3DVAR-based Data Assimilation for the 8-9 May 2007 Oklahoma Tornadic Mesoscale Convective System and Comparison with EnKF Results

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Abstract

The Advanced Regional Prediction System (ARPS) model is used to simulate a MCS and associated line-end vortex (LEV) that occurred on 8-9 May 2007 in Oklahoma. Simulations are performed on two (nested) grids at 2 km and 400 m horizontal grid spacings (Fig. 1). Data assimilation is performed using the ARPS 3DVAR on the 2 km and 400 m resolution grids beginning at 0100 UTC over a 60 and 80 min assimilation window, respectively. All 2 km and 400 m experiments assimilate conventional observations. The impact of assimilating radar data from WSR-88D and CASA IP-1 networks is examined through a variety of experiments

On the 2-km grid, the structure and evolution of the MCS and LEV are markedly better forecast throughout the forecast period in experiments in which radar data are assimilated. The assimilation of CASA radar data in addition to WSR-88D data improves the analyzed location of the convective gust front through improved low-level wind analysis, leading to a slightly better forecast track of the LEV on the 2 km grid. Results from the 0.4-km grid, show that highly accurate forecasts of mesovortices (smaller scale vortices associated with the LEV) up to 80 min in advance of their genesis are possible when the low-level wind and temperature fields are effectively analyzed. Accurate analysis of low-level wind and temperature fields relies on assimilating high-resolution low-level wind information. The most accurate analysis (and resulting prediction) is obtained in experiments that assimilate low-level radial velocity data from the CASA radars. Experiments that do not assimilate low-level wind data are unable to resolve the gust front structure, precluding accurate prediction of mesovortex development.

The same case is being studied by our group using the same data set with the EnKF data assimilation method. The specific EnKF results will be reported separately (See Nate Snook's talk Friday morning). However, comparison between deterministic forecasts from EnKF and 3DVAR show that forecasts produced from 3DVAR are qualitatively more similar to observations of the case than forecasts produced from the EnKF analysis.

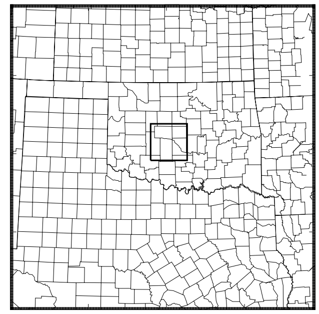

Fig. 1. Map of the 2 km resolution experiment domain. The black rectangle marks the 400 m resolution experiment domain.

2 km Results

- Experiments that assimilate radar data produce a highly accurate forecast of the 9 May 2007 LEV.

- The simulated LEV evolves in a way that closely resembles the observed evolution of the LEV.

- Qualitative comparison between reflectivity observations and model forecasted reflectivity reveals remarkable correspondence between observed and modeled features (Fig. 2 and Fig. 3).

-In addition to revealing great accuracy, examination of the analysis and forecast for the experiments shows a small but important impact from assimilating CASA data. Namely, assimilated CASA data leads to a more accurate analysis of the low-level wind field in the CASA domain (not shown). This in turn likely led to a more accurate evolution of the MCS and LEV in experiments that used CASA data.

400 m Results

The most important result at 400-m resolution is the large positive impact that CASA radial velocity (Vr) data had on the analysis and subsequent prediction of the low-level wind fields and cold pool. CASA Vr data led to substantial Improvements in the analyzed low-level shear profile ahead of and associated with the cold pool. These improvements continued into the forecast portion of the experiments, manifested in more accurate predictions of mesovortices when compared to experiments that did not use CASA radial velocity. Figure 4 presents an example of the improvement in gust front position when CASA Vr data are assimilated.

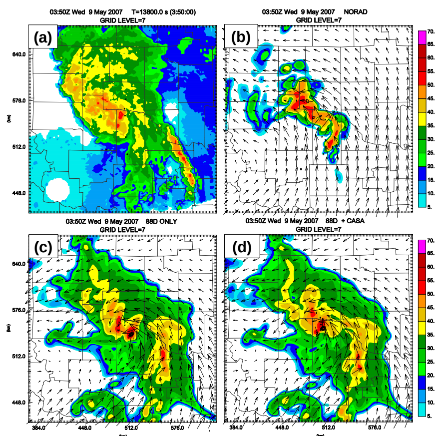

Fig. 2. (a) Observed reflectivity at 0350 UTC. 2 km resolution model reflectivity, horizontal wind vectors and vorticity (contoured) at 0350 UTC from (b) no radar experiment (c) 88D only experiment and (d) 88D and CASA experiment.

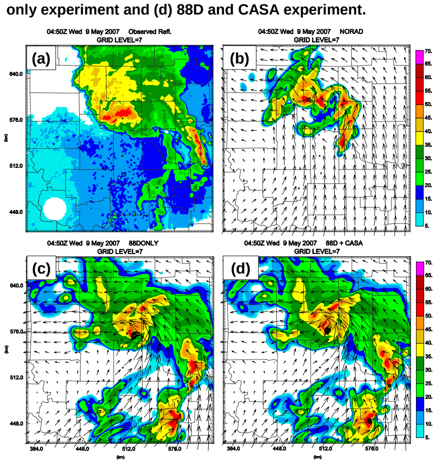

Fig. 3. As Fig. 2 but at 0450 UTC 9 May 2007.

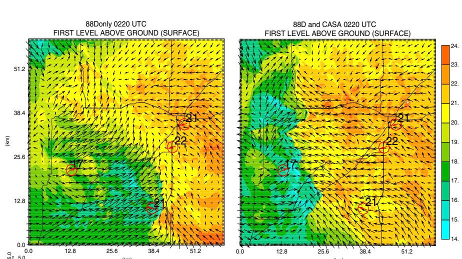

Fig. 4. Analyzed temperature (in °C) and wind field at 0220 UTC from (left) 88D only 400 m res. experiment and (right) 88D and CASA 400 m res. experiment. Red circles and wind vectors are observed mesonet wind field with large black numbers observed mesonet temperatures (°C).

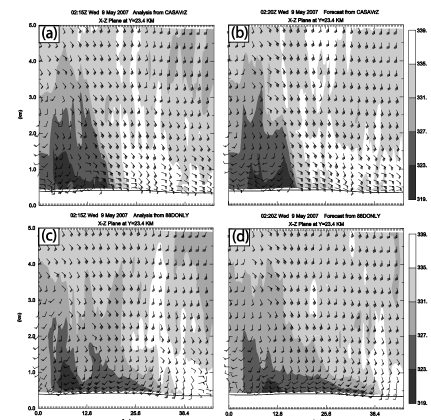

Fig. 5. Cross sections of the analysis in the X-Z plane at (left) 0215 UTC and the forecast at (right) 0220 UTC from (top) 88D and CASA experiment and (bottom) 88D only. Equivalent potential temperature is shaded at 4 K intervals and wind barbs are for horizontal wind in m s^{-1}.

3DVAR Vs. EnKF

EnKF has been used to produce analyses and forecasts of the 8-9 May 2007 case. Because of computational expense, only 2-km resolution EnKF experiments are available for comparison with the 3DVAR assimilation and forecast experiments. Results from the deterministic forecast initialized from the ensemble mean show that 3DVAR produces a much more accurate depiction of the convective system and LEV (Fig. 7).

The reasons for the poor performance of EnKF compared to 3DVAR have yet to be determined. It should be noted, however, that the EnKF forecast presented here did not assimilate conventional surface and upper-air observations. Additionally, the EnKF probabilistic forecasts show great accuracy when compared to observations (see Nate Snook's talk). Future work will examine the advantages of each method in more detail. In addition, to provide a more thorough comparison, the assimilation techniques will be applied to other case studies.

400-m Results (Cont'd)

Figure 5 shows how increased low-level shear in the 88D + CASA experiment leads to a deeper and slower moving cold pool than that of the 88D only experiment during the assimilation period. This leads to a very accurate forecast of the mesovortex responsible for a tornado near Minco, OK (Fig.6)

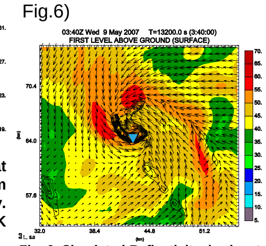

Fig. 6. Simulated Reflectivity, horizontal wind, and vorticity from the 88D + CASA 400-m resolution experiment at 0340 UTC. The blue triangle marks the location of a confirmed tornado.

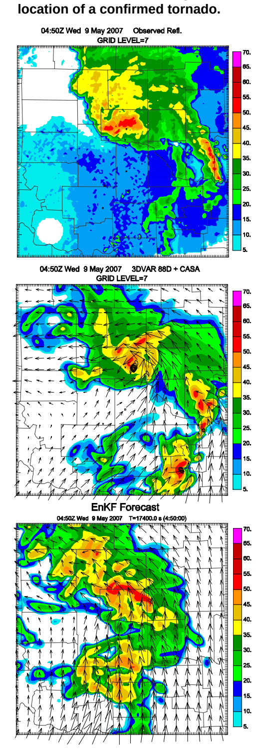

Fig. 7. 0450 UTC 9 May 2007 (top) observed reflectivity and forecast from (middle) 3DVAR and (bottom) EnKF. Fields plotted as in Fig. 2.