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A SEVERE WEATHER CLIMATOLOGY OF THE COUNTY WARNING AREA OF THE HOUSTON AREA NATIONAL WEATHER SERVICE OFFICE

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1. INTRODUCTION

Once modernization efforts are complete at the Houston Area National Weather Service (NWS) office, full forecast and warning responsibility for 23 southeast Texas counties (Fig. 1) known as the county warning area (CWA) will be assumed. Along with this new responsibility comes a greater need to understand the local climatology. The basic assumption is that an increased knowledge of the local climatology will lead to more accurate forecasts and warnings. The local climatology of severe thunderstorms was chosen because they often affect the weather across the CWA. One example of the frequency of severe weather occurrence in the CWA is Harris county (Fig. 1). Harris county is consistently among the top one or two counties in annual reports of tornadoes (Ostby, 1993).

According to standard NWS policy, a severe thunderstorm is defined as the occurrence of one or more of the following: tornado, hail greater than or equal to 3/4 inches in diameter, convective wind gust greater than or equal to 50 knots, or convective wind damage. The sections of this study are divided up according to the particular severe weather event.

Efforts to document severe thunderstorms and organize them into a climatology have been pursued by many authors. Grazulis (1993), Kelly et al. (1978) and Schaefer et al. (1980) developed a nationwide climatology on tornadoes while Knupp and Garinger (1993) concentrated on tornadoes of the Gulf Coast region. An extensive hail and wind climatology was developed by Kelly et al. (1985). The objective of this paper is to focus on the severe weather climatology of the CWA and relate the findings to national and regional work done previously.

2. DATA

The National Severe Storms Forecast Center (NSSFC) maintains a tornado database dating back to 1950 and severe hail and wind events dating back to 1955 for the United States. This extensive database is contained on the SVRPLOT program (Hart, 1993). The data used in this study came from these SVRPLOT files. From these national files, the data was screened first for Texas counties and then for the 23 counties in the CWA (Fig. 1). This process was repeated for each SVRPLOT file which contains a full year of national severe weather data. Since no hail and wind data were available for the year 1972 in the SVRPLOT files, the Storm Data publication was used to fill in this void.

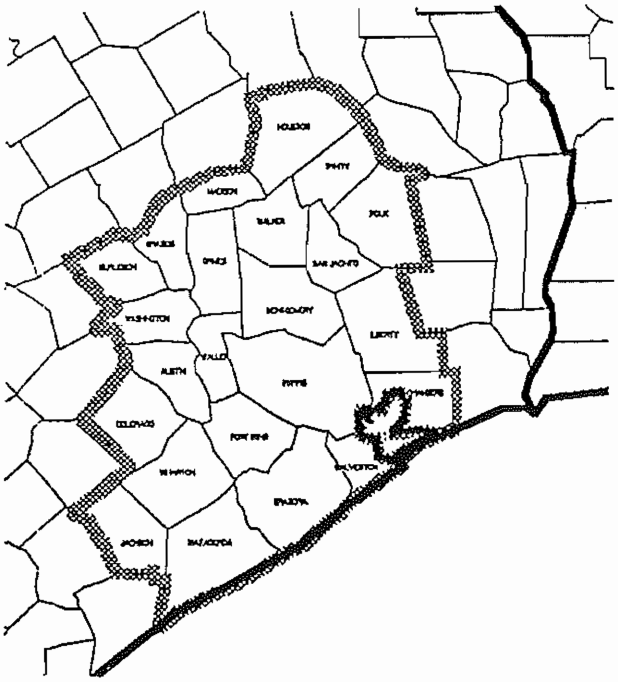

Figure 1. *County warning area for the Houston Area NWS Office.*

3. TORNADO CLIMATOLOGY

a) Yearly frequency

Even though factors such as population and increased emphasis on warning verification greatly influence the tornado database (Ostby, 1993), some fundamental conclusions can still be reached with the database of the

NSSFC. One of the first things noticed when examining the tornado reports for the CWA is the paucity of reports in the 1950's (Fig. 2). Certainly, the lack of reports can be partially attributed to the above-mentioned factors. However, the lack of reports in the mid to late 1980's can not be solely blamed on these factors. Instead, the synoptic scale weather pattern and other meteorological factors may have had a profound influence on the lack of tornadoes during this time. This same dropoff in tornado reports was also noted by Grazulis (1993) and Ostby (1993) for the United States.

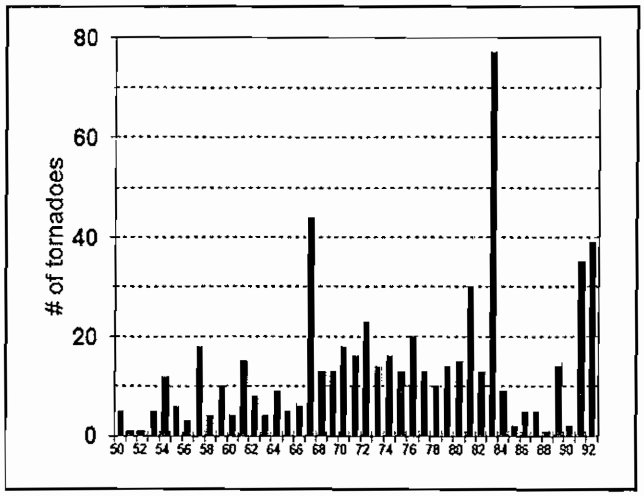

Figure 2. *Yearly frequency of all tornadoes in the CWA from 1950-1992.*

A total of 590 tornadoes were reported from 1950-1992 in the CWA. The years 1983 and 1967 were the most active years. In 1983 two major weather events accounted for almost 60% of the reported tornadoes. On May 20-21, 1983 a series of very strong mesoscale convective systems (MCS's) produced 25 tornadoes across the CWA. The first of these MCS's to affect southeast Texas is pictured in Fig. 3. Also in 1983 on Aug 17-18 Hurricane Alicia produced 21 tornadoes across the CWA. Excluding the tornadoes from Alicia and the outbreak on May 20-21, there were still 31 tornadoes across the CWA in 1983. This is more than double the 43 year tornado average of 13.7 tornadoes per year. The same cannot be said about the year 1967. Hurricane Beulah on Sep 19-21, 1967 produced an incredible 36 tornadoes in the CWA. The rest of the year was rather inactive with only 8 tornadoes. This actually makes 1967 a below average year if the tornadoes from Beulah are disregarded.

b) Monthly frequency

Monthly frequency (Fig. 4) of tornadoes shows a distinct maximum in the month of May. This is consistent with the national statistics (Grazulis, 1993; Kelly et al., 1978; Ostby, 1993; Schaefer et al., 1980). May's 115 recorded tornadoes account for almost 20% of the tornado database. After adding June's 60 tornadoes to May's total, the percentage of May-June tornadoes becomes 29.7%. Although this is not quite the 40.8% amount that Kelly et al. (1978) found for the U.S., it still shows a good agreement. The reason for this discrepancy is simply that the other 11% is distributed among other months. Namely, the months from Sep-Feb account for more than 40% of the tornadoes that occur in the CWA as opposed to only 20% nationally (Kelly et al., 1978). Several factors such as the seasonal migration of the polar jet stream, landfalling tropical systems, and nearly endless supply of warmth and moisture create a monthly tornado frequency which is more evenly distributed than the Great Plains tornado frequency (Grazulis, 1993). As a result, tornadoes in the Houston CWA have a higher probability of occurring in the cool season than in continental locations where the distribution is strongly skewed toward only the spring and summer months.

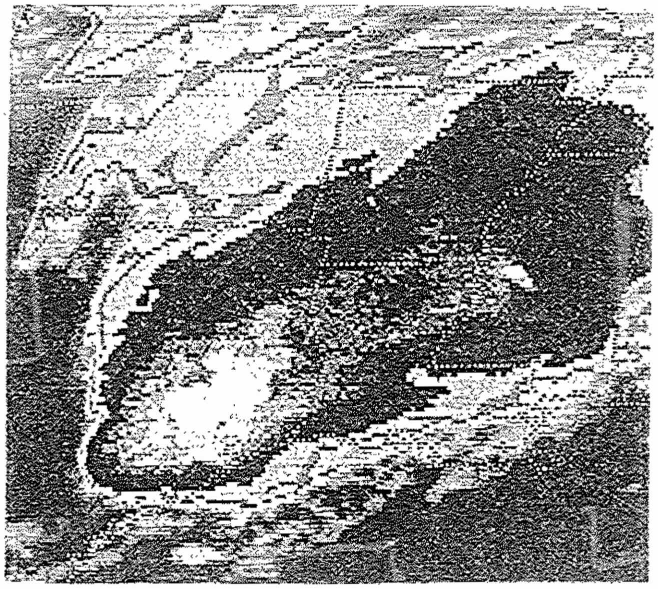

Figure 3. *0730 GMT IR image of the May 20, 1983 bow echo which produced widespread severe weather across southeast Texas.*

Another unique regional difference can be seen in Fig. 4. This is the secondary peak in September. The September secondary peak appears to be unique to this area. Texas as a whole, the surrounding states of Oklahoma and Louisiana, and even the United States all have a November secondary peak (Grazulis, 1993; Ostby, 1993; Schaefer et al., 1980) rather than a September secondary peak. The likely reason for the existence of the secondary September peak in tornadoes is quite simply that the peak in hurricane season is also in September. September therefore is the peak in the tropical tornado season. Tropical systems which can produce many tornadoes, as in the case of Beulah, do strike the Texas coast enough times to influence the tornado climatology.

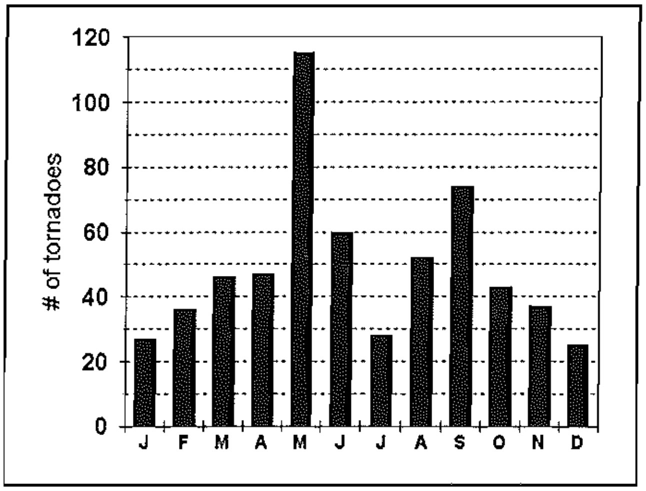

Figure 4. *Monthly frequency of all tornadoes in the CWA from 1950-1992.*

It is important to point out that September is not the so-called "second season" of tornadoes. As mentioned in the above paragraph, the "second season" occurs in November for most southern locations in the United States. The "second season" is the period of time when the westerlies become active again while warm and moist conditions still exist. Unlike the tornadoes produced during the "second season", most of the September tornadoes are produced by tropical cyclones in easterly flow. Once this distinction has been made, it is desirable to separate the tropical cyclone tornadoes from all the CWA tornadoes from 1950-1992 (Fig. 5). Tropical cyclone positions and times came from NOAA's *Tropical Cyclones of the North Atlantic Ocean, 1871-1986.* A total of 83 tropical cyclone tornadoes occurred in the CWA from 1950-1992. 58% of all tropical cyclone tornadoes occurred in the month of September and also 65% of all September CWA tornadoes were associated with a tropical cyclone.

After the tropical cyclone tornadoes were removed, the existence of the "second season" was apparent. Fig. 6 clearly shows that the "second season" of CWA tornadoes exists in the months of October and November. Recent evidence by Ostby (1993), together with the occurrence of two significant tornado outbreaks in the Houston CWA in the past two years, suggests that the month of November is the peak in the "second season" rather than October. Also, the significant tornado database which Grazulis (1993) has compiled indicates that a November secondary peak in significant tornadoes exists for the CWA. In summary, there exist three tornado seasons in the CWA. The primary season peaks in May while a less active one occurs in October and November. The tropical tornado season spans from June through October with a strong peak in September.

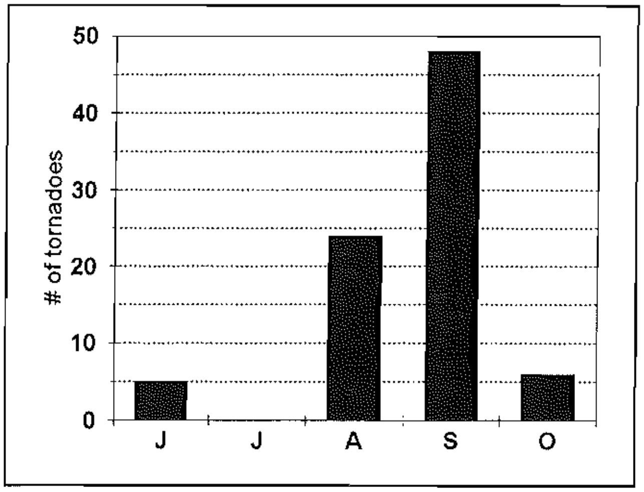

Figure 5. *Monthly frequency of all CWA tornadoes which were produced by tropical storms and hurricanes from 1950-1992.*

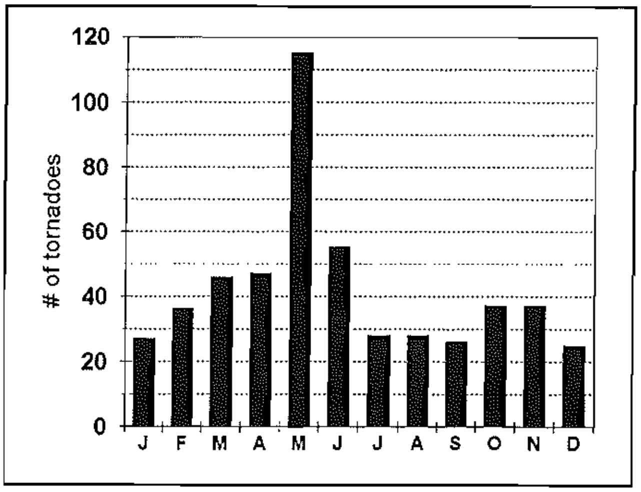

Figure 6. *Same as Fig. 4 except minus the tropical cyclone tornadoes.*

c) Diurnal trends

Again, regional differences come into play with the diurnal trend of tornadoes reported in the CWA (Fig. 7). The regional difference is not the middle to late afternoon peak in tornadoes which is widely recognized as the occurrence of most tornadoes (Grazulis, 1993; Kelly et al.,

1978) but the secondary peak in the morning. Specifically, the hours of 0900-1000 AM and 0700-0800 AM CST indicate secondary diurnal maxima. The primary peak for the CWA is between 0300-0400 PM CST with the mean hour of all tornadoes being 1257 PM CST. A secondary peak in the morning is by no means unusual for the Gulf Coast region. Knupp and Garinger (1993) found a similar secondary peak along the central Gulf Coast between 0800-1000 LST. Kelly et al. (1978) also found a similar bimodal configuration in their Southeast\ states distribution. Examining the hourly frequency of tornadoes during the spring (not shown) reveals that the morning secondary peak is not as easily as recognizable. Instead, the secondary peak shows up at earlier hours from midnight until 0700 AM CST. Also, the primary peak during the spring is earlier at 1200-0100 PM CST.

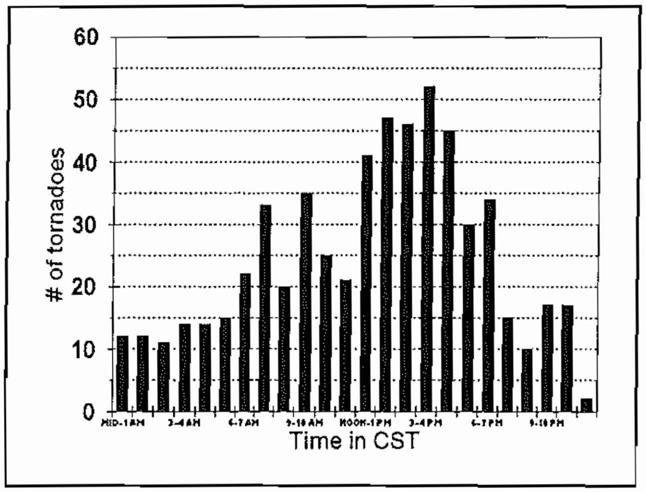

Figure 7. *Hourly frequency of all tornadoes in the CWA from 1950-1992.*

d) Magnitude

Table 1 describes the Fujita-Pearson Scale (Fujita and Pearson, 1973) which attempts to quantify the wind speed, path length, and path width of a tornado. Figs. 8-10 illustrate the F,P,P rating (Fujita Intensity Scale, Pearson Path Length Scale, Pearson Path Width Scale) for all tornadoes in the CWA which had ratings available. 74% of the tornadoes are weak (F0-F1), 25.6% are strong (F2-F3), and 0.4% are violent (F4-F5). The mean F-Scale is 0.96. Not surprisingly, there is a greater proportion of weak tornadoes in the Houston CWA dataset than the entire NSSFC database which classifies 68% of all tornadoes as weak (Grazulis, 1993). Also nationally, 30% of all tornadoes are strong while 2% are violent. The CWA climatology certainly indicates that strong tornadoes are possible but violent ones are extremely rare. In fact, only two F4 tornadoes have ever been reported in the CWA since 1950. The first one was associated with Hurricane Carla in the early morning hours on Sep 12, 1961 and affected Galveston county. The second one was associated with a significant tornado outbreak on Nov 21, 1992 and affected the Channelview area in eastern Harris county. No F5 tornadoes have ever been reported in the CWA.

Table 1. The Fujita-Pearson FPP Scales.

Scale	Fujita wind speed	Pearson path length	Pearson path width
0	40-72 mph	0.3-0.9 mi	6-17 yds
1	73-112 "	1.0-3.1 "	18-55 "
2	113-157 "	3.2-9.9 "	56-175 "
3	158-206 "	10-31 "	176-566 "
4	207-260 "	32-99 "	0.3-0.9 mi
5	261-318 "	100-315 "	1.0-3.1 "

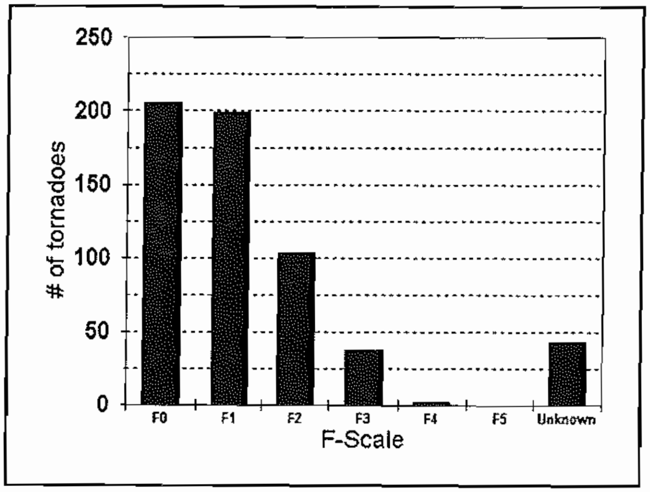

Figure 8. *F-Scale distribution of CWA tornadoes from 1950-1992.*

Path length and width scales show similar characteristics to the F-Scale distribution. Both scales have a disproportionate number of tornadoes in the P0-P1 category. Specifically, 85% of the tornadoes have a rating of PL0-PL1 and more than 75% have a rating of PW0-PW1. The revelation that the vast majority of CWA tornadoes are short-lived and narrow is not surprising. At the opposite end of the scale (P4-P5), less than 2% of all tornadoes are in this category. The average PL-Scale and PW-Scale are 0.57 and 1.06, respectively. However, after averaging the actual reported path lengths and widths, a slightly stronger average tornado emerges. The average path length is 3.1 miles while the average path width is 96.2 yards or 0.05 miles. According to Table 1, the 3.1 mile avg. path length corresponds to a PL1 rating and the 96.2 yd avg. path width corresponds to a PW2 rating. The discrepancy between the avg. scale rating and the actual avg. path length or width value seems to be caused by an incomplete database. Not all path length or width values had a scale rating associated with them in the NSSFC database.

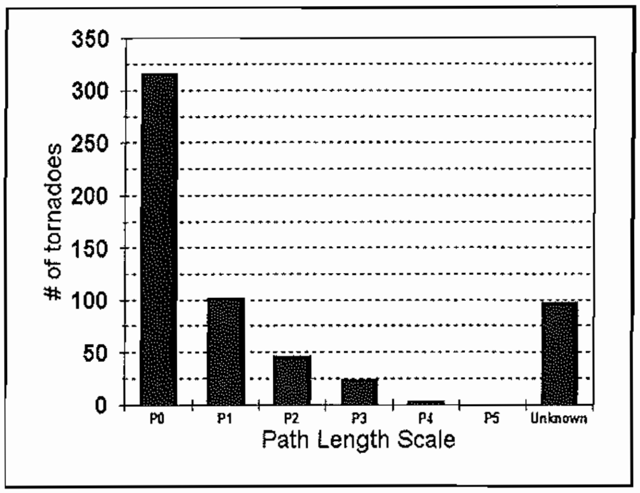

Figure 9. *Pearson Path Length Scale distribution of CWA tornadoes from 1950-1992.*

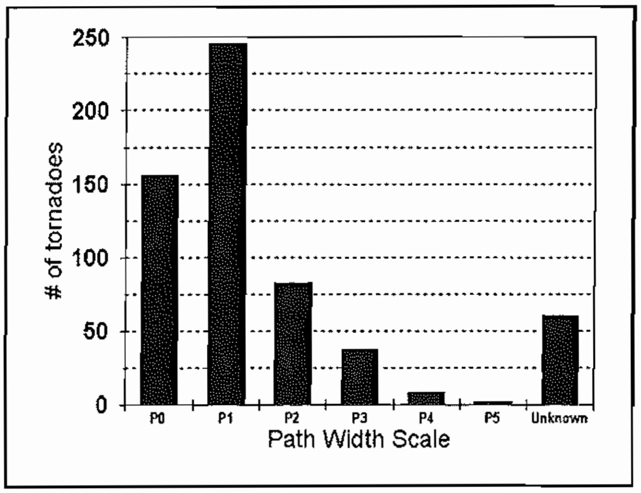

Figure 10. *Pearson Path Width Scale distribution of CWA tornadoes from 1950-1992.*

e) Significant tornadoes

For the purpose of this study, significant tornadoes will be defined as those which are F2 or stronger. Figs. 11 and 12 show many similarities to Figs. 4 and 7. The May peak and 0300-0400 PM CST peak are the same for significant tornadoes as they are for all tornadoes. However, differences do exist. Two secondary peaks exist in the months of February and October (Fig. 11). February appears to be a month when tornadoes start to become more prevalent and increase dramatically from a January minimum. A similar February dramatic rise was noted among other Gulf Coast states such as Louisiana and Mississippi (Grazulis, 1993). The October secondary peak can most likely be explained by not only landfalling tropical cyclones but also the first strong fronts of the season. The secondary diurnal peak from 0300-0400 AM CST for significant tornadoes (Fig. 12) is not as pronounced as the secondary diurnal peak associated with all tornadoes (Fig. 7). However, it is consistent with Fig. 7.

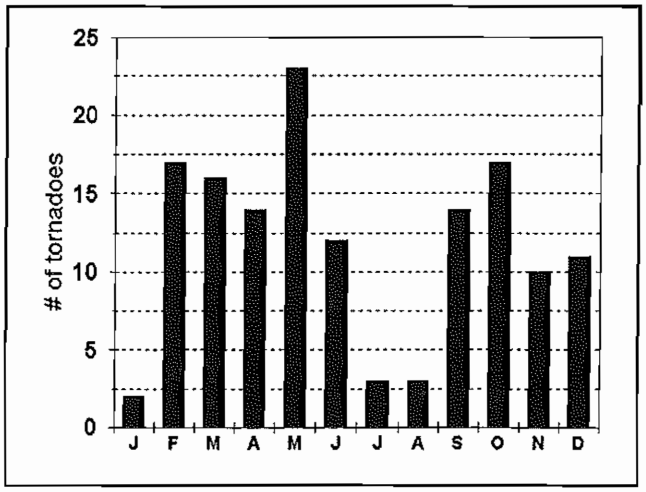

Figure 11. *Same as Fig. 4 except for significant tornadoes.*

Significant tornadoes are rather rare occurrences in the months of January, July and August. January's lack of significant tornadoes can be best explained by the cold temperatures and little or no convective available potential energy (CAPE). The lack of significant tornadoes in July and August can be best explained by the northward retreat of the westerlies. The only significant tornadoes during the summer appear to be strictly from tropical systems which often affect the CWA.

An interesting note on November significant tornadoes reveals that more than 50% occurred on Nov 21, 1992. As mentioned previously, this was a rather significant tornado outbreak for the CWA. The most violent tornado to affect the CWA was the Channelview tornado which had a F,P,P rating of 4,3,5. Historically, this event was a rare one for the CWA. However, as stated earlier, the data amassed by Grazulis suggests a November secondary peak in significant tornadoes in the CWA.

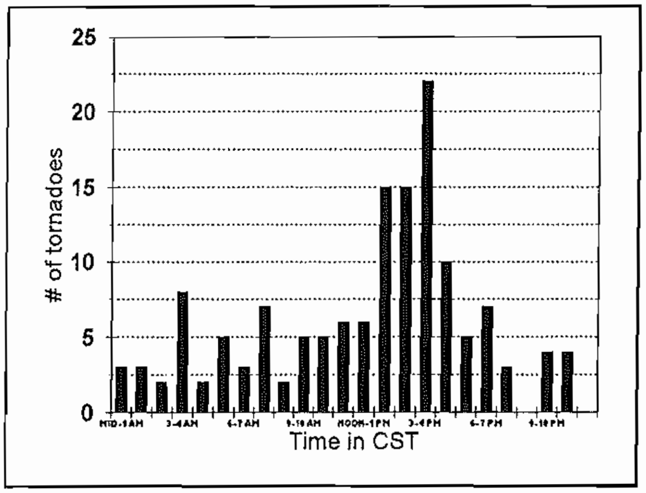

Figure 12. *Same as Fig. 7 except for significant tornadoes.*

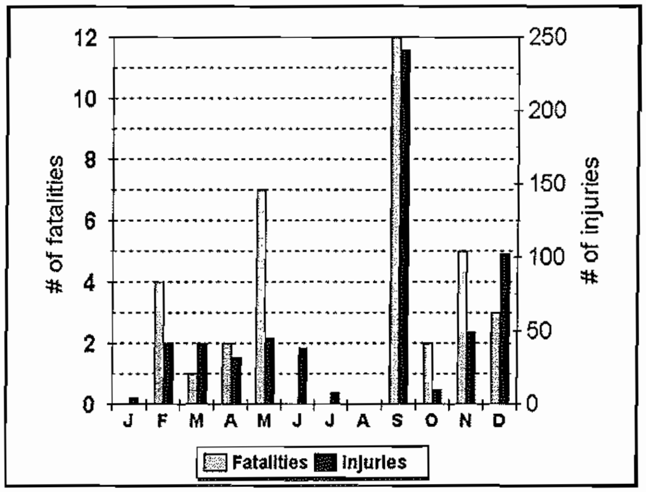

Figure 13. *Fatalities and injuries caused by significant tornadoes from 1950-1992.*

Finally, Fig. 13 depicts in human terms the "real" significance of tornadoes. The deadliest tornado outbreak occurred back on Sep 11-12, 1961 with Hurricane Carla. 8 people lost their lives and 200 people were injured due to a tornado which had a F,P,P rating of 4,1,2. Although fatalities are rather rare with all tornadoes, there is a 25% chance that if a significant tornado occurs in the CWA that a fatality will occur. 85% of all tornado fatalities which have occurred in the CWA were caused by strong and violent tornadoes. This compares favorably with the national figure of 99% of tornado fatalities due to significant tornadoes (Grazulis, 1993). An average of 4 injuries has occurred with each significant tornado that has affected the CWA from 1950-1992. Obviously, these statistics are skewed by major events such as Carla but that does not diminish what they tell about significant tornadoes.

Tornado climatology for the CWA is a unique subset of the national tornado climatology. Gulf Coast factors strongly influence the climatology. Logically, hail and wind climatologies should also be influenced by these factors.

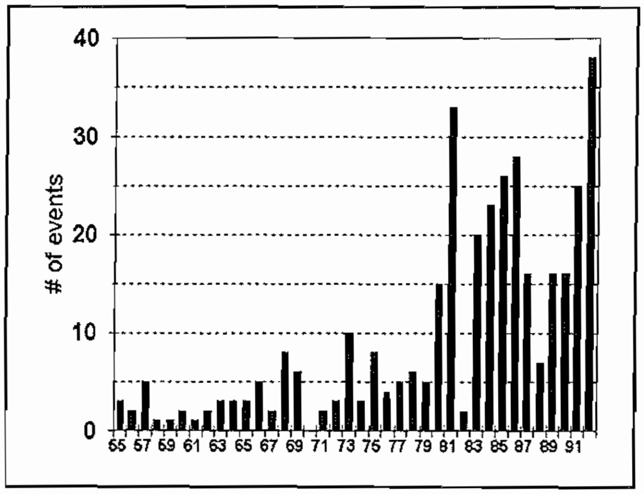

Figure 14. *Yearly frequency of all hail events in the CWA from 1955-1992.*

4. HAIL CLIMATOLOGY

a) Yearly frequency

In order to fully understand hail climatology, one must first realize the nature and significance of the hail reports. In 1980, the NWS began verifying severe thunderstorm and tornado warnings (Hales, 1993). The result of this action prompted NWS offices to "search" out for severe weather reports during and after the severe weather event. As can be seen in Fig. 14 the number of reports since 1980 has increased dramatically. 74% of all hail reports from 1955-1992 have occurred since 1980. From 1955-1979 the mean number of hail reports is only 3.7 while the period from 1980-1992 the mean number of reports is 20.4! Despite this obvious bias in the data, reasonable conclusions can still be reached.

Fewer hail reports occurred than tornadoes. Only 358 hail reports were recorded in the period 1955-1992. No hail was reported in the year 1970. The lack of reports for the years 1982 and 1988 is more likely due to an unfavorable weather pattern for the production of hail rather than a deficiency in the collection of reports or verification problems. The years 1981 and 1992 were particularly active. An active May of 1981 produced 23 hail reports in the CWA accounting for 70% of the total number of reports for 1981. 1992's April and May were equally as active producing 20 hail reports. 10 of these reports occurred on Easter Sunday April 19, 1992.

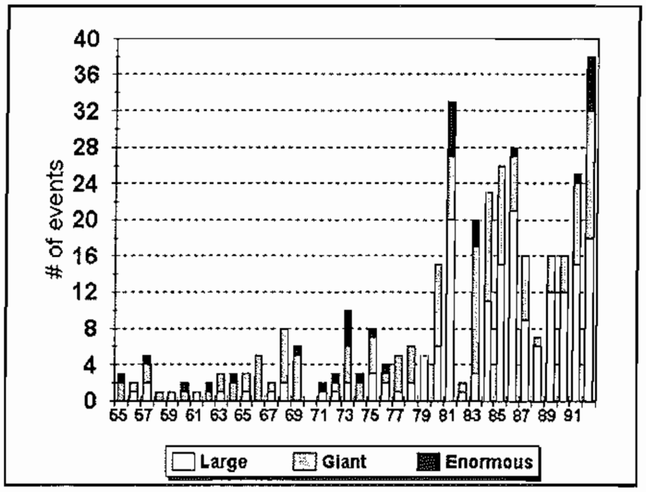

Figure 15. *Same as Fig. 14 except by hail category.*

b) Hail categories

In an attempt to separate the marginally severe hail events (1 inch or less) from the hail events greater than one inch or even two inches in diameter, the following classification scheme was devised:

Large hail:	0.75-1.00 inches in diameter
Giant hail:	1.25-1.75 inches in diameter
Enormous hail:	2.00 inches or greater in diameter.

This classification scheme is different from the one used by Kelly et al. (1985) which broke hail into two categories (2 inches or less and greater than 2 inches). The distribution by hail category is shown in Fig. 15. Large and giant hail show the same tendency of the entire hail frequency to grow in number from 1980 and on. For example, prior to 1980 large hail made up only 29% of all hail reports. However, since 1980 large hail accounts for 56% of all hail reports. Hales (1993) and Sammler (1993) have also found on a national basis that the percentage of marginally severe hail reports from all hail reports has been increasing since about 1980. Ostby (1993) also found similar results with tornadoes. These authors have hypothesized that the primary reasons for this bias are different data gathering methods, subjectivity of reports, population density, and warning verification. However, in order to alleviate this bias, the most extreme severe weather events should be analyzed. For hail, this is the enormous hail category. Enormous hail frequency displays a relatively constant rate for the entire period from 1955-1992. This rate of approximately one enormous hail report per year allows a less biased hail climatology to emerge. It is not muddied for the most part by external non-meteorological factors. Although it is unwise to disregard the large and giant hail reports, a clearer and less distorted picture of hail climatology is achieved by examining enormous hail.

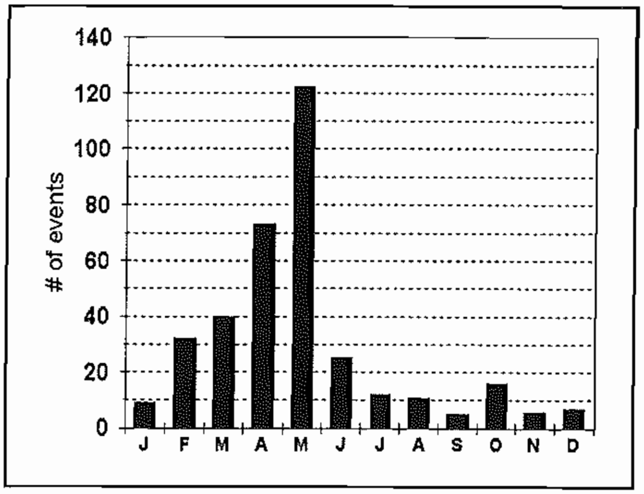

Figure 16. *Monthly frequency of all hail events in the CWA from 1955-1992.*

c) Monthly and diurnal trends

As with tornadoes, hail reports also peak in the month of May (Fig. 16). Although it is not shown, each hail category also peaks in May. On the average, May records at least three hail reports in the CWA per year. Hail reports are most numerous during the months from Feb-May accounting for three-fourths of all hail reports. Kelly et al. (1985) found that the period Mar-May accounts for 71% of all hail reports along the Gulf Coast region. For the CWA, the period Mar-May accounts for 66% of all hail reports. The agreement is good but would be better if Kelly et al. (1985) had included the month of February in the spring season period. February along the Gulf Coast appears to be the month when hail as well as tornadoes (Grazulis, 1993) start increasing in number from the relative minimum in activity during the months of December and January. Perhaps, the warmer temperatures which are experienced in February translate into a greater amount of CAPE available to growing thunderstorms and ultimately to hail production.

The relative rarity of hail reports from Jul-Jan (18% of all hail reports) across the CWA can be primarily explained by the high freezing level during the summer.

Even though thunderstorms are a common occurrence during this time across the CWA, the presence of warm middle level tropospheric temperatures inhibit hail formation. The secondary peak in October can be best explained by the first strong fronts of the season coupled with a warm and moist lower troposphere.

The diurnal peak for hail is between 0500-0600 PM CST which is two hours later than the tornado peak. 65% of the reports occurred between the hours of noon and 0800 PM CST (Fig. 17). Kelly et al. (1985) had a similar middle to late afternoon peak and large concentration of reports in the afternoon and early evening hours. A secondary peak is noted between the hours of 1100 PM CST and 0300 AM CST. 12% of the reports occurred during this time. By hail category, the results were basically the same except for enormous hail which had a primary peak between 0600-0700 PM CST and a secondary peak between 0000-0300 AM CST. The mean time for all hail reports is 0250 PM CST. At the opposite end, the minimum for all hail reports is between 0600-0700 AM CST. Only one report of hail in 38 years was recorded during this time!

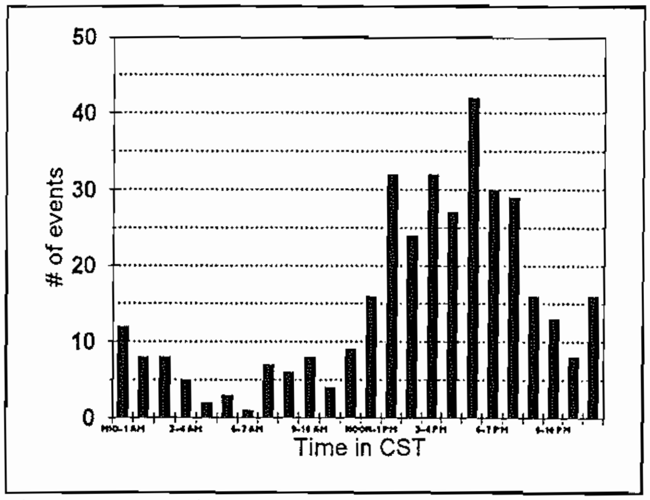

Figure 17. *Hourly frequency of all hail events in the CWA from 1955-1992.*

Obviously, the main reason for the primary peak is a maximum in instability during the afternoon and early evening hours. The secondary peak may be better explained by the development of what Fike (1993) describes as a nocturnal severe local storm outbreak (NSSO). The NSSO, according to the definition, develops at night or the early morning hours and is not merely a continuation of earlier severe weather. Fig. 18 reveals the main axis of activity extending from southeastern Oklahoma through east Texas to the central Gulf Coast. Specifically for hail (Fig. 19), the axis is further west but still affecting the CWA.

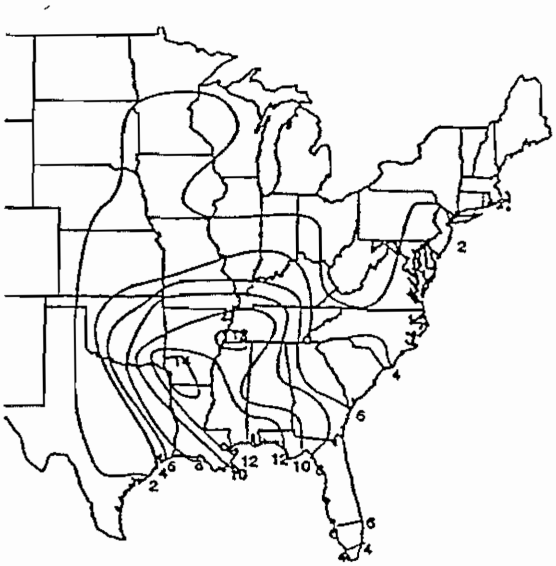

Figure 18. *Areal frequency of NSSO events from 1970-1991 (Fike, 1993).*

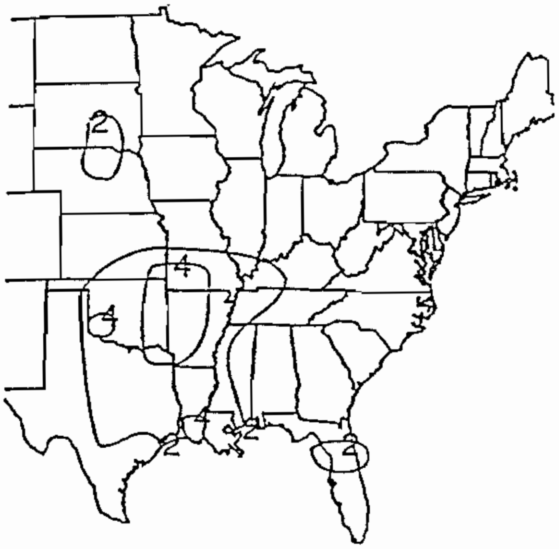

Figure 19. *Same as Fig. 18 except only for hail events.*

d) Hail size distribution

The hail size distribution clearly demonstrates the data being skewed by non-meteorological factors (Fig. 20). Certainly in an ideal world baseball size hail (2.75 in) is not more common than nickel size hail (0.88 in) or half dollar size hail (1.25 in). It appears the popularity of particular sizes is more to blame than anything else. Spotters most likely report golfball size hail (1.75 in) more often than other sizes because golfballs do in fact look like most hailstones. The largest number (35%) of all hail reports is golfball size while hail which is either one magnitude larger or smaller make up only 4% and 6% of all hail reports, respectively. The same is true of quarter size hail (1 in) which is also a popular reporting size. Dime size hail (0.75 in) can be partly explained by this. However, a better reason may be that the quest for high verification proficiency promotes more marginally severe hail reports making it into the database. Certainly the difference between 0.50 inch and 0.75 inch hail is minimal but great if the report is to be considered severe and therefore verify a warning. Authors such as Sammler (1993) and Hales (1993) have noted that marginally severe hail reports presently dominate the database and some may say corrupt it also.

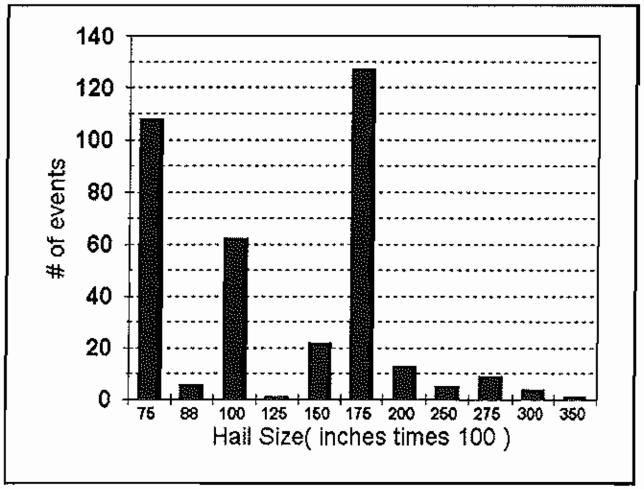

Figure 20. *Hail size distribution of CWA hail events.*

5. WIND CLIMATOLOGY

a) Yearly frequency

Wind events since 1980 do not show as dramatic a rise as hail events did. Instead, the wind events show a steady rise from the mid 1970's into the 1980's when reports begin to level off (Fig. 21). From 1955-1974, the CWA averaged just 5.6 wind events per year. However, from 1975-1992 the average number of wind events skyrocketed to 29.3 per year! A total of 638 wind events have occurred from 1955-1992 but an astonishing 83% of these occurred from 1975-1992. Once again, factors such as population and verification techniques are most likely the primary culprits.

The year 1987 recorded more wind events than any other year with 61. The year as a whole was rather active with wind events reported in almost every month. A particularly strong MCS in the early morning hours of November 16 produced 14 wind events, 3 of which were greater than 65 knots. Another active year was 1981. A powerful MCS ripped across the CWA in the morning hours of April 23 producing 13 wind events, 1 of which exceeded 100 knots. The only other recorded wind report which exceeded 100 knots was in association with the May 20, 1983 (Fig. 3) bow echo squall line which, to this date, is the most powerful to affect the CWA.

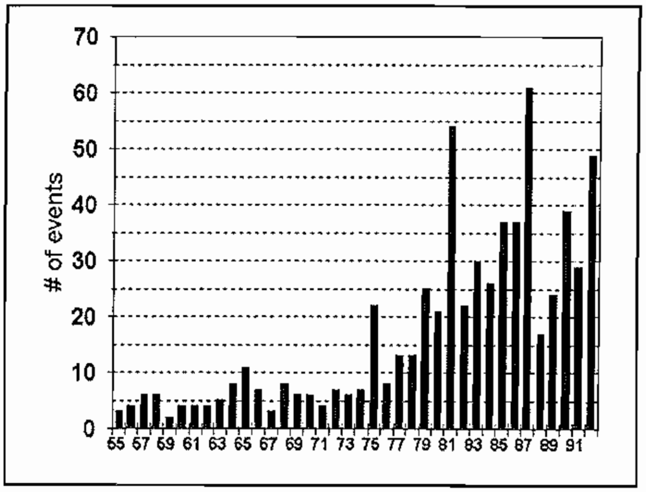

Figure 21. *Yearly frequency of all wind events in the CWA from 1955-1992.*

b) Wind categories

Just like hail, categorizing the wind events by strength leads to a clearer understanding of the climatology. The classification scheme used in this study is modeled after the one used by Kelly et al. (1985):

Wind damage:	Unknown strength
Strong wind:	50-65 knots
Violent wind:	Greater than 65 knots.

Of all the wind events, 69% were wind damage, 25% were strong and 6% were violent. Nationally, Kelly et al. (1985) found similar results in their study.

The all-encompassing wind damage category, which includes everything from one downed tree to a swath of damaged buildings, tends to skew the database in the same way that the hail climatology is skewed by marginally severe hail reports. Fig. 22 shows the dramatic increase in the wind damage reports over the past 15 years. Strong wind reports showed a lesser increase. On the other hand, violent wind reports showed consistency throughout the years even back to 1955. It is believed that the relatively constant rate of violent wind reports represents the wind climatology much better than the other two categories. External factors have little influence on the violent wind events.

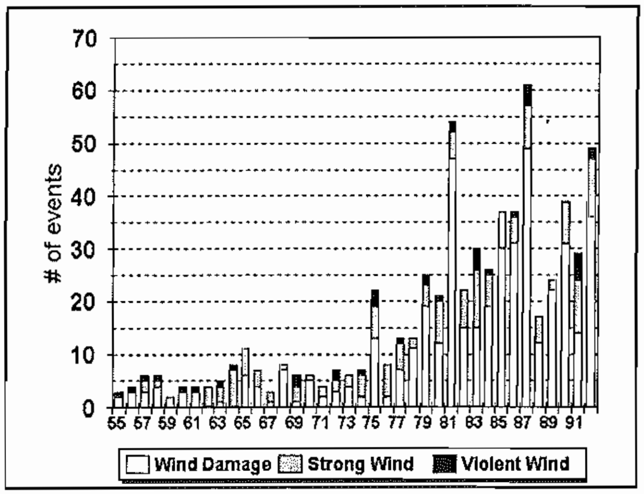

Figure 22. *Same as Fig. 21 except by wind category.*

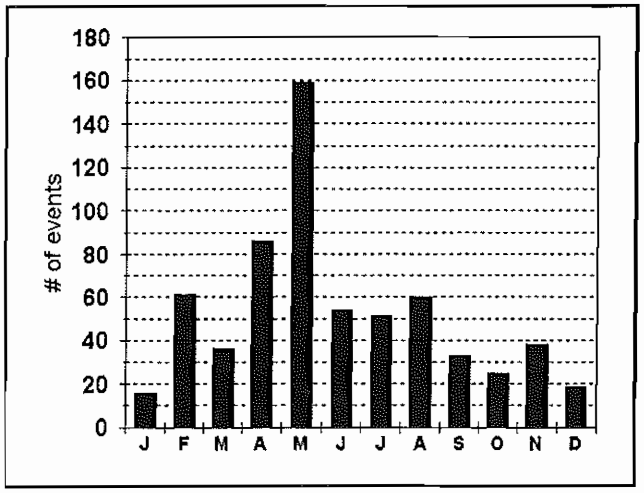

Figure 23. *Monthly frequency of all wind events in the CWA from 1955-1992.*

c) Monthly and diurnal trends

May is again the primary peak for all wind events (Fig. 23) and is also the primary peak for each wind category (not shown). 25% of all events occur during May. The most active months, not surprisingly, are from February through August with almost 80% of all wind events. Consistent with tornadoes and hail, the least active months for wind events are the months of December and January. Unlike hail however, wind events do not drop off as sharply after May. Instead, wind events tend to be more evenly distributed than hail events. Of all three types of severe weather, wind events are the most common with 50% of the months reporting more wind events than hail or tornadoes.

The summer months show a consistent pattern. Over the past 38 years an average of at least one wind event has occurred in the CWA during the summer. As noted in the tornado and hail climatologies earlier, the production of tornadoes and hail is at a relative minimum during the summer while wind events do not show a minimum until October. For example, the month of July reports more wind events than both tornadoes and hail combined. As a whole, summer records more than 25% of all wind events. The summer secondary peak is almost exclusively downbursts from pulse-type severe thunderstorms.

The November secondary peak in wind events is similar to results found by Kelly et al. (1985) and is also similar to the U.S. tornado secondary peak which occurs in November. Just as in the tornado climatology, the significance of November to wind climatology is not in doubt. The wind climatology, even the violent wind events (not shown) suggests that November is most definitely an important month.

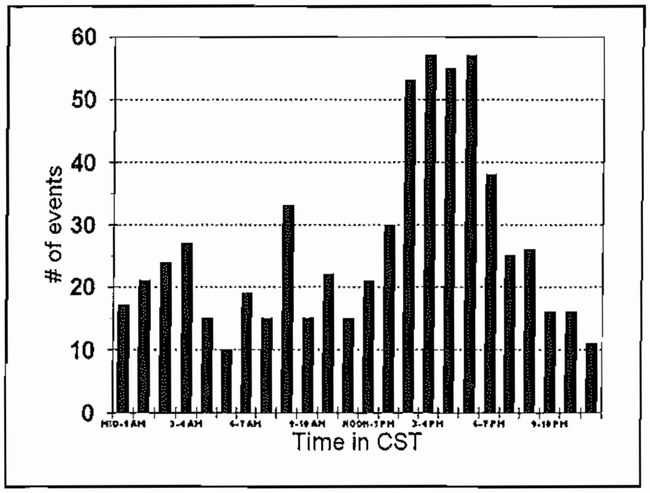

Figure 24. *Hourly frequency of all wind events in the CWA from 1955-1992.*

The diurnal trend of wind events shows many similarities to the previous tornado and hail climatologies. A broad middle to late afternoon primary peak exists between 0200-0600 PM CST (Fig. 24). 35% of all wind events occur during this time frame. Also, typical of the tornado and hail climatologies and evident in the wind climatology is the dramatic rise in the number of reports after about 1100 AM CST.

Another striking similarity is the occurrence of secondary peaks in activity in the morning hours. Specifically, between the hours of 0800-0900 AM CST and 0100-0400 AM CST display the sharpest peaks. In fact reports actually increase in number from 0000 AM

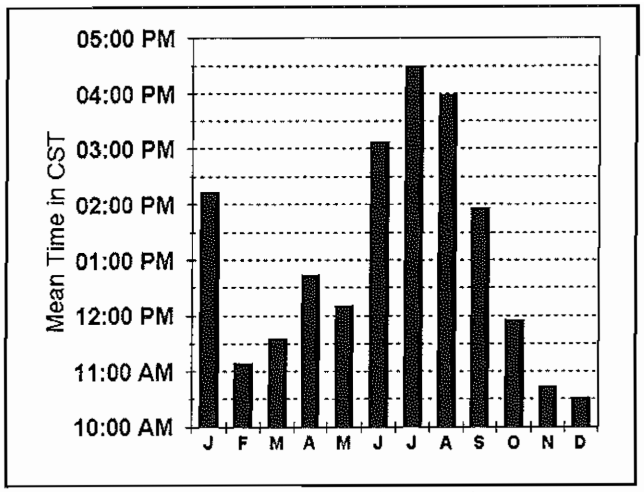

Figure 25. *Mean time of all wind events by month.*

CST and peak at 0400 AM CST! Reports then drop off and then sharply peak between the hours of 0800-0900 AM CST. Other authors (Knupp and Garinger, 1993; Kelly et al., 1985) have noted a similar morning secondary peak with wind events along the Gulf Coast region. The months with which they found the most prominent morning secondary peak were the springtime months.

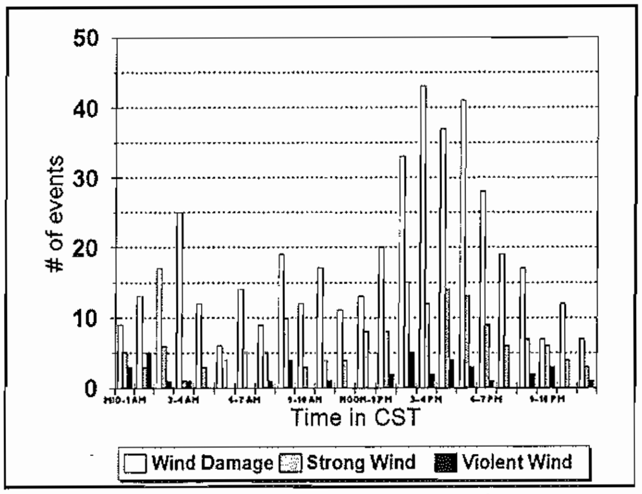

Figure 26. *Same as Fig. 24 except by wind category.*

Fig. 25 shows that for the months of Mar-May the mean time is approximately noon. Such an early time leads to the conclusion that morning wind events are just as common as afternoon wind events during the spring. In fact, the morning wind spring events are the most violent as noted in section 5a. Fig. 26 not only depicts the strength of the afternoon wind events but also the more violent morning wind events. Truly the morning secondary peak is just as important to the wind climatology as the primary peak.

6. CONCLUSIONS

The temporal distribution of severe weather which has occurred in the CWA of the Houston NWS for the past 40 years promises to be a useful tool for the entire operational staff at NWSO Houston. It is hoped that an increased knowledge of the local severe weather climatology will produce better forecasts, severe weather warnings and improve warning verification.

Additional studies on local severe weather should investigate the synoptic weather pattern so forecasters understand pattern recognition with particular types of severe weather outbreaks. Further investigation of the role of the NSSO needs to be done as it relates to the early morning secondary peak. Also, the significance of non-meteorological factors on the database should be closer scrutinized to determine a "true", unbiased severe weather climatology. Any further understanding of local severe weather will certainly aid the operations of NWSO Houston.

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