P4M.4 NUMERICAL INVESTIGATION OF THE MULTI-SCALE PROCESSES INDUCING CONVECTION INITIATION FOR THE 12 JUNE 2002 IHOP_2002 CASE STUDY.

S. Bastin[1], T. Weckwerth[1], F. Chen[1], K. Manning[1]
[1] National Center of Atmospheric Research, USA, bastind@ucar.edu

1. INTRODUCTION

This study, using numerical simulations, investigates a case of convection initiation observed during the International H_2O Project (IHOP_2002) experiment that took place in the Southern Great Plains of the U.S. during May-June 2002 (Weckwerth et al., 2004). This convective event was characterized by the propagation of several bands of thunderstorms across Kansas, Missouri and northern Oklahoma during the morning and afternoon. This study focuses on the late-day convection that developed over the Oklahoma/Kansas border. The small scale of early convective storms, as well as the complex interactions of multi-scale processes, makes the resultant severe storms difficult to forecast. The aim of this study is to better understand the influence of the processes at different scales, from the synoptic scale down to the scale of horizontal convective rolls, on the location and timing of convection.

In this paper, we present results from current work, which involves a high resolution mesoscale numerical simulation of this case. This simulation is designated to realistically depict high resolution water vapor features and late-day convection over the Oklahoma/Kansas border.

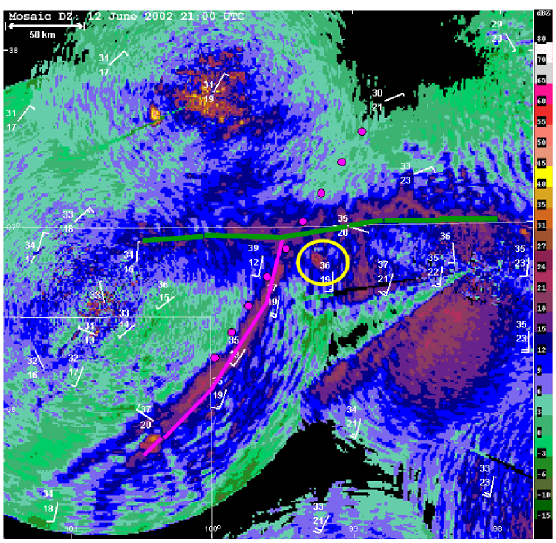

Figure 1: Composite of radar reflectivity measurements at 2106Z 12 June 2002. The pink and green lines designate the mesoscale dryline and outflow boundary, respectively. The yellow circle shows the initiation of convection at this time, several kilometers from the mesoscale features.

2. CI CASE DESCRIPTION

On June 12, the synoptic forcing is propitious to the development of deep convection, with the formation of a dryline and an outflow boundary that intersect near the Oklahoma/Kansas border. These two mesoscale features are indicated on Figure 1 by a pink and a green line, respectively. The light white line indicates the borders of Oklahoma. The dryline is generated by the convergence of a moist southerly flow coming from the Gulf of Mexico, and a drier continental air mass. The outflow results from a thunderstorm that developed over Kansas after 22Z on June 11, 2002 and that moved southwards. On June 12, radar reflectivity measurements, however, show that the late-day storms did not form directly along these mesoscale boundaries. Other physical processes in the boundary layer affect the initiation of convection. In particular, observations show the existence of gravity waves, a mesocyclone and horizontal convective rolls in the area where the convection developed.

3. MM5 SIMULATIONS

3.1. Model configuration

Simulations are performed using the NCAR-PSU MM5 mesoscale model (Grell et al., 1994) to assess the impact of forcing at different scales on the modeled pre-storm environment.

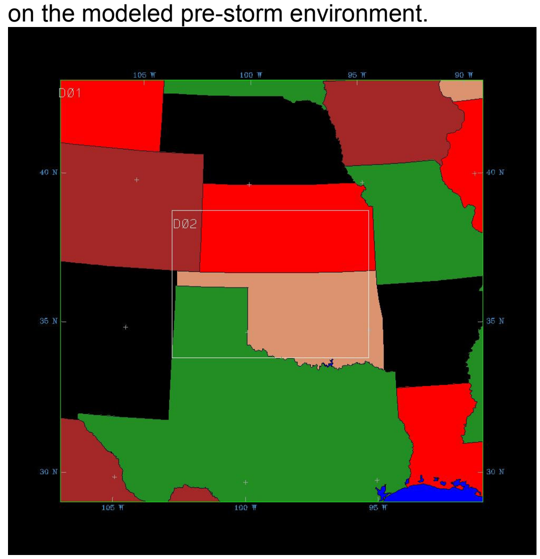

Figure 2: Domains 1 and 2 of the simulation.

In the simulation from which results are presented in this paper, the NCEP ETA analyses are used to initialize a nested MM5 domain at 12-km grid spacing for the outer domain and 4-km grid spacing for the inner domain (Fig. 2). The model is initialized using a high-resolution land-surface data assimilation system (HRLDAS) (Chen et al., 2004) to ensure a better surface forcing. Objective analysis is used to improve the NCEP analyses on the mesoscale grid by incorporating information from observations of temperature, humidity and wind from surface and radiosonde reports. The special IHOP observations are not included in this dataset and can be used to validate the simulation.

At the time of submission of this document, sensitivity testing is underway to determine the optimal model configuration. In particular, the use of analyses from the Rapid Update Cycle (RUC-II) Regional Modeling and Data Assimilation System (Benjamin et al., 2004a,b) or from the Local Analyses and Prediction System (LAPS) to initialize and force the boundary conditions is evaluated. A special configuration of LAPS was developed for IHOP, in which “Level-II” WSR-88D radar data, GOES sounder 3-layer precipitable water fields, and mesonet surface observations were all assimilated. Also, different cumulus and microphysics parameterizations are tested.

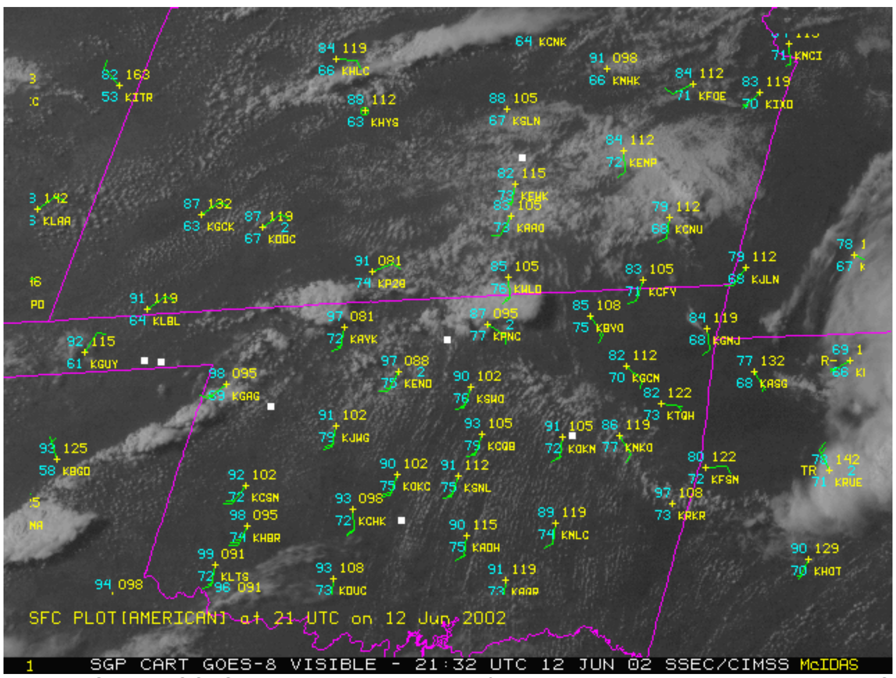

Figure 3: Satellite GOES-8 Visible Imagery with surface observations on June 12 at 2140 UTC.

3.2 Results

The dryline separates a region of strong low-level moisture in the south-eastern part of the investigated area with a region cooler and drier, to the west (see blue numbers on Fig. 3). West of the dryline, the wind has a northerly direction, while a southerly wind blows in the south. The outflow boundary induces a low-level wind shear over the Oklahoma/Kansas border, with southerly wind southern to this line and easterly-southeasterly wind north of it. At 2100 UTC, the outflow boundary is oriented east-west between -99 and -97ºE at latitude 37ºN and then it takes a northwest-southeast orientation.

Figure 3 shows the GOES-8 satellite visible imagery with surface observations at 2140 UTC. We can clearly see the development of convection above the dryline. Two points of stronger convection are discernable along the Oklahoma/Kansas border. Also, thin clouds illustrate the northwest-southeast orientation of an outflow boundary with a wind shear along it.

Model outputs at 2100 Z are shown in Figs. 4 and 5. Figure 4 displays the simulated lower-level water vapor mixing ratio in g kg^{-1}, superimposed with the low-level wind. The dryline is well simulated with a good location and orientation. The humidity gradient that defines the dryline is also consistent with observations. Concerning the outflow boundary, results are not so good. This boundary does exist in this simulation and not other, but the outflow boundary that has a east-west orientation over the Oklahoma/Kansas border does not exist and the one that is oriented northwest-southeast is located too far west. The consequences are important since the most important convergence areas are not well located.

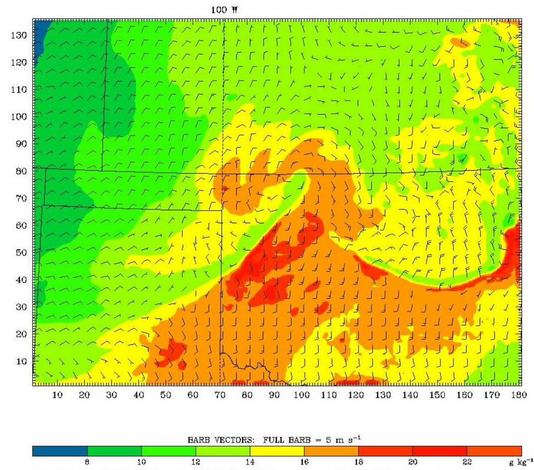

Figure 4: Simulated lower-level water vapor mixing ratio in g kg^{-1} in color, superimposed by the lower level wind field (arrows).

Figure 5 shows the column-integrated cloud liquid water at 2100 UTC. The convective system that initiates the outflow boundary is still present in the model while no convection is visible on the satellite imagery (Fig. 3). Additionally, no convection exists along the dryline. Figures 6 and 7 show that the convection along the dryline initiates and develops later. But the two points of strong convective activity that are visible on observations along the Oklahoma/Kansas border do not exist here, due to the bad location of the outflow boundary.

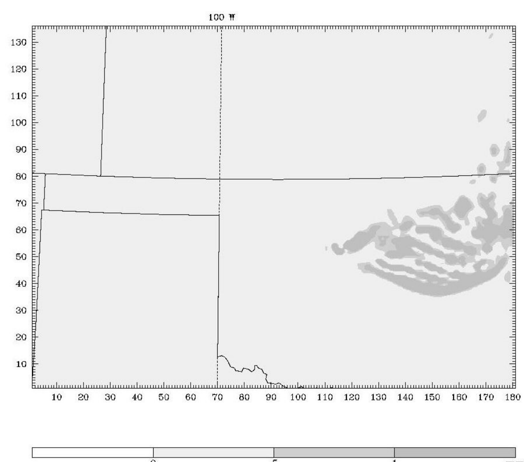

Figure 5: Integrated cloud water from model domain 2 on June 12 at 21 UTC.

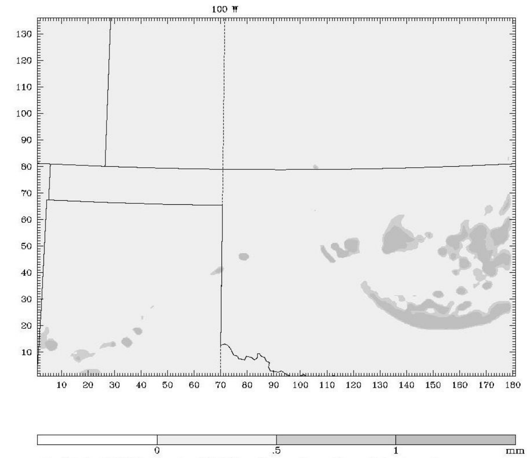

Figure 6: Same as Fig. 5 at 2230 UTC.

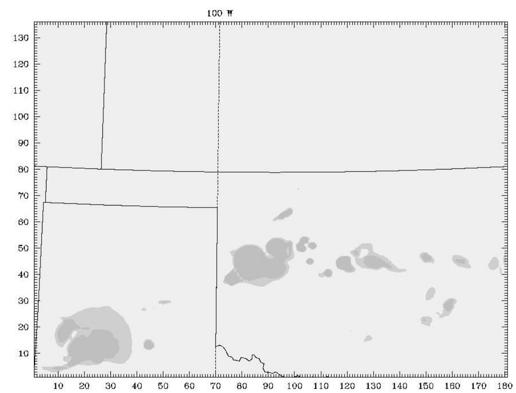

Figure 7: Same as Fig. 5 on June 13 at 0000 UTC.

4. CONCLUSION

This case has been shown to be a very difficult case for the actual models. Szoke et al. (2004) evaluated the performance of mesoscale models in determining storm type and evolution for the IHOP_2002 experimental period and they concluded that, in terms of simulating the upscale growth to a line, this case was difficult for all the various model runs. Nevertheless, it's interesting to understand the different reasons why the model runs fail to simulate this case. An analysis of the differences between the observations and the model outputs in the pre-storm environment will help to better understand the physical processes in the atmospheric boundary layer affecting convection initiation and will allow for the improvement of forecasting of such storms that can cause serious damage.

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