P1.34 AN ANALYSIS OF SEVERE HAIL SWATHS IN THE SOUTHERN PLAINS OF THE UNITED STATES

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1. Introduction

Severe hail is a common event in the Southern Plains of the United States. However, few studies have been conducted to quantitatively answer the question: how much hail occurs at any given location? Given the coverage of WSR-88D radars over the Southern Plains and recent technological advancements including hail detection algorithms, a compilation of severe hail swaths was completed for the period spanning 2001-2003 using data from 15 radar sites across 8 states.

The Hailswath algorithm developed at Weather Decision Technologies, Inc. was used to estimate the occurrence of severe hail for each individual storm and date during the study period. The initial raw output from the algorithm was contoured to complete a coherent swath of likely severe hail. The same analysis was then performed for hail greater than or equal to 2 inches in diameter. Finally, the results of these analyses were compiled monthly, annually, and for the total duration of the study period. A thorough demonstration of the data analysis process and results will be presented. Further, the benefits and limitations of the method used to investigate the occurrence of severe hail will be explained.

2. Previous Climatologies

Previous studies designed to quantify the spatial and temporal variability of long term hail occurrence have varied greatly. For example, regional studies have investigated hail occurrence over eight-year periods in Illinois and South Dakota (Changnon et al. 1967), 10 years in Alberta, Canada (Summers and Paul 1967), 100 years at 66 stations across most of the United States (Changnon and Changnon 2000), 24 years in Oklahoma (Passner 1984) and 20 years across the contiguous Unites States (Brooks 2000). Recent hail climatologies have focused on the development of probabilistic tools to determine the likelihood of severe hail within a certain distance of a given location (Brooks 2000). While this approach is useful in many aspects, the main benefit derived from such studies is the prediction of severe hail. Further, past long-term hail studies have relied on human observed storm reports (Storm Data) as the primary verification method.

3. Methodology

3.1 *Hail Days*

To determine a list of potential hail days during 2001-2003, Storm Data was used as a first guess. Thus, a query was performed for hail during the three-year period by searching the eight states included (whole or in part) in the study domain (Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas). Of the 1095 days spanning the 3-year period, 390 radar days (the convective day from 1200 UTC to 1200 UTC) were included.

For each radar day, radar data (NIDS) was retrieved from the Oklahoma Climatological Survey archive including, composite reflectivity (CREF) and base reflectivity (BREF).

3.2 *Hail Swath Generation*

The Hailswath algorithm was developed by WDT to process raw CREF radar and hail detection algorithm data from multiple radar sites into contoured swaths where hail was likely. The swaths from multiple radars are then combined to create a composite analysis across a domain larger than a single radar. This composite analysis is an XML grid file with a value of 0, 1, 3, or 4 for each point. The values correspond to hail

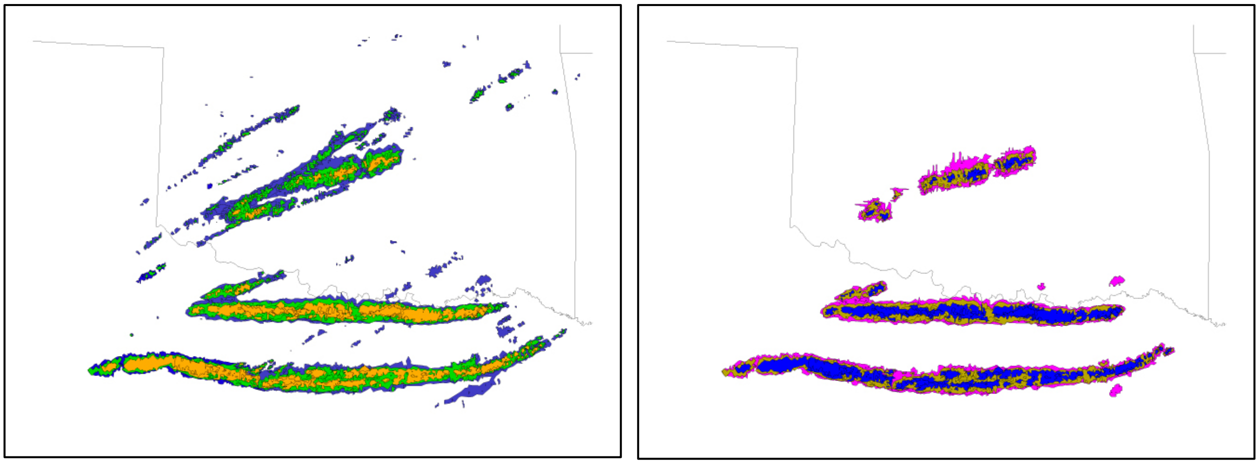

Figure 1. Raw severe (a) and significant (b) hail output from Hailswath for 5 April 2003, showing the critical values of 55 dbz (dark blue), 60 dbz (green), and 65 dbz (yellow) for severe and 55 dbz (pink), 60 dbz (yellow), and 65 dbz (blue) for significant.

size at each grid point determined by the Hailswath algorithm. A value of 0 corresponds to reflectivity was not observed while 1 represented reflectivity was present but severe hail was not detected. A value of 3 signifies severe hail (.75") was likely at that point, and a value of 4 indicates that significant hail (2.00") was likely.

Using specialized software, the XML hail files were contoured for all thresholds. Once the contouring was completed, six files were produced for each potential hail day (three for severe hail and three for significant hail at the 55, 60 and 65 dBZ thresholds were used in this study). Each file was converted to a shapefile and represented the raw output from the Hailswath algorithm. Data from 5 April 2003 will be shown as a sample case for further analysis. Raw images with all three thresholds for severe and significant (Fig. 1) hail were created.

Next, the raw images were smoothed manually for both severe and significant (Fig. 2) hail. This was the only step in which human subjectivity was part of the analysis process. The "best match" of the three reflectivity values was used, though no single contour was followed exactly; all contours were finalized based on the meteorological conditions present.

After manual contours were completed for each radar day, a method to quantify the number of swaths that overlapped was needed. A tool called Dissect Polygons (http://arcscripts.esri.com/

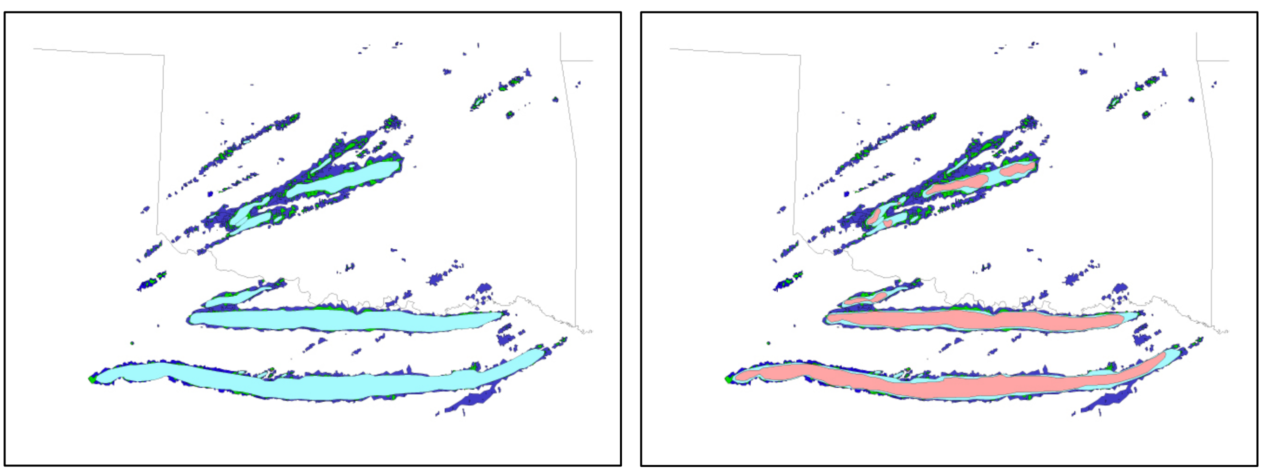

Figure 2. Same as Figure 1 with the manual contour of severe hail (a) overlaid in blue and significant hail (b) overlaid in pink.

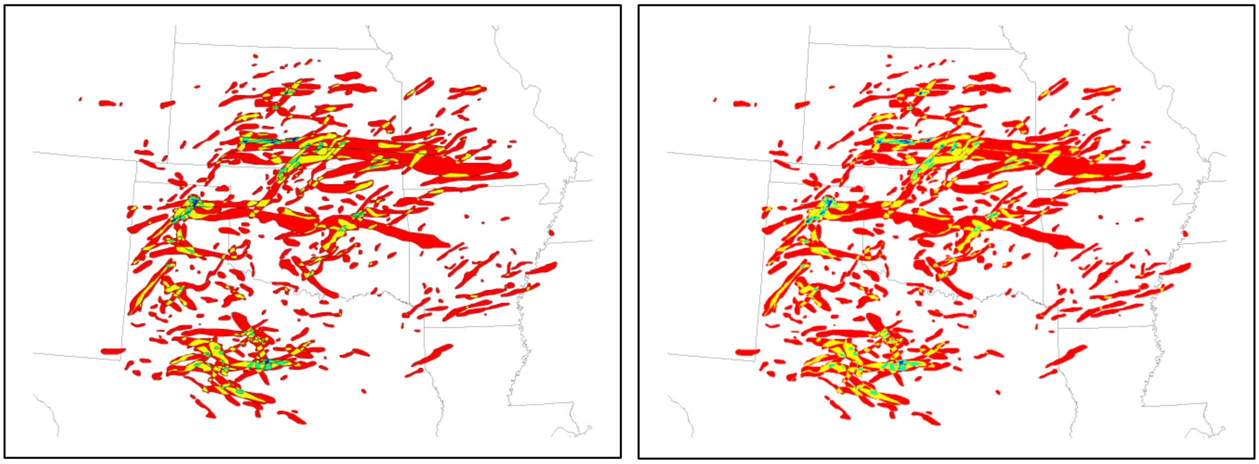

Figure 3. Resultant layer of polygon (hail swath) frequency for May 2002 severe swaths following the use of Dissect Polygons (a) and after rasterization (b).

details.asp?dbid=11126) was utilized for this procedure which merged multiple layers of polygons (i.e., the manually contoured swaths) and created a new image within the same data set that displayed the number of polygons that overlapped at each point (Fig. 3). For this study, this process was performed for each of the 36 months of data. Dissect Polygons was an excellent utility for a single month, however drawbacks existed to using this method for many days of data. Due to the complex nature of the swaths, and the many very small resultant polygons, the Dissect Polygon process was quite slow. As such, it became impractical to use for

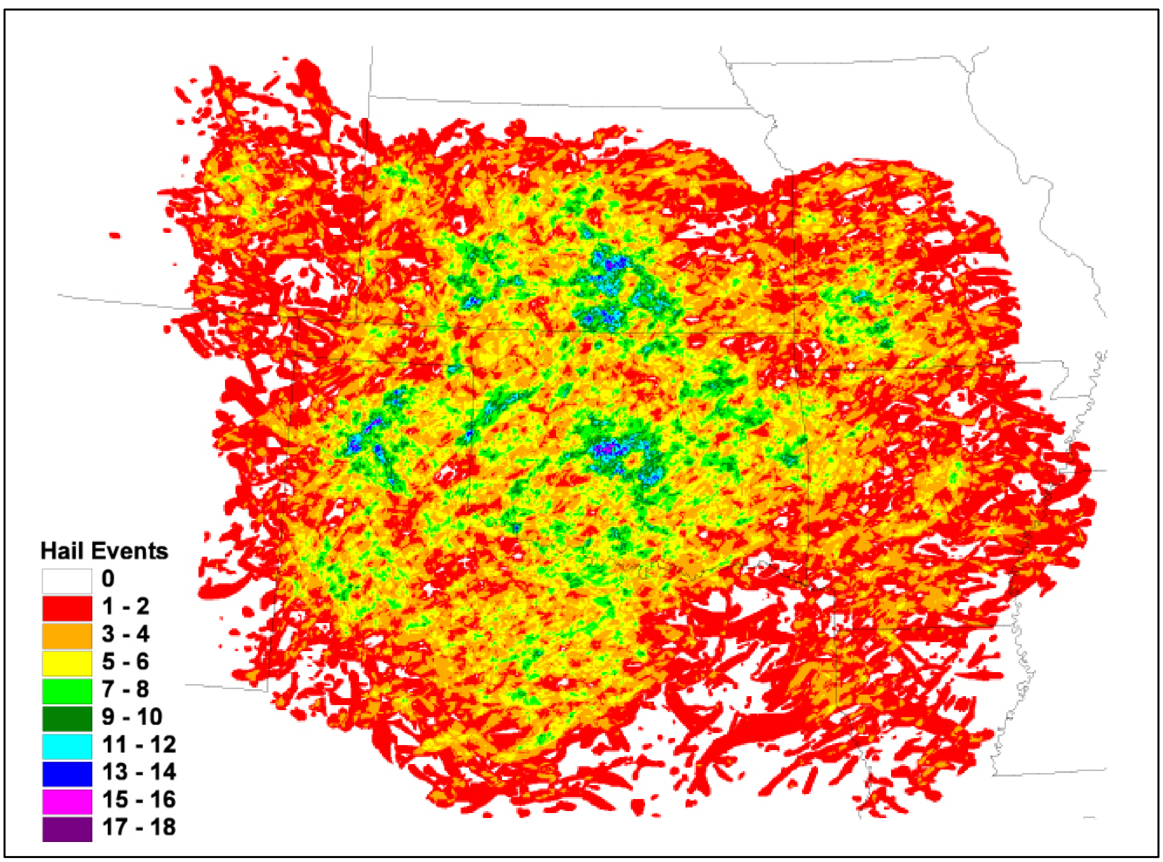

Figure 4. Analyzed severe hail occurrence for the period spanning 2001-2003.

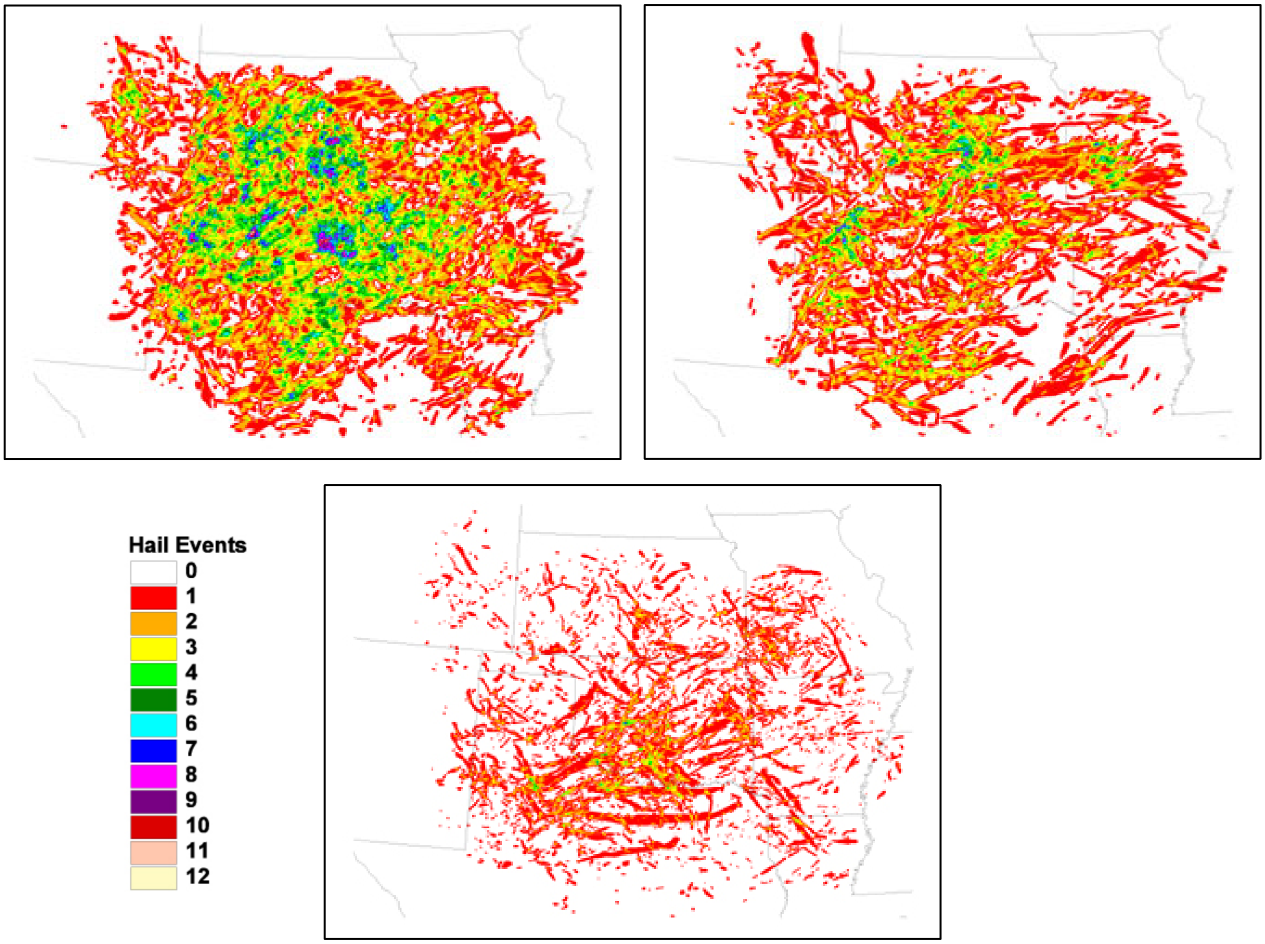

Figure 5. Analyzed severe hail occurrence for 2001 (a), 2002 (b), and 2003 (c).

more than a few months of data, and the completion of a years worth of data was virtually impossible. Thus, another method for quantifying the occurrence of hail swaths was needed.

Rasterization is the process of converting data into a grid, in which each grid box contains a value associated with that area (Chang 2002). Rasterizing the swaths for each month was beneficial in multiple ways. First, the computing resources needed for this process was a small fraction of that used by the Dissect Polygon program. Second, a raster grid allowed for multiple months of data to be summed together in an easier manner. Finally, the resolution of the raster grid (0.25 km^2 in this study) was set such that the data lost from the exact vector polygons was minimal and nearly invisible in plotted figures (Fig. 3). The only drawback to rasterization was the loss of the exact polygon vertices; however these impacts were minimized by increasing the resolution of the raster grid. In this study, the rasterization process was also repeated for multiple combinations of data. Primarily it was used to create composite analysis for individual months, combing all three years of a single month, individual years, and the entire three year data set.

4. Analysis

Every severe hail swath from the three-year study period was plotted in a single rasterized image (Fig. 4). Several features were immediately apparent including local hail maxima near three radars: Amarillo, TX (AMA), Oklahoma City, OK (TLX), and Wichita, KS (ICT). At the same time, other radars revealed no significant relationship to severe hail. In addition, multiple, compact, distinct maxima of hail were located large distances from any radar. Further, a relative minimum of hail swaths were noted in northeast Texas and southeast Colorado. Finally, the maximum number of overlapping severe hail swaths at any location was 18 in central Oklahoma.

	Years	Number of Swaths	Total Area (km^2)	Mean (km^2)	Median (km^2)	Max Swath Area (km^2)	Standard Deviation (km^2)
Severe	2001	2550	1941418	761	260.5	93926	2348
	2002	1726	993247	575	222	22137	1170
	2003	2890	353762	122	40	11233	392
	All	7166	3327720	457	131	93926	1550
Significant	2001	1241	482778	389	170	10567	714
	2002	1150	323770	282	101	11223	683
	2003	1802	126054	70	17	8308	309
	All	4193	932602	222	67	11223	582

Table 1. Statistics calculated for all hail swaths grouped by year and by hail size.

Annual composite analyses were created for each of the three years (Fig. 5). The largest annual maximum of severe hail occurred in 2001, with 12 events in central Oklahoma and near Shamrock, TX. In 2002, the maximum was nine events near Amarillo, TX and 2003 yielded a maximum of eight events in western Oklahoma. Initial inspection of the annual composite analyses suggested that there were fewer hail swaths each successive year. However, the main differences from year to year were the characteristics of the swaths, particularly the decreasing mean area (Table 1).

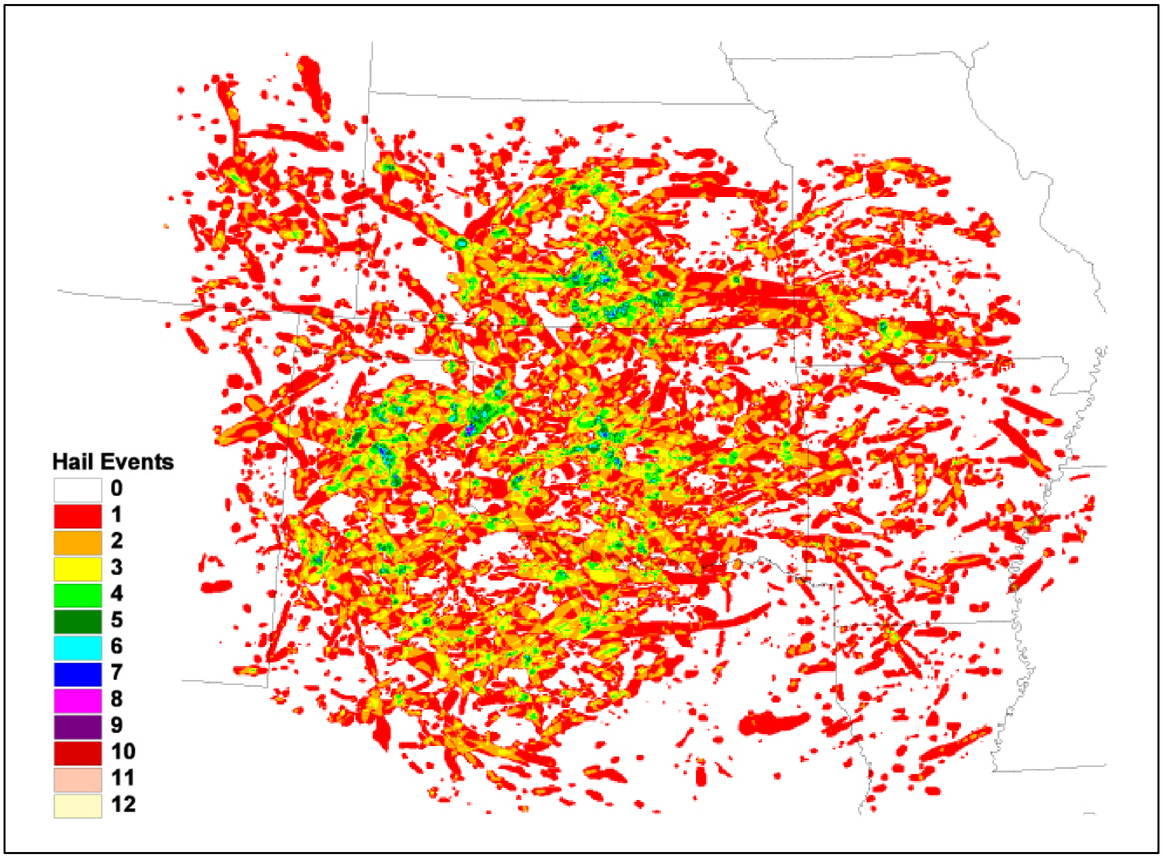

Figure 6. Analyzed significant hail occurrence for the period spanning 2001-2003.

In 2001, local maxima existed near Shamrock, TX, Perryton, TX and Goodland, KS. In addition, various minima were also evident. However, many areas yielded few or no swaths across parts of Oklahoma. The potential radar signal was most apparent near TLX. In contrast, the spatial features from 2002 were quite different and a relative minimum of overall hail was present across Oklahoma compared to portions of the Texas panhandle, southern Kansas, and Missouri. Furthermore, the magnitude of the maxima was less (2002 versus 2001) and the potential radar signal near AMA and ICT were more apparent than near TLX. Conversely, a very different distribution of swaths existed in 2003. The hail maxima occurred in the southern half of Oklahoma and much of Texas. In addition, Kansas and the Texas panhandle were distinct minima and nearly opposite of the general pattern in 2002. Furthermore, minimal signs of any radar signal existed. Finally, it should be noted that in all years the swaths that occurred in areas of relative minima were generally long track hail swaths. The reason for the relative minima was a lack of smaller swaths compared with the rest of the domain.

The discrepancies between successive years can be explained by: (a) human inconsistencies in swath contouring, (b) natural variation of hail occurrence, and (c) an increase in the resolution of the CREF data from four to one kilometer (e.g., 2003). Primarily, the differences between 2001 and 2002 were due to (a) and (b). The manual contouring of hail swaths became slightly more conservative with time in an effort to avoid exaggerating the amount of severe hail. However, even though the magnitude of hail occurrence was slightly lower in 2002 when compared to 2001, the general pattern still maintained significant physical differences. For 2003, the primary cause of the difference in hail swath appearance was increased resolution of the CREF data. As such, the raw output from Hailswath was far more detailed, and

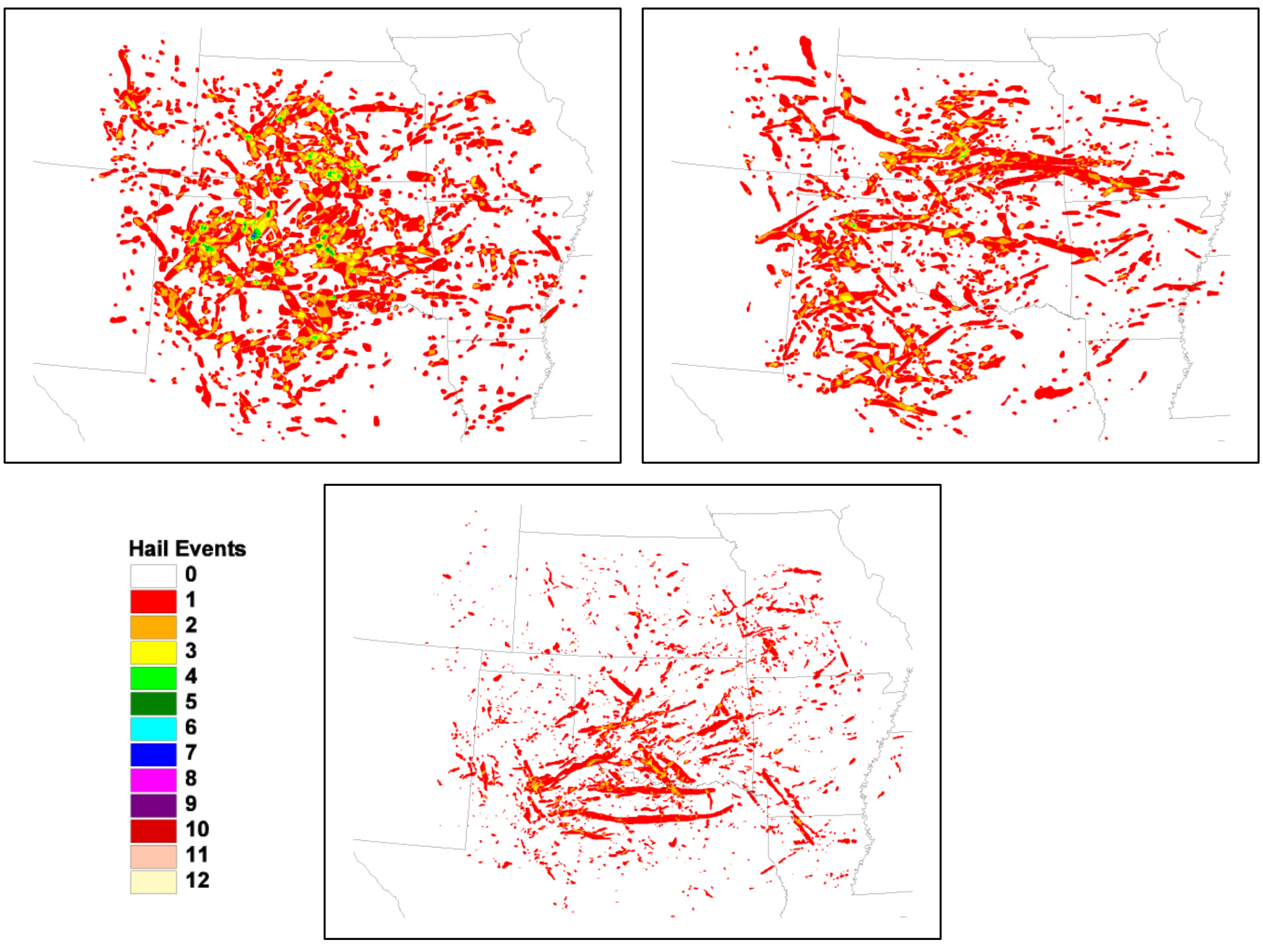

Figure 7. Analyzed severe hail occurrence for 2001 (a), 2002 (b), and 2003 (c).

thus, contoured swaths were more detailed and generally smaller. However, as noted in Table 1, the quantity of swaths actually increased, but average area of the swaths decreased significantly.

Every significant hail swath from the three-year study period was plotted in a rasterized image (Fig. 6). Similar features are present which were noted for severe hail (Fig. 7), particularly the maxima near AMA, TLX, ICT, and Shamrock, TX and the relative minima in northeast Texas, southeast Colorado, and northeast Oklahoma. The maximum number of overlapping significant hail events was 10 near Shamrock. The trend of significant hail closely matches the trend of severe hail; however the magnitudes were slightly lower.

Annual composite analyses for significant hail were created for each of the three years (Fig. 7). The largest annual maximum of significant hail occurred in 2001, with eight events near Shamrock, TX. In 2002, the maximum was five events near Wichita, KS and Amarillo, TX, while 2003 yielded a maximum of four events in multiple locations across southern Oklahoma and north Texas. In addition, the same general trend of decreasing hail swaths from year to year was present when compared to severe hail.

5. Potential Sources or Error

The calculation of hail occurrence over a three-year period was a substantial task and the analysis techniques presented in this project are unique. While they are an improvement over many current analysis methods, errors and limitations were identified, including: human bias, algorithm errors, changing technology, inconsistent radar coverage, radar biases, and variation in storm location and seasonal occurrence.

6. Concluding Remarks

This study sought an innovative and unique method for estimating hail occurrence across the Southern Plains of the United States. Radar data has been utilized for real-time prediction of severe hail for many years, however all past analyses of hail occurrence have relied heavily upon Storm Data. The combination of GIS and radar data made it possible to quantify likely hail occurrence in a new manner separate from human field observation.

The application of this type of analysis has been demonstrated and the combination of GIS and radar data can be used to create long term observational studies for hail occurrence. With improving radar technology, the potential exists to create accurate, long-term hail analyses and climatologies. Further, new radar technologies, such as polarmetric radar which has the ability to more accurately detect hail in thunderstorms (Balakrishnan and Zrnic 1990), will improve hail detection to an even greater accuracy and consistency and will provide further opportunities to verify the accuracy of the methodology presented in this study.

7. References

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