Using The RAMS Mesoscale Model For Meteorological Input Into A Photochemical Model For O_3 And CO Episodes For The El Paso, Texas / Juarez, Mexico Region

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ABSTRACT

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 Paso del Norte Airshed is located in desert 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 RAMS mesoscale model was used to produce three-dimensional meteorological fields that were used as input to the 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.

RAMS was initialized with meteorological data obtained from both U. S. and Mexican locations. Surface and upper-air data were obtained from routine weather observing stations. We also used the NCAR/NCEP Reanalysis data set that provided meteorological data at 2.5-degree latitude and longitude intervals at 46 vertical levels up to a height of 26 km. The Reanalysis data is a global data set that can be used to initialize mesoscale models at any location. Meteorological data from the EPA Aerometric Information Retrieval System (AIRS) was used to verify RAMS model output. AIRS sites were located in the U. S. and Mexico in the El Paso/Juarez area.

Output from RAMS provided the CAMx model with its required fine grid meteorological data. RAMS produces many meteorological parameters on a three-dimensional grid that are useful for air quality models. Parameters from RAMS used by CAMx were wind speed, wind direction,

temperature, pressure, water vapor, mixing height, and vertical diffusion coefficient.

This paper discusses the mesoscale modeling effort and the challenges encountered in using a combination of U. S. and Mexican meteorological data. The paper also discusses the RAMS model output and its use in providing data to a regional photochemical grid model. The photochemical modeling using CAMx is described in a companion paper by Emery.

INTRODUCTION

The purpose of the analysis was to model exceedance episodes of carbon monoxide and ozone that occurred in the Paso del Norte Airshed of El Paso, TX and Juarez, Mexico. 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.

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, non-hydrostatic, 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 mountainous desert terrain (Figure 1). 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.

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).

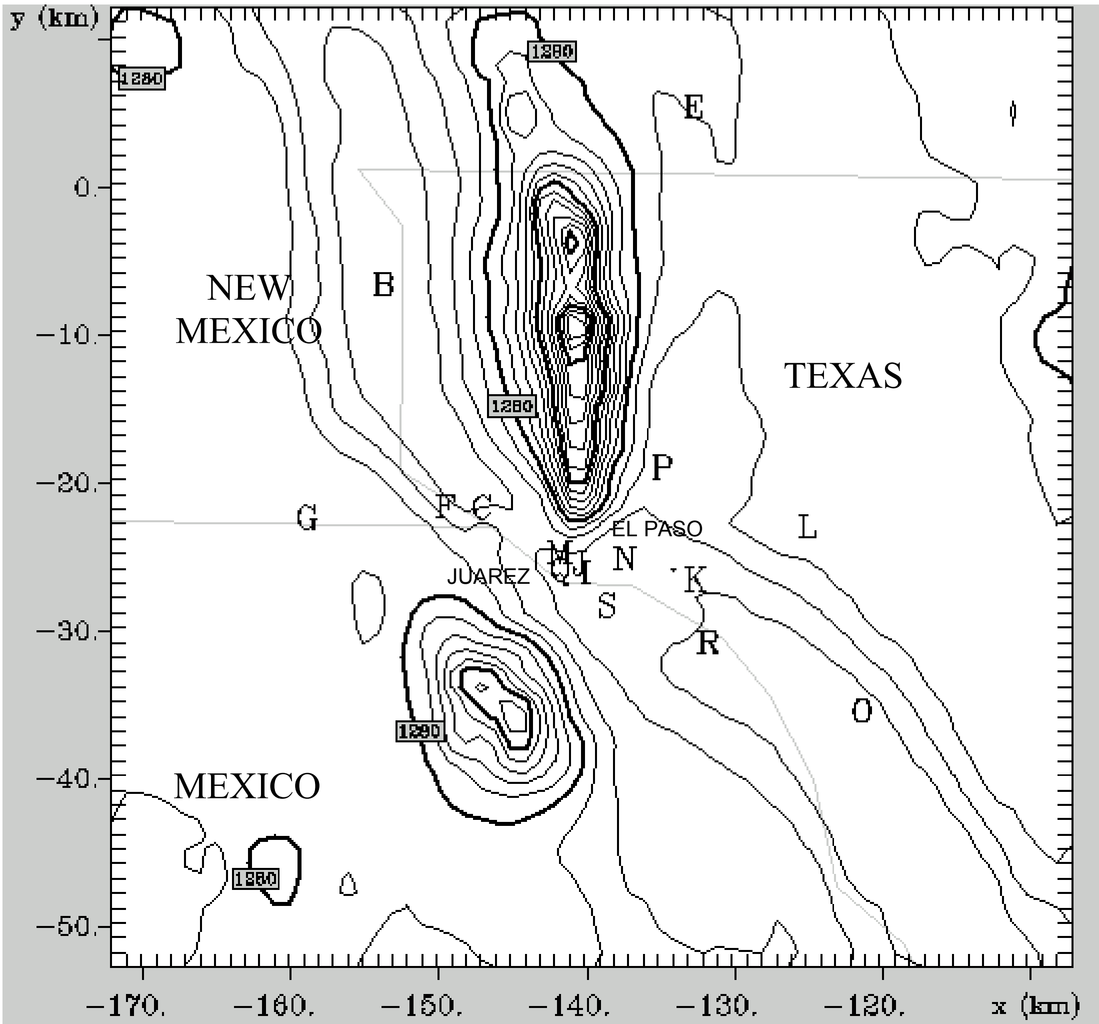
RAMS MODELING

RAMS Background

RAMS was developed at Colorado State University and MRC/ASTER to simulate weather systems spanning from the hemispheric scale 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).

RAMS contains many options which allow it to be applied to differing scales and scenarios. It uses two-way nesting which allows users to specify fine grid inner nests. Two-way nesting permits perturbations to enter and leave the fine mesh. The RAMS code has been parallelized for faster processing on multiple processor computer platforms.

Figure 1. Map showing topography (m) in El Paso along with AIRS stations (air quality monitoring locations) and the El Paso airport (P). The site locations, shown by the letter labels on the map are located in Mexico and the United States.



Basic RAMS Configuration

RAMS requires the user to set numerous variables to control the operation of the atmospheric model. Table 1 shows some of the parameter settings used for the simulations in this study.

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
Horiz. 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 additional layers at 25., 50., 75., 133., 167., 233., 267.,. and 350.			
Initialization and nudging data sources	NCAR/NCEP Reanalysis data at 2.5°, Standard surface and rawinsonde observations, El Paso radar wind profiler			
Boundary condition / nudging frequency	6 hr			
Length of simulations	84 hours, 72 hours			
Numerical scheme	Nonhydrostatic			
Microphysics scheme	Full (NLEVEL=3)			
Convective param.	Grids 1 & 2			
Radiation	Chen			
Soil moisture	15%, 5%			

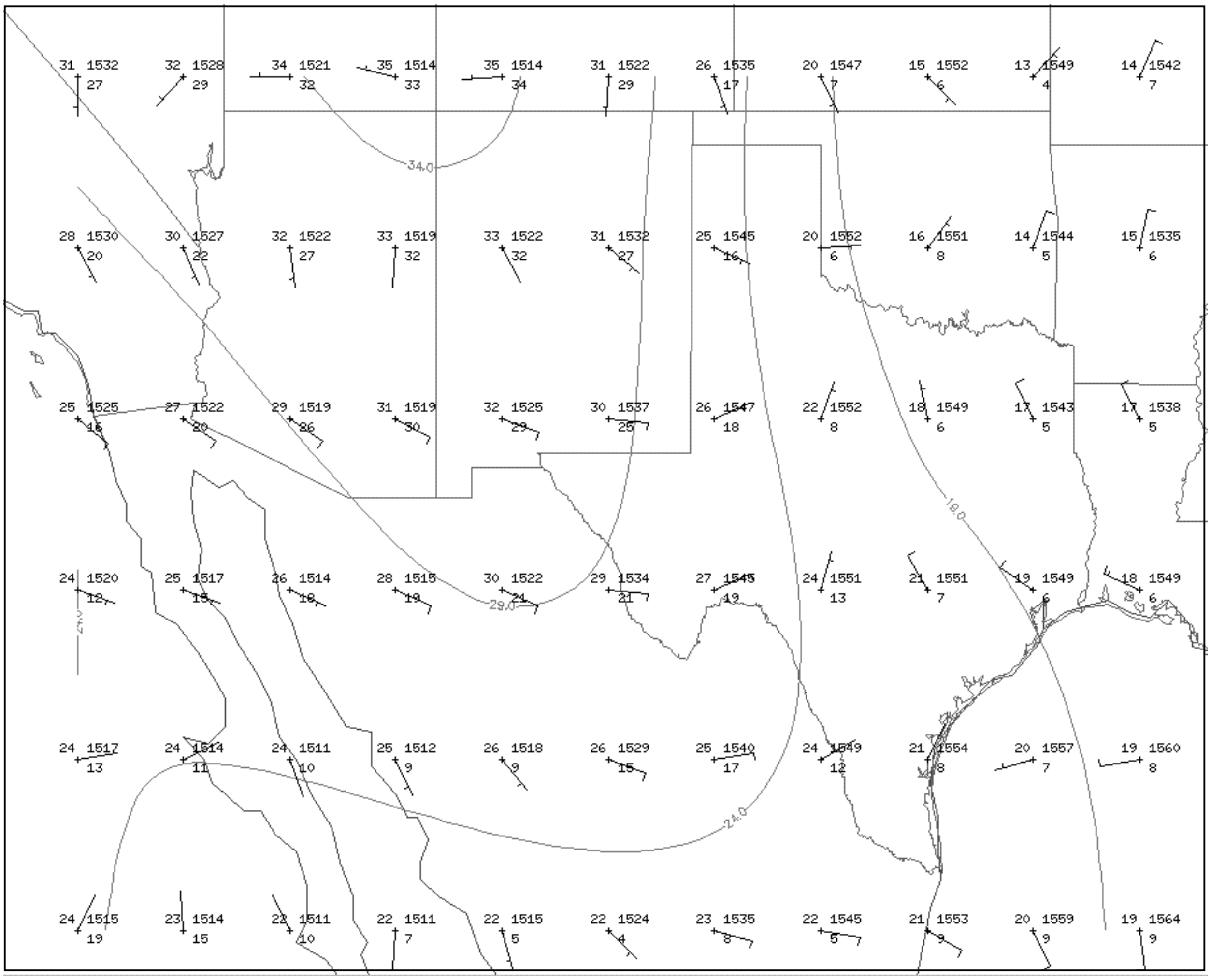
International Input Meteorological Data

We initialized RAMS and provided it boundary conditions using a combination of meteorological data sets. These data sets included data from the U.S. as well as Mexico.

Reanalysis data

One international data set available for studies which cross international borders is the NCAR/NCEP Reanalysis data. The NCAR/NCEP gridded Reanalysis data set (Kalnay et al., 1996) was used to initialize, nudge, and provide the lateral boundary conditions for RAMS. The grid spacing for the NCAR/NCEP data is 2.5 degrees(approximately 280 km). The Reanalysis data has proved to be extremely valuable for RAMS modeling because Reanalysis data provides information that the model needs on the large scale weather features (Figure 2) while the RAMS model produces mesoscale weather features associated with local forcing such as upslope and downslope flows.

Figure 2. Map showing the Reanalysis meteorological data at 850 mb at 2.5 degree intervals for southwest U.S. and northern Mexico for 0000 UTC, August 13, 1996. Data was used to provide RAMS boundary conditions and nudging at this time.



Reanalysis data refers to data assembled for the NCEP/NCAR 40-year Reanalysis Project (Kalnay et al., 1996). The reanalysis data were assembled in a global analysis effort which involved the recovery of land surface, ship, rawinsonde, pibal, aircraft, satellite, and other data. The data were quality controlled and assimilated using a consistent data assimilation system. The reanalysis data has horizontal resolution of 2.5 degrees with 28 vertical levels (1000 to 3 mb). The significant feature of this data set compared to other operational data sets is the comprehensive data base that was used compile the reanalysis data. The NCEP-NCAR Reanalysis Project was recognized with a Special Award by the American Meteorological

Society "for the design and production of a physically consistent multidecadal reanalysis dataset that has opened substantial new opportunities for climate diagnostics" (AMS 2000).

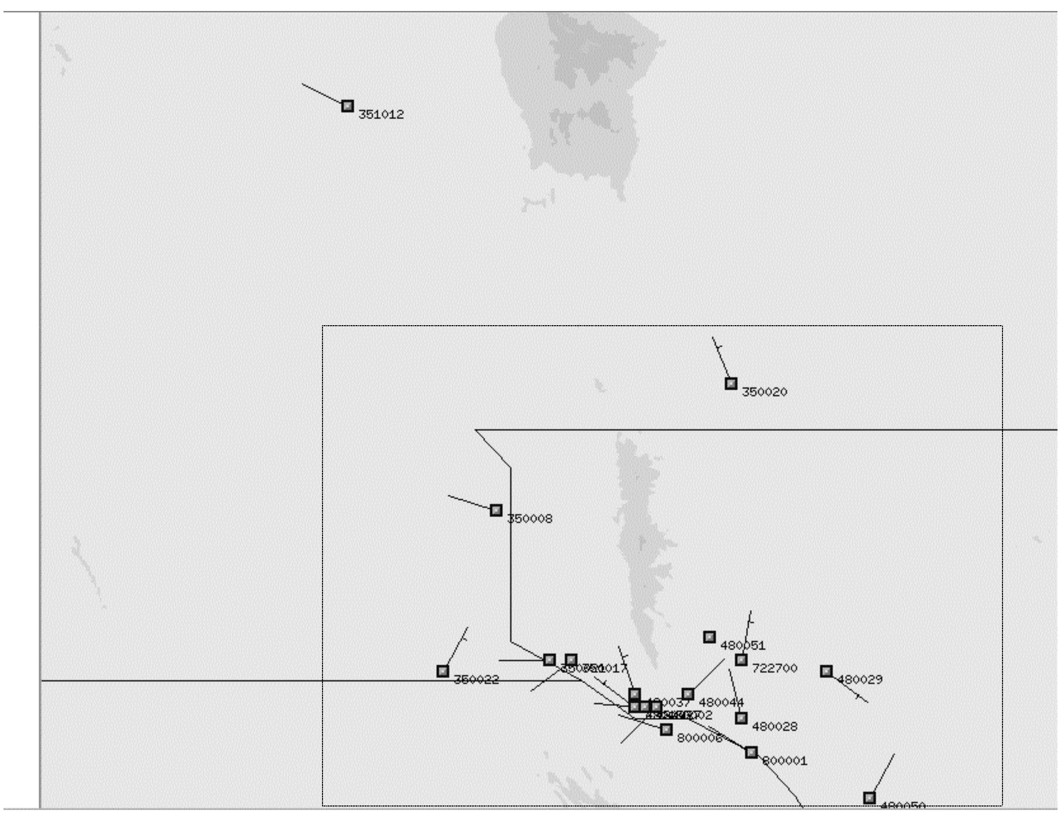
AIRS data

AIRS (Aerometric Information Retrieval System) is a computer-based repository of information about airborne pollution in the United States and various World Health Organization (WHO) member countries. The system is administered by the U.S. Environmental Protection Agency (EPA), Office of Air Quality Planning and Standards (OAQPS), Information Transfer and Program Integration Division (ITPID), located in Research Triangle Park, North Carolina. AIRS is installed on the IBM computer system at the EPA's National Computer Center (NCC) in Research Triangle Park, North Carolina. Any organization or individual with access to the EPA computer system may use AIRS to retrieve air pollution data.

Report generation capabilities allow states to access and use the data. It eliminates the need for individual states to maintain their own databases of air pollution information and to reformat or reorganize data for submission to the EPA's database. AIRS provides standard information requirements and information handling procedures, which enables OAQPS to compare and to use data from different states.

AIRS data was used in the El Paso analysis to provide nudging data at 6-hour intervals for modeling the December carbon monoxide case (Figure 3). The accuracy of the low-level transport winds were very important in trying to correctly model the CO episode with CAMx.

Figure 3. Map showing wind data from AIRS monitoring sites at 0200 MST, 20 December 1997. Outline shows section included in RAMS grid 4.



Problems Encountered/Troubleshooting

RAMS is a complex mesoscale model with an input namelist file of over 300 parameters. In order to model the two different episodes in the El Paso area, we ran approximately 70 different RAMS simulations. Different simulations were performed 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*. For mesoscale modeling, the spatial scales of the forcings and of the resultant perturbation fields determine the necessary domain size of the model as well as its grid spacing. To represent mesoscale systems properly, it is required that the averaging volume used to define the model grid spacings must be sufficiently small so that the mesoscale forcings and responses are accurately represented (Pielke 1984). For the El Paso domain, topography with steep slopes were an important forcing feature. Therefore, a fine grid spacing down to 1 km was desirable. However, modeling at such a fine scale causes a higher probability that numerical instabilities may occur. For this study we found that running RAMS with a fine grid spacing of 1 km led to more model crashes than with a 2 km grid spacing. One way we found to remedy the problem and then to obtain good results with a 1 km spacing was to raise the model top from approximately 20,000 to 26,000 m.

- *Soil moisture of 5% vs. 15%*. Soil moisture is important in mesoscale modeling because it directly affects surface heating during the day and because it affects the amount of microphysical cloud modeling that will occur. The drier the soil, the greater the heat flux at the surface and therefore the greater the vertical motions during the day. Large vertical motions within the model can sometimes lead to numerical instabilities which cause RAMS to crash. Higher soil moisture can cause RAMS to exercise the microphyical cloud model as RAMS generates clouds. For this study, we determined that for El Paso, soil moisture should be set to 5% based on the observed sandy soil type and the limited precipitation received prior to our study periods. However, when we first ran the model with soil moisture of 5%, it frequently crashed. The model would run successfully with soil moisture set to 15% but model output did not match observations. We once again remedied the problem and obtained good results by raising the model top from approximately 20,000 to 26,000 m.

- *Varying input data: 6-hr vs. 12-hr interval, Reanalysis data only vs. observation-supplemented*. RAMS has the option of initializing and nudging with input meteorological data from various sources and times (surface, upper-air, reanalysis). We found that changing the input meteorological data produced different RAMS results. Some of the different results were expected and significant while other differences were minor and unexpected. As expected, in most cases the more detailed data used for input, the better the RAMS results.

RAMS MODELING RESULTS

The results of the RAMS modeling were 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. As discussed earlier, both the CO and O_3 episodes presented unique challenges which had to be addressed as we tried to produce the most accurate 3-dimensional meteorological fields.

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

O_3 Case – 13 August 1996

The conceptual model for ozone formation during this episode involved the vertical diffusion and growth of the convective boundary layer during the intense summer weather conditions that occurred during the daytime hours of 11-14 August. Therefore, the mesoscale modeling effort focused on obtaining accurate meteorological output data for the period of peak ozone production.

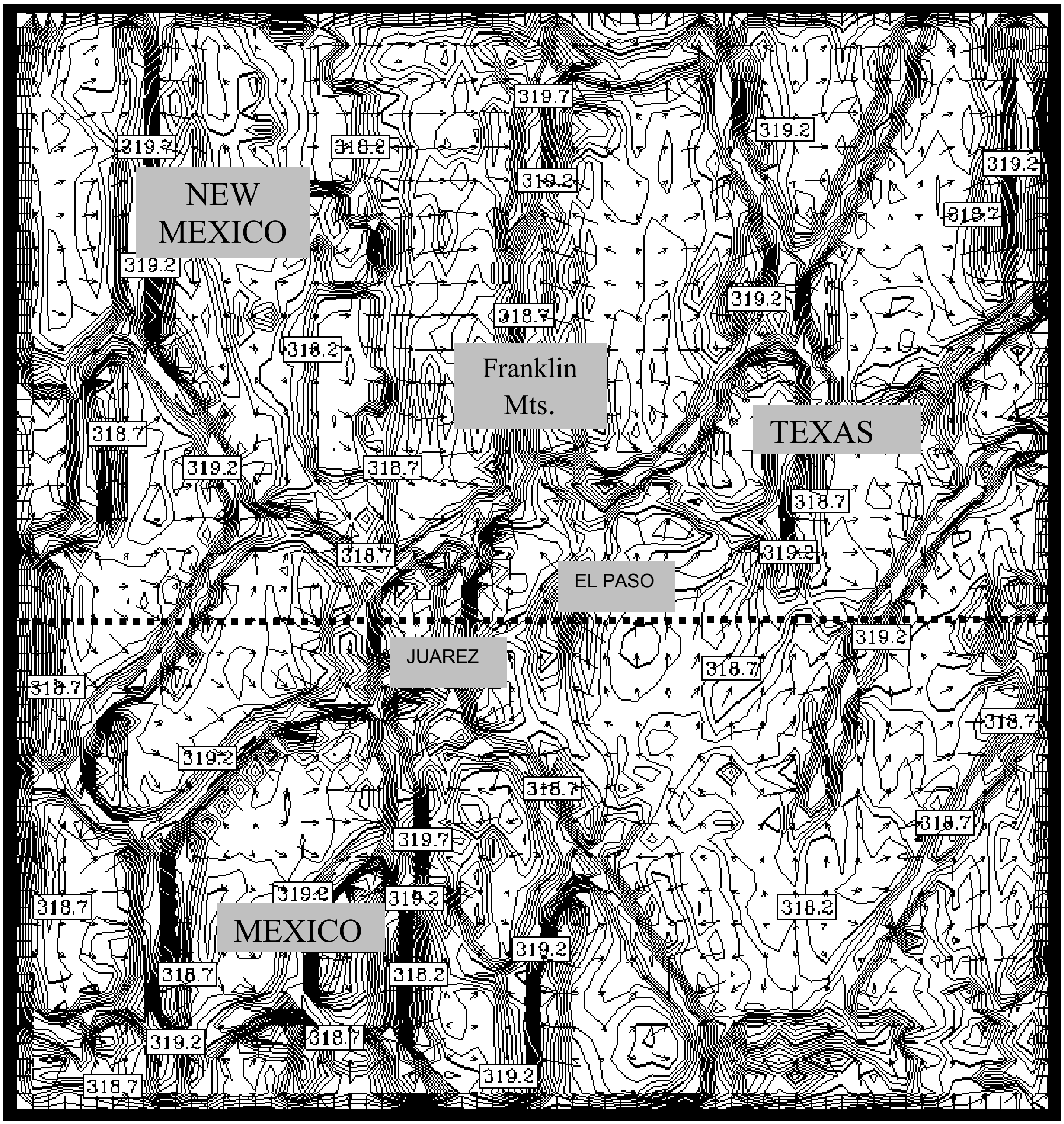
RAMS predictions

RAMS produced hourly output of meteorological data that we compared to observations. We also analyzed the RAMS-predicted wind flow patterns to determine if they followed the conceptual model based on the diurnal and topographic forcing within RAMS. For example, we looked to see if RAMS generated upslope/drainage flows around the mountains. We also looked to see if RAMS generated expected patterns of convection for a summer afternoon, desert location.

For the period 11-14 August 1996, RAMS predicted easterly surface winds during the daytime hours of 11 August and continuing into to the night. The easterly flow, which was a function of synoptic forcing, produced southeast flow up the valley through the El Paso/Juarez area during both day and night and contributed to downslope flow on the western side of the Franklin Mountains during the day. On 12 August, the easterly flow continued with wind speeds dropping to less than 2 m-sec^{-1} across much of the fine grid domain during the day but increased to 3-4 m-sec^{-1} during the night. On 13 August, the day of the observed ozone exceedance, RAMS wind speeds once again dropped to near calm at sunrise but then increased slightly from the east during the morning. RAMS produced a pattern of weaker convection on the afternoon of the 13 August and with less variability in wind direction and speed than predicted on 11 and 12 August.

One period of interest for the CAMx modelers was the late morning and early afternoon hours of 13 August 1996. During the morning, the mixed layer grew rapidly as the weak easterly flow prevailed. The RAMS model showed an intense convective period during the afternoon hours (Figure 4) where the mixing height reached to over 4000 meters above the ground. RAMS treatment of boundary layer eddies causes it to generate areas of intense updrafts and downdrafts during the strong convective periods. The locations of these eddies may not be precise because many factors affect the location of the eddies including topography and land cover. Therefore, we must be careful in using the RAMS vertical motion data at any one location for one particular time. Spatial and temporal averaging of the data affected by the convective vertical eddies may be needed. Also, the horizontal and vertical grid resolutions play an important part in the location and strength of the eddies. Running RAMS with a greater or lesser horizontal resolution than the 1 km used in our simulations would most likely change the location and intensity of the eddies.

Figure 4. Map showing the lowest level RAMS wind vectors plotted with potential temperature for El Paso/Juarez for 1500 MST, 13 August 1996. The mid-afternoon plot shows the unstable regime. The dashed line indicates the location of the cross-section in Figure 5.



A vertical cross-section of the turbulent kinetic energy (TKE) as predicted by RAMS is shown in Figure 5. 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.

At night, RAMS predicted considerably less chaotic meteorological conditions as a stable boundary layer developed during the nighttime and early morning of 13 and 14 August (Figure 6). Winds in the El Paso/Juarez area were from the southeast.

Figure 5. West-east cross-section across the center of the fine grid showing the vertical profile of TKE at 1600 MST on 13 August 1996. The cross-section cuts across El Paso/Juarez through the Rio Grande valley between the Franklin and Juarez Mountains (see dashed line, Figure 4).

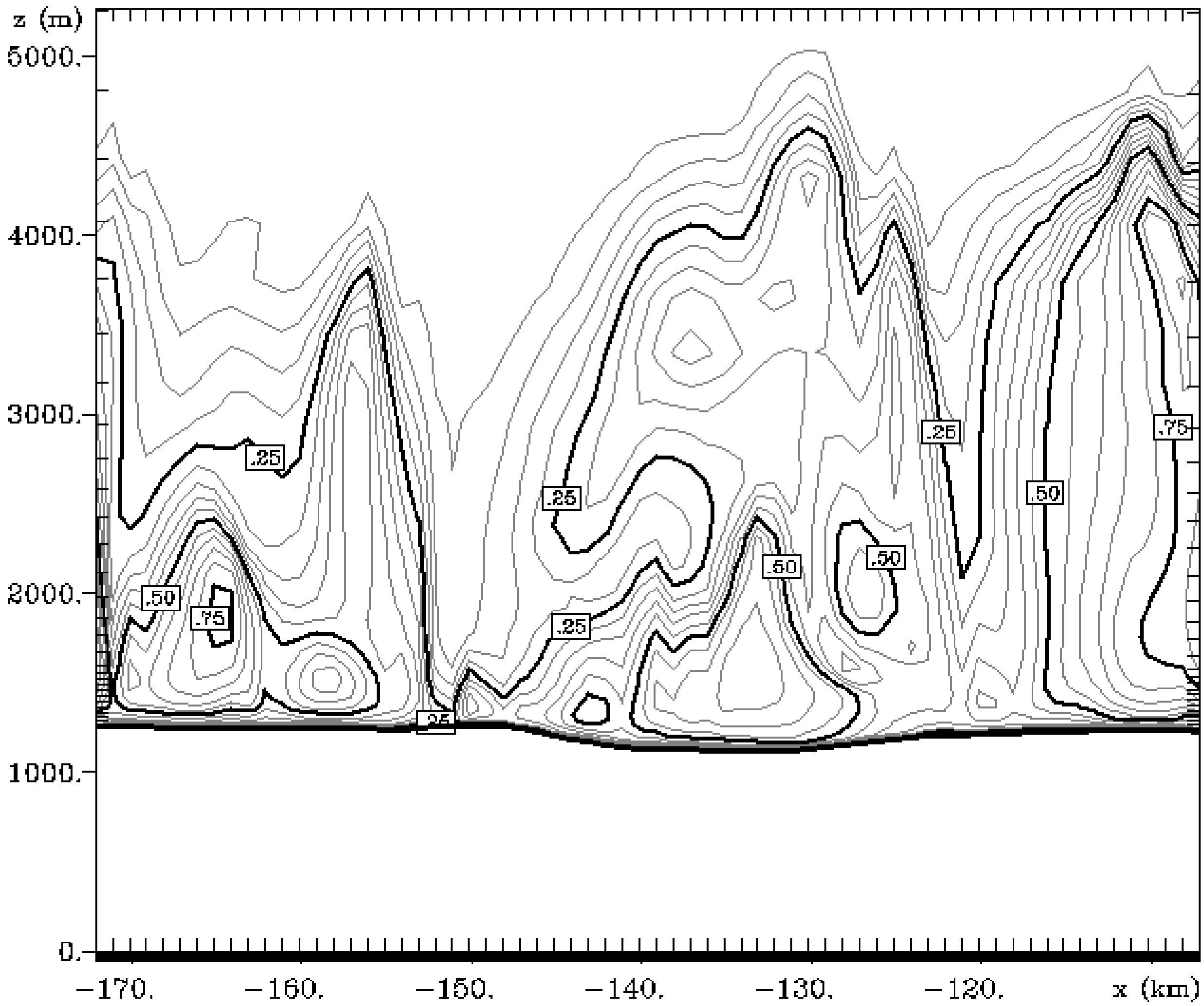
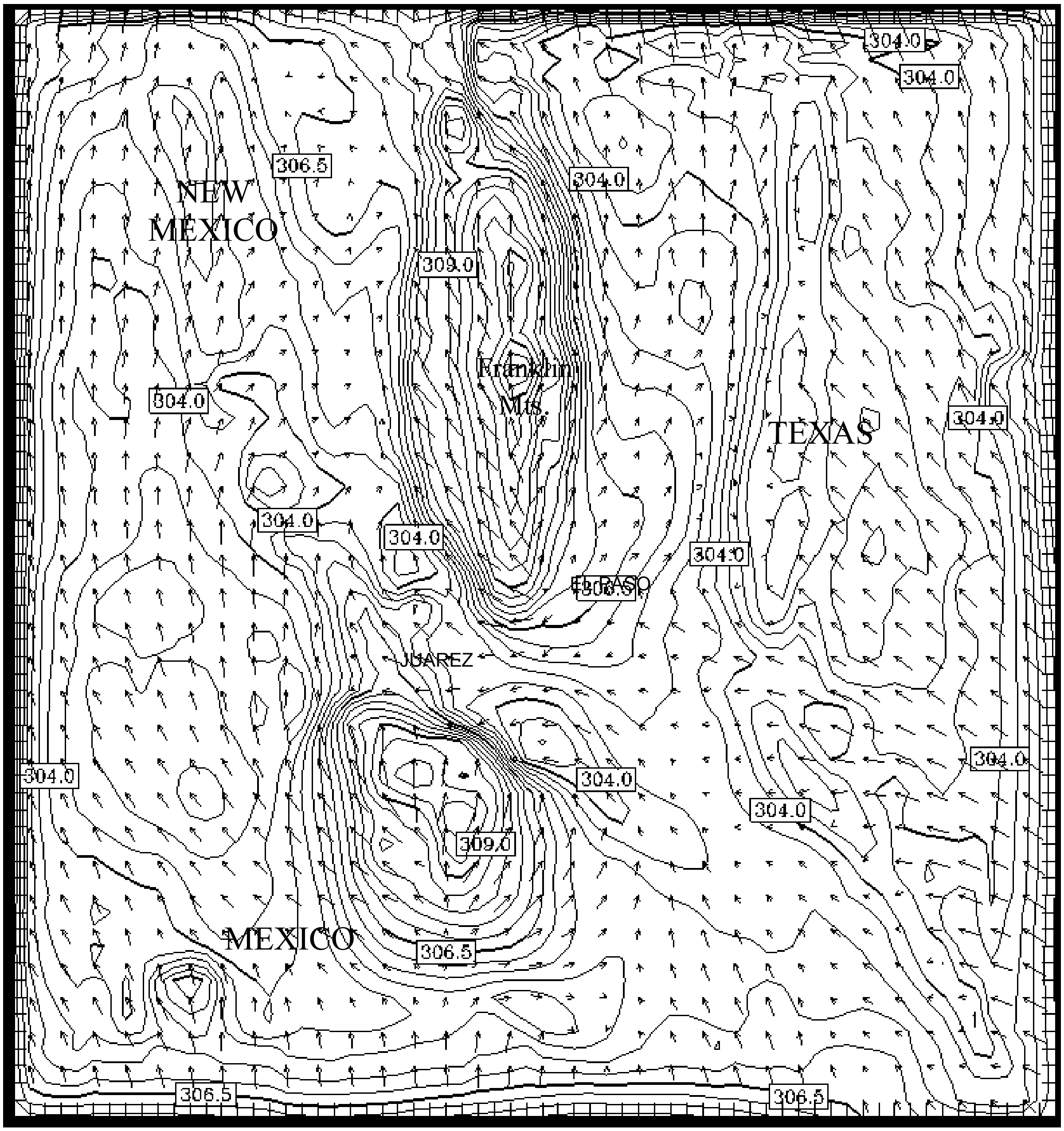


Figure 6. Map showing the lowest level RAMS wind vectors plotted with potential temperature for El Paso/Juarez for 0100 MST, 14 August 1996. The early morning plot shows the stable regime.

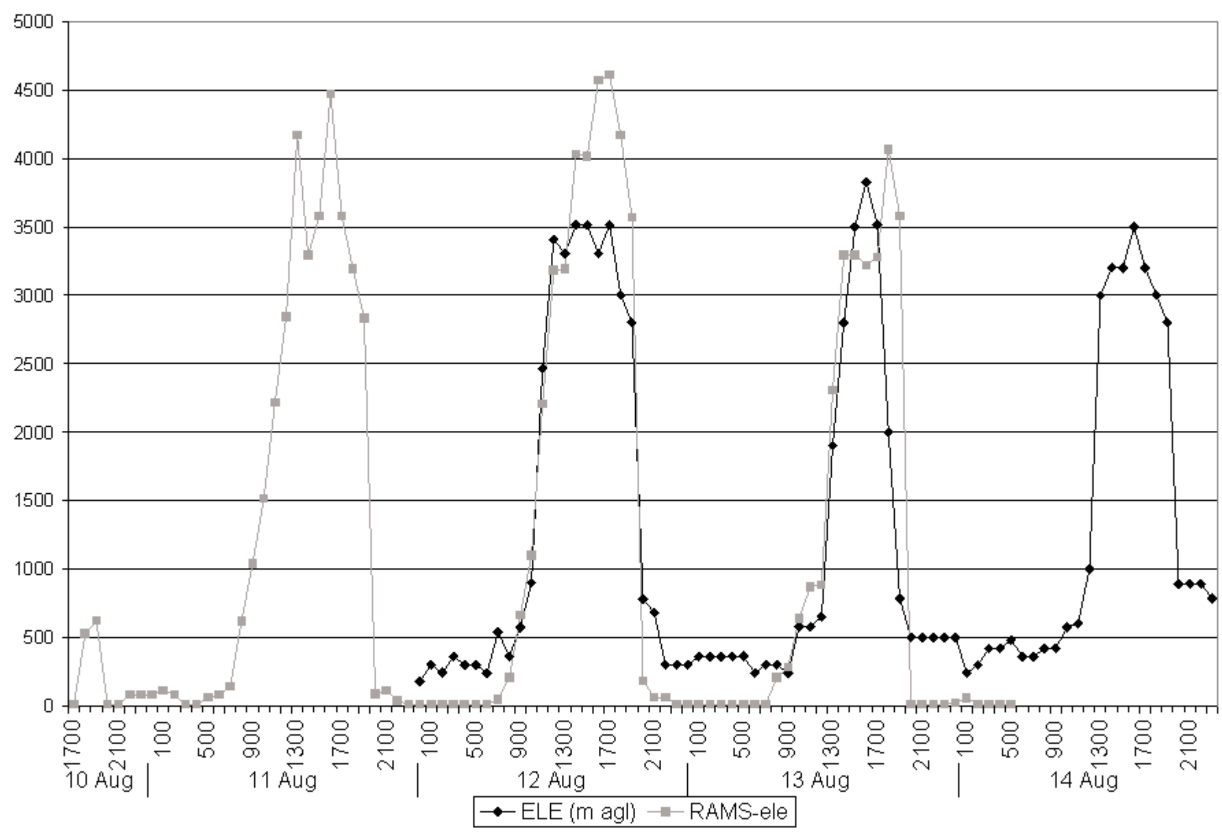


Observed vs. Predicted

For this study, we used available meteorological observations to compare with model predictions. Additional meteorological data were 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 7.

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). Profiler mixing heights topped out at approximately 3500 meters, whereas 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 RAMS mixed layer very closely matched the observed mixing layer growth during the morning hours from 0800 to 1300 MST.

Figure 7. 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.



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 Figure 8.

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.

For this study we generated graphs comparing the observed and predicted winds and temperatures at all the AIRS sites were generated. These graphs are not presented in this paper but show similar results as the graph shown in Figure 8.

Figure 8a. Comparison of observed (black) and predicted (gray) temperature, dew point, on 11-14 August 1996 at the El Paso airport.

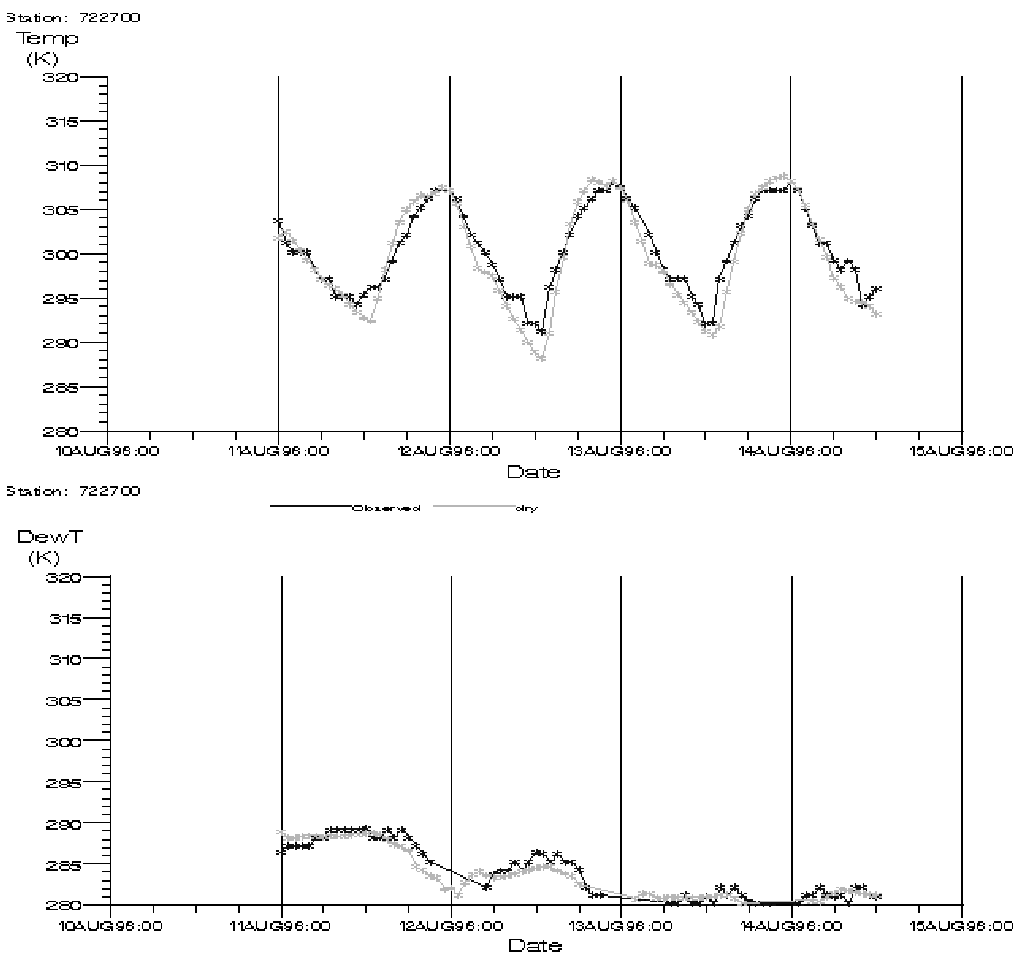
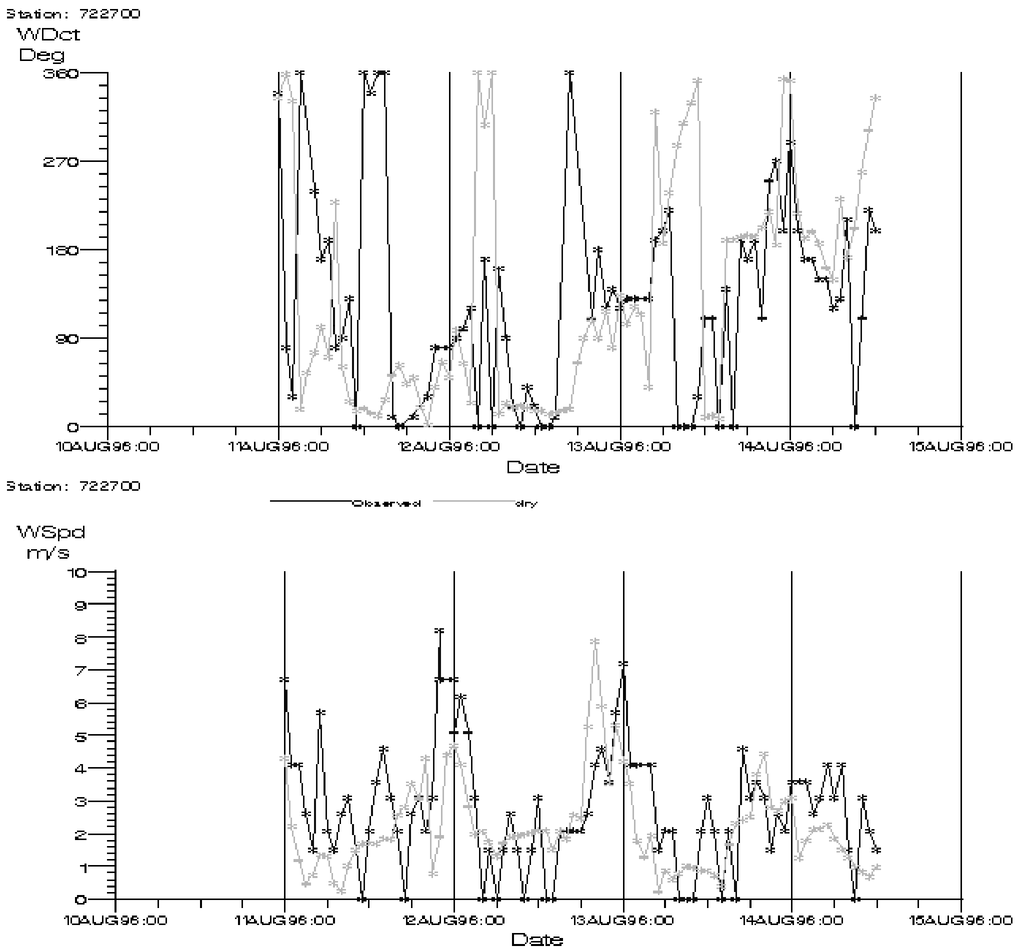


Figure 8b. Comparison of observed (black) and predicted (gray) wind direction, and wind speed on 11-14 August 1996 at the El Paso airport.



CO Case – 18-19 December 1997

The meteorology in El Paso/ Jurarez during the 17-20 December 1997 period was dominated by the presence of a high pressure system that led to an extended period of clear skies and extremely light winds. These light winds produced the stagnant conditions that contributed to the CO exceedance on 18-19 December. To determine the validity of the output data, we first analyzed graphical output of the RAMS data for this period.

We analyzed the RAMS output to see if it replicated the light wind conditions and nighttime drainage flow that produced the northwesterly down-valley wind flow during the night and early morning of 18-19 December. Measurements from the AIRS data indicated the occurrence of the drainage flow beginning around 2200 MST west of El Paso. Wind speeds at the AIRS sights were light at approximately 2 m-sec^{-1}.

To obtain the best and most accurate RAMS data for CAMx, we utilized the RAMS capability to nudge with observational data using the 4-dimensional data assimilation (4DDA) option. In addition to nudging with the 2.5-degree reanalysis data and the standard rawinsonde and surface observations every 6 hours, we nudged in the surface AIRS data from the 18 El Paso/Juarez locations every 6 hours. We modeled one RAMS run that did not include AIRS data for the first 41 hours (up to 2300 MST, 18 December) but nudged in AIRS data for the last 31 hours (after 2300 MST, 18 December). Output from this run is shown in Figures 9 and 10.

Figure 9 shows the RAMS-predicted wind vectors for the surface grid points at the 12-m grid level at 2000 MST on 18 December. This time of the RAMS run did not include AIRS data and shows southeasterly flow up the valley through El Paso/Juarez. Figure 10 shows the RAMS wind vectors at 2300 MST on 18 December. This time includes the AIRS data and shows the drainage flow with northwesterly winds that occurred before midnight and then continued through the early morning hours of 19 December. The following summarizes the meteorology and RAMS results on 17-20 December:

- The daytime hours of 17-19 December were characterized by sunny conditions with highs near 15°C and lows near -5°C (see Table 2).
- Surface winds were light and variable, especially on 18 December (Figure 11). With light winds, wind directions were generally, forced by the topographic flows. This was evident in the observed and RAMS winds.
- On the night of 18 December, southeast upslope flows were present during the day and early evening and then downslope, west and northwest drainage flows were present during the night (Figure 11).
- Conditions were dry during the period until 20 December and therefore RAMS was parameterized appropriately with soil moisture of 0.05. Accurately parameterizing the soil moisture produces better RAMS results because RAMS is very sensitive to the soil moisture. The soil moisture has been shown to affect the model predictions of temperature, winds, moisture and cloud formation throughout the RAMS domain. In RAMS, drier soil heats faster during the day and cools faster at night compared to soil with higher soil moisture.

Table 2. Weather data recorded at the National Weather Service location near the El Paso airport.

Date	Max (°C)	Min (°C)	Avg spd (m-sec^{-1})	Peak wind (m-sec^{-1})	Direction	% sun	Precip (in)
Dec 17	14.4	-5.5	2.0	4.9	220	100	0.0
Dec 18	16.1	-4.4	0.9	4.0	180	100	0.0
Dec 19	17.8	-2.8	3.5	11.6	050	93	0.0
Dec 20	10	0.6	5.1	11.6	040	0	0.22

The flow pattern produced by RAMS when modeled by CAMx, initially carried the pollutant emissions to the northwest but then transported some of the material back to the south and southeast with the northwest drainage flow.

The graph presented in Figure 11 compares the observed and predicted wind speed and wind direction over the episode period 17-21 December at one of the AIRS sites located in downtown El Paso. The graph shows that the RAMS wind speeds and directions compare favorably with observations. The run was nudged with AIRS data the last 31 hours of the run.

Figure 9. Map showing the RAMS wind vectors plotted on the topography for El Paso/Juarez for 2000 MST, 19 December 1997. The RAMS data was generated without using any of the AIRS data for nudging. The white dot indicates the location of the AIRS site in El Paso for which data is graphed in Figure 11.

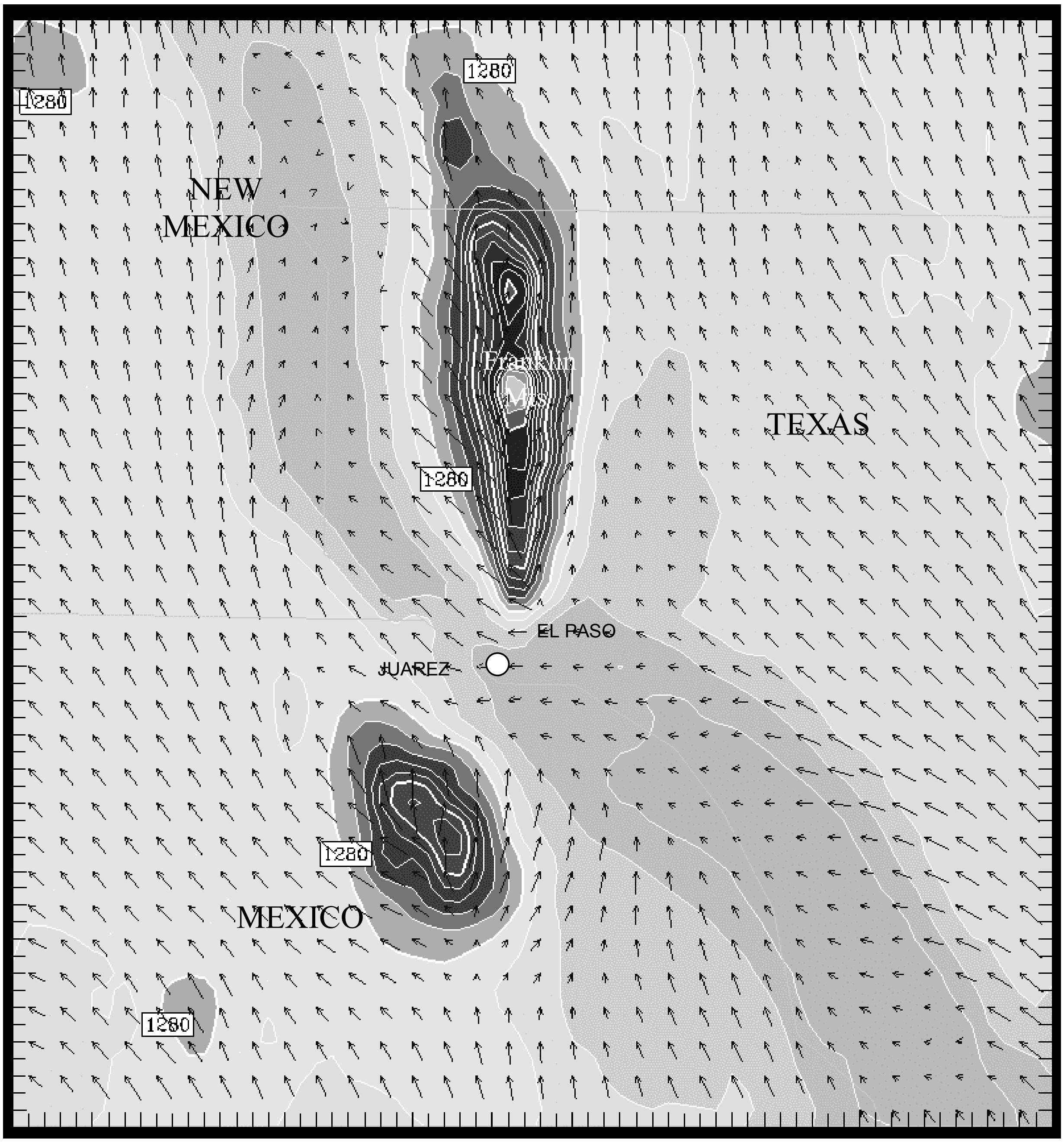


Figure 10. Map showing the RAMS wind vectors plotted on the topography for El Paso/Juarez for 2300 MST, 19 December 1997. The RAMS data was generated using AIRS data for nudging. The white dot indicates the location of the AIRS site in El Paso for which data is graphed in Figure 11.

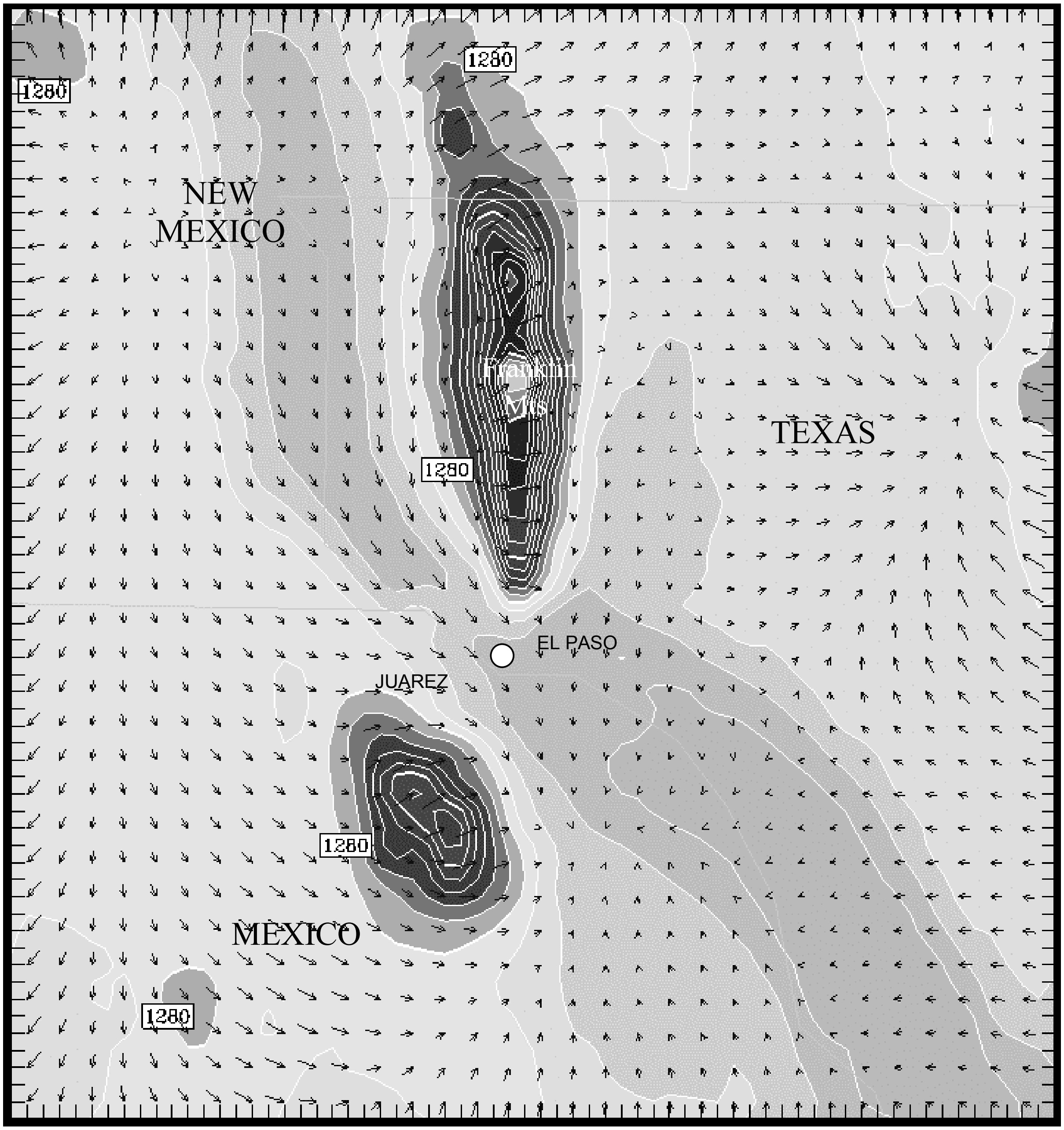
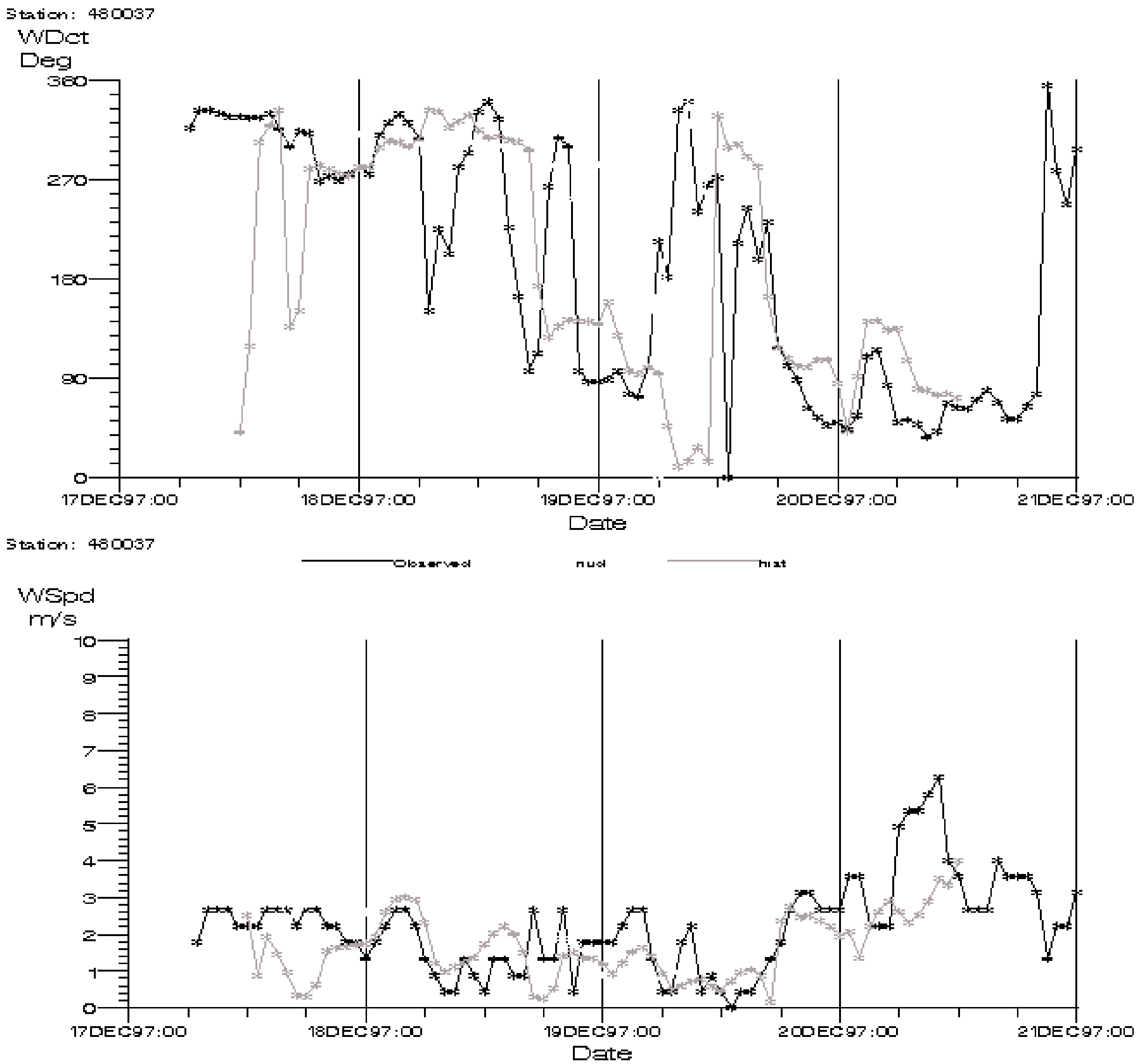


Figure 11. Comparison of observed (black) and predicted (gray), wind direction, and wind speed on 17-21 December 1997 at AIRS site in El Paso. The location of the site is shown by the white dot on the maps in Figure 9 and 10.



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 accurate 3-d wind fields proved extremely important to the CAMx modelers, there were numerous 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. Soil moisture strongly affects the surface heat and moisture flux which are important in mesoscale model processes.

- 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. This was done by adding several layers to the top of the model and by adjusting the surface and soil parameters.

- 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 control 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.

CONCLUSIONS

Data issues figured prominently into the analyses performed for this study. For meteorological modeling in areas of sparse data or in areas along international border, the NCAR/NCEP 2.5-degree Reanalysis data at 6-hr intervals provides an excellent data set for model initialization. Finer scale data may be required to define detailed meteorological features but the Reanalysis data provides excellent mesoscale model initialization.

A mesoscale model such as RAMS can be extremely valuable at providing data to photochemical models. This modeling exercise showed that careful analysis of all input and output data associated with the mesoscale model is required. Therefore, producers of the RAMS data must make sure reliable data goes into and comes out of the mesoscale model to produce valid results.

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.

ACKNOWLEDGMENTS

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