1.6 FORECASTS OF NEAR-SURFACE VARIABLES USING A COUPLED ATMOSPHERE-LAND SURFACE MODEL

Andrew A. Taylor*
School of Meteorology, University of Oklahoma, Norman, Oklahoma

Lance M. Leslie
School of Meteorology, University of Oklahoma, Norman, Oklahoma

David J. Stensrud
NOAA/National Severe Storms Laboratory, Norman, Oklahoma

1. INTRODUCTION

There have been a number of studies demonstrating the sensitivity of near-surface atmospheric variables, specifically air temperature, moisture, and wind fields, to land surface and sub-surface parameters. Skin temperature, soil moisture, and soil temperature are known to influence near-surface atmospheric variables, including 2 m (surface) temperature and 10 m wind fields. In earlier work, Crawford et al. (2001) demonstrated the effects of including satellite-derived land cover data in surface temperature predictions. Shao and Leslie (2002) used a coupled atmosphere-land surface-soil modeling system to show that realistic changes in vegetation characteristics can affect rainfall accumulations as well as the amount of cumulus versus stratiform precipitation.

In an effort to demonstrate the potential value of using higher resolution surface observations and more accurate land cover data to initialize numerical models, the first step involves constructing control runs initialized without these special sets of data. Using the OU HIRES model developed by one of the authors (LML), forecasts were run for the 24 hour period beginning on 17 June 2004 at 1200 UTC. At approximately 0100 UTC 18 June, a mesoscale convective system (MCS) moved southeast from Kansas and crossed into northwestern Oklahoma. The forecast values of cumulative precipitation, 2 m temperature, and 10 m wind for various times are compared against observations from the Oklahoma Mesonet (Brock et al. 1995), a high-resolution network of surface observing stations located across the state of Oklahoma.

* *Corresponding author address:* Andrew A. Taylor, School of Meteorology, University of Oklahoma, 100 E. Boyd Street, Suite 1310, Norman, Oklahoma 73019; e-mail: aataylor@ou.edu

Section 2 offers a brief overview of the OU HIRES model and discusses some of the details of the simulation run for this case study. Section 3 examines the results of the simulation and compares those results with observations, and Section 4 summarizes the results as they pertain to the forecasting of near-surface variables. In addition, plans for the future are outlined, including further work to be presented at the AMS Annual Meeting.

2. OU HIRES MODEL SIMULATION

The OU HIRES model, currently based at the University of Oklahoma, has the capability to assimilate diverse types of initial data. For this reason, it is thought to be appropriate for the job of testing how the inclusion of various kinds of land-surface data affects the forecast of near-surface variables. For the simulation discussed here, the model was initialized at 1200 UTC 17 June 2004 and run for a duration of 24 hours. Forecasts were made at grid resolutions of 35, 10, 3, and 1 km for four different nested grid domains. The domain sizes range from the continental United States to a subset of the southern Great Plains. Oklahoma, our area of interest for which a high density of observations is available, covers a majority of the fourth domain. Model initialization was carried out using the ETA initial analysis for 1200 UTC 17 June.

The model produces forecasts of a large variety of atmospheric and surface variables, but here we focus on three: 10 m wind, 2 m temperature, and cumulative precipitation. We will examine forecasts for the late afternoon (2100 UTC, near the clear-day time of maximum temperature) and the early morning (1200 UTC, near sunrise), in addition to forecasts for the overnight period during which the MCS affected Oklahoma. One aim here is to see whether the OU HIRES model produces reasonable forecasts of surface variables for this case; another aim is the determination of whether the higher resolution grids produce more accurate forecasts than the coarser grids. Future work will demonstrate whether any inaccuracies discovered in the forecasts can be improved through the assimilation of additional data at initialization.

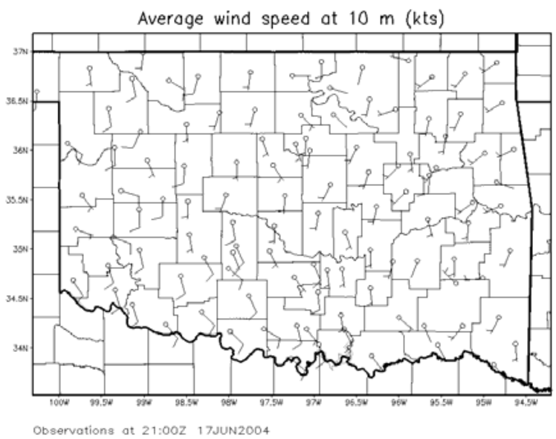

FIG. 1. Observed 10 m wind speed (kts) at 2100 UTC 17 June 2004. Wind barbs have their standard meaning.

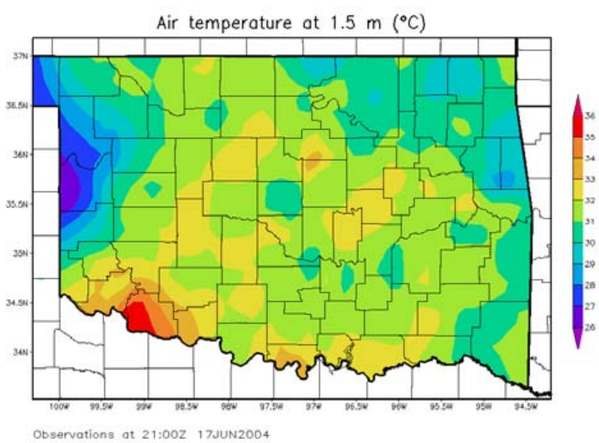

FIG. 2. Analysis of observed 1.5 m temperature (ºC) at 2100 UTC 17 June 2004.

3. RESULTS OF MODEL SIMULATION

Before presenting the OU HIRES model forecasts for the 17-18 June 2004 case, the observed conditions over the 24 hour period will be discussed. Prior to 1200 UTC 17 June, one MCS had already affected predominantly western Oklahoma, producing over 20 mm of rain at several stations. At 1200 UTC, temperatures were around 5ºC cooler in western Oklahoma than in the rest of the state. Winds were northerly to northeasterly across approximately the northern third of Oklahoma, with light winds elsewhere. By 2100 UTC (Figs. 1 and 2), winds in western Oklahoma were southerly to southeasterly with speeds between 5 and 10 knots (2.5 and 5 m s^{-1}). Temperatures exceeded 30ºC at all but the westernmost stations, which were cooler possibly due to higher soil moisture values and more cloudiness. No precipitation fell statewide during the daylight hours of 17 June.

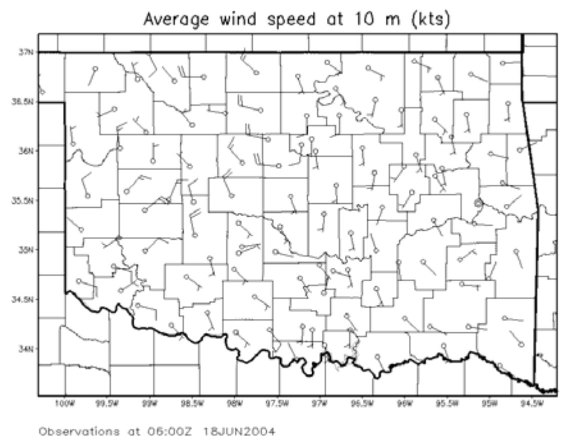

FIG. 3. Observed 10 m wind speed (kts) at 0600 UTC 18 June 2004.

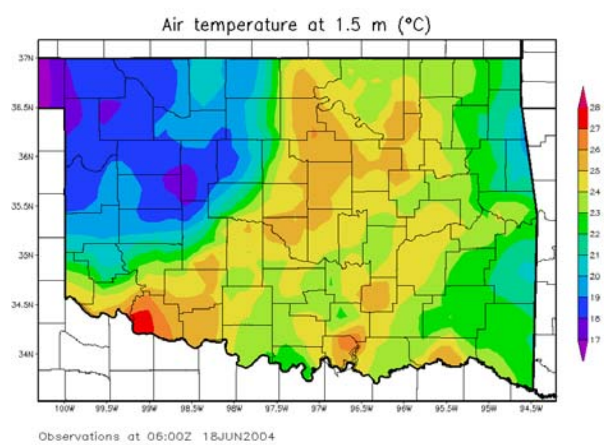

FIG. 4. Analysis of observed 1.5 m temperature (ºC) at 0600 UTC 18 June 2004.

Just after 0000 UTC 18 June, another MCS moved into the northwestern corner of Oklahoma, again bringing upwards of 20 mm of rain to many stations. Rain also affected parts of northeastern Oklahoma between about 0800 and 1200 UTC 18 June. MCS signatures can be seen in the observed wind and temperature fields at 0600 UTC 18 June (Figs. 3 and 4) in the form of outflow and a cold pool. By 1200 UTC 18 June (Fig. 5-7), winds in western Oklahoma were mostly northerly to northeasterly at speeds from 5 to 15 knots (2.5 to 7.5 m s^{-1}). Similar to 17 June, temperatures at 1200 UTC 18 June were again cooler in western Oklahoma than in the rest of the state.

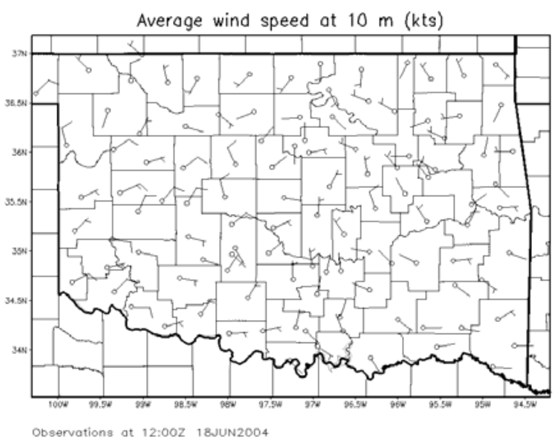

FIG. 5. Observed 10 m wind speed (kts) at 1200 UTC 18 June 2004.

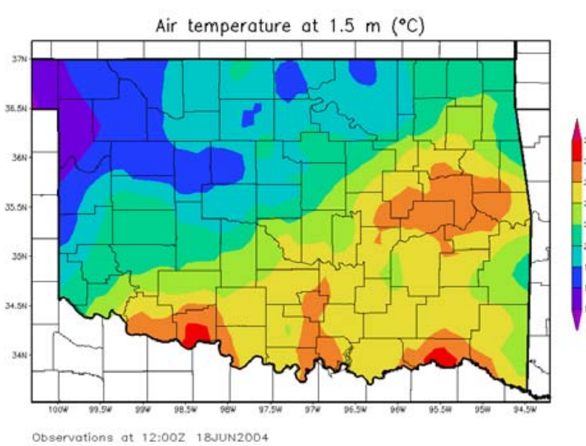

FIG. 6. Analysis of 1.5 m temperature (ºC) at 1200 UTC 18 June 2004.

The OU HIRES wind and temperature forecasts for 2100 UTC 17 June (Figs. 8 and 9) were reasonably accurate compared with observations. The wind forecast shows roughly 5 m s^{-1} (10 kt) winds in western Oklahoma, with roughly 2.5 m s^{-1} (5 kt) or lighter winds throughout the remainder of Oklahoma. The wind direction is mostly southerly, but the direction shifts to the east in the northwestern corner of the domain. This shift was not observed; however, the forecast speeds were very close to those observed. Overall, the temperature forecast was quite good, being slightly too cool only by about 1-2ºC in most locations. The temperature gradient forecast to be in northwestern Oklahoma at 2100 UTC was actually observed in southern Kansas. An area of cooler temperatures was located in far western Oklahoma, but the strength and orientation of the forecast gradient do not match with the observed temperatures.

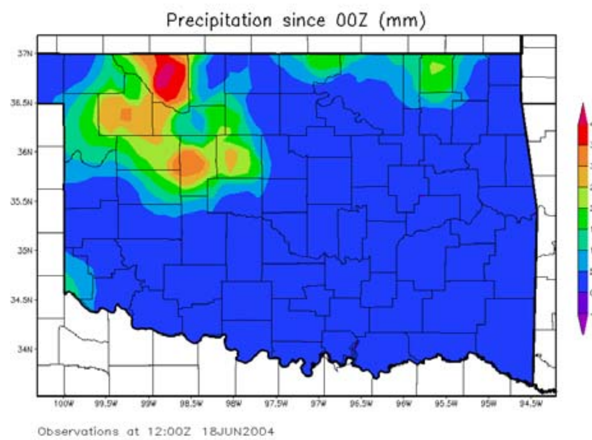

FIG. 7. Precipitation (mm) measured between 0000 UTC and 1200 UTC 18 June 2004.

Forecasts for 0600 UTC 18 June (Figs. 10 and 11) failed to predict the MCS that developed, and this negatively affected the predictions of wind, temperature, and precipitation. Spotty light amounts (< 5 mm) of precipitation were generated over Oklahoma by the model run at 1 km grid resolution between 0000 and 0600 UTC 18 June. Southerly winds were forecast statewide with wind speed increasing from east to west. Much of eastern and central Oklahoma did see southerly winds, but the winds in western Oklahoma were driven by outflow from the ongoing MCS. Away from the MCS, the forecast wind speeds were from 4-7 m s^{-1} (8-14 kt) when in reality they were mostly less than 2.5 m s^{-1} (5 kt). Not surprisingly given the higher forecast wind speeds, the model also forecast higher temperatures than those observed. The relative temperature minima and maxima in southwestern, central, and southeastern Oklahoma were placed correctly, but the values of those extrema were too warm by about 3ºC at best. In the northwestern corner of Oklahoma, affected by the unpredicted MCS, temperature forecasts were too warm by around 10ºC.

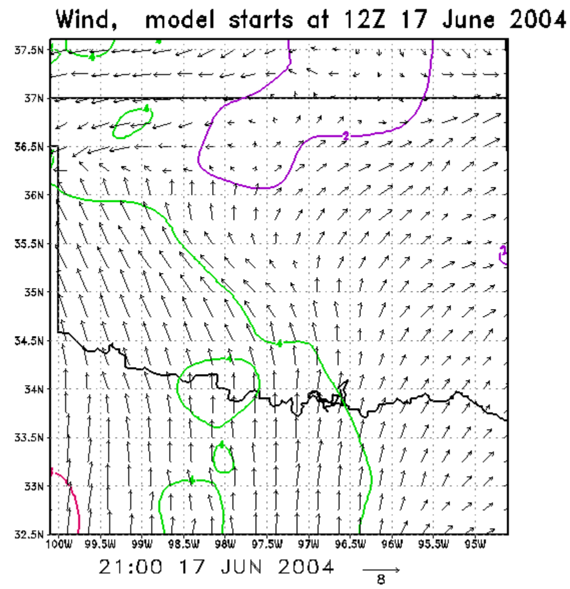

FIG. 8. OU HIRES model 10 m wind (m s^{-1}) forecast for 2100 UTC 17 June 2004. Contours are isotachs.

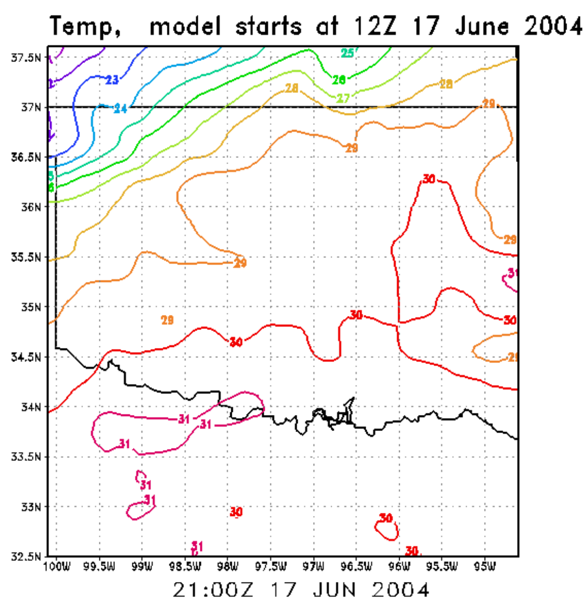

FIG. 9. OU HIRES model 2 m temperature (ºC) forecast for 2100 UTC 17 June 2004.

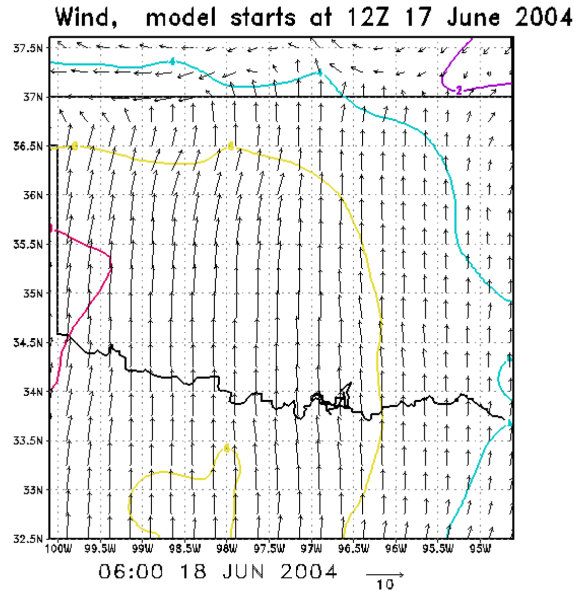

FIG. 10. OU HIRES model 10 m wind (m s^{-1}) forecast for 0600 UTC 18 June 2004. Contours are isotachs.

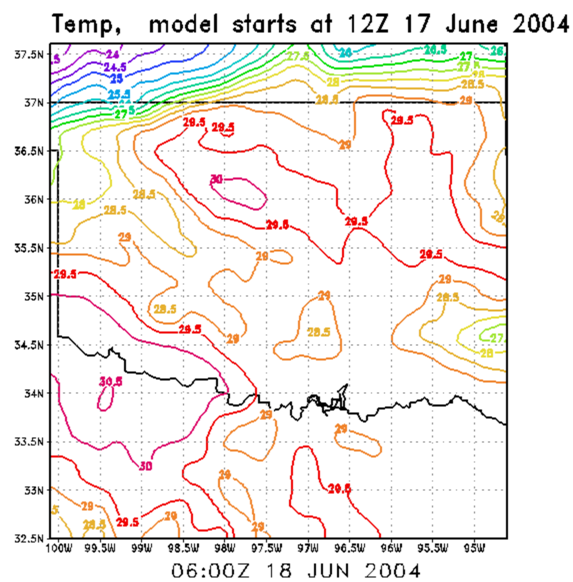

FIG. 11. OU HIRES model 2 m temperature (ºC) forecast for 0600 UTC 18 June 2004.

Aside from there being a little over 5 mm of precipitation in part of northwestern Oklahoma, the 1200 UTC 18 June forecasts (Fig. 12-14) were not much different from the 0600 UTC forecasts. The model forecasts diverted even farther from the observations. The model did produce a precipitation maximum in the correct place between 0600 and 1200 UTC, but the timing was late and the amount was about 30 mm too low. Forecast wind speed increased between 0600 and 1200 UTC while the observed wind speeds decreased overall, especially in western Oklahoma. Forecast winds were still predominantly southerly, while the observed winds in western Oklahoma were mostly northeasterly to easterly. The forecast temperatures did not drop much more than 1ºC or so between 0600 and 1200 UTC. However, the cooler air resulting from the MCS continued to spread south and east such that the temperature forecasts for 1200 UTC were 10ºC too warm over about the northwestern third of Oklahoma. The forecasts were 4-5ºC too warm across much of the rest of the state. It is as yet unclear why the forecast temperatures are so anomalously high.

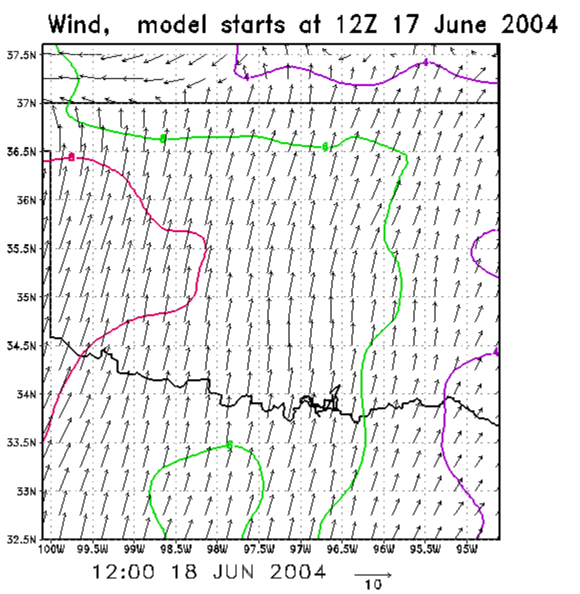

FIG. 12. OU HIRES model 10 m wind (m s^{-1}) forecast for 1200 UTC 18 June 2004. Contours are isotachs.

4. CONCLUSIONS AND FUTURE WORK

In view of the two aims mentioned earlier, there is considerable room for improvement in the model forecasts for this case. The 17-18 June 2004 period was chosen for this presentation primarily because forecasts run previously for this case using the MM5 model were notably poor (Godfrey, personal communication). The accuracy of the forecasts was reasonable at 2100 UTC 17 June, but was fair to poor from about 0000 UTC 18 June on. Much of the forecast error can be attributed to the MCS, and the surface variable forecasts would improve greatly if the model could resolve that feature correctly. For the most part, the forecast fields of near-surface variables over Oklahoma differed very little among the four nested domains. This is perhaps not surprising since we have not yet assimilated data into the model that are dense enough to expect improvement in the forecasts by increasing the horizontal grid resolution.

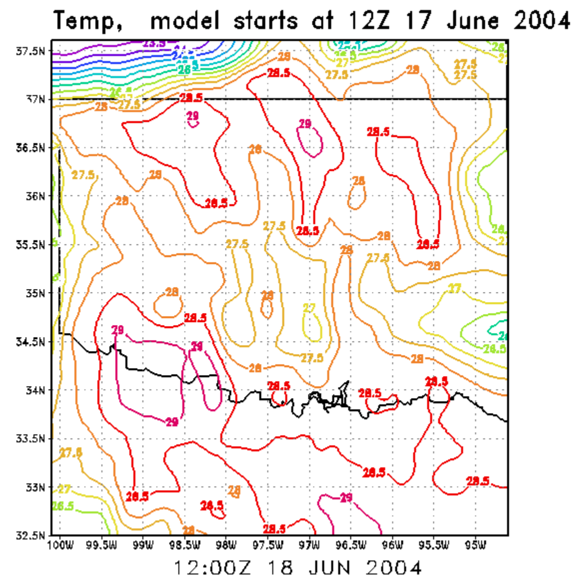

FIG. 13. OU HIRES model 2 m temperature (ºC) forecast for 1200 UTC 18 June 2004.

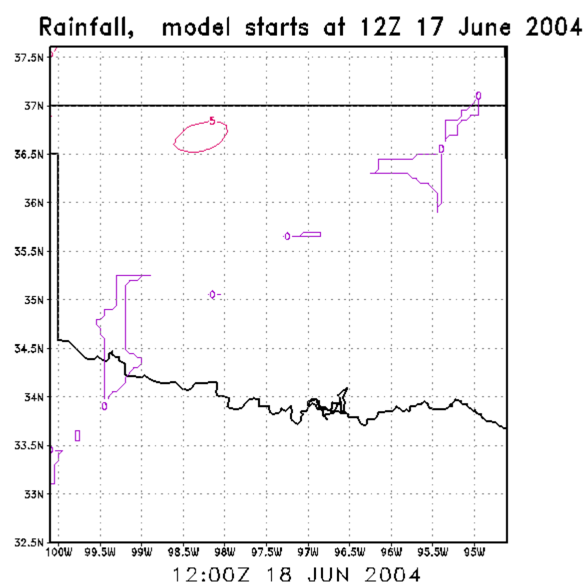

FIG. 14. OU HIRES model precipitation (mm) forecast for the 6 hour period from 0600 UTC to 1200 UTC 18 June 2004.

It is hoped that future work will yield improved forecasts for cases in which land surface characteristics play a significant role in determining the evolution of the near-surface atmosphere. We intend to assimilate Oklahoma Mesonet surface data into the OU HIRES model and re-run the forecasts for the 17 June 2004 case prior to the January AMS Annual Meeting, presenting results at that time. Following this, we plan to demonstrate the dependence of near-surface variables and deep soil moisture on vegetation characteristics, included in the model as leaf area index (LAI) and fractional vegetation coverage (FVEG). Using LAI and FVEG values obtained from the biweekly maximum normalized difference vegetation index (NDVI) composites at 1 km resolution obtained from daily observations from the Advanced Very High Resolution Radiometer (AVHRR), short range predictions of temperature and moisture will be carried out via the OU HIRES model over the southern Great Plains and will be verified against observations from the Oklahoma Mesonet.

Acknowledgments. The authors wish to thank Christopher Godfrey for creating an interface allowing us to quickly and easily generate plots of Oklahoma Mesonet observational data, and for his preliminary work that resulted in our selection of this case. Also, the Oklahoma Climatological Survey's quality assurance of the Oklahoma Mesonet data is greatly appreciated. We are grateful to Lixin Qi and Russel Morison at the University of New South Wales in Sydney, Australia for their help in configuring the OU HIRES model and the model runs for this project. This research was supported under NSF Grant ATM-0243720.

REFERENCES

Brock, F.V., K.C. Crawford, R.L. Elliott, G.W. Cuperus, S.J. Stadler, H.L. Johnson, and M.D. Eilts, 1995: The Oklahoma Mesonet: a technical overview. *J. Atmos. Oceanic Technol.,* **12,** 5-19.

Crawford, T.M., D.J. Stensrud, F. Mora, J.W. Merchant, and P.J. Wetzel, 2001: Value of incorporating satellite-derived land cover data in MM5/PLACE for simulating surface temperatures. *J. Hydrometeor.,* **2,** 453-468.

Shao, Y., and L.M. Leslie, 2002: Numerical simulation of atmosphere and land surface interactions on synoptic scales. *Meteor. Atmos. Phys.,* in press.