Report on NCAR task 09.5.24.2
Part of *"Test WRF Rapid Refresh model at 3-km resolution towards High-Resolution Rapid Refresh Task."*
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1. Introduction

In 2009, NCAR ran the WRF-ARW over the central United States for the spring convective season from May 5th to June 30th using initial conditions provided by the 13-km Rapid Refresh analysis. Figure 1 shows the area of the ARW 3-km domain, and a typical initial state from 12Z 25 June 2009, where the reflectivity shows some isolated regions of precipitation from the Rapid Refresh analysis. Forecasts were initialized at 00Z and 12Z each day resulting in a total of 114 ARW forecasts out to 48 hours with hourly outputs. However, due to technical difficulties 86 of these used the Rapid Refresh initial conditions, while 28 used the back-up GFS initial conditions. All forecasts used the GFS boundary conditions. We can take advantage of the sufficiently large sample sizes with and without Rapid Refresh initial conditions to evaluate their impact in a statistical sense by sub-sampling the 114 forecasts in these two categories. Table 1 shows that the GFS-initialized forecasts were mostly near the center of the two-month period, and these were equally divided, 14 at the 00Z and 14 at the 12Z initial times. This leads us to expect no significant bias related to seasonal change or diurnal effects. We also examine the results separately for 00Z and 12Z initializations.

The model was WRF Version 3.1. Physics options used in these forecasts were the newest Thompson microphysics with double-moment rain added, the MYJ PBL, the Noah land-surface model, RRTM longwave, and Goddard shortwave radiation. No cumulus scheme was employed due to the use of a cloud-permitting 3-km grid.

In this initial report, the analysis will be confined to domain-total precipitation averaged over the forecasts or sub-sets of them rather than looking at individual forecasts or areas. In particular we will focus on the hourly precipitation domain totals as a function of forecast time. This report does not address precipitation verification or observations, only the model forecasts.

2. Rainfall Spin-Up Analysis

Separating the forecasts into 00Z and 12Z initializations and RUC and No-RUC initial conditions shows distinct rainfall signals that last more than 12 hours into the forecasts. Generally in this period and region, there is a well-defined diurnal cycle in rainfall peaking just before 00Z and a minimum around 10Z to 15Z, during which the hourly rainfall varies by a factor of two from a domain-averaged 0.2 mm/hour down to 0.1 mm/hour. The characteristics of 00Z and 12Z runs with and without RUC initialization differ significantly and will be discussed separately.

The 00Z initialization times are close to the diurnal rainfall peak, and from Figure 2a it can be seen that, while the RUC runs are quickly able to reach a peak in the first few hours, the No-RUC runs never produce much more than the diurnal minimum in that period. The rainfall from RUC and No-RUC runs finally converge by the time of the minimum around 12Z. The 00Z RUC runs produce a peak at 03Z, 3 hours into the forecast and a little later than the peaks at 24 and 48 hours into the forecast. The 3-hour peak is also slightly larger than the later peaks in the forecast indicating that the rainfall is slightly overactive as a result of the delay. The later rainfall tends to be larger with the RUC initialization than with the GFS initialization through 48 hours.

The 12Z initializations shown in Figure 2b show quite a different set of characteristics. The RUC runs show a minor peak at 14Z, 2 hours into the forecast, indicating that even at the diurnal minimum there is some instability in the 13-km initial conditions that is released by the 3-km model. By 00Z these simulations are able to capture a realistic phase and amplitude of the normal diurnal peak, slightly larger than the second peak at 36 hours on average. The No-RUC runs spin up from almost zero rainfall in the first hour to catch up with the RUC runs by 8 hours, and then significantly overshoot the mean diurnal peak at 22Z to 23Z, giving 10% more hourly precipitation than the RUC runs at that peak. The later rainfall tends to be smaller with the RUC initialization than without it, opposite to what was seen with the 00Z runs. In both cases the later rainfall positively correlates with the relative amplitude of the first peak, suggesting that there perhaps exists a connection through land-surface soil moisture.

Another interesting difference, but speculative based on the limited cases, is the timing of the diurnal rainfall minimum later in the forecasts, i.e. 24 hours into the 12Z runs and 36 hours into the 00Z runs. These seem to show a characteristic that the RUC-initialized runs have a minimum near 15Z, while the No-RUC runs have an earlier minimum around 10Z, regardless of whether the run had a 00Z or 12Z initialization. This may be an interesting area for further study, but it is noted that the sample size may be small, so it is not clear whether this is a significant difference in a statistical sense.

3. Discussion and Conclusion

The RUC initialization has clearly helped in the spin-up of precipitation in the first few hours with impacts seen to twelve hours. For 00Z runs, the peak rainfall was represented well in the first six hours with this initialization, but the peak was largely missed without it. For the 12Z runs without the initialization, the rainfall took up to 8 hours to reach realistic levels. There is evidence, however, that the peak near 00Z is overestimated, while with the initialization the 00Z peak is realistic in amplitude and phase. There is some speculative evidence that the effects of the initial 12 hours last through the 48-hour forecast in some rainfall characteristics.

This study has focused on the gross characteristics of the forecasts, namely domain-averaged rainfall rates, but further study is needed on selected cases to evaluate the evolution of convection in the early hours of RUC-initialized forecasts, and especially the development of the convective mode from the 13-km initial conditions to the 3-km resolved state.

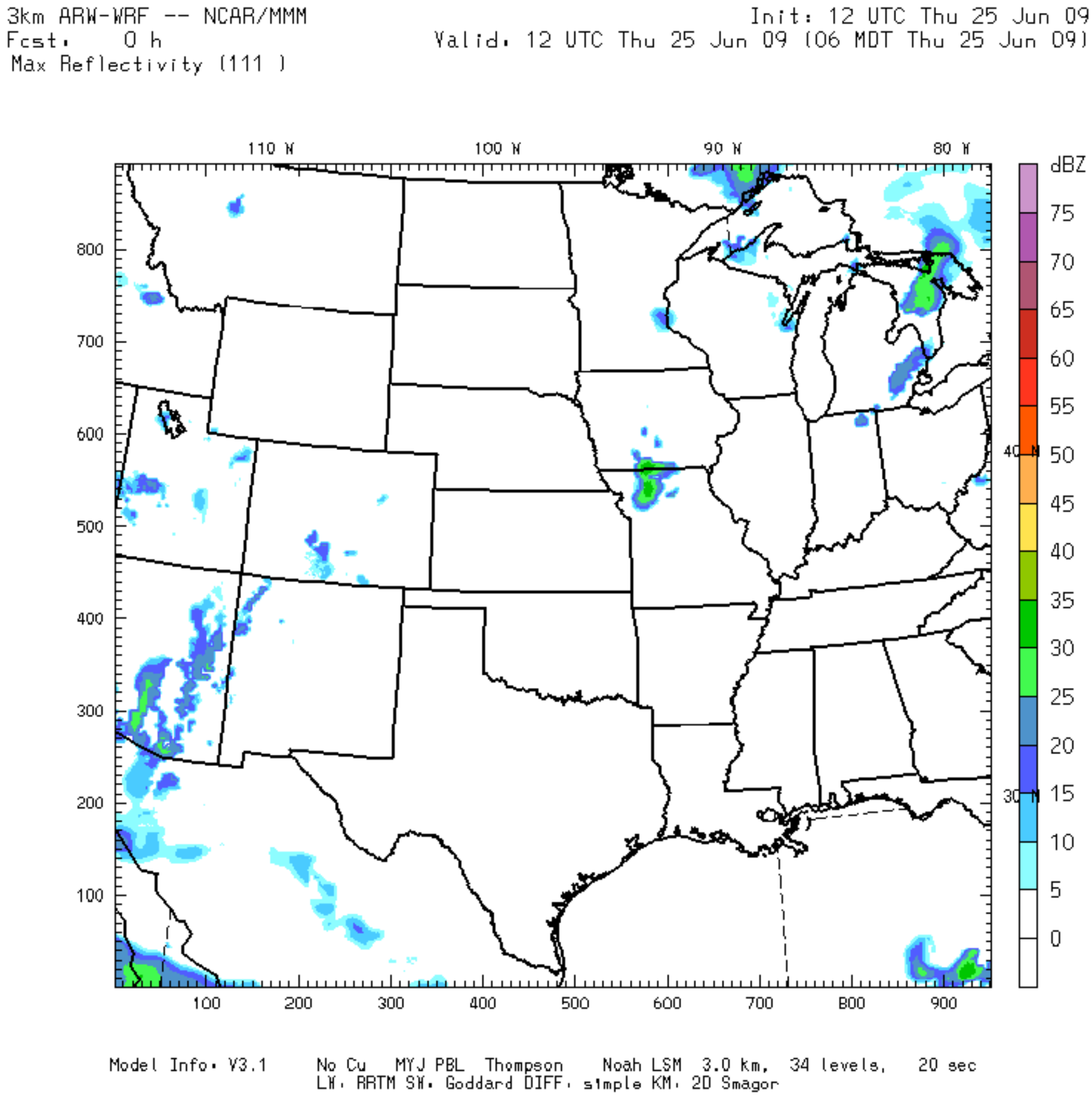

Figure 1. ARW 3-km domain with initial maximum column reflectivity for 12Z 25 June 2009.

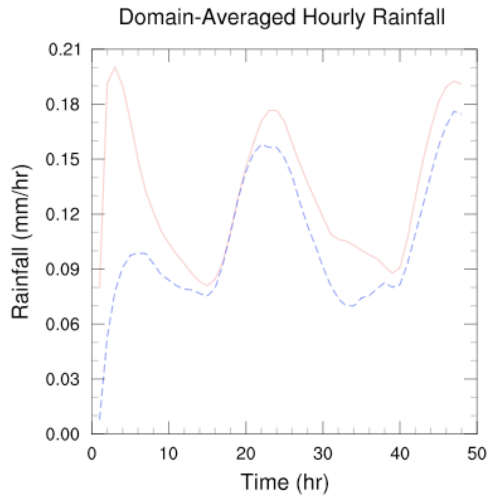

Figure 2a. 00Z initialization, RUC-initialized (red), No-RUC initialized (blue dashed)

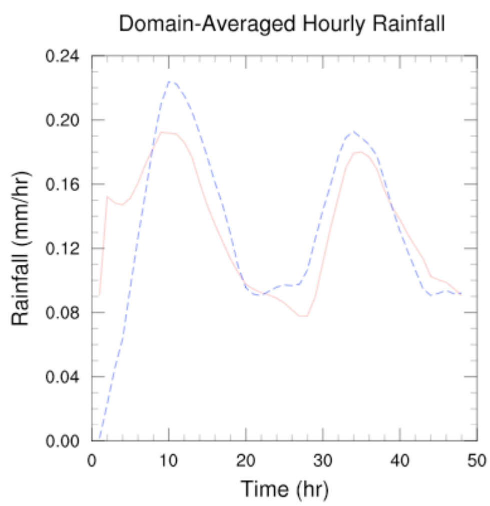

Figure 2b. 12Z initialization, RUC-initialized (red), No-RUC initialized (blue dashed)

May	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	3
00Z	-	-	-	-															x	x	x				x		x	x	x	x	x
12Z	-	-	-	-														x		x				x	x	x		x	x	x	x
June	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
00Z	x	x	x							x						x															-
12Z	x	x	x							x					x																-

Table 1. Forecasts from May 5th to June 30th 12Z and 00Z where x marks GFS-initialized forecasts