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

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.

<table>
<thead>
<tr>
<th>CM1</th>
<th>WRF</th>
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</thead>
<tbody>
<tr>
<td>Base-state</td>
<td>VORTEX2 near-inflow soundings: 2155, 2240, 2335, &amp; 0057 UTC</td>
</tr>
<tr>
<td>conditions</td>
<td>Model grid</td>
</tr>
<tr>
<td></td>
<td>spacing: Δx: 250 m, Δy: 400 m, Δz: stretched from 50 to 250 m, 29 vertical levels</td>
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<tr>
<td>Microphysics</td>
<td>Morrison double-moment</td>
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<tr>
<td>Run details</td>
<td>First 90 min: 2155 UTC sounding, 90—270 min: restart every 5 min (2153 to 0057 UTC sounding), 270—30 min: 0025 UTC sounding, Initiated: 1200 UTC 5 June 2009, Complete: 0600 UTC 6 June 2009</td>
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</tbody>
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Results

- 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