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SEVERE WEATHER CLIMATOLOGY FOR THE NWSFO MEMPHIS COUNTY WARNING AREA

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1. Introduction

One of the most basic tools available to the forecaster is a severe weather climatology showing trends in the annual, monthly, and hourly distribution of severe weather in a given area. Forecasters need to have an understanding of the severe weather climatology in their area of responsibility in order to effectively provide forecasts and warnings of tornadoes and severe thunderstorms.

The Memphis NEXRAD Weather Service Forecast Office (NWSFO) has warning responsibility for 57 counties in the Mid-South area which includes parts of Arkansas, Mississippi, Missouri, and Tennessee (Fig. 1). With the recent expansion of the county warning area (CWA), forecasters are now faced with new challenges associated with the greater diversity and higher frequency of severe weather events within this larger area.

The objectives of this study are to examine the temporal trends of severe weather events which include damaging winds, large hail, and tornadoes for the past 40 to 45 years in the expanded Memphis CWA and to relate these findings to previous climatological research. It is hoped this study will aid forecasters in understanding the characteristics of severe weather in the new CWA in order to be better prepared for future events.

2. Data

Data used in this study were obtained from the National Severe Storms Forecast Center (NSSFC) which maintains a damaging wind and hail database dating back to 1955 and a tornado database dating back to 1950. This database was modified by the CLIMO program (Vescio 1995) which generates useful severe weather statistics for individual CWAs. Damaging wind and hail data from 1972 were not included in the NSSFC database but were supplemented for this study with data obtained from the *Storm Data* publication (NOAA 1972).

Limitations of the data include many non-meteorological factors which have been documented in previous climatological studies (Kelly, *et al.* 1985). These limitations include population density, time of day, presence or absence of spotter networks, proper perception of the event by the public, apathy of the public to report events, and the lack of appropriate measuring devices. Also, Kelly *et al.* (1985) pointed out that while one might try to weight the climatological data in terms of using population data, other demographic factors such as degree of urbanization, highway distribution, education level of the populace, etc., must be considered. However, the fact that no spatial trends are evaluated in this study should minimize any adverse effects of population density limitations.

Another important limitation regarding the tornado database is the fact that the number of tornadoes reported corresponds to how many counties were affected. For example, if a single tornado tracked across two counties, it would appear in the data set as two tornadoes. While this obviously flaws the data in regard to the number of actual tornadoes, one can still use this database to assess the temporal trends of tornadoes, since the majority of multiple-county tornadoes are strong, long-lived tornadoes (F3 intensity or greater) which are not as common as their weaker, shorter-lived counterparts. Thus, it is assumed that there are not enough multiple-county tornadoes to sufficiently contaminate the database.

3. Damaging Wind Climatology

a) Yearly Distribution

In this study, "damaging wind" is defined as a convective wind gust that (1) reaches or exceeds 50 kt (58 mph), and/or (2) results in damage to trees, power lines, or other structures. Since the mid 1950s, the number of damaging wind days (a calendar day on which at least one damaging wind report was received) has steadily risen, with damaging wind reports rising dramatically. Figure 2 illustrates these trends and reveals that damaging wind reports increased markedly in the 1970s and again in the 1990s.

Although the rise in damaging wind days during these periods might have a meteorological explanation, the dramatic increase in damaging wind reports can most likely be attributed to improvements in the NWS spotter network and an increase in the Mid-South population. An organized amateur radio spotter network was implemented in the mid 1970s for the Memphis CWA, while the NWS warning verification program was begun in 1980 (Hales 1993).

b) Monthly Distribution

The monthly distribution of damaging wind events (Fig. 3) reveals that June is the most active month for damaging wind events in the Memphis CWA. Also, the majority of damaging wind events occur between March and July, with the three-month period of April through June accounting for nearly 50 per cent of all the reported damaging wind events during the year.

Previous studies of damaging wind climatologies (Kelly, *et al.* 1985) indicate that for the entire United States, the summer months of June through August account for nearly 55 per cent of all yearly reports. The fact that the highest frequency of damaging wind events in the Memphis CWA occurs earlier in the year is not surprising, since severe thunderstorms occur earlier in the year for the southern U.S. as compared with the rest of the country. A small secondary maximum is also evident in November for the Memphis CWA, which coincides with the previously documented November peak in severe weather throughout the southeastern U.S. (Kelly, *et al.* 1985).

c) Hourly Distribution

From Fig. 4, it is seen that in every season of the year, damaging wind reports reach a maximum during the late afternoon and early evening hours, specifically between 4 p.m. and 8 p.m. Local Standard Time (LST). In fact, the hours between noon and midnight account for nearly 75 per cent of all damaging wind reports. This is not surprising, since most damaging wind reports are the result of convection which follows a diurnal peak during the late afternoon and early evening.

4. HAIL CLIMATOLOGY

a) Yearly Distribution

The NWS classifies a thunderstorm as being severe if it produces hail equal to or greater than ¾ inch in diameter. Therefore, this study only examines reports of hail that meet or exceed this NWS criterion for severe thunderstorms. The annual distribution of hail reports and hail days (Fig. 5), like the damaging wind annual distribution, reveals an upward trend in the number of reported hail events in the Memphis CWA. The first substantial increase in hail reports was seen during the 1970s, with a decrease around the early 1980s, and then another substantial increase in reports since the mid 1980s (which is the same trend seen in Fig. 2). Although the number of reports has risen markedly since the mid 1980s, the number of hail days has increased only slowly, with not much difference seen since the 1970s. This once again emphasizes the fact that improved communications, increased verification efforts and a larger regional population have helped to increase the number of reports gathered per severe weather event.

b) Monthly Distribution

From Fig. 6, it is seen that hail occurs most frequently in the Memphis CWA during the months of March through June (74 per cent of all reports), with May being the most active month. Also, a secondary maximum of reports is observed for November. These findings are consistent with other documented hail climatologies for the contiguous U.S. (Kelly, *et al.* 1985 and Sammler 1993).

Monthly hail reports in this study were divided into three groups based on the size of the hail reported:

Large size hail:	0.75-1.74 in diameter
Giant size hail:	1.75-2.74 in diameter
Enormous size hail:	2.75 in or greater in diameter

Figure 6 shows that the number of giant hail reports reaches a maximum in May, nearly equal the number of large hail reports. This monthly distribution of hail sizes also reveals a greater percentage of large hail compared with giant hail during the cool season (January-March) than in the warmer months, which coincides with earlier findings by Sammler (1993). Reports of enormous hail are almost exclusively a March through June phenomenon, with November being the only other month in which enormous hail was reported.

c) Hourly Distribution

Figure 7 shows the hourly distribution of hail occurrences and demonstrates that the hourly hail distribution is strongly skewed toward the late afternoon and early evening hours for all seasons of the year. In fact, the hours between 4 p.m. and 8 p.m. account for 45 per cent of all hail reports, with the afternoon and evening hours between noon and midnight accounting for 86 per cent of all hail reports. This temporal trend of hail reports is the same for all seasons, with the spring months receiving the greatest amount of reports at all hours of the day.

5. Tornado Climatology

a) Yearly Distribution

From 1950 to 1993, 613 tornadoes were reported in the Memphis CWA, with an average of 14 occurring each year. These tornadoes killed 227 people, or about five each year. Tornadoes occurred during each of the 44 years, during every month of the year, and at all hours of the day.

A county-by-county analysis of reported tornadoes in the Memphis CWA indicates that population plays a large role in the number of reported tornadoes in the area. Over 80 per cent of the tornadoes reported in the CWA from 1950 to 1993 occurred in Shelby County, Tennessee (the area's most populous county, including the Memphis metropolitan area), with fewer tornadoes reported farther away from Memphis. As previous studies (McNulty, *et al.* 1979) have noted, more densely populated areas tend to generate higher numbers of reported tornadoes. But at the same time, it is interesting to note that no one was killed by tornadoes in Shelby County between 1950 and 1993. The lack of deaths in the county might be attributed to the fact that most of the major television and radio stations are in the immediate area, so dissemination of NWS warnings may be better than elsewhere in the CWA; but more likely it is related to the fact that the greater numbers of tornado reports include mainly weak tornadoes, not likely to be deadly in any event.

b) Monthly Distribution

Most Mid-South tornadoes occur during the spring months, with 52 per cent of the annual total reported during March, April, and May. Of these months, April is the most active, with 22.5 per cent of the yearly total. The least active tornado months are August and October, with 1.6 per cent of the annual total in each month. Figure 9 illustrates the monthly distribution of tornadoes.

Previous tornado climatologies (McNulty, *et al.* 1979), have noted the presence of a secondary "tornado season" during November and December over the southeastern United States. Analysis of the Memphis CWA tornado statistics clearly points out the presence of such a secondary maximum. In fact, 21 per cent of the annual tornado reports occur during the late autumn and early winter months, with 16.9 per cent occurring in November and December. Some of the area's most damaging and deadly tornadoes have occurred during the late autumn and early winter months.

c) Hourly Distribution

Mid-South tornadoes have occurred at all times of the day and night (Fig. 10), but strike most often between 3 p.m. and 7 p.m. LST which coincides with the time of maximum diurnal heating. Closer inspection of the hourly distribution graph indicates that strong tornadoes outnumber weak tornadoes during the morning hours between 6 a.m. and 9 a.m., which is opposite from the other hours of the day.

d) Intensity

Tornado researchers use the Fujita scale of tornado intensity to classify tornadoes according to the amount of damage they produce (Schaefer, *et al.* 1979). This study classifies tornadoes according to scale and uses the terms weak (F0 and F1), strong (F2 and F3), and violent (F4 and F5) in discussing the various statistics.

Of the 613 tornadoes reported in the area from 1950 to 1993, 606 have been assigned F-scale ratings. Of this total, 51.7 per cent (313) were classified as weak, 44.2 per cent (268) as strong, and 4.1 per cent (25) as violent. Only one F5 tornado has been reported in the CWA since 1950, and it struck Fayette County, Tennessee, on March 21, 1952, around 10 p.m. causing seven deaths and 50 injuries.

Figure 11 shows the number of tornadoes in each intensity category and illustrates several interesting characteristics of Mid-South tornadoes. First, statistics for the CWA seem to differ from statistics in other national tornado climatologies. Numbers from the Memphis CWA indicate that 4.1 per cent of tornadoes are violent, 44.2 per cent are strong, and 51.7 per cent are weak, while national statistics (Schaefer, *et al.* 1980) reveal that 2 per cent of all tornadoes are violent, 35 per cent are strong, and 63 per cent are weak. This is somewhat to be expected since the Mid-South area is adjacent to the Plains states ("tornado alley") where strong to violent tornadoes are more common than anywhere else in the country.

Examination of the monthly distribution of tornadoes by intensity category (Fig. 12) shows that weak and strong tornadoes reach a maximum during April, while violent tornadoes peak in March. The figure also shows that violent tornadoes strike the area between February and May, with no violent tornadoes being reported between June and January. It is also interesting to note that the curves for weak and strong tornadoes are somewhat similar, but that strong tornadoes outnumber weak ones during the first four months of the year.

e) Tornado Deaths

From 1950 to 1993, tornadoes killed 227 people in the CWA, an average of five each year. Over 40 per cent of the tornado deaths in the CWA occurred in association with a single outbreak of tornadoes on March 21-22, 1952, when 17 tornadoes struck the four-state area killing 98 people and injuring more than 500. This outbreak also produced the area's only recorded F5 tornado.

Most tornado deaths in the Mid-South occurred after dark, as most were reported between 8 p.m. and 10 p.m. LST, with a secondary maximum noted around midnight. No one was killed by tornadoes between 3 a.m. and 9 a.m. LST. The fact that most tornado deaths occur at night is also documented in other studies (Schaefer, et al. 1980) which conclude that darkness (not being able to see the tornado coming) and possible lack of access to warnings work together to make tornadoes that strike after dark more deadly.

Analysis of tornado deaths on a monthly basis shows that March, with 112 deaths, is by far the deadliest tornado month in the CWA, even though there are more tornadoes, on average, in April. This can be attributed in part, of course, to the 1952 outbreak; but it also reflects the fact that March is the most active month for violent tornadoes in the area, and that violent tornadoes produce 56 per cent of all tornado deaths in the Mid-South (Fig. 13.). Weak tornadoes, which make up the majority of Mid-South tornadoes, cause only about 3 per cent of the deaths in the Memphis CWA, while strong tornadoes are to blame for about 38 per cent of the area's tornado deaths.

6. Conclusion

Analysis of the Memphis CWA severe weather statistics reveals that June is the peak month for damaging wind reports, May is the peak month for hail reports, and April is the peak month for tornado reports. Figures 14 and 15 show the monthly and hourly distribution, respectively, of all severe weather reports for the area, including damaging wind, hail, and tornadoes. Figure 14 illustrates the fact that while the traditional severe weather season in the CWA is thought to be March through May, the most active season actually extends from April through June. Also, from Fig. 15 it can be seen that severe weather reports peak in the late afternoon and early evening hours which follows the expected diurnal trend for convective activity.

Tornadoes are found to pose a significant threat to the area, with an average of 14 being reported in the CWA each year. The majority of tornadoes in the CWA are weak, but a significant number of deadly strong and violent tornadoes affect the region each year. In fact, the number of strong and violent tornadoes in the Mid-South exceeds the national averages (Livingston and Schaefer 1993). Violent tornadoes, while relatively rare, kill more Mid-South residents than weak or strong tornadoes combined.

This severe weather climatology of the Memphis CWA illustrates that meteorologists who issue forecasts and warnings for the area have a formidable task, since the area is highly susceptible to all forms of severe weather. It is hoped that forecasters, armed with new technologies such as the WSR-88D and a firm knowledge of the area's severe weather climatology, will be able to issue the most timely and effective warnings.

Acknowledgements

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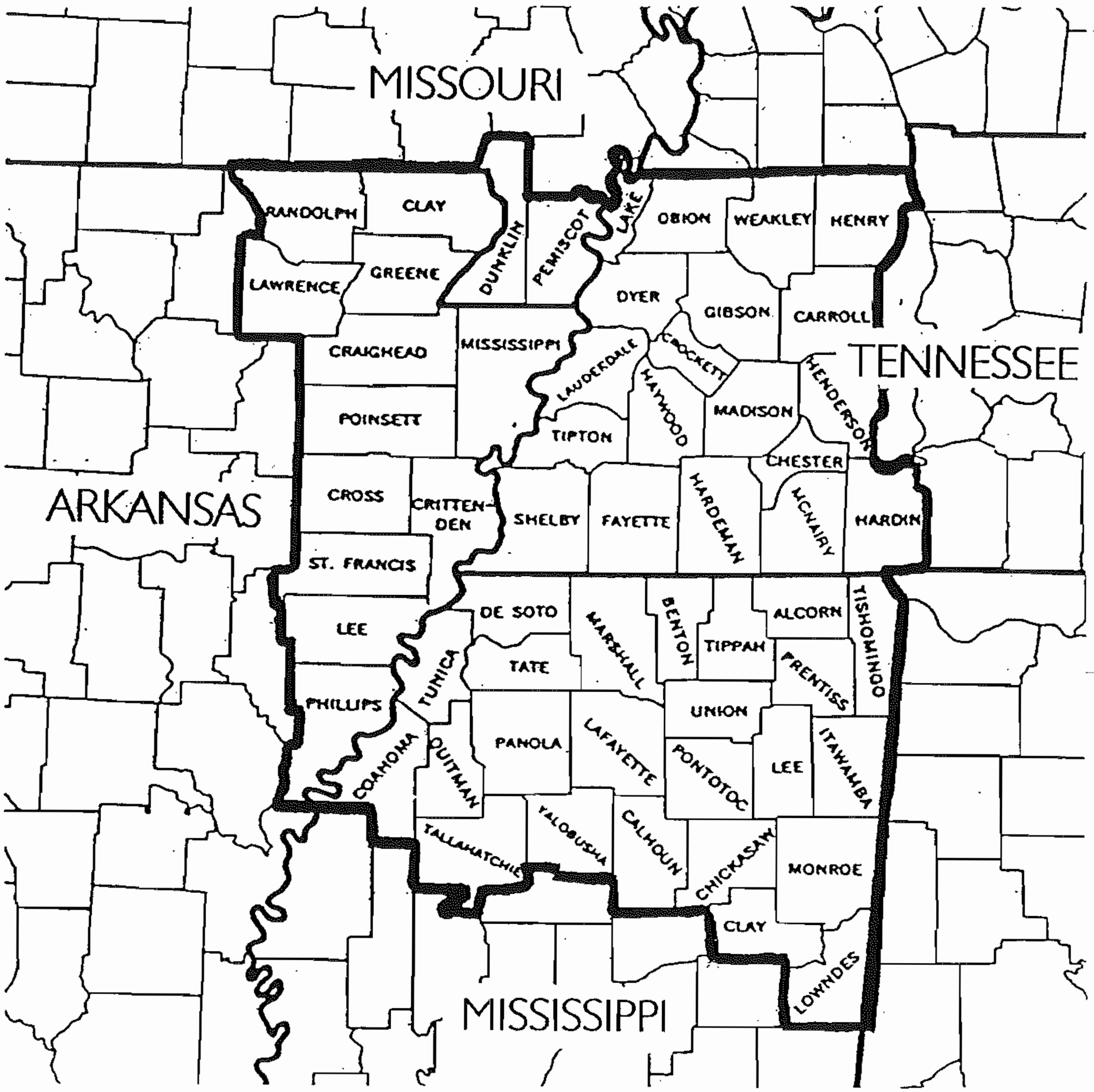
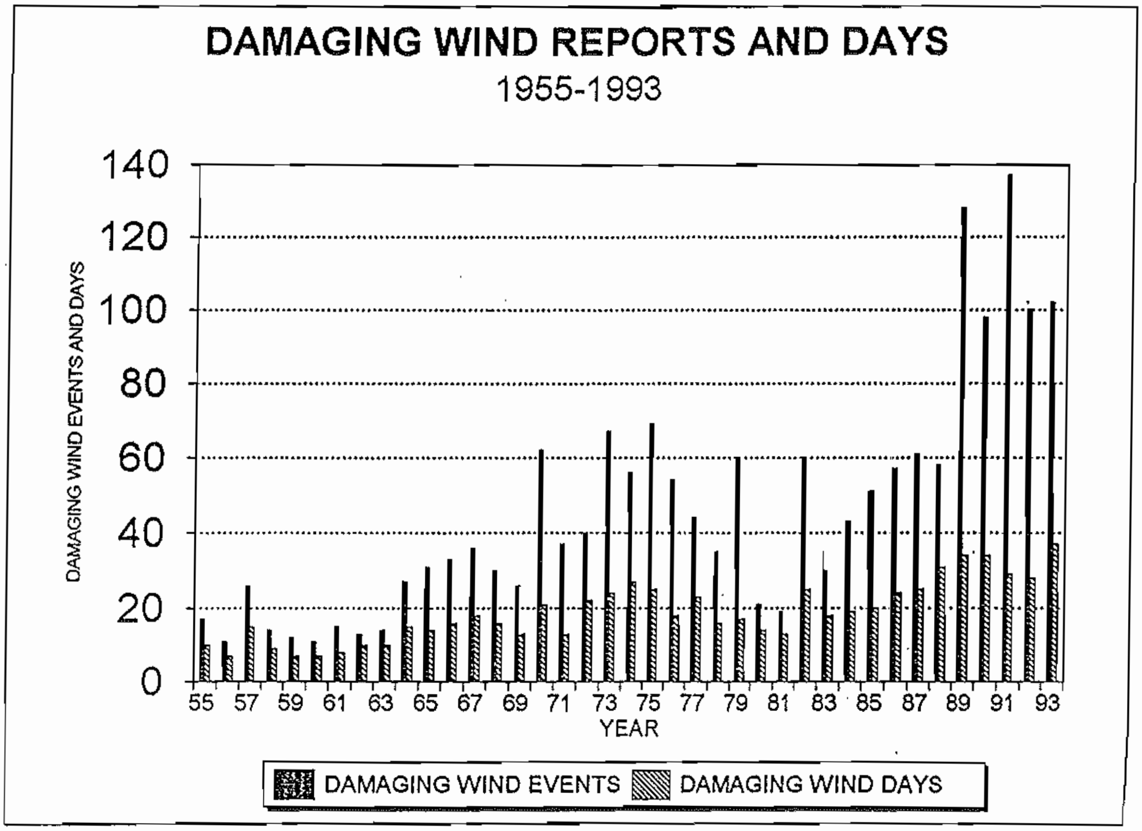


Fig. 1. WFO Memphis County Warning Area (CWA)



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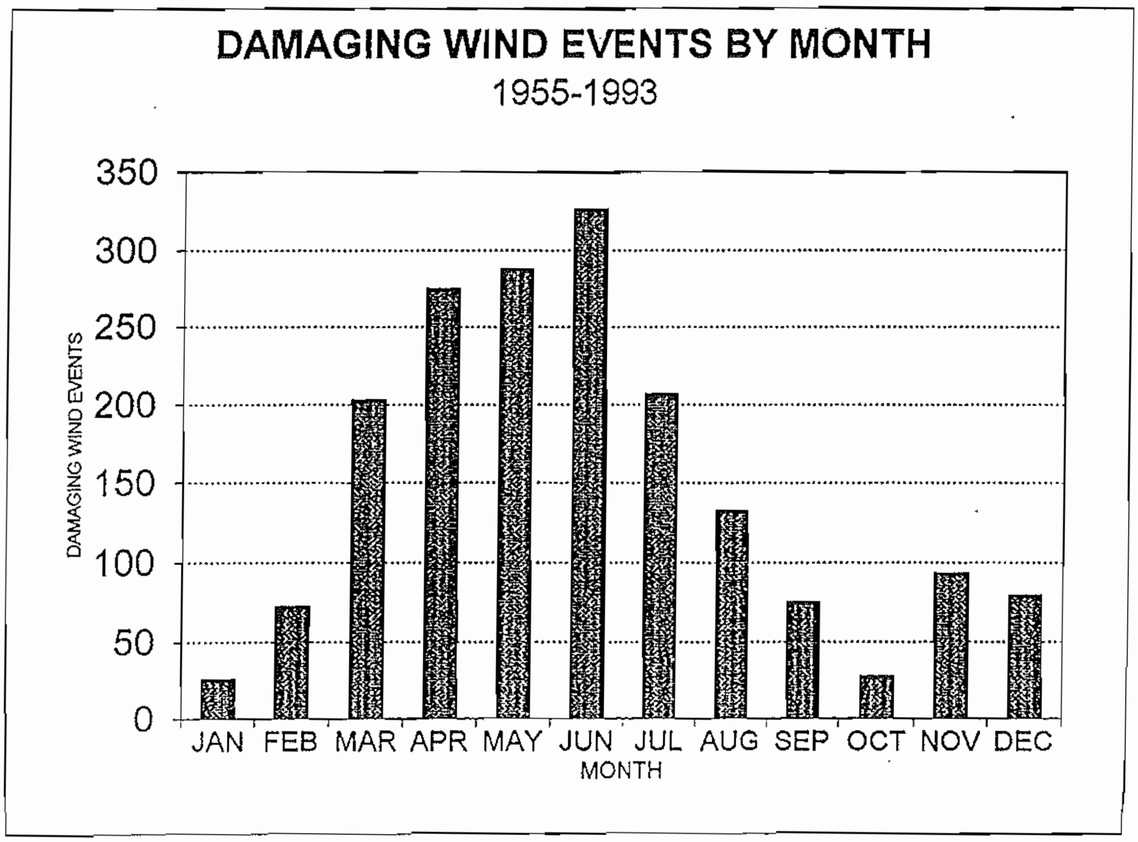

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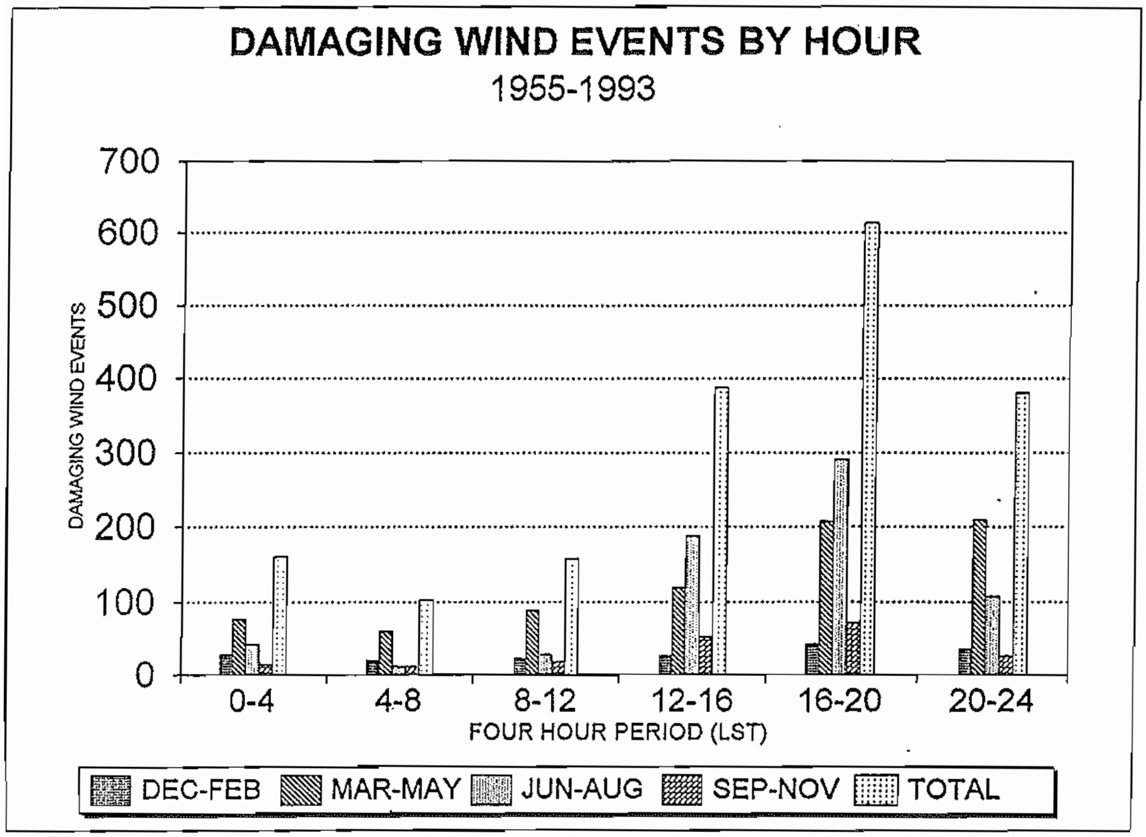

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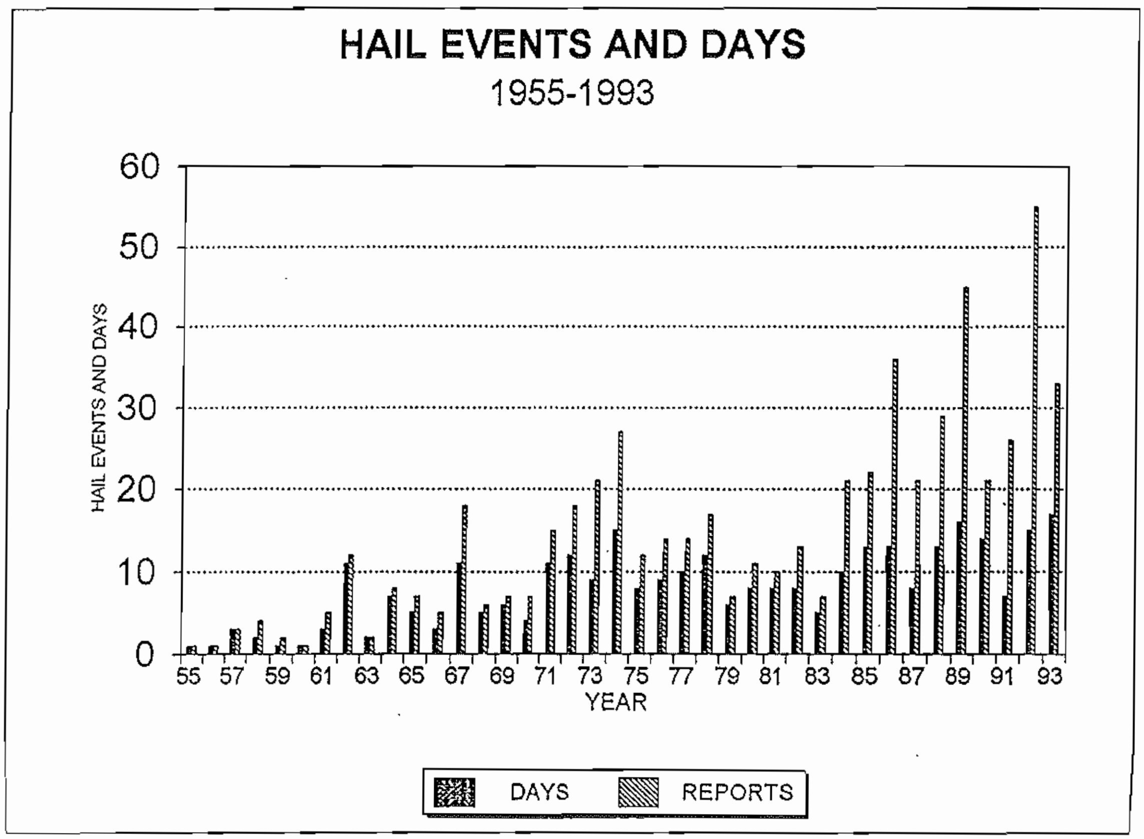


Figure 5.

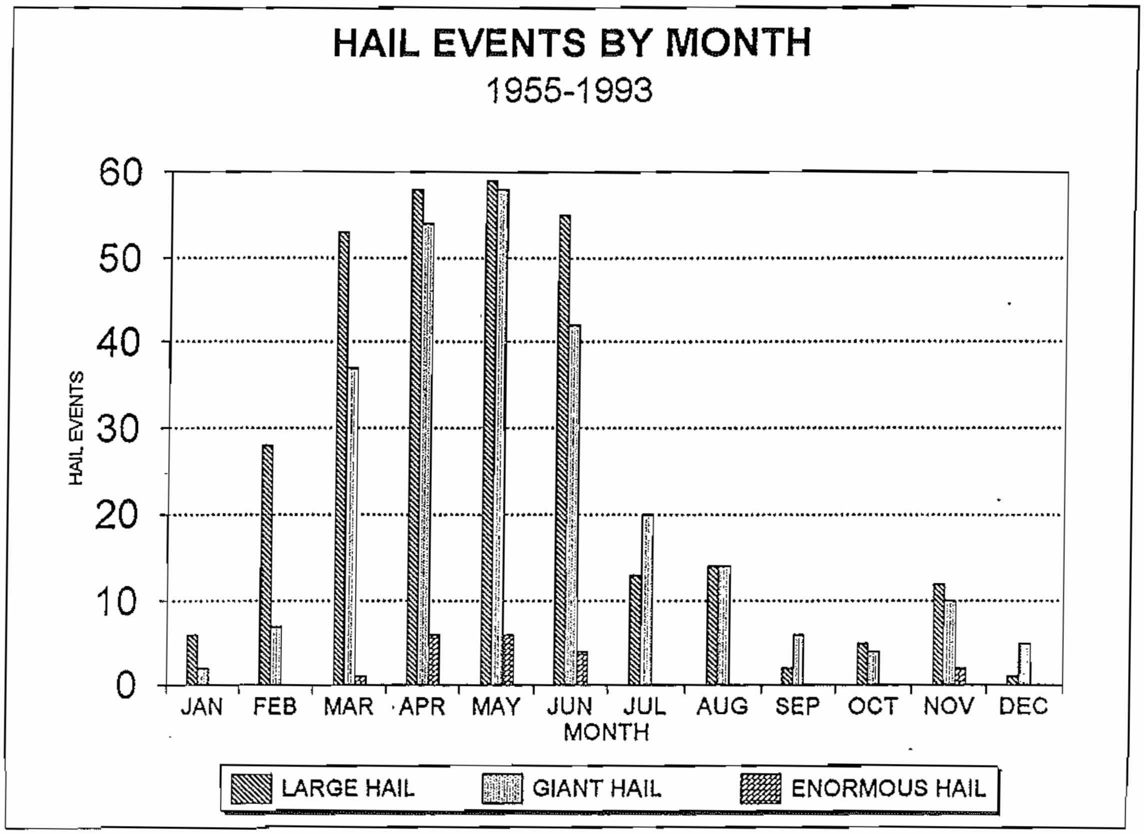


Figure 6.

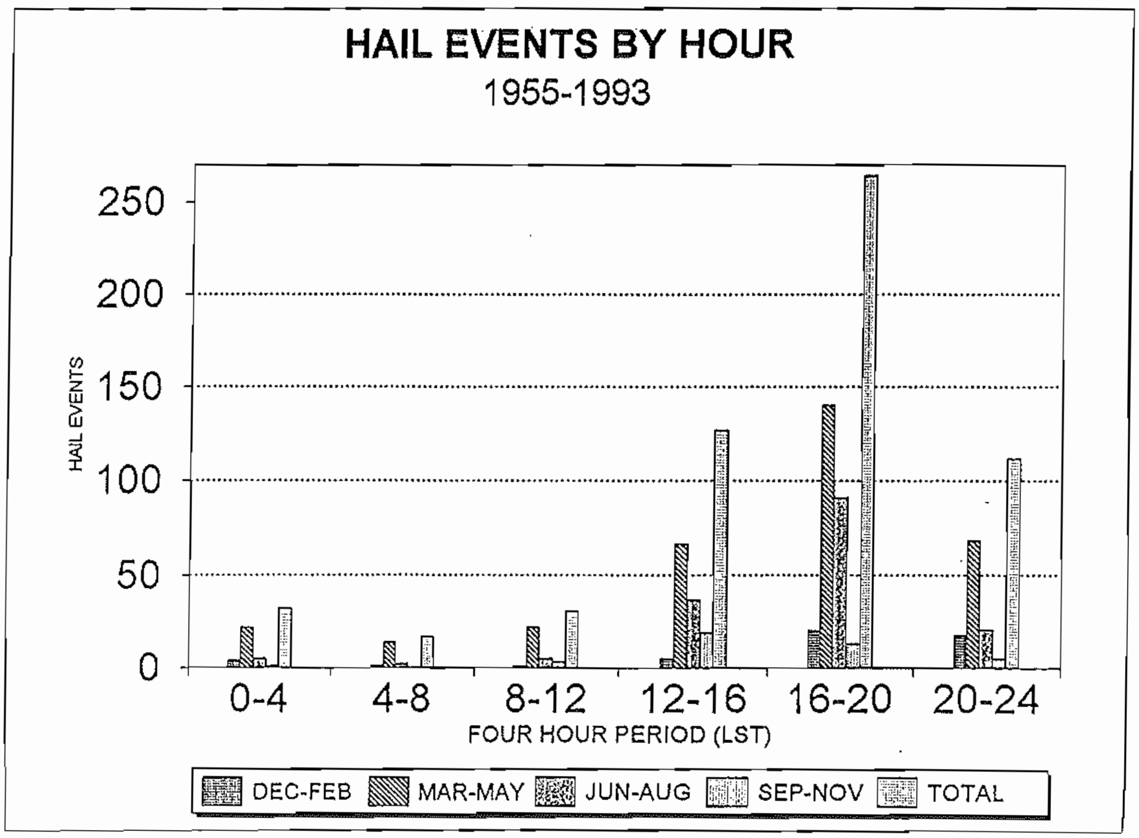
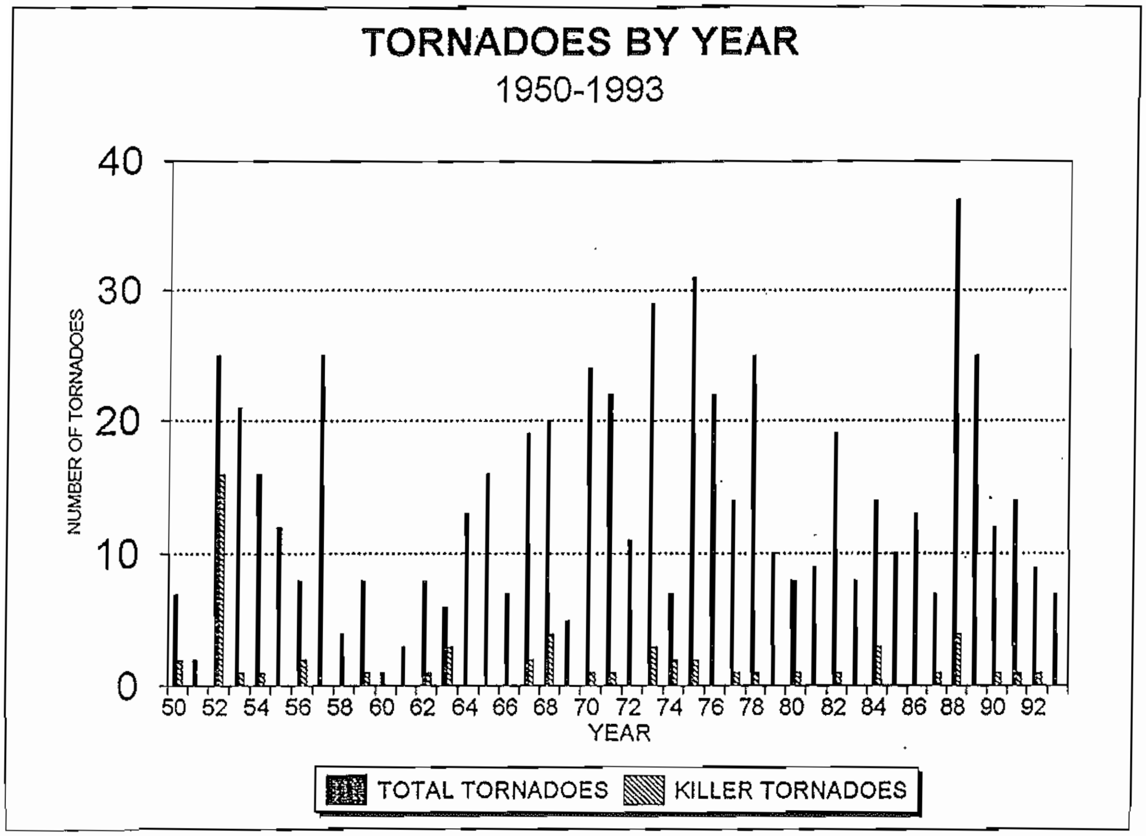


Figure 7.



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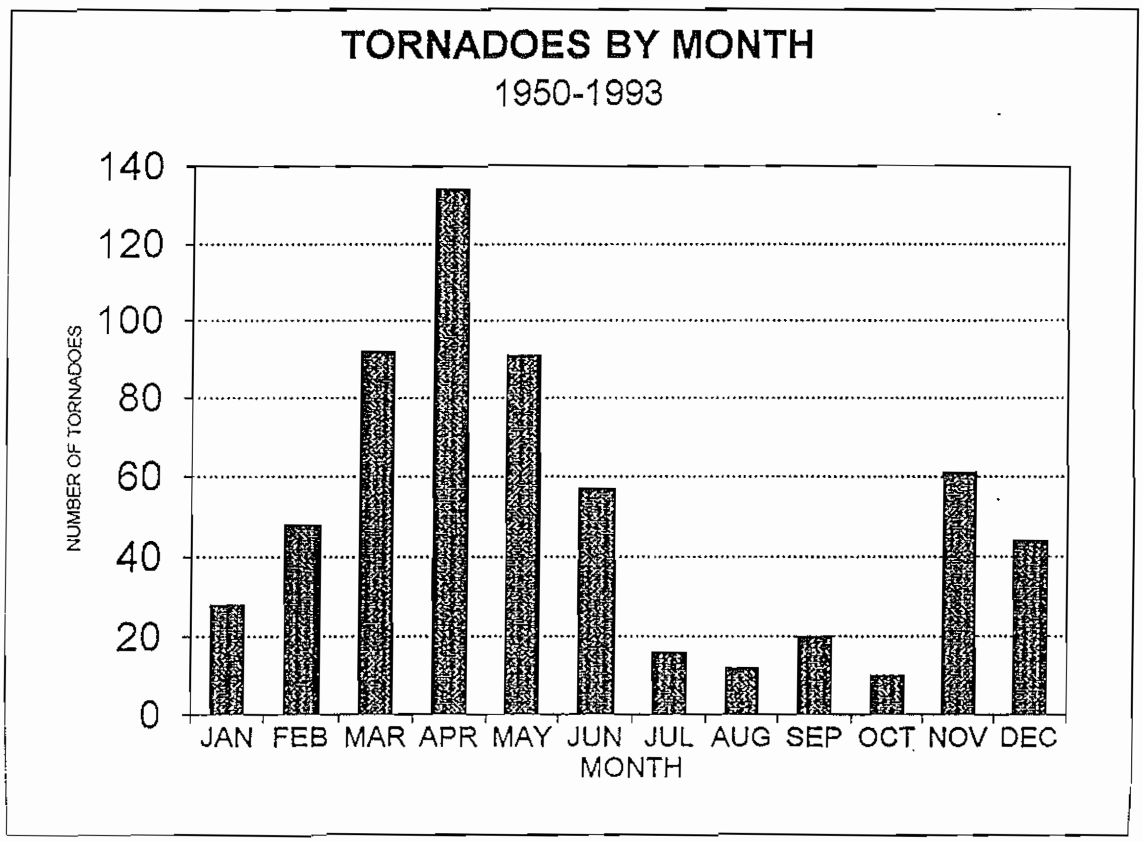


Figure 9.

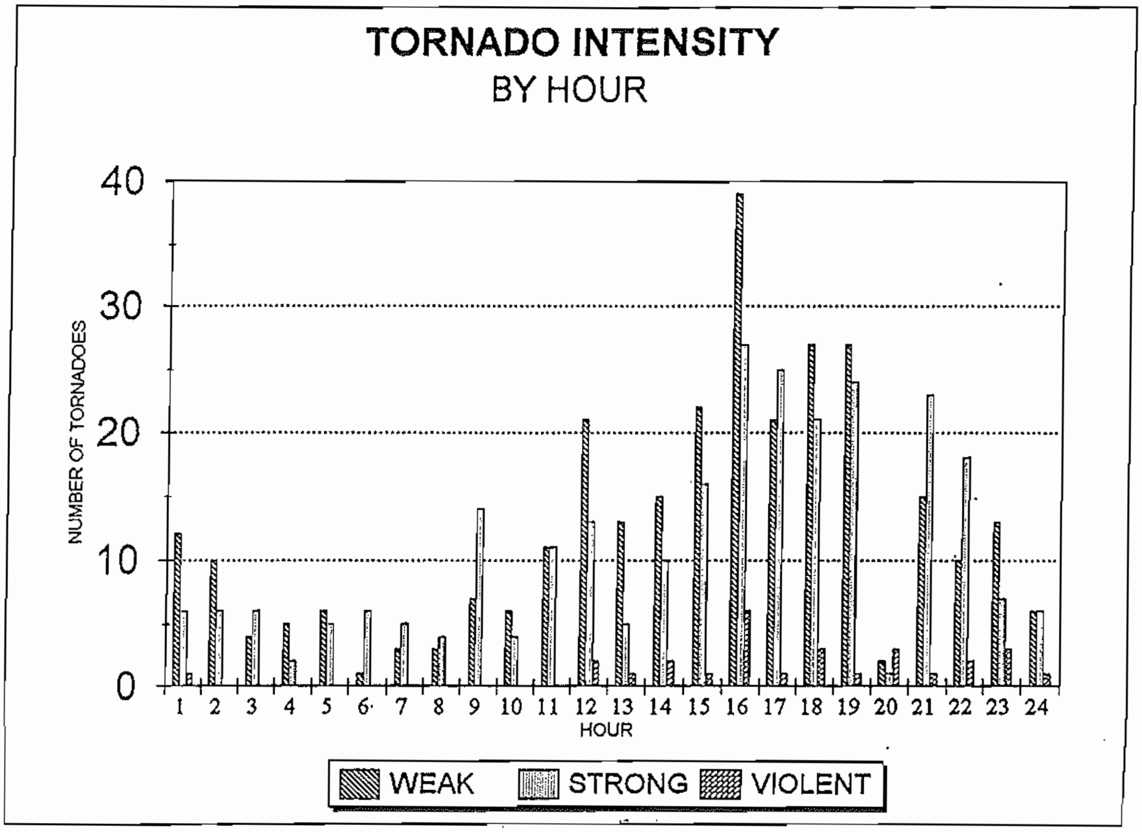


Figure 10.

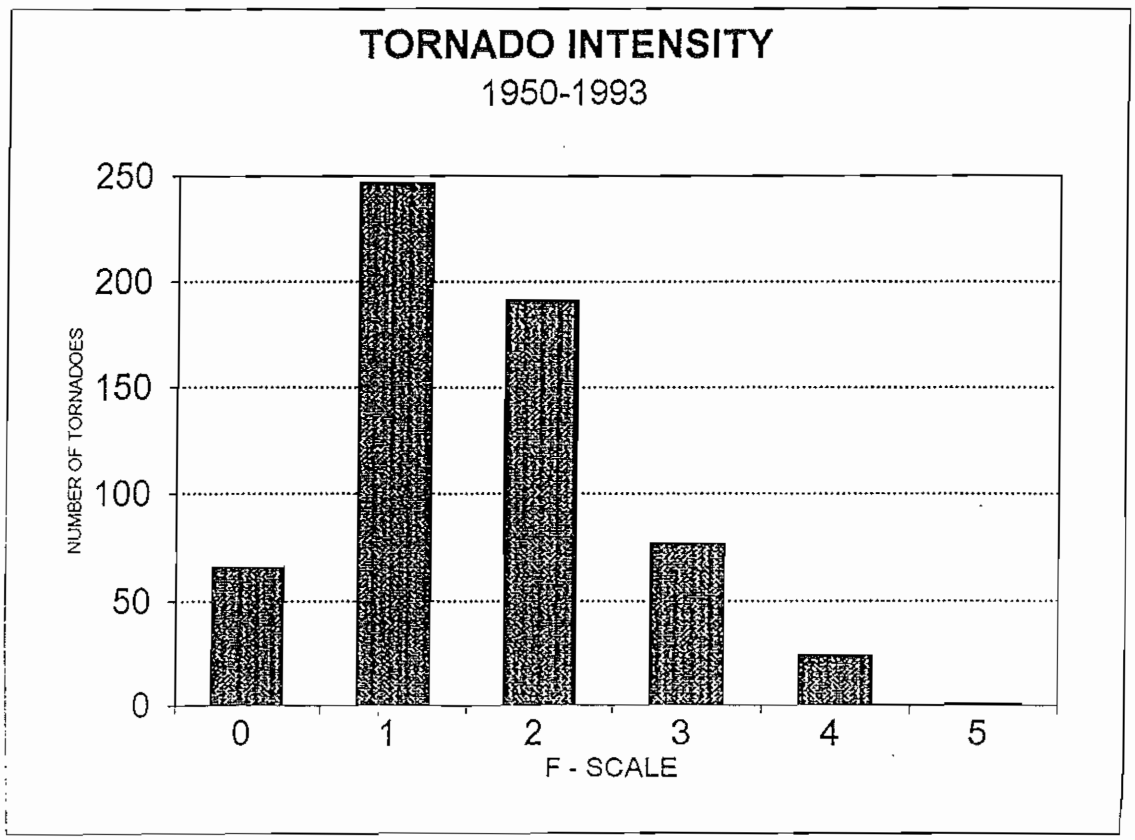
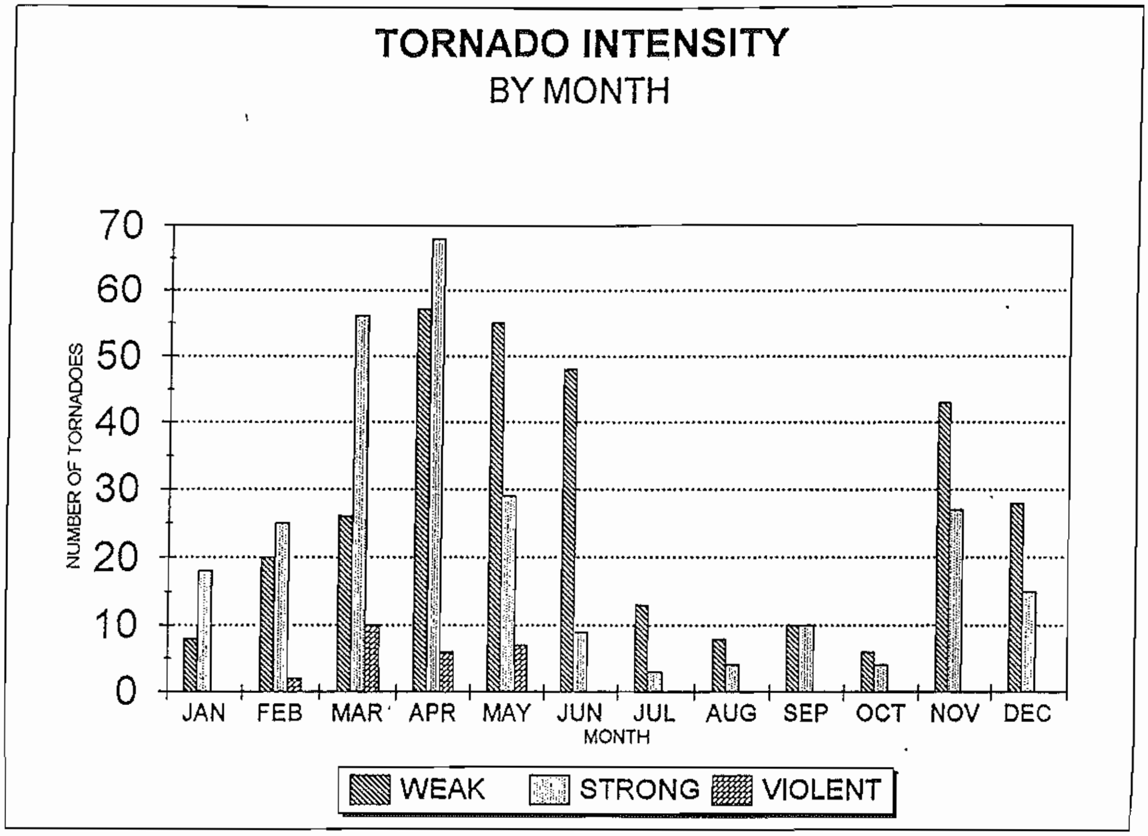


Figure 11.



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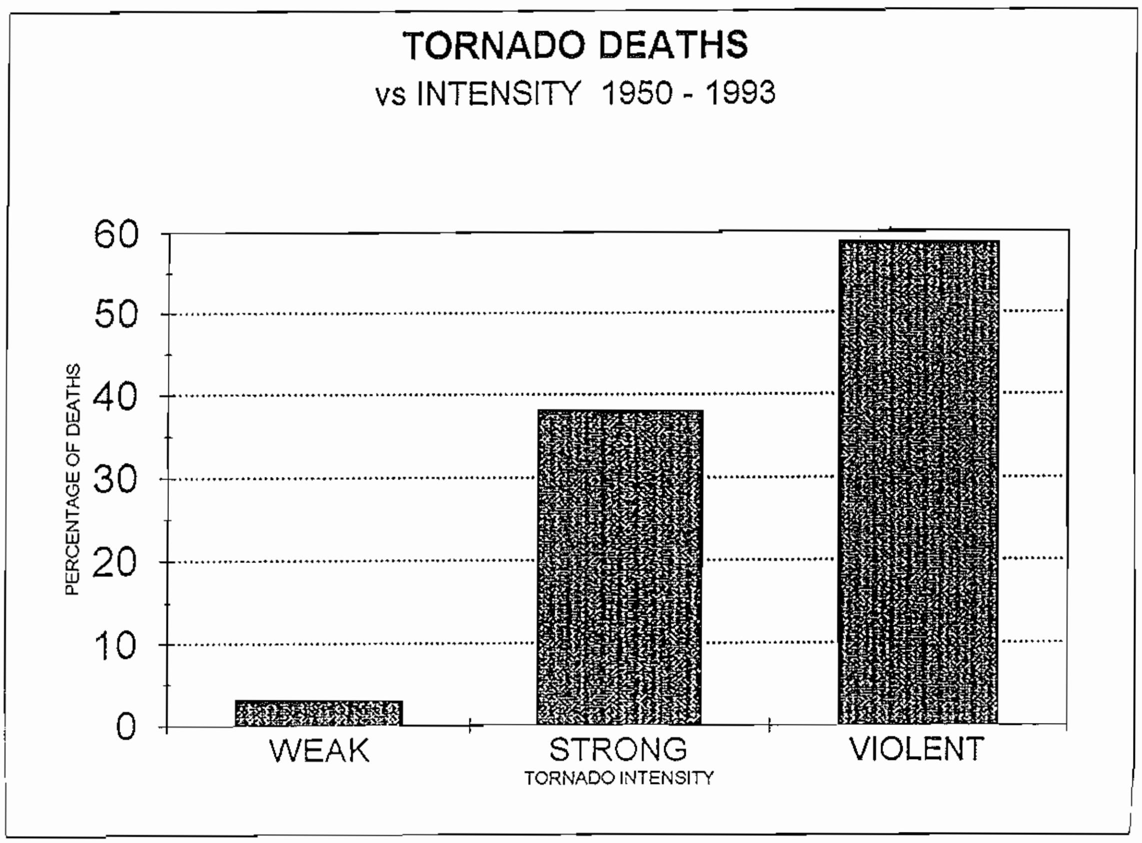

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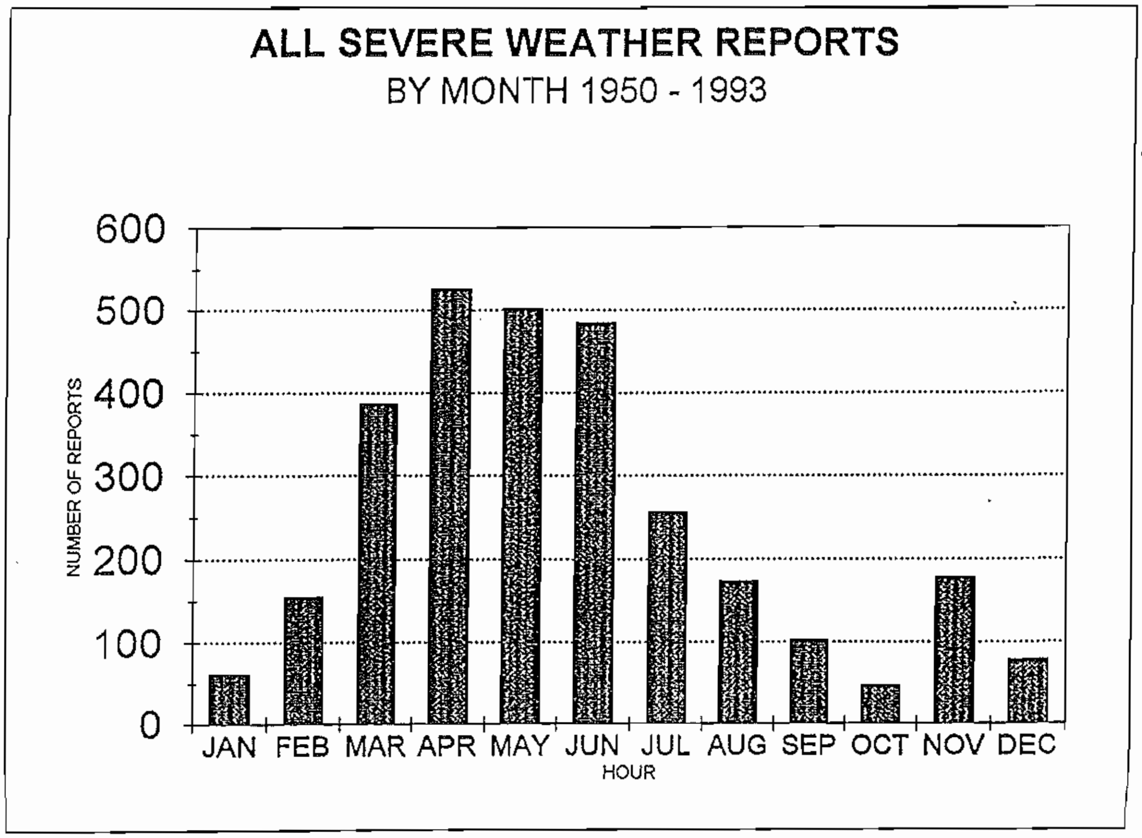

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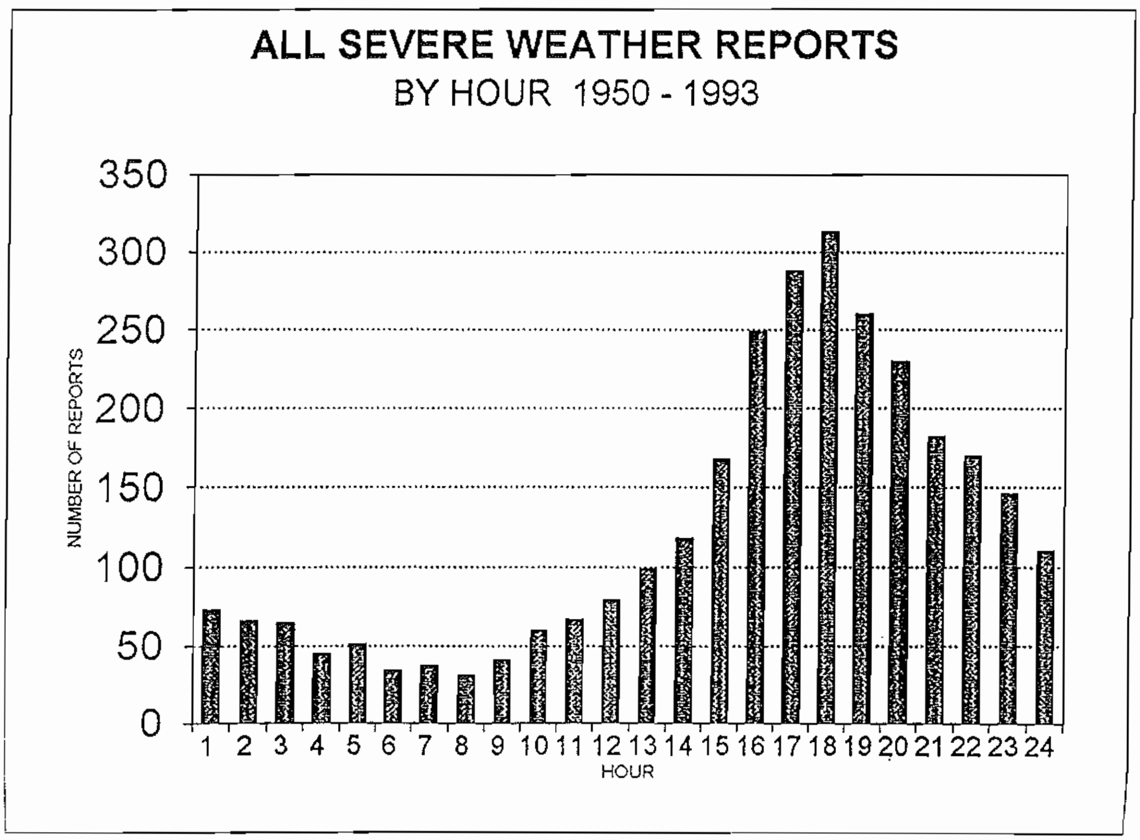

Figure 15.