5.4 INCREASING THE USEFULNESS OF A MESOCYCLONE CLIMATOLOGY

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1. INTRODUCTION

The advent of the WSR-88D Doppler radar and its associated vortex detection algorithms has had a positive impact on severe weather forecasting. These algorithms, while intended for use in real-time situations, also provide a beginning point for the large-scale, long-term quantitative study of the detected phenomenon. Here, mesocyclone detections from a realization of the NOAA National Severe Storms Laboratory (NSSL) Mesocyclone Detection Algorithm (MDA) (Stumpf *et al.* 1998) are used to illustrate the opportunities, the challenges, and some possible remedies in producing a mesocyclone climatology.

As examples of the challenges to be addressed in assembling such a climatology, radar beam geometry and inherent characteristics limit even a "perfect" detection algorithm. These limits include larger bin sizes (as range from the radar increases, resulting in lower resolution data), ground clutter, and spurious echoes due to Anomalous Propagation (AP) during certain atmospheric conditions.

Proper dealiasing of the radial velocity data is especially important in making accurate mesocyclone detections. Unfortunately, the current clutter filters and dealiasing algorithms leave much to be desired in this regard. Often, spurious data from ground clutter returns are dealiased to produce false circulations that are identified by the MDA as strong mesocyclones. While a human forecaster usually recognizes these spurious detections and discounts them during real-time operations, a study involving climatologies synthesized automatically from algorithm output must find other means of dealing with these erroneous detections.

Past work involving the creation of mesocyclone climatologies utilizing the MDA has been conducted by Mitchell et al. (2000), the results of which reveal similar challenges. The work reported here differs from this earlier study by attempting to improve the quality of the mesocyclone data sets. Several post-MDA filtering techniques have been developed to aid in the removal of false mesocyclone detections. These techniques are presented here along with some initial results.

2. DATA & METHODOLOGY

High resolution (sometimes called "base" or "level II") data have been acquired from multiple Southern Plains radars via the Collaborative Radar Acquisition Field Test (CRAFT) project being conducted by the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma and its collaborators. The principal goal of CRAFT is to demonstrate real-time compression and internet-based transmission of WSR-88D base data from multiple radars with a view toward nationwide implementation (Droegemeier et al. 2002). Full details on CRAFT may be found at *http://kkd.ou.edu/craft.htm*.

Convective cases from 2000 and 2001 from the initial set of six radars (KAMA, KFWS, KINX, KLBB, KSRX, and KTLX) have been processed on a case-by-case basis using the MDA. Full-time data retrieval and archive for these radars did not begin until 2001. As a result, the 2000 data set is somewhat incomplete and radar-specific. For a full list of these cases (including data plots), see the project's web site at *http://mesocyclone.ou.edu*. The algorithm output from these cases has been combined to create a two-year climatology of mesocyclone occurrences.

3. FILTERING TECHNIQUES

During a typical severe weather event, a single radar may provide thousands of mesocyclone detections. Many of these detections are most probably indicative of small, transient zones of wind shear. The first technique employed to create a more meaningful data set involves filtering out these weak areas of rotation using the Mesocyclone Strength Rank (MSR) attribute provided by the MDA. The MSR is a measure of the relative intensity of a mesocyclone detection and is provided as a nondimensional index ranging from 0 (very weak) to 25 (exceptionally intense). The MDA assigns a 3D strength rank to each 3D velocity feature by finding the strongest continuous vertical core of 2D features whose 2D strength ranks are greater than or equal to a given strength rank. This core must be at least 3 km in half-beamwidth depth, and the base of the core must be below 5 km above radar level (Stumpf et al. 1998). For this work, all detections with an MSR of "0" were discarded.

Under certain atmospheric conditions the MDA often produces a high number of spurious detections close to the radar site. Consequently, all detections at ranges less than or equal to 5 km were eliminated from the data sets.

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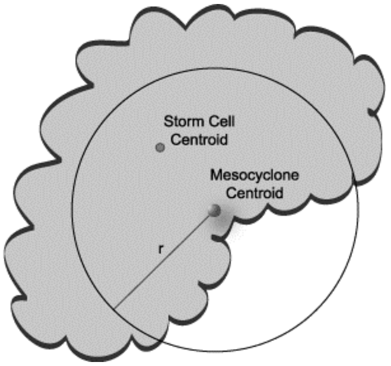

Figure 1: *A cartoon depicting the relationship between the SCIT filter radial search window and mesocyclone and storm cell centroids.*

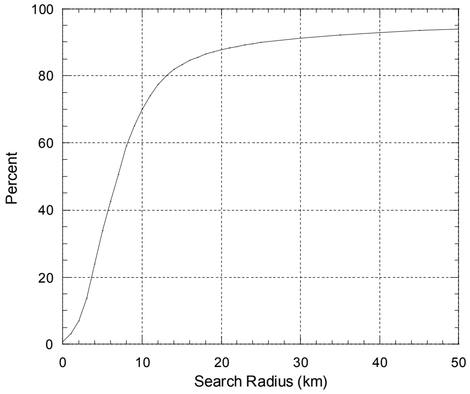

Figure 2: *Percentage of 2000 and 2001 KTLX mesocyclone detections retained as a function of SCIT filter search radii.*

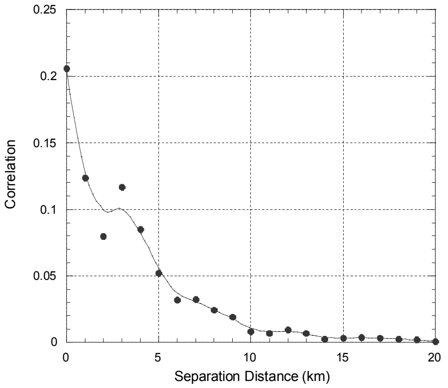

Figure 3: *The correlation of 2000 and 2001 KTLX MDA derived mesocyclone low-level rotational velocity and SCIT derived storm-cell vertically integrated liquid water as a function of separation distance between centroids.*

Concentrations of faulty detections may also be found at the radar's maximum unambiguous velocity range at the time of detection; these show as "rings" on plots of detections. The location of such a ring is a function of Volume Coverage Pattern (VCP) and Pulse Repetition Frequency (PRF) and results from incorrectly dealiased radial velocity data. For the vast majority of cases, this ring of spurious detections lies at a range of 147 km, though rings at several other ranges can occur and have occasionally been noted in particular data sets. For this initial study, the mesocyclone detections were plotted on a case-by-case basis and examined by hand to manually ascertain the presence and location of these rings of spurious detections. Although some real circulations may exist in these areas, the high number of false returns prompted removal of detections at these critical ranges.

For the next level of filtering, the assumption was made, using the most conventional definition, that mesocyclones must be associated with some sort of convection. If convection is occurring within the radar's domain, the radar should be operating in precipitation mode. To address this issue, any detection made in VCP 31 or 32 (i.e. clear air mode) was discarded.

Although the above multi-step filtering has reduced much of the "noise" in the data sets, there still exist many false detections that pass through the filters. These spurious detections are often ranked as strong and thus it's essential to remove them.

Accordingly, a filtering program was developed (henceforth referred to as the "SCIT filter") that attempts to correlate mesocyclone detections with the associated storm cells as defined by the NSSL Storm Cell Identification and Tracking (SCIT; Johnson et al. 1998) algorithm. This filter searches for storm cell centroids within a circular window centered on each mesocyclone detection centroid during the same volume scan (Fig. 1). Since the SCIT algorithm bases its detections solely on reflectivity data, velocity dealiasing errors will not produce false storm cell detections. Any mesocyclones that do not have a storm cell centroid simultaneously within the search window were discarded from the data set. Similar techniques are also being employed by this project to correlate mesocyclone detections with tornadoes. For more details, see the companion paper **5.5** by Jones et al.

4. PRELIMINARY RESULTS

4.1 *Determining SCIT Filter Search Radius*

Since there is no simple ground-truth method for determining mesocyclone characteristics, the quality of the filtering was determined using statistical, rather than direct comparison techniques. Combined 2000 and 2001 KTLX data were examined in order to establish a viable SCIT filter search radius. Analysis began by first removing weak mesocyclone detections, those close to the radar, and those at the rings of spurious detections. The MDA detected 262,382 circulations and after initial filtering was performed this number was reduced to 26,856 (a retention of ~10.2%). The data were then passed through the SCIT filter using different search radii. Figure 2 shows the percentage of mesocyclone detections retained as a function of search radii. At a search radius of 0 km, only about 0.9% of the mesocyclones were preserved. As the radius increases, the percentage eventually is asymptotic to ~94%.

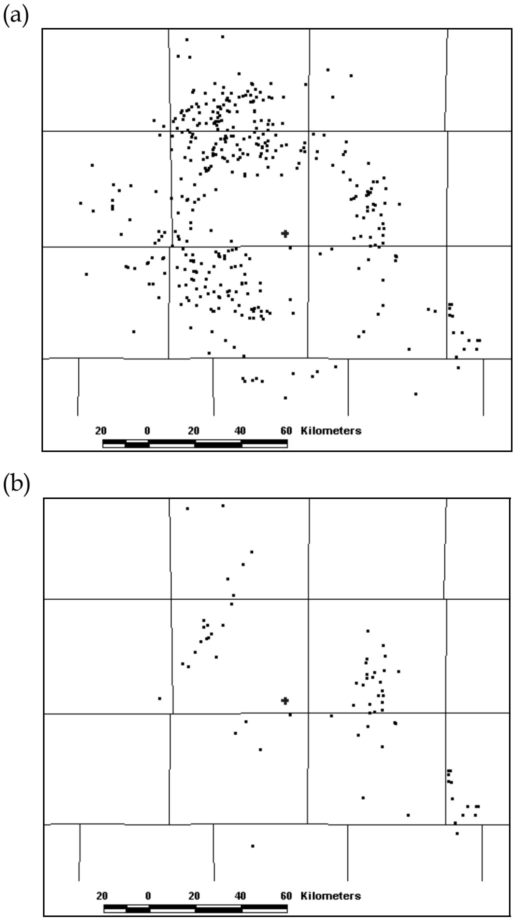

Figure 4: *Plots of KAMA MDA mesocyclone detections from 20010502 15Z – 20010504 0Z. (a) The detections before being passed through the SCIT filter. Radar location identified by plus symbol near center of plot. Note the region of spurious detections concentrated between 20 and 70 km from the radar site. (b) The detections remaining after passage through the SCIT filter, using a search radius of 10 km. Most of the anomalous detections, which were obscuring the tracks of the legitimate mesocyclones, have been removed.*

To further support these findings, the correlation between mesocyclone detections and storm-cell attributes were calculated as a function of separation distance between the centroids. The correlelogram in Figure 3 shows the correlation of MDA derived mesocyclone low-level rotational velocity and SCIT-derived storm-cell vertically integrated liquid water. Note that the correlation begins to flatten-out around a separation distance of 10 to 15 km. This is just one example of the many attribute combinations examined, most of which exhibited a similar decrease in correlation in the 10 to 15 km range.

Consequently, a search radius between 10 and 15 km seems to be a reasonable filter window. In order to corroborate this finding, many individual cases were ingested and plotted using the ArcView Geographic Information System (GIS) software. This allows the authors to identify mesocyclone tracks. After comparing these tracks with reflectivity data, suspect detections were noted, often occurring in areas free of convection. AP-induced ground clutter detections were also identified via their random temporal and spatial distribution. Different SCIT filter search radii were used to derive a search window that would remove as many of the spurious detections without removing an appreciable amount of bona fide detections.

Based on these comparisons, it has been determined that a window of radius between 10 and 12 km is near optimal. Once the radial distance passes 12 km the filter begins to retain an excessive number of false detections. To be conservative, a search radius of 10 km is being used for this study. While this filtering technique is successful in removing most of the spurious detections, a small number of genuine detections are unavoidably removed from the data set. However, this is considered an acceptable loss given the high number of anomalous detections removed.

4.2 *Sample Cases*

An example of data processed by the SCIT filter is shown in Figure 4a where KAMA MDA detections from 15Z 2 May to 0Z 4 May 2001 are plotted. Of particular concern are the regions exhibiting high densities of detections concentrated 20 to 70 km to the northwest and the west-southwest of the radar site. Many of these detections exhibited a random temporal and spatial distribution and do not correlate to regions of convection at the time of occurrences, indicative of erroneous mesocyclone detections. These detections were passed through the SCIT filter using a radial window of 10 km (Fig. 4b). Most of the suspect detections were removed, resulting in a much more obvious track of a mesocyclone to the northwest of the radar. This track was associated with thunderstorms observed in the reflectivity field.

A plot of the 2000 and 2001 KTLX mesocyclone detections reveals some interesting results. An area noticeably devoid of mesocyclones is seen at 147 km due to the removal of faulty detections at this range (Fig. 5a). Furthermore, the authors also note a lack of detections just beyond the 147 km ring out to approximately 155 km (similarly seen in the earlier study by Mitchell et al. 2000). It is believed that this is an artifact of the dealiasing algorithm, which has difficulty correctly resolving velocity data near the maximum unambiguous velocity range.

Due to limitations of radar sampling and beam geometry, vortices close to the radar have a greater horizontal and vertical resolution than those at farther distances and so have a greater chance of being detected. Accordingly, a considerable fraction of all detections is concentrated fairly close to the radar site (within ~50 km; Fig. 5b). The detections with the greatest range were located at 227 km. Assuming this is the extent of the radar's domain, the area within 50 km accounts for only 4.8% of the horizontally observable area yet contains 20.6% of the MDA

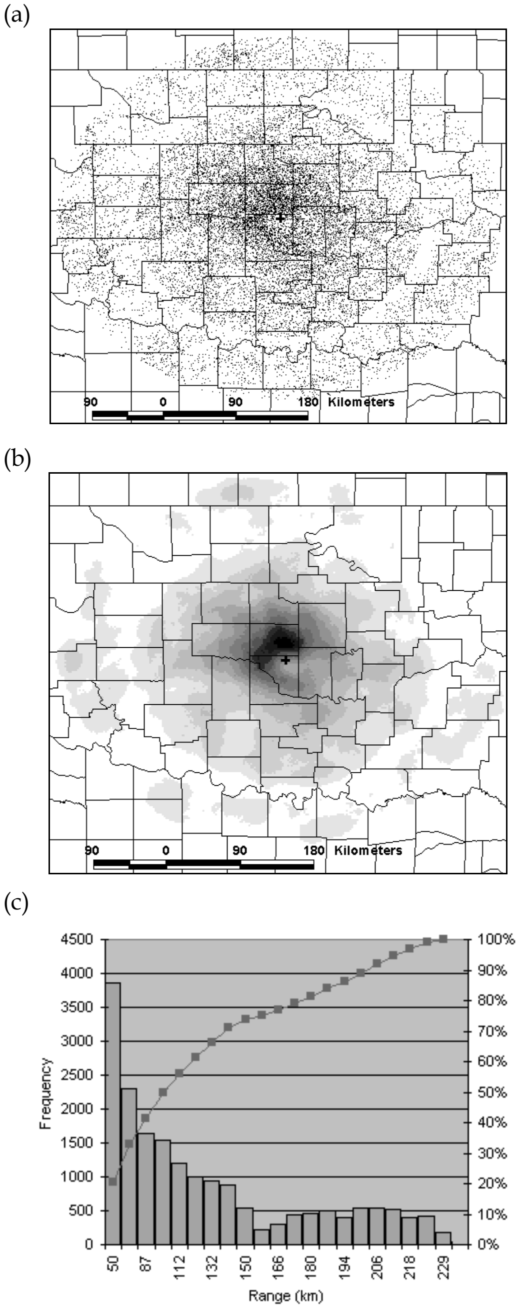

Figure 5: *SCIT filtered 2000 and 2001 KTLX mesocyclone detections. Radar location identified by plus symbol near center of plots. (a) Locations of detections. (b) Density plot of the detections. Note high concentration (20.6%) within 50km of radar. (c) Frequency and cumulative percentage of mesocyclone detections as a function of range. Note the abscissa shows values for equal area range bins.*

mesocyclone detections; the highest density of which is approximately found between the ranges of 10 and 45 km within a 90-degree arc centered to the NW. Figure 5c shows the frequency of mesocyclone detections as a function of range (note the abscissa shows values for equal area range bins). Though analysis of the combined 2000 and 2001 data sets only recently began, preliminary results show that 5 of the 6 radars considered in this study exhibit a similar NW bias (KAMA, KFWS, KINX, KLBB, and KTLX).

5. CONCLUDING REMARKS

Two years of WSR-88D level II base data have been processed using a realization of the NSSL MDA. The resultant data have been combined to produce a climatology of mesocyclone detections. The results reveal that the quality of a mesocyclone detection data set can be significantly improved using rather simple filtering techniques. Processing of 2002 data is underway. As the size of the data set increases, it is hoped that this work will result in more conclusive and statistically significant results. Future research will focus on tuning the filters and automating the removal of the rings of spurious detections to produce the highest quality mesocyclone data sets possible.

6. ACKNOWLEDGEMENTS

The NOAA Warning Decision Training Branch provided funding for this project. Additional funding provided by the Oklahoma NASA Space Grant Consortium.

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