# 11B.3 EXAMINATION OF MESOSCALE FEEDBACKS ON CONVECTIVE SCALE PREDICTABILITY DURING MPEX

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## 1. INTRODUCTION

The Mesoscale Predictability Experiment (MPEX) was conducted from 15 May to 15 June 2013 to study predictability of convective systems in the Great Plains region of the United States (Weisman et al. 2015). Supplemental, sub-synoptic observations were collected during the field campaign in an effort to 1) investigate the impact of such observations on mesoscale and convective-scale numerical weather prediction (NWP) and 2) quantify upscale feedbacks from deep convection on the surrounding environment and assess how these feedbacks subsequently impact convective-scale predictability.

The first objective was achieved via morning dropsonde observations, which aimed to sample upstream disturbances over the Intermountain West that might influence deep convection in the Great Plains later in the day. The second objective was undertaken by collecting ground-based radiosonde (i.e., upsonde) observations during afternoon operations activities. Mobile sounding teams from the National Severe Storms Laboratory, Purdue University, Colorado State University, and Texas A&M University sampled preconvective and convectively disturbed environments (Trapp et al. 2016). Several sampling strategies were employed to observe the environment surrounding isolated deep convection Upsondes launched in convectively disturbed environments could then be compared with preconvective soundings to assess how convection modified the environment.

Analysis of MPEX upsondes and complementary idealized modeling simulations reiterated that cold pools are a key effect of deep convection on the environment (Trapp and Woznicki 2016, in revision). Compared to convective effects like reduction in CAPE and midlevel lapse rates, surface cold pools were found to persist in the environment well after convection ended. This is a potentially significant environmental modification because cold pools can contribute to inhibition of surface-based convection. Furthermore, Stensrud et al. (1999) established that the presence of cold pools in mesoscale models has a substantial impact on the simulated evolution of deep convection.

Surface cold pools could have even more significance during active periods of severe weather outbreaks, such as those observed during MPEX. Trapp (2014) found that significant tornadoes and outbreak days often occur in multiday periods, and they are more likely to occur in the latter half of such periods. Considering the propensity for cold pools to persist over long time and spatial scales, it is reasonable that this mesoscale feedback could play a substantial role in driving convective evolution during consecutive days of severe weather.

The purpose of this work is to investigate the effect of cold pool representation in NWP models on prediction of severe convection in a period of consecutive days with significant tornado outbreaks. Specifically, this work focuses on the events of 19 May and 20 May 2013 in the central Great Plains during the MPEX field campaign. The Weather Research and Forecasting (WRF) model is employed to simulate this period, and the mesoscale environment and convective evolution are evaluated. Multiple microphysics parameterization schemes are used in this current work to modify cold pool representation, and future work will exploit data assimilation to do the same. It is emphasized that the primary interest in surface cold pools here is the mesoscale effect of surface-based convective inhibition. The potential for convection initiation along the interface of the

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cool pool and the ambient environment is not explicitly considered.

## 2. METHODOLOGY

### 2.1 Case of Interest

As noted, this work focuses on the period of 19-21 May 2013. 19 May and 20 May corresponded to intensive observing periods (IOPs) 4 and 5, respectively (Weisman et al. 2015). Upsonde observations were collected during the afternoon and evening hours of both days. Dropsonde observations were also collected during the morning hours of IOP 4, but those observations were not considered here.

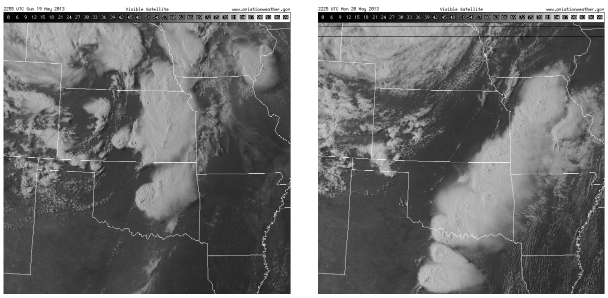

**Figure 1: Visible satellite imagery showing active convection across the Great Plains at 2300 UTC 19 May 2013 (left) and 2230 UTC 20 May 2013 (right)**

During this period, an active weather pattern instigated severe weather across much of the central United States, particularly in the Great Plains. Severe convection occurred in the central Plains during the afternoon and evening hours on 19 May (Figure 1). Convection continued during the overnight hours across areas of northeastern Oklahoma, southeastern Kansas, and southwestern Missouri. This convection produced an expansive cold pool over this region that persisted into the morning hours on 20 May before convection again broke out over this region in the afternoon. This case is of interest because isolated supercells produced multiple tornadoes across central Oklahoma on both days.

### 2.2 Model Settings

Retrospective forecasts were generated with the Advanced Research WRF (WRF-ARW; Skamarock et al. 2008) model version 3.6.1. Initial and boundary conditions were produced from 6-hourly final (FNL) analyses from the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) model (available online at http://rda.ucar.edu/datasets/ds083.2/). These 1° by 1° analyses were downscaled to the 15-km mesoscale domain, which encompasses the CONUS and other portions of North America. A convection-permitting 3-km nested domain was centered over the central Great Plains (Figure 2). Additional model configuration and physical parameterization settings are listed in Table 1.

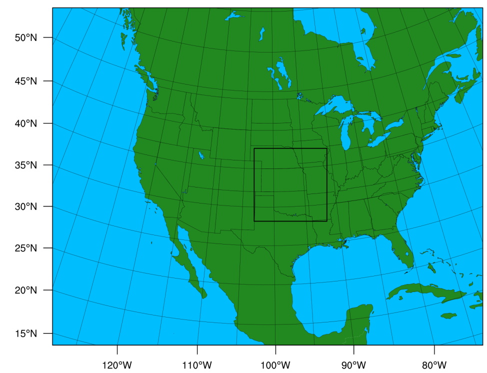


**Figure 2: 15-km mesoscale domain and nested 3-km convection-permitting domain over the Great Plains**

Because cold pool characteristics are sensitive to microphysical pathways in NWP simulations (e.g., Morrison et al. 2009), forecasts were produced with three different microphysics parameterization schemes to determine if such sensitivities were evident in this case. The Morrison double-moment scheme was used in addition to WRF single-moment 6-class (WSM6) scheme and Kessler scheme. The Morrison scheme solves mass and number concentration variables for rain, cloud ice, snow, and graupel. WSM6 includes mass mixing ratio variables for rain, cloud ice, snow, and graupel. The simplest scheme, Kessler, is a warm-rain scheme that only predicts cloud water and rain mixing ratio variables and does not include ice species.

| | **Outer Domain** | **Inner Nest** |
|---|---|---|
| Horizontal Grid Spacing | 15 km (415 x 325) | 3 km (350 x 350) |
| Vertical Levels | 40 | 40 |
| Cumulus | Tiedtke | none |
| PBL | MYJ | MYJ |
| SW & LW Radiation | RRTMG | RRTMG |
| Land Surface | Noah | Noah |

**Table 1: Model configuration and physical parameterizations**

A deterministic forecast was made using each microphysics scheme and the aforementioned physics settings. The forecasts were initialized at 1200 UTC on 19 May 2013 and integrated forward 42 hrs. Hereafter, the forecasts will be referred to as MORR, KESS, and WSM6.

## 3. RESULTS

Model-predicted surface temperatures at locations in the vicinity of the overnight cold pool were verified between 18 UTC 19 May and 20 UTC 20 May, which corresponds to the period of forecast hours 6 through 30. Surface temperatures reported at the following METAR sites were used to verify the forecasts: Enid, OK (KEND); Guthrie, OK (KGOK); Oklahoma City, OK (KOKC); Tulsa, OK (KTUL); Chanute, KS (KCNU); Joplin, MO (KJLN); Springfield, MO (KSGF); and Fayetteville, AR (KFYV). The hourly surface temperature biases at Oklahoma City, Chanute, and Joplin are shown in Figure 3.

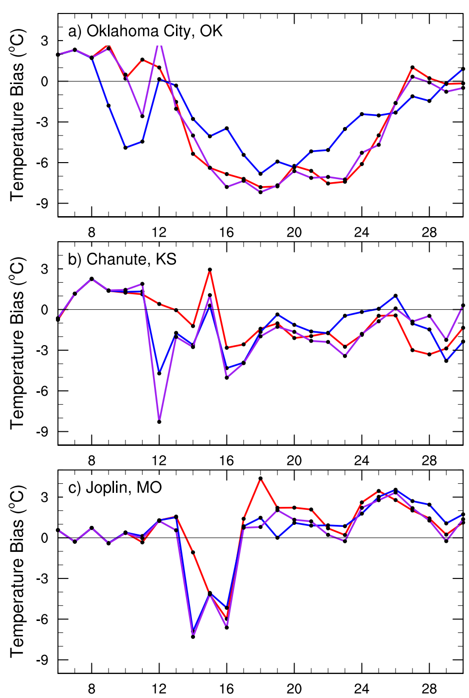


**Figure 3: Hourly model surface temperature bias in degrees Celsius at (a) Oklahoma City, OK; (b) Chanute, KS; and (c) Joplin, MO between forecast hours 6 and 30 (18 UTC 19 May to 20 UTC 20 May 2013). Model forecasts using Morrison double-moment, WSM6, and Kessler microphysics schemes are shown in red, blue, and purple, respectively.**

Overall, the surface temperature biases for all forecasts appear similar at a given location. More often than not, a warm bias in the KESS forecast is also reproduced in the WSM6 and MORR forecasts. However, on average, the single-moment microphysics schemes typically produced the coldest biases during this time period (Table 2). More specifically, the KESS and WSM6 forecasts displayed the coldest bias at two and five of the eight locations, respectively. This result is reasonable as evaporation (and associated latent cooling) is sensitive to the rain droplet size distribution, which is represented more explicitly in double-moment schemes like Morrison (Morrison et al. 2009).

| Average Surface Temperature Biases by Microphysics Parameterization Scheme (°C) | | | |
|---|---|---|---|
| | MORR | KESS | WSM6 |
| KEND | -0.5722 | -1.1041 | -0.6413 |
| KGOK | -1.9079 | -0.3722 | -1.7031 |
| KOKC | -2.3313 | -2.0965 | -2.5404 |
| KTUL | -2.1641 | -3.3763 | -3.2415 |
| KCNU | -0.6893 | -0.9702 | -1.0667 |
| KJLN | 1.0267 | 0.7222 | 0.4683 |
| KSGF | 0.2686 | 0.4394 | -0.3568 |
| KFYV | -1.1774 | -1.9284 | -2.4139 |

**Table 2: Average surface temperature biases**

While the forecasts of surface temperature do not appear highly sensitive to the choice of microphysical parameterization in this case, the spatial distribution of the bias trends seems more noteworthy. In Figure 3, the temporal trend in temperature biases is much different for Oklahoma City than Joplin. In fact, the average biases for this period are below -2° C at Oklahoma City, while the average biases at Joplin are between 0.5° and 1° C (Table 2). Moreover, this difference is likely attributable to model's difficulty with accurately predicting the timing and location of precipitation during the overnight hours after 00 UTC 20 May (forecast hour 12 in Figure 3).

Subjective assessments of the MORR and WSM6 forecasts found that the model was producing heavy precipitation across central Oklahoma through 06 UTC 20 May, but observed precipitation ended shortly after 01 UTC. This error in the model predictions likely caused the strong cold bias that was found through 12 UTC at Oklahoma City (Figure 3a). Conversely, the forecasts produced surface temperatures that were too warm at Joplin after 05 UTC (Figure 3c). After this time, the model forecasts were not producing rainfall over southwestern Missouri, but rainfall was still being observed through about 09 UTC. Furthermore, this sensitivity to the convective evolution is also evident on the whole. Averaging over all locations and all forecasts, the strongest (and coldest) surface temperature biases occurred between 00 UTC and 12 UTC 20 May. The biases were much weaker at other times when convection was more isolated or entirely absent over this portion of the domain.

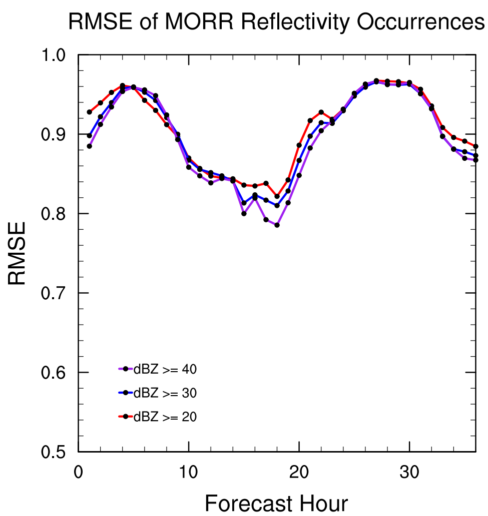


**Figure 4: Hourly root mean square error of simulated radar reflectivity factor threshold exceedances**

Finally, objective verification of simulated radar reflectivity factor (SRF) was conducted for the MORR and WSM6 forecasts; SRF is not predicted when microphysical processes are parameterized with the Kessler scheme. The SRF considered herein was computed as the maximum SRF in each vertical column. Reflectivity occurrences were defined in the SRF forecasts and composite reflectivity observations when any gridbox exceeded thresholds of 20, 30, and 40 dBZ. Figure 4 shows hourly root mean square error (RMSE) computed for MORR SRF occurrences. RMSE was not highly dependent on the reflectivity threshold. RMSE at each forecast hour was comparable at each threshold. A notable diurnal trend was apparent at all threshold values. This result shows an apparent sensitivity to the diurnal cycle of deep convection. RMSE peaked around 16-18 UTC on both days (forecast hours 4 to 6 and 28 to 30), which corresponds to the time when convection initiation began. The error in the model predictions then began to decrease as convection became more widespread and subsequently grew upscale and weakened. The WSM6 RMSE results showed a similar trend as those shown from the MORR forecast, and the values were slightly larger.

## 4. CONCLUDING REMARKS

Deterministic forecasts with varied microphysics parameterization schemes were produced to begin to examine the convective-scale predictability of a multiday outbreak of severe convection on 19-21 May 2013. The Morrison double-moment, Kessler, and WSM6 schemes were employed in this study. Surface temperature predictions at several locations in the Great Plains were verified to assess the sensitivity of a convectively generated cold pool to the model microphysics. The three forecasts showed similar degrees of bias based on location, but overall the MORR forecast more closely predicted the surface temperatures than the KESS and WSM6 forecasts, which incorporated less sophisticated microphysical schemes. Additional analysis is necessary to determine if these factors improved the MORR prediction of subsequent convection relative to the KESS and WSM6 forecasts.

Ensemble data assimilation is being employed to further examine this hypothesized relationship between cold pools and subsequent predictability on the mesoscale and convective-scale. Conventional observations (i.e., surface, upper air, aircraft, and marine) and radar reflectivity observations will be utilized to assess how the convective evolution on 19 May 2013 affected the production of surface cold pools and the convective evolution on the following day. The mesoscale environment will be assessed using surface observations and upper air soundings, including the supplemental MPEX observations. Predictability of supercells will be assessed using model diagnostics including simulated radar reflectivity, updraft helicity, and low-level vertical vorticity. Verification will be conducted using probabilistic verification methodology.

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