NOAA Technical Memorandum NWS SR-195

A SEVERE WEATHER CLIMATOLOGY FOR NWSFO FORT WORTH'S MODERNIZED WARNING AREA

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March 1998

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I. Introduction

As a result of the National Weather Service (NWS) Modernization and Restructuring, significant operational changes have occurred in the 1990s at the NWS Forecast Office in Fort Worth (FTW). One of these changes resulted in a reconfiguration of the office's County Warning Area (CWA). At the beginning of 1995, FTW was responsible for issuing severe weather warnings for a 57 county area in North Central Texas. By early 1997, the CWA had been reconfigured to include 48 counties (Figure 1). The data used in this study are based on these 48 counties. Recently, the warning responsibility for Haskell and Throckmorton counties was transferred to the weather office in San Angelo, Texas, leaving 46 counties in FTW's CWA. Eventually, FTW's public forecast responsibility will also be modified to encompass this same set of counties.

FTW's CWA is rather diverse in terms of both population and weather. The CWA, which is within the southern portion of what is popularly known as "Tornado Alley", includes highly populated urban areas, as well as rural areas with much smaller population bases. U.S. Interstate 35 runs north-south through the middle of the CWA, with the greatest population densities along and east of the highway. As Figure 2 shows, population density generally varies from less than 10 persons per square mile in several of the western counties to 2106 persons per square mile in Dallas County. It should be obvious how the severe weather climatology for these counties would reflect the population differences.

According to the latest U.S. Census, the population of the CWA is 5,201,252 (Rand McNally 1997). Based on population, the largest counties are Dallas and Tarrant with 3,022,913 total residents. These two counties and the eight surrounding counties make up the Dallas/Fort Worth Metroplex, and represent over 75 percent of the population of the 48-county CWA. Another population maximum (380,211 people), representing the Waco-Temple-Killeen area, is located in Mclennan and Bell Counties.

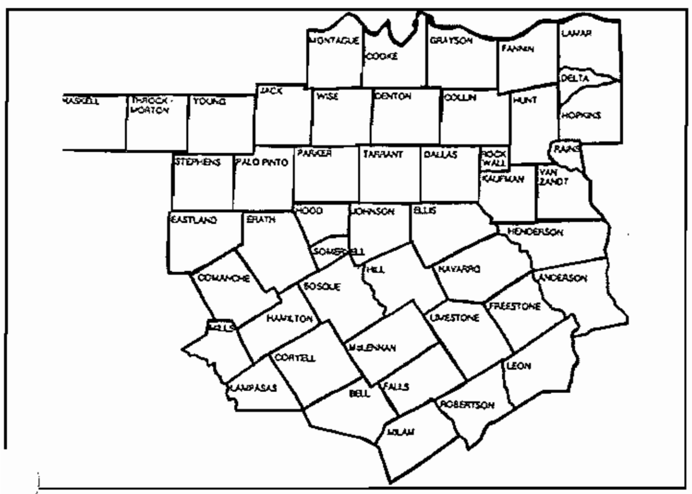

Figure 1 FTW's County Warning Area

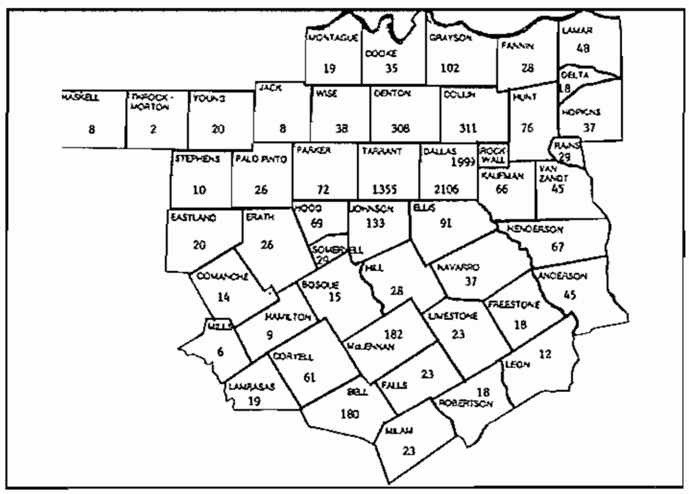

Figure 2 County Population Density (people per square mile)

The Fort Worth NWS office invests a great deal of effort on weather preparedness and safety, and in working with local Emergency Management personnel. There is high interest in the SKYWARN program (the NWS's storm spotter network) in the DFW Metroplex and Waco/Temple areas, and thus the number of severe weather reports is high. The remainder of the CWA varies greatly in its interest and involvement in the observing and reporting of severe weather. The pine and hardwood forests which make up the eastern third of the CWA can limit the observing, and therefore the reporting, of severe weather. This visibility hinderance is not as great a factor west of I-35, but there are several other considerations, including the lack of towns and the small population, that make obtaining severe weather reports difficult.

The weather across the CWA is greatly influenced by the Gulf of Mexico, the moisture source for a large portion of the United States east of the Rocky Mountains. The climate across the far western portion of the CWA, consisting of rolling plains, is relatively dry with an average annual rainfall of less than 26 inches. The piney woods of East Texas make up the eastern portion of the CWA, where average annual rainfall exceeds 46 inches (Bomar 1995).

The greatest meteorological threat to life and property in North Central Texas comes in the form of severe thunderstorm phenomena such as tornadoes, high wind, large hail, flash flooding, and lightning. NWS 1995 defines a severe thunderstorm as one which produces a tornado, hail with a diameter of at least three-quarters of an inch, or convective wind gusts that either result in damage or reach at least 50 knots (58 miles per hour). These storms can occur throughout the year and at all times of day. Due to the close proximity of moisture from the Gulf of Mexico, a forecaster in the Southern Plains must always consider the possibility of severe convection.

The purpose of this study is to document severe weather trends and produce a severe weather climatology that meteorologists can use as background knowledge for severe thunderstorm forecasting. Some of the tendencies that will be documented include the most likely time of year and time of day for severe weather occurrence and the times of year when certain severe weather types are more prominent than others. Section II will discuss the data used in this study; Section III will address severe wind events; Section IV will deal with severe hail occurrences; Section V will discuss tornado events; and other significant severe weather tendencies will be revealed in Section VI.

II. The Data

Data used in this study were obtained through the Storm Prediction Center (SPC), formerly known as the National Severe Storms Forecast Center, which keeps an ever-expanding database of severe weather reports for the entire nation. The database at SPC includes tornado events from 1950 through the present. Severe hail and wind data are available for years 1955 through the present, excluding the year 1972. Data for this year were obtained from Storm Data (NOAA 1972). The compiled reports of severe weather were run through the Climo program (Vescio 1995) on a CWA basis. A large number of "useful" variables and combinations of the data were produced by the program, and these make up the backbone of our research.

In perusing the data, a curious trend stands out. Data from the 1950s and 1960s appear highly underrepresented, with significantly fewer reports than later years. For instance, the total number of "hail days" in 1963 totalled 4, while there were 43 "hail days" in 1992! Taking this literally, one would believe that 1963 was an unusually slow year regarding severe weather in northern Texas. In fact, the data is skewed for other reasons. First, severe weather reports were obtained and archived by the State Climatologist prior to 1973 (Ely 1997). Owing to the large size of the state, collecting the data must have been quite a challenge for a single office, and only the most significant and damaging weather was included in Storm Data. The NWS assumed Storm Data responsibilities in 1973 and the data collection task was subsequently spread over several offices. Each office could then focus on a portion of the state and concentrate its severe weather research to this much smaller area. The NWS also began its verification program in the late 1970s. This had a direct effect on reported severe weather since each office became more concerned with obtaining these reports (Hales 1987). Additionally, the current, formal storm spotter training efforts that occur nationwide began in northern Texas in the mid 1970s (Moller 1978). All of these issues have effectively increased the reported number of severe weather events.

Before proceeding further, it is important to briefly discuss a few of the short-comings of the data used in this study. These underlying qualities make the data imperfect, but still usable if the problems are considered. Hales and Kelly (1985) and Hales (1987) examined a few of these issues which include population variances, the distance from the warning office, attitude of the county residents, and geography. Severe weather that occurs in a highly populated area has a better chance of being observed, and therefore reported, than an event that occurs in a rural area. The event could also have been underestimated or overestimated by the observing (reporting) party, leading to a bias in the severe weather database. Another limitation of the data is that severe events that are not reported, do not make it into the severe weather archive. Thus, an office that is active in educating the public, developing an effective storm spotter network, and seeking severe weather reports from all available sources after an event is more likely to develop a comprehensive severe weather climatology.

There are other factors that render the severe weather database less than perfect, particularly the tornado database. A minor imperfection concerns how the number of tornado occurrences is determined. In the SPC severe weather database, tornadoes are logged as segments rather than as actual tornadoes. Therefore, a long-track tornado that crosses from one county into another is documented as two tornado segments rather than as one tornado. Doswell and Burgess (1988) discussed another problem which regarded inconsistencies in the rating of tornadoes using the subjective Fujita damage/intensity scale (Fujita and Pearson 1973). Another imperfection arises from time and staff limitations in many NWS offices. These constraints result in an inability to conduct damage surveys on every reported tornado event. Therefore, tornado intensities must occasionally be estimated. These estimates take into account the analyses of others (such as Emergency Management Coordinators), newspaper articles written on the event, and other tornado damage that occurred on the given day in the area (i.e. were most tornadoes reported as brief touchdowns with little to no damage, or as large and damaging, long-track events?). If a tornado occurred in a rural area with no damage to structures or trees, the tornado was probably underestimated (regarding its true intensity) and possibly even unreported. Depending on the individual composing Storm Data, the event could be grossly underestimated (i.e. rating a large violent tornado as F0 because it affected unpopulated grasslands). Other tornadoes may be overrated when poorly engineered structures are damaged or destroyed.

In addition to the time of day and time of year distributions that will be discussed, we will document the change in types of severe weather in regard to season of the year and time of day. In this paper, the term "season" is not necessarily used in its typical sense. We have divided the year into four "seasons", each of which include three months that typically have the most similar weather when compared to the other months. We have included April, May, and June in spring; July, August and September for summer; and so on. In reality, it would be more appropriate to divide the months into weeks (i.e. allow spring to cover late March through early June) but unfortunately, the data could not be easily partitioned in this manner. To account for this, we will include graphs of each month's data, in addition to the graphs of the particular season in question. This will provide additional detail of the data.

III. Severe Wind Events

As stated earlier, a severe wind event is defined as an estimated or measured convective wind gust of at least 50 knots, or wind damage resulting from a convective gust that would be associated with wind of this magnitude. By far, spring is the time of year in northern Texas in which the most severe wind events are reported (Figure 3). In fact, more than twice as many events occur in spring (1610 events) than in summer (620 events), and five times as many occur in spring than in fall (295 events) and winter (314 events). May is the most likely month for severe wind events (702 events) followed by June (505 events). The maximum in this dataset occurs slightly earlier in the year than it did in Kelly et al 1985, which took into account wind events for the entire United States. The least likely time of year for damaging wind is in the late fall and early winter, with December and January having 39 and 38 events, respectively.

The most likely time of day for severe wind events to occur is late afternoon and evening, specifically between the hours ending at 1600 CST through 2100 CST (Figure 4). Forty-nine percent of all the wind events that were reported occurred in this time frame. More specifically, the most likely hour for damaging wind events to occur was 1800 CST (257 events), followed very closely by 1900 CST (256 events). These findings are quite similar to those of previous climatologies (Kelly et al 1985) that were national in scope. The number of events, which peaked in the early evening, gradually decreased to a minimum in the early morning hours (0400 CST).

In an effort to determine whether this diurnal tendency was consistent throughout the entire year, we divided the total wind events into seasons (Figures 5-8) and even into months (Figures 9-20). Comparing the seasonal data to the total number of wind events per hour, it is apparent that spring and summer months most closely match the distribution for all the data. The graphs for the fall and winter, although they do show a maximum number of events in the early evening hours (1800-2000 CST), indicate less consistent patterns. The tendency is not as solidly supported in this data, as the output graphs are more chaotic when compared to the nearly bell-shaped graphs of the spring and summer months. When considering the data on a monthly basis only, we see that a consistent diurnal pattern with maximum occurrence in the late afternoon and early evening appears in March and continues through October. There is no apparent diurnal tendency from November through February. A relatively small number of events occur in the fall and winter, and this could account for some of the apparent inconsistency with the spring and summer plots. Another possible explanation could be the predominance of strong baroclinic systems in the winter, in which shear (a nondiurnally-driven variable) is more important a severe weather ingredient than instability (a more diurnally-driven variable).

IV. Severe Hail Events

As defined previously, a severe hail event is defined by the NWS to be one in which the thunderstorm-produced hailstone is at least three-quarters of an inch in diameter. As Figure 21 shows, the most likely time of year in northern Texas for severe hail events to occur is the late winter and spring. Sixty-nine percent of the total reports occurred during this period. When compared to previous climatologies (Kelly et al 1985), our localized data set indicates a peak slightly earlier in the year. The data shows a typical bell-shaped curve that peaks in April (1051 events) and gradually tapers off to a minimum in the month of December (8 events). A secondary, and much smaller peak occurs in the fall, marking both the return of the polar jet stream to the southern United States and FTW's secondary severe weather season. When the total number of hail reports is stratified by hail size (i.e. diameter of hailstone 0.75-1.75 inches, 1.75-2.75 inches, and larger than 2.75 inches), this distribution remains consistent (Figure 22).

The most likely time of day for severe hail events to occur is the late afternoon and evening hours, specifically between the hours of 1600 and 2200 CST (Figure 23). Sixty-nine percent of the total hail events occurred in this time period. The hour in which the most events occurred was 1800 CST (416 events), seemingly consistent with the observations of Kelly et al 1985. The number of events gradually decreased from this hour through 0300 CST, then an even distribution occurred from 0400-1200 CST. A marked increase began at 1300 CST and continued through the early evening. The minimum number of events occurred at 0900 CST (21 events), but the percentage of hail that occurred in each hour from 0400-1200 CST was essentially the same. Figure 24 shows this distribution to be consistent when the total hail events are stratified by categories based on hail size.

The preference for severe hail to occur most often in the late afternoon and evening hours is a congruous occurrence throughout the year (Figures 25-28). The graphs are similar to those of wind events in the warm season in strongly suggesting this diurnal distribution. However, unlike wind events that can occur more randomly in the cool season, large hail events that occur in winter are also most likely to occur in late afternoon or evening. Therefore, it can be stated that instability supplied by solar heating is more important for cool season hail events than for many cool season wind events. The most likely time of day for large hail to occur in the summer and fall is 1700 CST. This preference varies little during the remainder of the year, as 1900 CST is the favored time in spring and 2000 CST is the most likely time of day for large hail during the winter. The distribution curves remain consistent even when the data is broken down by month (Figures 29-40). A noteworthy tendency revealed in the data is that few large hail events occur between midnight and noon during the summer and fall. The relatively small number of events that occur during these hours in the winter and spring tend to do so in a constant manner, rather than tapering off to an obvious diurnal minimum.

Because the size of hail produced by a thunderstorm is directly proportional to the amount of instability that is realized on a given day, and therefore on the strength of the storm's updraft, the diurnal distribution of severe hail events is not too surprising. It is a little surprising that this pattern continues into the cool season when, as Colman 1990 states, the majority of thunderstorm events that occur are elevated (i.e. not surface based where diurnal heating would play a part).

V. Tornado Events

As stated earlier, the NWS Fort Worth CWA is in the southern portion of what is popularly known as Tornado Alley. It is over this area that the opposing forces of warmth, cold, moisture, and strong low-level vertical wind shear frequently come together. Using data collected over the past 116 years, Texas ranks first in both the number of tornadoes reported and the number of tornado related fatalities (Grazulis 1993). Thus, it is not surprising that the FTW CWA has one of the highest frequencies of tornadoes in the world. Figure 41 shows the frequency of tornadoes that have been reported in the CWA since 1950 by year, and Figure 42 displays these reported events by county within the CWA.

A tornado is defined to be a narrow, violently rotating column of air in contact with the ground (Davies-Jones 1986). As can be expected across much of the southern United States, spring is the most prominent time of year for tornadoes in North Texas (Figure 43). Sixty-four percent of the total number of tornadoes reported in the CWA occurred in the months of March, April, and May. In the years 1950-1994, the greatest number of tornadoes occurred in the month of May (373 tornadoes) with the least reported in January (11 tornadoes). The number of tornadoes begins to increase in February and continues to rise through May. A significant decrease in tornadoes occurs in June and continues through the summer months. A secondary peak in the data is noted in October, as stated earlier, marking the Southern Plain's secondary severe weather season.

Consistent with the findings of Kelly et al 1978 for the Great Plains region, our data set indicated that 67 percent of tornadoes that occurred in northern Texas were classified as weak (F0-F1) and 32 percent were classified as strong (F2-F3). A very small percentage of tornadoes made up the violent (F4-F5) classification (1 percent). However, these rare events resulted in a disproportionate percentage of tornado related injuries and fatalities (Figure 44). Figure 45 shows a breakdown by county of all the tornado related fatalities that have occurred in the CWA since the late 1800s.

As illustrated by Figure 46, the most likely time of day for tornadoes to occur in northern Texas is 1800 CST (177 events), and the least likely time is 0400 CST (10 events). These results are somewhat consistent with those of Kelly et al 1978, a national tornado climatological study. Fifty-three percent of the tornadoes reported across the region occurred between the hours of 1600-2000 CST. The data indicate the likelihood of tornado development gradually increases from the early morning hours to a peak in the early evening. A steady decrease in the number of tornadoes occurs from 1800 to 0400 CST.

Figures 47-50 indicate that the higher likelihood for tornadoes to occur in the CWA during the late afternoon and evening hours, does not change when the data is broken down by season. In fact, the maximum number of tornado occurrences were during the same hour (1800

CST) in the spring, fall, and winter. A consistent diurnal pattern, indicated by nearly bell-shaped curves, is noted in the warm season with less predictability noted in the cool season. Again, this is suggestive of shear being more important a severe weather factor than instability in the cool season (i.e. we are probably more likely to have high shear/low instability tornado events in winter than in spring). The relatively small number of events that occur outside the spring months may also account for some of this apparent randomness. A noteworthy, secondary maximum in the data from 0700-1100 CST in fall and winter is likely associated with the nocturnal low-level jet maximum. When the hourly frequency of tornadoes is broken down by month, the resulting distributions are similar to those demonstrated by the seasonal graphs. Thus, the monthly graphs have not been shown.

VI. Other Severe Weather Tendencies

In an effort to document how the frequency of each severe weather element changes throughout the year, we produced Figures 51-54. The most obvious finding indicated by these charts is for hail to make up the largest percentage of reported severe weather events during the typical severe weather months (March, April, May, and October), and for wind to dominate reported severe events in all other months. A very evident transition from periods when hail reports dominate to when wind reports prevail occurs between the months of May and June. Wind events make up the overwhelming majority of reported severe weather during the summer, when conditions become less favorable for hail and tornadoes to occur in northern Texas (i.e. the freezing level and wet-bulb zero increase in altitude during the summer, making hail less likely because of extensive melting during descent to the ground; and the lack of wind shear due to the migration of the polar jet to the northern U.S. limits the tornado potential during these months). As Figures 51-54 depict, tornadoes make up the smallest percentage of reported severe weather in each month except January, September, and December. During January and September, wind events predominate but tornadoes and hail events are near equally likely occurrences. In December, the possibility of a tornado is nearly as likely as a severe wind event, both of which are much more probable than a severe hail event.

Diurnal variations of severe weather type also appear to show a definitive pattern. Severe thunderstorms are most likely to produce damaging winds during the climatologically cooler time of day. As Figures 55-64 show, damaging wind events are most likely to be the type of severe weather produced by thunderstorms from 0000-1300 CST. Severe hail events dominate the remainder of the day, namely the better part of the afternoon into late evening. When the data is stratified by season (graphs are not shown), these findings hold true for all seasons except summer when wind reports predominate in each hour of the day. The transition hours, in which a nearly equal percentage of severe hail and severe wind events occur, are 1300 CST and 2300 CST. (In order to save space, we have only included every third hour and the transition hours mentioned above).

Supercell thunderstorms, simply defined as storms with deep and persistent, rotating updrafts or mesocyclones, are Mother Nature's most violent thunderstorms. These storms are capable of producing the most damaging weather. The largest hail, strongest convective wind gusts, and most damaging and long-lived tornadoes are all possible from supercells (Moller et al 1994). They make up a small proportion of the total number of thunderstorms that develop annually, but they account for a disproportionate amount of destruction and loss of life. Figures 65-66 attempt to show the annual and diurnal tendencies of these storms by assuming most strong tornado events (F2 or greater) and all giant hail events (hail larger than 2.75 inches) are products of supercells. This assumption allows us to infer the distribution of supercell thunderstorms from the distribution curves of extremely severe events (i.e. strong to violent tornadic activity and giant hail) which are rarely produced by non-supercell storms.

As Figure 65 indicates, April is the favored month for these intense storms to occur and January is the least favored month. By far, most supercells occur between March and June in northern Texas, but a secondary increase in these storms is noted in October. As would be expected in this portion of the country, the favored time of day for supercell development is in the afternoon and evening. With the data used in this study, the greatest number of supercells occurred in the hour ending at 1800 CST, and the fewest occurred during the hour ending at 0200 CST (Figure 66).

Damage associated with these storms is relative, as a violent storm that occurs in a highly rural area will obviously produce less damage than one that affects an urban area. When these storms affect urban areas, they can be quite devastating. Table 1 shows the results of some of the most damaging supercells experienced in the Dallas/Fort Worth Metroplex in the last 20 years. It should be noted that to date, two of the nation's three most damaging thunderstorms have occurred in the FTW CWA. The hailstorm of May 5, 1995, which produced a prolific amount of softball size hail over a vast area and resulted in over $2.0 billion in damage, is the nation's most damaging thunderstorm event. The storm that affected the Dallas/Fort Worth Metroplex on April 28, 1992, is the nation's third most damaging hailstorm. These storms produced significant hail damage while others resulted in significant tornado damage. The one thing in common that each of these storms had was the excessive amounts of rain they produced which resulted in significant, and sometimes deadly, flash flooding. Historical data (shown in Table 1) suggests

Date	Deaths/Inj	Damage ($)	Hail Size	Wind Gusts	Rain Rate
5/5/95	20/120	2.0+ billion	4 inches	80 mph	5 in./hour
4/29/95	0/30	220 million	3.5 inches	70 mph	?
4/28/92	0/7	600 million	4 inches	100 mph	?
5/4/89	6/29	100 million	2.75 inches	100 mph	4.5 in./hour
5/24/86	2/14	?	3 inches	95 mph	4.5 in./hour
5/8/81	1/35	250 million	4 inches	120 mph	4.5 in./hour
4/2/80	0/4	60 million	4.5 inches	60 mph	?
5/3/79	1/37	50+ million	2.75 inches	120 mph	4.0 in./hour

Table 1 High-precipitation supercell thunderstorms that have affected the DFW Metroplex with major non-tornadic damage (1979-1995). Table by Alan R. Moller.

that the potential catastrophic results of flash flooding should be a major concern in the warning forecaster's mind when supercell thunderstorms interact with an urban community.

VII. Concluding Discussion

We have documented the annual, seasonal, and diurnal severe weather climatology for the current NWS Fort Worth CWA. It can be stated that the majority of all North Central Texas severe weather events occur in the warm season, during the late afternoon and evening hours. However, we have shown that a significant number of severe weather events occur during other times of year, as well. In fact, some of these atypical events can be just as devastating due to their unexpectedness. Therefore, forecasters in this area of the country must always consider the possibility of severe convection when proceeding through his/her normal forecasting routines. Studying research concerning these atypical events (for instance, Calianese et al 1996) will also help the forecaster identify and react to a potential cool-season severe weather episode as it unfolds.

In addition to the usual annual and diurnal severe weather tendencies that were documented, we also found patterns concerning severe weather types based on time of year and time of day. During the typical Southern Plains severe weather months (March, April, May, and October), large hail events tend to make up the largest percentage of reported severe weather events. Severe wind events occur more often during the other months of the year. These are probably associated with slow-moving, short-lived pulse storms in summer, and organized, fast-moving thunderstorm complexes in the cool season. During the winter, spring and fall, severe hail events make up the largest percentage of severe weather occurrences during the afternoon and evening hours, whereas wind events occur more often the remainder of the day. In the summer, severe wind events predominate all hours of the day.

This project should be considered just the beginning of a climatological documentation of severe weather in the NWS Fort Worth CWA. Future studies should include a comparison of instability and wind shear throughout the year, as well as the climatology of flash flooding in the region.

VIII. Acknowledgements

The authors thank Michael Vescio of the SPC for providing the raw data, upon which the majority of the figures used in this study are based. Skip Ely and Krista Villarreal of FTW provided valuable comments. Alan Moller and Mike Foster, also of FTW, provided thorough, critical reviews and their efforts were greatly appreciated!

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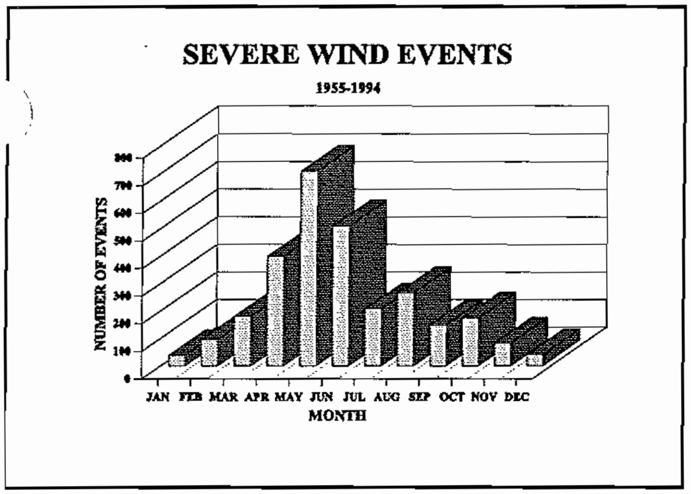

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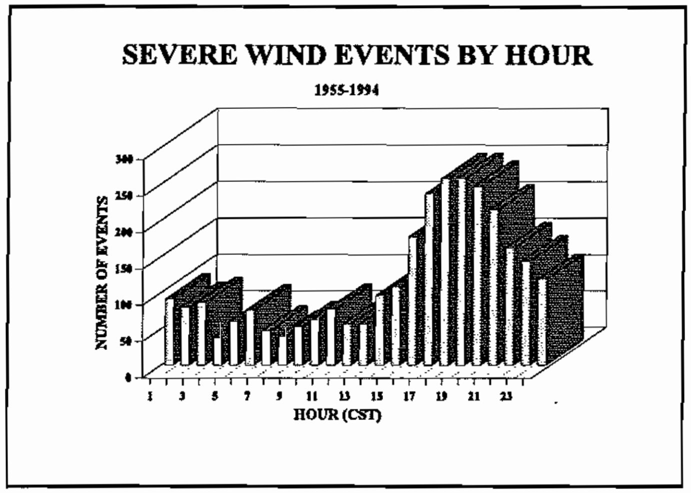

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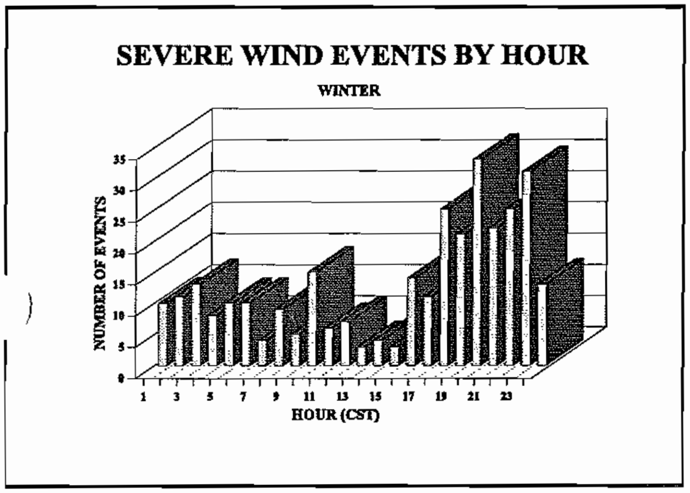

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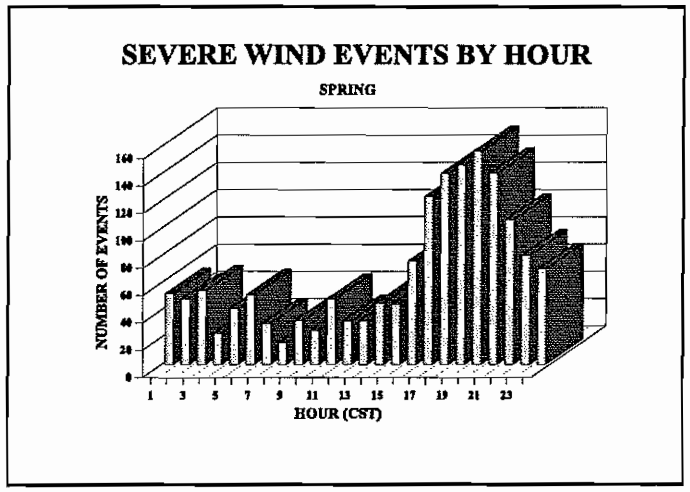

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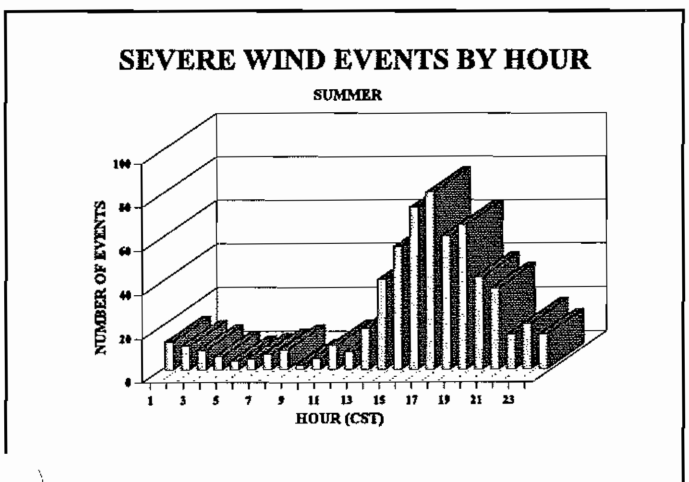


Figure 7

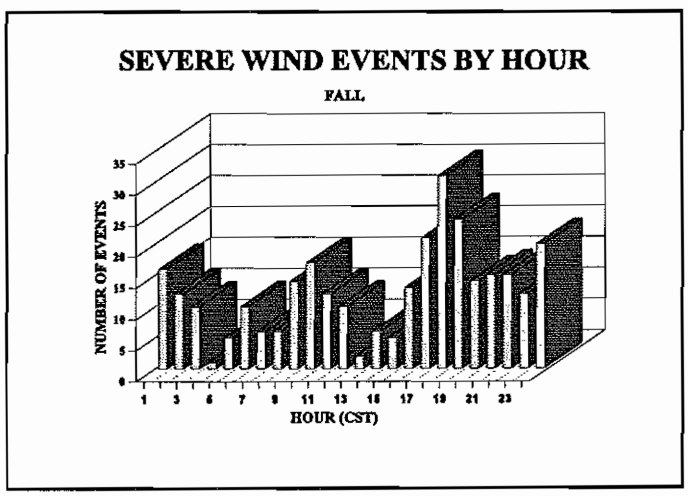
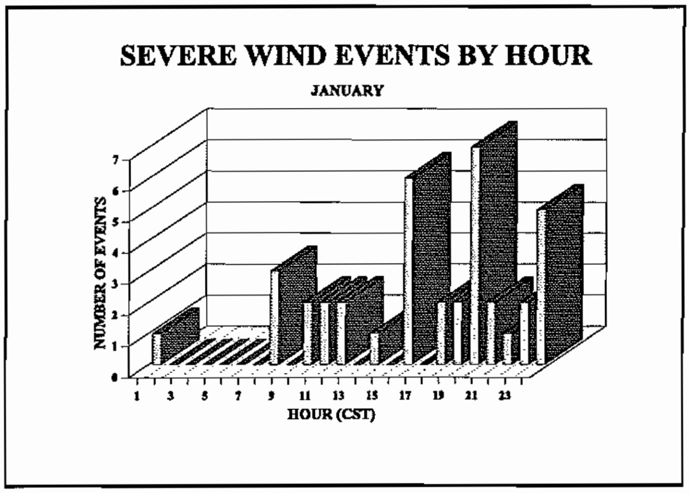


Figure 8



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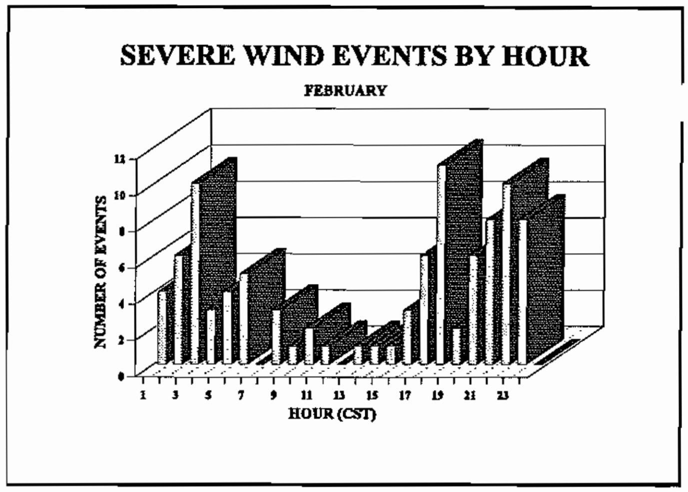

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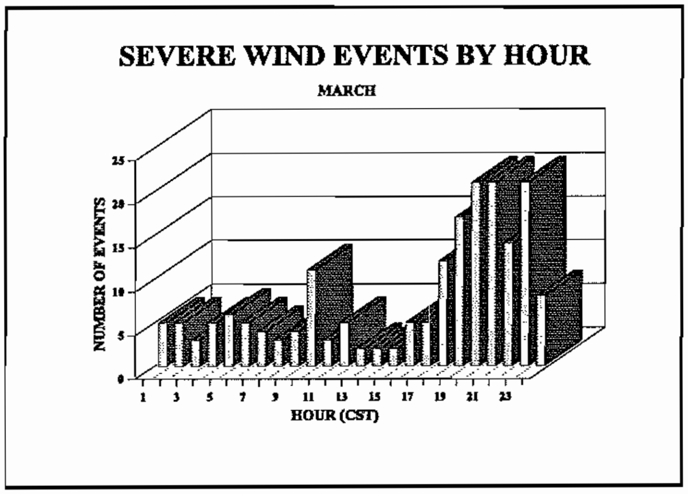

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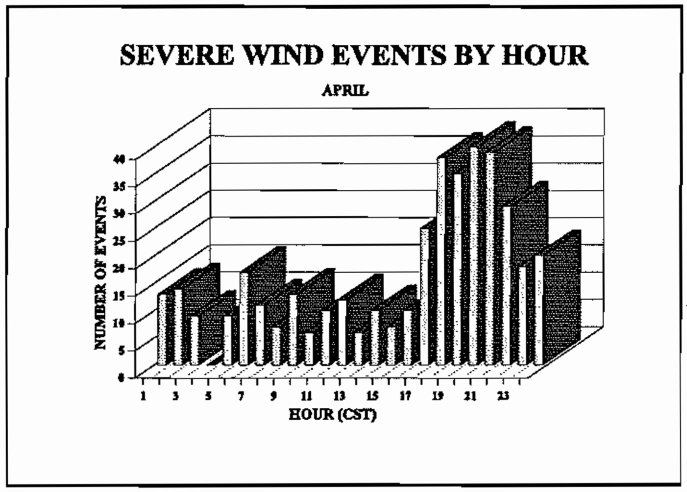

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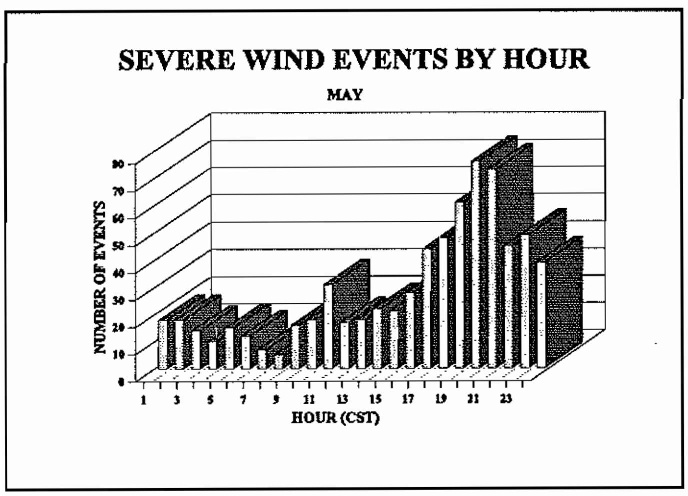

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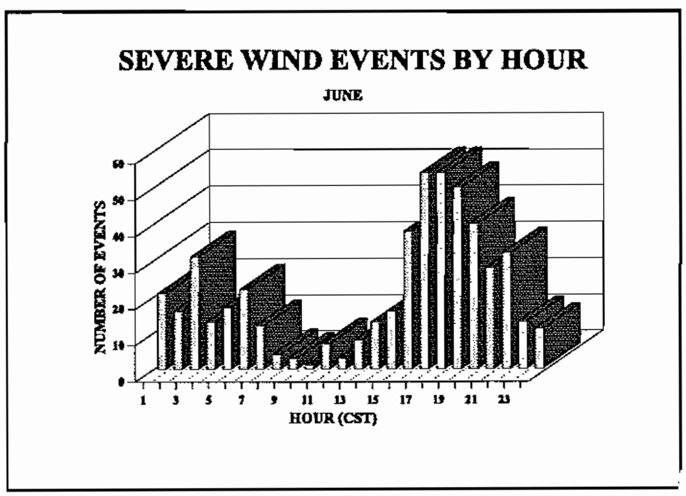

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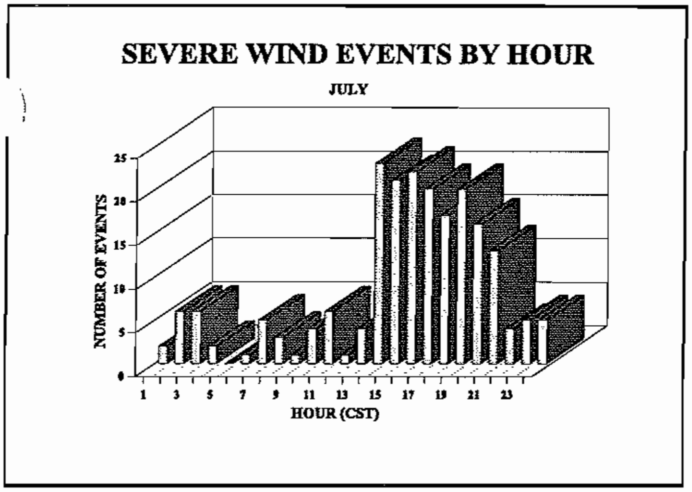

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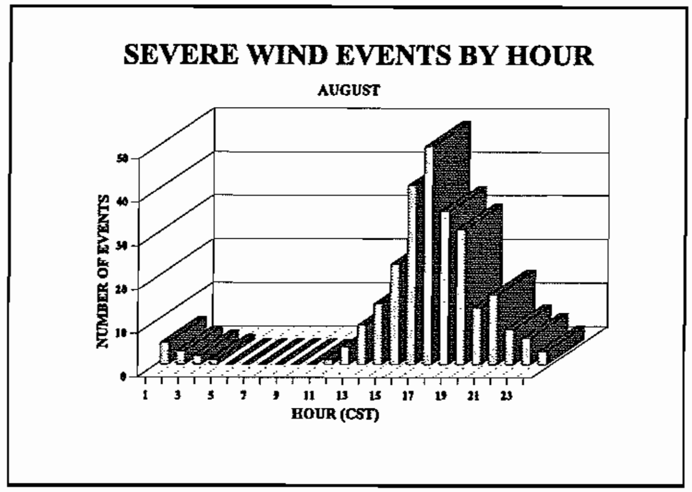

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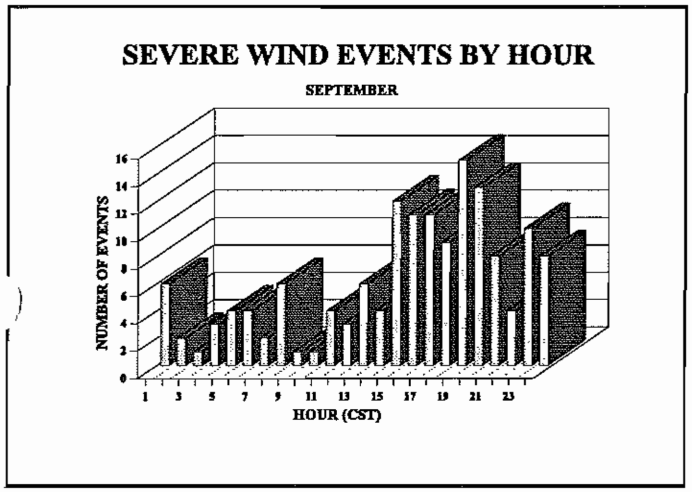

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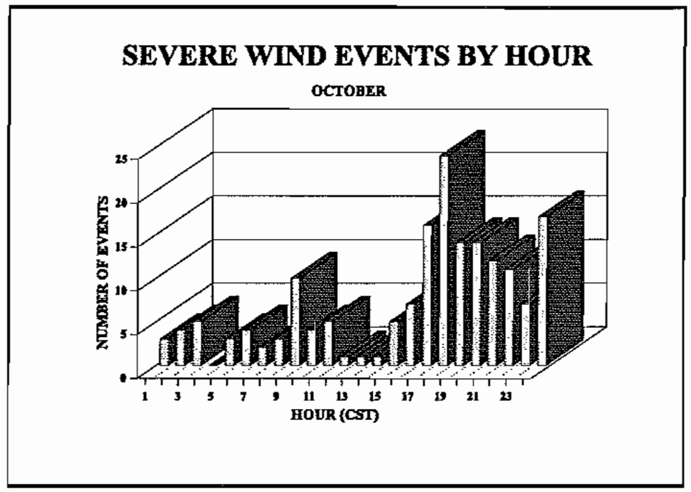

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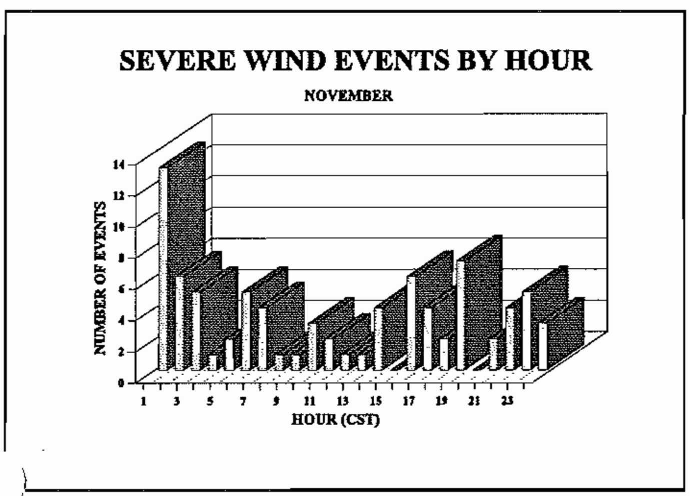

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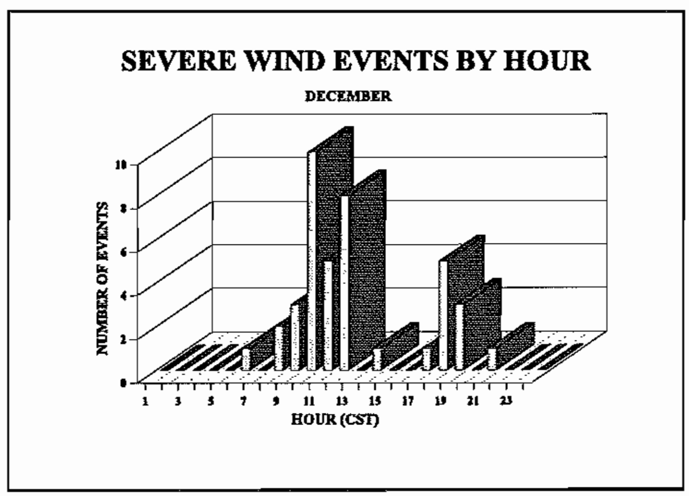

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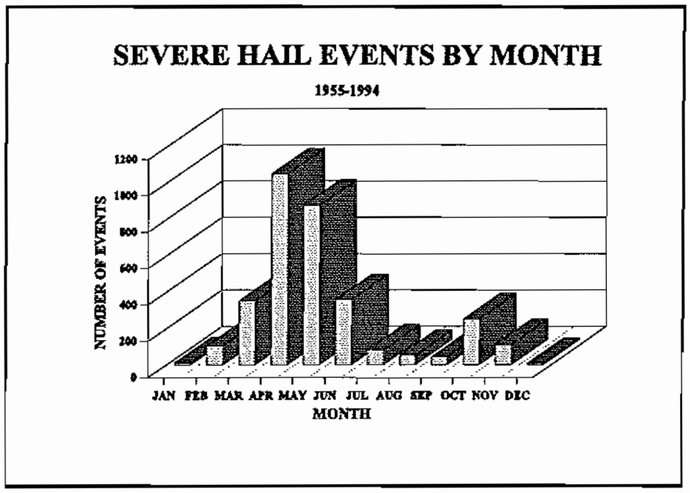

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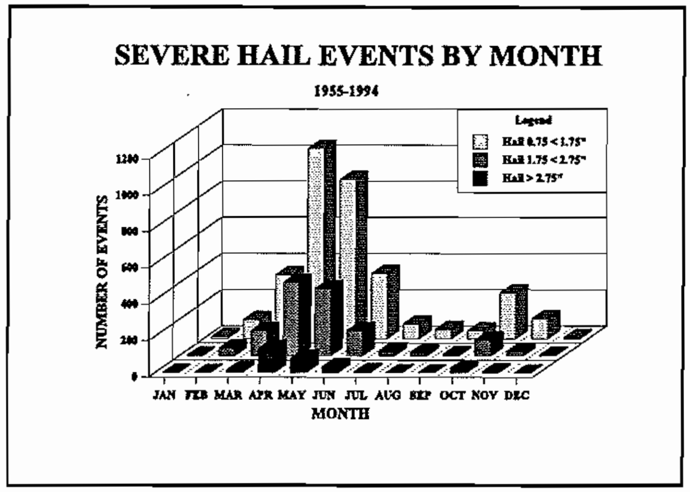

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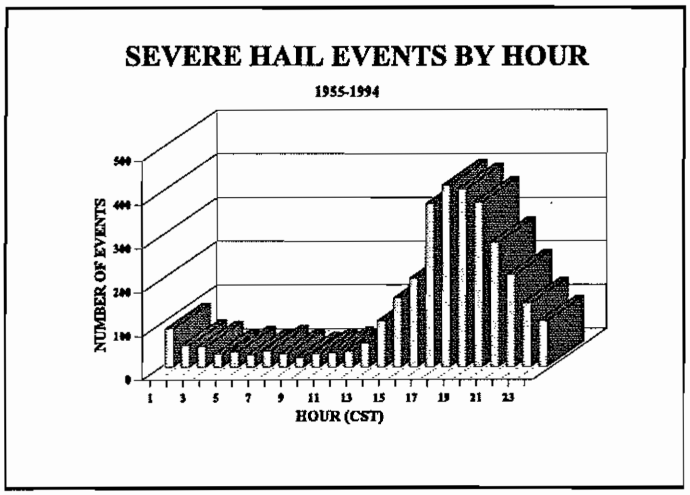

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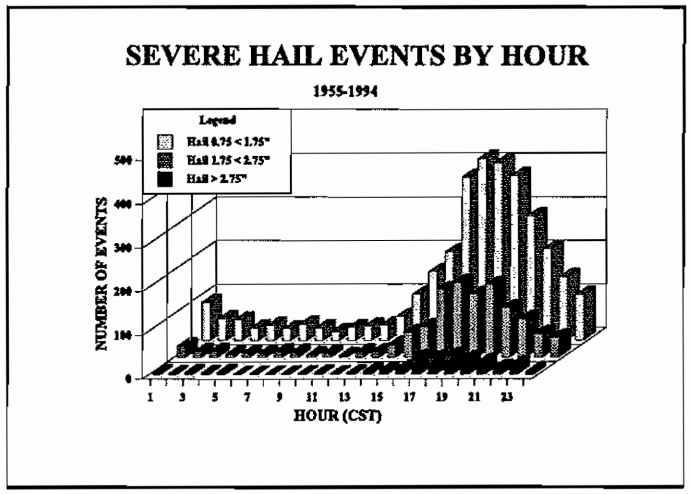

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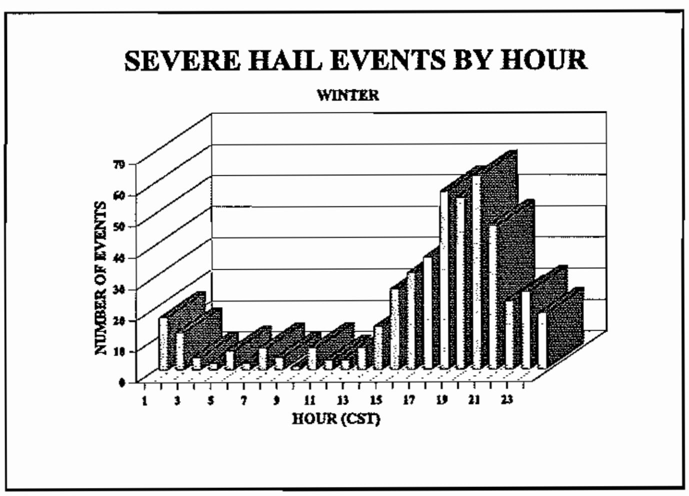

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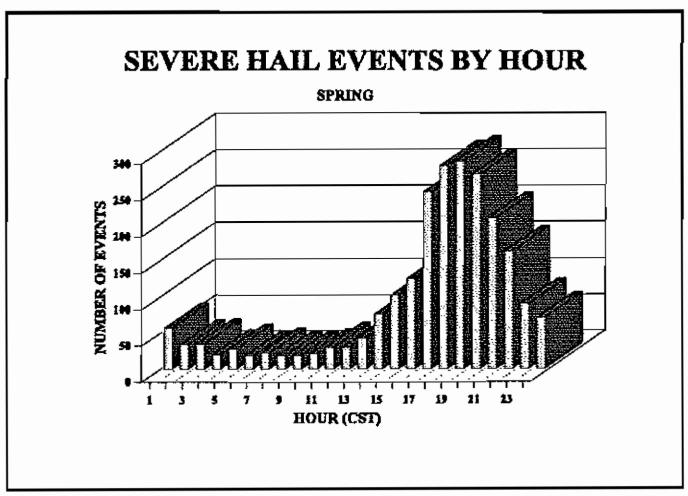

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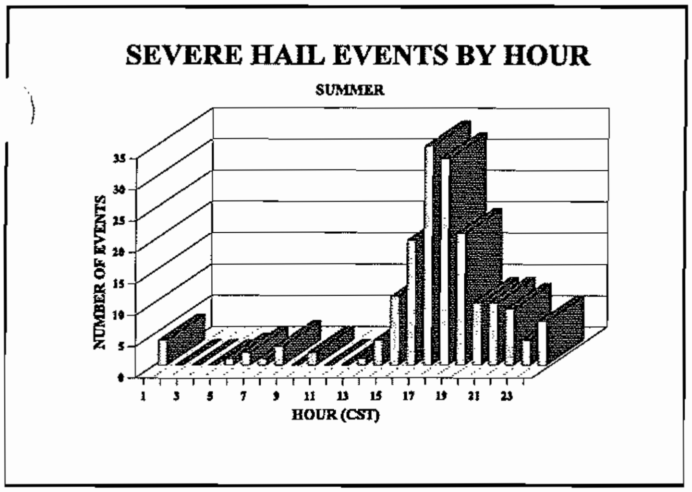

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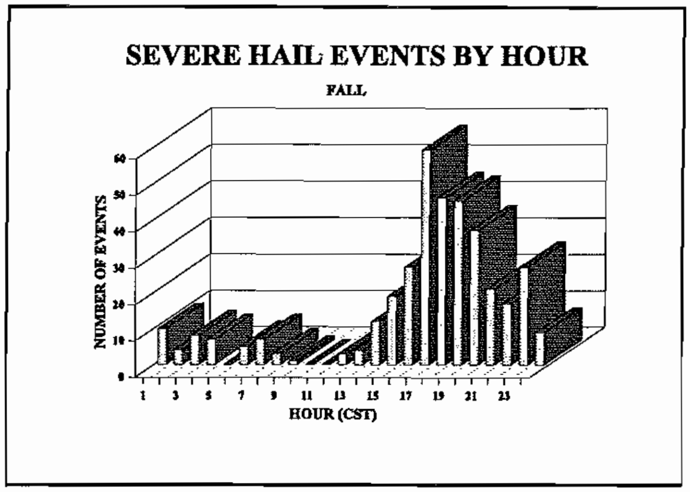

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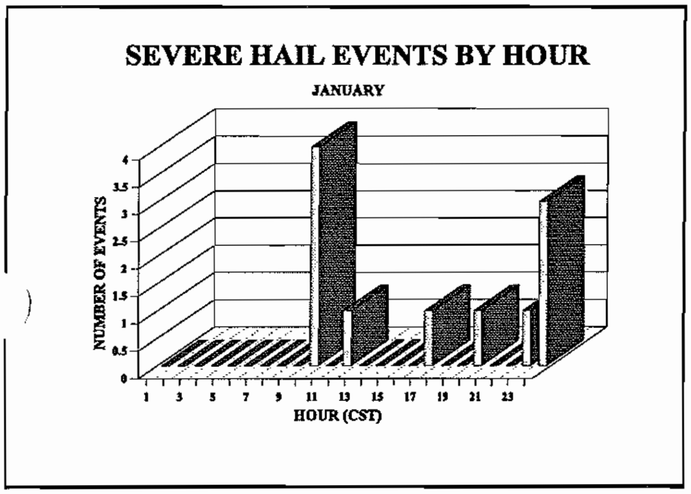

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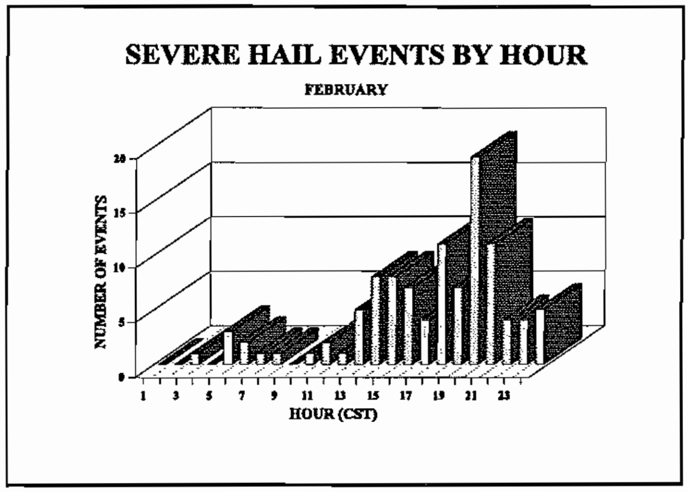

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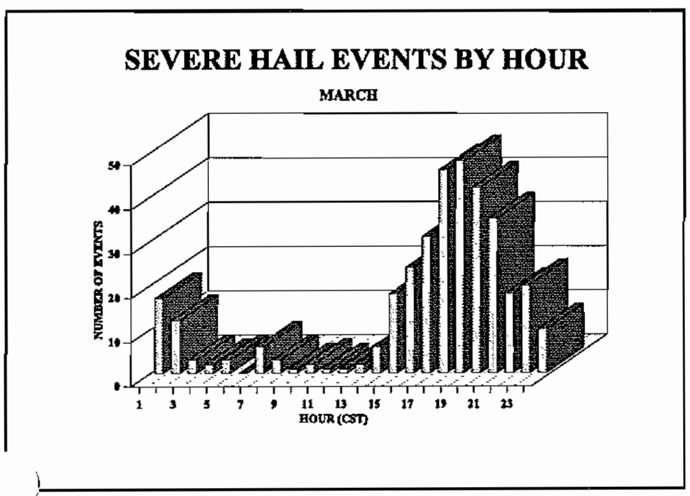

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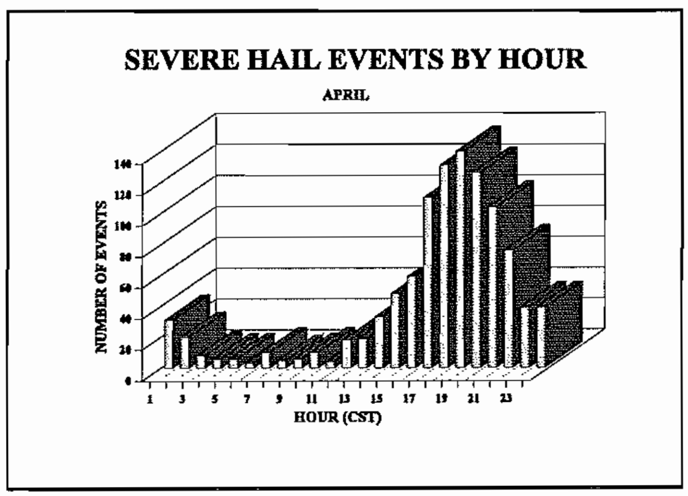

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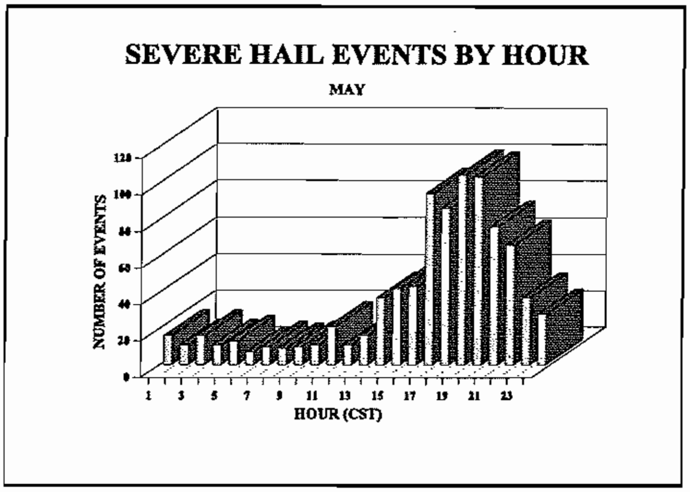

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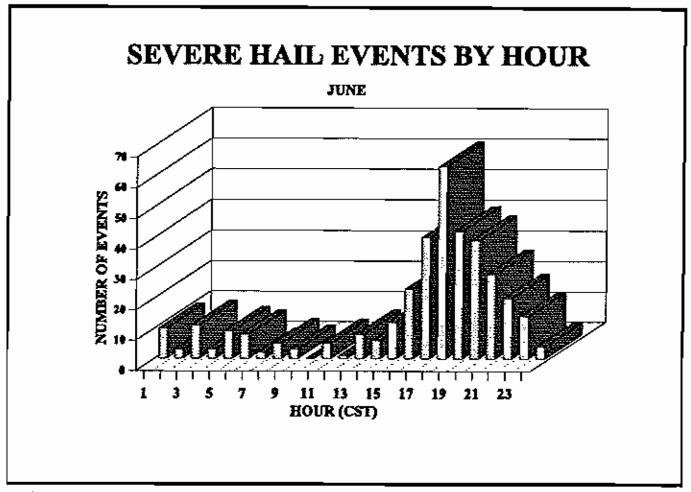

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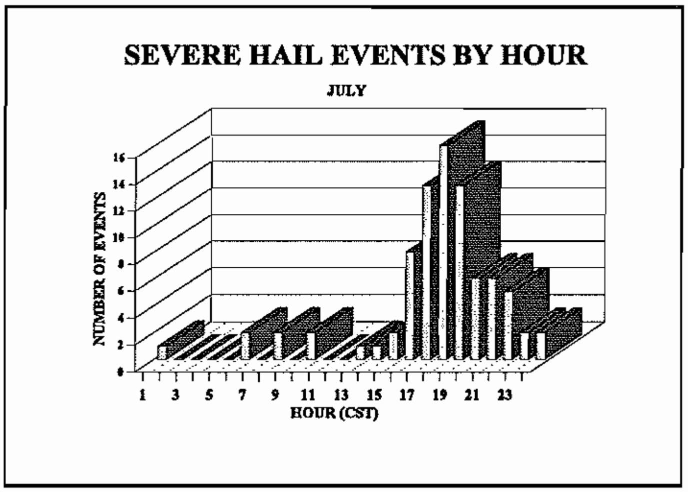

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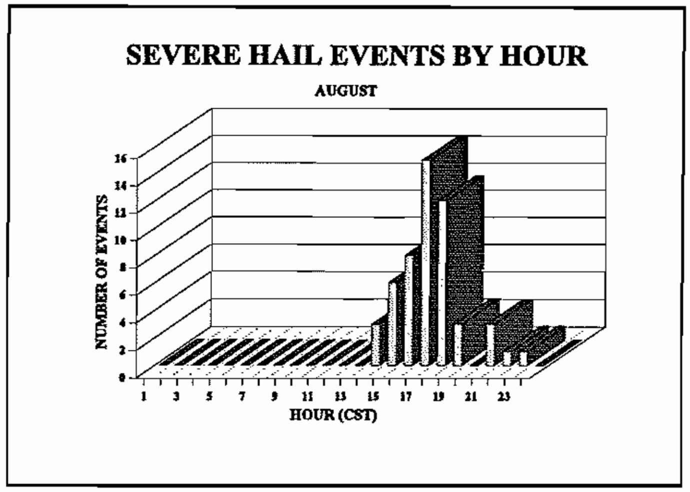

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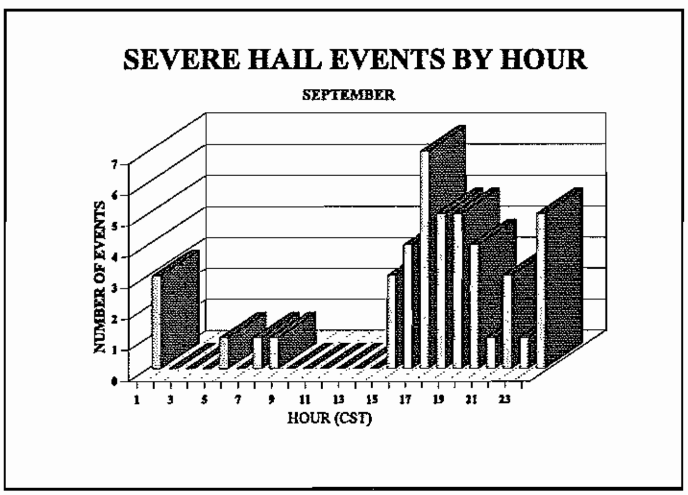

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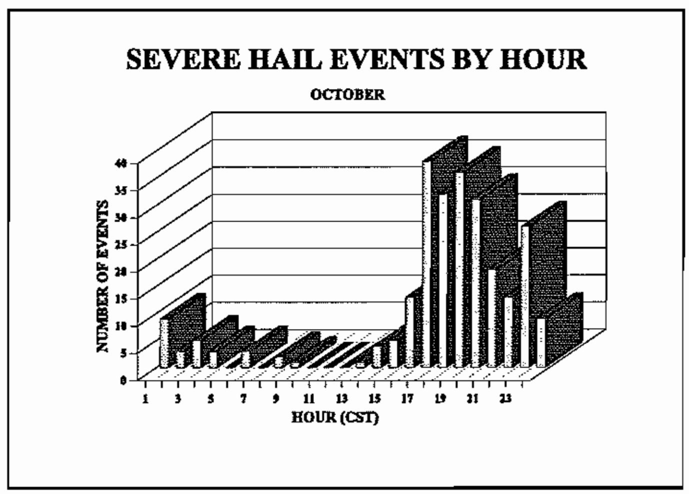

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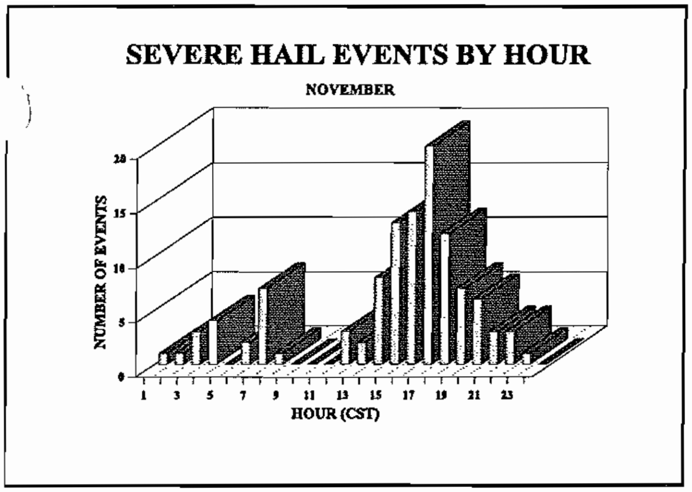

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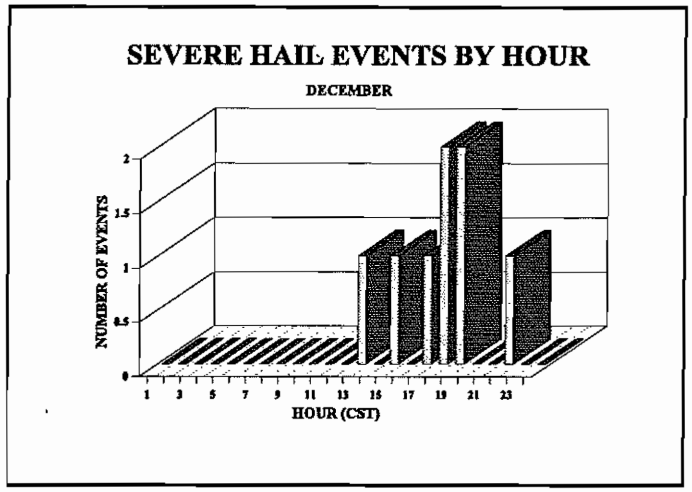

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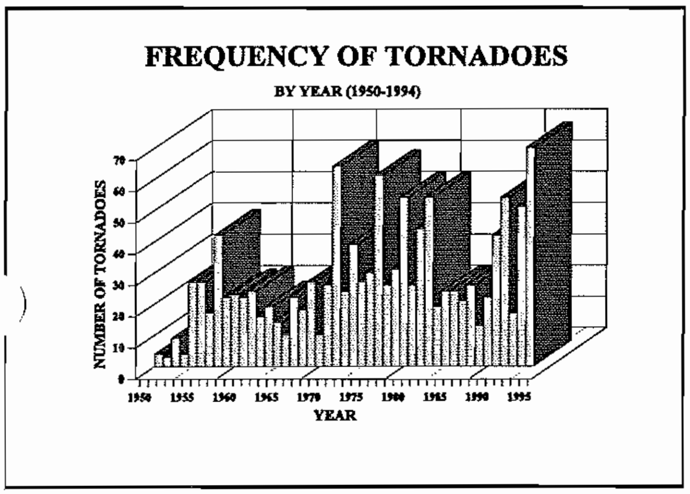

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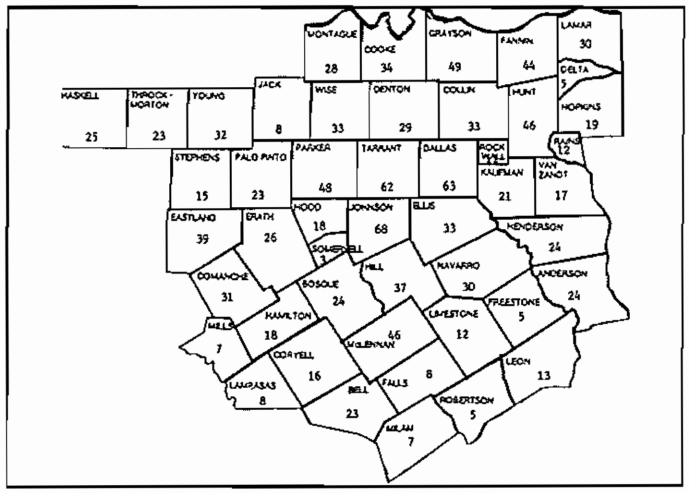
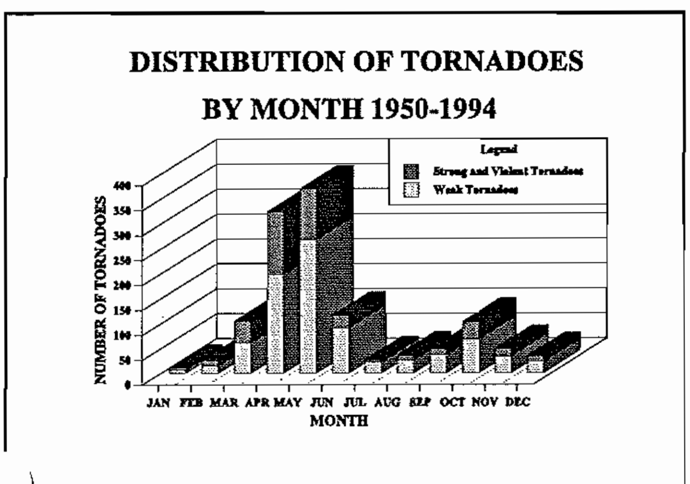


Figure 42 Tornadoes by County



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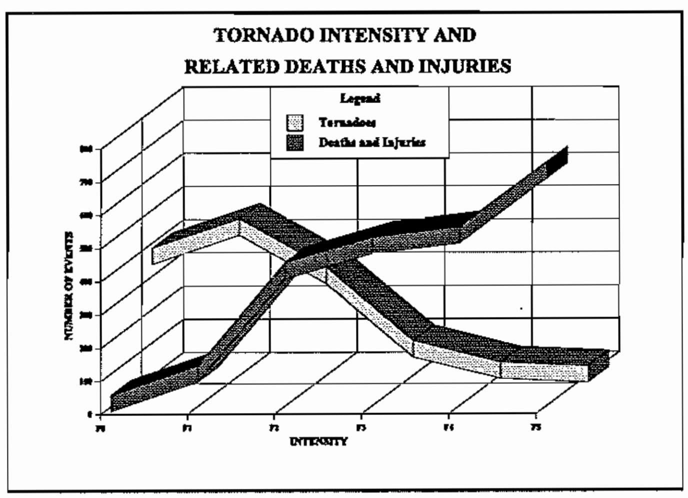

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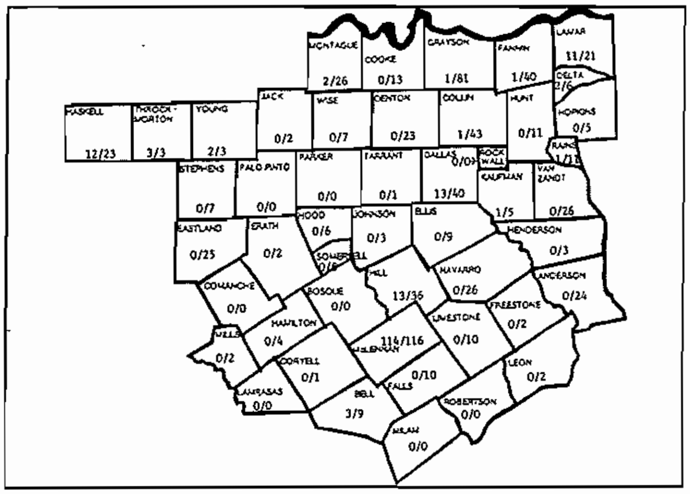


Figure 45 Tornado Related Deaths (1950 present/1880 present)

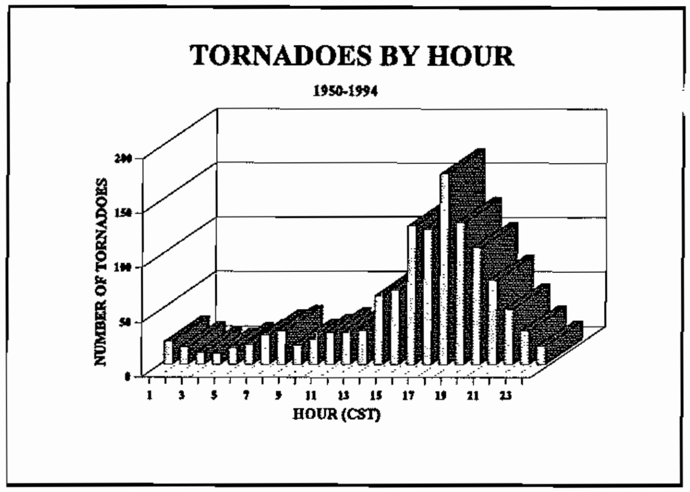
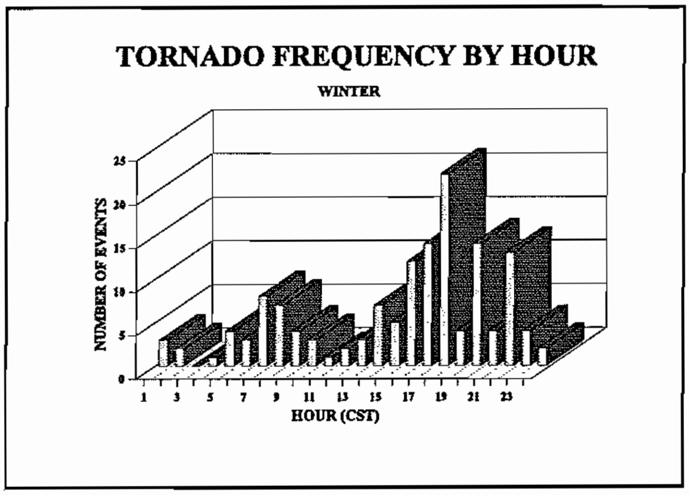


Figure 46



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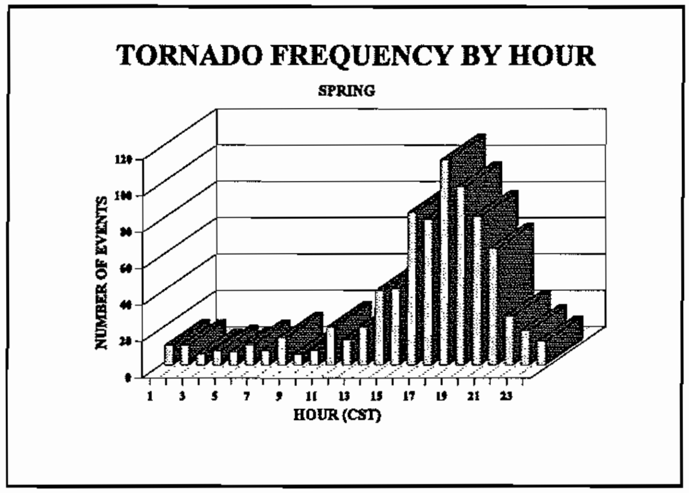

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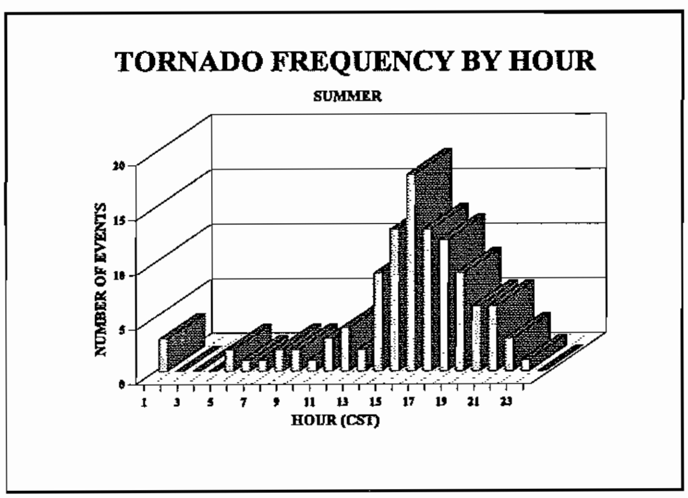

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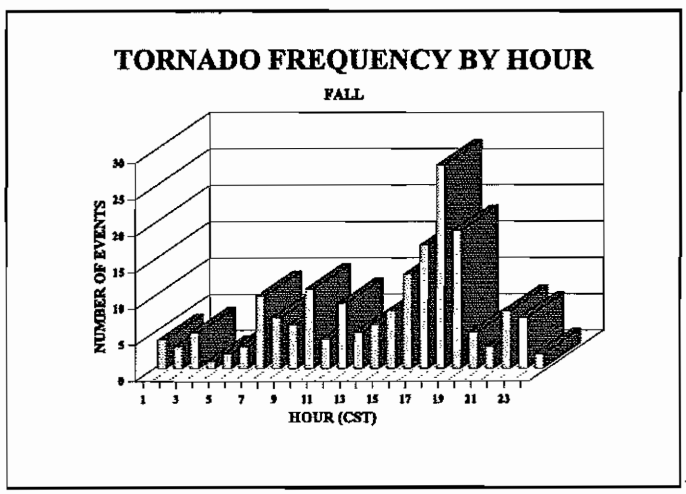


Figure 50

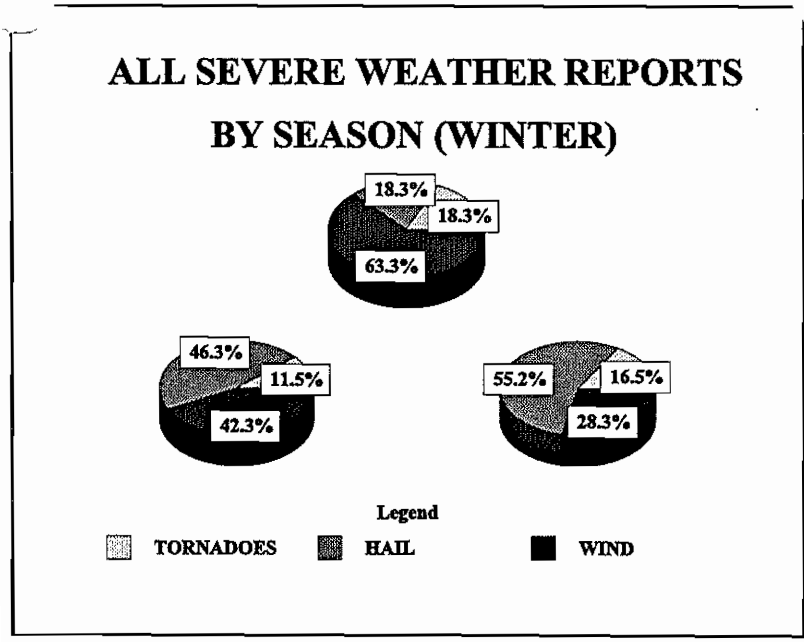


Figure 51 Jan, Feb and Mar counterclockwise from top

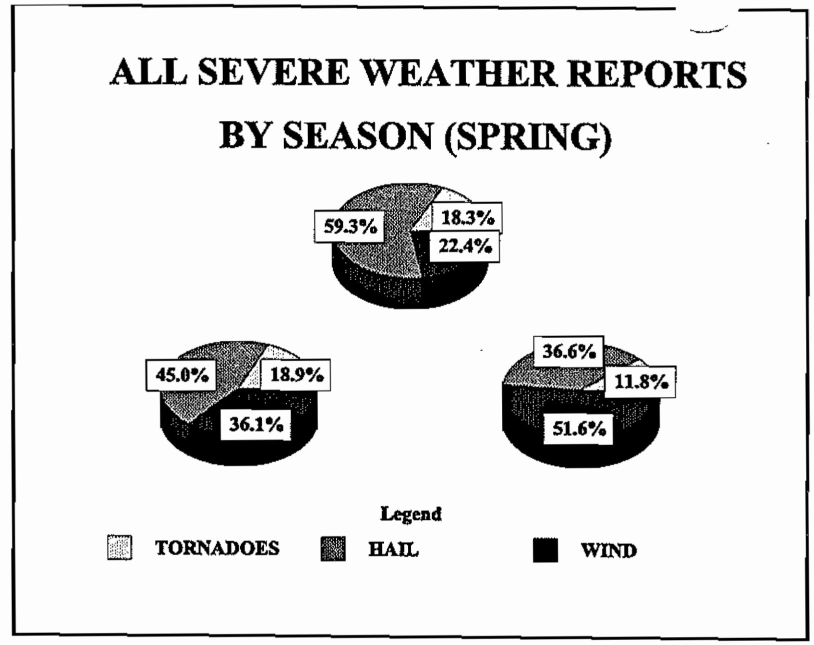


Figure 52 Apr, May and Jun counterclockwise from top

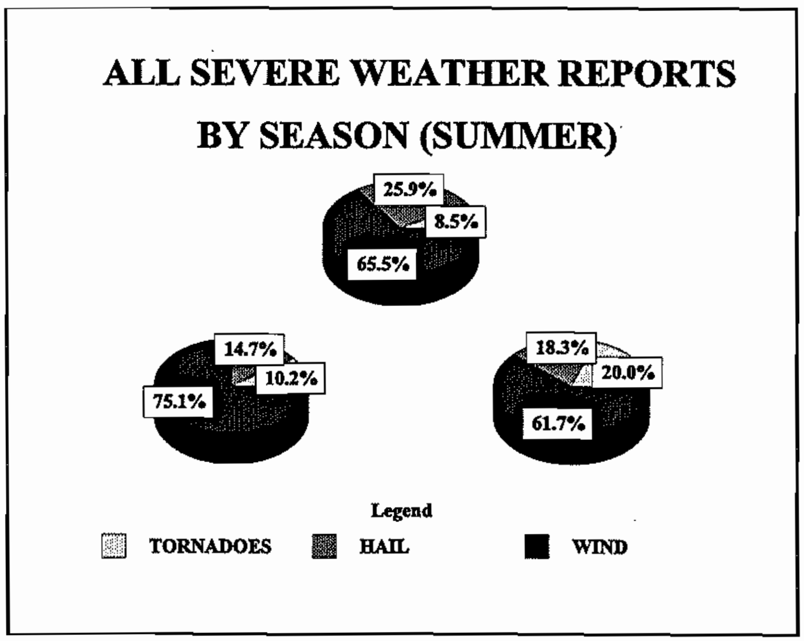


Figure 53 Jul, Aug and Sep counterclockwise from top

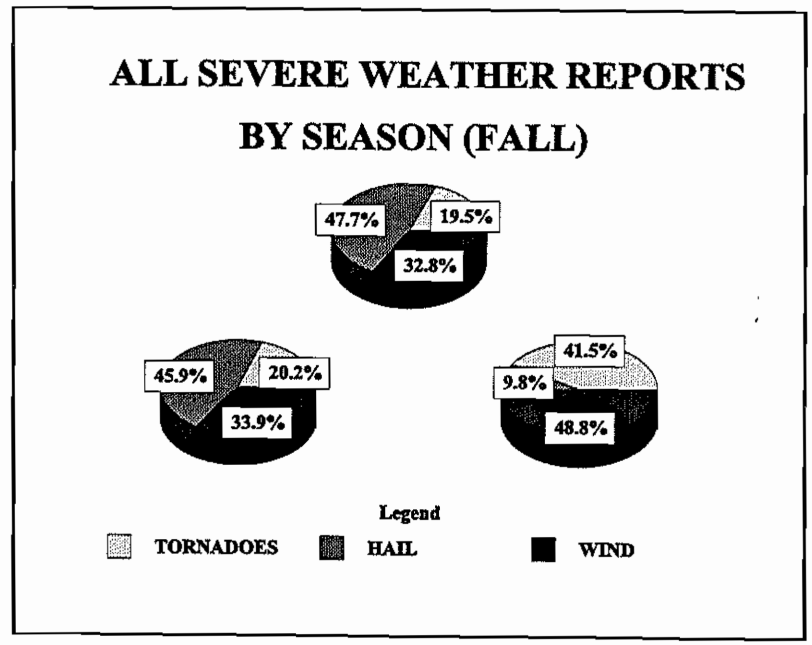


Figure 54 Oct, Nov and Dec counterclockwise from top

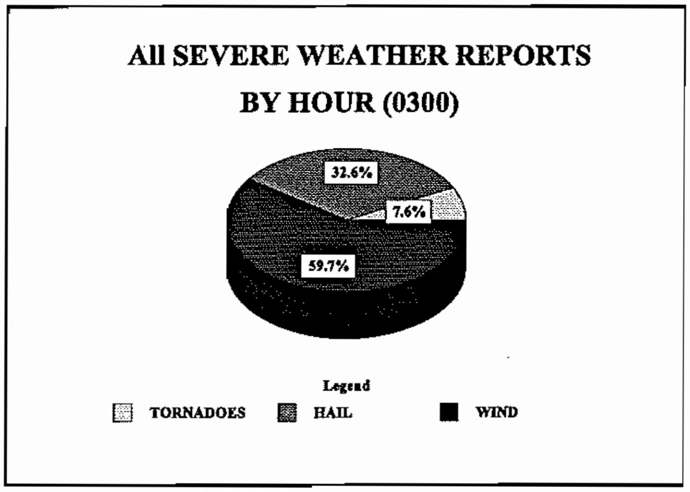
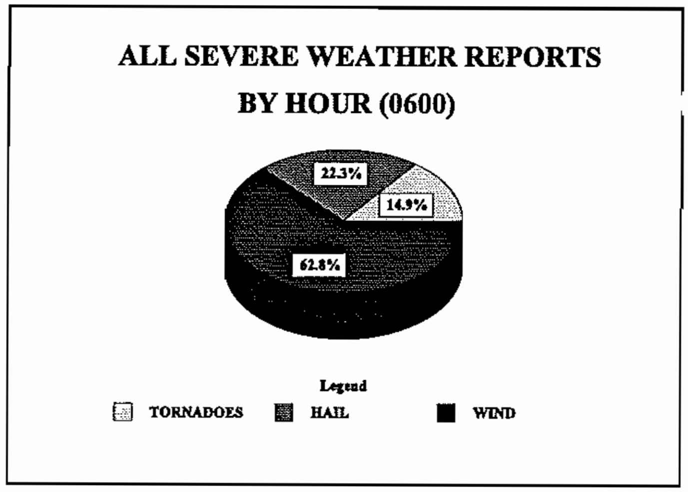


Figure 55



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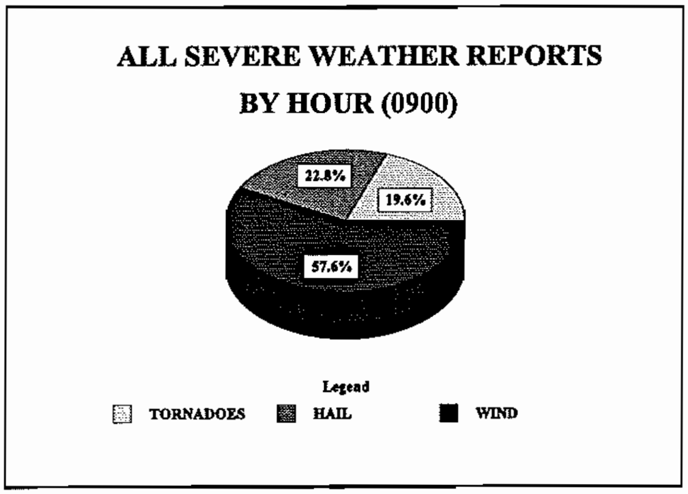

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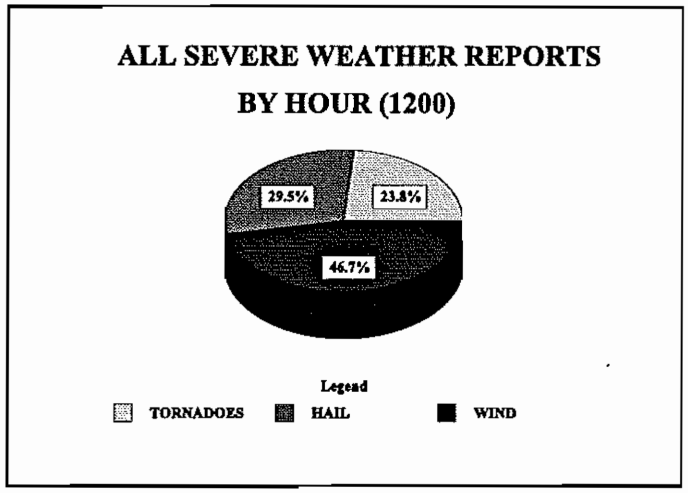

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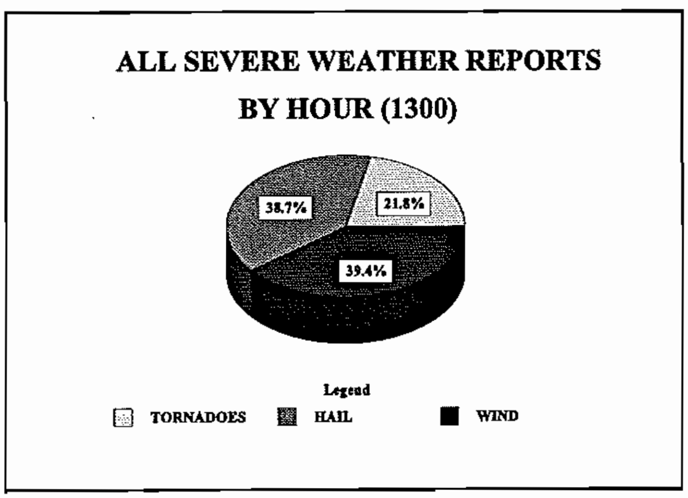

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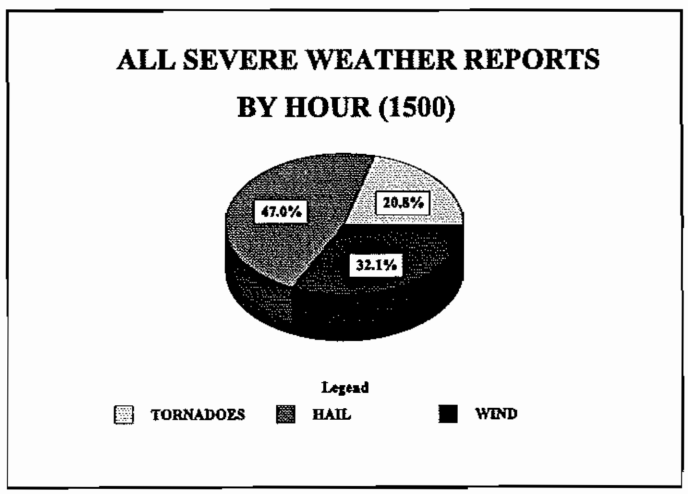


Figure 60

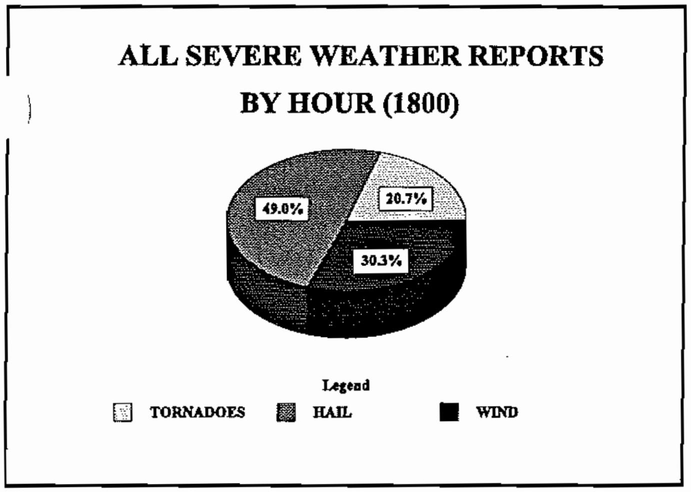
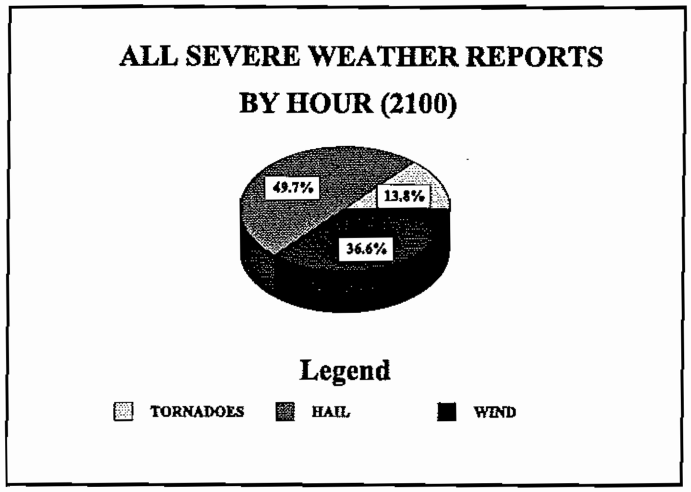


Figure 61



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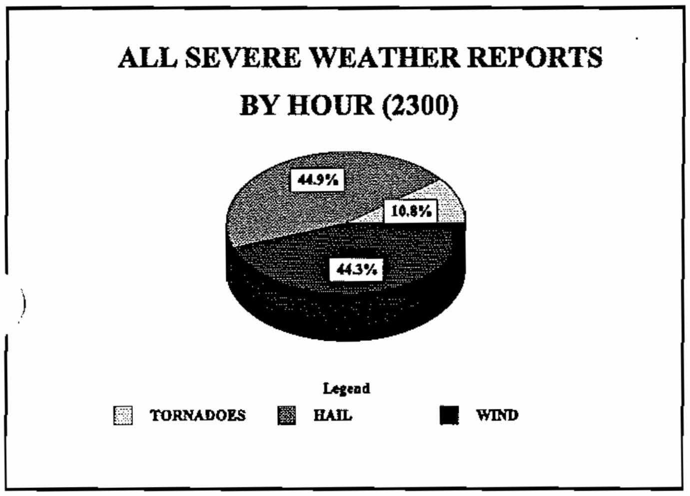

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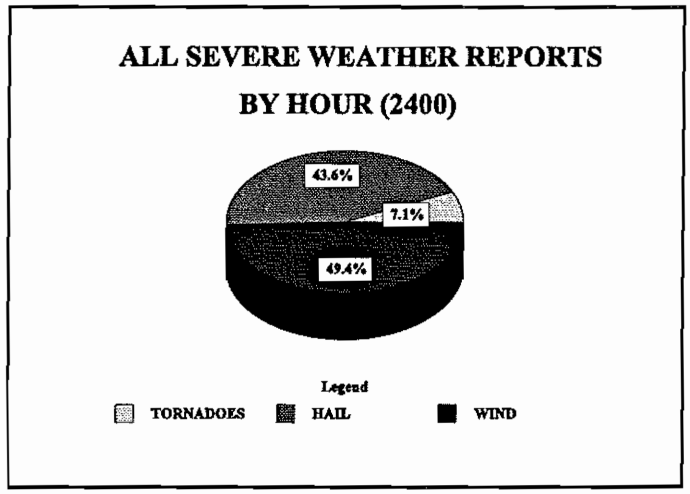

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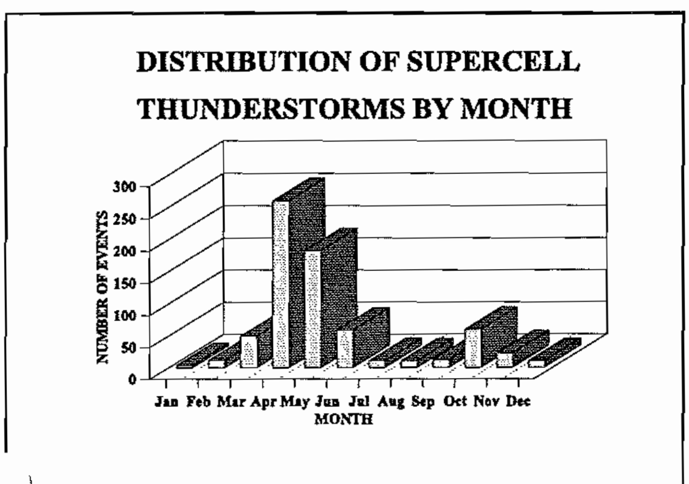

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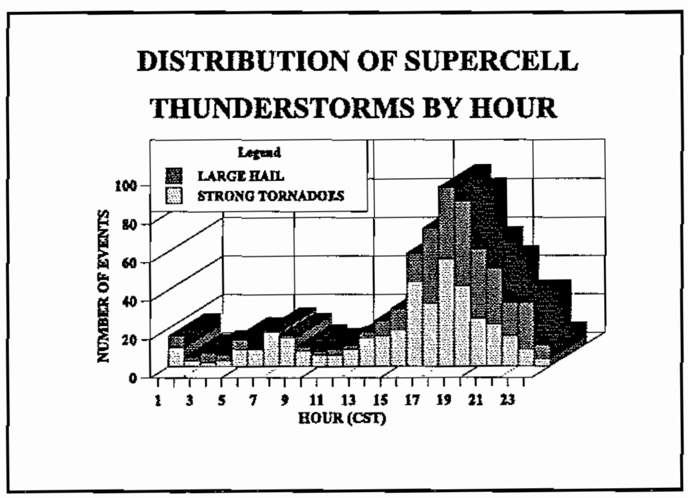

Figure 66