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A SEVERE WEATHER AND FLOOD CLIMATOLOGY OF WEST CENTRAL TEXAS

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1. Introduction

As part of the modernization of the National Weather Service, the National Weather Service Office in San Angelo, Texas, has undergone a transition to a Weather Forecast Officer (WFO), and is now responsible for full forecast operations. During this process, the County Warning Area (CWA) expanded to 24 counties, covering over 43,000 km^2 (27,000 mi^2). The increase in the CWA has been made possible by the addition of the WSR-88D radars to both the NWS office in San Angelo (KSJT) and to Dyess Air Force Base near Abilene (KDYX), and by the addition of meteorologists trained in the use of the new radars. Since these meteorologists come from various locations across the country, they are not readily familiar with the types of significant weather expected across West Central Texas. This study was conducted to provide a basic knowledge of the area severe weather and flood climatology to these new meteorologists.

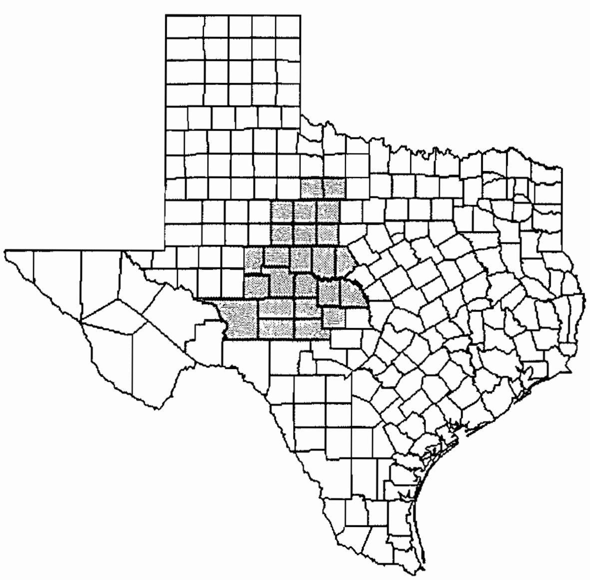

Fig. 1. County warning area of WFO San Angelo.

With a 2000 population of 401,000 (Census Bureau 2000), WFO San Angelo's CWA has a population density of 9.3 people km^{-2} (14.8 people mi^{-2}); however, half of the population is centered in just 2 counties, Taylor and Tom Green (encompassing the cities of Abilene and San Angelo), with a total population of around 230,500. Without the inclusion of these two cities, the population density drops to 4.0 people km^{-2}. In fact, 12 counties, encompassing almost 23,000 km^2 (or roughly 53% of the CWA), have population densities under 3 people km^{-2}.

This low population density marks just one of the problems with conducting a study of the severe weather climatology of West Central Texas, with many severe events having gone unreported due to the simple fact that few people live in that area. Many others have commented on the problem of population distribution and the changing nature of a national severe weather climatology (Hales 1993; Brooks 2000).

2. The Data

Three sets of data were used for this study. First, the CLIMO program by Michael Vescio was used to pull the data out of the National Severe Storms Forecast Center Database. This NSSFC database included all tornado reports since 1950, and all severe hail and convective wind reports since 1955 (excluding hail and wind data for 1972).

The second set of data came from the *Storm Data* publication. This data was used to fill in the missing hail and wind data from 1972, and also to compile the flood statistics. In addition, *Storm Data* was used to provide a county-by-county tabulation of severe weather and flood events and to provide more details on certain events.

The third data set included the hourly precipitation data and normal precipitation data for San Angelo and Abilene obtained from the National Climatic Data Center. This data was used to determine the monthly and diurnal trends in heavy rainfall.

NWS policy states that a severe thunderstorm is a storm that produces one of the following: a tornado, hail greater or equal to 1.9 cm (0.75 inch), convective wind gusts greater or equal to 26 m s^{-1} (50 kt or 58 mph), or convective wind damage that may imply the occurrence of a severe thunderstorm (NWS 1995). A flood is defined as an inundation of a normally dry area caused by an increased water level.

3. Tornado Climatology

a. Monthly frequency

As Fig. 2 clearly shows, the number of all tornadoes events begins to increase during the month of March, hits a substantial peak in May, and then declines rapidly from June through summer and fall. The pattern for just the strong and violent tornadoes (F2-F5) shows a very similar pattern, although the peak in May is less pronounced.

Very few tornadoes are reported during the cool season months of November through February. The few tornadoes that are reported in the cool season tend to be strong or violent, perhaps because of the stronger dynamics that often accompany these systems.

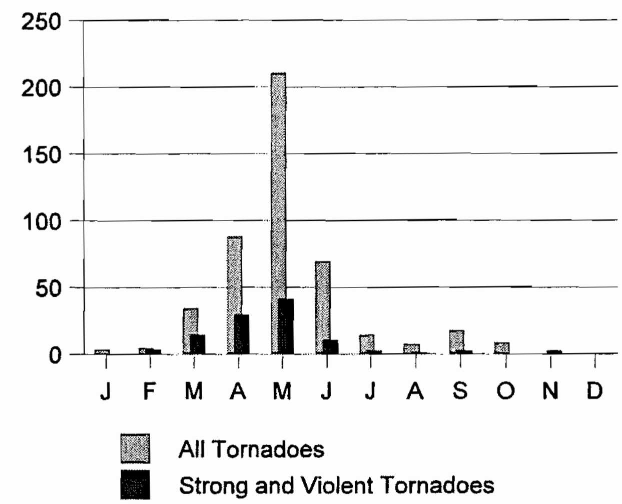

Fig. 2. Monthly distribution of West Central Texas tornadoes, 1959-2000.

West Central Texas does on occasion feel the effects of tropical systems as they move inland. In fact, the slight secondary peak in tornadoes noted in the fall is enhanced by the 10 tornadoes reported on 17 September 1988 as the remnants of Hurricane Gilbert skirted the southeast portion of the area.

b. Diurnal trends

As numerous other studies (Mead and Murdoch 1997; Calianese and Cain 1998) have shown for the plains states, the number of tornadoes across West Central Texas typically reaches its lowest point during the early morning hours (Fig. 3). This is also the time when the instability is at a minimum with the loss of diurnal heating. The frequency gradually rises through the daylight hours as temperatures and instability increase, reaching a peak during the late afternoon and early evening hours. At this time, not only are thunderstorms most numerous, but more people are outside, enhancing the chances that weak, short-lived tornadoes will actually be spotted.

It should be noted that although they may not occur as often, the early morning

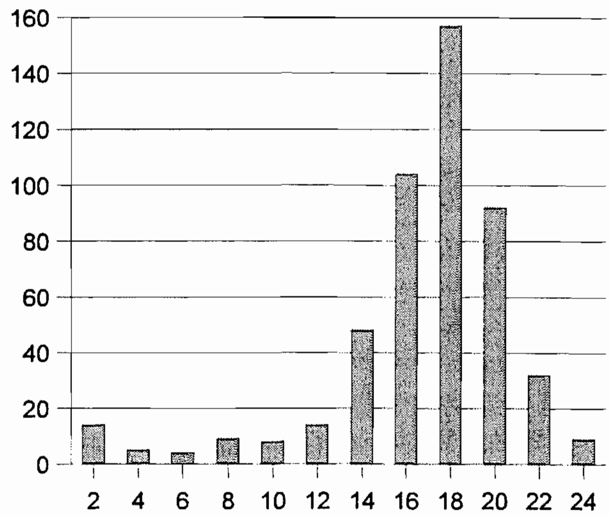

Fig. 3. Time distribution (CST) of West Central Texas tornadoes, 1959-2000.

tornadoes can be quite strong. For example, a tornado rated F3 struck the community of Sweetwater in Nolan County at 0715 CST on 19 April 1986. This tornado tore though much of the town, killing one person and injuring one hundred.

c. Magnitude

Figure 4 shows the strength distribution of West Central Texas tornadoes, with Fig. 5 showing the national average. There is a slightly lower percentage of strong and violent tornadoes across West Central Texas than the national average.

This is probably an effect of the low population density. Since the Fujita Scale is determined using damage estimates, a tornado must actually strike some sort of object to receive a strong or violent ranking. Since most of West Central Texas is made up of open farm and ranch land, there are few structures to hit, so a tornado that might receive a higher ranking in a more heavily populated area receives a lower ranking in a sparsely populated region such as West Central Texas.

There have been only five tornadoes rated F4 across West Central Texas since 1950. Four of the five were killer tornadoes, responsible for 31 of the 42 tornado-related deaths. Ironically, the lone F5 tornado killed no one and injured only 11 as it touched down near Brownwood on 19 April 1976.

4. Hail Climatology

a. Monthly frequency

Following the basic trend shown in the tornado data, reports of hail rise through the

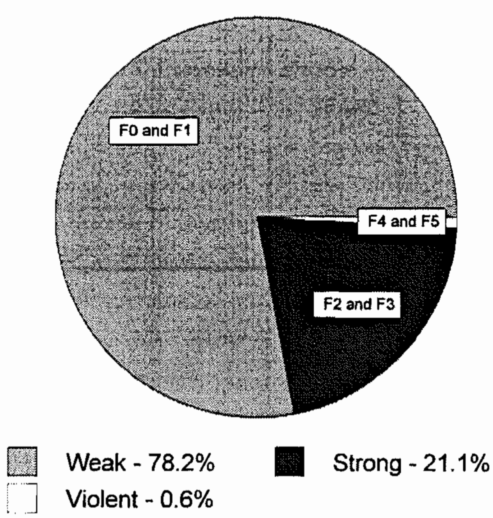

Fig. 4. Strength distribution of West Central Texas tornadoes, 1959-2000.

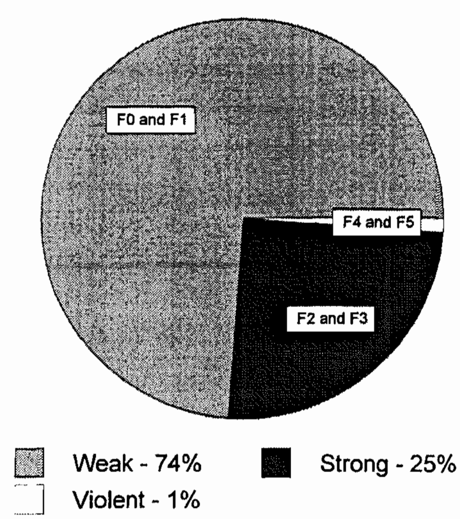

Fig. 5. Strength distribution of all U.S. tornadoes, 1950-1994.

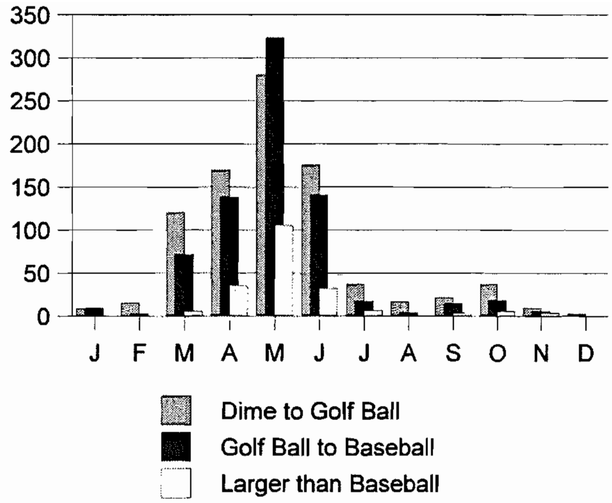

Fig. 6. Monthly distribution of West Central Texas hail reports, 1959-2000.

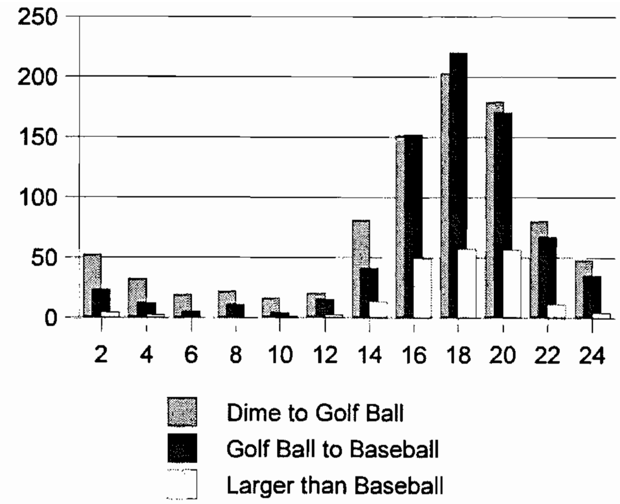

Fig. 7. Time distribution (CST) of West Central Texas hail reports, 1959-2000.

spring months, show a large peak in May, then decline rapidly through the summer and fall. As seen in Fig. 6, this trend holds true for all hail reports as well as the golf ball and larger reports.

There does appear to be a weak secondary hail peak during the autumn months, particularly September and October. This is the time of year when the jet stream begins to make a little more southerly dip, often pushing the first of the autumn cold fronts southward into Texas. Freezing levels and wet bulb zero levels also begin to lower, making the production of severe-size hail substantially easier than during the hotter months of summer.

c. Diurnal trends

Again, similar to the trend in tornadoes, hail reports are at a low during the overnight hours, pick up through the afternoon, and peak during the 1600 to 1900 CST time frame. As seen in Fig. 7, hail reports drop off shortly after sunset, as the loss of daytime heating usually leads to a decrease in thunderstorm strength.

5. Damaging Wind Climatology

a. Monthly frequency

Since damaging winds are often caused by the same thunderstorms that may produce hail and/or tornadoes, a similar climatology would be expected. The data from West Central Texas (Fig. 8) shows this same trend, although with one important addition: hail and tornado reports show a peak in May (Figs. 2 and 6), a substantial drop-off in June, and then very few reports through the remainder of the

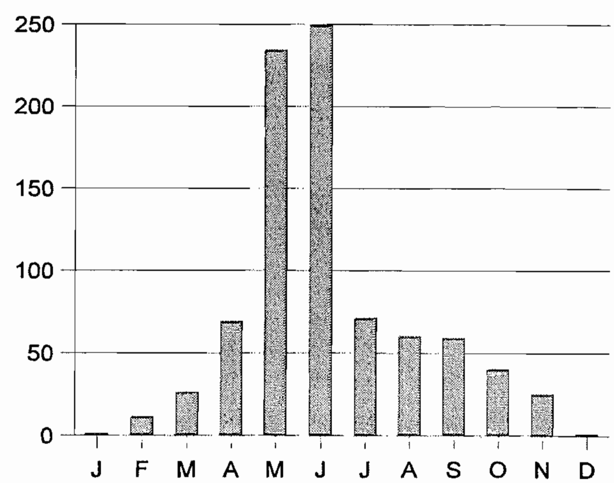

Fig. 8. Monthly West Central Texas severe wind reports, 1959-2000.

summer.

By the start of June, the freezing and wet bulb zero levels have usually risen to the point that only the most intense storms will produce hail that meets severe criteria and the number of hail producing storms begins to decrease rapidly. This trend does not hold for severe wind reports, where the totals for May and June are virtually identical, with a more gradual decline in reports through the summer. This pattern holds true at other locations across West Texas as well, where the Midland CWA shows a very similar trend (Mead 1997).

Over the western half of the area during the summer months, much drier and warmer air near the surface creates an "inverted-V" sounding profile. With cloud bases at 10,000 ft or higher, any thunderstorm that develops has a threat of producing a dry microburst. Across the eastern half of the area, where low level moisture is usually much deeper, very high moisture loads and wet microbursts become a factor. Thus, although severe hail reports are at a relative minimum through the summer months, the threat of damaging downbursts continues until the number of thunderstorms begins to decline in the late fall and winter.

b. Diurnal trends

Similar to the climatology for both tornadoes and severe hail, damaging wind reports tend to peak in the late afternoon and evening hours. As seen in Fig. 9, severe wind reports increase through the afternoon hours, peak around 2000 CST, and then steadily decline through the late evening and early morning hours.

The decline in severe wind reports, however, is less pronounced than the decline in hail reports through the late evening and early morning hours. There are two likely reasons for this.

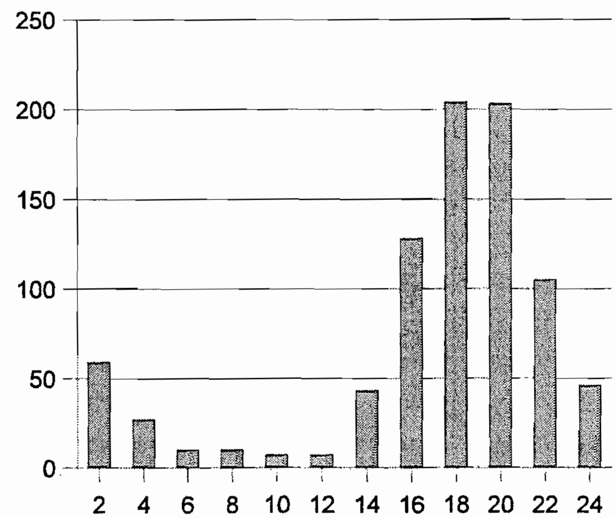

Fig. 9. Time distribution (CST) of West Central Texas wind reports, 1959-2000.

First, many of the severe winds occur when the thunderstorm collapses. Although severe hail may accompany this collapse, damaging outflow winds will spread away from the storm and may last for some time after the last hail report.

Second, occasionally thunderstorms over the higher terrain of Far West Texas and New Mexico will organize into a mesoscale convective complex (MCC) and move toward West Central Texas. Enhanced by a strong low level jet that is often located over the area, this MCC will often produce scattered reports of wind damage as it passes through the area during the late evening and early morning hours.

6. Flood Climatology

Flood reports were collected from the *Storm Data* publication for the years 1959-2000. Flood events were tallied by county, year of occurrence, and month of occurrence. The number of flood-related deaths and injuries were also collected, as well as information on how the flood deaths occurred. The time of occurrence of each flood event could not be determined accurately from the *Storm Data*

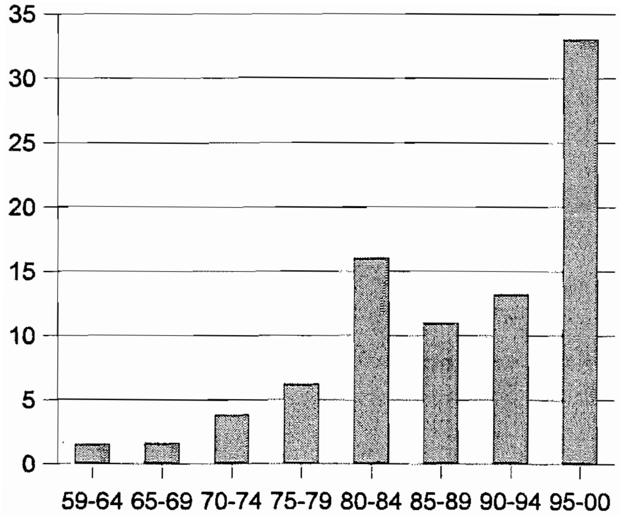

Fig. 10. Average annual county flood events across West Central Texas, 1959-2000.

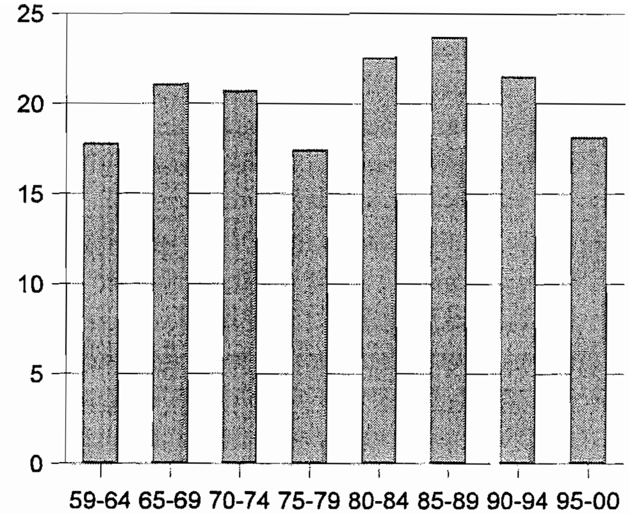

Fig. 11. Average rainfall at San Angelo, Texas, 1959-2000.

information, as many flood events occurred over several days, and an exact time was not assigned to most events. Hourly rainfall data from San Angelo and Abilene was used to roughly determine the distribution of heavy rainfall events by time of day.

a. Yearly trends

Figure 10 shows the average number of county flood events per year across the WFO San Angelo CWA, while Fig. 11 shows the average rainfall in San Angelo during the same period of time. Although the average rainfall was slightly lower over the last 6 years, the number of flood events reported in *Storm Data* increased significantly. This increase is most likely due to an increased effort by the National Weather Service to gather flood verification and also partly due to increased urbanization.

b. Monthly distribution

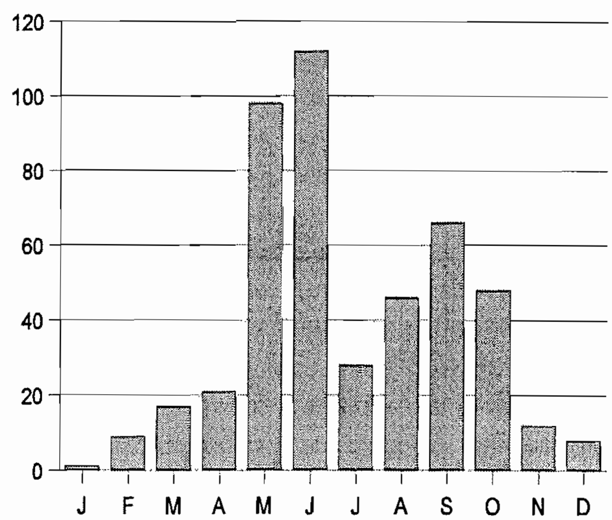

Fig. 12. Monthly distribution of flood events across West Central Texas, 1959-2000.

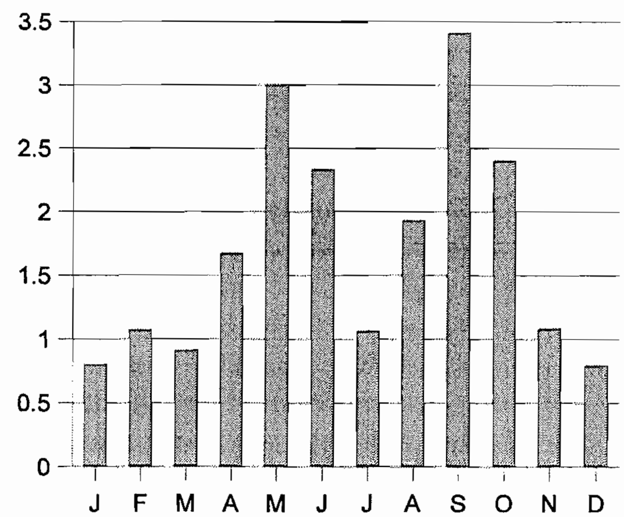

Fig. 13. Normal monthly precipitation for San Angelo, Texas 1961-1990.

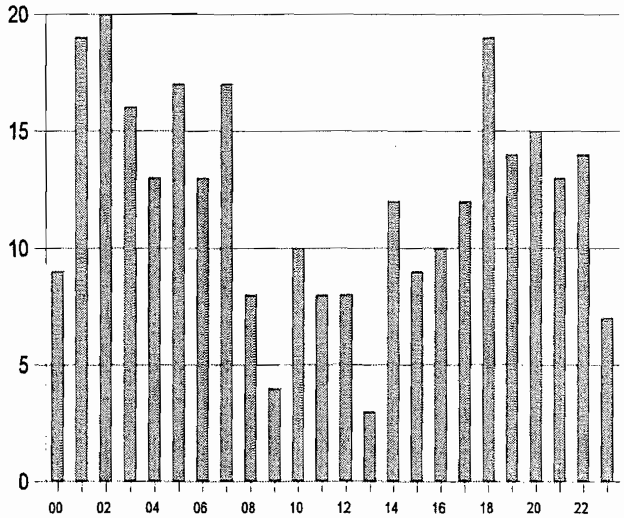

Fig. 14. Hourly (CST) frequency of 0.50 inch or more precipitation at San Angelo, Texas, 1959-2000.

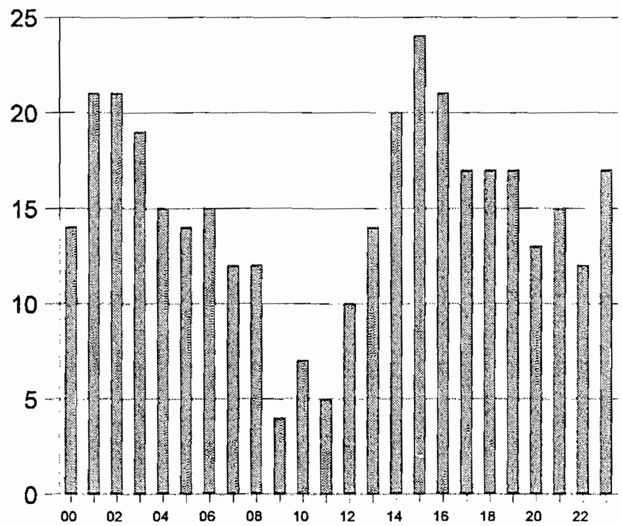

Fig. 15. Hourly (CST) frequency of 0.50 or more precipitation at Abilene, Texas, 1959-2000.

The monthly distribution of flood events is shown in Fig. 12. Figure 13 shows the monthly normal rainfall for San Angelo for the period 1930-1990. The spring and early fall peak periods of rainfall in West Central Texas are reflected in the increased frequency of flood events during the May through June and August through October periods. From the descriptions of the floods in *Storm Data*, it can be noted that flood events occurred more frequently in the spring, but covered fewer counties per event. The late summer and early fall events were often the result of the remnants of tropical systems and occurred less often, but affected larger areas covering more counties.

c. Daily distribution

Using hourly precipitation data for Abilene and San Angelo for the period 1959 to 2000, the number of hours where one half inch or more of precipitation occurred was tallied. Figure 14 shows the results for San Angelo, while Fig. 15 shows the same data for Abilene. These figures show that higher rainfall amounts occurred most frequently during the afternoon and overnight hours.

7. County by County Distributions of Severe Weather and Flood Events

In an attempt to show which areas of West Central Texas are most prone to significant weather, maps showing county by county distributions were constructed. Figures 16-19 show these distributions.

The five counties with the largest number of severe weather reports are Tom Green, Taylor, Brown, Nolan, and Jones. As expected, these are also the counties with the largest total populations. However, there does seem to be a general trend of increasing severe weather reports from south to north across West Central Texas, likely aided by the increasing population densities.

In an attempt to find out whether there really are more severe weather events across the north than across the south, a comparison was made of several selected counties. The counties were selected so that population density, number of communities within the counties, and general county population layout were equivalent (i.e., one main county seat surrounded by smaller communities spread throughout the remainder of the county). In each case, the main business in the county is

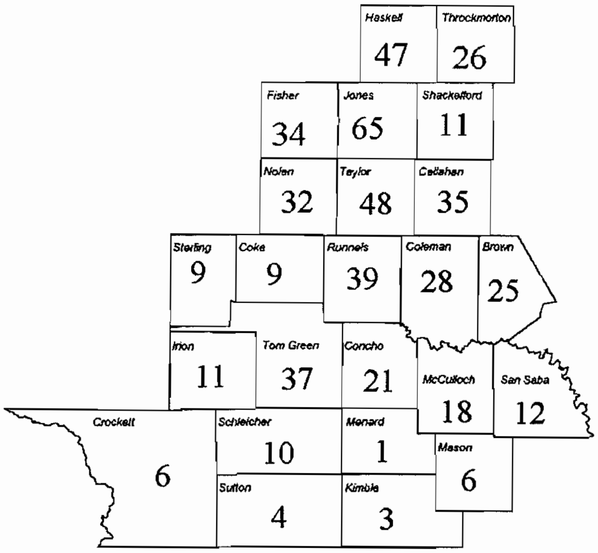

Fig. 16. West Central Texas tornado distribution by county, 1959-2000.

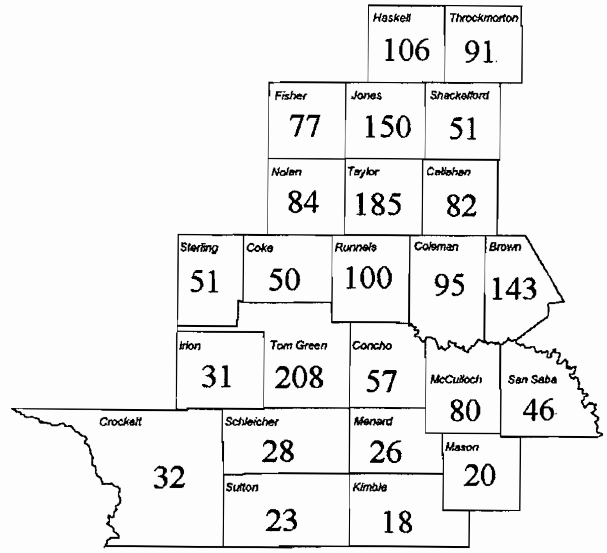

Fig. 17. West Central Texas severe hail distribution by county, 1959-2000.

agriculture, and thus the area between the communities is often covered by large individual farms and ranches. Across the north, the counties of Haskell, Throckmorton, Fisher, and Shackelford were selected. Across the south, the counties of McCulloch, San Saba, Mason, and Menard were chosen.

Overall, there were 564 severe weather reports (tornadoes, large hail, or severe winds) across the northern set of counties during the period 1959 to 2000, compared to 271 across the south. The difference in just the strongest of events (all tornadoes and golf ball or larger hail) is even more pronounced. There have been 118 tornadoes reported across the north and only 37 across the south, with 170 golf ball or larger hail reports from the north compared to just 87 across in the southern county selection. Thus, it does appear that the

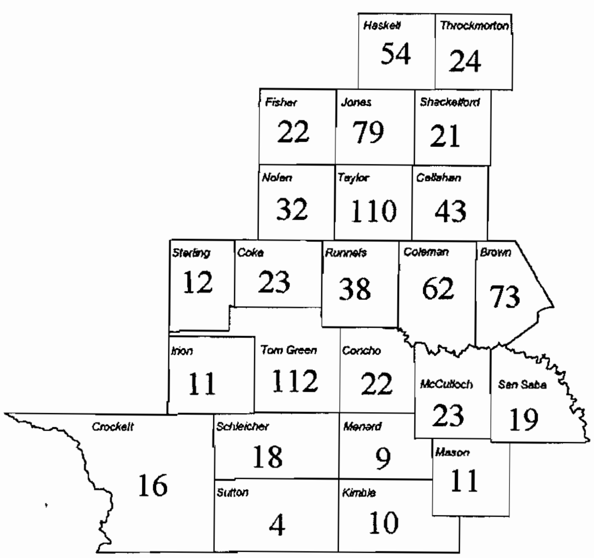

Fig. 18. West Central Texas severe wind distribution by county, 1959-2000.

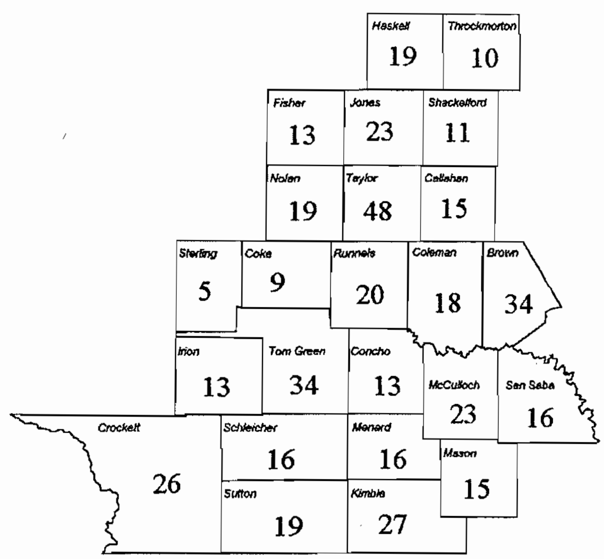

Fig. 19. West Central Texas flood event distribution by county, 1959-2000.

northern counties in the CWA are more likely to see severe weather than the southern counties. There does seem to be some meteorological sense to these statistics, with experience over just the last few years showing that upper level support is often stronger across the north than across the south. In addition, mid-level temperatures (acting as a cap) are often warmer across the south, as southwest winds blow off the high plateaus of northern Mexico. Finally, the upper dynamics are often much stronger across the north, with better vertical wind shear combining with the slightly cooler temperatures to enhance both the growth of large hail and the possibility of rotating supercells.

Figure 19 shows the distribution of flood events across the CWA. Like the severe weather distribution, Tom Green and Taylor show the highest number of reported floods. Brown County, where the city of Brownwood is located, also shows a larger number of flood events. These are the counties with the largest populations and largest urban areas. Urban street flooding is quite common in West Central Texas as most communities do not have storm drain systems. Runoff from heavy rainfall flows through the streets and collects in low-lying areas.

The flood event distribution differs slightly from the severe weather distribution when population density is taken into account. Crockett County has the lowest population density in the CWA, but it has the fifth largest number of reported flood events. Flooding in Crockett County is enhanced by the topography of the area. The land elevation is higher in Crockett County than much of the rest of the CWA, with several small river valleys cutting through the higher terrain. Runoff from heavy rainfall flows quickly downhill in the rocky terrain. Kimble County also shows a relatively high number of flood events. Kimble County is located on the northwestern edge of the Hill Country of Central Texas, where the hilly terrain enhances flooding.

8. Weather-Related Fatalities

Due to its low population, weather-related fatalities across West Central Texas have been relatively few, numbering just 43 since 1959. As noted on Fig. 20, the majority of the deaths occurred during flooding and flash flooding. Much of West Central Texas has an abundance of normally dry creeks and streams called arroyos, with area roadways passing across these areas as low water crossings. During heavy rain events, these arroyos fill with swiftly flowing flood water, easily flowing fast enough to sweep vehicles off the roadway as they attempt to cross.

Figure 21 shows a breakdown of the 22 flood-related deaths and 8 flood-related injuries in the 42 year period, classified by type. Clearly, most people were killed or injured while attempting to drive through flooded areas. Two people were killed and one was injured while trying to rescue others that had driven into flooded areas. The causes of seven of the deaths and injuries were not listed in *Storm Data.* Six of these deaths occurred in Albany, Shackelford County, on 3 August 1978 when 32 inches of rain fell in a 24-hour period. The deaths are believed to have occurred in the immediate vicinity of Prong Creek, but details are not known.

As expected with the number of tornadoes seen annually across the area, tornadoes ranked as the second biggest killer over the last 40 years. Seven tornadoes were responsible for the 11 deaths, with the deadliest being a tornado that killed 3 in extreme eastern Throckmorton County on 21 April 1985.

The remaining 10 deaths were evenly split between lightning and high winds (convective and non-convective).

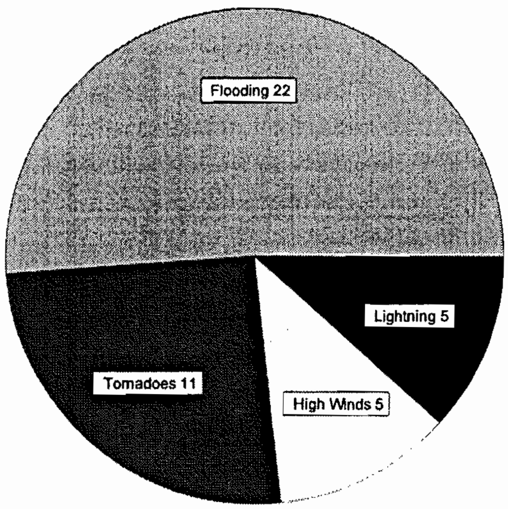

Fig. 20. West Central Texas weather-related fatalities, 1959-2000.

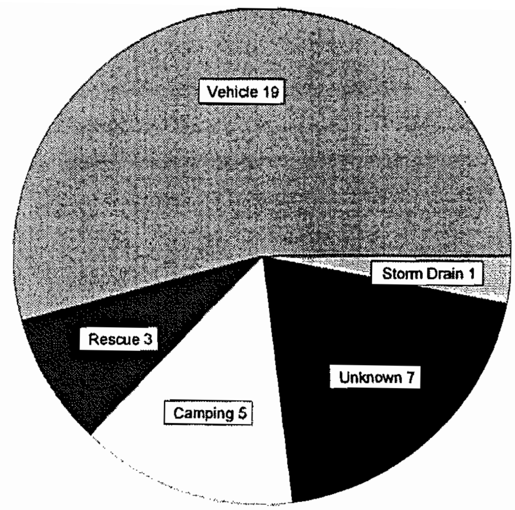

Fig. 21. Types of flood-related deaths and injuries across the CWA, 1959-2000.

9. Summary

– The West Central Texas severe weather season extends from March through June with a secondary peak during September and October.

– Tornadoes and large hail are most likely during the month of May with occurrences reaching a maximum between 1600 and 2000 CST.

– The peak months for severe winds are May and June with the peak time for occurrence between 1600 and 2000 CST.

– Flooding occurs most frequently during May and June, with a secondary peak from August through October.

– Heavy rainfall occurs most frequently during the evening and overnight hours.

– For a variety of reasons, the northern sections of West Central Texas are slightly more prone to severe weather than the southern areas.

– Flooding and flash flooding cause the majority of weather-related fatalities across West Central Texas with tornadoes a distant second.

– Most of the flood and flash flood fatalities were vehicle-related.

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