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A SEVERE WEATHER CLIMATOLOGY FOR THE WFO BLACKSBURG, VIRGINIA, COUNTY WARNING AREA

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1. INTRODUCTION

The purpose of this study is to provide forecasters climatological knowledge of the likelihood of severe weather across WFO (Weather Forecast Office) Blacksburg's, VA County Warning Area (CWA). The National Weather Service (NWS) definition of a severe thunderstorm (NWS, 2002) includes one or more of the following criteria: a tornado, hail three-quarters of an inch in diameter or larger, and/or convective winds of at least 50 knots (58 mph) or convective winds which cause damage, including power lines and large trees being blown down. This local severe weather climatological study provides forecasters an improved understanding of the type and frequency of seasonal and diurnal severe weather events, and better prepares them to anticipate such events.

The combination of topography, meteorological forcing and warm low-level moisture can aid the development of strong to severe thunderstorms across WFO Blacksburg's CWA. Warm moist air advecting from the Gulf of Mexico and the Atlantic Ocean is common in the summer months, and when weak frontal boundaries cross WFO Blacksburg's CWA during maximum surface heating time (2:00 to 6:00 pm), organized severe thunderstorms may develop. Other organized convection, such as a Mesoscale Convective System (MCS), moving from the Ohio or the Tennessee Valleys can bring severe weather into the area at any hour, day or night. Most of these MCS's weaken by the time they get to the WFO Blacksburg's CWA either due to loss of instability in the evening or because of typically lower instabilities in the higher elevations. Unorganized convection can also produce severe weather from orographically induced, "pulse" storms, or those that form along convergence zones across the mountains and lee side of the Blue Ridge. In addition to severe weather from deep convection in the spring and summer, the remnants of tropical systems can often produce tornados.

The National Weather Service's primary responsibility is to provide severe weather warnings "for the protection of life and property." The WFO's are tasked with issuing severe weather warnings for their area of responsibility or County Warning Area (CWA). The NWS Forecast Office located in Blacksburg, Virginia (RNK) has forecast and warning responsibility across Southeast West Virginia, Southwest Virginia, and Northwest North Carolina (Fig. 1). WFO Blacksburg CWA includes 40 counties and 11 independent cities (separate local governments not affiliated with any particular county). These counties cover an area from the Appalachians in the west, across the Blue Ridge Mountains, to the Piedmont in the east.

2. DATA

The data included in this study were compiled from 1950 to 2005. Data for this paper were collected from Local Storm Data publications and the National Climatic Data Center (NCDC) Storm Events database located in Ashville, North Carolina. Tornado intensity and track was also supplemented via the NWS Storm Prediction Center (SPC) archived database which includes tornado data from 1950 to 2004. This study consists of 3515 documented severe weather events across the WFO Blacksburg's CWA between 1950 and 2005. All of the times are referenced to Eastern Standard Time.

3. TOPOGRAPHY AND DEMOGRAPHICS OF THE COUNTY WARNING AREA

The topography of the WFO Blacksburg CWA (Fig. 1) is characterized by a rapid increase in elevation from southeast to northwest, starting from less than 1000 feet in the Piedmont, to mountainous terrain of 3200 to 5000 feet in the higher elevations of the Blue Ridge and Appalachian mountains of western Virginia (VA), southeastern West Virginia (WV), and northwestern North Carolina (NC).

WFO Blacksburg's CWA is approximately 20000 square miles and has a population of roughly 1.7 million. A majority of the population (1.1 million) resides in counties (Fig. 2) along and east of the Blue Ridge in Central Virginia, and Northwest North Carolina. The largest population centers east of the Blue Ridge are the independent cities of Roanoke (ROA), Lynchburg (LYH), and Danville (DAN), Virginia. Along and west of the Blue Ridge, the majority of the population lives in river valleys, particularly in the New River Valley of Virginia and the Greenbrier Valley of Southeastern West Virginia.

A majority of the WFO Blacksburg CWA is comprised of rural farmland or is heavily forested, and therefore sparsely populated, with only a few moderate populated cities. Thus, most counties have a very low population density, with a few obviously influenced by higher populated centers (Fig. 3). This uneven distribution of people across the CWA can lead to skewing of observed severe weather events toward the more heavily populated areas, especially before the Skywarn volunteer spotter network was increased significantly in the mid-to-late 1990s.

4. SEVERE WEATHER CLIMATOLOGY

4.1 ALL SEVERE WEATHER EVENTS

Monthly Frequency

Of 3515 documented events from 1950 to 2005, some form of severe weather (tornados, severe hail, and/or thunderstorm wind damage) has occurred within the WFO Blacksburg CWA in each of the 12 months. Monthly distribution of events is represented by a "bell-shaped" curve with a peak in late Spring and Summer (Fig. 4). The peak month for severe weather was May, where over 25% (891) of all events occurred. June and July are the 2nd and 3rd most active months for severe weather with 22.4% (786) and 21.9% (771) respectively. Overall, nearly 70% (2448) of all severe weather events occurred during the months of May, June, and July. Depending on global weather patterns, transitional months of April and August have a moderate showing of severe weather of 8% (297) and 12% (406) respectively.

Hourly Distribution

The vast majority (84%) of all severe weather events occurred between 12:00 pm and 8:00 pm (Fig. 5). A little over half of all severe weather events (54%) transpired between 2:00 pm and 6:00 pm, which coincides with peak surface heating. An additional 16% (567) of all severe weather events occurred during the early evening hours (6:00 pm to 8:00 pm) when instabilities are still high.

Typically, the atmosphere becomes more stable as the temperature decrease rapidly after 10:00 pm. However, Mesoscale Convective Systems (MCS) have occasionally occurred within the WFO Blacksburg CWA, often at night. A minimum number of events (about 2%) occurred from 1950 to 2005 during typical diurnal cooling from 2:00 am to 8:00 am.

4.2 TORNADO CLIMATOLOGY

Only 132 tornados have been reported across the WFO Blacksburg CWA from 1950 to 2005. A majority of the tornados (70%) touched down east of the Blue Ridge and mainly along and south of the Virginia and North Carolina state border (Fig. 6). West of the Blue Ridge, 40 (30%) tornados have been reported across the mountains of southeast West Virginia, southwest Virginia, and northwest North Carolina. Greater instability and lee side convergence likely played a role in creating more favorable environments for tornados east of the Blue Ridge. This difference may also be due in part to the lower population density across the mountains. On average, two tornados touched down within the WFO Blacksburg CWA per year.

Monthly Frequency

Fifty seven percent of the tornados occurred during the Spring and Summer months of April through July (Fig. 7). There is a secondary maximum of tornado (8 of 18 total for the month) occurrences in September, which is due to land-falling tropical system or their remnants. A few tornados have also occurred during the winter months, although none have been reported in December, between 1950 and 2005.

Hourly Distribution

The majority of the tornados (71%) occurred during the afternoon and early evening hours between 12:00 pm and 8:00 pm (Fig. 8). This time coincides with the typical hours of peak surface heating and maximum instability, especially during the summer. The vertical wind shear associated with cold frontal passages in the spring increases the potential for tornado development.

Magnitude

A majority (76%) of the 132 tornados reported between 1950 and 2005 (Fig. 9), were considered weak (F0-F1) based on the Fujita Scale (Fujita, 1981). The Fujita Scale (Table 1) is used to rate the intensity of a tornado by examining the damage caused by the tornadic winds. The other 24% (32) were classified as strong (F2-F3) tornados. More strong tornados occurred in the month of April than any other month. This was likely due to strong cold fronts still moving through the region in the spring. In fact, about half of all tornados in April (9 of 19) were classified as strong, i.e., F2 and F3 (Fig. 10). As evidenced by the historical track data (Fig. 6), the stronger and longer track tornados within the WFO Blacksburg CWA are usually confined to the Piedmont and Foothill regions and along the state border of Virginia and North Carolina. The most recent strong tornado (F2) in the WFO Blacksburg CWA was Stewartsville, VA, in Bedford County on 17 September 2004, and was associated with remnants from Hurricane Ivan. The strongest (F3) tornado in the CWA was Rockingham County, North Carolina on 20 March 1998, which produced most if its damage, including two fatalities, in Stoneville,

North Carolina. Six additional F3 tornados occurred, including Buckingham County (June, 1966), Halifax County (March, 1969), Greenbrier County (April, 1974), Smyth County (April, 1974), Surry County (April, 1978), and Charlotte County (October, 1986). The Greenbrier tornado, which was part of the 1974 Palm Sunday Super Tornado Outbreak, was the most significant, with a path length covering 18 miles, resulting in over 2 million dollars in property damage. The remainder of the F3 tornados were short-lived and did not cause as extensive damage as the Stoneville tornado. To this date, no violent tornados have been reported across the WFO Blacksburg CWA since 1950.

Associated with Tropical Systems

During hurricane season, tropical systems or their remnants can track through the Mid-Atlantic region and affect the Blacksburg CWA (Hudgins, et. al 2005). Seventeen percent (22) of all the tornados reported since 1950 have come from these tropical entities (Fig. 11). Of these, almost all (90%) were classified as weak (F0-F1) and touched down in the Piedmont of North Carolina and South Central Virginia. The other two tornados were of the stronger F2 variety and affected Stewartsville in Bedford County and Fieldale in Henry County on September 17, 2004 (remnants of Hurricane Ivan). These resulted in significant property damage to vehicles and structures, especially in Henry County where property damage of over 53 million dollars occurred. These tropical cyclone-induced tornados result in the secondary spike seen in September (Fig. 7). The most notable contribution to this maximum was from the September 17, 2004 tropical tornado outbreak associated with remnants of Hurricane Ivan. Five tornados tracked across the Foothills and Piedmont of Virginia, as well as Northwest North Carolina on this day. Three other September tornados were from the remnants of Hurricane Able (September, 1952), Frances (September, 2004), and Jeanne (September, 2004).

4.3 HAIL CLIMATOLOGY

Monthly Frequency

Of the1456 severe hail events (hail diameter exceeds 0.75 inches) across the WFO Blacksburg CWA since 1950, 87% (1268) of the reports occurred from April through July (Fig. 12). May is the peak month for the occurrence of severe hail, with 37% (541) of the events reported, as the freezing level is still relatively low. Autumn and Winter (October through February) is the least likely time to expect severe hail with only 13 events occurring since 1950. December is the only month with no reports of severe hail.

Hourly Distribution

The data showed that a vast majority of severe hail events (89%) usually occurred between 12:00 pm and 8:00 pm (Fig. 13), with 59% during the peak surface heating hours of 2:00 pm and 6:00 pm. This is similar to the curve for the hourly distribution of tornados, but with a slightly stronger diurnal signal.

Magnitude

Hail of 0.75 to1.00 inch constitutes 78% (1130) of all severe hail reports in the WFO Blacksburg CWA (Fig. 14). Only 20% (292) of the severe hail measured between one and two inches. Very large

hail, with a diameter of greater than 2 inches, was rare but did occur 2% (34) of the time between 1950 and 2005. The largest reported hail on record in the WFO Blacksburg CWA was softball size (4.0 inches), occurring 2 June 1998 in Boone, NC (Watauga County).

4.4 CONVECTIVE DAMAGING WIND CLIMATOLOGY

Monthly Frequency

The minimum wind speed for a thunderstorm to be considered severe is 58 mph (50 knots). The majority (82%) of the severe convective wind events occurred during the late Spring and Summer months of May through August (Fig. 15). Most of the events were associated with organized systems such as Mesoscale Convective Systems (MCS) as well as decaying pulse thunderstorms. A similar distribution curve compared to hail is observed, however, severe wind events maximize a little later in the summer with a peak in July (527).

Hourly Distribution

The diurnal distribution of convective severe winds were similar to that of severe hail, with the peak corresponding to maximum heating between 12:00 pm and 8:00 pm (Fig. 16). Eighty two percent (1570) of severe wind events occurred during this time, and 50% (967) occurred between the hours of 2:00 pm and 6:00 pm. Similar to the curve from the hourly distribution of severe hail, a decline in activity occurs at night, although the overall diurnal signal is slightly less pronounced (it doesn't drop off quite as sharply overnight).

5. CONCLUSIONS

The severe weather climatology for the WFO Blacksburg CWA is a historical resource for forecasters to use to increase their awareness prior to a severe weather event. Knowledge of the type and frequency of seasonal and diurnal severe weather events, as well as the local topography and demographics will greatly enhance severe weather warning decisions for the protection of life and property.

- If a storm does become severe, 55% of the events are from convective winds, 41% are from hail, and less than 4% are tornados, of which, 17% are from tropical systems.

- Tornados that touch down in the WFO Blacksburg CWA are generally east of the Blue Ridge and near the North Carolina and Virginia border.

- On average, two tornados touch down within the WFO Blacksburg CWA per year.

- Tornados developing within the WFO Blacksburg CWA usually occur between the months of April and July. There is a secondary peak of tornado touch downs in September. No tornados have been reported in the month of December.

- The majority (71%) of the tornados occur between 12:00 pm and 8:00 pm with a diurnal peak between 2:00 pm and 6:00 pm (49%).

- Weak tornados account for 76% of all the tornado events. Of the strong tornados (24%), most occur during the month of April. No violent tornados have been reported within the CWA.

- Ninety percent of the tropical cyclone-induced tornados are weak tornados.

- Severe hail occurs most often between the months of April and July (87%). The peak month for severe hail is May. No severe hail was reported in the month of December.

- The majority (89%) of severe hail occurs between 12:00 pm and 8:00 pm with a diurnal peak between 2:00 pm and 6:00 pm (60%).

- Severe hail of 0.75 to 1.00 inch constitutes 78% of all severe hail reports.

- Severe thunderstorm wind events are most likely to occur between the months of May and August (82%), with a seasonal peak in July.

- The majority (82%) of severe thunderstorm damaging winds occur between 12:00 pm and 8:00 pm, with a diurnal peak between 2:00 pm and 6:00 pm (50%).

ACKNOWLEDGMENTS

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FIGURES

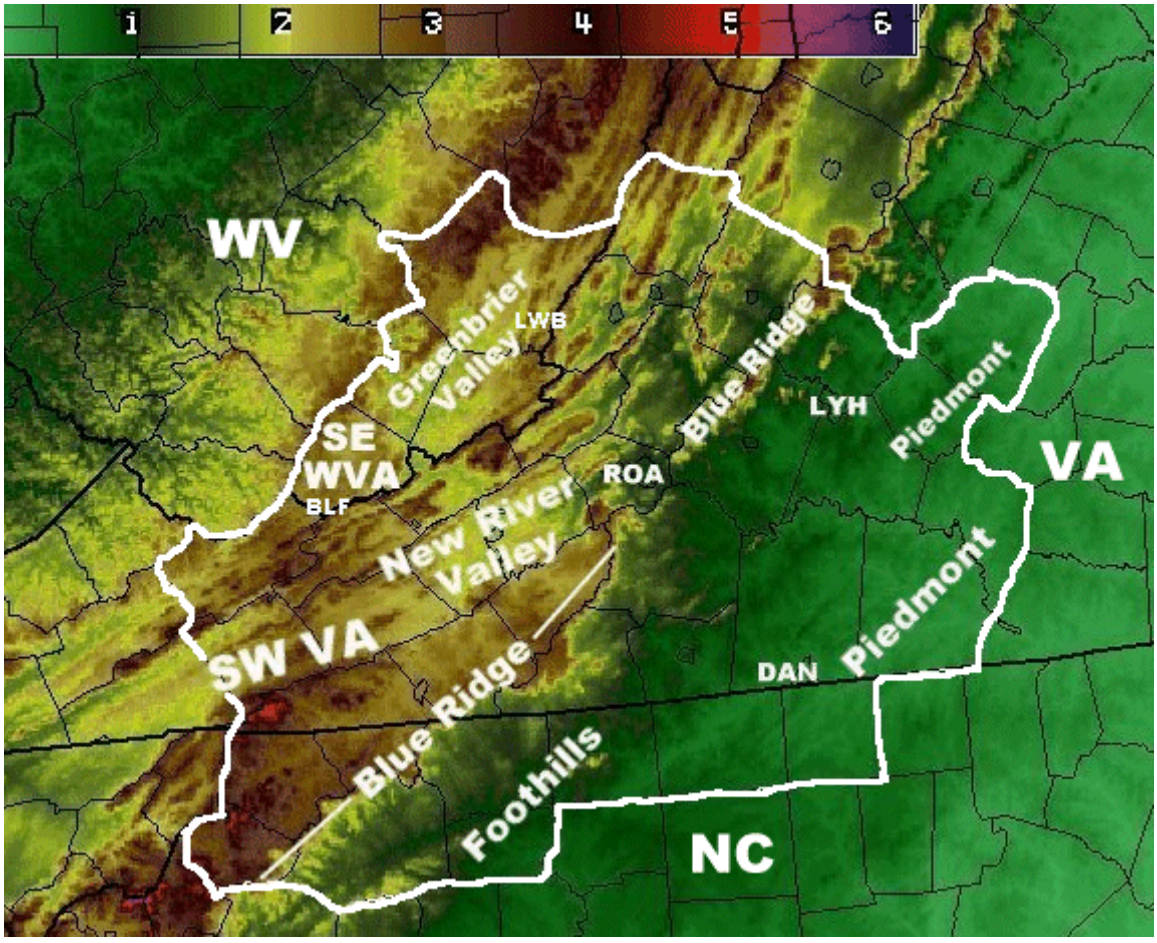

Figure 1. WFO Blacksburg, VA, (RNK) County Warning Area (white border) and regional/topographical map indicating geographical areas (scale in thousands of feet).

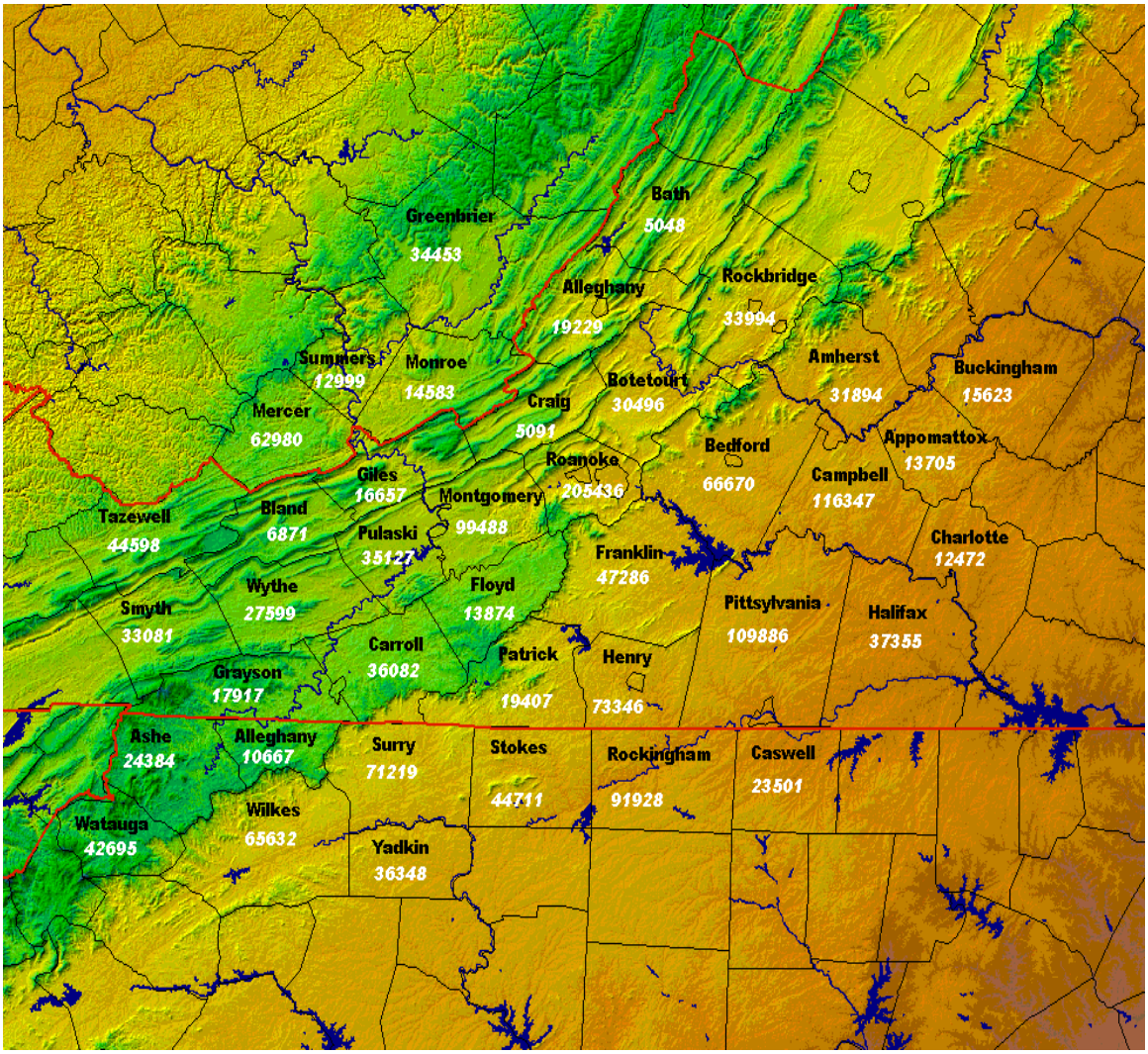

Figure 2. County population in thousands by county (white) based on 2000 Census Data.

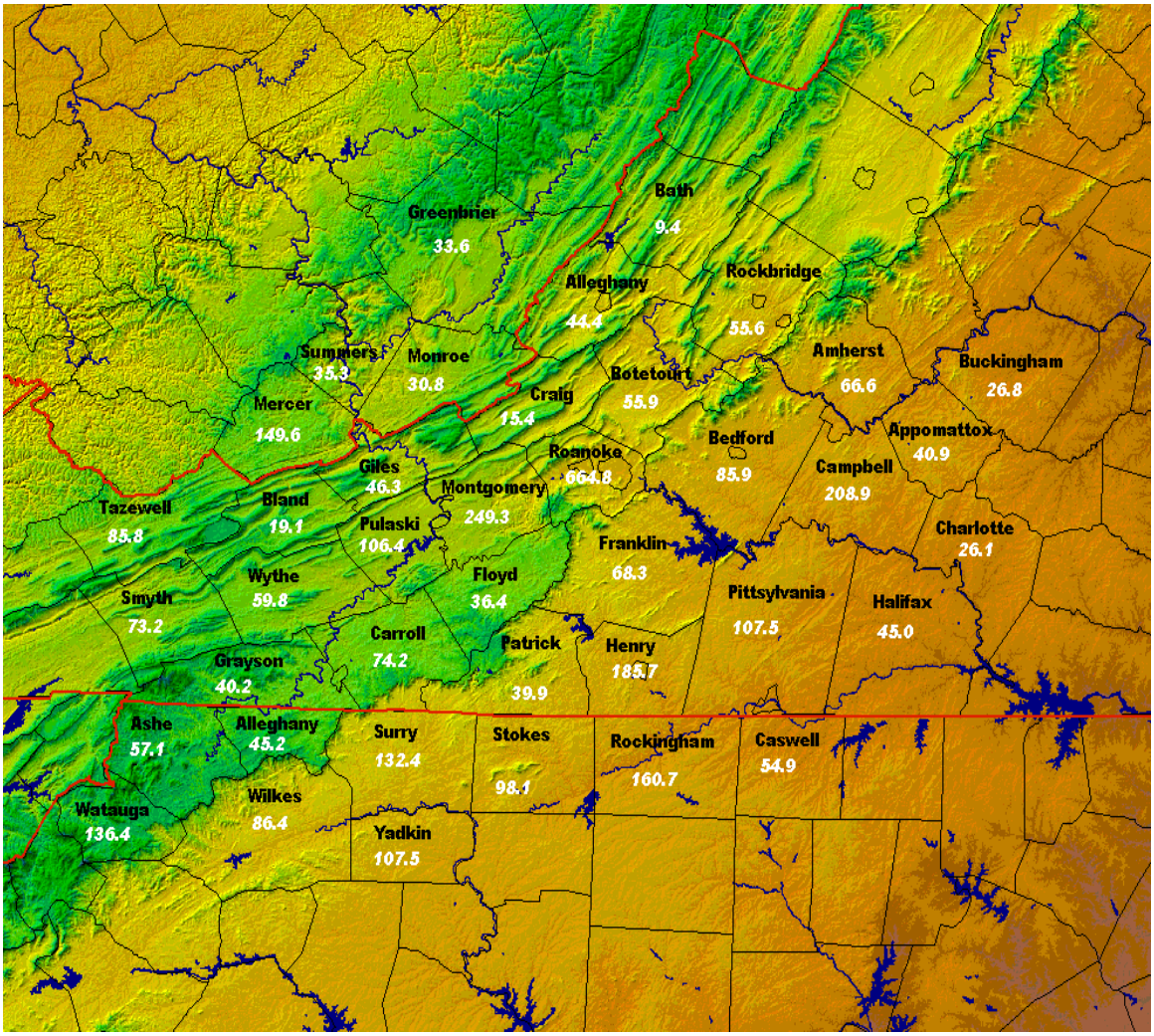

Figure 3. Population density (persons per square mile by county) (white) based on 2000 Census Data.

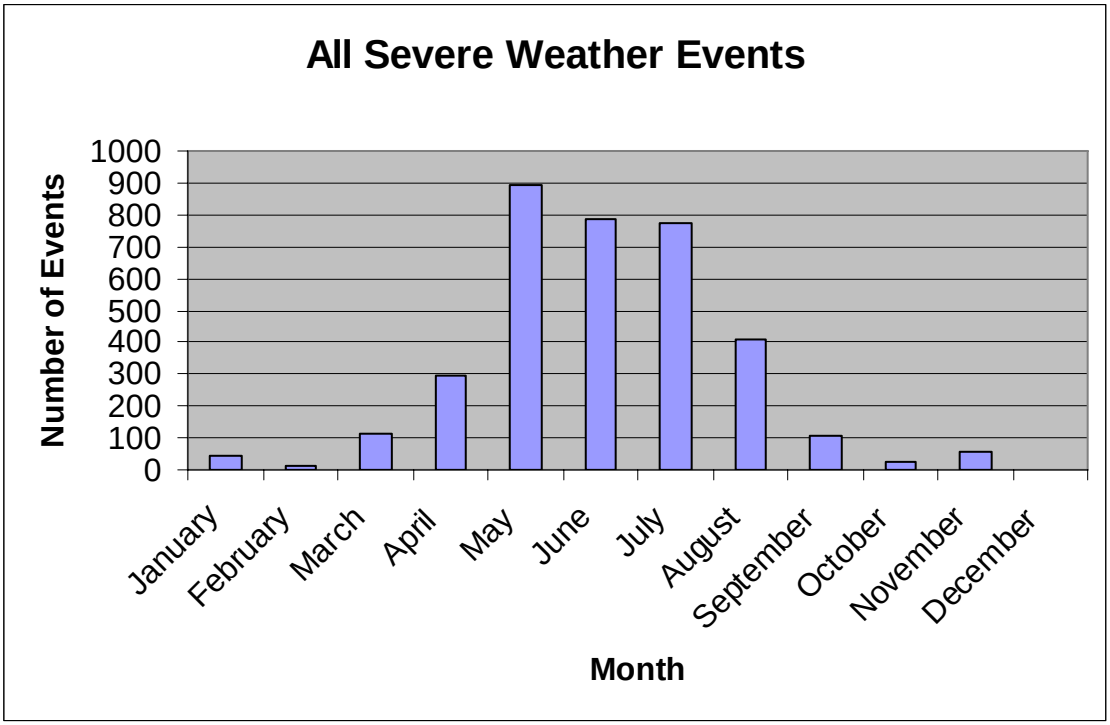

Figure 4. Total number of severe weather events by month from 1950 to 2005.

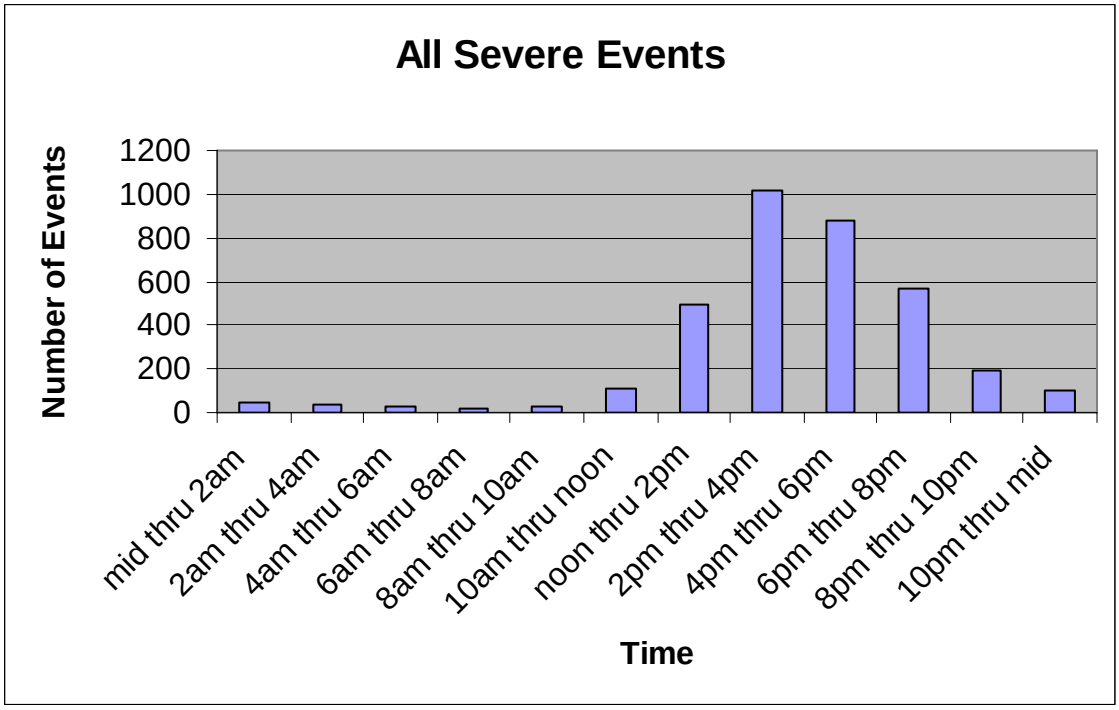

Figure 5. Severe thunderstorm wind events by time (1950-2005).

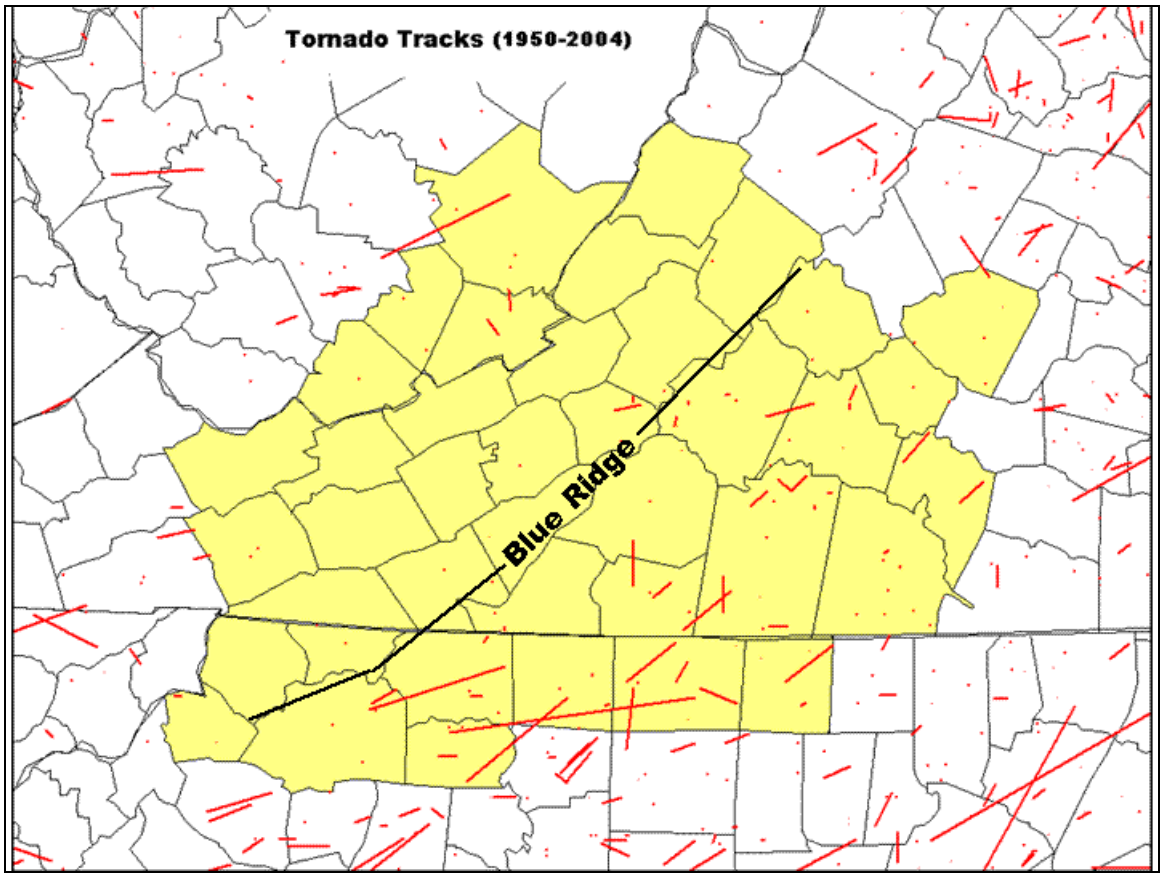

Figure 6. Historical tornado tracks (red lines) from 1950 through 2004. Yellow highlighted area depicts WFO Blacksburg CWA. (Note: Data for 2005 was not available for plotting at the time of this publication. Data courtesy of the Storm Prediction Center, Norman, OK).

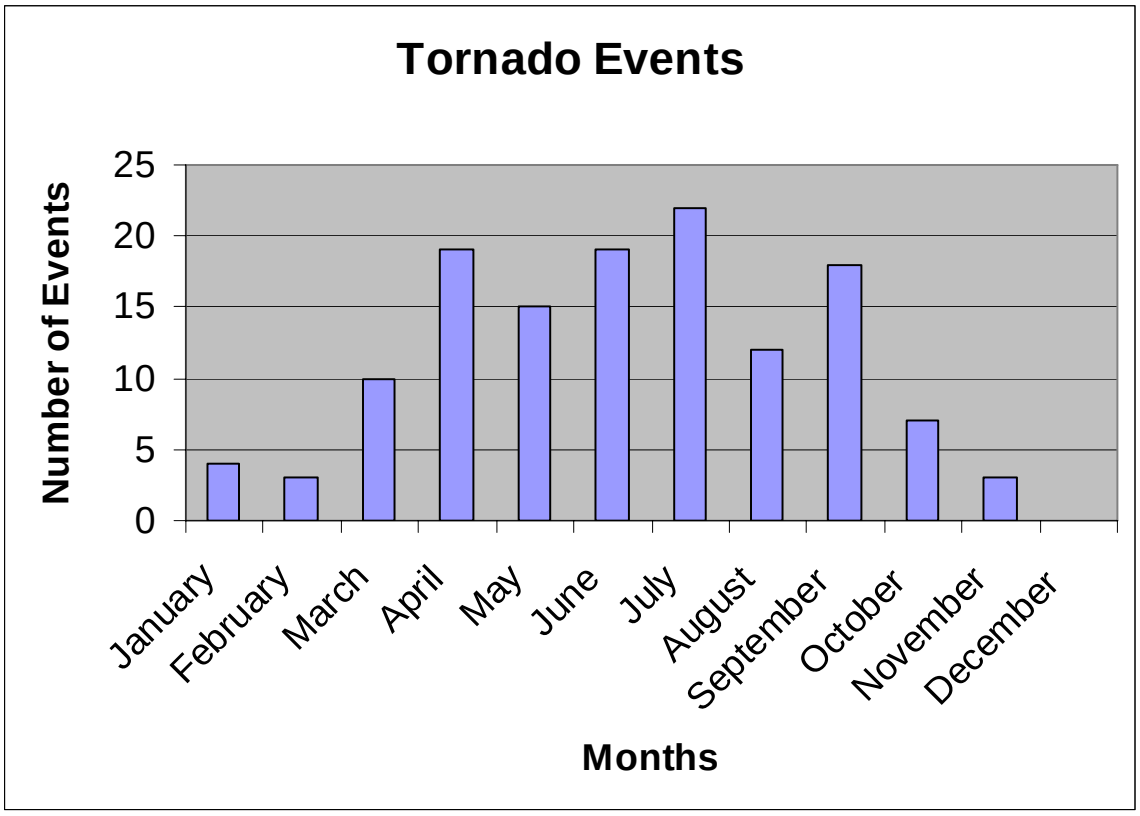

Figure 7. Tornado events by month (1950-2005).

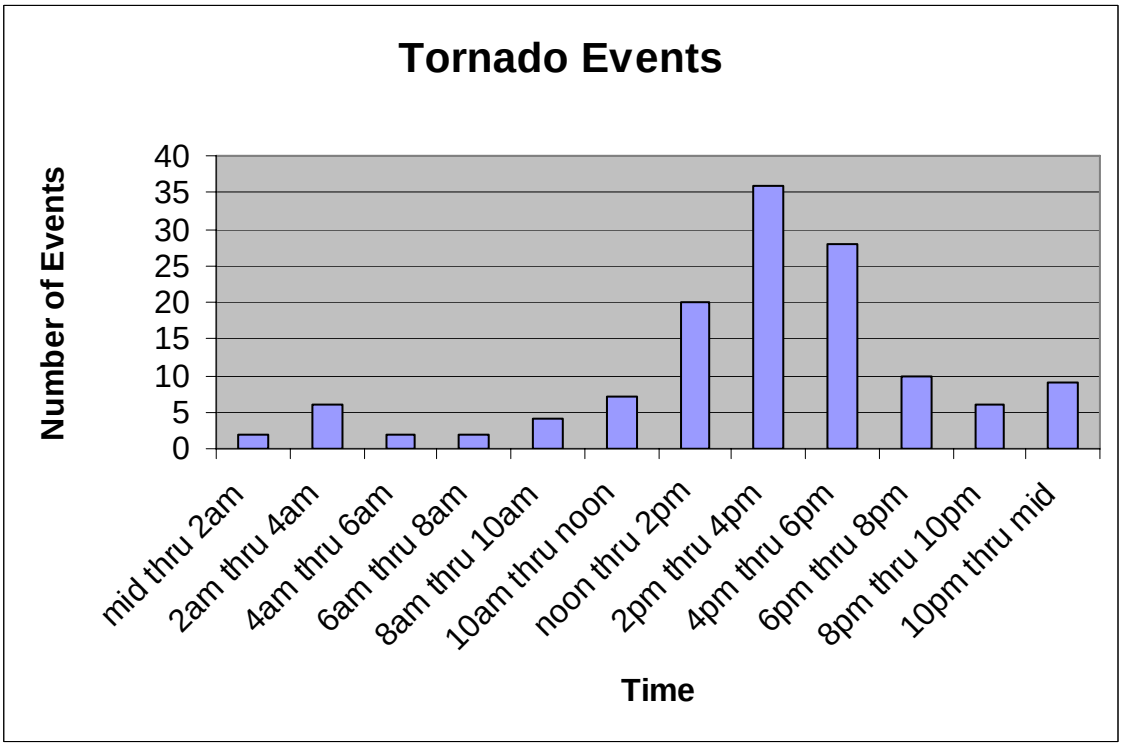

Figure 8. Tornado events by hour (1950-2005).

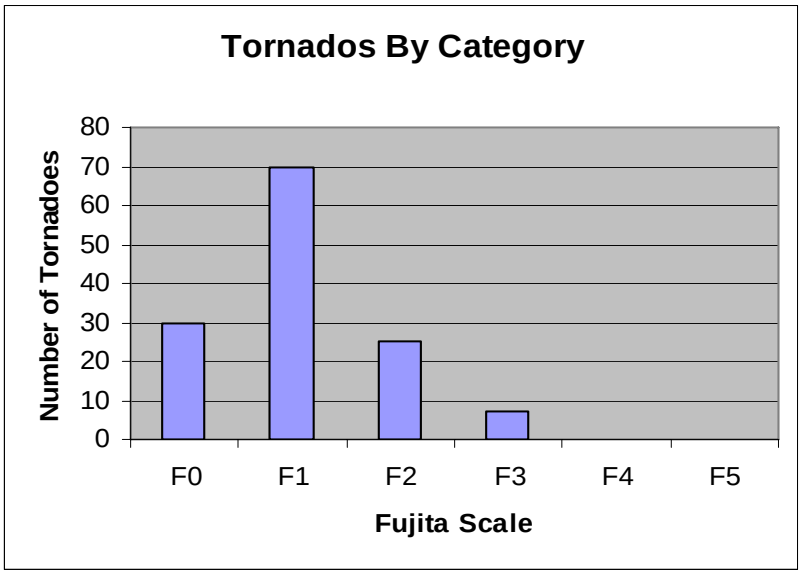

Figure 9. Tornados by the Fujita Scale (F0-F5) (1950-2005).

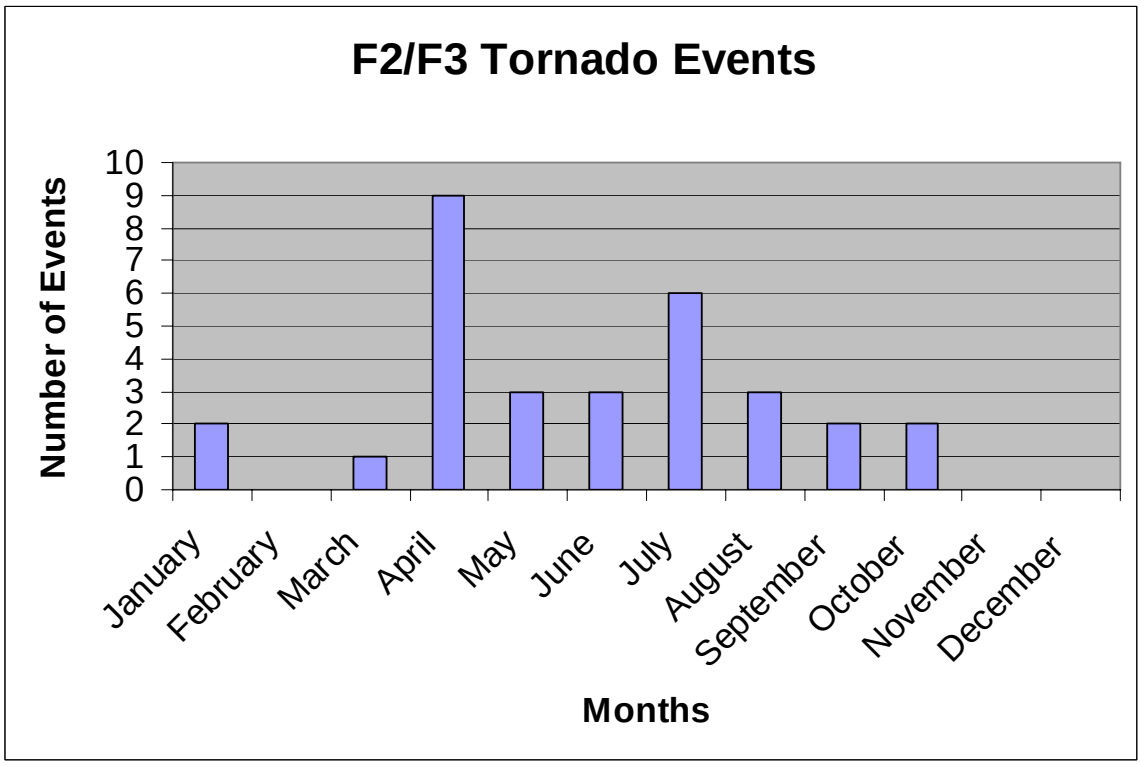

Figure 10. Strong (F2-F3) tornados across WFO Blacksburg CWA (1950-2005).

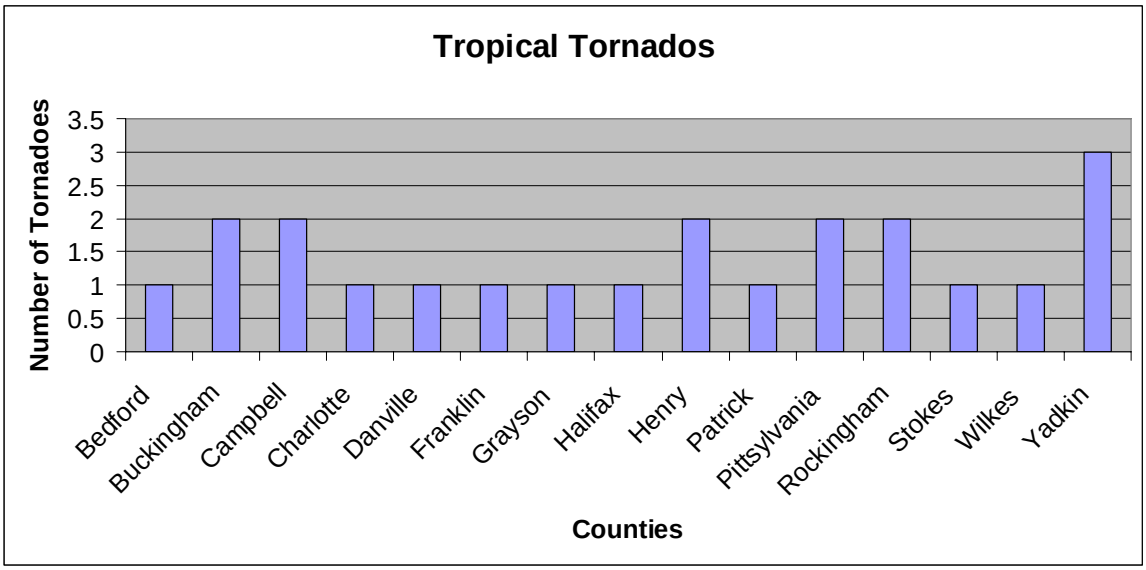

Figure 11. The number of tornados with tropical systems by county (1950-2005).

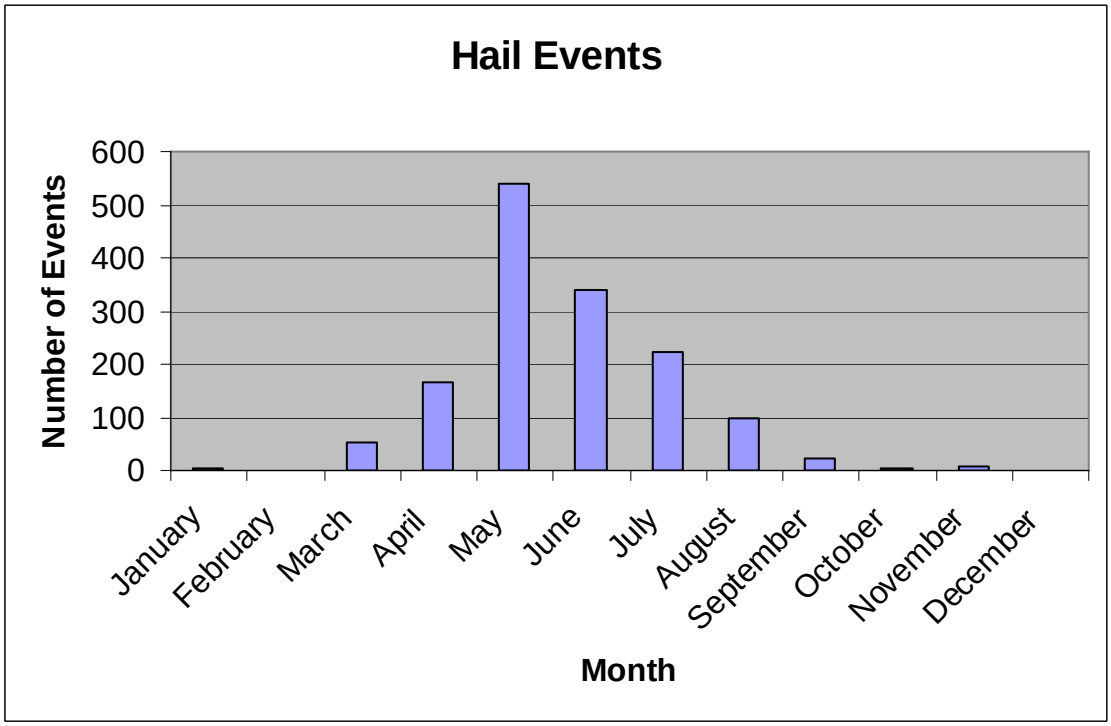

Figure 12. The distribution of hail events by month (1950-2005).

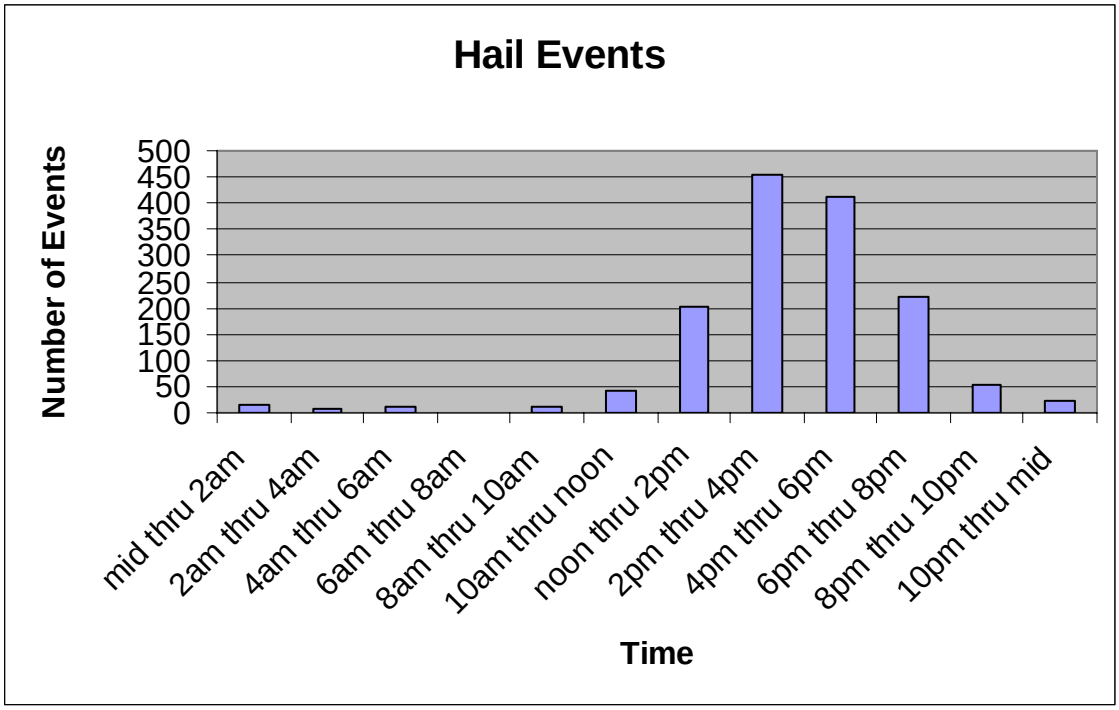

Figure 13. The distribution of hail events by hour (1950-2005).

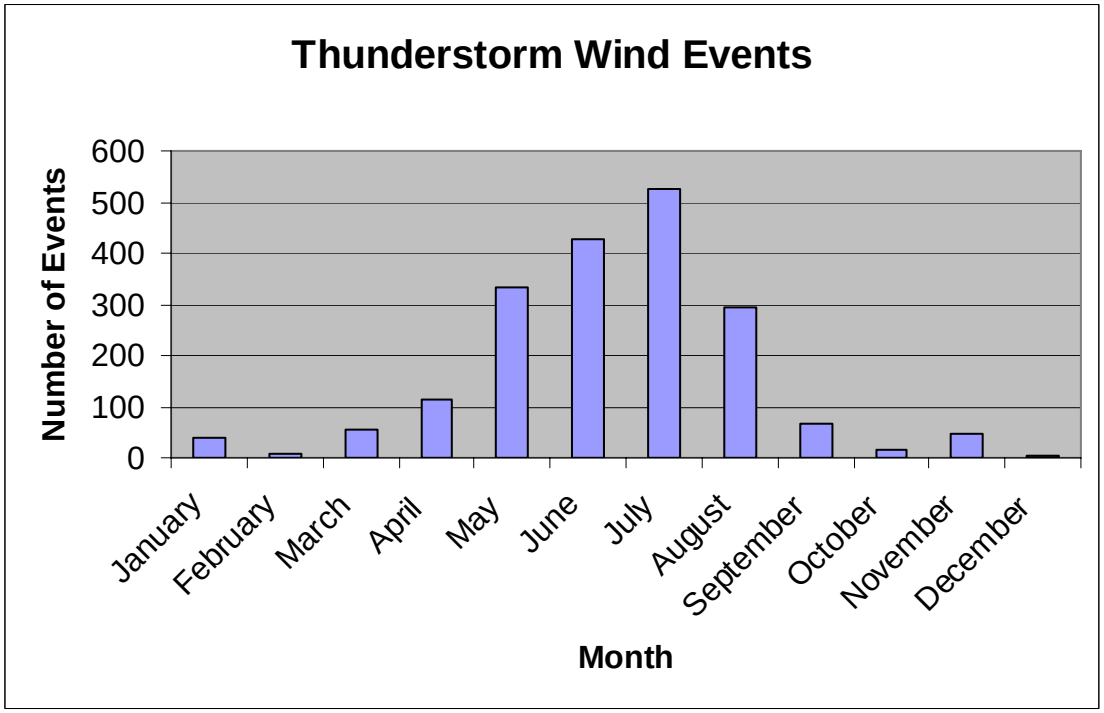

Figure 14. Severe thunderstorm wind event distribution by month (1950-2005).

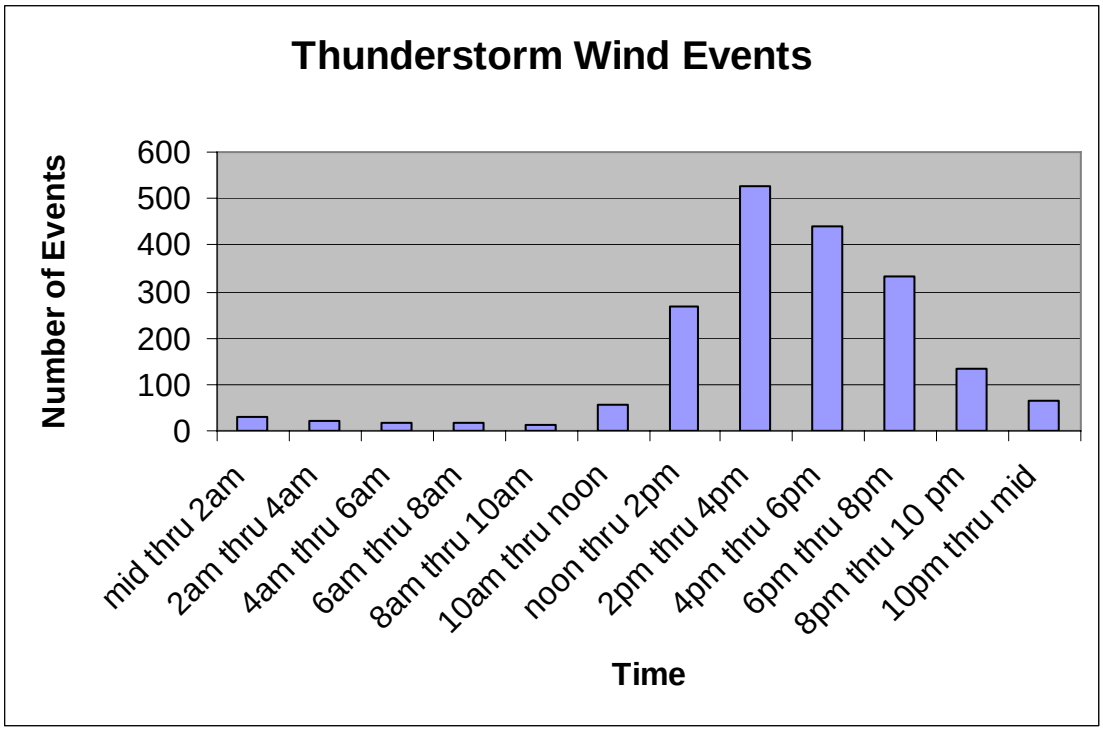

Figure 16. The distribution of severe thunderstorm wind events by hour (1950-2005).

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

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