2014 Experimental Warning Program (EWP2014)

NOAA Hazardous Weather Testbed, Norman, OK

Multiple-Radar / Multiple-Sensor Severe weather products Best Practices Experiment (MRMS-SBPE)

Operations Plan and 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.

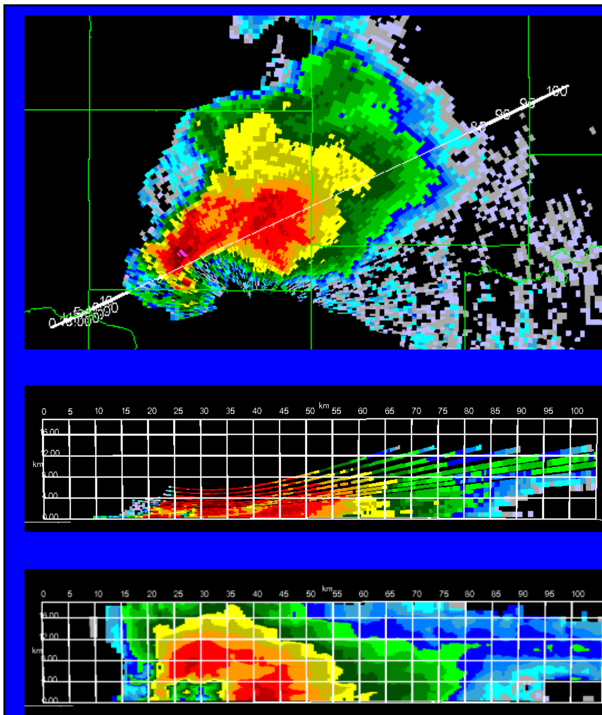


Figure 1: A vertical reflectivity cross-section through a thunderstorm (top) using single radar data (middle) versus using multi-radar blended data (bottom).

NSSL has developed an application that merges data from multiple radars into a rapidly-refreshing high-resolution 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 2-minute intervals. 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 (HWT) took place during the 2009, 2010 and 2013 spring experiments (EWP2009, EWP2010, EWP2013). 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.

For the 2014 version of the Experimental Warning Program spring experiment (EWP2014), we will build upon the work done in the previous experiments. Prior to 2014, the spring experiment was used to evaluate a whole host of experimental warning products at the same time. For the first time, we are running an MRMS evaluation completely independent of any other experimental product evaluation in the HWT. This will allow researchers to isolate the contributions that the MRMS severe weather products have to the warning decision making process. The underlying theme of the experiment is to gather feedback from forecasters in order to gather “best practices” information that will be useful to future users of MRMS products once they are made officially operational in CY15. Hence, the name of the experiment is the **MRMS-Severe Best Practices Experiment**, or **MRMS-SPBE** for short.

We will be conducting a number of controlled sub-experiments during each week using specifically-chosen archived severe weather cases in half-day exercises. Forecasters will be split into two groups, an experimental group that will have MRMS severe weather products as part of their arsenal of products to issue severe weather warnings, and a control group which will not have access to the MRMS data. During these exercises, forecasters in each group will be issuing Severe Thunderstorm Warnings (SVR), Tornado Warnings (TOR), or just helping the researchers evaluate the participants’ warning decision techniques with and without MRMS products. All activities will take place using the AWIPS2 workstations, and its WarnGen software for issuing severe weather warnings. The experimental warnings will be scored experimental geospatial verification techniques (Stumpf, http://tinyurl.com/experimental-warning-thoughts).

In addition, when opportunities permit, we may also work one or two real-time events from anywhere within the CONUS if a severe weather situation unfolds during our experiment period. During the real-time events, we will work the warning operations as a combined team and not as a controlled experiment, and we will be gather feedback from the forecasters via live discussions and post-analysis of the decision making process. We will operate as either one CONUS WFO, or split into two adjacent WFOs during real-time warning operations.

Specifically, our experiment objectives are to:

- Develop best practices that can be integrated into development of WDTB training. To this end:
    - Determine which MRMS products are the most useful for warning decision making.
    - Develop optimal AWIPS2 procedures for hail, wind, and tornado warning decision making, respectively. Start with default procedures.
    - Determine how MRMS products can be integrated into traditional severe weather diagnosis. We would want to inquire about users' current baseline decision making cycle. Will some of the traditional products be dropped off in favor of MRMS products?
    - Calibrate MRMS products against traditional products. Simultaneously, determine "significant" values that correlate with severe weather.
- Suggest new MRMS products and display ideas.
- Author a NWA electronic J. of Operational Meteor. article with forecasters as coauthors.

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. 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 aid the NWS Warning Decision Training Branch (WDTB) in developing their training and educational materials for the MRMS-Severe weather products, which are planned for release by October 1, 2014.

Experiment logistics:

The MRMS-SBPE will be conducted over two work weeks, from 7-11 April 2014, and from 21-25 April 2014 (there are no operations in the interim week) There will be four NWS field forecasters acting as evaluators for each of the two operational weeks. The weekly schedule will go as follows:

<u>Sunday</u>: This is the official travel day to the National Weather Center (NWC) in Norman, Oklahoma.

<u>Monday</u>: The work shift will be **9am – 5pm**. The day will begin with welcomes, orientation, a tour of the facilities, and learning about the MRMS system and its severe weather products in detail. Next, using an practice case from a significant severe weather outbreak event (24 May 2011, Oklahoma), forecasters will become familiar with accessing the products on the AWIPS2 workstations in the HWT, reviewing their procedures and the default procedures developed by the researchers, and building new

procedures. After work hours, at **630pm** there will be a social gathering for a group dinner at a Norman restaurant (to be determined).

Tuesday, Wednesday, Thursday: Archive cases, each taking about a half day, will occur on these days. Normally, the shift will run from **9am – 5pm**. However, if it appears there will be a very interesting real-time event to evaluate the MRMS data with, we may alter the shift times so that we can capture the real-time case. This is what we call our "**flex shifts**". The shifts will run either of these blocks of hours: **10am-6pm, 11am-7pm, 12-8pm, 1-9pm, 2-10pm, and 3-11pm**. The next day's shift time will be pre-determined the prior day via a day-2 forecast, and emailed to each forecaster's MIC so that appropriate shift times are recorded on their shift schedule.

Friday: The shift will run from **9am – 12pm**. An end-of-week de-briefing will be conducted during most of this time, gathering final feedback from the participants. At the final part of this short shift, both the forecasters and the researchers will gather to take a group photo somewhere outside at the NWC. After the shift ends is official travel time for the forecasters to return home.

Detailed shift schedules*

Monday (fixed time)

0845 Arrive at NWC at security desk
0900 NWC Tour (Garfield)
0920 NSSL Welcome (dev lab – Lans Rothfusz)
0930 Introduction to the MRMS-SBPE and the MRMS system (dev lab – Stumpf)
1100 Break
1115 Pre-Operations WDM Online Survey
1200 Lunch
1315 HWT orientation of products on AWIPS2, building procedures, etc.
1415 Break
1430 HWT orientation of products on AWIPS2, building procedures, etc. (cot'd)
1545 Break
1600 Discussion
1655 DAY2 shift time decision
1700 Adjourn
1830 Group Dinner (Interurban Restaurant, 1150 Ed Noble Pkwy, Group: NWS)

Tuesday (flex time in the event of a real-time case*)

0900 Case #1
- 0900 Shift briefing
- 0910 Build procedures
- 0935 Warning ops
- 1035 15-min warning break
- 1050 Warning ops

- 1135 Break
- 1145 Case discussion

1215 Lunch

1315 Case #2

- 1315 Shift briefing
- 1325 Build procedures
- 1350 Warning ops
- 1505 Break
- 1520 Warning ops
- 1620 Break
- 1630 Case discussion

1655 DAY2 shift time decision

1700 Adjourn

<u>Wednesday (flex time in the event of a real-time case*)</u>

0900 Case #3

- 0900 Shift briefing
- 0910 Build procedures
- 0935 Warning ops
- 1020 15-min warning break
- 1035 Warning ops
- 1135 Break
- 1145 Case discussion

1215 Lunch

1315 Case #4

- 1315 Shift briefing
- 1325 Build procedures
- 1345 Warning ops
- 1500 Break
- 1515 Warning ops
- 1625 Break
- 1635 Case discussion

1655 DAY2 shift time decision

1700 Adjourn

<u>Thursday (flex time in the event of a real-time case*)</u>

0900 Case #5

- 0900 Shift briefing
- 0910 Build procedures
- 0925 Warning ops
- 1010 15-min warning break
- 1025 Warning ops
- 1125 Break
- 1140 Case discussion

1215 Lunch

1315 Case #6
- 1315 Shift briefing
- 1325 Build procedures
- 1345 Warning ops
- 1545 Break
- 1600 Case discussion

1700 Adjourn

Friday (fixed time – dev lab)

0900 End of week debriefing
1030 Break
1045 End of week Online Survey
1145 Group photo (outside)
1200 Adjourn for the week

*We will replace archive cases if a suitable real-time case is worked instead. Only up to two real-time cases will be worked per week. A new shift schedule will be determined the night before the start of the shift for any day a real-time event is worked.

Participant expectations

1. Pre-visit Preparation

Unlike the past few EWP spring experiments, the MRMS-SBPE will not require forecasters to take a full 8-hour X-shift on station to prepare. Rather, the view-ahead and read-ahead material review should take no more than 2-3 hours. Forecasters should work with their station MICs if this time needs to be scheduled on shift at the forecaster's duty station. Otherwise, the materials can be perused on the plane or in the hotel room.

There is an MRMS presence on the new NWS Virtual Laboratory (VLab). All MRMS-SBPE participants **are required** to join the MRMS community if they already haven't done so. All of the MRMS-SPBE resources are accessible via the VLab at this URL:

https://nws.weather.gov/innovate/group/mrms/ewp2014-mrms-sbpe

The VLab MRMS-SBPE resource page contains the following:

a. MRMS-Severe Articulate

A 17-minute overview of the history and description of MRMS-Severe weather products.

b. Operations Plan

The plan you are reading right now.

c. Severe Hail Diagnosis Paper

We will be evaluating several techniques for diagnosing severe hail in storms including the Donavon Technique. Therefore, the forecasters should become familiar with this journal paper (Donavon and Jungbluth 2007).

d. MRMS-Severe Product Descriptions

On the MRMS-SBPE resources page is a link to a wiki page that contains short descriptions of the MRMS-Severe products.

2. Procedures

In addition, we will load the forecasters' warning and radar-based AWIPS procedures to use during HWT operations. Forecasters should packed these into a single .zip file. Their procedures will be converted to AWIPS2 format (if your WFO hasn't yet converted to AWIPS2). Procedure files should be delivered no later than the Thursday prior to the arrival day in Norman.

We will have time on Monday for forecasters to review their procedures, review the default procedures developed by the researchers, and build some new procedures using the 24 May 2011 practice case. However, it should be noted that procedures built in one WFO localization don't easily translate to other WFO localizations, so any procedures built on Monday are to be used as templates for altering procedures on later cases. Time has been built into the beginning of each case exercise for procedure alteration.

3. Archive case reviews

During our archive case reviews, two forecasters will be chosen for the control group, and two forecasters will be chosen for the experimental group, and each of these two forecasters will work independently from each other and from the other team. The control and experimental groups will be "sequestered", operating in different rooms within the HWT which are separated by a glass wall and door (the main operations area and the media "back room"). This is so that we can avoid one group's decision and discussion to influence the other group. After each archive case, the team assignments will be shuffled. This is so that each forecaster has a chance to operate at least one time within each of the two groups.

If a specific archive case review requires that the forecaster issues warnings, we will provide the constraints on the type and attributes of the warnings to be issued. For example, some cases will require that only Severe Thunderstorm Warnings (SVRs) be issued for hail. Some cases will require that only Tornado Warnings (TORs) are issued. And some cases may allow both SVRs (for hail, or both hail and wind) and TORs to be issued. Warning durations will be fixed (45-minutes for SVR, 30-minutes for TOR), and warnings are to be reissued at 15-minute intervals (no Severe Weather Statements, or

SVSs, will be issued). And all warnings are to be storm-based – county "clipping" (i.e. turning portions of warnings off or on by country boundaries) will not be allowed.

Each forecaster will be accompanied by a "proctor" who will guide that forecaster through the process of the case review. The proctors will set the warning guidelines (if applicable) for that specific case. The proctor will take notes during the review, gathering feedback information useful to informing the best practices development process. In addition, we will be using a desktop recording application that will record all activities on the computer desktop (e.g., where the mouse moves, what is being selected, etc.). No audio or video of the forecasters will be recorded.

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:

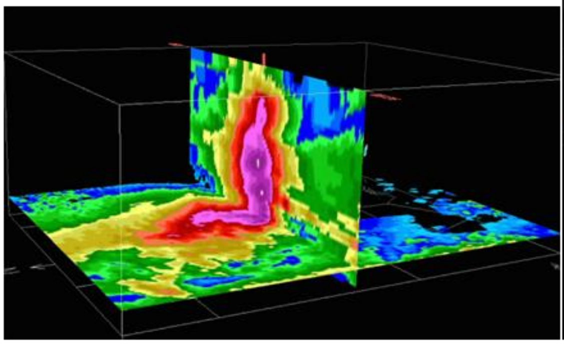
1. Hail Detection Algorithm (HDA) products: Severe Hail Index (SHI), Probability Of Severe Hail (POSH), Maximum Estimated Size of Hail (MESH), Hail Swaths (30-, 60-, 120-, 240- 360, and 1440-minutes).
2. Hail/Lightning/Convective diagnostic products: Composite Reflectivity, Reflectivity At Lowest Altitude (RALA), Isothermal Reflectivity at 0°C, -5°C, -10°C, -15°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-, 120-, 240-, 360-, and 1440-minutes).

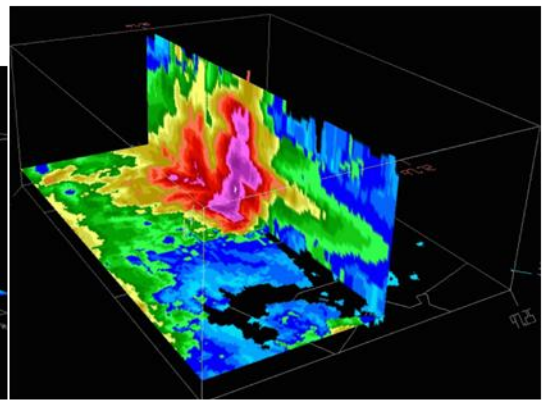
The MRMS reflectivity-derived data within the domains have a horizontal and vertical resolution of 1 km, and a refresh rate of 1 to 2 minutes. The merged azimuthal shear and rotation tracks products have a horizontal resolution of 500 meters.

On the NWS Virtual Laboratory MRMS-SBPE resources page is a link to a wiki page that contains short descriptions of the MRMS-Severe products. Additional description is here. These figures are from the 24 May 2011 case that is used as our practice case Monday afternoon.

3D Reflectivity Cube Levels

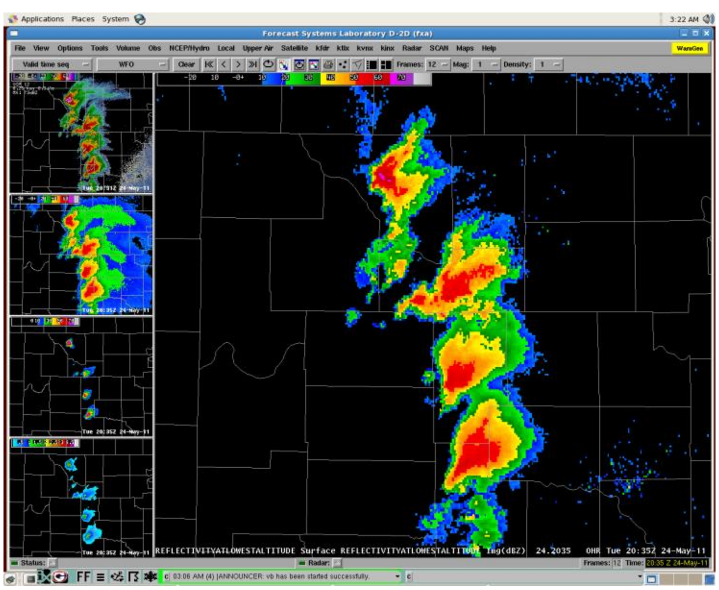
The three-dimensional reflectivity cube is "sliced" into 34 horizontal levels to create these 34 products. The altitudes are 500, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500, 2750, 3000, 3500, 4000, 4500, 5000, 5500, 6000, 6500, 7000, 7500, 8000, 8500, 9000, 10000, 11000, 12000, 13000, 14000, 15000, 16000, 17000, 18000, and 19000 meters above sea level (figures not shown). In the first or second build of AWIPS2 containing MRMS display capabilities will be an "all-tilts" function designed to quickly browse up and down and forward and backward through the 3D data cube. However, that all-tilts capability does not yet exist for the MRMS-SBPE.





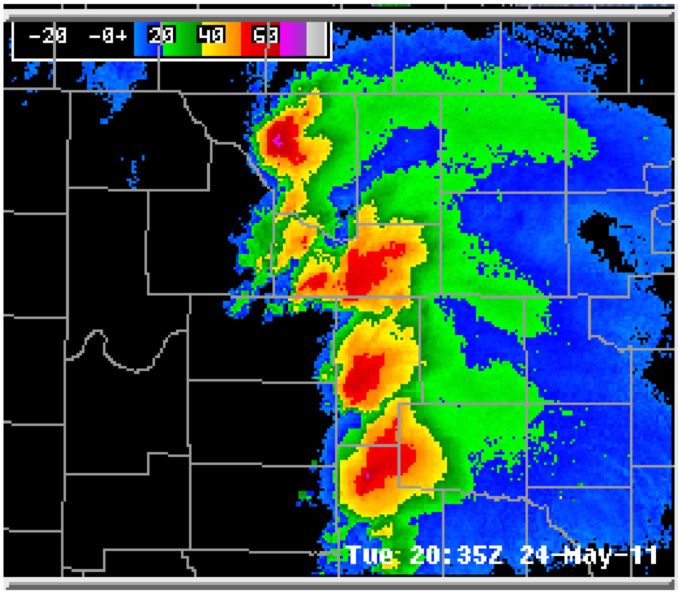
Reflectivity At Lowest Altitude (RALA)

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.



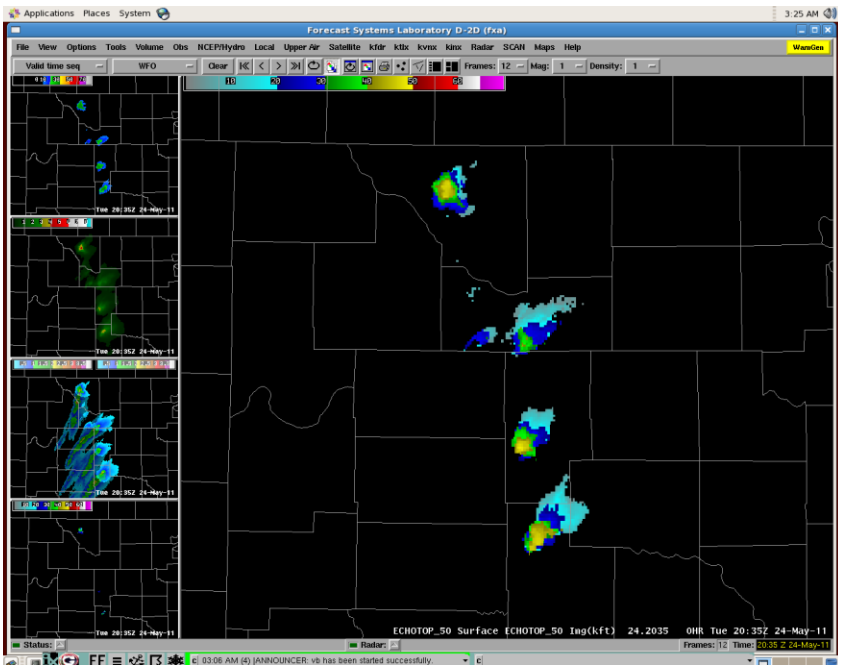
Composite Reflectivity (MergedReflecvitityQCComposite)

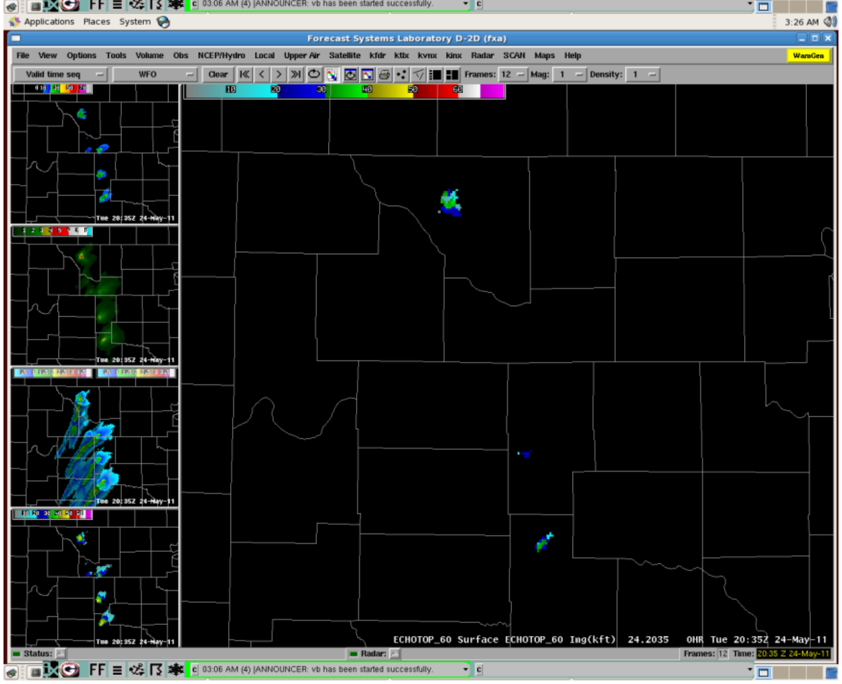
The maximum reflectivity in the vertical column over the MRMS grid is plotted as “composite reflectivity”. For the MRMS system, the reflectivity is quality controlled (QC) to remove AP, bright band contamination, clutter, and sun spikes (Lakshmanan et al. 2007a).



Echotop_60, Echotop_50, Echotop_30, Echotop_18

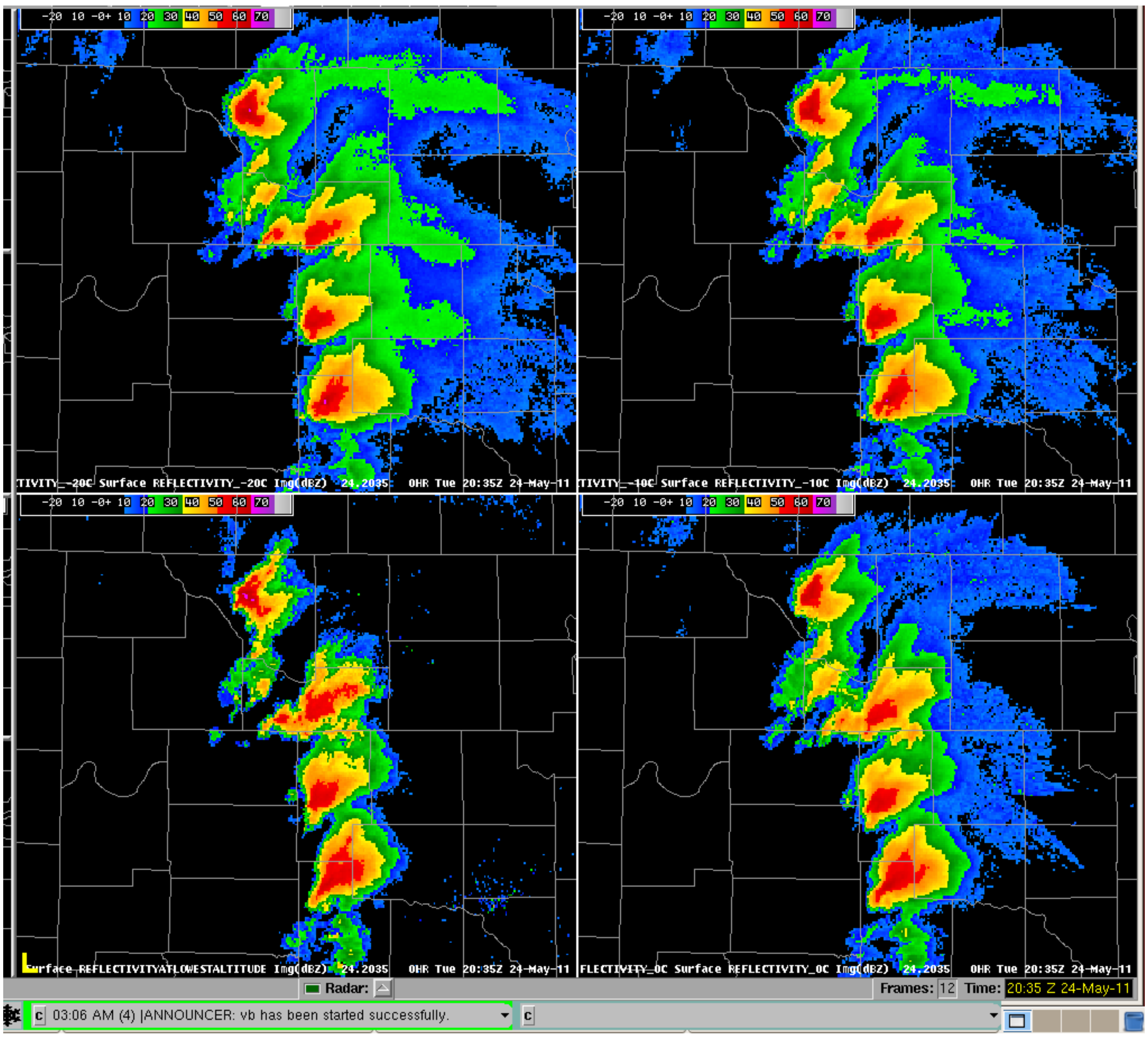
The echo top altitude is derived from the 3D merged reflectivity grid. At each grid point, this is the highest altitude in the vertical column where the particular reflectivity value is found (60, 50, 30, or 18 dB*Z*). These products can be useful for quickly identifying rapidly strengthening convection and assessing storm severity.





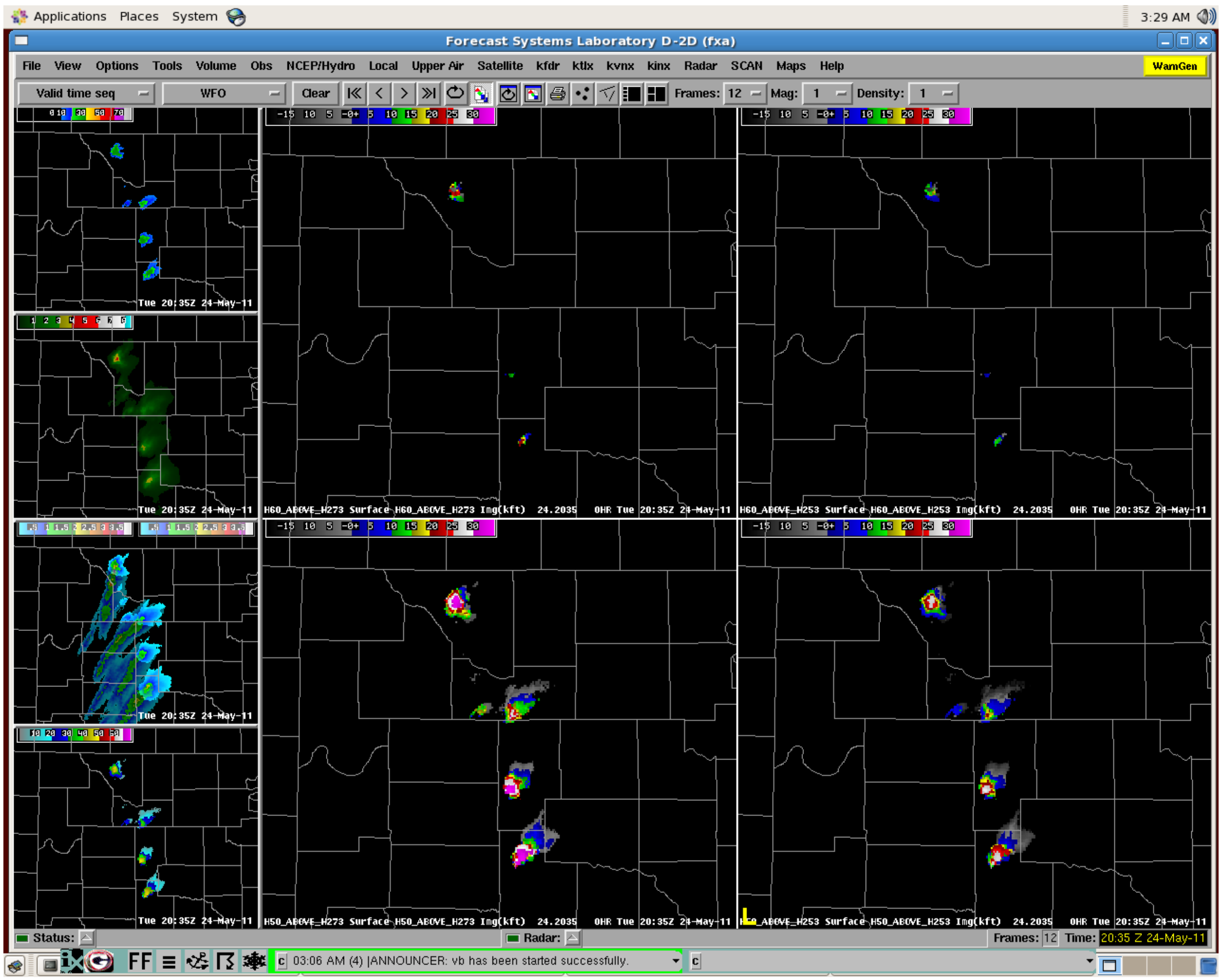
Isothermal Reflectivity

The "Isothermal Reflectivity" products interpolate the 3D reflectivity field to the altitude at which the temperature profile first reaches one of five altitudes, 0° C, -5° C, -10° C, -10° C, and -20° C respectively 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.



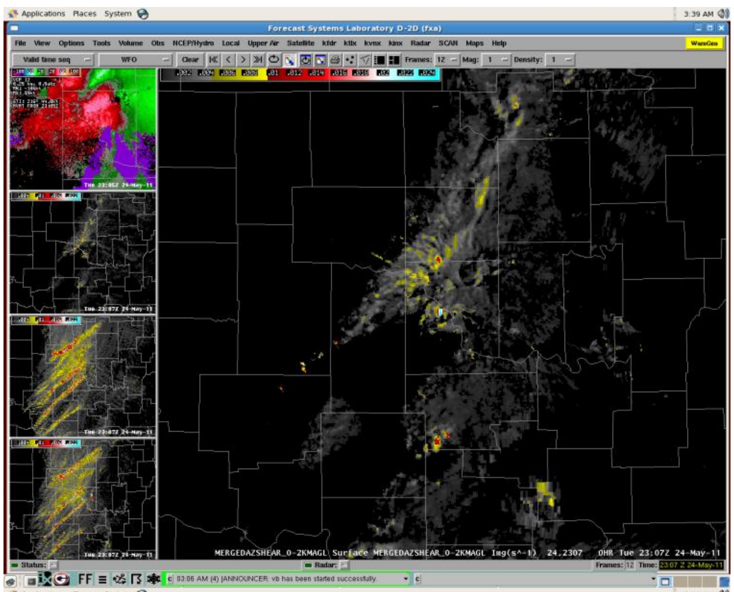
Thickness Products (H60 above H253, H60 above H273, H50 above H253, H50 above H273)

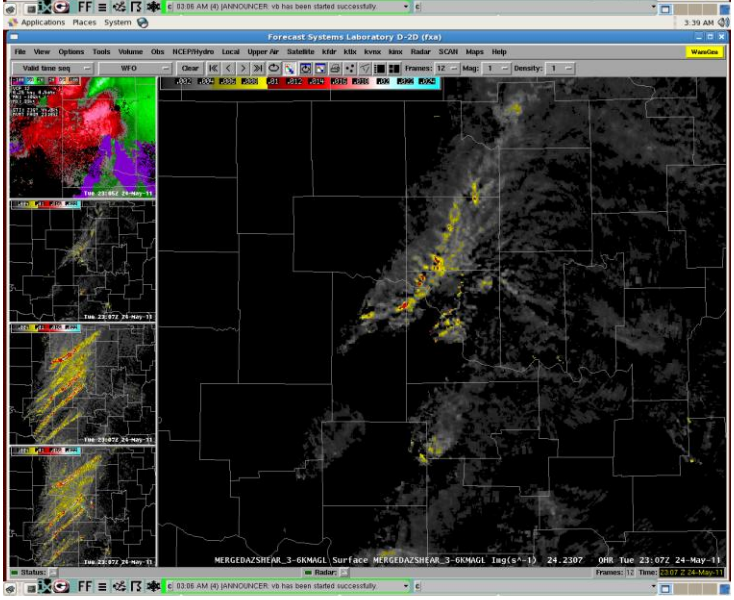
These products represent the height thicknesses between a reflectivity echo top altitude (60 or 50 dB*Z*) and the altitude of a specific temperature derived from RAP model analysis vertical temperature profiles (253K or -20° C; 273K or 0° C). These products can be useful for quickly identifying regions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



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 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.



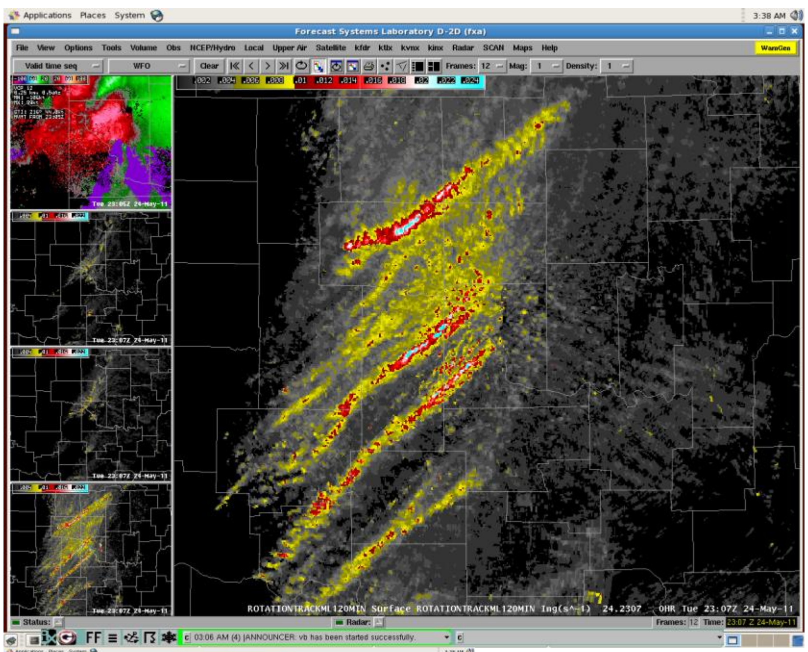


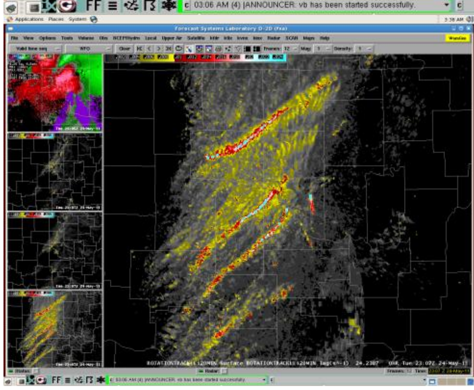
Rotation Tracks

The rotation track products plot the highest observed cyclonic shear (positive azimuthal shear) during a specific time interval (either 30-, 60-, 120-m 240-, 360-, or 1440-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, 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.

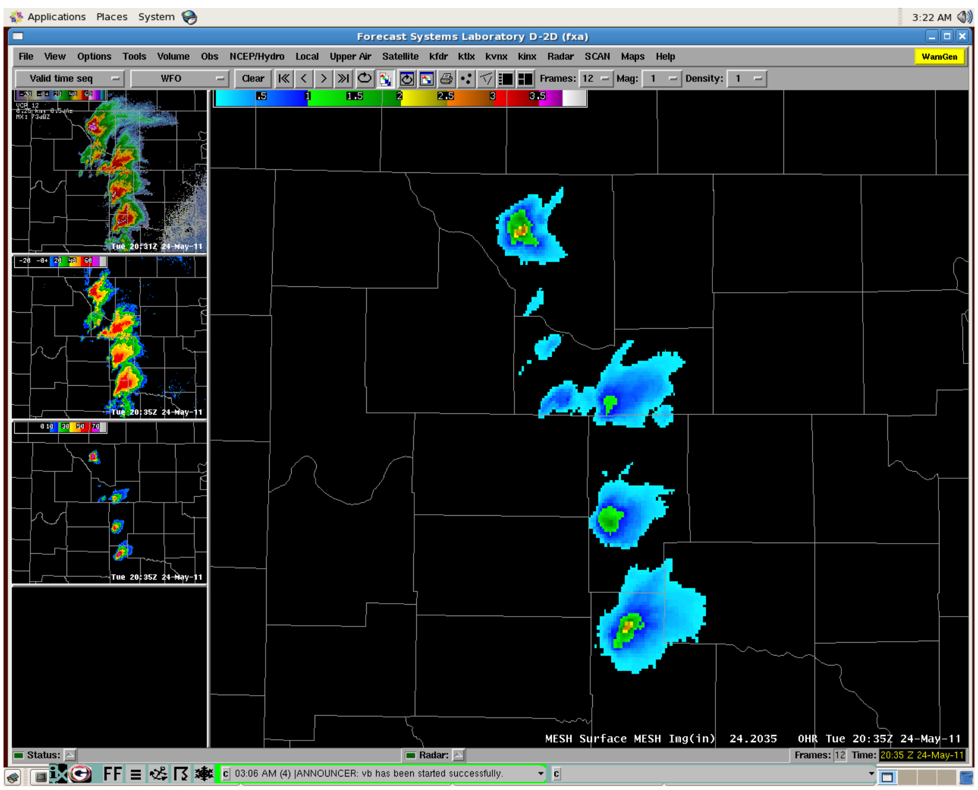




Maximum Estimated Size of Hail (MESH)

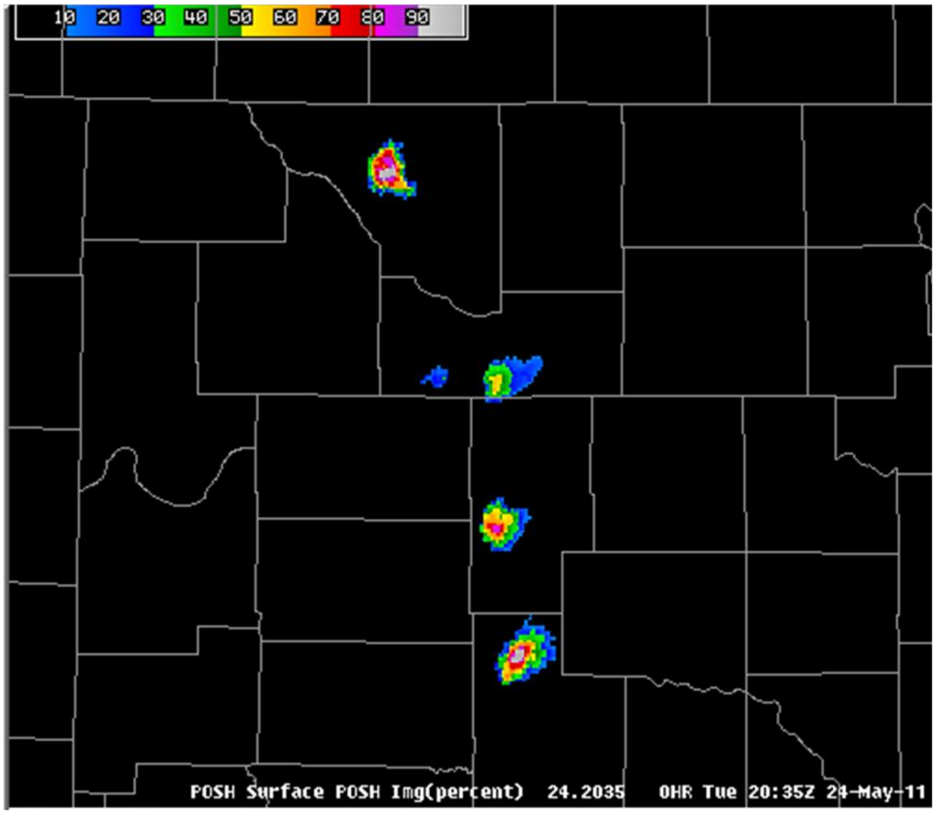
This is a gridded analog of the cell-based Maximum Estimated Size of Hail (MESH) within the Hail Detection Algorithm (HDA). WDSSII derives a gridded Severe Hail Index (SHI), which is essentially a vertically integrated reflectivity that is weighted toward higher reflectivity values, and toward those 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 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.



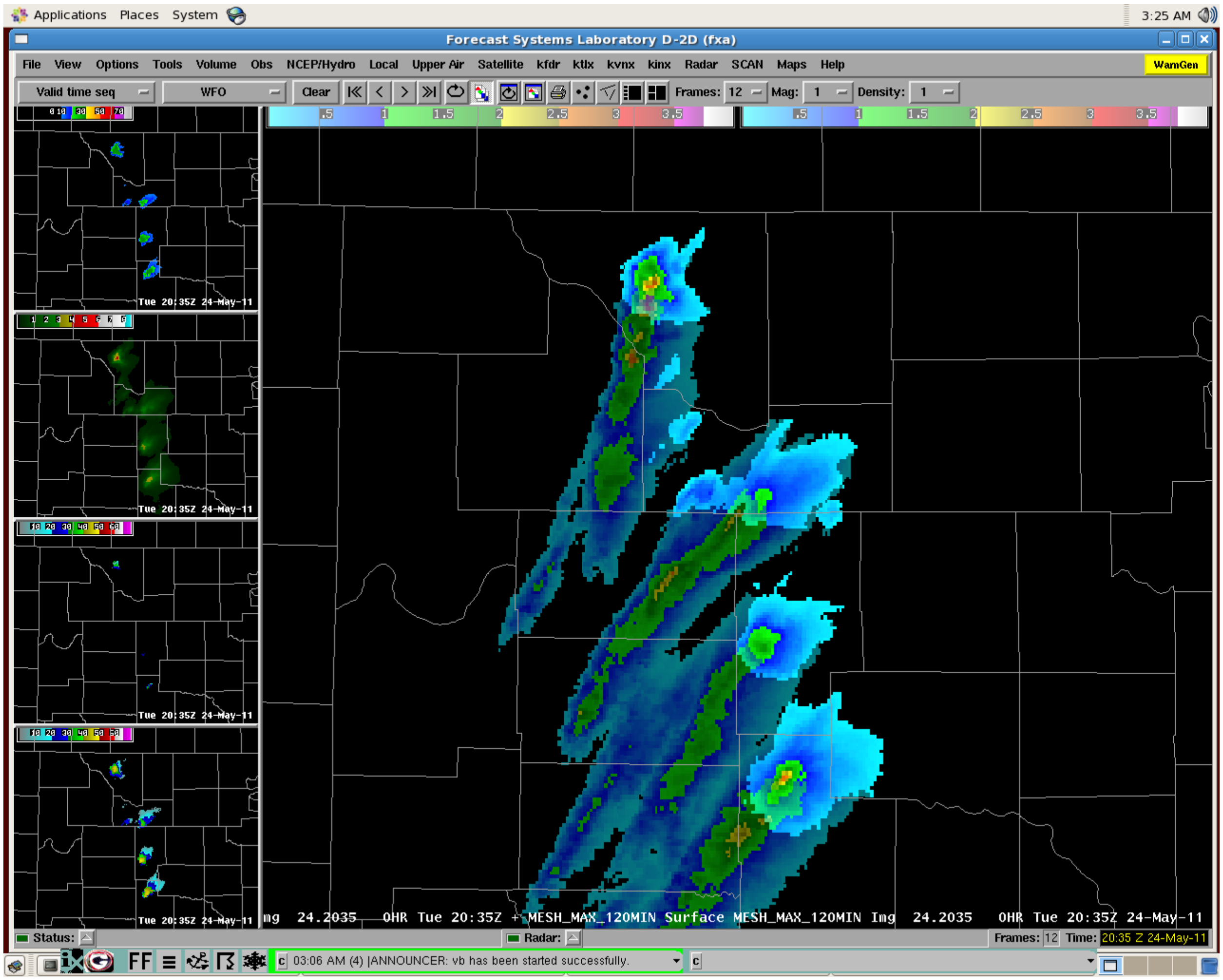
Probability Of Severe Hail (POSH)

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



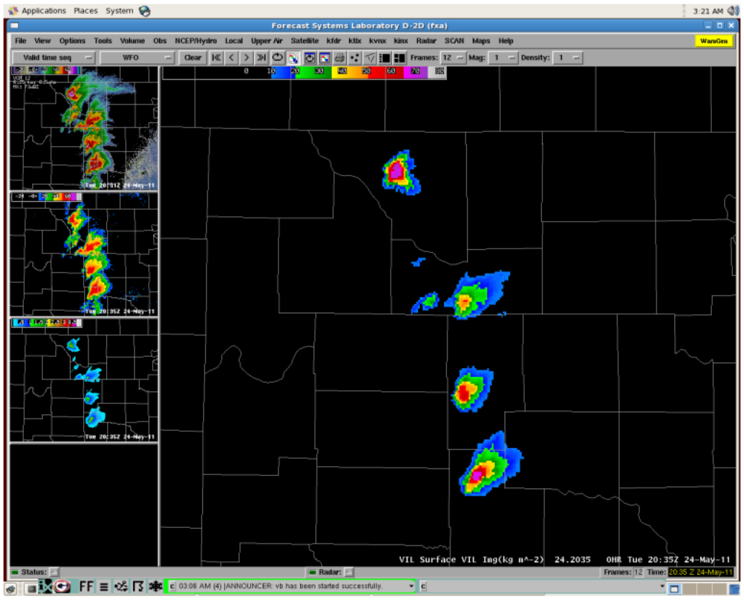
Hail Swath (MESH maximum)

One advantage of MESH data on a geospatial grid is that we can accumulate values on the grid over time. The hail swath products display the maximum MESH value observed at every grid point during the previous time interval (either 30-, 60-, 120-m 240-, 360-, or 1440-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.



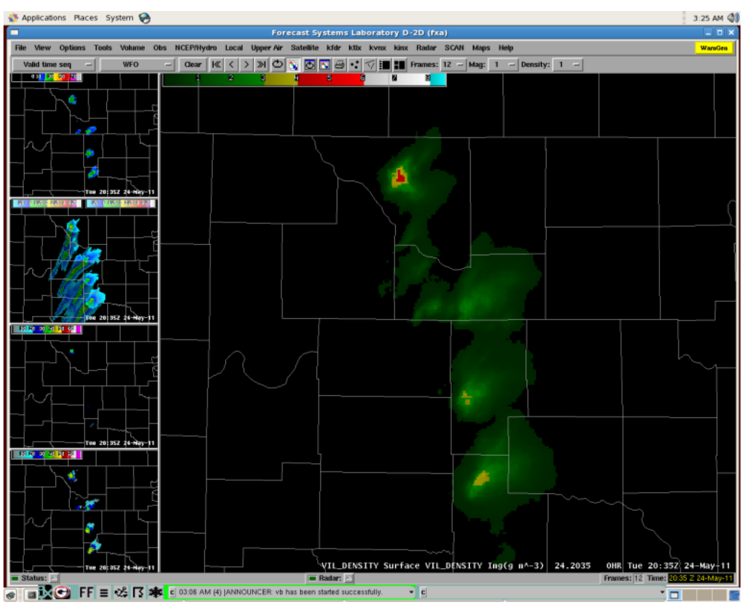
Vertically Integrated Liquid (VIL)

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.



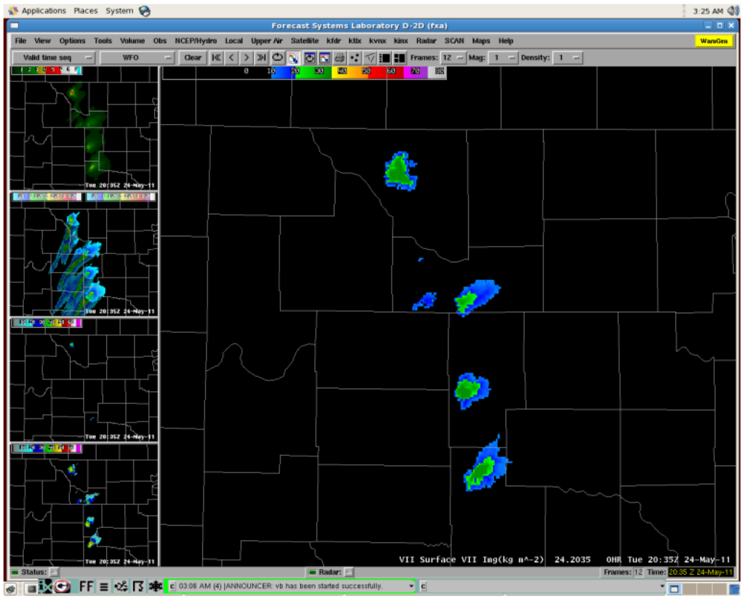
VIL Density

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).



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.



Additional Resources

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

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

Real-time and archive MRMS products for QPE and some severe are online at:

http://nmq.ou.edu/

The "On-Demand Severe Weather Verification System" for archived MRMS 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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