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A COMPARISON OF MULTI-SENSOR HAIL DIAGNOSIS TECHNIQUES

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1. Introduction

Stumpf et al (2004) summarize many operational and experimental techniques for diagnosing the presence of large hail using a combination of radar reflectivity, reflectivity derivatives, and environmental information. This manuscript represents an initial effort to compare the performance of these techniques in assessing hail size by reporting on a few select cases, and contains a brief overview of these cases.

There are many parameters that can affect the way storms are sampled by radar. Because most hail detection techniques require some amount of vertical integration of data, storm tilt and storm motion may adversely affect calculations. If a storm is near-range, the upper portions of the storm are not sampled (in the so-called "cone of silence"). If radars have overlapping coverage, a second radar may fill in the data missing from the first. If a storm is at long range but observed from multiple radars, the temporal sampling may be improved over a lone radar.

One must always maintain caution when using severe weather reports from *Storm Data* (Witt et al. 1998) in post-event analyses. One known problem with *Storm Data* hail reports is that the reported hail size may not be the maximum size that fell. Event times in *Storm Data* are sometimes erroneous as well.

2. Cases

For four cases, we examined the following products and compared them to severe hail reports in *Storm Data*:

- Single-radar, polar grid data (1° by 1 km) of Vertically Integrated Liquid (VIL) and Maximum Expected Size of Hail (MESH);
- Single-radar, cell-based VIL and MESH from the WSR-88D Hail Detection Algorithm (Witt et al 1998);
- Multi-radar, Cartesian grid data (1 km by 1 km) of VIL and MESH
- Multi-radar, cell-based VIL and MESH.

For a fifth case, we compared the grid-based products to a high-quality hail data set collected by observers during the J-POLE experiment (Schuur et al. 2003). The J-POLE data set consists of exact hail sizes and start/end times.

2.1 24 April 2003

A supercell thunderstorm formed southeast of the KEAX WSR-88D and moved over populated areas. The storm formed in an environment of 1500 to 2000 Jkg^{-1} of Convective Available Potential Energy (CAPE) and 30 ms^{-1} of 0-6 km shear. The storm was within 25 km range from the KEAX radar from its inception until about 2130 UTC, moving from west of the radar to north and northeast of the radar. Figure 1 shows a comparison among the four methods for this storm. Although the graph is noisy and there are substantial differences in VIL values among methods for this case, note that the multi-radar VIL values show peak intensities of the storm whereas the single-radar methods (which are missing data in the "cone of silence") do not.

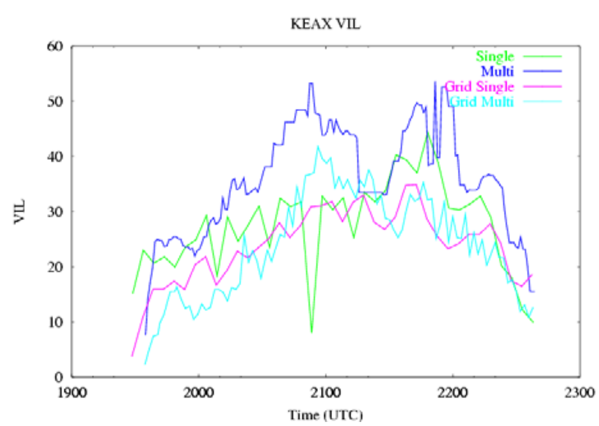

Figure 1: VIL for single-radar cell-based ("Single"), multi-radar cell-based ("Multi"), single-radar grid-based ("Grid Single") and multi-radar grid-based ("Grid Multi") techniques for the case of 24 April 2003.

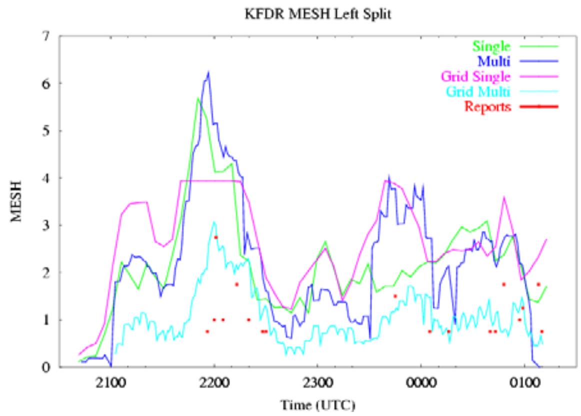

Figure 2: MESH (inches) for the case of 3 May 2003. The naming convension is the same as in Figure 1.

2.2 3 May 2003

A supercell thunderstorm developed east of Lubbock, TX, and split into two separate cells within the first hour of its life cycle. The left split moved rapidly to the northeast at about 30 ms^{-1}. Visual observations of this storm by the author indicated a very well defined hail shaft that consistently produced 1" to 2" hail. The tornadic right split produced larger hail, and kept a nearly constant range from the KFDR radar throughout its life cycle.

For the left split (Figure 2), the observed hail sizes were most closely approximated by the gridded multi-radar MESH. Both cell-based methods provided substantially higher values, as did the gridded single-radar method. Because the cell-based techniques integrate the maximum values of reflectivity from each level (elevation slice or constant-altitude level for single-radar or multi-radar, respectively) in the vertical, they should naturally have higher values than the grid-based methods that integrate in a much finer horizontal spatial scale and may miss important features such as the tilt of the storm core.

2.3 21 July 2003

A supercell thunderstorm formed in western Nebraska and moved due south toward northwest Kansas. This storm produced very large hail, causing more than one million dollars worth of damage. The storm formed in an environment of about 2000 Jkg^{-1} and 25 ms^{-1}. The range from the two primary radars, along with multi-radar MESH estimates is shown in Figure 3.

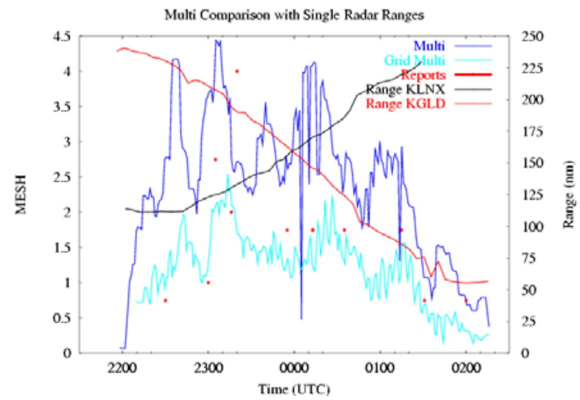

Figure 3: MESH (inches) and range of storm centroid from the radars for the case of 21 July 2003. The naming convention is the same as in Figure 1.

In this case, both single-radar methods gave similar results to the cell-based multi-radar method, albeit at a more course temporal and spatial resolution. The grid-based multi-radar method most closely approximated most reported hail sizes. However, the largest reports of 4" hail were severely underestimated by this technique while the cell-based multi-radar method gave a more realistic answer. In this case, it is likely that the cell-based method, which inherently corrects for storm tilt, provided better information about the maximum hail size possible with the storm than the grid-based method.

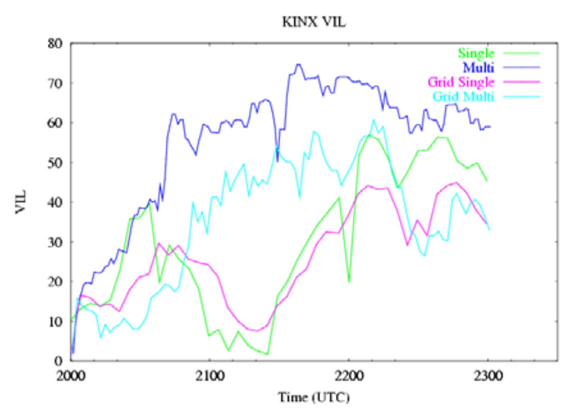

Figure 4: VIL for the case of 22 April 2004. The naming convention is the same as in Figure 1.

2.4 22 April 2004

A supercell formed near Tulsa and moved directly over the KINX radar. There were few hail reports with the storm, possibly due to forecasters focusing on a tornado threat at the time rather than hail verification, but this case provides an example of how merging data from multiple radars may be used to fill in data voids that may exist with a single radar.

In figure 4, the storm increases in intensity, as seen in both multi-radar VIL methods, as the storm moves into the "cone of silence" of the KINX radar. Figure 5 shows the range of the storm centroid from the radar in addition to the single-radar VIL products. In this case, the VIL values are very low for the single-radar methods at a time when the storm is clearly increasing in strength to the severe category.

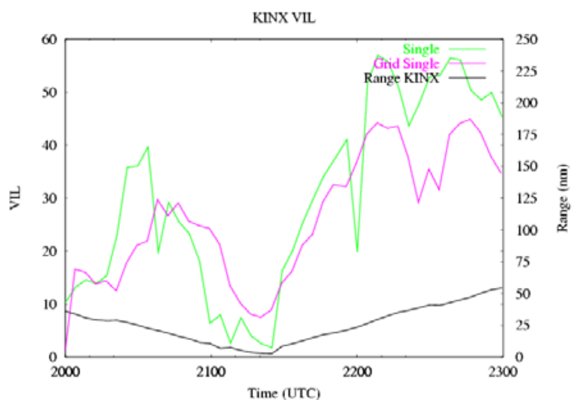

Figure 5: KINX VIL and range from radar for the case of 22 April 2004. The naming convention is the same as in Figure 1.

2.5 19 May 2003

This case included several hail reports collected by observers during the J-POLE experiment. Because of the accuracy of the event times, locations and hail size measurements for this event, we compare specific grid points in the gridded MESH fields to the individual hail observations. Additionally, we apply a dilation filter to the multi-radar gridded reflectivity before calculating MESH in order to test the theory that it will help eliminate some of the errors in the grid-based products that are caused by storm tilt.

Dilation of the reflectivity data results in a slight increase in MESH above non-dilated values (Figure 6). Calculations of Mean Square Error and Mean Absolute Error for these data points show a slight increase in errors for the dilated MESH versus the regular MESH. Both multi-radar techniques significantly outperform the single-radar MESH in this case. However, there are still a number of unknowns, and this is a very small sample size.

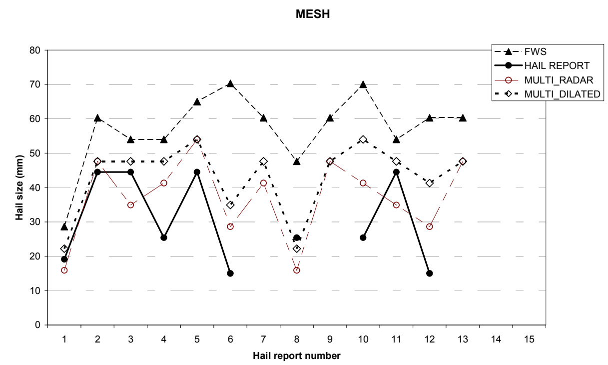

Figure 6: MESH from the KFWS single-radar grid, multi-radar MESH, and multi-radar MESH calculated from a dilated 3D reflectivity field.

3. Conclusions

This comparisons performed in this manuscript are very limited, as the data sample is very small. A much larger data sample is needed to prove or disprove hypotheses about the merits of these different hail-size estimation techniques. The eventual goal of this work is to determine the most robust method for hail detection with non-polarimetric radars. A wider variety of storm types need to be included in the sample as well.

Ideally, hail detection techniques should be unified to include the best of the grid-based and cell-based methodologies. Presently, most grid-based methods show the spatial extent of the likely areas of hail – a feature that is not available in cell-based methods. However, time trends of storm strength are shown more accurately by the cell-based methods. Cell-based methods also automatically take storm tilt into account, which is a feature yet to be fully realized in grid-based techniques.

Multi-radar, multi-sensor hail detection tools clearly have an advantage over single-radar applications. The current WSR-88D system does not fully sample storms near the radar, which is usually located near population centers and high-value properties. Additionally, the operation WSR-88D Hail Detection Algorithm requires operator intervention to update important environmental parameters that affect the hail guidance. These issues are not a concern with the multi-radar, multi-sensor applications.

This work will be expanded in the future to encompass the evaluation of most of the parameters described in Stumpf et al (2004) on a wide variety of hail-producing storm types from different environmental regimes. Of particular interest are storms that are currently problematic: storms in the “cone of silence”, highly sheared storms, and storms at long ranges but that may be sampled by multiple radars.

References

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