P25 ADDRESSING THE EFFICACY OF THE BASE-STATE SUBSTITUTION IDEALIZED MODELING TECHNIQUE: A COMPARISON OF SIMULATIONS

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1. INTRODUCTION

A common approach to understanding the fundamental processes of deep, moist convection has been to utilize idealized numerical simulations. These simulations often employ horizontally- and temporally-homogeneous base-state conditions to isolate the key processes at work, even though heterogeneity is inherent in many convective storm environments (e.g., Brooks et al. 1996; Weckwerth et al. 1996; Markowski and Richardson 2007). Accounting for environmental heterogeneity in an idealized setting has largely been avoided because of numerous complicating factors that can prevent a clean separation of cause and effect in experimental results.

Base-state substitution (BSS; Letkewicz et al. 2013) is a new idealized modeling method that approximates the temporal tendencies in temperature, moisture, and wind actually experienced by a storm as it encounters a changing environment; this is done without introducing horizontal gradients and their associated circulations to the simulation. A schematic of the procedure for BSS is shown in Fig. 1 and described in detail in Letkewicz et al. (2013). Briefly, after a certain amount of model run time, BSS separates out the storm-induced perturbations of temperature, moisture, and wind from the original base-state, and then replaces the original horizontally-homogeneous background environment with a new horizontally-homogeneous environment; this is completed at a prescribed temporal interval defined by the model user. This approach permits the user to *independently* modify temperature, moisture, or wind profiles as desired, which provides a significant amount of control over changes to the environment and consequently allows the user to more readily identify cause and effect in their experiments. Furthermore, this approach allows for the study of how the *same storm* would *respond* to different background environments (as opposed to triggering storms in different environments).

The primary assumption of BSS is that the *integrated* effect of a storm moving across an environmental gradient over time is larger than the *instantaneous* effect of local storm-scale gradients. This assumption is central not only to BSS, but to *all* idealized models with horizontally-homogeneous environments employing a representative proximity sounding to the entire domain. The key question is whether this assumption is valid. Will a BSS simulation, employing only temporal variability, produce a realistic storm evolution, comparable to a fully heterogeneous simulation that includes both temporal and spatial variations in the base-state environment? To address this question, a pair of simulations will be shown to compare the evolution of a storm utilizing different methods to account for environmental variability.

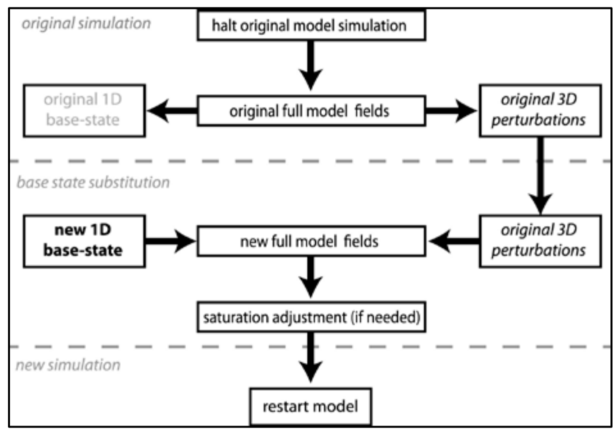

Figure 1: Schematic of the procedure followed for base-state substation. See Letkewicz et al. (2013) for more details.

2. METHODS

The Goshen County tornadic supercell observed on 5 June 2009 during the Verification of the Origins of Rotation in Tornadoes Experiment 2009-2010 (VORTEX2; Wurman et al. 2012) was chosen as the case study for this investigation, owing to the series of soundings launched in the inflow environment during the early evening hours, capturing modifications to thermodynamic and kinematic profiles (Fig. 2). A total of four soundings were collected in the far-inflow environment (at 2155, 2240, 2335, and 0057 UTC).

This VORTEX2 case study was simulated with a pair of idealized model simulations. One simulation utilized CM1 (Bryan and Fritsch 2002), release 17, which shifted the horizontally-homogeneous base-state environment over time using BSS. The second simulation utilized the WRF model (Weather Research and Forecasting model; Skamarock et al. 2008), version 3, which employed the North American Regional Reanalysis (Mesinger et al.

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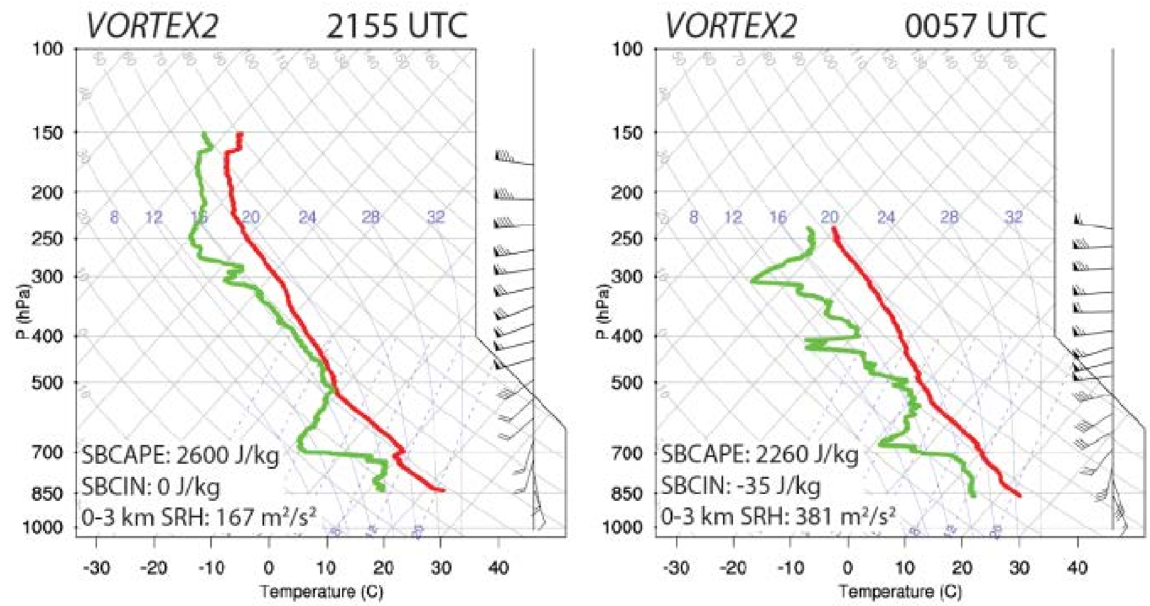

Figure 2: Skew-T log-p diagrams of observed far-inflow soundings from VORTEX2, 5-6 June 2009. These diagrams represent the first and last soundings collected to provide an overall sense of how the environment evolved.

2006) as the spatially- and temporally-varying base-state conditions. Other model setting details are given in Table 1.

	CM1	**WRF**
Base-state conditions	VORTEX2 inflow soundings: 2155, 2240, 2335, & 0057 UTC	North American Regional Reanalysis
Model grid spacing	Δx, Δy: 250 m Δz: stretched from 50 to 250 m	Δx, Δy: 4000 m Δz: stretched, 29 vertical levels
Micro-physics	Morrison double-moment	Morrison double-moment
Run details	• First 90 min: 2155 UTC sounding • 90—270 min: restart every 5 min (2155 to 0057 UTC sounding) • 270—300 min: 0057 UTC sounding	• Initiated: 1200 UTC 5 June 2009 • Complete: 0600 UTC 6 June 2009

Table 1: Model settings utilized for CM1 (using BSS technique) and WRF (fully heterogeneous, four-dimensional).

3. RESULTS

To provide context for the simulation results, the observed composite radar reflectivity from the Cheyenne, Wyoming WSR-88D is provided in Figure 3. An isolated supercell developed at the time the first inflow sounding was launched at 2155 UTC, with other nascent convection forming to the north. The storm of interest eventually merged with the other storms by 0055 UTC.

In the WRF simulation, which included both temporal and spatial variations in the background environment, a broadly similar storm evolution occurred. A weak isolated supercell formed by 2155 UTC, with other small convective showers in the vicinity. Over time, the storm of interest grew stronger, and eventually grew upscale to a larger convective complex (Fig. 4). Utilizing BSS in CM1 also resulted in largely the same type of convective evolution, with an isolated supercell growing upscale over time (Fig. 5). The most notable difference between the CM1 and WRF simulations is the larger number of small-scale convective features in CM1, owing to the much smaller grid spacing (the WRF simulation will be rerun with comparable grid spacing in the near future). Otherwise, the two simulations largely agree in terms of the basic storm development and progression.

Comparison of a couple of storm metrics further reveals the extent to which the CM1 and WRF simulations are indeed comparable. Figure 6 demonstrates that the maximum vertical velocity and vertical vorticity at 5 km was stronger overall in the CM1 simulation, which can be attributed to the smaller grid spacing allowing for stronger maxima to be resolved. Even so, the trends in both metrics are quite similar, which corresponds to the broad similarity of both simulations shown in Figs. 4-5.

4. SUMMARY AND FUTURE WORK

The base-state substitution technique is a new approach to accounting for the effects of environmental variability in an idealized setting while still maintaining a large degree of control over the simulations. However, it is unclear whether BSS's central assumption that the summative effects of heterogeneity on storm behavior are more important than instantaneous effects, an assumption that also underlies all idealized simulations, is valid.

To address this concern, two simulations were performed using the 5 June 2009 VORTEX2 tornadic supercell case. Preliminary results demonstrate that WRF (using a fully heterogeneous base-state environment) and CM1 (using a horizontally-homogeneous base-state environment with temporal variation via BSS) produce comparable storm evolution and intensity trends (Figs. 4-6). This result is encouraging, in that it appears to demonstrate the utility of using a simplified approach to accounting for environmental variability via BSS. While the simulations were not directly comparable owing to different grid spacings (Table 1), the similarities are nevertheless reassuring and prompt further investigation in validating the BSS technique.

This study is in its initial stages, with much additional work to be performed. Firstly, the WRF simulation will be re-run using nested grids to achieve the same grid spacing as the CM1 simulation. Once this is complete, additional storm metrics (such as cold pool intensity and storm track) will be compared among the simulations to identify any systematic differences produced by BSS. The microphysics scheme will also be varied to evaluate whether the technique is sensitive to the implementation of single vs. double moment schemes. Next, additional case studies will be simulated to test sensitivities of different storm modes and degrees of environmental variability. The summation of these efforts is intended to provide a "user's guide" for those who are interested in using the technique so that all caveats and appropriate uses are identified. If BSS is validated as a reliable and realistic approach in numerical modeling, future studies will investigate the effects of environmental variations on storm dynamics and subsequent storm behavior.

5. REFERENCES

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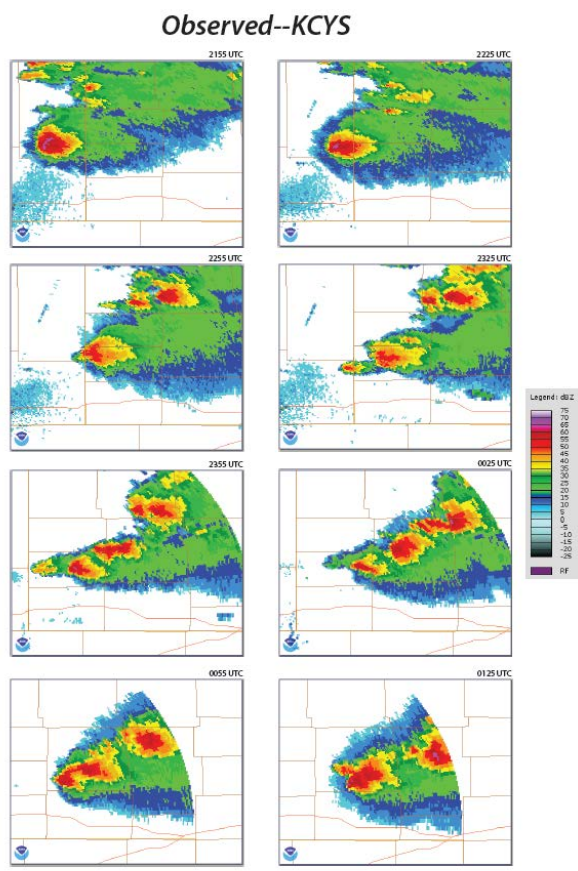

Figure 3: Observed composite radar reflectivity from KCYS on 5-6 June 2009.

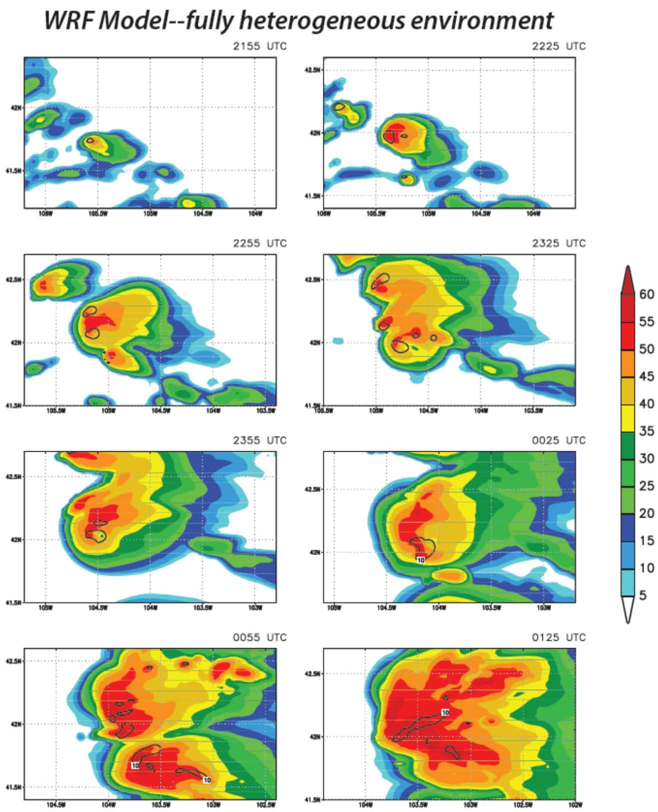

Figure 4: Composite simulated radar reflectivity (shaded) and 5 km vertical velocity (contoured at 10 m/s) from the WRF model.

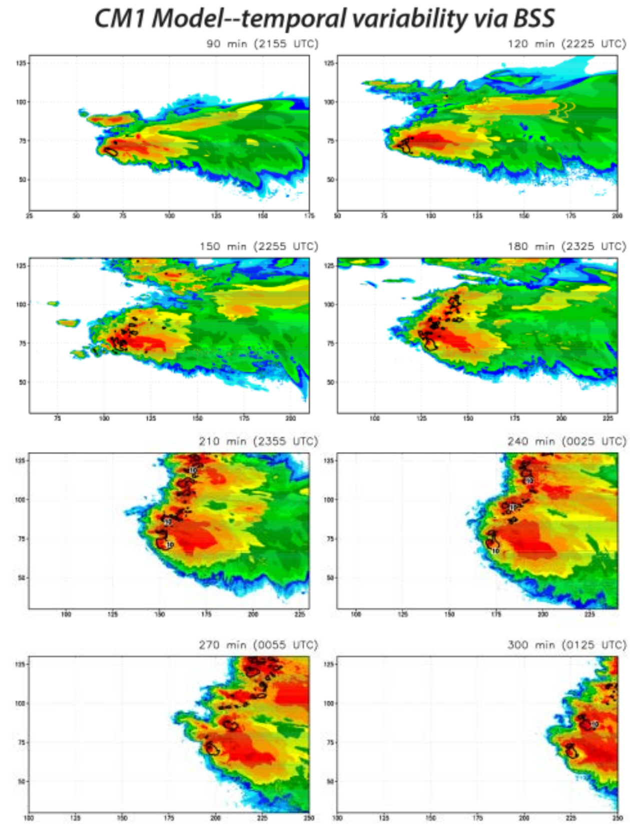

Figure 5: As in Fig. 4, but for the CM1 model.

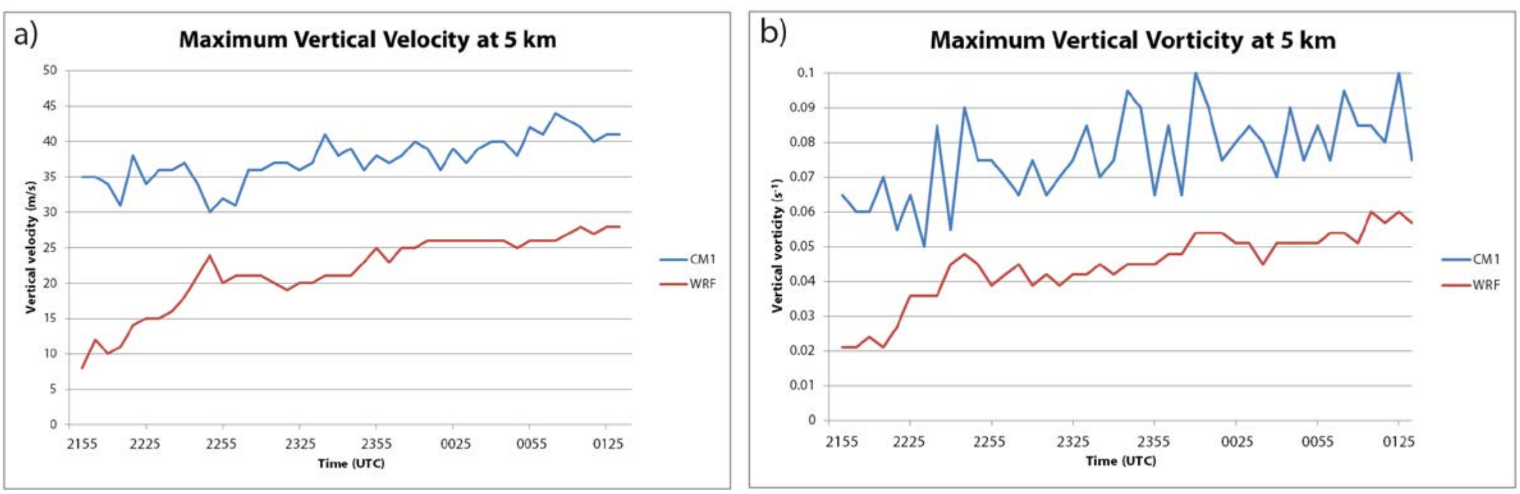

Figure 6: Time series of a) maximum vertical velocity and b) maximum vertical vorticity at 5 km between 2155 and 0125 UTC in CM1 (blue) and WRF (red).