WRF Forecasts of Recent Significant Weather Events: A Comparison of ARM and NMM Cores

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I. Introduction

During the past year, the Advanced Research WRF (ARW, formerly known as Eulerian Mass) and Nonhydrostatic Mesoscale Model (NMM) cores of the WRF model have been compared through extensive retrospective testing as part of the WRF Test Plan (Seaman et al. 2004; DiMego et al. 2004; Bernardet et al. 2004). These papers present summary statistics for 30-day retrospective time periods based on eight different model configurations (four configurations for each core). In contrast, this paper summarizes the forecasts from the control run of each core for individual events for the purpose of gaining physical understanding of the differences between the cores. These events feature heavy-precipitation from both warm and cool seasons. While it will be difficult to draw general conclusions from each case, we will focus on errors that reflect model biases uncovered within the larger statistical samples.

The data used in this study are forecasts and corresponding initial conditions that serve as truth for the verification of spatial patterns. Statistics are based on point-wise comparison with observations, either upper-air data or precipitation data derived from the NCEP River Forecast Center (RFC) analyses. Forecasts from both cores extend to 48 h daily during each retrospective period and are available at 3 h intervals. When comparing the forecasts from the control run of each dynamical core, it is important to keep in mind differences between these forecasts can also be the result of differences between the physics packages used for each core and differences between the initial conditions (ARM – RUC / NMM – Eta).

II. Case 1: 23-25 August 2002

For the warm season, we focus on the Central Domain forecasts initialized at 1200 UTC 23 August

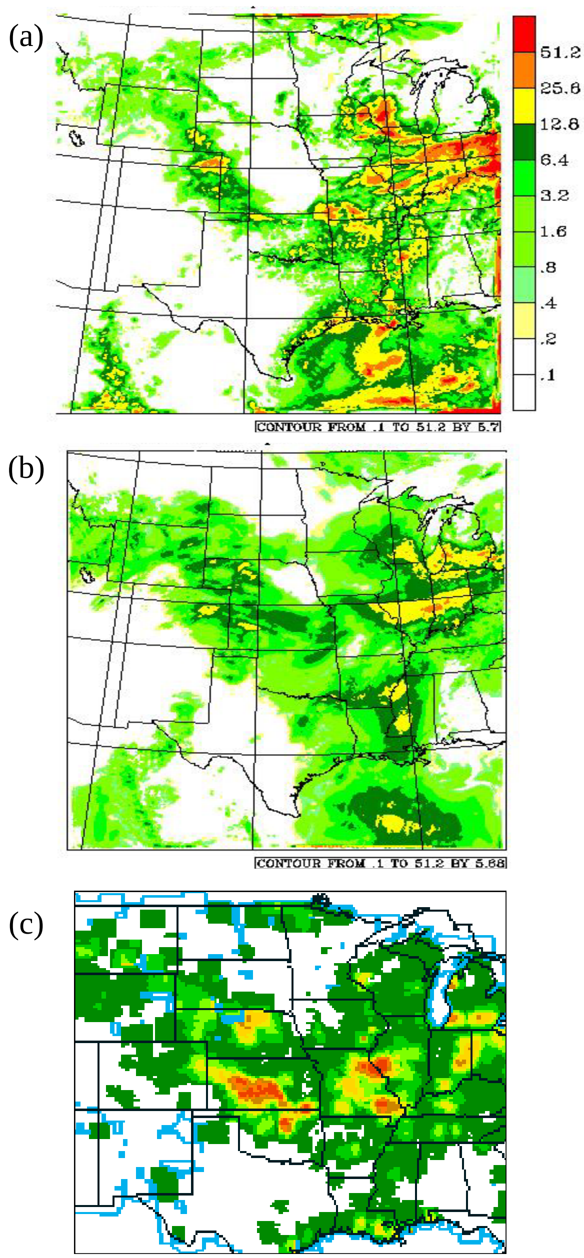

Figure 1. 24-h accumulated rainfall valid 1200 UTC 24 August 2002 for (a) ARW, (b) NMM, and (c) RFC analysis.

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2002. The 24 h precipitation forecasts from each core valid at 1200 UTC 24 August 2002, as well as the corresponding observations, are presented in Fig. 1. The most significant area of observed rainfall during this time period occurred over Kansas in association with a mesoscale convective system (MCS). Other systems initiating over Missouri produced more than 50 mm of rain, while weaker systems produced local rainfall maxima over central Nebraska, the Indiana/Ohio border, and southern Michigan.

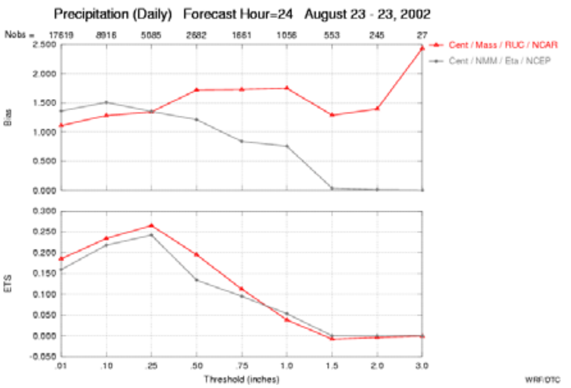

Figure 2: Bias (top) and ETS (bottom) for 24-h precipitation forecasts valid 1200 UTC 24 August 2002.

Neither core captured the heavy rainfall over Kansas, although the NMM did produce a swath of light rainfall in this area. Both models predicted heavy rainfall initiating over Missouri and extending to Ohio, with the rainfall generally being heavier in the ARW forecast. This area of heavy rainfall includes the observed local systems noted above, but the extensive swaths of predicted precipitation contrast to the more localized observed heavy rainfall. It is unlikely that the latter is an observational artifact.

The bias and equitable threat scores (ETS) corresponding to the precipitation fields shown in Fig. 1 reveal opposing biases for heavy rainfall with ARW above and NMM below observations (see Fig. 2). The ETS is near zero for amounts greater than 25 mm (1 inch). Thus, the skill of both cores for this case is even lower than is typical for warm season rainfall (Olson et al. 1995).

Winds and dew point temperatures at 850 hPa (Fig. 3) reveal that the low-level jet over the Texas Panhandle in the ARW was much weaker than in the NMM. The NMM agreed better with the corresponding analyses (not shown). Perhaps because of this error, the frontal boundary in the ARW was too far south, and because convection appeared tied to this feature (in both the model and real atmosphere), the convection in the ARW occurred in the wrong location.

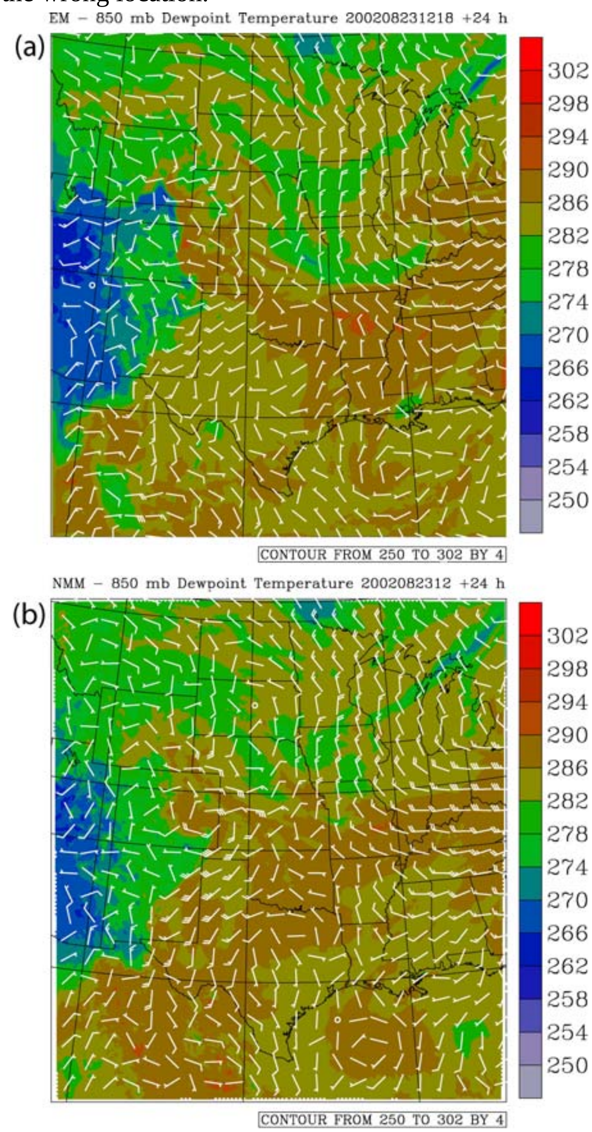

Figure 3. 24-h forecast of wind and dew-point temperature at 850 hPa valid 1200 UTC 24 August, 2002 from (a) ARW; (b) NMM.

III. Case 2: 15-17 February 2003

For the cool season, we focus on the Eastern Domain forecasts initialized at 1800 UTC 15 February 2003. The 24 h precipitation forecasts valid at 12 UTC 17 February 2003, as well as the corresponding observations, are presented in Fig. 4. Observed precipitation during this time period extended from

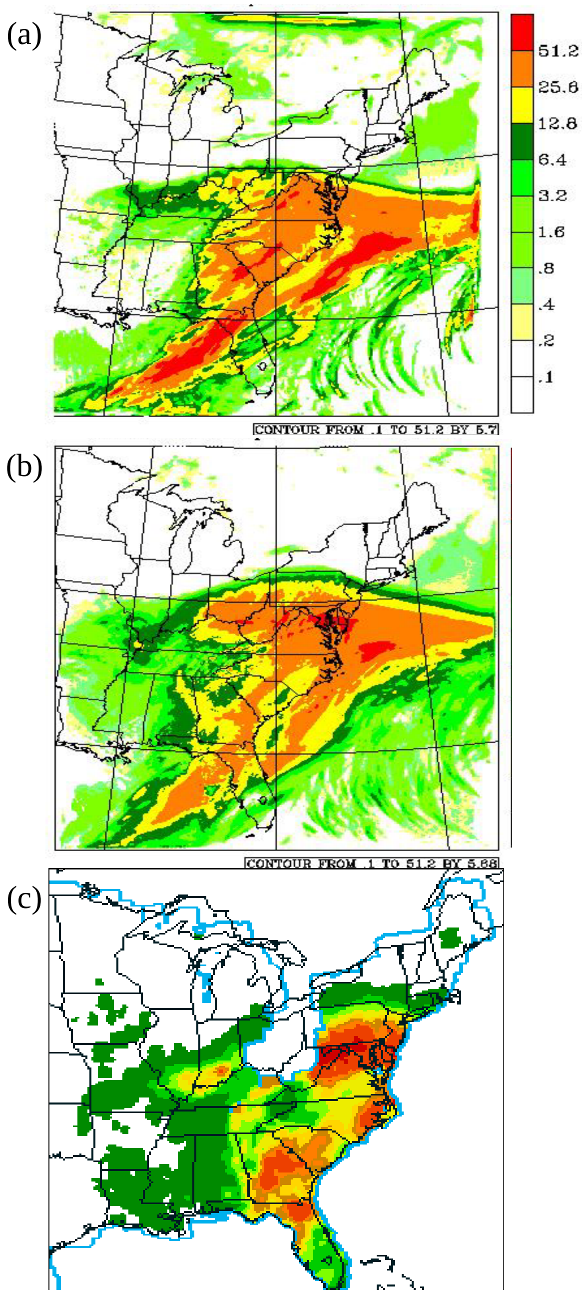

Figure 4: 24-h accumulated rainfall valid 1200 UTC 17 February 2003 for (a) ARW, (b) NMM, and (c) RFC analysis.

New York to Florida with four regions of significant accumulations: a region centered on the Pennsylvania/Maryland/Virginia border, the coast of North Carolina, central Georgia, and northern Florida.

Both cores predicted a strong storm would impact a significant portion of the East Coast during this time period. However, the ARW precipitation distribution

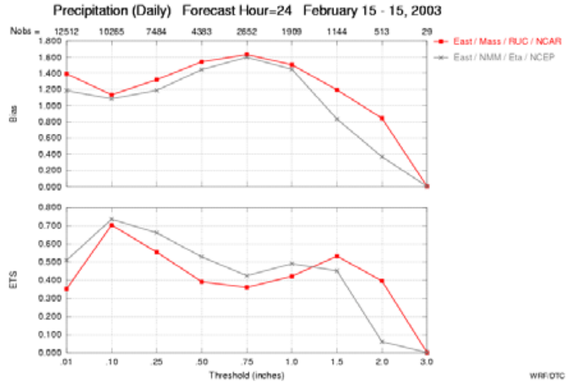

Figure 5: Bias (top) and ETS (bottom) for 24-h precipitation forecasts valid 1200 UTC 17 February 2003.

suggests the storm track predicted by this core configuration was south of that observed, whereas the NMM distribution suggests this core configuration handled the storm track fairly well. There was a corresponding large error in the location of the northern edge of the precipitation shield, with NMM much closer to observations.

Both cores failed to capture the actual intensity of the northernmost precipitation maximum, as well as any hint of a maximum along the coast of North Carolina. The NMM forecast also failed to capture the southernmost precipitation maxima, whereas the ARW forecast did manage to produce a precipitation maximum over northern Florida.

The bias and equitable threat scores (ETS) corresponding to the precipitation fields shown in Fig. 4 are similar (Fig. 5). The ARW maintains a slightly lower ETS than the NMM except for the heaviest precipitation thresholds. The bias in both cores is similar.

The temperature and winds at 850 hPa indicate that the ARW maintained enhanced cold advection relative to the NMM over the northeastern states (Fig. 6). The ARW also featured much weaker southeasterly flow and warm advection over the Mid-Atlantic states, and weaker southwesterly flow over Tennessee and Kentucky. Both of these factors contribute to more positive temperature tendencies in the NMM.

A vertical profile of temperature biases for this case indicates that the ARW was colder than NMM at all levels, especially at 850 hPa, although the bias error was largest at 700 hPa. While excessive cold advection to the north and a deficit of warm advection to the south both contribute to the temperature bias, and hence, are consistent with the position error in precipitation, the ultimate causes for these biases are still being investigated.

IV. Summary

We have conducted a preliminary verification of two cases from the extensive set of retrospective simulations performed by the DTC. One case was a warm season heavy rainfall case over the Midwest, the other a major winter storm along the East Coast. While we cannot generalize our results, we do note that the ARW had considerable difficulty producing low-level southwesterly jets with attendant warm advection in both cases and had the primary frontal boundaries and precipitation axes displaced further south as a result. Whether this is a general trend in the model, and whether it depends more on physical parameterizations or initial conditions is still a subject of investigation.

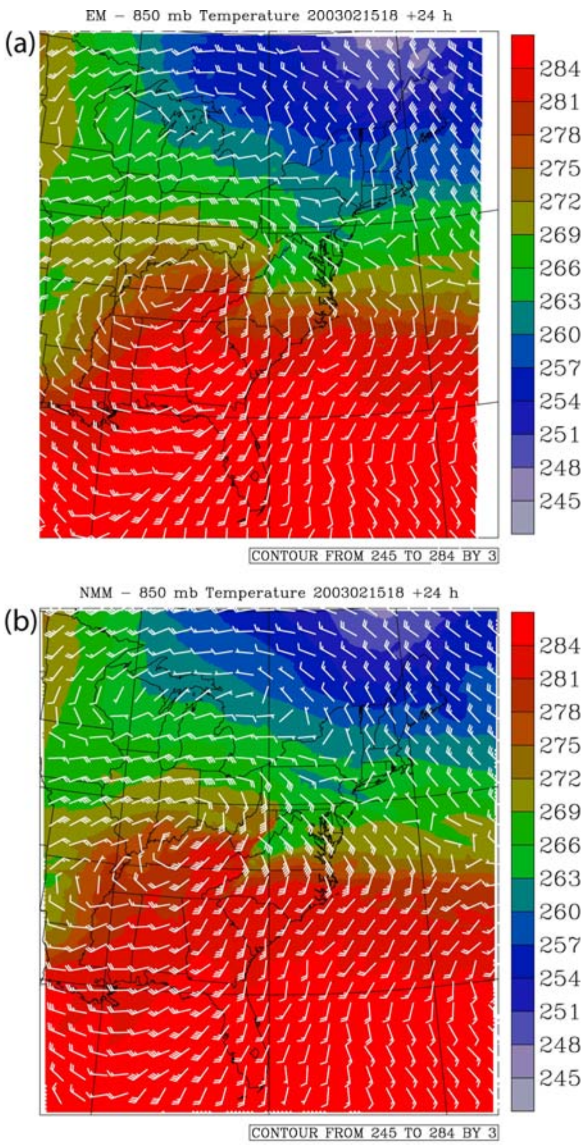

Figure 6. 24-h forecasts of wind and temperature at 850 hPa valid 1800 UTC 16 February, 2003 from (a) ARW; (b) NMM.

V. References

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