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# 16.5 High-resolution Three-dimensional Wind Analysis of CASA IP-1 and WSR-88D Radar Data using the ARPS 3DVAR

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## 1. Introduction

The advantages of using Doppler weather radar to track and forecast mesoscale severe weather events are widely known to both meteorologists and the public. With the use of Doppler radar, meteorologists can provide better information to the public, ultimately saving lives and property. To provide the better surveillance of severe weather, an National Science Foundation Engineering Research Center, the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), was established to develop low-cost, high spatial density and dynamically adaptive networks of Doppler radars for sensing the lower atmosphere (McLaughlin et al. 2005, Brotzge et al. 2007). The first test bed has been deployed in Oklahoma named IP1-A which consists of four scanning polarimetric Doppler radars located on average 25 km apart with ranges of the same distance. The network was designed to maximize dual-Doppler wind coverage and at certain parts of the network (Fig. 1).

In the spring of 2007, the data from four CASA radars and two WSR-88D radars were collected near-real-time for about two months in the CASA IP1 Spring Experiment-2007. Using reflectivity data from these CASA radars, along with NEXRAD, mesonet, satellite and conventional data, some real-time data assimilation and forecast experiments were performed at 1-km grid resolution using ADAS, Incremental Analysis Updating (IAU) and the ARPS non-hydrostatic forecast model developed at Center for Analysis and Prediction of Storms (CAPS, Brewster, 2003a, b; Xue et. al, 2000, 2001). Several 6-hour forecasts were made using various combinations of these data for each event day during the spring of 2007 (Brewster, et al. 2007). These forecasts were run in near-real time, a pair of 6-hour forecasts taking 8 hours using a local cluster of Pentium4 Linux computers. However, due to the time constraint, the radial velocity data were not used in real-time in 2007.

By using two or multiple Doppler radars scanning the same atmospheric volume simultaneously, it is possible to determine the 3-D wind from radial velocity data, and the quality of reflectivity data also can be greatly improved through some quality control steps. A 3DVAR data assimilation system (3DVAR) has been developed at CAPS (Gao et al. 1999, 2004, Hu et al. 2006). It uses a recursive filter (Purser et al. 2003a, b) and mass continuity equation and other constraints by incorporating them into a cost function yielding the 3-D wind and other model variables. In this study, this 3DVAR technique is used to do low-level on a May 9, 2007 severe convective storm case. The experiments with CASA and WSR-88D radar data is compared to those using only WSR-88D radar data. Our goal is to estimate the benefit of these small CASA radars to provide real-time low-level wind analysis, in addition to WSR-88D radars. Section 2 provides a brief description of experiment and presents preliminary analysis results; future work will be discussed in section 3.

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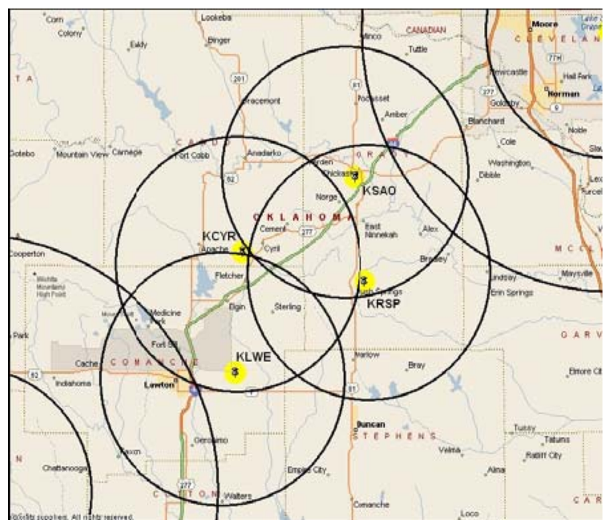


*Fig. 1. The 4-Node Oklahoma Test Bed – Casa Radar Network and analysis domain. (The analysis domain is about 140X140 km).*

## 2. Experiments and Results

The effectiveness of the CASA radar network combined with WSR-88D radars for stormscale data assimilation and forecast is evaluated by utilizing a set of simulated multiple-Doppler data (Gao et al. 2005, 2007) in our previous studies. To prepare for the 3DVAR high resolution wind analysis and forecast to be implemented in real-time during spring 2008, we are testing the 3DVAR system using data from the 8-9 May, 2007 case. Compared to conventional dual-Doppler synthesis methods, the 3DVAR system has the advantage of being able to use single, dual or multiple Doppler wind observations as well as the conventional observations (such as Oklahoma Mesonet data) and forecast background to obtain a complete 3D wind field and other model variables if necessary. In the current study, parameter settings for the analysis domain include 353x353x9 total grid points with grid spacing *dx* 400 m in both the horizontal and the vertical. We use only 9 levels in the vertical in order to focus only on low-level wind analysis.

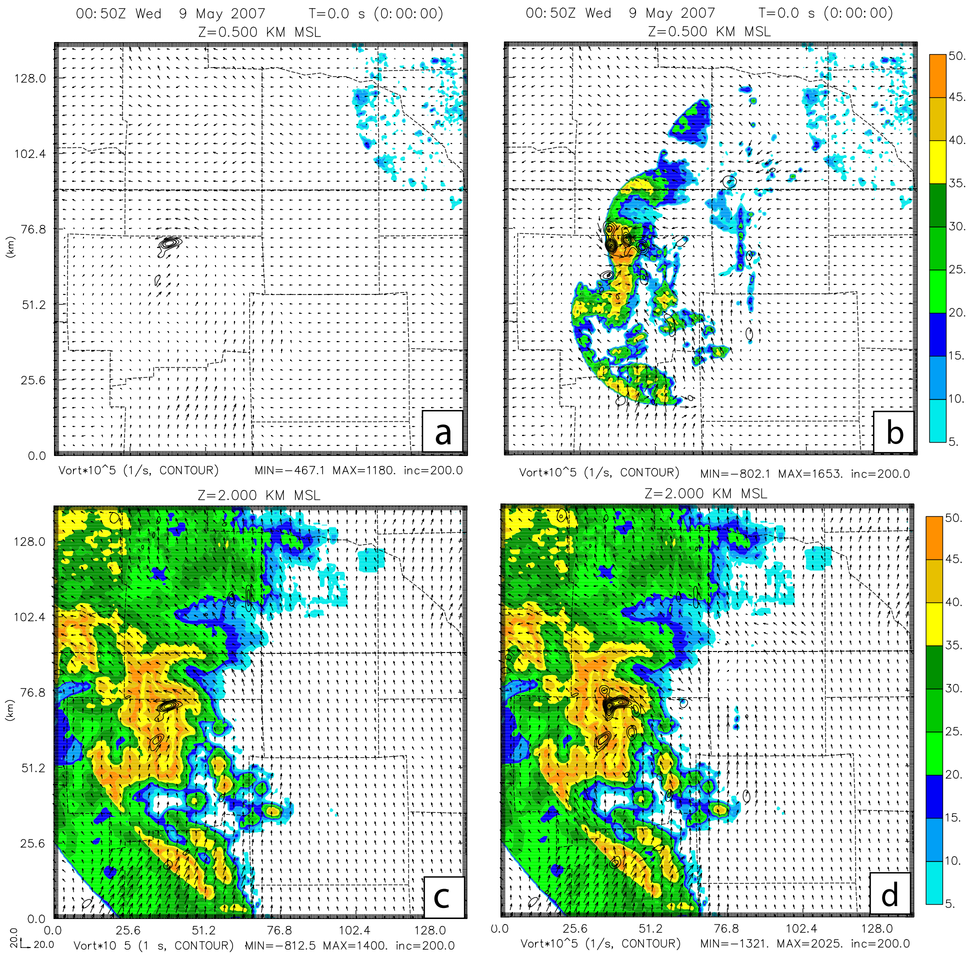


*Fig. 2. Horizontal cross-section of analyzed vertical vorticity (contours) together with observed reflectivity (color) at 500 m (upper panels) and 2 km (lower panels) AGL, using WSR-88D only (left panels) and WSR-88D and CASA data combined (right panels). The analyses are valid at 0050 UTC, 8 May 2007.*

Several experiments with CASA and WSR-88D radar data are compared to those using only WSR-88D radar data. The reflectivity field in Fig. 2 shows the NEXRAD covers only a very tiny area close to the KTLX, while the addition of the CASA radar data fills the analysis domain within the range of the CASA radar network. It is clear that a strong convection, including details of the storm outlines are generally well captured by CASA radars in this level, while the 88Ds almost completely miss it. Fig. 2a shows that at 2 km level, the NEXRADs can observe the reflectivity field very well. However, by including the CASA radars into the analysis (Fig. 2b), the convection is much stronger, and the maximum vorticity reaches to $2.5 \times 10^{-2}$ $s^{-1}$ (versus $1.4 \times 10^{-2}$ $s^{-1}$ without CASA radars). Two hours after this analysis, a tornado developed that produced damage in the town of Minco, Oklahoma.

## 3. Future work

In this work, a three-dimensional variational (3DVAR) analysis method is adapted to perform several low-level wind analyses for CASA radars. The main conclusion is that using CASA radar can greatly improve the quality of low-level wind analysis. In a separate study (Schenkman et. al 2008), The same ARPS3DVAR package is used to assimilate CASA and NEXRAD data with more traditional forms of data such as ASOS, RAOBs, profiler data, and observations from the Oklahoma Mesonet with the same case study. To explore the benefit of CASA data, experiments conducted on the high resolution grid utilize conventional data with NEXRAD alone, and NEXRAD and CASA together. The results were very promising.

The ARPS 3DVAR system will be an important tool for assimilating and examining the impact of the CASA radar data. In Ge and Gao (2007), several new features including equation constraints, direct reflectivity assimilation, anisotropic filter have been incorporated to this system. The preliminary experiments have shown positive impact from the new features on the improvement of the storm-scale assimilation and forecast. New development is underway for additional new observation operators, such as, differential reflectivity and specific differential phase from polarimetric radars. It will be used in the realtime forecast experiment of spring of 2008, and for creating low-level wind analysis for realtime displays. Active work is going on to implement an MPI (parallel) version of ARPS 3DVAR for realtime use during spring 2008.

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