Evaluation of different ensemble configurations for the analysis and prediction of high-impact mesoscale convective systems

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INTRODUCTION

• As ensembles of numerical models at convection-allowing grid spacing become used more frequently for research and operations, it is important to understand the strengths and weaknesses of different ensemble configurations
• Storm-scale ensembles can provide useful probabilistic forecast information about high-impact mesoscale convective systems (MCSs), and they can also be used to understand the key processes in those MCSs
• In this work, we focus on a multi-day period of heavy rainfall in the southern United States in June 2010 (Fig. 1). A series of MCSs associated with a long-lived mesoscale convective vortex (MCV) led to three days of extreme precipitation and flash flooding in Texas and Arkansas.

THE ENSEMBLE SYSTEMS

<table>
<thead>
<tr>
<th>Ensemble</th>
<th>CAPS storm-scale ensemble system (SSEF)</th>
<th>WRF-DART single physics</th>
<th>WRF-DART mixed physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of members</td>
<td>26</td>
<td>WRF-ARW at dx=4 km</td>
<td>Same as WRF-DART single physics, except mixed physics used during assimilation cycle (as in, e.g., Wheatley et al. 2010)</td>
</tr>
<tr>
<td>Models</td>
<td>WRF-ARW, ARPS</td>
<td>WRF-DART at dx=4 km</td>
<td>WRF-DART at dx=4 km</td>
</tr>
<tr>
<td>Initial boundary conditions</td>
<td>NAM-based perturbations from SREF, radar assimilation for most members (see Xue et al. 2010 and Clark et al. 2010).</td>
<td>WRF-DART single physics</td>
<td>As in the above panels, but for 6- hr accumulated precipitation (mm) from 0000-0600 UTC 11 June 2010.</td>
</tr>
<tr>
<td>Physics parametrizations</td>
<td>Variated microphysics, boundary layer, and land-surface schemes</td>
<td>Thompson microphysics, YSU boundary layer</td>
<td>Same as WRF-DART single physics, except mixed physics used during assimilation cycle (as in, e.g., Wheatley et al. 2010)</td>
</tr>
<tr>
<td>Forecast setup</td>
<td>0000 UTC 10 June for 36 h</td>
<td>0000 UTC 10 June for 36 h</td>
<td>Same as WRF-DART single physics, except mixed physics used during assimilation cycle (as in, e.g., Wheatley et al. 2010)</td>
</tr>
</tbody>
</table>

RESULTS – PRECIP FORECASTS

• Here we focus on the forecast initialized 0000 UTC 10 June. Early in the forecast (6–12 h) all of the ensemble systems show high probabilities of heavy precipitation in northeast Texas, consistent with the observed event (Fig. 2). All give some probability of heavy rain in Nebraska as well.
• By the 24–30-hour forecasts, however, the ensemble predictions start to diverge somewhat in the vicinity of the MCV (Fig. 3). The SSEF has its highest probabilities displaced somewhat, the SP moves the MCV too quickly, and the MP correctly locates the highest probabilities.

• The SSEF moves the MCV through more slowly, indicating heavier rainfall in east Texas, whereas the WRF-DART ensembles move the MCV faster to the east along with the rainfall (Fig. 4).

ACKNOWLEDGMENTS

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RESULTS – PROCESSES

• We now exploit differences between ensemble members with “good” and “bad” forecasts to understand what was favorable or detrimental for the MCS
• SSEF results shown here; WRF-DART analysis ongoing
• The strength of the remnant cold dome from the previous night’s convection, along with the strength of the MCV, were key to the development of the nocturnal heavy-rain-producing MCS (Fig. 5).

SUMMARY

Questions to address:
• What is the predictive skill of this type of high-impact MCS/MCV with a storm-scale ensemble?
• How does the configuration of the ensemble impact the answer to this question?
• What atmospheric features and processes are both necessary and sufficient for this type of event to occur? (and how can ensembles help us answer this question?)

As in the above panels, but for 6- hr accumulated precipitation (mm) from 0000-0600 UTC 11 June 2010.  Only a couple members have afternoon cold pools and MCVs similar to observations; these are the members that correctly predict the nocturnal MCSs

Fig. 5: Surface potential temperature from selected members of the Storm-Scale Ensemble Forecast (SSEF) system, a 26-member ensemble at 4-km grid spacing. The time shown is 1800 UTC 10 June 2010. Objectively analyzed observations are in (g).

Members with accurate representation of afternoon surface cold dome also correctly predict the overnight MCS

As in the top panels, but for simulated reflectivity at 0000 UTC 11 June (9 hours after the above images).