P3.38 Probabilistic Tornado Warning Plumes

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1. Introduction

In 2012 the National Weather Service (NWS) office in Kansas City/Pleasant Hill, Missouri participated in the Impact Based Warning (IBW) project. At the end of the convective season a review of the project was conducted. During the review NWS forecasters were asked to set aside the current NWS text warning system and discuss how severe weather threats could best be conveyed to those receiving NWS warnings. One of the suggestions was to create a grid of probabilities for various severe weather threats in the path of the storm, which is also an ambition of the "Forecasting A Continuum of Environmental Threats" (FACETS) project at the National Severe Storms Laboratory (NSSL). This grid set would portray forecaster confidence and diagnosis for a range of different threats and impacts.

Although the tools to do this directly are not currently available to NWS meteorologists, there is enough information in NWS warning text to make some general assumptions regarding threat levels. Specifically, using the initial storm location and motion from the warning text and combining this with a climatology from previous tornado warnings and reports, threat levels for tornadoes downstream from the forecaster-defined storm/tornado origin can be determined.

For this study, a climatology was developed using NWS tornado warnings and tornado reports from 2008 through 2013 for all NWS forecast offices. Warnings are separated into bins based upon initial storm speed and warning duration. A comparison of the distribution of tornado reports relative to the initial storm location is used to calculate a high resolution grid of strike probabilities in proximity to the storm. Applying regression and smoothing techniques to the probability grid produces a warning plume highlighting the highest tornado threat area. Calculation of the climatological tornado threat plumes are presented along with basic verification statistics for comparison against NWS warning polygons. Although skill scores for the NWS warning polygons were better compared to the warning plumes, there was a reduction in the average false alarm area for the warning plumes versus the warning polygons.

2. Data and Methodology

NWS tornado warning text from 2008 to 2013 was gathered from the Iowa State IEM Cow archive. Tornado reports for 2008 to 2013 were obtained from the Storm Prediction Center (SPC) web site. Using the storm origin latitude and longitude along with the storm motion from NWS warning text, the warnings were normalized so that all storm motions were from a common direction allowing all of the storms to share an origin point (Figure 1). Next storm reports were also normalized based on the storm origin latitude and longitude and then plotted relative to the common storm origin. For tornado reports that contained a starting point and an ending point, reports were added at 1.6 kilometer increments along the tornado path. To allow for varying warning plume sizes, the warnings were divided into bins based on initial storm speed and warning duration.

From the scatter plot in Figure 1 a high resolution gridded field of probabilities was produced by dividing the number of reports at or near that grid point by the number of warnings issued (Figure 2). Although the resulting values are quite low for any given grid point, the orientation of the probabilities resembles a plume shape downstream from the storm origin.

Finally, regression techniques applied to the gridded field of probabilities smoothed and normalized the data to present a tornado warning plume specifically for the storm speed and duration of the warning issued (Figure 3).

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3. Verification

Statistical analysis was performed for the tornado warning plume categories for the period 2008 to 2013 based on the data and methodology discussed above. In an effort to baseline the data set, plumes were only created and verified for warning polygons (and their associated storm origin) that contained at least one tornado report. Warning plume categories were produced in 10% increments from 30% (larger plume) to 80% (smaller plume) (Figure 4). The percentage of tornado occurrence within the plume (hit percentage) for each warning plume category is shown in Figure 4.

Warning false alarms are a concern for NWS operations, thus an analysis was generated to compute the percent improvement of false alarm area of the warning plumes over the NWS warning polygons. For the analysis a high resolution grid was calculated over both the warning polygons and the warning plumes. If the tornado report was within 3.2 km of the grid point it was considered a hit at that point. The number of grid points with hits was then divided by the number of total grid points and subtracted from 100 to obtain the percentage of the polygon or plume that was a "false alarm". Average percent improvement for false alarm area of the warning plumes over the warning polygons is presented in Figure 5 for each warning plume category.

4. Example

Figure 6 depicts a map of tornado warning plumes (varying shades of red) with their corresponding tornado warning polygons (red). The plot covers an 8-hour period beginning at 1800 UTC 31 May 2013, with several tornado warnings and reports in central Oklahoma. Tornado reports and tracks are plotted in yellow. Note in the SPC tornado report database, latitude and longitude values for the tornado starting and ending points are included, however points along that path are not shown in Figure 6. As a result, some of the paths represented as straight lines in the plot actually may have deviated from that path.

5. Discussion

Considering the climatological derivation of the plumes the hit percentage for the lowest threshold (82% for all tornadoes and 88% for tornadoes EF2/F2 and greater) is encouraging. Likewise, the percent improvement for false alarm area of the warning plumes over the warning polygons is positive. Probability of detection (POD) statistics were also calculated for the warning plumes (not shown). The POD results were not as favorable.

In an ideal warning situation the plumes should be used as "first look" guidance for the warning operator. Forecaster adjustment of the warning plume and the corresponding thresholds prior to issuance would provide the optimum balance between low false alarm area and high probability of a tornado occurring within the warning plume.

6. Acknowledgements

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Also thanks to Caleb Wilson (Summer 2013 Hollings Scholarship student at NWS Central Region Headquarters) for the initial verification work

7. References

FACETS - Forecasting A Continuum of Environmental Threats. National Severe Storms Laboratory (NSSL). http://nssl.noaa.gov/projects/facets

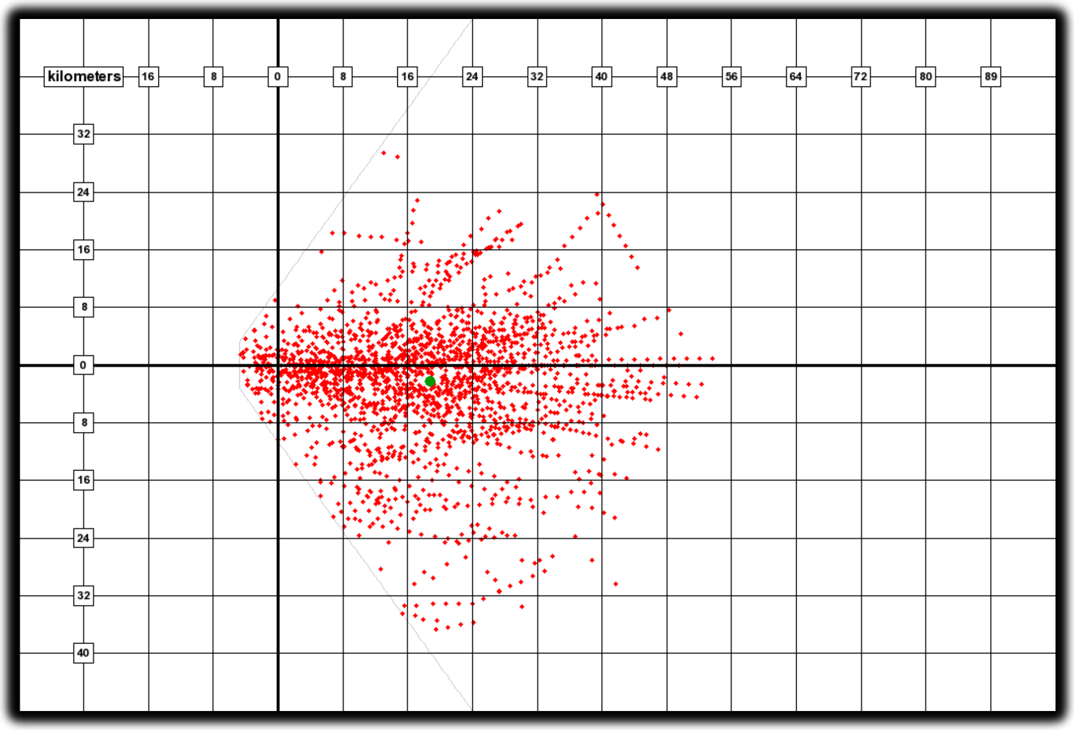

Figure 1. *Scatter plot of tornado reports relative to initial storm location for tornado warnings. Green dot represents mean location of reports. Storm Speed: 13 m* s^{-1} *Duration: 45 minutes*

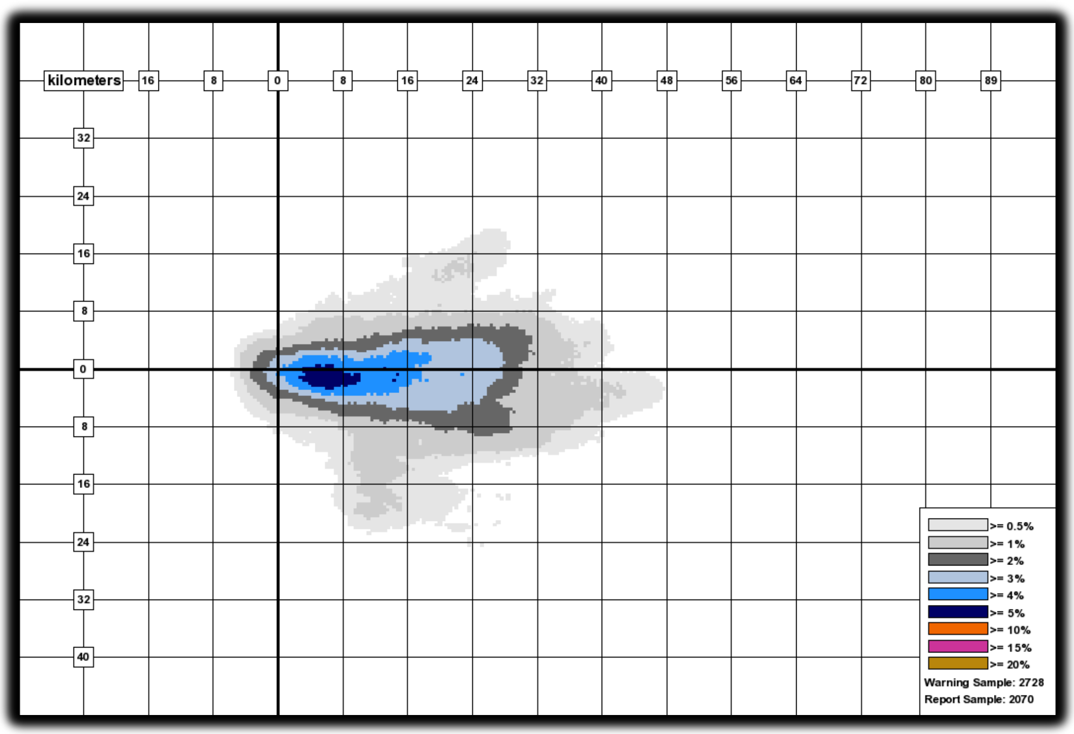

Figure 2. *Gridded field of probabilities of tornado reports relative to initial storm location for tornado warnings using report data from figure 1. Storm speed and duration as in Figure 1.*

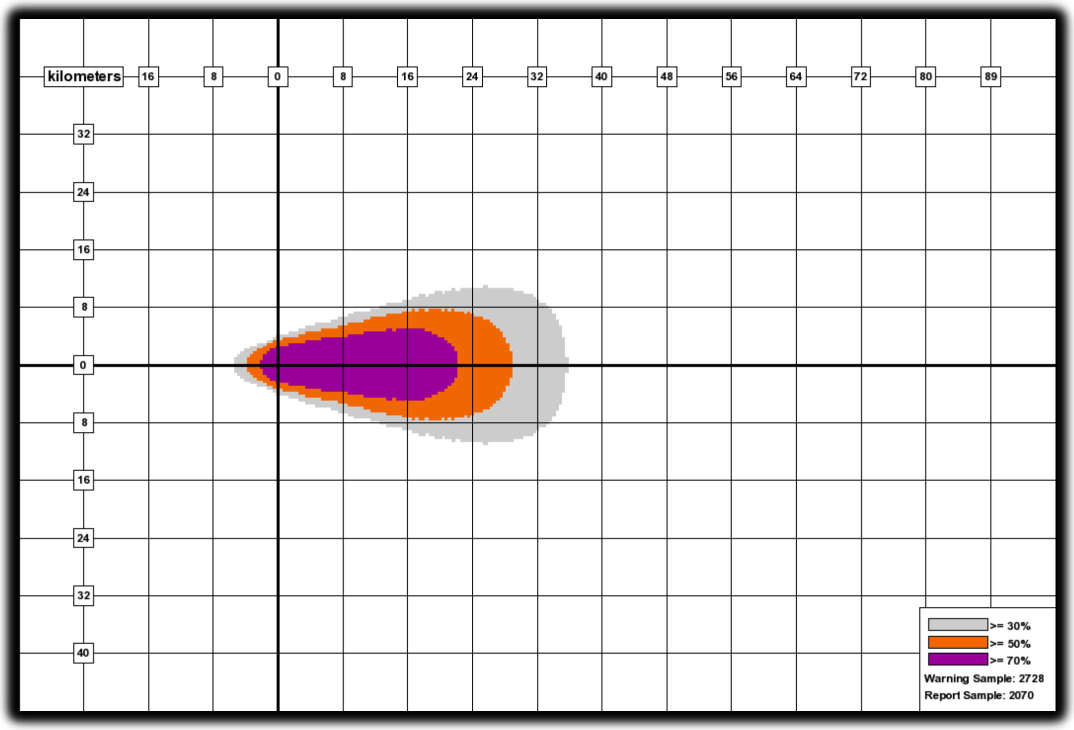

Figure 3. *Probabilities plume for tornado reports relative to initial storm location for tornado warnings applying regression techniques and smoothing to probabilities in figure 2. Storm speed and duration as in Figure 1.*

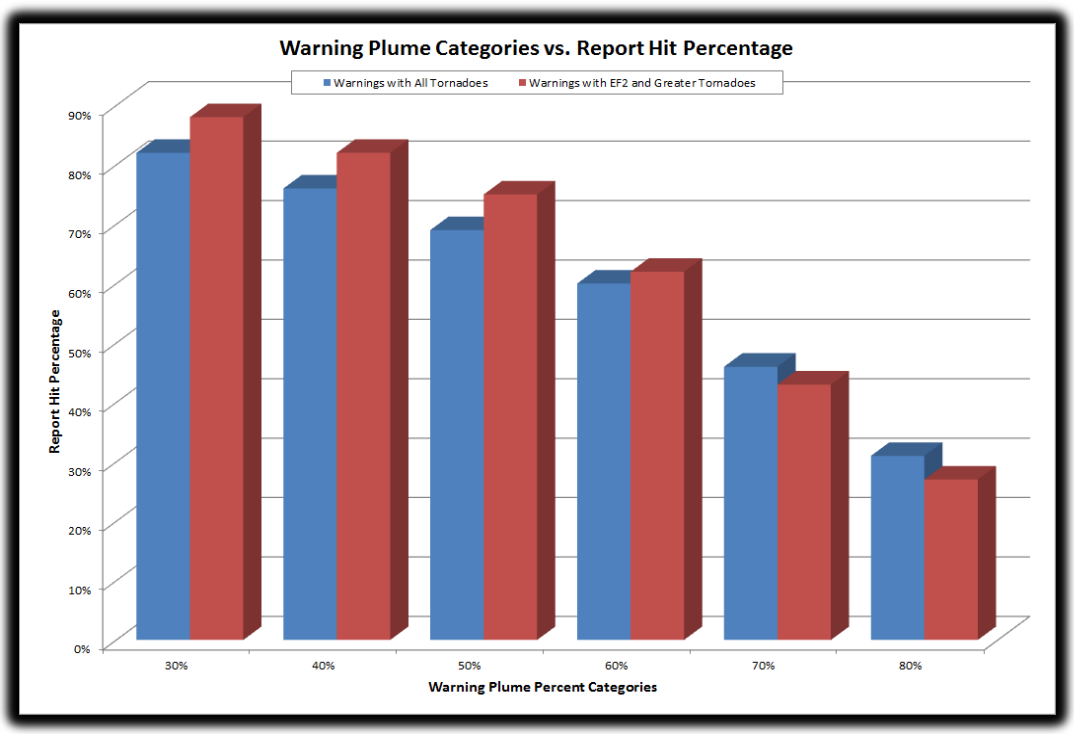

Figure 4. *Bar graph of warning plume percent categories vs. the percentage that the plume verified with at least one report. Blue represents all tornadoes. Red represents EF2 and greater tornadoes.*

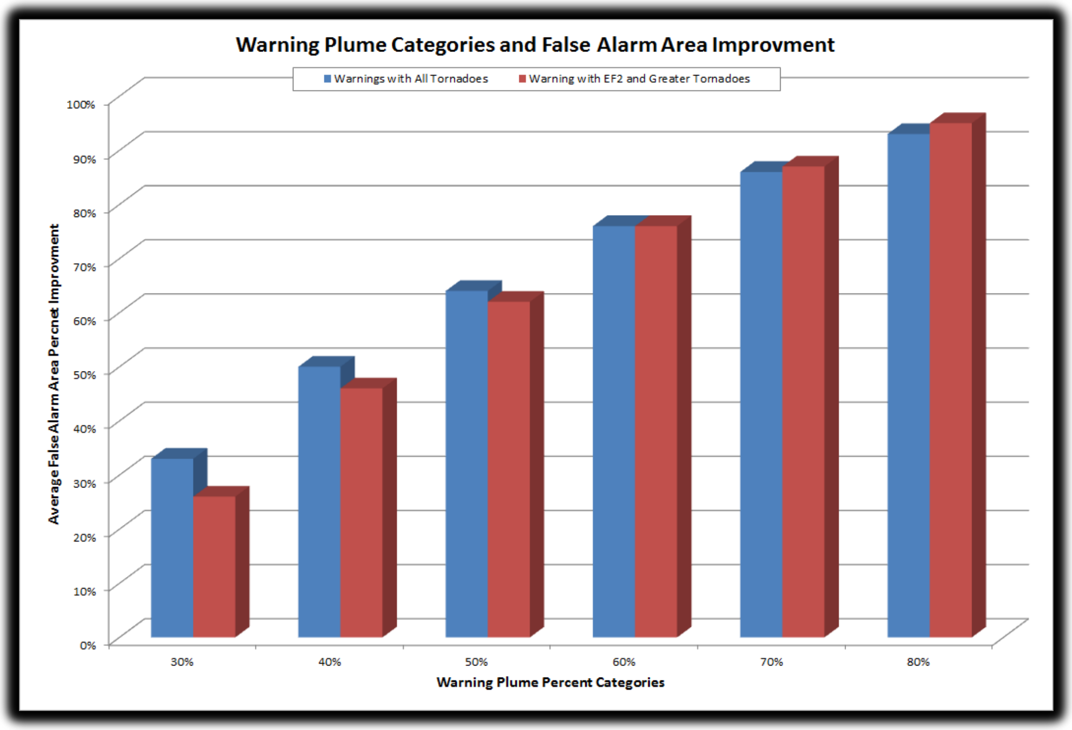

Figure 5. *Bar graph comparison of the average false alarm area percent improvement of warning plumes over warning polygons for each warning plume percent category. Blue represents all tornadoes. Red represents EF2 and greater tornadoes.*

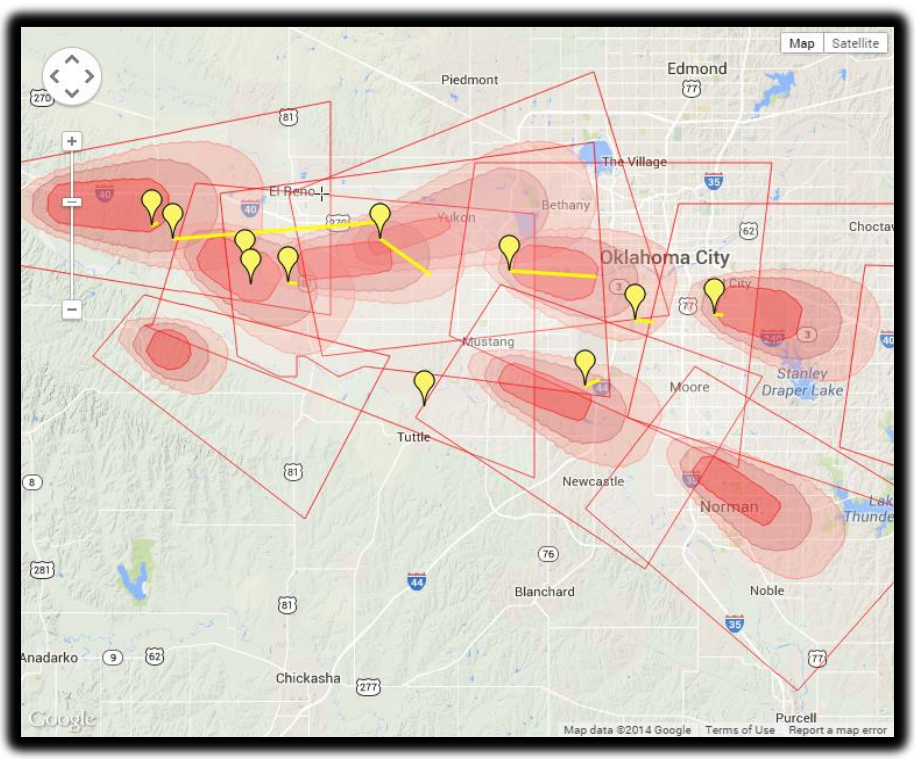

Figure 6. *Tornado warnings/plume and reports for an 8-hour period starting at 1800 UTC 31 May 2013. Tornado warning plumes in varying shades of red, tornado warning polygons in red. Tornado reports in yellow.*