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A SEVERE WEATHER AND HURRICANE CLIMATOLOGY FOR THE WFO CORPUS CHRISTI COUNTY WARNING AREA

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1. Introduction

This study describes the climatology of severe weather and hurricanes for the expanded County Warning Area (CWA) for the Corpus Christi Warning and Forecast Office (WFO). As part of the National Weather Service's Modernization and Associated Restructuring (MAR), the Corpus Christi WFO will assume many new responsibilities, including public, aviation and marine forecasts as well as warnings. In addition, WFO Corpus Christi will also acquire responsibility for several counties from other NWS offices.

Figure 1 shows the expanded WFO Corpus Christi County Warning Area. The current CWA includes the counties of Nueces, San Patricio, Jim Wells, Kleberg, Refugio, Aransas, Bee, Live Oak, and Duval. WFO Corpus Christi will acquire Webb, LaSalle, and McMullen Counties from WSFO Austin/San Antonio. The WSO in Victoria will be closed; and Corpus Christi will acquire Victoria, Calhoun, and Goliad Counties from that office. The three largest cities in the new CWA are Corpus Christi, Laredo, and Victoria.

This study is based on tornado, damaging wind, and severe hail reports from 1950 through 1994. These data were acquired from the National Severe Storms Forecast Center (now the NCEP Storm Prediction Center), using the CLIMO program (Vescio 1995). This study also details the impact of tropical cyclones that affected the Texas coast from Palacios to Brownsville between 1871 and 1995.

2. Terrain and climate of the Corpus Christi CWA

Figure 2a shows the geographical terrain of the state of Texas. The Corpus Christi CWA includes parts of the Coastal Bend, the Upper Coast, and Southern Texas. Figure 2b shows the regions of climate classification in Texas (Larkin and Bomar 1983). The CWA counties in the Coastal Bend and the Upper Coast are characterized as subtropical humid; summers are very warm and humidity is high year-round. Dense fog is a common occurrence at night. In addition, the coastal zone is also a convergence area, due to high pressure in the Gulf of Mexico and generally lower pressure in West Texas. As a result, strong winds occur frequently.

Most of the counties in southern Texas are considered to have a subtropical subhumid climate. The area is characterized by having hot summers and mild winters. It is also much drier in this area than in the coastal counties, and fog is not as much of a problem.

Webb County, the westernmost county in the CWA, lies on a boundary between subtropical subhumid and subtropical steppe. Subtropical steppe is characterized as being semi-arid to arid; summers are very hot, winters are mild, and there is little precipitation. Most of the Webb County population is in Laredo, which has a subtropical steppe climate.

3. Population and population density

Table 1 shows the population (1990 census) of each county in the Corpus Christi CWA, the population of the largest city in each county, and the percentage of each county's population that lives in its largest city. Other than Nueces, Webb, and Victoria, no county has a city with more than 30,000 people. Nine counties have populations of fewer than 30,000 total, and five have fewer than 10,000 residents. Of the three most populated counties in the CWA, the vast majority of their populations are in each county's largest city (Corpus Christi in Nueces County, Laredo in Webb County, and Victoria in Victoria County).

Table 1. Counties in the WFO Corpus Christi County Warning Area

County Name	Population	Largest City	Population	Pct. Of County Pop.
Nueces	291,145	Corpus Christi	257,453	88.4%
Webb	133,239	Laredo	122,899	92.2%
Victoria	74,361	Victoria	55,076	74.1%
San Patricio	58,749	Portland	12,224	20.8%
Jim Wells	37,679	Alice	19,788	52.5%
Kleberg	30,274	Kingsville	25,276	83.5%
Bee	25,135	Beeville	13,547	53.9%
Calhoun	19,053	Port Lavaca	10,886	57.1%
Aransas	17,892	Rockport	4,753	26.6%
Duval	12,918	San Diego	4,983	38.6%
Live Oak	9,556	George West	2,586	27.1%
Refugio	7,976	Refugio	3,158	39.6%
Goliad	5,980	Goliad	1,946	57.1%
LaSalle	5,254	Cotulla	3,694	70.3%
McMullen	817	Tilden	450	55.1%

Total Population in CRP CWA: 730,028

Source: Rand McNally 1996 Road Atlas
Population figures based on 1990 Census data

Clearly, much of the Corpus Christi CWA is rural, and this is shown by Table 2, which contains population density figures for each county. While Nueces County as a whole has a high population density (343.7 people mi^{-2}), if the population of Corpus Christi were excluded that figure would drop to only 47.3 people mi^{-2}. This effect is especially important for Webb County, which has by far the largest area of any county in the CWA. Ninety-two percent of the Webb County population of 133,239 residents live in Laredo, which makes up only one percent of Webb County's 3,363 mi^2 area. So while Webb's population density including Laredo is 39.6 mi^{-2}, excluding Laredo it is only 3.1 people mi^{-2}! Significantly, there are only two main roads in Webb County—Interstate 35 to San Antonio and Highway 59 to Alice—so if severe weather occurs away from Laredo and these roads, our ability to obtain severe weather reports is very limited.

Table 2. Population Density in the WFO Corpus Christi County Warning Area

County Name	Population	Area in square mi	Population Density*
Nueces	291,145	847	343.7
San Patricio	58,749	693	84.8
Victoria	74,361	887	83.8
Aransas	17,892	280	63.9
Jim Wells	37,679	867	43.5
Webb	133,239	3,363	39.6
Kleberg	30,274	853	35.5
Calhoun	19,053	540	35.3
Bee	25,135	880	28.6
Refugio	7,976	771	10.3
Live Oak	9,556	1,057	9.0
Duval	12,918	1,795	7.2
Goliad	5,980	859	7.0
LaSalle	5,254	1,517	3.5
McMullen	817	1,163	0.7

Population Density of Nueces County excluding Corpus Christi: 47.3
Population Density of Webb County excluding Laredo: 3.1
*Inhabitants per sq mi

Sources: County area data provided by 1990-1991 Texas Almanac and State Industrial Guide.
City area data provided by Statistical Abstract of the United States, 1994.
Population data provided by Rand McNally 1996 Road Atlas, based on 1990 Census data.

Webb County is certainly not the only county in the Corpus Christi CWA which has a low population density. Live Oak, Duval, Goliad, and LaSalle Counties all have densities under 10 mi^{-2}, and McMullen County has fewer than one person per square mile. This makes receiving severe weather reports (or any weather reports) very difficult, particularly for the western counties. It is hoped that during the next few years, this situation will be improved through the implementation of spotter networks wherever possible, coverage of the WSR-88D, and possibly wind profilers or automated mesonet observation sites.

Another problem involved in developing a severe weather climatology for the CWA is that no information can be received from Mexico, which makes up the western boundary of the CWA. Storm reports from adjacent WFOs (usually to the west) are important for offices which will likely experience the same storm system. Unfortunately, WFO Corpus Christi does not have the luxury of obtaining severe weather reports to the west of the CWA. In addition, the Gulf of Mexico makes up the eastern boundary of our CWA, and the only information that can be obtained in that direction must come from offshore buoys or ship reports.

4. Severe thunderstorm climatology

A severe thunderstorm is defined by the National Weather Service as a storm that produces either a tornado, hail at least ¾ inch in diameter, or wind gusts at least 50 kt. Kessler (1986) described the main factors necessary for the development of severe thunderstorms:

1. Strong convective instability
2. Abundant moisture at low levels
3. Strong wind shear usually veering with height
4. A dynamical lifting mechanism that releases the instability

In the Corpus Christi CWA, the first condition is rarely a problem in the summer, late spring, and early fall. Average high temperatures in the summer months usually range from the upper 80s to low 90s in the coastal counties, to the low- to mid-90s in the inland areas. Temperatures frequently reach the 100F mark. With low temperatures usually in the 70s throughout the summer, there is normally a large amount of instability at all times. Table 3 shows average stability indices taken from upper-air soundings at WFO Corpus Christi from May through September 1995.

Time (UTC)	Showalter Index (C)	Lifted Index (C)	C.A.P.E (J/kg)	Total Totals (C)	Precipitable Water (in)	Helicity $(m/s)^2$
0000	2.07	-4.48	2302.2	41.95	1.76	9.27
1200	1.88	-5.27	2676.6	43.01	1.79	6.95

Table 3. Average stability indices, precipitable water and helicity from May-September 1995. Corpus Christi upper-air soundings analyzed using the SHARP program.

The coastal areas of the CWA also have abundant amounts of moisture year-round due to the Gulf of Mexico. With the average wind direction being from the southeast, the Gulf provides moist air which can be used to produce severe and non-severe thunderstorms, as well as dense fog. Table 3 shows the average precipitable water in the warm season.

During the summer, then, two of the main criteria for severe thunderstorm development are easily met in the CWA. However, the other two criteria, strong wind shear and a lifting mechanism, are rarely ever met. Table 3 also shows the average storm-relative helicity values from the WFO Corpus Christi upper-air soundings. In the warm season, at least, the average helicity in the CWA is far less than what would ideally be desired for severe thunderstorm development, and it is an indication of the lack of significant wind shear in the area.

The fourth criterion for severe thunderstorm development is a dynamical lifting mechanism. The most common mechanisms in many areas include fronts, dry lines, and meso-lows. Most of the strong cold fronts that move through the Corpus Christi area occur in winter and early spring, when the atmosphere is much more stable than it is during the summer. In addition, many of these fronts are arctic or polar in nature, and move through South Texas with little moisture. During the months of peak instability (May-September), few fronts ever pass through deep South Texas. It is rare that dry lines or meso-lows ever appear. There is also little help from the topography of the area, since most of the terrain is flat.

There are some factors, however, that can occasionally produce severe thunderstorms. One is landfalling or nearby tropical storms, and another one is the sea breeze front, which is a common feature during the spring and summer. As the sea breeze front moves inland, the moist air behind it meets with the dry, relatively warmer air. This usually results in the formation of single-cell, non-severe thunderstorms; but the front may occasionally produce severe thunderstorms (usually involving hail). In addition, outflow boundaries from thunderstorms to the north of the CWA have been known to move south into the CRP CWA and produce severe weather, most often in the northern counties.

Another potential mechanism to trigger severe convection involves the Sierra Del Huacha mountains in northeast Mexico. Occasionally thunderstorms will form to the east of the mountains, then move eastward into our CWA. Some of these storms become severe, or they will create outflow boundaries which could produce severe storms.

In summary, while the WFO Corpus Christi CWA has an environment that is generally not favorable for the development of wide-spread severe weather, the statistics in following sections will show that severe weather is nonetheless a factor which forecasters must be prepared to deal with. The relative rarity of severe weather—at least compared with areas to the north in Texas—make that task all the more difficult. Of course, as already noted, there are also a number of factors such as population density that may tend to bias reports of severe weather even when it does occur.

a. Tornadoes

Figure 3 shows the yearly distribution of tornadoes in the Corpus Christi CWA. Two hundred and sixty-seven tornadoes were reported from 1950 through 1994, an average of seven per year. Of those tornadoes, 62 (23 percent) were associated with tropical cyclones. Forty-eight tornadoes were reported in 1967, which is by far the record for most tornadoes in one year. Note, however, that 42 of those tornadoes were associated with Hurricane Beulah. Only six of the tornadoes in 1967 were non-tropical cyclone-related. The record for non-tropical cyclone tornadoes in one year was in 1976, when 19 tornadoes occurred.

Figure 4 shows the monthly distribution of tornadoes in the CWA. There are clearly two peak seasons—one from April through June, during spring severe weather season, and another from August to October, associated with the tropical cyclone season. The peaks are similar in number of events, but the data are somewhat misleading. September is the month with the most tornado reports (74), but more than half of those tornadoes in September occurred with Hurricane Beulah in 1967. The May peak (63 tornadoes) contains no tropical storm-related tornadoes. During the period from 1950 to 1994, no tornadoes were reported in either January or December.

Figure 5 shows the distribution of tropical cyclone tornadoes, all of which occurred in July, August, and September. Of the 62 tornadoes associated with tropical cyclones, 48 occurred in September. Again, these results are heavily weighted by the 42 Beulah tornadoes. Of the remainder, 13 occurred in August, and only one occurred in July. No June or October tropical cyclone has produced a tornado in the CWA. Most tornadoes in general, and most of those from this study that were associated with tropical cyclones, were not very strong. Only 10 of the 62 tornadoes were categorized as F2 or greater (wind speed of 98 kt/113 mph or greater).

Figure 6 shows the hourly distribution of tornadoes associated with four hurricanes that have had significant impact on the Corpus Christi CWA: Beulah (1967), Celia (1970), Allen (1980), and Gilbert (1988). Beulah, which caused the most tornadoes, spawned most of those in the early morning hours. Celia's tornadoes were in the mid-afternoon, and the tornadoes associated with Allen and Gilbert were primarily in the evening. Of course, a primary factor in when a tropical cyclone spawns tornadoes is when the storm makes landfall.

Figure 7 shows the distribution of non-tropical cyclone tornadoes. May is, of course, the peak month, with 63 reported tornadoes, and 15 of those were F2 or greater in strength. The hourly distribution of all tornadoes is shown in Fig. 8. A clear peak is seen in the early afternoon at around 1400 CST. This is obviously not an artifact of tornadoes associated with Buelah or any of the major tropical storms that have affected the CWA (see Fig. 6), and it is quite different from other areas such as North Texas and Oklahoma, where prime tornado development is in the early evening. The relative lack of early evening storms in the Corpus Christi CWA may also be related to the fact that violent or extreme intensity tornadoes (F3 or greater) are all but unknown in the area.

The secondary peak in tornado occurrence around 5-7 a.m. is also interesting. This feature is similar to that found in many other coastal areas. Buchanan (1994), for example, detected an afternoon peak around 4 p.m., and also a secondary morning peak (after sunrise) in the distribution of tornadoes in the WFO Houston CWA. He noted as well that the morning peak shifted to the midnight to 7 a.m. period for spring tornadoes. He also cites similar patterns elsewhere along the Gulf Coast.

Figure 9 shows the distribution of tornadoes by the Fujita scale (Table 4), along with reported injuries. Cross-bars on the figure show the number of tornados or injuries at each F-scale that were associated with tropical cyclones. Of the 267 reported tornadoes in the CWA, 128 were F0, and only 2 injuries were caused by these tornadoes. Ninety-one tornadoes were rated F1, with 13 injuries. Thirty-nine tornadoes were F2, and they caused 24 injuries. Only nine tornadoes were classified F3, but they caused 46 of the 89 injuries caused by all tornadoes, and the only tornado-related fatality in the Corpus Christi CWA (on July 24, 1970). Thirty-seven tornadoes were of unknown intensity. No injuries were related to tornadoes of F0 or F1 intensity that were in turn associated with tropical storms.

Table 4

The Fujita Scale

F	*F*-scale damage specifications
(*F*0)	18–32 m s^{-1} (40–72 mph): Light damage; Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage sign boards
(*F*1)	33–49 m s^{-1} (73–112 mph): Moderate damage; the lower limit (73 mph) is the beginning of hurricane wind speed; peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads
(*F*2)	50–69 m s^{-1} (113–157 mph): Considerable damage; Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated
(*F*3)	70–92 m s^{-1} (158–206 mph): Severe damage; roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown
(*F*4)	93–116 m s^{-1} (207–260 mph): Devastating damage; well-constructed houses leveled; structure with weak foundation blown off some distance; cars thrown and large missiles generated
(*F*5)	117–142 m s^{-1} (261–318 mph): Incredible damage; strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 100 m; trees debarked; incredible phenomena will occur
*F*6–*F*12	142 *m* s^{-1} to Mach 1, the speed of sound; the maximum wind speeds of tornadoes are not expected to reach the *F*6 wind speeds

[a] The Fujita-scale (*F*-scale) wind speed was designed to connect smoothly the Beaufort force 12 with Mach number 1 in 12 steps. The mean increment of the wind speed per scale is 21 m s^{-1} (46 mph). *F*-scale wind speeds are computed from $V_F = 6.30(F + 2)^{1.5}$, where V_F denotes the *F*-scale wind speed (m s^{-1}).
From Fujita (1981).

Reprinted from *Synoptic-Dynamic Meteorology in Mid-Latitudes,*
by Howard B. Bluestein, 1992.

No F4 or F5 tornadoes have been reported in the CWA, but as many sources have noted, F-scale ratings are subjective. Doswell and Burgess (1988) state that tornadoes which strike a populated area are more likely to have a higher F-rating than those that remain over open country. Despite this, it seems clear that the Corpus Christi CWA does not experience the kind of intense, killer tornadoes that strike other areas of the United States.

b. Damaging wind events (wind 50 kt or greater)

Figure 10 shows the yearly distribution of damaging wind reports from 1955 to 1994. There were a total of 364 damaging wind reports, which occurred on a total of 199 damaging wind days. The record year for damaging wind events was 1980, with 46 reports on 14 days. There had never been more than ten reports in a single year before 1975, but there have been only three years since 1980 that have had fewer than ten reports. This is probably due to factors such as increased exposure and inflation of property values, along with population awareness, improvements in communication and enhanced verification efforts, all of which allow the NWS to receive more reports, just as more tornadoes are sighted each year. Most likely such trends are not meteorological.

It is the author's understanding that the CLIMO program (Vescio 1995), which provided data for this study, includes damaging wind reports associated with tropical cyclones. In light of that, it is worth noting that the number of reports received in 1967 and 1970 (6 and 5, respectively) are certainly not outstanding, even though two strong hurricanes occurred in those years—Beulah

(1967) and Celia (1970). No doubt this reflects the subjectivity of obtaining and recording wind events, many of which in those years, we may conclude, were simply compiled as "hurricane damage."

The monthly distribution of damaging wind events is shown in Fig. 11. The month with the most damaging wind events is May with 125. May has had more than twice the number of events as April, which has had 54, the second highest monthly total. It is not surprising that the May peak coincides with the month that has the greatest number of non-tropical storm associated tornadoes; and as we will see, May also has the greatest number of hail reports. Figure 12 shows the distribution of damaging wind reports by hour of the day. The peak period for damaging winds is the late afternoon to early evening hours, 1700 to 1900 CST. This is somewhat curious because the peak time for damaging winds seems to lag a few hours after the peak time for tornadoes (1400 CST). There are also smaller peaks in damaging wind reports around 1200-1400 and at 0700 CST, both of which correlate loosely with peaks in tornadoes (Fig. 8).

c. Hail (¾ inch in diameter or larger)

Figure 13 shows the yearly distribution of severe hail events from 1955 to 1994. Two hundred and fifty-one severe hail events were reported on a total of 126 days. The record year for severe hail events was 1993, with 21. As with wind events, the number of reports has greatly increased over the last two decades. From 1954 to 1975, only one year (1966) had more than ten events; but from 1976 to 1994, eight years had ten or more. Again, improvement in reporting these events has no doubt been the primary reason for the increase in reports.

As with non-tropical cyclone tornadoes and damaging wind events, May has by far the most severe hail events (116), as seen in Fig. 14. May was also the month which recorded the most occurrences of hail 1.75 to 2.75 in (53), and greater than 2.75 in (7). This clearly establishes May as the peak month for severe weather in the WFO Corpus Christi CWA. The vast majority of hail events occurred from March to May; these three months have had six times as many reports as the other nine months combined.

Figure 15 shows the distribution of hail events by hour of the day. The prime time for hail events is the late afternoon to early evening hours, from 1700 to 2100 CST. The peak hour is 1700 CST. This is consistent with the peak period for damaging wind events (Fig. 12), but the 0700 CST peak in occurrences for large hail is barely perceptible—much less so than for damaging winds. There appears to be a minor maximum at that time for thunderstorms in the CWA, but hail is not as significant a problem with those early morning storms as is wind.

The distribution of reported hail size is shown in Fig. 16. There was an equal number of hail reports indicating ¾ to 1¾ in diameter hail and 1¾ to 2¾ in diameter hail, both having 116 reports. There were only 19 reports of hail 2¾ inches or larger.

5. Hurricanes and tropical storms

Just as with many other areas on the Gulf of Mexico and Atlantic coasts, tropical storms are a major threat to the Corpus Christi CWA, especially to the city of Corpus Christi and Padre Island. While the area has not been hit directly by many storms, recent hurricanes, such as Hurricane Andrew have shown that it takes only one to cause certain widespread destruction and potentially many deaths. In addition, inland areas can be affected by floods caused by torrential rainfall from tropical cyclones, and we have already discussed the number of tornadoes that are associated with tropical storms.

Since most tropical cyclones that hit the upper Texas coast do not affect the Corpus Chrsiti CWA, this study will concentrate only on storms which have affected the middle and lower coast, from Palacios to Brownsville, during the period from 1871 to 1995. The data were acquired from Neumann et al. (1993), as well as local documentation maintained at the WFO. This study may be somewhat subjective; because while some storms did not make landfall between Palacios and Brownsville, they still affected this area. An example is Hurricane Gilbert in 1988, which landed in Mexico but still produced several tornadoes in the CWA and produced very heavy rainfall over much of Texas. On the other hand, Tropical Storm Gabrielle in 1995 landed not far from where Gilbert made landfall, but had little impact on the Corpus Christi CWA other than minor coastal flooding, and was thus not considered further.

Figure 17 shows the monthly occurrence of tropical cyclones between Palacios and Brownsville during the years studied. The peak month is September, which had nine hurricanes, five tropical storms, and two storms of unknown strength (tropical cyclones before 1886 were not classified as hurricanes or tropical storms). The peak month for hurricanes is August, with ten; but September is a close second (9). The difference is probably not statistically significant.

Table 5 lists the number of tropical cyclones of different strength categories that have affected the area from 1871 to 1995. A total of 46 tropical cyclones have occurred; 26 were hurricanes, 15 were tropical storms, and five occurred before 1886 and are unclassified. (Tropical depressions were not included in this study.) There has been an average of about one tropical cyclone every three years (0.37 per year). Martin and Edwards (1995) established that 94 tropical cyclones affected the entire Texas coast from 1871 to 1993. Including Tropical Storm Dean which hit Galveston in 1995, and was not included in the data they used in their study, the total is 95. The present study indicates that just under half (46) of all tropical cyclones that have hit the Texas coast (95) have affected the coastline between Palacios and Brownsville. Since Palacios is located around the middle of the Texas coast, the distribution of landfall appears to be fairly uniform along the Texas coast.

Table 5

YEARLY FREQUENCY OF TROPICAL CYCLONES AFFECTING THE TEXAS COAST FROM PALACIOS TO BROWNSVILLE, 1861-1995

(Note: Storms before 1886 were not classified as hurricanes or tropical storms)

YEAR	HURR	T.S.	UNK.	YEAR	HURR	T.S.	YEAR	HURR	T.S.
1871	0	0	0	1913	1	0	1955	0	0
1872	0	0	0	1914	0	0	1956	0	0
1873	0	0	0	1915	0	0	1957	0	0
1874	0	0	2	1916	1	0	1958	1	0
1875	0	0	1	1917	0	0	1959	0	0
1876	0	0	0	1918	0	0	1960	0	1
1877	0	0	0	1919	1	0	1961	1	0
1878	0	0	0	1920	0	0	1962	0	0
1879	0	0	0	1921	1	0	1963	0	0
1880	0	0	1	1922	0	0	1964	0	1
1881	0	0	1	1923	0	0	1965	0	0
1882	0	0	0	1924	0	0	1966	0	0
1883	0	0	0	1925	0	1	1967	1	0
1884	0	0	0	1926	0	0	1968	0	1
1885	0	0	0	1927	0	0	1969	0	0
1886	2	0	0	1928	0	0	1970	1	0
1887	1	0	0	1929	1	0	1971	1	0
1888	0	0	0	1930	0	0	1972	0	0
1889	0	0	0	1931	0	1	1973	0	1
1890	0	0	0	1932	0	0	1974	0	0
1891	0	0	0	1933	2	0	1975	0	0
1892	0	0	0	1934	1	0	1976	0	0
1893	0	0	0	1935	0	0	1977	0	0
1894	0	0	0	1936	1	1	1978	0	1
1895	1	0	0	1937	0	0	1979	0	1
1896	0	0	0	1938	0	0	1980	1	0
1897	0	0	0	1939	0	0	1981	0	0
1898	0	0	0	1940	0	0	1982	0	0
1899	0	0	0	1941	0	0	1983	1	0
1900	0	0	0	1942	1	0	1984	0	0
1901	0	1	0	1943	0	0	1985	0	0
1902	1	0	0	1944	0	0	1986	0	0
1903	0	0	0	1945	1	1	1987	0	0
1904	0	0	0	1946	0	0	1988	1	0
1905	0	0	0	1947	0	1	1989	0	0
1906	0	0	0	1948	0	0	1990	0	0
1907	0	0	0	1949	0	0	1991	0	0
1908	0	0	0	1950	0	0	1992	0	0
1909	1	1	0	1951	0	0	1993	0	1
1910	1	0	0	1952	0	0	1994	0	0
1911	0	0	0	1953	0	0	1995	0	0
1912	1	0	0	1954	0	0			

Notably, no more than two tropical cyclones have affected the Corpus Christi CWA in any one year, and two in the same year have not occurred since 1945. In that year a hurricane struck near Palacios, and a tropical storm landed just south of Baffin Bay, southeast of Kingsville.

6. Summary

As the data in this climatology show, severe weather does not occur in the Corpus Christi CWA with the frequency that it occurs in many other areas of the United States. While the local atmosphere is frequently moist and unstable—perhaps even to extreme degrees, especially in the summer—the necessary trigger mechanisms for initiating convection are simply not often in place at the same time, or they are lacking altogether.

May is the one month of the year when significant fronts move through the area, moisture is in place, and temperatures have warmed enough to produce large amounts of instability. Thus, May is by far the month with the highest incidence of tornadoes (not associated with tropical storms), severe hail, and damaging wind events. After May, fronts rarely move into South

Texas. Thunderstorms still occur frequently in the area, particularly in the coastal counties and supported by the sea breeze, but these storms are mostly single-cell type thunderstorms which usually only produce only brief heavy rain and no severe weather.

Not only are tornadoes infrequent in the Corpus Christi CWA, those that do form are not as strong as tornadoes in many other parts of Texas or the Midwest. No F4 or F5 tornado was reported between 1950 and 1994, and only nine F3 tornadoes have been reported. While the subjectivity regarding F-scale ratings must be considered, an important factor seems to be that the area does not have some of the main meteorological characteristics which favor tornado production.

It is noteworthy that the peak time for tornadoes in the CWA is around and shortly after noon (1100 to 1400 CST). In many other areas of the United States, the peak tornado time is in the late afternoon and early evening. In the Corpus Christi area the peak time for severe hail and damaging wind events is in the late afternoon and early evening as it is in many other places, but tornadoes do not share that same time distribution. Corpus Christi's CWA does have an additional tornado distribution feature common to other southern coastal areas, however, in that there is a secondary peak in tornadoes in the early morning (around 0500 to 0700 CST).

One possible reason why the primary peak in tornado occurrence is in the early afternoon is that many of the tornadoes in the coastal counties (which statistically should make up many of the tornadoes that were reported for the entire CWA) may have formed from waterspouts, which usually occur earlier in the day. This may also explain why most of the tornadoes in the Corpus Christi CWA are either F0 or F1, and there is a complete lack of violent to extreme tornadoes in the area. Most waterspouts rarely are stronger than F1. The subject of possible landfalling waterspouts in the CWA would be a good topic for future research.

Tropical cyclones are by far the most high-profile subject in terms of weather in the Corpus Christi CWA. The study shows that 46 hurricanes or tropical storms have affected the area since 1871. Thus, on average, the Corpus Christi area might expect to experience a hurricane or tropical storm about once every three years. The last significant storm to make landfall in the area was Tropical Storm Arlene in 1993, and three storms threatened the area in 1995. Whether the next storm will be a small tropical storm or minimal hurricane, or perhaps a major hurricane such as Andrew in 1992, is anyone's guess; but it will surely happen. With the major advances in technology that WFO Corpus Christi has made and will continue to make over the next few years, there is little doubt that the area will be ready and well prepared when that time comes.

Now, more than ever, the forecasts and warnings in the Corpus Christi CWA should assume major importance. With the passage of the North American Free Trade Agreement, the area will become the focal point of international commerce between the U.S., Mexico, and Canada. Large amounts of traffic will flow to and from Laredo, and Corpus Christi and Victoria will also see increased traffic coming to and from the Rio Grande Valley. In addition, Laredo is one of the fastest growing cities in America. As the area becomes vitally important to the U.S. and world economies, it is equally important that the NWS forecasters be knowledgeable and prepared as our ability to forecast and warn for severe weather improves. It is hoped that this study will help achieve this goal.

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REFERENCES

Bluestein, Howard B., 1992: *Synoptic-Dynamic Meteorology in Midlatitudes.* Oxford University Press, 431 pp.

Bomar, George W., 1983: *Texas Weather.* University of Texas Press, 265 pp.

Buchanan, Michael, 1994: A Severe Weather Climatology of the County Warning Area of the Houston Area National Weather Service Office. NOAA Technical Memorandum NWS SR-157, National Weather Service Southern Region, Fort Worth, TX, 12 pp.

Doswell, Charles A. III and Donald W. Burgess, 1988: On Some Issues of United States Tornado Climatology. *Monthly Weather Review, 116,* 495-501.

Hart, John A., 1993: SVRPLOT: A New Method of Accessing and Manipulating the NSSFC Severe Weather Data Base. Preprints, *17th Conference on Severe Local Storms,* St. Louis, MO American Meteorological Society, 40-41.

________, and Josh Korotky. The SHARP Workstation: A Skew-T/Hodograph Analysis and Research Program for the IBM and compatible PC. NWS Forecast Office, Charleston, WV.

Kessler, Edwin, 1986: *Thunderstorm Morphology and Dynamics.* University of Oklahoma Press, 411 pp.

Kingston, Mike, 1990: *1990-91 Texas Almanac and State Industrial Guide.* Dallas Morning News, 607 pp.

Larkin, Thomas J. and George W. Bomar, 1983: *Climatic Atlas of Texas.* Texas Department of Water Resources, Austin, TX, 151 pp.

Martin, Perry L. and Roger Edwards, 1995: A Severe Weather, Hurricane, and Flood Climatology for the Austin/San Antonio WFO County Warning Area. NOAA Technical Memorandum NWS SR-167, National Weather Service Southern Region, Fort Worth, TX, 27 pp.

Neumann, Charles J., Brian R. Jarvinen, Colin J. McAdie, and Joe D. Elms, 1993: *Tropical Cyclones of the North Atlantic Ocean, 1871-1992.* Historical Climatology Series 6-2, NOAA National Climatic Data Center, Asheville, NC, 193 pp.

Rand McNally and Company, 1996: *1996 Rand McNally Road Atlas.*

Reference Press, Inc., 1994: *Statistical Abstract of the United States, 1994.* United States Department of Commerce.

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

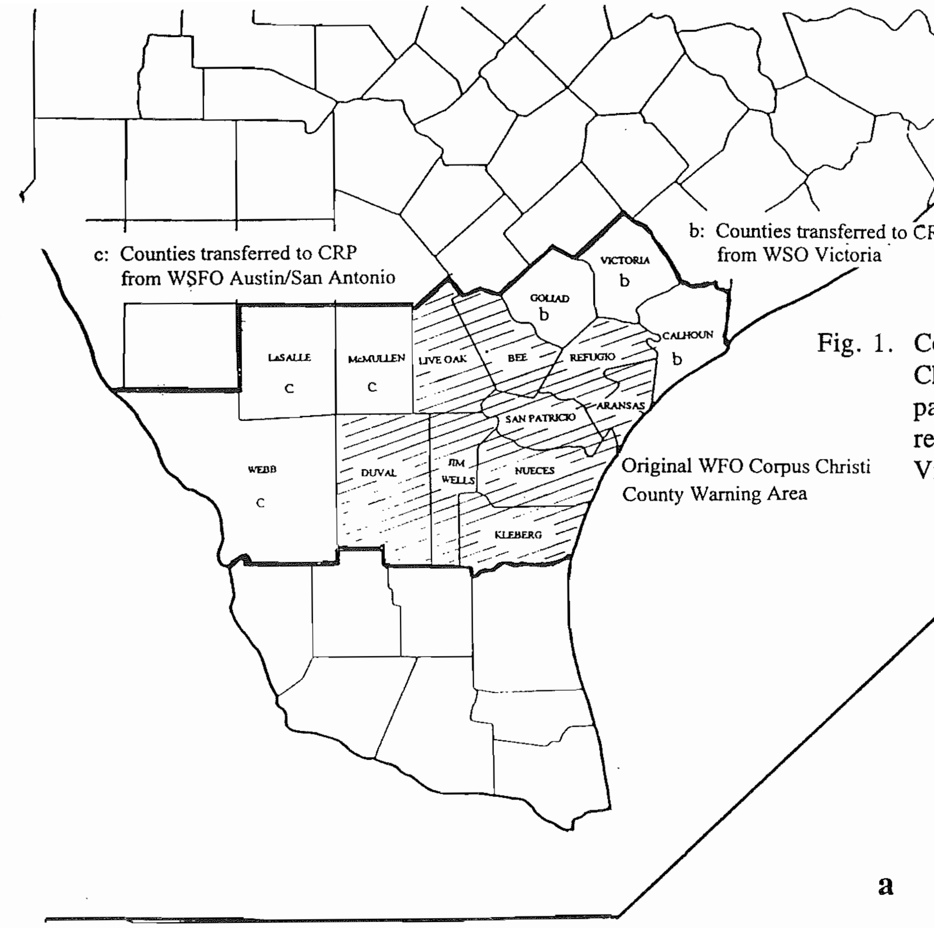
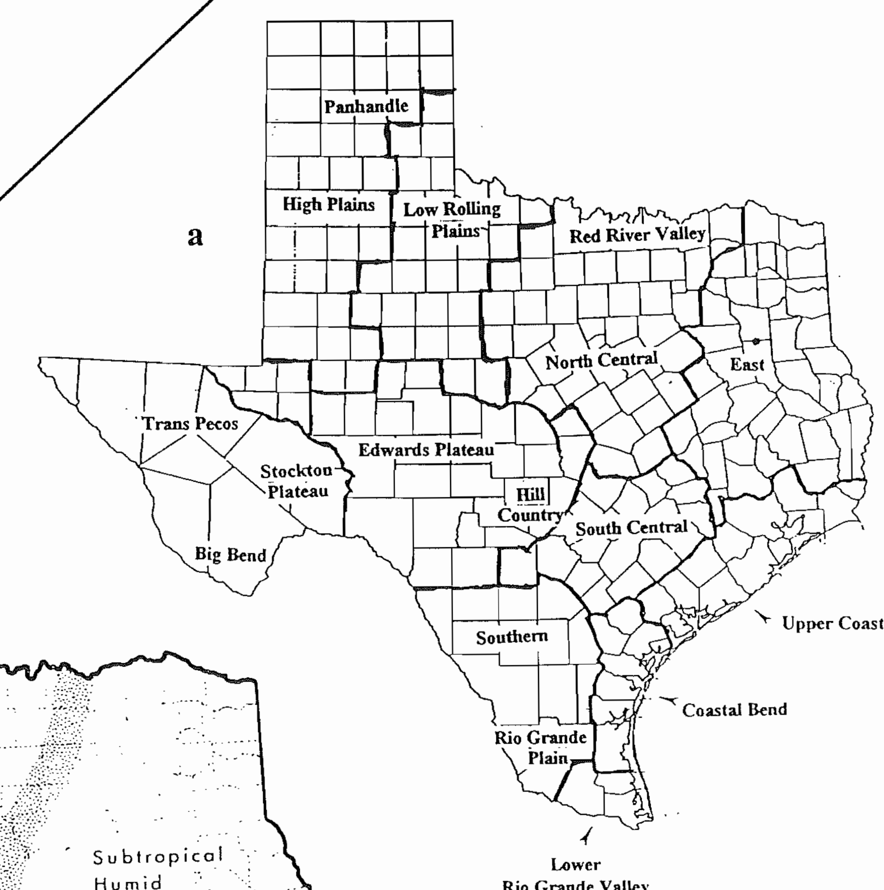


Fig. 1. County Warning Area (CWA) for WFO Corpus Christi. CWA for the former WSO is shaded. As part of NWS modernization, the WFO will assume responsibility for counties transferred from WSO Victoria (b), and WSFO San Antonio (c).

a



b

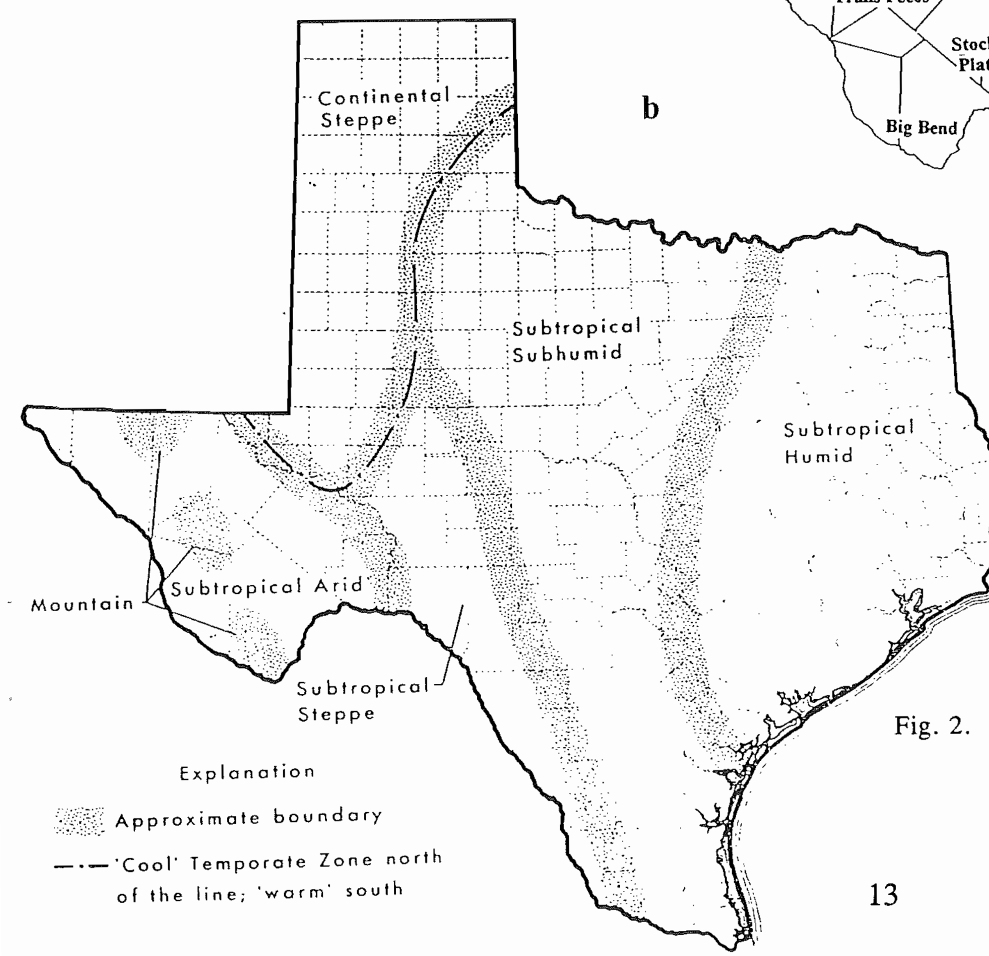
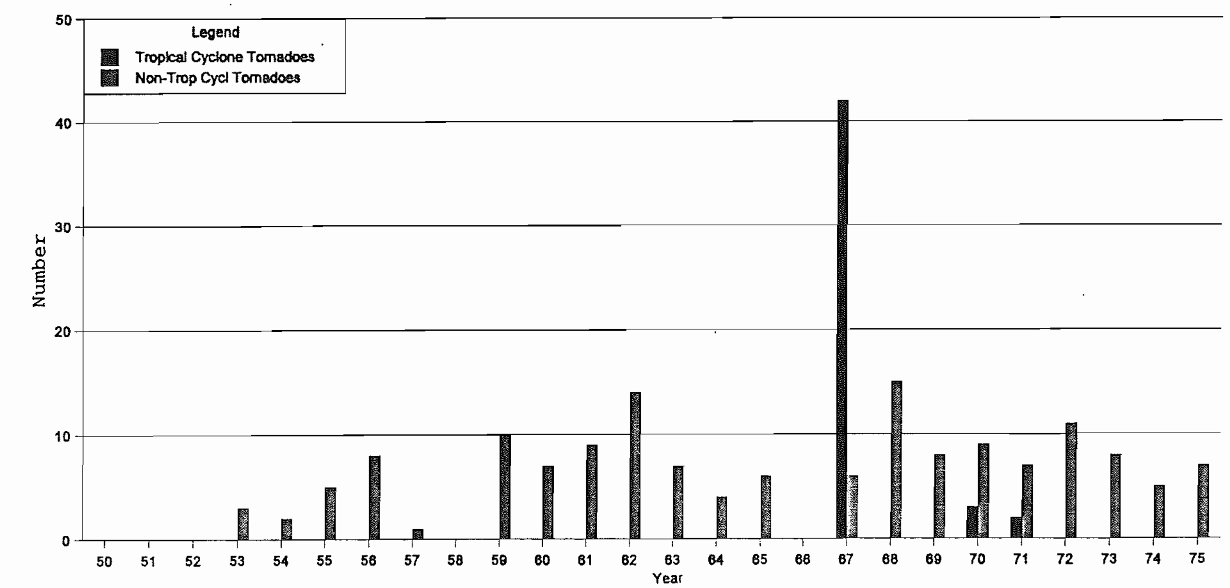


Fig. 2. Terrain (a) and regions of climate classification (b) in Texas.



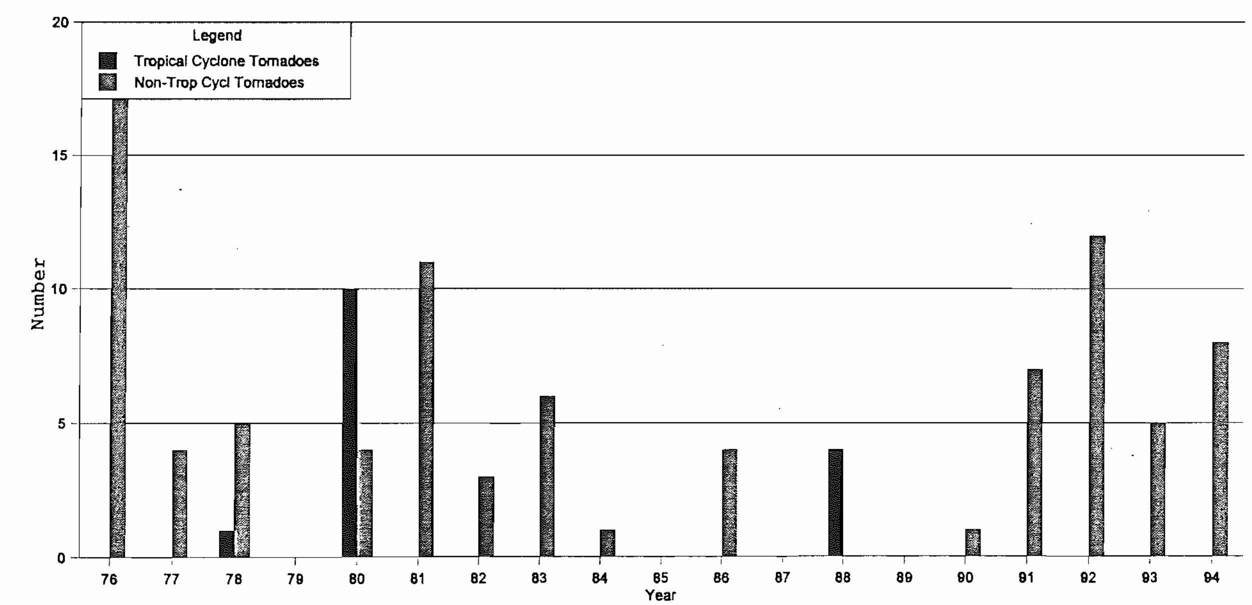


Fig. 3. Yearly distribution of tornadoes in the WFO Corpus Christi CWA, 1950-1994. Note the change in scales from top to bottom graphs.

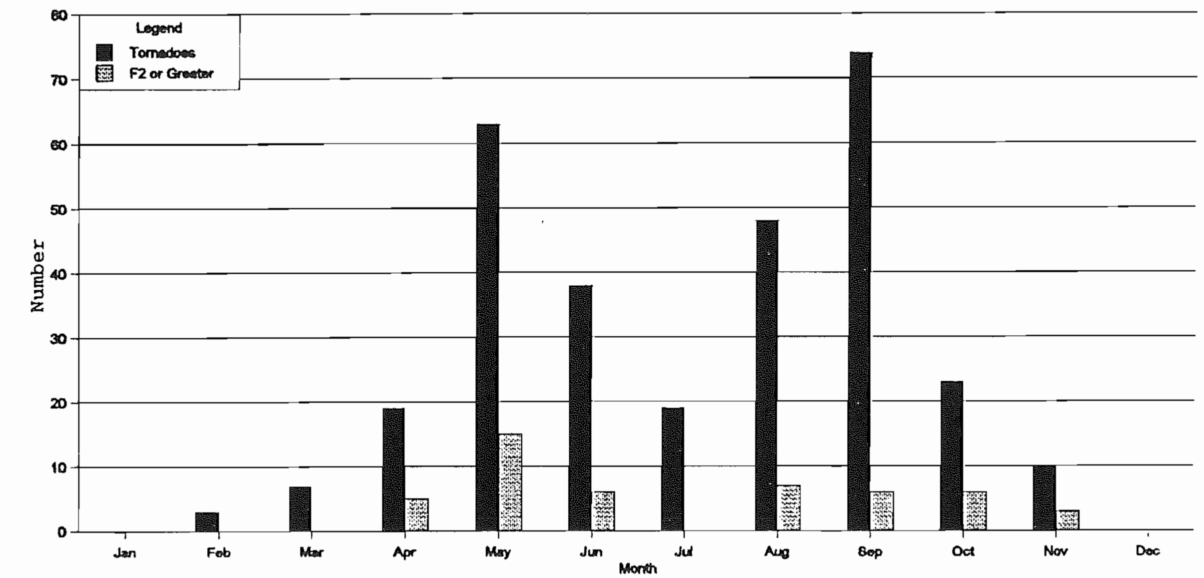


Fig. 4. Monthly distribution of tornadoes (1950-1994) in the Corpus Christi CWA.

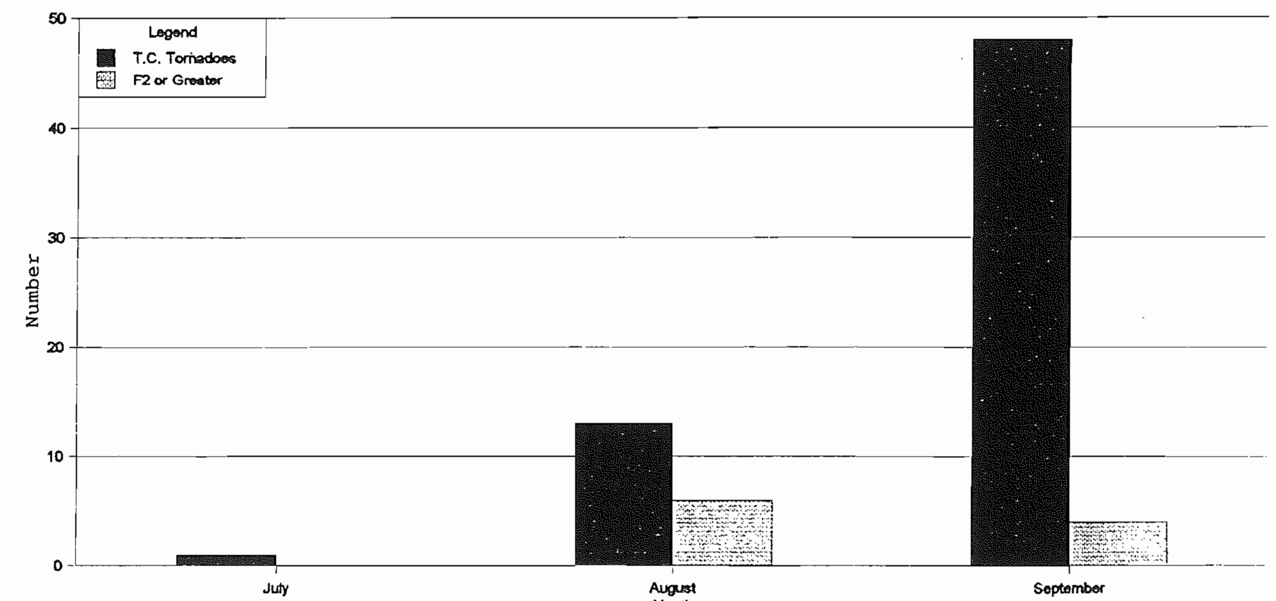


Fig. 5. Monthly distribution of tornadoes associated with tropical cyclones (1950-1994) in the Corpus Christi CWA.

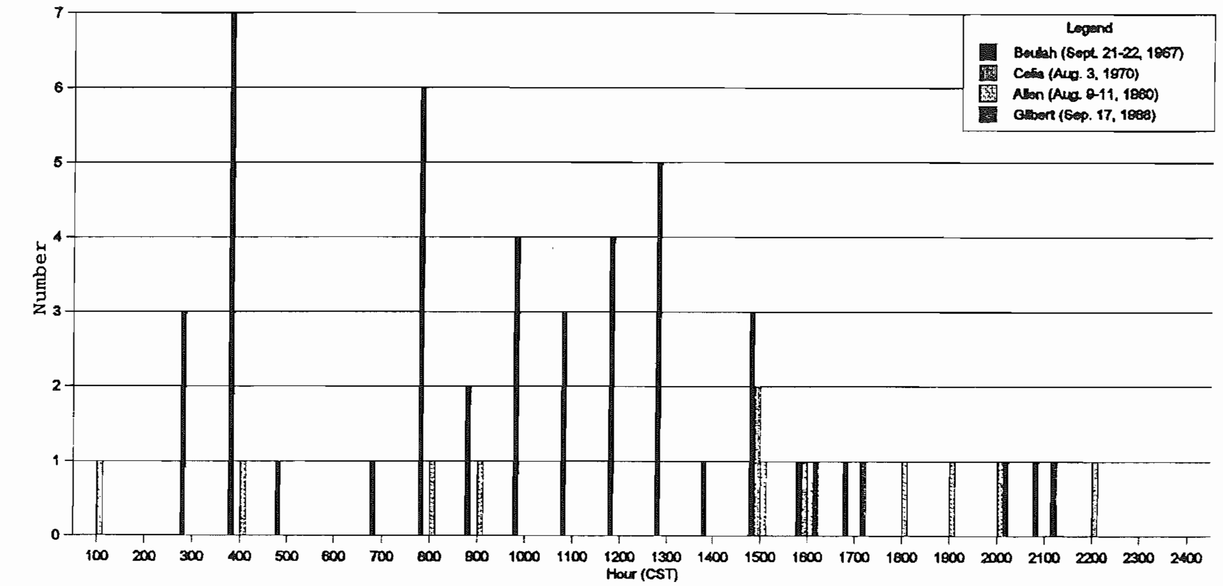


Fig. 6. Hourly distribution of tornadoes in the Corpus Christi CWA that were associated with Hurricanes Beulah, Celia, Allen and Gilbert.

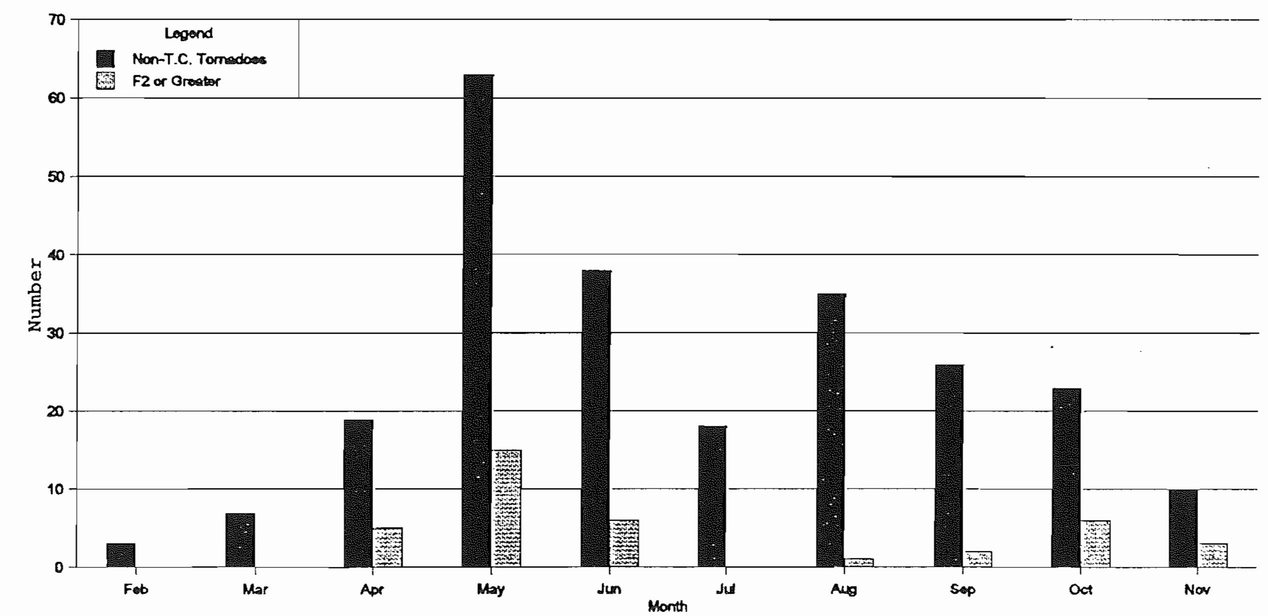


Fig. 7. Monthly distribution of tornadoes (1950-1994) that were not associated with tropical cyclones in the Corpus Christi CWA.

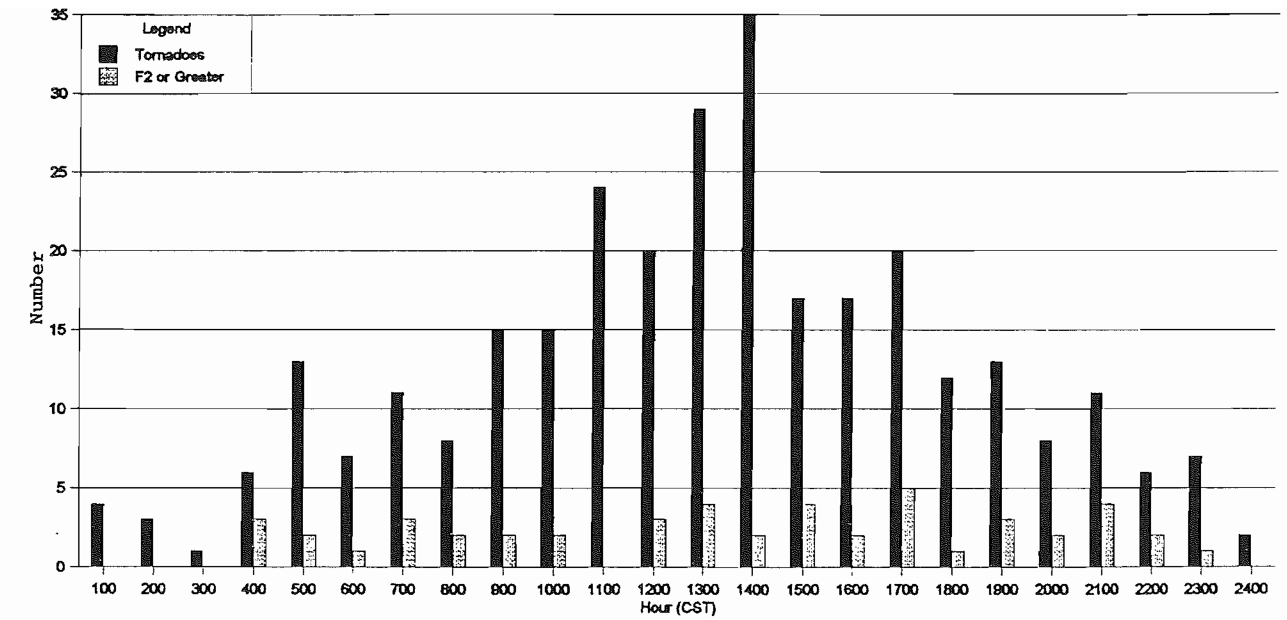


Fig. 8. Hourly distribution of tornadoes (1950-1994) in the Corpus Christi CWA.

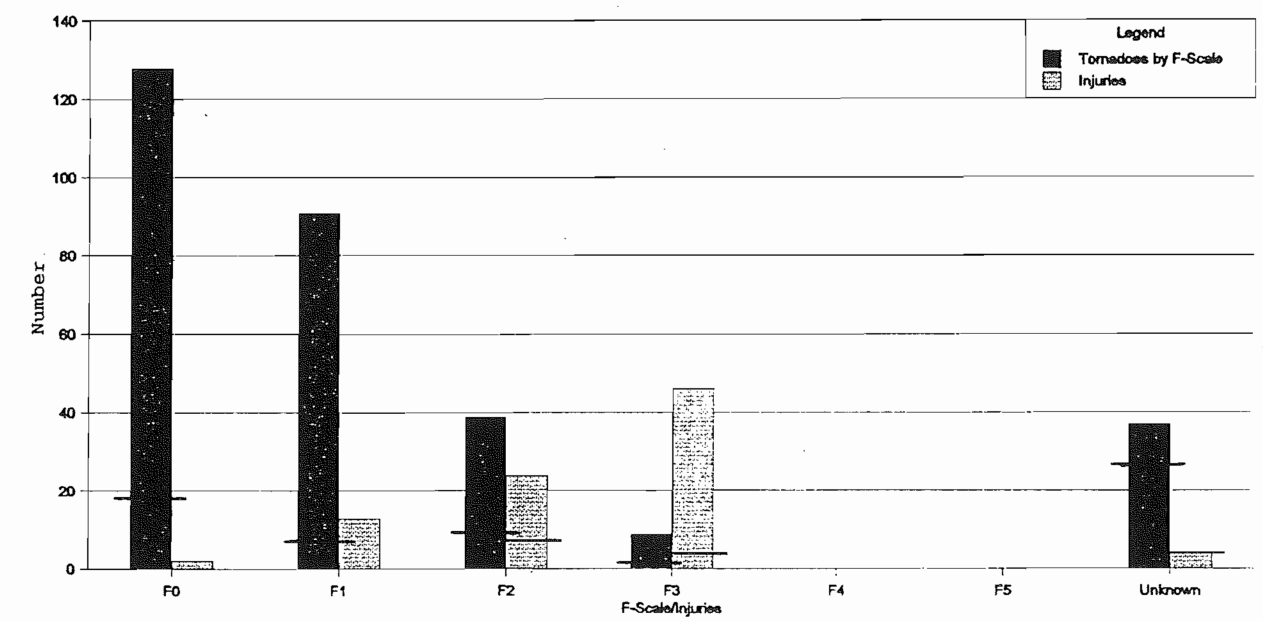


Fig. 9. Number of tornadoes by F-scale and injuries which occurred in the Corpus Christi CWA, 1950-1994. Cross-bars show numbers for tornadoes that were associated with tropical cyclones.

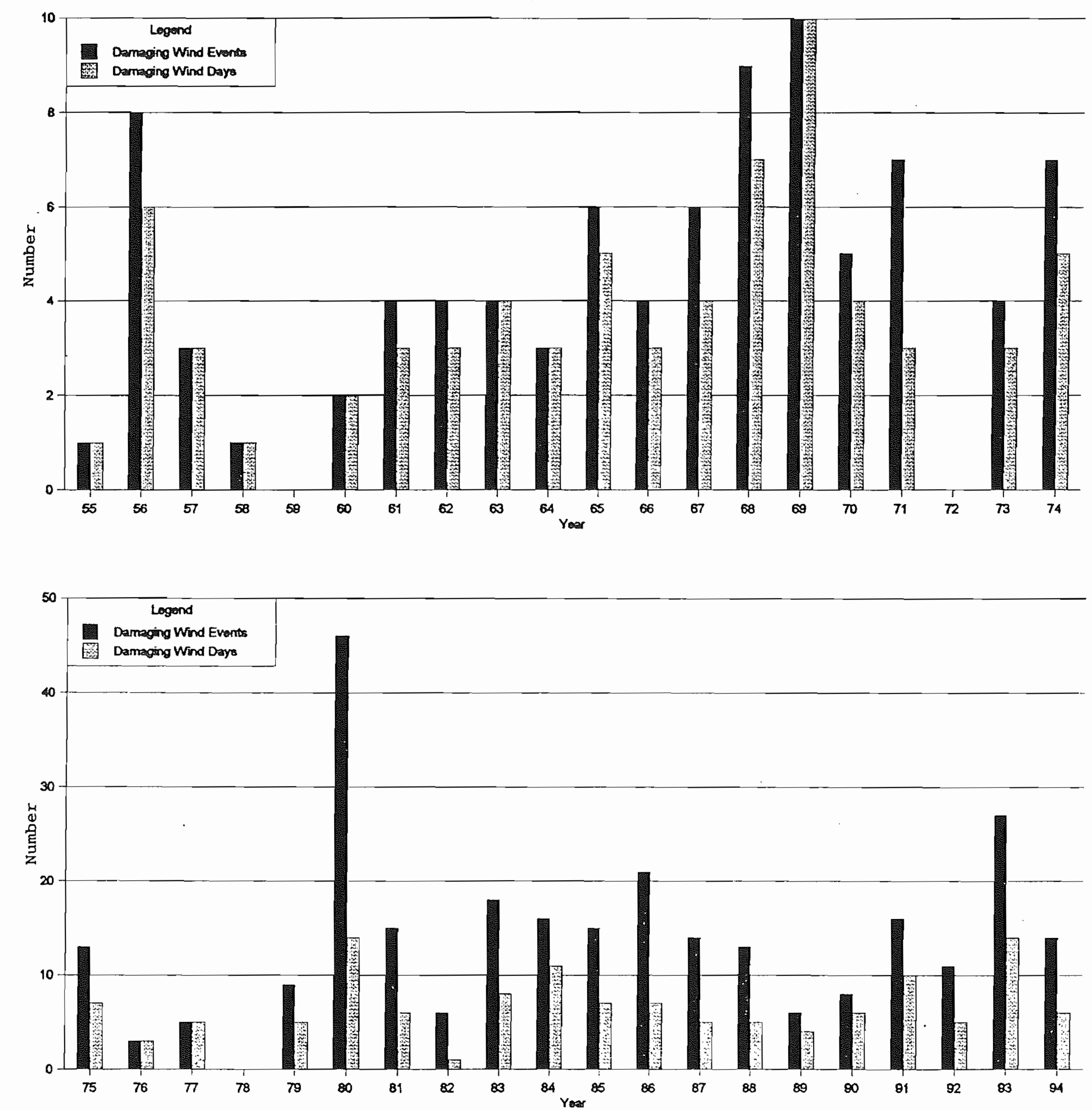


Fig. 10. Yearly distribution of damaging wind events and days (1955-1994) in the Corpus Christi CWA. Note the change in scales from top to bottom graphs.

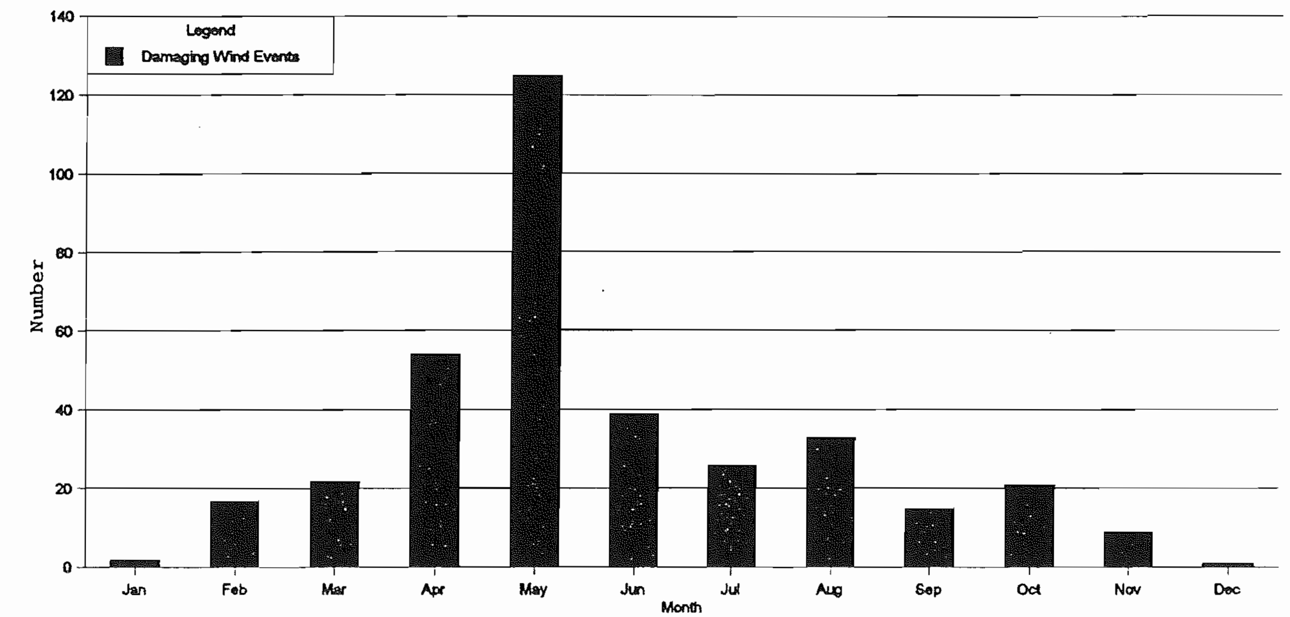


Fig. 11. Monthly distribution of damaging wind events and days (1955-1994) in the Corpus Christi CWA.

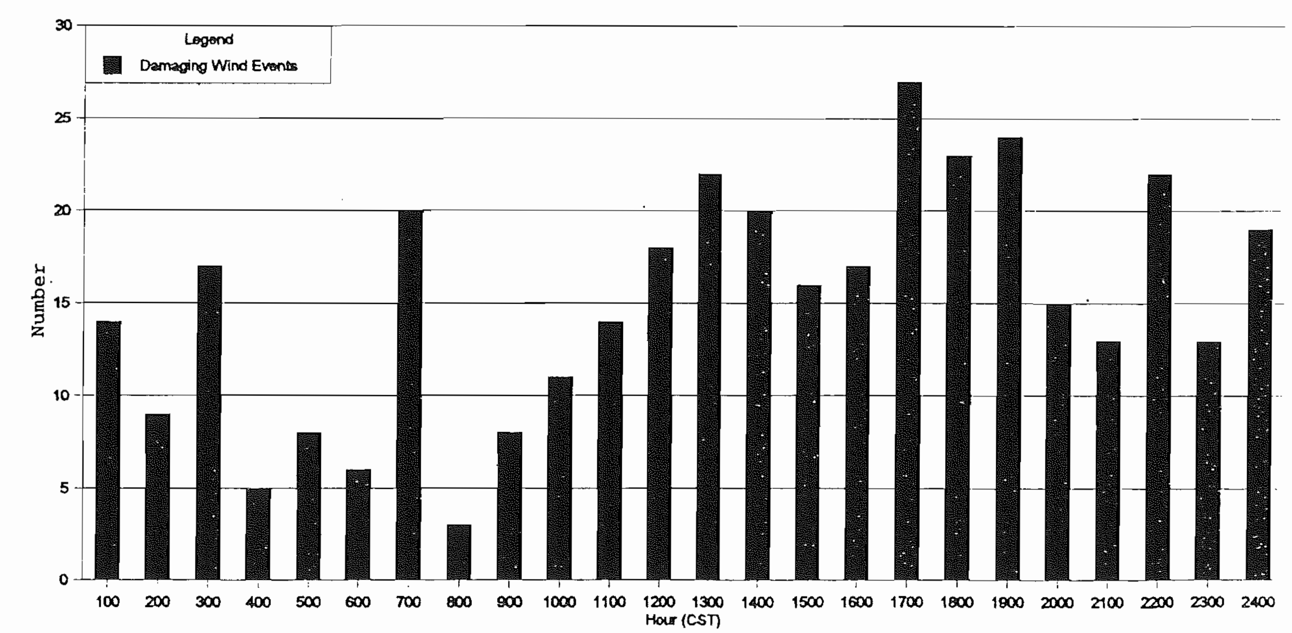
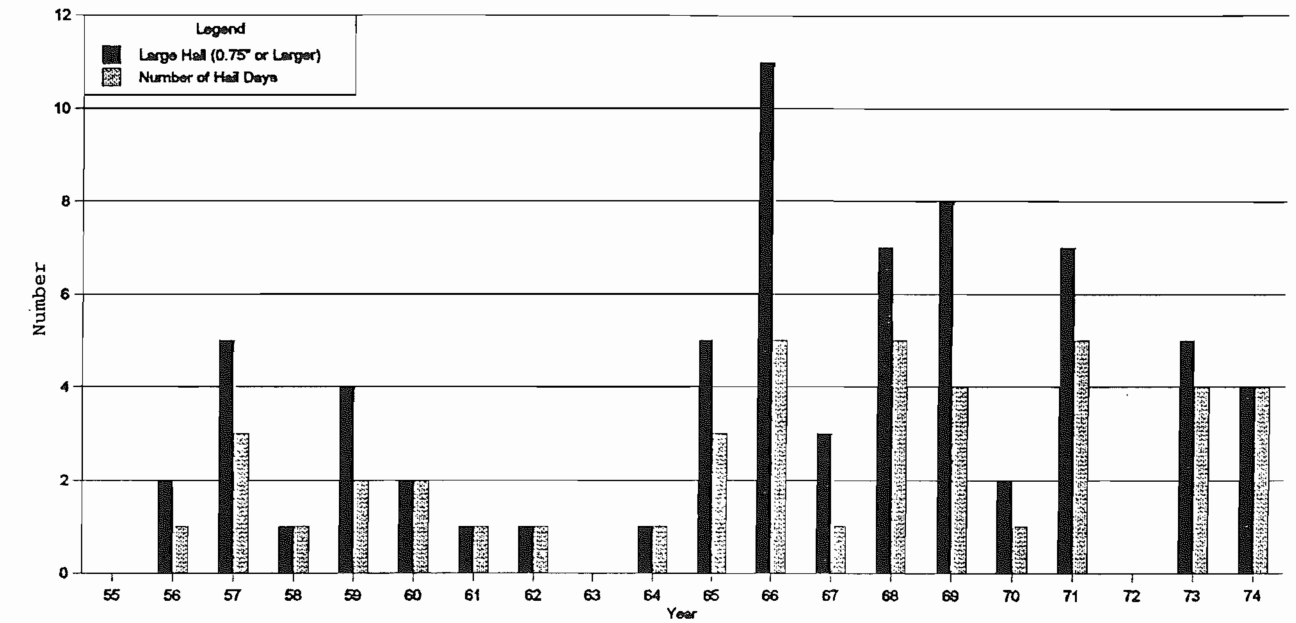


Fig. 12. Hourly distribution of damaging wind events (1955-1994) in the Corpus Christi CWA.



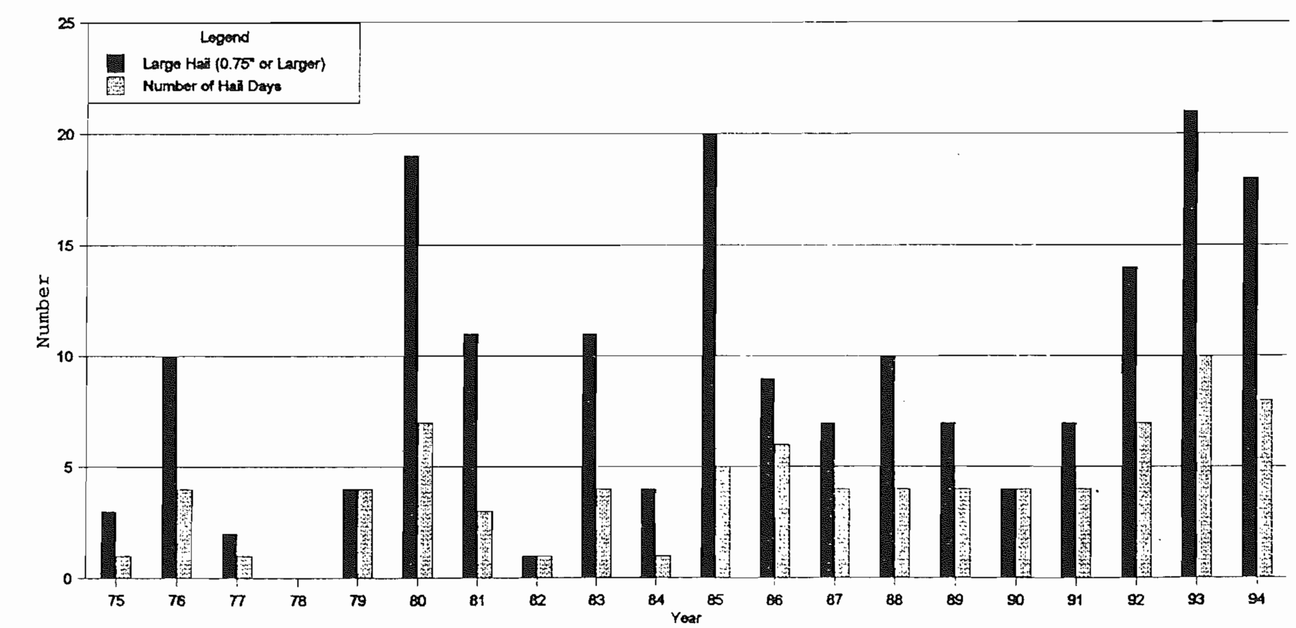


Fig. 13. Yearly distribution of severe hail events (1955-1994) in the Corpus Christi CWA. Note the change in scales from top to bottom graphs.

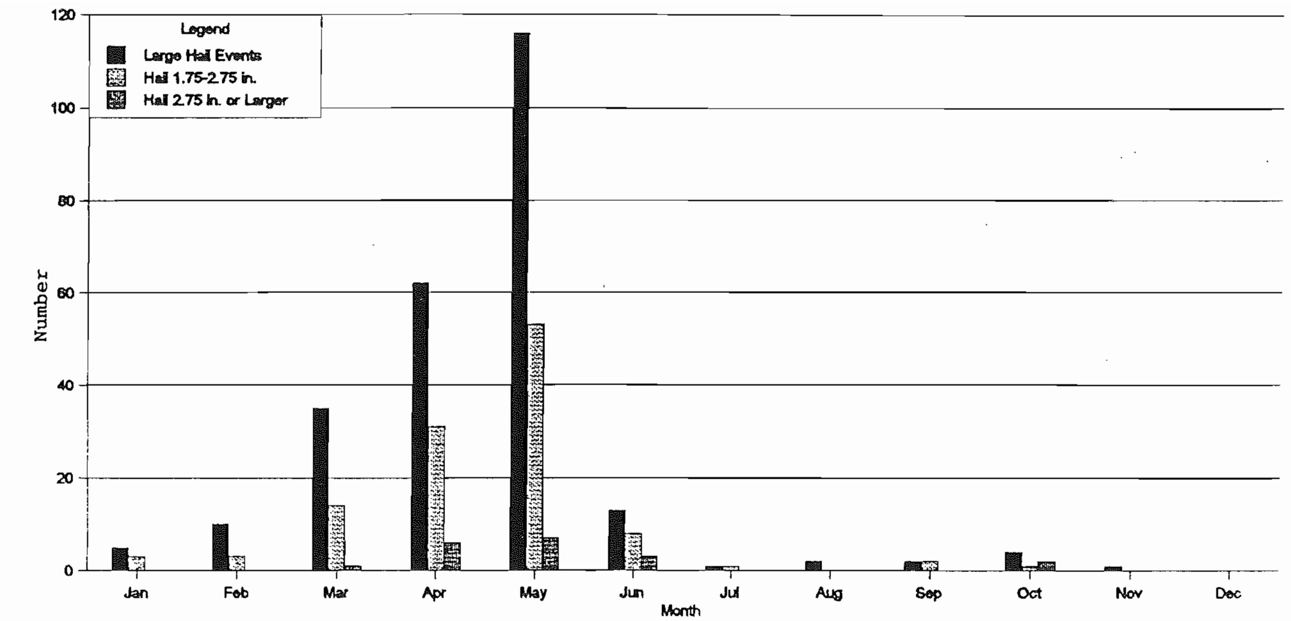


Fig. 14. Monthly distribution of severe hail events (1955-1994) in the Corpus Christi CWA.

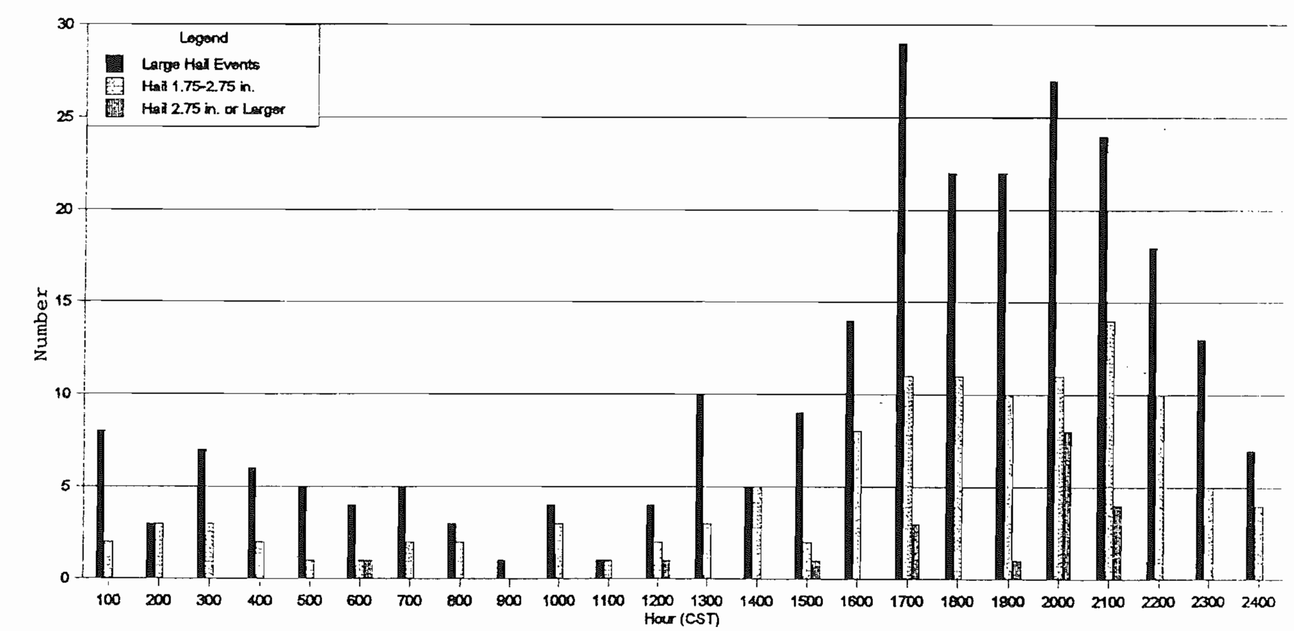


Fig. 15. Hourly distribution of severe hail events (1955-1994) in the Corpus Christi CWA.

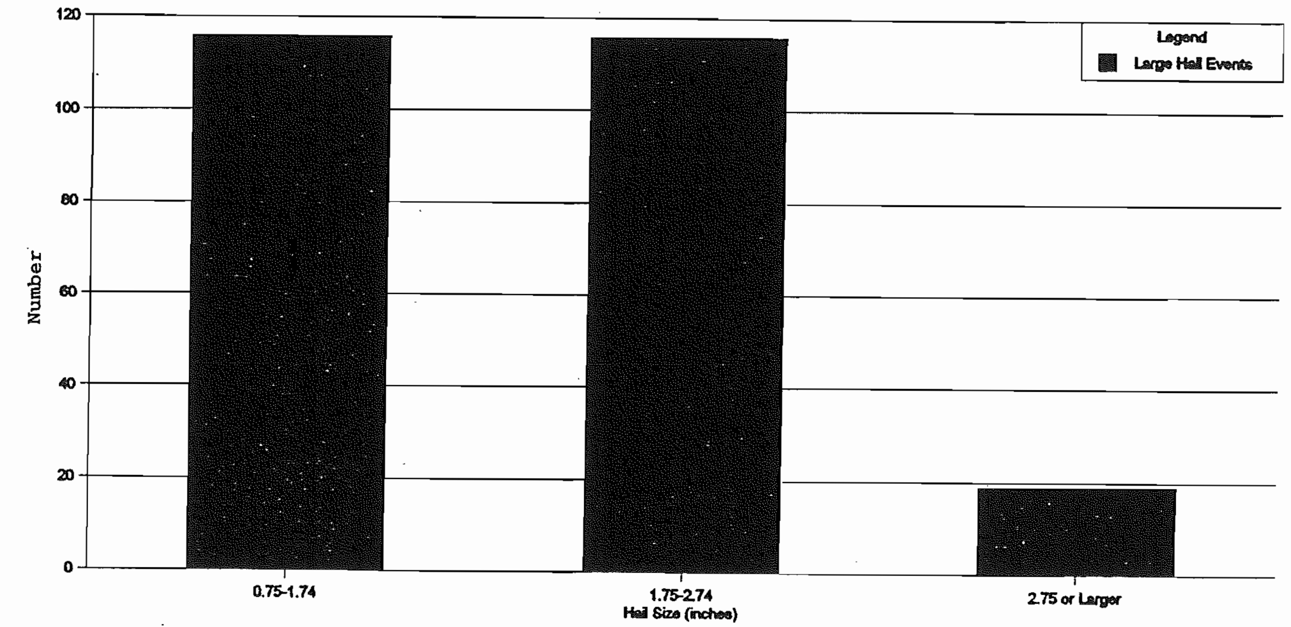


Fig. 16. Distribution of severe hail by size in the Corpus Christi CWA. 1955-1994 data set.

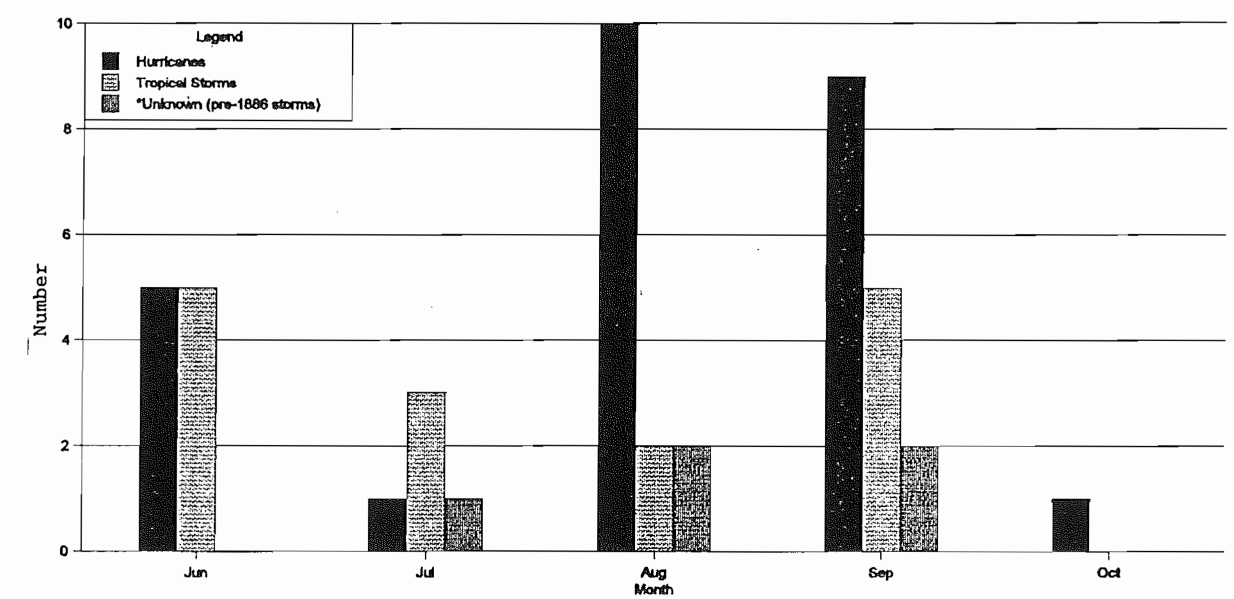


Fig. 17. Distribution by month of the tropical cyclones which have affected the Corpus Christi CWA, 1871-1995.