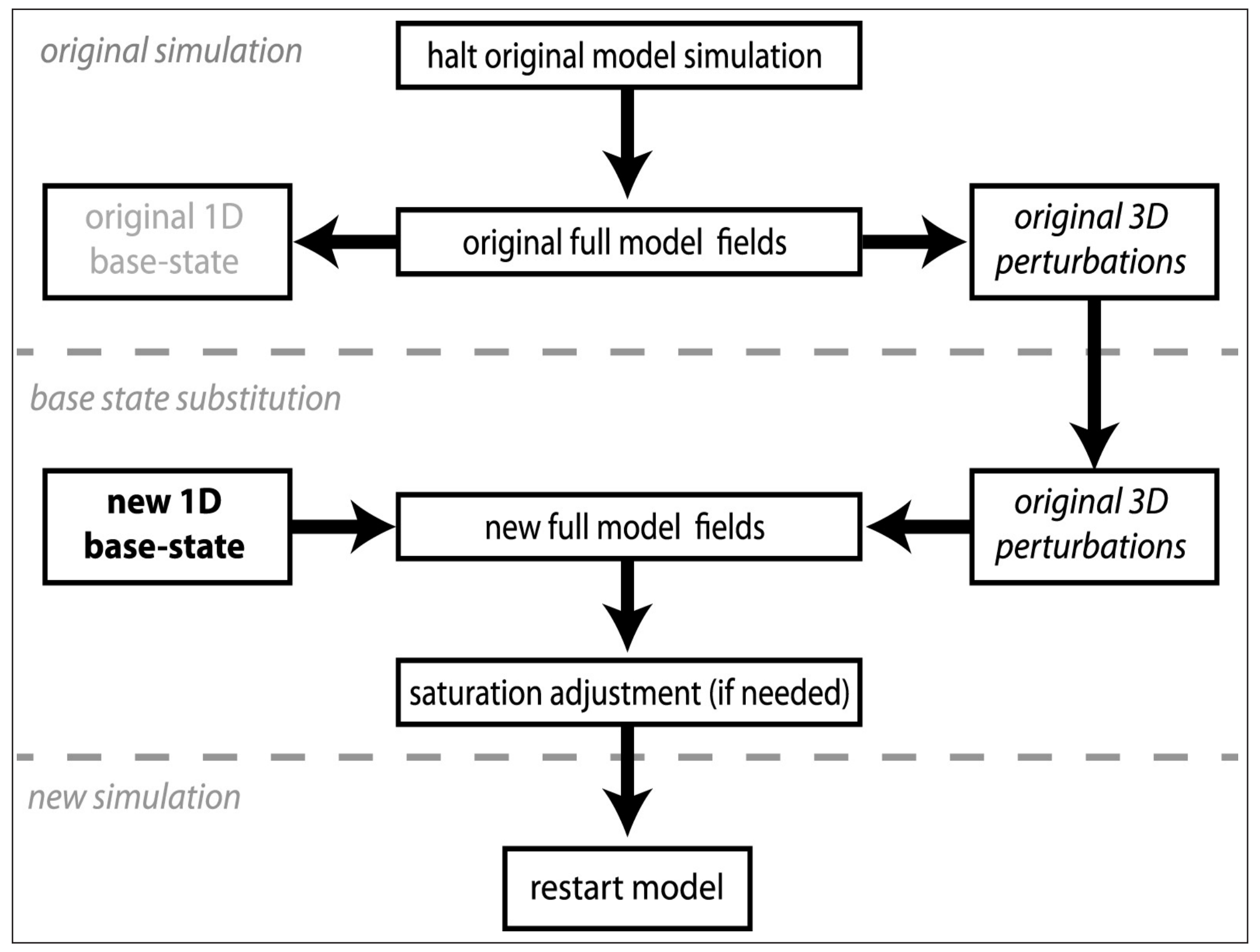
Addressing the Efficacy of the Base-State Substitution Technique: A Comparison of Simulations

Casey E. Davenport
Department of Geography and Earth Sciences
University of North Carolina at Charlotte

UNC CHARLOTTE

Base-State Substitution

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.



original simulation

halt original model simulation

original 1D base-state ← original full model fields → *original 3D perturbations*

base state substitution

new 1D base-state → new full model fields ← *original 3D perturbations*

saturation adjustment (if needed)

new simulation

restart model

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

Benefits:

- Clean separation of cause and effect
- Independent modification of wind, temperature, and moisture profiles, giving the model user a significant amount of control over changes to the environment
- Allows for the study of how the same storm would *respond* to different environments

Limitations:

- Total values of model variables are not conserved (perturbations are maintained, but not the base-state)
- The *integrated effect* of the storm moving across an environmental gradient over time is assumed to be greater than the *instantaneous effect* of small-scale spatial variations

This assumption is central not only to BSS, but to ALL idealized models with horizontally-homogeneous environments. ***Is this assumption valid?***

Methods

A pair of idealized model simulations, one using BSS (as formulated in CM1r17) and one using WRFv3, simulating the 5 June 2009 Goshen County storm during VORTEX2.

	CM1	**WRF**
Base-state conditions	VORTEX2 near-inflow soundings: 2155, 2240, 2335, & 0057 UTC	NCEP North American Regional Reanalysis (NARR)
Model grid spacing	Δx, Δy: 250 m Δz: stretched from 50 to 250 m	Δx, Δy: 4000 m Δz: stretched, 29 vertical levels
Microphysics	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).

Inflow Environments

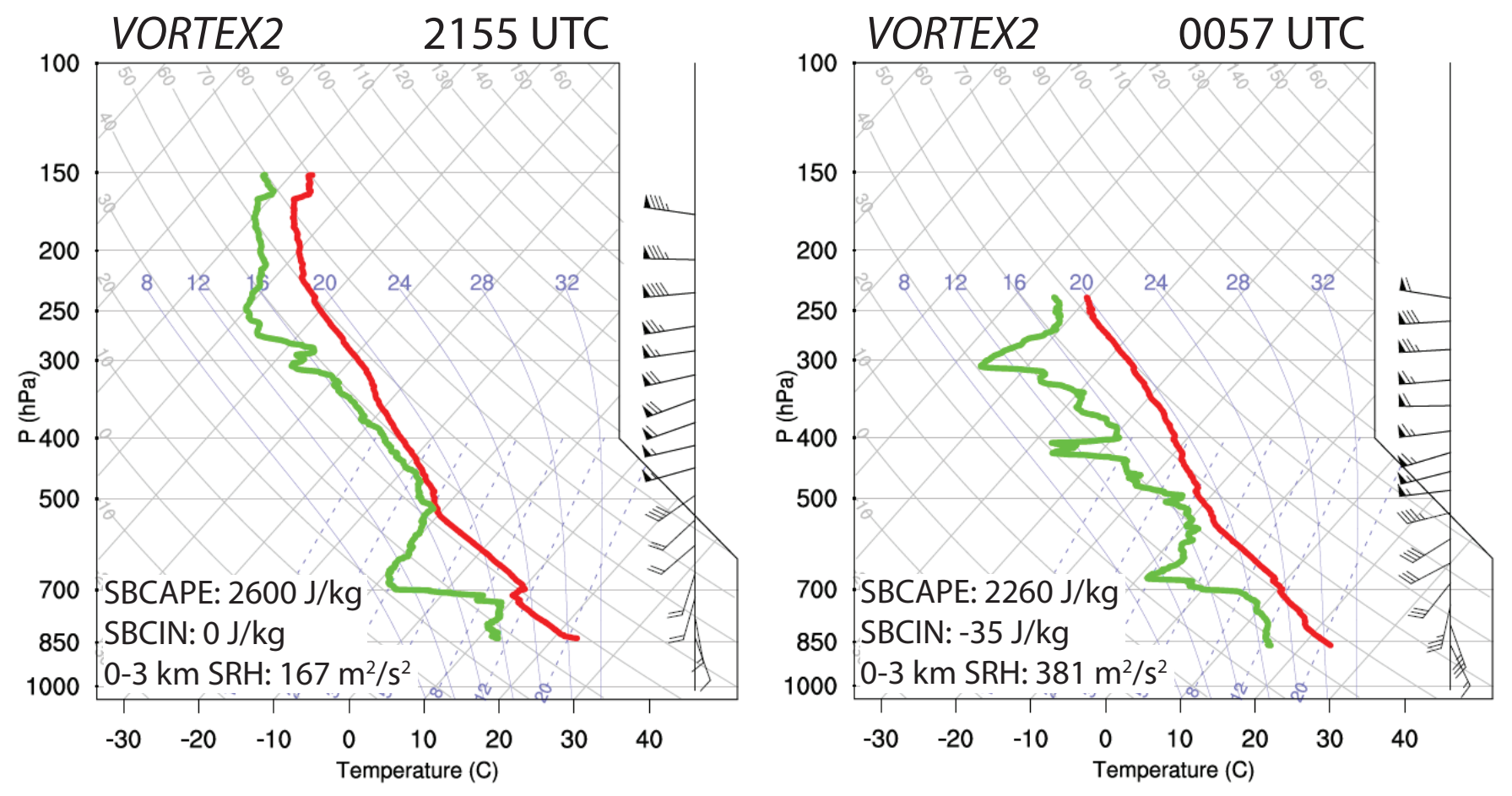


Figure 2: Skew-T log-p diagrams of observed far-inflow soundings from VORTEX2, 5-6 June 2009.

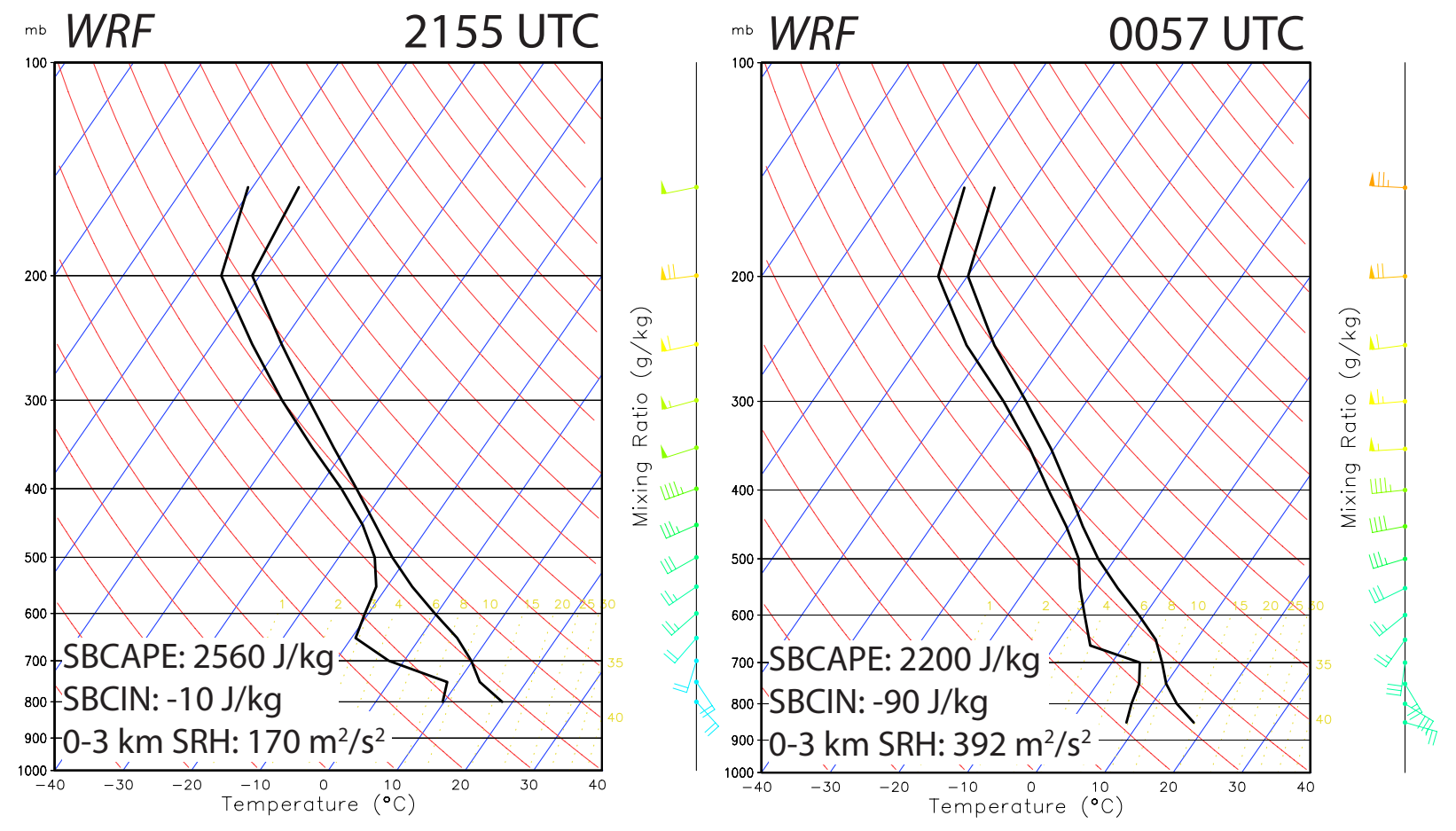


Figure 4: Skew-T log-p diagrams of the far-inflow soundings in WRF.

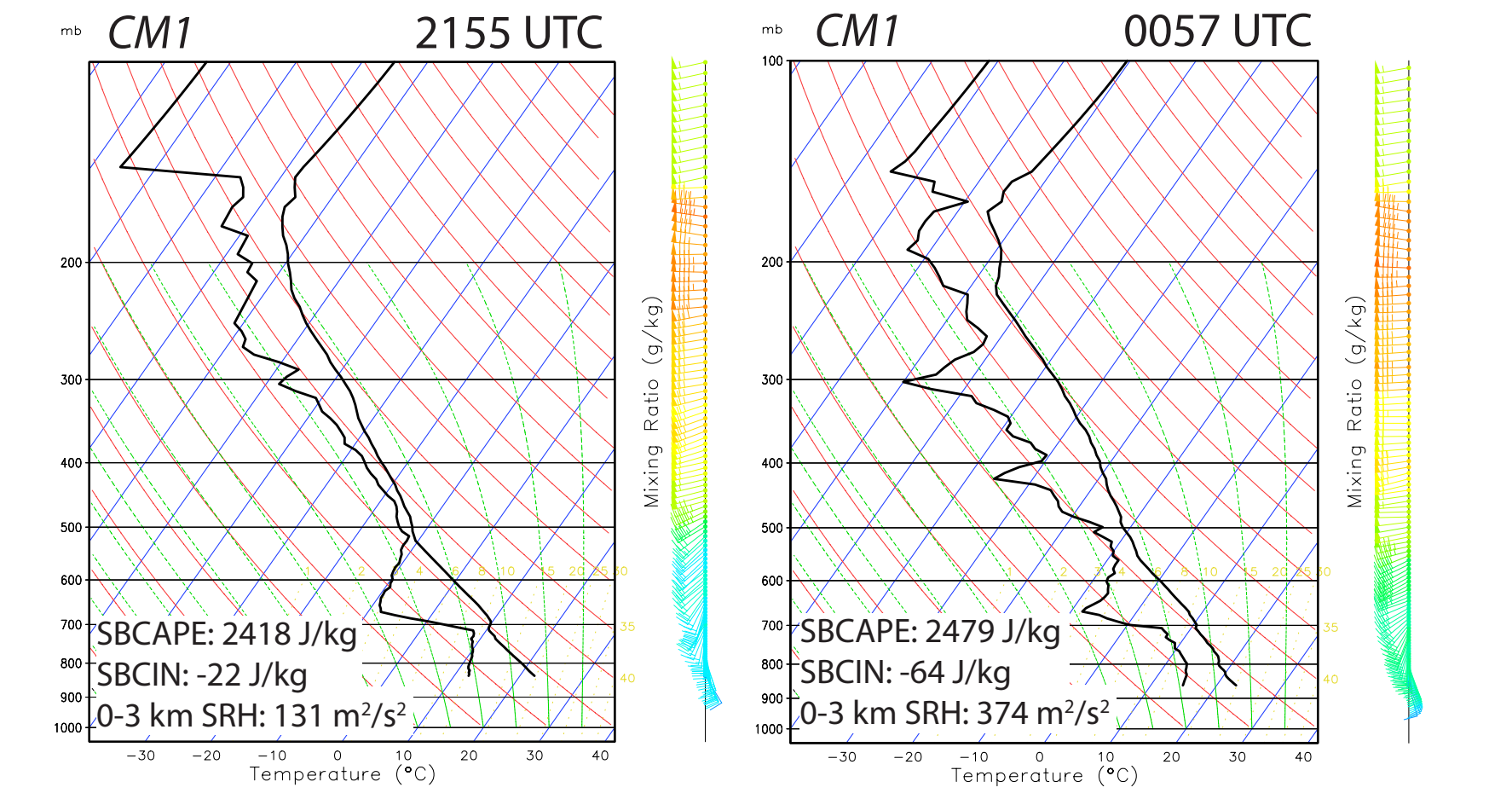


Figure 4: Skew-T log-p diagrams of the homogeneous base-state soundings in CM1 at the beginning (left) and end (right) of BSS.

Results

Observed--KCYS

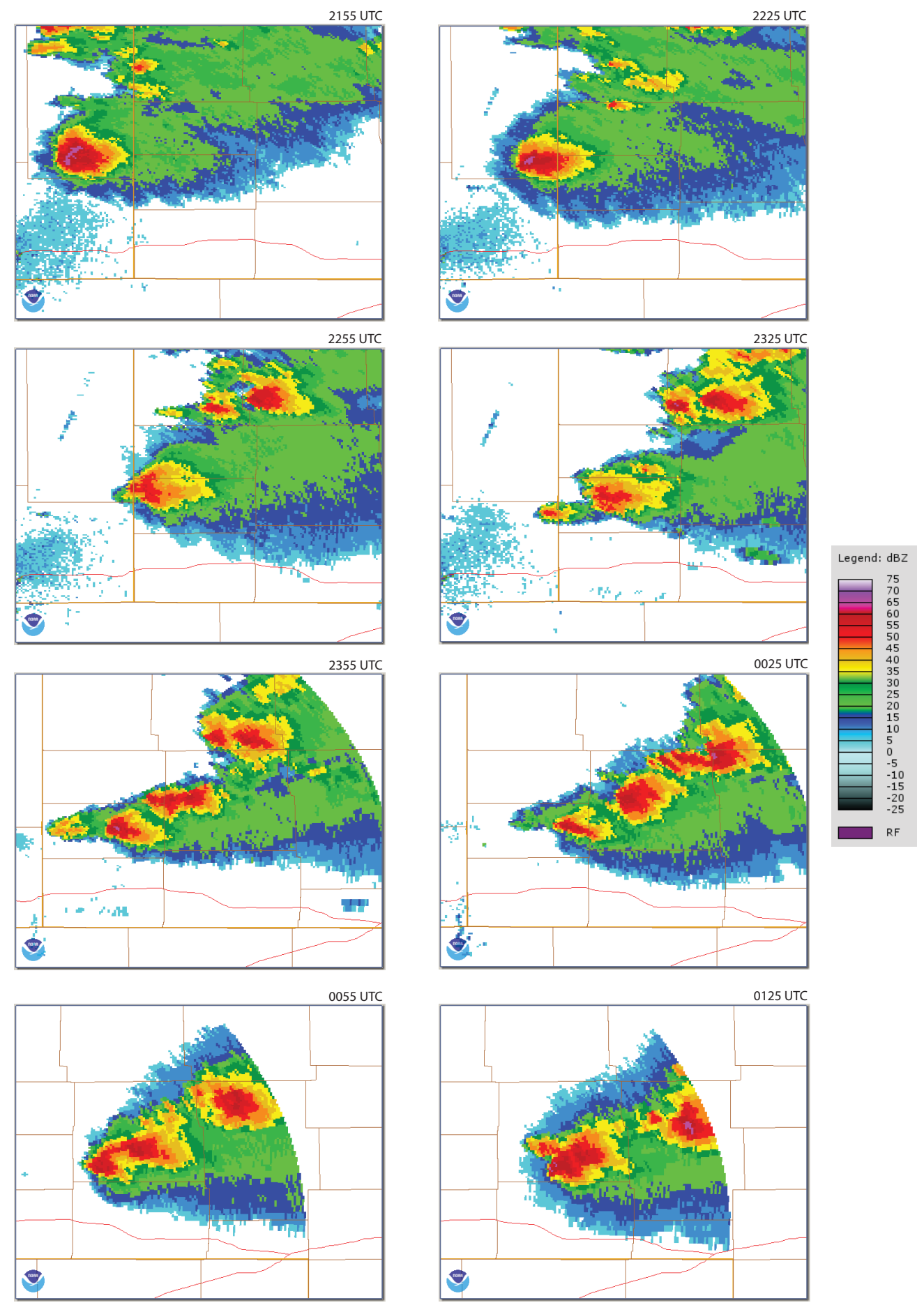


Figure 5: Observed composite radar reflectivity from KCYS on 5-6 June 2009.

WRF Model--fully heterogeneous environment

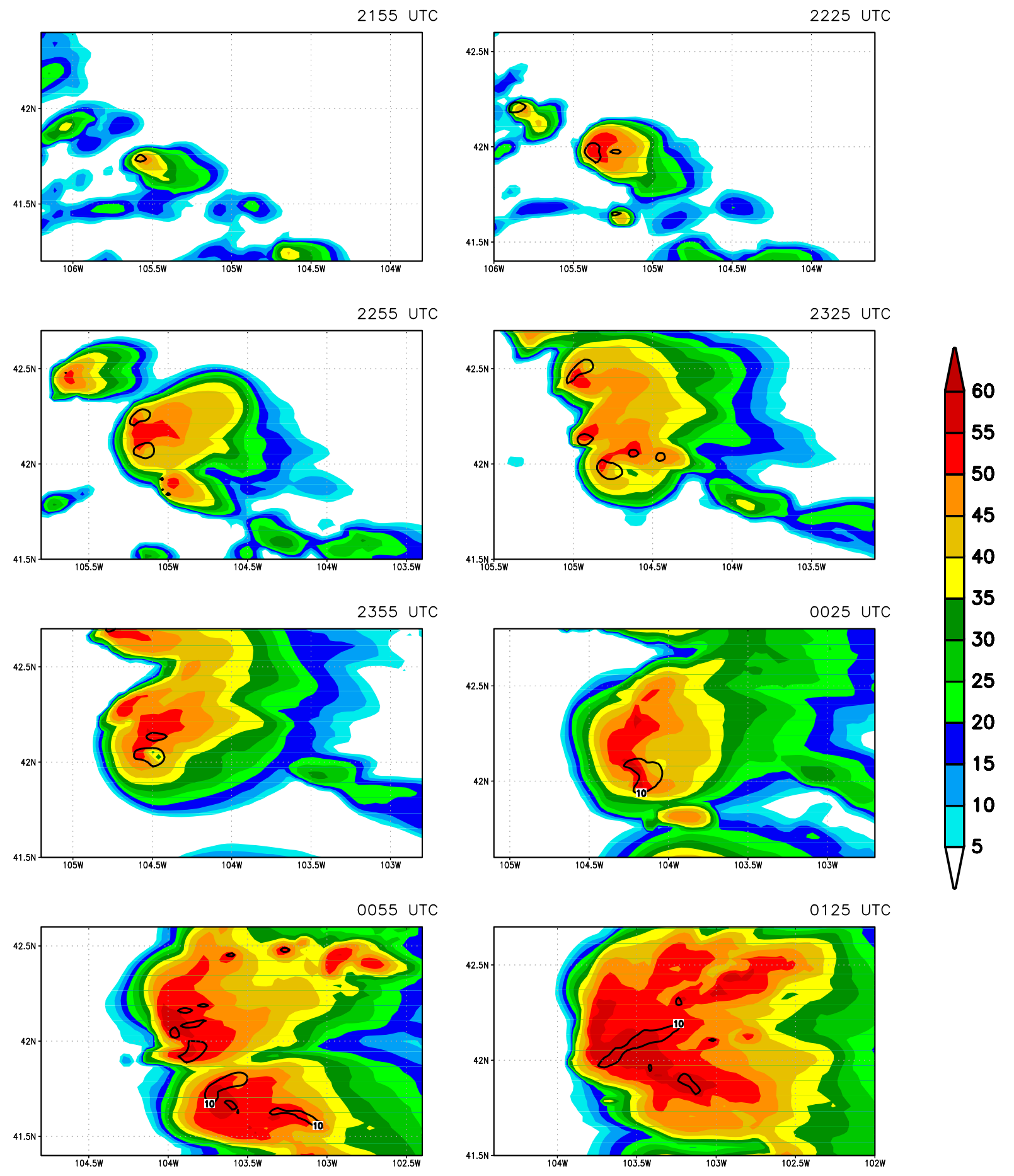


Figure 6: Composite simulated radar reflectivity (shaded) and 5 km vertical velocity (contoured at 10 m/s) from the WRF model.

CM1 Model--temporal variability via BSS

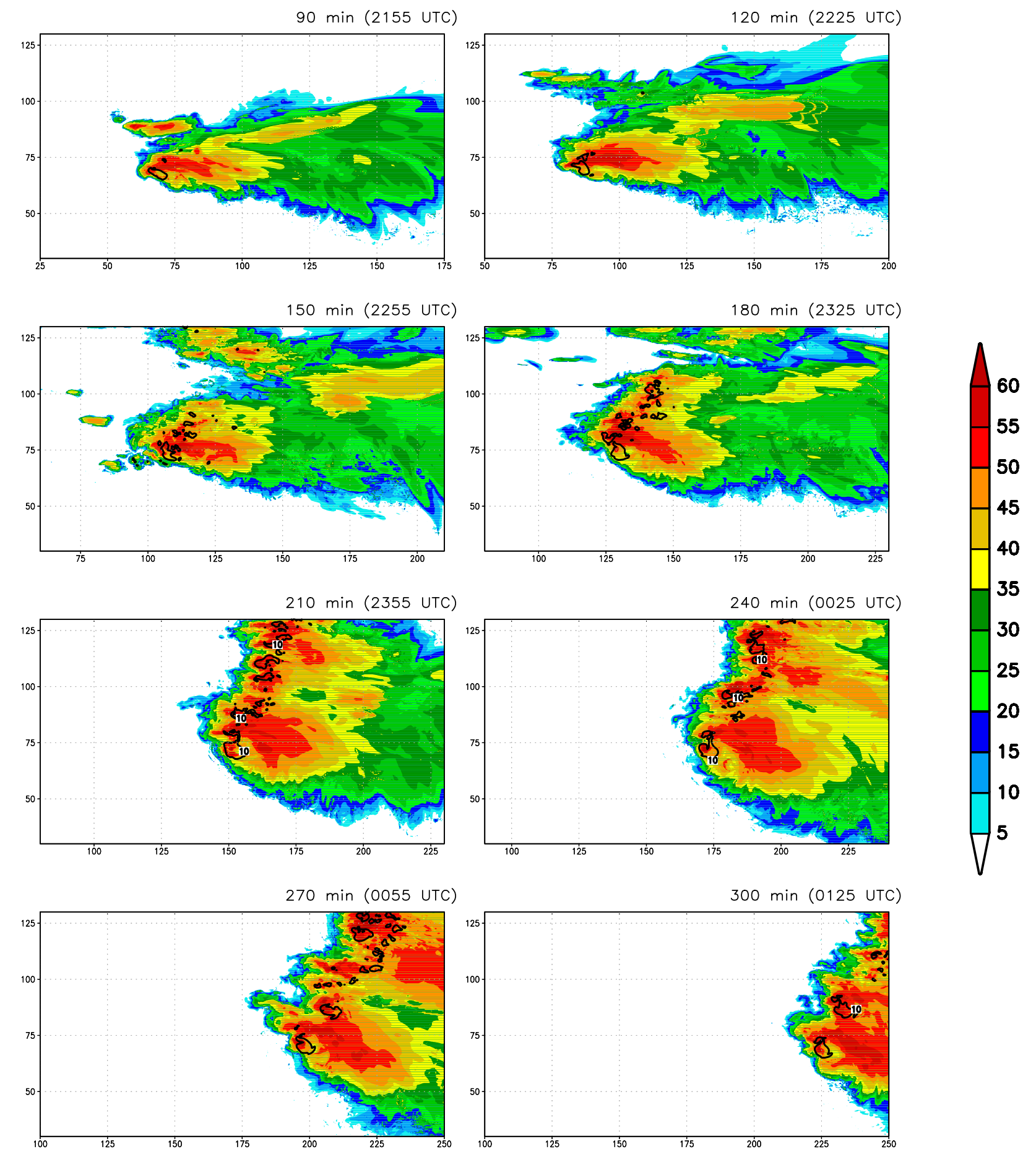


Figure 7: Composite simulated radar reflectivity (shaded) and 5 km vertical velocity (contoured at 10 m/s) from the CM1 model.

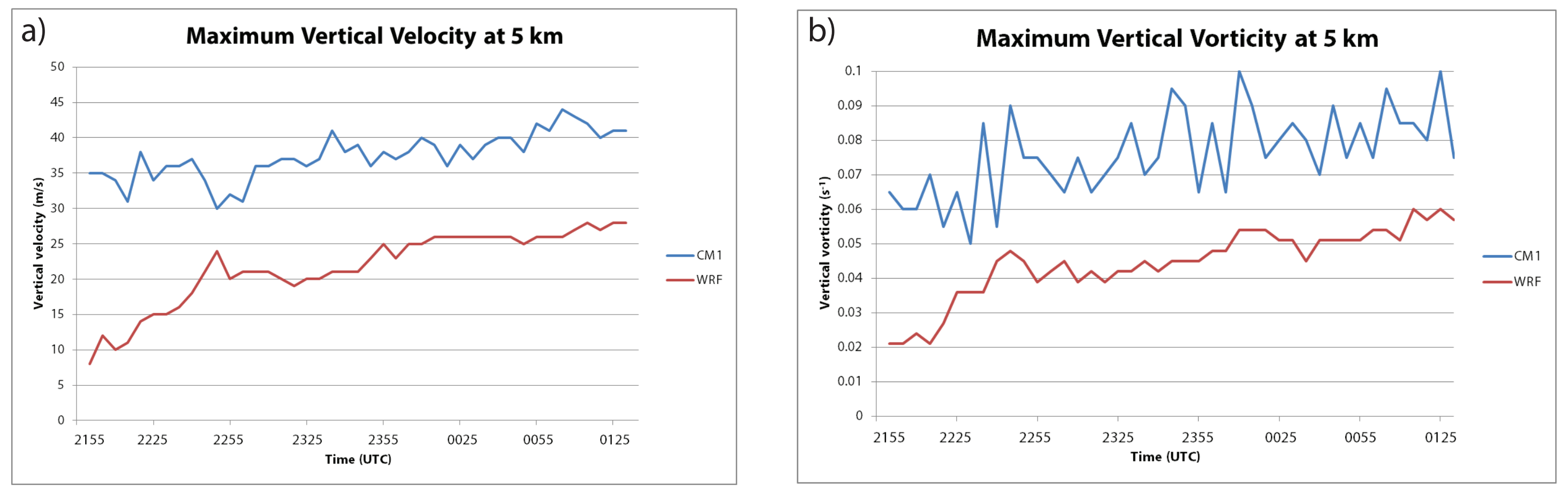


Figure 8: Time series of a) maximum vertical velocity and b) maximum vertical vorticity between 2155 and 0125 UTC in CM1 (blue) and WRF (red).

- Both WRF and CM1 largely reproduce observed storm evolution (cf. Fig. 5 to Figs. 6-7)
- Finer details of storm structure are poorly resolved in the WRF simulation due to larger grid spacing than CM1. Even so, both model simulations shown broad agreement in storm evolution (cf. Figs. 6-7).
- Measures of storm intensity such as 5 km vertical velocity and vertical vorticity also exhibit similar patterns (Fig. 8)

Summary and Future Work

- The BSS technique is being tested to determine whether its assumptions (and those of all idealized models) are appropriate
- Preliminary results demonstrate that WRF (using a fully heterogeneous base-state environment) and CM1(using a horizontally homogeneous base-state environment, temporally varying via BSS) produce comparable storm evolution and intensity trends
- The WRF simulation will be re-run using nested grids to achieve a similar grid resolution as the CM1 BSS simulation
- Additional cases from the VORTEX2 and BAMEX field projects will be simulated to test BSS in a variety of situations and environments
- Additional tests will evaluate BSS's sensitivity to varying microphysical schemes