Assessment of the Base-State Substitution Idealized Modeling Technique

Casey E. Davenport*, M.I. Biggerstaff+, and C.L. Ziegler^

*Department of Geography and Earth Sciences
University of North Carolina at Charlotte

+School of Meteorology
University of Oklahoma

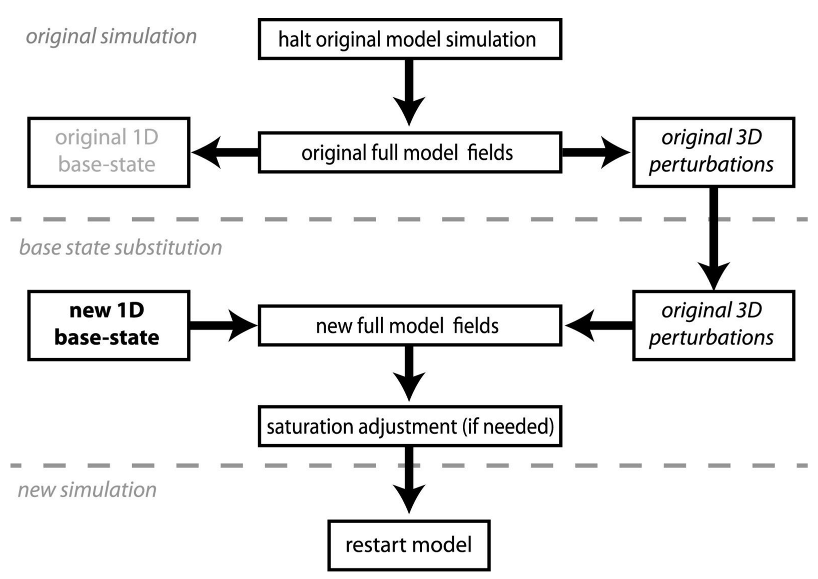
^National Severe Storms Laboratory

UNC CHARLOTTE

Introduction

Idealized simulations containing horizontally-homogeneous and temporally-fixed background environments have been extremely useful in elucidating the fundamental processes at work in severe convection. However, convective environments can often vary significantly over time and space, making it difficult to assess how these fundamental processes are modified in response to changes in the environment.

Base-state substitution (BSS) is a novel modeling technique for approximating environmental heterogeneity in idealized simulations. After a certain amount of model run time, BSS replaces the original horizontally-homogeneous background environment with a new horizontally-homogeneous environment while maintaining any storm-induced perturbations (Fig. 1); this is repeated at a prescribed temporal interval defined by the model user.



To assess the ability of BSS to faithfully recreate observed storm structure and behavior, the Kingfisher supercell thunderstorm, observed during the DC3 field experiment on 29 May 2012 will be simulated and compared to available dual-Doppler data.

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

Methods

- Observations
  - Multiple-Doppler wind retrieval of SMART-R and NOXP data between 2251 and 0000 UTC on 29 May 2012, using variational method described by Potvin et al. (2012)
    - Synced radar volumes collected every 3 min
  - The domain was 90 x 60 x 17.5 km with a horizontal and vertical grid spacing of 500 m
- Idealized modeling
  - CM1 model with 300 x 500 x 20 km grid with a horizontal and vertical grid spacing of 500 m
  - Convection initiated using moist convergence for first 30 min of simulation
  - NSSL microphysics scheme with variable hail and graupel densities explicitly predicted
  - Series of near-inflow soundings utilized for base-state conditions (Fig. 2):
    - 2029 UTC for first 3 hours (or 7 hours for control simulation)
    - Base-state gradually nudged to the 2255 and 0020 UTC environments; BSS applied every 3 min

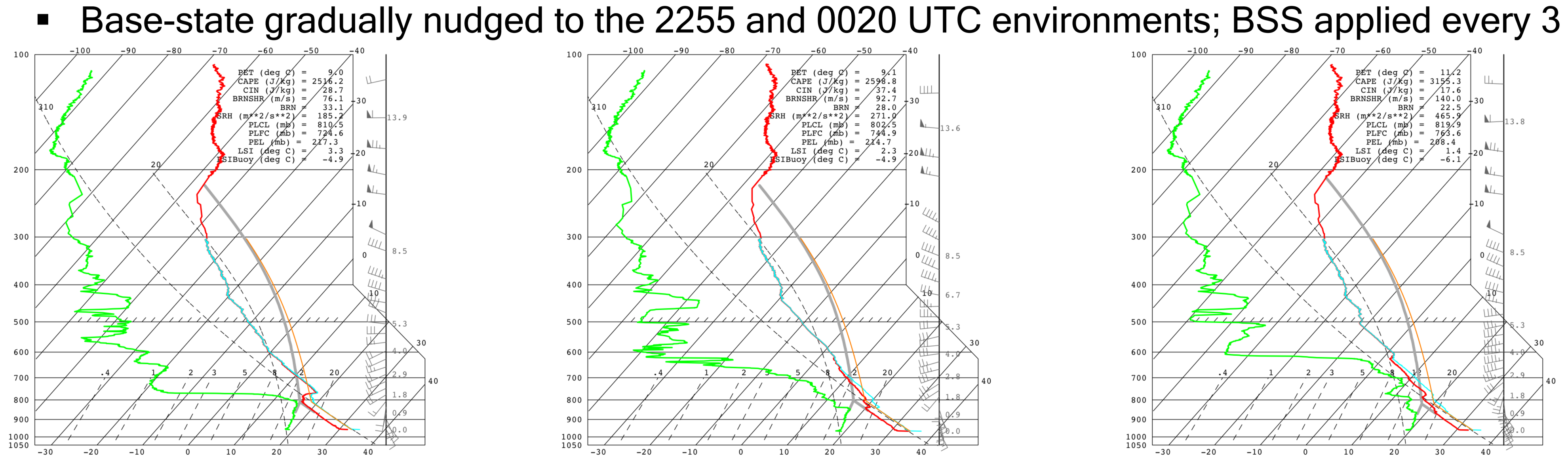


Fig. 2: Skew-T log-p diagrams of near-inflow soundings launched on 29-30 May 2012.

Results

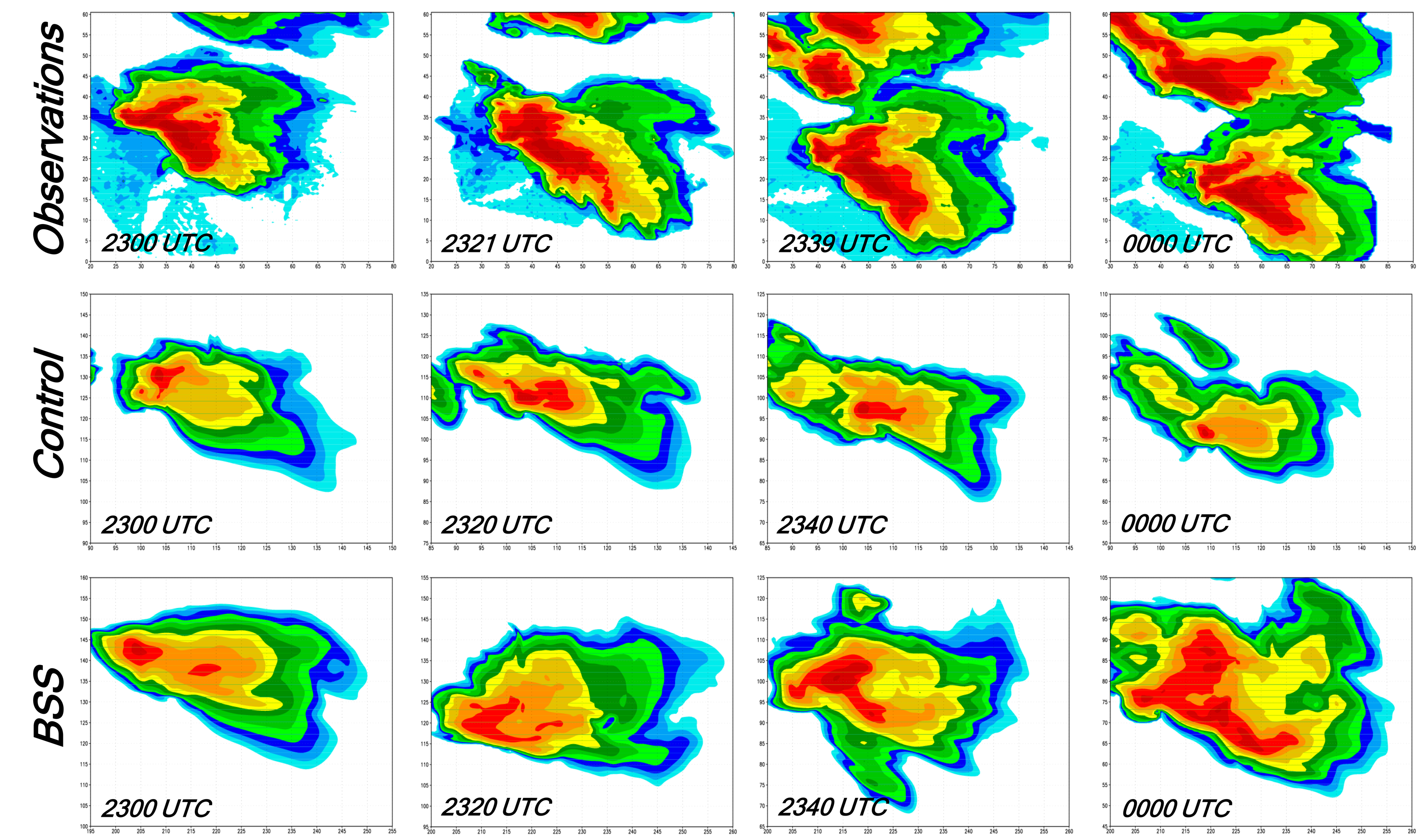


Fig. 2: Observed base reflectivity from SMART-Rs during dual-Doppler period on 29-30 May 2012 (top row); simulated surface reflectivity from the control (middle row) and base-state substitution (bottom row) simulations.

- Control and BSS simulations both produce long-lived supercells
- BSS supercell is larger overall than the control
- Qualitatively, low-level simulated reflectivity structure in BSS appears to be more consistent with the observations, especially at 0000 UTC

- Statistical comparisons are made between the observations and each simulation using the non-parametric two-way Kolmogorov-Smirov (KS) test
  - Distributions of vertical velocity and reflectivity are compared every 500 m throughout the depth of the storm (Fig. 3)
  - P-values indicate the likelihood that the distributions are different (small p-value) or similar (large p-value)
- Control and BSS simulated reflectivity are somewhat equally similar to the observations
- Over time, the structure of vertical velocities produced by BSS becomes increasingly similar to the observations, and the control becomes less similar

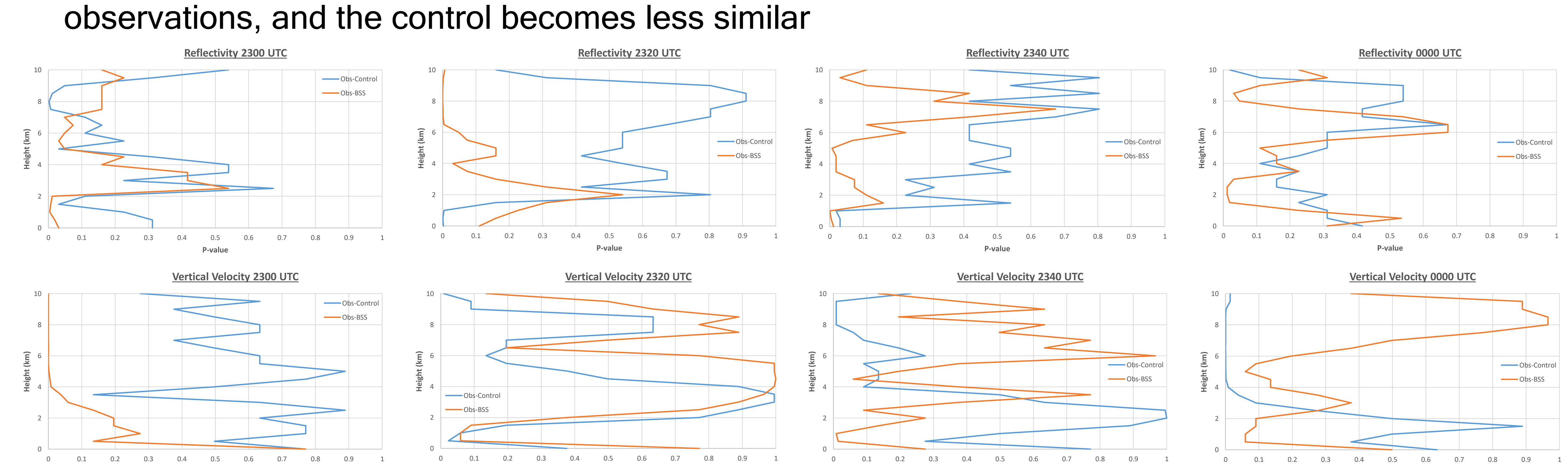


Fig. 4: Vertical profiles of p-values of the two-way KS-test comparing the observations to the control (blue) or BSS (orange) simulations.

Summary and Future Work

- BSS simulated supercell becomes increasingly similar to the observed 29 May 2012 storm, particularly when comparing vertical velocity distributions
- In the future, additional statistical tests (e.g., Wilcoxon rank sum test) will be run to confirm results
- Additional simulations will test sensitivities of the results to different microphysics schemes