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DEVELOPING QUALITY CONTROL TECHNIQUES FOR A CONUS-WIDE MULTI-YEAR RADAR-DERIVED ROTATION TRACK CLIMATOLOGY

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ABSTRACT

The Multi-Year Reanalysis Of Remotely-Sensed Storms (MYRORSS) project is a cooperative effort between the National Oceanic and Atmospheric Administration's (NOAA) National Severe Storms Laboratory (NSSL) and the National Climatic Data Center (NCDC) to reconstruct and evaluate numerical model output and radar products derived from the WSR-88D network over the CONUS since its installation. Several years of a hail climatology using the Maximum Estimated Size of Hail (MESH) parameter have already been processed and a rotation track climatology is nearly ready to begin processing.

The rotation track fields are created using the local, linear, least squares derivative (LLSD) algorithm to produce the azimuthal shear field (Smith and Elmore 2004). After performing quality-control on the reflectivity field and stamping out azimuthal shear areas associated with low reflectivity values, an azimuthal shear range-correction (Newman et al. 2011) is applied. Data from multiple radars are then merged together to form two-dimensional low-level (0-3 km) and mid-level (3-6 km) maximum azimuthal shear fields. These maximum azimuthal shear fields are accumulated over time to create rotation tracks.

Due to the inherent noisiness of velocity-derived fields, a great deal of quality control is needed before process the rotation track climatology.

Even small non-meteorological contaminants can become large problems when accumulated over time. To quality control the azimuthal shear fields, the wind field from a 20-km Rapid Update Cycle model (RUC) point sounding at each radar site is used as a first guess for the WSR-88D velocity dealiasing algorithm. Clusters of shear in the maximum azimuthal shear fields at each time step are then isolated using hysteresis segmentation. Multiple Hypothesis Testing (MHT) techniques are then used to identify and associate these clusters throughout time. A cost function based on size difference, segment proximity, and other factors is used to determine the ranked k-best associations. The associations with the lowest cost functions are then made and unassociated segments, usually non-meteorological contaminants, are pruned.

The effects of these quality control techniques will be applied to three tornadic multi-radar case studies.

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1. INTRODUCTION

The NSSL rotation track products have proven to be useful tools for minimizing response times to tornado-impacted areas (NOAA, 2011), isolating potential storm survey domains and analyzing case studies. Dealiasing errors inherent to the velocity fields used to create the rotation tracks often create noisiness and anomalous high shear signatures not associated with meteorological phenomena. These contaminants make the rotation tracks less meaningful and more difficult to use. In order to construct a meaningful rotation track climatology, the quality of these tracks must be improved.

To make these improvements, quality control strategies have been implemented at various stages of rotation track development. The purpose of this paper is to discuss these strategies in detail and show the qualitative improvements made in the rotation tracks for a few case studies.

2. CREATION OF ROTATION TRACKS

Rotation tracks are processed using algorithms in the Weather Decision Support System – Integrated Information (WDSS-II; Lakshmanan et al. 2007b; Fig. 1). Once the reflectivity, spectrum width and velocity fields have been generated, a quality control neural network (w2qcnn) is used to remove nonprecipitating targets such as insects, wind-borne particles and anomalous propagation from the input reflectivity field, creating a quality controlled output reflectivity field, ReflectivityQC (Lakshmanan et al. 2007a).

Next, the w2circ algorithm is used to produce azimuthal shear fields. These fields are calculated using a two-dimensional, local, linear least squares (LLSD) method to minimize variances in shear calculations (Smith and Elmore 2004). This strategy allows shear to be calculated with a higher noise tolerance than radial velocity data and with better adaptability to different spatial scales. This method also removes many radar dependencies involved in rotation detection. In addition to the standard multi-level azimuthal shear output field, two-dimensional maximum azimuthal shear fields within layers (0-3 and 3-6 km AGL) are also created. Azimuthal shear values associated with low ReflectivityQC values are removed in the hope that only data associated with storms will be retained. In order to keep the azimuthal shear within the low reflectivity regions within hook echoes, a 5x5 dilation filter is applied to the ReflectivityQC field before using it to stamp out the azimuthal shear fields.

Using the w2merger algorithm, the two-dimensional layer fields from each radar side can be merged together into a multi-radar Cartesian grid using a variety of different combination techniques (Lakshmanan et al. 2006). This multi-radar grid of maximum azimuthal shear can be accumulated over time using the w2accumulator algorithm to create rotation tracks. Figure 1 provides a diagram of this process.

3. QUALITY CONTROL TECHNIQUES

Various techniques were tested and implemented in different stages of rotation track processing. The techniques and the steps where they are applied are outlined in this section and can also be summarized in Figure 2.

3.1. Dealiasing

It is no secret that velocity products are still plagued with errors. Because azimuthal shear is the rotational derivative of shear in a given kernel of velocity data, any errors in the velocity field are carried over into the azimuthal shear fields. Regions of erroneous velocity data often create anomalously high values of azimuthal shear not associated with meteorological phenomena. In an attempt to mitigate these problems, the vertical wind fields from point soundings at each radar site derived from the 20-km RUC were used as first guess estimates of the wind fields for the WSR-88D dealiasing algorithm. These soundings contain wind data at roughly 35 levels, compared to the default seven levels used when no sounding is provided. The incorporation of these soundings made significant qualitative improvements in the velocity fields, removing many of the anomalously high shear areas associated with non-meteorological events. A representative example is shown in Figure 3.

3.2. Range-Correction

Because of radar beam geometry, azimuthal shear estimates at far ranges from the radar can often be underestimated. In an attempt to make the azimuthal shear values as meaningful as possible, an azimuthal shear range-correction (Newman et al. 2011) was incorporated into the w2circ algorithm. Both near range (within 85 km of the radar) and far range (within 135 km of the radar) equations were used to solve for “corrected shear” based on the diameter of the circulation, maximum measured velocity, azimuthal shear value and range from the radar. These corrected shear values replaced the original LLSD azimuthal shear calculation wherever a circulation qualified for the range correction. This new “corrected shear” field was used to create the rotation tracks.

3.3. Quality Control

Despite the improvement made in velocity dealiasing, many anomalous non-meteorological signatures remained. Long runs of anomalously high velocity values along a radial due to bad dealiasing caused radial “spikes” to appear in the azimuthal shear fields wherever these bad runs were adjacent to correctly dealiased velocity data (see Fig. 3). The shear between the two radials was quite high, causing very high azimuthal shear values. To remove these spikes, several different length and data value thresholds were set for different distances from the radar. If a given number of consecutive range gates over a certain data value exceeded the set thresholds, the data from those range gates were removed. These thresholds were tested on several single-radar case studies to make sure that the removal of real circulations was minimized.

Due to the way it is calculated, azimuthal shear is frequently anomalously high very near the radar because of the small range-gate sizes. To prevent these values from corrupting the long-term climatology, azimuthal shear values within a 5-km radius around each radar were removed. While this may remove some valuable data, it will also remove erroneous long-term azimuthal shear maxima near the radar sites.

It was also found that increasing the ReflectivityQC stamp out threshold of 20 dBZ to 40 dBZ helped to remove poorly-dealiased azimuthal shear values co-located with noisy low reflectivity areas. This minimum threshold increase helped to isolate the rotation tracks even more.

3.4. Thresholds

Since the primary interest in the accumulated fields are regions of high azimuthal shear values associated with strong circulations (mesocyclones or possibly tornadoes), the very low background azimuthal shear values can be removed to eliminate noise. To isolate the circulation signatures, hysteresis segmentation with seeding and growing thresholds of 0.005 s^{-1} and 0.002 s^{-1}, respectively, was used.

Azimuthal shear signatures associated with meteorological phenomena usually have a somewhat Gaussian data value distribution where the highest values are located at the center of the circulation and the values lessen as a function of distance from the center. Non-meteorological signatures associated with remaining dealiasing errors, however, typically have a more uniform distribution of high azimuthal shear values. In an effort to remove these non-meteorological signatures, any clusters composed of an unrealistically high percentage of azimuthal shear values above a given data threshold were also removed.

3.5. MHT techniques

After the azimuthal shear field was segmented and quality controlled, MHT techniques (Cox and Hingorani 1996) were used to correlate segments of high azimuthal shear between time steps. Any clusters that did not exist for at least 2 time steps were removed in hopes of isolating only lasting meteorological circulations. A cost function incorporating cluster sizes, ages, proximities to other clusters in different time steps and other characteristics was used to determine the k-best associations. The associations with the lowest cost functions are then made and unassociated clusters, usually non-meteorological contaminants, are pruned. The use of this technique helped to remove many of the remaining non-meteorological signatures.

4. RESULTS

The previously discussed dealiasing and quality control techniques were implemented on three multi-radar case studies from 2011: the April 14-16 outbreak across the southeastern United States, the April 27-28 outbreak across the southeastern United States and the November 7 mini outbreak across southwestern and central Oklahoma. By comparing the rotation tracks before and after the new techniques were implemented, it is easy to see that a great deal of the radial "spikes" and other non-meteorological signatures were removed, especially along the east coast in the two April cases. In the most extreme cases, rotation tracks are now visible and isolated where they had been completely covered by radial "spikes" or other non-meteorological signatures in the accumulated fields. The before and after rotation track fields can be seen in Figures 4, 5 and 6.

4.1. Mesocyclone Signatures versus Linear Signatures

In the rotation track fields generated currently, all azimuthal shear signatures associated with meteorological phenomena are retained. This means that both mesocyclone signatures associated with supercell storms and bands of high azimuthal shear that exist along linear phenomena (bow echoes, outflow boundaries, etc.) are retained.

Ideally, it would be possible to remove the bands of azimuthal shear associated with linear events to produce a strictly mesocyclone climatology. Removal of these more linear clusters based on both aspect ratio and size constraints have been tested but with limited success. Sometimes in the life cycle of a mesocyclone, the signatures can have a more elongated shape. This makes it difficult to remove all shear signatures above a given aspect ratio in hopes of only removing shear associated with linear events. Since very large mesocyclones can be associated with large shear signatures, it is hard to discriminate between linear signatures and large mesocyclone signatures in terms of size alone.

Further investigation will be done in the future to see if these bands can be removed without removing valuable mesocyclone data.

5. CONCLUSION

Through the use of the new first-guess wind field in the velocity dealiasing and various quality control and spatial analysis techniques, the NOAA NSSL rotation tracks are now less noisy, easier to interpret and more meaningful that ever before. These changes will soon be implemented in WDSS-II on-demand products. Using these new techniques, a rotation track climatology will be processed as part of the MYRORRS project using the process described in Cintineo et al. (2011).

6. REFERENCES

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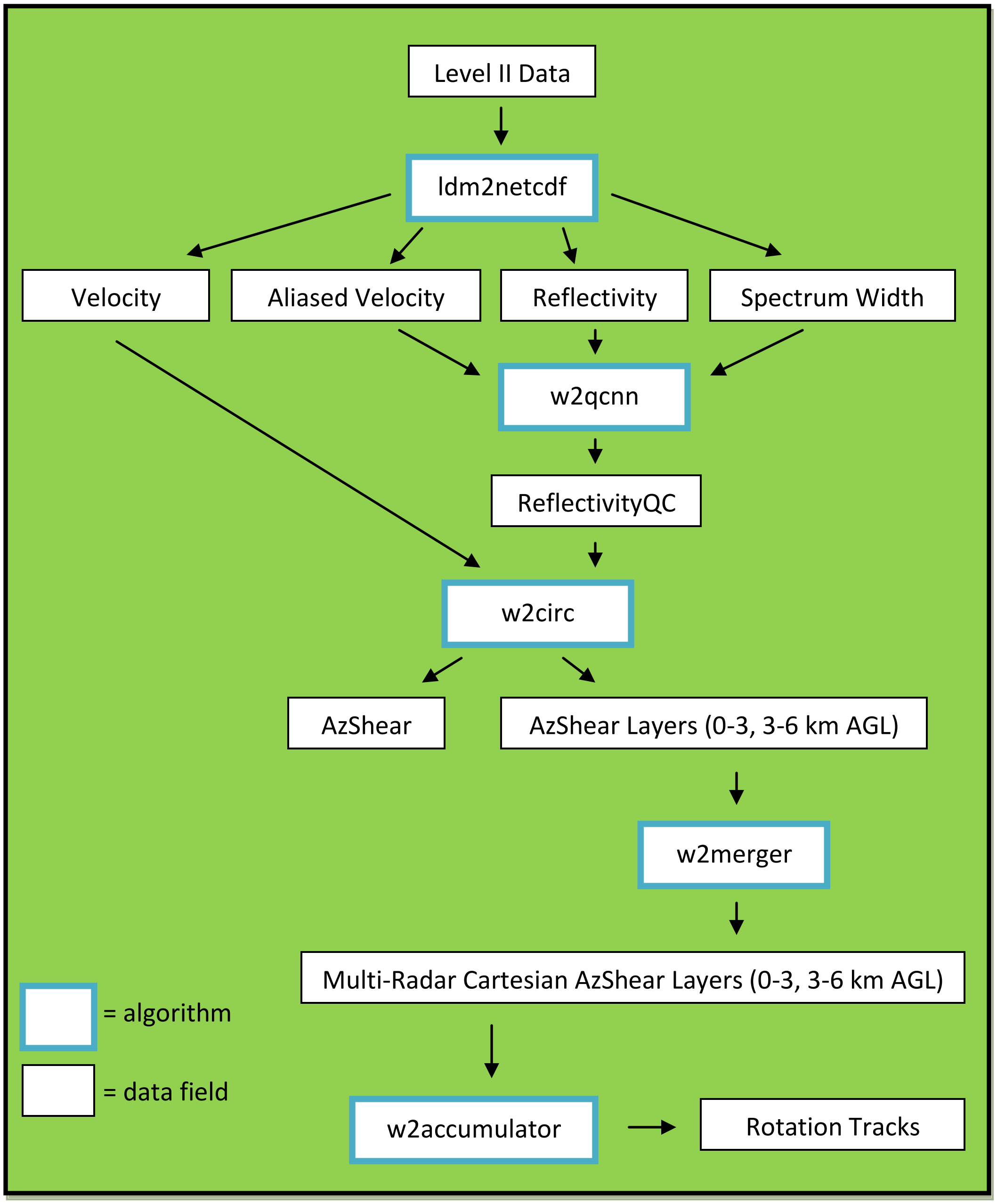


Figure 1: Data flow used to create 2D maximum azimuthal shear rotation tracks.

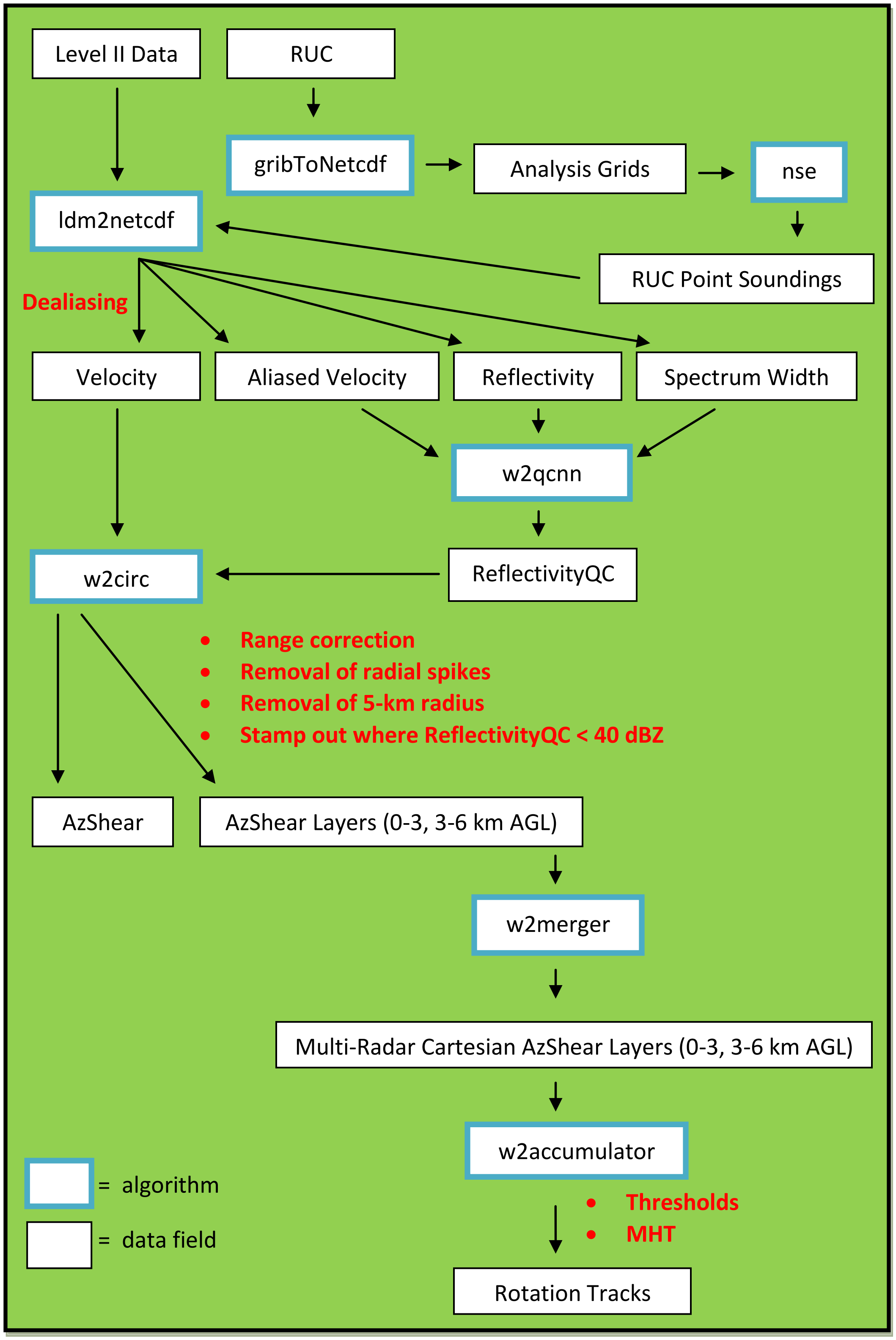


Figure 2: Data flow used to create 2D maximum azimuthal shear rotation tracks when incorporating the new dealiasing and quality control techniques. The new techniques are written in red next to the step where they are applied.

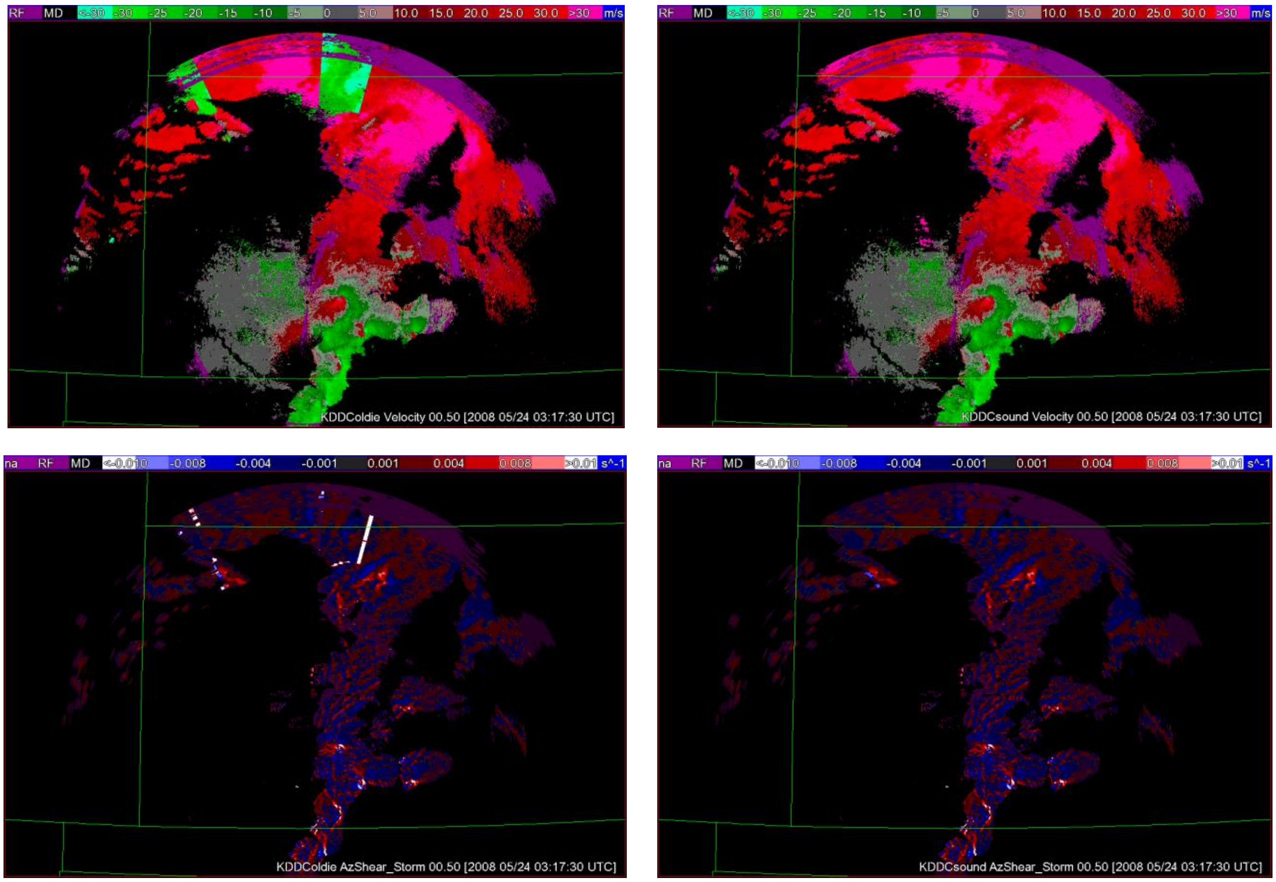


Figure 3: Radial velocity (top) and azimuthal shear (bottom) fields at 0.5° elevation at 17:30 UTC on 35 May 2008 at the Dodge City, Kansas radar. Top left: radial velocity before the wind field from 20-km RUC point sounding was incorporated into the dealiasing algorithm. Note the poor dealiasing north and northwest of the radar site, near the Kansas-Nebraska border. Bottom left: azimuthal shear generated from the radial velocity field above. Note the bands of high value azimuthal shear (radial "spikes") co-located with the dealiasing errors in the radial velocity field. Top right: radial velocity field after the point RUC sounding was put into the WSR-88D dealiasing algorithm. Note the improvement from top left to top right. Bottom right: the azimuthal shear field associated with the radial velocity from the top right image. Note the removal of the anomalous high values of azimuthal shear and radial "spikes. This particular example is a good qualitative representation of how the soundings improved most cases. Note that cases with many more dealiasing issues still had errors present after the soundings were incorporated.

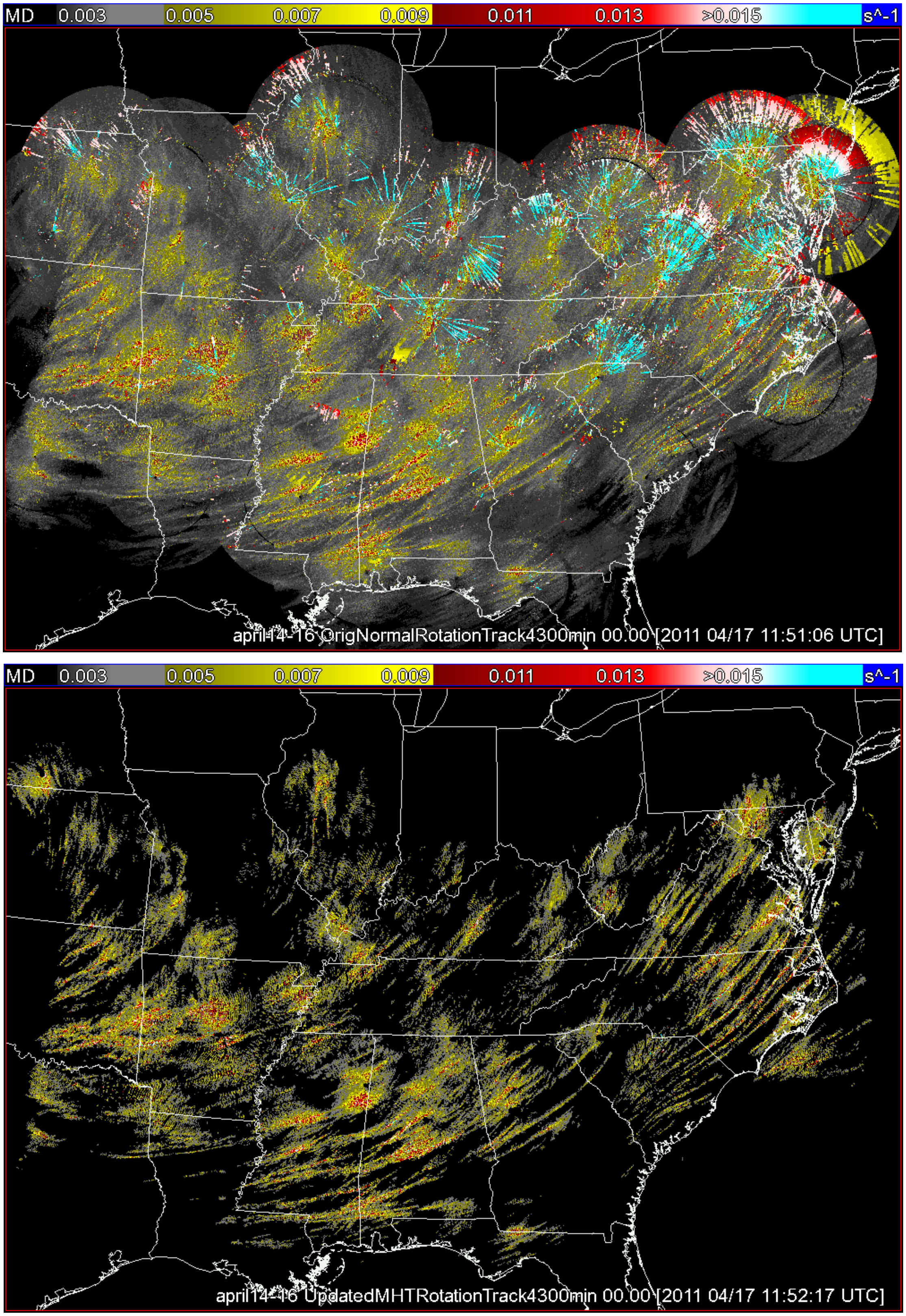


Figure 4: Top: Rotation tracks made from maximum azimuthal shear fields between 0-3km AGL from 12Z on 14 April 2011 to 12Z on 17 April 2011. Bottom: The same rotation tracks after the quality control was performed. Note the most isolated tracks and removal of the radial “spikes”.

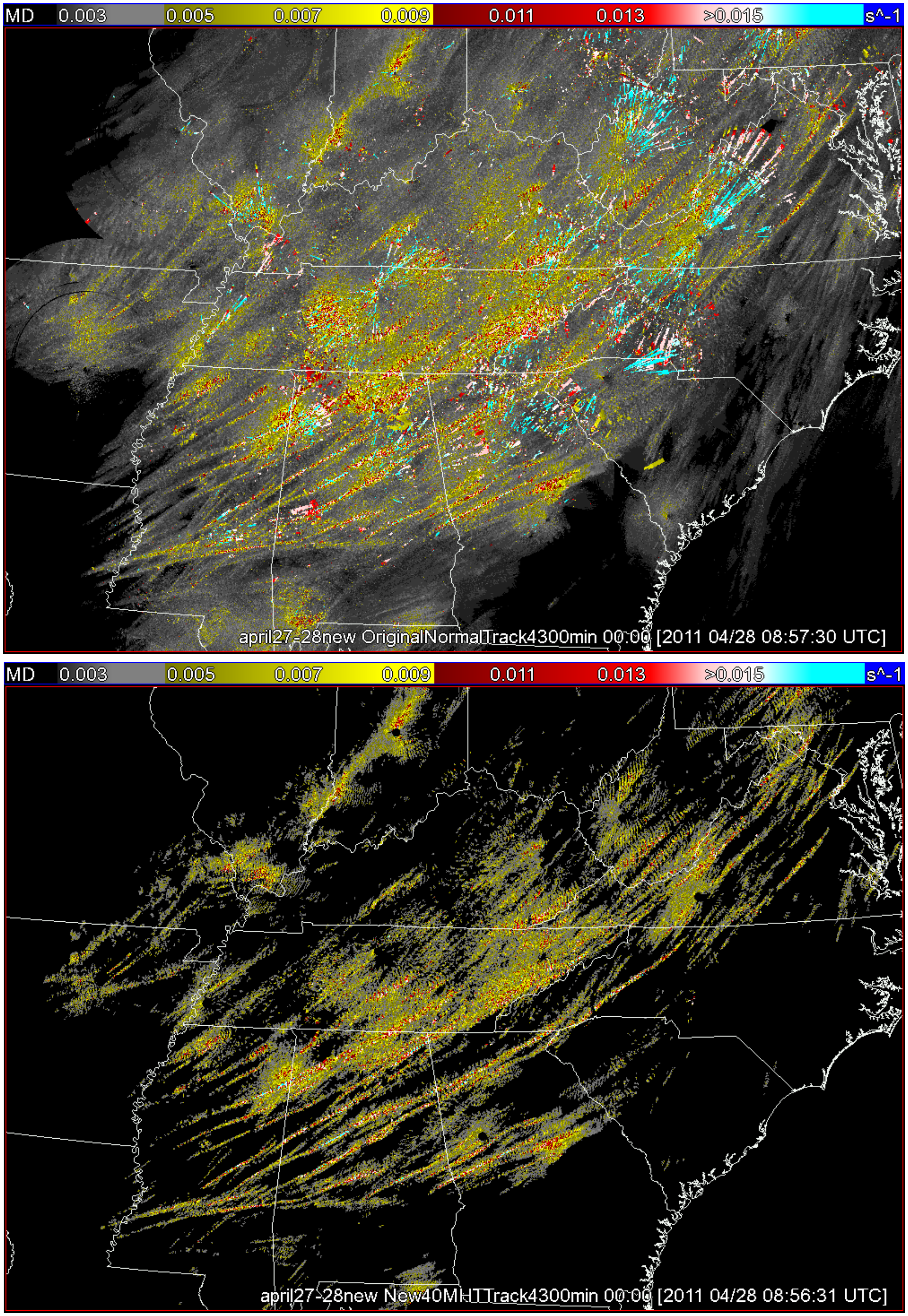
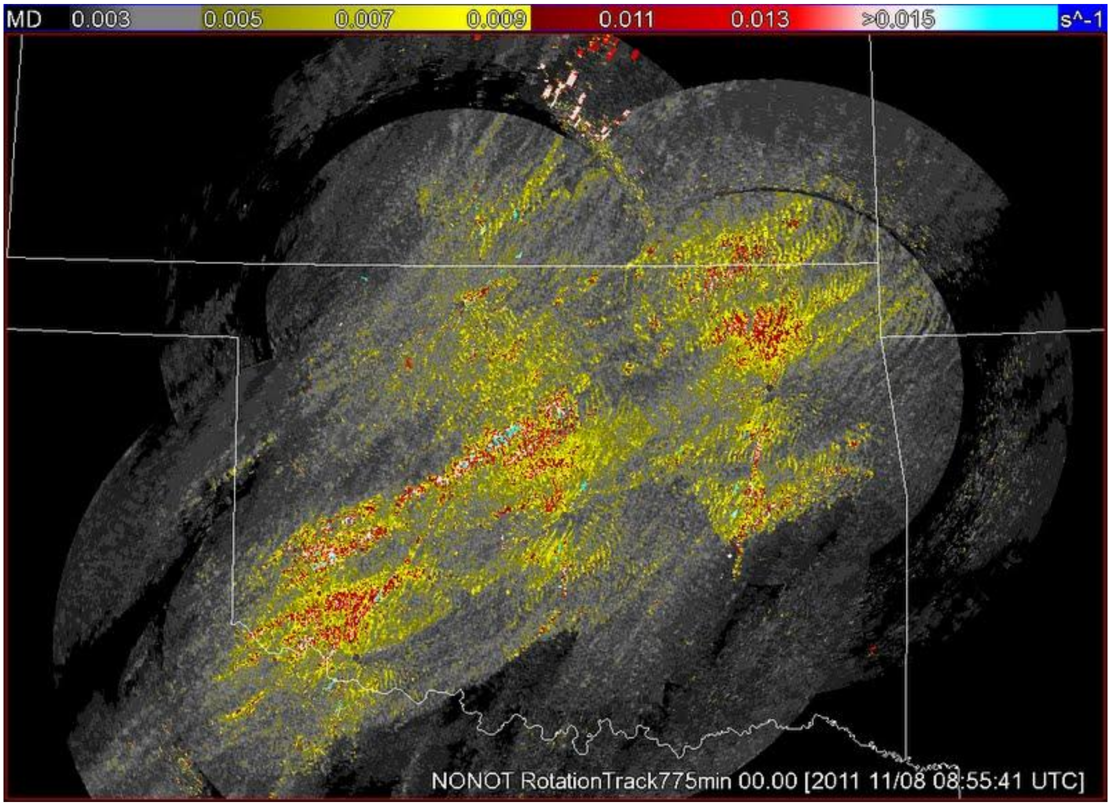


Figure 5: Top: Rotation tracks made from maximum azimuthal shear fields between 0-3km AGL from 16Z on 27 April 2011 to 08Z on 28 April 2011. Bottom: The same rotation tracks after the quality control was performed. Note the most isolated tracks and removal of the radial "spikes".



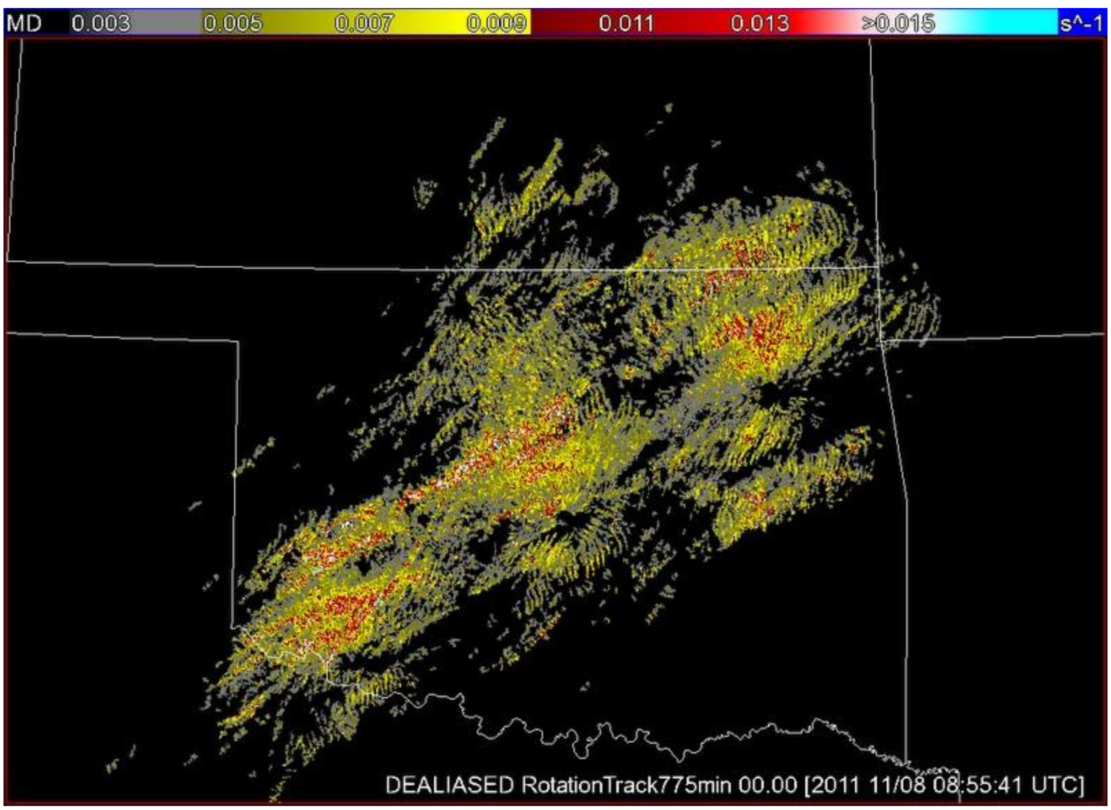


Figure 6: Top: Rotation tracks made from maximum azimuthal shear fields between 0-3km AGL from 20Z on 07 November 2011 to 09Z on 08 November 2011. Bottom: The same rotation tracks after the quality control was performed.