Evaluating Likely Hail Impacts from SPC Day One Outlooks

Brittany Recker[1, 2], S. Mark Leidner[3], Daniel Gombos[3]

[1]National Weather Center Research Experience for Undergraduates Program

[2]The Pennsylvania State University, University Park PA

[3]Atmospheric and Environmental Research, Inc.

ABSTRACT

The purpose of this study is to interpret the Storm Prediction Center (SPC) convective outlooks for potential impacts. Radar data was used to provide the link between what has been forecast by SPC outlooks to what actually occurred. Several metrics, such as total area (km^2) of SPC outlooks and radar-determined hail, and center of mass positions, were calculated in order to evaluate SPC outlooks. It was found that, over the sample size in this study (n = 108 case days), the percentage of radar hail probability area inside the SPC Slight Risk threshold is approximately 23%, while the percentage of SPC Slight Risk or greater covered by radar data is approximately 12%. A correlation coefficient of 0.595 was also found by looking at the relationship between SPC area-weighted probability and the area of radar data that overlaps the SCP Slight Risk areas. These values, along with the other metrics, will allow convective outlook forecast users to be better prepared for the impacts of severe hail.

---

1. INTRODUCTION

The Storm Prediction Center (SPC) distributes convective outlooks for the contiguous United States. These outlooks are a forecast, identifying potential locations where severe weather could occur. The categorical convective outlook assesses the risk of severe weather in terms such as “Slight”, “Moderate”, or “High”. The SPC commenced issuing probabilistic convective outlooks for small scale dangerous weather phenomenon of hail, damaging wind, and tornadoes in March of 1999 (Kay and Brooks, 2000).

The SPC convective outlooks are currently evaluated using storm reports. This method of evaluation determines the forecast quality, which is defined as the relationship between observations and the forecast (Murphy, 1993). Radar data, however, appears to be a better way to assess the SPC convective outlooks. It is much more democratic in its spatial sampling. While it too evaluates the quality, it can also be used to estimate the value, or user benefits derived from these forecasts, of the SPC convective outlooks (Murphy, 1993). The question this analysis addresses is “Given an SPC probabilistic hail outlook, what can be expected to actually happen?” The answer came from examining properties of both radar-estimated hail probability and SPC probabilistic hail outlooks over 108 case days.

The Data and Methods section describes the process by which the results were obtained. The Results section, which follows, details the numerical findings of this study through discussion of several figures and a table. Finally, the Conclusions section summarizes the research and outlines both additional and future work.

2. DATA AND METHODS

The SPC probabilistic convective outlooks, including estimates of wind, hail and lightning risks, were acquired from the Shreveport National Weather Service forecast office. They were archived as shapefile polygons

[1] Brittany Recker
6812 Ridge Avenue, Finleyville PA 15332
bnr5027@psu.edu

with latitude-longitude vertices that are identical to the operationally drawn polygons from the forecasts. Figure 1 shows an example of an SPC day 1 hail outlook valid April 5th, 2012. The 12z convective outlooks were predominately used for each day. But because outlooks were only archived if they contained at least a “Slight” risk in them, not all case days had an outlook in the database (four days were missing because no Slight risk area was forecast). A 12z convective outlook means that the outlook is valid from 12z and to 12z the following day; regardless of what time an outlook is issued, it is always valid until 12z the next day. If a 12z outlook was not issued, the first available SPC convective outlook for that day was used. First available forecasts that were not issued at 12z were used in this analysis on 15 of the 108 case days. Both the probability threshold and its corresponding categorical term are used in this comparison (i.e., “Slight” risk is approximately equivalent to 15% probability). The 24-hour probability of severe hail (POSH) summaries were generated by Atmospheric and Environmental Research, Inc. (AER). Figure 2 displays a small portion of the convective outlook for hail and radar summaries for the same day, April 5th, 2012, identified by the black box in Figure 1. POSH is derived from the NEXRAD hail detection algorithm (HDA) using the warning threshold and severe hail index (Witt et al., 1998). Data sets from both sources were gathered for the period March 8th to July 8th, 2012, with the exception of several days missing due to corrupted or missing data.

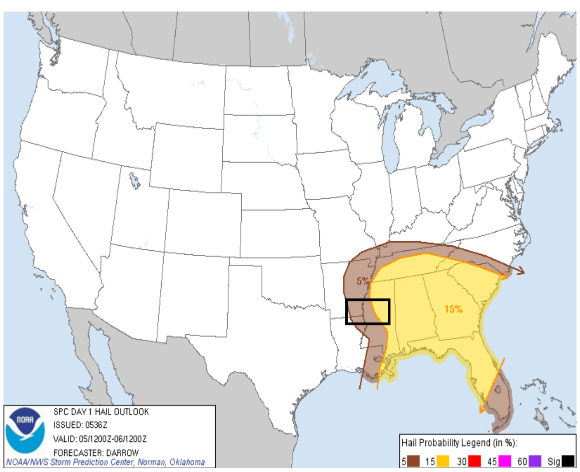

Figure 1. A sample SPC Probabilistic Hail Convective Outlook, valid from 12z April 5th to 12z April 6th, 2012.

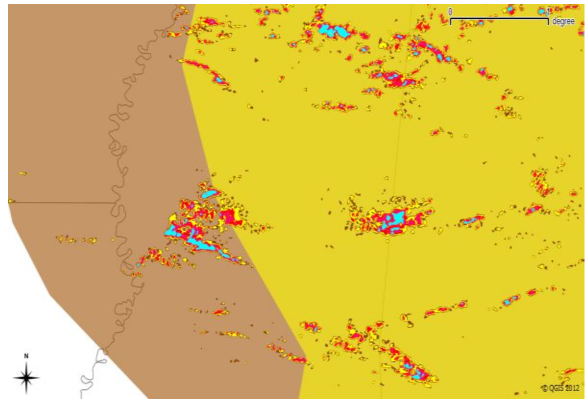
Figure 2: Small portion of the sample SPC Convective Outlook (identified by the black box in Figure 1) with radar hail probability over plotted. Radar-derived hail probability is contoured at the same thresholds [5%, 15%, 30%, 45%, 60%] and colors as the SPC Outlook (Figure 1), except the 60% radar threshold is plotted in cyan instead of purple.

The radar data was filtered to remove any echoes that did not intersect with the continental United States. For each case day in the data set, the following list of parameters was calculated:

- SPC convective outlook total area
- SPC outlook threshold areas
- Radar total area
- Radar probability threshold areas
- SPC outlook center of mass (CoM)
- Radar CoM
- Displacement vector between CoM positions
- Area-weighted radar probability
- Area-weighted outlook probability

A figure was also created for each case day displaying the date, the SPC convective outlook polygons, the radar-estimated hail probability polygons, the CoM locations for both the outlook and radar-estimated hail probability areas, and the displacement vector between the CoM positions over the United States. Figure 3 is an example case day figure for April 5th, 2012. The direction and magnitude of the vector, area-weighted radar probability, and area-weighted outlook probability are included in a text box on the figure.

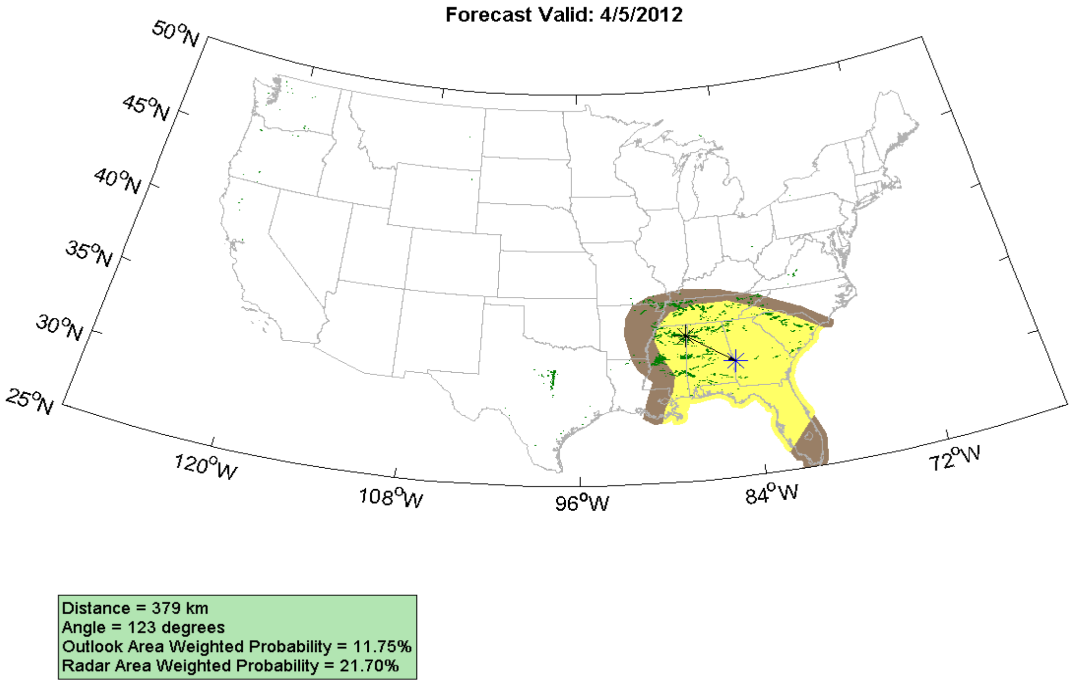

Figure 3. Sample plot generated for each case day. The radar-estimated hail probability polygons (green) are overlaid on top of the SPC day 1 hail outlook. The SPC day-1 hail outlook center of mass (CoM) is marked with a blue asterisk and the radar-estimated hail probability CoM is marked with a black asterisk. A black arrow points from the radar CoM to the outlook CoM. The textbox in the lower left corner displays the magnitude and angle (degrees from North) of the CoM displacement vector, and the area-weighted probabilities for both the outlook and radar data.

The center of mass position (***R***) for POSH and SPC outlooks is found by the equation

$$\boldsymbol{R} = \frac{1}{M}\sum m_i \boldsymbol{r_i} \qquad (1)$$

where $\boldsymbol{r_i}$ is an individual hail probability area centroid, m_i is the product of the hail probability threshold and its respective area, and M is the sum of the products of all hail probability thresholds and their respective areas. The area-weighted probability is calculated in a similar manner, just replacing the centroid coordinates (longitude or latitude) with probability thresholds.

Before evaluating the SPC outlooks, the two data sets had to be made more directly comparable. Each set of data has a different definition of risk. The SPC defines the convective outlook probabilities as the likelihood “of one or more events occurring within 25 miles of any point during the outlook period” (SPC Probabilistic Outlook Information). The definition of radar-derived hail risk is the probability that one or more severe hail events occur within one kilometer based on the HDA (Witt et al., 1998). The radar hail probability shapefile data were generated using the same probability thresholds as the probabilistic outlooks, and during the same timeframe: 12z to 12z. In addition to the previous metrics, the following overlap metrics were also computed for each case day: (a) the fraction of the POSH area (>5% probability) that falls inside the SPC Hail Slight/15% outlook area, (b) the fraction of POSH area (>5% probability) that falls outside the SPC Hail Slight/15% outlook area (i.e., *1*-(a)), and (c) the fraction of the SPC Hail Slight/15% outlook area that is covered by POSH areas (>5% probability). The hail probabilities at all thresholds were used for the area calculations. Use of 5% or 15% radar-derived hail probability for the comparison would not change the results significantly, since the gradient in radar-derived 5% and 15% hail probabilities are very sharp (e.g., usually just a few kilometers). Figure 4 displays an example of radar probabilities in various stages of intersection with an SPC Slight risk area.

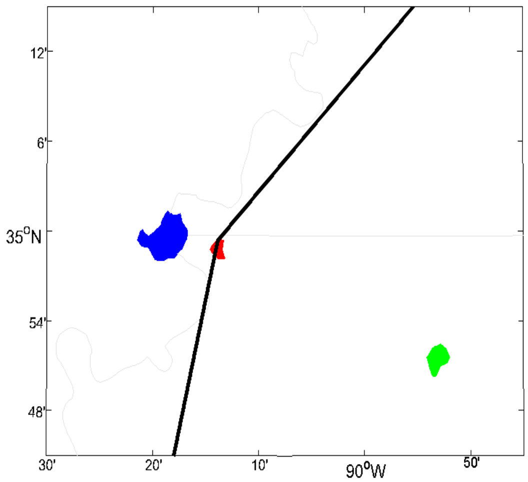

Figure 4. Sample of several radar polygons with an SPC Slight Risk area (i.e., the area east of the bold, black line). The blue radar polygon on the left has 0% area intersection, the red radar polygon in the middle has 64% area intersection, and the green radar polygon on the right has 100% area intersection.

3. RESULTS

The first topic that is discussed is a summary of average parameter values. Following is a comparison of outlook and radar areas from the statistical table. This section concludes with an example of correlation between computed metrics over the time series.

Table 1 shows the average and standard deviation calculated for each parameter. The average distance between the center of mass positions is 463 ± 360 km. The average percentage of SPC Slight Risk or greater covered by radar data is 12%; while the average percentage of radar hail probabilities inside the SPC Slight Risk threshold is 23%.

Parameter	Average	Standard Deviation
Outlook 5-15% Probability Threshold Area (km^2)	1055664	640527
Outlook 15-30% Probability Threshold Area (km^2)	343860	262924
Outlook 30-45% Probability Threshold Area (km^2)	44972	85955
Outlook 45-60% Probability Threshold Area (km^2)	5919	34781
Outlook 60+% Probability Threshold Area (km^2)	0	0
Radar 5-15% Probability Threshold Area (km^2)	12868	8321
Radar 15-30% Probability Threshold Area (km^2)	11131	7762
Radar 30-45% Probability Threshold Area (km^2)	6880	5199
Radar 45-60% Probability Threshold Area (km^2)	4035	3329
Radar 60+% Probability Threshold Area (km^2)	3465	3370
Outlook Total Area (km^2)	1055664	640527
Radar Total Area (km^2)	38378	26946
Distance (km)	463	360
Angle (Degrees from North)	11	89
Outlook Area Weighted Probability (%)	9	3
Radar Area Weighted Probability (%)	21	3
Area of Radar Data Inside 15% Outlook Threshold (km^2)	44145	49100
Percent of Radar Data Inside 15% Outlook Threshold (%)	23	21
Area of Radar Data Outside 15% Outlook Threshold (km^2)	146201	76577
Percent of Radar Data Outside 15% Outlook Threshold (%)	77	21
Percent of SPC Slight or Greater Area Intersected by Radar (%)	12	10

Table 1. Average parameter values and their standard deviations for evaluation metrics used in this study. All results computed from 108 case days (n=108).

Table 1 shows that the average Slight Risk area was forecast to be 343,860 ± 262,924 km^2 and the average area covered by radar probabilities is 38,378 ± 26,946 km^2. As seen by these averages and in Figures 2 and 5, the comparison of total areas between the two data sets for each case day, the SPC convective outlook total area is consistently larger than the area covered by radar data by roughly an order of magnitude.

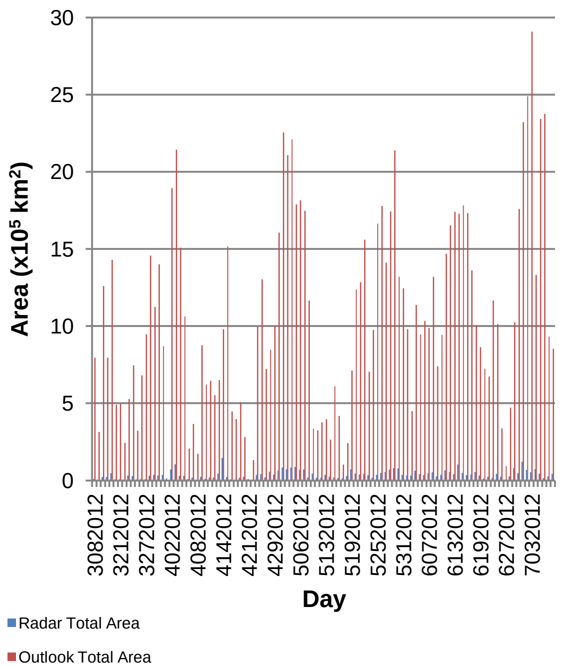

Figure 5. Graph showing the total area covered by SPC day-1 hail outlooks and the total area covered by radar hail probabilities (>5%) for each case day.

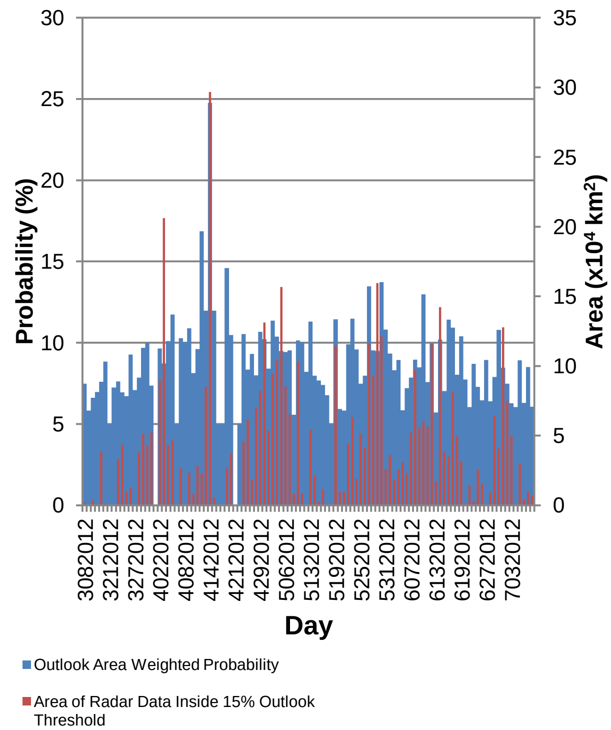

Figure 6: Graph showing the area-weighted SPC convective outlook probabilities (blue) and the area of radar-derived hail probability (>5%) inside the Slight outlook area (red) for each case day.

In addition, numerous coefficients between SPC outlook and radar metrics were calculated; the one was the most positively correlated was between the areas of radar data that overlaps the SPC Slight Risk areas and SPC area-weighted probabilities. Figure 6 shows the relationship between the areas of radar data that overlaps the SPC Slight Risk areas and SPC area-weighted probabilities. The SPC area-weighted probability represents the overall likelihood of severe hail occurring in the continental United States. The Pearson correlation coefficient (Wilks 1995, pp. 45-50) between these two variables is 0.595. This shows that when SPC outlooks suggest hail is more likely, the total radar area intersecting the Slight risk outlook area is generally greater.

4. CONCLUSIONS

This investigation is a preliminary analysis of two data sets that assess the risk of severe hail. While the research question was successfully answered, a thorough examination of all of the parameters measured could be conducted for further evaluation of the SPC convective outlooks.

In this study it was found that the SPC outlooks are much larger in comparison to radar observed hail areas (343,860 km^2 to 38,378 km^2). Although there is a large discrepancy between the outlook and radar areas, there is still great utility in the outlook's ability to warn in advance where severe weather might occur. Approximately 23% of radar hail probability falls inside the SPC 15% threshold, while only approximately 12% of SPC Slight risk or greater thresholds are covered by radar hail probabilities. A correlation of 0.595 was found between SPC area-weighted probability and the area of radar data that overlaps the SPC Slight Risk areas. In conclusion, POSH radar data can be used to evaluate SPC Hail Convective Outlooks in such a way that builds a relationship between the forecast and what actually occurs.

Users of the convective outlooks will then be able to better anticipate consequences from severe hail. Additional work will focus on using U.S. census population figures to estimate the number of people who may be affected severe hail, and analyzing trends (by season, airmass or region) in the center of mass positions of the two data sets.

Future work might be done using different radar data to evaluate the SPC probabilistic outlooks of tornadoes and damaging wind. Another study may perhaps focus on evaluating them on a temporal scale (i.e. Day 2 and Day 3 convective outlooks) as this research only focuses on assessing the outlooks spatially. Also, because this work only evaluates one convective outlook per day, additional research could be done to assess the SPC outlook forecasts as they are updated throughout the day.

5. ACKNOWLEDGEMENTS

The authors would like to thank Daphne LaDue, Kevin Kloesel, Amber Cannon, and the Research Experience for Undergraduates (REU) Program for making both the project and this paper possible.

The authors are also indebted to Matthew Duplantis from the NWS Shreveport Office for providing the archive of the Storm Prediction Center's convective outlooks.

The authors would also like to thank Greg Carbin (SPC) and Harold Brooks (NSSL) for the context they provided about verifying SPC outlooks and for their suggestions.

This material is based upon work supported by the National Science Foundation under Grant No. AGS-1062932.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

6. REFERENCES

Kay, M. P., and H. E. Brooks, 2000: Verification of probabilistic severe storm forecasts at the SPC. Preprints, *20th Conference on Severe Local Storms,* Orlando, Florida, American Meteorological Society, 285-288.

Murphy, A. H., 1993: What Is a Good Forecast? An Essay on the Nature of Goodness in Weather Forecasting. *Wea. Forecasting,* **8,** 281-293.

"SPC Probabilistic Outlook Information." NOAA's National Weather Service: Storm Prediction Center. NOAA/NWS, 30 Mar 2011. Web. 28 Jun 2012. <http://www.spc.noaa.gov/products/outlook/probinfo.html>.

Wilks, Daniel S. Statistical Methods in the Atmospheric Sciences. San Diego: Academic Press, 1995. pp. 45-50

Witt, Arthur, Michael D. Eilts, Gregory J. Stumpf, J. T. Johnson, E. De Wayne Mitchell, Kevin W. Thomas, 1998: An Enhanced Hail Detection Algorithm for the WSR-88D. *Wea. Forecasting,* **13,** 286–303.