<u>**WDSSII multiple-radar / multiple-sensor algorithm products**</u>

Objectives

To evaluate the accuracy and the operational utility of the **WDSSII multiple-radar/multiple-sensor severe weather applications** in supporting NWS hazardous convective weather warning decision making. Specific objectives include:

1. To provide feedback on the ability of these applications to enhance traditional base-radar data analysis in warning decision making.
2. To suggest improvements or new multiple-radar/sensor products that will aid warning decision making.
3. Provide an introduction to the products which will also be available (via Google Earth) after the participants return to their forecast offices.

Each week, the forecaster 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.
5. Storm tracking and trends based on a KMeans clustering algorithm.

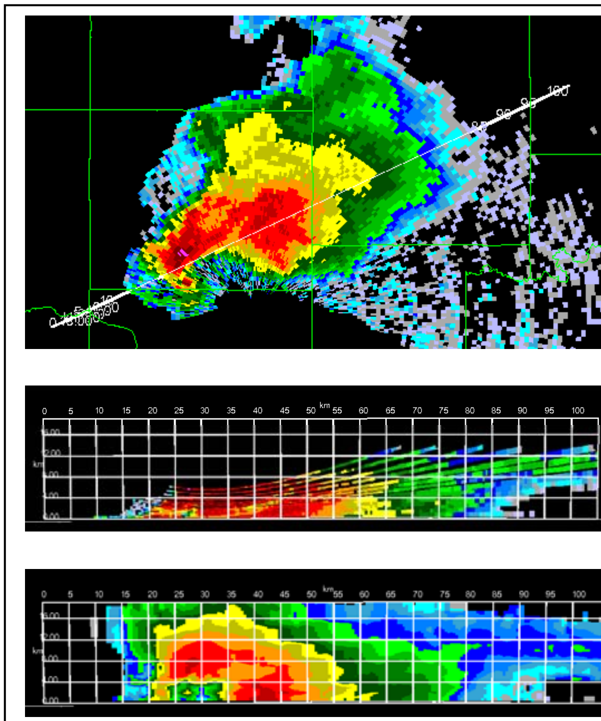

Figure 1: A vertical reflectivity cross-section through a thunderstorm (top) for single radar (middle) and multi-radar (bottom) blended data.

6. Satellite products (to be evaluated by EFP as well): Convective Initiation, Overshooting Tops, Warm Wake.

The 3D multi-radar/sensor grids

The NSSL Warning Decision Support System – Integrated Information (WDSSII) possesses a suite of experimental algorithms which combine information from multiple-radars and other sensor data, 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, 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 for at vertical sample.

NSSL has developed an application that merges data from multiple radars into a rapidly-refreshing 3D grid. The grids can be updated as fast as any new elevation scan update from one of the radars in the grid, although we “throttle” the updates to a 1- or 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

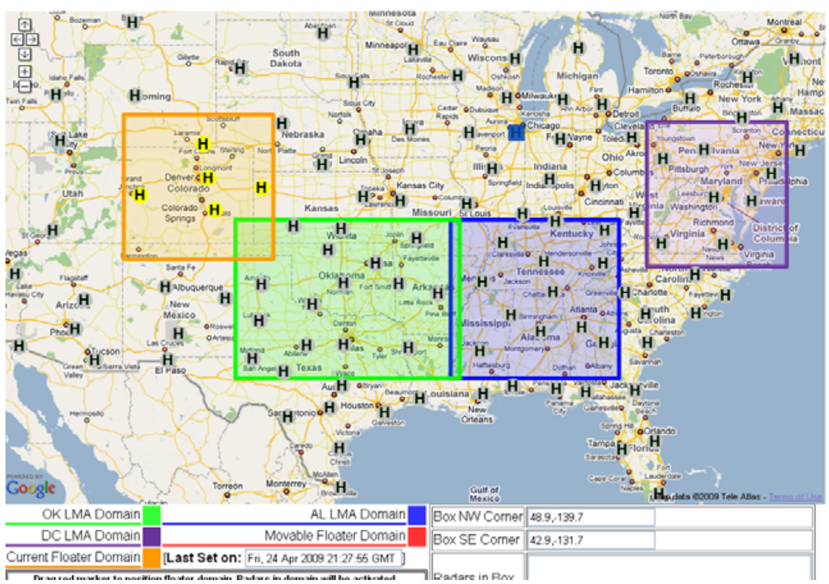

Figure 2: The three “fixed” rapid-update WDSSII domains (green, blue, and purple) for the 2009 spring experiment are shown. The yellow “floater” domain will be moved each day depending on region of expected severe weather threat.

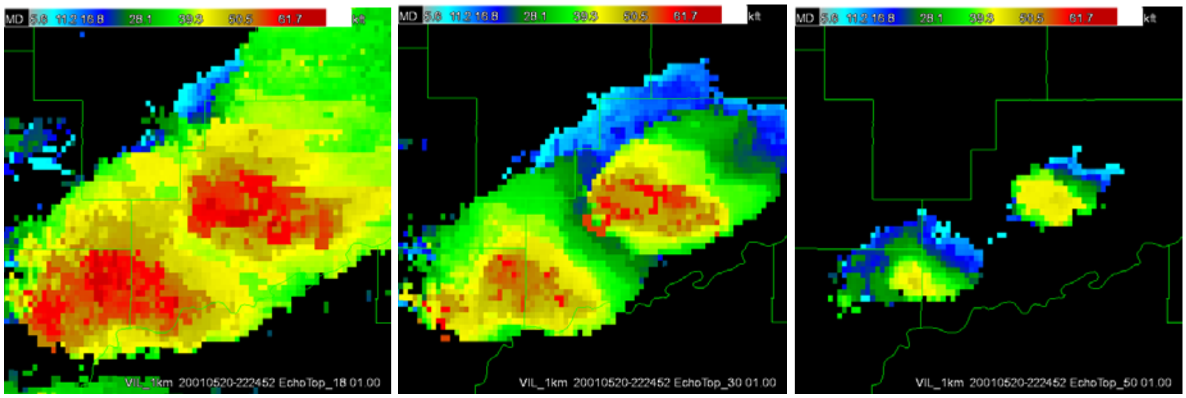

Figure 3: Multi-radar echo tops for 18 dBZ (left), 30 dBZ (middle) and 50 dBZ (right).

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.

There will be four WDSSII domains (Fig. 2) for the 2009 EWP spring experiment. Three of the domains are fixed and centered on the three Lightning Mapping Array domains covering central Oklahoma, northern Alabama, and the Washington DC area. A fourth domain will "float" and be positioned each day over an area where storms are expected. During the active periods of VORTEX2 (beginning 10 May 2009), 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.

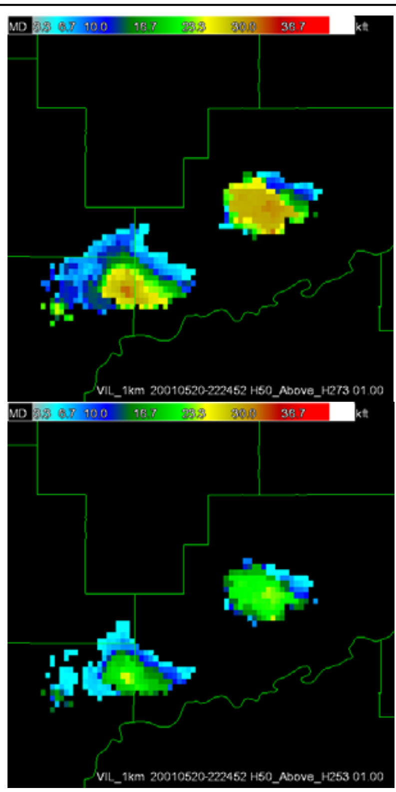

Figure 4: Height of the 50 dBZ echo top above the 0 C isotherm (top), and above the -20 C isotherm (bottom).

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 dBZ). These products can be useful for quickly identifying rapidly strengthening convection and assessing storm severity.

H50 above H253, H50 above H273, H30 above H263

These products (Fig. 4) represent the difference in height between a reflectivity echo top altitude (50 or 30 dBZ) 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.

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.

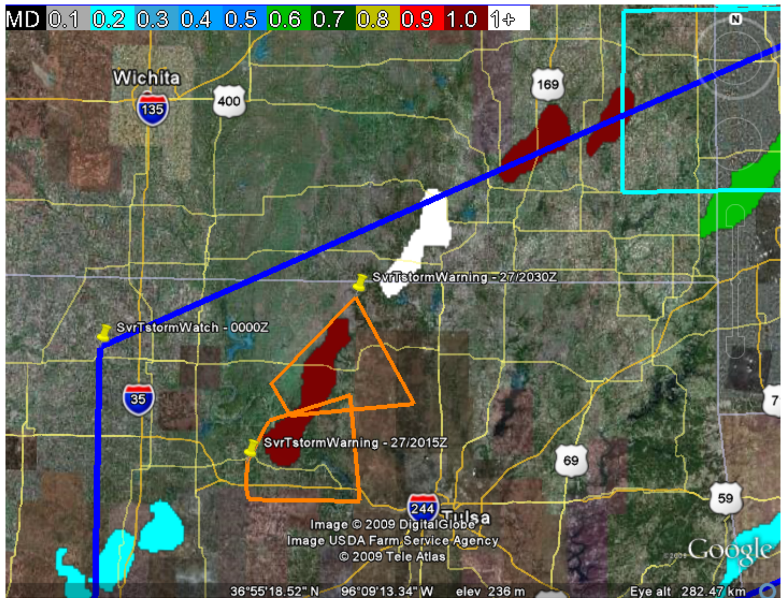

Figure 5: Probability of a cloud-to-ground lighting strike in the next 30 minutes (LightningProbability30min).

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 (Fig. 5). 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. Only the positive (cyclonic) azimuthal shear is calculated. 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.

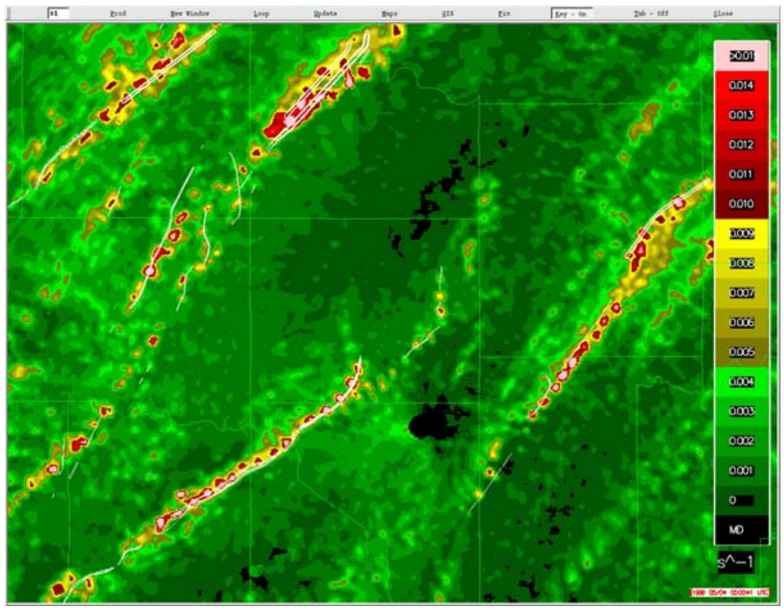

Figure 6: 0-2 km Rotation Tracks for the May 3, 1999 tornado outbreak in Central Oklahoma, shown with actual tornado paths from post-event damage surveys (white lines).

Rotation Tracks

The rotation track products (Fig. 6) plot the highest observed cyclonic shear (positive merged azimuthal shear) during a specific time interval (either 30 minutes or 2 hours). 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:

1. It provides a simple diagnostic of the radial velocity data (avoiding the use of rules and thresholds to classify "mesocyclones", which tend to be unstable). With a single grid, it is possible to determine the past track of rotation signatures, 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.

MESH

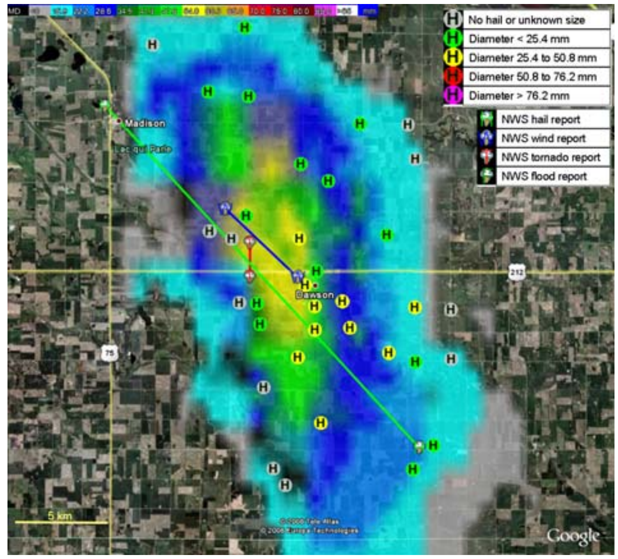

Figure 7: 2-hour "Hail Swath" product, overlaid with reports from the SHAVE experiment and NWS local storm reports.

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 recent comparison of the MESH products to several thousand reports from the SHAVE experiment. It will typically have lower values than the original MESH products.

MESH_max_30min, MESH_max_120min ("Hail Swath")

One advantage of MESH data on a geospatial grid is that we can accumulate values on the grid over time. The MESH swath products (Fig. 7) display the maximum MESH value observed at every grid point during the previous time interval (either 30 minutes or 2 hours), revealing "swaths" of estimated hail size. This product can be very useful for hail verification efforts, since the locations of the largest hail are now known (these are unknown with the cell-based HDA).

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

These reflectivity (dBZ) 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 dBZ Echo Tops].

VILMA

The experimental Lightning Mapping Arrays (LMA) can detect the "source points" of total lightning on a 3D grid, where total lightning equals both the traditional cloud-to-ground (CG) data, along with intra-cloud (IC) flashes. For each vertical level, a source point density grid is calculated. The Vertically-Integrated LMA (VILMA) product sums up the source point density in the vertical over each 2D grid point, and projects that value to a single 2D grid. The 2D VILMA grid is updated every 60 or 120 seconds, and contains all the source point information over the past 5 minutes. This 5 minute time window marches along with each data update.

Several studies have indicated that increasing trends in intra-cloud lightning are useful indicators of the onset of severe weather, and can be observed prior to increasing trends in just CG lightning data alone.

Multi-scale cluster tracking and trends

We use a multi-scale "KMeans" image processing technique to identify, track, and develop statistics for storm cells. For this experiment, we are tracking reflectivity areas on the -10 C isotherm level and collecting statistics from several data fields. The trends may be viewed in the WDSSII "wg" or Google Earth (Fig. 8) displays.

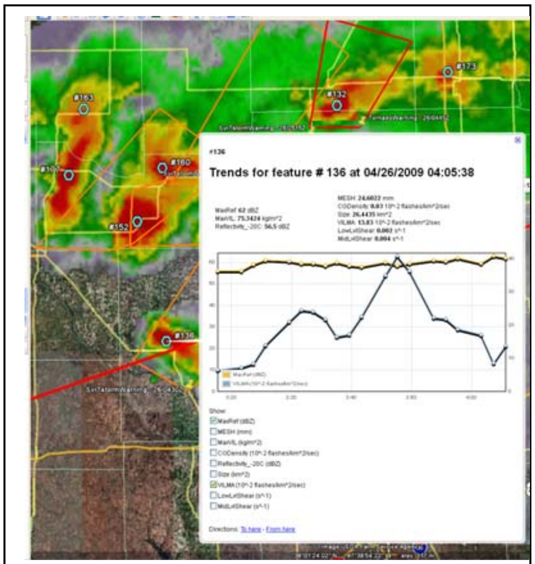

Figure 8: Reflectivity cluster identification with trends of reflectivity and Azimuthal Shear.

Satellite Products for Convective Initiation (CI) nowcasting:

This UW-CIMSS CI nowcasting (UWCI) algorithm objectively identifying rapidly developing cumulus clouds in a pre-convective initiation state during both day and night. Convective initiation is defined here as the transition of the maximum composite reflectivity from below to above 35 dBZ for a given storm cell. Cloud-top cooling rates are objectively computed using a box-average methodology for pixels with a cloud microphysical type of liquid water, super-cooled water, mixed phase, and ice. The UWCI algorithm is executed each time a new image is collected over a domain covering the eastern two-thirds of CONUS. Both rapid and operational scan strategy data are incorporated.

Three products are being provided to NSSL/SPC: 1) An instantaneous CI nowcast using the most recent GOES-12 image ("cloud stage"), 2) A 60-min time accumulated CI nowcast which incorporates all CI nowcast information over the last 60 mins to improve the spatial coherency of the output, and 3) A 60-min time accumulated 10.7 micron IR window channel cloud-top cooling rate field. The fields are parallax-corrected so that they overlay atop WSR-88D radar reflectivity to aid in product validation.

This is a very experimental product, and its operational utility is still under investigation. Contact Wayne Feltz (waynef@ssec.wisc.edu), Kristopher Bedka (krisb@ssec.wisc.edu), and/or Justin Sieglaff (justins@ssec.wisc.edu) with detailed questions about the UWCI products.

Resources

The multi-radar / multi-sensor products are available online at:

http://wdssii.nssl.noaa.gov

The "Ondemand" web site for archived Rotation Tracks and Hail Swath products:

http://ondemand.nssl.noaa.gov

The EWP web page is located at:

http://ewp.nssl.noaa.gov

EWP Multi-radar / Multi-sensor Data Survey

1. Are you a NWS employee?________If so, for how long?______________________

2. How many years (total) forecasting experience?________________________________

3. Current date/time:____

4. During this event what type of weather / warnings were your greatest concern?
(please provide a brief discription of event) [e.g., Severe or near severe multicell thunderstorms, Supercell thunderstorm (tornadic or nontornadic). QLCS, Mesoscale Convective System. Embedded supercells…]

5. On a scale of 0 (Lowest) to 10 (Highest) please rate:

   a) The concept of multi-radar / multi-sensor applications for warning decision-making

   Not Useful **Very Useful**

   0 1 2 3 4 5 6 7 8 9 10

   b) How often you would multi-radar / multi-sensor products during warning operations?

   Never **All the time**

   0 1 2 3 4 5 6 7 8 9 10

6. Please provide some comments about the usefulness of multi-radar / multi-sensor products in comparison to traditional base radar data analysis methods (e.g. “all tilts”, 4-panel displays).

7. Rate the impact of the following products on any warning (or forecast) you made:
(0 to 10) (not important to most important; leave blank if you did not use a product).

echotop_18………………………..	0	1	2	3	4	5	6	7	8	9	10
echotop_30………………………..	0	1	2	3	4	5	6	7	8	9	10
echotop_50………………………..	0	1	2	3	4	5	6	7	8	9	10
h30_above_h263………………….	0	1	2	3	4	5	6	7	8	9	10
h50_above_h253………………….	0	1	2	3	4	5	6	7	8	9	10
h50_above_h273………………….	0	1	2	3	4	5	6	7	8	9	10
layeraveragereflectivity_-20_0…..	0	1	2	3	4	5	6	7	8	9	10
lightningdensity_15min………….	0	1	2	3	4	5	6	7	8	9	10
lightningprobability30min………	0	1	2	3	4	5	6	7	8	9	10
mergedazshear_0-2kmagl……….	0	1	2	3	4	5	6	7	8	9	10
mergedazshear_3-6kmagl……….	0	1	2	3	4	5	6	7	8	9	10
mesh………………………………	0	1	2	3	4	5	6	7	8	9	10
meshb……………………………..	0	1	2	3	4	5	6	7	8	9	10
meshb_max_120min……………..	0	1	2	3	4	5	6	7	8	9	10
meshb_max_30min………………	0	1	2	3	4	5	6	7	8	9	10
mesh_max_120min………………	0	1	2	3	4	5	6	7	8	9	10
mesh_max_30min………………..	0	1	2	3	4	5	6	7	8	9	10
posh……………………………….	0	1	2	3	4	5	6	7	8	9	10
reflectivity_0c……………………	0	1	2	3	4	5	6	7	8	9	10
reflectivity_-10c…………………..	0	1	2	3	4	5	6	7	8	9	10
reflectivity_-20c…………………..	0	1	2	3	4	5	6	7	8	9	10
rotationtrack120min……………..	0	1	2	3	4	5	6	7	8	9	10
rotationtrack30min………………	0	1	2	3	4	5	6	7	8	9	10
rotationtrackml120min…………..	0	1	2	3	4	5	6	7	8	9	10

rotationtrackml30min……………	0	1	2	3	4	5	6	7	8	9	10
vil…………………………………	0	1	2	3	4	5	6	7	8	9	10
vil_density…………………………	0	1	2	3	4	5	6	7	8	9	10
storm tracking / trending………..	0	1	2	3	4	5	6	7	8	9	10

8. What were the strengths / weaknesses of the products during this particular event?

9. What additional (new) multi-radar / multi-sensor products would you recommend be developed and tested?