2013 Experimental Warning Program (EWP2013)

NOAA Hazardous Weather Testbed, Norman, OK

Multiple-Radar / Multiple-Sensor (MRMS) Severe Weather Algorithm Experiment

Project Overview

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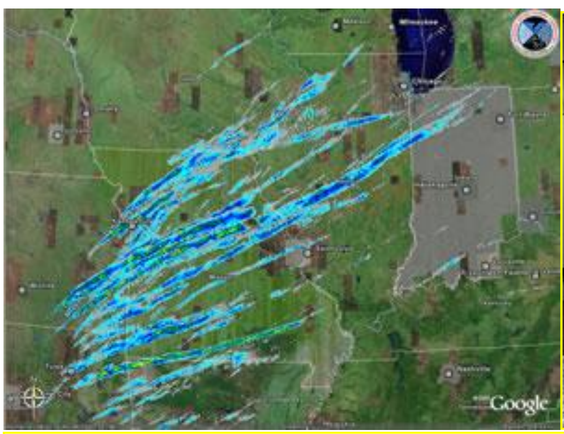

1. Introduction

The NSSL Warning Decision Support System – Integrated Information (WDSSII; Lakshmanan et al. 2007b) possesses a suite of experimental algorithms which combine information from **Multiple Radars and Multiple Sensors (MRMS)**, including numerical model 3D temperature analysis grids (Lakshmanan et al. 2006). This is in contrast to the WSR-88D algorithms, which only use a single radar and a single vertical temperature profile for data input.

Multiple-radars offer better diagnosis of storms by increasing the number of samples in the vertical as well as providing more rapid temporal updates. In addition, multiple radars provide more-complete data in "radar-hostile" regions, for example, within single-radar cones-of silence (Fig. 1), at far ranges from one radar, and in areas where terrain is blocking the beam from one radar. Multiple-radar sampling also has the effect of reducing, on average, the height uncertainties of radar information.

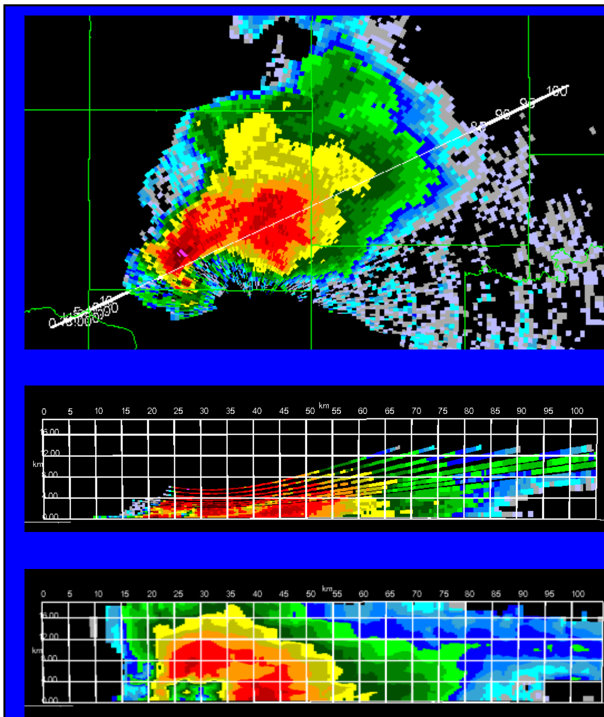

Figure 1: A vertical reflectivity cross-section through a thunderstorm (top) using single radar data (middle) versus using multi-radar blended data (bottom).

NSSL has developed an application that merges data from multiple radars into a rapidly-refreshing 3D grid covering the CONUS. The grids can be updated as rapidly as any new elevation scan update from one of the radars in the grid, although we "throttle" the updates to a 1-2 minute interval. The process at each 3D grid point involves combining the interpolated values from each radar using an inverse-distance weighting scheme. Any scalar radar product can be merged from multiple radars into a 3D grid. For the WDSSII algorithms under evaluation, WDSSII computes a 3D grid of reflectivity. In addition, the multiple-radar merger process can also operate on derived 2D grids from single radars. We do this for azimuthal shear (from radial velocity) and dual-pol correlation coefficient for several of the tornado-related diagnostic products.

Many of the WDSSII products are derived by integrating the 3D radar grids with 3D temperature grids from the Rapid Refresh (RAP) numerical model zero-hour analysis fields. Because temperature information can vary over space and time, integrating 3D temperature information can be more effective than using a single temperature profile across a radar domain. For each grid point, there is a unique reflectivity profile and a unique temperature profile, which updates at frequent intervals. In addition, we can integrate data from satellite sensors, cloud-to-ground and 3D lightning sensors, surface observations, upper-air observations, and rain gauge reports.

Experiment Objectives

MRMS product evaluation in the NOAA Hazardous Weather Testbed took place during the 2009 and 2010 spring experiments (EWP2009, EWP2010). Visiting NWS forecasters used MRMS products on AWIPS to issue experimental real-time warnings, and these experimental warnings were compared to the actual official warnings issued by the WFOs that we were emulating in the testbed. Via discussions and surveys, the forecasters provided feedback on the accuracy and operational utility of the MRMS products. Results of the HWT testing helped provide the final push to approve MRMS for official operational implementation.

Our objectives for EWP2013 are two-fold. First, we have a number of research hypotheses that we would like to test. And second, we want to develop "best practices" information that will be useful to future users of MRMS products once they are made officially operational in about 2 years.

We hypothesize that the products derived using automated rapidly-updating MRMS integration will help improve severe weather warning decision making, and we hope that the experiments within the HWT will play a part at proving this hypothesis. Specifically, we hypothesize that MRMS products will:

- Speed up diagnosis and aid in keeping track of most-significant storms.
- Improve analysis of storms near cones-of-silence on high tilts versus 4-panel base-data analysis.
- Improve polygon alignment and precision (lower False Alarm Area).
- Give the most lead time to onset of first severe after CI, versus the other experimental products (see below) being tested during EWP2013 (with product latency considered)

How will we prove or refute these hypotheses? Using real-time events (collected from anywhere in the CONUS), participants will issue experimental severe thunderstorm (SVR) and tornado (TOR) warnings using WarnGen on the AWIPS2 machines in the testbed. Participants will be augmenting their traditional warning decision analysis techniques (using base sensor data, "all-tilts", "4-panels", etc.) with the MRMS products which will be fed into AWIPS and available for viewing within the Volume Browser. The experimental warnings will be scored using experimental geospatial verification techniques (Stumpf, http://tinyurl.com/experimental-warning-thoughts).

While using the MRMS data for issuing experimental warnings, you will also be evaluating several other experimental data sets. These include:

1. A new single-radar dual-pol Hail Size Discrimination Algorithms (HSDA) which is the next-generation Hydrometeor Classification Algorithm (HCA). Instead of one “Hail” classification (which is colored red in AWIPS), there will be three hail classifications: small (<1”), large (1-2”), and giant (>2”),
2. Cloud Top Cooling (CTC) algorithm, a GOES-R product that relates the rate of CTC to eventual storm severity, and
3. Pseudo Geostationary Lightning Mapper (pGLM), a GOES-R product that provides total (intra-cloud and cloud-to-ground) lighting data. “Jumps” in total lightning can be a pre-cursor to severe weather.
4. We may have access to real-time crowd-sourced precipitation reports from the Precipitation Identification Near the Ground (PING) experiment.

All of these data sets are to be used in concert to issue experimental warnings. Above, we hypothesize that the MRMS data will provide the greater lead time (with product latency considered – MRMS is typically the lowest latency) than the other products. Although we don’t necessarily know at this point whether that can be proven, and any of these products might offer the greatest lead time, we will test this.

We would also like the participants to consider the fact that we are issuing experimental warnings that are being used only by researchers, and not going out the public (“fake” warnings, if you will). Within the testbed, we can conduct these activities at no risk, so it is important that participants not fall into their “comfort zones” and use their traditional diagnosis methods versus the experimental products.

Additionally, we want to determine answers to these questions:

- How will forecasters integrate MRMS products into their traditional diagnosis?
- Which MRMS products are most useful?
- What new MRMS products, menus, and displays should be considered?
- What data values should be considered operationally significant?

The tangible output to all of this will be the development of optimal AWIPS procedures for wind, hail, and tornado warnings. We will wrap this all up into a comprehensive NWA electronic Journal of Operational Meteorology article to be co-authored by the experiment participants. Our collaboration will help inform the development of WDTB training materials for MRMS as it is rolled out to official operations.

Finally, we hope that you will learn enough about the MRMS products from your testbed experience to take that information back to your WFOs and Regions and begin (or continue) to use the experimental MRMS products during WFO operations via the AWIPS LDM feed, Google Maps, and On-Demand interfaces. Your advocacy of the operational benefits of these products will facilitate an expedited integration into AWIPS2.

Domain locations

There will be seven WDSSII domains (Fig. 2) for EWP2013. Six of the domains are fixed and centered on the six Lightning Mapping Array (LMA) domains.

1. Oklahoma and west Texas
2. Northern Alabama
3. East-central Florida
4. Washington DC
5. Houston
6. Northeast Colorado

The last domain will “float” and be positioned each day over an area where storms are expected. Any time severe weather threatens one of the fixed LMA domains, we will operate there, even if there is a higher severe weather chance elsewhere. This is because we must maximize our chances to evaluate the pGLM data.

We will operate as either one CONUS WFO, or split into two adjacent WFOs during warning operations. Because we will have six participants each week, during warning operations we will have two warning desks and one mesoscale desk. More details are in the EWP2013 operations plan.

The MRMS reflectivity-derived data within the domains have a horizontal and vertical resolution of 1 km, and a refresh rate of 1 to 2 minutes. The merged azimuthal shear and rotation tracks products have a horizontal resolution of 500 meters.

The Multi-Radar/Multi-Sensor (MRMS) Algorithms

Each week, participants will have the opportunity to evaluate some or all of the following experimental MR/MS applications:

1. Hail Detection Algorithm (HDA) products: Probability Of Severe Hail (POSH), Maximum Estimated Size Hail (MESH), Hail Swaths (30-, 60-, 120-minute).
2. Hail/Lightning/Convective diagnostic products: Composite Reflectivity, Reflectivity At Lowest Altitude (RALA), Isothermal Reflectivity at 0°C, -10°C, and -20°C, Echo Tops of various reflectivity values (50 and 60 dB*Z*), height thicknesses between various echo top heights and temperature altitudes (e.g., height of 50 dB*Z* above the -20°C altitude), Vertically Integrated Liquid (VIL), VIL Density, and Vertically Integrated Ice (VII). Gridded temperature profile information is integrated from numerical model analysis fields.
3. Derived Shear products: 0-2 km AGL azimuthal shear (LL = low-level), 3-6 km AGL azimuthal shear (ML = mid-level), accumulated “Rotation Tracks” (30-, 60-, and 120- minutes).
4. Dual-Pol Tornado Debris Signature (TDS) products: TDS (instantaneous) and accumulated “TDS Tracks” (30-, 60-, and 120- minutes).

Product Descriptions

These figures are from the 24 May 2011 case that is used in the Weather Event Simulator (WES). Some of the images are derived from the WDSS-II GUI (wg) instead of D2D, hence the slightly different appearance. They are shown here to highlight how they compare to each other. The actual depictions in AWIPS will be seen when you use the data on the WES or the HWT real-time AWIPS2 system.

Reflectivity At Lowest Altitude (RALA)

Owing to the radar horizon and terrain blockage, each radar can only sense down to a certain altitude above the earth's surface. For multiple-radars, the MRMS product uses the lowest altitude from all of the radars for each grid point. That ensures that the reflectivity at the lowest altitude is depicted. This is useful for precipitation estimation.

Composite Reflectivity (MergedReflecvitityQCComposite)

The maximum reflectivity in the vertical column over the MRMS grid is plotted as "composite reflectivity" (Fig. 2). For the MRMS system, the reflectivity is quality controlled (QC) to remove AP, bright band contamination, clutter, and sun spikes (Lakshmanan et al. 2007a).

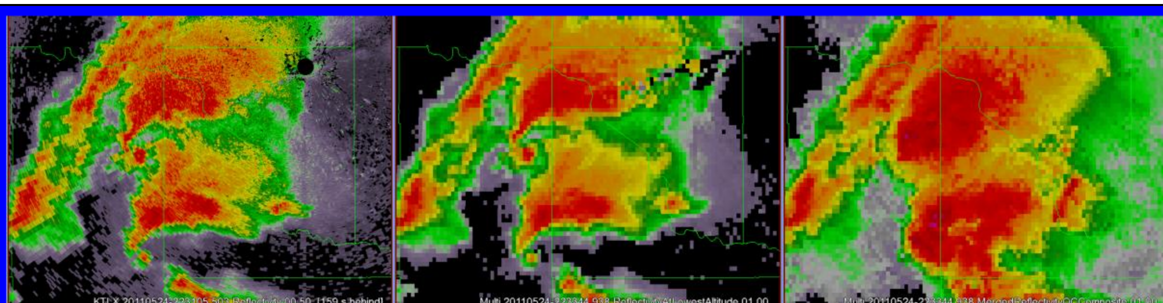

Figure 2: Left: KTLX 0.5° reflectivity (single radar); Middle: Reflectivity At the Lowest Altitude; Right: Composite Reflectivity.

Echotop_60, Echotop_50

The echo top altitude (Fig. 3) is derived from the 3D merged reflectivity grid. At each grid point, this is the highest altitude in the vertical column where the particular reflectivity value is found (60 or 50 dB*Z*). These products can be useful for quickly identifying rapidly strengthening convection and assessing storm severity.

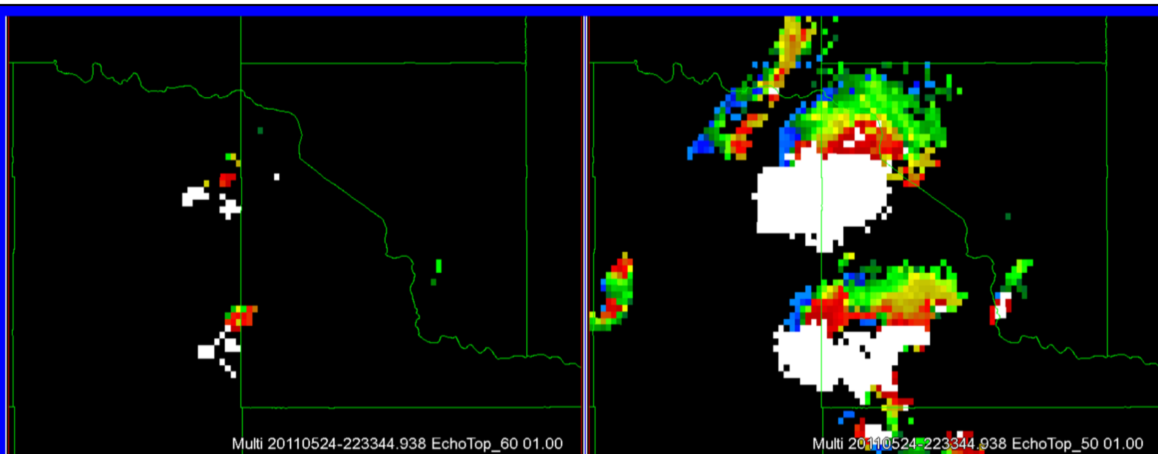

Figure 3: Multi-radar echo tops for 60 dBZ (left), and 50 dBZ (right).

Thickness Products (H60 above H253, H60 above H273, H50 above H253, H50 above H273)

These products (Fig. 4) represent the height thicknesses between a reflectivity echo top altitude (60 or 50 dB*Z*) and the altitude of a specific temperature derived from RAP model analysis vertical temperature profiles (253K or -20° C; 273K or 0° C). These products can be useful for quickly identifying regions where cloud-to-ground lightning may initiate or become more frequent. They can also be useful for diagnosing severe hail potential.

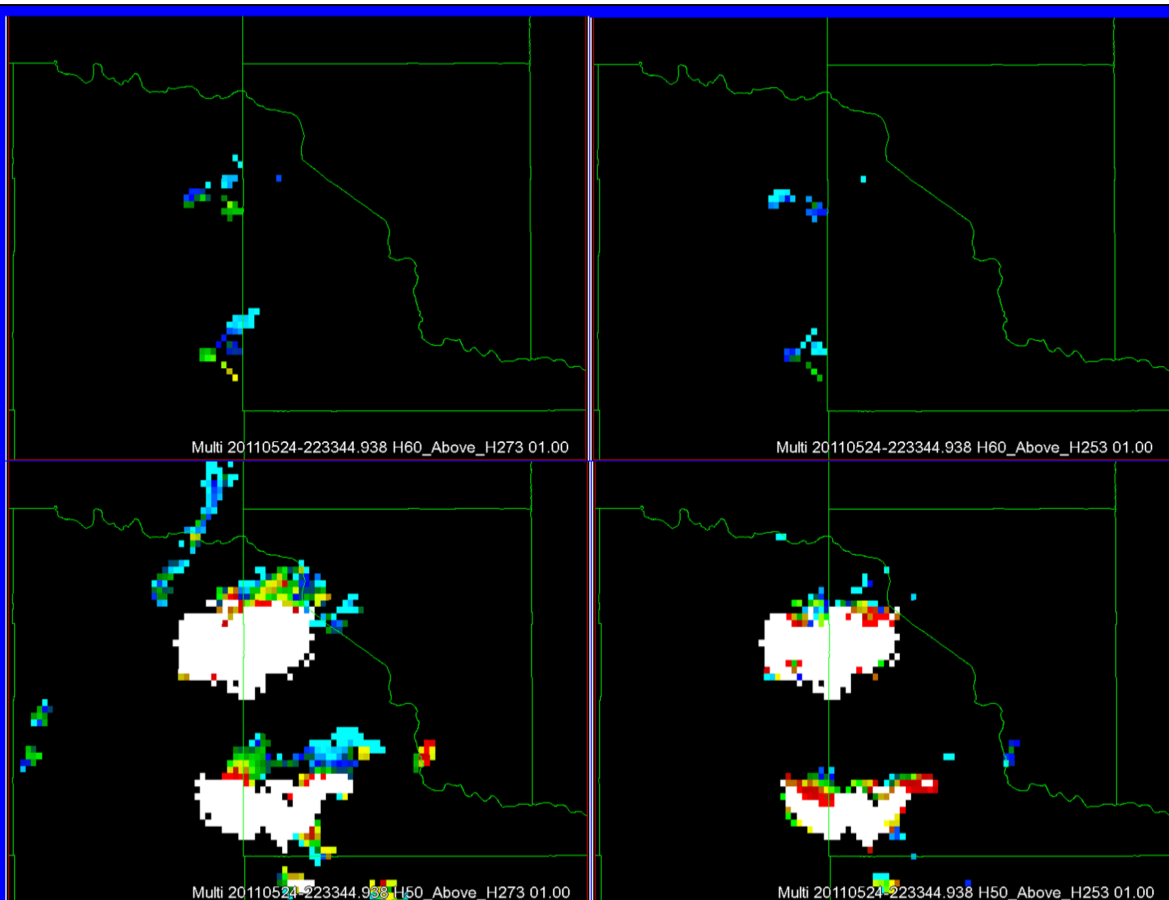

Figure 4: Height of the 60 dBZ echo top above the 0°C (273K) isotherm (top-left); height of the 60 dBZ echo top above the -20°C (253K) isotherm (top-right); height of the 50 dBZ echo top above the 0°C (273K) isotherm (bottom-left); height of the 50 dBZ echo top above the -20°C (253K) isotherm (bottom-right).

Maximum Azimuthal Shear (0-2 km AGL and 3-6 km AGL)

Azimuthal shear is calculated using a Linear Least Squares Derivative (LLSD) method (Smith and Elmore 2004). This method is applied to all the single radar radial velocity products for all scans within the multiple radar domains. The velocity data are quality controlled (QC) to remove non-precipitation echoes from the velocity field prior to the LLSD process. This ensures that only rotation within thunderstorm echoes is processed. For each radar, azimuthal shear layer maxima are computed for the 0-2 km AGL (LL = low-level) and the 3-6 km AGL (ML = mid-level) layers. The 0-2 km layer (Fig. 5) is useful for diagnosing low-level rotation associated with mesocyclones and tornado vortex signatures. The 3-6 km layer (not shown) is useful for diagnosing storm mid-level rotation which could be a precursor to severe downburst winds or tornadoes.

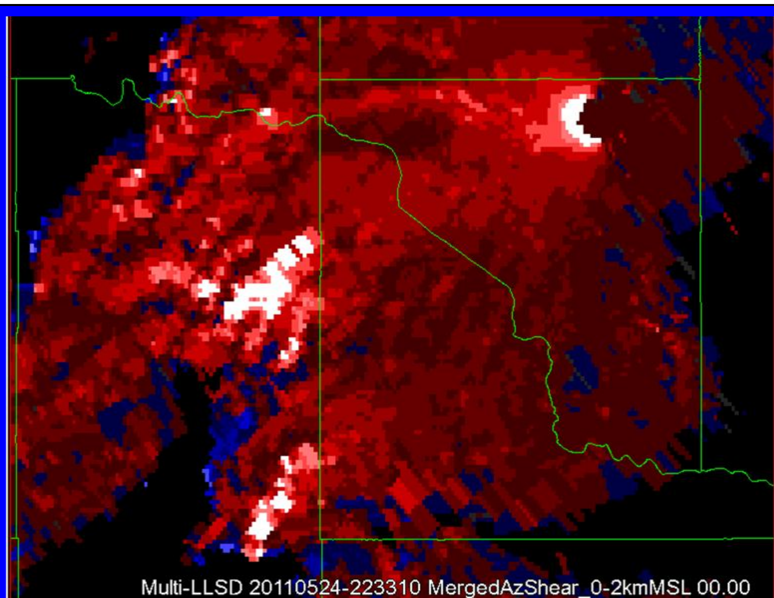

Figure 5: 0-2 km layer maximum azimuthal shear from multiple radars.

Rotation Tracks

The rotation track products (Fig. 6) plot the highest observed cyclonic shear (positive azimuthal shear) during a specific time interval (either 30-, 60-, or 120-minutes). Two sets of rotation tracks are produced at these three time accumulation intervals, the 0-2 km “low-level” (LL) layer rotation track, and the 3-6 km “mid-level” (ML) layer rotation track.

This product has two important functions:

1. It provides a simple diagnostic of the radial velocity data. With a single grid, it is possible to determine the past track of rotation signatures (useful for warning polygon alignment), as well as the trend of the intensity of that rotation, without the possibility of “broken tracks”.
2. This field is geospatial, and it is possible to locate the history and path of the strongest cyclonic shear. This can be very useful in post-storm tornado verification surveys, and eliminates the time-consuming process to replay back radar data and manually identify mesocyclone locations on each volume scan.

Watch out for the occasional dealiasing error, which might corrupt some data points at times.

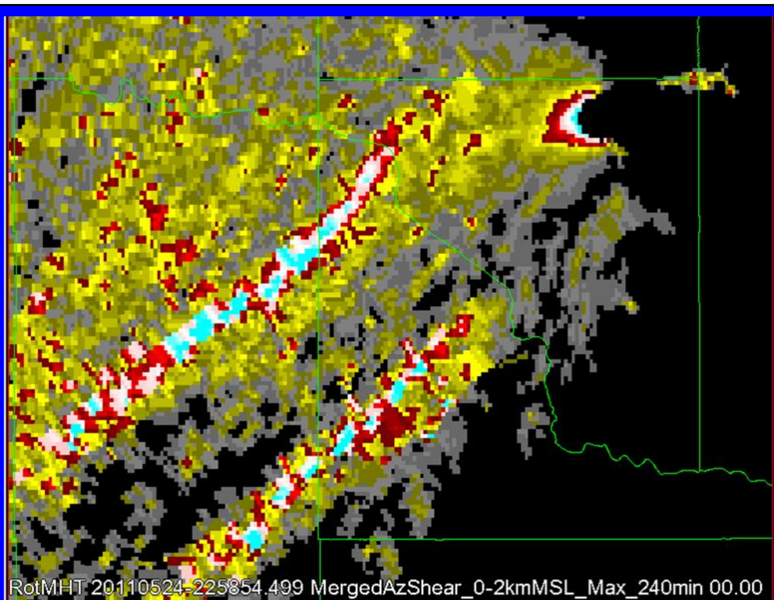

Figure 6: Low-level (LL) Rotation Tracks for the entire event. Two tornadic storms are depicted.

Maximum Estimated Size of Hail (MESH)

This is a gridded analog of the cell-based Maximum Estimated Size of Hail (MESH; Fig. 7) within the Hail Detection Algorithm (HDA). WDSSII derives a gridded Severe Hail Index (SHI), which is essentially a vertically integrated reflectivity that is weighted toward higher reflectivity values, and toward those above the melting layer. Particular weight is given to reflectivities exceeding 50 dBZ which are above the -20° C altitude.

Instead of using the reflectivity profile of the storm cell and producing a single value per storm cell, the reflectivity profile within a vertical column of the 3D grid is used to calculate the grid-based SHI, which is then translated to a MESH product which displays the maximum expected hail size on a geospatial grid. The MESH differs from the operational single-radar HDA product in that the reflectivity profile used is always vertical (cell-based profile can be tilted). Thermodynamic data are automatically integrated using a 2D RAP analysis field, which gives higher spatial and temporal resolution than single values updated from sounding data. The data represent an estimation of hail size on a grid, so it is now possible to determine the spatial extent of the largest hail, rather than just a single hail size estimate tagged to the cell.

Probability Of Severe Hail (POSH)

In addition to the multiple-radar/sensor gridded MESH product, the gridded Severe Hail Index (SHI) can be used to derive a gridded Probability of Severe Hail (POSH; Fig. 7). Note that this algorithm was developed while the threshold for severe hail was still 0.75 inches.

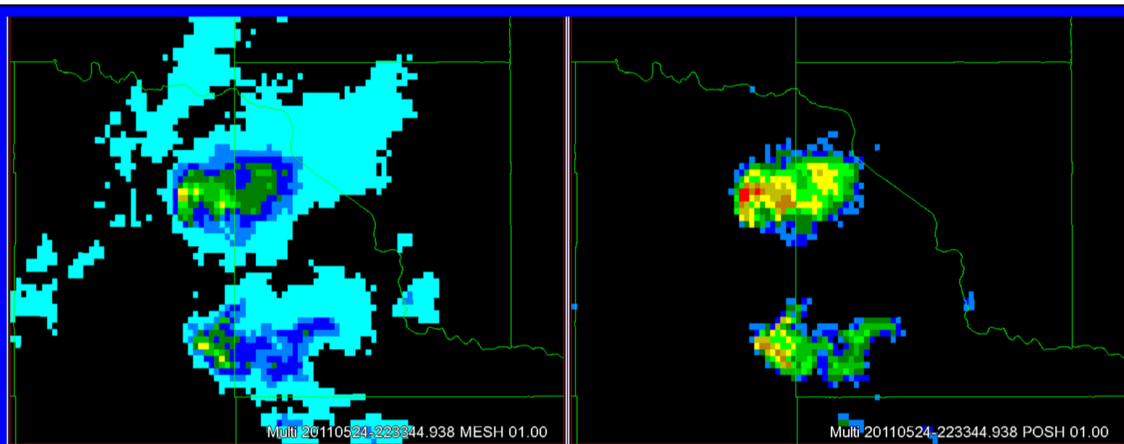

Figure 7: Left: Maximum Estimated Size of Hail (MESH); Right: Probability Of Severe Hail (POSH).

Hail Swath (MESH maximum)

One advantage of MESH data on a geospatial grid is that we can accumulate values on the grid over time. The hail swath products (Fig. 8) display the maximum MESH value observed at every grid point during the previous time interval (either 30-, 60-, or 120-minutes), revealing "swaths" of estimated hail size. This product can be very useful for hail verification efforts, since the hail estimates are represented geospatially. The hail swaths are also very useful for warning polygon alignment.

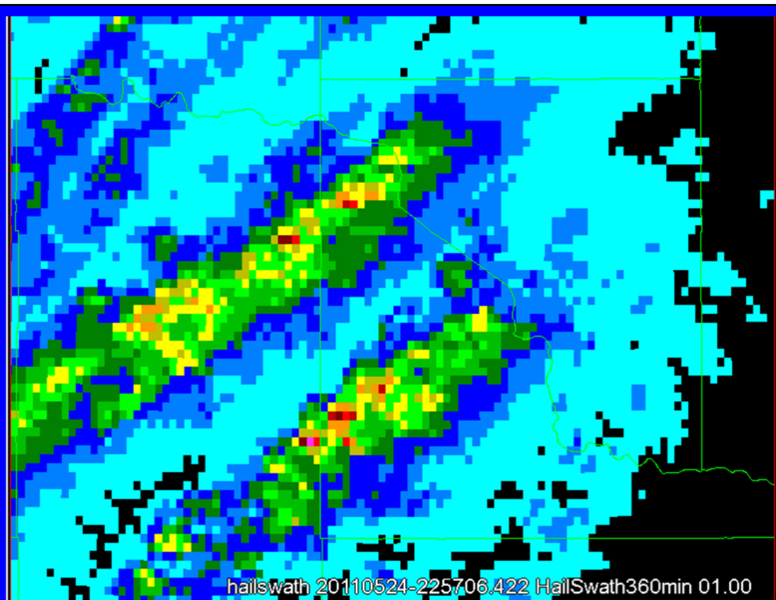

Figure 8: Hail swaths (using MESH) for the entire event.

Reflectivity_0°C, Reflectivity_-10°C, Reflectivity_-20°C

The “Isothermal Reflectivity” products interpolate the 3D reflectivity field to the altitude at which the temperature profile first reaches one of three altitudes, 0° C, -10° C, and -20° C respectively (Fig. 9) as defined by RAP model analysis vertical temperature profiles. Because the 3D temperature profiles can change rapidly over space and time, this method can be more effective than looking for certain reflectivity values at a constant altitude. These products can be useful for quickly identifying regions where cloud-to-ground lightning may initiate or become more frequent. They can also be useful for diagnosing severe hail potential.

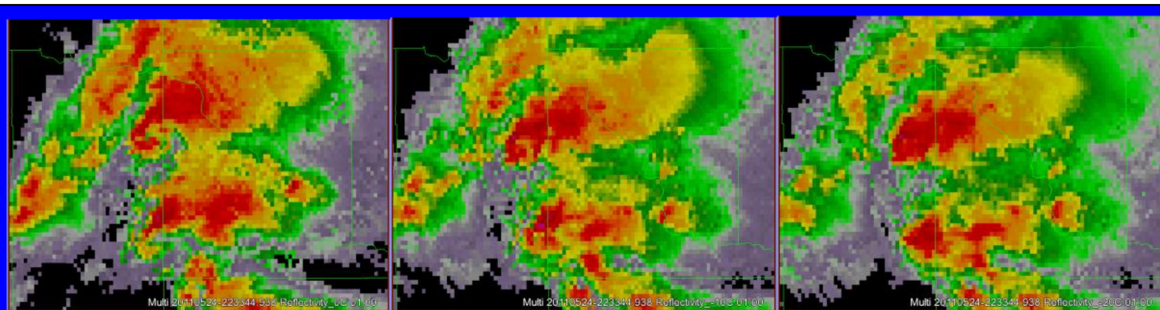

Figure 9: Isothermal Reflectivity products: 0°C (left), -10°C (middle), -20°C (right).

Vertically Integrated Liquid (VIL)

This is a gridded Vertically-Integrated Liquid (Greene and Clark 1972) product that is derived from the multiple-radar 3D reflectivity grid using the vertical profile of reflectivity at each grid point (Fig. 10).

VIL Density

This is calculated by dividing the multi-radar gridded Vertically-Integrated Liquid product by the height of the 18 dBZ echo (Amburn and Wolf 1997; Fig. 10).

Vertically Integrated Ice (VII)

This is a gridded Vertically-Integrated Ice (Mosier et al. 2011) product that is derived from the multiple-radar 3D reflectivity grid using the vertical profile of reflectivity at each grid point, and gridded temperature profile information is integrated from numerical model analysis fields (figure not shown).

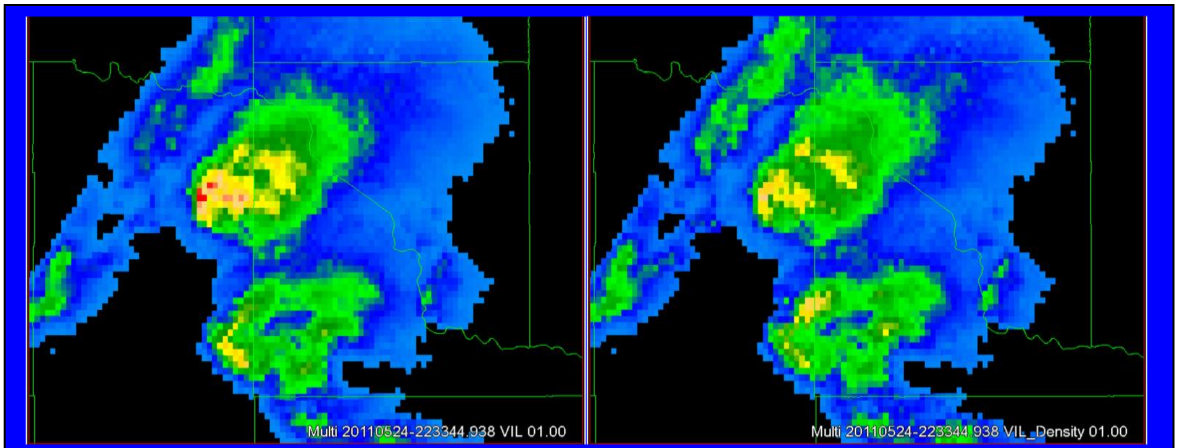

Figure 10: Left: Vertically Integrated Liquid (VIL); Right: VIL Density.

Tornado Debris Signature (TDS) algorithm

Single-radar dual-pol correlation coefficient (CC) data are combined with the LLSD azimuthal shear products to identify possible Tornado Debris Signatures (TDS; Fig. 11). Since the LLSD data are quality controlled to remove all non-precipitation echoes, what's left are areas that are within storms, and within rotation areas of the storms, two requirements for TDS detection. These data are used to "stamp out" areas of "eligible" CC data, from which *minimums* are extracted. The minimums are also tracked with time to product TDS track products.

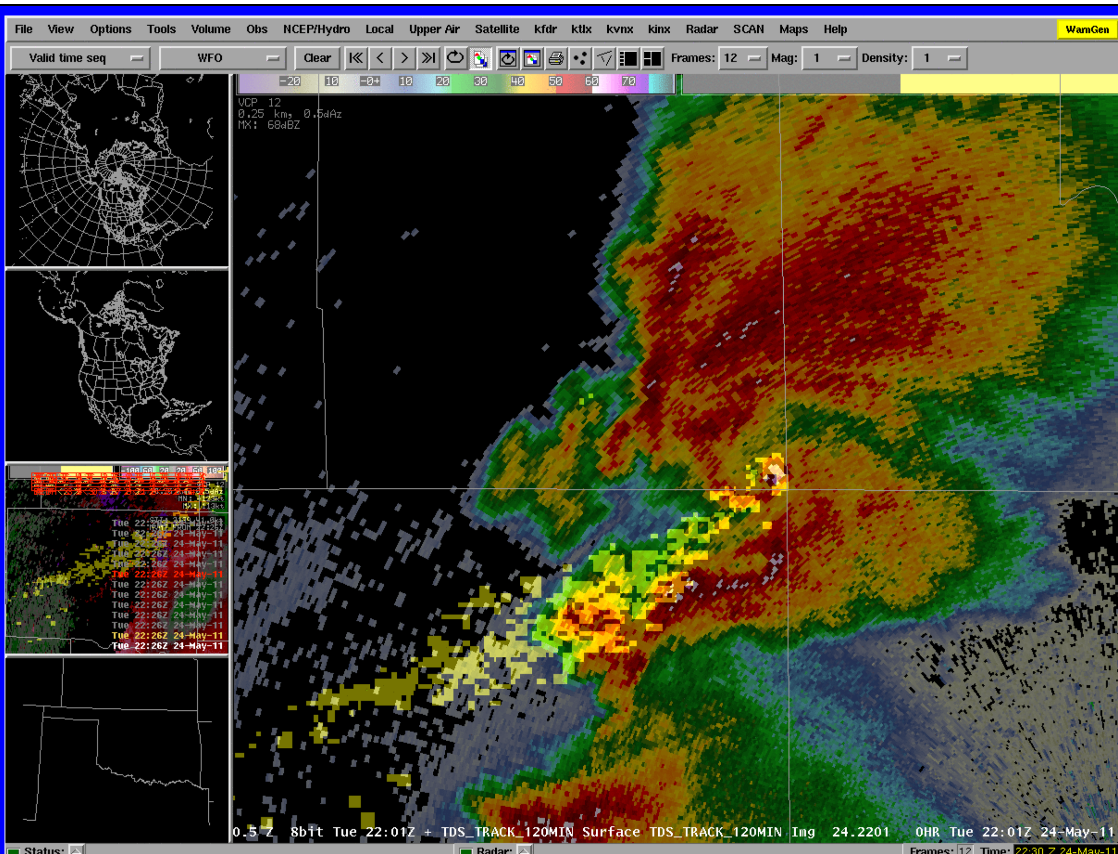

Figure 11: KTLX 0.5° reflectivity combined with TDS track data (bright yellow)) for 24 May 2011.

Additional Resources

Real-time WDSSII multi-radar / multi-sensor products are available online at:

http://wdssii.nssl.noaa.gov/maps

The “On-Demand Severe Weather Verification System” for archived Rotation Tracks and Hail Swath products is available at:

http://ondemand.nssl.noaa.gov/

The EWP web page is located at:

http://hwt.nssl.noaa.gov/ewp/

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