A Tornado Climatology of Middle Tennessee (1830-2003)

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1. Introduction

Tennessee does not lie in what is known as the "tornado alley" of the Southern Plains, but its geographical location still allows for a relatively high frequency of tornado occurrences. Since 1830, 469 individual tornadoes that have occurred in Middle Tennessee have been catalogued (Middle Tennessee Tornado Database). In the past decade, during which time the National Weather Service has increased its emphasis on documentation and storm surveys, Middle Tennessee has averaged nearly 16 tornadoes annually.

For purposes of this paper, "Middle Tennessee" is defined as the thirty-nine counties that comprise the county warning area of the National Weather Service Office in Old Hickory, plus three additional Tennessee counties which are covered by the National Weather Service Office in Huntsville, Alabama, but are still considered part of Middle Tennessee (Figure 1).

Troutman and Rose (1997) published a severe weather climatology of Middle Tennessee, which included a section on tornadoes. However, this project only included tornadoes contained within the National Climatic Data Center (NCDC) database, which contains no reports prior to 1950. This climatology expands upon the previous work by Troutman and Rose by including the 109 tornadoes that occurred prior to 1950, as well as the 126 events not covered by the 1997 study (1997-2003).

In this study, the tornado data are sorted into many different categories, including tornadoes by F-scale, hour of day, month of the year, path length vs. F-rating, fatalities per tornado by F-scale, and fatalities per tornado by decade. Separate rankings of the largest tornado outbreaks, longest individual path lengths, deadliest and costliest storms, and tornadoes by county will also be presented and discussed.

2. The F-scale

This study relies heavily on the F-scale in presenting tornado intensity data (Fujita 1971). The F-scale has been reproduced here in order to provide ready-reference (Table 1).

Scale	Wind Estimate (mph)	Typical Damage
F0	< 73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73-112	Moderate damage. Peels surface off roofs; mobile homes pushed off

		foundations or overturned; moving autos blown off roads.
F2	113-157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158-206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207-260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261-318	Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds); trees debarked; incredible phenomena will occur.

Table 1. Fujita Tornado Damage Scale

Please note that F-scale winds are estimates according to observed damage, and have never been scientifically verified. Different wind speeds may cause similar-looking damage from place to place, even from building to building. Without a thorough engineering analysis of tornado damage in any event, the actual wind speeds needed to cause that damage are unknown.

Accurate and consistent assignment of the F-scale is of prime importance both historically and climatologically, however, there are certain deficiencies in this rating system that must be addressed. Although ratings are now conducted by qualified National Weather Service meteorologists, "ratings can vary depending on the experience, background knowledge, and time spent by the person doing the survey..." (Guyer and Shea 2003).

It is also important to remember that the F-Scale rating is based solely on the most extreme damage found along the damage path (that may indicate only a momentary increase in intensity). If the most extreme damage is never seen or reported, the F-Scale rating may be unreliable.

A study by Gordon et. al. (2000) discussed tornadic storms which occurred prior to the implementation of the F-scale. His study discussed that Dr. Schaeffer at the National Severe Storms Forecast Center hired more than 50 college students. One student was hired per state, except Texas, which required several students. Students used such data as photographs, newspaper articles, and information from emergency management. Since information prior to 1950 is typically more "sketchy," F-Scale ratings should be considered more suspect than those determined during the latter 20th century.

3. Tornadoes in Middle Tennessee

The Middle Tennessee Tornado Database was compiled using several sources. Thomas Grazulis' (1993, 1997) exhaustive catalog *Significant Tornadoes* was used to develop Middle Tennessee's pre-1950 tornado climatology, with most subsequent reports taken from the NCDC Storm Events database.

a. Tornadoes by F-Scale Rating

Sorting the dataset -- which contains 467 rated tornadoes -- according to F-Scale shows a peak of activity under the F1 and F2 classifications, within which a full 69% of tornadoes have been rated. Predictably, the frequency of tornadoes beyond the F2 classification declines rapidly (Figure 2). Only fifty-eight F3 tornadoes are known to have occurred in Middle Tennessee, with twenty-two tornadoes having achieved an F4 rating, and only one F5[1].

When only tornadoes prior to 1950 are considered, an interesting trend in tornado detection and documentation is revealed (Figure 3). Weak tornadoes (F0 and F1) are almost non-existent, while the distribution of F2+ storms retains similar characteristics to the entire database. That no F0 tornadoes and only one F1 tornado (out of 106 rated storms) were reported prior to 1950 are likely the result of at least three factors.

First, the population across Middle Tennessee was significantly lower, and far more rural. This would increase the likelihood of tornadoes, especially weaker ones, passing undetected. Second, the Weather Bureau prior to 1950 did not issue tornado warnings, and the warning coordination and awareness efforts of the present were not in place then. Therefore, the process of pursuing documentation on tornadic activity was minimal when compared to the processes today. Third, storm damage may not have been considered newsworthy unless it was very significant.

To further investigate this trend, let us now consider tornadoes only within the past decade (Figure 4). The distribution across the F-scale is now far more even, much heavier toward the lower end of the scale, and therefore a more realistic portrayal of the actual distribution of tornado occurrence.

The dramatic increase in detection and documentation of weaker storms is likely a reflection of population increases, greater awareness by the public and media, and the installation of Doppler radar, which is able to detect tornadoes that occur in sparsely populated regions, thereby prompting National Weather Service employees (and the media) to actively pursue storm reports. In fact, 157 tornadoes, or more than one-third of the entire database, have been catalogued within the last decade alone.

b. Tornadoes by Hour of Day

Of the 464 tornadoes reported with a time, most tornadoes in Middle Tennessee, not surprisingly, occur during the late afternoon and evening (Figure 5). The most common hour of the day for tornadoes is between 1700 and 1759 Central Standard Time (CST). More than half (58%) of tornadoes touch down during the seven-hour period between 1400 and 2059 CST. Although tornadoes are possible at any time of the day or night, they are least common during the early daylight hours of 0700-0959 CST.

c. Tornadoes by Month of the Year

When sorted by month of the year, Middle Tennessee's peak tornado season of March, April, and May becomes obvious, as shown in Figure 6. Nearly two-thirds (66%) of Middle Tennessee's tornadoes have occurred during these three months. Again, tornadoes have occurred in every

month, but are least common during September, during which only four tornadoes (less than 1%) have occurred. Also note that a secondary peak in activity is centered around November, during which thirty tornadoes (6% of all events) have struck, including a significant outbreak in 2002. Another off-season tornado outbreak occurred in January, 1997 (Table 2).

Rank	Tornadoes	Date
1	24	3 Apr 1974
2	14	18 May 1995
3	13	24 Jan 1997
3	13	7 May 1984
5	12	4-5 May 2003
5	12	10 Nov 2002
7	10	16 Apr 1998
8	8	24-25 May 2000
9	6	11 May 2003
9	6	5 May 1999
9	6	3 Apr 1998
9	6	29-30 Apr 1909

Table 2. Largest Tornado Outbreaks in Middle Tennessee

Again, the data presented in table 2 are obviously skewed toward later years, given the overall increase in tornadoes that are reported. That only one of the aforementioned outbreaks occurred prior to 1974 -- and none prior to 1909 -- does not in any way suggest that tornado outbreaks are recent phenomena, but merely reflects the trend in tornado documentation.

d. Average Tornado Path Length vs. F-Scale Rating

An analysis of tornado path lengths yields typical results. (Path lengths were available for 442 of the 469 tornadoes in the Middle Tennessee Tornado Database, and include the entire track for each tornado -- even portions of tornado tracks that may have occurred outside of Middle Tennessee.) Predictably, average path length increases with F-rating (Figure 7). The average path length for all tornadoes is approximately eight miles. However, this figure increases dramatically beyond F2-rated storms. The average path length for F3 tornadoes, for instance, is 18.7 miles, and increases to 27.3 miles for F4 storms. The only F5 tornado in the database produced a 62½-mile path (Table 3).

Rank	Date	Time	Deaths	Injuries	Path Length (miles)	F-Scale	Middle Tennessee County(ies) Affected
1	27 May 1917	1630	6	21	80	F3	Benton, Stewart (also Gibson, Carroll, and Henry Counties in West Tennessee)

2	16 Apr 1998	1550	3	36	62½	F5	Wayne, Lawrence, Giles, Maury
3	18 Mar 1925	1700	39	95	60	F4	Sumner (also Allen, Barren, Monroe, and Metcalfe Counties in Kentucky)
4	16 Mar 1942	1630	5	68	55	F3	Stewart (also Carroll and Henry Counties in West Tennessee)
5	27 May 1917	1800	5	67	50	F4	Perry (also McNairy, Chester, Henderson, and Decatur Counties in West Tennessee)
5	21 Mar 1932	1800	3	8	50	F2	Williamson, Davidson, Wilson
5	7 May 1971	1745	3	137	50	F4	Benton, Humphreys (also Gibson and Carroll Counties in West Tennessee)
5	5 Apr 1936	2215	5	13	50	F3	Lincoln (also Lauderdale, Limestone, and Madison Counties in Alabama)
5	3 Apr 1974	1825	22	250	50	F4	Lincoln (also Limestone and Madison Counties in Alabama)
5	13 Mar 1913	1430	7	15	50	F3	Giles, Marshall, Rutherford

Table 3. Longest Tornado Paths in Middle Tennessee

e. Tornado Fatalities

Although tornado-related fatalities are now relatively infrequent due to the National Weather Service's warning system and its persistent storm awareness efforts, Middle Tennessee has suffered its share of deadly storms in past years. Typically, as the F-rating increases, so does the potential for fatalities (Figure 8). Throughout the database, there have been 411 deaths attributed to tornadoes. Eighty-six percent of these fatalities have been caused by F3+ tornadoes, which in reality constitute just 17% of all tornado occurrences. And more than half of all fatalities (55%) have been caused by the twenty-two documented F4 tornadoes, which represent 4% of all tornado occurrences (translating to an average of more than 10 fatalities per event). In addition, the four deadliest tornadoes in Middle Tennessee's history were rated F4 (Table 4).

Rank	Date	Time	Deaths	Injuries	Path Length (miles)	F-Scale	Middle Tennessee County(ies) Affected
1	18 Mar 1925	1700	39	95	60	F4	Sumner (also Allen, Barren, Monroe, and Metcalfe Counties in Kentucky)
2	10 May 1933	0015	35	150	20	F4	Overton, Pickett
3	29 Apr 1909	2300	29	95	25	F4	Giles, Lincoln (also Limestone County, Alabama)

4	20 Nov 1900	2130	27	75	8	F4	Maury
5	14 Oct 1909	1730	24	80	40	F3	Wayne (also McNairy and Hardin Counties in West Tennessee)
6	3 Apr 1974	1825	22	250	50	F4	Lincoln (also Limestone and Madison Counties in Alabama)
7	14 Mar 1933	1930	15	45	45	F3	Davidson, Wilson, Smith
8	18 Apr 1877	2200	10	50	40	--	Lewis, Maury, Williamson, Davidson, Rutherford
8	29 Apr 1909	2215	10	40	45	F3	Hickman, Maury, Williamson
8	3 Apr 1974	1915	10	51	32	F4	White, Putnam, Overton

Table 4. Deadliest Tornadoes in Middle Tennessee

Of the deadliest tornadoes in the database, none have occurred since the two reported during the 1974 Super Outbreak. All of the remaining eight occurred prior to 1934. This is particularly remarkable, given the increases in population which have occurred since then. Davidson County (Nashville), long the population center of Middle Tennessee, received only two of these eight. The city of Columbia (Maury County) saw an F4 tornado on the evening of 20 November 1900 claim 27 lives. The remaining five tornadoes struck primarily rural areas.

To provide direct evidence of the decrease in tornado-related deaths, mean fatalities per tornado have been provided for each decade of the last century (Figure 9). During the first decade of the 1900's, for example, tornadoes produced an average of seven fatalities per event. True, this figure is likely inflated due to the number of non-fatal tornadoes that were never documented. Still, the decade saw 109 Middle Tennesseans fatalities as the result of tornadoes. By comparison, a total of 102 fatalities have occurred since 1950 due to tornadic activity, and 54 of these deaths occurred during the Super Outbreak of April 3, 1974.

f. Costliest Tornadoes

No proper tornado climatology would be complete without some mention of the costliest storms to have struck Middle Tennessee (Table 5). Unfortunately, the NCDC Storm Events database does not contain entries prior to 1950, so details of tornadoes prior to this date are sketchy. Therefore, some of Middle Tennessee's most notorious tornadoes are missing from the following list. (For example, the Nashville tornado of March 14, 1933 caused $2.2 million in damage -- 31.1 million in 2003 dollars.)

Rank	Date	Time	Cost (millions of dollars)	Deaths	Injuries	F-Scale	Location or County
1	16 Apr 1998	1430	112.8	1	60	F3	Nashville

2	22 Jan 1999	0415	80.2	0	5	F3	Clarksville
3	24 Dec 1988	0604	38.8	1	7	F4	Williamson County
4	22 Mar 1991	1805	33.7	1	14	F2	Lewis County
5	29 Feb 1952	1630	17.3	2	150	F4	Lincoln County
6	22 Jan 1957	1630	16.4	0	4	F2	Davidson County
7	10 Jan 1963	2355	15.0	0	4	F3	Maury County
8	4 Mar 1964	1130	14.8	0	4	F3	Wayne County
8	25 Dec 1964	2200	14.8	0	0	F1	Davidson County
10	16 Apr 1998	1635	12.4	0	4	F3	Byrdstown

Table 5. Costliest Tornadoes in Middle Tennessee Since 1950 (NCDC 2004). Costs have been indexed for inflation, and are reported in 2003 dollars (Federal Reserve Bank of Minneapolis 2004).

4. Geographical Considerations

Sorting the tornado database geographically reveals a sizeable range of distribution of tornadoes across Middle Tennessee. Tornado occurrence per county ranges from zero in Clay County to thirty-seven in Davidson County (Nashville). However, because the size of Middle Tennessee's counties is also quite variable, ranging from 737 mi^2 (Wayne County) to 114 mi^2 (Trousdale County), a more equitable method for comparing tornado occurrence among the forty-two counties involves computing events per unit of area. For purposes of this study, the number of tornadoes per 100 mi^2 has been tabulated for each county, in order that a truer comparison can be made (Table 6).

Normalizing tornadoes by land area on a county-by-county scale does not erase the obvious inequalities in population density. Thus, even this method of comparison is not devoid of some deficiencies. However, given the constant change in population growth and shifts, it would be nearly impossible to derive a statistical method to geographically display tornado frequency that is normalized demographically.

In Middle Tennessee, average tornadoes per 100 mi^2 ranged from 0.0 in Clay County to 7.4 in Davidson County. The largest such cluster encompasses five counties that include the Nashville Metropolitan Area and areas east (Davidson, Rutherford, Sumner, Trousdale, and Wilson Counties) (Figure 10). True, Davidson County has historically been Middle Tennessee's most populous and urbanized county, greatly lowering the probability of tornadoes passing undetected. However, the maximum in tornado activity across this geographic area spreads eastward into counties that are much more sparsely populated, including rural Trousdale County, which ties its southern neighbor Wilson County with 6.1 tornadoes per 100 mi^2 (Figure 1).

Interestingly, of the seven tornadoes in the Trousdale County subset, four occurred entirely within the county. The remaining three were continuations of tornadoes which touched down in counties upstream. Two of the three touched down at nearly identical points (three miles northwest of Lebanon, in Wilson County, which borders Trousdale County to the south). The third tornado

touched down 6.1 miles southwest of Nashville, and traveled for 32 miles before lifting in Trousdale County.

The fact that nearly half the tornadoes in Trousdale County originated near the cities of Lebanon and Nashville may have some bearing on the reason this cluster, east of Nashville, exists. Indeed, this cluster may be influenced by the fact that tornado paths that originate near large cities or towns will likely be investigated more intensely and followed to their endpoint (which may be located in more sparsely populated counties). Perhaps, if the same tornadoes had occurred in areas farther away from population centers, they might not have even been reported.

The second cluster is in southern Middle Tennessee, near what is known as the Tennessee Valley of northern Alabama. Specifically, the counties of Giles and Lincoln, which are much more sparsely populated than the northern cluster, are found to have experienced 4.7 tornadoes per 100 mi^2, and their northern neighbor, Marshall County, has recorded 5.3 tornadoes per 100 mi^2.

When focusing on a subset of F4+ tornadoes, a maximum of occurrence is found to exist in three clusters (Figure 11). The first cluster encompasses a three-county area in southern Middle Tennessee (Giles, Lincoln, and Moore Counties). A second cluster is found over western Middle Tennessee, and includes the rural counties of Benton, Lewis, and Perry. The final cluster is found in northeast Middle Tennessee, and consists of Overton and Pickett Counties, which are also relatively sparsely populated. In fact, Pickett County has the highest frequency of F4+ tornadoes per 100 mi^2 in all of Middle Tennessee, with 1.2. Based on this data, there does not appear to be a particular area that is most vulnerable to F4+ tornadoes in Middle Tennessee.

In addition, the subset of F4+ tornadoes may not even be large enough to permit us to draw reliable conclusions. Until a larger data set is acquired, it would probably be improper to make any definitive statements regarding the possibility that one part of the mid state is more prone than another to F4+ tornadoes.

An investigation of the geographic distribution of F3+ tornadoes provides further evidence that strong tornadoes in Middle Tennessee are not generally confined to a particular geographic region. As shown in Figure 12, the number of tornadoes per 100 mi^2 ranges from 0.0 to 1.8. There were eight counties in which the frequency exceeded 1.0 tornadoes per 100 mi^2. This group includes Giles, Lincoln, and Marshall Counties, but also extends all the way northward to Pickett County on the Kentucky border.

County	Land Area (mi^2)	All Tornadoes		F3+ Tornadoes		F4+ Tornadoes	
		Total	Per 100 (mi^2)	Total	Per 100 (mi^2)	Total	Per 100 (mi^2)
Bedford	474	14	3.0	2	0.4	0	0.0
Benton	395	10	2.5	4	1.0	2	0.5
Cannon	266	9	3.4	1	0.4	0	0.0
Cheatham	303	5	1.7	1	0.3	0	0.0
Clay	236	0	0.0	0	0.0	0	0.0

Coffee	429	20	4.7	2	0.5	1	0.2
Cumberland	682	15	2.2	3	0.4	0	0.0
Davidson	502	37	7.4	3	0.6	1	0.2
Dickson	490	11	2.2	3	0.6	0	0.0
De Kalb	305	10	3.3	2	0.7	0	0.0
Fentress	499	11	2.2	1	0.2	1	0.2
Franklin	555	12	2.2	3	0.5	2	0.4
Giles	611	29	4.7	11	1.8	4	0.7
Grundy	361	5	1.4	1	0.3	0	0.0
Hickman	613	6	1.0	1	0.2	0	0.0
Houston	200	2	1.0	2	1.0	0	0.0
Humphreys	532	10	1.9	3	0.6	1	0.2
Jackson	309	4	1.3	0	0.0	0	0.0
Lawrence	617	24	3.9	5	0.8	2	0.3
Lewis	282	7	2.5	1	0.4	2	0.7
Lincoln	570	27	4.7	6	1.1	4	0.7
Macon	307	5	1.6	1	0.3	0	0.0
Marshall	375	20	5.3	4	1.1	0	0.0
Maury	613	23	3.8	7	1.1	2	0.3
Montgomery	539	25	4.6	5	0.9	1	0.2
Moore	129	1	0.8	1	0.8	1	0.8
Overton	433	8	1.8	3	0.7	2	0.5
Perry	415	2	0.5	2	0.5	2	0.5
Pickett	163	6	3.7	3	1.8	2	1.2
Putnam	401	9	2.2	2	0.5	1	0.2
Robertson	476	18	3.8	4	0.8	1	0.2
Rutherford	619	36	5.8	9	1.5	2	0.3
Smith	314	8	2.5	2	0.6	0	0.0
Stewart	458	13	2.8	2	0.4	0	0.0
Sumner	529	27	5.1	4	0.8	2	0.4
Trousdale	114	7	6.1	2	1.8	0	0.0
Van Buren	273	3	1.1	1	0.4	0	0.0
Warren	433	12	2.8	1	0.2	0	0.0
Wayne	734	12	1.6	5	0.7	2	0.3
White	377	9	2.4	2	0.5	1	0.3

Williamson	583	20	3.4	6	1.0	2	0.3
Wilson	571	35	6.1	7	1.2	0	0.0

Table 6. Tornadoes by County

5. Conclusions

The Middle Tennessee Tornado Database contains 469 individual tornadoes occurring during the years 1830-2003. The database has been sorted according to several different variables in order to thoroughly analyze the climatology of tornadoes in Middle Tennessee. Several conclusions have resulted.

- Sixty-nine percent of tornadoes have been rated F1 or F2. Population growth and warning coordination and awareness efforts have dramatically increased the number of documented tornadoes -- especially weak tornadoes -- in recent years, while simultaneously lowering the number of tornado-related fatalities.
- The most common hour of the day for tornadoes to touch down is between 1700 and 1759 CST. Fifty-eight percent of tornadoes touch down during the seven-hour period between 1400 and 2059 CST. Tornadoes are least common during the early daylight hours of 0700-0959 CST.
- Two-thirds (66%) of Middle Tennessee's tornadoes have occurred during the months of March, April, and May. Tornadoes are least likely to occur during September.
- The average path length for all tornadoes is approximately eight miles. However, this figure increases dramatically beyond F2-rated storms. The average path length for F3 tornadoes is 18.7 miles, and increases to 27.3 miles for F4 storms.
- Eighty-six percent of tornado fatalities have been caused by F3+ tornadoes, which in reality constitute just 17% of all tornado occurrences. Fifty-five percent have been caused by the twenty-two documented F4 tornadoes, which represent 5% of all tornado occurrences.
- During the first decade of the 1900's, tornadoes produced 109 fatalities (an average of seven fatalities per event). By comparison, a total of 102 tornado fatalities have occurred since 1950.
- The costliest tornado was the F3 twister which struck downtown Nashville during the afternoon of 16 April 1998. The $100+ million dollar storm greatly overshadowed a much larger supercell which produced the only F5 tornado in Tennessee's history later that day in Lawrence County.
- Nine counties across Middle Tennessee have documented at least 4.7 tornadoes per 100 mi^2, and are largely clustered in two geographic locations. The first cluster encompasses five counties that include the Nashville Metropolitan Area and areas east (Davidson, Rutherford, Sumner, Trousdale, and Wilson Counties). The second cluster is formed in southern Middle Tennessee by the three counties of Giles, Lincoln, and Marshall.
- However, when only F3+ tornadoes are considered, there does not appear to be any one part of Middle Tennessee that can be considered most prone to strong tornadic activity.

[1] "The Forgotten F5" hit rural Lawrence County on April 16, 1998, and is the only known F5

tornado to have occurred in Tennessee's history.

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