A Study of Severe Weather Prior to Significant Tornado Occurrences

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Abstract

The purpose of this study was to determine if there was a pattern between strong to violent tornadoes and the severe weather preceding them. The study was based on a 13 year period between 1990 and 2002. Using the severe weather reports which were classified by time and distance preceding the strong/violent tornado, probabilities of occurrence were plotted against all strong/violent tornado cases, as well as the first significant tornado cases of each day. There were a total of 1,803 strong/violent tornado events during the study period, which included 10 F5, 95 F4, 406 F3, and 1,292 F2 cases.

1. Introduction

Between 1990 and 2002, strong/violent tornadoes killed 653 people and injured another 12,026 individuals. Strong/violent tornadoes are classified as any tornado with an F2 through F5 damage rating. In the same time period, F0 and F1 tornadoes only killed 54 people and injured 2,161 others, even though their numbers of tornadoes were much greater with 13,558 occurrences. Issuing watches well in advance, especially for strong to violent tornadoes, can help to limit the number of related deaths and injuries. Forecasting the location and time of tornadoes still remains a major challenge for forecasters. However, issuing watches has improved as the understanding of favorable environments for severe storms and tornadoes have become better understood.

This paper takes a look at the type and number of severe weather events prior to the occurrences of strong/violent tornadoes. The study will determine if there is a reliable pattern concerning severe weather prior to a strong/violent tornado touchdown. By looking at the relationship between the tornado and the severe weather that precedes it may provide important information as to when and where strong/violent tornadoes are likely to touchdown, given favorable environment conditions.

This research also includes a study of the severe weather that occurred prior to the first significant tornado touchdown of each day. The information will provide more knowledge on the typical severe weather reports that precede the first significant tornado of an event.

2. Data

The National Weather Service (NWS) criteria for a severe thunderstorm are a tornado, and/or winds of at least 50 knots (58mph), and/or hail at least 0.75 inch in

diameter. The data for this study came from the Storm Prediction Center (SPC) National Severe Weather Database. This database contains all severe thunderstorm reports that were received by the NWS between 1950 and 2002 in the United States. Tornado reports in the database date back to 1950, but reports for hail and wind are available only back to 1955. Structural wind damage is also used to imply the occurrence of a severe thunderstorm. Other information related to the severe weather reports is also available in this database. For example, information on tornadoes include touchdown time, path length, average track width, latitude/longitude of touchdown, F-scale estimate, and the number of deaths and injuries. For hail and wind reports, the database contains information of time, latitude/longitude, hail size or gust intensity (if known), and the number of deaths and injuries (Schaefer 1999).

The SPC Report Relationships (local program developed by John Hart) is a database interface program accessing the SPC National Severe Weather Database. It examines tornadoes of F2 and greater strength between the years of 1950 and 2002, and provides the user with the types of severe weather that occurred before and after the tornado touchdown. It also displays the time and distance of the severe weather reports relative to the F2-F5 tornado location. Users can examine the number and distribution of severe weather reports that occurred before the tornado. There is one limitation in the program. When there are wind and hail reports closer than 15 minutes or 10 miles of each other, the duplicates are deleted.

Severe Plot (Hart and Janish 1993) is another database interface program that accesses the SPC National Severe Weather Database. It is a similar to Report Relationships in that it examines data from severe thunderstorm occurrences in the nation

between the years of 1950 and 2002. One useful feature of this program is to plot regional and national maps of severe weather reports during any period of time. Another feature of Severe Plot is that it has the capability to plot when and where tornado watches were issued by the SPC.

3. Methodology

To begin the research, specific categories based on time and distances from a strong/violent tornado were established. Severe weather events that occurred within 15 minutes and 10 miles from a strong/violent tornado were put in category 1. Category 2 consisted of severe weather reports that occurred within 30 minutes and 20 miles of a significant tornado; a category 3 within 60 minutes and 35 miles; a category 4 within 90 minutes and 52 miles; and category 5 within 120 minutes and 70 miles (Table 1). The categories were chosen based on a 35 knot storm motion. A map of Oklahoma with the 5 categories placed on it as if there was a strong/violent tornado touchdown in Oklahoma City is on Figure 1. The severe weather reports that occurred in these categories prior to the occurrence of a F2-F5 tornado were used in this study to determine if a relationship existed.

After the categories were determined, each significant tornado within the specified years had to be analyzed. The SPC Report Relationship dataset listed each individual tornado and the weather that occurred prior to the touchdown. This database displays the same information on tornadoes as the SPC Severe Weather Database. An example of this database is in Figure 2 and shows the severe weather preceding (to the left of the middle line) and following (to the right of the middle line) the significant tornado. The lines represent tornado tracks, while hail is depicted by black dots and wind

by grey dots. The x-axis is the time prior to and after the tornado, with negative numbers the time before the significant tornado and the positive numbers the time after the initial touchdown. The y-axis is the miles in distance away from the tornado occurrence. For this study, only the weather reports preceding the strong/violent tornadoes were used.

All F5, F4, F3, and F2 tornado cases from 1990-2002 were examined and the information was documented in Microsoft Excel to help determine the relevant relationships. The information that was taken from Report Relationship to Excel was the general information from each tornadic event as well as each individual severe weather report and the appropriate category. The study was limited to 1990-2002 since there was much less severe weather reported prior to those years. There was a dramatic increase in the number of reports between 1980 and 1990, so the data before prior to 1990 was skewed.

Using the data in the Excel spreadsheet, calculations of probabilities could be determined. The first calculation was the percentage of each type of severe weather report occurring prior to an F2- F5. The next calculation was determining the probabilities for either wind or hail, or tornado or hail, etc. preceding the strong/violent tornado. A graph of each severe weather event and each tornado intensity were also plotted to determine a time/distance relationship.

The first significant tornadoes of each day were also studied to find distinctive patterns of severe weather occurring prior to touchdown. The same percentage calculations were performed with these tornadoes as with all the significant tornado cases.

4. Results

This study examined 1,803 strong/violent tornadoes between 1990 and 2002. There were a total of 10 F5 tornadoes, 95 F4's, 406 F3's, and 1292 F2 tornadoes during that period. A total of 604 cases (about 45 days a year) were identified as the first significant tornadoes of the day, including 2 F5's, 19 F4's, 105 F3's, and 478 F2's.

The plot in Figure 3a shows that there has been a general upward trend in the number of severe weather events in the 13 year time period, similar to research by Weiss and Vescio (1998). The total number of reports, which include all tornadoes, damaging wind, and hail, more than doubled within the study period. The plot in Figure 3b shows hail reports have increased more than 300% from 1990 to 2002, rising from 3,618 reports in 1990 to 12,533 reports in 2002. Wind reports have almost doubled in the last 13 years (Figure 3). However, the total number of tornado reports during these years has held relatively steady with around 1,181 occurrences a year (Figure 3d).

Once the first F2-F5 tornado touchdown for each day was identified, the distance and time of other severe weather preceding the tornado was tabulated. In the 604 cases of first significant tornadoes, hail was found to be more likely to precede an occurrence of a strong/violent tornado than weak tornadoes or wind reports (Figure 4). Hail precedes the first significant tornado of the day approximately 50% of the time. This is worth noting since there were nearly 1000 more wind reports than hail reports over the 13 year period (Weiss et al., 2002).

When all severe weather reports prior to the significant tornado were considered, severe weather occurred 78% of the time prior to touchdown (figure 5). Approximately

22% of the time, there were no reports of severe weather within 120 minutes and 70 miles prior to the first significant tornado touchdown. However, Doswell and Burgess (1988) showed that severe weather tends not to be reported with storms in sparsely populated areas. Also, they showed that hail and wind may not be reported when in close temporal or area proximity to significant tornadoes. Thus, it is possible that severe weather did occur, but was not reported. Figure 5 also suggests that most of the severe weather reports, preceding the first tornado, occurred between 30 and 120 minutes, and 20 and 70 miles of the F2-F5 tornado occurrence. When looking at all occurrences of significant tornadoes, not just the first tornadoes of the day, there is greater than a 90% chance for any type of severe weather to occur within 120 minutes or 70 miles of a touchdown (Figure 6). It is worth noting that over half of the time, these reports will also occur within 30 minutes and 20 miles of the F2-F5 tornado occurrence.

While the presence of hail seems to be a strong indicator of a strong/violent tornado, significant hail does not. Referring back to Figure 4, it is evident that significant hail only precedes a strong/violent tornado a small percentage of the time. The data indicates there is a 40% chance of a severe weather event preceding an F2 or greater tornado. While significant hail is not a good indicator of a significant tornado, the absence of significant hail does not decrease the chances of a F2-F5 tornado either.

Figure 7 shows that the chances of having either wind or hail precede a F5 tornado are greater than 60% for categories 2-5. Also, there is a 50-70% probability of having hail or wind preceding an F3- F5 tornado. In this figure, for a F5 tornado there was no hail or wind events reported within 15 minutes or 10 miles. This likely is a

reporting problem (Doswell and Burgess 1988) as opposed to no severe weather occurring.

5. Summary

The study included identifying the trends of severe weather preceding strong to violent tornadoes using 13 years of data. Over these years there was a general upward trend in the number of severe weather reports. The total number of reports doubled between 1990 and 2002, hail reports even increase by 300%. It was found that hail was most likely to precede a strong/violent tornado than wind, even though there were more wind reports annually than hail reports. Only one out of every five significant tornadoes had no severe weather reports preceding it, and most reports occurred between 30 and 120 minutes, and 20 and 70 miles of the first F2- F5 occurrence of the day. There tends to be less severe weather reports within 15 minutes and 10 miles of a significant tornado, but this is likely reports being under reported due to a nearby damaging tornado.

There is an 80% or higher probability of severe weather preceding strong/violent tornadoes, especially 60-120 minutes prior to the significant tornado event.

Future research would include looking at different probabilities of severe weather preceding strong/violent tornadoes in different regions of the United States. It would be interesting to see if wind reports are more likely to precede significant tornadoes in the Northeast, or tornadoes are more likely to precede a F2-F5 in the plains.

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Category	Time	Distance
1	**15**	**10**
2	**30**	**20**
3	**60**	**35**
4	**90**	**52**
5	**120**	**70**

Table 1: This table shows the five time/distance categories that were used in this study. Each category is containing events within the specified time and distance.

Fig.1. This is an example map with the 5 category rings to give a general idea of the time/distance involved for each category.

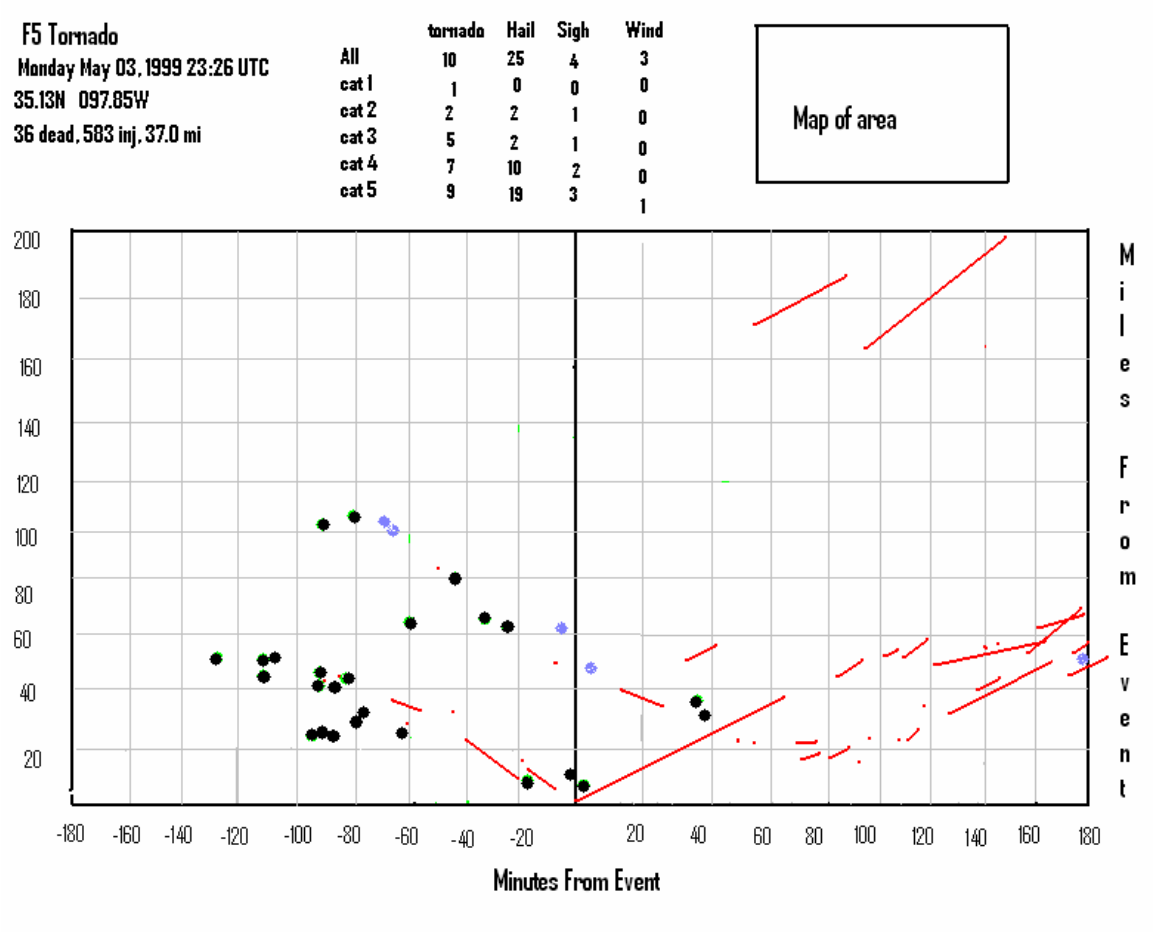

Fig.2. This is a sample display from the Report Relationship database. The solid black line in the middle of the graph indicates where the significant tornado occurred. Black dots indicate hail reports, grey dots are wind reports and the lines and smaller dots are tornado reports. All dots and lines to the left of the center black line indicate the severe weather reports preceding the tornado, and everything to the right are the weather reports after the tornado.

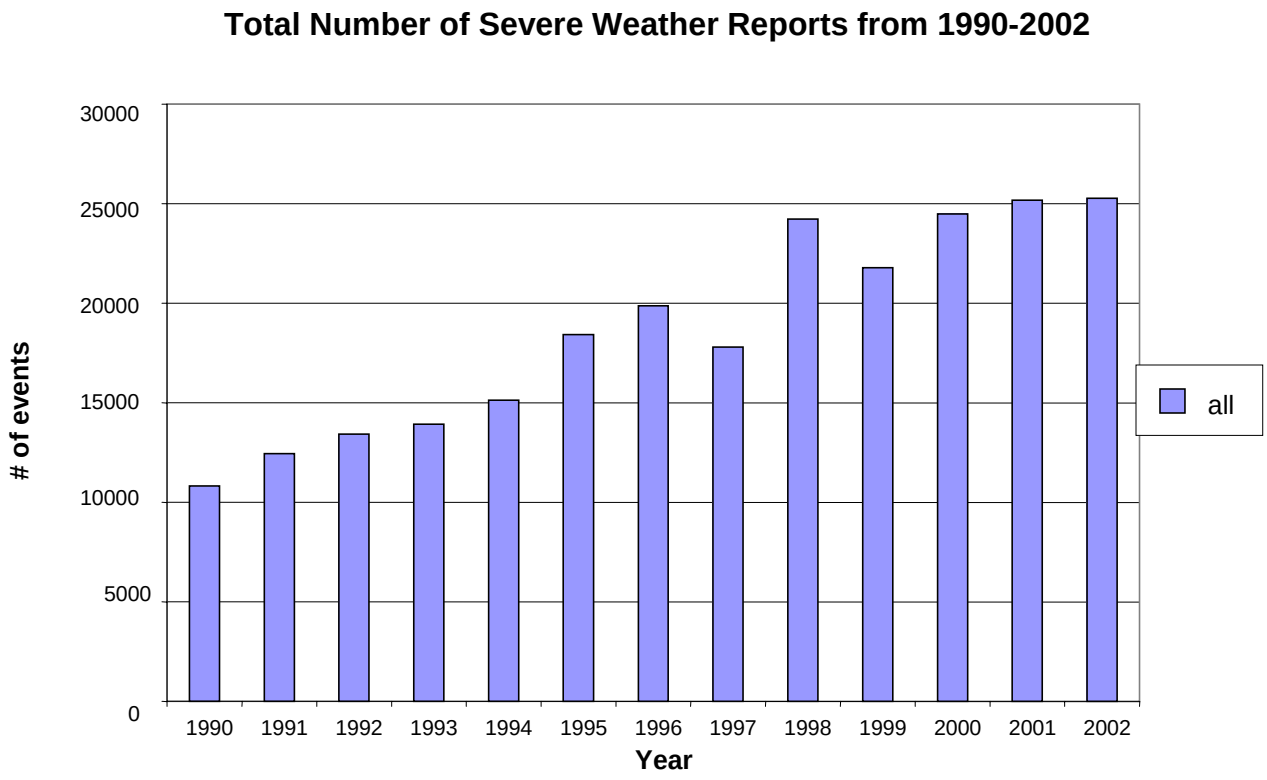

Fig.3a. All reports of tornadoes, severe wind, and hail from 1990 to 2002.

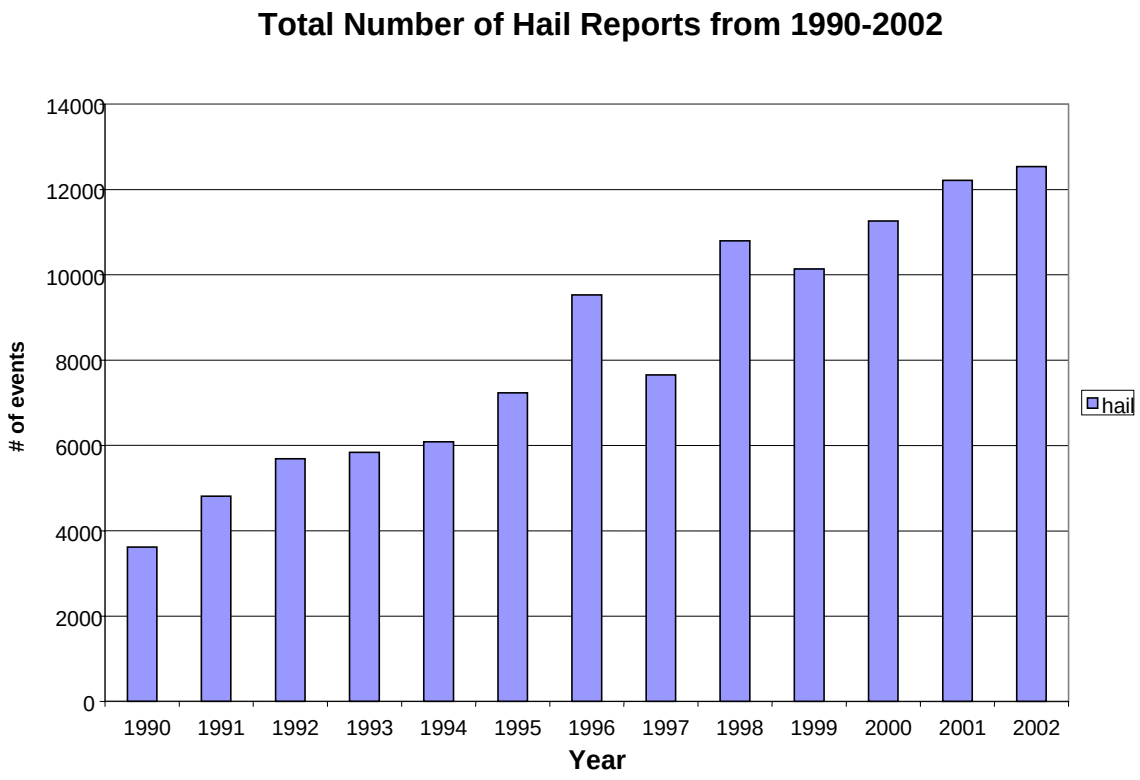

Fig.3b. Severe hail reports from 1990 to 2002.

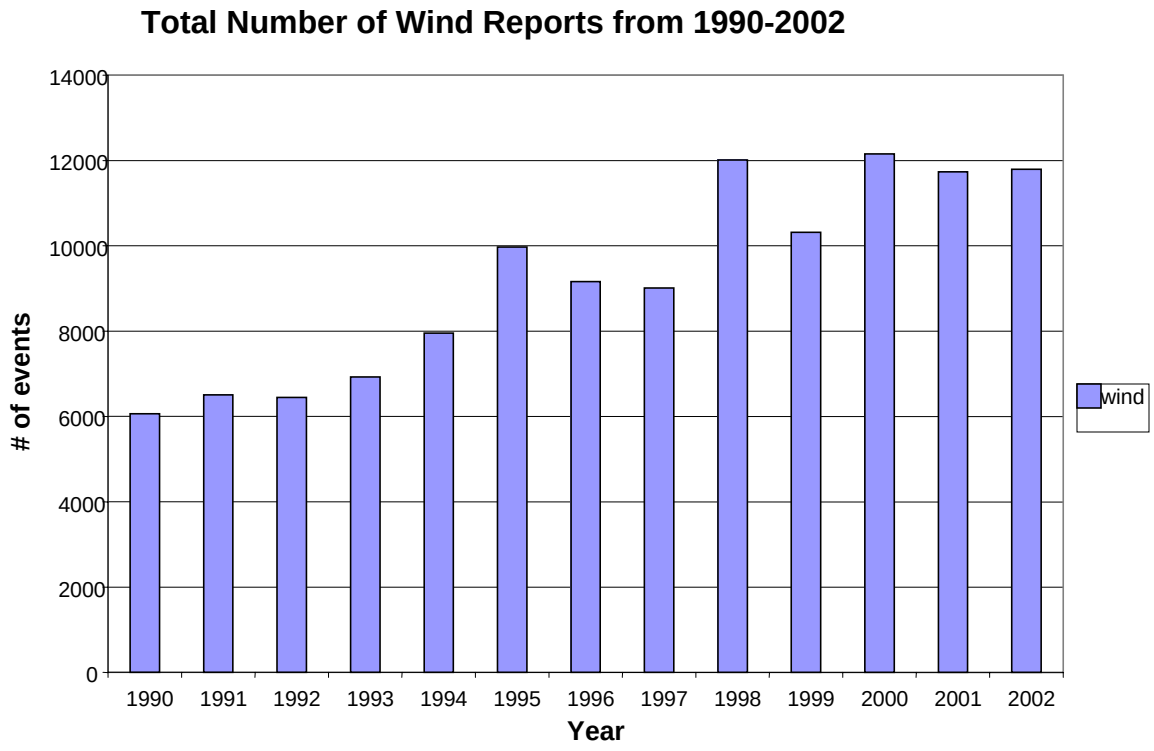

Fig.3c. Severe wind reports from 1990 to 2002.

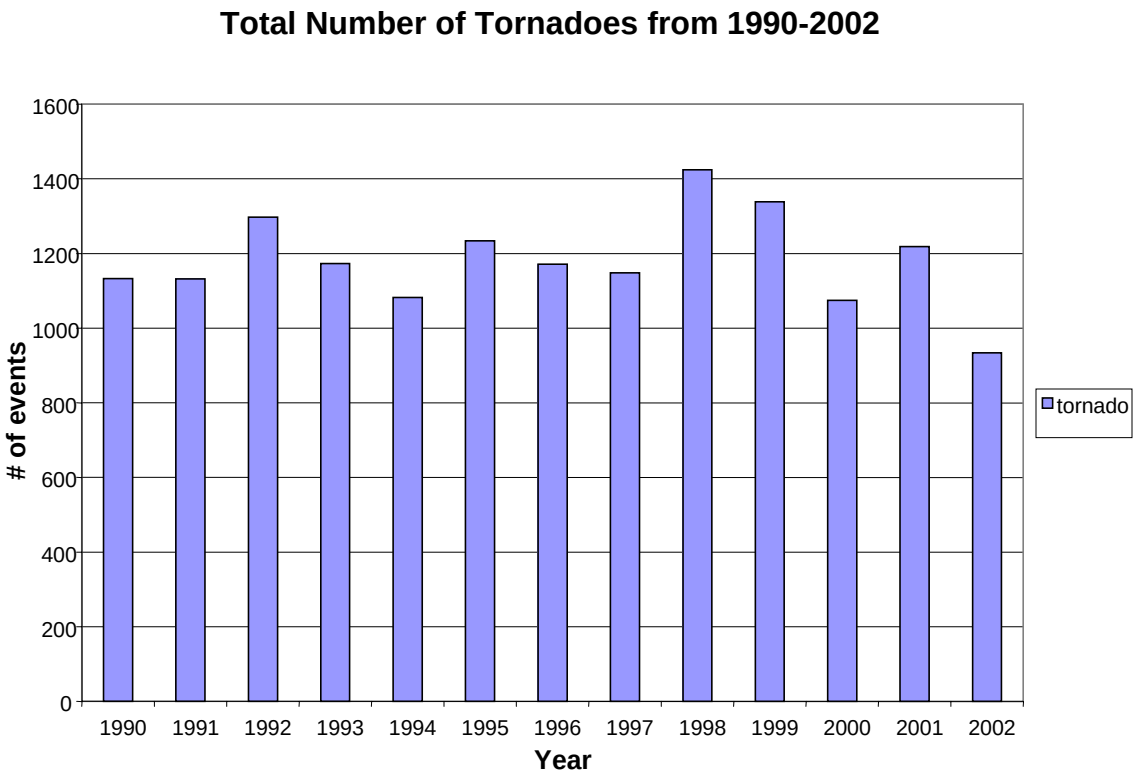

Fig.3d. Number of tornadoes for each year from 1990 through 2002.

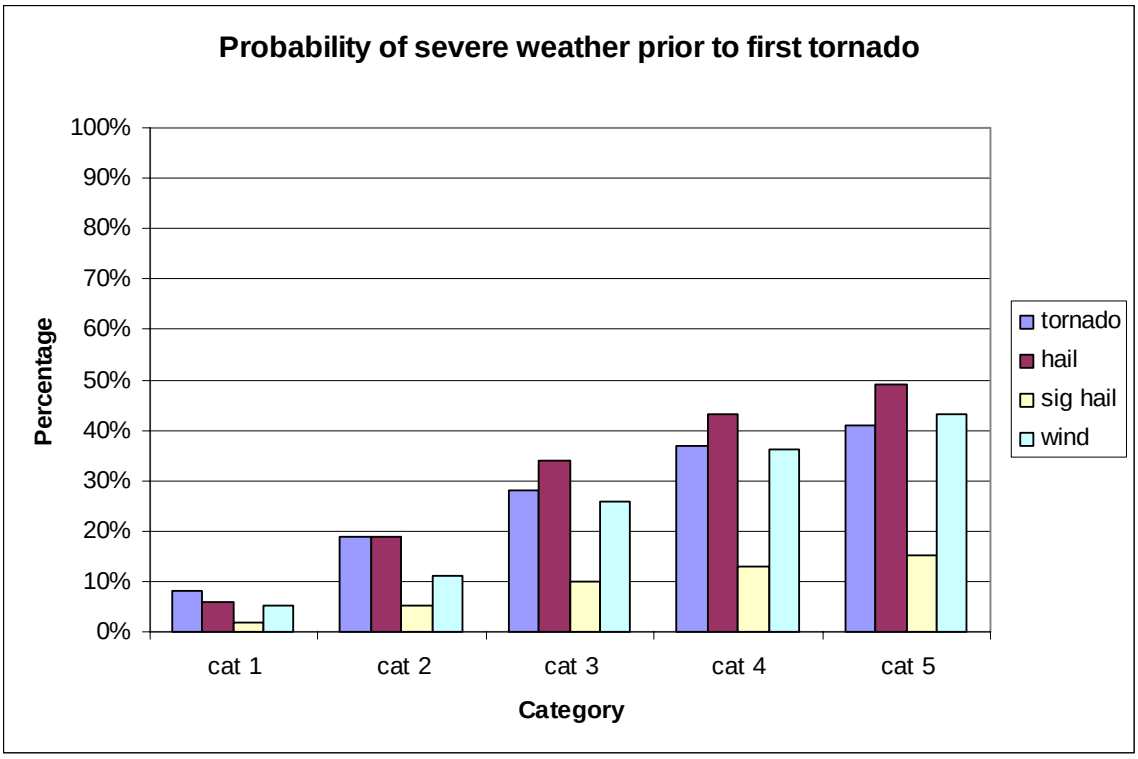

Fig.4. This graph is the same as figure 3 except displays as a bar graph to better display the data.

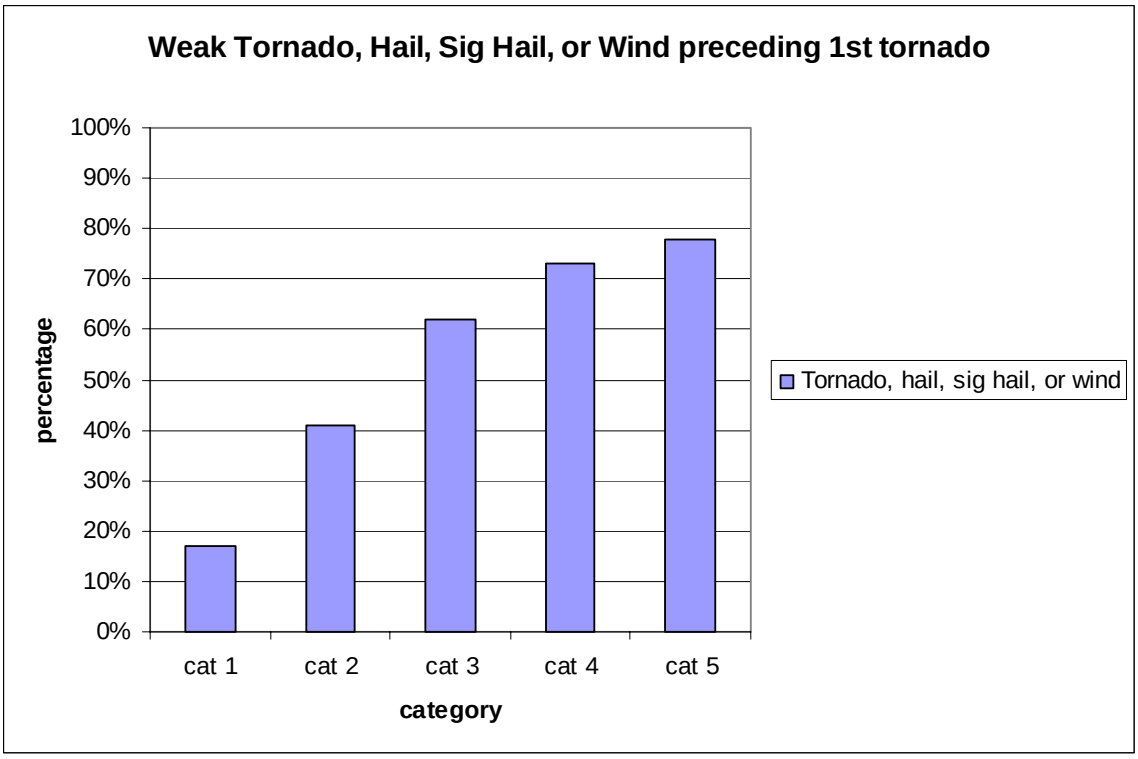

Fig.5. Shows the probabilities of having a weak tornado, hail, significant hail, or wind reports preceding the first significant tornado of a day.

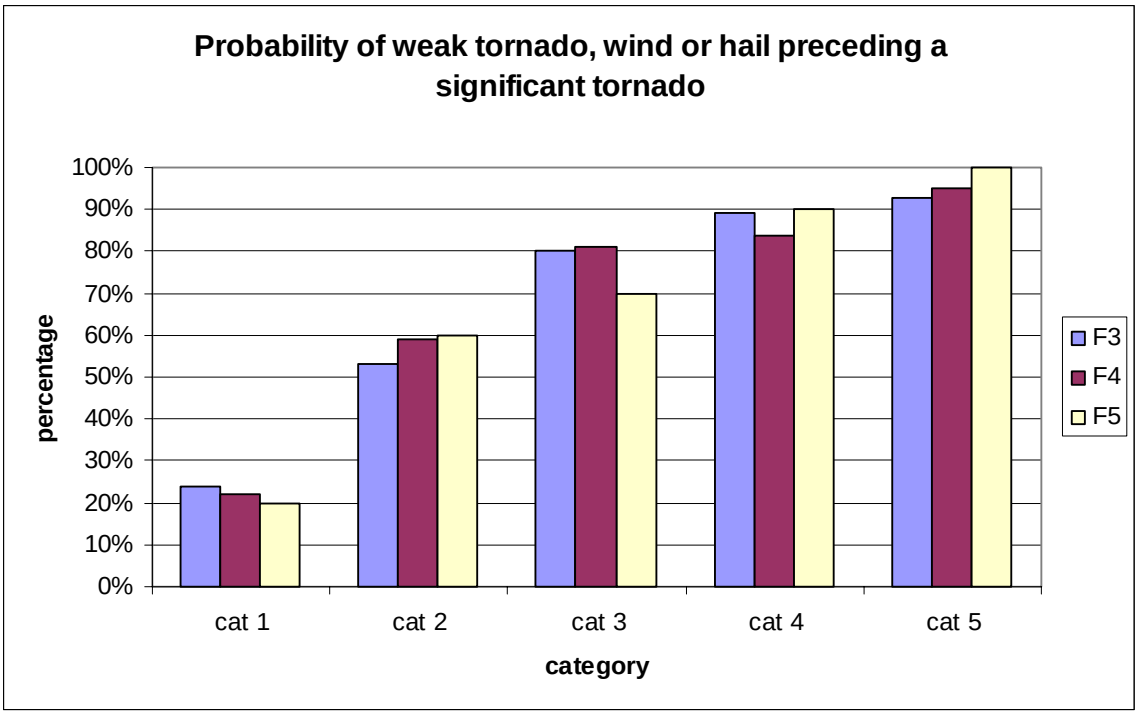

Fig.6. This graph shows the probabilities of weak tornadoes, wind, or hail preceding an F3-F5.

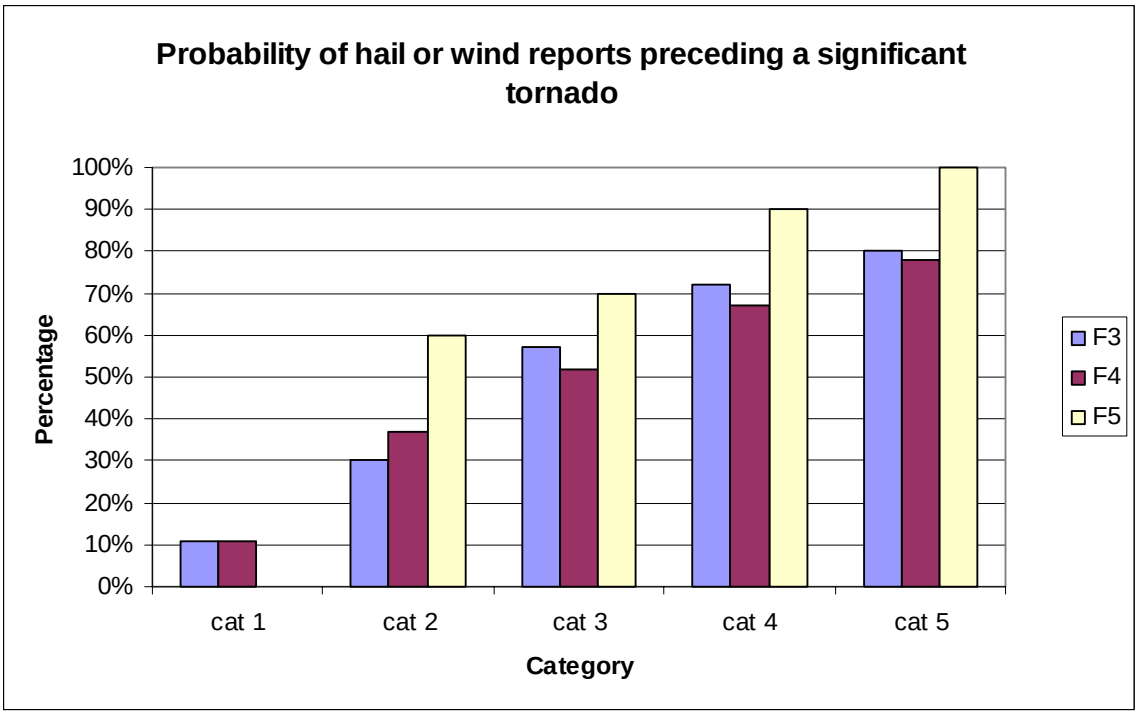

Fig.7. This graph shows the probabilities of hail or wind preceding a F3, F4, or F5.