Classification of Rarity of Tornadic Outbreaks

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ABSTRACT

Tornadic outbreaks cause widespread devastation mentally, physically, and financially. This project focuses on rare tornadic outbreaks by implementing climatological estimates of daily tornadic probability in the United States. The data consists of (E)F1 and greater tornado reports from 1954-2015 from the Storm Prediction Center (SPC). A Gaussian smoother was applied to each day for both space and time. Then a climatology was created by taking the mean of each day over the 62-year span. To obtain the rarity factor, each individual day was then divided by the climatology. Rarity was classified in three states; maximum rarity factor, how large an area was affected, and how intense the event was. These results show that intensity and area have a strong correlation. This topic is critical because rare events cause a state of uproar in the public and with a lack of preparedness cause lead to multiple complications

1. INTRODUCTION

Tornadic outbreaks can cause substantial damage to an area and devastation to people. Forecasters are tasked with providing information in an adequate amount of time to allow people to take protective action. Understanding the rarity of an event is critical because rare events are likely to be troublesome due to a lack of preparedness for the event. There are a couple of ways that rare outbreaks can be difficult for the public to respond to. First, the area they are in may not see much tornadic activity so residents may not know how to respond to the potential threat in their area. Second, without having knowledge of the severity of the situation, emergency vehicles may not respond fast enough or it may be difficult to get to those in need. Finally, if the outbreak occurs when the area doesn't experience much tornadic activity while during school hours, the institution may not have been prepared to put special procedures in action. This project focuses on rare tornadic outbreaks by using climatological estimates of daily tornadic probability for the United States. There are many ways to define how "rare" an event is. Some events may classify by being rare at a place or time. The area of the event could also tell us how rare an event is. Also, how intense these outbreaks were and what type of tornadoes were produced could also fall into a rarity factor.

2. Methods

(E)F1 and stronger tornado reports from the Storm Prediction Center (SPC) from 1954-2015 (Krocak and Brooks 2018) were used to create the dataset. This 62-year span was chosen due to numerous changes with reporting practices in the earlier years. Reports were then placed in a 80-km grid box for each convective day (1200 UTC- 1200 UTC) (Krocak and Brooks 2018). To get long-term climatological estimates for tornado

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occurrence, the data is smoothed in space and time using a 120-km Gaussian smoother. Each individual day was fist smoothed in space to create a single day's field. Since we are initially interested in large outbreak days, we only looked at days in which at least 10 grid points had a report. This gave us an outlook of 422 days in the dataset. The equation for the Gaussian smoother is shown below,

$$(1)\ P = \sum_{n=1}^{N} \frac{1}{2\pi\sigma^2} e^{-r^2/2\sigma^2}$$

where, P represents the probability of the smoother, N is overall number of grid boxes accompanied with the event, r is the distance from the grid location to the location it was reported, and σ is the standard deviation of the smoother. The climatology acts as a function of year, time, and location. After averaging the 62 years within the data set, they were then smoothed in time defined by a 15 day standard deviation. (Krocak and Brooks 2018).

The climatology acts as a function of year, time, and location. After averaging the 62-year span, to calculate the rarity factor, the individual day was divided by climatology which is a function of year, time, and location. The rarity factor could be large or small depending on the numerator or denominator. For example, in the month of May the climatology is high for tornadic activity in the state of Oklahoma, resulting in it to be difficult to peak in max rarity values. If the month switched to January where the climatology is low then that rarity factor would get larger. For this work, we focus on maximum rarity factor (individual day / climatology) at any point, and the size of the area with a rarity factor over a certain threshold. Then, we also look at the intensity of the tornadoes within the outbreak. These three classifications will show how different the rarity of an event can be just based on what variables we investigate.

4. Results

Max rarity rank	Area rank	Intensity rank
5/25/2011	4/27/2011	4/3/1974
5/25/1980	4/3/1974	4/27/2011
6/25/1975	11/22/1992	4/11/1965
3/26/1991	4/11/1965	4/2/1982
10/18/2007	3/20/1976	5/31/1985
6/17/2010	4/26/2011	3/13/1990
5/12/1982	11/10/2002	3/1/1997
3/27/1991	5/5/1964	11/22/1992
6/14/1962	5/18/1995	5/4/2003
6/11/1976	5/15/1968	6/16/1992

Table 1 Top 10 Rare Rankings: The table above shows the top ten rankings within each category.

Table 1 shows the top ten outbreak rankings within the three categories; maximum rarity, the size of the area impacted, and the intensity of the event. The maximum rarity factor focused mainly on areas where tornadic activity isn't that frequent. Tornado reports during the spring in northern California (May 25, 2011) or the spring in northern Michigan (March 27 1991) is unusual for the area's climatology, which makes the rarity factor very large, so rare in fact that they've ranked within the top ten of maximum rarity factor days.

The area ranking focused on how many grid points exceeded 100 times the climatology. The intensity ranked the days based off of the number of (E)F3 or greater tornado reports. Some dates may occur in more than one category, which could show relatable aspects of the classifications. After investigating the three types of rarity classifications, we find that maximum rarity differs from the other two categories. Four out of ten dates are shared between area and intensity. This means that these two categories may have some correlation within rarity. As the maximum rarity classification did not share any dates with neither classification.

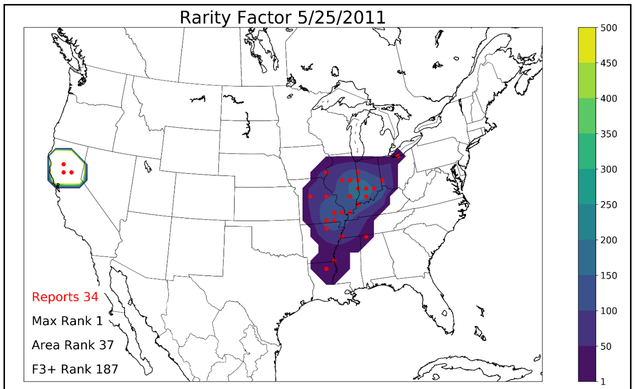

Figure 1: The May 25th, 2011 outbreak: The color bar represents how rare the climatology of the affected area is. The red dots represent each report. Each category is present at the bottom left followed by how the outbreak rank from 1 to 422. A lot of activity is shown within some parts of the Midwest and southeast, but those max rarity values are coming from the three reports in northern California. Being that California doesn't experience that much tornadic activity, the climatology is extremely small.

The day with the highest value of peak rarity is May 25th, 2011 (Figure 1). There are two areas of tornado occurrence this on this day. Much activity and reports are shown in some parts of the Midwest and Southeast, but the max values are coming from the three reports in California. This is because California doesn't experience much tornadic activity, causing the climatology to be extremely small. Even though having tornadoes in California is very unlikely, there would be more information about the tornadoes that affected the Midwest than those that occurred in California.

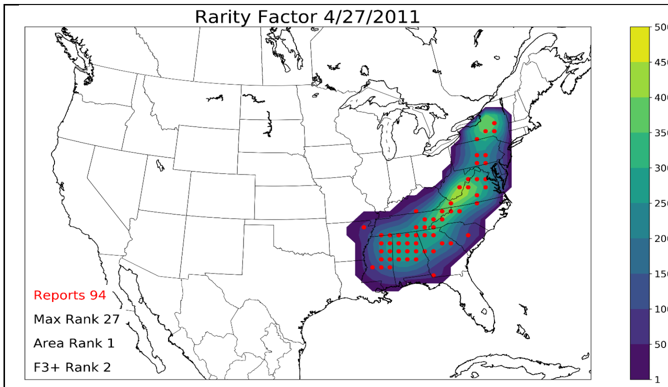

Figure 2: The April 27th, 2011 "Super Outbreak": This outbreak ranked first for area and second for intensity. Much activity shown in the southeast but max rarity values are appearing in Virginia and some parts of New York.

The day with the largest area affected is April 27th, 2011 (Figure 2). This outbreak affected most of the southeast and Midwestern. This outbreak is often referred to as the "largest outbreak on record". This event places first for the largest area and second for intensity (proceeded by the April 3, 1974 "Super Outbreak), yet the event did not place within the top ten for maximum rarity factor being that the southeast does experience a lot of tornadic activity within the month of April. While analyzing the map in Figure 2, there are some max rarity values in the states of Virginia and New York of about 450 times climatology.

The outbreak that produced the most (E)F3 and greater tornadoes occurred on April 3rd, 1974 also known as, the "1974 Super Outbreak" (Figure 3). It impacted 13 states along the eastern region of the United States and was the first on record to produce more than 100 tornadoes in a 24 hour period having 30 of them classified as (E)F3 and greater. The outbreak actually placed within the top 20 for maximum rarity, having values of about

450 times the climatology in the West Virginia area.

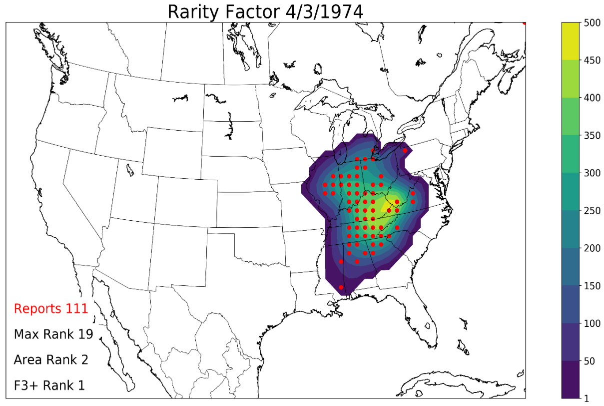

Figure 3: The April 3rd 1974 outbreak: This outbreak impacted 13 states across the eastern & southern region of the U.S. The outbreak placed first intensity but second in area proceeded by the April 27’ 2011 outbreak.

It’s interesting to consider when the different measures of rarity occur during the year. Three charts illustrate each classification of rarity in the months in which they occur:

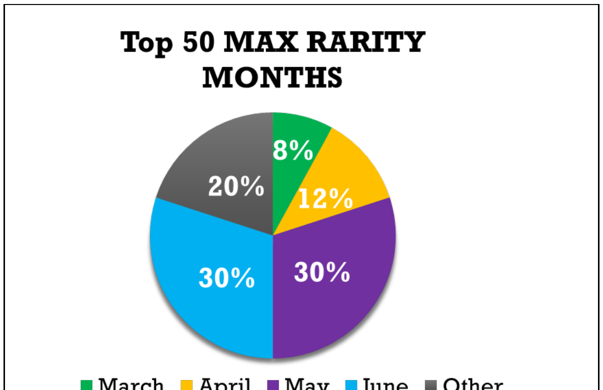

Figure 4: The months where the top 50 in maximum rarity factor occur.

The max rarity factor (Figure 4) holds 60 percent of their top 50 dates in the months of May and June.. Looking back in table 1, 7 out of the top 10 dates occur in both the months of May and June. It seems that max rarity values are favorable to the two months. As area (Figure 5) seems to get started in the month of march but doesn’t seem to be significant as the months of April and May. Lastly intensity (Figure 6) seems to get started in March, look fairly well in April and continue into the month of May. This information explains that intensity occurs earlier than area, but both categories occur earlier than max rarity. There still is that correlation between area and intensity being that not only do they occur earlier than max rarity but they have similar values in the month of April. Maximum rarity still seems to not share or present any correlation factor between either categories.

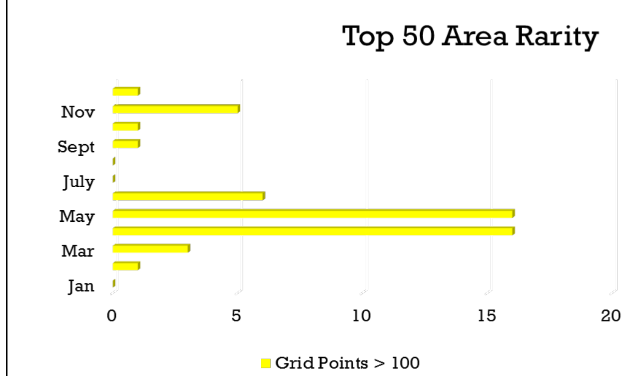

Figure 5: The months where the top 50 in area occur.

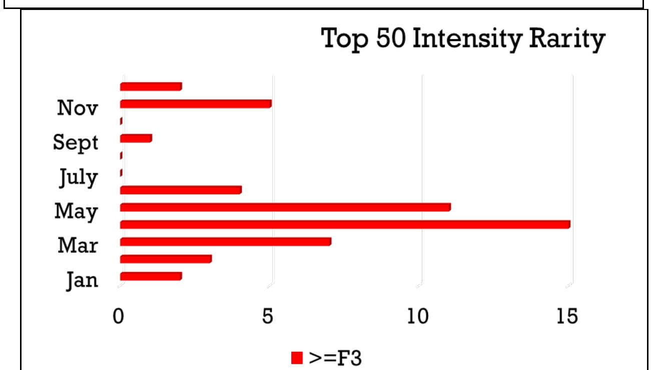

Figure 6: The months where the top 50 in intensity occur.

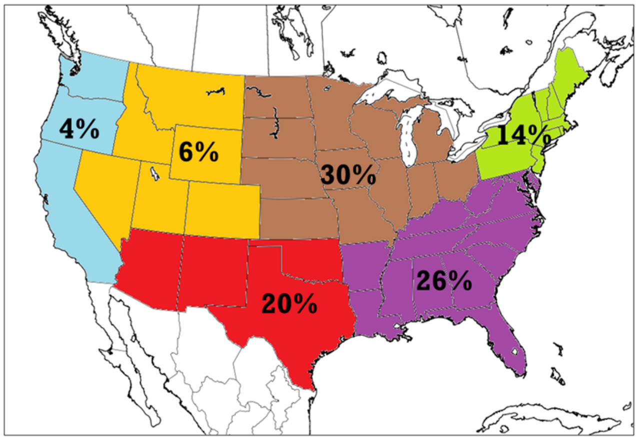

Figure 7a: The areas in which the top 50 maximum rarity factor are located

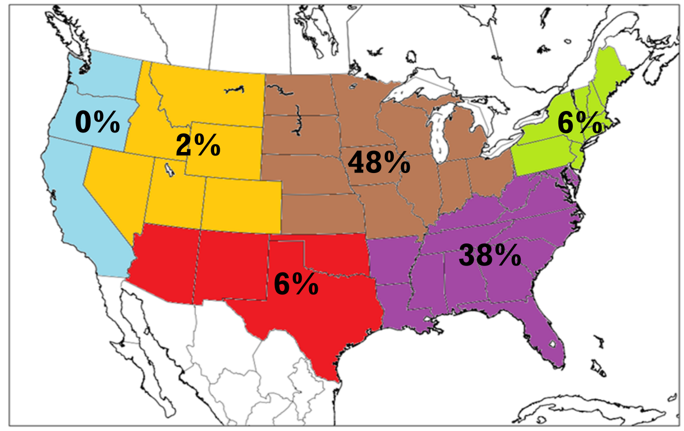

Figure 7b: The areas in which the top 50 in area are located.

It's also interesting in observing the geographical distribution of where the rarity categories are occurring. Two maps were created and then separated into six regions; the Pacific, Rocky Mountains, Southwest, Midwest, Southeast, and Northeast. The comparison will be made by the maximum rarity and area category. Since area and intensity show some correlation, their values may be similar as well (Figure 7a and 7b). While observing the max rarity map (Figure 7a) there is a distribution between four regions. There's little more than half of the occurrences are within the Midwest and southeastern part of the United States. The area map (7b) shows that well than over half of the events are occurring within just two regions. The Midwest and Southeast share 86 percent of the top 50 within the category of area. Even though there are some differences within these two maps, they both seem to follow the same trend by the Midwest with the most weight, followed by the Southeast, Southwest, Northeast, Rockies, and lastly the Pacific.

4. Conclusion/Summary

The purpose of this project is to identify rare tornadic outbreaks while using daily climatological estimates of tornadic probability in the United States. The data was comprised of (E)F1 and greater tornado reports from 1954-2015. A Gaussian smoother was used to smoothed both time and space. To create the rarity days, all the reports on that day were smoothed first in space. Then the day was divided by the climatology, which is an average of the 62-year span. Rarity was then separated into three categories, maximum rarity factor, the amount of area that was affected, and how intense the outbreak was. There seems to be a closer relationship between area and intensity than max rarity. Within the chart 4 out of 10 outbreaks are shared between area and intensity while maximum rarity shares none. Maximum rarity seems to focus on areas where tornadic activity is minimal to none, areas such as northern California and western Oregon are places where one would see these max rarity values. This may show that max rarity may not be the best way to classify these events as "rare". A tornadic event that occurs in northern California (May 25, 2011) may be unusual given its climatology, but is it as rare as twenty reports occurring in the Great Plains.

Charts were then created to display the months that the top 50 in each category occur. The results show that the maximum rarity factor occurs later than intensity and area. The months of April and May are favorable to area and intensity while the months of May and June are favorable to max rarity.

After identifying the months the top 50 events occurred, locating the areas where they occurred was the next task. Two maps were then created in python then separated into six regions; the pacific, rocky mountains, southwest, Midwest, southeast, and northeast. The information from the maps showed that 86 percent of occurrences out of the top 50 for area occur in the Midwest and southeastern part of the United States. While the max rarity map shows a more distributed map with more occurrences happing in the southwest and northeast compared to the area map. This project is important because rarity could affect public preparedness. Even though an area may have an idea of when to expect numerous tornadic activity, will the same area be prepared in a month or location where the climatology is expectedly low?

6. ACKNOWLEDGMENTS

I'd like to thank both my mentors Makenzie Krocak and Harold Brooks for guiding me throughout the project and challenging my mind to complete and explore task that I usually don't come across. Also thanks for the climatological survey department for allowing office space for me to conduct my research. Lastly, I'd like to thank all the graduate students for all their assistance with coding. This work was prepared by the authors with funding provided by National Science Foundation Grant No. AGS-1560419, and NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA11OAR4320072, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Science Foundation, NOAA, or the U.S. Department of Commerce. Also thanks to Dr. Daphne Ladue who allowed me to be a part of The Research for Undergraduate students program. Lastly, thanks to all the graduate students for their coding assistance!

7. REFERENCES

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