Climatological Study of Significant Hazards from 1979–2018

Introduction and Literature Review

Knowing the frequency of severe weather hazards is beneficial to a forecaster, researcher, and the public. Severe weather climatological studies in the past have used Gaussian smoothers to calculate nonparametric density estimations of tornadic and nontornadic events, and another study used a Gaussian spatial smoother for hail days (Brooks et al. 2003; Doswell at al. 2005; Allen and Tippett 2015). Also, ArcGIS Pro was used to calculate the kernel density estimation of severe weather hazards, and a Gaussian low pass filter was used to smooth tornadic data (Ashley 2007; Smith et al. 2012; Coleman and Dixon 2014). The goal of this project was to use ArcGIS Pro's Kernel Density Estimation (KDE) tool to analyze any temporal or spatial trends of severe weather hazards in the CONUS. I wanted to produce KDE maps of the significant hazards and to find if there were spatial, temporal, or unique trends in the data. I also wanted to look at any trends with significant winds both at 65 knots and 80 knots. The last goal I wanted to accomplish was to look at the possible spatial and temporal trend of injuries and deaths caused by significant tornadoes.

Severe weather hazards occur year-round and could lead to a noisy dataset. Therefore, only significant severe weather hazards were used. The National Weather Service (NWS) definition of a significant tornado based on the Enhanced Fujita Scale (EF-Scale) is EF-2 and higher. A hailstone diameter of 2 inches and greater is considered a significant hail report. Lastly, a significant damaging wind event is 65 knots and higher. This would remove the biases of weakly rated tornadoes and noise from the dataset.

Data and Methodology

The U.S. national outline shapefile was used to mask the KDE, and the U.S. state shapefile was also used to help with spatial reference (Shapefiles available at https://www.census.gov/geographies/mapping-files/time-series/geo/carto-boundary-file.html). To calculate the KDE's, point data shapefiles provided by the Storm Prediction Center (SPC) were used in this study (Shapefiles available at https://www.spc.noaa.gov/gis/svrgis/). The severe weather shapefile data was available as a point or line features. This study only looks at the point data of a significant storm report, for simplicity in performing the KDE analysis. The points are the initial latitude and longitude of the storm report. The shapefiles additionally include magnitude (wind speed, hailstone diameter, and EF-Scale rating) and the number of injuries and deaths per report. The period between 1979–2018 was broken into four 10-year subperiods (1979–1988, 1989–1998, 1999–2008, 2009–2018) for significant wind and hail reports. For significant tornadoes, the period between 1989–2018 was broken into 6-year subperiods (1989–1993. 1994–1998, 1999–2003, 2004–2008, 2009–2013, 2014–2018). The subperiods are used to analyze spatial and temporal trends of the significant weather hazards.

The following steps were used to perform the KDE analysis of the data. 1) Four maps were created for significant wind and hail reports, and 6 maps for significant tornadoes. The point data shapefile was dragged to each appropriate map, and data was queried by year and magnitude. For example, if the map was significant wind events from 1989–1998, we would choose "year" greater than or equal to 1989 and "year" less than or equal to 1998 and "magnitude" greater than or equal to 65 knots. The data for significant winds was broken up into two groups of 65 and 80 knots. 2) The data was projected onto the USA Contiguous Albers Equal Area Conic PCS to have meters as units. 3) A 60-kilometer grid was created using the Create Fishnet tool. The latitude range used was -125.164867 to -66 degrees west, and the longitude range is 49.921890 to 24.114861 in the northern hemisphere. This approximately creates a 60 by 60 kilometer grid and was used to intersect with the national outline to contain it within the U.S. boundary. 4) The “Summarize Within” tool was used to count and sum the reports in each grid cell. For significant tornadoes, the “Summarize Within” tool was used to sum the injuries and deaths per grid cell. This step was done for each hazard and subperiod. 5) The summarize within layer was then converted to a point layer using the “Feature to Point” tool. Next, this layer was projected onto the USA Contiguous Albers Equal Area Conic PCS, to ensure the units were in meters. 6) The project feature to point layers were then used to create the KDE maps. The Kernel Density tool was used to make the 20+ maps! The population field was either the point count (hail, wind, tornadoes) or injuries and deaths for tornadoes. The output cell size was 1000 m, and the area units were square kilometers. A 120 km bandwidth was chosen as the search radius, as previous studies have also used 120 km (Brooks et al. 2003; Doswell et al. 2005; Allen and Tippett 2015). Lastly, the national outline was used to mask the KDE analysis to ensure there were no values over water or outside the U.S. These same steps were used to produce a map for each subperiod and hazard.

Preliminary Results

I was able to produce high-quality maps for each subperiod and weather hazard. Looking at the significant hail maps, there is a distinct increase in density stepping through each 10-year subperiods. This could be due to meteorological and non-meteorological reasons such as radar or an increase in population. Additionally, there is a high concentration or maximum of significant hail events in the Great Plains in comparison to other regions throughout each subperiod, also found in previous studies (Doswell et al. 2005; Smith et al. 2012; Allen and Tippett 2015).

There were equivalent results in the significant hail event analysis, there was a sharp increase in density spatially for significant damaging wind events, both 65 and 80 knots. Comparing the results of the 1979–1988 and 2009–2018 KDE analysis, there is a higher frequency in significant wind events over the CONUS between 2009–2018. Furthermore, there appears to be a higher frequency in the Upper Plains, Central Plains, and in the Midwest. Additionally, the last subperiod (2009–2018) has the highest density overall, with a bullseye over the Central Plains. For 80 knots and later subperiods, there is a temporal increase in density. Spatially, the higher frequencies are concentrated in the Plains and Midwest. Particularly, the state of Nebraska has a maximum in three out of the four subperiods and has the highest density in the last subperiod. Overall, Nebraska sees the highest frequency in significant wind events (65 and 80 knots).

There is not a dramatic temporal increase in the density of significant tornadoes. The maximum density also changes spatially for each subperiod; however, the maximum stays in either the Central Plains or in the Southeast, particularly over Mississippi, Alabama, and Georgia. The density in significant tornadoes for the last subperiod (2014–2018) in comparison to the other periods is oddly less. The standout subperiod (2009–2013), was a statistical phenomenon. One of the deadliest super tornadic outbreaks and tornadoes in the U.S. occurred during this period; the April 27–29, 2011 super outbreak, the Joplin EF-5 tornado in May, and several EF-3+ tornadoes occurred in Oklahoma during May. The injury and death maps mirror this.

Conclusion

There are, however, a few issues with the shapefile datasets, specifically the storm report alone. Issues such as the duplications of local storm reports, hail or wind measurements/estimations, diurnal effects, and low-density areas are all possible influences or gremlins that have been documented about the dataset. The possible reasons for the influx of reports for significant hail and damaging winds events could be due to meteorological or nonmeteorological influences. Allen and Tippett (2015) found an increase in the popular activity of “storm chasing” could have led a possible increase in reports in the last two decades. Meteorological influences such as the development of the radar network in the 1990s, the increase of mesonet or meteorological stations, or advancement in meteorological equipment could all be possible reasons for the increase in reports. To answer these questions, an in-depth study would be needed to understand increase in local storm reports. This could be done by possibly using a Bayesian Hierarchical Model using covariates such as road or population density.

Overall, I am incredibly happy with my results and feel I have achieved my goals for this project. The three main findings from this project were there is a high frequency of significant hail events over the Central Plains, there is a significant wind bullseye over the state of Nebraska, and the significant tornadic 5-year subperiod between 2009–2013 was a statistical phenomenon in terms of deaths, tornado frequency, and injuries. The only main issue I had conducting the project was when I went to change the name of the projects, and somehow, I corrupted some of the files, in which I had to painfully redo some of the layers. So, if there was something I truly learned, it is to always give the proper name to the project and never rename it, ever.

References

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