**16.10** METEOROLOGICAL AND PHOTOCHEMICAL MODELING OF OZONE AND CARBON MONOXIDE EPISODES FOR THE PASO DEL NORTE AIRSHED. PART I: MESOSCALE MODELING

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## 1. INTRODUCTION

The purpose of the analysis was to model episodes of carbon monoxide and ozone exceedences in the Paso del Norte Airshed of El Paso, TX and Juarez, Mexico. The Regional Atmospheric Modeling System (RAMS) mesoscale model was used to produce three-dimensional meteorological fields that were used as input to the Comprehensive Air Quality Model with eXtensions (CAMx) model. RAMS is a three-dimensional, multiple nested grid prognostic mesoscale model. CAMx is a three-dimensional photochemical grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating the physical and chemical processes in the atmosphere. The Paso del Norte Airshed is located in a region characterized by rough terrain. North Franklin Mountain (elev. 2192 m msl), is located approximately 15 km north of El Paso (elev. 1147 m msl). The soil characteristics and rough terrain significantly affected the RAMS modeling because of the strong surface and terrain forcing of the meteorological processes. For this modeling exercise we tried many different modeling configurations before we obtained RAMS data which was useful for CAMx.

The episodes in the El Paso area that were modeled were identified by the U. S. EPA because of the detection of high ozone ($O_3$) on 13 August 1996 and high carbon monoxide (CO) on 18-19 December 1997.

This paper discusses the mesoscale modeling effort, the problems encountered, and provides insight into configuring a mesoscale forecast model for use as a data provider to a regional photochemical grid model. Model results and comparisons with surface observations, rawinsondes, and radar wind profiler are presented. The photochemical modeling using CAMx is described in a companion paper (Emery et al. 2000).

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## 2. RAMS MODELING

### *2.1 RAMS Background*

RAMS was developed at Colorado State University and MRC/ASTER to simulate weather systems spanning in scale from the hemispheric down to large eddy simulations (LES) within the planetary boundary layer. Initially, it was developed to perform research into the areas of modeling physiographically-driven weather systems such as land/sea breezes, and thermally driven mountain circulations. Summaries of RAMS features and recent meteorological applications can be found in Pielke et al. (1992).

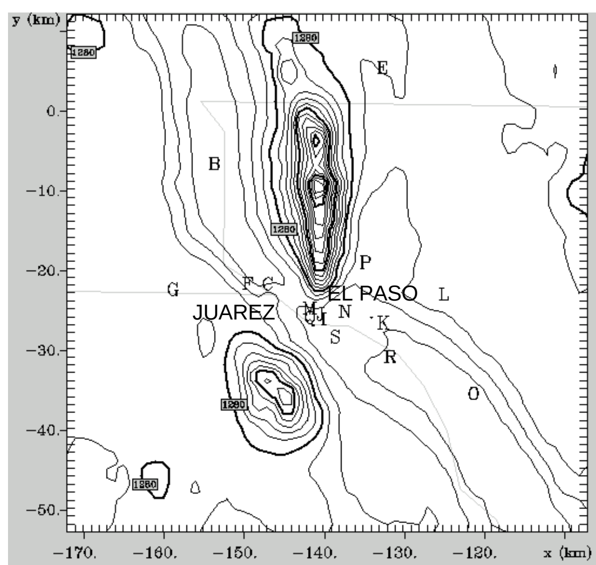


Figure 1. Map showing topography in El Paso along with air quality monitoring locations.

RAMS contains many options which allow it to be applied to differing scales and scenarios. It uses twoway nesting which allows users to specify the fine grid inner nests. The RAMS code has been parallelized for faster processing on multiple processor platforms.

### *2.2 Basic RAMS Configuration*

Table 1 shows some of the parameter settings used for the simulations.

Table 1. RAMS Model Configuration

| | | | | |
|---|---|---|---|---|
| Simulation Dates | Aug 11-14, 1996; Dec. 17-20, 1997: hourly output | | | |
| Number of nested grids | 4 | | | |
| Grids | 1 | 2 | 3 | 4 |
| Horizontal grid points | 38x42 | 50x58 | 62x66 | 66x66 |
| Vertical grid points | 38 | 38 | 38 | 46 |
| Horizontal grid spacing (km) | 64 | 16 | 4 | 1 |
| Time step (seconds) | 90 | 30 | 10 | 3.33 |
| Topography grid spacing | 10-min | 30-sec | 30-sec | 3-sec |
| Vertical grid spacing on Grids 1, 2, & 3 (m) | 0., 100., 200., 300.,400.,500., 600., 704., 839., 1000., 1164., 1330., 1500., 1686., 1910.,2178., 2500., 2822., 3176., 3566., 4000., 4521., 5146., 5896., 6796., 7796., 8796., 9796., 10796., 11796.,12796., 13796., 14796., 15796.,17796., 19796., 21796., 23796., 25796. | | | |
| Vertical grid spacing on Grid 4 (m) | Same as Grids 1, 2, & 3 with addtional layers at 25., 50., 75., 133., 167., 233., 267.,. and 350. | | | |
| Initialization data source | NCAR/NCEP Reanalysis data at 2.5 degrees (Kalnay et al. 1996), Standard surface and rawinsonde observations, El Paso radar wind profiler | | | |
| Nudging frequency | 6 hr | | | |
| Length of simulations: | 84 hours, 72 hours | | | |
| Numerical scheme | Nonhydrostatic | | | |
| Microphysics scheme | Full (NLEVEL=3) | | | |
| Convective parameteriza-tion | Grids 1 & 2 | | | |
| Radiation | Chen | | | |
| Soil moisture | 15%, 5% | | | |

### *2.3 Problems Encountered/Troubleshooting*

RAMS is a complex mesoscale model with an input namelist file of over 300 parameters. For the modeling of the two different episodes in the El Paso area, we ran approximately 50 different RAMS simulations. The reason different simulations were performed was to test the model's sensitivity to varying input and to correct faulty input parameter settings which caused RAMS to hang or bomb. At first, most of the simulations focused on getting RAMS to run to completion. After numerous simulations, most of the problems were ironed out and the RAMS simulations were successfully completed. Later simulations tested various input settings and/or meteorological data.

Some of the parameters we focused on which presented challenges in RAMS modeling were:

- Fine grid spacing of 1 km vs. 2 km
- Soil moisture of 5% vs. 15%
- Varying input data: 6-hr vs. 12-hr interval, Reanalysis data only vs. observation-supplemented

## 3. RAMS MODELING RESULTS

The results of the RAMS modeling was provided to the CAMx modelers who then used the RAMS data as input meteorological data. We analyzed the RAMS output to verify that the predicted meteorological data was suitable for CAMx.

### *3.1. Predicted Meteorological Data*

RAMS produced output of numerous meteorological parameters. CAMx required the following: u- and v-wind component, temperature, pressure, water vapor, vertical diffusivity, and turbulent kinetic energy.

To determine the validity of the data, we first looked at graphical output of the RAMS data. Figure 2 shows the RAMS-predicted wind vectors for the surface grid points at the 12-m grid level. RAMS developed upslope flow surrounding the Franklin Mountains to the north of El Paso and near-calm winds in the El Paso/Juarez area.

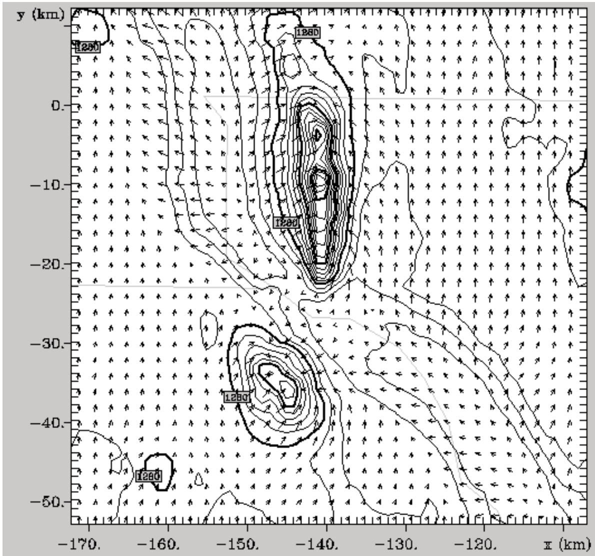


Figure 2. Map showing the RAMS wind vectors plotted on the topography for El Paso/Juarez for 1200 MST on 18 December 1997.

Figure 3 shows a vertical cross-section of the turbulent kinetic energy (TKE) as predicted by RAMS. The TKE is a good indicator of the vertical mixing. The plot shows that RAMS predicted the mixing to reach approximately 4000 m above the ground at 1600 MST on 13 August 1996. The cross-section also shows the organized pattern of convection with upward and downward vertical motion due to the strong afternoon heating.

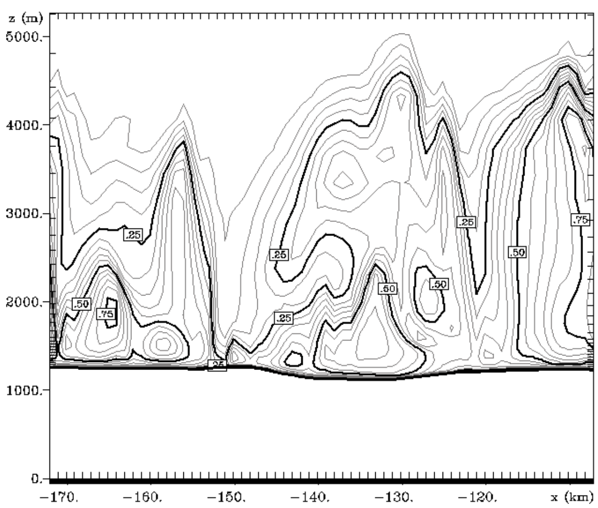


Figure 3. West-east cross-section across the center of the fine grid showing the vertical profile of TKE at 1600 MST on 13 August 1996.

### *3.2. Observed vs. Predicted*

For this study, we used available meteorological observations to compare with model predictions. Additional meteorological data was available from the EPA Aerometric Information Retrieval System (AIRS) sites (Figure 1) which provided hourly surface data for verification of the model. Standard surface and rawinsonde observations were also available. Mixing height data were available from an air quality study which used radar wind profiler data (winds, radio acoustic sounder, and signal-to-noise ratio) to determine the mixing height. A comparison of the predicted and observed mixing height from the profiler located near O in Figure 1 is shown in Figure 4.

The graph shows that the hourly RAMS-predicted mixing heights compared favorably with the observed profiler mixing heights for the two days the data overlapped. It is important to note that the profiler can not reliably measure the mixing heights when they are below its lowest range gate (approximately 150 m) or above its highest range gate (approximately 3500 m). RAMS predicted the mixing height to grow from near the surface up to peaks of 4500 m on 12 August and 4000 m on 13 August. The predicted growth of the mixed layer by RAMS very closely matched the observed mixing layer growth during the morning hours from 0800 to 1300 MST.

Graphs comparing the hourly observed and predicted temperature, dew point, wind direction and wind speed for 10-14 August from the El Paso airport (located just east of P in Figure 1) are presented in Figures 5 and 6. The graphs show that RAMS' temperatures and dew points closely matched the observed except RAMS minimum temperatures were approximately 1 to 3° K lower than observed. For winds, RAMS predicted wind speeds close to those observed especially between the hours of 1800 to 0000 UTC (1100 to 1700 MST) on all three days of the simulation. During the afternoon of 12 August, the wind speeds peaked at 7 m-sec$^{-1}$ with a wind direction of 100°**.** RAMS predicted a peak of 8 m-sec$^{-1}$ with a direction of 100°. This easterly flow at the airport located east of the Franklin Mountains was due to the upslope flow generated because of the topography.

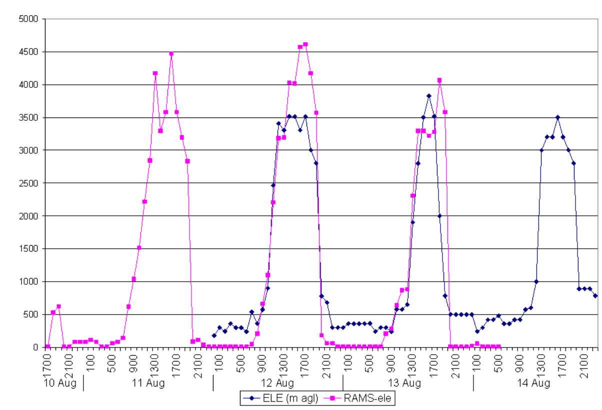


Figure 4. Comparison of mixing heights observed from profiler (black) and predicted by RAMS (gray) for the period 1700 MST, 10 August 1996 to 0500 MST, 14 August 1996.

### *3.3. CAMx implications*

The CAMx model used output from RAMS to model the CO and $O_3$ episodes. The CAMx modeling is described in Emery et al. (2000). While using the mesoscale model to generate 3-d wind fields proved extremely valuable to the CAMx modelers, there were adjustments in the input to RAMS and CAMx that were made and lessons learned in the process. These lessons were:

- Small changes in the RAMS soil moisture parameter caused significant changes in the predicted wind, temperature, and vertical diffusion fields.
- RAMS was vulnerable to numerical instability at the very fine vertical and horizontal grid spacing required by CAMx. CAMx required 25 m vertical grid spacing in the lowest 100 m and 1 km horizontal grid spacing on the inner-nested grid. After several unsuccessful runs, we successfully configured RAMS to handle the fine grid spacing.
- CAMx, much like other transport and diffusion models, was especially sensitive to RAMS predictions of the wind and the mixing heights. The 3-dimensional wind speed and direction controls the movement of trajectories. The mixing height and related parameters (vertical diffusion coefficient and TKE) control the depth and strength of vertical diffusion. CAMx uncertainties existed for this study because of uncertainties in the input data such as the RAMS meteorological data and the emissions inventory data. Therefore, when RAMS predictions did not closely match observations, as they did for several time periods during each episode and in some locations, then uncertainties in the CAMx modeling existed and had to be resolved.

## 4. CONCLUSIONS

RAMS runs were made for periods when episodes of CO and $O_3$ occurred in the El Paso, TX / Juarez, Mexico area. These runs provided meteorological data to the CAMx photochemical model that enabled CAMx to successfully model the transport, diffusion, and chemistry of the pollutants of interest. To successfully run RAMS required that we make numerous iterations of the model. We succeeded in producing runs that ran to completion and produced data which we determined were accurate and suitable for the CAMx model.

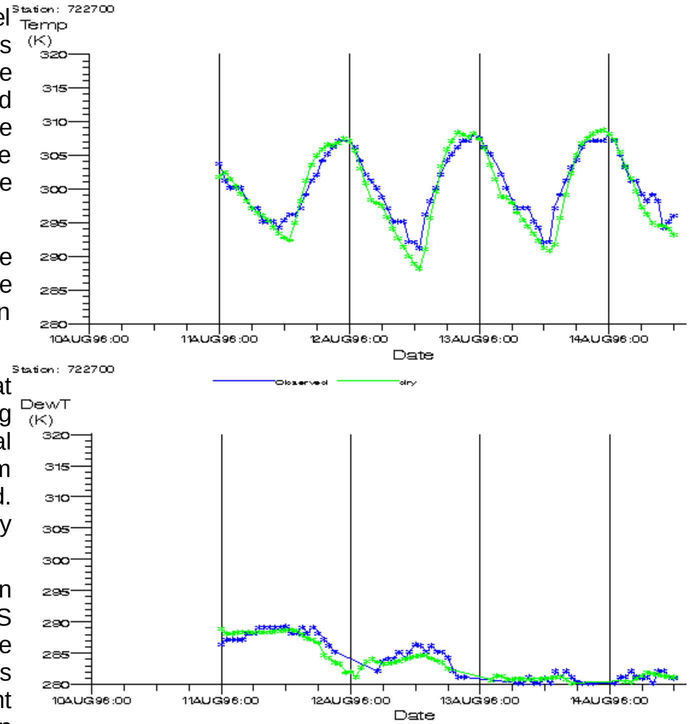


Figure 5. Comparison of observed (black) and predicted (gray) temperature and dew point on 11 August 1996 at the El Paso airport.

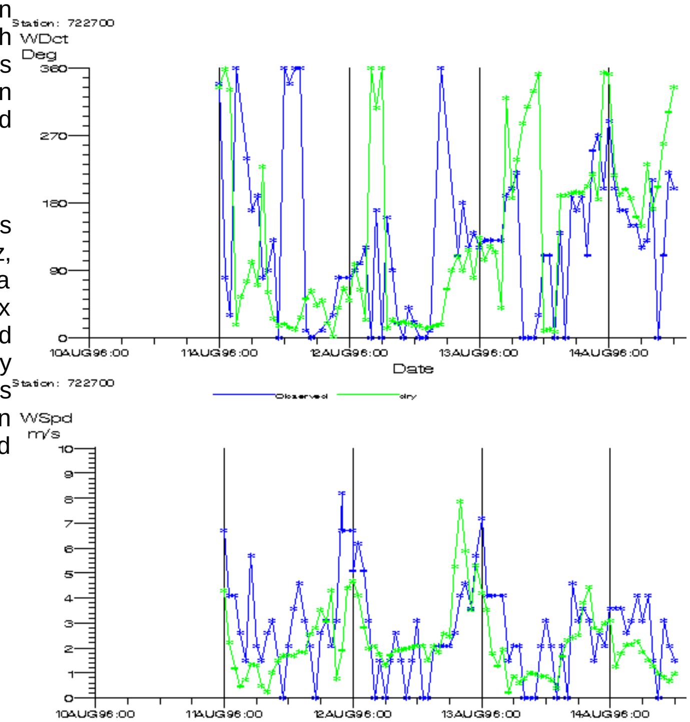


Figure 6. Comparison of observed (black) and predicted (gray) wind direction and wind speed on 11 August 1996 at the El Paso airport.

## 5. ACKNOWLEDGMENTS

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## 6. REFERENCES

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