INVESTIGATING THE RELATIONSHIP OF MULTI–RADAR MULTI–SENSOR PARAMETERS TO TORNADO INTENSITY

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Abstract

Derived radar parameters were investigated to determine the correlation between radar products and tornado intensity. More than four–hundred tornadoes from eleven tornado outbreaks between 2008 and 2011 were analyzed using WSR–88D radar sites. Radar reflectivity data was quality controlled, Doppler velocity data was dealiased and then merged in order to fill in any potential data gaps related to volume coverage geometry or blockages. Derived parameters included reflectivity values at certain heights and maximum azimuthal shear values within certain layers of the atmosphere. The lifetime maximum values of these fields surrounding tornado tracks were extracted and compared to the reported tornado intensities. It was found that lifetime maximums of radar derived parameters showed little discrimination of tornado intensity. However calculations of azimuthal shear area of the tornado paths did show some discrimination.

1. INTRODUCTION

Tornado strength is traditionally accessed after a severe weather event through damage surveys. In regions with low population densities it is potentially difficult to determine the strength of a tornado due to limited structures and eyewitness accounts (Toth et al., 2011). If it is possible to use radar data to determine the intensity of a tornado, meteorologists may be able to quickly estimate the strength of a tornado, and possibly improve archived data in regions where analysis is difficult.

Several studies have researched the applications of radar parameters with respect to determining the intensities of tornadoes. Using both a mobile radar and the Weather Surveillance Radar 88 Doppler (WSR–88D), Toth et. al (2011) surveyed the differential wind components within tornadoes. Comparisons between these two radars show that mobile radars have more accurate readings than the WSR–88D data, and report higher differential velocities captured within tornadoes however there may be a relationship between what the differential velocities observed by the WSR–88D to that of the differential velocities observed by the mobile radar.

Kingfield et al. (2012) used Mesocyclone Detection Algorithm (MDA) (Reference) output from WSR–88D's to investigate the correlation between these outputs and tornado intensity. The Low Level Rotation Velocity (LLVr) was found to be an important field. However, initial results show no significant differences between individual tornado strengths and LLVr values.

This study will continue to investigate the potential relationship between radar parameters and tornado strength. Instead of studying single radar data this study will use a multi–radar multi–sensor approach for investigation.

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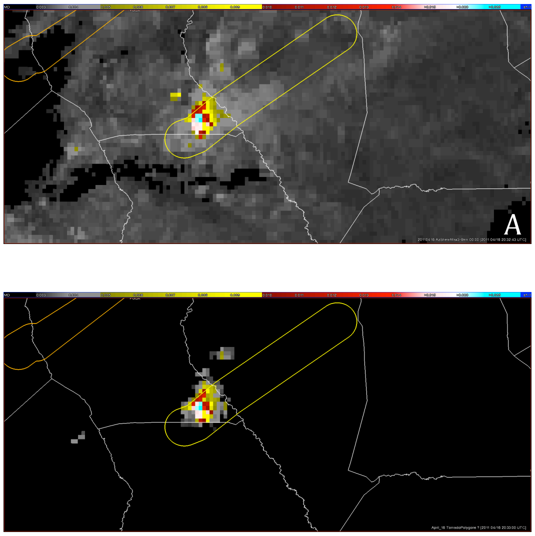

Figure 1a) The azimuthal shear between 3 and 6 km for a mesocyclonic system with an overlaid tornado track 1b) The range corrected field of the same mesocyclonic system

2. METHODS AND METHODOLOGY

2.1 Data

Eleven different tornado outbreaks between the years of 2008 and 2011 were analyzed for this study. These eleven outbreaks yielded 405 tornadic events. WSR–88D Level–II archived radar data used was acquired through the National Climatic Data Center (NCDC), and the vertical wind profiles used to dealias the velocity fields was from the Rapid Update Cycle (RUC) (Jing and Weiner, 1993).

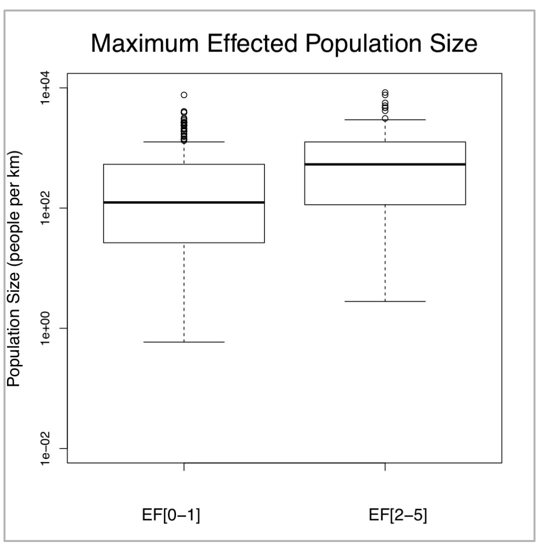

Figure 2: The distribution of the Maximum impacted population. The dark lin is the median line, and the top and bottom lines of the box are the 25th and 75th percentiles. Error bars are 1.5 the interquartile range.

2.2 Investigated Fields

The output data analyzed for this study came for the Warning Decision Support System and Integrated Information (WDSS–II) (Lakshmanan, et al. 2007). WDSS–II provided the radar data ingest and merger software (Lakshmanan, et al. 2006). Radar reflectivity data was quality controlled using a neural network (Lakshmanan et al. 2007). Multi radar data was used in this study to avoid potential limitations of single radar data such as volume coverage geometry and blockages. Doppler velocity fields were dealiased using a two–dimensional dealiasing technique described in Jing and Weiner (1993). A linear least squares derivatives method (Smith and Elmore 2004) was used to derive azimuthal shear from Doppler velocity fields. The azimuthal shear fields were range corrected before output (Newman et al. 2011). Additionally gate–to–gate velocity differences were calculated within high shear areas. A population grid was used to investigate potential usefulness of population counts to the final rating.

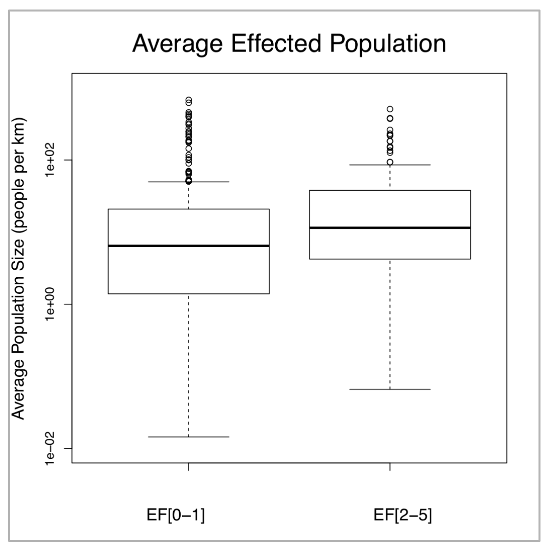

Figure 3: The same as Fig. 2 except the distribution of the average population

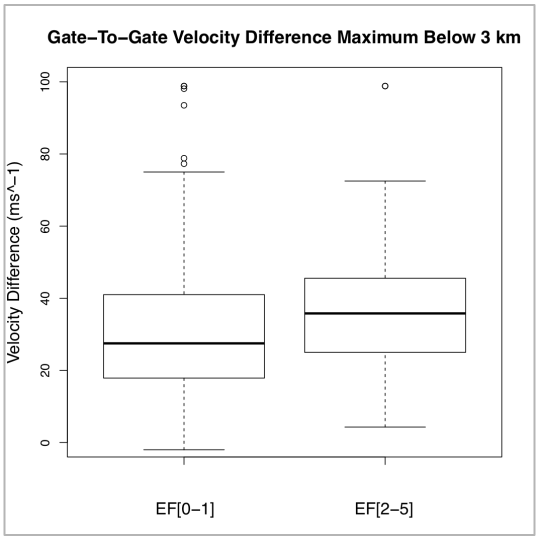

Figure 4: The same as Fig.. 2 except for the distribution of gate–to–gate velocity difference below 3km

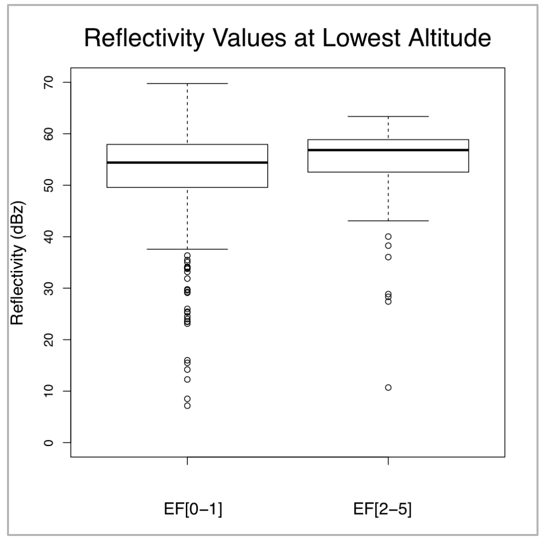

Figure 6: The same as Fig. 2 except for the distribution of Reflectivity values.

Reflectivity and shear fields were extracted for certain layers and altitudes in the atmosphere within the WDSS–II merging software. This ability allows for potentially significant levels, such as lifting condensation levels (i.e. cloud base rotation) to be investigated. This study investigates these levels including: surface lifting condensation level, below surface lifting condensation level, most unstable lifting condensation level, between the surface and three kilometers, at the lowest altitude, and between three to six kilometers above ground level within the atmosphere.

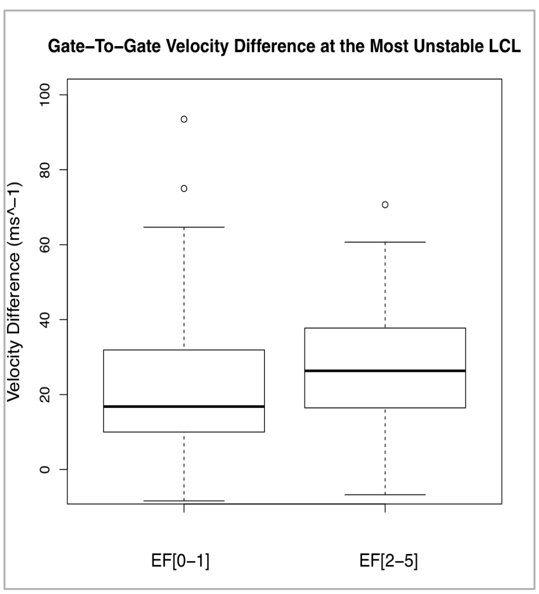

Figure 5: Same as Fig.. 2 except for the distribution of the gate–to–gate velocity difference at the MULCL

2.3 Data Mining

Tornado data were acquired through the National Weather Service Performance Branch (https://verification.noaa.gov). The tornado data is stored in county segments and for multiple county tornadoes these segments were combined together to make one tornado path. The highest rating of any of these segments was used as the tornado's strength. Polygons were then created from these tornado paths using a five kilometer buffer.

Using WDSS–II software radar data was matched to the tornado polygons and within the polygons maximums and counts of the different parameters were calculated. For analysis the lifetime maximum of reflectivity and shear values were matched to the tornado strength. Also the maximum and average populations were matched to the tornado strength. Distributions of these values were created.

3. RESULTS

Most parameters investigated show little difference between weak and strong tornadoes. The distributions of maximum (Fig. 2) and average (Fig. 3) populations within the tornado paths have significant overlap between weak and strong

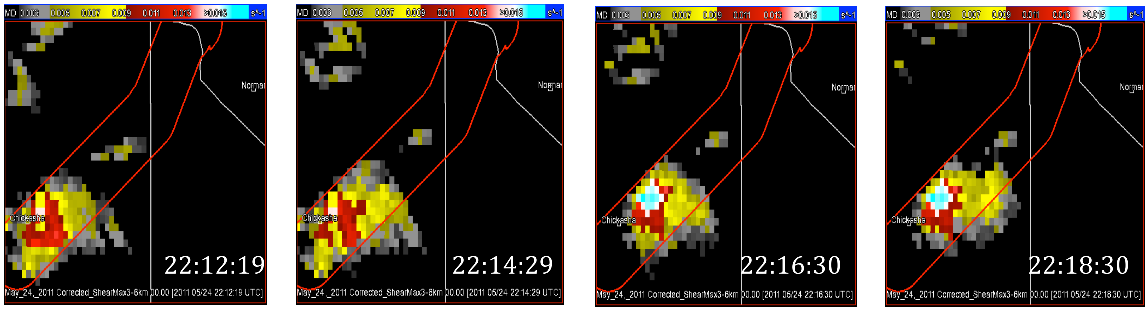

Figure 7: Time step interval of mesocyclonic system during May 24, 2012. As can be seen in the time series the shear areas overlap, causing areas to be counted twice during out break.

tornadoes. One extension of the population analysis might include an analysis where only populations affected by different shear thresholds are tallied.

Distributions of shears at different layers or altitudes showed significant overlap as illustrated in Figs. 4 and 5, which show the overlap for values between the 25th and 75th percentiles. The use of layers though would be a better choice in overcoming radar geometry issues concerning altitudes near the earth's surface.

Calculations of the areas of azimuthal shear have the largest differences between the distributions for weak and strong tornadoes. (Reference the figure here). However, these larger areas for stronger tornadoes may be due to the stronger tornadoes having longer path lengths and our selection of tornado outbreaks as compared to more limited tornado event days. Even with this caveat, the area information could be useful when investigating rotation track products created by Miller et al. (2012) (Fig. 9). Rotation track products are more accurate in calculating shear area because it creates a net swath of shear opposed to current methods that add areas over time, potentially causing double counting of areas (Fig. 7). These products can then be used to find the percentage of azimuthal shear within a tornado path, removing path length dependencies.

When changing the definition of weak tornado from EF[0–1] to EF[0–2] and a strong tornado from EF[2–5] to EF[3–5] median values of both bins separated further. As shown in Fig. 10, there is still considerable overlap though, and there are few strong tornado reports, making data insignificant.

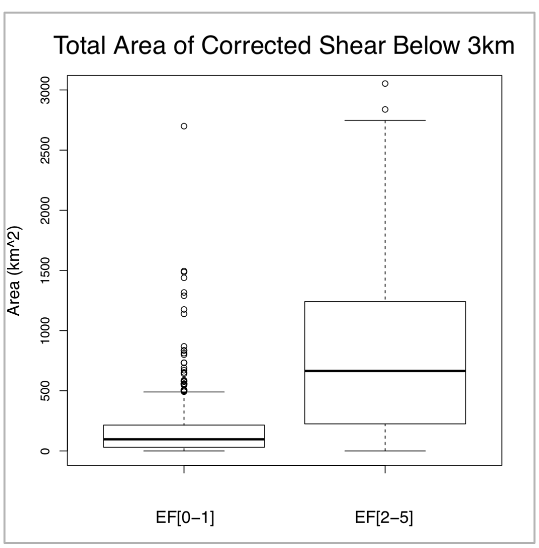

Figure 8: Same as Fig. 2 excepts showing distribution of Corrected Shear below 3km and above the surface.

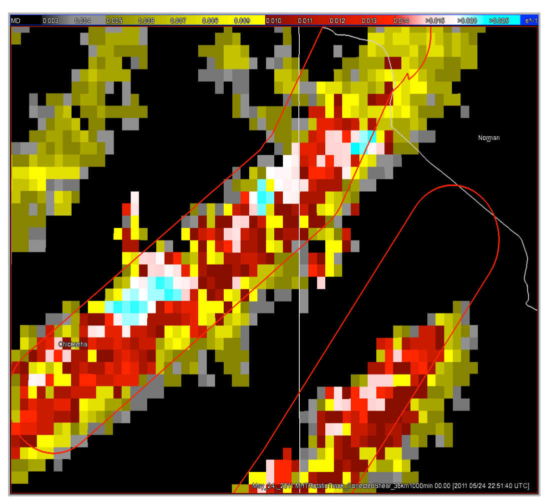

Figure 9: The rotation track field for a mesocyclonyic system on May 24, 2010 that produced a tornado near Norman Oklahoma.

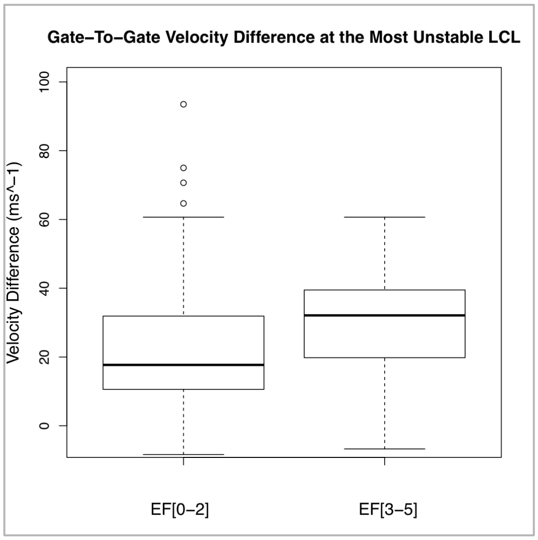

Figure 10: Same as Fig. 5 except with redefined weak and strong tornado strengths.

6. ACKNOWLEDGMENTS

Many thanks to Christopher Reidel and Jenifer Tate who provided environmental data throughout the project.

This work was prepared by the authors with funding provided by National Science Foundation Grant No. AGS–1062932, 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.

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