Mesoscale Simulations of Convective Systems with Data Assimilation During June 1993 in the Southern Great Plains

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Introduction

An intensive observation period (IOP) took place at the Southern Great Plains Cloud and Radiation Testbed (CART) site from June 16-26, 1993. Additional observations came from two integrated sounding systems (ISSs) and three National Center for Atmospheric Research (NCAR) cross-chain loran atmospheric sounding system (CLASS) sites to complement the central CART site and the seven National Weather Service (NWS) profilers of the demonstration network in the area.

The NCAR/Penn State Mesoscale Model (MM5) has been used to simulate this period on a 60-km domain with 20- and 6.67-km nests centered on Lamont, Oklahoma. Simulations are being run with data assimilated by the nudging technique (Kuo and Guo 1989, Stauffer and Seaman 1990) to incorporate upper-air and surface data from a variety of platforms.

Objectives

One goal of this work is to use all the available data collected in the Southern Great Plains CART area in conjunction with a continuously running mesoscale model to provide complete hourly datasets of the wind, temperature, humidity, and cloud distributions at high resolution. The model maintains dynamical consistency between the fields, while the data correct for model biases that may occur during long-term simulations and provide boundary conditions.

In this study the feasibility of driving the model with surface data, rawinsonde data, profiler winds, microwave radiometer moisture data, and radio-acoustic sounding system (RASS) temperatures is being demonstrated. Independent data from supplementary CLASS soundings will be used to evaluate the effectiveness of the data assimilation in achieving an accurate state.

The dataset provided will be a valuable resource for comparison with general circulation model (GCM) parameterizations of cloud and radiation fields, as well as for mesoscale studies of convective events during this period.

The MM5 Model

The model features and options used in this study are as follows. Equations are for nonhydrostatic, compressible motion, in terrain-following coordinates with a polar-stereographic map projection. Prognostic equations exist for wind components, vertical velocity, pressure perturbation, temperature, water vapor, ground temperature, and microphysical water and ice content variables. It has B-grid staggering, an upper radiative boundary condition, relaxation lateral boundary conditions, and second-order centered spatial and leapfrog temporal differencing with short step for sound-wave terms.

It includes microphysics with cloud, rain, snow/graupel, and ice processes on resolved scales for all domains. The Grell single-cloud mass-flux cumulus parameterization scheme is adopted only on the 60- and 20-km domains. The Blackadar high-resolution planetary boundary layer has four stability regimes; there are five layers in the lowest kilometer, and implicit vertical diffusion acts above the boundary layer. A surface energy budget calculation is used to predict ground temperature. An atmospheric longwave and shortwave radiation scheme interacts with model clouds and land surface.

Data Assimilation Method

The method adopted to assimilate data in this work is that of nudging either toward an analyzed field or directly toward point observations. For more information on the method see Guo and Kuo in this issue. This study comprises two experiments. Both are 10-day simulations on 60/20/6.67-km grids.

- Experiment I - Assimilates data from the Mesoscale Analysis and Prediction System (MAPS) 3-hourly 60 km only on the 60-km domain by the analysis nudging technique. No assimilation on the 20- or 6.67-km grids.
- Experiment II - In addition to MAPS data, assimilates surface observations, NWS upper air observations, wind profiler demonstration network data, and additional profiler data near the central CART site by the station nudging technique.

Domain and Data Coverage

Figure 1a shows the areas covered by the three MM5 domains. Figure 1b shows the NWS rawinsonde sites in the 20-km domain. The 6.67-km domain is centered on the profiler hexagon around the Southern Great Plains site and covers a 480-km square.

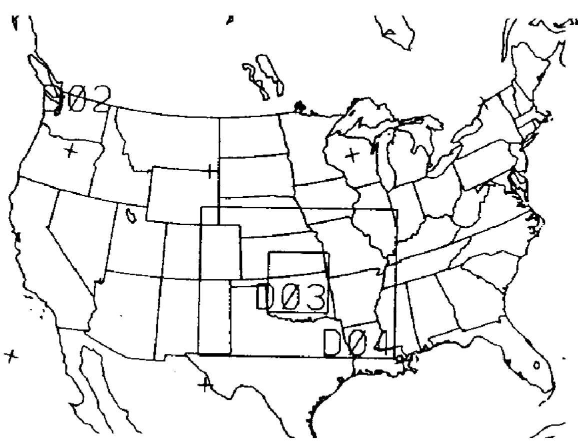

Figure 1a. Domains for the data assimilation runs (60 km, 20 km, 6.67 km).

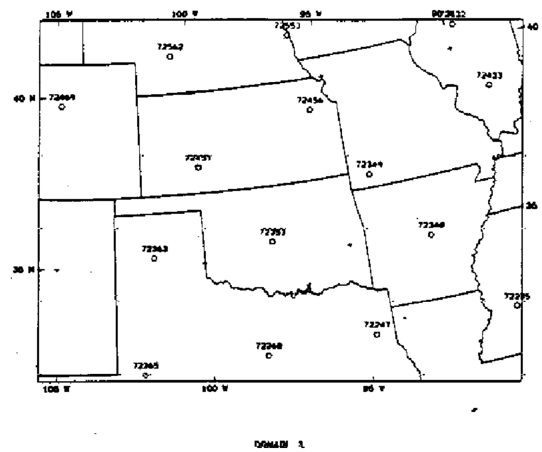

Figure 1b. The 20-km domain with the NWS rawinsonde sites.

Results

So far, the control experiment (I) has been completed. The period 00Z 16th June until 00Z 26 June 1993, during which two convective cold fronts moved into the inner domain, was simulated.

Figures 2 and 3 show selected 20-km model surface layer fields and observations for two cold front passages during the period.

The 6.67-km grid size is sufficient to almost resolve individual deep convective cores as seen in Figure 4. Here the total water above a threshold of 0.1 g/kg is plotted for the 6.67-km domain, as viewed from the SE at 550 mb. This plot shows the complex layering of clouds that needs to be represented in GCM radiation packages.

Plotted at the same time, Figure 5 shows the cold front as a sharp wind shift line near the surface.

Even with limited data assimilation, the model captures the overall rain patterns during the 10-day period, although not always with perfect positioning or timing. In the case of the 24 June front, the development of strong convection along the cold air boundary was reproduced well.

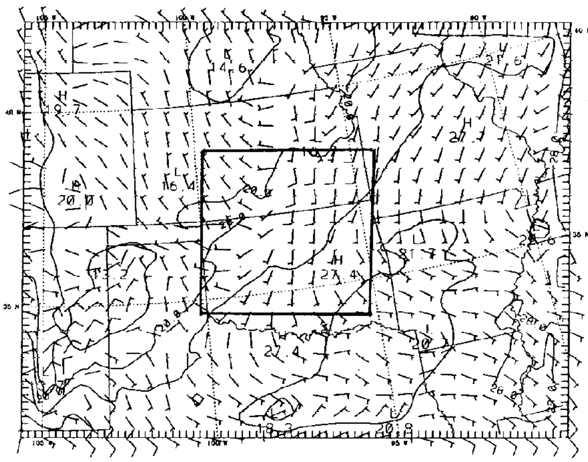

Figure 2a. 20-km domain winds with temperature for 18Z 19 June 1993. Barbs in m/s, temperature contours 4°C.

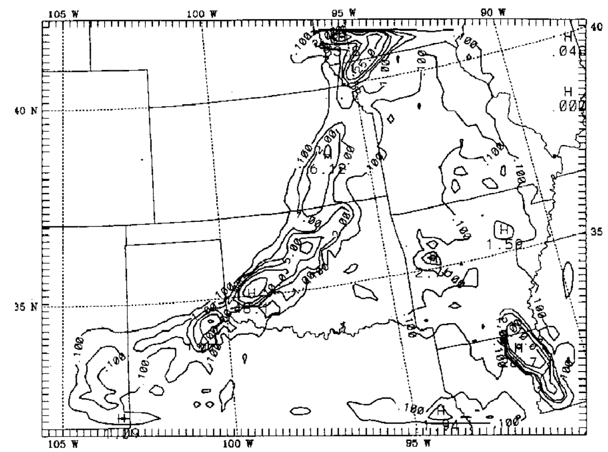

Figure 3a. 20-km domain 3-hr rainfall for 15Z-18Z 24 June 1993.

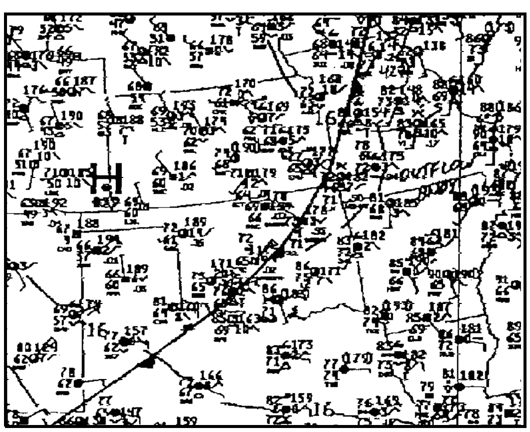

Figure 2b. Surface analysis for 18Z 19 June 1993.

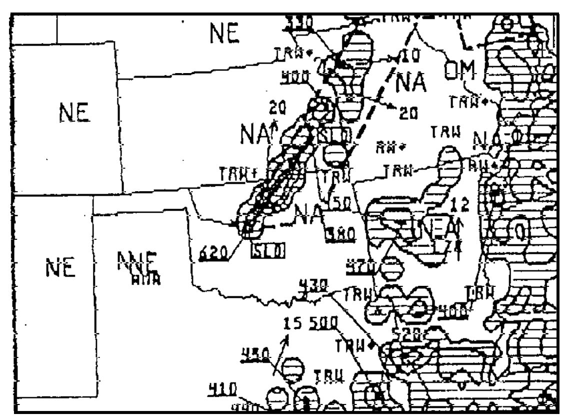

Figure 3b. Radar summary for 1935Z 24 June 1993.

Conclusions

The experiments done so far suggest that even assimilation of MAPS data alone can provide a useful four-dimensional (4D) dataset that is qualitatively in agreement with observations on the fine mesh. The model possesses adequate physics to keep the results from diverging significantly from the atmospheric behavior; and although not all the rainfall events are collocated with observed ones, the general convective and nonconvective periods were well simulated.

Further work is required to assess the impact of assimilating the full data, including surface, profiler and raob data, into the model. The high time resolution and broad spatial coverage of the demonstration profiler network are likely to provide not only better wind fields, but also improved thermal fields through the model's large-scale adjustment. Surface data too are likely to affect the simulation because of its spatial resolution and 3-hr time resolution, while rawinsondes, although infrequent and sparse, give valuable information on the upper-air moisture that would affect the model cloud prediction.

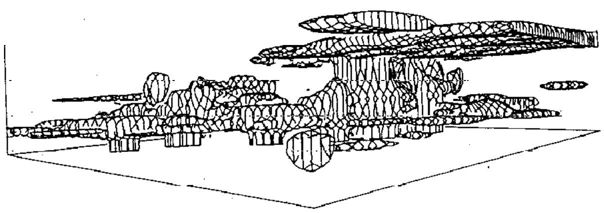

Figure 4. Cloud plus rain water in 6.67-km domain at 18Z 19 June 1993. Threshold is 0.1 g/kg. Viewed from SE at 550 mb. Vertical scale linear in pressure 1000 to 100 mb.

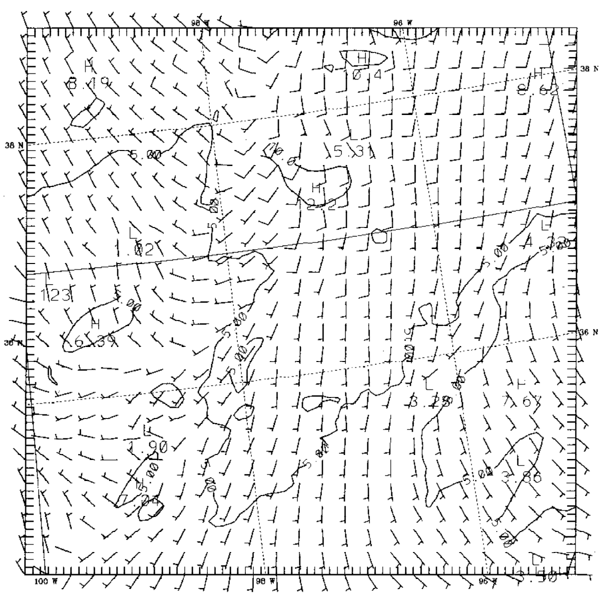

Figure 5. Surface layer winds in 6.67-km domain at 18Z 19 June 1993. Barbs in m/s, contours 5 m/s.

It will be interesting to see if these added data improve the precipitation verification, or whether an inherent unpredictability in summertime convection prevents this.

Acknowledgments

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References

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