3.4 TORNADO TRENDS OVER THE PAST THIRTY YEARS

Daniel McCarthy[1] and Joseph Schaefer
NOAA/NWS/NCEP/Storm Prediction Center, Norman, Oklahoma

1. INTRODUCTION

Dr. Stanley Changnon has done extensive work in climatological studies that included tornado frequency. He studied these frequencies using tornado statistics across Illinois using data from storms that occurred between 1916 and 1980 (Changnon, 1982). He also guided work done at the Illinois State Water Survey on the significance of long-track tornadoes (Wilson and Morgan, 1971). One of the conclusions from their studies was that only half of all tornadoes are reported, and that half of those that were reported were really not tornadoes! This agrees with Grazulis (2001), who referred to a similar study by Iowa State University in 1978 that also concluded that only half of all tornadoes are actually counted!

This paper looks at the reported frequencies of tornadoes and their characteristics over the contiguous United States since 1970. There was a significant increase in tornado occurrence during two periods in the last 33 years – in the early 1980s when National Weather Service (NWS) warning verification began, and in 1990 when the WSR-88D became operational. The frequency of tornadoes is also compared to fatalities and tornado days over the same period. Also, tornado frequency is compared to F-scale damage categories (Fujita, 1971). Finally, it will be seen that the number of strong and violent tornadoes has not varied much since 1970, and that long-track and very-long-track tornadoes as defined by the Illinois State Water Survey remain a very low percentage of all tornadoes reported.

2. TORNADO FREQUENCY AND F-SCALE RATING

Figure 1 shows the number of tornadoes during the past 33 years. This period does not include the tornado growth period that occurred as official records began to be kept in *Tornado Data* (through 1957) and *Storm Data* (in subsequent years.) Also, the years 1950-1969 were a growth period because it was the start of the public awareness and communication revolution that gave tornadoes increased publicity due to television news coverage and graphic depictions of tornadoes and tornado damage. Severe thunderstorm meteorology advanced during these years because of events such as the Waco, TX; Flint, MI; and Worcester, MA tornadoes of 1953, and the Palm Sunday Tornado Outbreak of April 11, 1965. In the 1970s, there was an average of 858 tornadoes per year. In the 1990s, this increased by almost 30% to an average of a little over 1200 tornadoes per year.

Corresponding author address: Daniel W. McCarthy, NOAA, NWS Storm Prediction Center, 1313 Halley Circle, Norman, OK 73069-8493;
email: daniel.mccarthy@noaa.gov

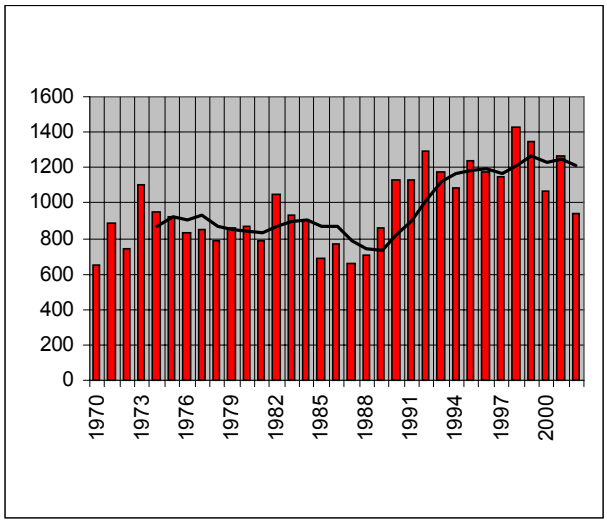

Figure 1: Frequency of tornadoes since 1970. Black line represents the 5-year trend analysis.

While the peak in tornado frequency in the early to middle 1970s included the 1974 Super Outbreak, the year with the most tornadoes during that span was 1973! The increase in reported tornado frequency during the early 1990s corresponds to the operational implementation of Doppler weather radars. Other non-meteorological factors that must be considered when looking at the increase in reported tornado frequency over the past 33 years are the advent of cellular telephones; the development of spotter networks by NWS offices, local emergency management officials, and local media; and population shifts. Changnon (1982) and Schaefer and Brooks (2000) both discuss these influences on tornado reporting.

The growing "hobby" of tornado chasing has also contributed to the increasing number of reported tornadoes. The capability to easily photograph tornadoes with digital photography, camcorders, and even cell phone cameras not only provides documentation of many weak tornadoes, but also, on occasion, shows the presence of multiple tornadoes immediately adjacent to each other. (Are these individual tornadoes or manifestations of one tornado undergoing vortex breakdown?)

Dr. Changnon has long advocated the use of "event days" because of its mitigation of the impact of reporting biases (Changnon and Schnickedanz, 1969). When tornado days are plotted against year (Fig. 2), the rapid inflation that is apparent in the numbers of reported tornadoes is no longer present. Instead, only small changes are seen over the period 1970 through 2002;

the annual number of tornado days varies between 211 in 2000 and 151 in 1987. This implies that the decrease in tornado frequency in the mid-1980s and perhaps the one over the past few years is real and is likely related to changes in the prevailing sub-synoptic scale meteorological conditions.

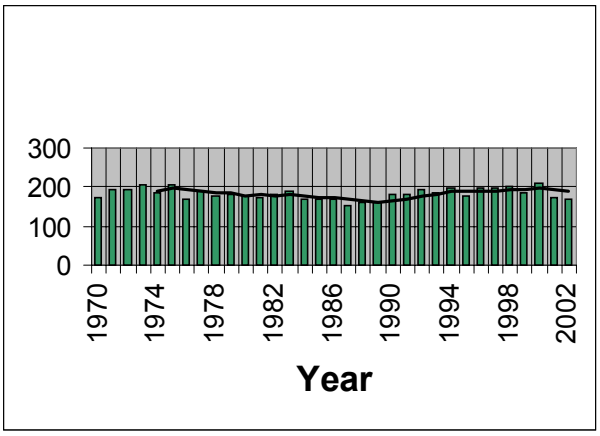

Figure 2: Tornado days by year. Black line represents 5-year trend.

Changnon (1982) noted that although the frequency of tornadoes and the number of tornado days increased in Illinois between 1950 and 1980, the number of tornadoes producing one or more fatalities did not increase. From this, he inferred that the increase in tornadoes was due to an increase in minor (weak) tornadoes, changes in data collection techniques, and population shifts. Figure 3 confirms this assessment. There has been a large increase in tornado damage rated F0 since 1970. This is especially evident during the late 1980s when there was a reversal in the ratio of F0 to F1 rated damage. In the 1970s, there was more damage caused by tornadoes rated as F1 than by other Fujita categories. However, since the mid 1980s, F0 damage is the predominant type. Part of this is because the F-Scale was not widely used by the NWS until the mid-1970s. Before then, damage ratings were based on newspaper accounts, with their associated hyperbole, rather than actual *Storm Data* descriptions.

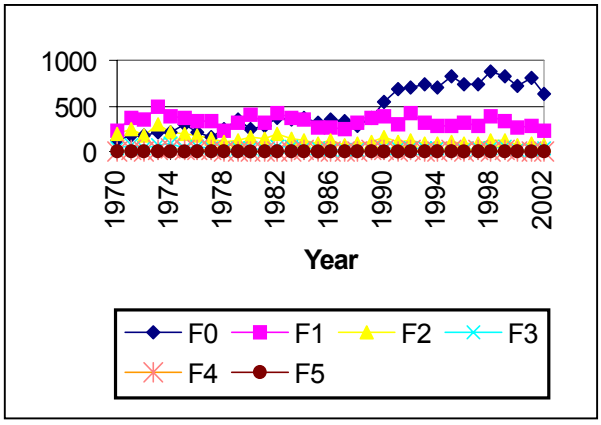

Figure 3: Plot of tornado damage as estimated using the Fujita Scale.

Warning Preparedness Meteorologists began to organize damage surveys and report F-scale values after the 1974 Super Outbreak. During the NWS modernization in the late 1980s, this program accelerated further with each NWS Forecast Office having a Warning Coordination Meteorologist to collaborate with emergency management and media personnel in collecting storm reports. Figure 4a shows the distribution of tornadoes by F-scale over the 33-year period. During this time, 39% of all tornadoes were rated as F0. However, this long term F-scale

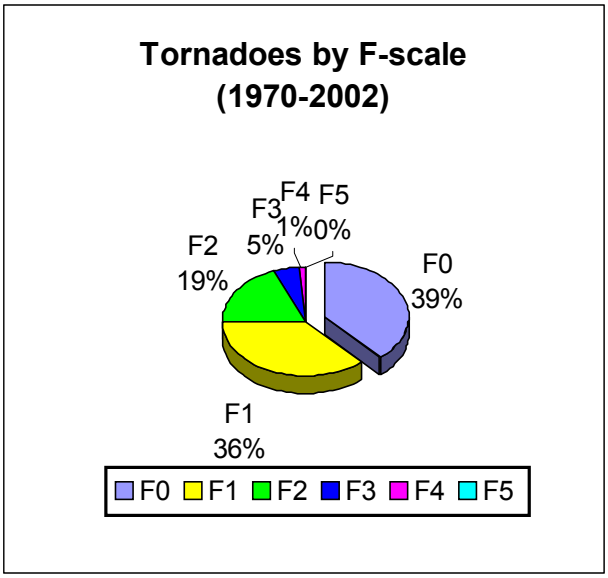

Figure 4a: Percentage of tornadoes, 1970-2002, by F-scale damage

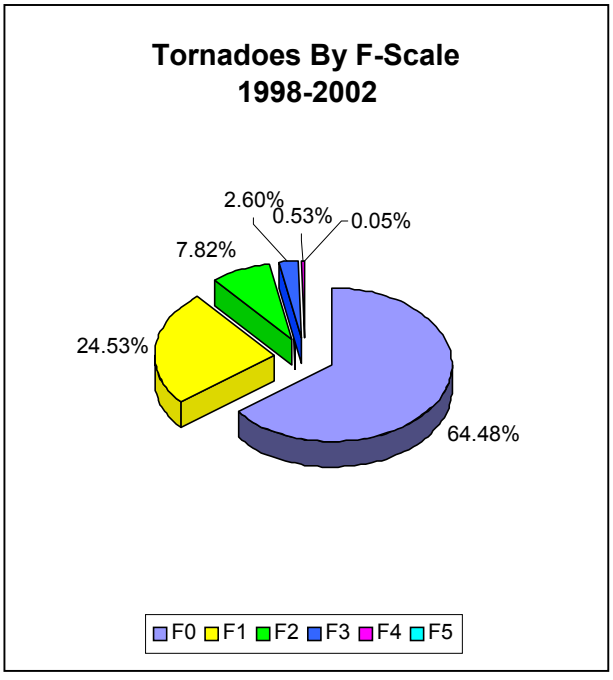

Figure 4b: Percentage of tornadoes, 1998-2002, by F-scale damage.

breakdown is quite misleading; for the most recent five-year period (1998 through 2002), F0 tornadoes accounted for 64% of reported tornadoes (Fig. 4b).

Since F0 roughly corresponds to winds of only 18-32 m/s (40-72 mph), how many of the reports were based on damage rather than visual observation of actual tornadoes? Some of these reported storms could have actually been damaging straight-line winds caused by weak downbursts or rear flank downdrafts.

3. LONG-TRACK AND VERY-LONG-TRACK TORNADOES

Wilson and Morgan (1971) defined "long-track tornadoes" as those with paths longer than 185 km (100 mi.), and "very-long-track tornadoes" as those with paths longer than 278 km (150 mi.). Charts showing all long-track and very-long-track tornadoes reported between 1950 and 1969, and from 1970 through 2002, are given in Figure 5a and 5b, respectively. The earlier period recorded ten more long-track tornadoes but fewer fatalities (155 v. 141) than the later period. The vast majority of long and very-long-track tornadoes in both periods were rated strong or violent. Interestingly, since 1970, three long-track tornadoes were rated as weak.

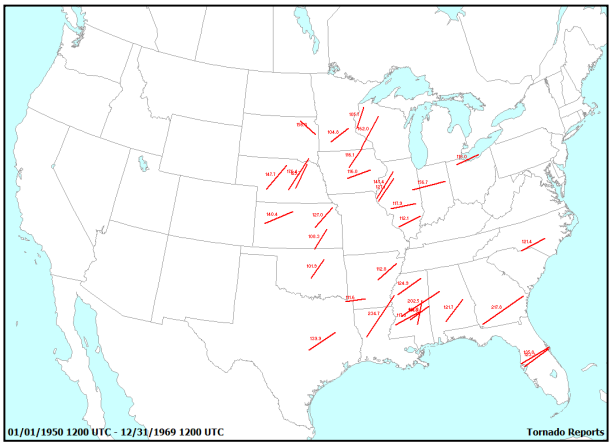

Figure 5a: Plot of long-track tornadoes between 1950 and 1969 with path lengths greater than 185 km (100 mi.)

Plots of long and very-long-track tornadoes are consistent with the studies of Wilson and Morgan (1971). A majority of these tornadoes have occurred across parts of Mississippi and Alabama with a secondary area from Nebraska into Indiana. (The area appears to surround an area of more infrequent activity over the Ozark Plateau of southern Missouri and northeast Arkansas.) Furthermore, there have not been any long-track tornadoes west of the Rocky Mountains since 1950.

Evaluating path lengths from the data is not the simple exercise of measuring the distance from where the tornado began to where it ended. Tornadoes are recorded by segment, and each segment belonging to the same tornado has to be identified. Prior to 1994, the segments were primarily determined by counties in which tornado related fatalities occurred. A new "tornado segment" was recorded every time a tornado entered or left a county in which a tornado caused a fatality or injury occurred. (There were other reasons for segmenting tornadoes, e.g. crossing a state border or a sudden change in track orientation, but separating counties with fatalities and injuries was the main primary cause of segmentation.) From 1994 on, tornadoes were recorded as county segments, one segment for each county the tornado traveled. For example, if a tornado tracked through six counties, it would be listed as six segments having the beginning point where it first developed to where it exited the county, followed by the beginning and ending point in the following counties until the point where it lifted or dissipated. Because of this change in procedure, tornadoes recorded after 1994 contain more segments than those of earlier years.

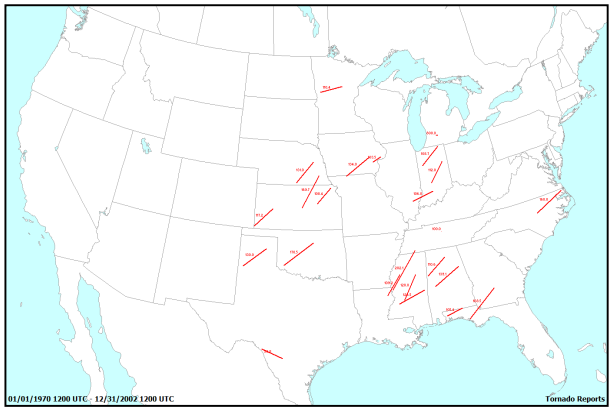

Figure 5b: Plot of long-track tornadoes between 1970 and 2002 with path lengths greater than 185 km (100 mi.)

Segmenting impacts tornado path length calculations. The beginning and ending locations of segments are not reported as latitude, longitude couplets, but as the azimuth and range (AZRAN) from a town. If different reference points were used for two adjacent segments, their beginning and ending points will not exactly match and the segments of the same tornado will be counted as a separate tornado. Thus the more segments reported, the higher the probability that a single long-track tornado will appear as two or more individual tornadoes.

Also, in the data from the earlier years, it is common to see reports of tornadoes that "skipped," that is, they lifted for a short distance and than touched down again. Today, such reports are relatively rare. Using the arguments presented in Doswell and Burgess (1988), a series of individual tornadoes following the same basic path are reported rather than a single skipping tornado. Which of these concepts is correct? Is a tornado only "a violently rotating column of air in contact with the ground," as defined by the Glossary of Meteorology (Glickman, 2000), or can a tornado's circulation momentarily lose contact with the ground?

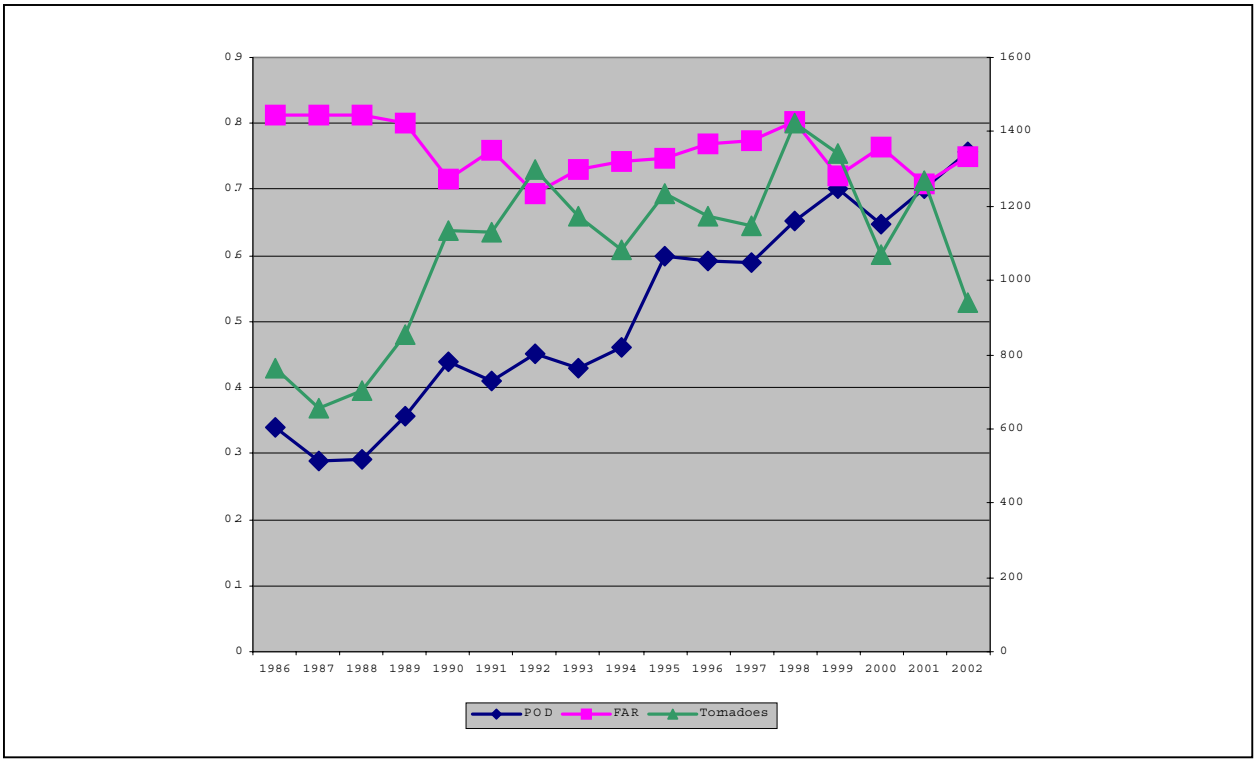

Figure 6: Probability of Detection (POD) and False Alarm Rate (FAR) and the number of tornadoes since 1986.

4. Discussion

Tornado reports have been on a general increase since the late 1980s. Part of this is due to an aggressive effort to establish a large network of storm spotters. Figure 6 shows verification of NWS tornado warnings and the number of tornadoes reported since 1986. The Probability of Detection (POD) is simply the percent of tornadoes that occurred within valid tornado warnings. The False Alarm Rate (FAR) is the percentage of tornado warnings in which no tornado was reported. Thus, nearly 6 out of every 8 counties

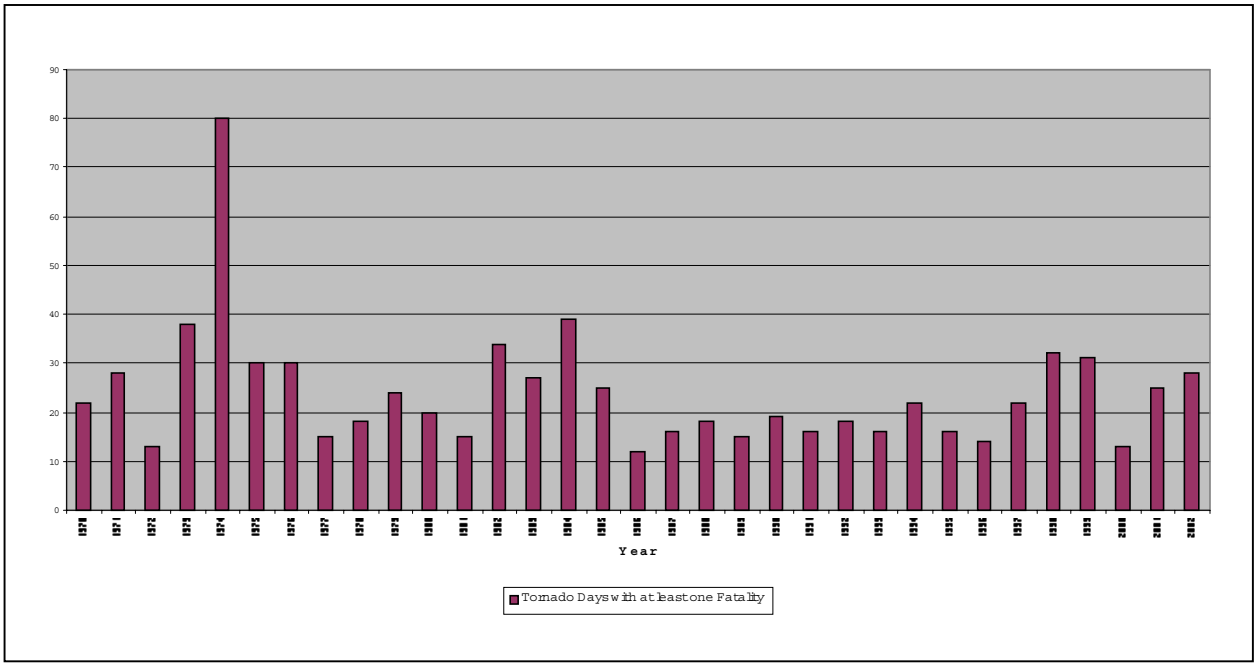

Figure 7: Days with a tornado fatality per year since 1970.

warned are not verified by a tornado occurrence. This basically means that for every county warned in which a tornado occurs, there are three counties warned where a tornado does not occur. Warnings are often issued because of indications on radar either by actual rotation or algorithms leading to warnings, yet are not verified by observation. Distinguishing between damaging winds caused by downbursts or gusts under 45 m/s (100 mph) and tornadoes causing F0 or F1 damage can remain very challenging without actual accounts of a tornado being present. The relative steadiness of the FAR between 1986 and the present indicates that conceptual models of how to interpret radar signatures are at or above their maximum utility. Either new theory or new observational systems, i.e., phased array radar (Forsyth et al., 2002) may be necessary before large decreases in the FAR occur.

However, 75% of all tornadoes cause only F0 or F1 damage (Fig. 4). They are quite weak storms. During the F5 tornado of May 3, 1999, the NWS Forecast Office in Norman issued a warning headlined "Tornado Emergency" to indicate the presence of an extreme event. The local emergency managers and media all credit this innovative wording as helping to save lives during this storm. Would it be scientifically possible and sociologically advisable for the NWS to work on developing a new category of warning to indicate that there is a high likelihood of a strong or violent tornado occurring in the very near future?

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5. References

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