Tornadic Storm Modes across the Southern Appalachian Mountains

James Morrow and Steve Keighton
National Weather Service Forecast Office
Raleigh, NC. and Blacksburg, VA.

Background Information

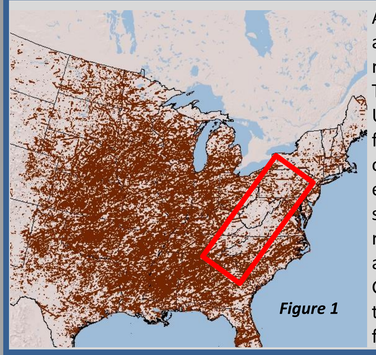


Figure 1

A relative minima in Tornado occurrences is apparent across the Appalachian Mountains sub-region when analyzing the 1950 – 2016 Tornado Track distribution (***figure 1***) across the contiguous U.S. Even with the lesser event frequency, forecasting and warning for such events in areas of complex physiographic characteristics can be exceptionally difficult, thanks to a tendency for shorter-lived events, smaller and more moisture rich (HP) parent storms, lower population density, and an utter lack of storm spotters and chasers. Given these challenges, a better understanding of the unique aspects in this region, specifically the favored storm mode characteristics, is sought.

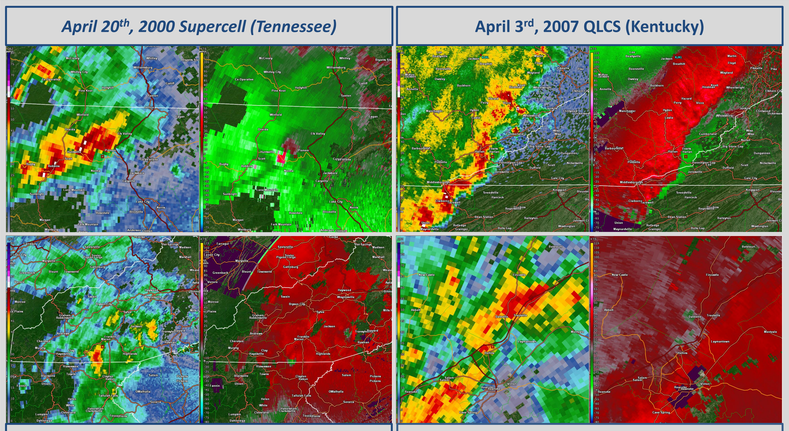
Study Objectives

- Analyze the distribution and characteristics of 210 elevated (events with mean event track elevation > 300 meters, ~ 984 feet) tornado occurrences across the southern Appalachian Mountains region that span the years 2000 - 2016.
- Utilize archived radar imagery and other environmental datasets to subjectively classify higher elevation tornado occurrences into one of four unique storm mode classifications: Supercell, Quasi-linear Convective Systems (QLCS), Multicellular..

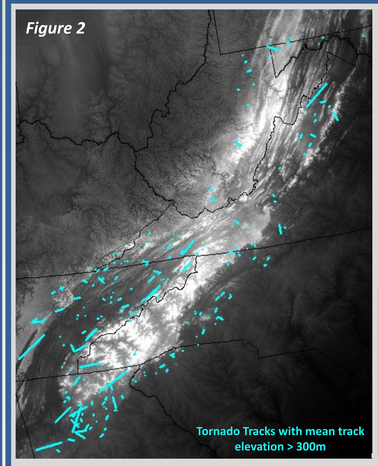
Storm-Mode Classification Definitions

Supercell	Tornado producing storms that clearly showcased one quasi-steady, sustained, rotating updraft. This includes discrete supercells as well as embedded supercells in a non-homogenious line that retained their own parent circulations.
QLCS	Tornado producing storms embedded into a greater convective line that showcase primarily low-level rotation. Often cold pool or FROPA propagating, and both “Squall Line” and “Bow Echo” type events were included.
Tropical	Tornado producing storms that are associated with any sort of named or formerly named tropical disturbances.
Multicell	Weaker storms that often relied on other boundaries to produce usually brief spin-ups. Also, any storms that didn’t fall into any of the categories above were classified here.

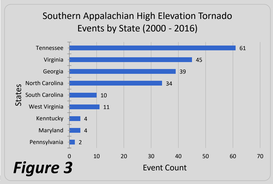
Idealized Storm-Mode Cases

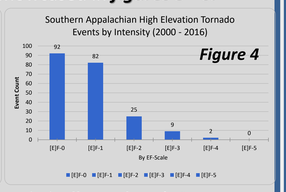


Study Region

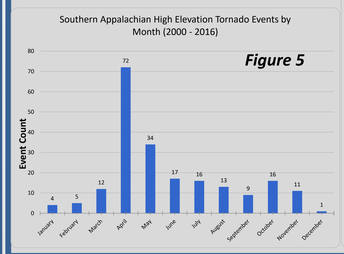


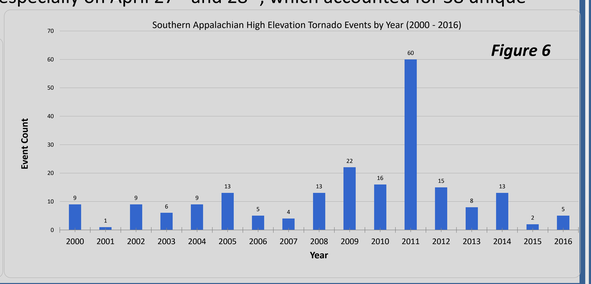
Tornado tracks were overlaid on a 2km by 2km Digital Elevation Model (DEM) layer (***figure 2***) allowing for a mean elevation for each tornado track to be derived via GIS Statistical/Spatial analysis. 213 events between 2000 – 2016 occurred at or above a 300 meters (~984 feet) mean elevation in our study area stretching from near the Mason Dixon line southwest through the Tennessee Plateau and northern Georgia. Three of the events were disqualified due to unavailable archived radar data or inconsistencies in the National Weather Service (NWS) Storm Data publication, leaving 210 valid cases to be classified. Statistics for all 210 events are showcased in ***figures 3 - 6.***





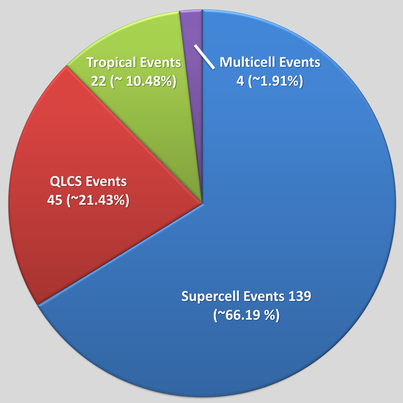
Prior to storm mode classification, the high elevation tornado events were statistically analyzed. A greater distribution of events that met criteria occurred across the southern portions of the Appalachian Region, with the higher elevations of Tennessee (61), Virginia (45), Georgia (39), and North Carolina (34) witnessing the majority of the events (***figure 3***). In terms of tornado event strength, the higher elevation tornadoes tended to cluster around the weaker [Enhanced] Fujita damage classification ranges (***figure 4***), with the majority of the events occurring in the Spring (April – June) time period with a secondary (more minor) peak in the Fall (October – November) time period (***figure 5***). A time series plot of the high elevation tornado events (***figure 6***) showcase a rather variable distribution of events through time, with a significant jump in occurrences in April 2011. This jump is correlated to several “outbreaks” that occurred across the southeastern and mid Atlantic States, especially on April 27th and 28th, which accounted for 38 unique events on its own.





Storm Mode Classification and Statistics

Figure 6

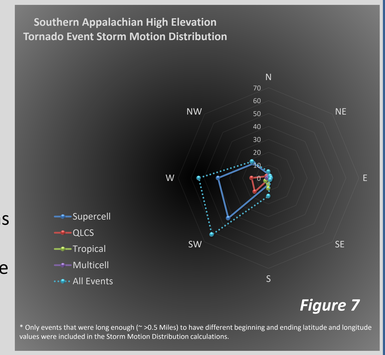


A subjective storm mode classification was conducted using a variety of environmental datasets, including; national, regional, and local level archived radar images along with other environmental data. Post classification, (***figure 6***), the majority of tornado events fell under the **Supercell Events** (~66%) category, while both **QLCS** (~21%) and **Tropical Events** (~10%) roughly made up the other 1/3 of the events. Only 4 (~2%) of the events were classified as **Multicellular** in nature. Specific storm mode statistics such as tornado intensity (***figure 9***), seasonality (***figure 8***), storm motion (***figure 7***), tornado track length, maximum track width, and injuries/fatalities (***Table 1***) were calculated and compared with one another. In general, Supercell Tornado events tended to be stronger, longer, and wider compared to the QLCS, Tropical, and Multicell storm modes (***Table 1***). They also tended to be more destructive, accounting for the majority of injury and fatality cases, likely correlated to the stronger [Enhanced] Fujita Scale rating assigned by the NWS.

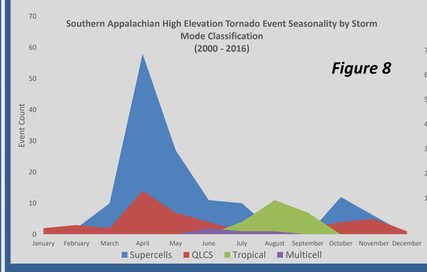
Storm Mode Classification and Statistics

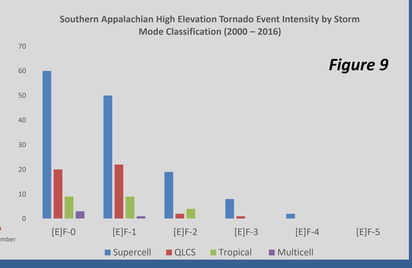
	Supercells	QLCS	Tropical	Multicell	Totals/Average
Number of Events	139	45	22	4	210
% of Total	66.19%	21.43%	10.48%	1.90%	
Average Length	4.20 Miles	3.51 Miles	3.86 Miles	0.69 Miles	3.95 Miles
Average Width	189.60 Yards	175.56 Yards	162.50 Yards	57.50 Yards	181.24 Yards
Number of Injuries	292	41	11	0	344
Number of Fatalities	25	4	0	0	29

One of the biggest differences noted between storm mode classifications was the seasonality of classified events (***figure 8***). Both Supercell and QLCS classified events showed a peak occurrence in the Spring (April to May) time- frame with a secondary peak noted in the Fall (October to November) while Tropical showcased a peak that better aligned with peak Atlantic Tropical Season (Aug to Sept). Multicells, albeit a small dataset, has a peak occurrence primarily during the summer months (Jun – Aug). Storm motions (***figure 7***) were fairly uniform, with westerly to southwesterly motions favored with a bit more of a southerly motion noted during the Tropical events.



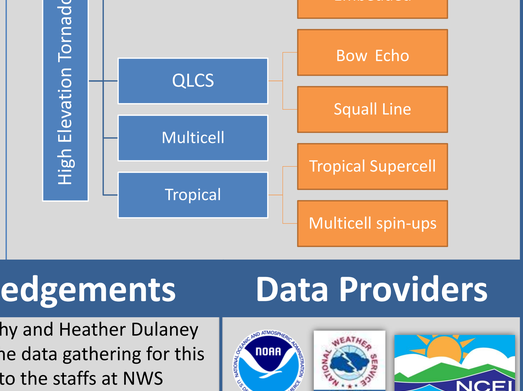
* Only events that were long enough (~>0.5 Miles) to have different beginning and ending latitude and longitude values were included in the Storm Motion Distribution calculations.





Future Steps

- Modernize Study
- Additional Sub-classifications
- Account for 2011 event biases
- Further environmental analysis by classification



Other Acknowledgements

We’d like to thank Megan McCarthy and Heather Dulaney (Virginia Tech) for assisting with the data gathering for this project. Also, a special thank you to the staffs at NWS Blacksburg and Raleigh for their moral support and input.

Data Providers