P4.8 Assimilation of CASA and WSR-88D radar data via 3DVAR to improve Short term convective weather forecasting

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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 30 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).

By using two or multiple Doppler radars scanning the same atmospheric volume simultaneously, it is possible to determine the 3-D wind, and the quality of reflectivity data also can be greatly improved. Gao et al. (1999, 2004) described a variational approach (3DVAR) that uses mass continuity and smoothness constraints by incorporating them into a cost function yielding the 3-D wind. In this study, this 3DVAR analysis method is upgraded by including radar reflectivity as part of observations in the cost function, so that the analysis variables will also include rain water, snow and hail which are part of ARPS model variables (Xue et al. 2000, 2001). It is adapted to perform multiple Doppler radar data assimilation for 4-node CASA radars, together with data from the Oklahoma City (KTLX) and Fredrick, Oklahoma (KFRD) WSR-88D radars using simulated data, sampled from model-simulated thunderstorms (Gao 1999, 2004). The KTLX and KFRD radars provide coverage at the upper levels, and are located respectively to the northeast and southwest of and about an equal distance from the CASA network.

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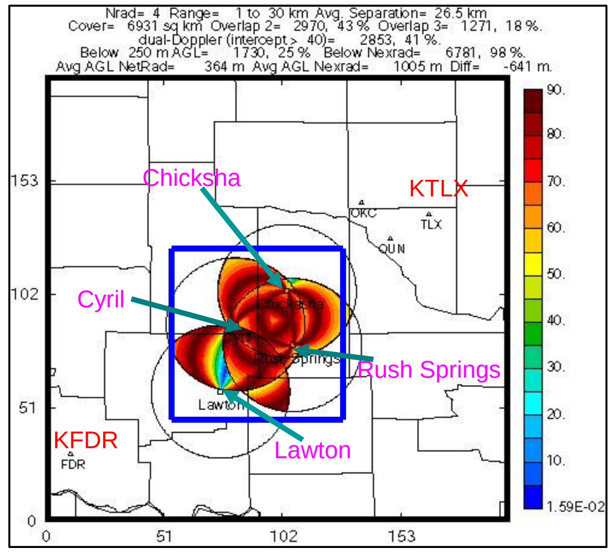

Fig. 1. The 4-Node Oklahoma Test Bed – Casa Radar Network and analysis domain. (The big area is 200X200 km. The small area is 67x67 km is our analysis and forecast domain).

Experiments are performed in which the CASA radar data are collected using current scanning strategy, with a goal of determining if the system can help improve the analysis and forecasting of severe thunderstorm within the current analysis and assimilation framework. This technique is often called Observation System Simulation Experiments (OSSE). In this short paper, section 2 provides a brief description of experiment design; section 3 presents preliminary analysis results; section 4 contains a concluding remark.

2. Experiments Design

As mentioned earlier, this study utilizes an upgraded version of variational technique developed by Gao et al (2004) that performs an analysis in a Cartesian coordinate system and permits flexible use of radar data in combination with other information, such as soundings, and previous ARPS model forecast. Furthermore, it allows for the use of mass continuity and smoothness constraints by incorporating them into a cost function. In particular, by applying the anelastic mass conservation equation as a weak constraint, the severe error accumulation in the vertical velocity can be reduced because the explicit integration of the anelastic continuity equation is avoided. This technique performs well in both idealized OSSE and real data cases (Gao et al. 2004).

The effectiveness of the CASA radar network combined with WSR-88D radars is evaluated by utilizing a set of simulated multiple-Doppler data. A simulated supercell thunderstorm is modeled by the Advanced Regional Prediction System (ARPS; Xue et al. 2000) developed by the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma. A well-documented tornadic supercell storm that occurred near Del City, Oklahoma, on 20 May 1977 is used for the experiments (Ray et al. 1981). This storm was chosen to provide the reference truth simulation because it has been studied extensively, using both multiple-Doppler analysis and numerical simulations. Ray et al. (1981), and Klemp and Rotunno (1983) provide detailed analyses on its morphology and evolution.

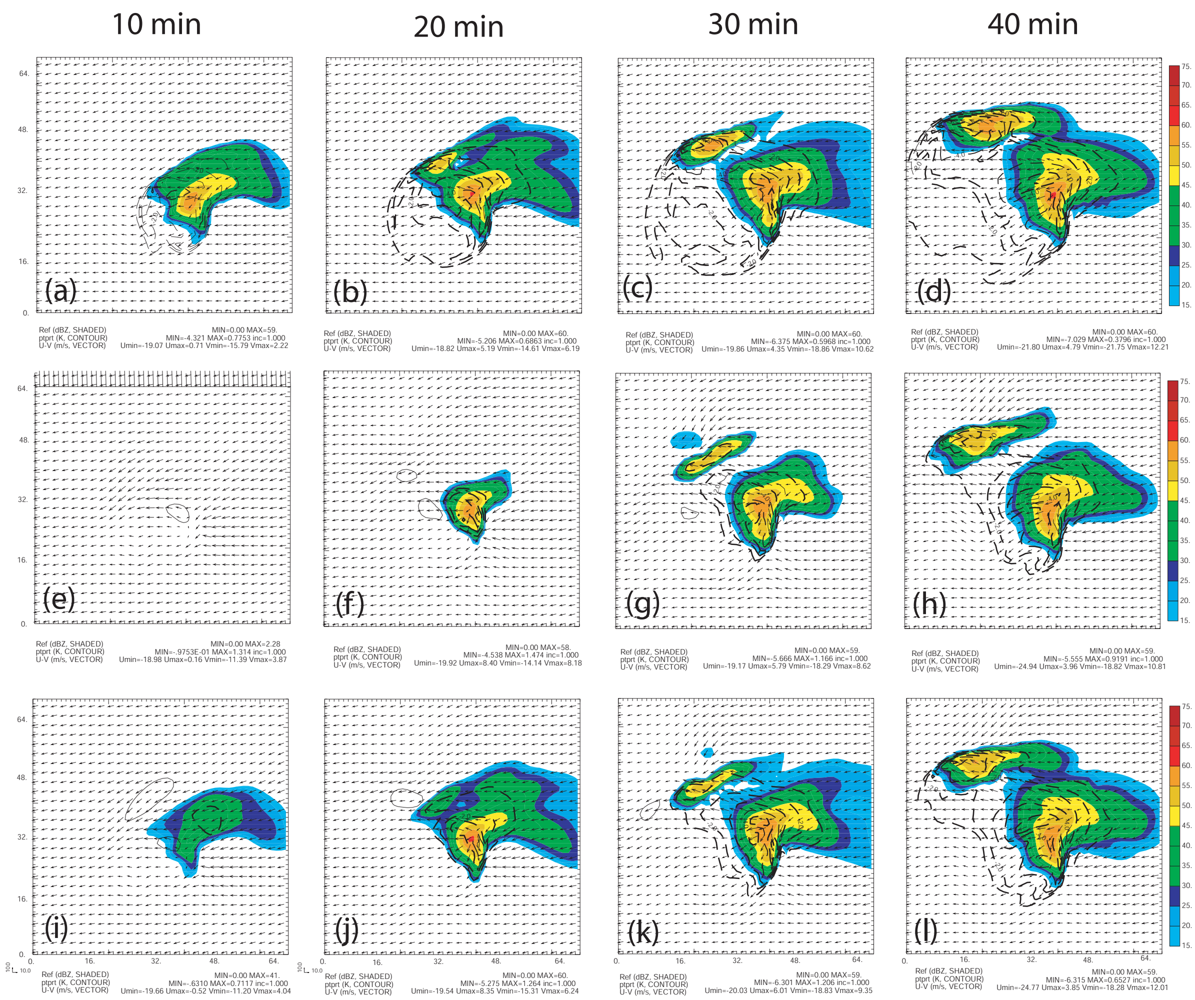

Fig. 2. Horizontal winds (vectors; ms^{-1}), perturbation potential temperature (contours at 1 K intervals) and simulated reflectivity (shaded contours, in dBZ) at 250 m AGL, for the truth simulation (1km) (a)-(d); the cycled 3DVAR analyses without assimilating reflectivity data (e)-(h), and the cycled 3DVAR analysis with assimilating reflectivity data (g)-(l). The times shown are 10, 20, 30 and 40 min of assimilation. The assimilation interval is 5 min.

Parameter settings for the ARPS model include 67x67x35 total grid points with grid spacing *dx* = *dy* =1 km in the horizontal and *dz* =500 m in the vertical. During the truth simulation, the initial convective cell strengthens over the first 30 min. The strength of the cell then decreases over the next 30 min or so, which is associated with the splitting of the cell to two at around 55 min (Fig. 1a-b). The right moving (relative to the storm motion vector which is towards north-northeast) cell tends to dominate the system. The evolution of the simulated storm is qualitatively similar to that described by Klemp and Wilhelmson (1981). The simulated 3-D convective-scale wind field and reflectivity are sampled by several pseudo-radars, including the four CASA radars and two WSR-88D radars, KTLX and KFDR from 30 min to 120 min of model simulation. The locations of these radars relative to the grid are shown in Fig. 1.

A Cressman (1959) scheme is used to interpolate the wind components and the reflectivity field from the model grid points to the sampling locations along the radar beams with the influence radius R = 2.5 km, and are projected to radial direction to obtain radial velocities according to a technique described by Mohr (1988). The elapsed times for the volume scans of the radars are neglected, and thus we presume that the radial wind observations are simultaneous.

3. Experiments and Results

We start the 3DVAR analysis and forecast cycle at 30 min of the model integration time when the storm cell reaches peak intensity. The radial velocity and/or reflectivity observations are simulated and assimilated every 5 min. The first analysis is done at 35 min. We perform two basic experiments. In the first experiment only radial velocity observations are assimilated, while in the second one both radial velocity and reflectivity observations are assimilated. The analysis domain is the same as the domain used in the ARPS simulation described in the last section.

For the first experiment, Fig. 2e-h shows that the analysis can capture the characteristics of storm quite well after 40 min assimilation, or seven cycles of assimilation. However, comparing with the truth simulation (Fig. 2a-d), the development of the precipitation is significantly delayed. By 10 min assimilation, the rain has not reached ground yet, though there exist some disturbances in the wind field. After two more cycles, at 20 min assimilation, the strong signatures of super cell appear. However, in the truth simulation, the storm is already in a stage of splitting to two cells. For the second experiment, when the reflectivity field from these radars is also assimilated, the development of the storm is much earlier. At 10 min, the precipitation already reached the ground, though it is weak at this time (Fig. 2i). But by 20 min, it is in good shape comparing to the truth (Fig 2j).

To judge the analyses quantitatively, the root-mean-square (rms) errors of the analyzed field for reflectivity is calculated against the truth (Fig. 3). Not surprisingly, Inclusion of the assimilation of reflectivity field leads to much lower RMS and a faster decrease during the first several assimilation cycles.

4. Summary and Conclusion

In this study, a three-dimensional variational (3DVAR) analysis method is adapted to perform two multiple Doppler data assimilation experiments for CASA radars using OSSE. The main conclusion of this study is that the inclusion of assimilation of reflectivity data in the 3DVAR data assimilation system significantly reduces the severity of the spin-up problem and has potential to improve the short-range forecast for precipitation systems. Further experiments will be done to test the impact of directly assimilating the reflectivity to the short-range forecast.

In our on-going study, a real data case for a May 08, 2007 severe thunder storm which passed the CASA radar network is tested. The impact of the observations on the analysis of convective storms and the subsequent forecast will be assessed and reported in the conference.

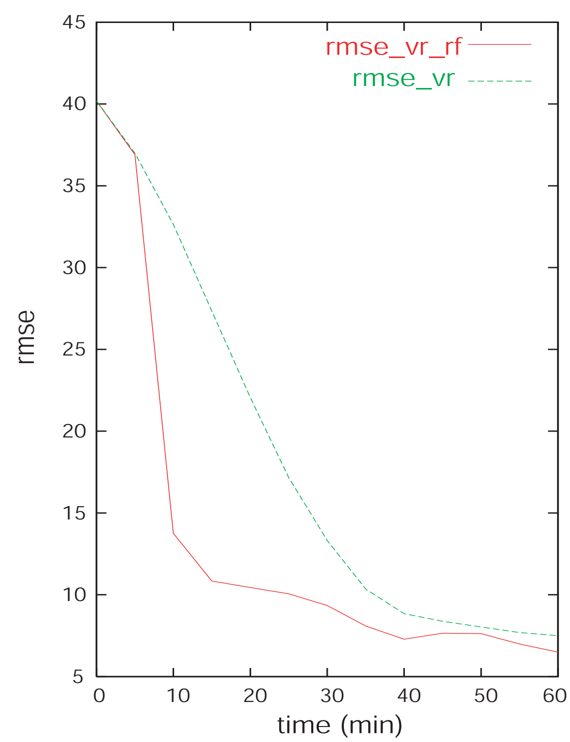

Fig. 3. The rms errors of the cycled 3DVAR analyses and forecast, averaged over points at which the reflectivity is greater than 10 dBZ.

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