2010 Experimental Warning Program

NOAA Hazardous Weather Testbed, Norman, OK

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

Project Overview

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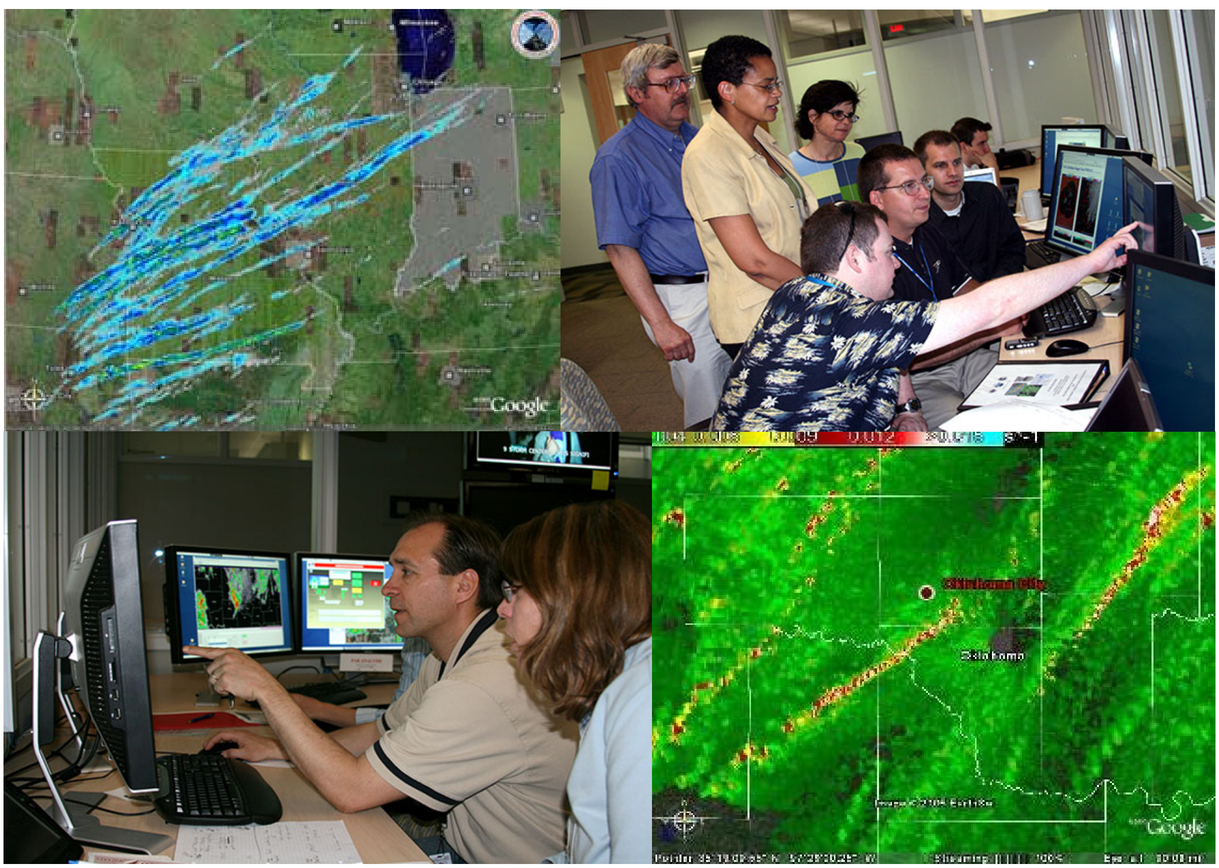

1. Introduction

The NSSL Warning Decision Support System – Integrated Information (WDSSII) possesses a suite of experimental algorithms which combine information from **Multiple Radars and Multiple Sensors (MRMS)**, including numerical model 3D temperature analysis grids. 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.

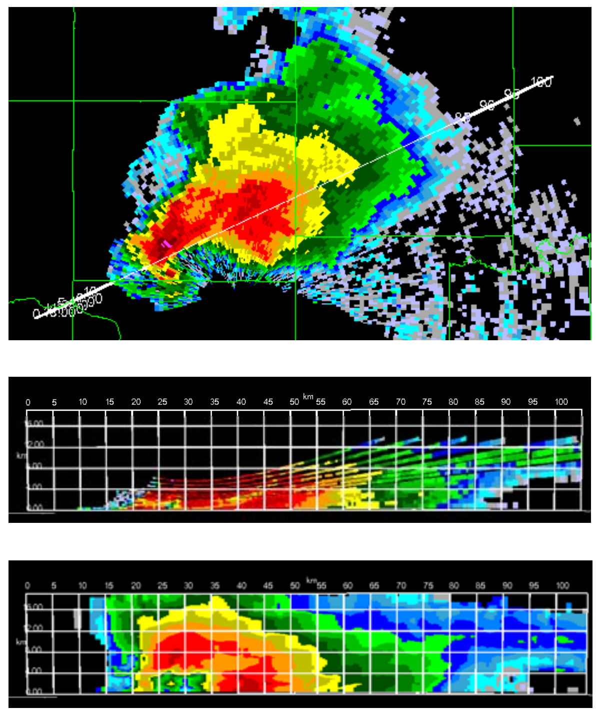

Figure 1: A vertical reflectivity cross-section through a thunderstorm (top) using single radar data (middle) versus using multi-radar blended data (bottom).

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 2-minute heartbeat. Three-dimensional grid pixels (or “voxels”) sensed by more than one radar are assigned a value based on a scheme which places different weights on the data from each radar based on their distance from the voxel. 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, and a 3D grid of azimuthal shear derived from single-radar radial velocity fields. In the future, WDSSII may also produce 3D grids of radial shear, and some polarimetric variables.

Many of the WDSSII products are derived by integrating the 3D radar grids with 3D temperature grids from the Rapid Update Cycle (RUC) numerical model 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

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.

In the testbed, we hope to answer some of the following research questions:

1. How can the MRMS products be used to produce more efficient, more precise, and more accurate severe weather warnings?
2. What are the operational impacts of MRMS products on the warning decision process?
3. Do the automated MRMS products adequately augment contemporary NWS warning decision making procedures?
4. Do the automated MRMS products offer faster analysis time versus "traditional" manual AWIPS base data analysis procedures, and will this improve situational awareness during events with many storms or rapidly-evolving storms?
5. Do the MRMS products offer improved guidance in "radar hostile" regions (cones-of-silence, distance from radars, terrain blockage)?
6. Do the MRMS products provide improved guidance where there are large spatial and temporal "gradients" of near-storm environment?
7. Does repeated use and increased familiarity of the MRMS products over time steadily improve warning decision making?
8. Are there benefits of a future MRMS system that will allow forecasters to develop new and unique "on-demand" MRMS products?

How will we answer these questions? Using real-time events (collected from anywhere in the CONUS), participants will issue experimental severe thunderstorm (SVR) and tornado (TOR) warnings using the AWIPS 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. In addition, we will attempt to target events where the MRMS products should provide an advantage, including:

1. Environments characterized by a large number of storms
2. Environments characterized by rapid storm evolution
3. Storms in "radar hostile" regions (cones-of-silence, distance from radars, terrain blockage)
4. Storms within areas of large spatial and temporal "gradients" of near-storm environment

We will do this in a series of 3-hour "Intensive Operations Periods" (IOPs), usually in the evenings, in which the participants will be issuing warnings and statements as they would during WFO operations. After each IOP, we will have a 30-minute discussion and review the MRMS products and compare your experimental warnings to the official NWS warning polygons. We will continue the discussion of the IOP events at the start of the operational shift on the following day. This second de-briefing will offer new light on the events after a good night's rest, and will be conducted with a larger group of scientists in attendance. A short survey questionnaire will also be given at the end of each operational shift.

In addition, the participants will review the MRMS products for 1 or 2 archive data sets. The first archive event (from eastern North Dakota) will serve as the introduction to the new data types, and will be presented early in the week by the project scientists using the WDSSII display. If time permits (meaning, there is a break in the severe weather activity in the CONUS), the forecasters will also look at a second archive event set using the AWIPS Weather Event Simulator (WES) in displaced real-time mode, and issue experimental warnings for that event.

After testbed operations have concluded in mid-June, EWP scientists will quantitatively compare the experimental warnings issued by the participants in the HWT to the official NWS warnings issued for the same events. The following measures will be determined:

1. Improvements in **Probability Of Detection** (POD), in other words, fewer missed events.
2. Improvements in **Lead Time** due to the fast automated integration of MRMS data for each storm at rapid updates.
3. Improvements in polygon coverage - or smaller **false alarm area.**
4. Improved **polygon orientation** along the storm paths.
5. Improved **estimation of storm intensity** (hail size, wind speed) in warnings.

We would like you to keep these metrics in mind as you go through your week in the testbed. Use the MRMS products to your advantage and try to "beat the system"! But since we cannot replicate the exact environment of any WFO, we understand that this may not be a direct one-on-one comparison to official warnings. Nevertheless, along with the experimental warning data, we anticipate that our post-event discussions will provide additional qualitative feedback to be used in the development of the Operations and Services Improvement Plan (OSIP) for the integration of the MRMS severe weather products into AWIPS2 over the next 1-2 years.

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 Google Earth and On-Demand interfaces. Your advocacy of the operational benefits of these products will facilitate an expedited integration into AWIPS2.

Weekly Activities

Since the MRMS and GOES-R experiments will be conducted simultaneously, each participant will have opportunities to experience both experiments. During real-time events, there will be opportunities to combine data from both the MRMS and GOES-R data sets during experimental warning operations. Therefore, we will include a discussion of the GOES-R operational procedures here.

On Monday, we will start the day at 1pm with an introduction to the Experimental Warning Program and a brief description of the experiment logistics. After that, the weekly coordinator will conduct a weather briefing to determine if, when, and where we will be conducting real-time operations in the evening. After the weather briefing, the weekly coordinator will establish our schedule for the evening, assigning the various participants to either GOES-R or MRMS activities. Then starting at 2pm, the participants will begin orientation and training for both the MRMS and GOES-R experiments, and this training is expected to last 3 to 4 hours. Afterwards, depending on the weather, we will begin to look at actual data, either via archive cases, or via your first real-time IOP. The shift will end at 9pm.

On Tuesdays, Wednesdays, and Thursdays, we will begin each 1-9pm shift with a 30-minute debriefing of the previous day's events, and follow it with a 30-minute weather briefing conducted by the weekly coordinator. After the weather briefing, the weekly coordinator will establish our schedule for the day, assigning the various participants to either GOES-R or MRMS activities. From 2-9pm, participants will be active with either archive cases or a real-time IOP, depending on the weather outlook for the day. Note that the participants who will be assigned GOES-R duty will be paring up with other GOES-R participants in the Experimental Forecast Program (EFP, or SPC Spring Experiment) in the final 2 hours of their shift (2-4pm) to monitor the weather and/or review archive cases.

On Fridays, our shift is from 10am-1pm. The first two hours will be devoted to an end-of-week debriefing, with a group discussion to summarize the entire weekly testbed experience. Finally, from 12-1pm, the participants will be invited to give short seminars on any topic of interest during an informal brown-bag lunch seminar. The experiment adjourns each week at 1pm, after which the participants will begin their journeys back home.

Domain locations

There will be five WDSSII domains (Fig. 2) for the 2010 EWP spring experiment. Four of the domains are fixed and centered on the four Lightning Mapping Array domains covering central Oklahoma, northern Alabama, east-central Florida, and the Washington DC area. A fifth domain will "float" and be positioned each day over an area where storms are expected. During the active periods of VORTEX2, our floater domain may coincide with the VORTEX2 data collection area. Most of the domains have a horizontal and vertical resolution of 1 km, and a refresh rate of 1 or 2 minutes. The merged azimuthal shear and rotation tracks products have a horizontal resolution of 500 meters.

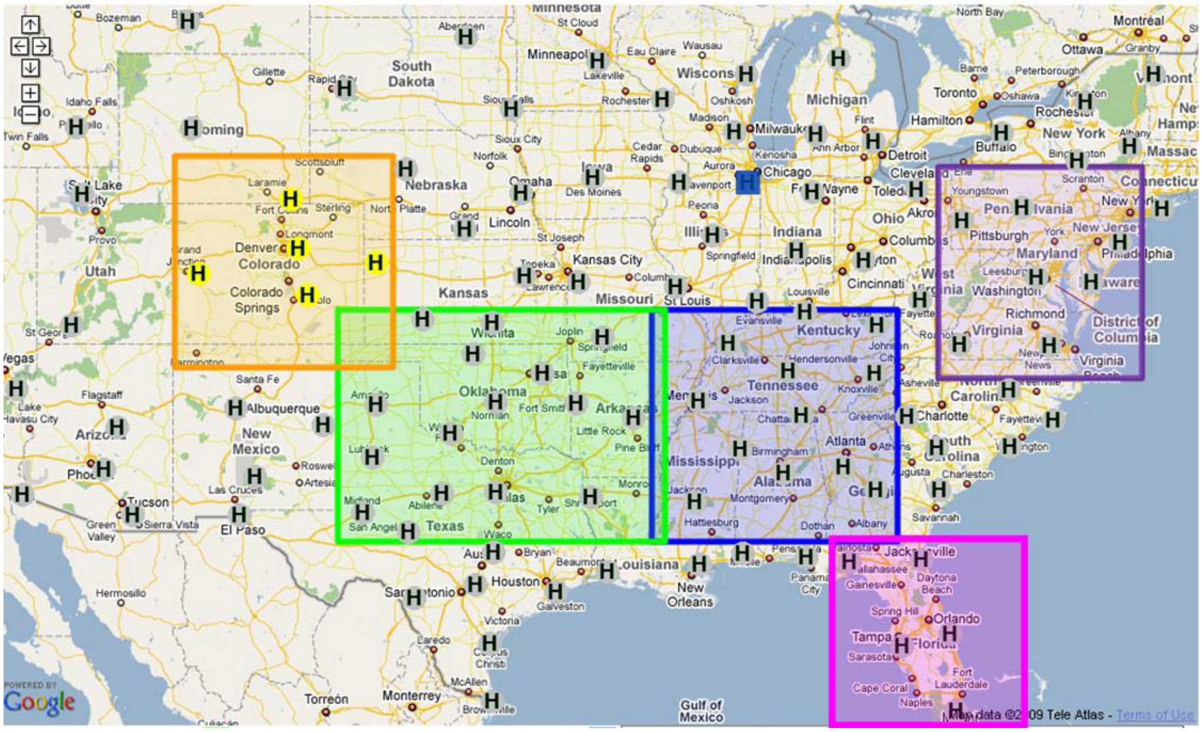

Figure 2: The four "fixed" rapid-update WDSSII domains (OK = green, AL = blue, DC = purple, and FL = magenta) for the 2010 spring experiment are shown. The yellow "floater" domain will be moved each day depending on region of expected severe weather threat.

The Multi-Radar/Multi-Sensor Algorithms

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

1. Gridded Hail Detection Algorithm (HDA) products: Probability Of Severe Hail (POSH), Maximum Expected Hail Size (MEHS), bias-corrected MEHS (MEHSb), Hail Swaths of MEHS and MEHSb (30- and 120- minute).
2. Hail/Lightning/Convective diagnostic products: Reflectivity at 0°C, -10°C, and -20°C temperature altitudes, Echo Tops of various reflectivity values (e.g., 50 dB*Z*), height differences between various echo top heights and temperature altitudes (e.g., height of 50 dB*Z* above the -20°C altitude), layer reflectivity average define by temperature altitudes (e.g., LRA between 0°C and -20°C) , VIL, VIL Density. Gridded temperature profile information is integrated from numerical model analysis fields.
3. Derived Shear products: 0-2 km AGL azimuthal shear, 3-6 km AGL azimuthal shear, accumulated "Rotation Tracks" (30- and 120- minutes).
4. Cloud-to-Ground lightning products: CG Lightning Density, CG Lightning Probability Prediction.

Detailed descriptions of each product is provided next:

Echotop_18, Echotop_30, 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 (18, 30, or 50 dB*Z*). These products can be useful for quickly identifying rapidly strengthening convection and assessing storm severity.

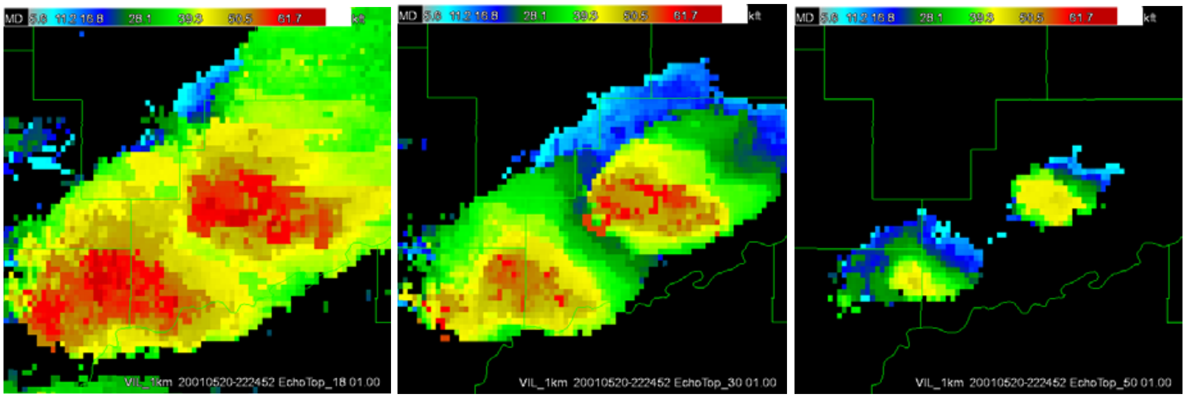

Figure 3: Multi-radar echo tops for 18 dBZ (left), 30 dBZ (middle) and 50 dBZ (right).

H50 above H253, H50 above H273, H30 above H263

These products (Fig. 4) represent the height thicknesses between a reflectivity [echo top altitude] (50 or 30 dB*Z*) and the altitude of a specific temperature derived from RUC model analysis vertical temperature profiles (253K or -20° C; 263K or -10° 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.

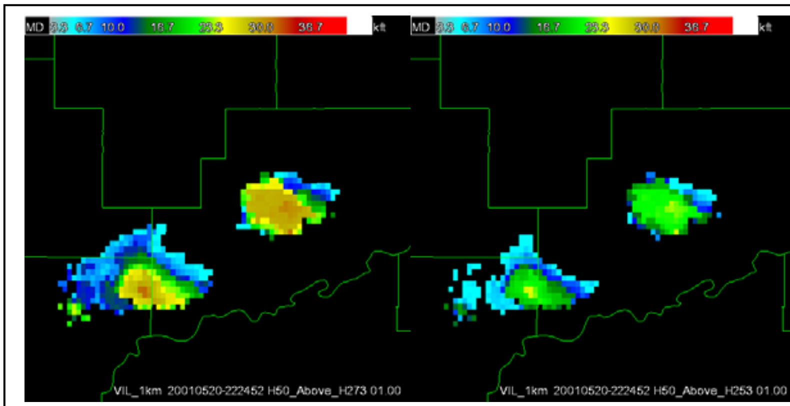

Figure 4: Height of the 50 dBZ echo top above the 0 C isotherm (left), and above the -20 C isotherm (right).

Layer Average Reflectivity -20° C to 0° C

This is the average reflectivity value within a vertical column of the 3D reflectivity grid between the altitudes of -20° C and 0° C as defined by RUC model analysis vertical temperature profiles. This product can be useful for quickly identifying regions where cloud-to-ground lightning may initiate.

Lightning Density

At every 2D grid point, this product provides the number of cloud-to-ground (CG) lightning flashes that have been recorded at the grid point in the previous 15 minutes. The grid is also smoothed in a 3x3 neighborhood. The information is obtained from the National Lightning Detection Network (NLDN).

Lightning Probability

At every 2D grid point, shows the probability of a cloud-to-ground (CG) lightning strike at that grid point in the next 30 minutes. The algorithm uses current lightning density, a storm motion estimate, and reflectivity at 0° C, -10° C and -20° C to determine this probability. The actual probability is computed using a neural network that was trained on historical data from across the CONUS.

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

Azimuthal shear is calculated using a Linear Least Squares Derivative (LLSD) method. This method is applied to all the single radar radial velocity products for elevation scans within the multiple radar domain. Each single radar set of azimuthal shear elevation scan data are merged with their counterparts from multiple radars to produce a 3D grid of azimuthal shear calculated along horizontal levels.

Next for each vertical grid point within the merged 3D azimuthal shear field, we calculate two products. One is the maximum azimuthal shear within the 0-2 km above ground level (AGL) layer. This is useful for diagnosing low-level rotation associated with mesocyclones and tornado vortex signatures. The second products is the 3-6 km AGL maximum azimuthal shear, which can be useful for diagnosing storm mid-level rotation which could be a precursor to severe downburst winds or tornadoes. The velocity data are quality controlled to remove non-precipitation echoes from the velocity field prior to the LLSD process. This ensures that only rotation within thunderstorm echoes is processed.

Rotation Tracks

The rotation track products (Fig. 5) plot the highest observed cyclonic shear (positive merged azimuthal shear) during a specific time interval (either 30- or 120-minutes). Two sets of rotation tracks are produced at these two time accumulation intervals, the 0-2 km layer rotation track, and the 3-6 “mid-level” (ML) layer rotation track.

This product has two important functions:

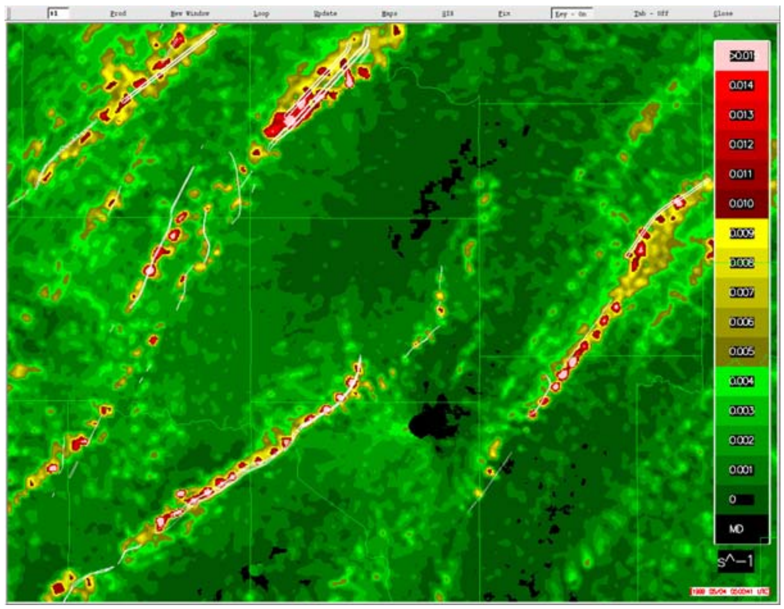

Figure 5: 0-2 km Rotation Tracks for the May 3, 1999 tornado outbreak in Central Oklahoma, shown with actual tornado paths from post-event damage surveys (white lines).

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.

Maximum Expected Size of Hail (MESH)

This is a gridded analog of the cell-based Maximum Expected Size of Hail (MESH) 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 RUC analysis field, which gives higher spatial and temporal resolution than single values updated from rawinsonde 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.

MESHb is a bias-corrected product based on a comparison of the MESH products to several thousand reports from the Severe HAzards Verification Experiment (SHAVE). It will typically have slightly lower values than the original MESH products.

Hail Swath

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. 6) display the maximum MESH value observed at every grid point during the previous time interval (either 30- 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.

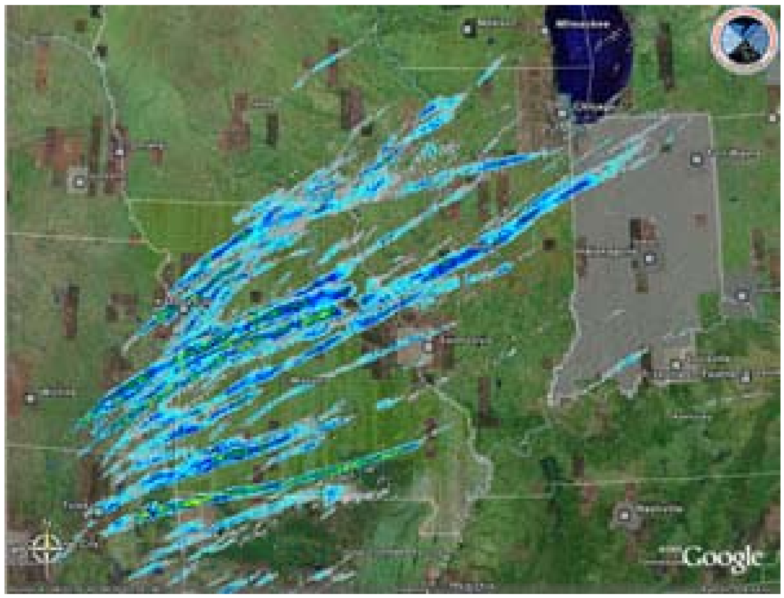

Figure 6: Hail swaths (using MESH) over a 12-hour period of the 12 March 2006 mid-Mississippi Valley severe weather outbreak.

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). Note that this algorithm was developed while the threshold for severe hail was still 0.75 inches.

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 as defined by RUC 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.

VIL

This is a gridded Vertically-Integrated Liquid product that is derived from the multiple-radar 3D reflectivity grid using the vertical profile of reflectivity at each grid point.

VIL Density

This is calculated by dividing the multi-radar gridded Vertically-Integrated Liquid product by the multi-radar gridded 18 dB*Z* Echo Tops.

Additional Resources

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

http://wdssii.nssl.noaa.gov

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://ewp.nssl.noaa.gov