Temporal Aspects of Illinois Tornadoes: 1950-1998

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ABSTRACT

Tornado statistics covering the period of 1950 to 1998 are used to examine tornado frequency, deaths, and injuries by year and month in Illinois. The upward trend found in tornado frequency is the result of more F-0 events being reported in recent years. No trends are evident in the number of deaths and injuries over time. On a monthly basis, April is the month with the most tornadoes, fatalities, and injuries. While tornado frequency remains high in May and June, deaths and injuries decline rapidly. These decreases are explained in part by concurrent decreases in the frequency of more intense tornadoes during May and June. Tornadoes are most likely to occur in the afternoon or early evening hours. However, 80% of the fatalities occurred between 2 and 5 pm. F-0 tornadoes are the most numerous and least deadly in Illinois. On the other end of the scale, F-5 tornadoes are the rarest and most deadly. F-0 tornadoes have the narrowest widths and the shortest paths; F-4 tornadoes have the largest widths and the longest paths. F-5 tornadoes tend to have smaller widths and paths than F-4 tornadoes.

INTRODUCTION

Tornado climatology is of interest to a number of groups including weather forecasters, emergency management agencies, and the general public. Tornadoes have captured the imagination of the public like no other weather phenomena. The science behind understanding and predicting tornadoes has increased dramatically over time. In addition, the widespread deployment of Doppler radar and National Oceanic and Atmospheric Administration (NOAA) Weather Radios, along with the availability of weather products in near real-time over the Internet and cable TV, have increased warning times and preparedness while ensuring that interest in tornadoes remains high.

Illinois has experienced some of the worst tornadoes in U.S. history. The infamous Tri-State tornado occurred on March 18, 1925, leaving 695 dead, 2000 injured, and $130 million in property damage. The tornado developed near Ellington, Missouri, at 1 pm, moving through southeastern Missouri before crossing the Mississippi River, destroying the town of Gorham, Illinois, at 2:30 pm. From there it cut a wide swath through Murphysboro, De Soto, West Frankfort, and Parrish. The tornado proceeded to enter southwestern Indiana before dissipating (Wilson and Changnon 1971).

The Mattoon tornado of May 26, 1917, left 101 dead, 638 injured, and $55 million in property damage. The tornado developed near Louisiana, Missouri. From there it tracked due east, passing through Nebo, White Hall, Modesto, Owaneco, Westervelt, Mattoon, Charleston, and Marshall. The heaviest hit were Mattoon (53 killed, 409 injured) and Charleston (38 killed, 182 injured).

In addition, the first documented case of a tornado being detected by radar occurred in Illinois. On April 9, 1953, staff of the Illinois State Water Survey tracked the development, growth, and movement of a tornado, as identified by the distinctive "hook echo" (Huff et al., 1954). This discovery led to the development, in the 1950s, of a nationwide network of radar sites to track tornadoes.

Changnon and Stout (1957) summarized the statistics for tornadoes in Illinois using data from 1927 to 1952. They identified some of the key features of Illinois tornadoes that still exist today. Among their findings was that 72 percent of all tornadoes occurred during spring, the peak tornado season. Central Illinois experienced the most tornado activity (76 tornadoes), followed by southern Illinois (40 tornadoes), with northern Illinois being last (24 tornadoes). They also noted that tornado frequency was at a minimum between 4 am and 8 am. Maximum activity was found during the afternoon hours with 57 percent of all tornadoes occurring between 3 pm and 7 pm.

Wilson and Changnon (1971) developed a tornado climatology based on data from the 1916-1969 period. They described basic characteristics of tornadoes such as the time of day of occurrence, frequency over time, and their geographic distribution across Illinois. In addition, they provided more detailed meteorological accounts of the Mattoon and Tri-State tornadoes (as described above). They found that 65% of all tornadoes occurred between March and June. Nearly 65% of all tornadoes occurred between the hours of 2 and 8 pm. While they found an increase in tornado frequency over time, this was attributed to changes in reporting procedures within the U.S. Weather Bureau.

Wendland and Guinan (1988) focused on one of the more difficult aspects of tornado reporting, the geographic distribution within the state. An inherent problem with the tornado data collection effort is a bias towards greater tornado frequency as population density increases. The authors adjusted for this bias by taking into account the population density of each county. They found that west-central, north-central and northeastern, and southern Illinois experienced higher tornado frequencies than elsewhere in the state.

This paper examines tornado frequency, deaths, and injuries by year and by month for the period of 1950 to 1998. While previous studies have examined these statistics, none of them contain data after 1986. An update is important because of public perception of increased tornado activity and because of ongoing changes in the detection and reporting of tornado events. Tornado frequency, deaths and injuries will be compared to tornado strength, size, and path length. New relationships are explored, especially tornado intensity and how it relates to deaths, injuries, path length, and path width. By quantifying these relationships, better decisions can be made regarding the risks involved with tornadoes and their intensity, leading to such things as more effective building practices and more efficient emergency management.

DATA

The tornado data in this study were obtained from the NOAA Storm Prediction Center (2000) and include all reported Illinois tornadoes from 1950 to 1998. The data set contains information for each tornado with regards to strength, path coordinates, path length, path width and any deaths, injuries, or damage associated with each. These data were used to construct plots of tornado frequency, strength, path length, path width, as well as deaths and injuries related to tornadoes on selected time scales (yearly, monthly, and hourly).

The tornado data were based on damage surveys conducted by National Weather Service (NWS) personnel after the events. The damage site usually provides clues regarding the strength of the tornado and the distinction between tornado and straight-line wind damage. As discussed in Wendland and Guinan (1988) one problem with tornado statistics is the strong relationship between tornado sightings and population density. As the population of Illinois and the United States in general has increased, so has the number of reports of tornadoes. In addition, the U.S. Weather Bureau and later the National Weather Service increased their emphasis on damage surveys over time, leading to better statistics from 1950 onward. Finally, the installation of a nationwide network of improved Doppler radars in the 1990s increased the detection of weaker tornadoes, particularly F-0 events that might have gone unnoticed before (Brad Kechum, NWS, personal communication, 2000).

Tornadoes are typically classified using the Fujita or F-scale (Table 1), proposed by Fujita (1971) to identify the wind speed of a tornado based on the amount of damage it caused. As Fujita recognized, the weakness of this approach is that it is dependent on the quality of construction (e.g., poorly built houses disintegrate at lower wind speeds than well-built houses). It will not work in the special case of a strong tornado passing through open country and causing only minor damage. However, there is no other widely available way of measuring or estimating the wind speeds associated with tornadoes.

ANALYSIS

Annual Statistics

The distribution of tornadoes by year in Illinois (Figure 1) shows an increase in the number of tornadoes since 1950. The peak year of tornado activity was 1974, largely due to the infamous Super Outbreak of April 3-4, 1974, that included 148 tornadoes in 13 states. The average number of tornadoes per year is 29. The total number of tornadoes per year has increased significantly in the 1990s. This includes the 39 tornadoes on April 19, 1996, the largest single outbreak in Illinois. Meanwhile, the number of tornadoes per year rated as F-1 or above has shown no appreciable trend (heavier line in Figure 1). Therefore, this trend reflects recent changes in tornado reporting procedures that captures more of the F-0 events, rather than an actual increase in tornado activity.

Illinois averages four tornado-related fatalities per year. However, the number does vary widely from year to year with the larger numbers of deaths in certain years, usually associated with one or two particular events (Figure 2). For example, in 1967 two tornadoes on the same day caused 57 deaths. The first was an F-4 tornado that occurred on April 21,

1967, around Belvidere in Boone County. This storm killed 24 and injured 410. The second F-4 tornado occurred on the same day in Cook County, tracking from Palos Hills through Oak Lawn to Lake Michigan. Thirty-three people were killed and approximately 500 injured. This was the deadliest year in the 1950-1998 record. The high number of fatalities in 1990 was due to the 29 deaths in the F-5 tornado that occurred on August 28, 1990. The 16-mile path extended from Oswego to Joliet and caused $165 million in damages. A majority of the deaths and injuries from this event occurred in Plainfield.

The number of injuries per year in Illinois (Figure 3) is strongly related with fatalities per year. Illinois experiences about 82 injuries per year. However, a large portion of the injuries occurred in relatively few of the events, namely the Boone and Cook County tornadoes of 1967 and in the Plainfield tornado of 1990.

Monthly Statistics

Figure 4 shows the distribution of tornadoes, fatalities, and injuries by month. Tornado season in Illinois is generally considered to start in March and continue through the warm season. Even so, tornadoes, fatalities, and injuries have occurred in every month of the year. Most of the winter events have occurred in southern Illinois where warmer temperatures prevail and thunderstorms are still prevalent. Most of the tornadoes in Illinois occur in the peak months of April, May, and June, some 63% of the annual total. All three tornado statistics (frequency, fatalities, and injuries) peak in April, the most dangerous month in Illinois. Both fatalities and injuries decline more rapidly than the total tornado frequency in May and June. Fatalities and injuries reach a secondary peak in August that is due to the August 28, 1990, Plainfield event.

Hourly Statistics

Figure 5 shows the distribution of tornadoes, fatalities, and injuries by hour of the day. The frequency of tornadoes is low between midnight and 10 am before rising into the mid-afternoon to early-evening hours. The frequency declines through the remainder of the evening hours. The number of fatalities and injuries follow the number of tornadoes by remaining low in the morning and then increasing into the afternoon hours. While the number of tornadoes gradually declines after 5 pm, the frequency of fatalities and injuries decline much more rapidly. In fact, 152 of the 189 deaths (80%) documented in this study occurred between 2 and 5 pm, which is similar to the national statistics in Kelly et al. (1978). The explanation for this appears to be that a majority of the stronger tornadoes (F3 or greater) occur during this time of day and most deaths and injuries are associated with the stronger events (see next section).

Statistics by F-scale

Table 2 shows the distribution of tornadoes (expressed as a percentage), average number of fatalities per storm, and average number of injuries per storm for each level of the F-scale. F-0 tornadoes are the most common tornadoes in Illinois with F-1 tornadoes being only slightly less frequent. These two categories account for 70% of all tornadoes in Illinois, yet the risk to death or injury is very small. F-2 tornadoes are less common than F-0 and F-1 events. However, the risk begins to become noticeable. The frequency declines rapidly for tornadoes stronger than F-2. However, the risk of death and injury increases rapidly. F-5 events account for only one-tenth of a percent of all tornadoes between 1950 and 1998 while causing an average of 15 deaths and 178 injuries. The frequency of tor-

nadoes and deaths in each category of the F-scale agrees with the nation-wide results in Kelly et al. (1978).

Figure 6 shows the number of tornadoes by month for two classes. After examining the relationship between F-scale and deaths/injuries (Table 2), it was decided to group tornadoes into "non-destructive" (F-0 to F-2) and "destructive" (F-3 to F-5) categories. The preponderance of tornadoes in Illinois falls into the "non-destructive" category. April, May, and June all experience a high number of these events, accounting for 63% of the total. This is followed by a sharp drop in July. After rising slightly in August, the frequency of "non-destructive" tornadoes drops through October. Surprisingly, they increase in frequency in November before declining through the winter months. However, most of the events in the colder months are confined to southern Illinois.

The monthly pattern for "destructive" tornadoes is different in some respects. April is the most active month, with 37 events compared to 16 in May and 13 in June. Referring back to Figure 4, between April and May deaths and injuries dropped by 77 and 71 percent respectively, while the number of "destructive" tornadoes dropped by 57 percent. Between May and June both deaths and injuries dropped by another 50 percent while the number of "destructive" tornadoes dropped by only 19 percent. From June to July, deaths dropped by 80 percent, injuries by 67 percent, and "destructive" tornadoes by 62 percent. The decline in deaths and injuries after April is clearly related to the drop in the number of "destructive" tornadoes. However, the drop in deaths and injuries occurs at a faster rate from April to May and from May to June than do the concurrent drops in "destructive" tornadoes. One factor for this may be an improved public response to National Weather Service watches and warnings once the tornado season is underway. As with the "non-destructive" tornadoes, the frequency of "destructive" tornadoes drops off in July to September and is negligible in October. November also is marked by low frequencies. However, December shows a significant increase in frequency before tapering off again in the remaining winter months. The spike in December is largely due to an outbreak of tornadoes in southern Illinois on December 18, 1957.

Figure 7 shows the relationship between path length and F-scale. F-0 events are relatively short-lived, lasting about 1.6 km (1 mile) on average. Path length increases dramatically with F-scale, reaching a maximum of 35 km (22 miles) at F-4. The path length drops in half for F-5 tornadoes. It remains unclear as to why this is the case, but it could be the result of the small sample size of F-5 tornadoes. Grouping path length into three categories, Kelly et al. (1978) found a similar relationship where stronger tornadoes frequently had longer lengths.

Figure 8 shows the strong positive relationship between path width and F-scale. An F-scale from 0 to 2 yields relatively small tornadoes, increasing by 30 meters (100 feet) per increment in the scale. A large increase in width occurs at F-3, three times the average of F-2 tornadoes. The width increased by another 20% for F-4 and F-5 events. The jump in size at F-3 may help explain why there is a concurrent jump in the number of deaths and injuries involved in tornadoes (Table 2). By cutting such a wide swath and over a longer path (as shown in Figure 7), their chances of hitting occupied structures are greatly increased. Combined with their higher wind speeds, it is no surprise that the most serious threat is from the larger events.

SUMMARY

Tornado statistics covering the period of 1950 to 1998 were used to examine tornado frequency, deaths, and injuries by year, month, and time of day. Tornado frequency has increased over time. However, there was no trend in the number of stronger tornadoes (F-1 or greater), suggesting that the trend is the result of more F-0 tornadoes being reported in recent years. No trends are evident in the number of deaths and injuries over time despite the trend in total tornado frequency, providing further evidence that the trend in total tornado frequency is an artifact of the data collection process.

On a monthly basis, April is the month with the most tornadoes, fatalities, and injuries. While tornado frequency remains high in May and June, deaths and injuries decrease rapidly. This drop is due primarily to the concurrent drop in strong tornadoes that are known to cause most of the casualties. However, the fact that the death and injury rates drop more rapidly than the frequency of intense tornadoes suggests that the precautions and responses by the public to tornadoes *may be* increasing as the season progresses. This pattern suggests that increased public awareness as the season progresses has reduced the toll on human life. Tornadoes are most likely to occur in the afternoon or early evening hours with 80% of the fatalities occurred between 2 and 5 pm.

An examination of frequency, deaths, and injuries reveals that F-0 tornadoes are the most numerous and least deadly in Illinois. On the other end of the scale, F-5 tornadoes are the rarest and most deadly. F-0 tornadoes have the narrowest widths and the shortest paths. F-4 tornadoes have the largest widths and longest paths. F-5 tornadoes tend to have smaller widths and paths than F-4 tornadoes. However the number of F-5 events in the record (2 events) is too small for reliable statistics.

Finally, this study shows that more public education is needed earlier in the spring, preferably before April, the most dangerous month in the tornado season. There appears to be some indirect evidence that a re-education process is occurring each year once the tornado season begins in earnest.

ACKNOWLEDGMENTS

LITERATURE CITED

Changnon, S.A., Jr., and G. E. Stout, 1957: Tornadoes in Illinois. Illinois State Water Survey Circular 63, Champaign, IL, pp. 11.

Fujita, T. T., 1971: Proposed characterization of tornadoes and hurricanes by area and intensity. SMRP Research Paper 91, University of Chicago, Chicago, IL, 42 pp. [Available from Wind Engineering Research Center, Box 41023, Lubbock, TX 79409].

Huff, F. A., H. W. Hiser, and S.G. Bigler, 1954: Study of an Illinois tornado using radar, synoptic weather and field survey data. Report of Investigation 22, Champaign, IL, pp. 73.

Kelly, D. L., J. T. Schaefer, R. P. McNutty, C. A. Doswell III, and R. F. Abbey, Jr., 1978: An augmented tornado climatology. Monthly Weather Review, 106 (8), 1172-1183.

NOAA Storm Prediction Center, 2000: Historical Tornado Data Archive. [Available online at http://www.spc.noaa.gov/archive/tornadoes/].

Wendland, W. M., and P. Guinan, 1988: A tornado and severe windstorm climatology for Illinois: 1955-1986. Transactions of the Illinois Academy of Science, 81, 1, pp. 131-146.

Wilson, J. W., and S. A. Changnon, 1971: Illinois Tornadoes. Circular 103, Champaign, IL, pp. 58.

Table 1. Fujita or F-scale categories used to define tornado strength.

Scale	Wind Speed	Typical Damage
F-0	18-32 m/s (40-72 mph)	Tree branches broken
F-1	33-50 m/s (73-112 mph)	Mobile homes pushed off foundations
F-2	51-70 m/s (113-157 mph)	Considerable damage, mobile homes demolished, trees uprooted
F-3	71-92 m/s (158-205 mph)	Roofs and walls blown down, cars thrown
F-4	93-116 m/s (207-260 mph)	Well-constructed buildings leveled
F-5	117-142 m/s (261-318 mph)	Massive destruction, autos thrown as far as 100 meters

Table 2. Distribution of number of storms, average number of fatalities per storm, and average number of injuries per storm for each level of the Fujita scale.

F-scale	Number of Storms and Percent of Total	Average Fatalities per Storm	Average Injuries per Storm
0	517 (37.2%)	0.004	0.02
1	454 (32.7%)	0.019	0.46
2	298 (21.5%)	0.045	2.38
3	91 (6.6%)	0.409	8.73
4	26 (1.9%)	3.846	77.19
5	2 (0.1%)	15.000	178.00

Figure 1. Distribution of tornadoes by year in Illinois, 1950-1998.
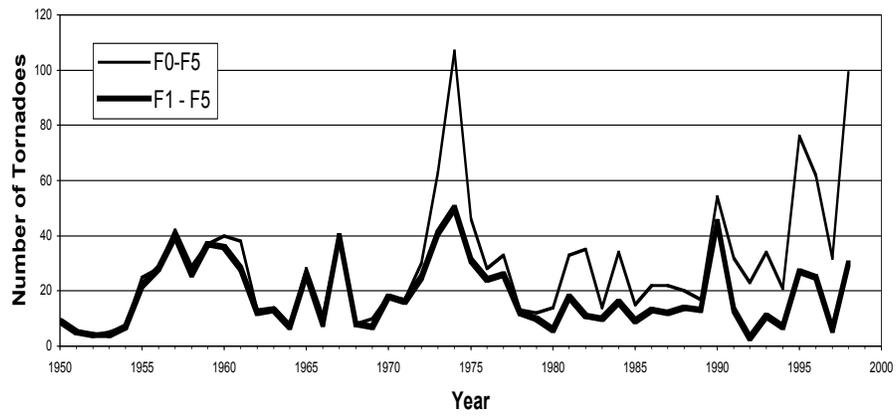

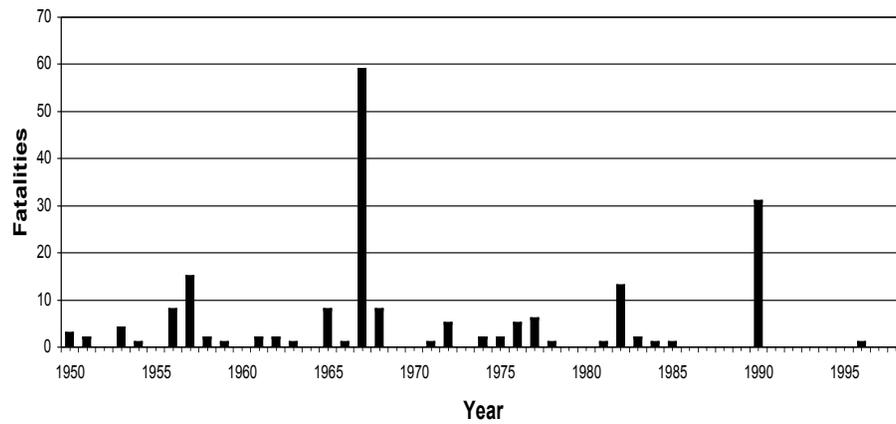Figure 2. Illinois tornado-related fatalities per year, 1950-1998.

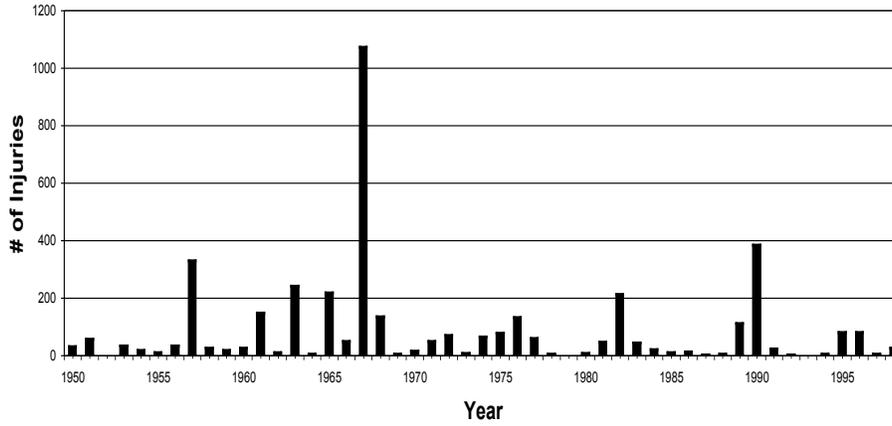Figure 3. Illinois tornado-related injuries per year, 1950-1998.

Figure 4. Monthly distribution of tornadoes, related fatalities, and injuries in Illinois, 1950-1998.
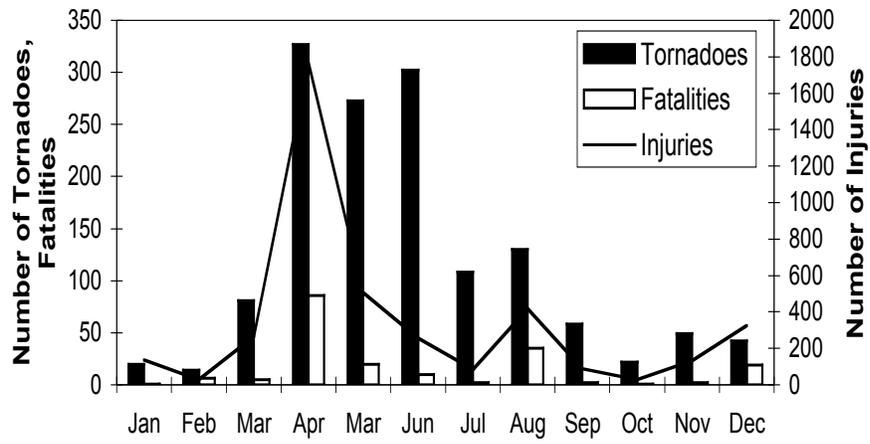
Figure 5. Hourly distribution of tornadoes, related fatalities, and injuries in Illinois, 1950-1998.
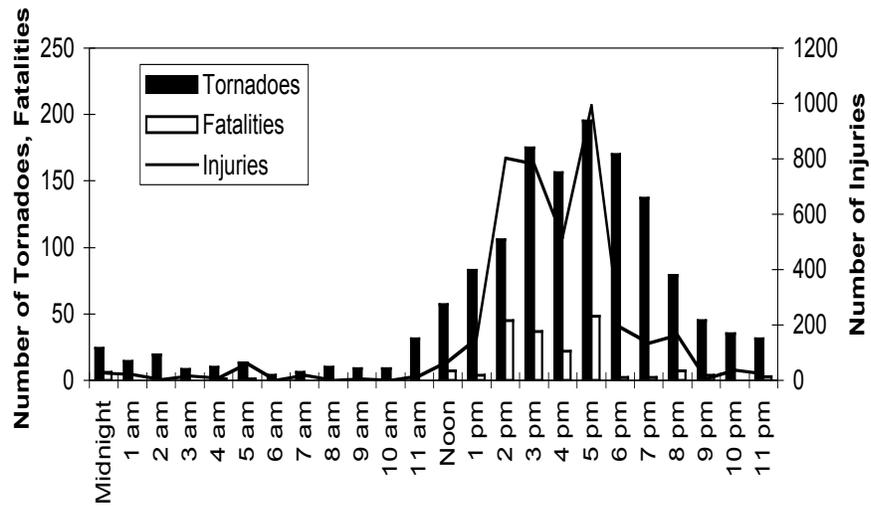

Figure 6. Number of "non-destructive" (F-0 to F-2) tornadoes and "destructive" (F-3 to F-5) tornadoes in Illinois by month, 1950-1998.
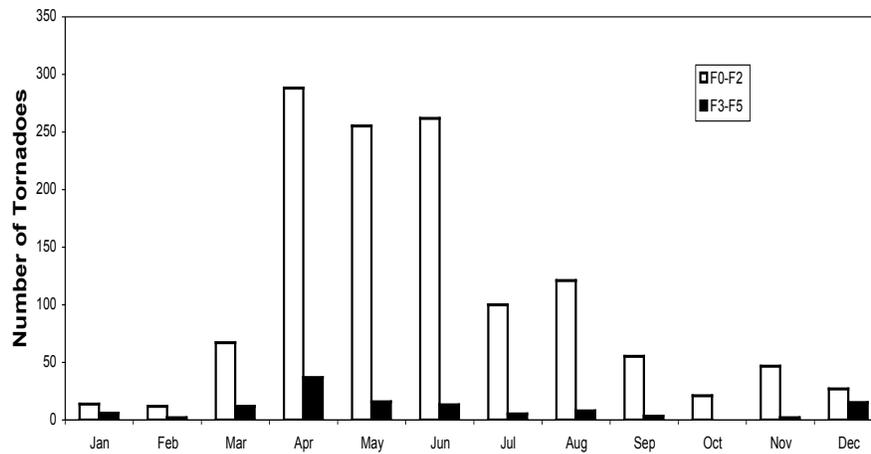
Figure 7. Relationship between tornado path length and F-scale in Illinois, 1950-1998.
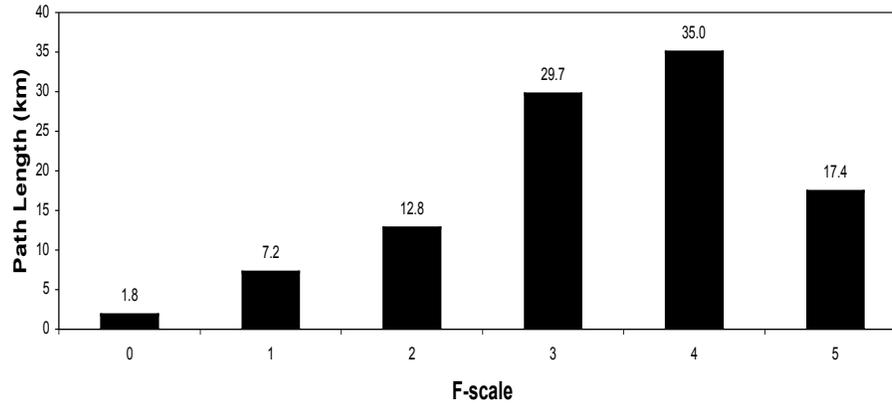

Figure 8. Relationship between tornado path width and F-scale in Illinois, 1950-1998.