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NWS ER-96

A SEVERE WEATHER CLIMATOLOGY FOR THE WFO WAKEFIELD, VA COUNTY WARNING AREA

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NWS ER 42 A Case Study of Radar Determined Rainfall as Compared to Rain Gage Measurements. Martin Ross. July 1971. (COM-71-00897).
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NWS ER 44 Forecasting Precipitation Type at Greer, South Carolina. John C. Purvis. December 1971. (COM-72-10332).
NWS ER 45 Forecasting Type of Precipitation. Stanley E. Wasserman. January 1972. (COM-72-10316).

(CONTINUED ON INSIDE REAR COVER)

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Table of Contents

1. Introduction

The National Weather Service (NWS) provides severe weather warnings “for the protection of life and property”. NWS field offices are tasked with issuing severe weather warnings for their areas of responsibility or County Warning Area (CWA). The Weather Forecast Office (WFO) located at Wakefield VA has forecast and warning responsibility for 66 political jurisdictions, which include 51 counties, and 15 independent cities. WFO Wakefield’s CWA encompasses the lower Maryland Eastern Shore, central and eastern Virginia, and northeast North Carolina (Fig.1).

The purpose of this climatological study is to provide a baseline of knowledge of the likelihood of severe weather types for forecasters in the WFO Wakefield CWA. A local severe weather climatology serves as an excellent source for training, especially with regard to frequency of seasonal and diurnal severe weather event maxima and minima. Using a baseline climatology of severe weather, forecasters can become familiar with which types of severe weather occur with greater (or lesser) frequency, at certain times of the day, or certain seasons of the year. This base knowledge of local climatology will aid forecaster’s ability to recognize severe storms.

2. Data and Methodology

2.1 Data Sources

The NOAA’s NWS Storm Prediction Center (SPC) in Norman, OK and the NOAA’s National Climatic Data Center (NCDC) in Asheville, NC provide online access to documented severe weather events across the United States. For the purposes of this study, tornado intensity and track data from 1950 through 1995 were compiled using the archive available from the SPC website. Hail and wind data were provided by Local Storm Data publications from 1996 through 2000. The wind data is separated into convective and non-convective wind gust events. All times are referenced to Eastern Standard Time.

WFO Wakefield’s CWA experiences a wide variety of weather phenomena, including severe thunderstorms that produce tornados, large hail, and damaging wind gusts. By NWS definition, a severe local storm is one that is sufficiently intense to threaten life and/or property, including thunderstorms with large hail, damaging wind, or tornados (National Weather Service 1995). Severe thunderstorms are further defined as producing tornados, hail ¾ inch or greater in diameter, and/or wind gusts 50 knots (58 mph) or greater (National Weather Service 1995).

The paper examines all severe weather storm types (tornados, ¾ inch hail or greater, and convective wind gusts 50 kts or greater) affecting the Wakefield CWA to develop a local severe weather climatology.

2.2 County Warning Area Topography and Demographics

Topography

The topography of WFO Wakefield’s CWA is characterized by a gentle rise in elevation from sea level along the Atlantic coast, Chesapeake Bay and the northeast North Carolina Sounds to the rolling hills in the Piedmont areas of central Virginia and interior northeast North Carolina. A notable increase in elevation occurs west of the “fall line” which runs roughly along Interstate Route I-95. The highest elevations reach 500 to 600 feet in the extreme western part of the CWA located over the east central Virginia Piedmont.

Topography is a contributing factor in the initiation of convective storms. During hot weather, compression of air east of the Blue Ridge Mountains forms a leeside trough of low pressure, which can help initiate and enhance convective development. In addition, sea breeze boundaries that form when there is significant temperature differences between the air-water interface can help initiate and maintain convection. Sea breeze boundaries are especially prevalent over the central and southern Delmarva Peninsula, western shores of the Chesapeake Bay, the Hampton Roads areas of southeastern Virginia; and along the northern shore of the Albemarle Sound in northeast North Carolina.

Demographics

The population of the WFO Wakefield's CWA is roughly 3 million people. The largest population center includes the Hampton Roads area in extreme southeast Virginia, which has a population base of roughly 1.5 million people. Hampton Roads includes the cities of Norfolk, Portsmouth, Virginia Beach, Chesapeake, Suffolk, Hampton, Newport News and Williamsburg. The Greater Richmond, VA metropolitan area, which includes the Tri-Cities (Hopewell, Petersburg, and Colonial Heights), has the only other large population base, roughly 1.1 million people. Although the CWA contains these large population centers, the CWA has a low population density. Outside of these population centers, the CWA is mainly rural farmland or heavily forested, and contains sparse population. This uneven distribution of people across the CWA can lead to skewing of observed phenomena toward the more heavily populated locations.

3. Severe Weather Climatology

3.1 Tornado Climatology

Monthly Distribution

The monthly distribution of tornados (Fig. 2) shows the Wakefield CWA can experience tornados at any time of the year. However, tornados are most likely to occur during the spring and summer months with the peak frequency in May. A total of 230 tornados occurred in the Wakefield CWA, of which, 43 tornados (19% of the total) were in May. The data suggests a secondary peak occurrence in August, however the data is likely biased by the large tornado outbreak of Aug 6, 1993. This event produced a total of 18 tornados, including the infamous "Petersburg Tornado". There is a pronounced, but lesser tornado occurrence peak in the fall. Fall tornados often are associated with land-falling tropical systems. Also, the November data is likely biased by a major tornado outbreak on Nov 11, 1995, which was actually non-tropical in nature.

Hourly Distribution

Diurnal trends indicate an increase in tornados after the noon hour (Fig. 3). Tornado activity peaks in the late afternoon between 4 and 6 PM. Sixty-nine tornados (30% of the total) occurred during the 4 PM to 6 PM time frame. The data shows a gradual decrease in the occurrence of tornados during the evening hours, and that tornados occur infrequently during the late night through early-to-mid morning hours. Atmospheric instability is a key ingredient in the generation of tornadic storms and is usually maximized during the mid- to late-afternoon hours.

Intensity (Fujita Scale)

Tornado intensity can be rated using the Fujita Scale (Table 1), which is based on the extent of the associated wind damage. Of the 230 tornados that were reported to have occurred in Wakefield's CWA, nearly three-quarters (167 or 73% of the total) were classified as weak F0 or F1 tornados (Fig. 4). Sixty-one tornados (or 27%) were rated strong (F2 or F3) and only 2 (<1%) were rated as violent F4 tornados. (The Petersburg Tornado was one of those rated F4). There were no documented F5 tornados.

Intensity Variations

Tornados that occur in the Wakefield CWA are most often weak (F0-F1), and only infrequently classified as strong (at least F2), and even rarer still, as violent. However, it is evident from historical tornado track data (Fig. 5) that stronger (usually F2 or greater), long track (usually covering 50 miles or greater) tornados are more likely to occur over the inland locations versus the coastal region. Usually, these longer-track tornados are developed on and are maintained by low-level wind shear and instability generated along strong temperature and moisture boundaries. These atmospheric discontinuities decrease in the more stable environment nearer the coast. Long-track tornados are generally stronger, and thus likely to cause more damage than the weaker short-track tornados.

When historical tornado data is further broken down by intensity, a subtle trend in diurnal occurrence is noted (Fig. 6). The occurrence of all tornados peaks during the late afternoon hours (between 4 and 6 PM); however, weaker F0/F1 tornados are more numerous than stronger tornados (F2 and above) during the early afternoon.

3.2 Hail Climatology

Monthly Distribution

The monthly distribution of severe hail (3/4 inch diameter or greater) indicates a strong inclination toward the spring season (Fig. 7). Occurrences of severe hail peak in May, with 100 severe hail events of the total 370 (or 27%) recorded during the month. Secondary severe hail event maxima are apparent in April and June, and the three month total (April through June) accounted for 65% (241 of 370 events) of all occurrences. Severe hail occurrences show a steady decline during the summer months, and a well-defined minima is noted in the fall and early winter.

Hourly Distribution

Severe hail typically occurs during the early to mid afternoon time frame (Fig. 8). Two hundred twenty-one severe hail events of the 370 total occurrences (60%) were during the hours of 2 PM to 6 PM. A steady decline of severe hail occurrences was indicated during the late afternoon and evening hours. Severe hail is rare during the morning.

The peak occurrence of hail frequency in spring during early-to-mid afternoons can be attributed to several factors. The first is the natural evolution of thunderstorms in which updrafts of the storm are strongest during the formative or initial stage. Strong updrafts are more favorable for hail formation. Another essential factor for hail formation and development is low zero wet-bulb temperature height. Zero wet-bulb temperatures heights are typically lower during the spring months due to the cooler atmospheric conditions common during the season.

Seasonal Variations

When the historical severe hail reports are broken down by season (Fig 9.), it becomes apparent that a peak occurs during the spring months of March, April, and May. A secondary maximum is indicated during the summer months (June through August). Severe hailstorms are infrequent during the fall and winter months.

Magnitude (Hail Size)

The majority of severe hail reported (188 events or 51% of the total) in the Wakefield CWA was less than one-inch diameter (Fig. 10). Occurrences of hailstones ranging from one to two inches accounted for almost half of the reports. Severe hail of over 2 inch diameter accounted for only a small percentage (<1%). The largest hailstone measured in the Wakefield CWA during the period was 3-inch diameter.

3.3 Damaging Wind Climatology

Monthly Distribution

Damaging wind events from convective storms show a steady increase during the spring and peak in June (Fig. 11). One hundred sixty-three events (23% of the total) occurred in June. During the late spring and early summer months of May, June and July, 417 events (59%) occurred. A secondary damaging wind maxima was indicated in January, but the data is biased due to a climatologically anomalous large event that occurred on Jan 19, 1996. This event produced 40 separate reports of convective wind damage. Convective wind damage was infrequent during October through December.

Hourly Distribution

Damaging winds peak in the late afternoon between 4 PM and 6 PM (Fig 12). Two hundred twenty-four events (32% of the total occurrences) were during this time frame. There is a steady increase of wind damage during the early to mid afternoon, then steady decline during the evening hours. Damaging winds due to convection were infrequent through the morning hours, especially around sunrise.

The natural evolution of thunderstorms is such that downdrafts become more prevalent in the decaying or mature stage of the storm, and thunderstorms are most likely to be in these latter stages of development during the mid to late afternoon. Strong downdrafts during the late stage of thunderstorm development are a major contributor to downburst winds.

Seasonal Variations

When damaging wind data is broken down by season (Fig. 13), it is apparent that damaging wind gusts are most likely to occur during the summer months (June through August). A secondary maximum is indicated during the spring months (March through May). Relatively few reports of damaging convective winds occurred in the autumn and winter.

Magnitude (Wind Gust Speed)

Exact measurement of convective wind gusts are limited by the number of wind recording instruments in the CWA. Most severe wind events are determined by the amount of structural and/or tree damage that coincide with the wind event. When exact wind speeds were recorded, by far the majority fell in the 50-60 knot range (58-69 mph) (Fig. 14). Of the 107 total measured events, 93 wind gusts (or 87%) fell within this range. There were few reports of wind gusts in excess of 60 knots (69 mph). The highest recorded convective wind gust was 76 knots (87 mph) which on April 23, 1999 at Cape Henry, VA.

4. Overview

Seasonal and diurnal maxima of severe local storms occur during the spring and early summer months in the WFO Wakefield CWA. Typically during this time of year, a deep south to southwest flow of air ahead of transitory mid-latitude troughs, brings in moisture from the Gulf of Mexico and western Atlantic Ocean into the Middle Atlantic region. Also during the spring and early summer seasons, cold fronts at the surface penetrate the region and provide a lifting focus mechanism to help generate convection. Increased solar insolation during this time of year produces greater instability of the atmosphere. Also, warm fronts lifting north through the Middle Atlantic region can provide both a lifting mechanism and vertical wind shear to help initiate and maintain convective storms. Therefore, the key ingredients needed to initiate and maintain convection (moisture, lift, instability, and wind shear) are maximized during the spring and early summer months.

5. Conclusion

In the WFO Wakefield, VA CWA, severe convective storms can occur at any time of year and anytime of the day, but are most common during the spring and summer months during the mid afternoon to early evening time frame. Severe hailstorms are more common in the spring months, while summer severe storms are more likely to result in convective wind gusts. Hail is more common during the early spring due to the natural evolution of thunderstorm cells from the formative or initial stages in which updrafts are dominant. This is in contrast to the mature or decaying stages of thunderstorms in which downdrafts are more dominant later in the spring. Downdrafts are more directly related to convective wind gusts (downbursts).

Forecasters at WFO Wakefield should use this paper as a baseline in severe storm warning decision making. It can serve as a climatological reference point for spatial and temporal distribution of severe weather types, and as an aid to forecaster's situational awareness and expectations of severe weather threats.

Acknowledgements

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Reference

Fujita, T. T., 1981: Tornados and downbursts in the context of generalized planetary scales. *J. Atmos. Sci*., **38**, 1511-1534.

National Weather Service, 2002: *National Weather Service Instruction 10-511*. [Available on-line at: http://www.nws.noaa.gov/directives/010/pd01005011b.pdf]

Figures

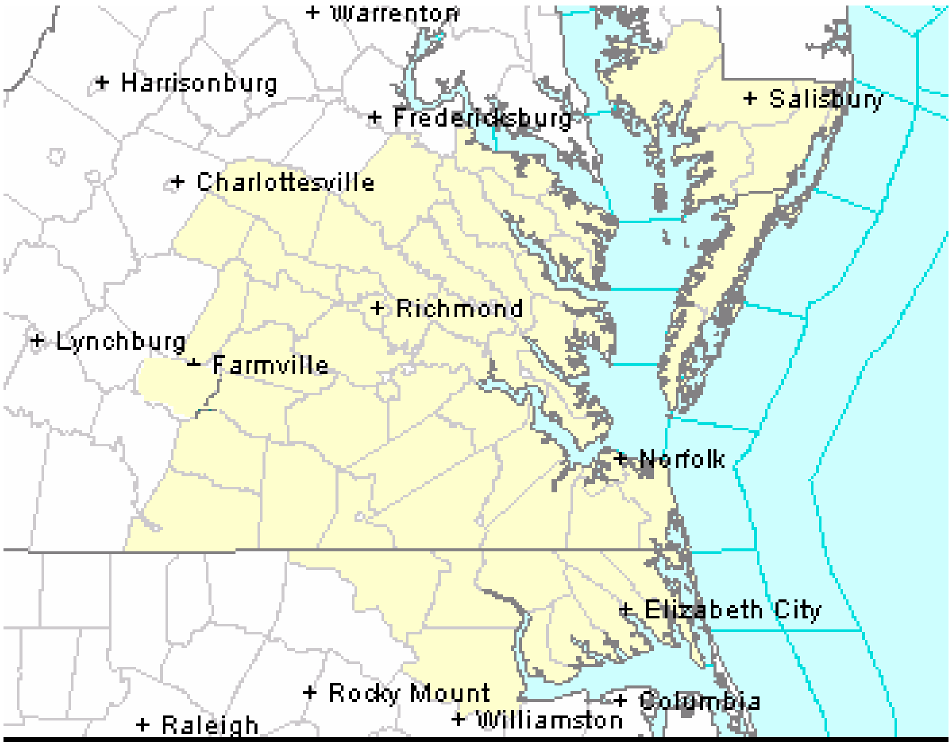

Figure 1. WFO Wakefield, VA County Warning Area (CWA) shaded in yellow.

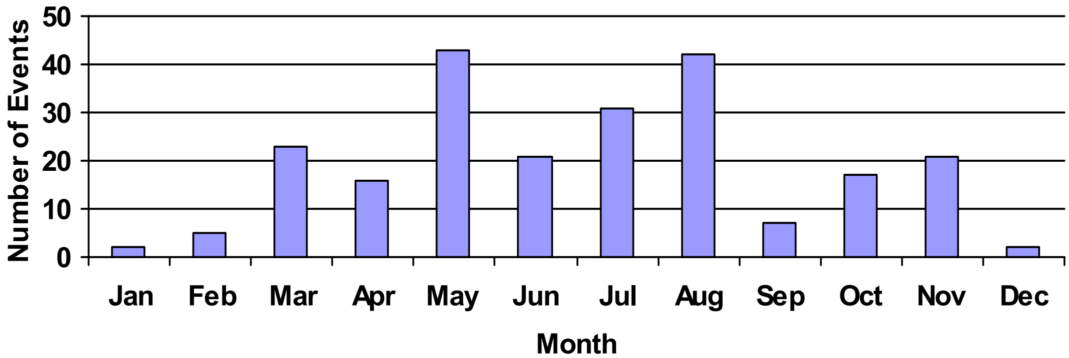

Figure 2. Monthly tornado distribution for WFO Wakefield, VA CWA for the period 1950 to 1995.

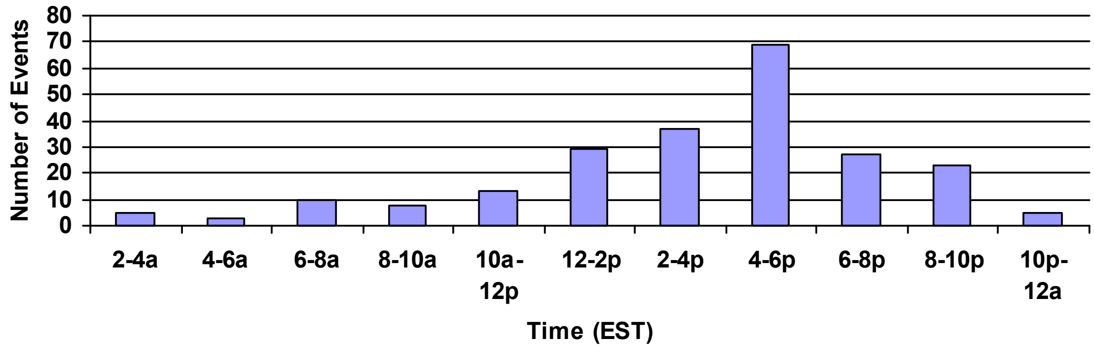

Figure 3. Hourly tornado distribution for WFO Wakefield, VA CWA for the period 1950 to 1995.

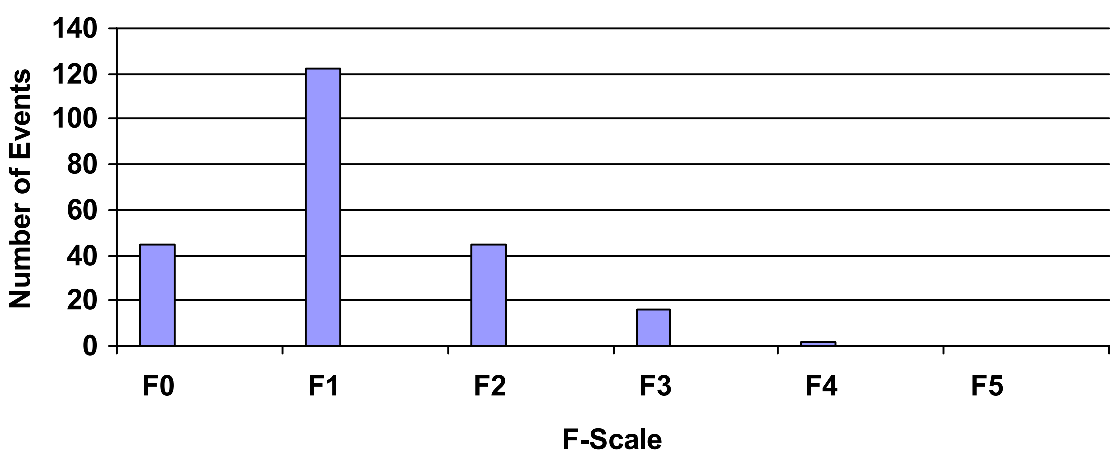

Figure 4. Tornado intensity distribution for Wakefield, VA CWA for the period 1950 to 1995.

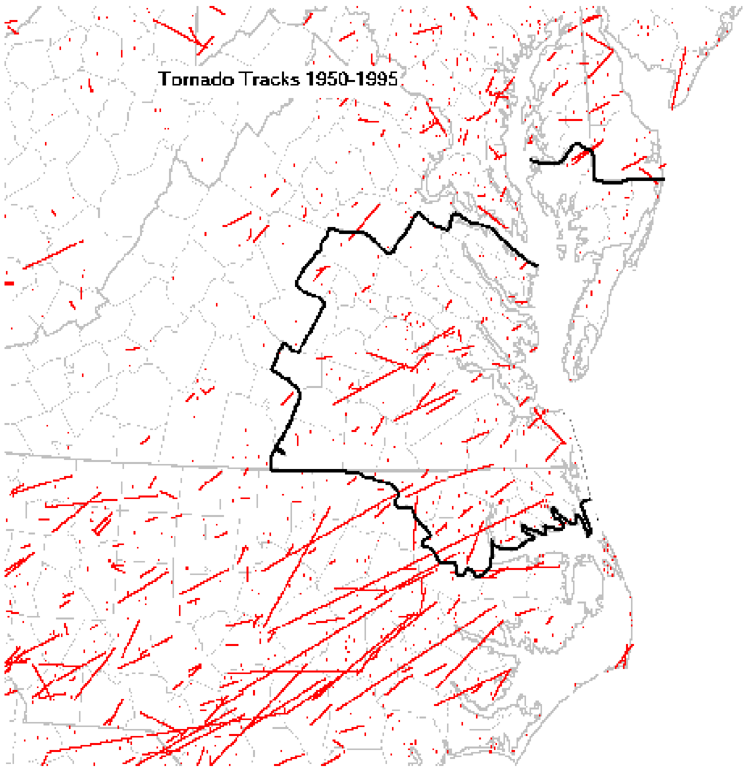

Figure 5. Historical tornado tracks for the period 1950 to 1995. The black line encompasses the Wakefield, VA CWA.

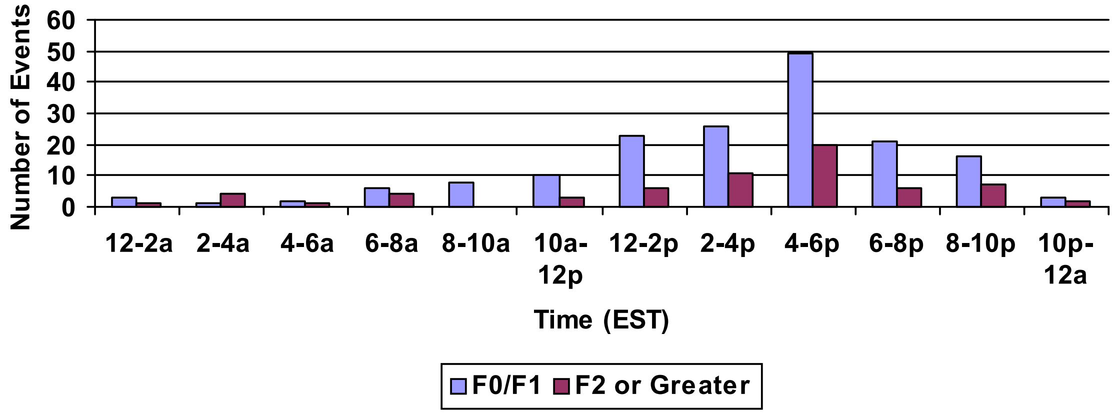

Figure 6. Hourly distribution of strong versus weak tornados distribution for WFO Wakefield, VA CWA for the period 1950 to 1995.

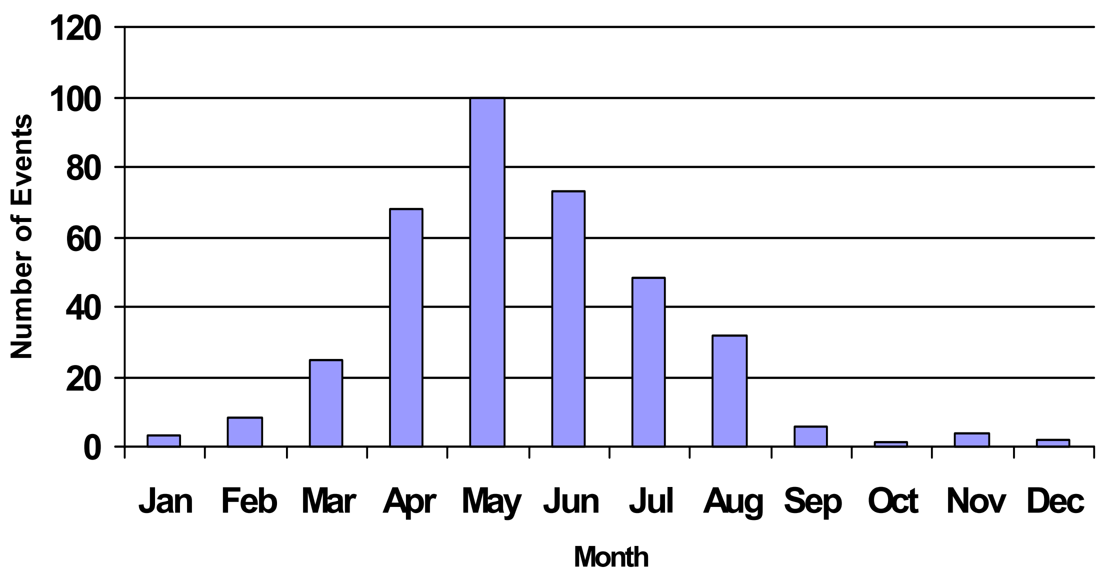

Figure 7. Monthly hail distribution for WFO Wakefield, VA CWA for the period 1996 to 2000.

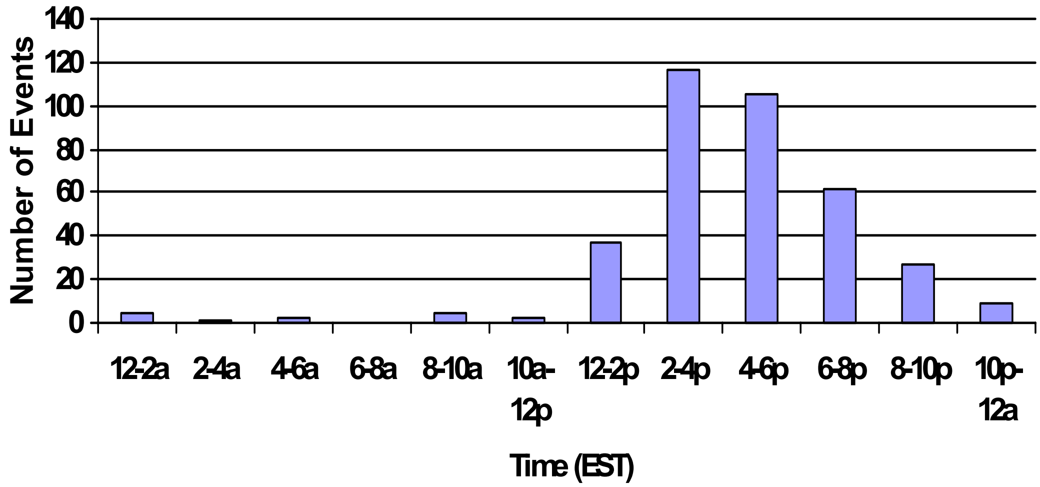

Figure 8. Hourly hail distribution for WFO Wakefield, VA CWA for the period 1996 to 2000.

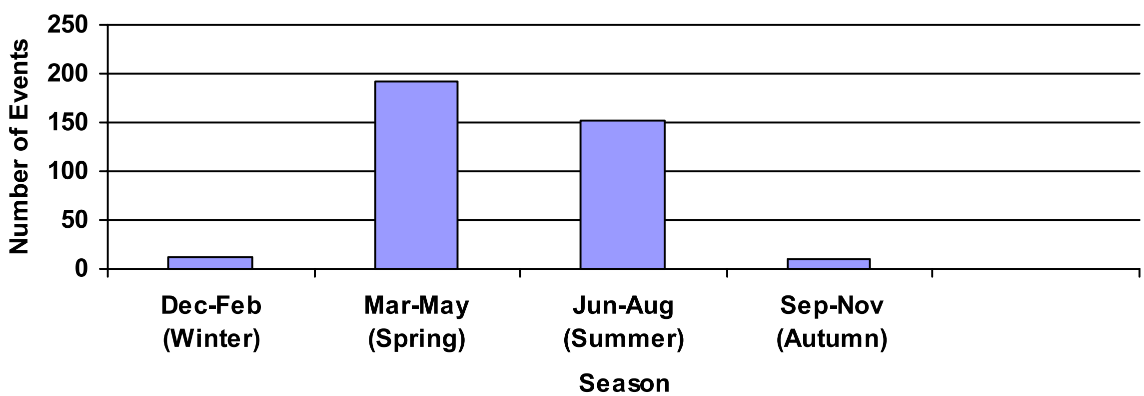

Figure 9. Seasonal hail variation for WFO Wakefield, VA CWA for the period 1996 to 2000.

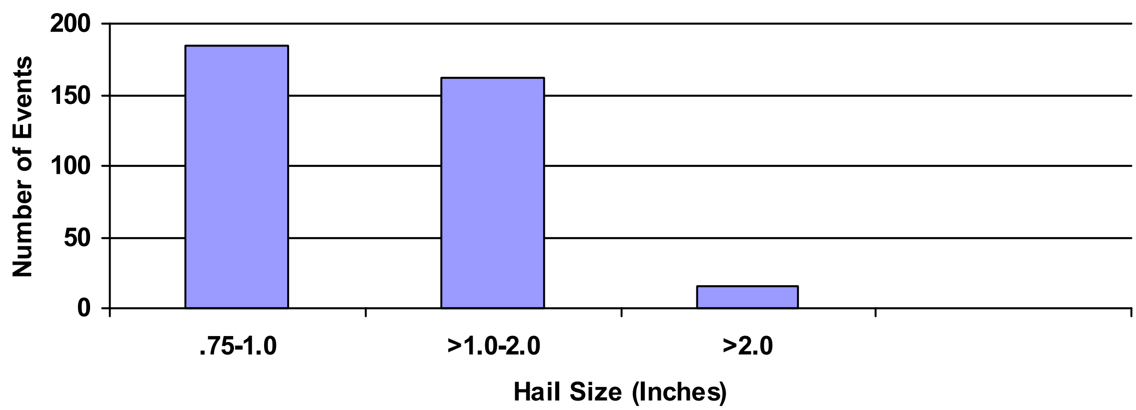

Figure 10. Hail size distribution in the Wakefield, VA CWA for the period 1996 to 2000.

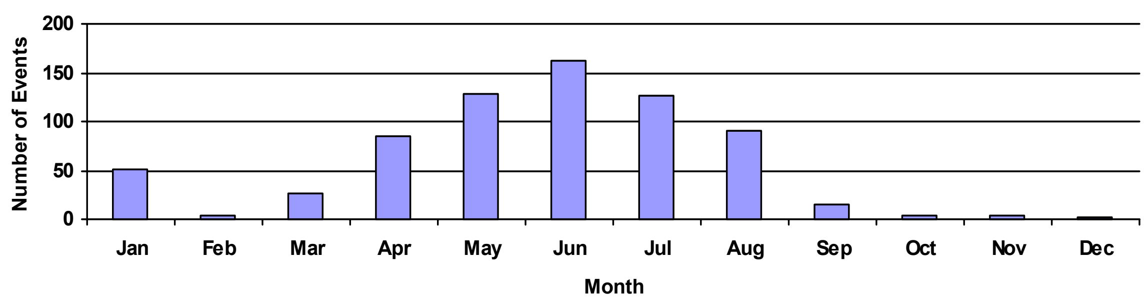

Figure 11. Monthly distribution of convective damaging wind events for WFO Wakefield, VA CWA for the period.

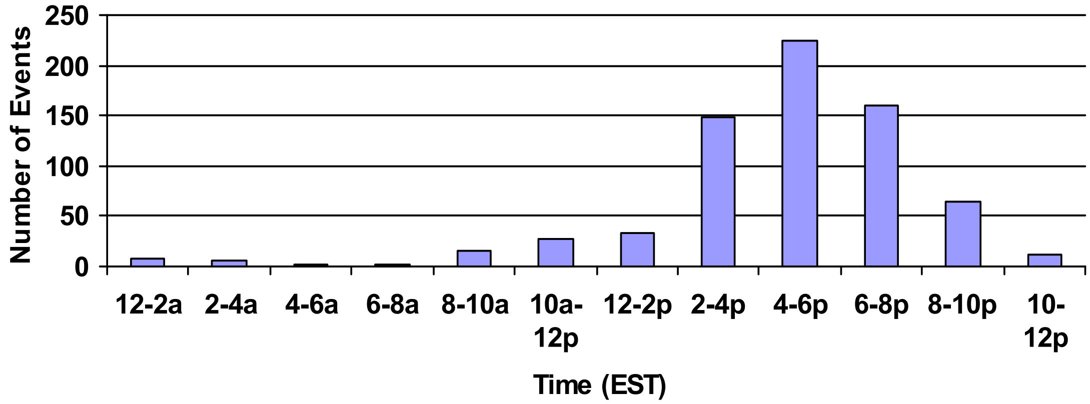

Figure 12. Diurnal wind distribution for WFO Wakefield, VA CWA for the period 1996 to 2000.

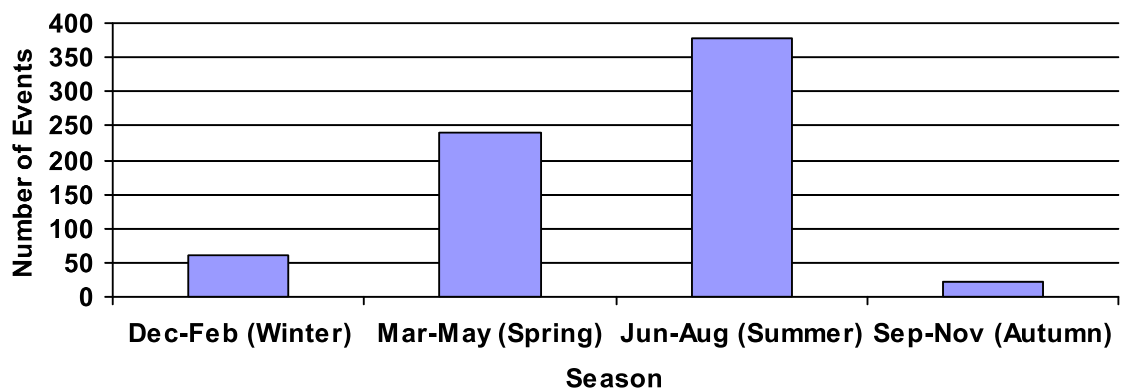

Figure 13. Seasonal wind distribution for WFO Wakefield, VA CWA for the period 1996 to 2000.

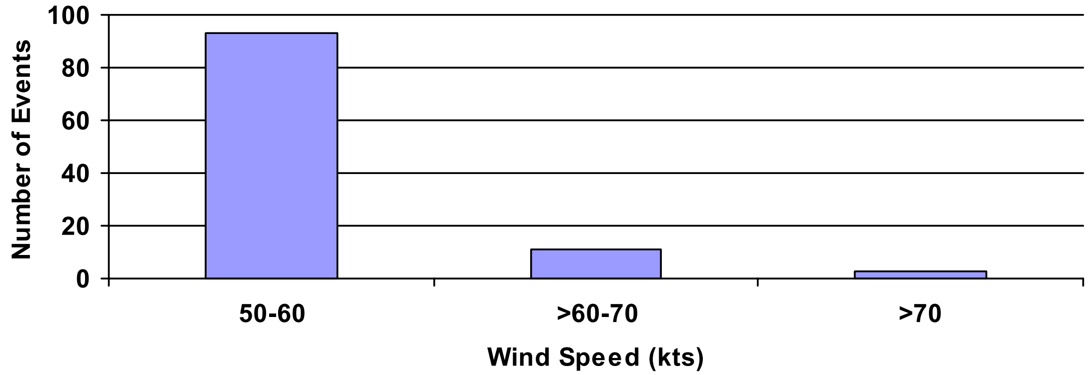

Figure 14. Wind intensity distribution for WFO Wakefield, VA CWA for the period 1996 to 2000.

Table 1. Fujita Scale. (Fujita, T.T., 1981)

Fujita Scale	**Wind Speed (mph)**	**Tornado Character**
F0	47-73	Weak
F1	74-110	Weak
F2	111-150	Moderate
F3	151-199	Strong
F4	200-255	Intense
F5	>255	Devastating

NWS	ER 46	An Objective Method of Forecasting Summertime Thunderstorms. John F. Townsend and Russell J. Younkin. May 1972. (COM-72-10765).
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NWS	ER 58	An Analysis of Forecasters' Propensities In Maximum/Minimum Temperature Forecasts. I. Randy Racer. November 1974. COM-75-10063/AS).
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