2011 Experimental Warning Program

NOAA Hazardous Weather Testbed, Norman, OK

Real-time 3D Radar Data Assimilation Experiment

Project Overview

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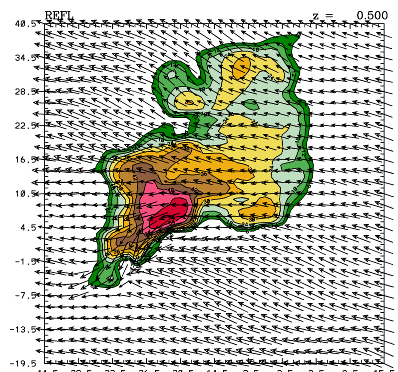

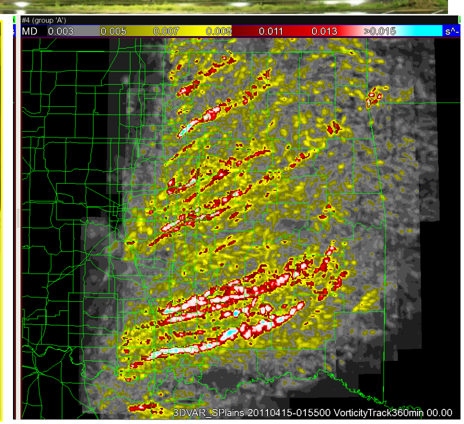

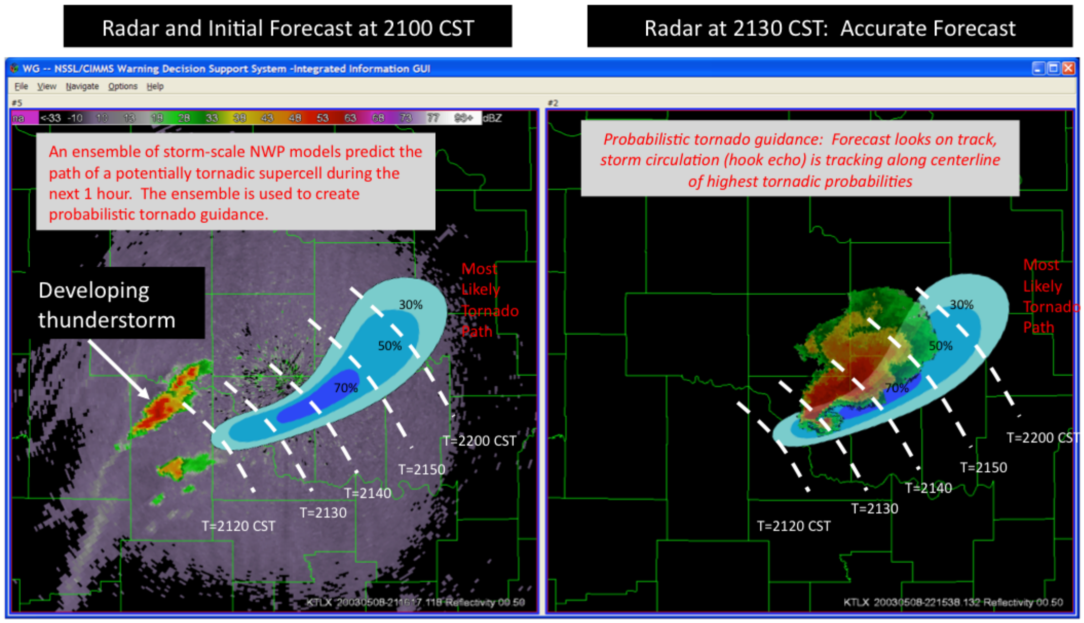

Figure 1: a hypothetical forecast from a storm-scale ensemble, with verification. From Stensrud et al. (Oct 2009 BAMS).

Introduction

A dynamically-adaptive three-dimensional variational data assimilation (3DVAR) system is running in real-time as part of the 2011 Experimental Warning Program (EWP) spring experiment conducted in the NOAA Hazardous Weather Testbed. The EWP brings scientists and operational forecasters together to provide feedback and enable collaboration on research projects related to improving National Weather Service warning services for severe convective weather events. 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 high time frequency (every 5 minutes) using data primarily from the national WSR-88D radar network, and NCEP's North American Mesoscale (NAM) model product. It is 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 (Fig. 1).

Experiment Objectives

The primary objectives of the experiment are:

1) To create real-time weather-adaptive 3DVAR analyses at high horizontal resolution and high time frequency with all operationally available radar data from the WSR-88D network.

2) To use the analysis product to help detect supercells and determine if these analyses can improve forecasters awareness of the hazardous weather event.

This year's experiment is the first step in a decade-long project directed at providing reliable storm-scale ensemble model guidance as part of the warning decision-making and dissemination process for severe convective weather events. The initial real-time experiment will show that real-time assimilation of high space-and-time resolution data is possible using a 3DVAR analysis scheme by Gao et al. (2009). Future experiments may test other assimilation techniques such as 4DVAR and Ensemble Kahlman Filter, as well as storm-scale numerical weather prediction.

We ask that forecasters evaluate the 3DVAR system by thinking about how the 3DVAR storm structure and morphology compare to how one 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?

Finally, as these are early examples of how future storm-scale NWP data might look, we ask participants to think long-term – 5, 10, and 15 years into the future – and consider how storm-scale ensemble prediction will affect warning decision-making and communication of warning information on that times scale.

Weekly Activities

Each week's schedule is flexible, but will follow this general format:

- Monday: training for various EWP experiments
- Tuesday-Thursday: discussion/briefings; Intense Operations Period (IOP); surveys
- Friday: Group discussion and wrap-up; lunch seminars

The early part of each workday is spent debriefing the prior day's operations, and choosing an operational target for that afternoon and evening's IOP. During the IOP, forecasts will use the 3DVAR analysis to help with warning decision assistance. Experimental data are displayed in AWIPS, and may be viewed alongside operationally available data. Products that cannot be displayed in AWIPS may be displayed in WDSS-II or on a web page.

Researchers will sit alongside forecasters to provide guidance and record feedback. Data are collected via real-time observation and discussion (recorded to the EWP blog), web-based surveys at the end of each shift, and a "post-mortem" discussion held on the following day during the EWP briefing.

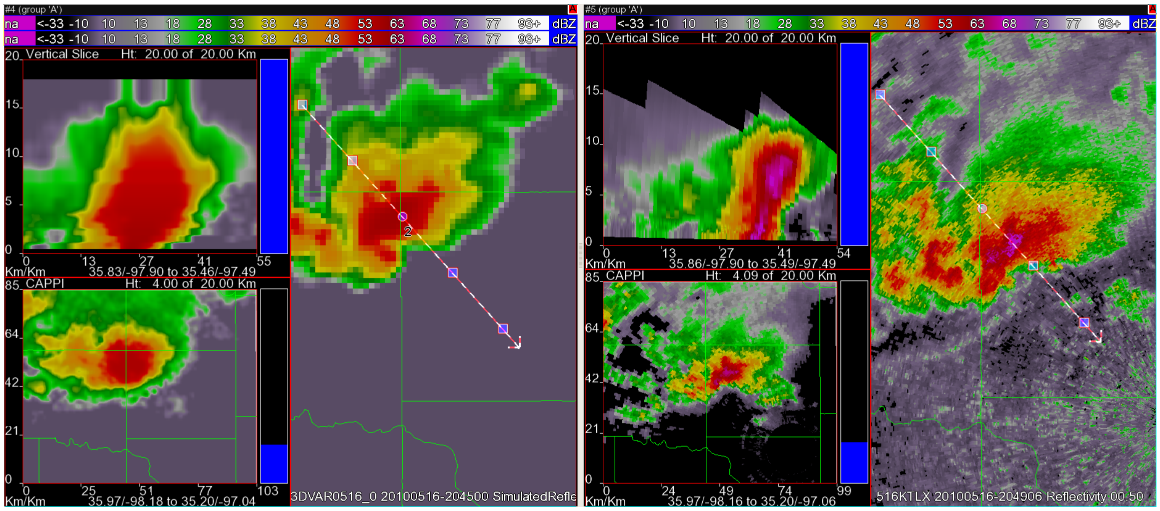

Figure 2: Simulated reflectivity (left) vertical cross-section and 4 km MSL CAPPI versus KTLX reflectivity (right) vertical cross-section and 4 km CAPPI for the May 16, 2010 Oklahoma City hail storm.

3DVAR Products

NSSL's real-time 3DVAR analysis runs concurrently on 4 domains from 12pm to 9pm daily. An automated process controls the locations of three of the domains and "floats" every 30 minutes based on where the most intense storms are located, while the fourth is user-selectable. Each domain has the following properties:

- 1 km horizontal resolution
- 31 vertical levels
- 200x200 horizontal grid points
- 5 minute updates
- 3-4 minute latency

The NCEP 12 km NAM forecast valid at the analysis time is used as a first-guess background field. The analysis is not cycled – that is, it does not use the previous analysis as a first-guess field.

The products that are of interest in this year's evaluation are listed below.

Simulated Reflectivity

A simulated 3D reflectivity field (Fig. 2) 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. However, users may choose to view either data field.

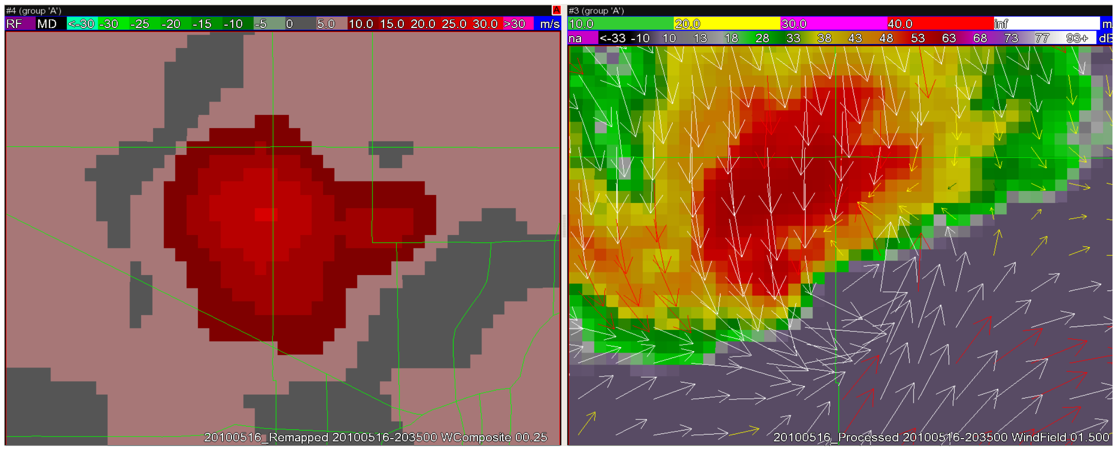

Figure 3: Maximum vertical velocity (left) and two-dimensional wind vectors with simulated reflectivity at 1.5 km MSL (right) for the May 16, 2010 hail storm in Oklahoma City.

3D Wind vectors

The three-dimensional wind field is the primary output of the 3DVAR analysis, from which other output fields are derived. Fig. 3 shows the maximum updraft

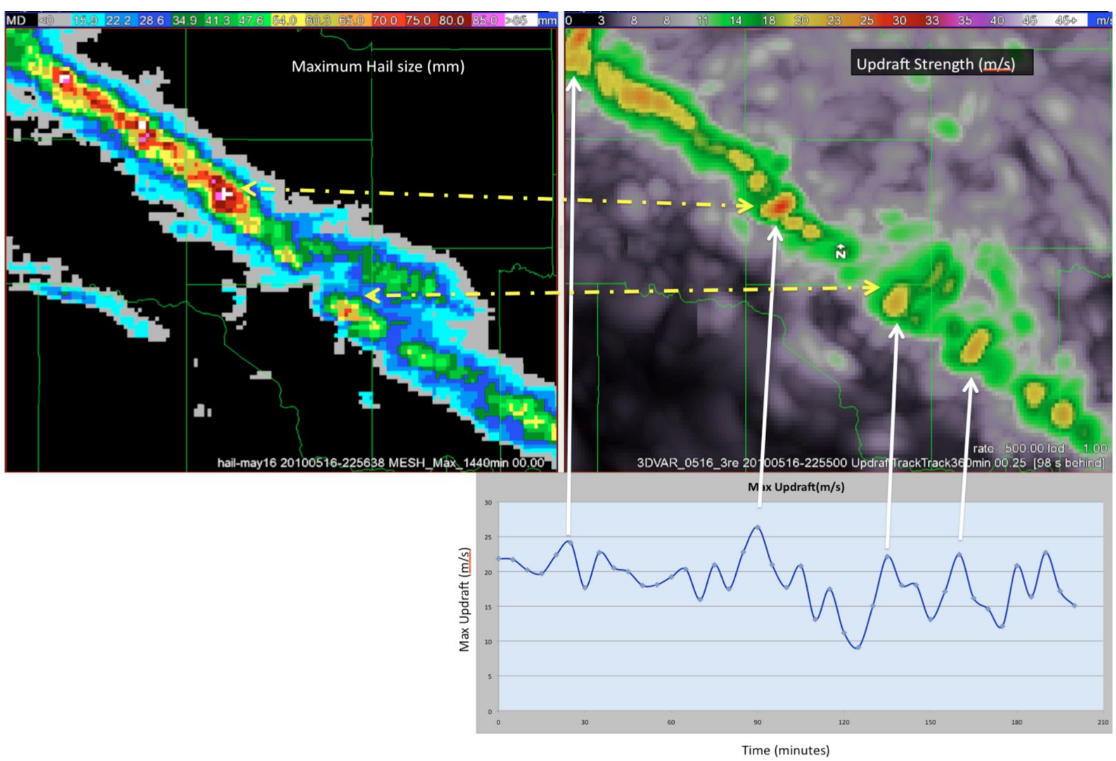

Figure 4: The 4-hour track of Maximum Expected Size of Hail (MESH; left) from a multi-radar/multi-sensor hail algorithm compared to the maximum updraft intensity over the same time period for May 16, 2010. The graph shows a time trend of updraft strength.

intensity in the vertical column at each grid point along with the horizontal wind vectors. For 20 previously sampled supercell events, the range of estimated values for updraft intensity ranged from 15 ms^{-1} to 25 ms^{-1}, and may vary depending on range from the nearest radar.

Updraft / Downdraft Track

Data fields that are unique to the 3DVAR analysis and not directly available in the radars observations may also be indirectly assessed with independent data fields. A radar reflectivity-based hail swath – Maximum Expected Size of Hail (MESH; Ortega et al. 2010) for the 4-hour period from 19 UTC to 23 UTC – is compared to the trend of updraft intensity (vertical component of the wind) for the same time period in Fig. 4. In this case, strong pulses of high vertical velocity values are followed, as would be expected, by observations of larger hail sizes. Even though large hail is not detected directly by the assimilation, the derived vertical velocity field may be correlated to very large hail.

Maximum downdraft intensity (not shown) is also calculated.

Vertical Vorticity / Vorticity Tracks

Vertical vorticity (Fig. 5) is calculated from the horizontal wind field. Users should pay most attention to the vorticity values in the 3km to 7km layer. Near-surface vorticity values are usually not accurate due to radar sampling limitations, but will be improved in future years.

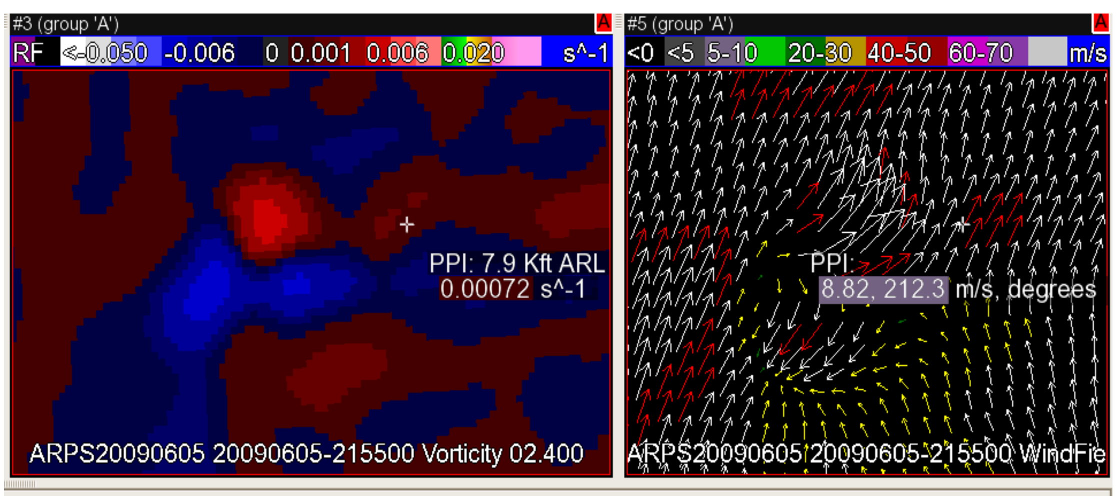

Figure 5: Vertical Vorticity (left) and the horizontal wind field (right) at 2.4 km MSL.

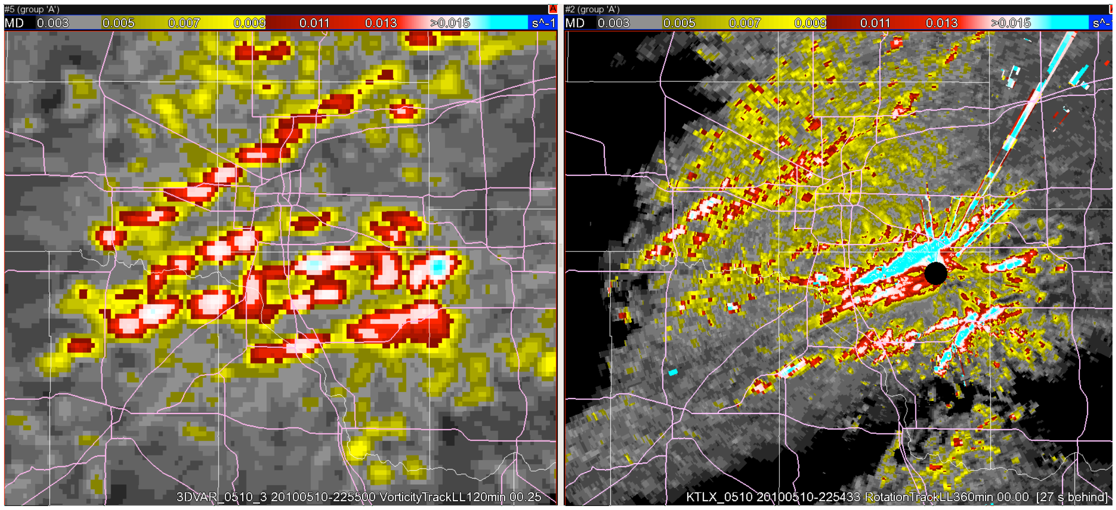

Figure 6: 3DVAR maximum vorticity (left) and maximum Azimuthal Shear derived from KTLX Doppler Velocity (right) accumulated over the period from 2130 UTC to 2300 UTC on May 10, 2010 in Central Oklahoma for the 0-3 km vertical layer.

Figure 6 and Figure 7 show the 3DVAR vorticity compared to an Azimuthal Shear field (essentially half the true vorticity; Smith and Elmore 2004) derived directly from Doppler velocity from the KTLX radar, both showing the maximum values over a 1.5-hour time period at different elevations. The KTLX data have a horizontal resolution of 0.5° by 250 m, so the tracks of smaller circulations may appear in those data while not appearing in the 3DVAR field. Although the radar-derived Azimuthal Shear values should, in theory, be approximately one half the true value of vorticity in the storm, the smoothed 3DVAR data show maximum values that are smaller than expected due to the larger grid spacing than the radar data. A 250m-resolution 3DVAR analysis is needed, in this case, to do a direct comparison of values.

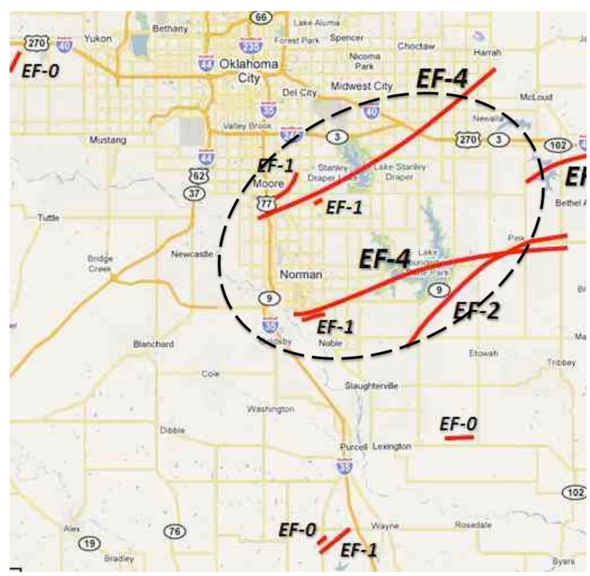

Figure 7: A summary of tornado damage paths from May 10, 2010 (courtesy the Norman, OK, National Weather Service Forecast Office).

Figure 7 shows reported tornado tracks and intensities for this event, with the tornados that occurred during the time period of Figure 6 circled. The larger-scale 3DVAR vorticity tracks match up well with the tracks of mesocyclones that occurred during the event; however, it does not detect a shallow circulation southeast of the radar site that produced an EF2 tornado. Close inspection of the radar data reveals that the associated radial velocity signature was small and in an area of noisy data and was likely filtered out by the larger

Maximum values of vertical vorticity in a sample of 20 supercells that occurred in 2010 ranged from 0.012 to 0.032 s^{-1}, and typically were associated with storms that had observed severe weather.

Additional resources and references

Gao, J., D. J. Stensrud, and M. Xue 2009: Three-dimensional Analyses of Several Thunderstorms observed during VORTEX2 field operations. *34th Conference on Radar Meteorology*, Willimsburg, VA., Online publication.

Smith, T. M. Smith1, K.M. Kuhlman, K. L. Ortega1, 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. *Extended Abstract*, *25th Conference on Severe Local Storms*, Denver, Colorado.

Stensrud, D. J., J. Gao, T. M. Smith, K. Manross, J. Brogden, and V. Lakshmanan, 2010: A realtime weather-adaptive 3DVAR analysis system with automatic storm positioning and on-demand capability. *Abstract*, *25th Conference on Severe Local Storms*, Denver, Colorado.

Web archive / real-time images:

- http://www.nssl.noaa.gov/users/jgao/public_html/analysis/RealtimeAnalysis.htm
- or http://tiny.cc/3DVAR