Jobsheet

The Three-Dimensional Variational (3DVAR) Data Assimilation System Products

Objective:

- To understand and use multiple 3DVAR products to help detect mesocyclones and diagnosis storm intensity.

Product Overview:

A dynamically-adaptive three-dimensional variational data assimilation (3DVAR) system is running in real-time as part of the 2012 Experimental Warning Program (EWP) spring experiment conducted in the NOAA Hazardous Weather Testbed. The real-time 3DVAR system has the ability to automatically detect and analyze severe local hazardous weather by identifying mesocyclones at high spatial resolution (1km horizontal resolution) and time frequency (every 5 minutes). It is considered a first step in the long-term "Warn-on-Forecast" research project to enhance tornado warning lead times by assimilating multiple data sources into a dynamically consistent analysis that provides the initial conditions for storm-scale numerical model forecasts. The real-time 3DVAR data assimilation method used in this project is the ARPS 3DVAR system formulated in an incremental form (Gao et al 2004). This system has the advantage of being able to analyze single, dual or multiple Doppler wind observations as well as conventional observations (e.g., Oklahoma Mesonet data) and includes background fields typically from forecast models. The current analysis includes data from nearby (within 400 km of domain center) WSR-88D radars and NCEP NAM 12 km resolution NWP products (background field) (Gao et al, 2009; Smith et al., 2010).

During the experiment, four separate 200 km x 200 km 3DVAR domains will be maintained. An automated process automatically locates three of the domains to regions of thunderstorm activity using the NSSL WDSSII CONUS merged composite reflectivity product. A fourth domain will be chosen by a scientist or forecaster in the HWT specific to the domain of operations. Data used in this training exercise below comes directly from EWP 2011 operations and you will see these automated 200 km x 200 km 3DVAR domains appear and disappear throughout the analysis time period.

The products available within in AWIPS-2 platform will include: simulated reflectivity, updraft (mergedWcomposite and 30/120 min tracks), and vertical vorticity (0-3 km, 3-7 km, composite, and 30/120 min tracks) and updraft helicity. [Three-dimensional wind vectors will also available to forecasters via the WDSSII platform and will be displayed real-time on the situational awareness display in the HWT, however are currently unavailable within AWIPS]. Data latency relative to the current WSR-88D display will typically be about 4-5 minutes due to computational time and data transfer.

Jobsheet Overview:

This jobsheet contains a sequential set of procedures that you will follow to view and observe 3DVAR output in the AWIPS environment. In addition, you will answer 3 questions along the way. Answers to these questions will be provided in the answer key document.

Instructions:

1. If AWIPS D2D is not currently open, double-click on the Launch AWIPS D2D icon to start up an AWIPS D2D session.

2. Left click on the D2D clock in the lower-right corner of D2D.

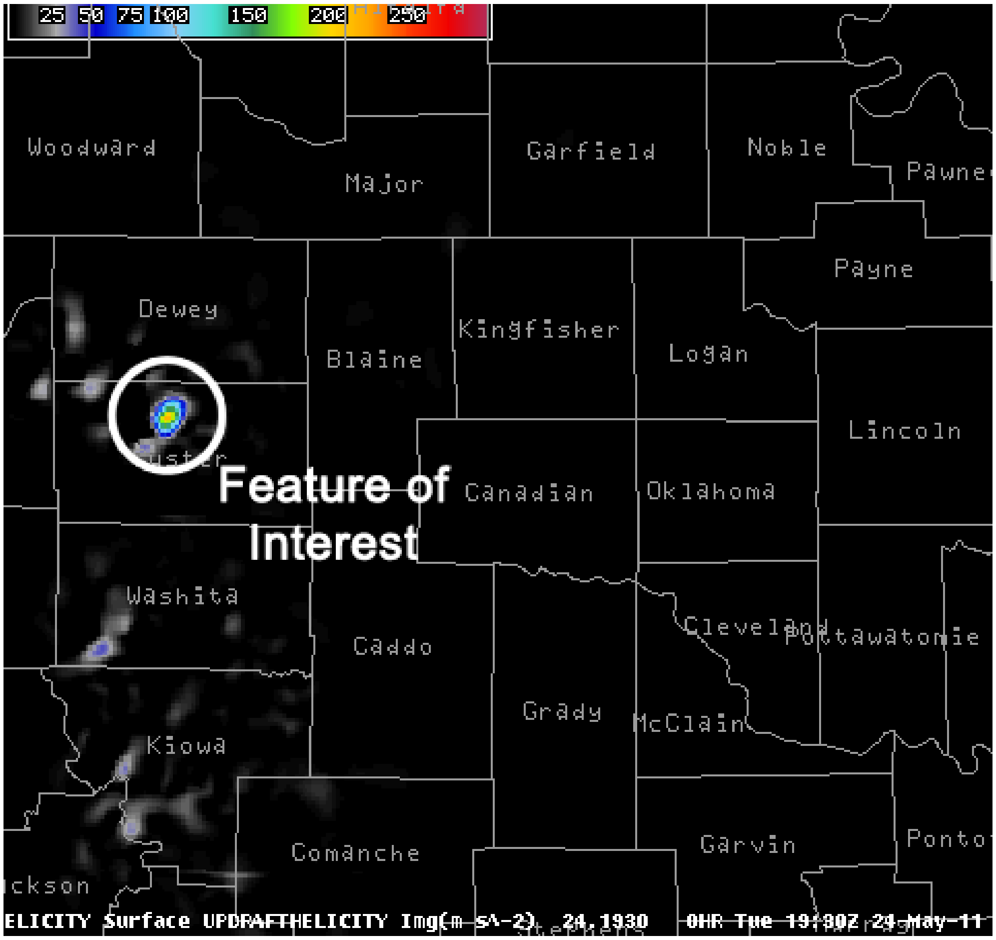
3. Inside the "Set Time" window, set the D2D clock to **2011 May 24 23:55** UTC (don't bother changing the seconds) and check the "Freeze Time at This Position" box.

4. The product combinations for this jobsheet are located in an AWIPS procedure folder called **NSSL_3DVAR**. This can accessed from the D2D menu by selecting File → Procedures → Open…, selecting WRF_GOESR from the list, and clicking on the OK button. This will open up a new window called **Procedure – NSSL_3DVAR**.

5. Select **PROC 1 – KVNX** or **PROC 1 – KTLX** from the procedure window and click on the **Load** button to open the products into D2D. This will load a four-panel display of time-matched Updraft Helicity (Upper-Left), KVNX or KTLX Vorticity Composite (Upper-Right), Merged W Composite (Lower-Left), and KVNX 0.5º Z/V (Lower-Right). You can browse through these products in the 4-panel plot or rotate through them using the 1,2,3 keys at the top of the keyboard. You can return to the 4-panel layout by right-clicking on the D2D map and selecting *Four Panel Layout*.

    a. The data window is from 1930 UTC to 2035 UTC on 24 May. Cycle through these products and answer the following questions:

    At 1930 UTC, focus on the storm in north central Custer County moving into Dewey Co. See the graphic below for the location of this storm at 1930 UTC with the Updraft Helicity product.



Note: While the 3DVAR analysis appears to be offset from the current radar scan, the analysis is using radar data from the previous volume scan for as the ingest.

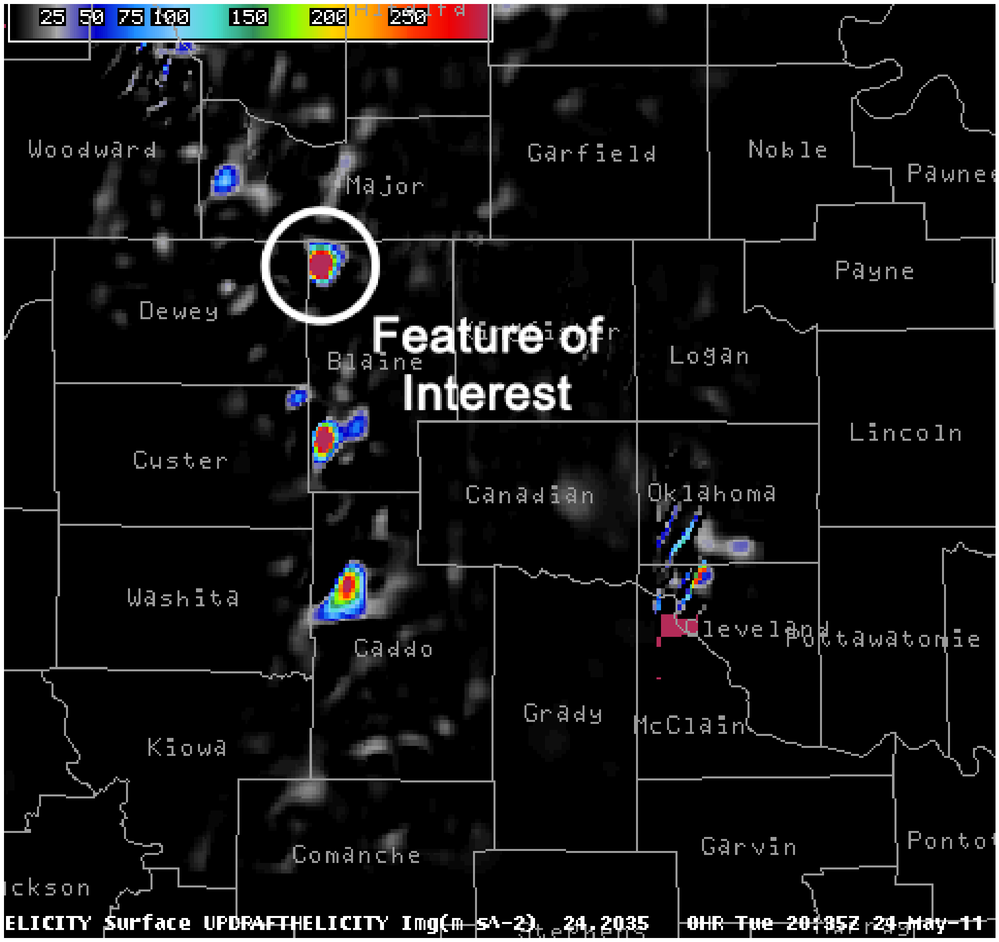
Question 1: Using the cursor readout, what are the maximum updraft helicity, vorticity, and mergedWcomposite values seen on the 1930 UTC Custer/Dewey storm?

Updraft Helicity: ________________ **s^{-2}**

Vorticity: ________________ **s^{-1}**

MergedWComposite: ________________ **m/s**

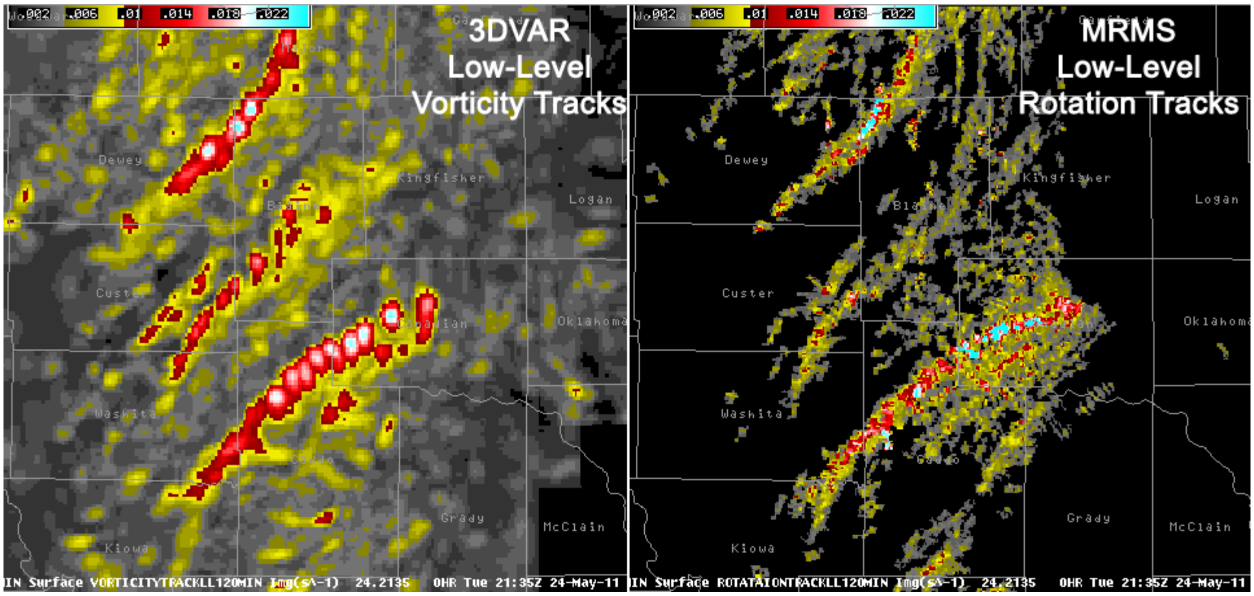
Follow the storm northeast from Dewey Co. into Blain Co and note the changes in intensity over the next hour. Storm surveys place the start of the EF3 tornado at 2020 UTC, lifting briefly at 2043 UTC. See the graphic below for the location of this storm at 2035 UTC with the Updraft Helicity product.



Question 2: Using the cursor readout, what are the maximum updraft helicity, vorticity, and mergedWcomposite values seen on the 2035 UTC Blaine County storm?

Updraft Helicity: ________________ **s^{-2}**
Vorticity: ________________ **s^{-1}**
MergedWComposite: ________________ **m/s**

6. Select **PROC 2 – 30min** from the procedure window and click on the **Load** button to open the products into D2D. This will load a four-panel display of time-matched 3DVAR 30-minute Low-Level Vorticity Track (Upper-Left), KFDR MRMS 30-minute Rotation Tracks (Upper-Right). You can browse through these products in the 4-panel plot or rotate through them using the 1 and 2 keys at the top of the keyboard. You can return to the 4-panel layout by right-clicking on the D2D map and selecting *Four Panel Layout*. See the graphic below for an example comparison of these 2 products:



A comparison of 30-minute track products: 3DVAR Low-Level Vorticity Tracks vs. MRMS Low-Level Rotation Tracks

7. Looking at the 2100 UTC image, compare the 3DVAR vorticity track products vs. the MRMS rotation track (derived from azimuthal shear multi-radar data, see the MRMS training for more details) products over the same time period. Notice the similarities in location and intensity of the storm tracks between the products.

8. Additional violent tornadoes occurred with the storm moving across northern Caddo Co. from 2030 to 2045 UTC (EF3) and into Canadian, Kingfisher, and Logan counties in central OK between 2050 and 2235 UTC (EF5). Take some time and examine the same 3DVAR parameters described above relative to KTLX reflectivity and velocity from 2050 – 2235 UTC.

9. Select **PROC 3** from the procedure window and click on the **Load** button to open the products into D2D. This will load a four-panel display of time-matched 3DVAR Low-Level Vorticity 0-3km (Upper-Left), 3DVAR Mid-Level Vorticity 3-7km (Upper-Right), KTLX 0.5º Z/SRM (Lower-Left), and KTLX 5.1º Z/SRM (Lower-Right). You can browse through these products in the 4-panel plot or rotate through them using the 1,2,3 keys at the top of the keyboard. You can return to the 4-panel layout by right-clicking on the D2D map and selecting *Four Panel Layout*.

    a. The data window is from 2200 UTC – 2315 UTC on 24 May. Cycle through these products and answer the following questions:

Two EF4 tornadoes were produced by storms moving from Grady into McClain County during this time period. The first tornado began in Chickasha and moved through Blanchard, OK from 2206 to 2301 UTC. The second moved through the Washington and Goldsby, OK covering the time period from 2206 to 2305 UTC. For each of these storms, compare the vorticity at low and mid-levels to the KTLX SRV data. Noting again that the 3DVAR output is from data assimilation period of the previous volume scans from KTLX and surrounding radars.

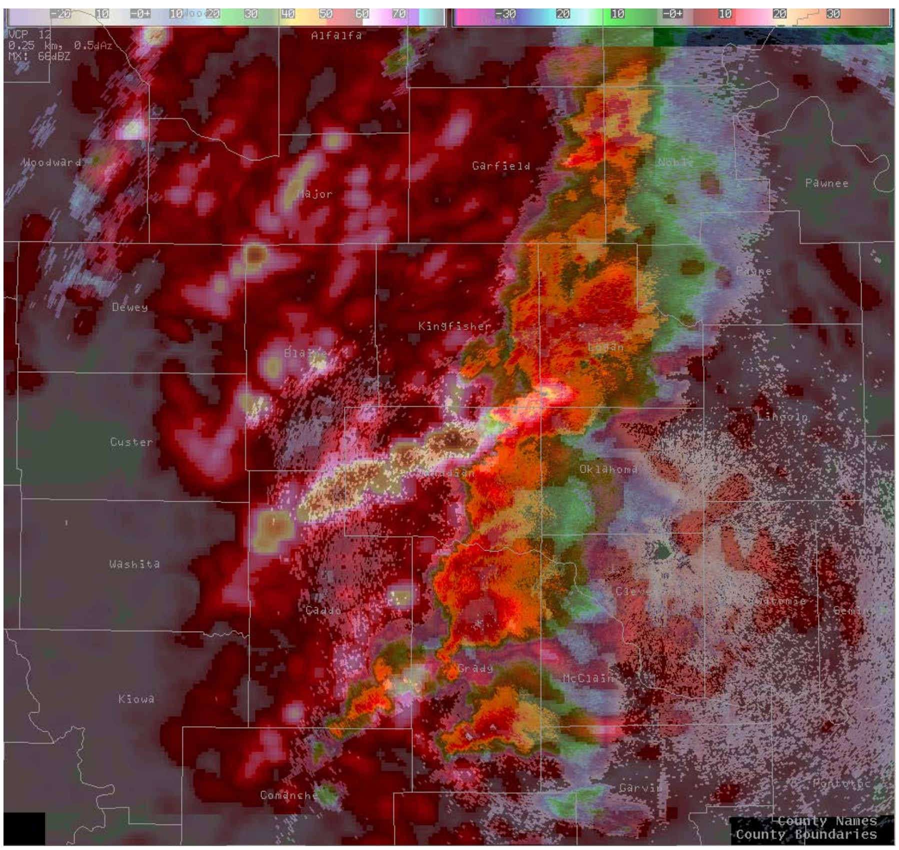
Question 3: At what time (between 2200 and 2315 UTC) and what height (LL or ML) do you find the highest vorticity value? What is this vorticity value?

NOTE: Near-surface (low-level) vorticity values can often be lower than expected (particularly at further distances from the radar) due to sampling issues.

Additional Information:

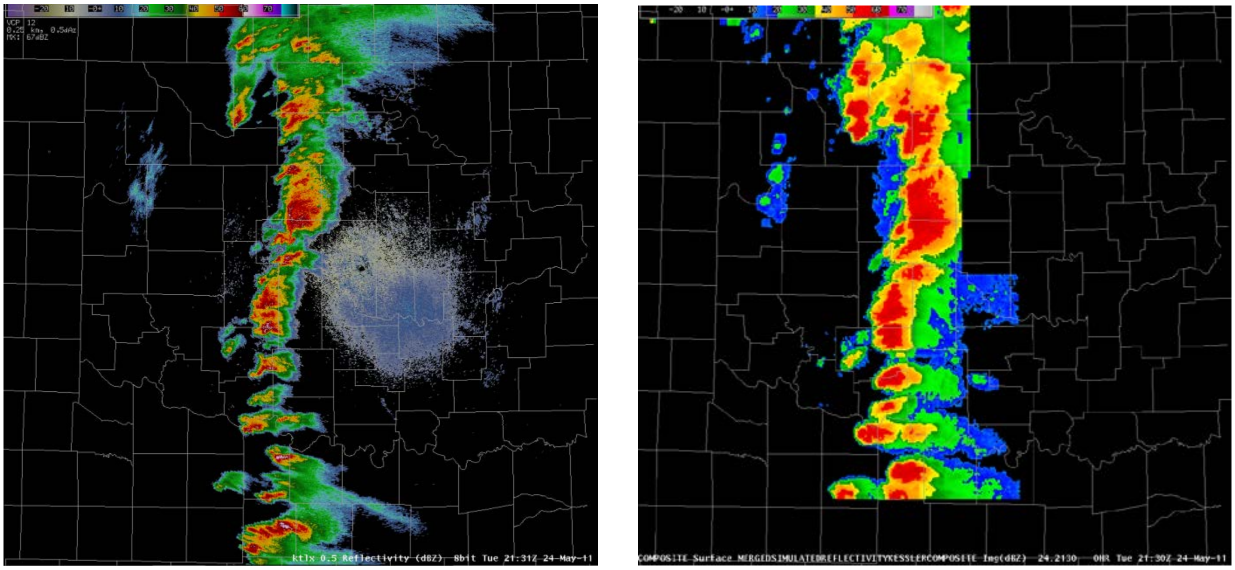
Additional products not specifically examined during this training exercise, but are available via the volume browser include: updraft tracks (30/120 min) and composite reflectivity.

Updraft tracks: Swaths of maximum updraft occurring at any height over the previous 30 or 120 min period. For previously sampled supercell events, the range of estimated values for updraft intensity ranged from 15 ms^{-1} to 35 ms^{-1} and can vary depending on range from the nearest radar.



The 30-minute Updraft Track product with 0.5º reflectivity product from the KTLX radar

Simulated Reflectivity: A simulated 3D reflectivity field is calculated from the cloud moisture analysis. Note that the simulated field typically has weaker gradients and smaller peak values than the original WSR-88D data. A composite grid of simulated reflectivity is included in this training case. However, users may choose to view either data field and often this product is used solely for noting the storm location within the current 3DVAR analysis.



A comparison of 0.5º reflectivity product from the KTLX radar (left) and the 3DVAR Simulated Reflectivity product (right)

What to Expect in the HWT:

There will be additional products shown during the experiment, including: downdraft (instantaneous and track) products and wind vectors. The wind vectors product is the primary output from the 3DVAR analysis and is what is used to derive other products (e.g., vorticity, updraft). This product may not be viewable in AWIPS2, but will be included in the HWT on situational awareness displays.

During your participation in the EWP we ask that you think about how the 3DVAR storm structure and morphology compare to how you would analyze the data during typical forecast/warning operations in your office. Does it provide a useful integration of multiple data streams? Does it produce realistic values of vertical vorticity and updraft intensity? How might such products, when perfected, affect the warning decision-making process? How might the current products be improved?

Product References:

Gao, J., D. J. Stensrud, and M. Xue 2009: Three-dimensional Analyses of Several Thunderstorms observed during VORTEX2 field operations. *34th Conf. on Radar Meteor.*, Willimsburg, VA. 10 pp.

Gao, J., M. Xue, K. Brewster, and K. K. Droegemeier 2004: A three-dimensional variational data assimilation method with recursive filter for single-Doppler radar, J. *Atmos. Oceanic. Technol.* **21**, 457-469.

Smith, T. M. Smith, K.M. Kuhlman, K. L. Ortega, K. L. Manross, D. W. Burgess, J.Gao, and D. J. Stensrud, 2010: A survey of real-time 3DVAR analyses conducted during the 2010 experimental warning program spring experiment. *25th Conf. on Severe Local Storms*, Denver, CO. 5 pp.