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A SEVERE WEATHER CLIMATOLOGY FOR THE WFO TULSA COUNTY WARNING AREA

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UNITED STATES
DEPARTMENT OF COMMERCE
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1. Introduction

As its number one mission priority, the staff at National Weather Service field offices have no higher calling than to issue timely severe weather warnings for the protection of life and property. At WFO Tulsa, staff members are responsible for issuing severe weather warnings for 32 counties in the eastern third of Oklahoma and in northwestern Arkansas, a map of which is shown in Figure 31 at the end of the Appendix.

A thorough understanding of the area's severe weather climatology can better prepare forecasters for anticipating the timing, strength, extent, and nature of severe weather. Therefore, the purpose of this study is to quantitatively describe the severe weather climatology of the WFO Tulsa County Warning Area (CWA) to build a better understanding of the area's severe weather potential. This study should also help emergency managers, the media, and the general public in severe weather readiness and in planning preparedness activities.

2. Data

The data used for this study came from several sources. The majority of the data was generously provided by the National Weather Service Storm Prediction Center (SPC), which maintains a database of severe weather reports dating from 1955-1994 for hail and wind reports, and from

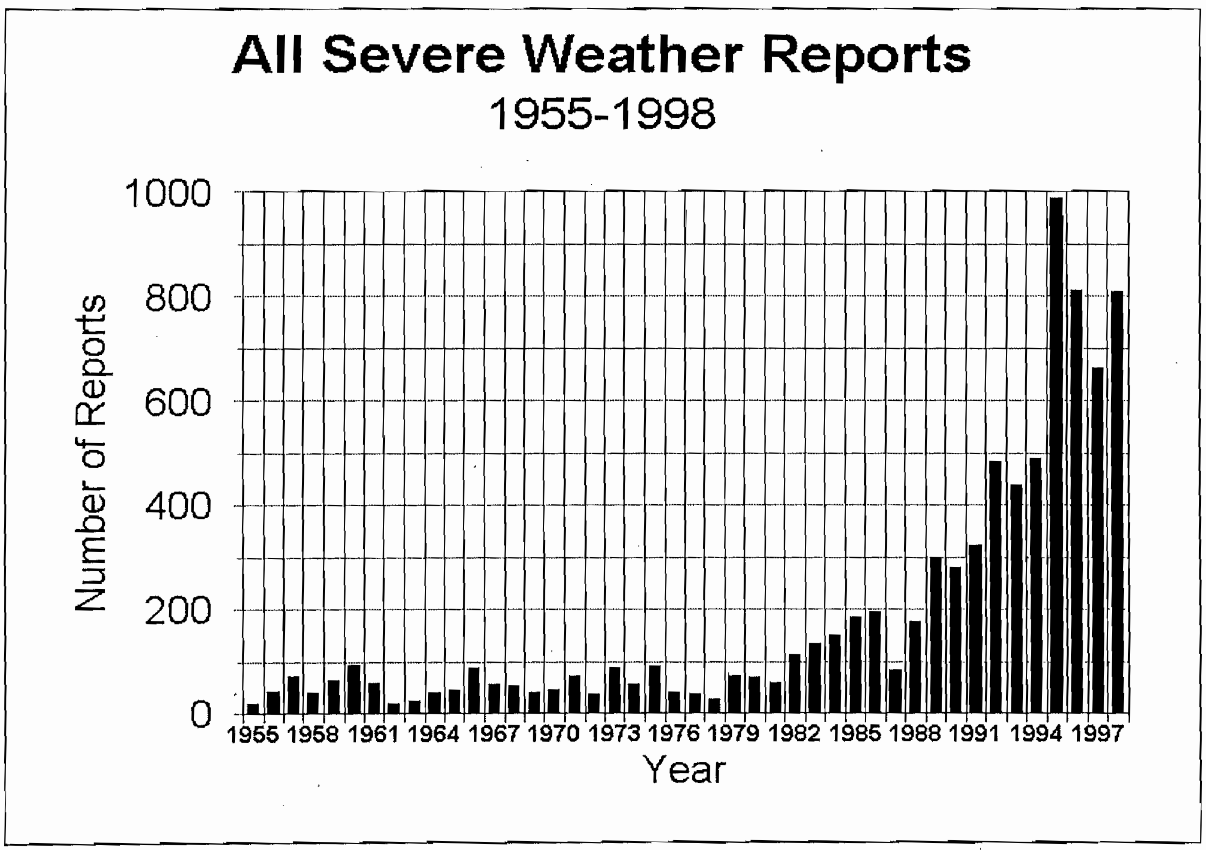

Figure 1. Yearly Distribution of All Severe Weather Reports, 1955-1998.

1950-1994 for tornado reports. Those data were analyzed by the CLIMO software developed by Vescio (1995). However, damaging wind and hail data were unavailable for 1972, so data from the 1972 monthly *Storm Data* (NOAA 1972) publications were used. Data for 1995 were obtained from the 1995 *Storm Data* (NOAA 1995) publications. Data for 1996 through 1998 were obtained from WFO Tulsa's local storm data software.

There are several factors that make this data set under-representative but still usable. One can see in Figure 1 that there has been a dramatic rise in the number of annual severe weather reports since the mid 1950s. This does not necessarily mean there has been a real increase in the amount of severe weather over the years. Instead, this is largely a reflection of an increased population and an increased weather awareness (Hales 1993). In addition, the National Weather Service started its warning verification program in 1980, and new management at the National Weather Service in Oklahoma in the mid 1980s supported aggressive post-event verification. This largely explains the dramatic rise in severe weather reports starting in the mid 1980s through the early 1990s. This has the effect of skewing the data to be more representative of the later years in this study than the earlier years.

Prior to the aggressive verification effort, only the more significant weather events were reported. In the latter years, reports of marginally severe weather were aggressively sought, resulting in a significant shift in the character of reported severe weather in the CWA. Figures 2 and 3 demonstrate the increase in marginal reports by showing a comparison of reported hail size categories from 1955-1984 and from 1985-1998. The dramatic increase in the number of marginally severe hail reports is a direct result of aggressive verification efforts following 1984. Similar tendencies may also be true for wind reports, but the lack of a similar breakdown in the degree of severity makes that determination impossible to prove at this time. The data set is further skewed since verification efforts are limited to warned storms, leaving out some unwarned events that would likely add to the number of marginal reports in the database.

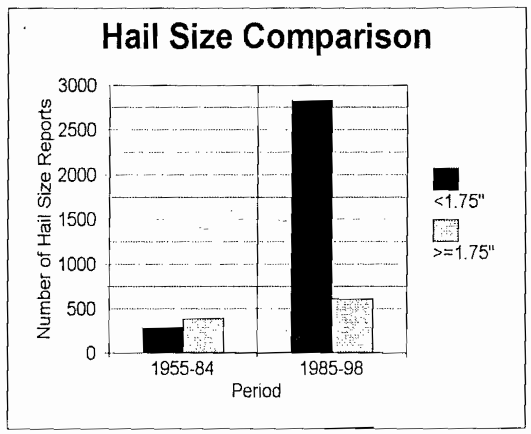

Figure 2. Comparison of Number of Marginal Hail Reports

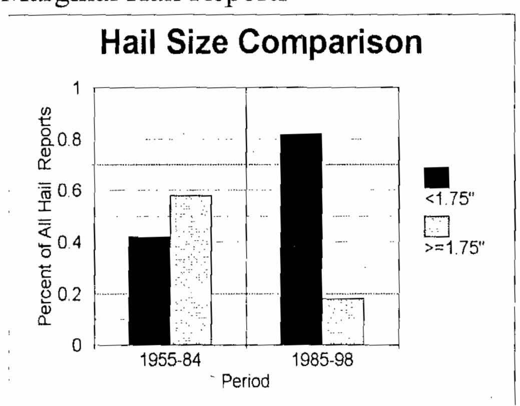

Figure 3. Comparison of Percent of Marginal Hail Reports

Another factor that makes the data under-representative is the difference in population density over the CWA. If severe weather occurs over one of the larger cities in the area, it would likely be reported and therefore be included in the data set. Severe weather over an unpopulated area is less likely to be reported and included in the data set. For those reasons and the fact that the author would not want to encourage population-weighted warnings, this study does not address the geographical coverage of severe weather in the CWA.

Instead, it focuses on temporal trends in the severe weather climatology. Even with the faults of this data set, it is still usable since the data is subject to the same biases given the temporal focus of this study.

3. Severe Weather Climatology

Severe hail, strong winds, and tornadoes are the three types of severe weather analyzed in this study. Of those three, large hail is the most common type of severe weather observed in WFO Tulsa's CWA. From 1955 through 1998, there were 3,954 reports of hail that were dime-sized (3/4" diameter) or larger, comprising 49% of the severe weather database. Severe wind (≥50 knots or 58 miles per hour) was the second most common type of severe weather with 3,340 reports, comprising 41% of the severe weather database. Tornadoes round out the top three with 844 reports from 1950-1998, comprising 10% of the severe weather database.

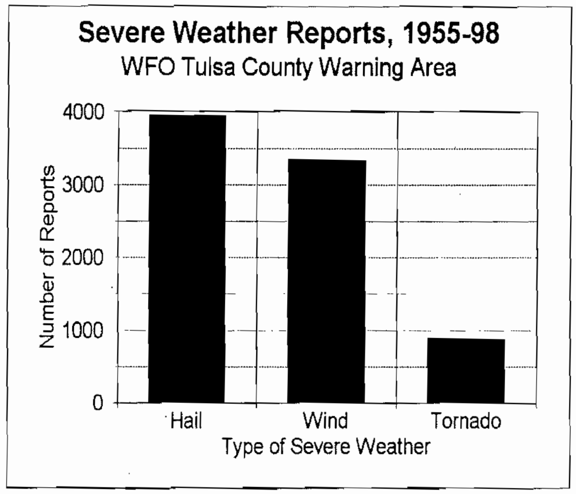

Figure 4. Number of Severe Hail, Wind and Tornado Reports Compared.

a. Monthly Distribution of Severe Hail, Wind and Tornadoes

The most active months of the year for severe weather are April, May and June. This is when the ingredients for severe weather (atmospheric instability, moisture, surface boundaries and wind shear) come together most frequently. Sixty percent of all severe weather reports occurred during this three-month period. Figure 5 shows that May is the most active month of the year for all three kinds of severe weather combined.

However, Figure 6 illustrates that each of the three major severe weather types peaks in different months, eg. hail reports peak in April; tornado reports peak in May; and severe wind reports peak in June. While the overall number of hail reports is slightly less in May than in April, May experiences more <u>very</u> large hail, i.e. hail that is golfball-sized (1.75" diameter) or larger. (See Figure 27 in the

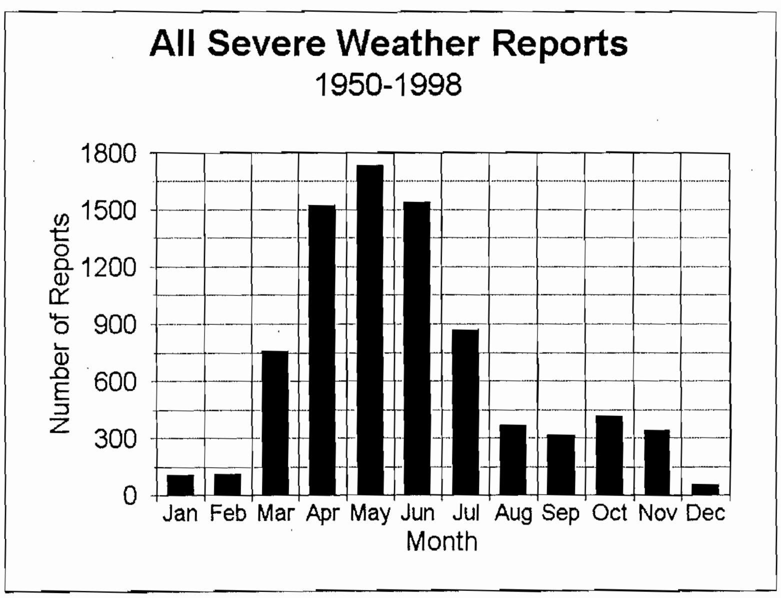

Figure 5. Monthly Distribution of All Severe Reports.

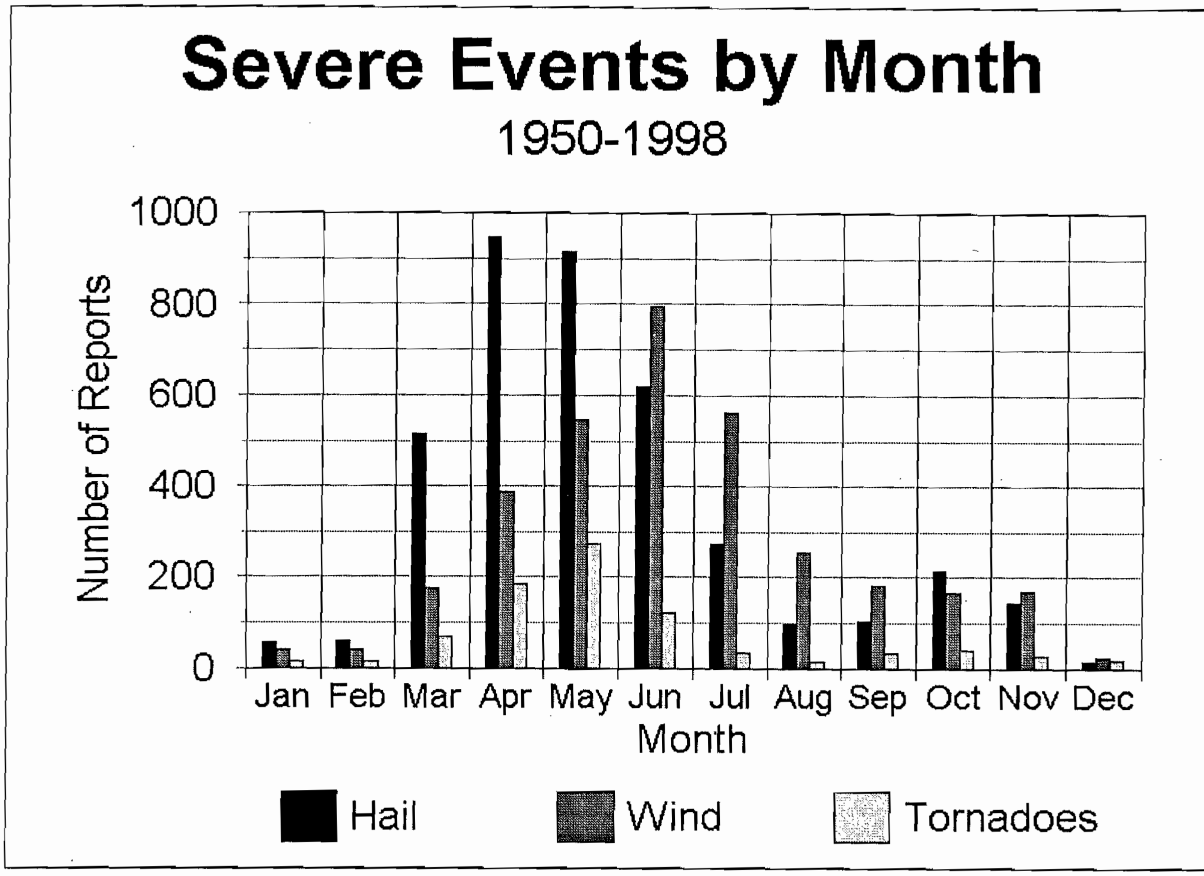

Figure 6. Monthly Distributions for Severe Hail, Wind and Tornadoes Compared.

Appendix). By June, the number of hail and tornado reports decreases significantly. However, severe wind reports peak in June, surpassing the number of hail reports each month through September.

The total number of severe weather reports continues to drop each month from July through September with wind reports remaining the most common type of severe weather during the late summer. In the autumn months of October and November, there is a small secondary peak in the total number of severe weather reports. Still, severe activity in the autumn remains well below the levels experienced in the spring and early summer.

December, January and February are the least active months for severe weather with December having the fewest hail and wind reports. From 1955-1998, there were no reports of golfball-sized (1.75" diameter) or larger hail for any December-February period. (This climatological trend was broken in January 1999 when golfball-sized hail caused over $2 million damage in southeast Oklahoma.) Despite the relative inactivity of the winter months, tornadoes have killed or injured people during this, and every other time of year.

Finally, March marks the transition from winter to spring, with significant increases in each type of severe weather, but most notably hail. This leads us back into the very active months of April, May and June.

b. Hourly distribution of severe hail, damaging winds and tornadoes

Late afternoon and evening are the most active times of day for severe weather in the Tulsa CWA. When all three major kinds of severe weather are combined, the hour from 700 to 759 PM CST is the most active of the day. The period from 500 PM to 959 PM CST contains 43% of all severe weather reports, even though this period comprises only 21% of the day.

With few exceptions, most months follow the trend of late afternoon and evening being the most climatologically favorable time of day for severe weather. However, a few other trends are worth comments.

In most months, the number of severe weather reports falls off rapidly after midnight. However, the month of May experiences a secondary severe weather peak around 3 AM CST as shown in Figure 8. This is primarily due to nocturnal Mesoscale Convective Systems (MCS) moving south out of the central Plains and into the Tulsa CWA at night during the late spring. This trend is not as pronounced in June (shown by Figure 20 in the Appendix), but there is still a plateau in the number of severe reports during the overnight hours.

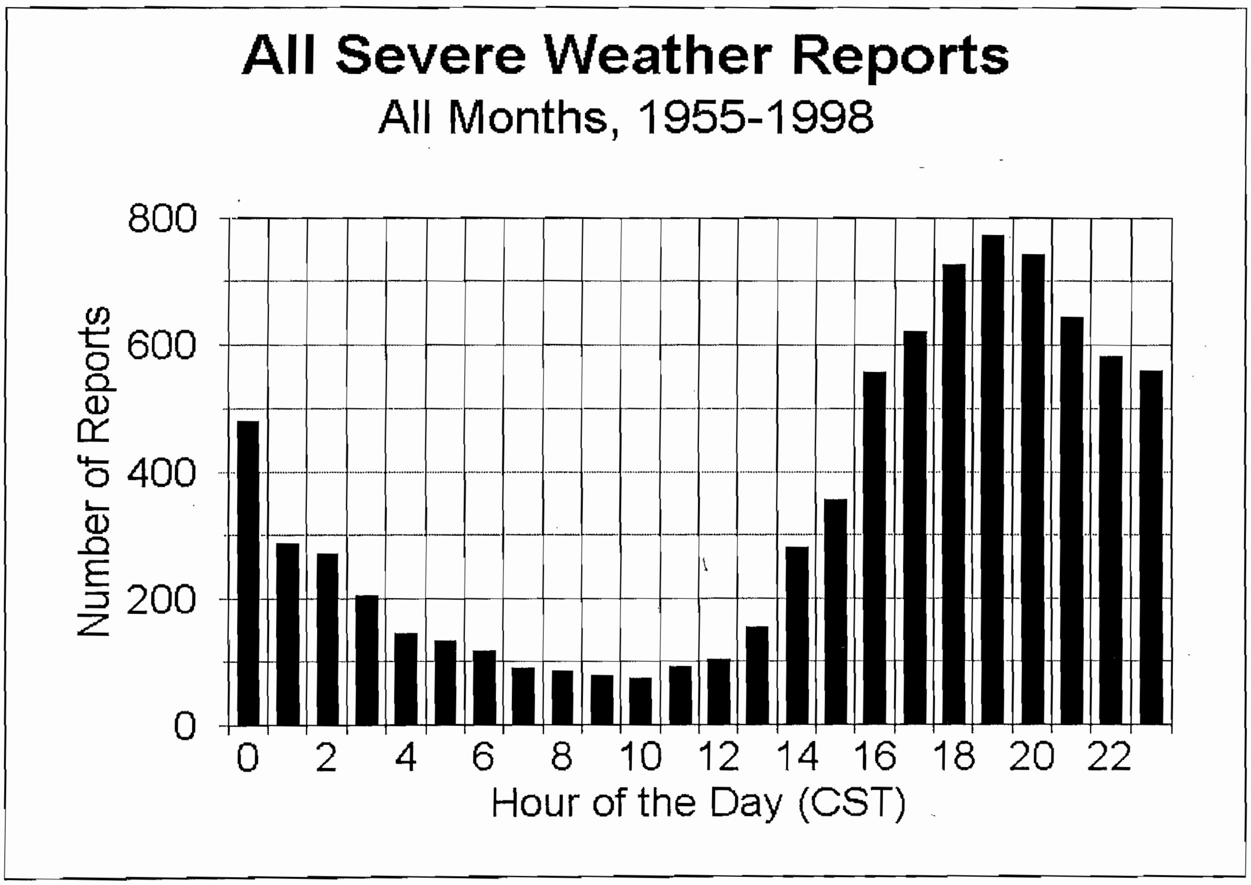

Figure 7. Year-Round Hourly Distribution of All Severe Reports.

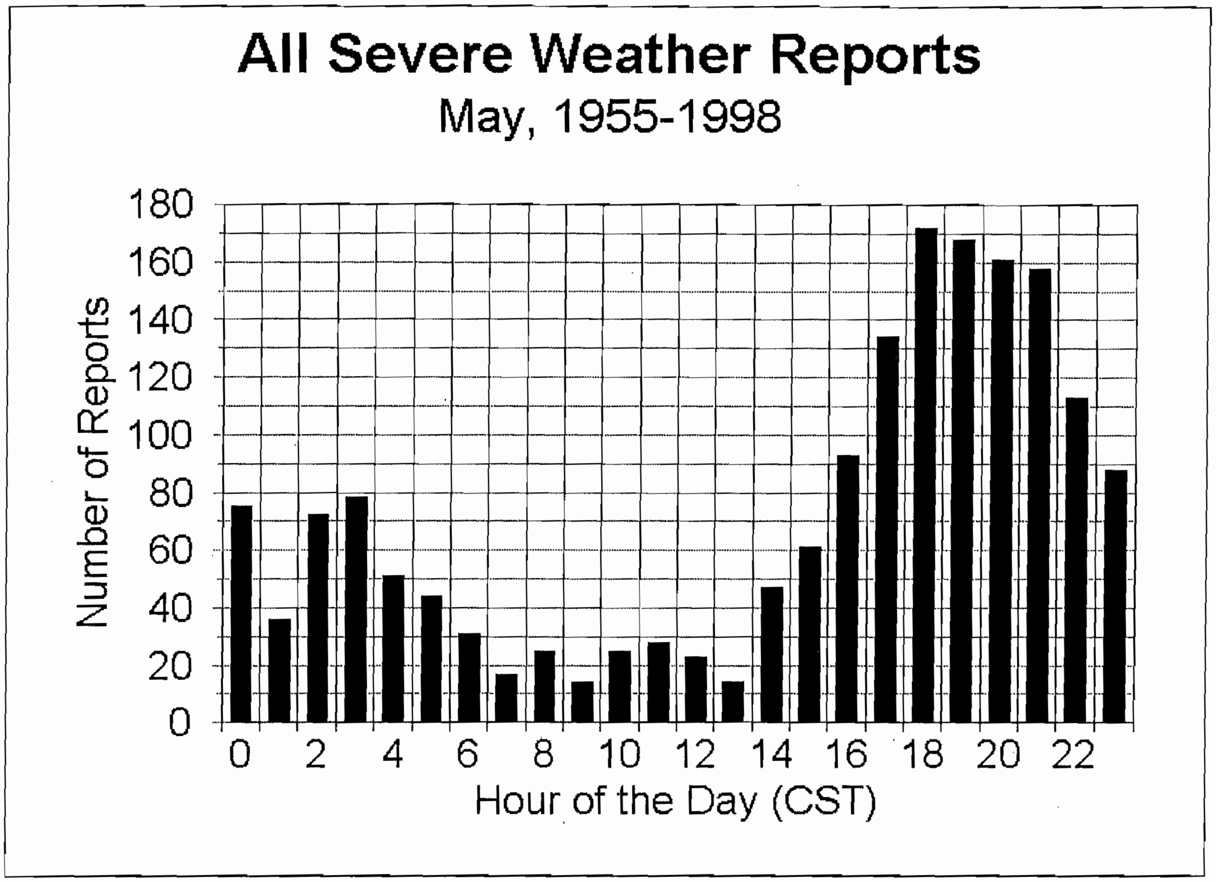

Figure 8. Hourly Distribution of All Severe Weather Reports in May. Note secondary peak around 3 AM.

The month of November shows a sharp peak in severe activity from 11 PM to 2 AM (shown by Figure 25 in the Appendix). However, this is caused almost completely by one large widespread severe weather outbreak in November 1998, accounting for more than half of all severe weather reports in the data set for the month of November.

December data shows little variation from one time of day to another, likely due to the weak diurnal effects of the December sun and the small sample size of severe events for the month. Graphs showing hourly distributions of severe weather individually for each month are included in the Appendix in Figures 15 through 26.

Not all types of severe weather peak at the same time each day. The number of hail reports peaks around 6 PM, the number of tornado reports peaks around 7 PM, and the number of wind reports peaks around 11 PM with a close secondary peak around 8 PM. Figure 9 illustrates this trend.

The trend for different severe weather types peaking at different hours of the evening closely follows the life-cycle of many severe weather events in the WFO Tulsa CWA. In a generic spring/early summer severe weather outbreak, thunderstorms will initially develop late in the afternoon around 5 PM, producing large hail about one hour into their life cycles during the 6

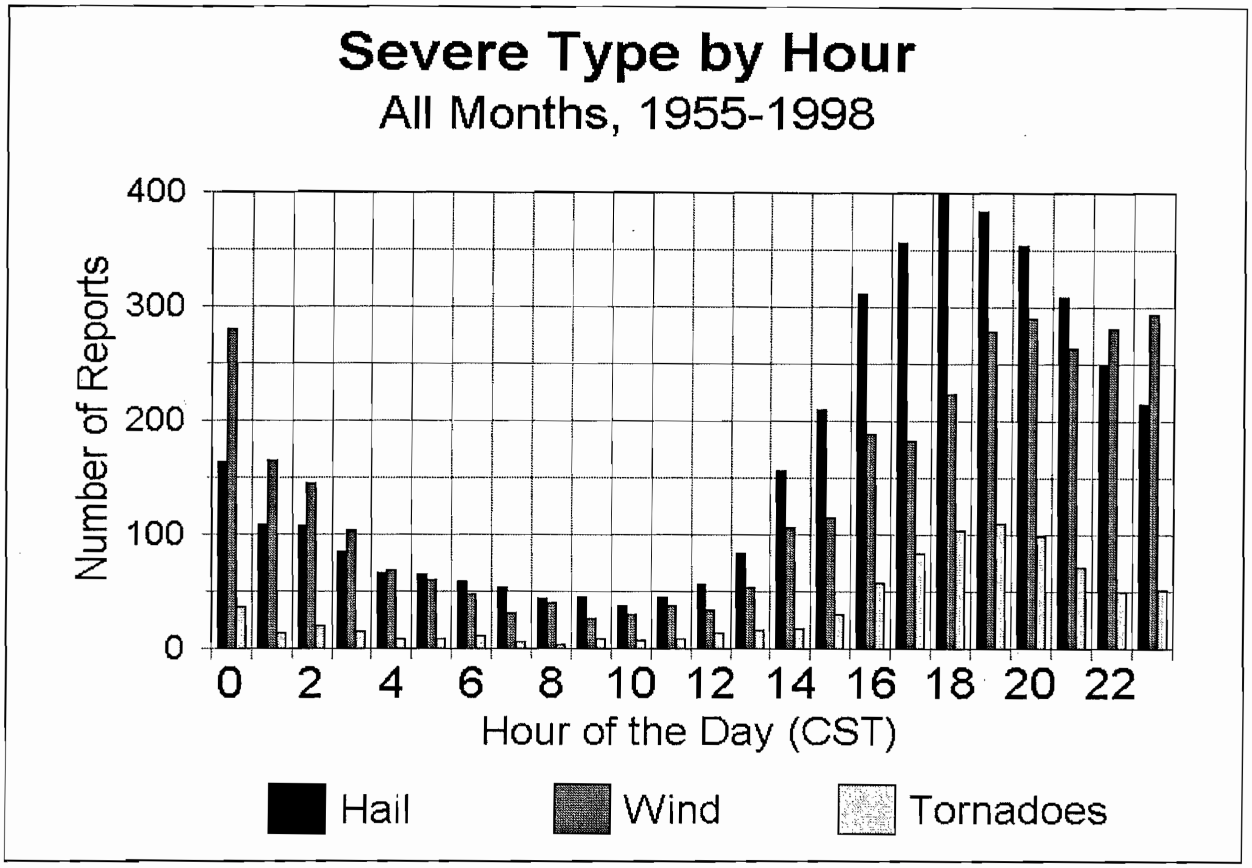

Figure 9. Hourly Distribution of Severe Hail, Wind and Tornadoes Compared. Hail peaks around 6 PM, Tornadoes around 7 PM, and Wind from 8-11 PM.

PM hour. Around 7 PM, thunderstorms often take on supercell characteristics, making the 7 PM hour the most likely time for tornadoes. Following this stage, storms often merge and form lines of thunderstorms which are responsible for more numerous wind reports after 8 PM. While no two severe weather outbreaks are ever alike, the houly climatological peaks in each type of severe weather paint a picture of the most generic severe outbreak in the WFO Tulsa CWA.

When looking at the types of severe weather each hour on a year-round basis, hail is the most common type of severe weather from 5 AM through 959 PM, while wind is the most common type of severe weather from 10 PM through 459 AM.

4. Other Tornado Trends

The WFO Tulsa CWA lies along the eastern edge of what is commonly referred to as "Tornado Alley". Oklahoma ranks second among the states, behind the geographically large state of Texas, in the number of reported tornadoes, while Arkansas ranks sixteenth (Storm Prediction Center online archive). In fact, there has been at least one tornado in the WFO Tulsa CWA each year since 1950. For this reason, tornadoes represent a significant threat to life and property and require further consideration in this severe weather climatology.

a. Intensity Trends

Tornado intensity is ranked on the Fujita scale which ranks tornadoes on a scale of F0 to F5, with F0 being the weakest and F5 being the strongest (Fujita 1981). The WFO Tulsa CWA has experienced every intensity on the scale. Figure 10 shows the most common tornado intensity is F1 followed closely by F0, both of which are considered weak tornadoes. There were 260 and 241 F1 and F0 tornadoes reported respectively from 1950-1998. The number of tornadoes then decreases progressively with each move up the intensity scale from F2 through F5. The violent F5 tornado is extremely rare. Only three F5 tornadoes have occurred since 1950, accounting for less than 1% of all tornadoes in the WFO Tulsa CWA.

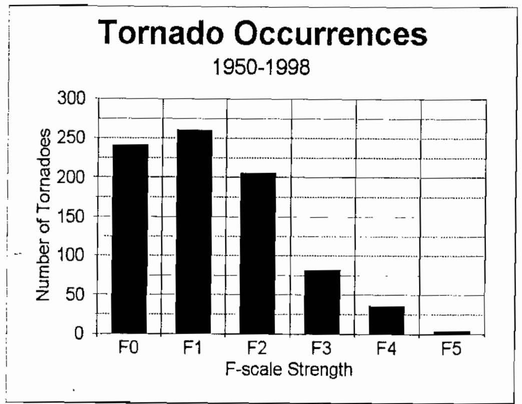

Figure 10. F-Scale Distribution of Tornado Reports.

b. Human Toll

From 1950-1998, there were 2,063 tornado-related injuries and 138 tornado-related deaths in the Tulsa CWA. Out of these, Figure 11 shows a disproportionately high number of deaths was caused by violent F4 and F5 tornadoes. In fact, F4 and F5 tornadoes account for only **5%** of all tornadoes in the data set but account for **72%** of all tornado-related deaths and **52%** of all tornado-related injuries. Conversely, relatively weak F0 and F1 tornadoes account for **60%** of the tornadoes in the data set, yet account for only **2%** of tornado-related deaths and **6%** of tornado-related injuries. In between are the strong F2-F3 tornadoes, which account for **35%** of all tornado reports while making up **25%** of tornado-related deaths and **42%** of tornado-related injuries.

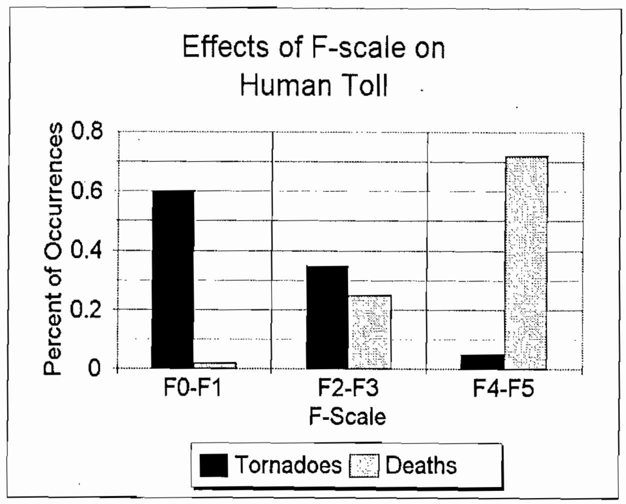

Figure 11. Percent of F-Scale Occurrences vs. Tornado-Related Deaths.

When comparing Figures 12 and 13, one can see that the hourly distribution of killer or injury-causing tornadoes follows closely the hourly distribution of all tornado occurrences. In fact, the hour of the day with the highest number of killer or injury-causing tornadoes is from 600 to 659 PM CST. This is a close match with the hourly distribution for all tornado occurrences.

The only exception to the closely-matched distributions is during the morning hours around and shortly after sunrise, when a jump in the number of killer or injury-causing tornadoes takes place, despite this being a generally inactive time of day for tornadoes. Despite the small sample size, one might cautiously conclude that tornadoes occurring around and just after sunrise, ie. from 600 to 959 AM CST, are more likely to result in injury or death. This conclusion is worthy of further study to find out if human or meteorological factors contribute to the disproportionately high number of injury-causing and killer tornadoes around and shortly after sunrise.

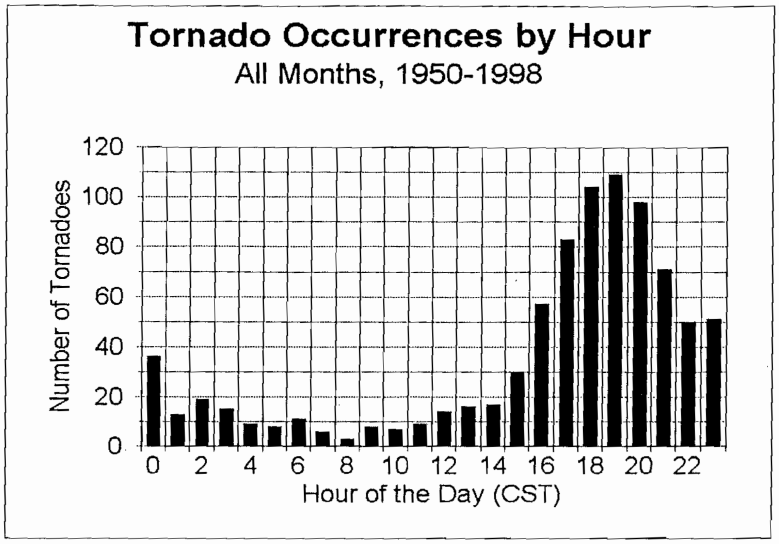

Figure 12. Hourly Distribution of All Tornadoes.

c. Decadal Tornado Cycles

As stated in the Data portion of this study, there has been a dramatic increase in the total number of all severe weather reports since the mid-1950s, most appreciably since the mid-1980s. However, this statement is not accurate when dealing with tornado reports alone. Figure 14 shows that the annual number of tornado reports has not shown any appreciable increase since the start of this study in 1950. This is likely due to the phenomenal nature of tornado events, making tornadoes the least likely type of severe weather to go unreported. This makes year-to-year trends in tornado occurrences especially meaningful.

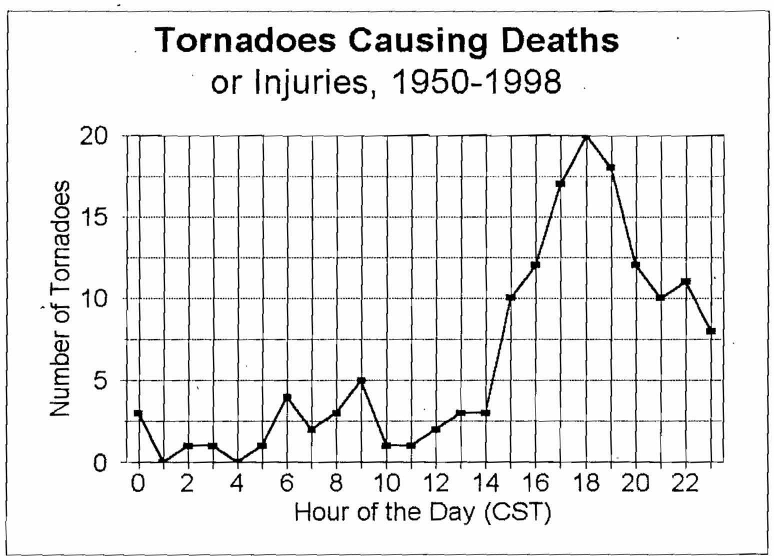

Figure 13. Hourly Distribution of Tornadoes Resulting in Injuries and Death.

While there is considerable year-to-year variability in the number of reported tornadoes, a careful examination of Figure 14 reveals a decadal cycle in tornado activity in the Tulsa CWA. The most active years tend to fall during the early and latter portions of a decade, while relatively inactive periods tend to take in the middle portion of a decade. As we near the end of the 1990s, tornado activity has again shown an increase. As of this writing, 1999 (not shown in Figure 14) has been the most active year for tornadoes since 1960. This trend is worth further study to determine causes of the decadal tornado cycle. While at least one tornado has occurred in the Tulsa CWA each year since 1950, the decadal cycle should lead to more conscientious preparedness efforts during the early and latter years of a decade.

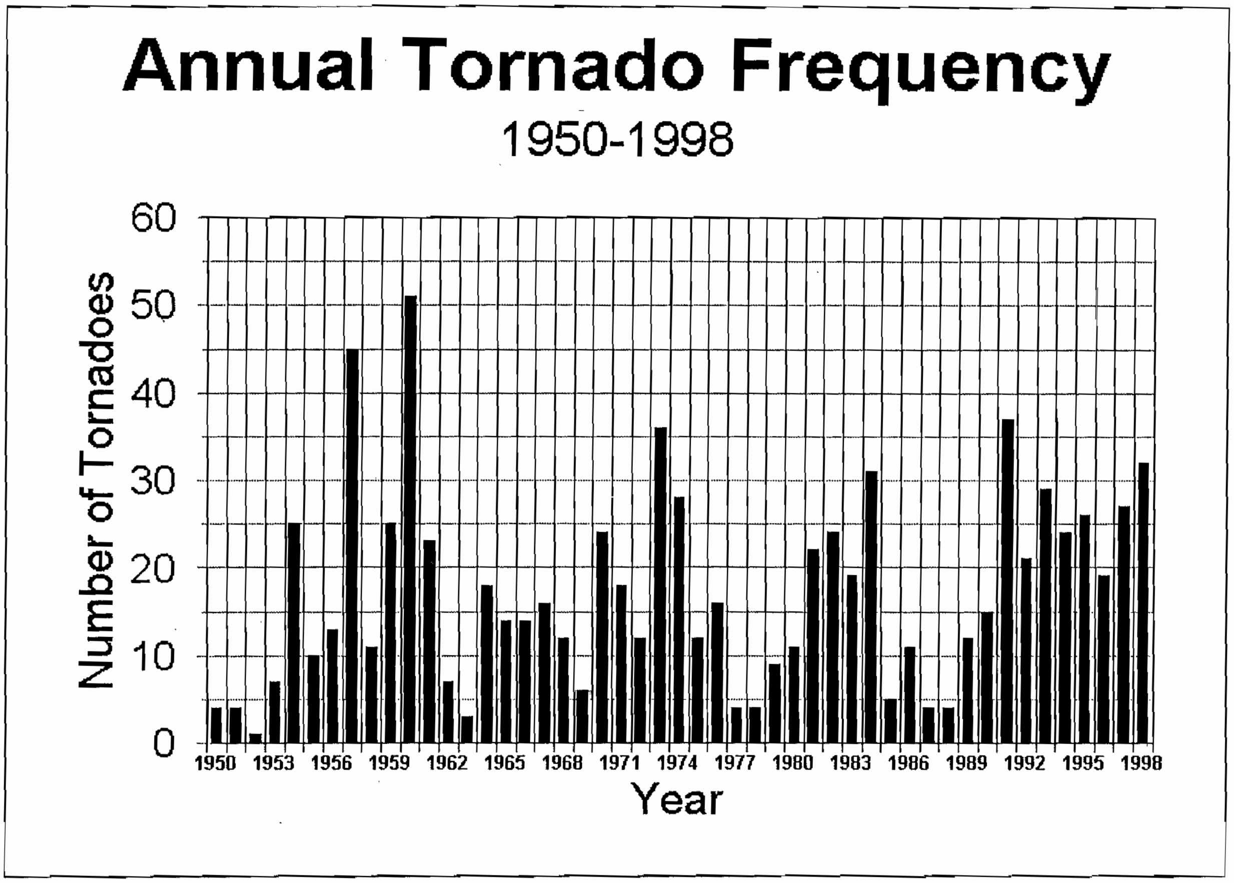

Figure 14. Yearly Distribution of Tornado Reports.

5. Summary

- Large hail is the most common type of severe weather, followed closely by severe wind. Tornadoes come in a distant third.

- April, May and June are the most active severe weather months of the year. There is a small secondary peak in October and November. The winter months are the least active.

- Hail reports peak in April; tornado reports peak in May; wind reports peak in June.

- Late afternoon and evening are the most active times of day for severe weather. In May, there is a secondary maximum around 3 AM LST.

- Hail reports peak around 6 PM; tornado reports peak around 7 PM; wind reports peak at 11 PM with a close secondary maximum at 8 PM.

- F1 and F0 tornadoes are the two most common tornado intensities.

- Violent F4 and F5 tornadoes account for a disproportionately high number of tornado-related deaths and injuries.

- The hourly distribution of killer and injury-causing tornadoes closely follows the hourly distribution for all tornadoes. However, there is a curious peak in killer and injury-causing tornadoes around and just after sunrise despite this being the most inactive time of day.

- There may be a decadal tornado cycle, with the early and latter years in recent decades being relatively active years, while the middle years in recent decades have been relatively inactive periods.

Acknowledgements. The author wishes to thank Mike Vescio at the Storm Prediction Center for providing the raw data from 1950-1994 used in this study. Special thanks to Steve Amburn, SOO at WFO Tulsa, for his patience in proofreading and revising this report.

6. References

Fujita, T.T., 1981: Tornadoes and Downbursts in the Context of Generalized Planetary Scales. *J. Atmos. Sci.,* **38,** 1511-1534.

Hales, John E., 1993: Biases in the severe thunderstorm data base: ramifications and solutions. *Preprints, 13th Conf. Wea. Forecasting and Analysis*, Vienna, VA, Amer. Meteor. Soc., 504-507.

National Oceanic and Atmospheric Administration, 1972: *Storm Data.* National Climatic Data Center, Asheville, NC, **14**, Nos. 1-12.

---------, 1995: *Storm Data.* National Climatic Data Center, Asheville, NC, **37**, Nos. 1-12.

Storm Prediction Center Online Archive, 1999: *www.spc.noaa.gov/archive/index.html*

Vescio, Michael D., 1995: CLIMO: Software to Generate Severe Weather Statistics for NWS County Warning Areas. NCEP Storm Prediction Center, Norman, OK.

7. Appendix

The next twelve Figures show hourly distributions of all severe weather reports for each month.

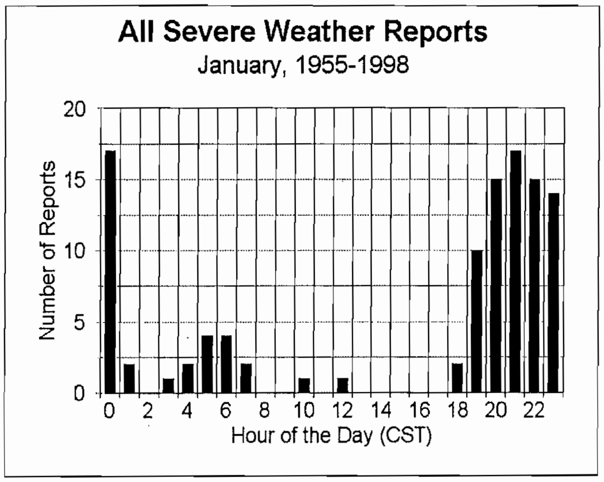

Figure 15. Hourly Distribution of All Severe Weather in January.

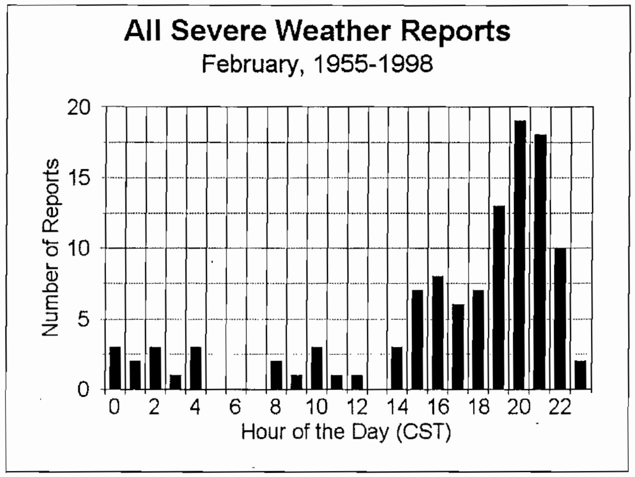

Figure 16. Hourly Distribution of All Severe Weather in February.

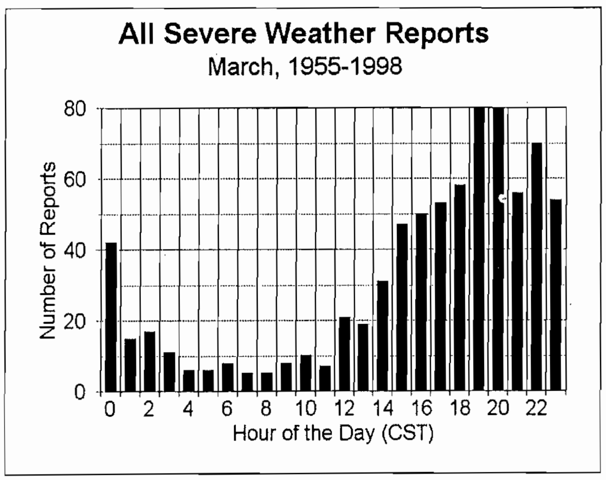

Figure 17. Hourly Distribution of All Severe Weather in March.

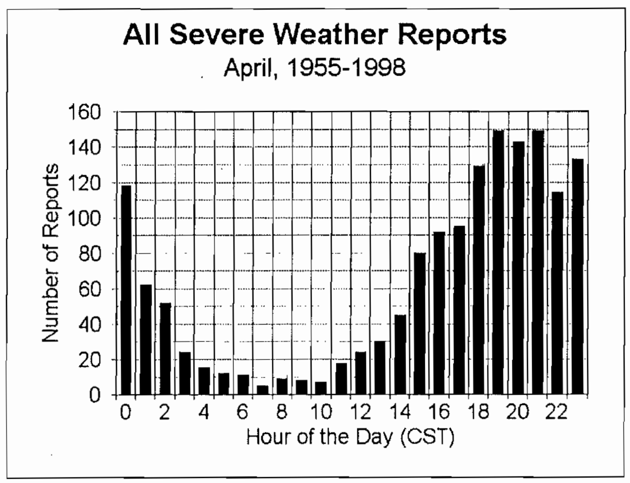

Figure 18. Hourly Distribution of All Severe Weather in April.

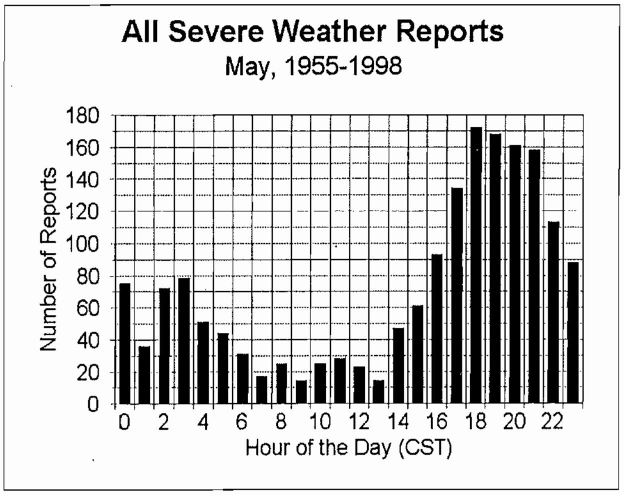

Figure 19. Hourly Distribution of All Severe Weather in May.

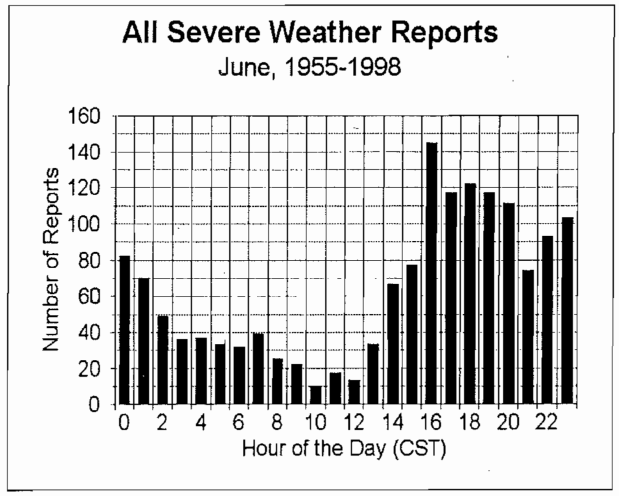

Figure 20. Hourly Distribution of All Severe Weather in June.

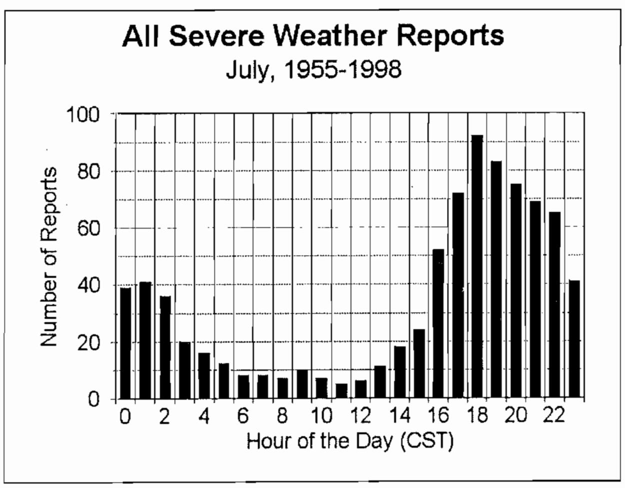

Figure 21. Hourly Distribution of All Severe Weather in July.

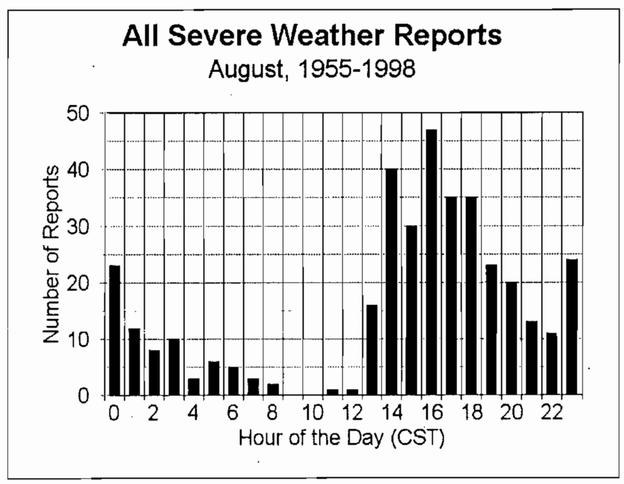

Figure 22. Hourly Distribution of All Severe Weather in August.

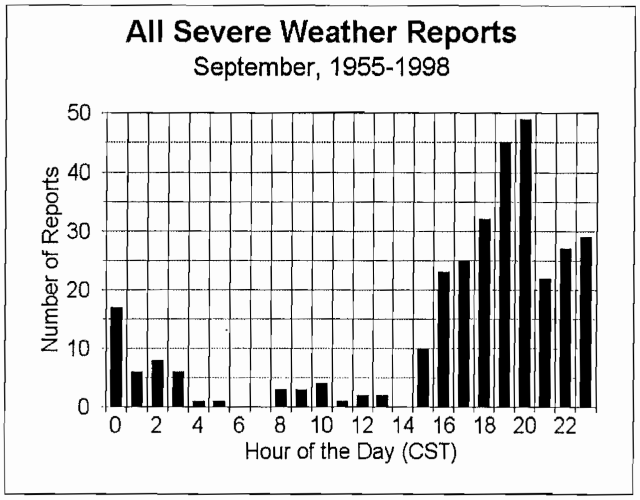

Figure 23. Hourly Distribution of All Severe Weather in September.

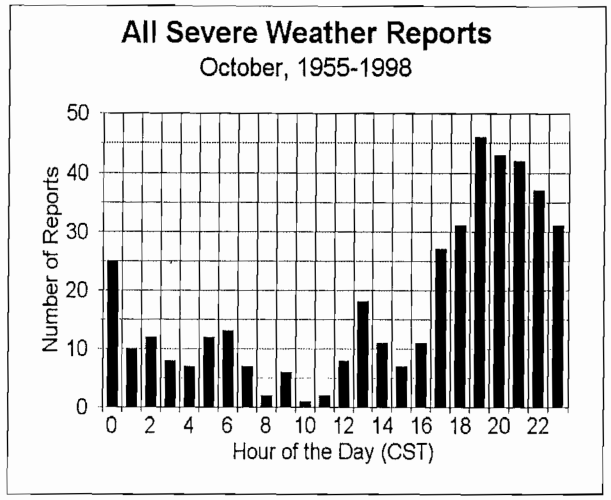

Figure 24. Hourly Distribution of All Severe Weather in October.

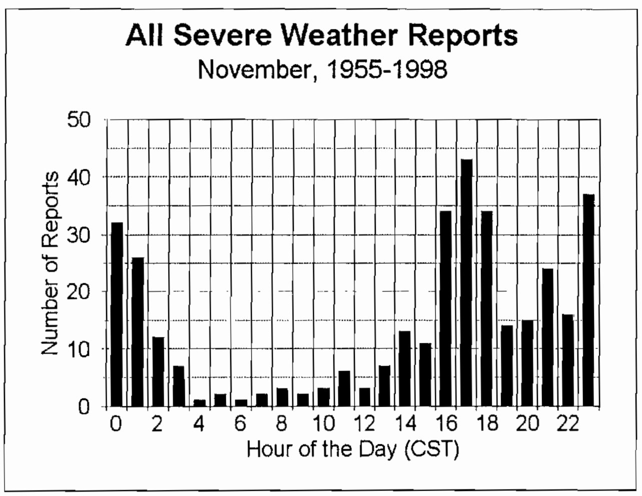

Figure 25. Hourly Distribution of All Severe Weather in November.

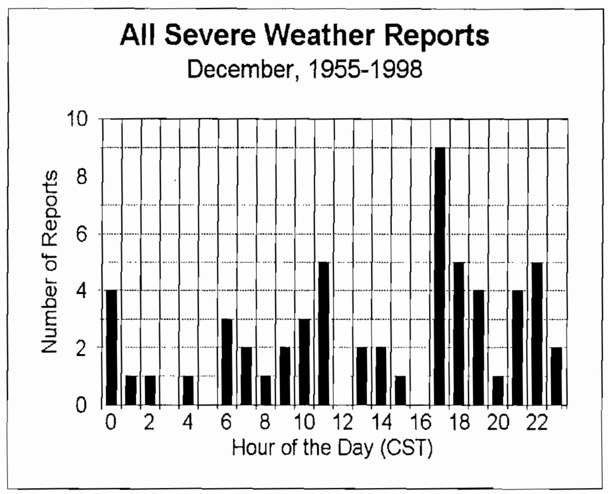

Figure 26. Hourly Distribution of All Severe Weather in December.

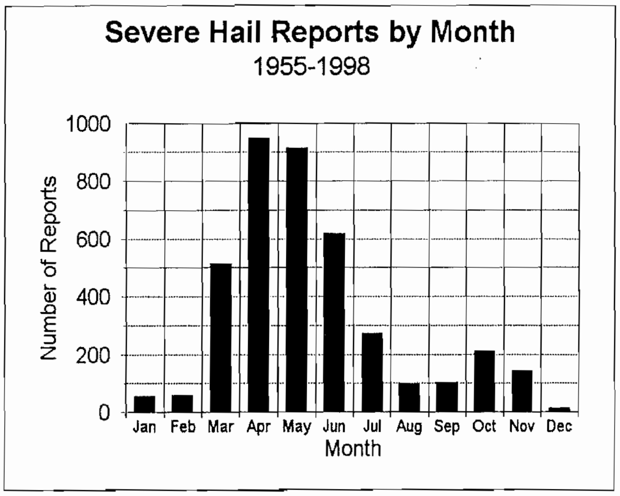

Figure 27. Monthly Distribution of Severe Hail Reports.

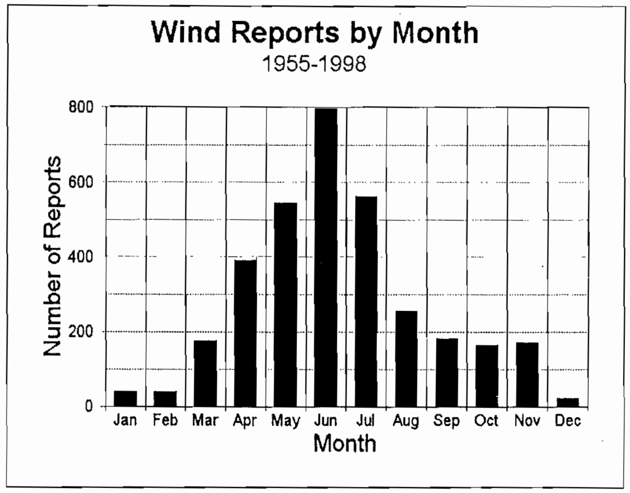

Figure 28. Monthly Distribution of Severe Wind Reports.

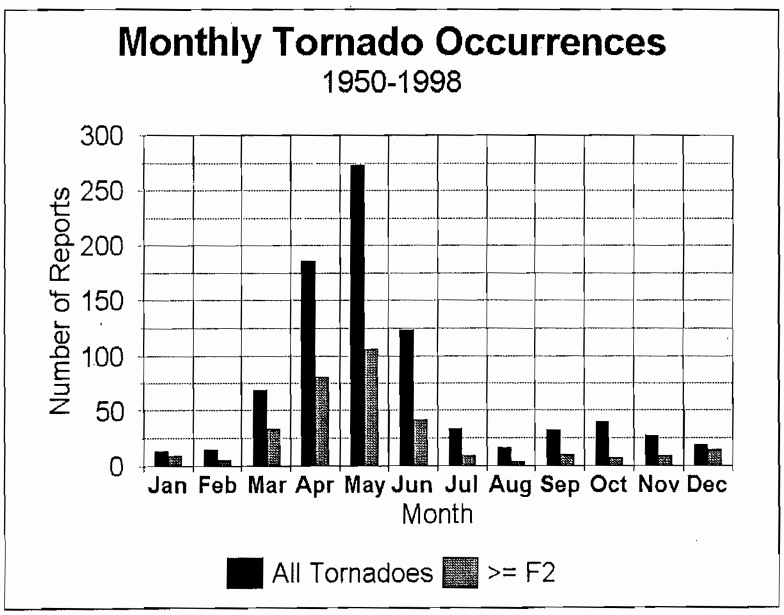

Figure 29. Monthly Distribution of All Tornadoes and Strong (≥F2) Tornadoes.

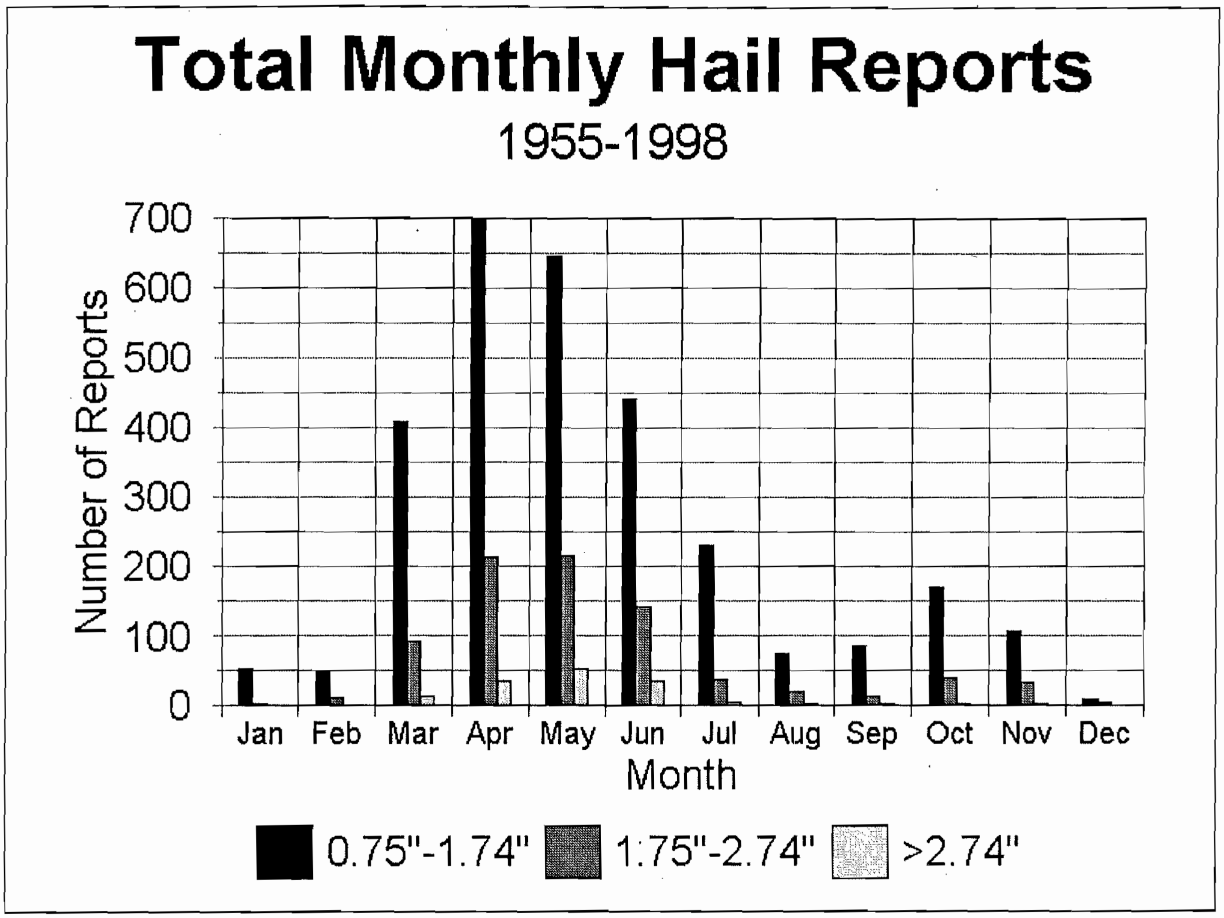

Figure 30. Monthly Distribution of Hail Size Categories.

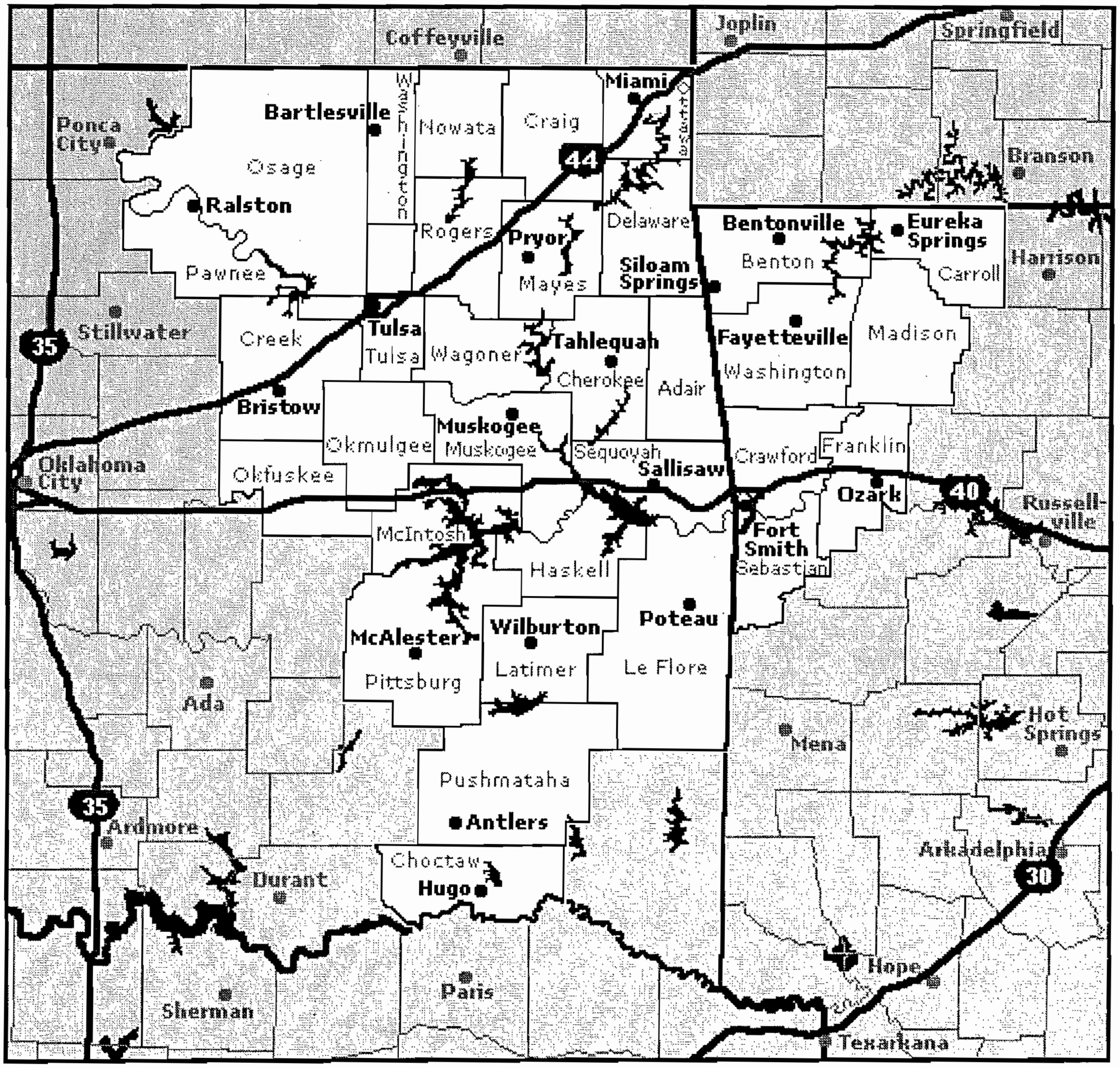

Figure 31. Map of the WFO Tulsa County Warning Area of responsibility covering 25 counties in the eastern third of Oklahoma and 7 counties in northwest Arkansas.