MM5- AND WRF-SIMULATED CLOUD AND MOISTURE FIELDS DURING
A CONVECTIVE INITIATION EVENT

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1. INTRODUCTION

In this paper, a comparison of high-resolution MM5- and WRF-simulated cloud and moisture fields will be presented for a convective initiation event that occurred on 12 June 2002 during the International H_20 Project (IHOP). This convective event was characterized by the propagation of several bands of thunderstorms across Kansas, Missouri, and northern Oklahoma during the morning and afternoon. By 2100 UTC, an additional line of strong convective cells had developed along a weak low-level trough from western Texas into southeastern Kansas (Fig. 1). This region of convective initiation was characterized by strong low-level moisture convergence and by very complex lower-tropospheric water vapor structures and wind patterns.

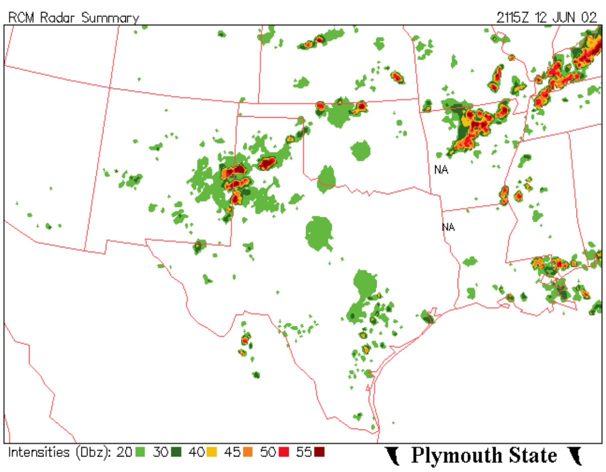

Figure 1. WSR-88D radar summary at 2115 UTC on 12 June 2002.

2. MODEL CONFIGURATION

Simulated atmospheric fields were generated using version 3.6.1 of the MM5 and version 1.3 of the WRF. Both model simulations were initialized at 0000 UTC 12 June 2002 using 1 degree GFS data. Each simulation was then run for 30 hours on a single 280 x 280 grid point domain with 4 km horizontal grid spacing and 60 vertical levels. The geographical region covered by this domain is shown in Fig. 2.

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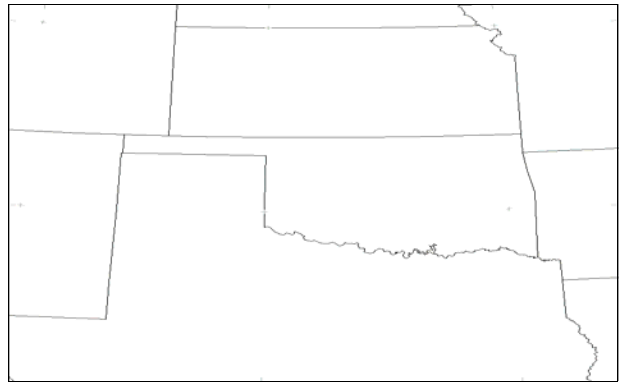

Figure 2. Model domain used by the MM5 and WRF simulations.

In order to facilitate a comparison of model results, similar parameterization schemes were chosen when possible. Common parameterization schemes used by both simulations include:

- RRTM/Dudhia radiation
- MRF planetary boundary layer
- OSU land surface model
- Explicit cumulus (no cumulus parameterization)

The WRF simulation also employed the NCEP 5-Class microphysics scheme while the Reisner-1 scheme was used for the MM5 simulation.

3. SIMULATION RESULTS

Fig. 3 shows the total model precipitation for the MM5 and WRF simulations. Though both model simulations produced copious amounts of rainfall in excess of 15 cm over eastern Kansas and western Missouri, a complete absence of precipitation occurred over western Oklahoma and the panhandle of Texas during the WRF simulation. Analysis of the hourly precipitation totals revealed that the MM5 simulation successfully captured the initiation (albeit 1-2 hours late) and subsequent development of the thunderstorms along the dry line over western Texas (refer to Fig. 1) while the WRF model was unable to generate any deep convection over this region. The lack of thunderstorm development during the WRF simulation will be examined in greater detail in section 4.

Comparison of the total model precipitation also indicates that the WRF model generally produced less precipitation over eastern Kansas and western Missouri than the MM5 simulation. It is also evident that the

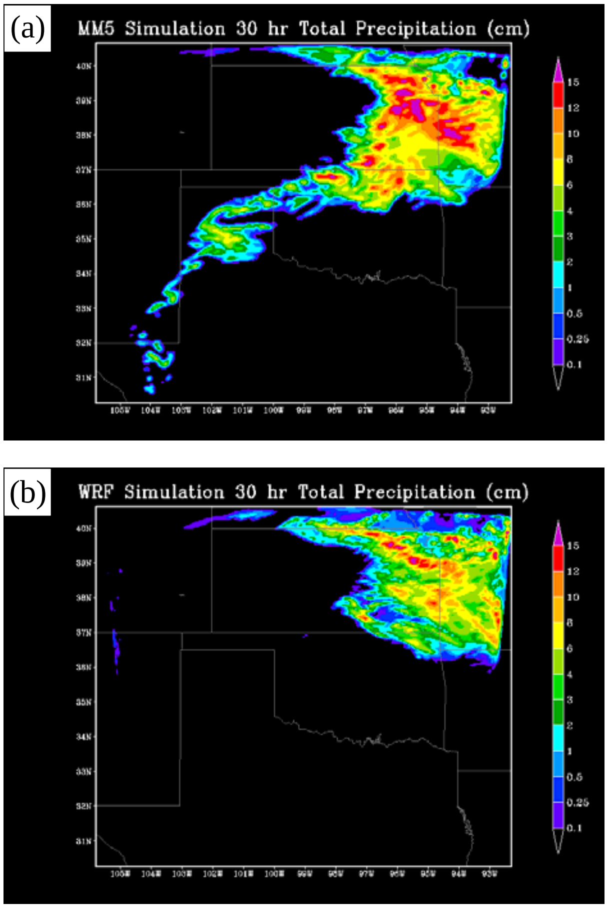

Figure 3. Total model precipitation (cm) from 00 UTC 12 June 2002 to 06 UTC 13 June 2002 for the (a) MM5 simulation and the (b) WRF simulation.

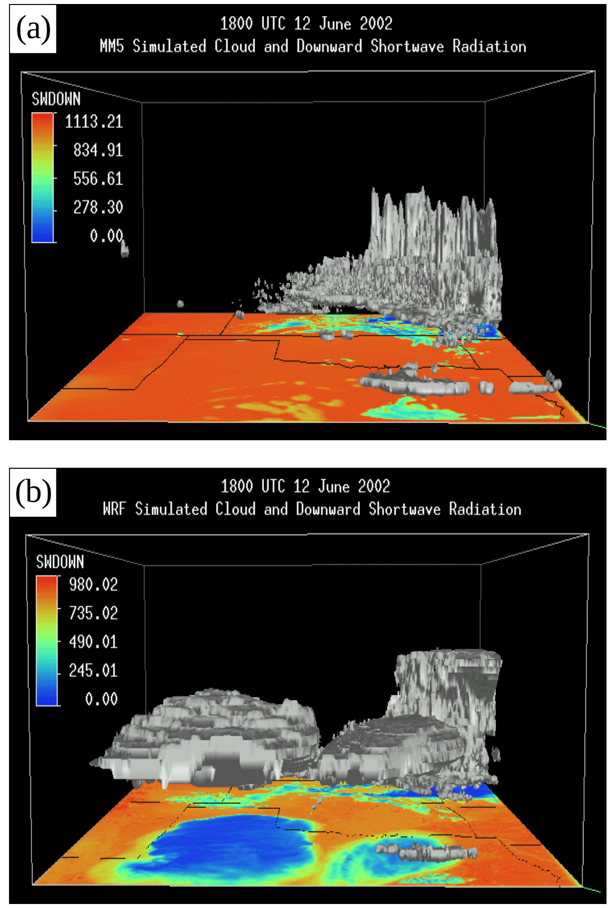

Figure 4. Simulated liquid cloud water (mixing ratios greater than .0001 kg/kg shown in white isosurfaces) and downward shortwave radiation flux (W m^{-2}) at the surface (shown in colored horizontal field) valid at 1800 UTC 12 June 2002 for the (a) MM5 simulation and the (b) WRF simulation.

WRF total precipitation field qualitatively contains more spatial variability than the MM5 total precipitation field. The improved ability of the WRF model to simulate fine-scale precipitation structure is likely due to the model's use of numerical methods that are more appropriate than the MM5's at such a high resolution.

4. TEXAS PANHANDLE CONVECTIVE INITIATION

As discussed briefly in Section 3, the WRF model was unable to generate any deep convection over the Texas panhandle. Analysis of the simulated cloud fields revealed that the MM5 simulation was characterized by generally clear conditions and by substantial downward shortwave radiation flux in excess of 1000 W m^{-2} across much of Texas and Oklahoma (Fig. 4a). This situation stands in sharp contrast to the very thick (~4-5 km deep) mid-level cloud layer extending across much of western Texas in the WRF simulation (Fig. 4b). Time animations show that this cloud field initially developed within a small region of ascent over extreme southwestern Texas that was not present in the MM5 simulation. The cloud field expanded very rapidly toward the northeast as additional clouds developed downstream within a region of weak ascent. The development of this thick cloud shield greatly diminished the amount of incoming solar radiation reaching the surface in western Texas.

The presence of the thick cloud layer in the WRF simulation and the subsequent reduction of the incoming solar radiation had a profound influence on the amount of sensible heating at the surface. At 2100 UTC, surface temperatures ahead of the dryline in western Texas were below 80° F with a small area near the initial convection (refer to Fig. 1) remaining below 75° F (Fig. 5b). Meanwhile, surface temperatures in the MM5 simulation had reached over 90° F across most of this region with some areas experiencing temperatures in excess of 95° F (Fig. 5a). Thus, the surface temperatures near the region of convective initiation were nearly 20° F cooler in the WRF simulation than in the MM5 simulation. The dramatically lower surface temperatures in the WRF simulation severely limited the growth of instability near the dry line, which resulted in the complete suppression of thunderstorms across this region.

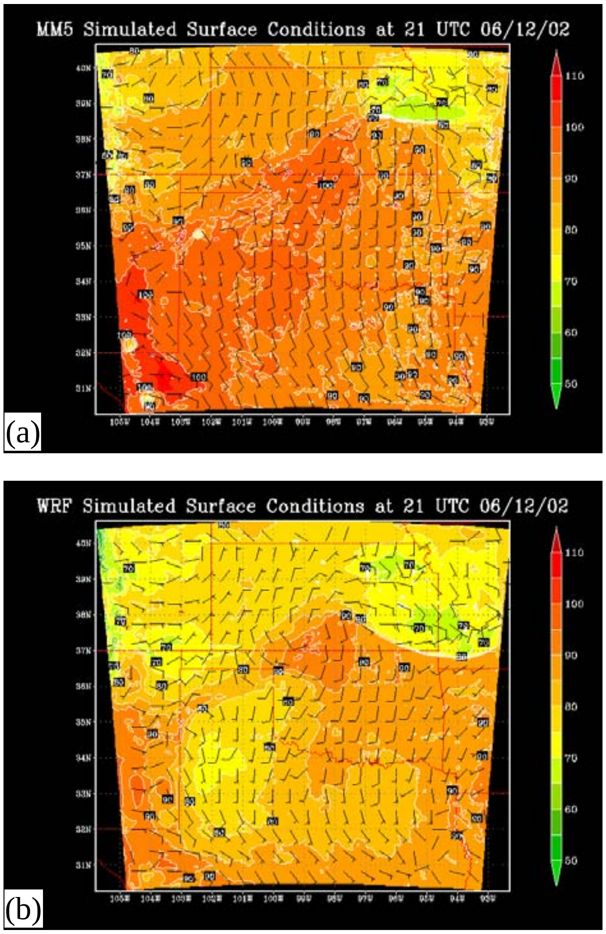

Figure 5. Simulated surface temperature (°F) and surface wind (m s^{-1}) valid at 2100 UTC for the (a) MM5 simulation and the (b) WRF simulation.

5. CONCLUSION

Very high-resolution MM5 and WRF simulations were performed for a convective initiation event during the 2002 International $H_2$0 Project (IHOP). The MM5 simulation was able to successfully capture the development of a line of strong convective cells over western Texas while the WRF model was unable to generate any deep convection over this region. The lack of deep convection in the WRF simulation was traced back to the presence of a deep (4 to 5 km thick) mid-level cloud layer over western Texas that severely limited the daytime warming at the surface. The presence of much lower surface temperatures greatly reduced the convective instability, thereby suppressing the development of deep convection during the WRF simulation.

6. ACKNOWLEDGEMENTS

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