P98 SPATIAL VERIFIFCATION OF CONVECTIVE SYSTEMS DURING THE HAZARDOUS WEATHER TESTBED 2010 SPRING EXPERIMENT

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1. Introduction

The collaboration between the Developmental Testbed Center (DTC) and the Hazardous Weather Testbed (HWT) 2010 Spring Experiment (SE) provided objective evaluation using both traditional and object-based verification techniques as a supplement to the subjective evaluation produced by the participants during the experiment. The emphasis of this study will be placed on using an object-based, or spatial, verification method to evaluate the quality of the model forecasts provided during the 2010 SE. Using object-based verification methods provides forecasters with information regarding the forecast and observed fields in terms of displacement, orientation, areal coverage, and intensity. Specifically, the goal of this study is to assess the performance of three deterministic, convection-allowing model forecasts with differing microphysics schemes. Select members of the Center for Analysis and Prediction of Storms (CAPS) Storm-Scale Ensemble Forecast (SSEF) system are used to determine each configurations' ability to accurately forecast the timing, location, and structure of convection.

2. Data

2.1 Model Data

The CAPS SSEF system is a multi-model ensemble with varying configurations (e.g., varying initial and boundary conditions and physics schemes); all members have 4-km grid spacing, are initialized at 00 UTC, and provide forecasts out to 30 h. The DTC evaluated all 26 members of the CAPS SSEF; however, this study will focus mainly on the three members of the ensemble that differ in microphysics scheme only. All the members evaluated in this study were run using the Weather Research and Forecasting (WRF) model with the Advanced Research WRF (ARW) dynamic core. Table 1 shows the individual members assessed in this paper and microphysics scheme used for each.

2.2 Composite Reflectivity Analyses

The National Severe Storms Laboratory (NSSL) National Mosaic and Multi-Sensor Quantitative Precipitation Estimates (QPE; NMQ) three-dimensional composite radar reflectivity data was used as the observational "truth" when computing the verification statistics. The mosaic composite radar reflectivity represents data from all available radars. The data undergoes a set of quality controls before being unified on a 1-km Cartesian grid. More information pertaining to NMQ data can be found at: http://www.nssl.noaa.gov/projects/q2/.

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Table 1. Table showing selected members of the CAPS SSEF and their respective model configurations, including initial conditions (ICs), boundary conditions (BCs), microphysics scheme, land surface model (LSM), and planetary boundary layer (PBL) scheme.

Member	IC	BC	Microphysics	LSM	PBL
arw_m15	arw_cn	00Z NAMf	WRF double-moment six-class (WDM6)	Noah	MYJ
arw_m16	arw_cn	00Z NAMf	WRF single-moment six-class (WSM6)	Noah	MYJ
arw_m17	arw_cn	00Z NAMf	Morrison	Noah	MYJ

3. Verification Methods

Objective evaluation was performed using version 2.0 of the DTC's Model Evaluation Tools (METv2.0), a highly-configurable, state-of-the art verification package. Spatial verification was executed in MET using the Method for Object-Based Diagnostic Evaluation (MODE) tool. The steps taken to identify and verify objects in MODE, as defined in Davis et al. (2006) are: 1) define forecast and observed objects by taking the raw field, then apply a convolution operation to smooth the field; 2) apply a user-defined threshold, which results in a binary mask of resolved objects; 3) depending on user-defined criteria, objects within each field may by merged; 4) matching, if applicable, is performed between the forecast and observation field, with additional merging done, if necessary; 5) quality of the forecast is assessed using output statistics that summarize the objects. For this study, the following configurations were used for both the forecast and observed fields: a convolution radius of 5 grid squares, a convolution threshold of 30 dBZ, and a merging threshold of 27 dBZ. For reference, all configuration files used for objective evaluation for the 2010 SE are found at http://verif.rap.ucar.edu/eval/hwt/2010/configs.php?tab=2.

Verification output for composite reflectivity was calculated every hour, out to 30 h for two domains. The VORTEX-2 domain (see Fig.1 for example of domain configuration) was held constant throughout the experiment, and a second, moveable domain was chosen each day by the forecasters, focusing on an area of meteorological interest for that particular day. MODE output describing the objects and object pairs was loaded into a MySQL database, where aggregated statistics were computed and plotted.

4. Results

4.1 *19 May 2010 Case Study*

On 19 May 2010 a severe, convective weather event occurred over the VORTEX-2 domain. The event produced several tornadoes, large hail, and high wind. Both the dynamic environment (e.g., shortwave trough at 500 hPa, moderate upper-level jet, and strong diffluence) and thermodynamic environment (e.g., warm-air advection accompanied by copious low-level moisture) supported severe weather, including supercells. In short, it provided a classic severe weather setup, for which model performance could be assessed.

Lingering convection from the previous day was centered over the domain throughout the late morning hours (Fig. 1a). As the convection over northern Oklahoma dissipated, the area experienced strong surface heating. Convective initiation occurred in the early afternoon over northwest Oklahoma (Fig. 1b), where a discrete cell formed over the area that experienced clearing and strong daytime heating during the late morning hours. During the active convective stage, several discrete supercells were present over north central Oklahoma, with more cells initiating directly south (Fig. 1c). The objects defined by MODE from the observational field (Figs. 1a-c) are shown in Figs. 1d-f, respectively. The simulated reflectivity fields, as well as the forecast and observed objects, for the WRF Double Moment 6-class (WDM6), WRF Single Moment 6-class (WSM6), and Morrison (double moment) schemes are shown (Figs. 2, 3, and 4, respectively) for the pre-convective period (16 UTC), the convective initiation (21 UTC), and the active convection (23 UTC).

In the pre-convective window, all three models produced horizontal convective rolls on the southwest edge of the convection (i.e., over the panhandle of Texas and western Oklahoma). A slight westward displacement of the forecast field as compared to the observed field is also noted. All three microphysics schemes over-forecast widespread, weak convection. This over-forecasting has potential to enhance the moisture in the environment and minimize the surface heating.

During convective initiation, all three microphysics schemes generally over-forecast the area of convection, especially with the weaker convection. All of the model forecasts develop deep, convective cells; however, they lack the discrete nature and are spatially displaced from the observed objects. The WDM6 scheme over-predicts the peak intensity of the convective cells as compared to the observations and has the highest over-prediction of forecast object area as compared to the other

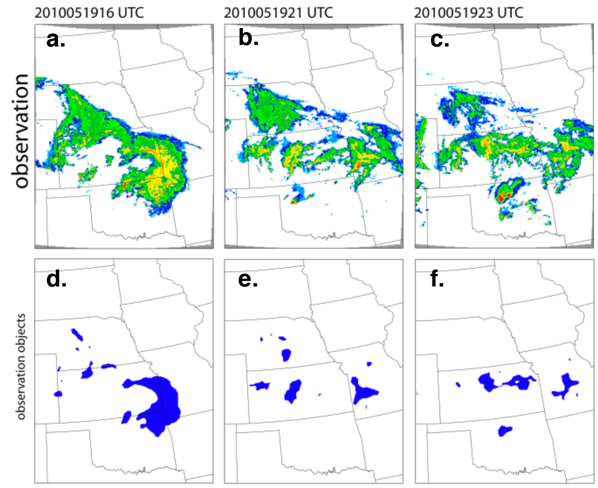

Figure 1. *Top panels show the observed reflectivity field at (a) 16 UTC, (b) 21 UTC, and (c) 23 UTC on 19 May 2010. Bottom panels show the objects (in blue) created by MODE from the reflectivity fields at (d) 16 UTC, (e) 21 UTC, and (f) 23 UTC on 19 May 2010.*

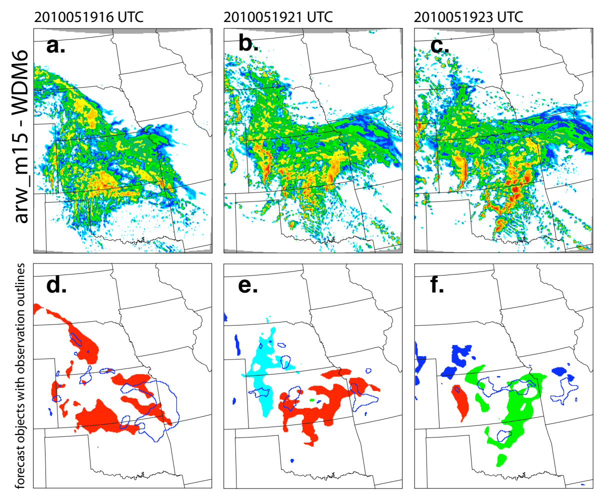

Figure 2. *Top panels show the simulated reflectivity field using the WDM6 scheme at (a) 16 UTC, (b) 21 UTC, and (c) 23 UTC on 19 May 2010. Bottom panels show the objects created by MODE from the reflectivity fields for the observed field (blue outlines) and forecast field (filled shapes) at (d) 16 UTC, (e) 21 UTC, and (f) 23 UTC on 19 May 2010. The royal blue objects in the bottom panel indicated a forecast object that was not matched to an observed object.*

microphysics schemes examined. Note that the observed convection initiated where all three models produced horizontal convective rolls in the pre-convective environment, indicating the residual moisture and cloudiness in the model fields during the pre-convective time period aided in incorrectly forecasting the convective initiation.

A continual trend of over-forecasting weak convection is present during the active convective stage. Both the WSM6 and Morrison schemes produce relatively discrete deep convection during this time; however, the size of the forecast objects is larger than the observed objects. Both of these schemes also appear to slightly under-predict peak intensity. The WDM6 scheme continues to over-forecast in regards to both areal coverage and peak intensity, and produces a more linear convective mode, with deep convective cells embedded within the line.

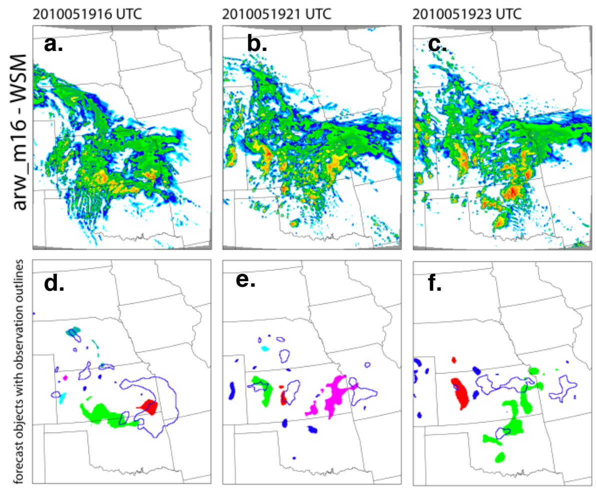

Figure 3. *Same as Fig. 2 except for the WSM6 scheme.*

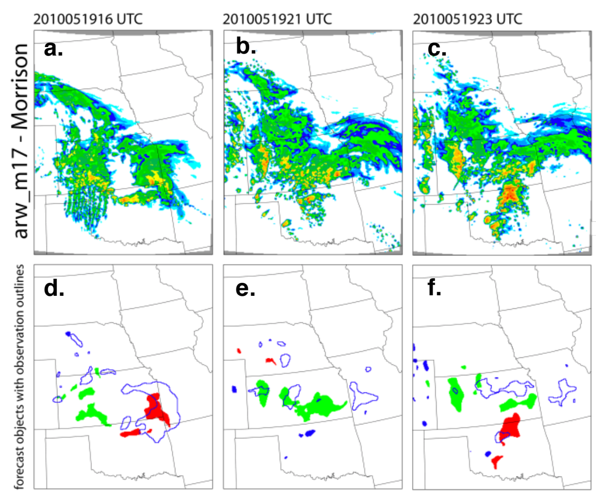

Figure 4. *Same as Fig. 2 except for the Morrison scheme.*

4.2 *Aggregated Results*

Sample size is small (approximately 25), due to the length of the experiment; therefore, it is difficult to attach statistical significance to the assessment of the results. Results were aggregated over the VORTEX-2 domain over the 5-week period of the 2010 SE. In general, the results form the case study above show results that parallel the aggregated results.

4.2.1 Total Object Counts

Fig. 5 shows the total count of all (matched and unmatched) simple forecast and observed objects in the reflectivity fields that have been summed over the 2010 SE. Ideally, the number of forecast objects should be similar to the number of observed objects; at most lead times, all three microphysics schemes overestimate the number of objects. At lead times valid in the morning hours (approximately 12 – 16 UTC), the WSM6 and Morrison schemes have similar object counts to the observations. All three microphysics schemes follow the same general trend of severely over-forecast the number of objects during the active convective time with a peak centered around valid times near 00 UTC (i.e., 00-h and 24-h lead times). Compared to the WSM6 and Morrison schemes, the WDM6 scheme has a consistently larger over-prediction of the number of forecast objects.

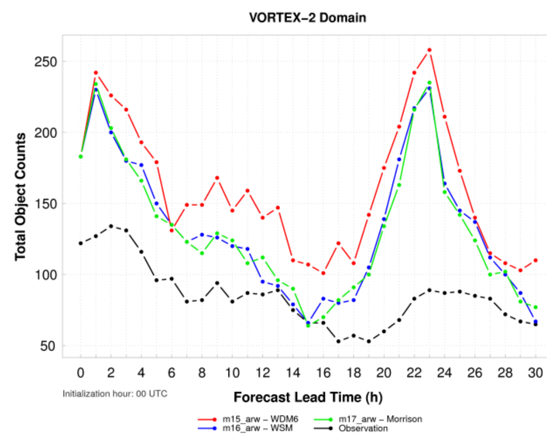

Figure 5. *Plot of total object counts by lead time of the observations (black), WDM6 (red), WSM6 (blue), and Morrison (green) over the VORTEX-2 domain aggregated across all 00 UTC initializations.*

4.2.2 Area Ratio

Fig. 6 shows area ratio of all forecast objects to all observed objects, which is equivalent to the traditional statistical metric frequency bias. Scores greater than 1 indicate an over-forecast, while scores less than 1 signify an under-forecast. A value of 1 is considered a perfect forecast. All three models have the same general trends, with a noticeable peak (i.e., over-forecast) centered on the 23-h lead time; however, the WSM6 scheme exhibits the lowest peak, indicating it over-predicts the least in terms of area forecasted. During the active convective time period prior to the peak, the WDM6 scheme indicates a consistent over-prediction of the forecast object area. During the pre-convective and convective initiation time periods, the WDM6 displays larger area ratios than the WSM6 and Morrison schemes. Similar to the WSM6 scheme, the

Morrison scheme displays under-prediction during the pre-convective time period; however, during the active convective stage, the scheme exhibits a larger peak than then WSM scheme. Compared to the other two physics schemes, the WSM scheme under-predicts at the most lead times (valid from 6 – 17 UTC).

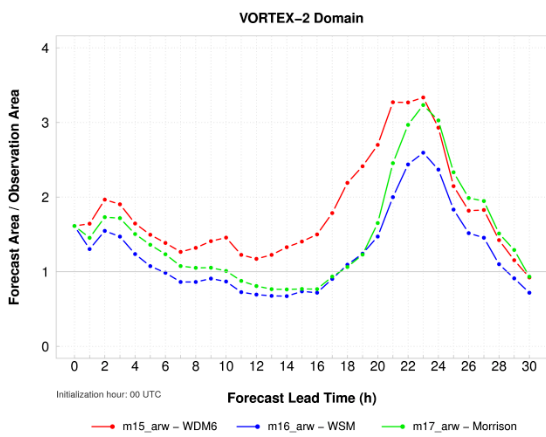

Figure 6. *Plot of median area ratio by lead time of all forecast objects to all observed objects for WDM6 (red), WSM6 (blue), and Morrison (green) for the VORTEX-2 domain aggregated across all 00 UTC initializations.*

4.2.3 Median 90th Percentile Intensity Differences

The median 90th percentile intensity differences between the forecast and observed values is used to assess how the microphysics schemes forecast near-peak intensities (i.e., the intensity of the strongest convective cores). For all forecast lead times, the WDM6 scheme consistently over-forecasts the near-peak intensities (Fig. 7). The median differences for WSM and the Morrison schemes are generally lower than the WDM6 values. These two schemes also indicate a trend towards under-predicting the near-peak intensities between the 22-h and 25-h lead times. While the WDM6 scheme is still over-predicting near-peak intensities during this time, the median values also decrease in magnitude, possibly indicating the difficulty each of these three schemes have with predicting near-peak intensity during the active phase of convection.

5. Discussion and Summary

Three members of the CAPS SSEF system, with differing microphysics schemes, were investigated using spatial verification techniques to determine how or if the microphysics scheme impacted the quality of the forecast. The use of MODE reveals characteristics of the differing microphysics that may assist forecasters in their forecasting process. Overall, the results from the objective evaluation mirrored the findings of the 19 May 2010 case study. On the whole, the WDM6 scheme over-predicted in terms of object counts, area, and near-peak intensities. In general, the WSM6 and Morrison

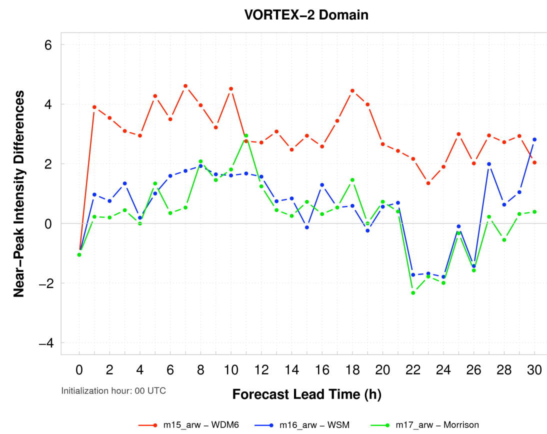

Figure 7. *Plot of the median 90th percentile intensity differences between the forecast and observed values for all observed objects for WDM6 (red), WSM6 (blue), Morrison (green for the VORTEX-2 domain aggregated across all 00 UTC initializations.*

schemes were better performers than the WDM6 scheme; however, when comparing the WSM6 and Morrison schemes, it is difficult to declare a superior microphysics scheme using the results from the spatial verification with this small sample size. Both schemes forecast similar object counts and similar median near-peak intensity differences. In general, the WSM6 scheme had lower median area ratios than the Morrison scheme, thereby favoring the Morrison scheme at lead times valid in the morning hours (~10 – 16 UTC), while the WSM6 scheme was favored at lead times valid during active convection (~21 – 04 UTC). During the active convection (~00 UTC), the WSM6 scheme has similar object counts to the Morrison scheme, but has a smaller area ratio, indicating the objects produced by the WSM6 scheme are smaller in area than the Morrison scheme.

Acknowledgements

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References

Davis, C., B. Brown, R. Bullock, 2006: Object-based verification of precipitation forecasts. Part I: Methodology and application to mesoscale rain areas. *Mon. Wea. Rev.,* **134**, 1772-1784.