A SEVERE WEATHER CLIMATOLOGY FOR THE CHARLESTON, SOUTH CAROLINA, COUNTY WARNING AREA

Stephen Brueske, Lauren Plourd, Matthew Volkmer
National Weather Service Forecast Office
Charleston, South Carolina
24 April 1998

INTRODUCTION

The operational staff of the National Weather Service (NWS) Weather Forecast Office (WFO) in Charleston, South Carolina issues severe weather warnings for 20 counties in eastern South Carolina and Georgia (Fig 1). New technologies, such as the AWIPS (Advanced Weather Interactive Processing System) and the WSR-88D (Weather Surveillance Radar-1988 Doppler) has enhanced the analysis of the potential for, and occurrence of, severe weather. The forecast process employed by local forecast offices and the Storm Prediction Center (SPC) of the National Centers for Environmental Prediction (NCEP), depends upon the scientific evaluation of the evolving pre-storm environment, severe weather pattern recognition, and climatology (Johns and Doswell 1992). This study provides one of these necessary tools, a detailed severe weather climatology for the Charleston, SC, County Warning Area (CWA).

The motivation to research and document this severe weather climatology of the Charleston, SC, CWA, was to provide the essential tool of climatology to better prepare forecasters to anticipate the frequency, timing, and magnitude of severe weather events, and to provide a baseline for assessing the likelihood and type of severe weather. This study also reveals severe weather trends and highlights the importance of anticipating atypical severe weather. This is especially important in that each NWS forecast office will eventually take on additional severe weather related responsibilities as a result of the planned NWS Convective Watch Decentralization (Alexander et al., 1997).

METHODOLOGY

Data used in this research were obtained from the NWS Storm Prediction Center's Verification Unit, using a statistical database entitled CLIMO (Vescio 1995). The CLIMO program stratified all severe weather events by type, time of occurrence, intensity, and in the case of tornadoes, path length and path width. Locations of severe events were plotted on maps of the Charleston, SC, CWA using a program titled SEVERE PLOT (Hart 1992; 1993). The total number of plotted events is less than the total number of reports due to the lack of specific location information in some severe weather reports.

Three different types of severe weather were investigated: tornadoes, severe convective wind, and severe hail. Each tornadic event was recorded as a tornado segment, defined as a portion of a tornado track through a given county. For example, one tornado which moved uninterrupted through two counties was considered two tornado segments. Therefore, the total number of tornadoes was less than the number of tornado segments represented in this database. A severe convective wind event was defined as either an event with a convective wind gust of 50 knots or greater, or visible structural damage due to convective wind. Severe hail was defined as hail greater than or equal to 0.75 inches in diameter. The tornado data covered the period from 1950 through 1993, while both severe convective wind data and large hail data covered the period from 1955 through 1993, excluding 1972 when no records were stored.

SEVERE WEATHER CLIMATOLOGY

A total of 745 severe weather reports were recorded in the Charleston, SC, CWA during the period studied. This number represents 112 tornado segment reports (Fig. 2), 478 severe convective wind reports (Fig. 3), and 155 severe hail reports (Fig. 4). The distribution of reports was fairly uniform across the county warning area, though reports were more concentrated in highly populated regions around Charleston, Beaufort and Savannah. Fewer reports were noted across less populated areas, especially east of Interstate 95 in Georgia, though no large data-void regions existed in the record. This differs from Richard Anthony's severe weather climatology for the Jacksonville, FL, CWA (Anthony 1994) in which there was an obvious void in reports from the Okefenokee swamp area.

The following sections summarize the climatological record of each type of severe weather event. The data provide a baseline for anticipating the likelihood, severity, and timing of the most frequently observed severe weather in the CWA.

TORNADO CLIMATOLOGY

In the WFO Charleston CWA, tornadoes were most frequently reported in April and May (Fig. 5). Forty percent of all tornado reports occurred during these months, 22 percent in May, and 18 percent in April. Minimal tornado activity was reported in the late fall through the winter, with no tornadoes reported in December. Kevin Knupp (1992) identified enhanced storm-relative helicity as a primary environmental factor involving tornado formation in the spring, when the polar jet stream is further south. This enhancement may help account for the significant rise in April and May tornado reports.

Most tornado injuries occurred in March, April, and May, with a secondary maximum in September (Fig. 6). May was the primary month for tornado injuries and the only month since 1950 in which deaths were reported. Eighty-five injuries and three deaths were attributed to tornadoes during the 43-year period. Fifty-eight percent of the injuries were caused by F1 tornadoes (Fujita 1971); F2 and F3 tornadoes accounted for 39 percent, and F0 tornadoes caused the remaining 3 percent of injuries (not shown). The 18 injuries in September were due to two separate tornadoes spawned by hurricanes that passed near South Carolina, but did not make landfall. The first tornado, spawned by Hurricane Donna in 1960, caused 10 injuries, while the second tornado, spawned by Hurricane Eloise in 1975, injured eight.

Tornadoes were most frequently reported to occur between 1400 and 1700 EST (Fig. 7). Two-thirds of all tornado events occurred between 1100 and 1900 EST with minimal activity reported during the late evening through morning hours. The afternoon and early evening peak demonstrates the importance of surface heating in maximizing the convective available potential energy (CAPE) available for severe storm development.

Tornadoes were generally weak, with short path lengths and narrow path widths. Eighty-two percent of reported tornadoes were classified as F1 or less, and only one F3 was reported during the 43-year period (Fig. 8). No tornadoes stronger than F3 were documented in these data; however, an F4 tornado did hit southeast Georgia in 1929 (Grazulis 1993) and is discussed in a later section. Sixty-two percent of the tornadoes had path lengths less than 1 mile and 84 percent of the path lengths were less than 3.2 miles (Fig. 9). Path widths were narrow, with 94 percent of tornadoes having path widths less than 176 yards (Fig. 10).

SEVERE CONVECTIVE WIND

May, June, and July were the three months with the highest number of recorded severe convective wind events, with July accounting for one quarter of the total severe wind events (Fig. 11). No damaging wind events were reported during December. Physical reasons for this midsummer maximum may include the fact that precipitable water values and tropopause heights are near their highest for the year, allowing deep, moist convection, capable of producing wet microbursts. Johns and Doswell (1992) note that deep convection and large precipitable water amounts help to enhance damaging winds by promoting strong downdrafts. A sharp decline in severe wind reports is noted in August, which may be due to the climatologically stronger Bermuda High Pressure System off the Southeast Atlantic Coast, which produces large-scale subsidence and tends to inhibit the formation of deep convection.

The most frequent time of occurrence for damaging wind events was 1700 EST, with 63 percent of wind events reported between 1500 and 1900 EST (Fig 12). There is a relatively uniform distribution of minimal reports between 2300 EST and 1100 EST. The mid-afternoon to early evening maxima in damaging wind reports indicate the important role surface heating plays in increasing the CAPE necessary for pulse-type severe thunderstorms.

SEVERE HAIL

Severe hail reports were highest during April, May, and June (Fig. 13) with no severe hail reported from September through January. Johns and Doswell (1992) have identified the melting level and height of the wet-bulb zero as two parameters that affect hail stone size. One reason for the April maximum in hail reports may be that lower wet-bulb zero heights and a climatologically cooler layer from the surface to the freezing level exists in April, as opposed to the summer months when higher wet-bulb zero levels and a warmer layer from the surface to the freezing level typically occur.

Not surprisingly, most severe hail events occurred in the afternoon and early evening hours (Fig. 14), just as with tornado events. Eighty-eight percent of severe hail events occurred between 1400 EST and 2200 EST, with a peak at 1600 EST. A minimal number of hail events were reported during the overnight and morning hours. As mentioned, late afternoon is a time when the CAPE for thunderstorm development is usually maximized; notably, though, it is also a time when sea-breeze fronts frequently provide a convergence boundary which aids in the initiation and enhancement of thunderstorms.

METEOROLOGICAL REASONS FOR OBSERVED CLIMATOLOGICAL PATTERNS

As elsewhere, the timing and intensity of severe weather in the Charleston, SC, CWA are related to the availability of moisture, instability, lift, and vertical wind shear. The first three parameters are typically necessary for the initiation of convection; the fourth to establish organization and persistence of thunderstorms (Weisman and Klemp 1984). A closer examination of typical weather conditions in the Charleston CWA shows a lack of one or more of these conditions throughout most the year.

Climatologically, Spring is the most active severe weather season, and the time of year when tornadoes and hail are most commonly observed. Moisture is typically abundant; however significant low-level atmospheric instability is often lacking along the coast due to the advection of relatively cool, moist air off the Atlantic Ocean where water temperatures are typically in the lower 50's. Fronts that penetrate the region provide a lifting mechanism for convection, while significant vertical wind shear , which helps to organize convection, is common due to the seasonal proximity of the polar jet stream. Significant vertical wind shear, strong frontal lifting mechanisms, and relatively low 0 C wet-bulb heights are primarily responsible for the tornado and hail report maxima during April and May.

Summer is, in particular, a time of abundant moisture with precipitable water amounts often near 2 inches. In addition, strong surface heating creates highly unstable afternoon conditions with a great deal of CAPE. In spite of these destabilizing effects, the Bermuda High's strong influence over the area at this time of year effectively blocks any frontal penetration, so few lifting mechanisms and little vertical wind shear exist.. The sea-breeze front is the only consistent lifting mechanism during the summer that tends to focus convection. With high instabilities and little environmental wind shear, pulse thunderstorms are frequent and provide the primary summertime severe weather threat, wet microbursts. This is evident in the July maximum for severe wind events and the less frequent number of tornado and severe hail reports relative to spring.

Fall is a time of decreasing occurrence of severe convective weather. Moisture availability remains, but shorter days and cooler surface temperatures lead to an increasingly stable atmosphere, in contrast to summer instability. The temperature gradient between the land and ocean diminishes, so any sea breeze that develops is usually weak. The Bermuda High continues to inhibit the penetration of fronts and the polar jet stream, so significant lifting mechanisms and vertical wind shear are infrequent.

Winter is a time of sufficient moisture but inadequate instability for convection, due to relatively cool surface temperatures. Fronts that do enter the area provide a lifting mechanism for convection, while significant vertical wind shear often exists as the jetstream descends to lower latitudes. Atmospheric stability is at its yearly maximum during the winter and this stability is evident in the lack of severe weather reports.

SEVERE WEATHER TRENDS

The total number of severe weather reports in the Charleston CWA increased sharply during the 43-year period studied; sixty-nine percent of the events (517 of 745) occurred from 1983 to 1993 (Fig. 15). This impressive trend may be attributed to numerous causes: improved technology for severe weather detection, more aggressive verification procedures, improved spotter networks, an increase in public awareness and knowledge of severe weather, and an increase in the population and urbanization of coastal areas. Between 1970 and 1990, the population of the South Carolina counties in the Charleston CWA increased by over 50 percent (South Carolina Office of Research and Statistics 1998). Interestingly, while the total number of recorded severe weather events has increased, the average yearly number of *tornadic* events has decreased slightly during the same period (Fig.16). This is likely due to improved damage surveys and increased awareness of the difference between straight-line wind damage and tornado damage, leading to better identification of severe convective wind events that previously were erroneously identified as tornado damage.

ATYPICAL TORNADOES

The data clearly show that strong tornadoes (F3 or higher) are highly atypical in the Charleston, SC, CWA. While unusual, they pose the deadliest threat to the region and are a difficult forecast challenge due to their anomalous nature. Two of the deadliest tornado events in the history of the Charleston CWA were highly atypical, and occurred before the time period covered by data used for this paper. The deadliest tornado in the history of the CWA occurred in Georgia on 25 April 1929, at 2200 EST; at least 40 people were killed and 300 injured. The tornado was highly unusual in its time of occurrence, size, and duration; it is also the only F4 tornado ever recorded in the CWA. It had an average path width of 800 yards, reaching a path width of 1 mile in Bulloch County, where 31 people were killed. The 55-mile path length was the longest on record (Grazulis 1993).

Another significant tornado outbreak occurred in and around Charleston on 29 September 1938, at approximately 0800 EST, a climatologically rare time of day for tornado development. Five tornadoes (three F1s and two F2s) were reported in the Charleston area. The two F2 tornadoes occurred within 10 minutes of each other and followed parallel tracks 1.7 miles apart through the city. The first tornado occurred at 0750 EST, killing five people and injuring 20 others. Its path was fairly typical, with an average width of 100 yards and length of 2 miles. The second tornado occurred at 0800 EST and caused 27 deaths and 80 injuries along a 3-mile path that averaged 70 yards wide (Grazulis 1993).

Although these types of tornadoes are climatologically rare, they can, and do, form under the proper conditions. This knowledge, combined with environmental analysis using observations, Doppler radar, satellite, and model data will allow forecasters to anticipate and warn for these atypical severe weather events.

CONCLUSION

This study provides valuable insight into the climatologically favored months and time of occurrence of various types of severe weather in the Charleston, SC, CWA. As such, the information it has yielded is a valuable tool for forecasters in the Charleston, SC, office. Improving knowledge of the pre-storm convective environment in the context of a detailed local climatology can only improve on the overall severe weather forecast and warning effort.

Similar to the Anthony (1994) study, the Charleston CWA data show that tornadoes occurred most often during April and May, most frequently during the afternoon. In this study, the only reported deaths occurred between 1950 and 1993, and the most injuries occurred in May. Most tornadoes were weak, with short path lengths and narrow path widths.

The data also indicated an increasing trend for severe wind reports from April through July, while severe hail showed the opposite trend, with a maximum in April and a decreasing trend through July. Climatologically, the most likely months for severe hail were April and May, while severe convective wind events showed an increasing trend from April through July.

The yearly totals of all severe weather reports have shown a marked increase since the 1980s, and the authors suspect that recent years may be more typical of the number of severe weather events that occur in the Charleston CWA. Aggressive verification procedures, extensive spotter networks, increased population density, and improved detection technologies have allowed better identification and documentation of most severe weather events.

Results of this study were also similar to those revealed in a study conducted by Knupp (1992) for the entire Southeastern United States (Knupp 1992). One of the most significant differences is the pronounced lack of F2 or greater tornadoes in the Charleston, SC, CWA relative to the rest of the Southeastern United States. This research suggests additional studies are needed to explain what environmental parameters are responsible for this phenomena.

REFERENCES

Alexander, W., E. Jacks, L. Laurence, S. Keighton, L. Phillips B. Browning, B. Grant, E. Quoetone, R. Prentice, J. Griffin, P. Parrish, W. Abshire, D. Wesley and B. Johns, 1997: Preparing Forecasters for the Convective Watch Decentralization: A Training Plan. *Internal NWS draft training plan*. 35 pp.

Anthony, R.W., 1994: Severe Thunderstorm Climatological Data for the New Jacksonville, Florida, County Warning Area. *NOAA Tech. Memo. NWS SR-155* 19 pp.

Fujita, T. T., 1971: Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity. *SMRP Res. Paper No. 91*, University of Chicago.

Grazulis, T.P., 1993: *Significant Tornadoes 1680-1991*. Environmental Films, pp. 825, 881.

Hart, J. A., 1992: Severe Plot Version 1.0: SELS Severe Weather Archive Display Program. NCEP Storm Prediction Center, Norman, OK.

Hart, J. A., 1993: SVRPLOT: A new method of accessing and manipulating the NSSFC severe weather database. *Preprints, 17th Conf. On Severe Local Storms*, St. Louis, Amer. Meteor. Soc., 40-41.

Johns, R. H. and C.A. Doswell III, 1992: Severe Local Storms Forecasting. *Weather and Forecasting*, **7**, 588.

Knupp, K.R., 1992: Climatology of Severe Weather Events for the Southeastern United States. *Southeast Regional Climate Center Research Paper #040192* pp. 30,36.

Schmocker, G.K., D.W. Sharp and B.C. Hagemeyer, 1990: Three Initial Climatological Studies for WFO Melbourne, Florida: A First Step in Preparation for Future Operations. *NOAA Tech. Memo. NWS SR-132. 52pp.*

South Carolina Office of Research and Statistics, cited 1998: Statistical Abstract of South Carolina 1995 (Population Data). {Available online from www.state.sc.us/drss/pop/pop3.html}

Vescio, M. D., 1995: CLIMO: Software to generate severe weather statistics for NWS County Warning Areas. NCEP Storm Prediction Center, Norman, OK.

Weisman, M L. and J. B. Klemp (1984): The structure and classification of numerically simulated convective storms in directionally varying wind shears. *Monthly Weather Review*, 112, 2479-2498.

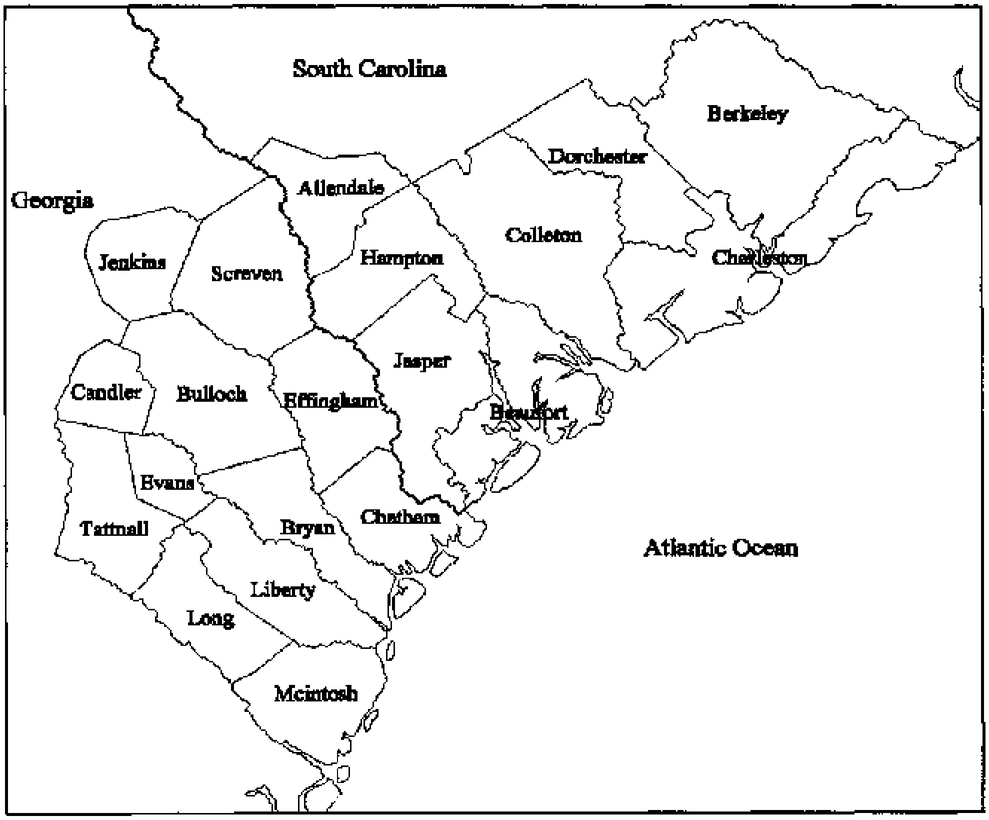


Figure 1. The 20 counties that define the County Warning Area (CWA) of the NWSO Charleston, SC.

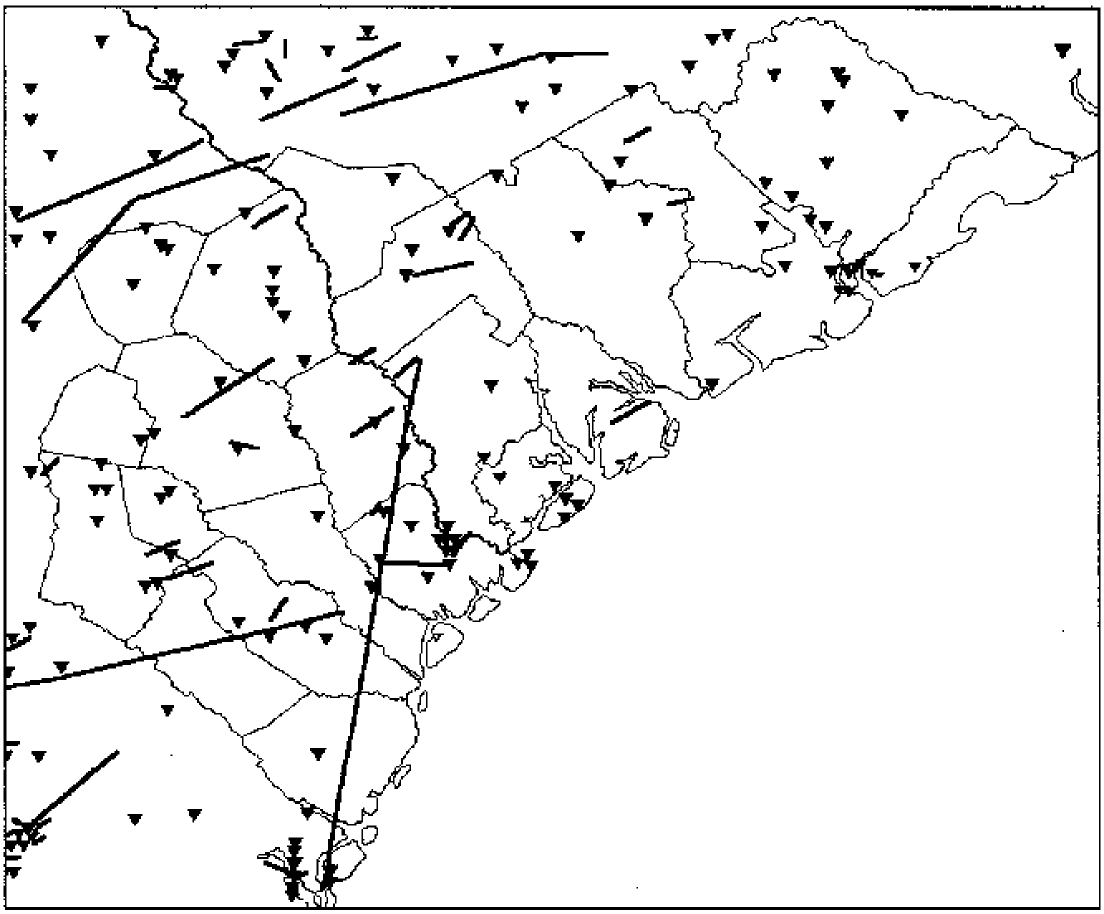


Figure 2. Plot of the approximate location of tornadoes reported from 1955 through 1993 within the CWA of NWSO Charleston, SC. Inverted triangles identify tornado touchdowns and line segments identify tornado paths.

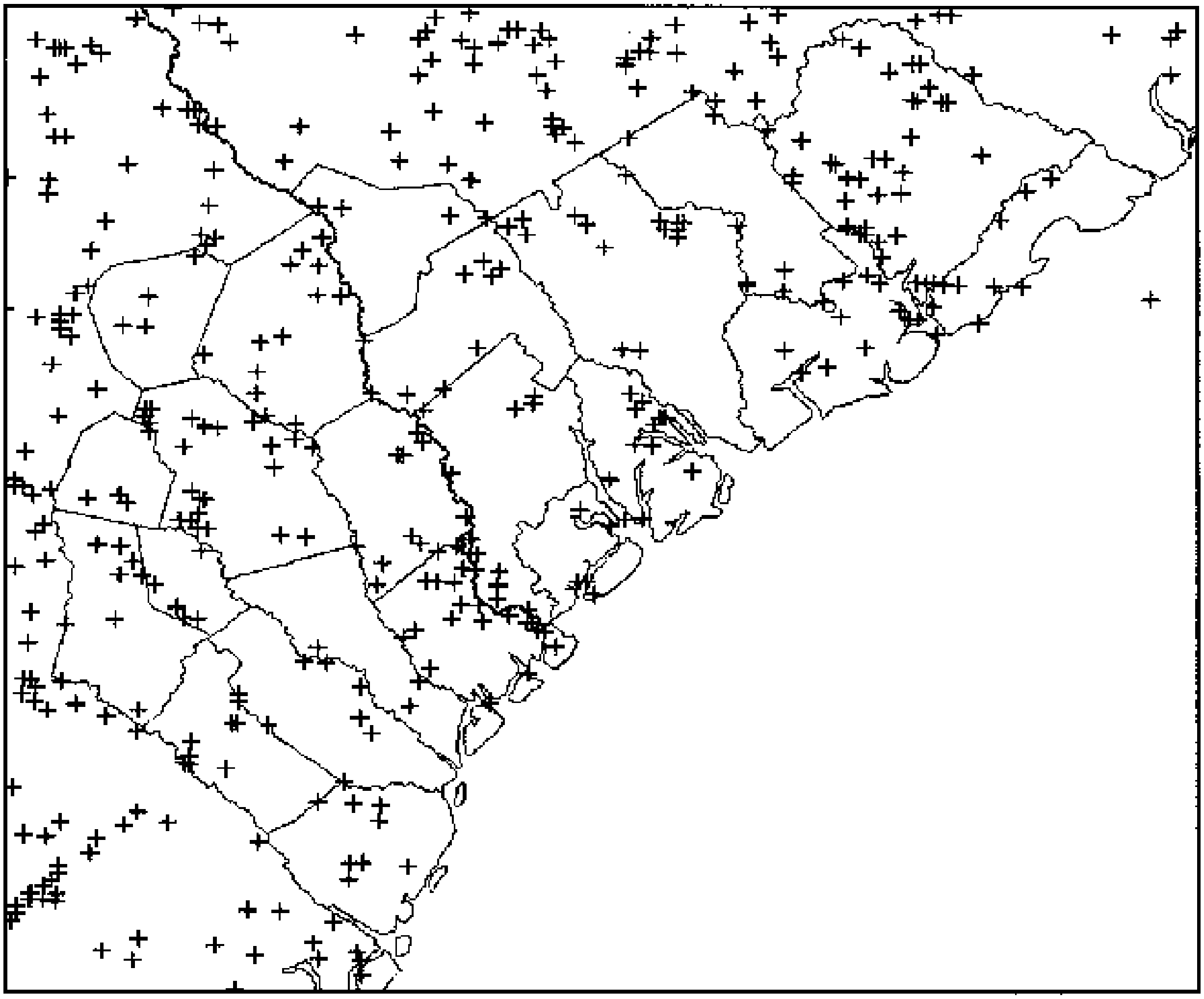


Figure 3. Plot of approximate location of reported severe convective wind events within the Charleston, SC CWA from 1955 through 1993, excluding 1972. Plus (+) symbols indicate the approximate location of reports.

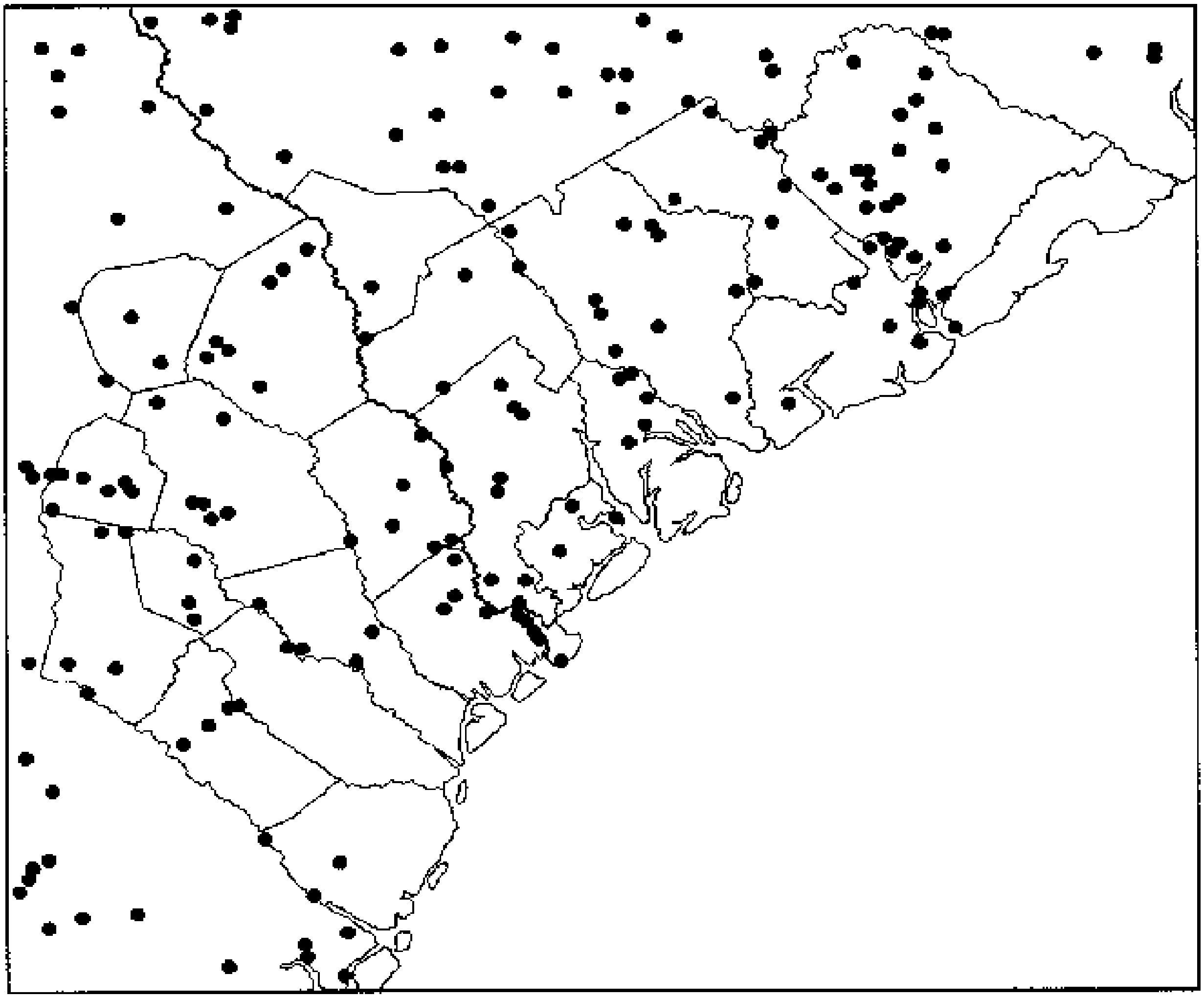


Figure 4. Plot of approximate location of reported severe hail reports within the Charleston, SC CWA from 1955 through 1993, excluding 1972. Solid circles indicate the approximate location of reports.

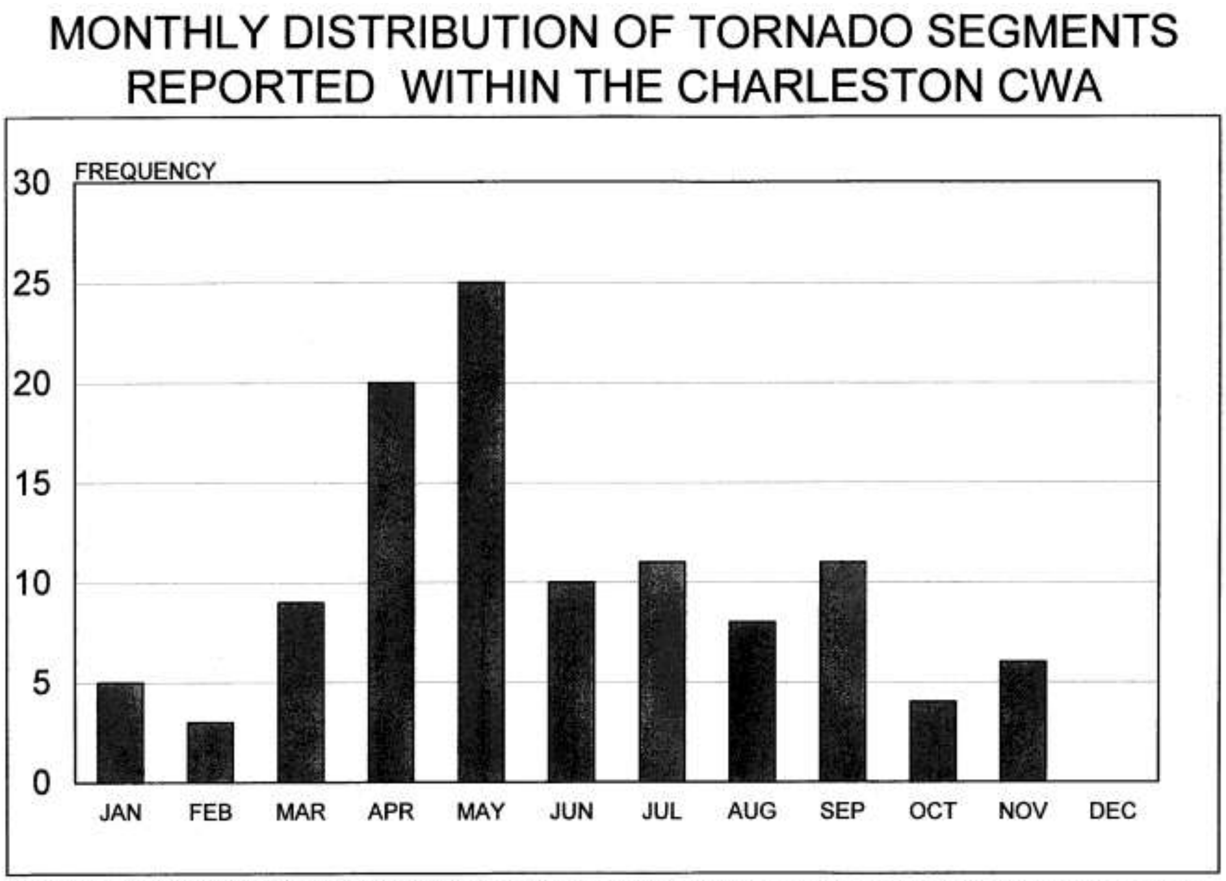
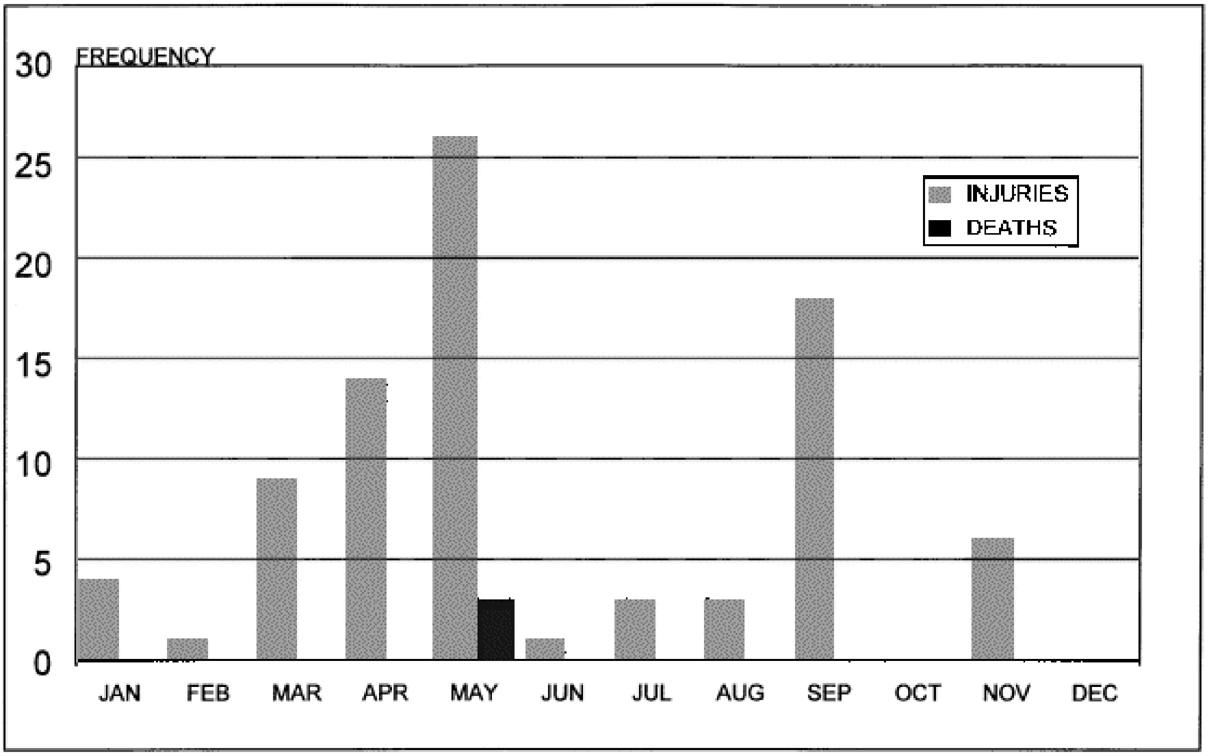


Figure 5. Monthly distribution of all tornado segments reported within the Charleston, SC, CWA during the time period 1950 through 1993. Total tornado segments equal 112.



TOTAL DEATHS AND INJURIES CAUSED BY TORNADOES WITHIN THE CHARLESTON CWA

Figure 6. Total deaths and injuries caused by tornadoes within the Charleston, SC, CWA during the time period 1950 through 1993. The lighter shading represents total injuries reported (85). The darker shading represents total deaths reported (3).

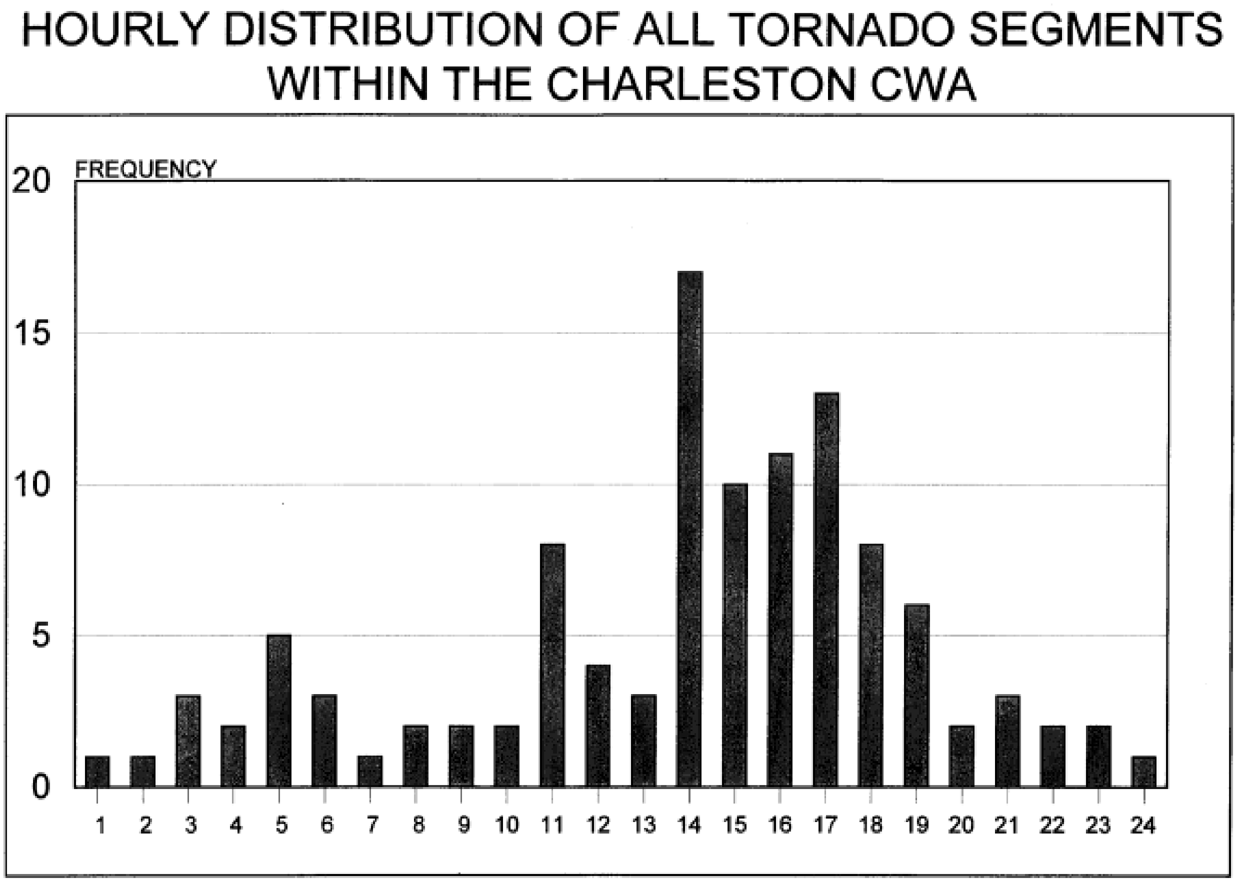


Figure 7. Hourly distribution of all tornado segments reported within the Charleston, SC, CWA during the time period 1950 through 1993. Hours labelled on the x-axis are in Eastern Standard Time.

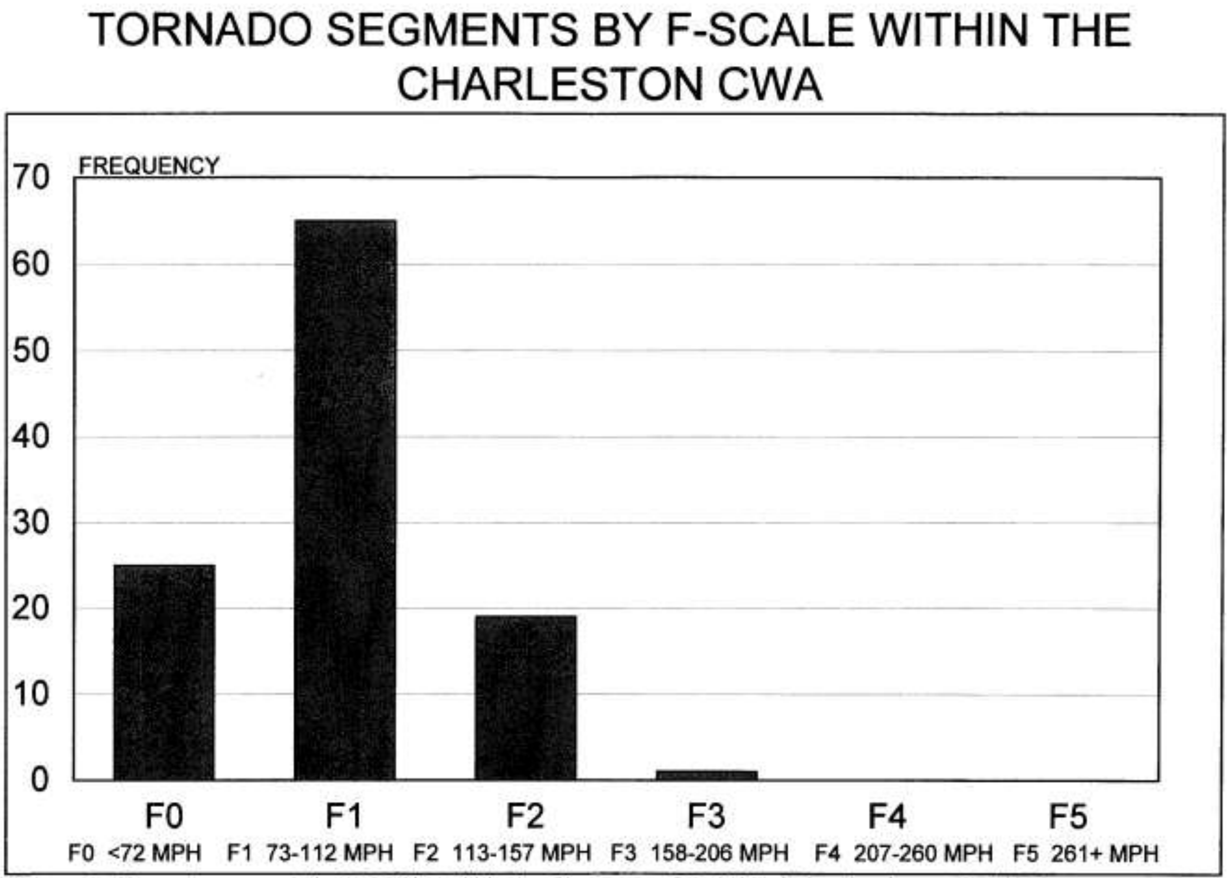


Figure 8. Tornado segments by F-SCALE within the Charleston, SC, CWA during the time period 1950 through 1993.

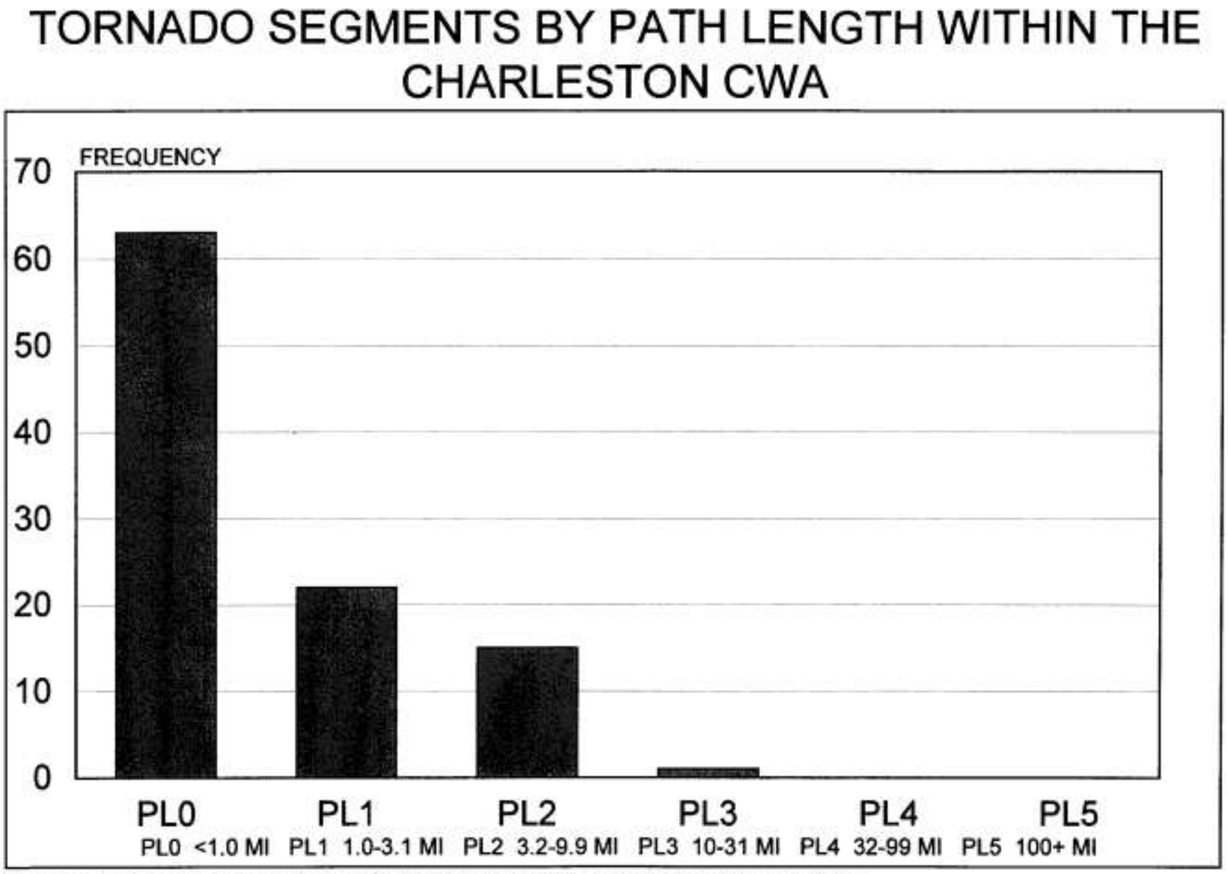


Figure 9. Tornado segments by path length (miles) within the Charleston, SC, CWA.

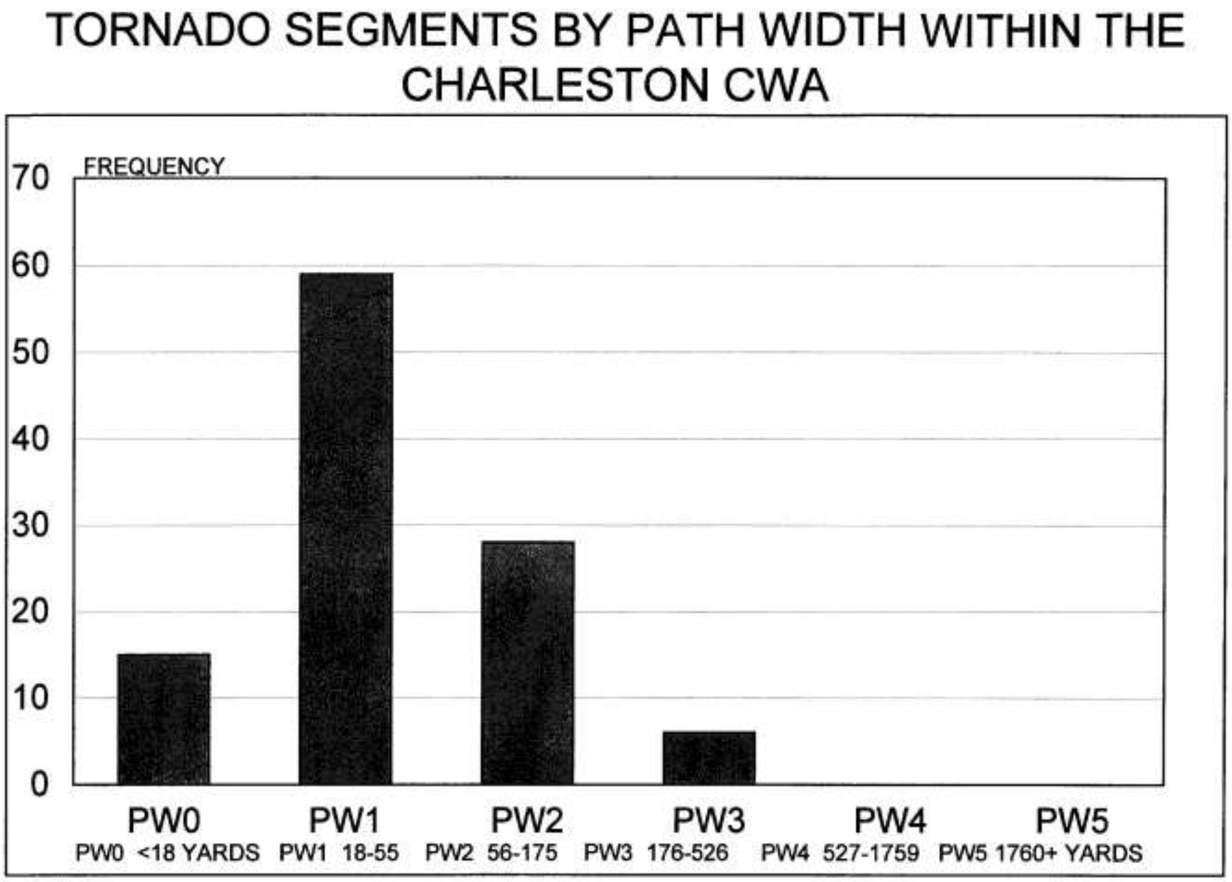


Figure 10. Tornado segments by path width (yards) within the Charleston, SC, CWA.

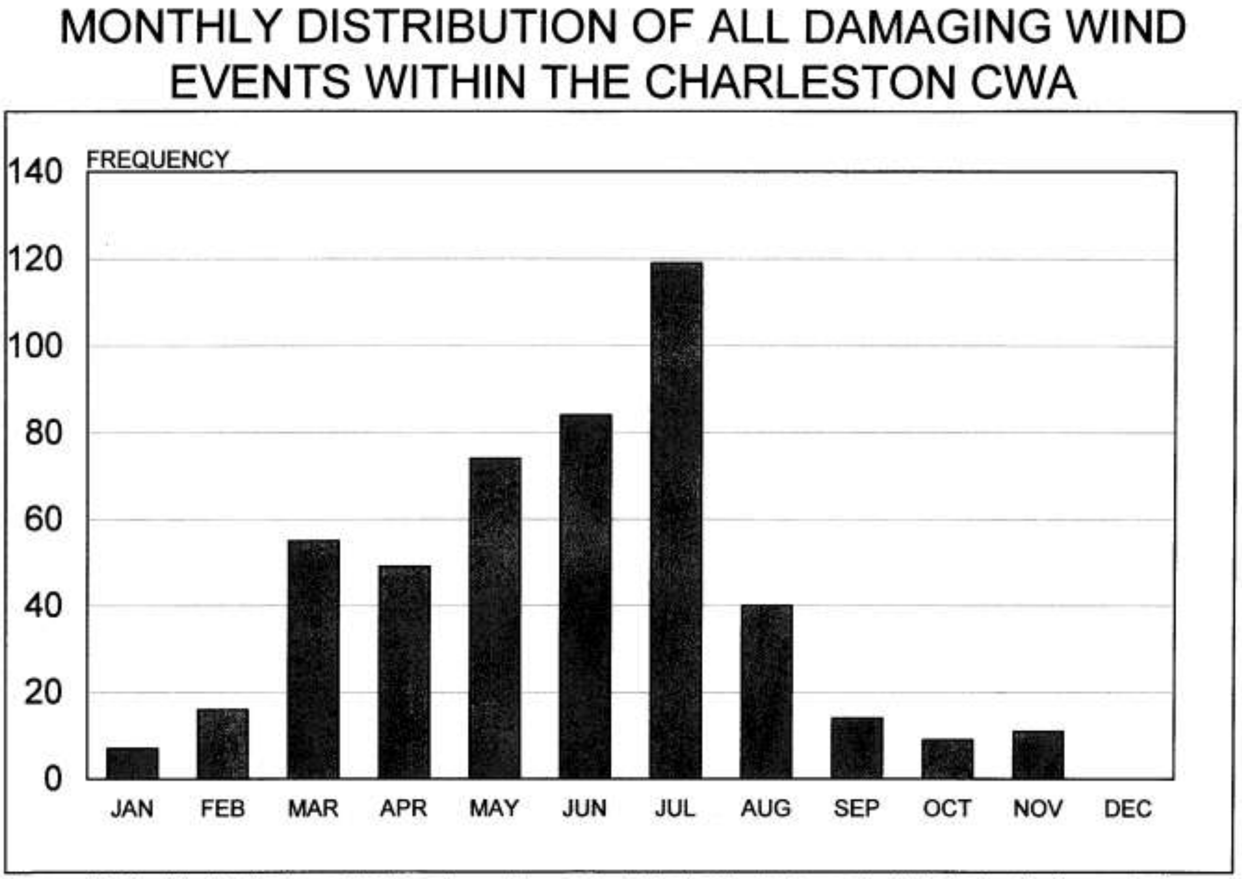


Figure 11. Monthly distribution of all damaging wind events within the Charleston, SC, CWA during the time period 1955 through 1993, excluding 1972. The total number of wind events equal 478.

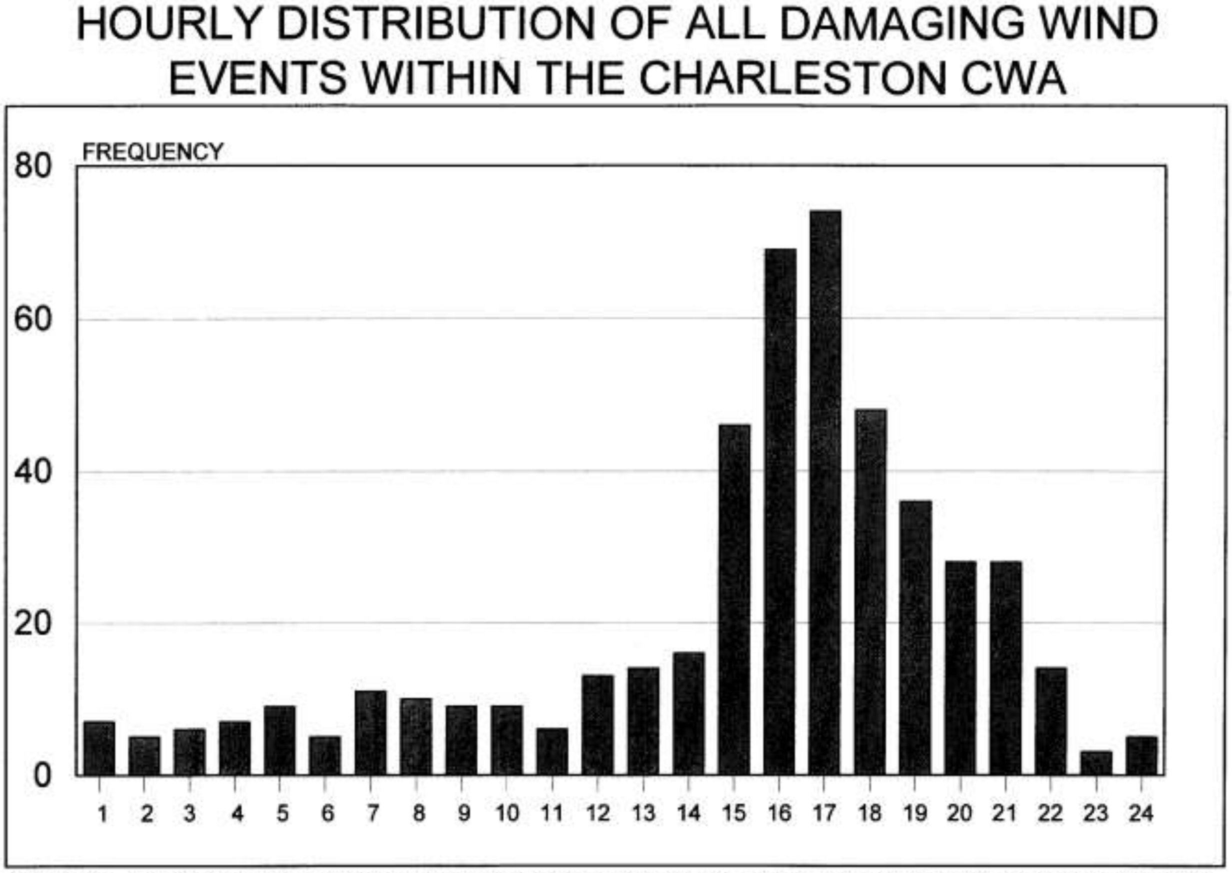


Figure 12. Hourly distribution of all damaging wind events within the Charleston, SC, CWA during the time period 1955 through 1993, excluding 1972. Hours labelled on the x-axis are in Eastern Standard Time.

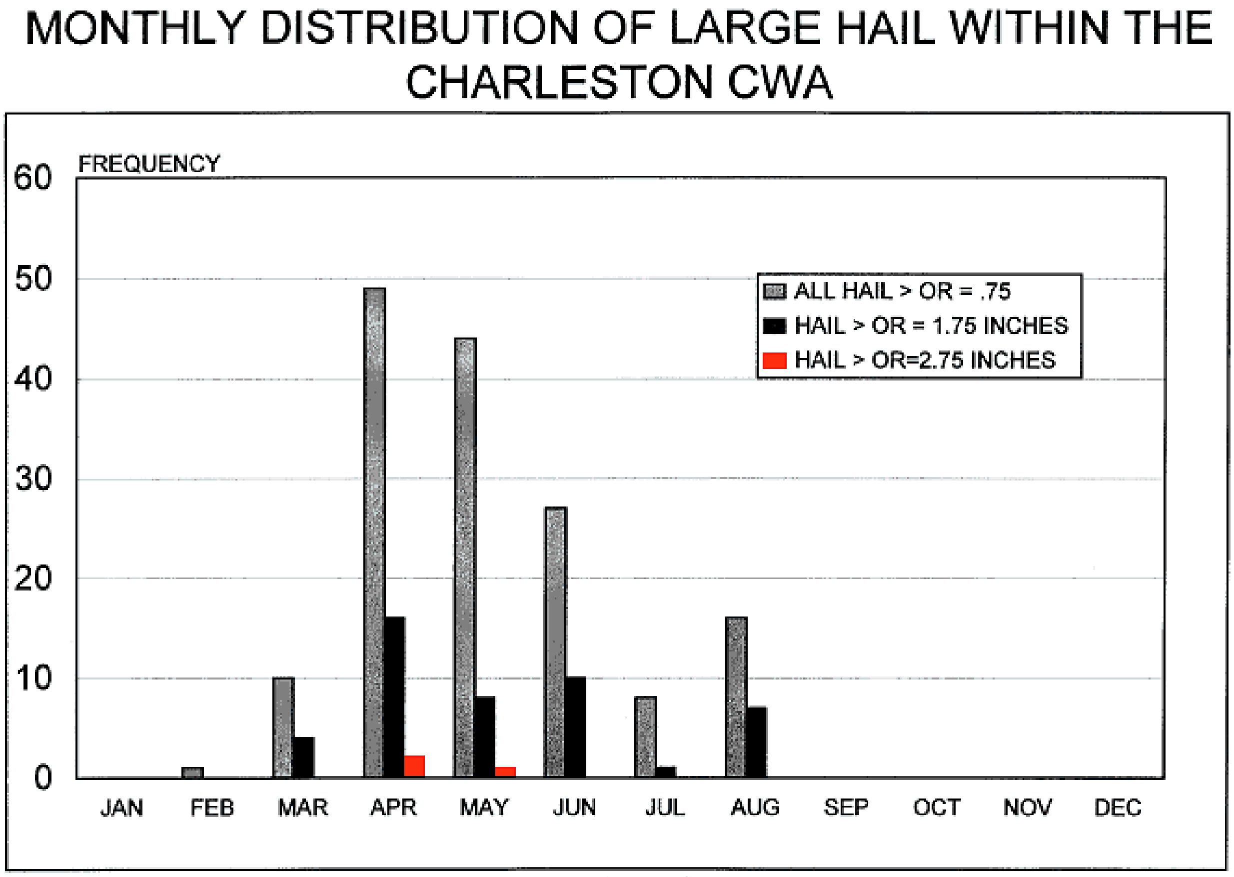


Figure 13. Monthly distribution of all large hail reported within the Charleston, SC, CWA during the time period 1955 through 1993, excluding 1972. The light shading represents all hail greater than or equal to 0.75 inches in diameter. The medium shading represents hail greater than or equal to 1.75 inches in diameter. The dark shading represents hail greater than or equal to 2.75 inches in diameter. Total hail reports equal 155.

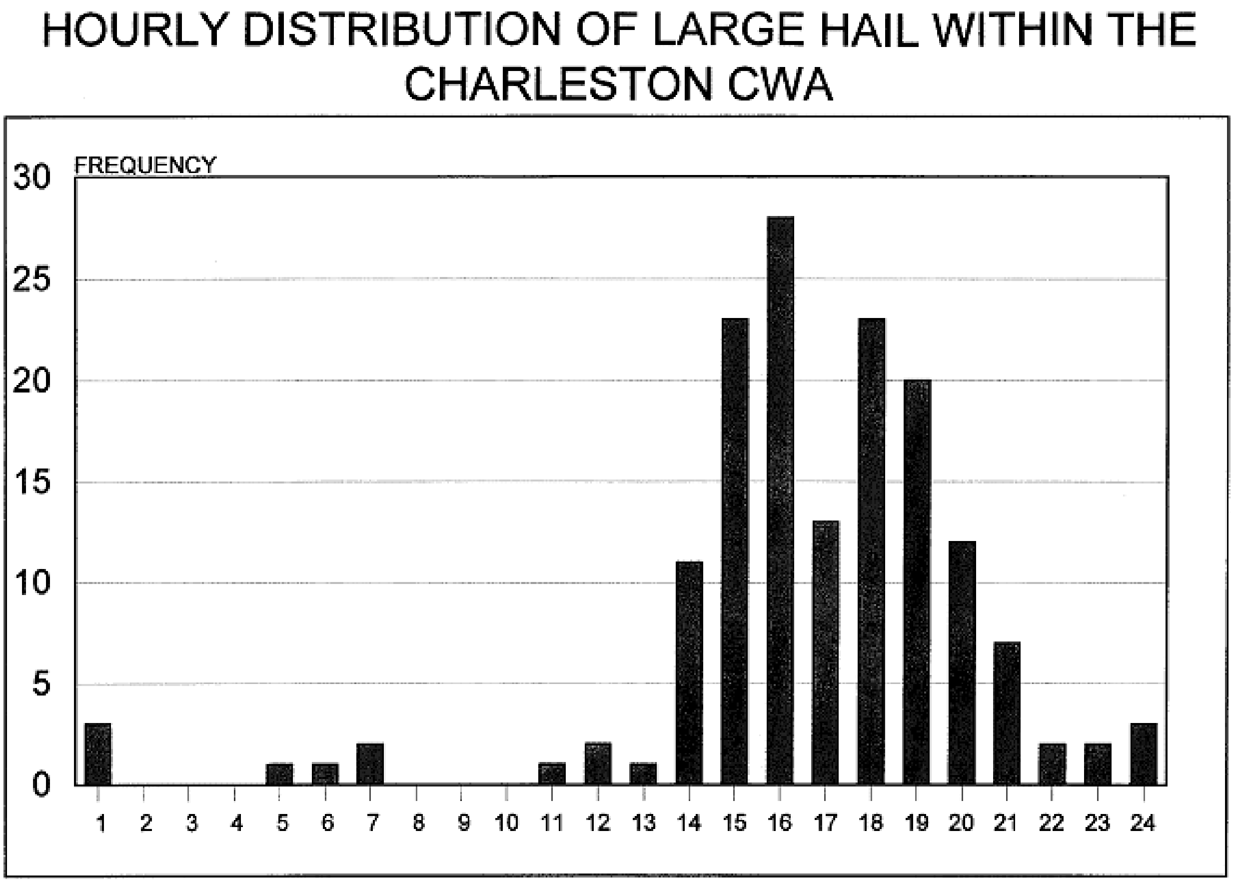


Figure 14. Hourly distribution of all large hail greater than or equal to 0.75 inches in diameter reported within the Charleston, SC, CWA during the time period 1955 through 1993, excluding 1972. Hours labelled on the x-axis are in Eastern Standard Time.

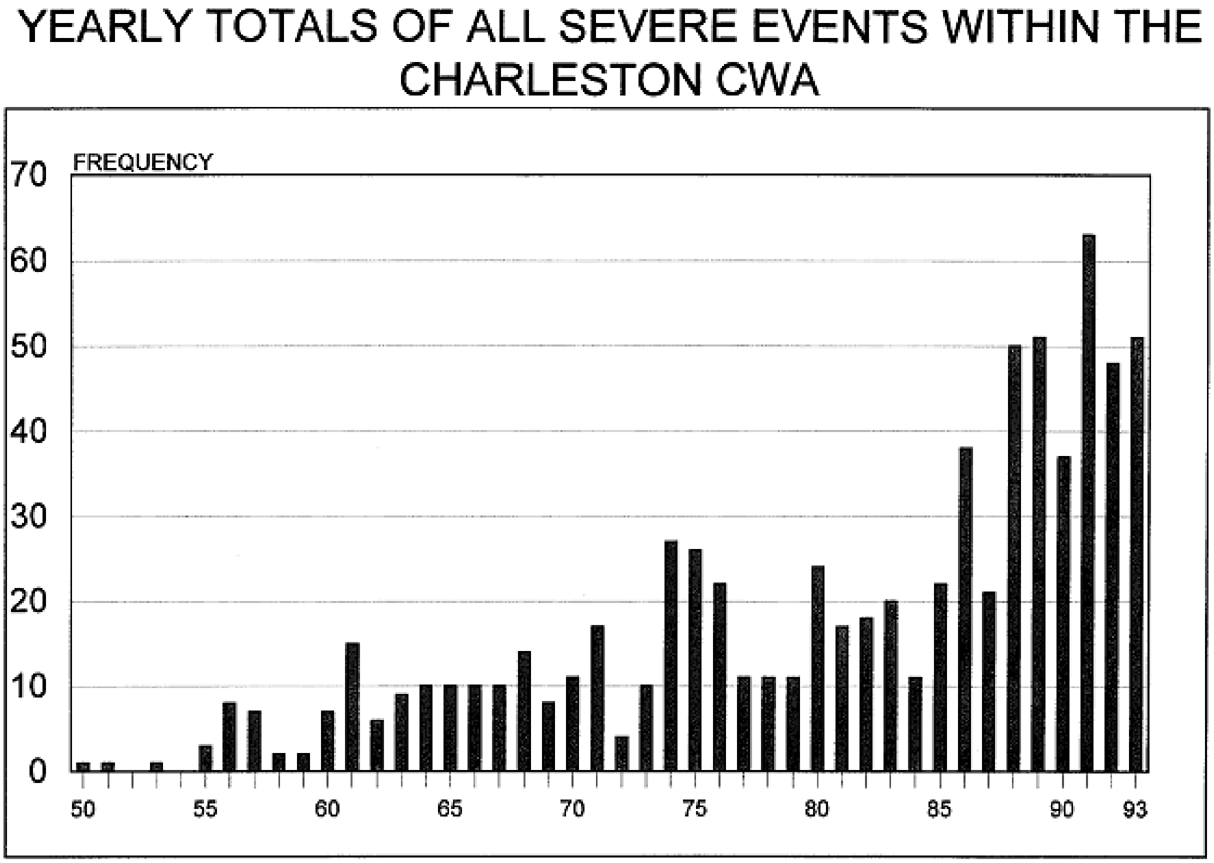


Figure 15. Yearly totals of all severe events reported within the Charleston, SC, CWA. X-axis is labelled in years from 1950 to 1993.

YEARLY TOTALS OF TORNADOES, DAMAGING WIND AND LARGE HAIL REPORTED WITHIN THE CHARLESTON CWA

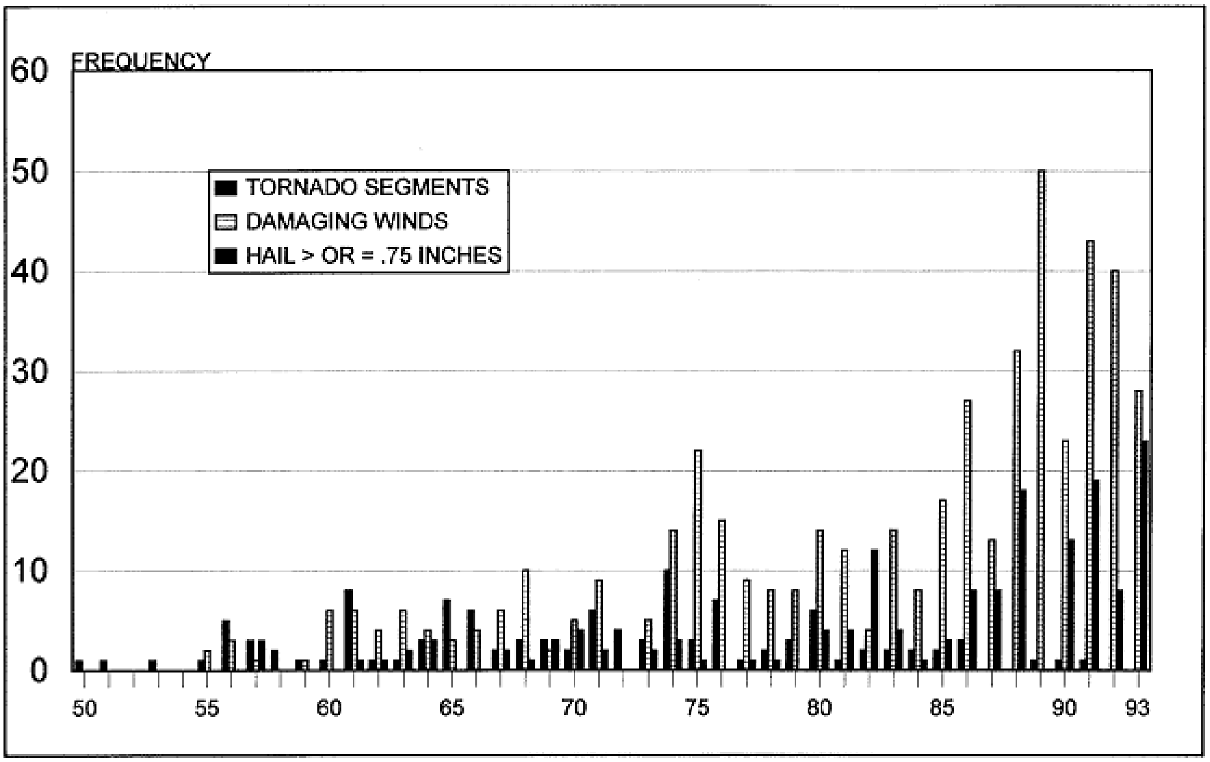


Figure 16. Yearly totals of all severe weather events reported within the Charleston, SC, CWA. The total number of severe weather events equal 745. The dark shading represents all tornado segments reported (112). The hatched shading represents all damaging wind events reported (478). The medium shading represents all hail greater than or equal to 0.75 inches in diameter reported (155).