased from 19 to 5 per year (factor of about 4). The average number of tornado-related injuries remained essentially constant, i.e., 110 and 95 per year. The increase in number of tornadoes is probably the result of a better, more complete data gathering program, rather than an actual change in tornado frequency. The substantial decrease in deaths is undoubtedly related to a better understanding of tornadoes by the general public, and to a much better communication system whereby advisories and warnings are quickly disseminated to inhabitants of the potential area of impact. Incidently, if the 1,061 injuries of 1967 are neglected, the average number of injuries per year in Illinois would only be 64, as opposed to 95.

Of all the years with data, 1973 and 1974 clearly stand out as the years with more tornadoes reported in Illinois than in any other year. However, deaths and injuries were below the 32 year average.

Using 1916-1969 data, Changnon (1971) showed that most Illinois tornadoes occurred during April followed by May, March and June, in decreasing order. These 4 months included 66% of the annual tornadoes. The data from 1955 through 1986 indicate that June exhibits the most frequent tornadoes, followed by April, May and August (see Fig. 1). Indeed, these 4 months include 72% of the total annual number of tornadoes in Illinois. The reason for this difference is unknown. It may

be related to the observed cooling trend in Illinois since about 1930, but this suggestion has not been rigorously tested.

Illinois ranks eighth of all states in the total number of tornadoes since 1955, it ranks ninth in the number of tornado-days, and tenth in the total number of tornado-related deaths for the same period. If data since 1916 had been included, Illinois would rank first of all states in the number of tornado-related deaths because of the Tri-State Tornado, a phenomenal event of 18 March 1925 which moved from Missouri through Illinois into Indiana (described by Changnon & Semonin, 1966), and accounted for 606 deaths, making it the single worst tornado event in terms of loss of life in United States tornado history.

Fig. 2 shows the total tornadoes observed within each of the 102 counties of Illinois from 1955 to 1986. The distribution of tornadoes in the state changed somewhat from that of 1916 to 1969 data (Changnon, 1971). Recent data show maximum frequencies in the northeast, the east-central and central sections of Illinois, and also within a small area east of St. Louis (Fig. 2). To compensate for small and large area counties, the raw county frequencies were adjusted for the area of each county, and are reported as tornadoes per 100 square miles in 32 years of record in Fig. 3. Note that although the absolute values change, the overall pattern and locations of maximum and minimum frequencies remain much the same.

Areas with maximum tornado activity in Fig. 3 suspiciously congregates around the major population centers of the state, suggesting that perhaps reports of tornadoes are at least in part, influenced by population density, i.e., more people in an area (up to a point) enhance the possibility that a tornado will be seen and recorded, or conversely, few observers may be spread so thin that tornadoes occur, but are not seen.

To test the impact of varying population densities, a tornado index was constructed after that suggested by Agee (1970). The index is calculated as follows.

$$\text{Tornado Index (county)} = \frac{\dfrac{\textit{tornadoes}}{\text{rural population (county)}}}{\dfrac{\textit{tornadoes}}{\text{rural population (state)}}}$$

This index "corrects" raw data for urban population densities (assuming that the high population densities of urban areas will amplify frequencies), and presents each county value relative to that for the entire state, i.e., an index of 1.0 is equivalent to the state average, 2.0 is twice that of the state, etc. The distribution of indices (Fig. 4) show values greater than 1.0 from west-central counties toward the northeast, east and southeast, and a second area in southern counties. These findings differ only slightly from those compiled from 1916 to 1969 data presented by Changnon (1971), where he showed the greatest indices from roughly the St. Louis area toward the northeast. The similarity in the 2 patterns is largely the result of 15 years of common data (1955-1969) in the 2 studies. Although the pattern of high index counties is essentially the same in the 2 studies, Changnon identified a total of 48 counties with indices greater than 1.0, whereas we only identified 31 such counties. Twenty of our high index counties are common with those of Changnon, and 11 of ours were identified as low index counties in Changnon's study. There is no systematic change from his pattern (his Fig. 7) to that in ours. The reason(s) for

these observed differences are unknown. They may only reflect differences in potentially discontinuous data sets, such as are tornado observations.

Tornado intensities have been defined according to wind speed and damage by Fujita (1981) and are summarized in Table 3. The frequency of various intensity storms in Illinois since 1970 are presented in Table 4. For each of the years with more than about 30 tornadoes, the distribution of the various intensity storms is heavily skewed toward the lower intensities, i.e., tornadoes with maximum winds of 112 mph or less, comprising about 2/3 of the total.

6. Severe straight line winds not associated with tornadoes

Strong straight line (non-rotating) winds can occur during any season of the year in Illinois, though they are most frequently observed during the warmer months. Indeed, 86% of all reported straight-line windstorms from 1960 through 1986 occurred from March through August. Their mean monthly distribution is shown in Fig. 1. Note the interesting, but inexplicable month-to-month increases from January through July. The climatology of straight line windstorms in Illinois was reviewed by Changnon (1980) and will not be duplicated here. In the present paper, we look only at the distribution of straight line windstorms from data extracted from *Storm Data*, published by the National Weather Service.

Straight line winds are caused by strong cyclones (low pressure cells or storm centers) or near strong fronts primarily in winter, or by non-tornadic thunderstorms primarily in spring and summer. The resulting winds from either source are essentially the same, i.e., non-rotating, but with speeds greater than about 40 mph, but generally less than 100 mph. The strong winds associated with moving storm centers may persist for hours or an entire day. Those associated with thunderstorms generally persist for 30 minutes or less. Damage, however, may be great, since the damage is largely a function of the strength of the wind, rather than its duration.

The distribution of straight line windstorms by county from 1960 to 1986 is shown in Fig. 5, and per 100 square miles per county in Fig. 6. Note that both patterns generally conform to those of tornado distributions found in Figs. 2 and 3.

7. Change in tornado and straight line winds from 1955 to 1986

The number of straight-line windstorm days and tornado days per year for 1960 to 1986 (extracted from *Storm Data* from 1960 to 1986) are shown in Fig. 7. Annual windstorm days occurred more frequently than tornado days except during the 9 years from 1962 to 1970. Although the correlation coefficient between these 2 variables is only +0.56, a similarity is noted in the trends of each of the 2 curves. There are three episodes: (1) relatively low frequencies until about 1971 or 1972, (2) rising to a relatively high frequency for 3 to 6 years until 1975 or 1977, and (3) falling again to the present value.

8. Summary and Conclusions

Illinois' relatively flat, low-relief topography enhances the possibility of strong winds. Such winds occur because of intense cyclones, cold fronts, and coldwaves in winter, and thunderstorms and tornadoes in spring and summer, and to a lesser extent, in fall. Destructive winds can occur during all months of the year. Those in winter tend to range from 40 to 60 mph, and continue for several hours or even from

one day into the next; whereas thunderstorm-related winds during the warmer months tend to be stronger (perhaps greater than 100 mph), but usually exhibit a tenure measured in only a few tens of minutes.

Although tornado observations are more complete today than they were in the 19th century, records of individual storms from the last decade are still suspect due to population spatial density differences, and mis-identification of tornadoes and straight line winds. We believe that errors in the record tend to be random and therefore averaged data are meaningful.

The mean annual frequencies of tornadoes and straight line winds in Illinois are similar, *i.e.*, about 10 each per year from 1960 to the early 1970s; followed by about 35 tornadoes (15 straight line windstorms) per year to about 1976; and about 25 tornadoes (10 straight line windstorms) per year thereafter. We do not know whether these discontinuous episodes reflect actual frequency changes, or, rather, reflect changes in observation verification, or recording procedures.

Both strong straight-line and tornadic winds are most frequently observed in west central, north central and northeastern, and in southern Illinois. During the last 32 years of record, June has recorded the greatest monthly tornado frequency, followed by April, May and August; those months include 72% of the annual mean. Straight line winds occur with increasing frequency from January through July. There has been no change in the annual tornado frequency since the mid 1950s. Changes prior to that time were likely due to incomplete records.

Using tornado data since 1955 (1960 for straight line winds), Illinois experiences about 28 tornadoes, 12 days with tornadoes, and 24 days with straight line windstorms annually. Monthly tornado frequencies increase from about 1 per month from October to February, to about 5 per month in April, May and June. Straight line windstorms, on the other hand, increase rather linearly from fewer than 1 per month in October to February, to more than 5 per month in July, with a general decline to October.

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Table 1. Date and location of tornadoes in Illinois during the nineteenth century through 1870 (from Ludlum, 1970), and from 1900 to 1915 (from Weather Bureau records, 1900-15). County of occurrence given in parentheses.

Date	Location
5 June 1805	St. Louis and east into St. Clair County
27 May 1850	Nauvoo (Hancock)
30 April 1852	Golconda (Pope) into Indiana
13 June 1857	Pana (Christian)
31 May 1858	Ellison (Warren)
26 May 1859	Calhoun-Greene-Scott-Morgan Counties
2-3 June 1860	Camanche IA to Whiteside County to the east-northeast to Elgin area (Cook)
9 November 1864	Chester (Randolph) and Hoyleton (Washington)
12 April 1903	Logan, Dewitt and Piatt Counties
17 April 1903	Henry and Walnut (Bureau and Marshall)
18 April 1903	Cambridge (Henry)
11 April 1905	Hillsboro (Montgomery)
28 April 1905	Crawford County
10 June 1905	Galva (Henry)
19 June 1905	Rushville (Schuyler)
27 March 1908	Knoxville (Knox), Monmouth (Warren) and Pontiac (Livingston)
11 May 1908	Mercer County
28 May 1908	Pike County
25 November 1908	southeast St. Clair County, 125 ft. wide path
11 July 1909	Vermilion County
15 April 1910	Madison, Macoupin and Montgomery Counties, ½ mile wide path. "Enormous" hailstorm at Hillsboro
22 May 1910	Cairo (Pulaski), 6 houses moved off foundations
12 September 1910	Iroquois County
11 November 1911	Tornado characteristics noted prior to a severe coldwave in Illinois
21 April 1912	LaSalle and Livingston Counties, path was 100 to 1,300 ft. wide. 18 dead in Illinois. Damage estimated $1 million in 1912 dollars. Another tornado reported in Murphysboro where 9 people were killed, 75 injured, 22 houses lost and 106 houses damaged.
26 April 1912	Carbondale (Williamson) and east. 1 person killed. Path width from 400 to 500 ft.
3 May 1914	Galva (Henry) and Peoria (Peoria). 2 dead.

Table 2. Tornado and windstorm statistics for Illinois for the years 1955 through 1986.

Year	Tornadoes	Tornado Days	Deaths	Injuries	Windstorm Days
1955	23	10	0	9	*
1956	27	18	8	31	*
1957	42	12	15	319	*
1958	27	13	2	17	*
1959	36	20	1	5	*
1960	36	18	0	31	32
1961	35	16	2	142	33
1962	10	9	0	2	9
1963	13	8	2	114	10
1964	7	4	0	3	14
1965	27	12	8	211	12
1966	11	8	1	50	11
1967	40	14	59	1061	12
1968	8	3	8	135	10
1969	10	8	0	4	17
1970	17	12	0	2	8
1971	16	13	1	48	9
1972	30	14	5	81	32
1973	63	25	0	11	27
1974	107	25	2	67	50
1975	46	28	2	78	45
1976	27	13	4	118	30
1977	33	7	6	61	45
1978	13	7	1	4	20
1979	12	11	0	1	21
1980	14	9	0	7	33
1981	33	14	1	48	20
1982	35	17	13	287	31
1983	14	5	2	43	28
1984	34	13	1	20	27
1985	15	12	1	20	25
1986	21	9	0	12	35
Total	882	396	150	3,042	646
Mean, per year	27.6	12.4	4.7	95.1	23.9
Std. Dev.	19.5	5.9	10.6	193.7	12.1

*data not available.

Table 3. Tornado intensities, after Fujita (1981).

Intensity	Characteristic
F –	Little or no damage, 40 mph or less
F 0	Light damage to branches, signboards, 40 to 72 mph
F 1	Moderate damage, roofs, mobile homes and moving automobiles particularly susceptible, 73 to 112 mph
F 2	Considerable damage, boxcars overturned, large trees uprooted, 113 to 157 mph
F 3	Severe damage, walls of structures blown down, most trees in forest blown down, cars lifted off road and blown, 158 to 206 mph
F 4	Devastating damage, houses leveled, buildings blown off foundations, 207 to 260 mph
F 5	Incredible damage, large houses lifted off foundation and blown substantial distances or demolished, automobile-sized missiles fly through air, 261 to 318 mph
F 6	Inconceivable damage, 319 mph or greater

Table 4. The frequency of Illinois tornadoes according to the "F" intensity scale of Fujita (1981).

Year	F0	F1	F2	F3	F4	F5	F6	Unk	Total
1970		8	5					4	17
1971	2	12	1	1					16
1972	5	15	7	2	1				30
1973	22	27	13	1					63
1974	57	15	18	9				8	107
1975	15	12	15	4					46
1976	4	2	13	5	3				27
1977	7	13	2	2	1			8	33
1978	1	5	5	1				1	13
1979	1	4	1	1				5	12
1980	8	1	5						14
1981	14	14	2	1	2				33
1982	24	3	3	3	1			1	35
1983	4	5	3	2					14
1984	19	12	2	1					34
1985	6	6	3						15
1986	9	9	3						21
Total	198	163	101	33	8			27	530
Percent of Total	37	31	19	6	2			5	

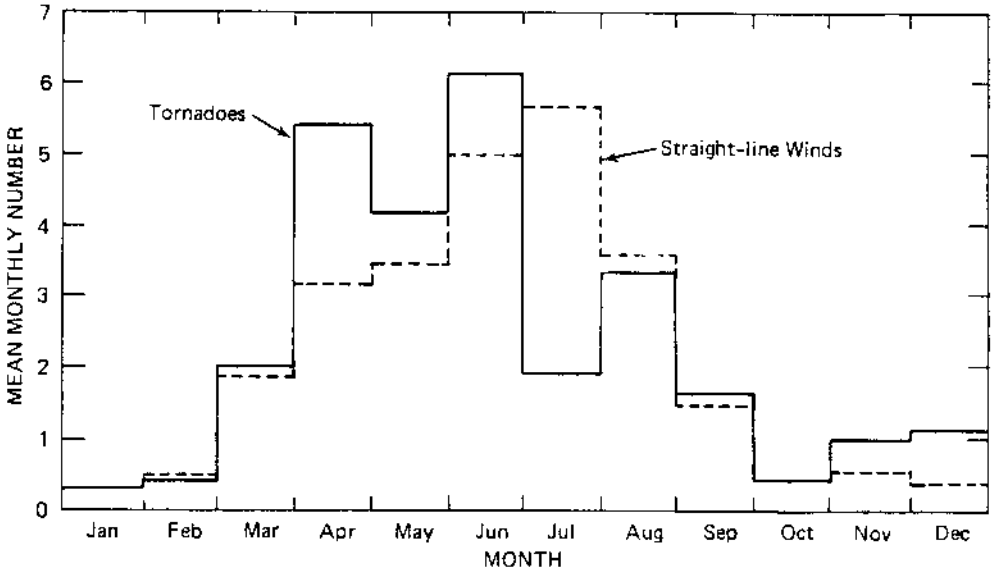

Fig. 1. Mean number of days per month with tornadoes, and straight line windstorms (1955-1986 data).

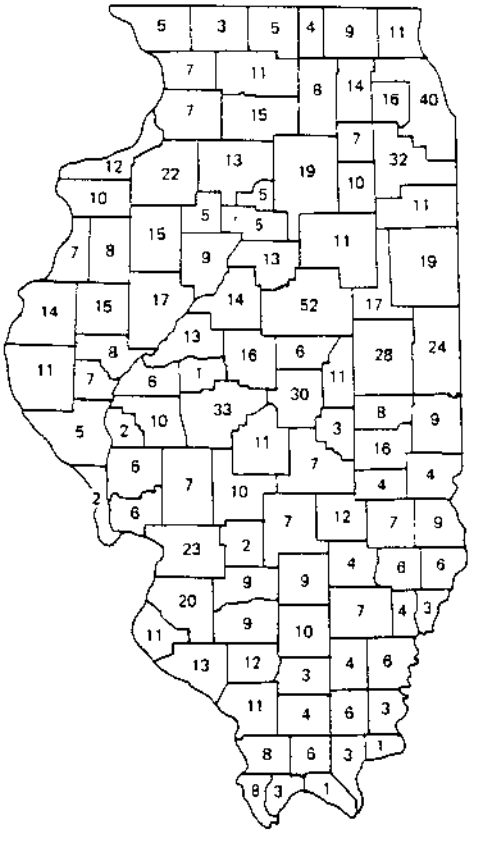

Fig. 2. Total tornadoes reported by county from 1955 through 1986.

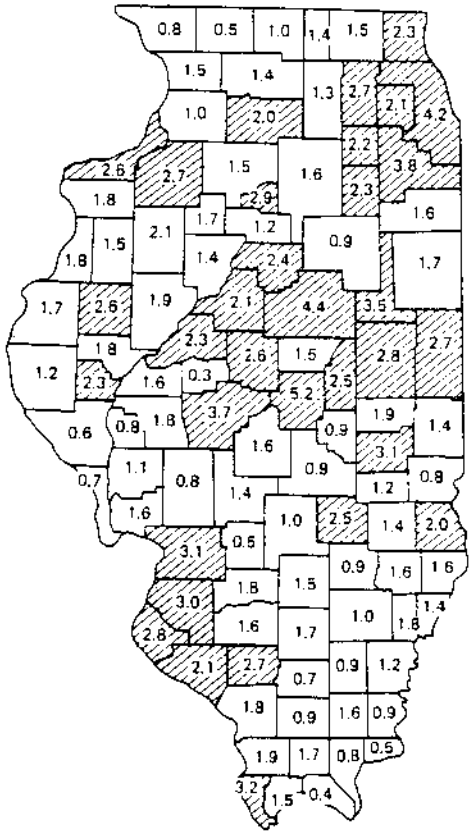

Fig. 3. Total tornadoes reported by county from 1955 through 1986, expressed as total tornadoes per 100 square miles. Totals of 2.0 or greater are shaded.

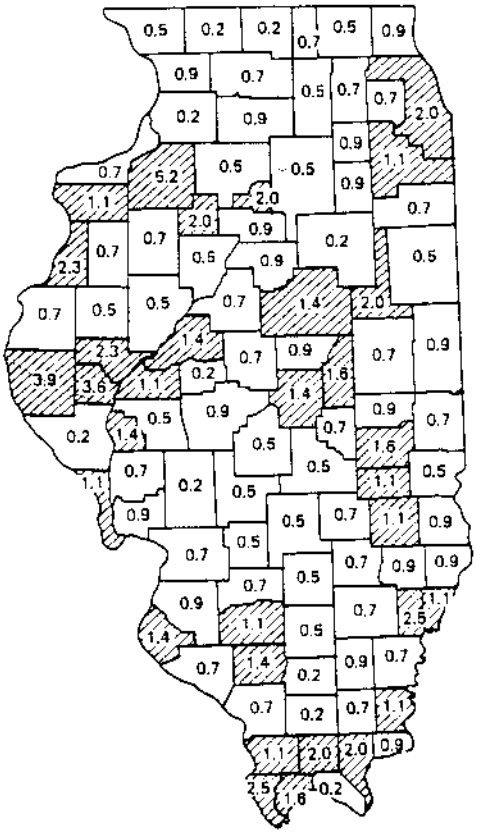

Fig. 4. Tornado index by county (1.0 = statewide mean; see text for explanation) (1955-1986 data). Totals of 1.0 or greater are shaded.

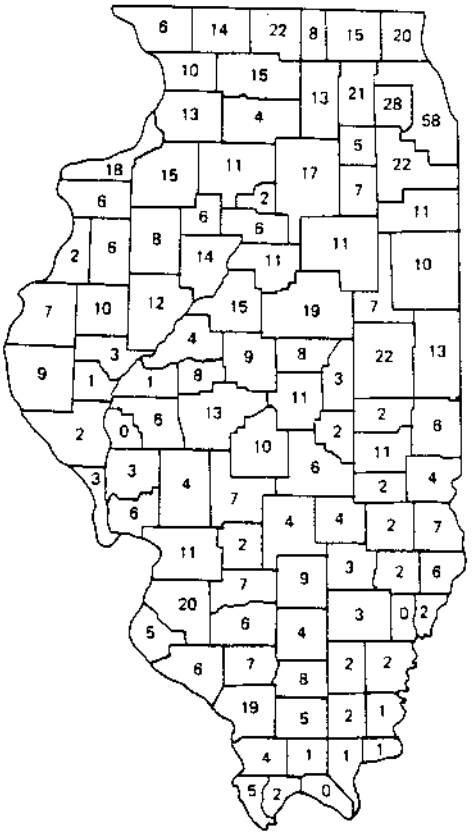

Fig. 5. Total straight-line windstorms by county, reported from 1960 through 1986.

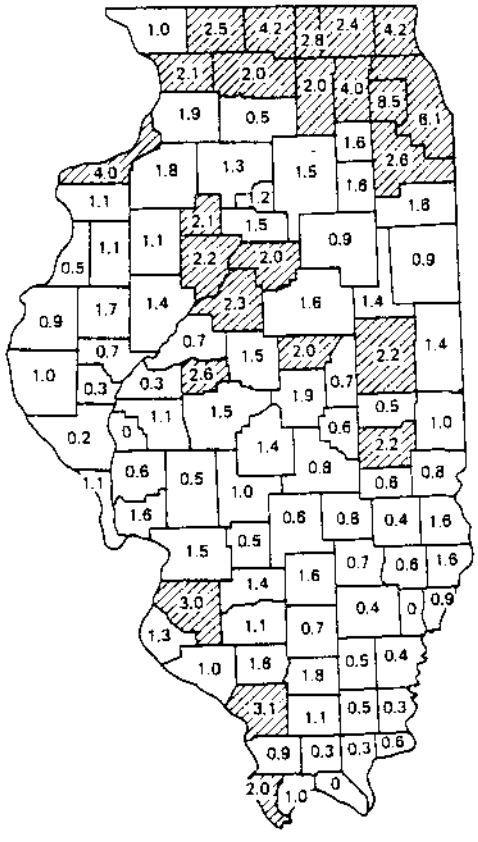

Fig. 6. Total number of straight-line windstorms by county, per 100 square miles, reported from 1960 through 1986.

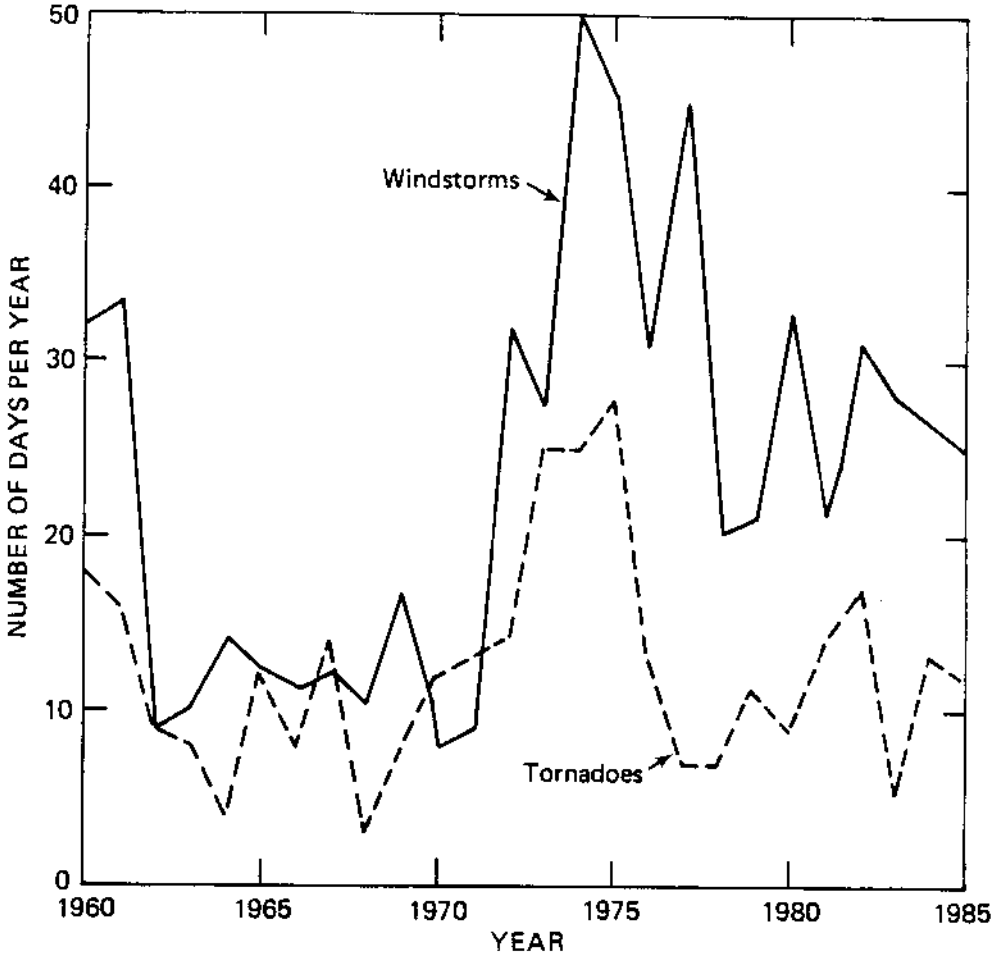

Fig. 7. Annual numbers of tornadoes and straight-line wind events from 1960 to 1985.