8.4 A LARGE EDDY SIMULATION OF A TORNADIC SUPERCELL: COMPARISON WITH OBSERVATIONS

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1. INTRODUCTION

Numerical simulations of supercells containing low-level mesocyclones and even smaller scale vortices were first generated during mid 1980's (Klemp and Rotunno JAS 1983; Grasso and Cotton JAS 1995; Wicker and Wilhelmson JAS 1995). With the existing numerical methods and computational resources of the time one could reproduce in some detail the observed features within tornadic storms. However, the lack of knowledge regarding the turbulence near the surface, the imperfect representation of appropriate surface friction, and the inability to further refine the numerical grid limited confidence as to whether the models were capturing the correct physics. Conclusions regarding the physics of tornadogenesis were therefore limited. Another significant limitation was the lack of observational data on a scale similar to the model grid. For all these reasons, validation of modeling results with observations was essentially impossible.

With the advent of mobile Doppler radars (Doppler On Wheels, UMASS 3mm Doppler radar, and the SMART radars) in the last ten years, there now exist many Doppler datasets with high-resolution scans of mesocyclones and their associated tornadoes. Combining these data with detailed thermodynamic measurements (soundings and surface mobile mesonet observations) around tornadic supercells (e.g., VORTEX-95) now permits modelers to attempt to quantitatively compare some aspects of their numerical simulations to the new observational data.

2. DOPPLER DATA ANALYSIS

Any model solution containing a supercell and smaller scale vortices should not be considered to be a de facto representation of the observed storm, despite some of the “mythic” successful simulations from the past. For example, during most tornado outbreaks, there are a significant number of storms that do not produce tornadoes or that even do not have supercell characteristics. Comparison of a particular observed storm to an individual simulated storm within the model solution is therefore somewhat misleading. Even if an observed storm and modeled storm could be compared directly, one would need to “sync” the observed storm evolution to the model evolution. This would again involve subjective choices.

Another approach to compare model solutions to observations is presented here. Shown in Fig. 1 are objectively analyzed fields at z = 300 m from DOW observations of the tornadic storm near Almena, Kansas on 3 June 1999. A 1D spectral analysis (Erico MWR 1985) is computed on each field at low levels to determine the power that exists in each of the scales resolved by the radar (Fig. 2). In order to reduce contamination of the spectra from missing data, a 12 x 12 km region where data exists at each point is used for the analysis.

The spectra are computed to examine whether the model output contains the same slope and power density observed by the radar. Similar comparisons have been done by Harris et. al (JHYDRO, 2001) for precipitation data. If the spectra from the model solution are similar to the observations, then it is likely that the physical processes responsible for the observed spectra are represented in the model solution. Thus a higher level of

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confidence can be assigned to results obtained from analysis of the model data.

3. LES MODEL SIMULATION

Previous simulations have attempted to resolve supercell storms and their associated tornado-producing features at grid spacings approaching one hundred meters. Tornado vortex simulations by Lewellen and Lewellen (JAS, 1997) have indicated that a significant amount of the turbulence within the vortex is on a resolved scale when the grid spacing approaches ten meters in the horizontal. Current capabilities are such that a simulation having ten-meter resolution that encompasses the entire supercell is not easily computable (or more importantly even analyzable). Through the use of three-dimensionally stretched grids within a cloud model domain and cluster-type computing methods, we plan to simulate the mesocyclone region of a supercell with a horizontal grid spacing of fifty meters. The numerical grid resolution is then approximately the same as the resolution of the DOW observations. Comparison of the observed velocity and reflectivity spectra from several cases with the high-resolution model simulation will be shown at the conference.

References available upon request.

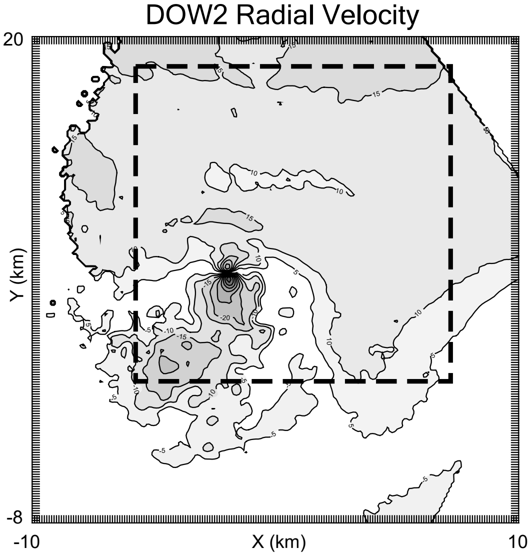

Figure 1a: DOW2 radial velocity (m s^{-1}) from 3 June 1999 Almena supercell. Lowest analysis level is shown. Dashed box is the region where spectra were computed.

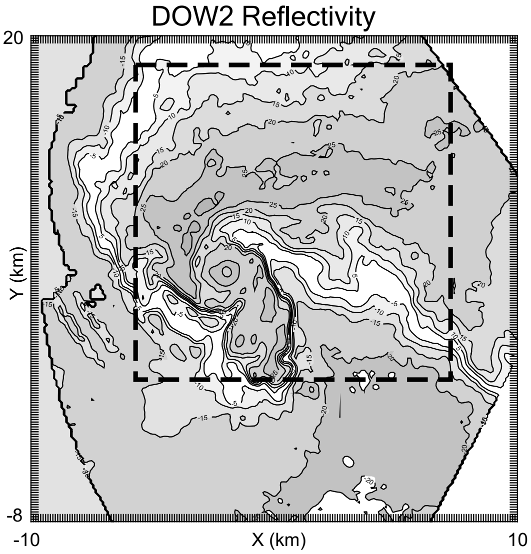

Figure 1b: DOW2 reflectivity (dBZ, uncalibrated) from 3 June 1999 Almena supercell. Lowest analysis level is shown. Dashed box is the region where spectra were computed.

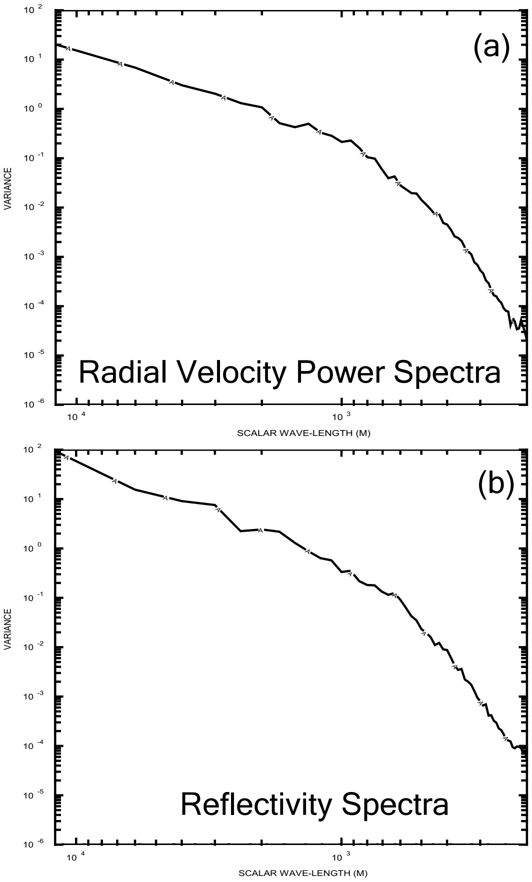

Figure 2: Power spectra from the a) radial velocity and b) reflectivity fields shown in Fig. 1.