A SEVERE WEATHER CLIMATOLOGY FOR THE CHARLESTON, WV WFO COUNTY WARNING AREA

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1. INTRODUCTION

The National Weather Service's (NWS) primary responsibility is to provide the public with information on impending severe weather that threatens life and property. A forecaster can be better prepared to anticipate and react to the timing, strength and nature of severe weather, with a general understanding of local severe weather. This is the motivation for conducting this local study.

The NWS Weather Forecast Office (WFO) in Charleston, WV has warning and forecast responsibility for 49 counties (Figure 1). This combination of counties, referred to as the County Warning Area (CWA), includes four counties in northeast Kentucky, two counties in southwest Virginia, nine counties in southeast Ohio and thirty-four counties in West Virginia.

Figure 1

The Charleston, WV CWA is comprised of 21,963 square miles. The terrain across the CWA is quite variable. The higher mountain peaks of the Appalachian Mountains, with some elevated inhabited valleys, define the eastern third of the CWA. The highest point within the CWA, Snowshoe Mountain (4765 feet), lies within Pocahontas County. Across the middle third of the CWA, west of the Appalachians, the terrain transitions into very steep, densely wooded hilltops and carved river valleys. A slope of 400-500 feet from any hilltop to river is not uncommon. Finally, the western third of the CWA is made of rolling hills and is more agricultural in land use; with the main stem Ohio River flowing through it. The lowest point in the CWA is along the Ohio River in Greenup County, KY (495 feet) near South Shore.

The population in the CWA is comprised of several metro areas with higher population density, surrounded by less dense rural areas (Figure 2).

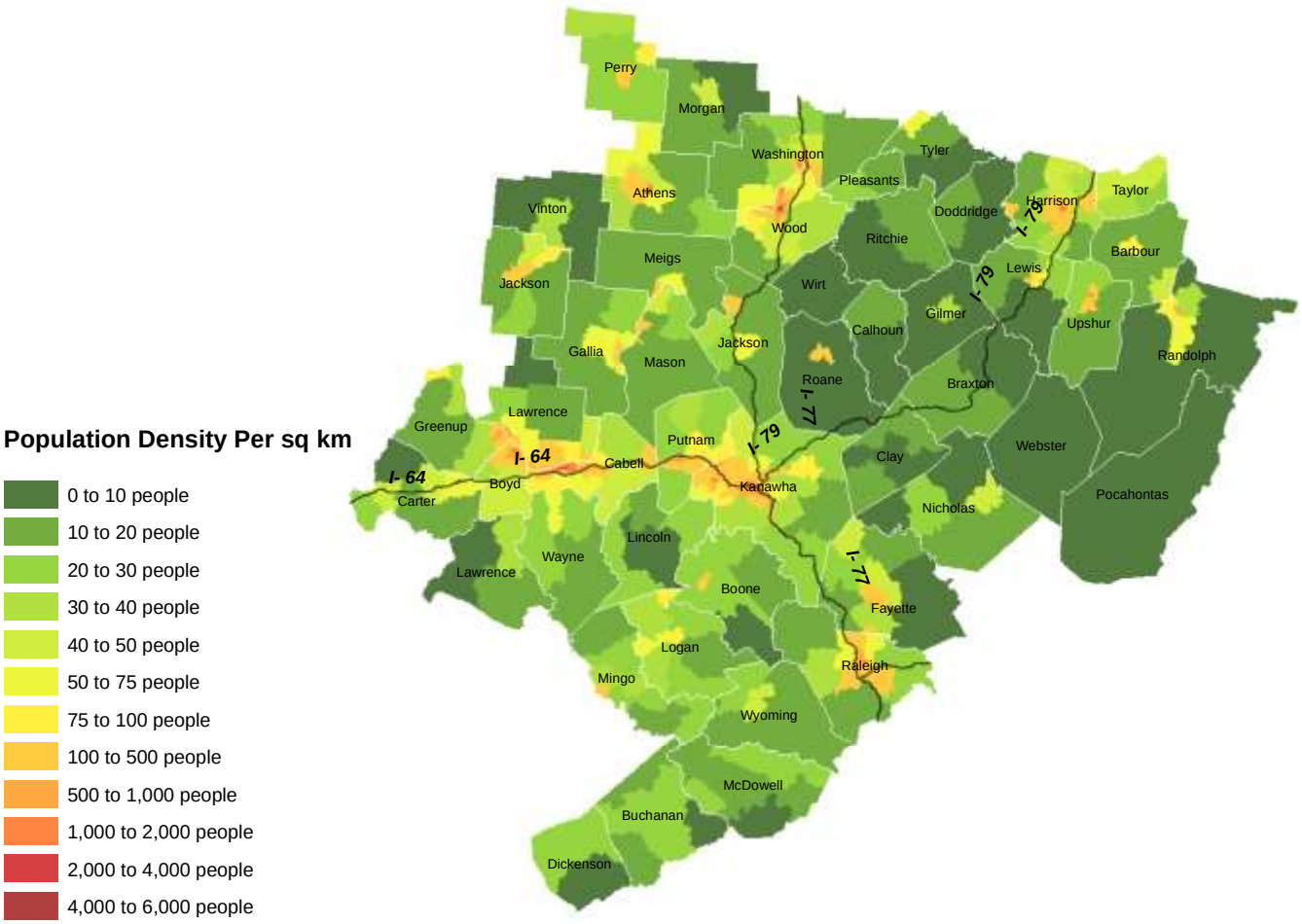


Figure 2

2. DATA

The National Climatic Data Center (NCDC) in Asheville, NC provides online access to severe weather data all across the country. Weather offices send local storm reports from a severe weather event to the Storm Prediction Center (SPC), located in Norman, Oklahoma. The storm reports are verified and then archived at NCDC. Storm data archived at NCDC includes tornado, hail and thunderstorm wind gust reports from 1950 through the present.

Data used for this study includes any tornado, hail, and thunderstorm wind gust reports for each county in the Charleston, WV CWA. Data for tornadoes is from January 1, 1950 to December 31, 2013, while data for hail and thunderstorm wind gusts is from January 1, 1950 to December 31, 2014. The times of severe weather events are all in Eastern Standard Time.

The NWS defines a severe thunderstorm as a storm that meets one or more of the following criteria:

- A tornado
- Hail one inch in diameter or larger (.75" before 2010)
- Wind of at least 50 knots (58 mph) or wind which causes damage, including trees or power lines blown down

3. CLIMATOLOGY

A. All Severe Events

The frequency and distribution of severe weather events (including tornadoes, hail one inch or larger, and severe thunderstorm wind gusts/damage) varies from year to year. An overall increasing trend can be seen in the yearly graph below (Figure 3). Much of this can be attributed to an increase in population, infrastructure, spotter training and technology, as well as a more concerted effort by the WFO to find reports. Spatially, there are report "hot spots" around population centers in the CWA, with fewer reports from the more rural locales (Figure 4).

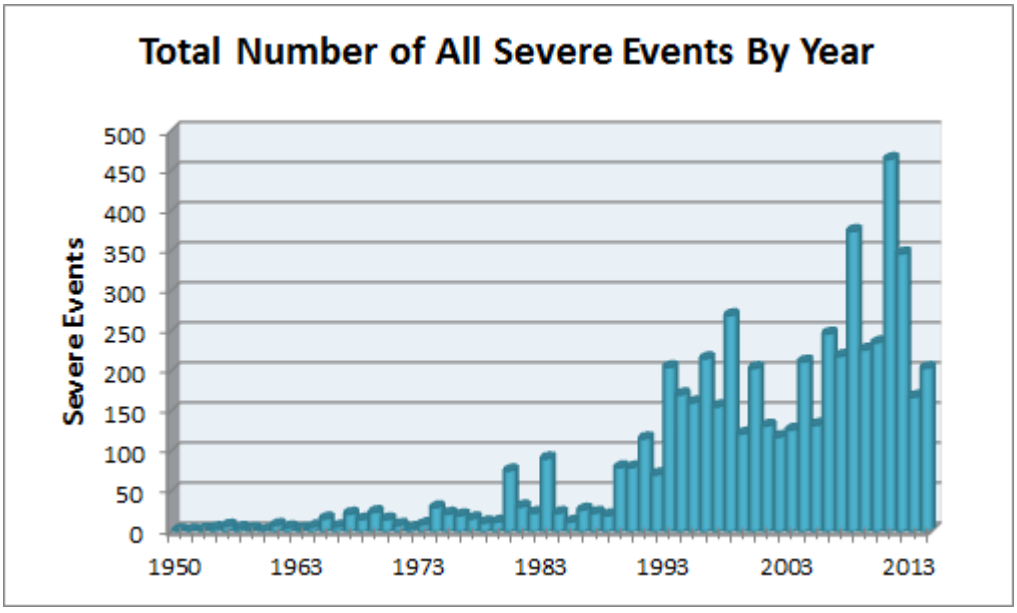


Figure 3

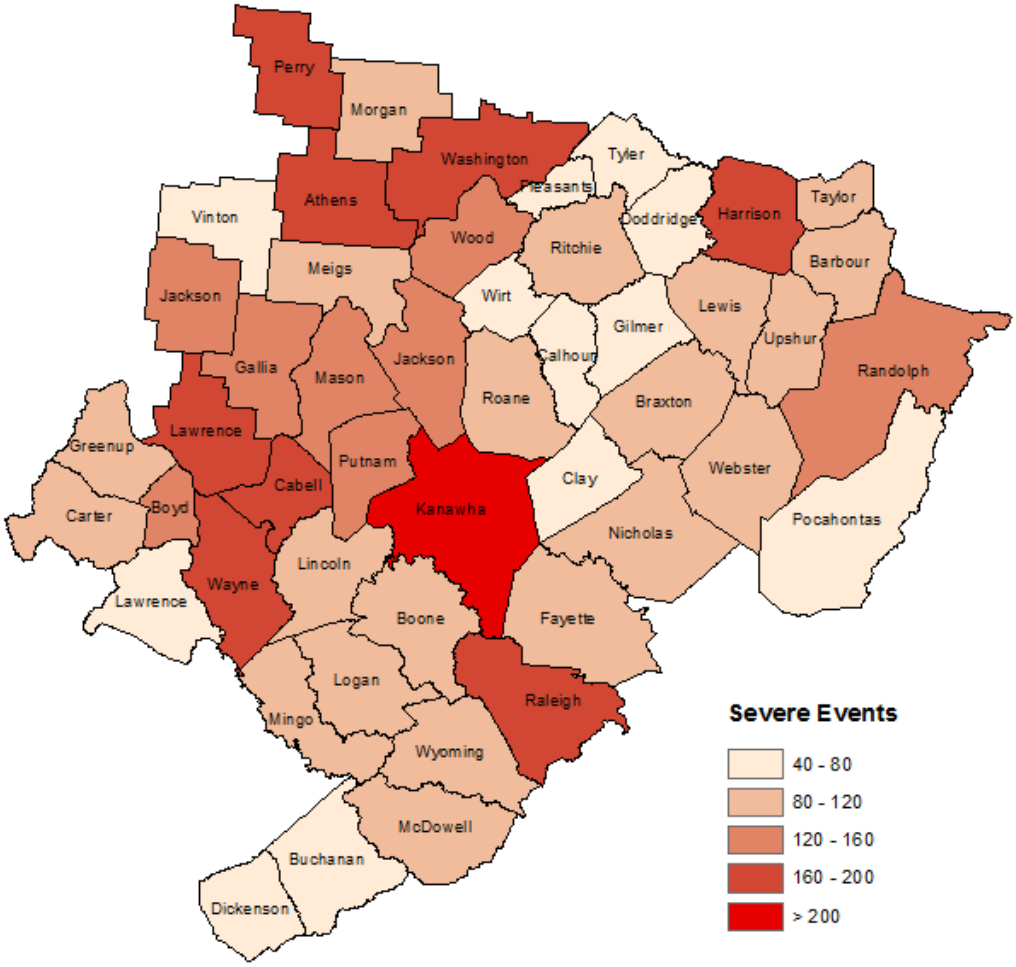


Figure 4

1. *Monthly Frequency*

The monthly distribution of severe weather events across the Charleston, WV CWA represents a “bell-shaped” curve (Figure 5). There have been a total of 5663 severe weather events during the study period. The peak month for severe weather is June, during which over 26% (1497) of all severe weather events occurred. Just over 61% (3479) of all severe weather events occur during the typical summer months of May, June and July. The number of events dramatically drops off after August with the transition to fall. However, severe weather is possible, and has been observed in all 12 months.

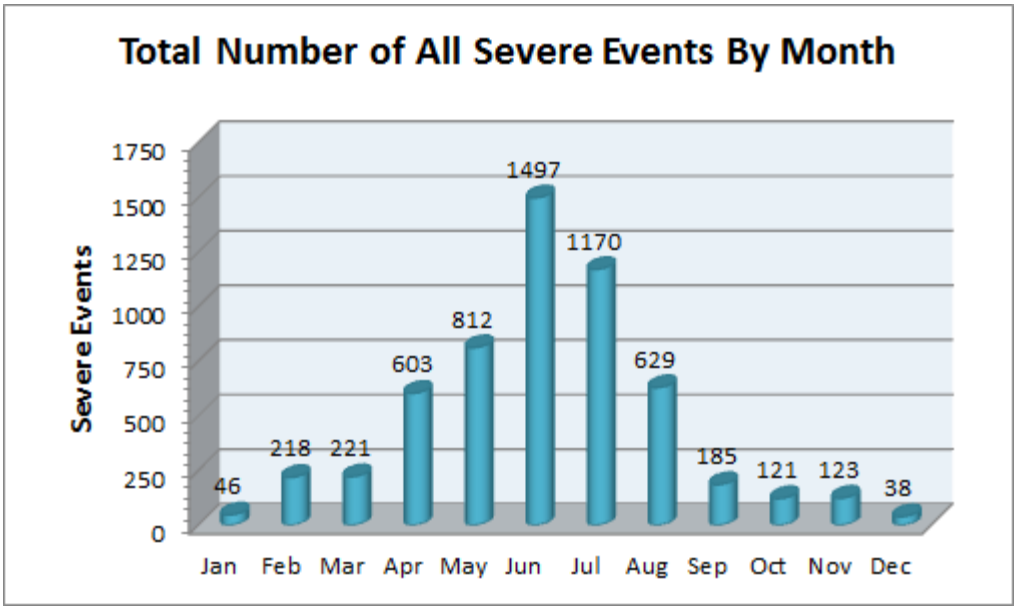


Figure 5

2. *Hourly Frequency*

The majority of severe weather events occur during the afternoon and evening hours, which coincides well with the peak heating of the day and highest instability in the atmosphere. About 82% (4670) of all severe weather events occur between 1 PM and 9 PM (Figure 6). The peak time of day for all events occurs between 4 PM and 6 PM. A secondary mode appears around midnight, which is may be due to Mesoscale Convective Systems (MCS) that develop upstream in the afternoon and push through during the late night hours. Severe weather is least likely to occur during the morning hours between 4 AM and 9 AM, during which less than 3% (141) of all events occurred.

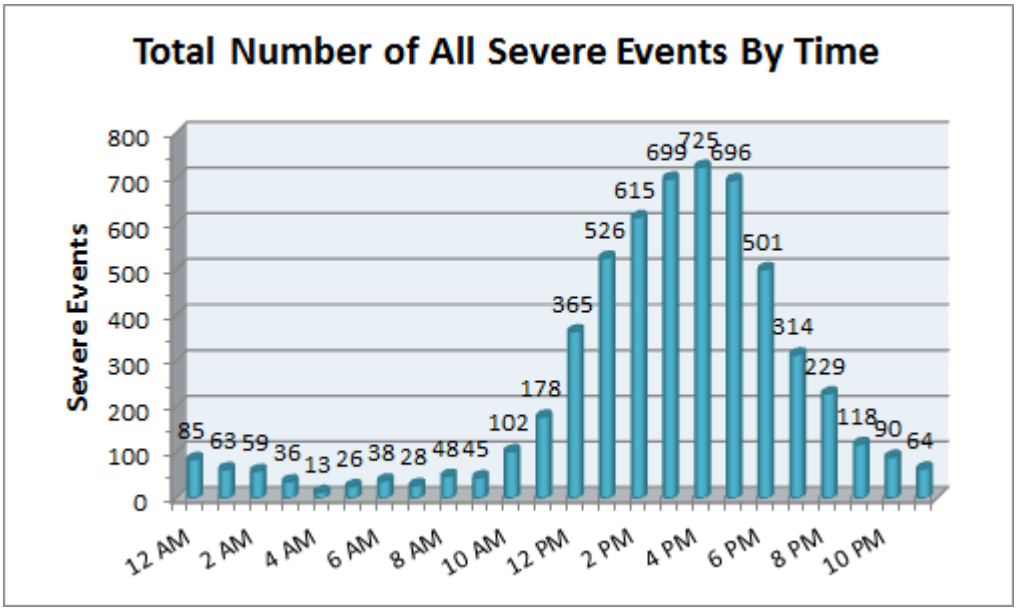


Figure 6

B. <u>Tornadoes</u>

The frequency of tornadoes across the Charleston, WV CWA is very low compared to other areas of the country. Over the 63 year period, there were 119 confirmed tornadoes. This is an average of about 2 tornadoes per year, although there is a slow increasing trend to the data (Figure 7). This is likely due to the increase in population resulting in more reports and a more organized effort to investigate tornado reports by the WFO. With the exception of Raleigh County, most of the tornadoes were observed in counties along the Ohio River and extending into Southeast Ohio (Figures 8, 9). This is graphically represented through a “hot spot” analysis which shows where tornadoes are most likely to occur based on statistically significant spatial clusters of confirmed tornadoes (Figure 10). It is theorized that the lack of rugged steep terrain plays a role in the density of tornadoes in Southeast Ohio and along the Ohio River. This idea may also be a contributing factor to the anomaly in Raleigh County where all of the tornadoes reported were across the eastern part of the county which is more high plateau and slope is not as great.

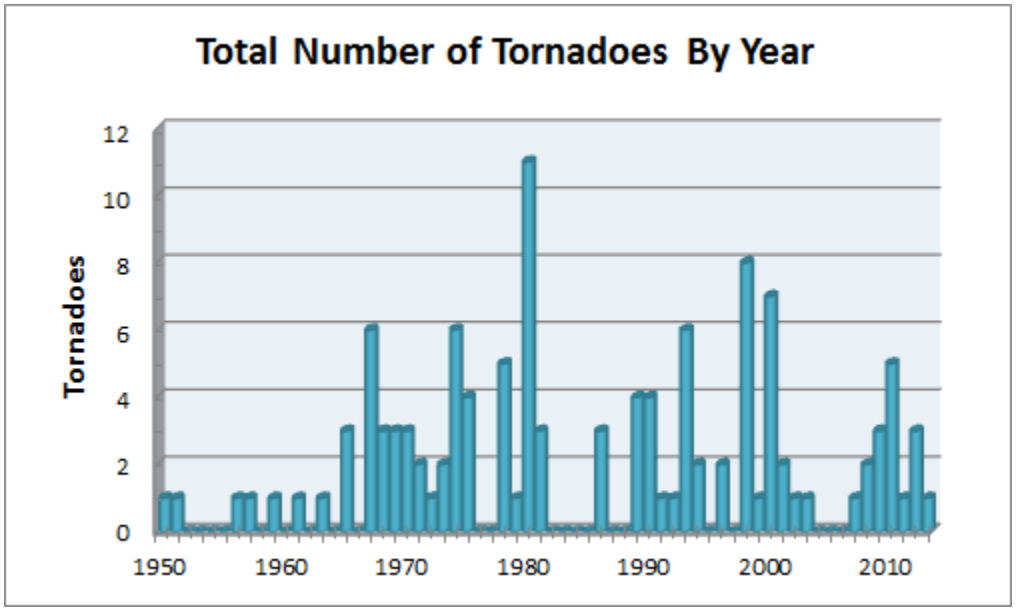


Figure 7

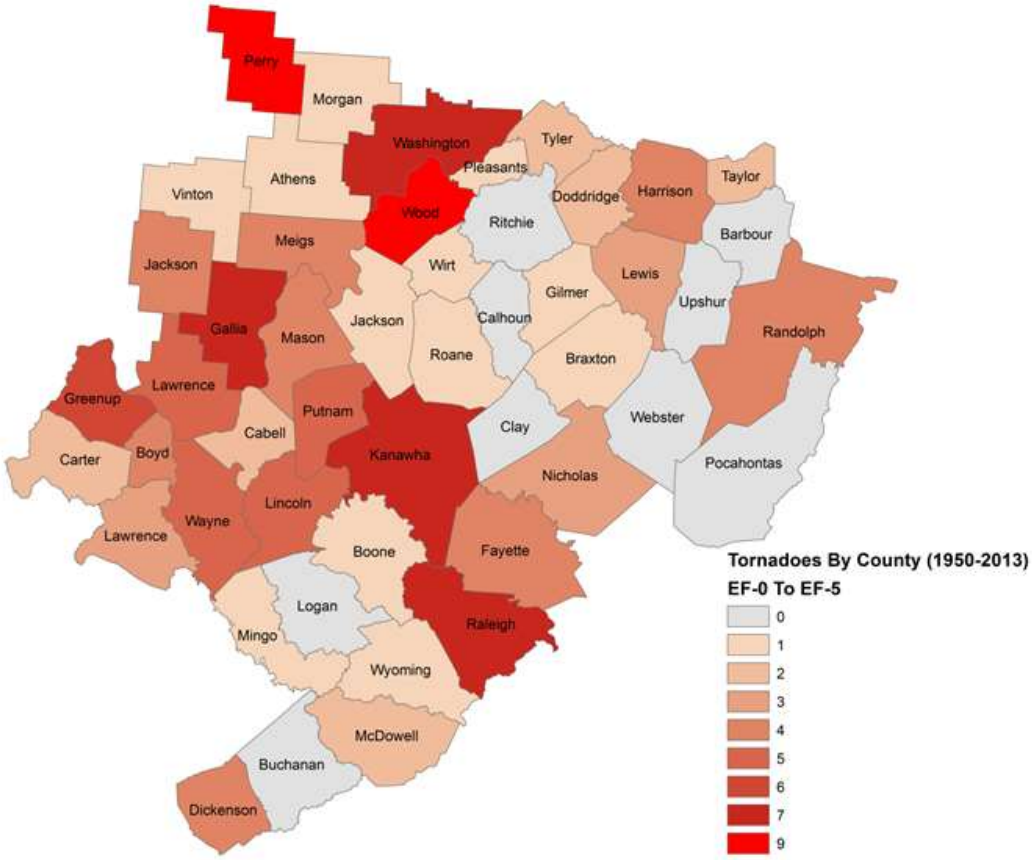


Figure 8

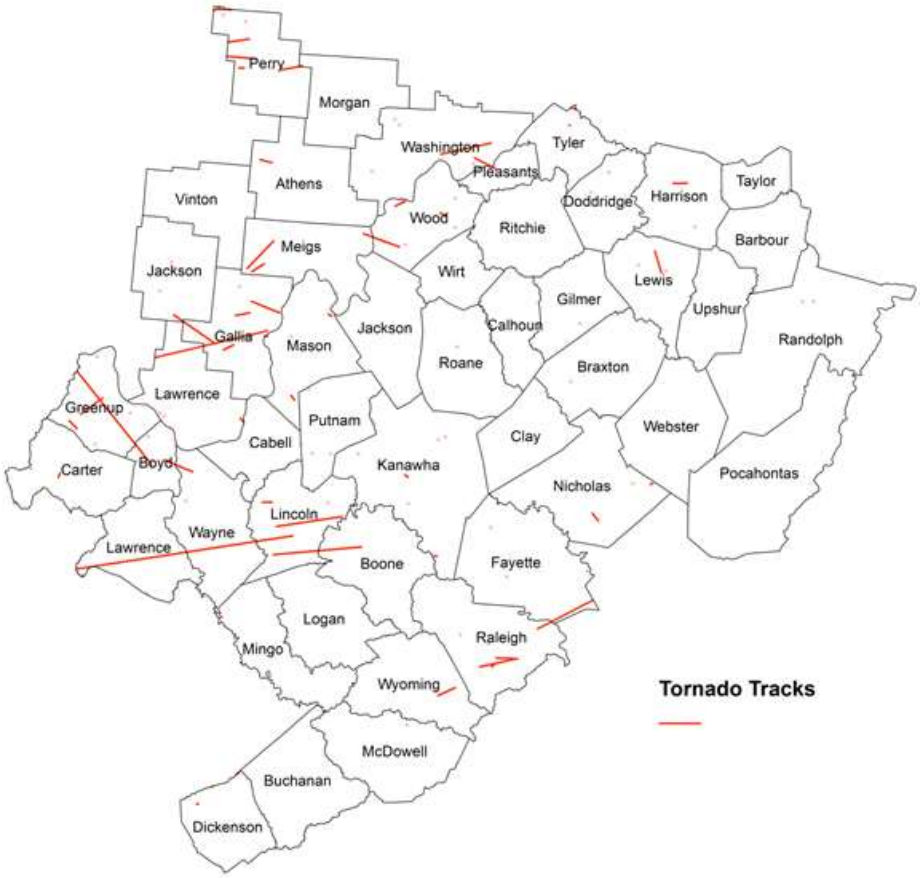


Figure 9

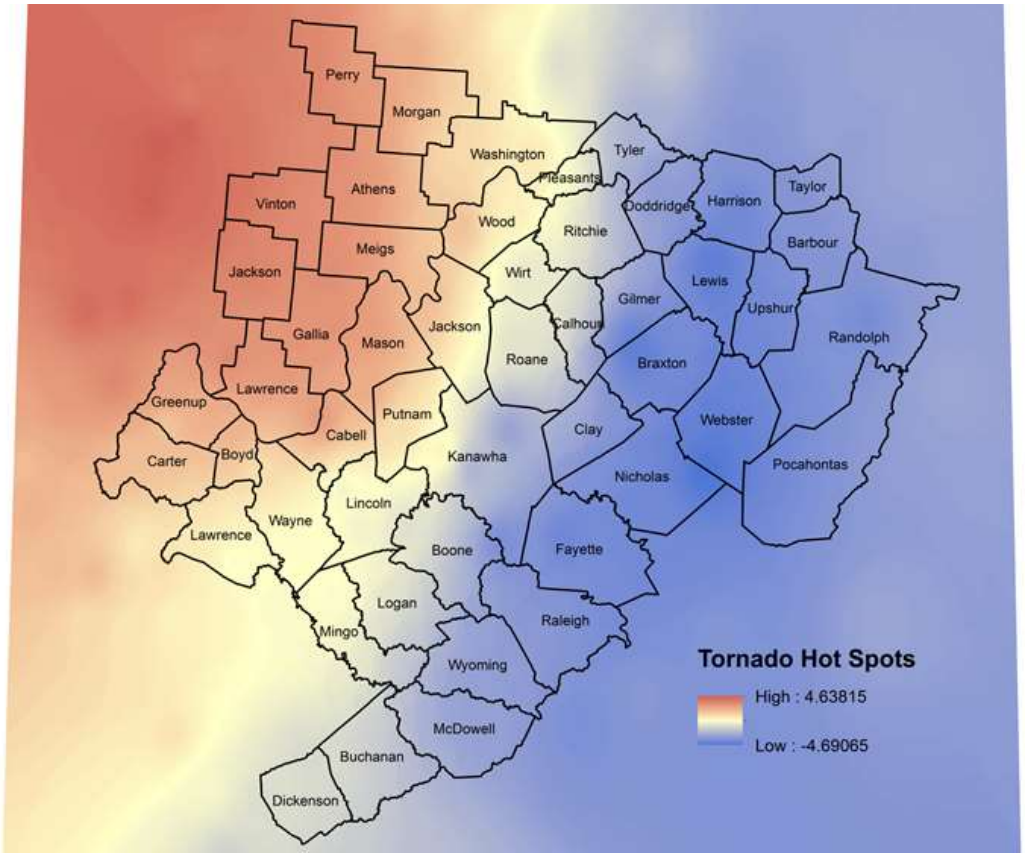


Figure 10

A. Magnitude

Tornado magnitude, or strength, is determined by using the Enhanced Fujita (EF) Scale (Table 1). Most of the tornadoes observed in the Charleston, WV CWA were weak in magnitude (Figure 11). In fact, 92% of all confirmed tornadoes since 1950 were rated EF2 or weaker. Strong tornadoes (EF3-EF5) are not very common across the area. Only 9 of the 119 tornadoes that have been confirmed in the CWA since 1950 were considered strong (Figures 13-15). Strong tornadoes are most likely to occur during the early to mid-Spring, which is a bit earlier than the overall peak tornado season, and during the afternoon and evening. However, with such a small sample size, monthly and hourly statistics should be used with caution.

EF Number	Estimated 3 Second Wind Gust (MPH)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200

Table 1

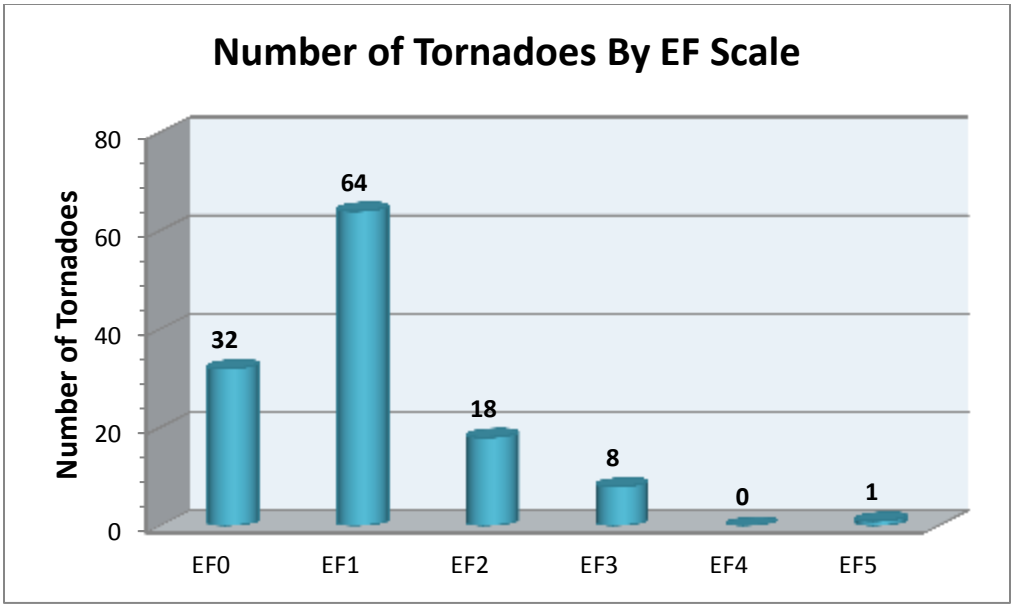


Figure 11

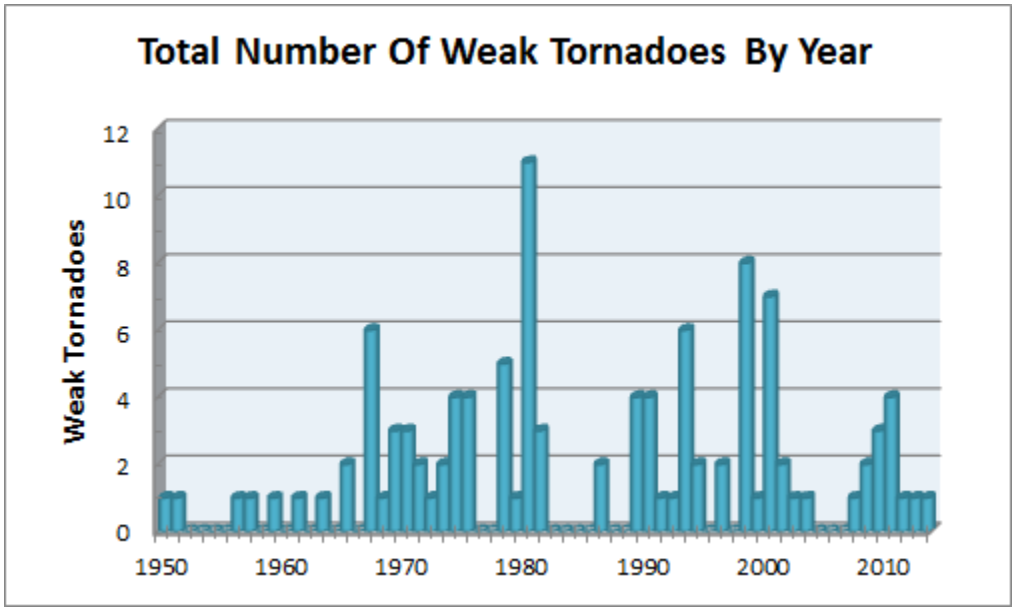


Figure 12

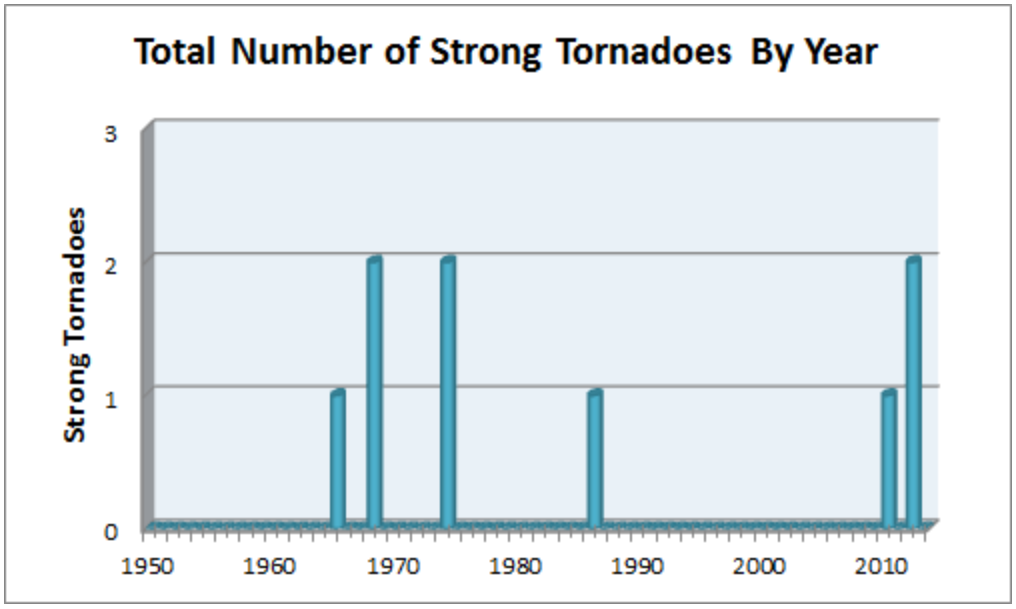


Figure 13

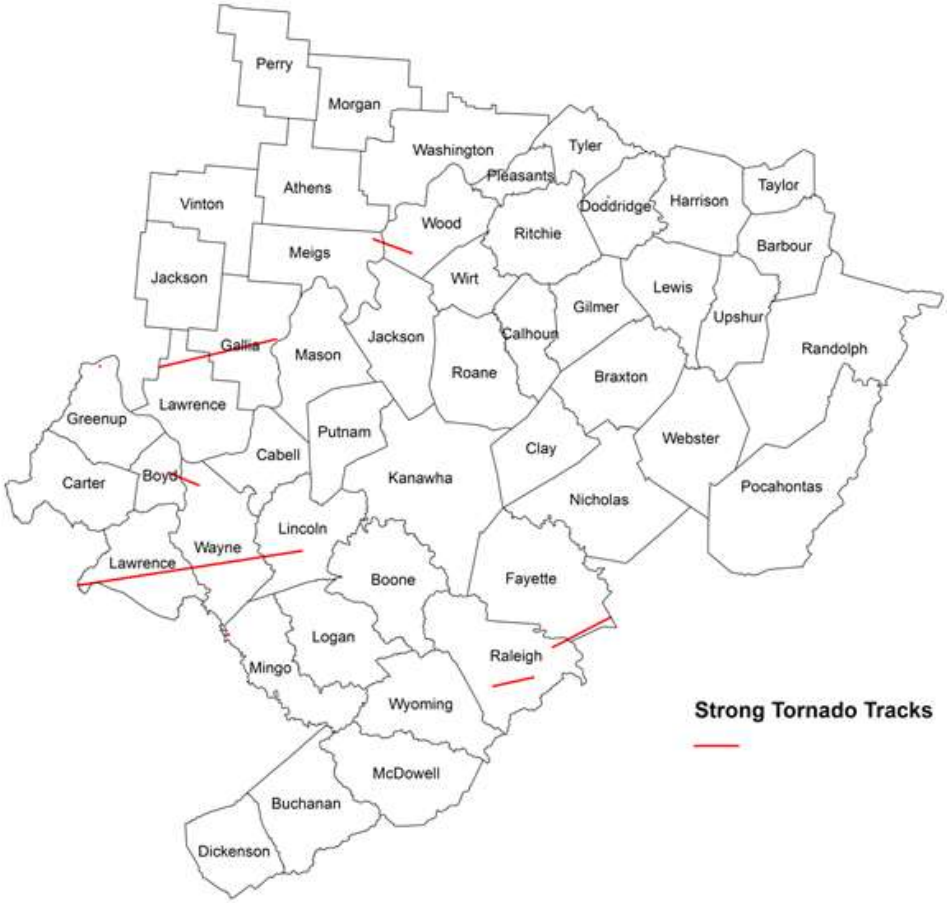


Figure 14

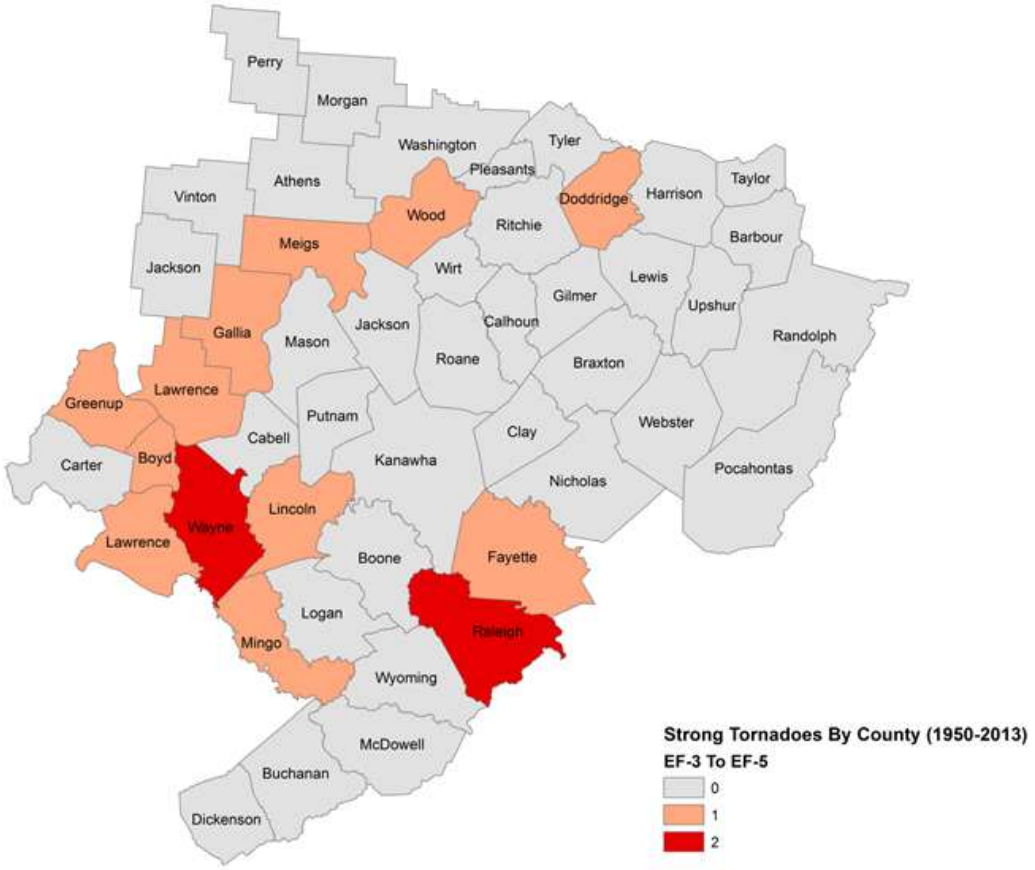


Figure 15

B. *Monthly Frequency*

Almost 75% (85) of tornado events occurred during the four month period of April through July, with the peak month being June (Figure 16). The occurrence of tornadoes decreases rapidly on either side of this four month period. However, it should be noted that tornadoes have occurred in all 12 months. As mentioned earlier, the peak for strong tornadoes is a bit earlier (Figure 17).

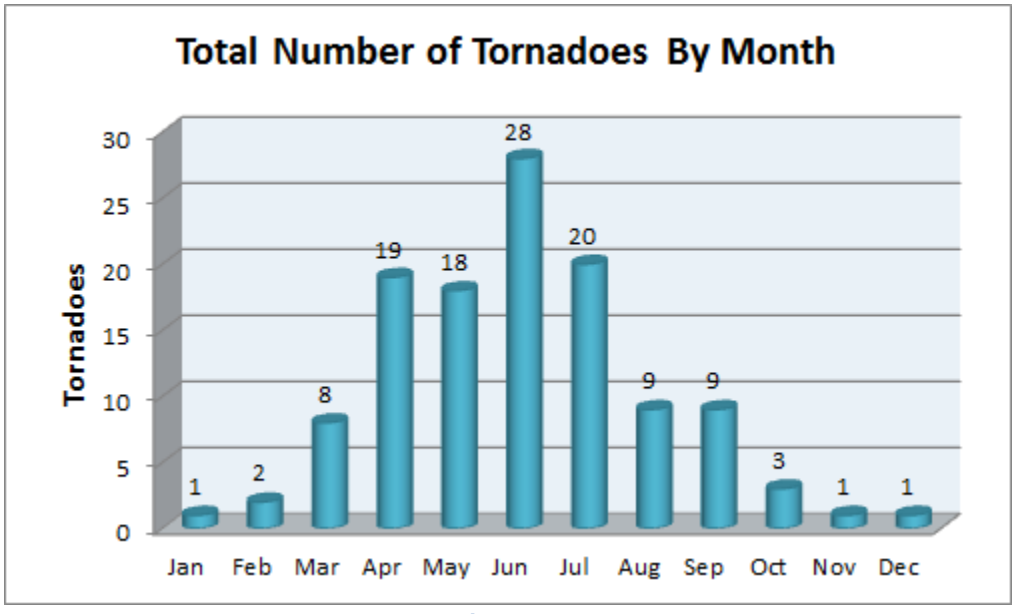


Figure 16

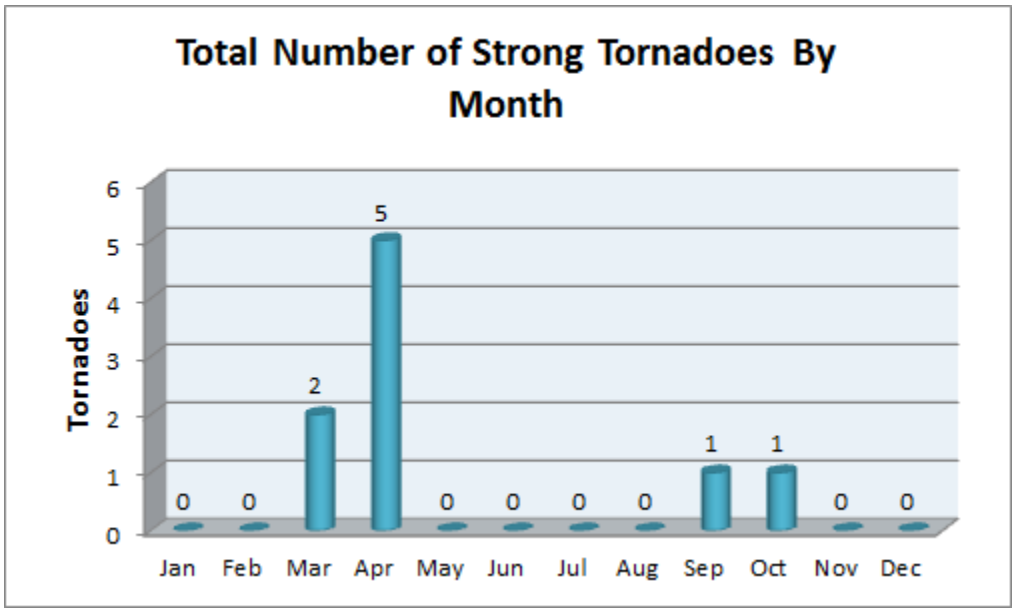


Figure 17

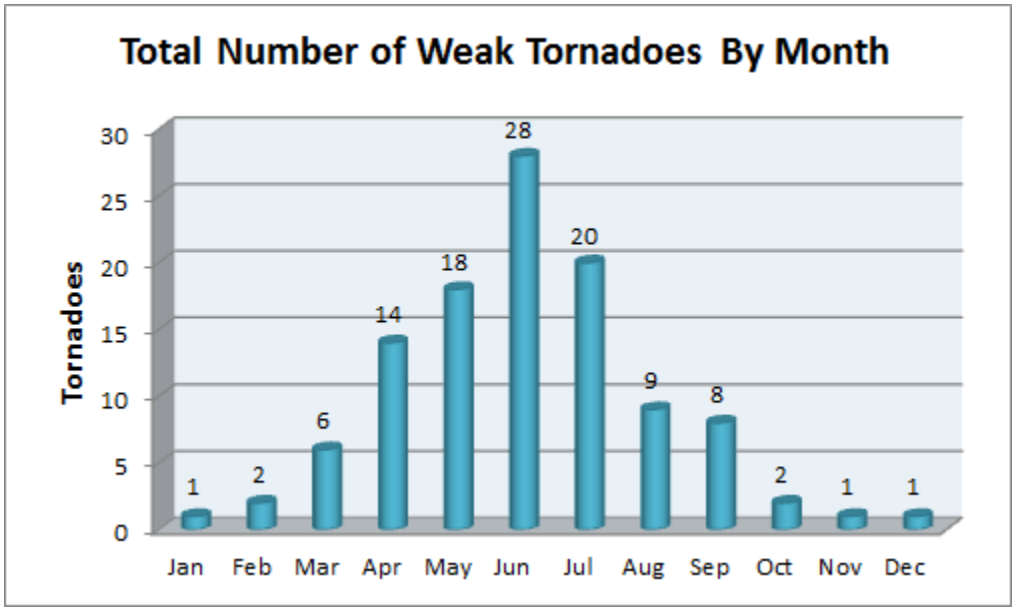
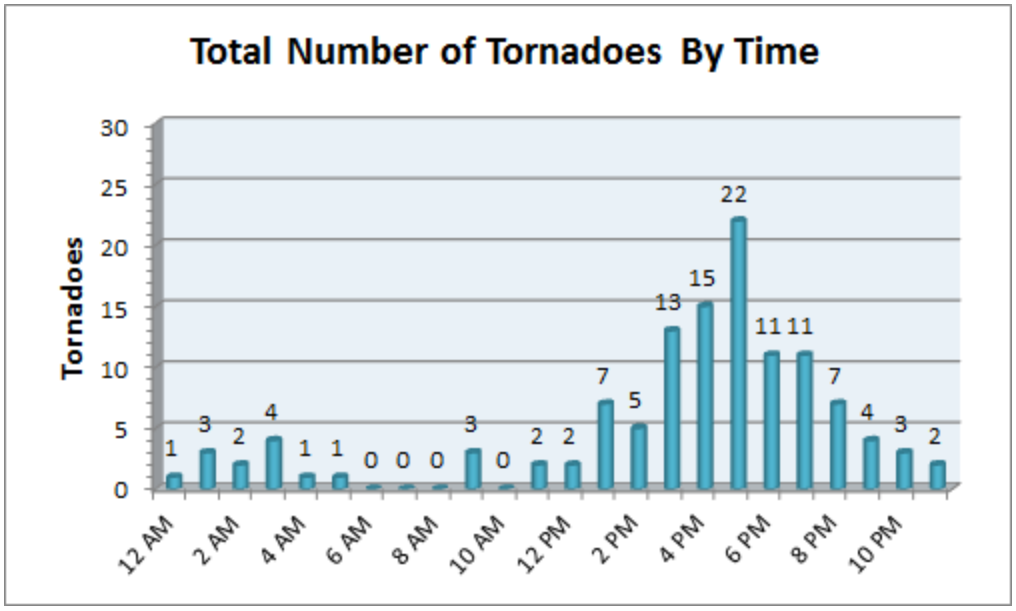


Figure 18

C. *Hourly Frequency*

Tornadoes typically occur during the afternoon and evening hours, peaking during the 5 to 6 PM hour (Figure 19). Over 60% (72) of tornadoes occur between the hours of 3 PM and 8 PM. Almost no tornadoes occurred (only 3 in the 63 year period) between 6 AM and 11 AM. Strong tornadoes are also most likely to occur during the afternoon and evening; however there are 2 outliers that occurred in the early morning (Figure 20).



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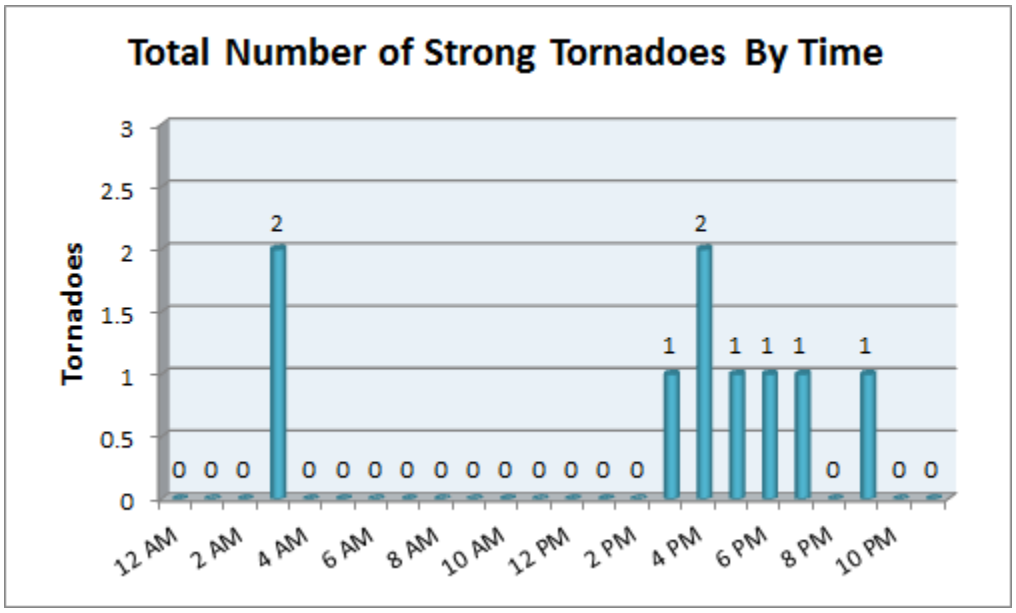
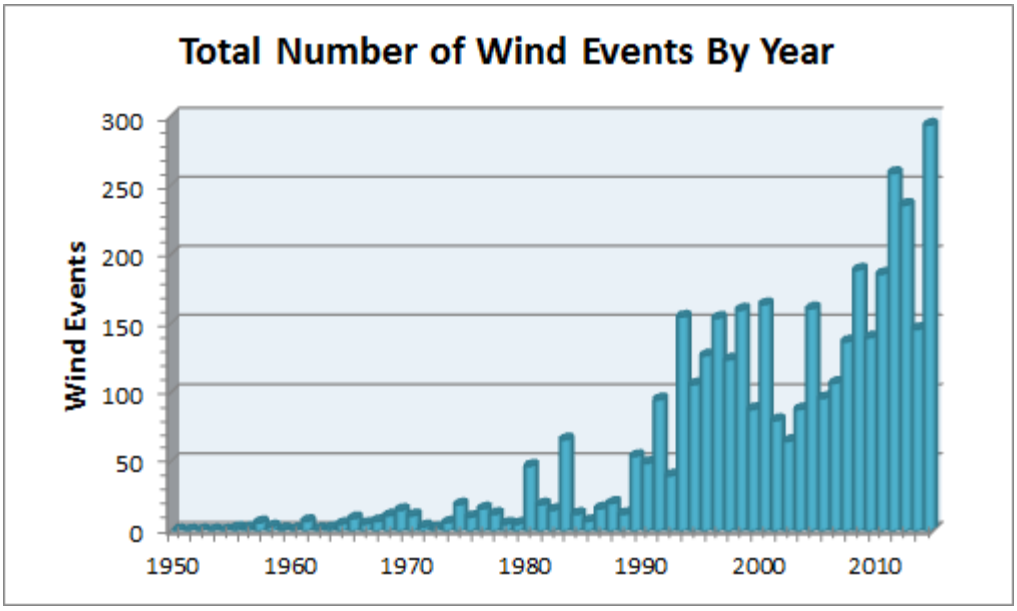


Figure 20

C. Thunderstorm Wind Events

Strong, damaging winds resulting from intense thunderstorms, fast moving squall lines or bow echoes are the most frequent severe weather event across the Charleston, WV CWA. Over the 64-year period between 1950 and 2014, there were 3880 thunderstorm wind events (nearly 69% of all severe events). With thunderstorm wind events comprising the bulk of the severe events for the CWA, it is no surprise that the year to year wind trends are similar to all events combined (Figures 21-23).



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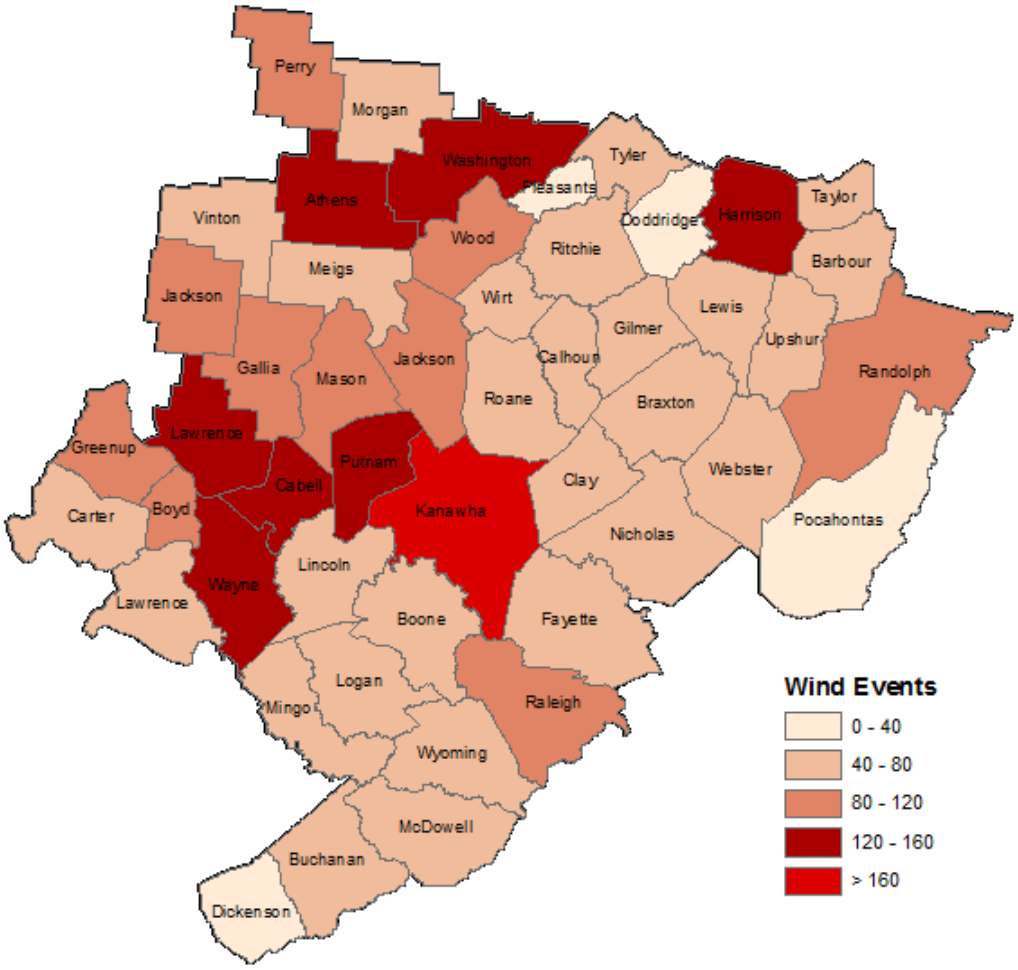

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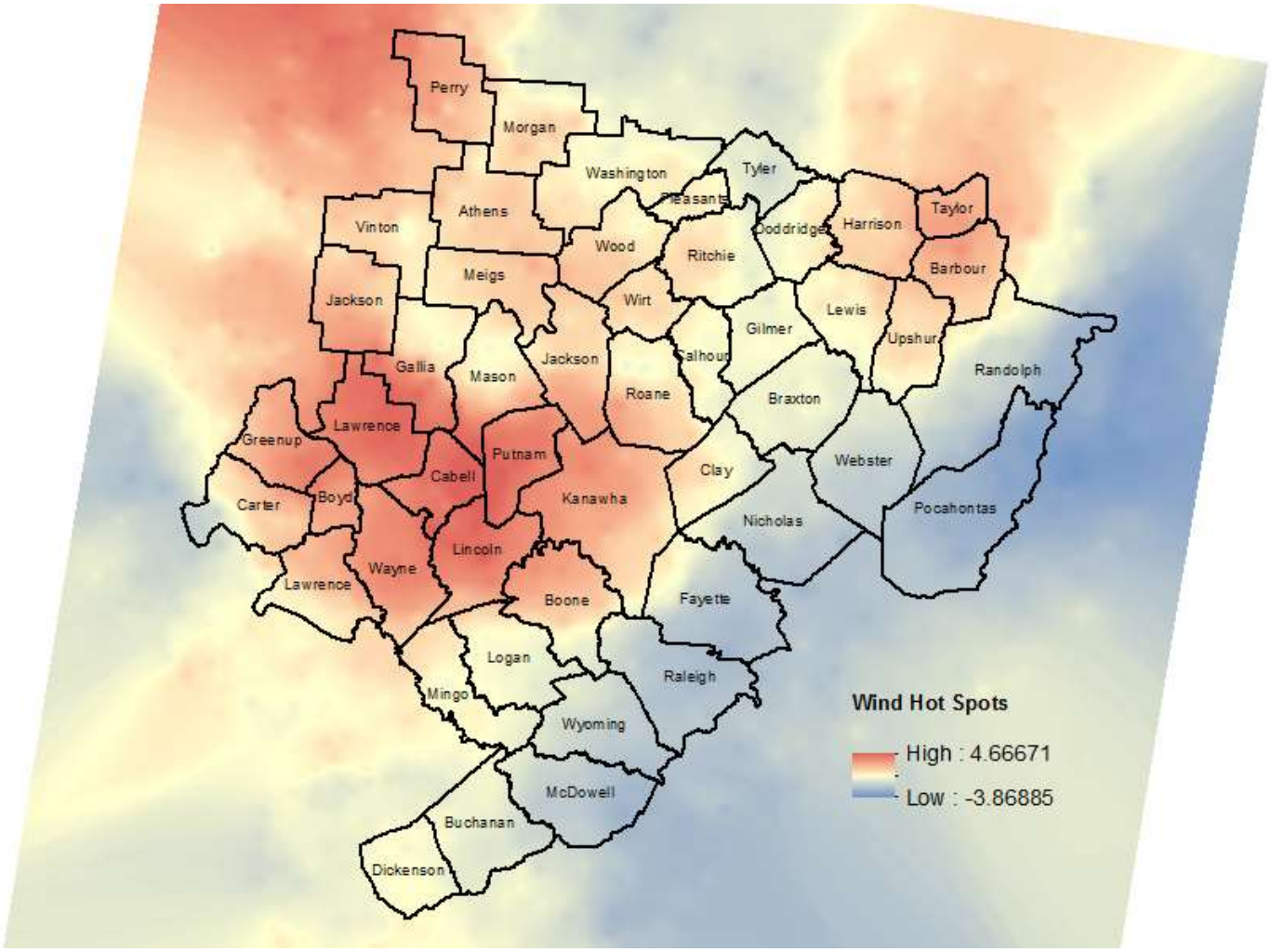


Figure 23

1. *Magnitude*

Most of the wind events in the Charleston, WV CWA fall in the low end of the severe range (50-60 kts). In general, less than 10% of the wind events contain gusts over 60 kts (Figures 24-25).

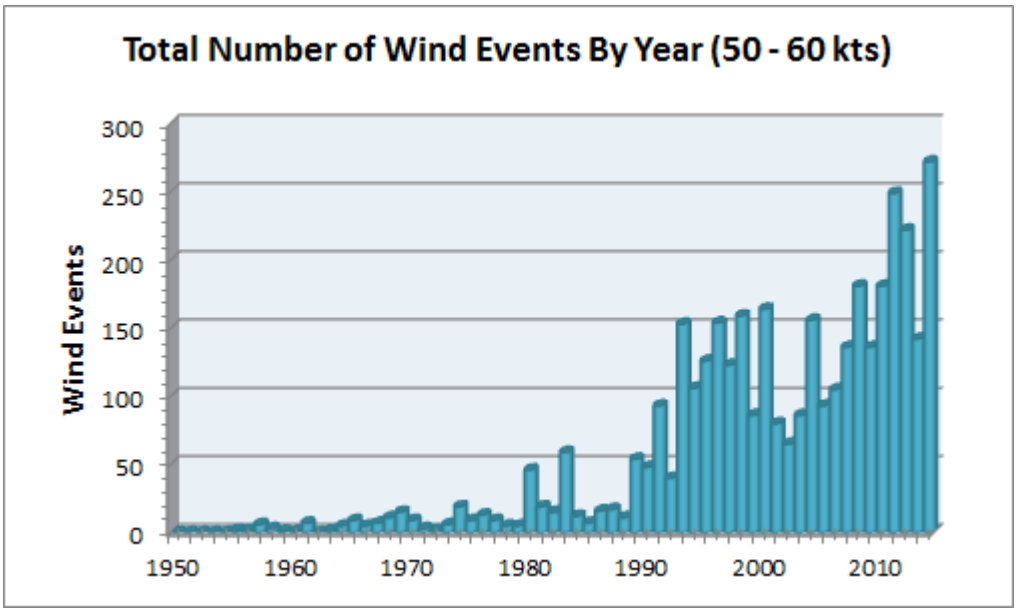


Figure 24

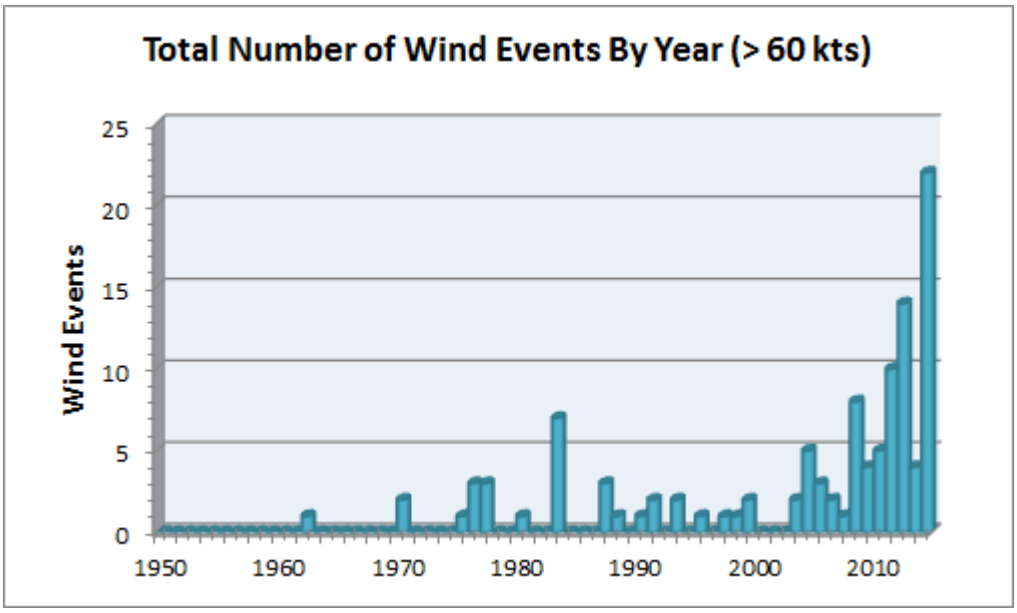


Figure 25

2. *Monthly Frequency*

There is a sharp increase in thunderstorm wind events from March to April (76 events to 327 events, respectively) and a continual increase in events to the peak month of June (Figure 26). The month of June represents 25% (971) of the annual thunderstorm wind events. The months between April and August contain 83% (3226) of the thunderstorm wind events. An equally sharp decline in events occurs between August and September (525 events to 91 events, respectively). The least active months for thunderstorm wind events are December and January during which less than 2%, or 68 events have been documented. Interestingly, thunderstorm wind events of over 60 kts are most likely in July (Figure 28).

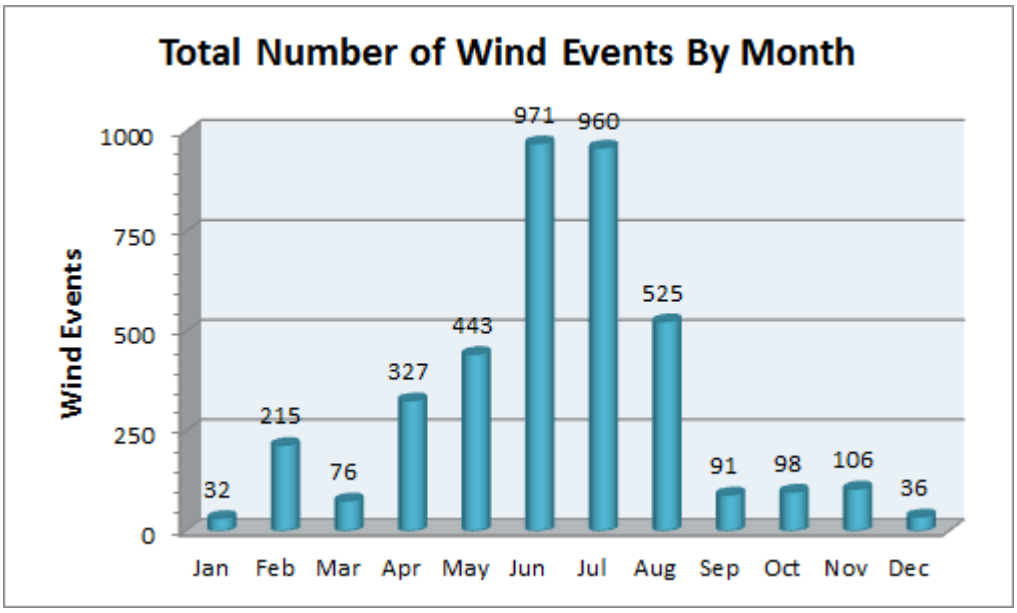


Figure 26

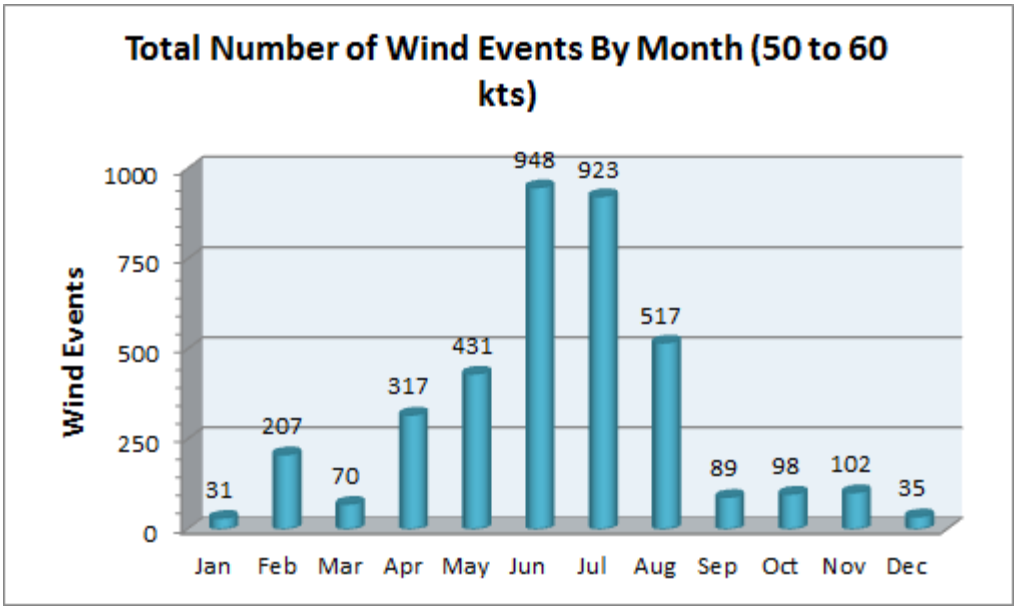


Figure 27

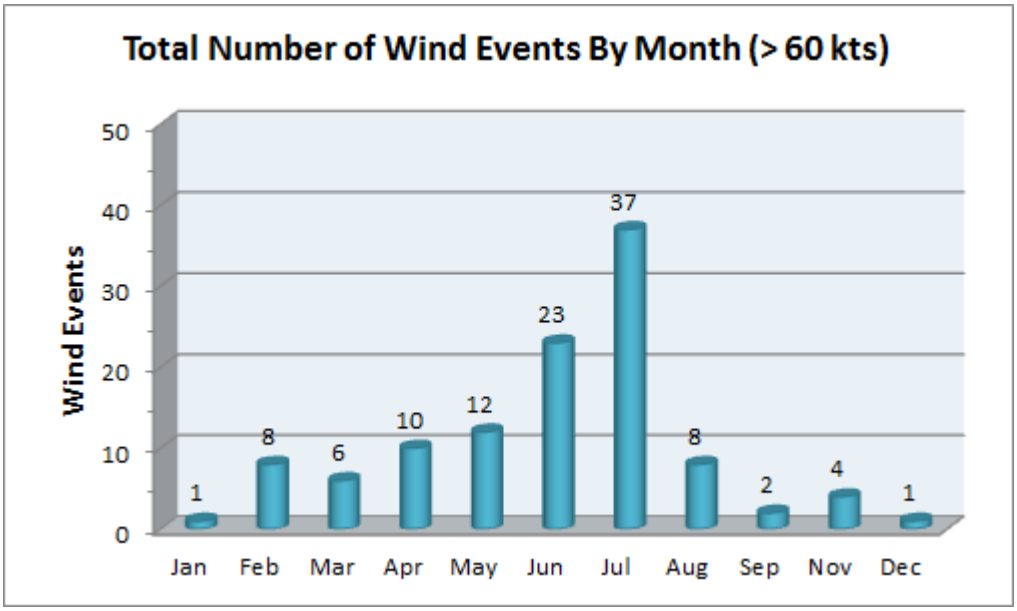


Figure 28

3. *Hourly Frequency*

Thunderstorm wind events are most common during the afternoon and evening hours (Figure 29), 76% (2965) of all thunderstorm wind events occur between noon and 8 PM. Thunderstorm wind events peak between 3 PM and 6 PM, with 38% (1461) of events occurring during this time.
Much like when comparing all severe weather events, wind events have a secondary mode around and just after midnight, this is believed to related Mesoscale Convective Systems (MCS) that develop upstream in the afternoon and push through during the late night hours. Thunderstorm wind events drop off significantly between 3 AM and 8 AM. However, thunderstorm wind events may occur during any hour of the day.

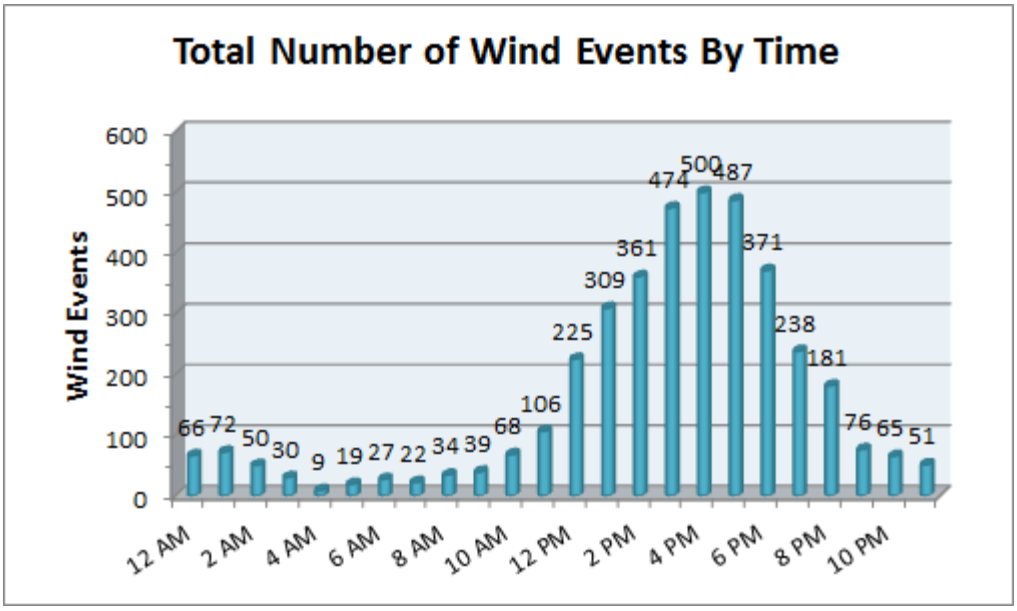


Figure 29

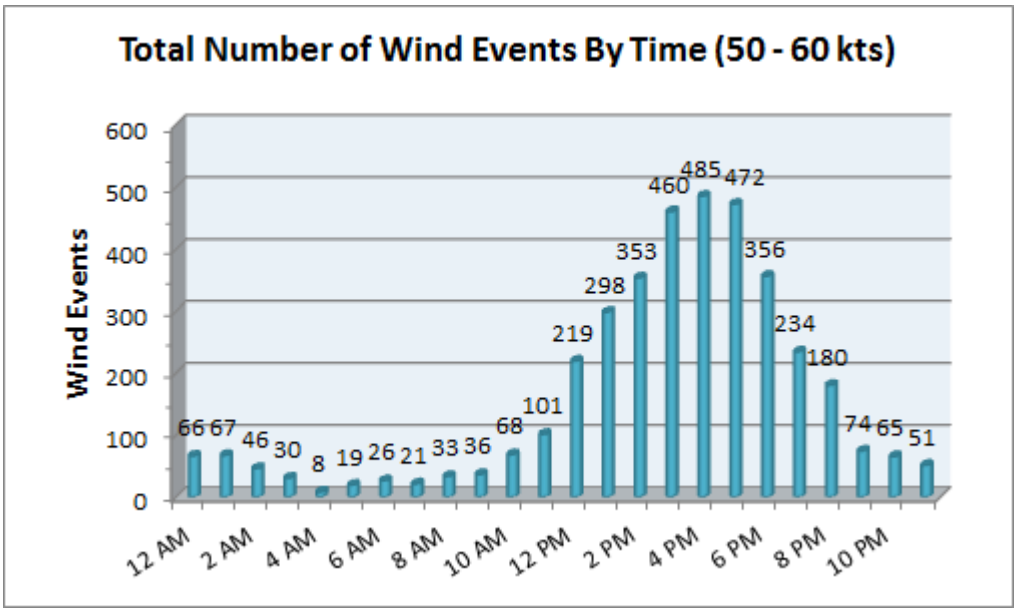


Figure 30

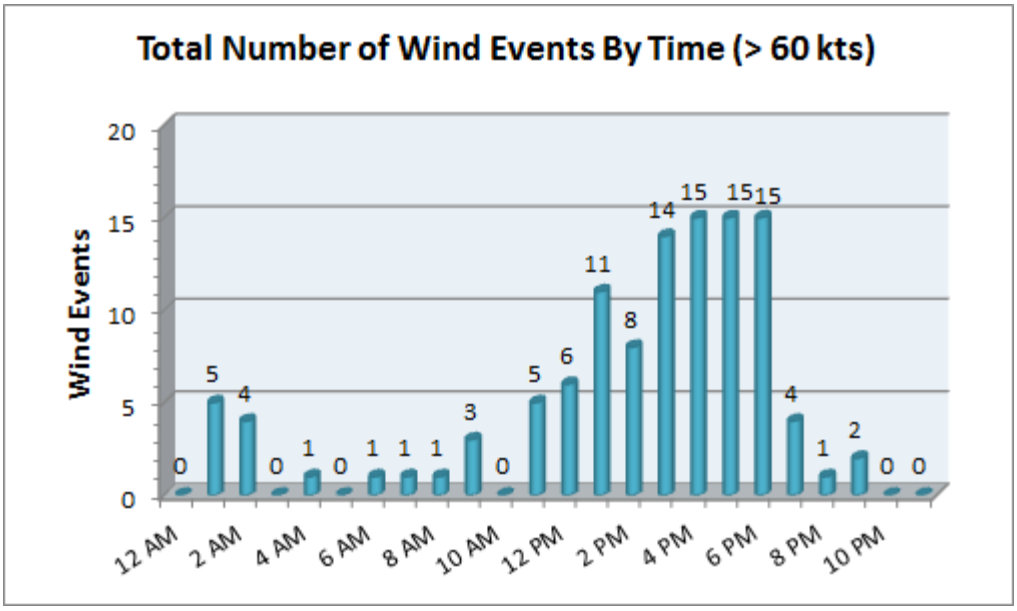


Figure 31

D. Hail Events

Hail reports require special handling when looking at climatology because the criterion for severe hail was changed in 2010. Up to 2010, severe hail was identified as any stones 0.75 inches or larger. However, this was increased to one inch or larger after studies determined that damage is not common with hailstones less than one inch in diameter. This creates a bit of a quandary when looking at severe statistics, especially in the Charleston, WV CWA, where large hail is not as common as other locations, such as the Midwest and Southern Plains. Statistics are still maintained for all hail 0.75” and larger in an effort to keep data sets consistent despite the change in criteria. For the purpose of this study, hail will be broken down into marginal (0.75” to 1”) and large (greater than 1”). There have been 1814 hail events, and event counts vary quite a bit from year to year (Figure 32). Spatial and hot spot maps indicate that hail reports are well correlated with population density (Figures 33-34). It is surmised that a number of hail reports are missed in the more rural and wooded areas of the CWA, where real time observation is less common.

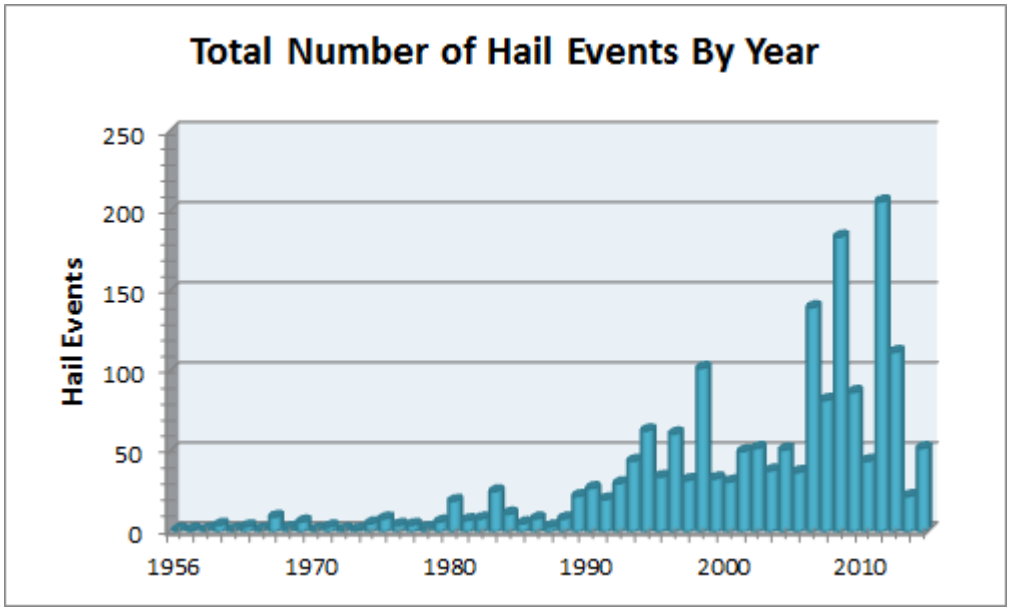
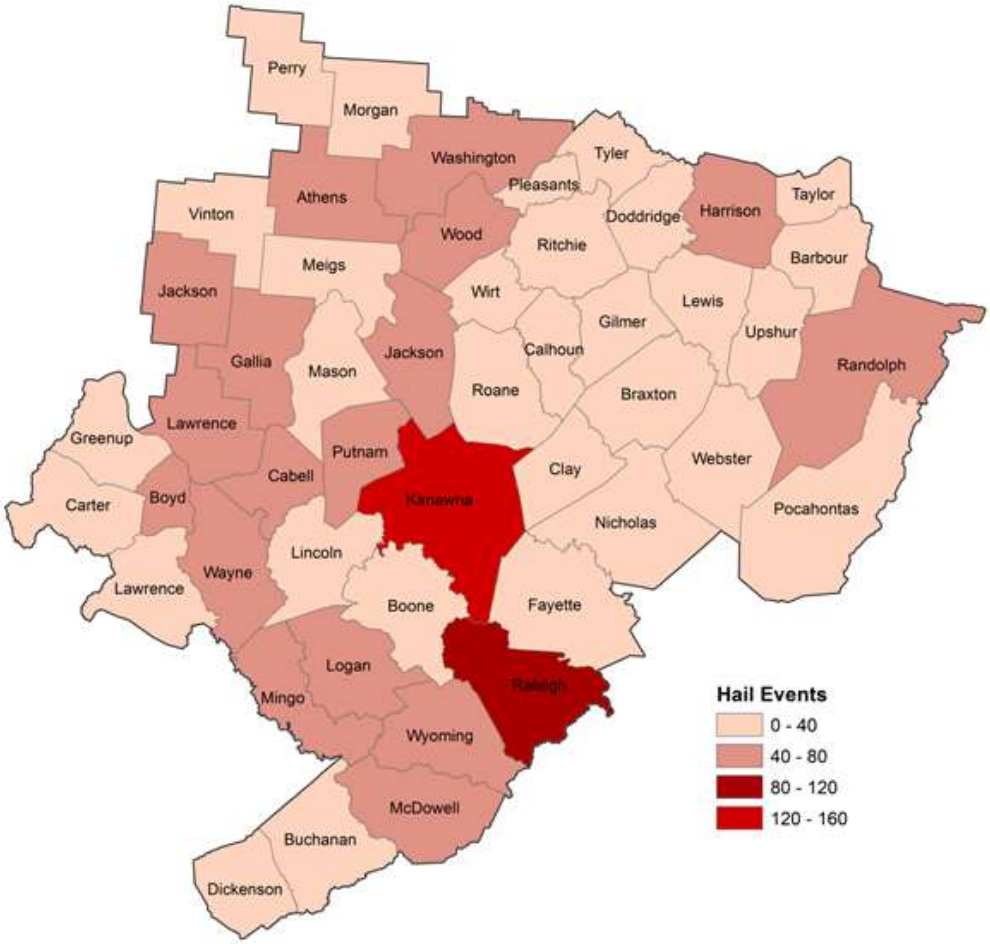


Figure 32


Perry
Morgan
Washington
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Taylor
Ritchie
Barbour
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Lewis
Gilmer
Upshur
Gallia
Mason
Jackson
Calhoun
Randolph
Roane
Braxton
Lawrence
Greenup
Putnam
Webster
Clay
Cabell
Carter
Boyd
Kanawha
Pocahontas
Nicholas
Lincoln
Wayne
Lawrence
Boone
Fayette
Logan
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Wyoming
McDowell
Buchanan
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Hail Events
0 - 40
40 - 80
80 - 120
120 - 160

Figure 33

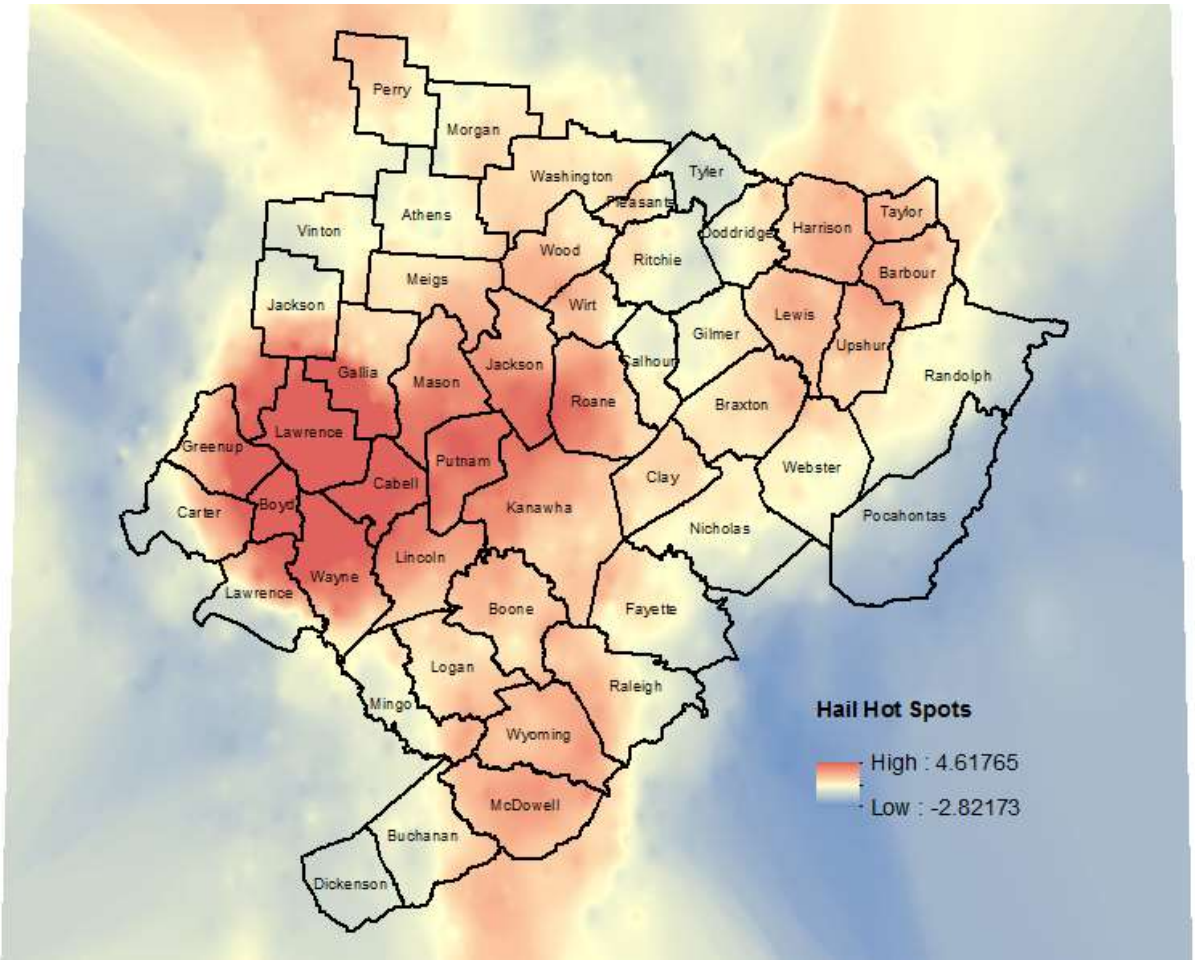

Figure 34

1. *Magnitude*

Large hail is relatively rare in the Charleston, WV CWA. When considering only large (1 inch or larger) hail, there have been 351 events, which is less than 20% of all hail events, and about 6% of all severe events. Just like with all hail events, the yearly count can vary quite drastically (Figures 35-36).

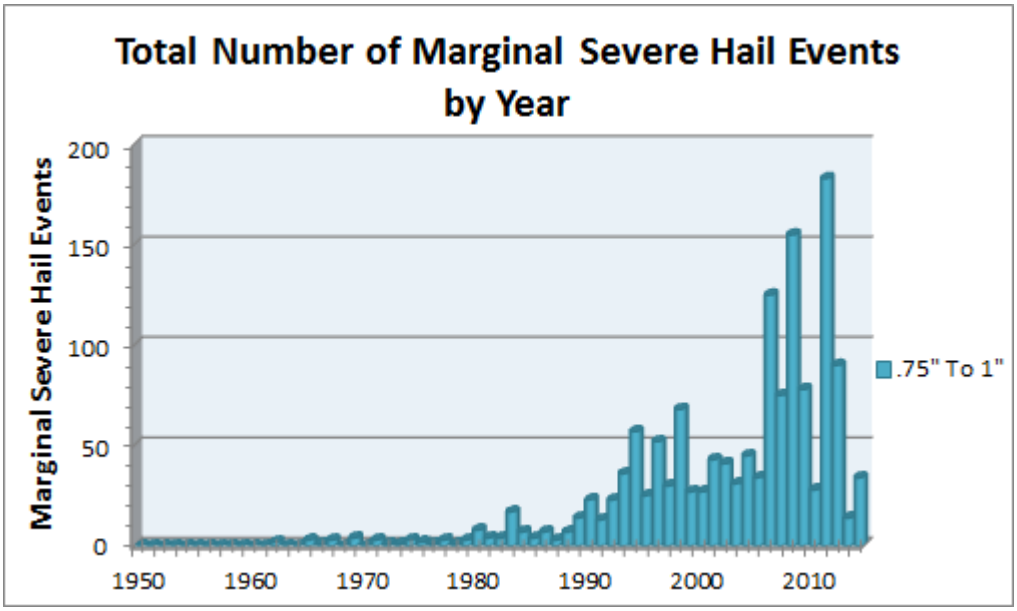

Figure 35

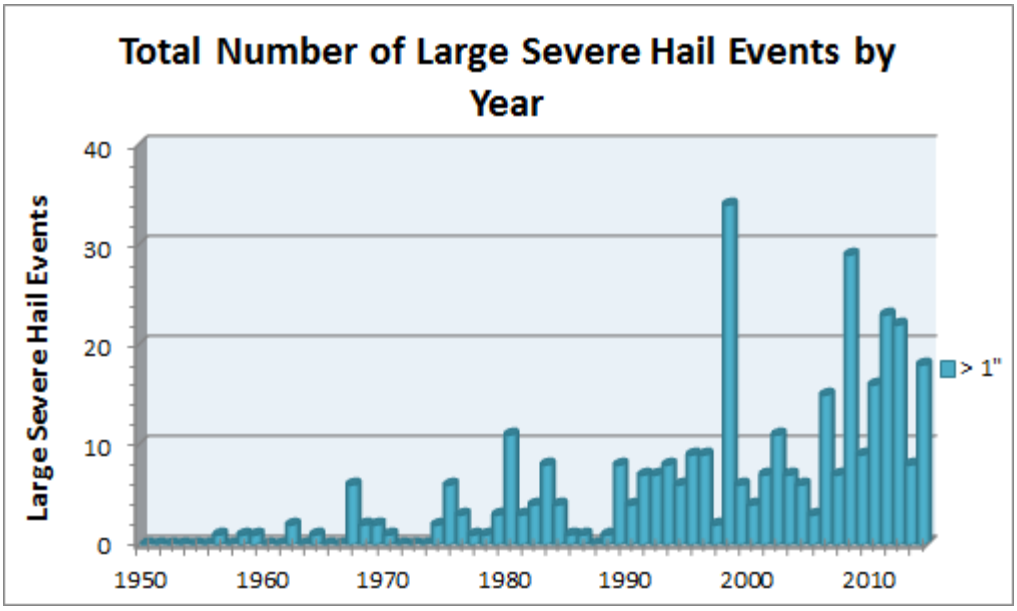

Figure 36

2. *Monthly Frequency*

Typically, the spring and summer months are the most common for thunderstorms which produce hail (Figure 37). There is a sharp increase in the number of hail reports from March (138) to the peak month of June (538). Nearly 80% of the hail events occur from April through July.

There is a significant decrease in thunderstorms that produce hail during the transition from summer to fall (84 events in September compared to 28 events in October). The three month period of November through January is very inactive (32 events). When separating marginal and large hail, the trends remain very similar (Figures 38-39).

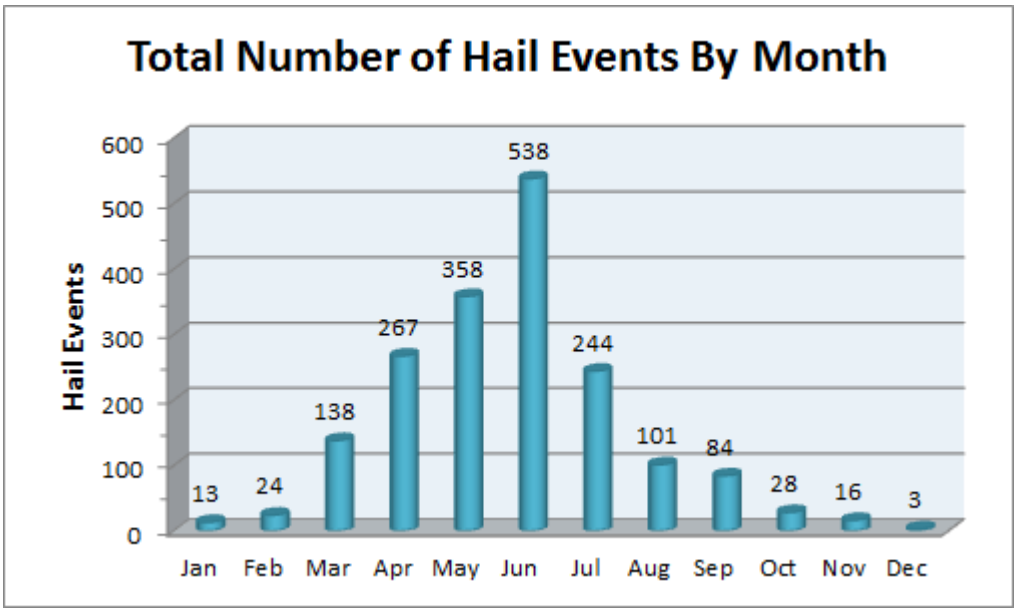

Figure 37

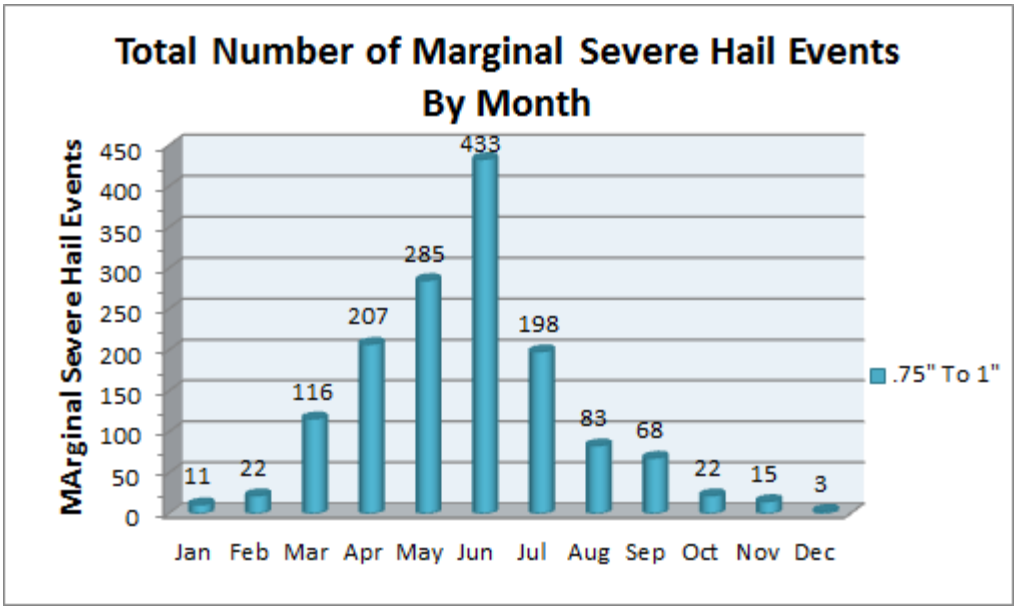

Figure 38

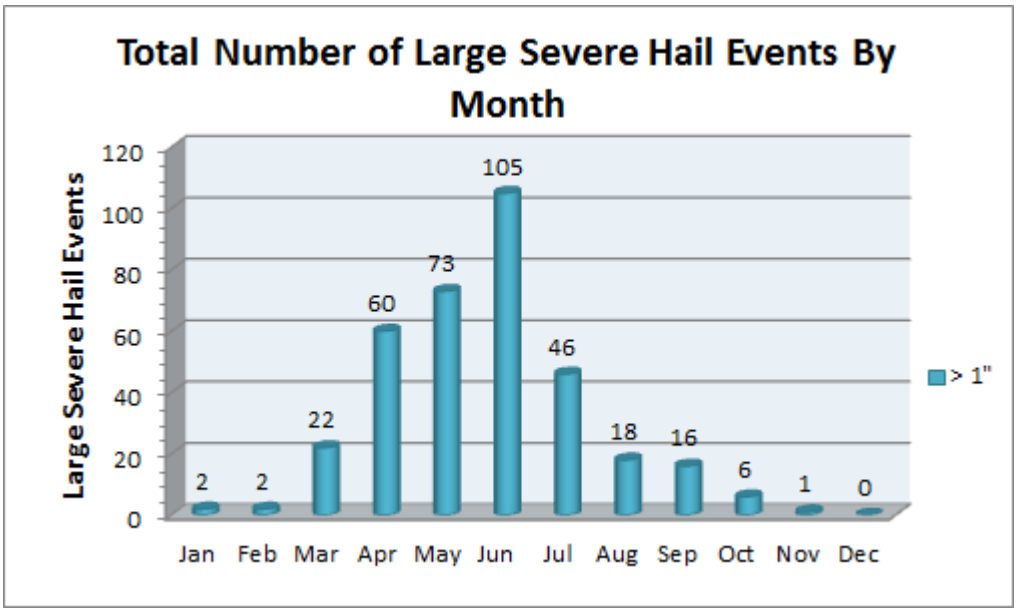

Figure 39

3. *Hourly Frequency*

The frequency of hail events is highest in the afternoon and evening hours (Figure 40). Over 70% (1279) of all events occurred between 1 PM and 7 PM, with the peak occurring between 2 PM and 3 PM. Hail events are least frequent between 1 AM and 10 AM, however much like other severe weather types, hail can occur any time of day. When separating marginal and large hail, the trends remain very similar (Figures 41-42).

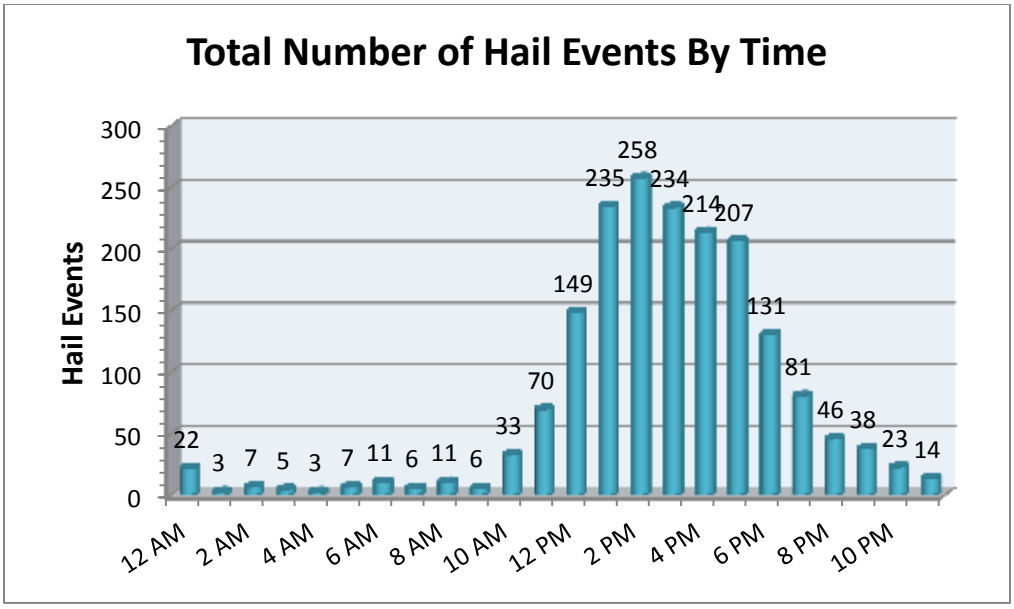

Figure 40

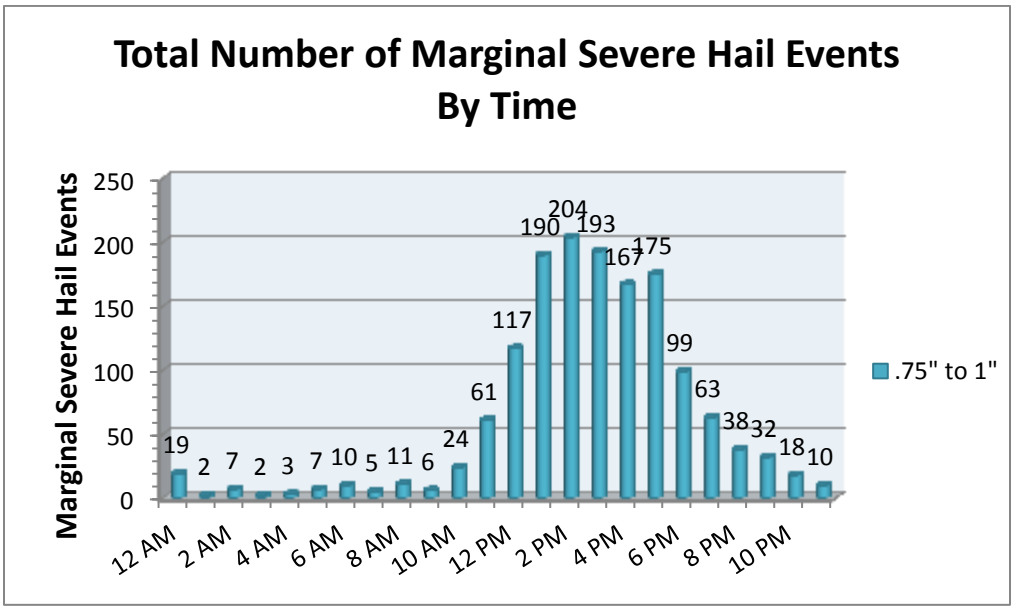

Figure 41

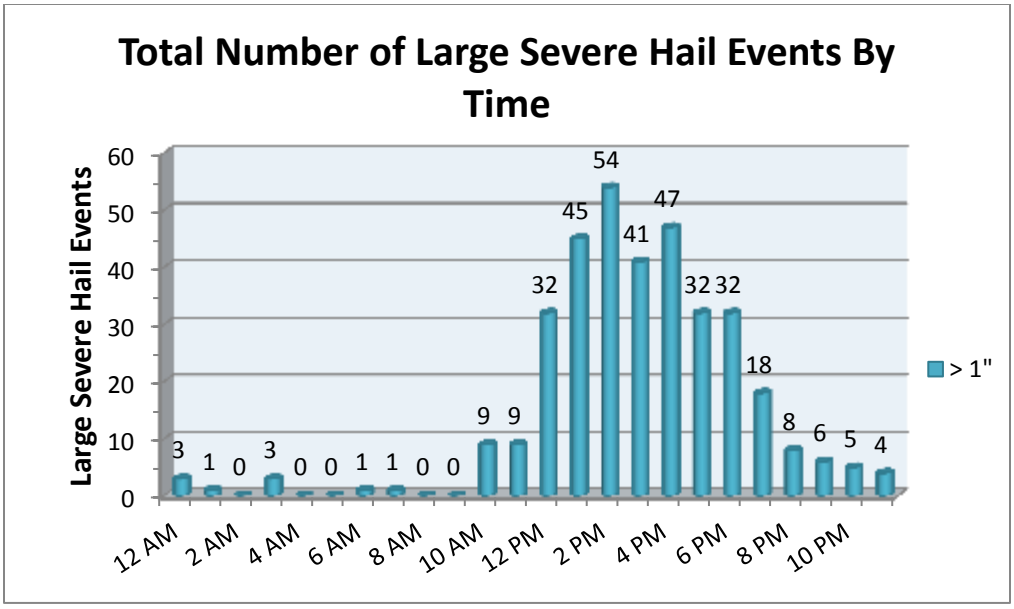

Figure 42

4. SUMMARY AND CONCLUSIONS

- The peak month for all severe modes combined is June, with the period of May through July comprising over 61% of severe events.
- Over 80% of all severe weather events occur during the afternoon and evening, with a peak between 4 and 6 PM.
- Tornado events are not very common in the CWA, with an average of around 2 tornadoes per year.
- Over 92% of tornadoes are rated EF2 or weaker.
- Nearly 75% of all tornadoes occur from April through July, with June being the peak month. The peak period for strong tornadoes is earlier (March and April).
- Tornadoes are most likely to occur in the late afternoon and early evening, with a peak from 5 to 6 PM.
- Thunderstorm wind events are the most frequent type of severe weather, comprising of nearly 70% of all severe events.
- The majority (over 90%) of thunderstorm wind events fall in the low end range of severe criteria (50-60 kts).
- Thunderstorm wind events are most common in the late spring and summer, with a peak in June and July.
- Strong thunderstorm wind events (> 60 kts) are most common in July.
- Over 75% of thunderstorm wind events occur in the afternoon and evening. However, there is a secondary weak peak around and just after midnight.
- Hail reports vary from year to year, likely related to population density and storm paths.
- Large hail (greater than 1 inch) is relatively rare.
- Hail is most likely during the spring and early summer, peaking in June and falling off fairly quickly through the rest of the summer.
- Like other forms of severe weather, hail is most likely during the afternoon and evening, peaking between 2 and 3 PM.

The advantage of establishing a local severe weather climatology is to provide a historical database and resource for the staff at WFO Charleston, WV, to use in efforts of improving severe weather warning service. Becoming familiar with the peak times of year and day that severe weather occurs, the staff will have an increased awareness and will be able to make more informed decisions regarding warnings and staffing needs.