A PROTOTYPE REALTIME BOUNDARY LAYER FORECAST MODEL RUNNING ON CLUSTERS OF PC'S

Douglas C. Schuster*, William R. Cotton, Robert L. Walko

Department of Atmospheric Science/Center for Geosciences

Colorado State University
Fort Collins, CO 80512

*Phone: (970) 491-8593, Fax: (970) 491-8449, Email: cotton@atmos.colostate.edu

OBJECTIVE:

The Regional Atmospheric Modeling System(RAMS), developed at Colorado State University has been run as a prototype mesoscale forecast model since 1991. A general description of the model can be found in Cotton et al. (1982), Tripoli and Cotton (1982), Tremback et al. (1985), Tripoli (1986), Tremback (1990), and Pielke et al. (1992). The simulations have been done with utilizing the nonhydrostatic version of RAMS with a parent grid covering the western U.S. and a fine-grid with grid spacing of 12-14km over Colorado, Wyoming, and eastern Utah. The earlier forecast model was run on single-processor and clusters of UNIX workstations (Cotton et al. 1992). Beginning in the fall of 1999, a new version of the forecast model was implemented on clusters of 450-400mhz Pentium PC's to provide mesoscale forecasts of boundary evolution. The parent grid with 100 x 72 points and horizontal spacing of 48km, covers the continental U.S. The second grid, with 46 x 46 points and horizontal spacing of 12km, can be located anywhere within the parent grid, and a boundary layer(BL) grid with 38 x 38 points and 3km horizontal grid spacing can be located anywhere within grid 2. Grids 1 and 2 have 36 vertical levels with spacing starting at 150m near the ground, stretching to 1000m near the model top, which is fixed at 19,191m. Grid 3 has 46 vertical levels and is vertically nested within grid 2 at 50m spacing over the first 12 grid levels, up to 600m above ground level, where the spacing increases to 75m over the next 4 grid levels. Above this level, grid 3 vertical spacing coincides with that of grids 1 and 2. In the vertical, RAMS uses a sigma-z terrain-following coordinate and in the horizontal, grids are mapped on the earth's surface using a polar stereographic projection. The forecast model configuration implements a single-moment version of RAMS microphysics for cloud and precipitation prediction . The turbulence scheme used the Mellor/Yamada TKE scheme (Mellor and Yamada, 1974) to predict vertical eddy mixing coefficients and a local deformation scheme for horizontal mixing (Tripoli and Cotton, 1982). Radiation is driven by the Maher/Pielke scheme (Mahrer and Pielke, 1977), which considers the influence of water vapor, ozone, and carbon dioxide on short wave and long wave radiative transfer.

Over the period of October 1999, grids 2 and 3 were centered over the Leon, KA in support of the CASES99 field project, within the parent U.S. grid. The forecast model was initialized with the daily 12z ETA gridded pressure dataset. ETA datasets provided forecasts at the following times: 0, 6, 12, 18, 24, 30, 36, and 48 hours. The lateral boundary conditions were first updated at 6 hours and then all subsequent ETA forecast times listed. If the ETA forecast dataset was complete, forecasts were produced out to 48 hours. In the event of missing ETA data, a 48 hour forecast could not be completed, or lateral boundary conditions would be updated at a larger time interval. Generally a 48 hour run took from 5 to 6 h of wall-clock time on a cluster of 17 processors composed of sixteen 400 mhz Pentium nodes, and one 450 mhz Pentium master node.

Verification analysis utilizing data from the CASES99 field project will investigate model performance. In this instance, initial verification efforts involving relative humidity, temperature, wind, and pressure fields have been completed for intensive operational period (IOP) #7, covering the time period from October 17, 2000 at 2200Z to October 18, 2000 at 1300z.

RESEARCH ACCOMPLISHED:

Initial research involved verification analysis of the model forecast data vs. observational sounding data from the CASES99 field project. The sounding site of interest was the central site located in Leon, KA with an elevation of 436 meters above sea level. Pressure, relative humidity, and temperature data were averaged over the period from 10/17/2000, 2200z to 10/18/2000, 1300z. Eight quality soundings taken at differing time periods through the IOP were averaged to obtain mean pressure and temperature values. Nine quality soundings were averaged to obtain mean relative humidity values over the IOP. Averaging was done after the sounding data was vertically interpolated to model grid point elevations linearly. Model data was averaged over the same respective times as sounding data.

Figures 1 and 2 display plots of observed and model pressure vs. fixed height along with the difference field multiplied by a factor of 10 for 24 and 48 hour forecasts respectively. The difference field is defined as (model value – observed value). Both the 24 and 48 hour forecasts appear to follow similar trends in pressure fields. Predicted pressure does not drop as sharply as observed pressure. This leads to a difference of about 17 mb at 1764m above the ground.

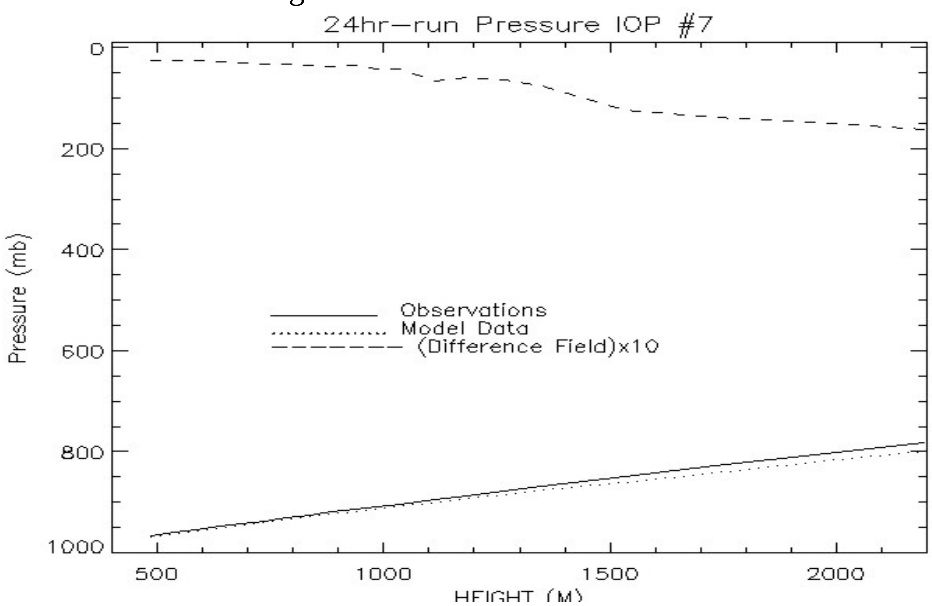

Figure 1. 24 hr. Forecast Model and Observed Pressure vs. Height.

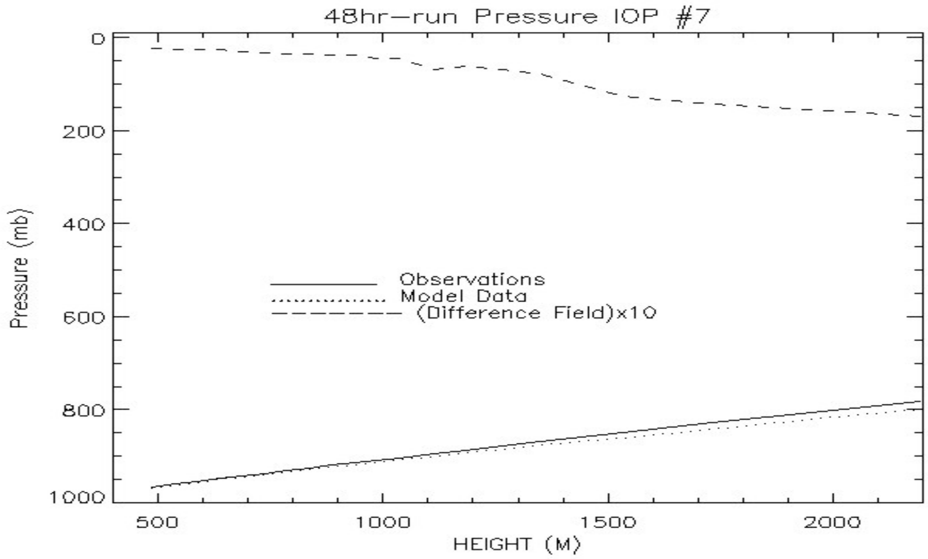

Figure 2. 48 hr. Forecast Model and Observed Pressure vs. Height.

Figures 3 and 4 display plots of model and observed relative humidity vs. height for 24 and 48 hour forecasts respectively. The 24 hour forecast relative humidity appears to coincide well with the observed atmospheric values above the first 100m. 48 hour forecast relative humidity follows a similar structure up to about 1050m above ground level. At this point the observed RH decreases rapidly while the model values continue to increase, followed by a drop in a similar manner about 500m above the observed drop.

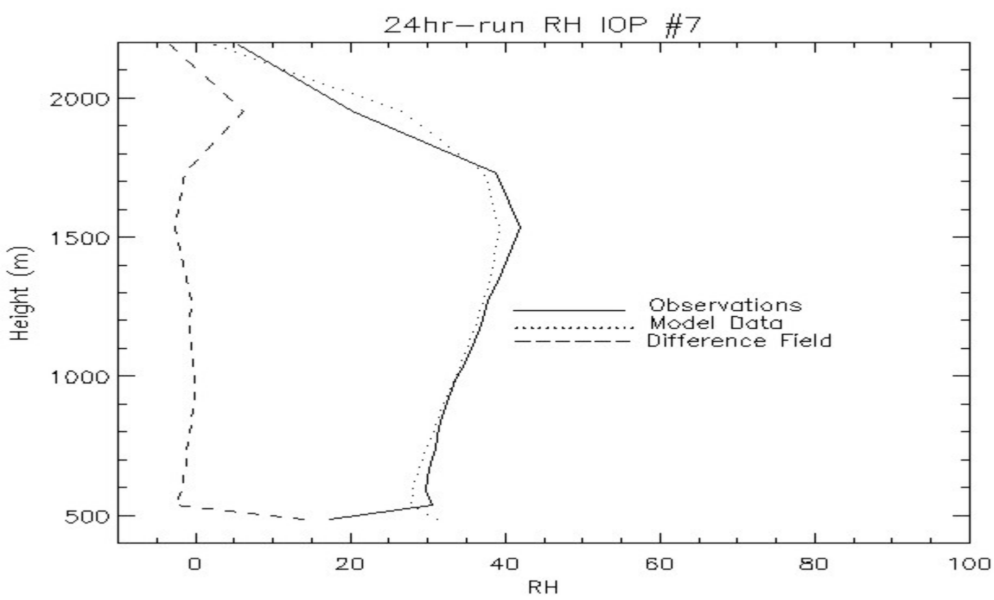

Figure 3. 24 hr. Forecast Model and observed RH vs. Height.

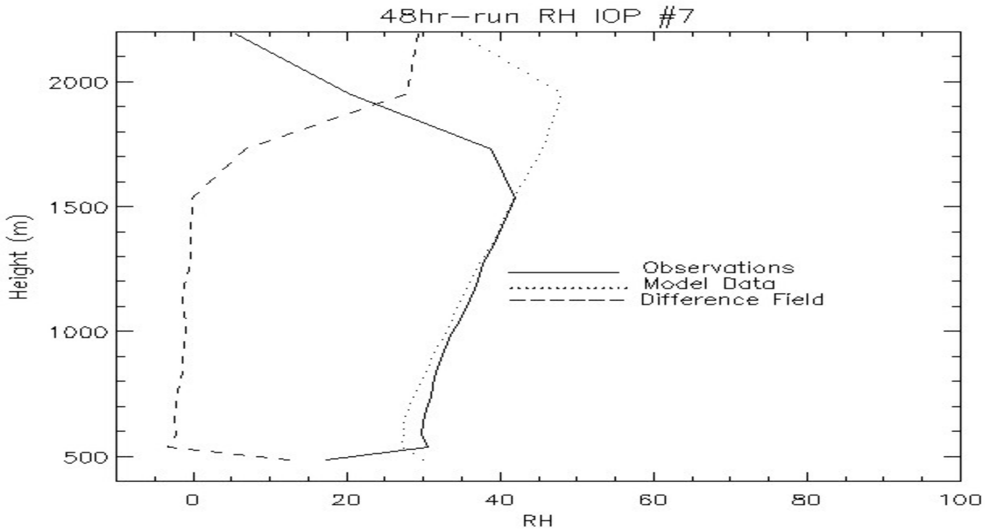

Figure 4. 48 hr. Forecast Model and observed RH vs. Height.

Figures 5 and 6 display plots of model and observed temperatures vs. height for 24 and 48 hour forecasts respectively. The 24 hour forecast displays a model bias of about + 2 degrees C. through 1550 m above ground level, while the 48 hour forecast displays a model bias of about + 4 degrees C through 1350m above ground level. In regards to temperature structure, the 24 hour forecast appears to start warming in a similar manner as the observations at 1550m above ground level, while the 48 hour forecast lacks the warming at this level.

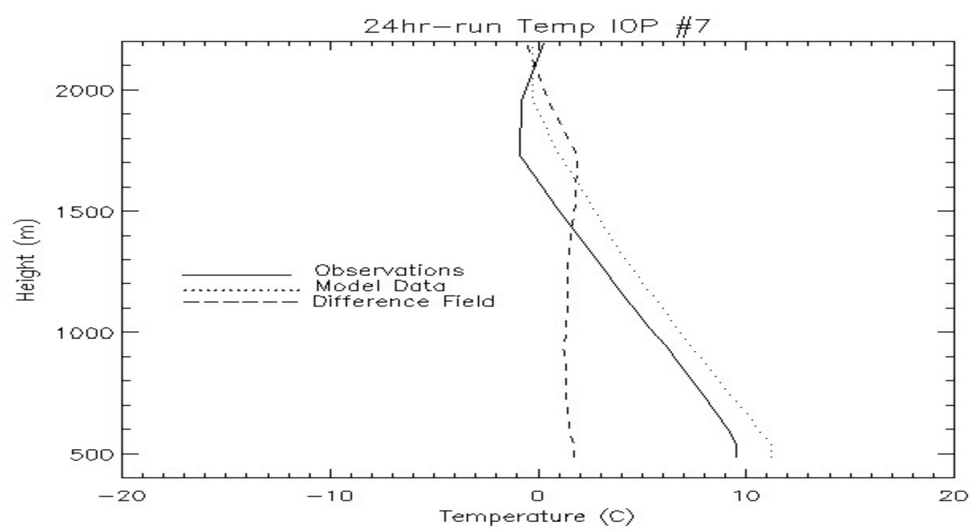

Figure 5. 24 hr. Forecast Model and Observed Temperature vs. Height

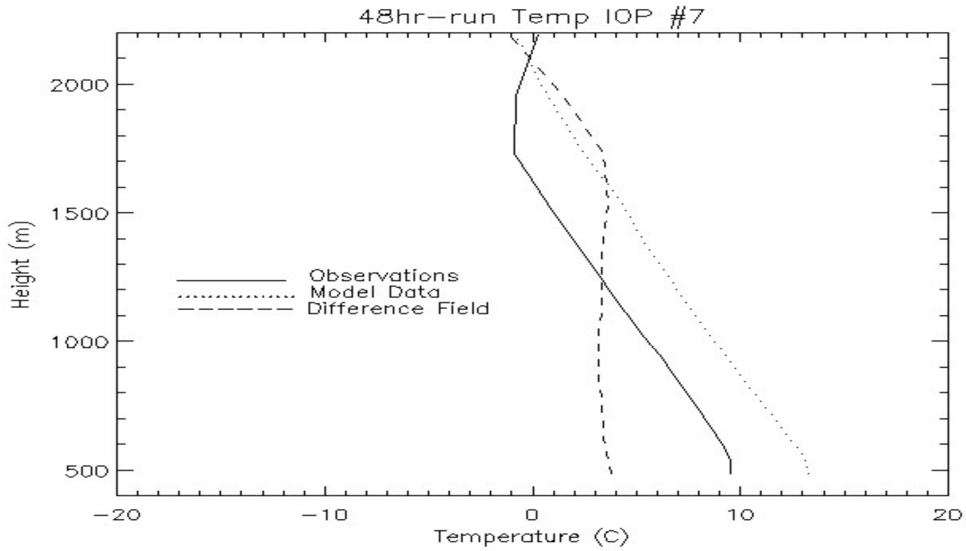

Figure 6. 48 hr. Forecast Model and Observed Temperature vs. Height.

Figures 7 and 8 display plots of model and observed U-wind for the 24 and 48 hour forecast cycles respectively at 10/18/1999, 0500z. These plots are representative of a specific forecast time due to lack of quality wind data for averaging over additional times. The 24 hour forecast data follows the structure of the U-wind fairly well up to the end of the observations at 1750m above ground level. The 48 hour forecast data doesn't appear to resolve the structure of the U-wind nearly as well as the 24 hour data.

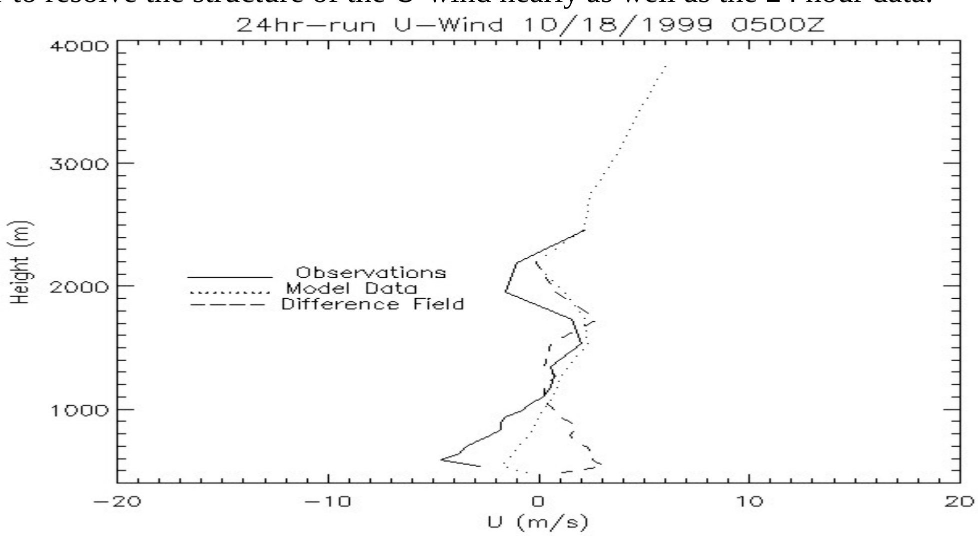

Figure 9. 24 hr. Forecast Model and Observed U-wind vs. Height.

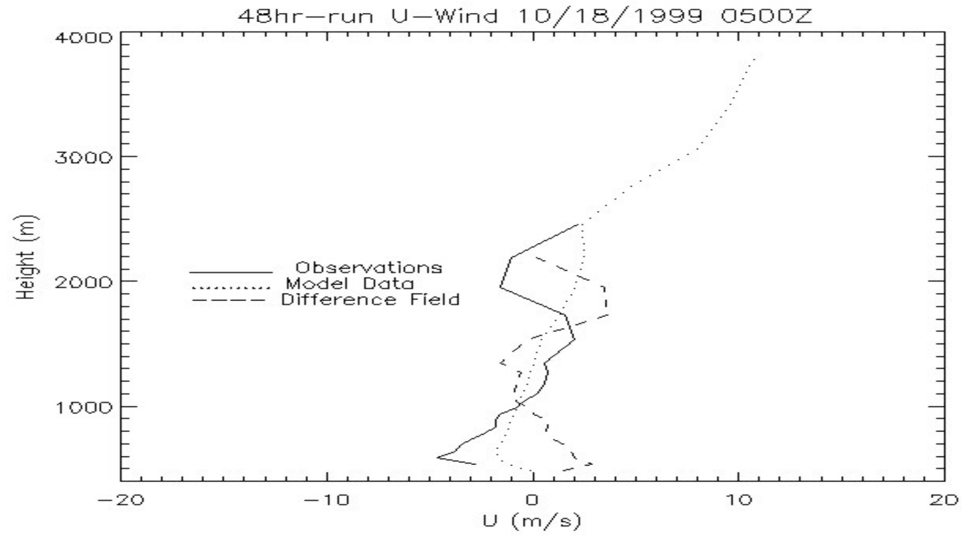

Figure 10. 48 hr. Forecast Model and Observed U-wind vs. Height.

Figures 11 and 12 display model and observed V-wind vs. height for 24 and 48 hour forecast data respectively, from the same time period as the U-wind data. The vertical structure of the model V-wind utilizing the 24 hour forecast data appears to follow the same trend as the observed data, with a lower magnitude, up to 1500m above ground level. The 48-hour forecast data doesn't seem to resemble the observations very well at all.

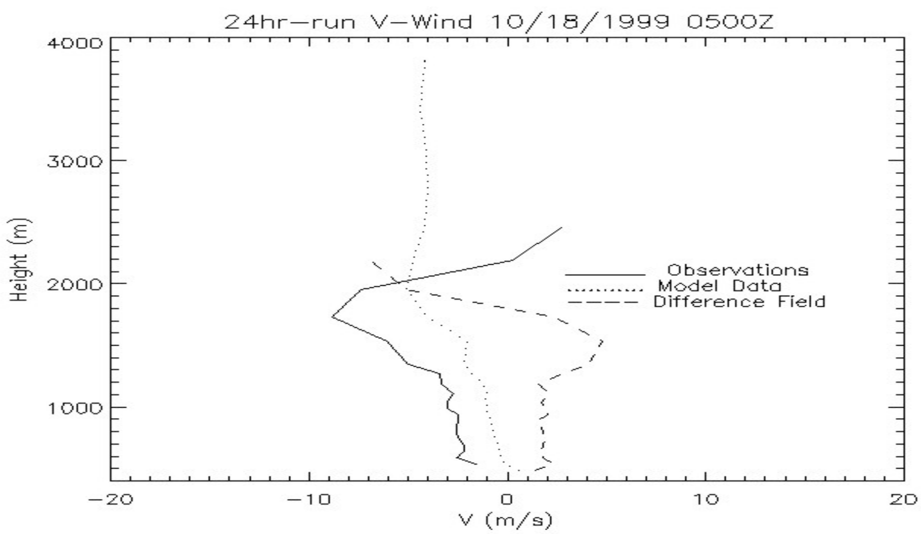

Figure 11. 24 hr. Forecast Model and Observed V-wind vs. Height.

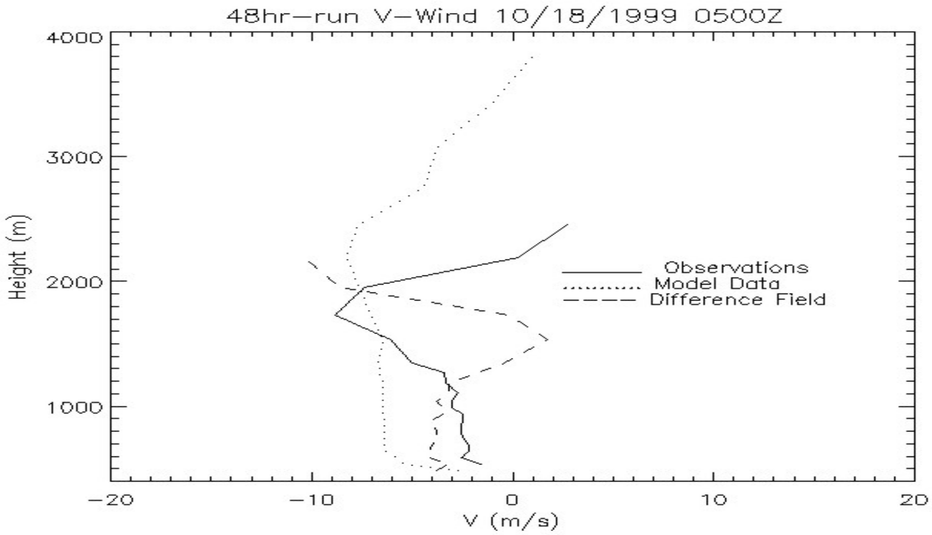

Figure 12. 48 hr. Forecast Model and Observed V-wind vs. Height.

CONCLUSIONS AND RECOMMENDATIONS:

Verification analysis of model vs. observed sounding data shows that the model does a fairly accurate job of predicting the structure of the atmosphere in terms of pressure, relative humidity and temperature, especially where the vertical grid spacing is finest. As would be expected, errors grow from a 24-hour forecast to a 48-hour forecast. This particularly can be seen in the analysis of the temperature data, where a + 2 degree C bias appears in the 24 hour forecast, which increases to a + 4 degree bias in the 48 hour forecast. Sensitivity studies involving soil moisture levels may need to be completed in order to examine how soil moisture may impact the temperature bias. In regards to wind field structure, it appears that the model can somewhat resolve the vertical wind structure in a 24 hour forecast with a slight difference in magnitude, but has difficulties resolving wind field structure in a 48 hour forecast.

Further analysis involving sensitivity studies and in depth statistical analysis will play an important role in determining model bias and cause of model error. As further data becomes available, additional sounding and surface observations will help in spatial analysis of model performance.

ACKNOWLEDGMENT:

This work was supported by the Department of Defense Center for Geosciences/Atmospheric Research Agreement #DAAL01-98-2-0078.

REFERENCES:

Cotton, W. R., M. A. Stephens, T. Nehrkorn, and G. J. Tripoli, 1982: The Colorado State University three-dimensional cloud/mesoscale model—1982. Part II: An ice parameterization. *J. Rech. Atmos*., **16**, 295-320.

----, G. Thompson, and P.W. Mielke, 1994: Real-Time Mesoscale Prediction on Workstations. *Bulletin of the American Meteorological Society*, **75**, 349-362.

Mahrer, Y. and R. A. Pielke, 1977: A numerical study of airflow over irregular terrain. *Beitrage zur Physik der Atmosphare*, **50**, 98-113.

Mellor, G. L., and T. Yamada, 1974: A hierarchy of turbulence closure models for planetary boundary layers. *J. Atmos. Sci*., **31**, 1791-1806.

Pielke, R. A., W. R. Cotton, R. L. Walko, W. A. Lyons, L. D. Grasso, M. E. Nicholls, M. D. Moran, D. A. Wesley, T. J. Lee, and J. H. Copeland, 1992: A comprehensive meteorological modeling system—RAMS. *Meteorol. Atmos. Phys*., **49**, 61-91.

Tremback, C. J., 1990: Numerical simulation of a mesoscale convective complex: Model development and numerical results. Ph.D. dissertation, Atmos. Sci. Paper No. 465, Colorado State University, Dept. of Atmos. Sci., 274 pp. [Available from Dept. Atmos. Sci., Colorado State University, Fort Collins, CO 80523.]

----, G. J. Tripoli, and W. R. Cotton, 1985: A regional scale atmospheric numerical model including explicit moist physics and a hydrostatic time-split scheme. Preprints, *7th Conf. On Numerical Weather Prediction*, Montreal, Canada, Amer. Meteor. Soc., 355-358.

Tripoli, G. J., 1986: A numerical investigation of an orogenic mesoscale convective system. Ph.D. dissertation, Atmos. Sci. Paper No. 401, Colorado State University, Dept. of Atmos. Sci., 290 pp. [Available from the Dept. of Atmos. Sci., Colorado State University, Fort Collins, CO 80523.]

----, and W. R. Cotton, 1982: The Colorado State University three-dimensional cloud/ mesoscale model—1982. Part I: General theoretical framework and sensitivity experiments. *J. Rech. Atmos*., **16**, 185-220.