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A SEVERE WEATHER CLIMATOLOGY FOR THE WILMINGTON, OH WFO COUNTY WARNING AREA (1950-2004)

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National Weather Service

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1. INTRODUCTION

The National Weather Service Forecast Office (WFO) in Wilmington, Ohio, has forecast and warning responsibilities for 52 counties across southwest Ohio, north-central Kentucky, and southeast Indiana (Fig. 1). Severe convective storms can occur at any time of the year in this area, although they are most frequent during the spring and summer.

The motivation for producing a severe weather climatology for the Wilmington, Ohio, county warning area (CWA) is to provide forecasters with a historical baseline of the likelihood and type of severe weather on annual, seasonal, monthly and hourly scales. A severe weather climatology can supply forecasters with an extensive background in assessing the frequency and magnitude of different types of severe weather on temporal and spatial scales, and assist in anticipation of local severe weather. The period of the study extends from the early 1950s to 2004.

Section 2 will explain the methodology employed in producing the data for this study. Section 3 will introduce the demographics and topography of the Wilmington CWA. Section 4 will present an analysis of the tornado, severe convective wind and hail events across the Wilmington CWA over the period of study, and provide a climatological basis for observed trends in severe weather across the Wilmington CWA. Section 5 will offer a summary of the findings. It is hoped that this study may contribute to additional climate-related research on severe convective storms affecting the Wilmington CWA.

2. DATA AND METHODOLOGY

Data used in this research were collected using the National Weather Service's Storm Prediction Center (SPC) Svrplot v2.0 program (Hart 2004), which lists all severe convective wind and severe hail events from 1955 to 2004, as well as all tornado events from 1950 to 2004. All severe weather events can be categorized by event type, intensity, occurrence time, and with tornadoes, according to F-scale, path length and width. Event times are referenced to Eastern Standard Time (EST).

The Fujita Scale is used to classify tornadoes into five categories based on the amount of damage that is produced (Fujita 1981). Estimated wind speeds are then provided for each category, with F0 being the weakest and F5 the strongest (Table 1). The total number of tornadoes included in this database is less than the number of tornado segments identified in this study. Many tornadoes track through more than one county. To accurately account for the number of tornado occurrences in a given county, these multi-county tornadoes are broken up into tornado segments. For example, a tornado that tracks uninterrupted through three counties would be identified as three separate events (three segments). Beginning in 1994, tornado occurrences were recorded according to this method. Thus, according to McCarthy and Schaefer (2004), this change in procedure has led to an increase in the number of tornado segments recorded since 1994.

A severe convective wind event, according to the National Weather Service, is defined by winds of 50 kts (58 mph) or greater, or winds causing damage to structures. Likewise, a severe hail event, also defined by the National Weather Service, requires hail size to reach a minimum diameter of 0.75 inches.

3. COUNTY WARNING AREA DEMOGRAPHICS AND TOPOGRAPHY

3.1 Demographics

The Wilmington, Ohio, CWA covers over 20,000 square miles (Fig. 2), with a total population for the area estimated at nearly 5.5 million people as of 2000 (Fig. 3). There are two major metropolitan areas that account for nearly 80% of the total population. The largest population center is the Tri-State metropolis across southwest Ohio, northern Kentucky and southeast Indiana, with a population base of around 3 million people. The Tri-State metropolis consists of the cities of Cincinnati, Hamilton, and Covington and extends northward to encompass Dayton, Xenia, and Springfield. The greater Columbus metropolitan area, which includes the cities of Newark, Lancaster, and Delaware, has a population base of nearly 1.5 million people (U.S. Census Bureau 2000).

The remainder of the forecast area is largely rural and sparsely populated. This contributes to an average population density across the CWA of 256 people per square mile (Fig. 4), lower than the population densities in the metropolitan areas. Some skewing of observed severe weather towards the higher population centers is likely given the uneven population distribution of people across the CWA.

3.2 Topography

The topography of the Wilmington, Ohio CWA varies, ranging from plains across west-central Ohio and eastern Indiana to gently rolling to hilly terrain over southern Ohio and northern Kentucky. The Till Plains of western Ohio mark the eastern extent of the Midwestern Corn Belt, and are found across the northwest portion of the CWA. Terrain becomes gently rolling and dotted by hills further to the south, as the Great Miami, Little Miami and Scioto rivers carve valleys oriented north-south through the CWA. More rugged terrain is found across southern Ohio and northern Kentucky, in closer proximity to the Ohio River and on the western fringes of the Appalachian plateau. Elevations throughout the CWA range from 500 to 1000 feet above ground level (AGL), as shown in Fig. 5.

4. SEVERE WEATHER CLIMATOLOGY

A total number of 6,131 severe weather events occurred across the Wilmington, Ohio, CWA during the period 1950-2004. Of this total, 4,175 severe convective wind events were reported, or nearly 68% of the total number of events (Fig. 6). A total of 1,470 severe hail events (Fig. 7) and 405 tornadoes (Fig. 8) were reported. As a whole, observed events tended to be more concentrated in the metropolitan areas surrounding Cincinnati, Columbus and Dayton. Fewer events, however, were reported across more rural areas of the Wilmington CWA, in particular across southeast Indiana and portions of northern Kentucky and south-central Ohio.

4.1 Tornado Climatology

Between 1950 and 2004, 405 tornadoes, or 486 tornado segments (see Section 2) occurred across the Wilmington, Ohio, CWA. An annual distribution of tornadoes (Fig. 9) shows that despite a gradual increase in the number of reported tornadoes since the 1950s and 1960s, the number of tornadoes remains highly variable from year to year. This is due at least in part to the yearly variability of weather patterns that affect the Ohio Valley. The Palm Sunday outbreak in April 1965 and the Superoutbreak in April 1974 were two of the most significant tornado outbreaks to occur in recorded history across the Midwest and Ohio Valley. These tornado outbreaks were noteworthy in terms of the number of violent tornadoes (F4-F5) within each outbreak. 1992 was the most active year for tornadoes with 24. The number of tornadoes producing F2 damage and greater has largely remained unchanged since 1950. There has, however, been a noted increase in the yearly proportion of the total number of tornadoes to the number of significant tornadoes. This has likely been influenced by an overall increase in public severe weather awareness and the development and expansion of the trained spotter and amateur radio networks (McCarthy and Schaefer 2004).

Tornadoes were most commonly reported across the Wilmington, Ohio CWA between April and July (Fig. 10), making up approximately 73% of all tornadoes in this study. Many of the tornadoes that occurred during this same period (April-July) demonstrated the tendency to produce F2 damage or greater (Fig. 11). A minor secondary peak is noted in November, with half of these being F2 and greater. Tornadoes most frequently occurred between the mid-afternoon and evening hours (Fig. 12). Just over 50% of all tornadoes occurred between 3-7 PM EST, with the least amount of activity occurring between midnight and 10 AM EST.

While 80% of all tornado-related fatalities across the Wilmington CWA occurred during the late afternoon and evening hours, only 5% of the total number of fatalities took place between midnight and 1 PM (Fig. 13). Likewise, nearly 75% of all tornado-related injuries occurred during the late afternoon and evening, with 45% of these injuries occurring between 3-4 PM (Fig. 14). The anomalous spike during this time is clearly biased by the 3 April 1974 Xenia, Ohio, tornado, which accounted for 1,150 injuries alone.

Approximately 70% of all tornadoes examined across the Wilmington CWA between 1950 and 2004 were classified as "weak" tornadoes (F0-F1) with winds of 60-115 mph (Fig. 15). While close to half of all tornadoes were classified as F1, nearly 30% were categorized as significant tornadoes (F2-F5). The percentage of tornadoes then decreases by nearly a factor of three for each successive category. Violent tornadoes (F4-F5), while having made up only 4% of all tornadoes, accounted for approximately 82% of all tornado-related fatalities (Fig. 16) and 76% of all tornado-related injuries (Fig. 17). The 1974 Xenia, Ohio tornado, however, contributed significantly to the higher percentage of fatalities and injuries in the violent tornadoes category. This tornado, which was a part of the Superoutbreak, overwhelmingly produced the highest number of fatalities (36) and injuries (1150) of any tornado during the 1950-2004 period.

The tracks of all tornadoes producing F2 damage and greater across the Wilmington CWA can be seen in Fig. 18. The map hints at a favored track pattern that extends from southern Indiana northeast through the Cincinnati area, then on into the Columbus area. A weaker signal can be seen across the far northern portion of the CWA, where tornadoes appear to track in a more west to east direction. This supports the findings of Broyles and Crosbie (2004), who provided evidence indicating that both of these favored tracks are actually portions of two smaller tornado alleys for long track tornadoes that produced F3 damage and greater over a 124-year period. They identified an area of increased long- track significant tornadoes extending from southern Missouri northeast into southwest Ohio, with a second area extending from central Illinois east-northeast into northwest Ohio.

To better assess path lengths and widths, tornadoes were grouped into three F-scale related categories (F0-F1, F2-F3, and F4-F5) and average path lengths and widths were calculated for each group. Figure 19 indicates that the path length increases by nearly a factor of four for each category, with violent tornadoes rated as F4 and F5 averaging just over 32 miles in length. Figure 20 shows a similar increase, but for path width, expanding by nearly a factor of three for each successive category.

4.2 Convective Wind Climatology

The annual distribution of severe convective wind events shows a dramatic increase in observed events over the period of study (Fig. 21). This corresponds to the national trend which has shown more than a 400% increase in the number of annual severe convective wind reports between 1970-2000 (Weiss et al. 1999). As with tornado reports, the development of the trained spotter and amateur radio networks have certainly contributed to this. Note that wind data are missing from 1972. This coincides with a change in procedure in the collection of wind data in the NOAA publication *Storm Data*. Prior to 1972, convective wind and hail data were collected by the U.S. Air Force (Schaefer and Edwards 1999). An increase in reports occurred in the 1980s, corresponding to the implementation of a national warning verification program within the National Weather Service.

An additional rise in annual reports in the early 1990s coincides with the deployment of the WSR-88D NEXRAD Radar network (Weiss et al. 1999).

Severe convective wind events have occurred in each month of the year across the Wilmington CWA. The number of events per month increase through the spring, and peak during June and July (Fig. 22). This peak in convective wind events corresponds with the annual peak in severe weather events during the early summer. The frequency of convective wind reports decrease during the late summer, with a secondary maximum observed in events noted in November. Damaging wind events are most frequent during the late afternoon and evening hours, with 67% of the total number of events occurring between 2-9 PM, and 52% between 3-7 PM (Fig. 23). This coincides with the time period when surface heating and atmospheric instability values are normally greatest. The frequency of severe convective wind events decreased during the late evening and overnight hours, with the minimum occurring between 4-10 AM.

4.3 Hail Climatology

The annual distribution of severe hail events shows a noted increase beginning in the early 1990s (Fig. 24). This distribution is similar to that previously noted for the severe convective wind events between 1955 and 2004 (Fig. 21), and corresponds to the overall increase in reports nationally since 1955. This too is likely influenced heavily by the increase in trained spotter and amateur radio networks (Schaefer et al. 2004). Fluctuations in synoptic patterns, particularly those supporting severe convection, will have an obvious influence on the total number of severe weather reports. This may be part of the reason behind both the 1997 and 1999 datasets indicating a significantly lower number of severe hail events when compared to the average annual number of hail events during the period 1994-2004.

For the period 1955-2004, severe hail was recorded in every month but December (Fig. 25). The frequency of severe hail events is greatest from April through June. As with the monthly tornado and severe convective wind distributions, a small secondary maximum is noted in November. Severe hail events are most frequent during the afternoon and early evening hours, with 65% of the total number of events occurring between 2-8 PM (Fig. 26). A minimum number of severe hail events occurred during the overnight and early morning hours, with only about 7% of the total number of events taking place between the hours of 1-11 AM.

Hail of 1.00 inch in diameter or smaller accounted for nearly 73% of the total number of severe hail events, with penny-size hail (0.75 inches in diameter) being the most widely reported hail size. Two and one-half (2.5) inch diameter hail and larger were rare in the CWA, making up only about 3% of the total number of severe hail reports (Fig. 27).

5. SUMMARY

Over 6,000 severe weather events consisting of tornadoes, severe convective wind and hail were compiled during the period 1950-2004 using the Svrplot v2.0 program from the National Weather Service's Storm Prediction Center. Events were categorized by severe weather type on annual, monthly and hourly time scales.

Tornadoes were found to be most frequent during the spring and early summer, primarily between April and July. Significant tornadoes rated as F2 and greater (see Table 1) peaked in April, and were strongly influenced by the large tornado outbreaks that occurred on 11 April 1965 and 3 April 1974. Severe convective wind events were most frequent between April and August, while severe hail events were most common between April and July. All three severe weather types showed a weaker secondary maximum in November. Additional research is needed to help understand this minor secondary peak.

The annual number of severe weather reports has increased dramatically since 1990, with nearly 70% of all of the reports included in this study occurring from that point. Several reasons can be attributed to this increase.

These include:
1) The development of the trained spotter and amateur radio networks beginning in the 1990s;
2) An increase in public severe weather awareness via the NWS, media and other sources;
3) Increases in population throughout the CWA;
4) Improved detection capabilities as a result of the advent and deployment of the WSR-88D Doppler radar network throughout the NWS in the early 1990s.

The information presented in this study identifies historical trends in location and types of severe weather at the Weather Forecast Office (WFO) in Wilmington, Ohio. The data presented within this climatology will provide forecasters with a background for evaluating the frequency and impact of different types of severe weather on temporal and spatial scales, and act as an additional resource for forecasters in anticipation of severe weather within the CWA. Also, it is envisioned that the results documented in this study will spawn subsequent locally focused severe convection climatologies that impact the Wilmington CWA.

ACKNOWLEDGMENTS

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Table 1. The Fujita Damage Scale (Fujita, 1981)

Scale	**Wind Speed (mph)**	**Tornado Character**	**Damage Intensity**
F0	40-72	Weak	Light
F1	73-112	Weak	Moderate
F2	113-157	Strong	Considerable
F3	158-206	Strong	Severe
F4	207-260	Violent	Devastating
F5	261-318	Violent	Incredible

FIGURES

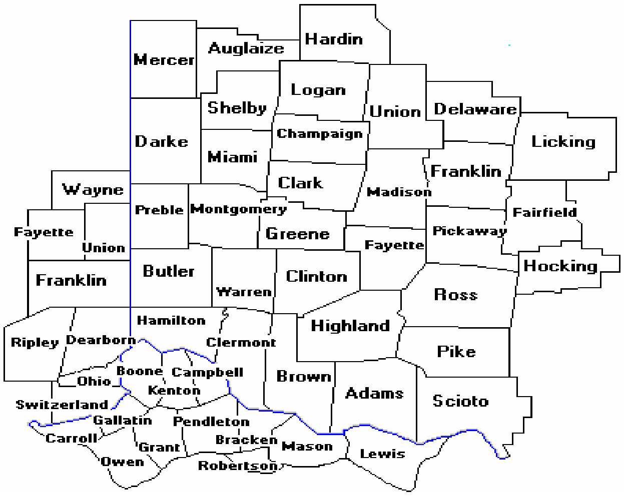

Figure 1. The 52 counties that comprise the Wilmington Ohio County Warning Area (CWA), including southwest Ohio, north-central Kentucky and southeast Indiana. The blue line indicates the state borders.

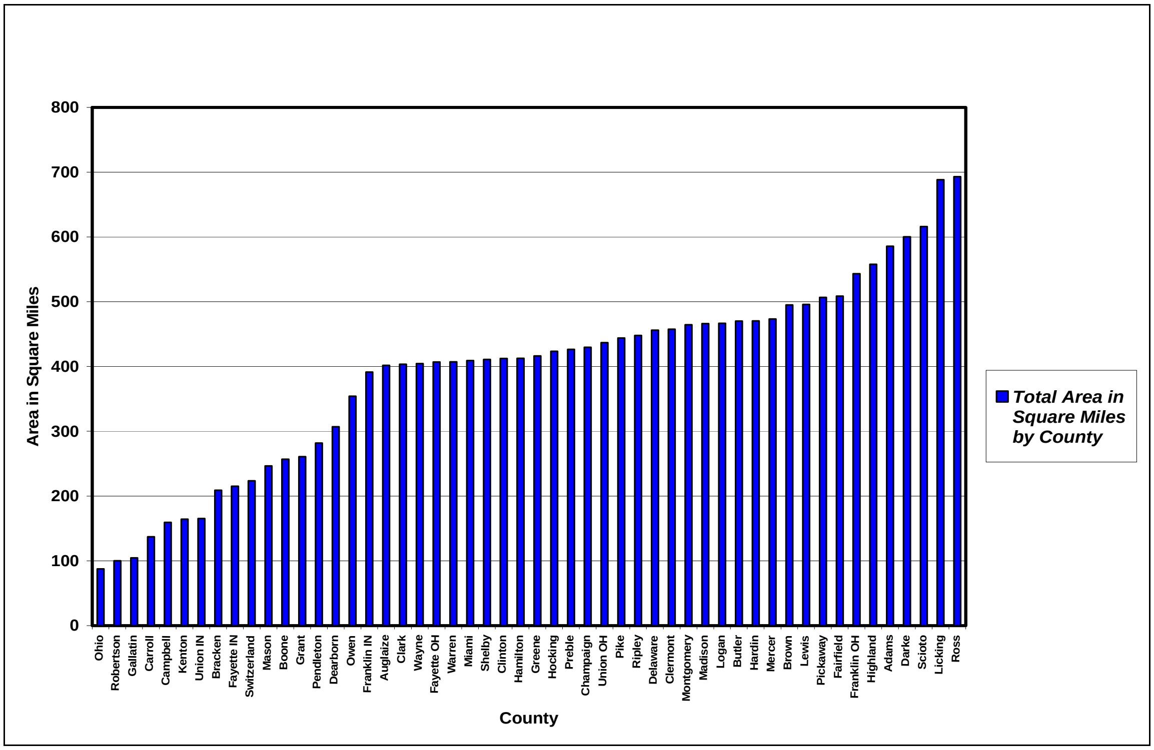

Figure 2. The total area in square miles by county across the Wilmington, Ohio CWA.

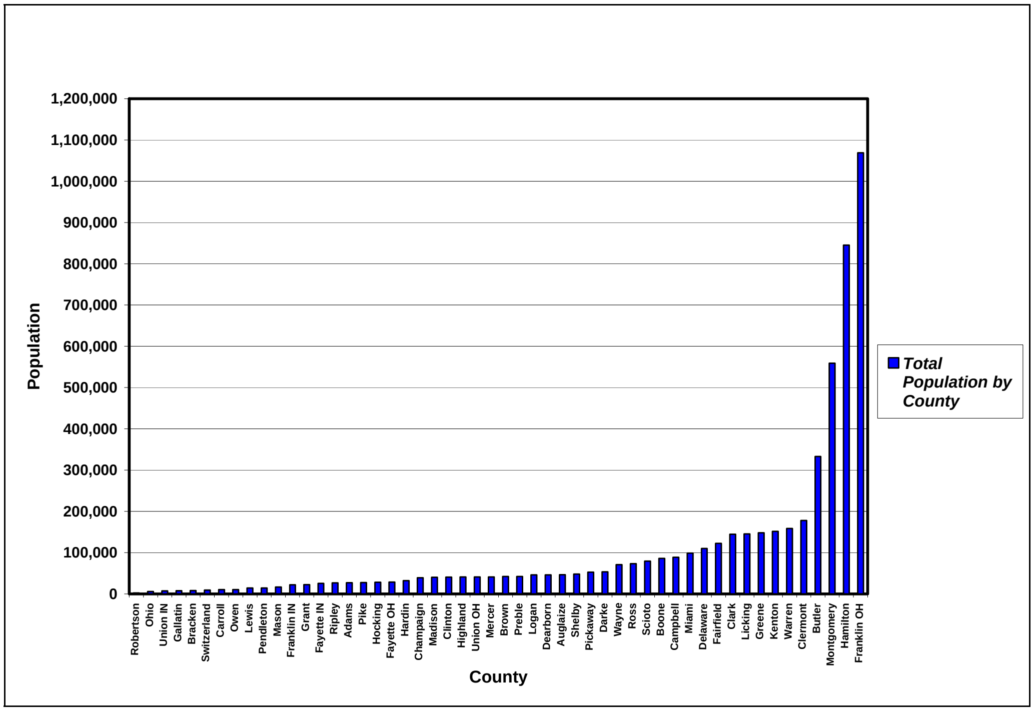

Figure 3. The population by county across the Wilmington, Ohio CWA based on the 2000 U.S. Census Bureau numbers.

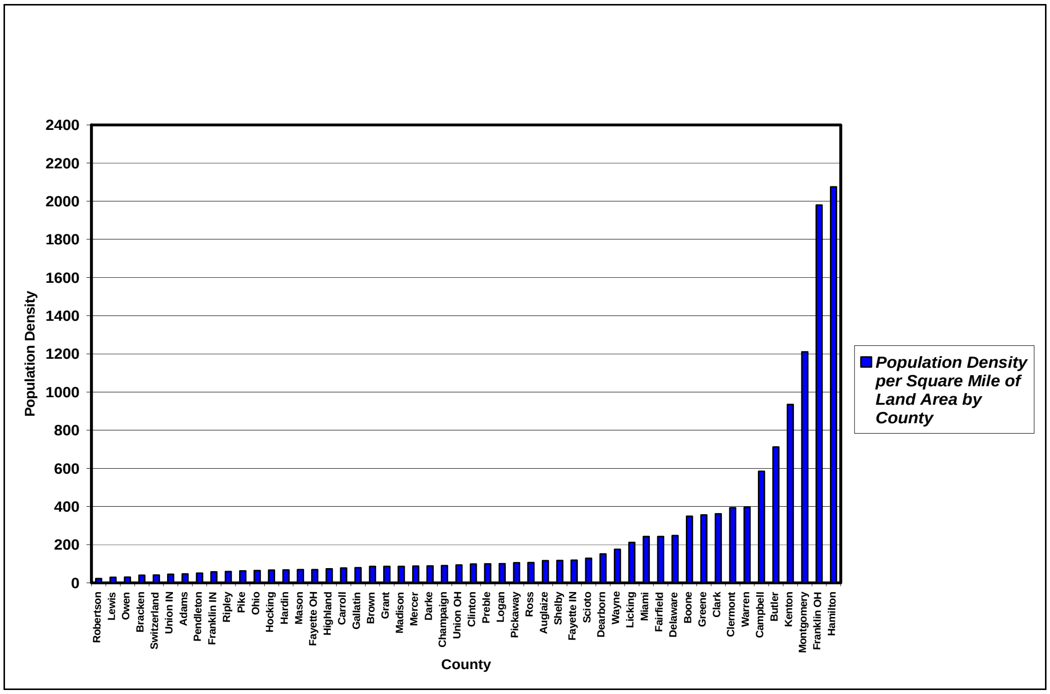

Figure 4. The county population density across the Wilmington, Ohio CWA based on the 2000 U.S. Census Bureau numbers.

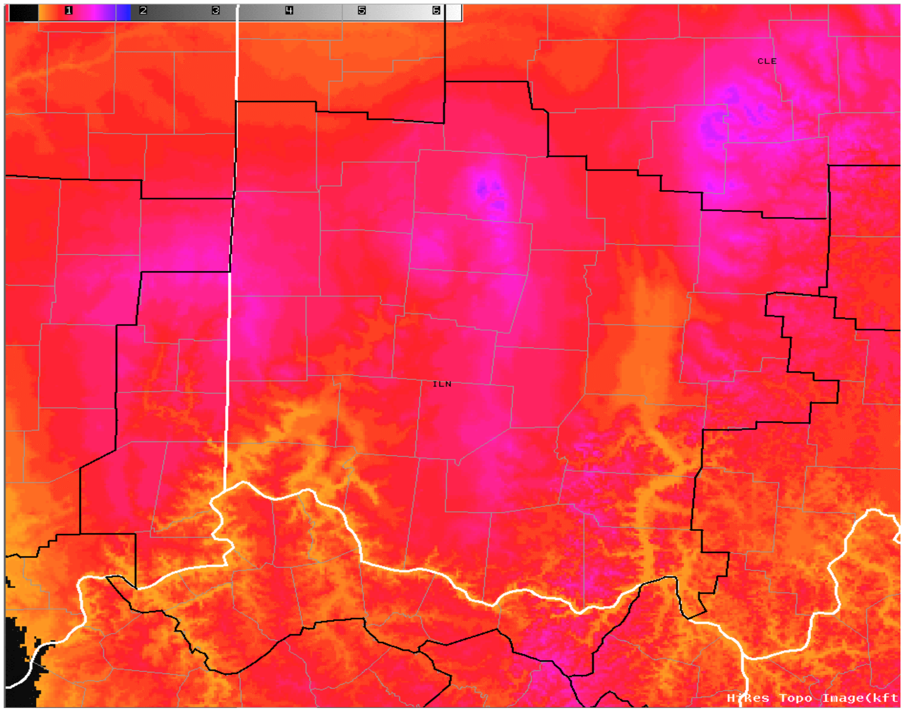

Figure 5. A high-resolution topographic map of the Wilmington, Ohio CWA, taken from the Advanced Weather Information Processing System (AWIPS). Heights range from 500 feet (lighter yellow-orange) to 1500 feet AGL (purple).

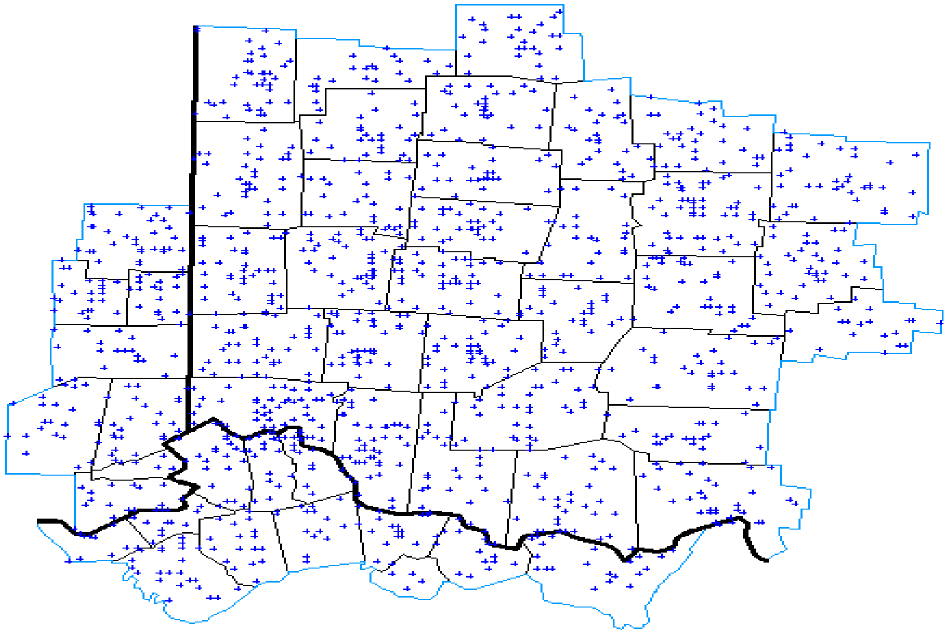

Figure 6. The total number of severe convective wind events across the Wilmington, Ohio, CWA from 1955-2004.

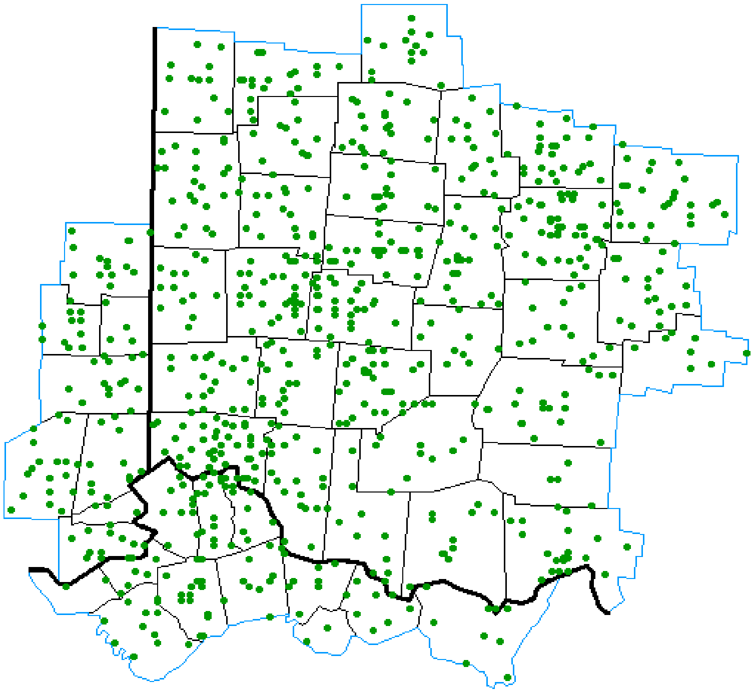

Figure 7. The total number of severe hail events across the Wilmington, Ohio CWA from 1950-2004.

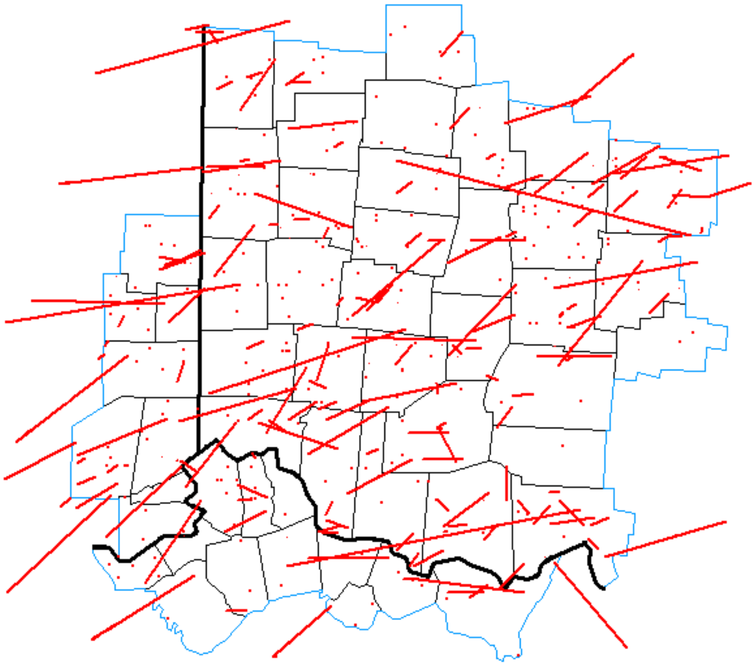

Figure 8. The total number of tornadoes across the Wilmington, Ohio CWA from 1950-2004.

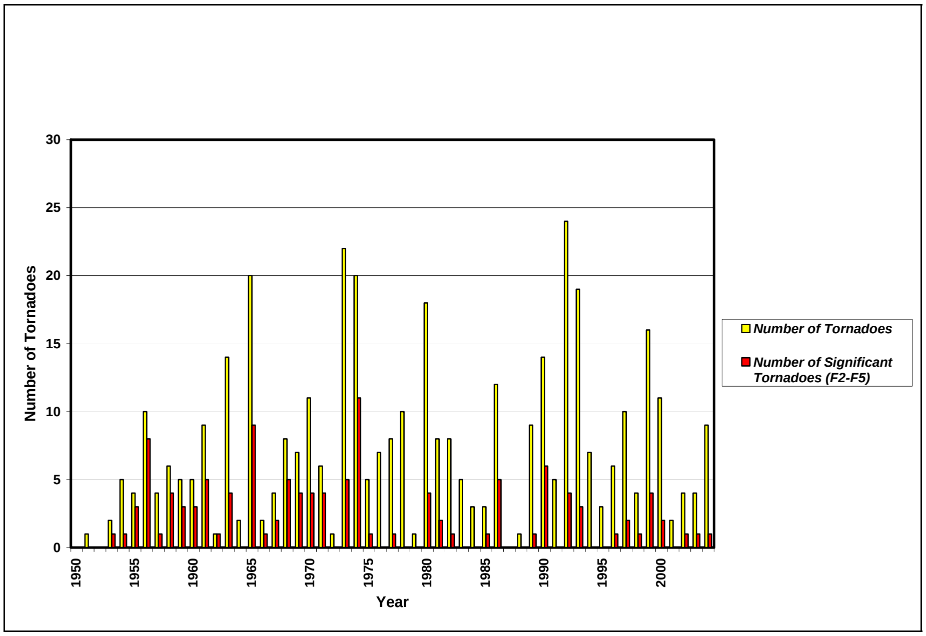

Figure 9. The annual distribution of tornadoes across the Wilmington, Ohio CWA, from 1950-2004.

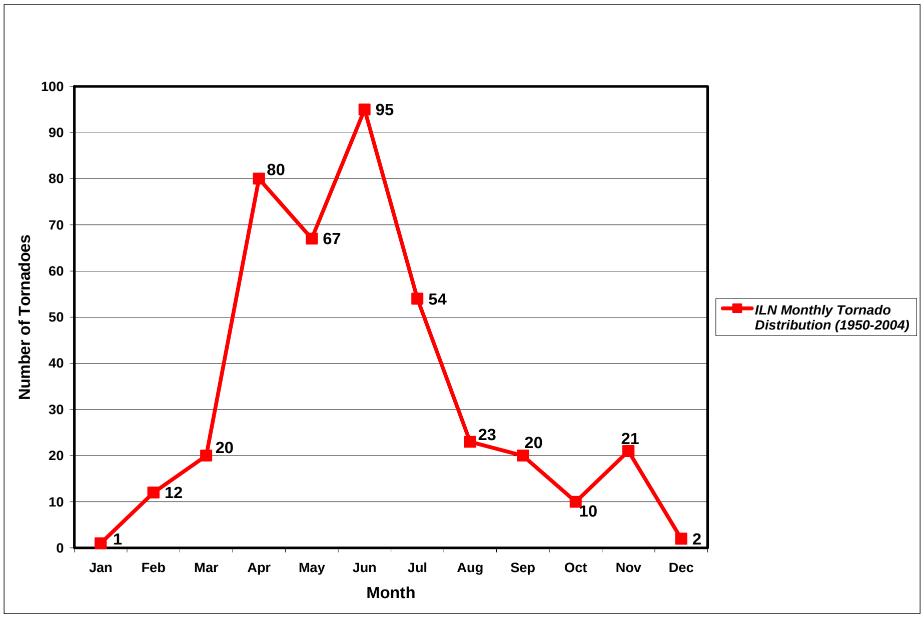

Figure 10. The monthly distribution of tornadoes across the Wilmington, Ohio CWA from 1950-2004.

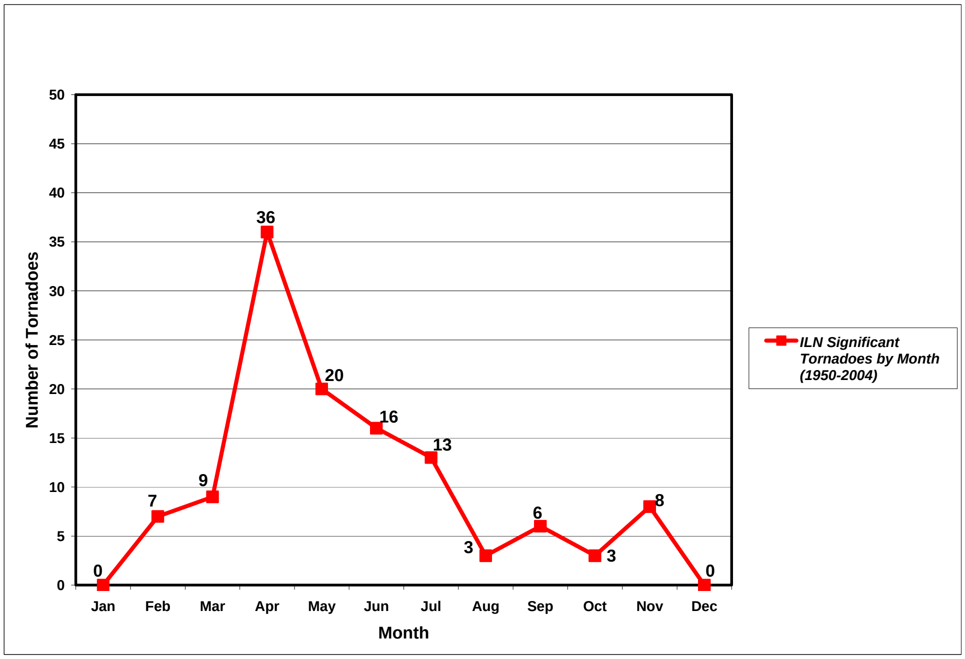

Figure 11. The monthly distribution of significant tornadoes (F2-F5) across the Wilmington, Ohio, CWA from 1950-2004.

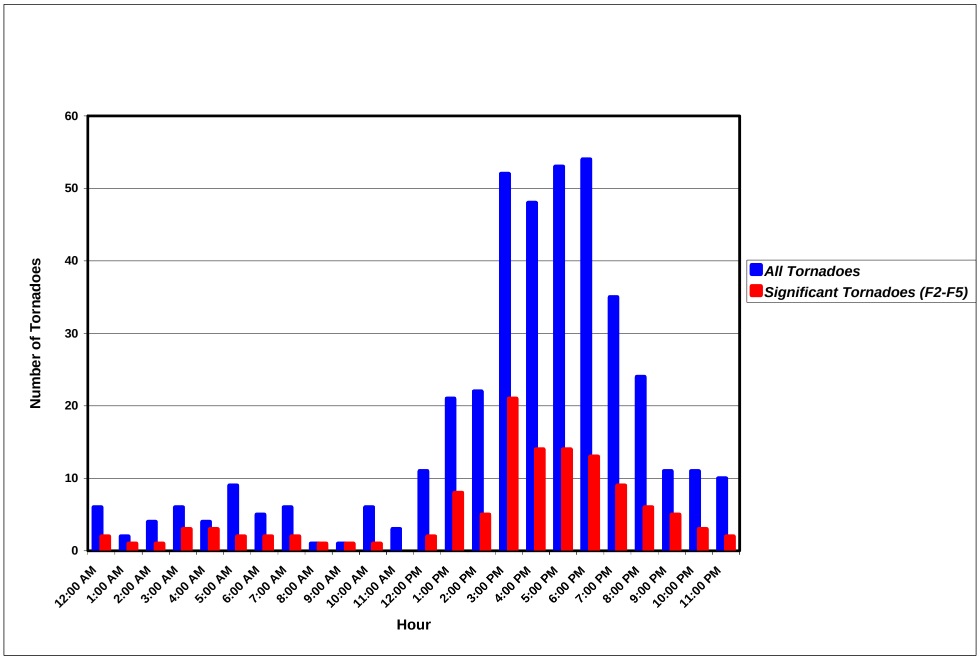

Figure 12. The hourly distribution of tornadoes across the Wilmington, Ohio CWA from 1950-2004. Hours are in Eastern Standard Time.

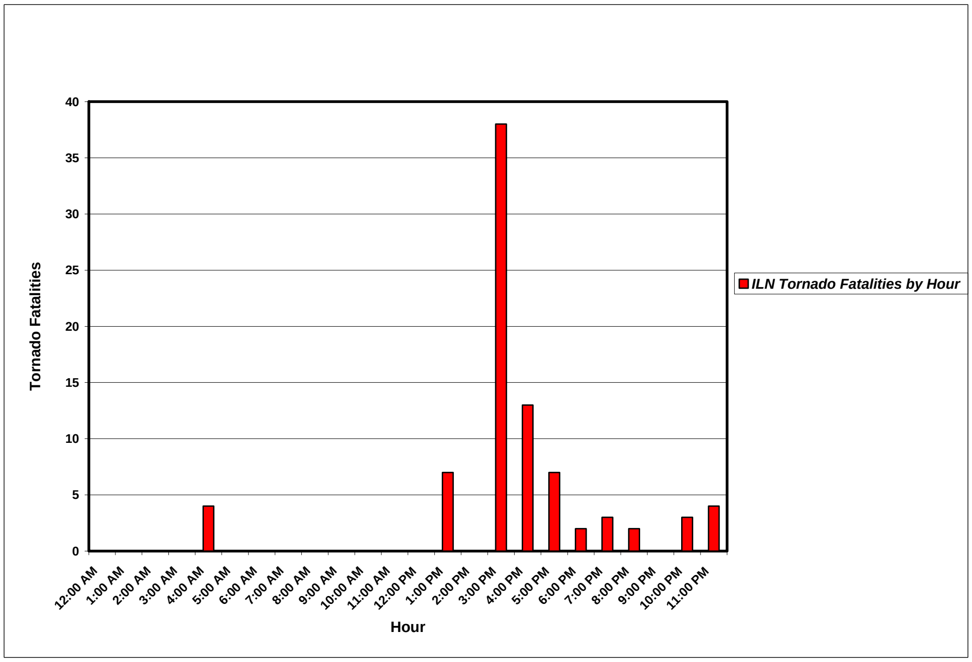

Figure 13. Tornado-related fatalities by hour across the Wilmington, Ohio CWA from 1950-2004. Hours are in Eastern Standard Time.

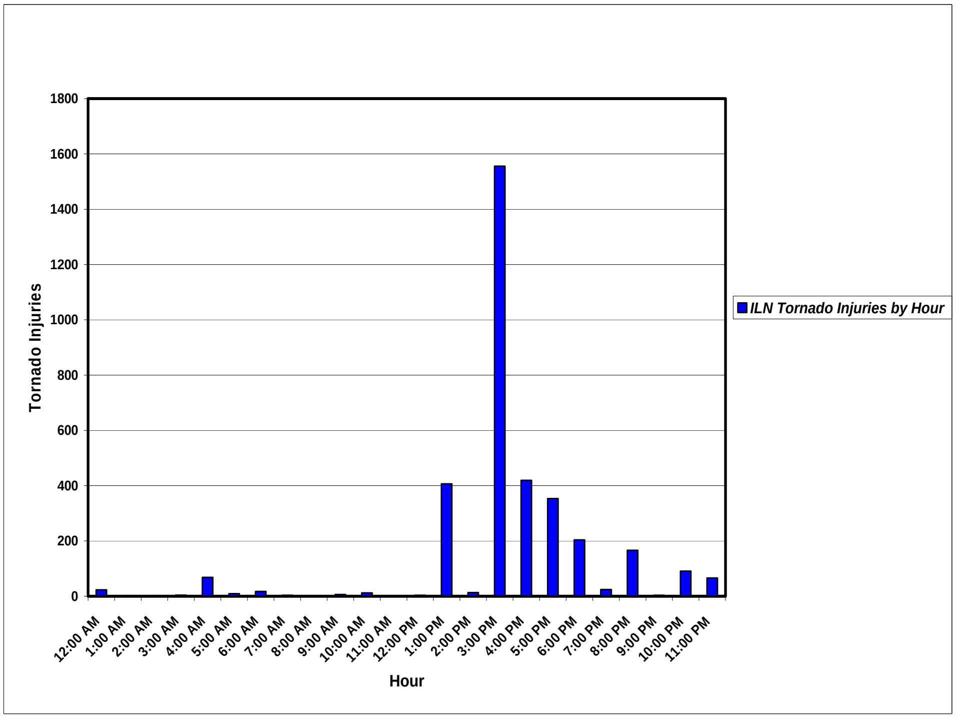

Figure 14. Tornado-related injuries by hour across the Wilmington, Ohio CWA from 1950-2004. Hours are in Eastern Standard Time.

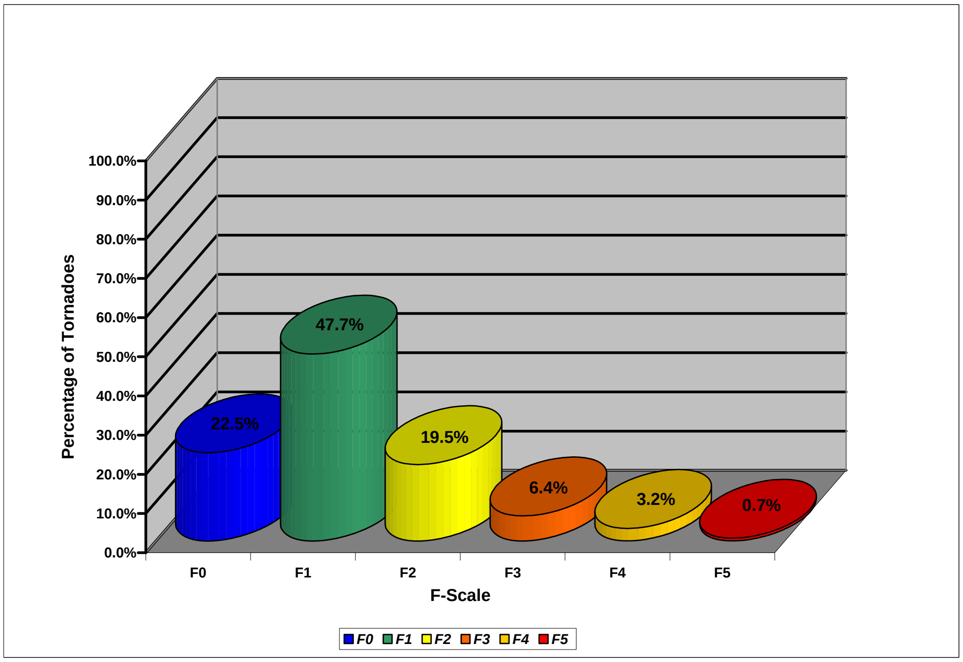

Figure 15. Percentage of tornadoes by F-Scale across the Wilmington, Ohio CWA from 1950-2004.

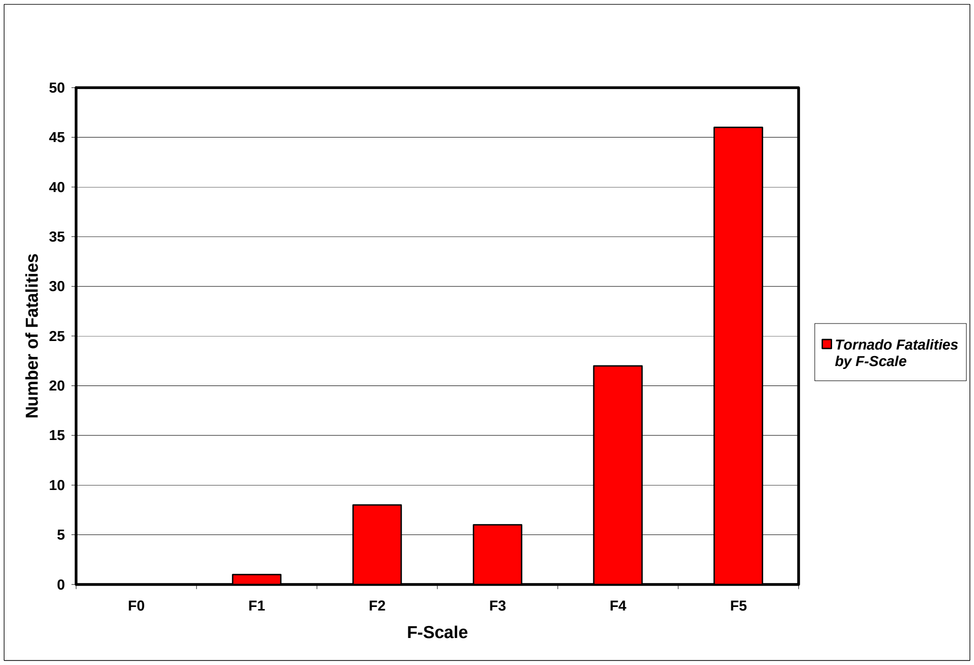

Figure 16. The number of tornado fatalities by F-scale across the Wilmington, Ohio CWA from 1950 to 2004.

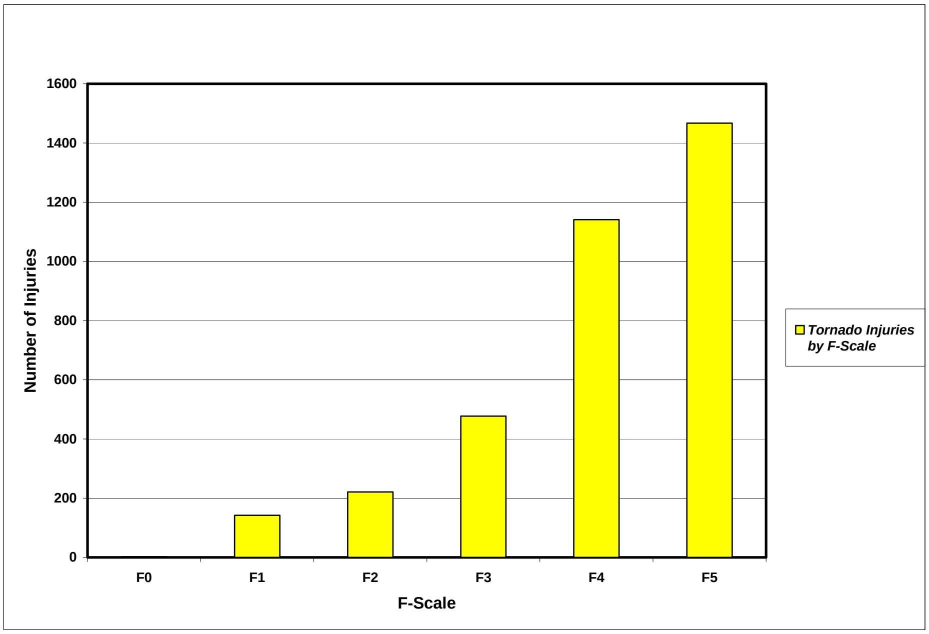

Figure 17. The number of tornado injuries by F-scale across the Wilmington, Ohio CWA from 1950 to 2004.

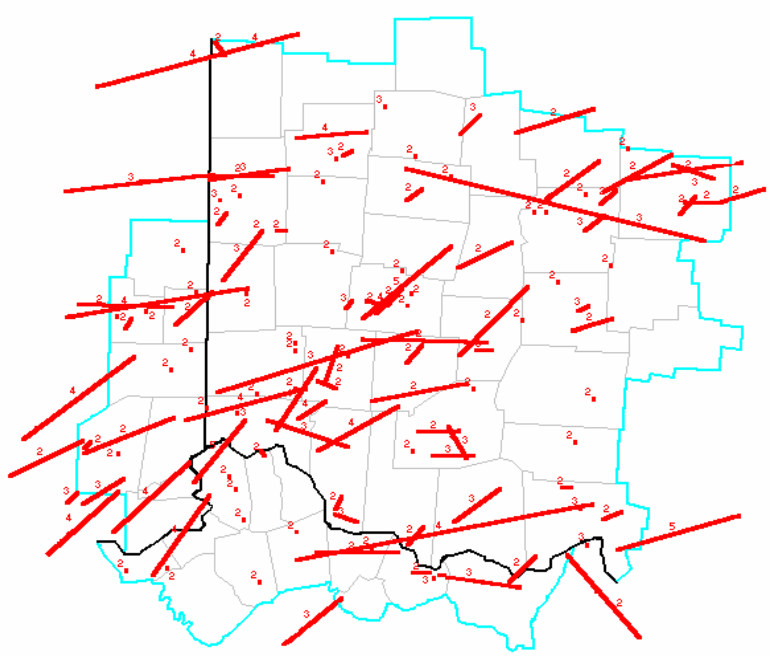

Figure 18. The significant tornado (F2-F5) tracks across the Wilmington, Ohio CWA from 1950-2004.

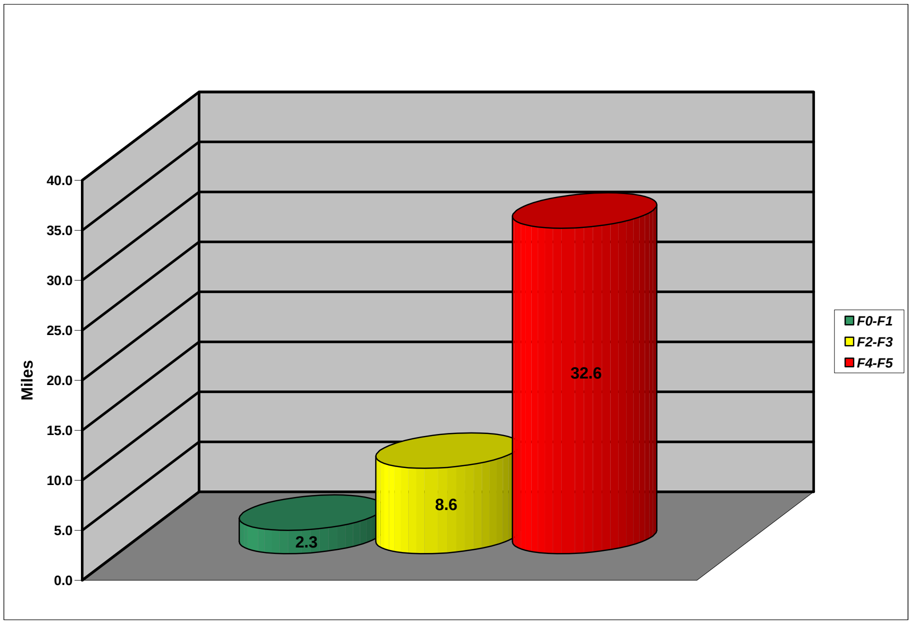

Figure 19. The average tornado path length (in miles) for weak (F0-F1), strong (F2-F3) and violent (F4-F5) tornadoes across the Wilmington, Ohio CWA from 1950-2004.

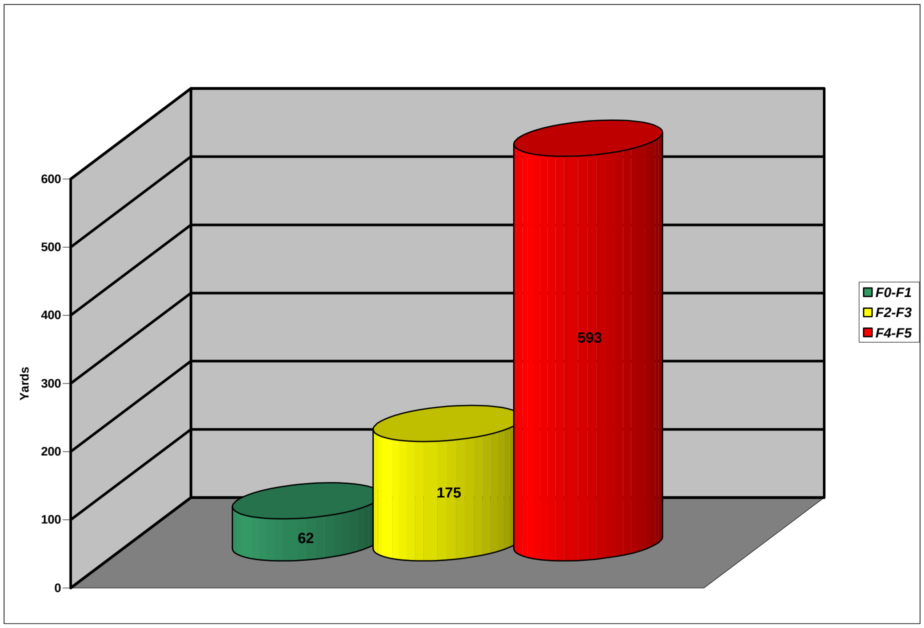

Figure 20. The average tornado width (in yards) for weak (F0-F1), strong (F2-F3) and violent (F4-F5) tornadoes across the Wilmington, Ohio CWA from 1950-2004.

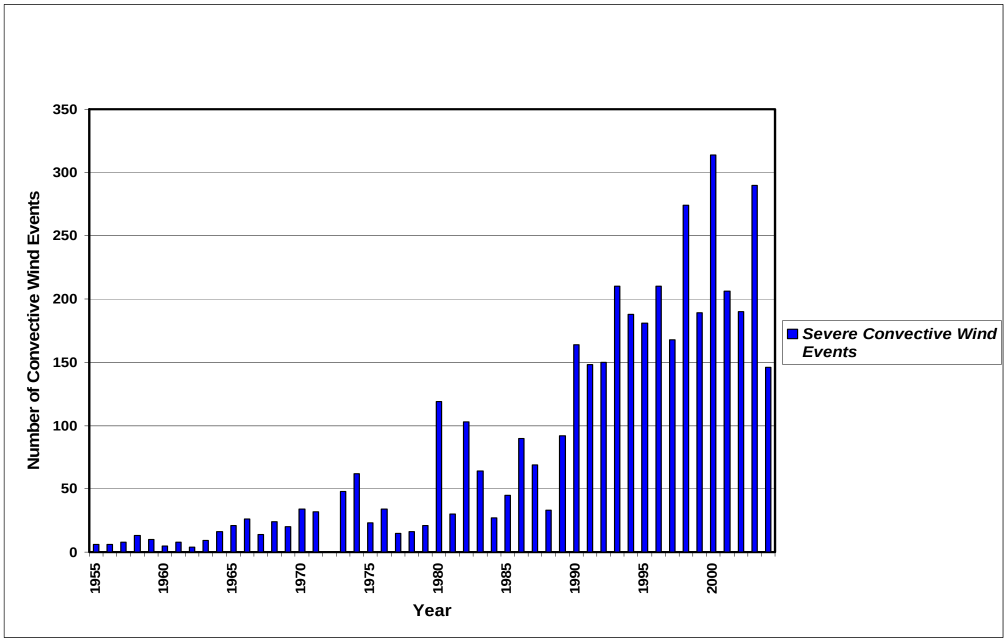

Figure 21. The annual distribution of severe convective wind events across the Wilmington, Ohio, CWA from 1955-2004. Wind data from 1972 are missing.

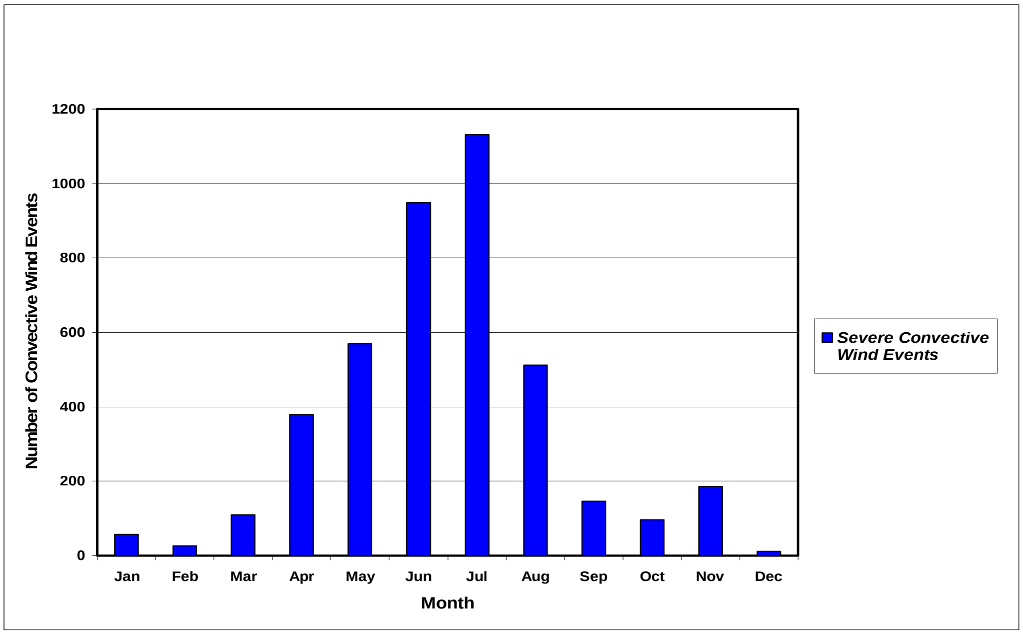

Figure 22. The monthly distribution of severe convective wind events across the Wilmington, Ohio CWA from 1955-2004.

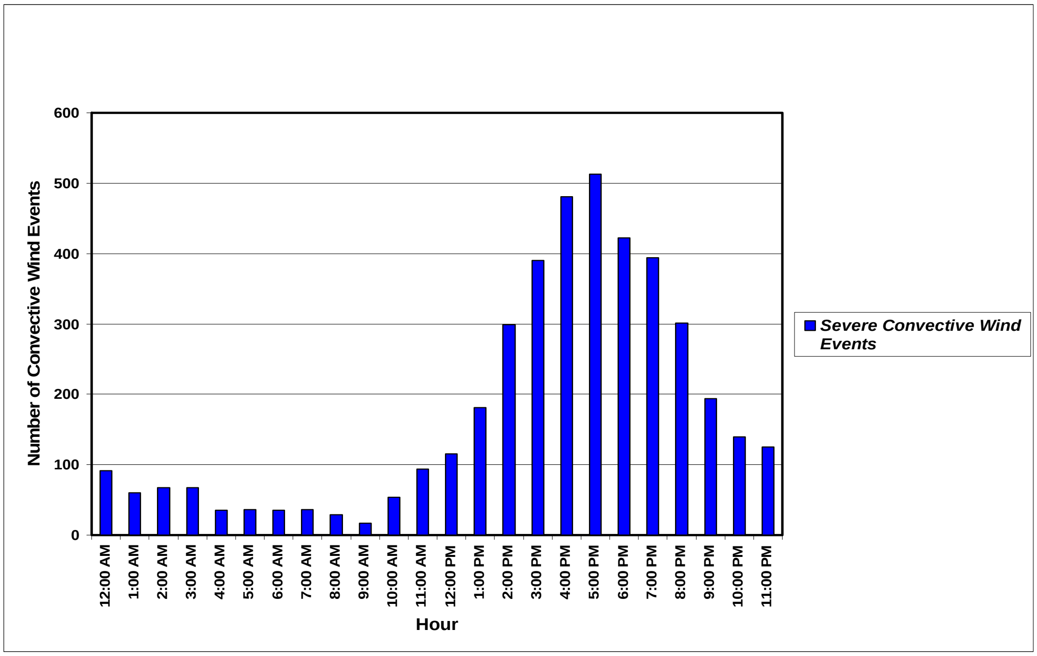

Figure 23. The hourly distribution of severe convective wind events across the Wilmington, Ohio, CWA from 1955-2004. Hours are in Eastern Standard Time.

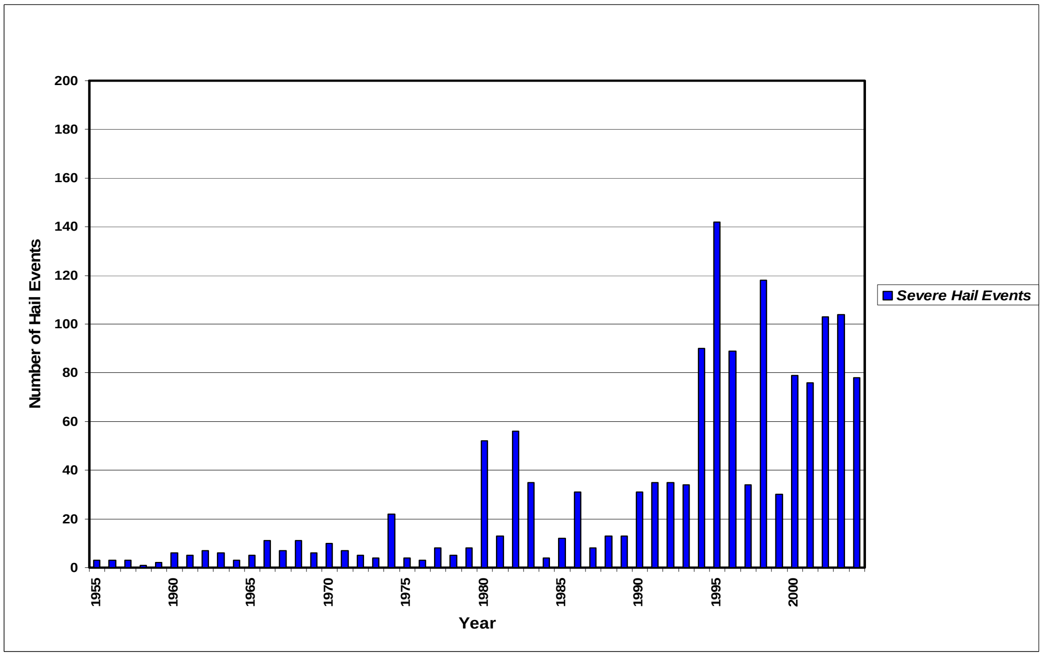

Figure 24. The annual distribution of severe hail events across the Wilmington, Ohio CWA from 1955-2004.

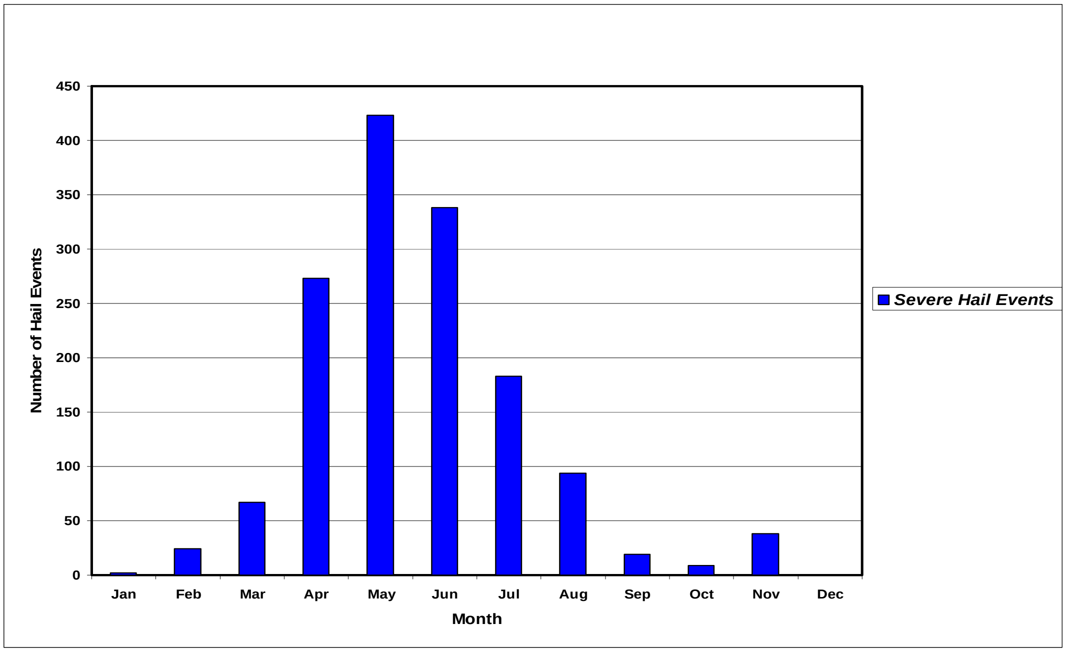

Figure 25. The monthly distribution of severe hail events across the Wilmington, Ohio CWA from 1955-2004.

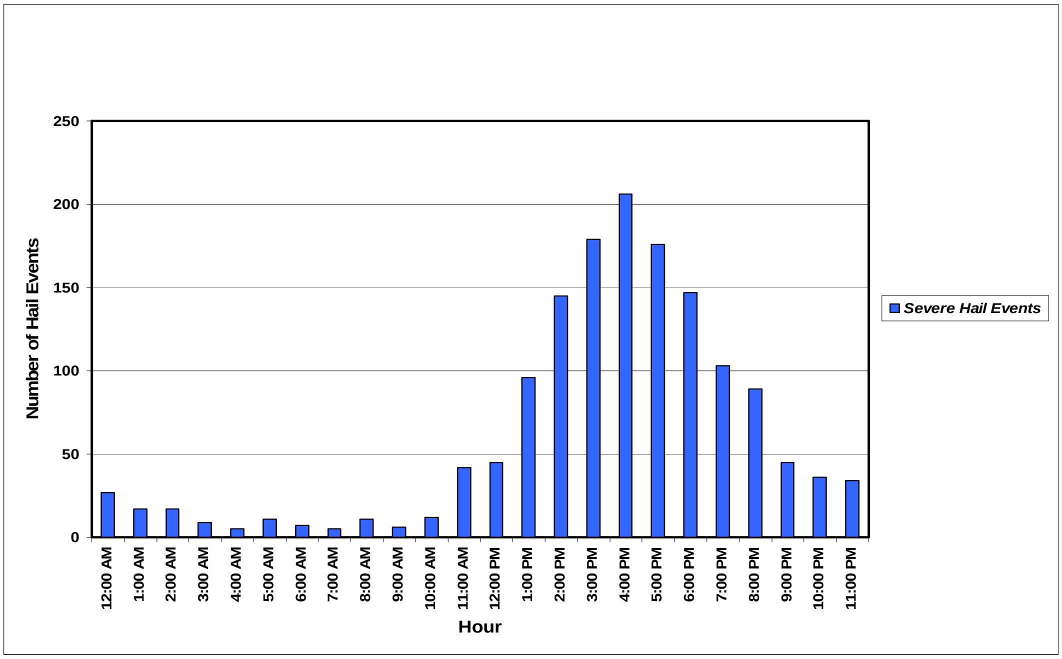

Figure 26. The hourly distribution of severe hail events across the Wilmington, Ohio CWA.

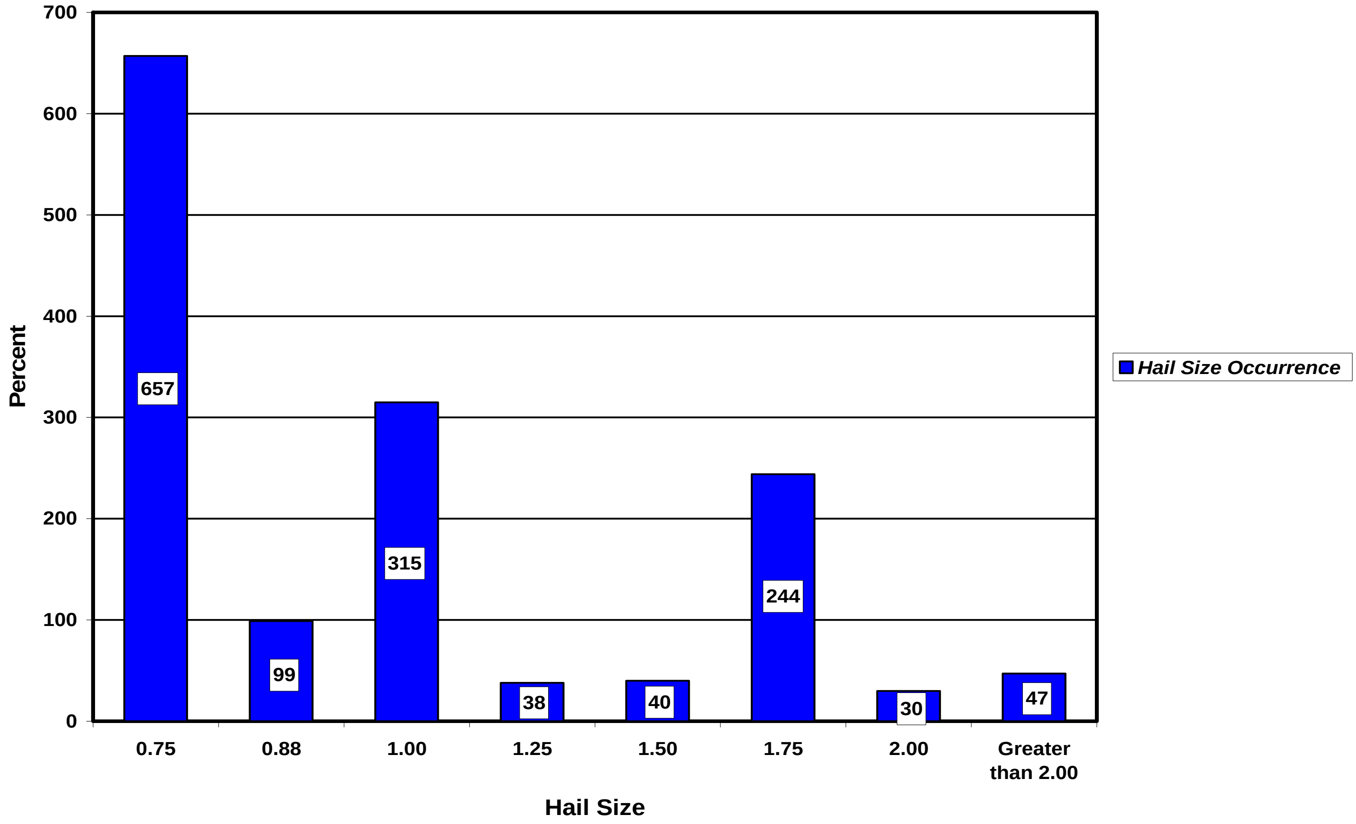

Figure 27. The distribution of severe hail by size across the Wilmington, Ohio CWA.

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