Final Report

Development of Base Case Photochemical Modeling to Address 1-Hour and 8-Hour Ozone Attainment in the Dallas/Fort Worth Area

Prepared for

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EXECUTIVE SUMMARY

The US Environmental Protection Agency (EPA) currently has a 1-hour ozone National Ambient Air Quality Standard (NAAQS) that, simply stated, says no monitor can measure more than three exceedances (0.12 ppm or 124 ppb) in a three-year period. With complete data capture, compliance with the 1-hour ozone NAAQS requires that the fourth highest daily maximum 1-hour ozone concentration in three years at every ozone monitor in the area be less than or equal to 0.12 ppm. However, the standard is defined in terms of an expected exceedance rate (to compensate for inadequate data capture) that allows no more than one expected exceedance per year calculated over three consecutive years. Areas that have more than three exceedances violate the 1-hour ozone NAAQS and are classified as ozone nonattainment areas. Ozone nonattainment areas must develop an ozone emissions control plan and demonstrate that they will attain the ozone NAAQS by the date specified in the Clean Air Act Amendments (CAAA) in a State Implementation Plan (SIP). The SIP ozone attainment demonstration is usually accomplished using air quality modeling.

This report describes the development of the databases and the air quality simulations performed in support of SIP modeling efforts for the August 1999 ozone episode in North Central Texas. It should be noted that the current modeling activities undertaken as part of this project do not include future case control strategy evaluation. However, the current air quality modeling assumed that all planned regional controls in effect at the time of the August 1999 episode (e.g., Tier 2/Low Sulfur and Heavy Duty Diesel on-road mobile source rules) and local Texas controls (e.g., DFW, HGA, Northeast Texas ozone control plans) will be included in the base case modeling.

The high 1-hour and 8-hour ozone period selected for modeling was August 15th-22nd, 1999. After including 2 additional days to "spin up" the ozone model, this results in modeling the 10 day period August 13th-22nd, 1999. This period was selected based on a conceptual model and episode selection for Dallas/Fort Worth, which is summarized in Section 2 of this report. The modeling procedures and modeling domain were developed in an ozone modeling protocol for the August 1999 episode. The Comprehensive Air Quality Model with extensions (CAMx) was selected for ozone modeling.

Meteorological modeling used the Fifth Generation NCAR/Penn State Mesoscale Model (MM5) version 3.6. The MM5 model configuration and run options were chosen based on experience gained through previous modeling of the East Texas 1999 ozone episode. Section 4 summarized the meteorological modeling and extensive details are given in a supporting meteorological modeling report.

Section 3 of the report describes the emission inventory development for the 1999 base year. Emission inventories developed previously for air quality modeling in East Texas and Oklahoma were the basis for the emissions in the regional domains. Inventory data provided by the Texas Commission on Environmental Quality were as used for development of emissions within the DFW 4-km modeling domain.

The preparation of other CAMx model inputs is described in Section 5 while the 1999 base case air quality modeling is discussed in Section 6. The 1999 base case was refined through a series of improvements to the meteorology, emissions and CAMx inputs. The final 1999 base case was designated "Run7c". Section 7 provides a summary of results and recommendations for further refinement of the modeling performed during this project.

In summary, there was a general tendency of the model to under-predict the 1-hour and 8-hour ozone concentrations in the DFW non-attainment area. Based on EPA model performance goals for 1-hour ozone, the Run7c model simulation met the peak accuracy goals in the DFW 4-km modeling domain for all but the last episode day. Excluding the two spin-up days, the simulation met the normalized bias goals in the DFW domain on 5 of 8 episode days with one additional day only marginally outside the accepted range. The gross error performance goal was met for all days except the first spin-up day of the episode.

Diagnostic simulations involving modification of various model inputs and configuration options simulations were undertaken in an attempt to improve model performance. It was determined that the modeling results within the DFW non-attainment region were particularly sensitive to the specification of boundary conditions, highlighting the influence and importance of long-range transport. It was also noted that, while the peak ozone levels were generally well represented, biases in the location and timing of the predicted ozone levels resulted in a general negative bias in the predicted ozone concentrations within the DFW 4-km modeling domain.

Based on the results of the simulations conducted as part of the project, the following recommendations are made regarding further analysis and refinement of the air quality modeling databases and model configurations:

- The evaluation of the final base case simulation, Run7c, revealed a possible deficiency in the estimated mixing heights in the model, as well as possible biases in wind speeds and directions. While a further review of the meteorological modeling might possibly reveal areas for improvement, additional observational data for incorporation into the simulations would likely be required. As noted in Section 4, the model configuration and simulation options have already been optimized based on previous modeling efforts for Texas and Oklahoma. Therefore, it is recommended that the meteorological fields be further review for possible refinements only if additional data are available.

- The specification of initial and boundary conditions for the regional modeling domain appeared to have a significant impact on the predicted ozone levels within the DFW 4-km domain. It is recommended that a more detailed investigation into the appropriateness of the current boundary conditions specifications for the 1999 episode.

- Emission sensitivity simulations should be undertaken to evaluate the response of the model to changes in NOX and/or VOC emissions. These simulations would provide valuable information concerning the development of future year control strategies.

- The Ozone Source Apportionment Technology (OSAT) and the Anthropogenic Precursor Culpability Assessment (APCA) are very powerful tools within the CAMx are quality model. As seen in the analysis of Appendix A, the use of OSAT and APCA can provide a great deal of information concerning source regions and emission source categories which are contributing to elevated ozone levels in an air quality simulation.

It would be useful to further evaluate the use of these technologies both in the investigation of model performance of the 1999 base case and in the development of future year control strategies.

1. INTRODUCTION

The US Environmental Protection Agency (EPA) currently has a 1-hour ozone National Ambient Air Quality Standard (NAAQS) that, simply stated, says no monitor can measure more than three exceedances (0.12 ppm or 124 ppb) in a three-year period. With complete data capture, compliance with the 1-hour ozone NAAQS requires that the fourth highest daily maximum 1-hour ozone concentration in three years at every ozone monitor in the area be less than or equal to 0.12 ppm. However, the standard is defined in terms of an expected exceedance rate (to compensate for inadequate data capture) that allows no more than one expected exceedance per year calculated over three consecutive years. Areas that have more than three exceedances violate the 1-hour ozone NAAQS and are classified as ozone nonattainment areas. Ozone nonattainment areas must develop an ozone emissions control plan and demonstrate that they will attain the ozone NAAQS by the date specified in the Clean Air Act Amendments (CAAA) in a State Implementation Plan (SIP). The SIP ozone attainment demonstration is usually accomplished using air quality modeling.

In 1997, EPA promulgated a new ozone NAAQS that is potentially much more stringent than the old 1-hour standard. The new form is based on ozone measurements averaged over eight hours; violations of the 8-hour ozone standard occur when the fourth highest 8-hour ozone concentration each year, averaged over three consecutive years, at an individual monitor exceeds 0.08 ppm (84 ppb). The actual nonattainment designations are likely to be based on ambient measurements taken during the three years between 2001-2003. Regions that are currently designated as nonattainment of the 1-hour ozone NAAQS must still attain the 1-hour standard (i.e., have three consecutive years over which the fourth highest hourly ozone concentrations at all monitors are 124 ppb or less). Once an ozone nonattainment region attains the 1-hour ozone NAAQS, then the 1-hour standard can be revoked by EPA and the area would be required to meet only the 8-hour standard.

On May 14, 1999, the D.C. District Court declared that EPA exceeded their authority in setting the 8-hour ozone standard and remanded it back to EPA. EPA appealed the decision to the US Supreme Court who upheld the new 8-hour ozone standard in February 2001 but remanded implementation issues back to the lower court. The lower court issued a ruling in March 2002 that required EPA to develop a new 8-hour ozone implementation approach and EPA plans to propose such an implementation rulemaking soon. Although EPA has not officially proposed a new implementation schedule, it would likely require states to recommend to EPA their 8-hour ozone nonattainment areas and boundaries by mid-2003. EPA would likely then make 8-hour ozone nonattainment designations by April 2004 based on 2001-2003 ambient air quality data.

The Texas Commission on Environment Quality (TCEQ) operates several Continuous Air Monitoring Stations (CAMS) in Dallas/Fort Worth (DFW) non-attainment area of Texas. Figure 1 displays the location of the CAMS monitors. These stations monitor compliance with the National Ambient Air Quality Standard (NAAQS) for ozone. Ozone levels in North Central Texas have exceeded the level of the ozone NAAQS in recent years.

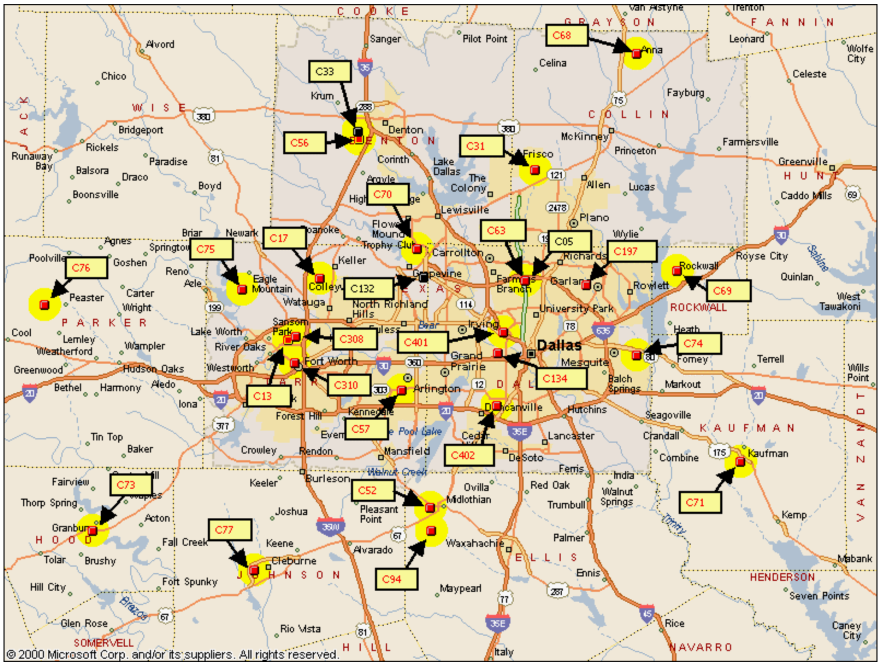


Figure 1-1. TCEQ CAMx monitoring site locations in the DFW area.

Previous Ozone Modeling Studies in the DFW Nonattainment Area

The 1990 Clean Air Act Amendments authorized the EPA to designate areas failing to meet the NAAQS for ozone as nonattainment and to classify them according to severity. The Dallas/Fort Worth area was classified a "moderate" nonattainment area and was required to demonstrate attainment by November 1996. A SIP was submitted with controls focused almost entirely on volatile organic compounds (VOCs); this SIP failed to help the DFW area reach national air quality standards by the deadline. As a result, the EPA reclassified the DFW area from "moderate" to "serious," resulting in a new attainment deadline of November 15, 1999.

The DFW area also failed to reach attainment by the November 1999 deadline. A new SIP was prepared based upon photochemical modeling for two episodes, June 20-22, 1995 and July 2-4, 1996. In April 2000, the TCEQ adopted a final attainment demonstration SIP based upon those episodes, which asserted the importance of local NOx reductions as well as the transport of ozone and its precursors from the Houston/Galveston area. Based on additional photochemical modeling demonstrating transport from Houston/Galveston, the agency requested an extension of the DFW attainment date to November 15, 2007, the same attainment date as for Houston/Galveston.

During this period, federal lawsuits were filed challenging extensions to attainment dates based upon transport. The courts have determined that the Clean Air Act Amendments do not give the EPA authority to grant extensions to the 1-hour attainment dates. Therefore, EPA has not approved the most recent DFW SIP, and it appears that the DFW area will be reclassified again, from “serious” to “severe”, with an attainment deadline of November 2005. A new

SIP will need to be prepared within a year of redesignation, probably not later than the spring of 2004.

Purpose and Objectives

Given the short time available until a new SIP must be submitted, DFW and the state of Texas has had to move quickly to develop the emissions and photochemical modeling databases needed to develop 1-hour and 8-hour ozone plans by 2004. The first step in the development of a photochemical modeling database for SIP planning was the development of a Modeling Protocol (ENVIRON, 2003a) that conforms to the requirements in the EPA guidance documents (EPA, 1991, 1999). The key objectives in developing an all-new photochemical modeling database for the DFW area were as follows:

- To select representative 1-hour and 8-hour ozone modeling episode(s) for the 4-county Dallas/Fort Worth Nonattainment area;

- To create a photochemical modeling domain consistent with the Texas standard domain using a Lambert Conformal Projection (LCP) to be consistent with the MM5 meteorological model. The coarse grid domain must be sufficiently large to treat multi-day transport of ozone and precursors from significant source areas outside of Texas;

- To create a nested-grid with 4-km grid spacing large enough to include the DFW 4-county nonattainment area as well as the 8 surrounding counties that constitute the Consolidated Metropolitan Statistical area. All nested grids will telescope at a 3:1 ratio (e.g., 36, 12, 4-km) to be compatible with the MM5 meteorological modeling grid system;

- To produce refined meteorological inputs for the entire domain using version 3 of the Fifth-Generation Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5), while optimizing performance in the fine-grid DFW subdomain containing the DFW CMSA;

- To incorporate the latest available emissions data for Texas as well as other areas within the regional-scale grid domain;

- To create a Comprehensive Air Quality Model with extensions (CAMx) Base Case simulation of the selected episode, including diagnostic tests, performance evaluation, and basic sensitivity analyses to provide directional guidance for follow on work;

- To perform Base Case VOC/NOx emissions reduction sensitivity tests and estimate appropriate near term categorical control strategies under different VOC/NOx emission reduction regimes; and

- To provide the CAMx modeling database, pre- and post-processor systems, display programs, and other data and programs developed to meet these objectives to the

TCEQ staff, the EPA, designated representatives from the DFW area, and other interested parties.

It should be noted that the current modeling activities undertaken as part of this project do not include future case control strategy evaluation. However, the current air quality modeling assumed that all planned regional controls in effect at the time of the August 1999 episode (e.g., Tier 2/Low Sulfur and Heavy Duty Diesel on-road mobile source rules) and local Texas controls (e.g., DFW, HGA, Northeast Texas ozone control plans) will be included in the base case modeling.

The high 1-hour and 8-hour ozone period selected for modeling was August 15th-22nd, 1999. After including 2 additional days to "spin up" the ozone model, this results in modeling the 10 day period August 13th-22nd, 1999. This period was selected based on a conceptual model and episode selection for Dallas/Fort Worth (ENVIRON, 2003b), which is summarized in Section 2 of this report. The modeling procedures and modeling domain were developed in an ozone modeling protocol for the August 1999 episode (ENVIRON, 2003a). The Comprehensive Air Quality Model with extensions (CAMx) was selected for ozone modeling and the modeling domain is shown in Figure 1-2 and 1-3.

The preparation of ozone model inputs is described in Sections 3 through 5 of this report. Section 3 describes the emission inventory development for the 1999 base year. Section 4 summarizes the meteorological modeling and extensive details are given in a supporting meteorological modeling report (ENVIRON, 2003c). Section 5 describes the preparation of other CAMx inputs.

Section 6 describes the development of the 1999 base case including model evaluation procedures, diagnostic tests and sensitivity tests. The 1999 base case was refined through a series of improvements to the meteorology, emissions and CAMx inputs. The final 1999 base case was designated "Run7c".

A summary of the 1999 Base Case modeling efforts for the Dallas/Fort Worth non-attainment area and recommendations for further analysis and refinenement of the base case modeling are presented in Section 7.

Appendix A describes a detailed evaluation of which emissions sources were primarily responsible for high ozone levels in North Central Texas during the August 1999 episode. This analysis used the ozone source apportionment technology (OSAT) tools available on CAMx.

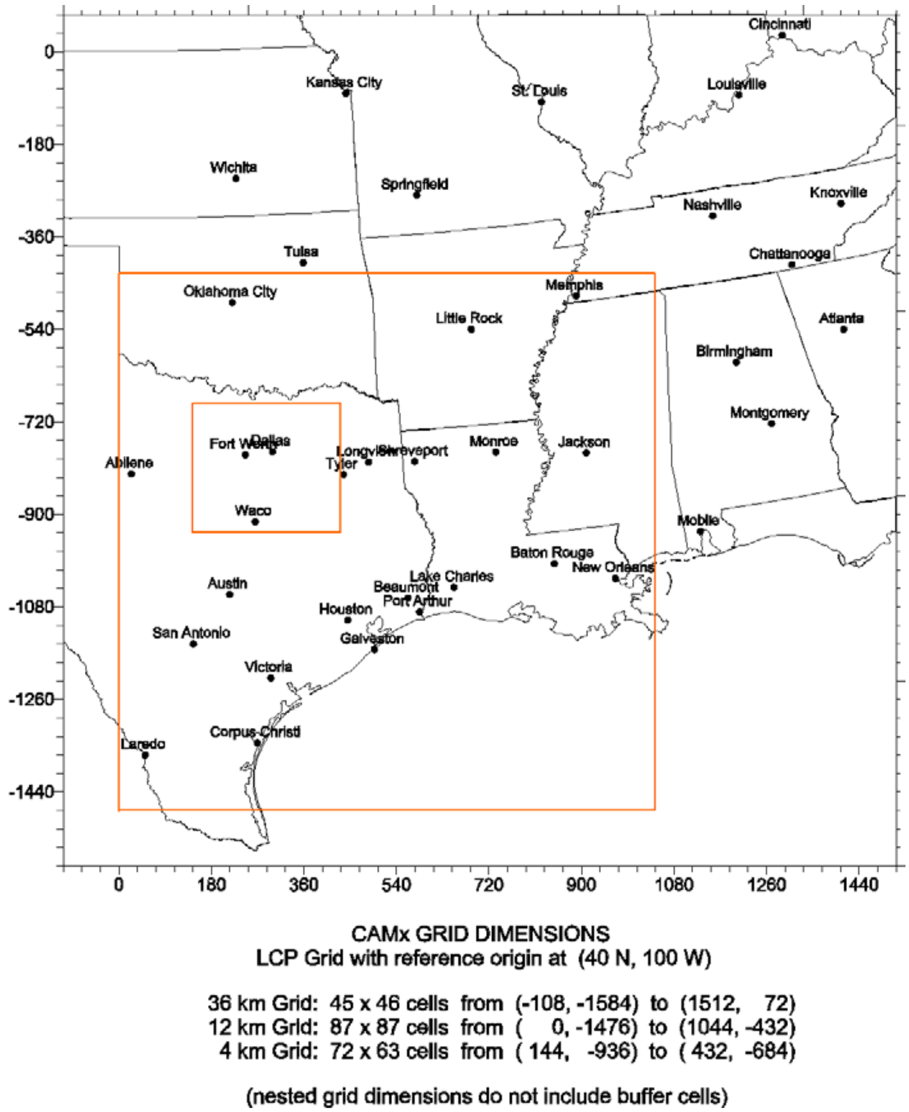
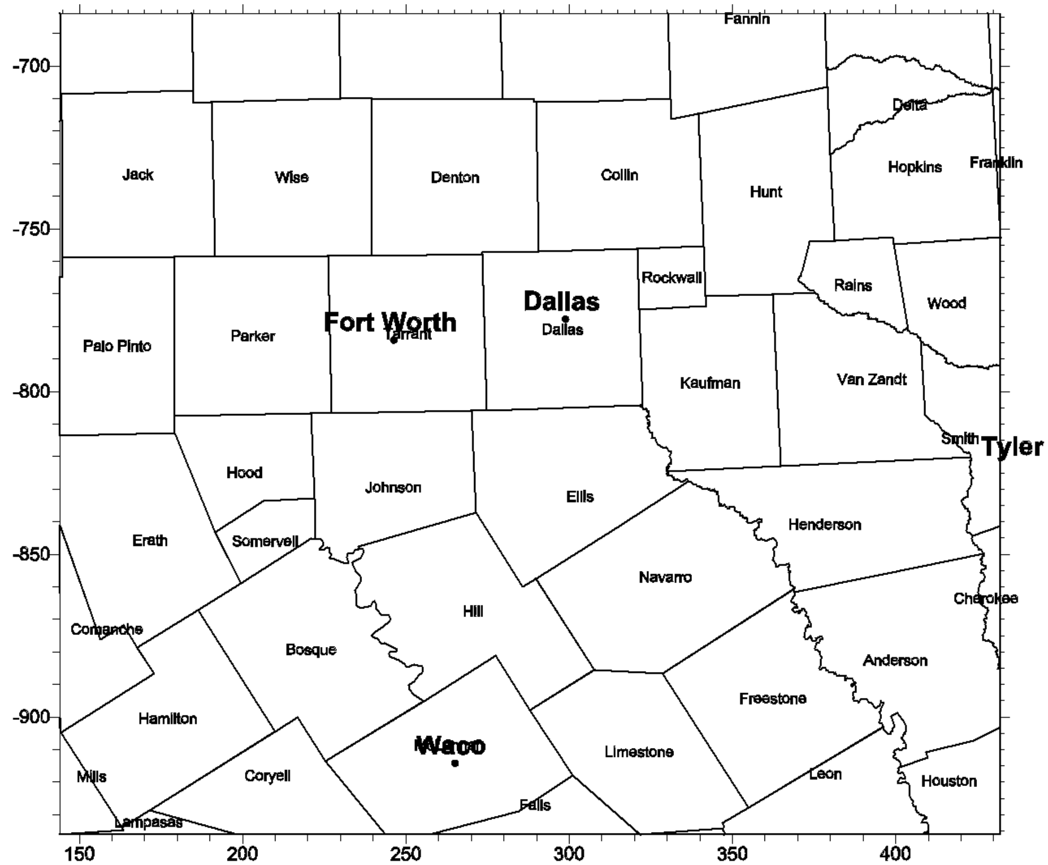


Figure 1-2. CAMx modeling domain for the August 1999 episode showing the 36-km regional grid and the nested 12-km and 4-km fine grids.



CAMx GRID DIMENSIONS
LCP Grid with reference origin at (40 N, 100 W)

4 km Grid: 72 x 63 cells from (144, -936) to (432, -684)

Figure 1-3. CAMx 4-km fine grid covering Dallas/Fort Worth for the August 1999 episode.

2. EPISODE SELECTION

An episode selection analysis was performed to identify periods with representative high 1-hour and 8-hour ozone levels that were suitable for developing a new regional ozone model (ENVIRON, 2003b). There has been considerable evolution in the EPA procedures since the 1-hour demonstration requirements were first promulgated. As a result, this report refers frequently to the more recent conceptualizations of 1-hour and 8-hour ozone analysis procedures and the evolving 8-hour attainment demonstration procedures as proposed by the EPA.

EPA's GUIDANCE FOR EPISODE SELECTION

EPA's draft 8-hour ozone modeling guidance has four primary criteria for selecting meteorological episodes for 8-hour ozone attainment demonstration modeling (EPA, 1999):

- Select a mix of episodes that reflect a variety of meteorological conditions that frequently correspond with observed 8-hour daily maximum ozone concentrations > 84 ppb at different monitoring sites;
- Select periods during which observed 8-hour ozone concentrations are close to the 8-hour ozone Design Value (i.e., three-year average of fourth highest 8-hour ozone concentration) at each key monitor;
- Select periods for which extensive air quality/meteorological databases exist; and
- Model sufficient number of days so that the model attainment test can be applied at all of the key ozone monitoring sites.

As noted in the draft EPA guidance, these four criteria may conflict with each other, and there may be other secondary criteria that can be used in the episode selection:

- Prior experience modeling an episode may result in it being chosen over an alternative;
- Choosing episodes corresponding to the three-year period being used to make the 8-hour ozone attainment designation may be desirable;
- May want to choose a modeling period in which days have 8-hour ozone concentrations near the 8-hour ozone Design Values at all violating monitors;
- If observed 8-hour ozone exceedances occur on weekends, weekend days should be considered; or
- If multiple areas are being modeled, then episodes that have 8-hour ozone exceedances in other areas may be considered.

The latest national emissions inventory information is from the 1999 National Emissions Inventory (NEI99). The next national emissions inventory update will be in 2002. This national inventory would likely be available in early 2004. In discussions with EPA on 8-hour ozone modeling they noted that they would prefer episodes from 1999 to present. Thus, we focused our episode selection procedures on episodes that occurred between 1999 and 2002.

EPISODE SELECTION PROCEDURE

In the fall of 2002, ENVIRON, under contract to the TCEQ, developed a revised conceptual model of ozone formation in the DFW ozone non-attainment area (ENVIRON, 2002). Following EPA's guidelines, candidate modeling episodes were identified and analyzed for use in attainment demonstration for the DFW area. The development of the conceptual model for ozone formation involved the compilation and analyses of various data regarding air quality, emissions and meteorology. In particular, the following analyses were included in the assessment:

- Ozone and air quality trends. Trends in ozone air quality within the DFW nonattainment region were considered. Both the ozone design values and Air Quality Index were evaluated with respect to variations from year to year and over the past 25 years. Comparisons with other nonattainment areas within Texas were also conducted. One-hour and eight-hour ozone exceedances were examined within the area to determine the frequency of exceedances during various time periods.
- Emission inventory trends. Trends in emissions of NOx and VOC were evaluated within the DFW area. The relationship between emission reductions from 1990 to 2001 and ozone air quality were considered. Comparisons with other nonattainment regions in Texas were also examined. These relations provide insight into the relative improvements in air quality and emission reduction strategies with respect to attainment of the NAAQS.
- Meteorological factors associated with high ozone events. The meteorological factors associated with high (and low) ozone events in the DFW area were evaluated. Surface winds provide an indication of the importance of local emission sources on air quality while upper level, or transport, winds reveal the influence of regional scale emissions and air quality. Evaluation of the general synoptic and mesoscale meteorological factors associated with ozone exceedances provide some guidelines for selection of appropriate episodes for further analysis and possible air quality modeling.
- Episode selection. The development of the conceptual model provides the basis for the selection of representative modeling episodes required to demonstrate attainment of the ozone NAAQS. Based on the analysis conducted as part of the model development, several candidate episodes were identified.
- EPA Guidance documents. The EPA has developed guidance documents for evaluating and selecting modeling episodes for demonstration of attainment of both the 1-hour and 8-hour ozone standards. These guidance documents and the recommendations therein provide a basis for the selection of candidate episodes for the DFW nonattainment area.

The development of the conceptual model of ozone formation in the DFW non-attainment area is documented in detail in ENVIRON, 2002.

Previous Air Quality Modeling

The TCEQ has previously developed and modeled two ozone episodes for the Dallas/Fort Worth non-attainment area. These consisted of the June 18-22, 1995 and June 30 - July 4, 1996 episodes and were used for attainment demonstrations of the 1-hour ozone standard.

As pointed out previously, any new candidate episode should be relatively recent so that it represents the current emissions and be typical so its represents frequently occurring meteorological phenomena. New episodes should also satisfy the current 3-year design value window criteria. Finally, with the advent of the new 8-hour ozone standard, it is now desirable to develop episodes that would be useful for both 1-hour and 8-hour analysis.

The previously modeled 1995 and 1996 episodes both represented the most frequent transport direction, flow from the south and occurred during June/July, which was the secondary seasonal peak. The draft conceptual model and episode selection analysis reviewed several different candidate episodes that represent characteristics from missing time periods and/or transport directions. Thus the selection process considered episodes from the missing August/September seasonal peak ozone period and those representing transport from the east and/or southeast. However, some selected episode must represent transport from the primary direction.

Candidate Modeling Episodes

The selection and evaluation of candidate modeling episodes was based on EPA guidance and also considered the applicability and consistency with other non-attainment areas within the region. The conceptual model evaluated several possibilities from 1998 and 1999, as well as some possible 2000/2001 episodes. The goal was to select one or more episodes that could be utilized for both the 1-hour and 8-hour attainment demonstration and could be used to support photochemical modeling in other nearby areas.

All 1-hour and 8-hour exceedance days in the DFW nonattainment area from 1997 through 2002 were first identified from data obtained from the TCEQ. Back trajectory plots developed using the HySplit model were analyzed for each exceedance day to identify days associated with the primary transport directions. Preference was given to exceedance days and episodes that occurred during the primary ozone season (July, August and September). Although the current focus is on selection of 1-hour ozone modeling episodes, consideration was also given to periods that also experienced 8-hour ozone exceedances.

Each of these preliminary episode periods was further evaluated with respect to EPA episode selection criteria. In addition, in accordance with EPA guidance, exceedance days occurring within the current 3-year design value period were given preference. Based on these criteria, a number of preliminary episodes were identified for further analysis. The preliminary episodes identified are as follows:

- August 25-27, 1997
- July 14-18, 1998
- September 1-5, 1998
- August 4-7, 1999
- August 13-22, 1999
- August 31 - September 5, 2000

Episode Selection

Based on the analyses conducted as part of the development of the conceptual model of ozone formation in the Dallas/Fort Worth nonattainment area and the EPA selection procedures, two candidate episodes from this field of six were selected as possible candidates for the 1-hour attainment demonstration air quality modeling in DFW. The candidate episodes are August 4-7, 1999 and August 16-21, 1999. The screening criteria used to reduce the field of six episodes down to two primary candidates were as follows:

- Both episodes occur during the seasonal peak ozone period of August/September;
- Both episodes represent previously un-modeled trajectory directions, transport from east southeast;
- Both have multiple 1-hour and 8-hour ozone exceedances in Dallas/Fort Worth;
- Both supported by robust meteorological data; and,
- Both occur during the last 3 years.

As it is desirable to replace the existing 1995 and 1996 episodes with a single modeling episode, the new candidate episode must also represent transport from the primary direction (i.e., flow from the South/Southeast). Further, the August 4-7, 1999 episode had widespread thunderstorm activity, which complicates the meteorological modeling. Therefore, the August 16-21, 1999 episode became the primary candidate for 1-hour modeling. However, since the period surrounding the 1-hour exceedances is also a strong candidate for 8-hour modeling, the August 13-22, 1999 extended period was selected as the preferred modeling episode. Details of the final selection process are explained in the conceptual model (ENVIRON, 2002).

SUMMARY OF THE AUGUST 13-22, 1999 OZONE EPISODE

Table 2-1 shows the peak 1-hour and 8-hour ozone measured during the August 13-22, 1999 episode. The extended episode allows ramp up days for modeling and continues through the entire high ozone period. One-hour exceedances occur four days during the middle of the period, and 8-hour exceedances occur nine out of the ten days of the episode.

Table 2-1. 1-hour and 8-hour exceedances during August 13-22, 1999 ozone episode.

Date	1-Hour Peak Ozone (ppb)	# 1-Hour Exceedances	8-Hour Avg. Ozone (ppb)	# 8-Hour Exceedances
Aug 13, 1999	88	0	67	0
Aug 14	115	0	**103**	4
Aug 15	107	0	**97**	5
Aug 16	**127**	1	**107**	6
Aug 17	**150**	4	**126**	7
Aug 18	**131**	2	**116**	4
Aug 19	**128**	1	**108**	2
Aug 20	108	0	**98**	1
Aug 21	111	0	**98**	5
Aug 22	101	0	**89**	3

Synoptic Analysis

Based on analyses of NWS weather maps, meteorology associated with this episode can be characterized as follows. Pressure gradients were very weak over Texas during the first four days. Winds were calm to 5 knots in the morning and southerly or easterly at 5-10 knots in the afternoon. Strong high pressure aloft and temperatures close to 100F on most days were recorded. Aloft, pressure was strongest during August 15-18, when the Dallas Ft Worth region was enclosed in a 5940m 500mb height contour with 10-20 knot winds. At the surface, a positively tilted 1023mb high was centered over the Great Lakes on August 15. To its east and south, a cold front stretched from eastern Maine to eastern Texas. As this high drifted eastward the next couple of days, a weak low followed, but stayed well to the north of Texas. On August 19, 500mb heights fell below 5940m, but stayed above 5880m through August 31. A 1011mb surface low was observed over southern Illinois on this morning with the associated cold front crossing the Dallas region around midday. Afternoon thunderstorms were detected near Dallas on that afternoon.

Behind this front, weak high pressure settled over the Great Lakes from August 20-22. Near Dallas, winds were north northeasterly following the frontal passage and then southeasterly late on August 21 and all day August 22. On August 22, Hurricane Bret made landfall near the southern tip of Texas. Clouds spread over Dallas on August 22 and 23, but precipitation was confined to its south and west.

Trajectory Analysis

Figures 2-1a-j display the DFW back trajectories for the August 14-23, 1999 period. These trajectories are based on archived wind data from the NOAA/NCEP Eta Data Analysis System (EDAS). Long-range transport during the episode is seen to shift from the north, to northeast and to the southeast. Also considerable subsidence occurred during the period, which suppresses mixing and encourages accumulation of local emissions. Subsidence also reduces cloudiness, which allows more sunlight to reach the surface layers, increase temperatures and react with the local emissions to form ozone.

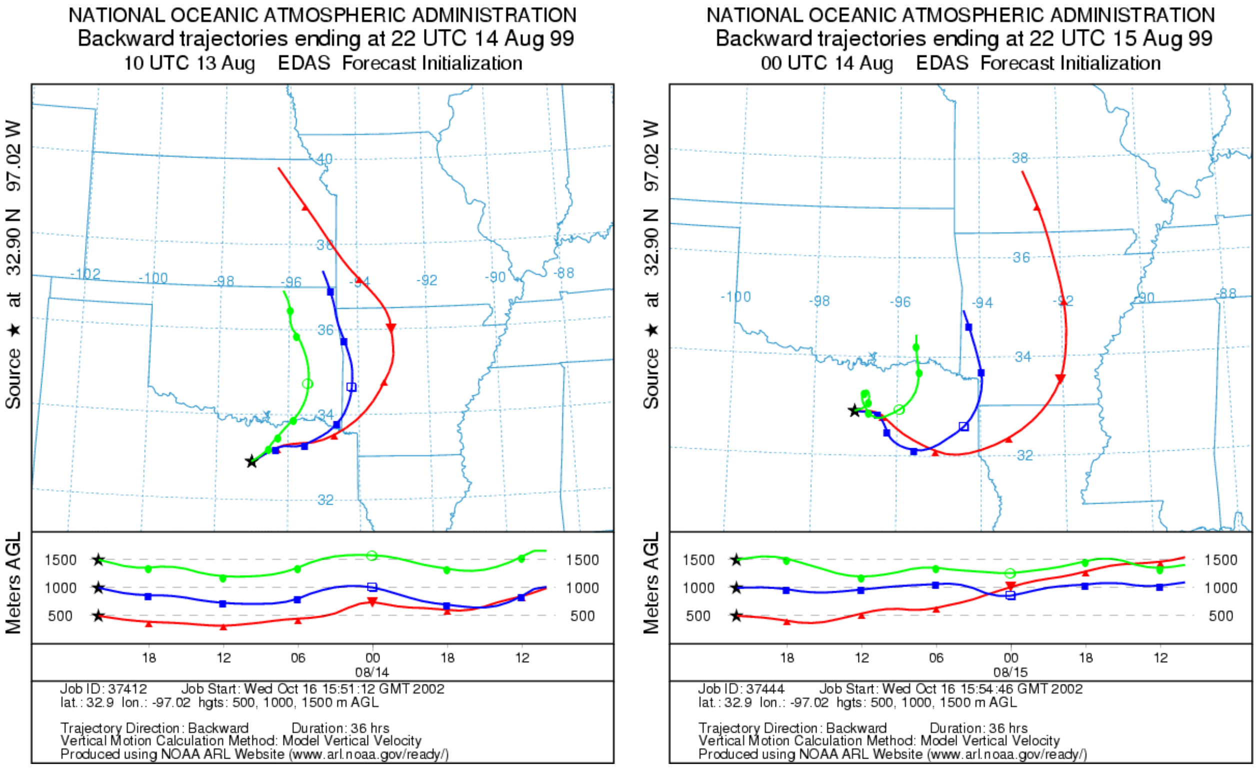


Figure 2-1 a-b. DFW back trajectories for August 14-23, 1999.

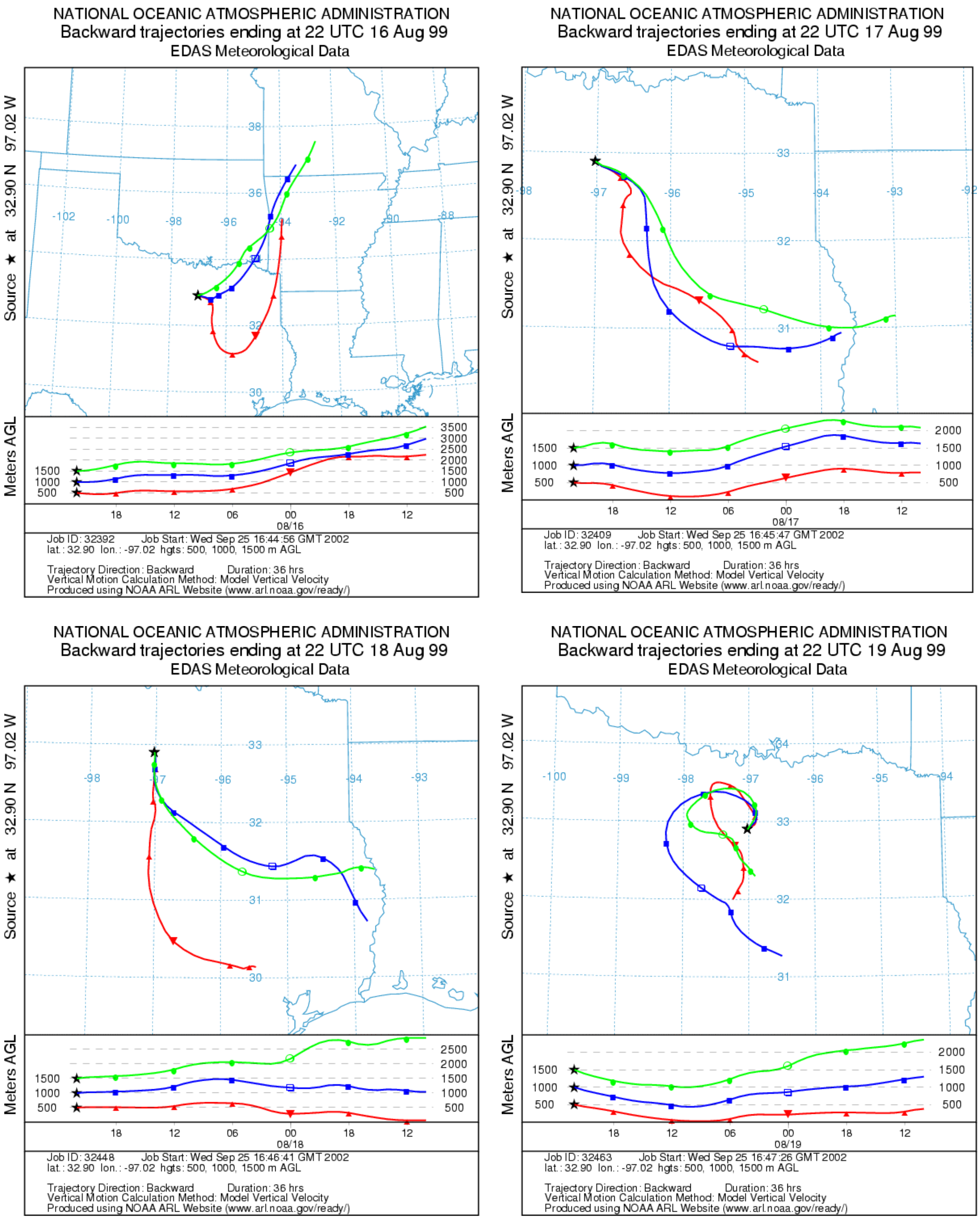


Figure 2-1 c-f. DFW back trajectories for August 14-23, 1999 continued.

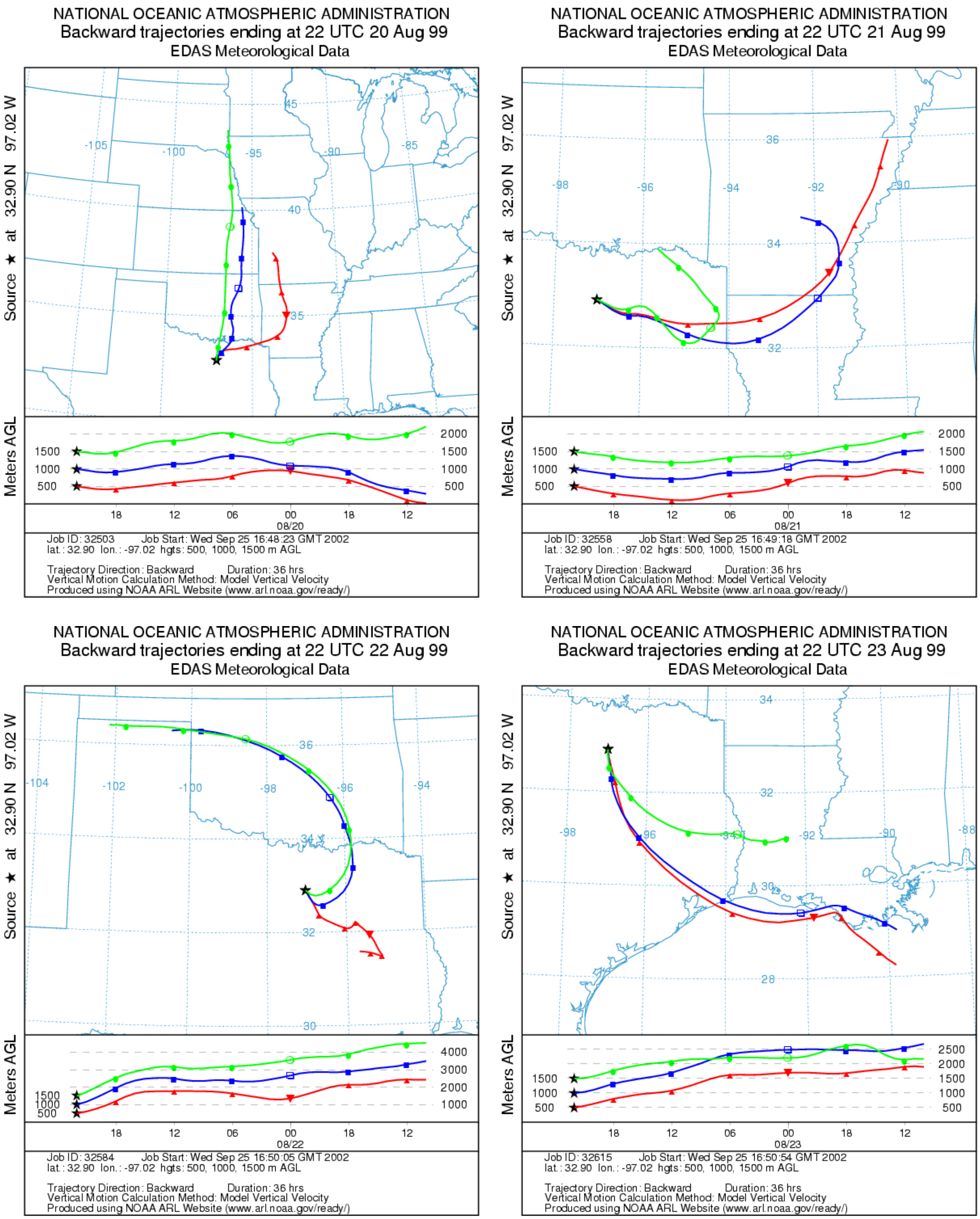


Figure 2-1 g-j. (Concluded). DFW back trajectories for August 14-23,1999.

Wind Speeds vs Ozone Concentrations

An analysis of local DFW surface winds and average monitored ozone concentrations in the area indicates that this episode is characteristic of typical conditions associated with elevated ozone concentrations. Figure 2-2 displays the average morning and afternoon surface wind speeds and ozone concentrations during the period August 13-22, 1999. Examination of Figure 2-2 reveals the relationship between surface wind speed and 1-hour and 8-hour ozone concentrations.

During the 1-hour exceedances period, August 16-19, 1999, wind speeds are seen to be very low and are inversely related to the peak 1-hour and 8-hour ozone concentrations. During the beginning and end of the episode, surface wind speeds are considerably higher, with correspondingly lower ozone concentrations. One-hour exceedances were measured ~~at~~ on four days during the episode, with four monitors measuring exceedances on August 17th. The peak 8-hour average was also measured on August 17th, and 7 monitors exceeded the standard on that day.

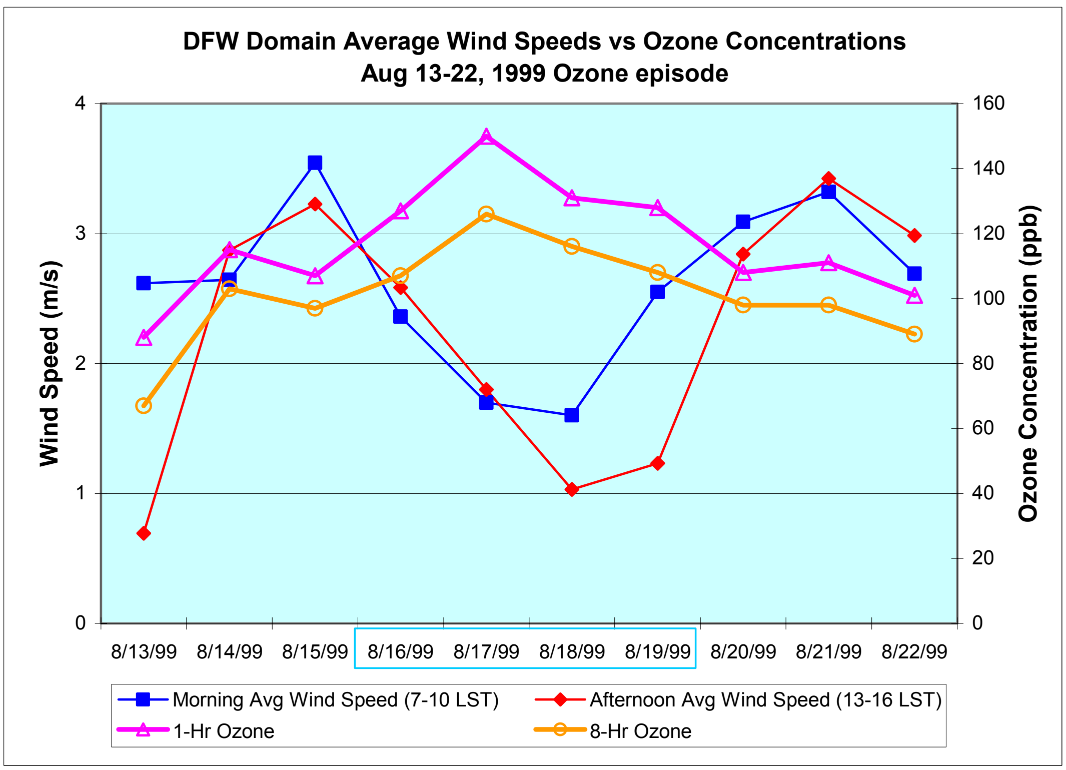


Figure 2-2. DFW domain average wind speeds and ozone concentrations (TCEQ).

Figure 2-3 shows the hourly time series of 1-hour ozone concentrations at monitors in the DFW area during the episode period.

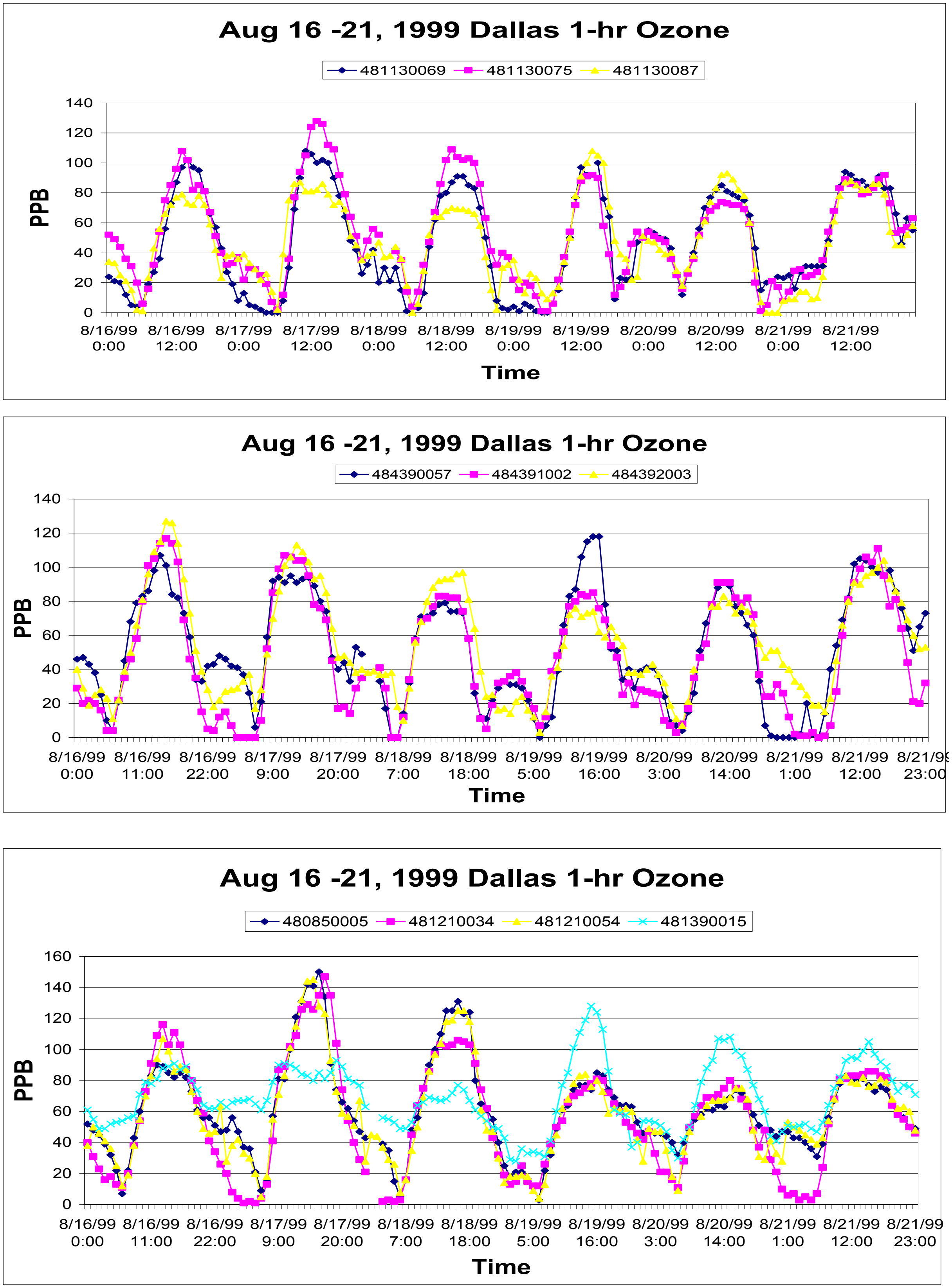


Figure 2-3. Time series of 1-hour ozone concentrations in DFW for August 16-21,1999.

Background Concentrations

The background concentrations were quite high during this episode averaging nearly 80 ppb during the 9 days with 8-hour exceedances. These relatively high background concentrations of ozone and precursors will affect DFW's ability to control the 1-hour and 8-hour ozone peaks occurring in the area. An important part of this modeling effort was to evaluate transport of ozone and precursors into the DFW area and the ability of the CAMx model to replicate the background concentrations.

Figure 2-4 shows the peak 1-hour and 8-hour ozone concentrations measured each day during the episode, as well as the background concentrations estimated each day. In this application we have defined the background concentration as the lowest peak ozone measured upstream of the DFW urban complex to reflect the ozone concentration that would have occurred if DFW had not added any emissions to the incoming air mass.

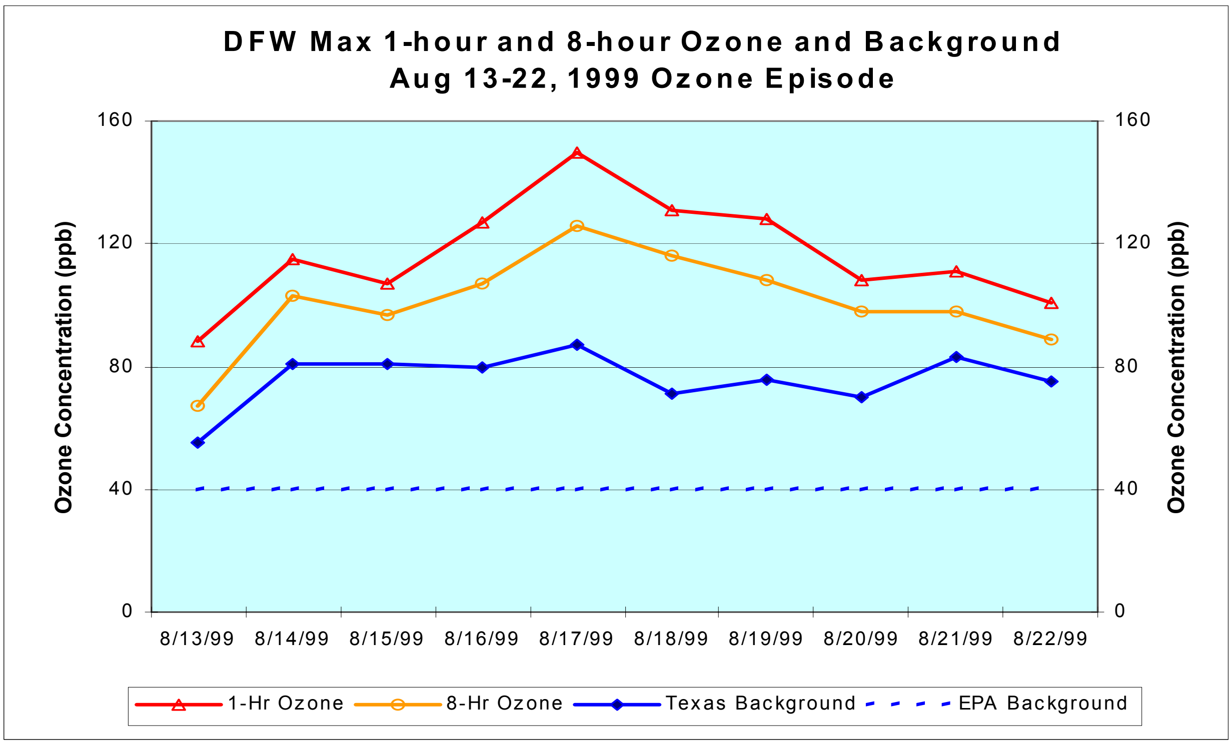


Figure 2-4. Ozone background concentrations during August 13-22, 1999 episode (TCEQ).

Finally, it is important to point out that this episode is also being used for air quality modeling for the 8-hour ozone standard in East Texas. ENVIRON is currently modeling the TLM (Tyler/Longview/Marshall) area for the East Texas Council of Governments. The MM5 meteorological model has been applied for this time period with high resolution nested grids over both East Texas and the Dallas/Fort Worth areas. Thus, the current DFW modeling effort takes advantage of previous air quality assessments, emissions inventory, and meteorological modeling completed to date, including the experience gained from resolving issues and/or problems associated with the TLM modeling project.

3. EMISSIONS MODELING

This section describes the emission inventory preparation for the August 13-22, 1999 modeling episode for the Dallas/Fort Worth (DFW) Non-Attainment Area. Emission inventories are processed using version 2x of the Emissions Processing System (EPS2x) for area, off-road, onroad mobile and point sources (ENVIRON, 2001). The purpose of the emissions processing is to format the emission inventory for CAMx photochemical modeling.

CAMx requires two types of emission input files:

(1) Surface emissions from area, mobile, off-road, low-level point and biogenic sources are gridded to the CAMx nested grid system. This means that separate surface emissions files will be prepared for the 36-km, 12-km and 4-km grids. The surface emissions are injected into the lowest layer of the model.

(2) Elevated emissions from major point sources are injected into CAMx at the coordinates of each source. The plume rise for each source is calculated by CAMx from stack parameters so that the emissions are injected into the appropriate vertical layer. Emissions from selected major NOx emitters may be treated with the CAMx Plume-in-Grid (PiG) module.

The emission files were prepared using version 2x of the Emissions Processing System (EPS2x). The emissions model performs several tasks:

Temporal adjustments: Adjust emission rates for seasonal, day-of-week and hour-of-day effects.

Chemical speciation: Emission estimates for total VOC are converted to the more detailed chemical speciation used by the Carbon Bond 4 (CB4) chemical mechanism in CAMx. Total unspeciated NOx emissions are allocated to NO and NO_2 components.

Gridding: The spatial resolution of the emissions must be matched to the CAMx grid(s). Area sources are often estimated at the county level, and are allocated to the grid cells within each county based on spatial surrogates (e.g., population and economic activity). Mobile source emissions may be link specific (from transportation models) so links must be allocated to grid cells.

Growth and Controls: Emissions estimated for one year may need to be adjusted for use in a different year. In this project, the base year inventory is the same year as the modeling episode (1999) and so no adjustments are needed.

Quality Assurance: The emissions model includes powerful QA and reporting features to keep track of the adjustments at each processing stage and ensure that data integrity is not compromised.

The outputs from the emissions model are called the "model-ready" emissions, and are day-specific, gridded, speciated and temporally (hourly) allocated. EPS2x performs all of the processing steps for the anthropogenic emissions. The biogenic emissions are prepared using a different model (GloBEIS) because they are based on different input data and have specialized processing requirements (e.g., dependence on temperature, solar radiation and drought conditions).

Emissions for different major source groups (e.g., mobile, off-road mobile, area, point and biogenic) are processed separately and merged together prior to CAMx modeling. This simplifies the processing and assists quality assurance (QA) and reporting tasks. The biogenic inventories were generated with both GloBEIS version 2.2 and GloBEIS version 3.1, which includes various enhancements to estimate the effects of drought conditions on biogenic emissions.

The August 13-22,1999 episode, a Friday through Sunday, is being modeled in CAMx using a Lambert Conformal Projection (LCP) nested grid configuration with grid resolutions of 36, 12 and 4-km (Figure 1-1). In CAMx, emissions are separated between surface (surface and low level point) emissions and elevated point source emissions. For the surface emissions, a separate emission inventory is required for each grid nest, i.e., three inventories. For elevated point sources, a single emission inventory is prepared covering all grid nests.

Two emissions modeling domains are used to generate the required CAMx ready inventories:

1. **Dallas/Fort Worth Non-Attainment Area 4-km Grid**. The DFW emissions grid has 72 x 63 cells at 4-km resolution and covers the same area as the CAMx 4-km nested grid shown in Figures 1-1 and 1-2.

2. **Regional Emissions Grid**. The regional emissions grid has 135 x 138 cells at 12-km resolution and covers the full area shown in Figure 1-1. This emissions grid is used for the 12-km CAMx grid by "windowing out" emissions for the appropriate region. In addition the regional emissions grid is aggregated from three by three 12-km cells to one 36-km cell over the entire area to generate the CAMx 36-km grid.

Emission inventories were prepared for the 1999 base year. The emissions data sources and processing are described separately below for point, onroad mobile, area and off-road, and biogenic sources. Following the data descriptions are summary tables.

DATA SOURCES FOR 1999

A summary of data sources for the development of the modeling emissions inventory is provided in Table 3-1.

Table 3-1. Summary of emissions data sources.

Category	Region	Data Source
Mobile	DFW	NCTCOG link-based, MOBILE6
	Texas major urban	TTI link-based, MOBILE6 via TCEQ
	Other Texas	TTI county level, MOBILE6 via TCEQ
	Outside Texas	EPA NEI99 Version 2, MOBILE6
Offroad	Texas	NONROAD 2002 model
	DFW	NCTCOG local data and NONROAD 2002 model
	Outside Texas	EPA NEI99 Version 2
Area	Texas	TCEQ
	Outside Texas	EPA NEI99 Version 2
Point	TX and LA EGU	EPA acid rain hourly data processed by TCEQ
	Texas other	1999 PSDB
	Louisiana other	LA DEQ provided to TCEQ
	OK EGU	EPA acid rain hourly data processed by ENVIRON
	OK other	EPA NEI99 Version 2 with ODEQ corrections
	Other	EPA NEI99 Version 2
Offshore	Texas	TCEQ offshore and shipping emissions
Biogenic	Texas	GloBEIS3 with TCEQ LULC data and drought adjustment
	Outside Texas	GloBEIS3 with BELD3 LULC data

Point Sources

Point source data were obtained from several different sources, processed separately and merged prior to modeling. The data include:

- Texas electric generating units (EGUs)
- Texas non-EGU point sources
- Texas minor point sources
- Louisiana EGUs
- Louisiana non-EGUs
- Oklahoma EGUs
- Oklahoma non-EGUs
- Other State point sources

The point source data are processed for a typical peak ozone (PO) season weekday and weekend day. The exception is Texas, Louisiana and Oklahoma EGUs, which are hourly episode day specific data, based on continuous emissions monitor (CEM) data that were reported to EPA's "Acid Rain" database.

The 1999 Texas and Louisiana point source data were provided by TCEQ in EPS2 AFS input format.

The hourly EGU data for Texas, Louisiana and Oklahoma are taken from the EPA's Acid Rain Program Database. The TCEQ Point Source Data Base (PSDB) version 15a for 1999 is the basis of the non-EGU Texas data. Louisiana Department of Environmental Quality (LDEQ) provided TCEQ with a copy of their point source inventory. The files were downloaded from two separate TCEQ ftp sites as follows:

ftp://ftp.TCEQ.state.tx.us/pub/OEPAA/TAD/Modeling/DFWAQSS/Modeling/EI/:

TX EGU	hourly_TXegu_990813-990822.v15a.lcp.3pols
TX Non-EGU	afs.tx_negu.990813-990822.V15a.lcp.3pols

ftp://ftp.TCEQ.state.tx.us/pub/AirQuality/AirQualityPlanningAssessment/Modeling/file_transfer/NearNon/:

TX Minor Points	afs.0813-2299minorpts_nna
LA EGU	hourly_LAegu_0813-2299.afs_v4_latlon
LA Non-EGU	afs.LA_0813-2299v4_latlon_negu

The Houston point source inventory does not include the "PTO2N2" adjustments for highly reactive VOC (HRVOC) emissions. The TCEQ developed the PTO2N2 that scales HRVOC emissions to NOx emissions for certain industrial sources to improve Houston model performance and agreement with ambient data. However, the PTO2N2 adjustment is not part of the TCEQ PSDB and so was not included in this inventory.

For all states other than Texas, Louisiana and Oklahoma the National Emission Inventory (NEI) 1999 Final Version 2 for Criteria Pollutants data is used. The files SS*99CritPt1002.zip* (where "SS" is the 2-character state name) were downloaded from EPA's ftp site. These files contain a set of related point source files in Microsoft Access97. The data is processed to (1) relate separate data tables by common fields, (2) query to extract peak ozone season data for those states within the regional modeling domain other than Texas and Louisiana and (3) export the resultant data table to an ASCII text file for processing through EPS2x.

The criteria for selecting NOx point sources for plume in grid treatment within the 4-km modeling domain is 2 tons NOx on any episode day. For the regional emissions grid, the NOx criteria is 25 tons per day on any episode day.

Mobile Sources

The Texas Transportation Institute (TTI) prepared mobile source emissions for all Texas counties under contract to the TCEQ. (See Technical Note "Near Nonattainment Area Support – Rider 13 / 1999 Analysis by Dennis Perkinson, TTI for Mary McGarry-Barber, TCEQ dated 22 May, 2001). Emission factors are from the EPA's MOBILE6 model. Vehicle miles traveled (VMT) for 1999 are based on transportation models in all NNA counties that have a complete transportation model and were based on a rural HPMS method elsewhere. The NNA counties for which link based transportation model data are used:

East Texas:	Gregg, Smith
Austin:	Hays, Travis, Williamson
San Antonio:	Bexar
Corpus Christi:	Nueces, San Patricio
Victoria:	Victoria

TTI calculated emissions for each hour for four day-of-week scenarios: Monday-Thursday, Friday, Saturday and Sunday. The link-based emissions based on transportation models were processed by TCEQ and provided in model-ready format.

For Oklahoma, day-specific on-road mobile emissions were generated based on HPMS county-level VMT, MOBILE6 emissions factors and day-specific temperature data.

The NEI 1999 Final Version 2 for Criteria Pollutants is the basis for the onroad mobile regional emissions inventory for those counties outside Texas and Oklahoma. The data file *99neiv2asciimobile.zip* was acquired from EPA's ftp site (ftp.epa.gov). The NEI 1999 onroad emission inventory is processed to (1) extract the typical peak ozone season day data, (2) reformatted to the EPS2x AMS input file format and (3) processed through EPS2x. A road type distribution is used to spatially allocate the onroad sources.

DFW On-Road Mobile Source Emissions

Under contract to the TCEQ, the North Central Texas Council of Governments (NCTCOG) developed on-road mobile source emissions for the four core DFW counties (Dallas, Collin, Denton, and Tarrant) and Rockwall County from link-based data. Emission estimate for seven perimeter counties (Ellis, Henderson, Hood, Hunt, Johnson, Kaufman, and Parker) were developed using a methodology similar to the core counties except link-based data was not used. For the remaining counties within the DFW 4-km modeling grid, the NCTCOG developed emission estimates based on county-level data. A completed set of model-ready on-road mobile source emissions files were provided by the NCTCOG and were obtained via anonymous ftp from ftp://ftp.tnrcc.state.tx.us/pub/OEPAA/TAD/Modeling/DFWAQSE/Modeling/EI/Mobile/. The development of the on-road mobile source emissions are documented in NCTCOG, 2003. Summaries of on-road mobile source emissions by county and by day are presented in Tables 3-2 and 3-3.

Table 3-2. On-road mobile source emissions for DFW core counties (tpd).

VOC	Collin	Dallas	Denton	Tarrant	Rockwall	Total
August 13 (Friday)	18.34	92.74	18.01	54.43	2.34	185.85
August 14 (Saturday)	12.84	65.45	12.77	38.83	1.65	131.54
August 15 (Sunday)	10.15	51.68	10.06	30.87	1.31	104.07
August 16 (Monday)	16.38	82.13	16.27	49.11	2.04	165.93
August 17 (Tuesday)	16.90	84.35	16.70	49.94	2.09	169.98
August 18 (Wednesday)	17.12	85.82	16.84	50.58	2.12	172.48
August 19 (Thursday)	17.44	85.83	17.03	50.63	2.13	173.07
August 20 (Friday)	18.18	91.10	17.98	53.93	2.29	183.48
August 21 (Saturday)	12.57	63.47	12.45	37.80	1.59	127.88
August 22 (Sunday)	10.32	52.23	10.21	31.01	1.33	105.09
CO	**Collin**	**Dallas**	**Denton**	**Tarrant**	**Rockwall**	**Total**
August 13 (Friday)	240.58	1,201.80	243.70	736.37	37.09	2,459.54
August 14 (Saturday)	174.36	902.33	180.82	547.95	26.91	1,832.36
August 15 (Sunday)	138.73	713.16	144.98	447.70	21.11	1,465.67
August 16 (Monday)	203.42	1,004.91	208.09	629.97	30.60	2,076.99
August 17 (Tuesday)	210.18	1,042.49	213.61	641.56	31.63	2,139.46
August 18 (Wednesday)	216.64	1,094.37	219.90	671.25	32.86	2,235.02
August 19 (Thursday)	222.10	1,094.09	224.51	668.87	33.09	2,242.65
August 20 (Friday)	222.49	1,117.95	226.74	677.82	33.84	2,278.84
August 21 (Saturday)	167.11	849.06	172.43	522.95	25.48	1,737.02
August 22 (Sunday)	143.99	725.94	148.71	449.79	21.92	1,490.36
NOx	**Collin**	**Dallas**	**Denton**	**Tarrant**	**Rockwall**	**Total**
August 13 (Friday)	35.17	190.91	37.44	119.16	5.75	388.41
August 14 (Saturday)	28.83	156.51	30.87	99.76	4.63	320.61
August 15 (Sunday)	23.66	129.11	25.16	80.38	3.80	262.12
August 16 (Monday)	33.24	180.00	35.37	112.28	5.36	366.25
August 17 (Tuesday)	33.49	180.75	35.83	113.31	5.35	368.73
August 18 (Wednesday)	32.71	177.72	34.98	110.50	5.25	361.16
August 19 (Thursday)	33.04	178.20	34.85	110.32	5.28	361.68
August 20 (Friday)	37.47	198.96	39.63	126.57	6.02	408.66
August 21 (Saturday)	29.29	159.12	31.12	99.65	4.69	323.86
August 22 (Sunday)	23.26	128.99	25.02	80.14	3.75	261.15

Table 3-3. On-road mobile source emissions for DFW perimeter counties (tpd).

VOC	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Total
August 13 (Friday)	6.66	4.21	1.69	5.62	5.97	6.67	5.49	36.31
August 14 (Saturday)	5.57	3.50	1.43	4.66	4.98	5.54	4.66	30.35
August 15 (Sunday)	5.02	3.12	1.31	4.15	4.48	4.94	4.23	27.25
August 16 (Monday)	5.22	3.31	1.35	4.40	4.68	5.22	4.38	28.55
August 17 (Tuesday)	5.23	3.33	1.36	4.44	4.70	5.27	4.40	28.74
August 18 (Wednesday)	5.31	3.37	1.38	4.49	4.78	5.33	4.48	29.14
August 19 (Thursday)	5.45	3.40	1.38	4.52	4.90	5.37	4.48	29.50
August 20 (Friday)	6.55	4.09	1.67	5.45	5.87	6.47	5.44	35.54
August 21 (Saturday)	5.33	3.36	1.38	4.47	4.76	5.32	4.48	29.09
August 22 (Sunday)	5.03	3.16	1.31	4.20	4.49	5.00	4.23	27.43
CO	**Ellis**	**Henderson**	**Hood**	**Hunt**	**Johnson**	**Kaufman**	**Parker**	**Total**
August 13 (Friday)	103.90	55.93	23.47	79.78	83.54	98.45	80.57	525.64
August 14 (Saturday)	90.69	47.10	20.11	67.23	71.83	83.71	69.34	450.00
August 15 (Sunday)	81.79	41.76	18.63	59.70	64.68	74.21	64.21	404.98
August 16 (Monday)	78.06	41.78	17.88	59.19	62.99	72.93	61.46	394.30
August 17 (Tuesday)	79.36	42.73	18.09	60.57	64.09	74.78	61.67	401.29
August 18 (Wednesday)	81.86	43.75	18.94	62.09	66.80	76.79	64.32	414.53
August 19 (Thursday)	84.15	43.92	18.83	62.12	68.52	76.99	64.36	418.90
August 20 (Friday)	100.32	52.03	22.08	73.64	79.53	90.99	75.67	494.27
August 21 (Saturday)	85.27	44.46	18.79	63.47	66.93	79.04	65.22	423.18
August 22 (Sunday)	82.78	42.97	18.69	61.58	65.20	76.65	64.40	412.27
NOx	**Ellis**	**Henderson**	**Hood**	**Hunt**	**Johnson**	**Kaufman**	**Parker**	**Total**
August 13 (Friday)	24.34	5.55	2.57	13.47	13.05	16.37	15.60	90.95
August 14 (Saturday)	22.28	5.07	2.36	12.44	12.04	15.08	14.60	83.87
August 15 (Sunday)	20.78	4.83	2.20	11.70	11.25	14.23	13.45	78.44
August 16 (Monday)	19.75	4.71	2.13	11.15	10.78	13.59	12.84	74.95
August 17 (Tuesday)	19.82	4.68	2.12	11.12	10.69	13.50	12.88	74.80
August 18 (Wednesday)	19.73	4.54	2.05	10.93	10.49	13.26	12.69	73.69
August 19 (Thursday)	19.70	4.55	2.08	10.98	10.59	13.29	12.67	73.85
August 20 (Friday)	24.74	5.94	2.74	14.06	13.66	17.04	16.32	94.49
August 21 (Saturday)	22.53	5.22	2.43	12.59	12.28	15.28	14.72	85.06
August 22 (Sunday)	20.87	4.74	2.20	11.53	11.25	14.01	13.44	78.04

Area and Off-Road Sources

The TCEQ provided emission inventories for Texas area and off-road sources. The data were downloaded from the TCEQ domain at /pub/AirQuality/AirQualityPlanningAssessment/Modeling/file_transfer/TX99AreaNR. The files ams. TX_99.area_base1 and ams.TX_99.NR_base1 are in EPS2x input file format.

For all areas outside Texas, the NEI 1999 Version 2 for Criteria Pollutants, released by EPA 20 March 2001, is the basis for the area and nonroad regional emissions inventory. The data file *a99100txt.zip - 1999 NEI Version 1 Criteria Emissions from Area and Nonroad Sources in ASCII text format* was acquired from EPA's ftp site. The file format documentation is provided at http://www.epa.gov/ttn/chief/eidocs/index.html#pack. The NEI 1999 area and off-road emission inventory is (1) processed to extract the typical peak ozone season day data, (2) reformatted to the EPS2x AMS input file format and (3) processed through EPS2x.

DFW Off-Road Mobile Source Emissions

Under contract to the TCEQ, the North Central Texas Council of Governments (NCTCOG) developed a select subset of off-road mobile source emissions for the four core DFW counties and the surrounding 8 perimeter counties. The NCTCOG provided emission estimates for lawn and garden equipment, locomotives and aircraft emissions, recreational marine and construction equipment. The development of these off-road mobile source emissions are documented in NCTCOG, 2003. These data were reviewed and evaluated prior to incorporation into the emission inventory. Based on the evaluation of the methodologies, activity data used, and the resulting emission estimates, only the aircraft, locomotive and lawn and garden source categories were considered acceptable for inclusion in the modeling inventory. The remaining categories (recreational marine and construction equipment) were judged in need of further review and validation.

The NCTCOG provided aircraft emission estimates for 49 airports, both commercial and general aviation, within the DFW 4-km modeling domain. Emission estimates for the two major commercial airports, Dallas/Fort Worth International Airport and Dallas Love Field, were provided separately, allowing for the inclusion of their emissions as point sources (low-level). The remaining airport emissions were provided at the county-level and spatially allocated using gridding surrogates.

Locomotive emissions estimates were provided by county for each of the 12 core and perimeter counties in the 4-km DFW modeling domain. Emissions were estimated for the three Class I railways in the DFW metropolitan area in addition to all other railways operating freight locomotives. Emissions were calculated based on the consumption of diesel fuel and EPA's emission factors for gallons of fuel burned. Locomotive emissions were processed at the county-level and spatially allocated using railway lengths as a gridding surrogate.

Emission estimates for lawn and garden equipment as developed by the NCTCOG were based on the NONROAD2002 model and activity data derived from local surveys. Estimates were provided for select lawn and garden equipment source categories based on local activity data. The remaining source categories were developed using the NONROAD2002 model. Use of local activity data increased the emissions estimates above those obtained with NONROAD2002. Of the emissions estimates provided by the NCTCOG, only those for specific SCCs (as listed in Table 3-6) were incorporated into the inventory since the remaining categories were provided as a lumped emission totals precluded the appropriate chemical speciation and temporal and spatial allocation required for air quality modeling.

Emissions for recreational marine and construction equipment were also considered by the NCTCOG. Recreational marine emissions estimates developed by NCTCOG showed striking deviations from the default NONROAD 2002 estimates (NCTCOG, 2003). As noted in NCTCOG 2003, these estimates warrant further investigation prior to inclusion in a modeling inventory and were therefore not included in the current study. Emissions from certain construction equipment were also developed by the NCTCOG. However, since the data were not provided by specific equipment type as necessary for appropriate chemical speciation and temporal and spatial allocation, it was not possible to include these data in the current inventory.

Tables 3-4 through 3-6 summarize the county-level emission estimates of NOx, VOC and CO for the three off-road emission source categories considered for inclusion in the present air quality modeling study.

Table 3-4. Off-road mobile source emission summary – Aircraft.

1999 Episodic Emission Inventory
Dallas-Fort Worth Modeling Domain
Daily Emissions by County

	Typical day, August 1999 (tons)		
County	**CO**	**VOC**	**NOx**
Collin	0.9950	0.0770	0.0520
Dallas	11.2185	2.1130	6.0845
Denton	2.4900	0.1460	0.2260
Tarrant	17.3955	3.2630	6.9105
Ellis	0.2640	0.0370	0.0330
Henderson	0.0460	0.0060	0.0060
Hood	0.1160	0.0160	0.0140
Hunt	0.3750	0.0520	0.0460
Johnson	0.2850	0.0390	0.0350
Kaufman	0.2920	0.0410	0.0360
Parker	0.6870	0.0940	0.0850
Rockwall	0.5640	0.0550	0.0780
Wise	0.2380	0.0330	0.0290
Total	34.9660	5.9720	13.6350

Table 3-5. Off-road mobile source emission summary – Locomotives.

	Daily Emissions (tons/day)		
County	**VOC**	**CO**	**NOx**
Collin	0.0240	0.0614	0.6198
Dallas	0.1063	0.2722	2.7489
Denton	0.1020	0.2613	2.6383
Tarrant	0.2119	0.5426	5.4797
Ellis	0.1416	0.3626	3.6622
Henderson	0.0517	0.1323	1.3357
Hood	0.0016	0.0040	0.0405
Hunt	0.0251	0.0643	0.6498
Johnson	0.0775	0.1985	2.0050
Kaufman	0.0325	0.0831	0.8393
Parker	0.0425	0.1088	1.0989
Rockwall	0.0010	0.0025	0.0255
12-County Total	0.8176	2.0937	21.1436

Table 3-6. Off-road mobile source emission summary – Lawn and Garden equipment, August 1999 weekday.

			Tons per day		
FIPS	**SCC**	**EQUIP**	**CO**	**NOx**	**VOC**
48085	Collin				
	2260004015	Rotary Tillers < 6 HP	0.0449	0.0001	0.0203
	2260004020	Chain Saws < 6 HP	0.5002	0.0006	0.2622
	2260004025	Trimmers/Edgers/Brush Cutter	1.4590	0.0017	0.7012
	2260004030	Leafblowers/Vacuums	0.6235	0.0007	0.3013
	2265004010	Lawn mowers	15.2464	0.0606	1.3283
	2265004015	Rotary Tillers < 6 HP	0.3486	0.0014	0.0308
	2265004025	Trimmers/Edgers/Brush Cutter	0.0517	0.0002	0.0043
	2265004030	Leafblowers/Vacuums	0.0939	0.0004	0.0073
	2265004040	Rear Engine Riding Mowers	2.3974	0.0114	0.0670
Total			20.7655	0.0771	2.7227
48113	Dallas				
	2260004015	Rotary Tillers < 6 HP	0.1994	0.0002	0.0901
	2260004020	Chain Saws < 6 HP	2.2234	0.0025	1.1656
	2260004025	Trimmers/Edgers/Brush Cutter	6.4845	0.0077	3.1164
	2260004030	Leafblowers/Vacuums	2.7710	0.0031	1.3390
	2265004010	Lawn mowers	67.7637	0.2694	5.9035
	2265004015	Rotary Tillers < 6 HP	1.5495	0.0062	0.1370
	2265004025	Trimmers/Edgers/Brush Cutter	0.2296	0.0010	0.0192
	2265004030	Leafblowers/Vacuums	0.4174	0.0018	0.0326
	2265004040	Rear Engine Riding Mowers	10.6555	0.0507	0.2978
Total			92.2940	0.3427	12.1013
48121	Denton				
	2260004015	Rotary Tillers < 6 HP	0.0364	0.0000	0.0165
	2260004020	Chain Saws < 6 HP	0.4064	0.0005	0.2130
	2260004025	Trimmers/Edgers/Brush Cutter	1.1852	0.0014	0.5696

			Tons per day		
FIPS	SCC	EQUIP	CO	NOx	VOC
	2260004030	Leafblowers/Vacuums	0.5065	0.0006	0.2447
	2265004010	Lawn mowers	12.3849	0.0492	1.0790
	2265004015	Rotary Tillers < 6 HP	0.2832	0.0011	0.0250
	2265004025	Trimmers/Edgers/Brush Cutter	0.0420	0.0002	0.0035
	2265004030	Leafblowers/Vacuums	0.0763	0.0003	0.0060
	2265004040	Rear Engine Riding Mowers	1.9475	0.0093	0.0544
Total			16.8682	0.0626	2.2117
48139	Ellis				
	2260004015	Rotary Tillers < 6 HP	0.0112	0.0000	0.0051
	2260004020	Chain Saws < 6 HP	0.1251	0.0001	0.0656
	2260004025	Trimmers/Edgers/Brush Cutter	0.3647	0.0004	0.1753
	2260004030	Leafblowers/Vacuums	0.1559	0.0002	0.0753
	2265004010	Lawn mowers	3.8116	0.0152	0.3321
	2265004015	Rotary Tillers < 6 HP	0.0872	0.0004	0.0077
	2265004025	Trimmers/Edgers/Brush Cutter	0.0129	0.0001	0.0011
	2265004030	Leafblowers/Vacuums	0.0235	0.0001	0.0018
	2265004040	Rear Engine Riding Mowers	0.5994	0.0028	0.0167
Total			5.1914	0.0193	0.6807
48213	Henderson				
	2260004015	Rotary Tillers < 6 HP	0.0088	0.0000	0.0040
	2260004020	Chain Saws < 6 HP	0.0983	0.0001	0.0516
	2260004025	Trimmers/Edgers/Brush Cutter	0.2868	0.0003	0.1378
	2260004030	Leafblowers/Vacuums	0.1226	0.0001	0.0592
	2265004010	Lawn mowers	2.9971	0.0119	0.2611
	2265004015	Rotary Tillers < 6 HP	0.0685	0.0003	0.0061
	2265004025	Trimmers/Edgers/Brush Cutter	0.0102	0.0000	0.0009
	2265004030	Leafblowers/Vacuums	0.0185	0.0001	0.0014
	2265004040	Rear Engine Riding Mowers	0.4713	0.0022	0.0132
Total			4.0821	0.0152	0.5352
48221	Hood				
	2260004015	Rotary Tillers < 6 HP	0.0044	0.0000	0.0020
	2260004020	Chain Saws < 6 HP	0.0489	0.0001	0.0257
	2260004025	Trimmers/Edgers/Brush Cutter	0.1427	0.0002	0.0686
	2260004030	Leafblowers/Vacuums	0.0610	0.0001	0.0295
	2265004010	Lawn mowers	1.4914	0.0059	0.1299
	2265004015	Rotary Tillers < 6 HP	0.0341	0.0001	0.0030
	2265004025	Trimmers/Edgers/Brush Cutter	0.0051	0.0000	0.0004
	2265004030	Leafblowers/Vacuums	0.0092	0.0000	0.0007
	2265004040	Rear Engine Riding Mowers	0.2345	0.0011	0.0066
Total			2.0313	0.0075	0.2663
48231	Hunt				
	2260004015	Rotary Tillers < 6 HP	0.0086	0.0000	0.0039
	2260004020	Chain Saws < 6 HP	0.0958	0.0001	0.0502
	2260004025	Trimmers/Edgers/Brush Cutter	0.2794	0.0003	0.1343
	2260004030	Leafblowers/Vacuums	0.1194	0.0001	0.0577

			Tons per day		
FIPS	SCC	EQUIP	CO	NOx	VOC
	2265004010	Lawn mowers	2.9199	0.0116	0.2544
	2265004015	Rotary Tillers < 6 HP	0.0668	0.0003	0.0059
	2265004025	Trimmers/Edgers/Brush Cutter	0.0099	0.0000	0.0008
	2265004030	Leafblowers/Vacuums	0.0180	0.0001	0.0014
	2265004040	Rear Engine Riding Mowers	0.4591	0.0022	0.0128
Total			3.9769	0.0148	0.5214
48251	Johnson				
	2260004015	Rotary Tillers < 6 HP	0.0122	0.0000	0.0055
	2260004020	Chain Saws < 6 HP	0.1357	0.0002	0.0711
	2260004025	Trimmers/Edgers/Brush Cutter	0.3958	0.0005	0.1902
	2260004030	Leafblowers/Vacuums	0.1691	0.0002	0.0817
	2265004010	Lawn mowers	4.1357	0.0164	0.3603
	2265004015	Rotary Tillers < 6 HP	0.0946	0.0004	0.0084
	2265004025	Trimmers/Edgers/Brush Cutter	0.0140	0.0001	0.0012
	2265004030	Leafblowers/Vacuums	0.0255	0.0001	0.0020
	2265004040	Rear Engine Riding Mowers	0.6503	0.0031	0.0182
Total			5.6328	0.0209	0.7385
48257	Kaufman				
	2260004015	Rotary Tillers < 6 HP	0.0073	0.0000	0.0033
	2260004020	Chain Saws < 6 HP	0.0815	0.0001	0.0427
	2260004025	Trimmers/Edgers/Brush Cutter	0.2376	0.0003	0.1142
	2260004030	Leafblowers/Vacuums	0.1015	0.0001	0.0491
	2265004010	Lawn mowers	2.4833	0.0099	0.2163
	2265004015	Rotary Tillers < 6 HP	0.0568	0.0002	0.0050
	2265004025	Trimmers/Edgers/Brush Cutter	0.0084	0.0000	0.0007
	2265004030	Leafblowers/Vacuums	0.0153	0.0001	0.0012
	2265004040	Rear Engine Riding Mowers	0.3905	0.0019	0.0109
Total			3.3822	0.0126	0.4435
48367	Parker				
	2260004015	Rotary Tillers < 6 HP	0.0088	0.0000	0.0040
	2260004020	Chain Saws < 6 HP	0.0985	0.0001	0.0516
	2260004025	Trimmers/Edgers/Brush Cutter	0.2873	0.0003	0.1381
	2260004030	Leafblowers/Vacuums	0.1228	0.0001	0.0593
	2265004010	Lawn mowers	3.0022	0.0119	0.2616
	2265004015	Rotary Tillers < 6 HP	0.0686	0.0003	0.0061
	2265004025	Trimmers/Edgers/Brush Cutter	0.0102	0.0000	0.0009
	2265004030	Leafblowers/Vacuums	0.0185	0.0001	0.0014
	2265004040	Rear Engine Riding Mowers	0.4721	0.0022	0.0132
Total			4.0890	0.0152	0.5361
48397	Rockwall				
	2260004015	Rotary Tillers < 6 HP	0.0043	0.0000	0.0020
	2260004020	Chain Saws < 6 HP	0.0481	0.0001	0.0252
	2260004025	Trimmers/Edgers/Brush Cutter	0.1404	0.0002	0.0675
	2260004030	Leafblowers/Vacuums	0.0600	0.0001	0.0290
	2265004010	Lawn mowers	1.4670	0.0058	0.1278

			Tons per day		
FIPS	SCC	EQUIP	CO	NOx	VOC
	2265004015	Rotary Tillers < 6 HP	0.0335	0.0001	0.0030
	2265004025	Trimmers/Edgers/Brush Cutter	0.0050	0.0000	0.0004
	2265004030	Leafblowers/Vacuums	0.0090	0.0000	0.0007
	2265004040	Rear Engine Riding Mowers	0.2307	0.0011	0.0064
Total			1.9980	0.0074	0.2620
	SCC	EQUIP			
	2260004015	Rotary Tillers < 6 HP	0.1479	0.0002	0.0669
	2260004020	Chain Saws < 6 HP	1.6499	0.0018	0.8649
	2260004025	Trimmers/Edgers/Brush Cutter	4.8119	0.0057	2.3126
	2260004030	Leafblowers/Vacuums	2.0563	0.0023	0.9936
	2265004010	Lawn mowers	50.2843	0.1999	4.3807
	2265004015	Rotary Tillers < 6 HP	1.1498	0.0046	0.1017
	2265004025	Trimmers/Edgers/Brush Cutter	0.1704	0.0007	0.0143
	2265004030	Leafblowers/Vacuums	0.3097	0.0014	0.0242
	2265004040	Rear Engine Riding Mowers	7.9070	0.0376	0.2210
Total			68.4871	0.2543	8.9798

Biogenic Sources

Biogenic emissions were prepared using both version 2.2 and version 3.1 of the GloBEIS model (Yarwood et al., 1999 a,b). The GloBEIS model was developed by the National Center for Atmospheric Research and ENVIRON under sponsorship from the TCEQ. Biogenic emissions developed using GloBEIS 2.2 have been used previously for air quality modeling in East Texas (ENVIRON, 2003d). Sensitivity simulations suggest the importance of drought effects on biogenic emissions as well as air quality modeling results. These effects have been documented by Hoats et al, 2003 and Yarwood et al., 2003. While version 3.1 of GloBEIS was still under development during the modeling efforts for East Texas, the model has recently been completed and so is available for the development of biogenic emission inventories for this project.

GloBEIS version 2.2 is based on the EPA BEIS2 model with the following improvements:

- Updated emission factor algorithm (called the BEIS99 algorithm).
- Compatible with the EPA's BELD3 landuse/landcover (LULC) database (EPA, 2000).
- Compatible with the TCEQ's Texas specific LULC database (Yarwood et al., 1999b) which includes local survey data for Northeast Texas developed by NETAC (ENVIRON, 1999).
- Ability to use solar radiation data for photosynthetically active radiation (PAR).

GloBEIS 2.2 requires input data for LULC, temperature and solar radiation. The TCEQ provided these data for the August 1999 episode period (Yarwood et al., 2001). Briefly, these data are:

- TCEQ LULC data for Texas and Mexico.

- EPA BELD LULC data for all other U.S. States.
- Hourly temperature data from interpolated NWS observations.
- Hourly solar radiation (PAR) based on GOES satellite data as analyzed by the University of Maryland.

GloBEIS, version 3, was released in April 2002 (Guenther et al., 2002). GloBEIS3 includes new options such as effects of drought stress and prolonged periods of high temperature. The GloBEIS3 and GloBEIS2 codes calculate the same emissions when using the same input data, so the GloBEIS2 emissions for this study are fully consistent with the newer GloBEIS3 model. GloBEIS was used to calculate day specific, gridded, speciated, hourly emissions of biogenic VOCs and NOx for each modeling grid (36-km, 12-km, 4-km). The BEIS99 emission factor algorithm was used with no correction for seasonal variation in biomass density. Biogenic emissions with/without drought conditions were estimated using the advanced features of GloBEIS3 for sensitivity testing, but will be otherwise consistent with GloBEIS2.2.

EMISSIONS SUMMARIES FOR 1999

All emission estimates in the following tables reflect gridded, model ready emissions. This means that for partial counties and/or states at the edge of a modeling domain, only the portion of emissions that is within the modeling domain is reported. In addition, emission totals for biogenic emissions are based on results from GloBEIS2.2 (i.e., without drought stress effects). A comparison of drought stress effects on biogenic emissions is presented in Hoats, et al., 2003.

Tables 3-7 to 3-9 present episode day emission summaries by major source type for the DFW non-attainment counties and the surrounding 8 perimeter counties.

Table 3-10 indicates, by episode day, NOx emissions for the elevated point sources within the 4-km grid that have been flagged for plume in grid treatment in CAMx modeling.

Table 3-11 represents total gridded Texas emissions for each episode day.

Table 3-12 summarize the gridded emissions by major source type for states other than Texas.

Table 3-13 presents the gridded biogenic emissions for states other than Texas.

Table 3-7. Episode day NOx emission summaries by major source type for the DFW non-attainment counties and the surrounding 8 perimeter counties.

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	Source	48085	48113	48121	48139	48213	48221	48231	48251	48257	48367	48397	48439
Friday, August 13	Area	1.54	13.25	1.24	0.24	2.65	2.87	0.21	0.23	0.14	10.88	0.09	6.72
	Non-road	24.35	71.85	17.53	7.69	5.94	0.44	3.04	7.66	4.36	5.81	0.85	54.26
	On-road	35.33	191.89	37.63	24.42	5.57	2.58	13.51	13.10	16.43	15.65	5.78	119.85
	Points	6.61	61.09	5.10	29.81	9.42	31.56	0.50	6.03	0.86	3.18	0.00	41.91
	Subtotal	67.83	338.08	61.50	62.15	23.58	37.45	17.26	27.02	21.79	35.52	6.71	222.74
	Biogenic	12.16	4.48	8.59	15.61	0.69	0.22	7.45	5.25	5.45	0.71	1.81	3.09
	Total	79.99	342.55	70.08	77.76	24.27	37.67	24.71	32.27	27.24	36.23	8.52	225.83
Saturday, August 14	Area	1.20	9.78	0.99	0.20	2.62	2.85	0.18	0.18	0.11	10.85	0.07	4.93
	Non-road	20.41	64.85	16.27	7.48	6.08	0.47	2.93	7.47	4.31	5.74	0.80	48.48
	On-road	28.87	156.73	30.94	22.23	5.06	2.36	12.42	12.02	15.06	14.58	4.64	99.89
	Points	6.33	51.87	5.12	29.80	9.63	28.89	0.65	6.00	0.86	3.56	0.00	32.66
	Subtotal	56.80	283.23	53.31	59.72	23.39	34.58	16.17	25.67	20.34	34.72	5.51	185.95
	Biogenic	11.78	4.50	8.46	15.74	0.67	0.23	7.09	5.38	5.37	0.72	1.77	3.16
	Total	68.58	287.73	61.78	75.46	24.06	34.81	23.26	31.05	25.71	35.44	7.28	189.11
Sunday, August 15	Area	0.85	6.32	0.74	0.16	2.59	2.84	0.15	0.13	0.08	10.82	0.06	3.13
	Non-road	16.10	55.98	14.57	7.19	5.86	0.43	2.61	7.24	4.14	5.61	0.65	41.88
	On-road	23.29	127.04	24.76	20.65	4.80	2.18	11.63	11.18	14.15	13.36	3.74	79.10
	Points	5.57	50.38	3.88	29.80	9.50	25.85	0.24	6.00	0.86	3.24	0.00	37.13
	Subtotal	45.81	239.73	43.96	57.80	22.75	31.30	14.63	24.56	19.23	33.03	4.44	161.24
	Biogenic	11.13	4.20	8.14	14.81	0.62	0.22	6.61	5.14	4.98	0.71	1.65	3.02
	Total	56.94	243.92	52.10	72.61	23.37	31.52	21.24	29.70	24.21	33.73	6.09	164.26
Monday, August 16	Area	1.54	13.25	1.24	0.24	2.65	2.87	0.21	0.23	0.14	10.88	0.09	6.72
	Non-road	24.35	71.85	17.53	7.69	5.94	0.44	3.04	7.66	4.36	5.81	0.85	54.26
	On-road	33.20	179.83	35.34	19.71	4.71	2.13	11.13	10.76	13.56	12.81	5.36	112.22
	Points	6.45	63.24	5.37	29.81	9.11	30.26	0.80	6.03	0.86	4.24	0.00	40.96
	Subtotal	65.54	328.17	59.47	57.44	22.41	35.70	15.18	24.68	18.93	33.74	6.29	214.16
	Biogenic	10.85	4.08	7.96	14.30	0.59	0.22	6.42	4.97	4.80	0.69	1.60	2.93
	Total	76.39	332.24	67.43	71.73	23.00	35.92	21.60	29.65	23.73	34.43	7.89	217.09
Tuesday, August 17	Area	1.54	13.25	1.24	0.24	2.65	2.87	0.21	0.23	0.14	10.88	0.09	6.72
	Non-road	24.35	71.85	17.53	7.69	5.94	0.44	3.04	7.66	4.36	5.81	0.85	54.26
	On-road	33.45	180.51	35.80	19.78	4.67	2.12	11.10	10.68	13.48	12.86	5.35	113.20

Date	Source	Collin 48085	Dallas 48113	Denton 48121	Ellis 48139	Henderson 48213	Hood 48221	Hunt 48231	Johnson 48251	Kaufman 48257	Parker 48367	Rockwall 48397	Tarrant 48439
Tuesday, August 17	Points	5.76	60.41	5.30	29.81	7.95	30.10	0.61	6.02	0.86	4.06	0.00	39.90
	Subtotal	65.10	326.02	59.87	57.51	21.21	35.52	14.96	24.59	18.84	33.60	6.28	214.08
	Biogenic	11.18	4.18	7.99	14.51	0.63	0.21	6.78	4.94	5.02	0.67	1.67	2.92
	Total	76.28	330.20	67.86	72.02	21.84	35.73	21.74	29.52	23.87	34.27	7.95	217.00
Wed, August 18	Area	1.54	13.25	1.24	0.24	2.65	2.87	0.21	0.23	0.14	10.88	0.09	6.72
	Non-road	24.35	71.85	17.53	7.69	5.94	0.44	3.04	7.66	4.36	5.81	0.85	54.26
	On-road	32.68	177.53	34.95	19.71	4.53	2.05	10.92	10.48	13.24	12.67	5.25	110.43
	Points	7.01	65.70	5.42	29.81	9.76	35.57	0.92	6.03	0.86	2.39	0.00	42.64
	Subtotal	65.58	328.33	59.14	57.44	22.88	40.93	15.08	24.40	18.60	31.75	6.18	214.05
	Biogenic	12.11	4.57	8.63	15.84	0.69	0.22	7.35	5.34	5.50	0.71	1.82	3.17
	Total	77.70	332.90	67.77	73.28	23.57	41.16	22.43	29.74	24.10	32.46	8.00	217.23
Thursday, August 19	Area	1.54	13.25	1.24	0.24	2.65	2.87	0.21	0.23	0.14	10.88	0.09	6.72
	Non-road	24.35	71.85	17.53	7.69	5.94	0.44	3.04	7.66	4.36	5.81	0.85	54.26
	On-road	33.12	178.49	34.91	19.70	4.55	2.09	10.98	10.59	13.29	12.66	5.29	110.52
	Points	7.81	65.88	5.35	29.81	9.04	34.55	0.52	6.03	0.86	2.39	0.00	40.63
	Subtotal	66.83	329.47	59.03	57.42	22.19	39.94	14.75	24.51	18.65	31.74	6.23	212.14
	Biogenic	12.47	4.73	8.76	16.44	0.73	0.22	7.61	5.41	5.74	0.70	1.89	3.18
	Total	79.30	334.20	67.79	73.86	22.92	40.17	22.36	29.91	24.39	32.44	8.11	215.31
Friday, August 20	Area	1.54	13.25	1.24	0.24	2.65	2.87	0.21	0.23	0.14	10.88	0.09	6.72
	Non-road	24.35	71.85	17.53	7.69	5.94	0.44	3.04	7.66	4.36	5.81	0.85	54.26
	On-road	37.62	199.99	39.85	24.83	5.96	2.75	14.10	13.71	17.10	16.38	6.06	127.28
	Points	7.07	63.63	6.18	29.81	9.27	23.15	0.82	6.03	0.86	3.31	0.00	37.34
	Subtotal	70.59	348.72	64.80	62.55	23.82	29.21	18.17	27.63	22.46	36.38	6.99	225.60
	Biogenic	10.80	4.17	7.59	14.84	0.68	0.20	6.62	4.88	5.12	0.62	1.66	2.81
	Total	81.38	352.89	72.40	77.40	24.50	29.41	24.79	32.51	27.58	37.00	8.65	228.41
Sat, August 21	Area	1.20	9.78	0.99	0.20	2.62	2.85	0.18	0.18	0.11	10.85	0.07	4.93
	Non-road	20.41	64.85	16.27	7.48	6.08	0.47	2.93	7.47	4.31	5.74	0.80	48.48
	On-road	29.33	159.28	31.16	22.48	5.21	2.43	12.57	12.26	15.25	14.68	4.70	99.79
	Points	7.06	63.40	4.72	29.80	8.28	2.16	0.12	5.98	0.86	3.26	0.00	31.75
	Subtotal	58.00	297.32	53.14	59.96	22.18	7.91	15.79	25.89	20.54	34.53	5.57	184.94
	Biogenic	10.71	4.06	7.67	14.23	0.63	0.20	6.46	4.77	4.90	0.63	1.61	2.81
	Total	68.71	301.38	60.81	74.19	22.81	8.12	22.26	30.66	25.43	35.17	7.18	187.75

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	**Source**	**48085**	**48113**	**48121**	**48139**	**48213**	**48221**	**48231**	**48251**	**48257**	**48367**	**48397**	**48439**
Sunday, August 22	Area	0.85	6.32	0.74	0.16	2.59	2.84	0.15	0.13	0.08	10.82	0.06	3.13
	Non-road	16.10	55.98	14.57	7.19	5.86	0.43	2.61	7.24	4.14	5.61	0.65	41.88
	On-road	22.86	126.83	24.61	20.73	4.71	2.19	11.45	11.18	13.92	13.35	3.68	78.83
	Points	6.93	53.65	5.19	29.80	8.80	23.40	0.01	6.00	0.86	2.69	0.00	26.39
	Subtotal	46.74	242.79	45.11	57.88	21.96	28.86	14.23	24.56	19.01	32.47	4.39	150.23
	Biogenic	11.87	4.44	8.42	15.32	0.66	0.22	7.17	5.15	5.34	0.69	1.77	3.04
	Total	58.62	247.23	53.54	73.20	22.62	29.07	21.40	29.70	24.35	33.17	6.16	153.28

Table 3-8. Episode day VOC emission summaries by major source type for the DFW non-attainment counties and the surrounding 8 perimeter counties.

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	Source	48085	48113	48121	48139	48213	48221	48231	48251	48257	48367	48397	48439
Friday, August 13	Area	11.72	63.98	12.72	8.56	8.43	3.64	8.69	8.20	9.58	10.48	2.28	48.02
	Non-road	12.81	53.52	7.98	1.48	2.08	0.54	1.68	1.73	1.12	1.10	0.86	28.73
	On-road	18.26	92.34	17.95	6.64	4.20	1.68	5.60	5.95	6.65	5.46	2.34	54.24
	Points	0.99	12.63	2.68	6.46	0.73	0.38	0.09	0.42	0.88	0.98	0.00	12.80
	Subtotal	43.77	222.47	41.33	23.14	15.43	6.24	16.05	16.29	18.23	18.02	5.48	143.79
	Biogenic	24.94	47.78	52.42	87.80	270.77	29.24	66.90	89.97	102.23	108.72	3.28	48.72
	Total	68.72	270.25	93.75	110.93	286.20	35.48	82.95	106.26	120.47	126.74	8.76	192.51
Saturday, August 14	Area	8.73	38.71	8.09	6.91	6.88	2.92	4.63	5.02	4.96	8.45	1.56	25.88
	Non-road	15.14	63.44	12.39	2.34	6.40	1.41	4.17	2.03	2.36	1.61	2.00	33.20
	On-road	12.80	65.25	12.75	5.55	3.49	1.43	4.64	4.96	5.52	4.64	1.65	38.73
	Points	0.65	8.36	1.49	6.36	0.74	0.38	0.04	0.41	0.86	0.98	0.00	6.58
	Subtotal	37.32	175.76	34.71	21.17	17.51	6.14	13.48	12.42	13.70	15.68	5.21	104.39
	Biogenic	27.84	55.51	63.41	94.23	274.45	36.68	74.66	113.29	109.44	134.33	3.69	64.04
	Total	65.16	231.28	98.12	115.40	291.97	42.82	88.14	125.71	123.13	150.02	8.90	168.43
Sunday, August 15	Area	6.86	30.12	6.61	4.96	6.01	2.51	2.85	3.49	3.58	7.38	1.12	20.17
	Non-road	14.33	61.66	12.07	2.28	6.36	1.41	4.10	1.98	2.33	1.59	1.97	31.91
	On-road	10.10	51.43	10.03	4.99	3.11	1.30	4.13	4.46	4.91	4.20	1.29	30.77
	Points	0.65	8.46	1.49	6.36	0.74	0.38	0.04	0.41	0.86	0.98	0.00	6.58
	Subtotal	31.94	151.67	30.20	18.60	16.21	5.60	11.12	10.34	11.67	14.15	4.38	89.44
	Biogenic	25.42	48.95	60.56	82.51	230.43	35.33	66.00	104.71	93.77	131.95	3.24	59.68
	Total	57.36	200.62	90.75	101.11	246.64	40.93	77.12	115.05	105.45	146.10	7.62	149.12
Monday, August 16	Area	11.72	63.98	12.72	8.56	8.43	3.64	8.69	8.20	9.58	10.48	2.28	48.02
	Non-road	12.81	53.52	7.98	1.48	2.08	0.54	1.68	1.73	1.12	1.10	0.86	28.73
	On-road	16.33	81.79	16.23	5.20	3.29	1.34	4.38	4.67	5.20	4.36	2.04	48.96
	Points	0.99	12.63	2.68	6.46	0.73	0.38	0.09	0.42	0.88	0.98	0.00	12.80
	Subtotal	41.84	211.92	39.61	21.70	14.53	5.90	14.83	15.01	16.78	16.92	5.18	138.51
	Biogenic	25.72	49.59	61.60	82.66	231.67	34.72	67.06	104.12	94.89	131.12	3.26	60.22
	Total	67.56	261.52	101.20	104.36	246.19	40.63	81.89	119.12	111.68	148.04	8.45	198.74
Tuesday, August 17	Area	11.72	63.98	12.72	8.56	8.43	3.64	8.69	8.20	9.58	10.48	2.28	48.02
	Non-road	12.81	53.52	7.98	1.48	2.08	0.54	1.68	1.73	1.12	1.10	0.86	28.73
	On-road	16.87	84.12	16.69	5.22	3.33	1.35	4.43	4.69	5.26	4.39	2.09	49.87

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	**Source**	**48085**	**48113**	**48121**	**48139**	**48213**	**48221**	**48231**	**48251**	**48257**	**48367**	**48397**	**48439**
	Points	0.99	12.63	2.68	6.46	0.73	0.38	0.09	0.42	0.88	0.98	0.00	12.80
	Subtotal	42.38	214.26	40.07	21.72	14.56	5.92	14.88	15.03	16.85	16.95	5.23	139.42
Tuesday, August 17	Biogenic	27.37	51.14	62.39	84.35	248.62	32.99	74.21	100.61	101.34	126.55	3.51	59.67
	Total	69.75	265.40	102.46	106.07	263.18	38.91	89.09	115.64	118.18	143.50	8.74	199.10
	Area	11.72	63.98	12.72	8.56	8.43	3.64	8.69	8.20	9.58	10.48	2.28	48.02
	Non-road	12.81	53.52	7.98	1.48	2.08	0.54	1.68	1.73	1.12	1.10	0.86	28.73
	On-road	17.08	85.57	16.83	5.30	3.36	1.38	4.48	4.77	5.32	4.46	2.12	50.49
Wed, August 18	Points	0.99	12.63	2.68	6.46	0.73	0.38	0.08	0.42	0.88	0.97	0.00	12.80
	Subtotal	42.60	215.70	40.20	21.80	14.60	5.94	14.92	15.11	16.90	17.01	5.26	140.05
	Biogenic	29.50	55.34	66.21	91.30	269.69	34.85	79.64	107.25	109.25	132.32	3.81	63.65
	Total	72.10	271.04	106.41	113.10	284.28	40.79	94.56	122.36	126.15	149.33	9.07	203.69
	Area	11.72	63.98	12.72	8.56	8.43	3.64	8.69	8.20	9.58	10.48	2.28	48.02
	Non-road	12.81	53.52	7.98	1.48	2.08	0.54	1.68	1.73	1.12	1.10	0.86	28.73
	On-road	17.44	85.74	17.04	5.45	3.40	1.38	4.52	4.90	5.37	4.47	2.14	50.62
Thursday, August 19	Points	0.99	12.63	2.68	6.46	0.73	0.38	0.09	0.42	0.88	0.97	0.00	12.79
	Subtotal	42.96	215.87	40.42	21.95	14.63	5.94	14.97	15.24	16.95	17.02	5.28	140.16
	Biogenic	30.90	58.87	68.30	98.82	297.09	36.42	83.84	114.86	117.00	133.77	4.00	66.11
	Total	73.86	274.74	108.73	120.77	311.72	42.35	98.81	130.10	133.95	150.79	9.28	206.28
	Area	11.72	63.98	12.72	8.56	8.43	3.64	8.69	8.20	9.58	10.48	2.28	48.02
	Non-road	12.81	53.52	7.98	1.48	2.08	0.54	1.68	1.73	1.12	1.10	0.86	28.73
	On-road	18.11	90.70	17.93	6.53	4.08	1.67	5.43	5.85	6.45	5.42	2.29	53.76
Friday, August 20	Points	0.99	12.63	2.68	6.46	0.73	0.38	0.09	0.42	0.88	0.98	0.00	12.79
	Subtotal	43.63	220.83	41.31	23.03	15.31	6.23	15.88	16.19	18.03	17.98	5.43	143.30
	Biogenic	25.12	49.93	56.28	87.45	268.22	31.89	69.06	100.81	101.82	114.81	3.38	56.14
	Total	68.75	270.76	97.59	110.48	283.53	38.13	84.94	117.00	119.85	132.79	8.81	199.45
	Area	8.73	38.71	8.09	6.91	6.88	2.92	4.63	5.02	4.96	8.45	1.56	25.88
	Non-road	15.14	63.44	12.39	2.34	6.40	1.41	4.17	2.03	2.36	1.61	2.00	33.20
	On-road	12.54	63.32	12.44	5.31	3.35	1.37	4.46	4.74	5.31	4.46	1.60	37.74
Sat, August 21	Points	0.65	8.46	1.49	6.36	0.74	0.05	0.04	0.41	0.86	0.98	0.00	6.54
	Subtotal	37.06	173.93	34.41	20.93	17.37	5.75	13.30	12.19	13.48	15.51	5.15	103.36
	Biogenic	24.38	47.95	56.24	82.07	241.99	31.79	65.47	97.77	95.11	116.78	3.21	55.63
	Total	61.44	221.89	90.65	103.00	259.36	37.55	78.77	109.97	108.59	132.29	8.36	159.00

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	**Source**	**48085**	**48113**	**48121**	**48139**	**48213**	**48221**	**48231**	**48251**	**48257**	**48367**	**48397**	**48439**
Sunday, August 22	Area	6.86	30.12	6.61	4.96	6.01	2.51	2.85	3.49	3.58	7.38	1.12	20.17
	Non-road	14.33	61.66	12.07	2.28	6.36	1.41	4.10	1.98	2.33	1.59	1.97	31.91
	On-road	10.27	51.98	10.18	19.70	4.55	2.09	10.98	10.59	13.29	12.66	1.31	30.91
	Points	0.65	8.46	1.49	6.36	0.74	0.38	0.04	0.41	0.86	0.98	0.00	6.54
	Subtotal	32.11	152.23	30.35	33.30	17.66	6.38	17.98	16.47	20.05	22.61	4.41	89.54
	Biogenic	26.10	49.01	58.86	82.15	240.53	33.03	69.19	98.26	96.24	124.47	3.37	56.80
	Total	58.21	201.23	89.20	115.45	258.19	39.41	87.17	114.73	116.29	147.08	7.78	146.33

ENVIRON

Table 3-9. Episode day CO emission summaries by major source type for the DFW non-attainment counties and the surrounding 8 perimeter counties.

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	**Source**	**48085**	**48113**	**48121**	**48139**	**48213**	**48221**	**48231**	**48251**	**48257**	**48367**	**48397**	**48439**
Friday, August 13	Area	10.36	26.59	6.32	2.42	2.75	2.08	1.67	1.76	1.73	7.53	0.63	12.99
	Non-road	186.28	817.42	103.69	16.13	14.19	6.18	14.34	23.65	13.36	13.62	10.31	400.89
	On-road	240.85	1203.50	244.09	104.01	55.90	23.48	79.81	83.62	98.50	80.59	37.18	737.20
	Points	2.75	16.53	1.30	17.06	5.10	5.10	0.15	1.23	0.07	1.43	0.00	12.98
	Subtotal	440.24	2064.04	355.39	139.61	77.94	36.84	95.97	110.25	113.66	103.18	48.11	1164.06
	Biogenic	2.19	4.01	3.18	6.91	17.32	5.93	5.00	6.84	5.95	10.88	0.30	3.95
	Total	442.43	2068.05	358.57	146.52	95.27	42.77	100.97	117.09	119.62	114.06	48.42	1168.02
Saturday, August 14	Area	7.23	14.98	5.16	1.78	2.44	1.98	1.42	1.25	1.12	7.33	0.41	7.46
	Non-road	219.43	1122.47	131.65	23.05	27.00	10.12	22.57	27.71	21.63	19.11	15.40	511.26
	On-road	174.25	902.60	180.89	90.53	47.03	20.09	67.11	71.69	83.55	69.22	26.94	548.54
	Points	2.60	14.33	1.27	17.04	5.17	5.10	0.15	1.22	0.07	1.43	0.00	12.69
	Subtotal	403.52	2054.37	318.96	132.40	81.63	37.29	91.25	101.87	106.37	97.09	42.74	1079.95
	Biogenic	2.12	4.09	3.19	6.96	16.51	6.18	4.70	7.16	5.84	11.35	0.30	4.18
	Total	405.63	2058.47	322.15	139.36	98.14	43.48	95.95	109.02	112.20	108.43	43.04	1084.13
Sunday, August 15	Area	4.17	3.60	4.00	1.15	2.14	1.89	1.18	0.75	0.52	7.14	0.19	2.03
	Non-road	211.97	1103.46	128.61	22.27	26.61	10.04	21.87	27.18	21.24	18.84	15.13	497.98
	On-road	137.33	704.13	143.51	81.31	41.59	18.55	59.44	64.33	73.88	63.91	20.84	442.66
	Points	2.60	15.84	1.27	17.04	5.17	5.10	0.15	1.22	0.07	1.43	0.00	12.69
	Subtotal	356.08	1827.02	277.38	121.77	75.51	35.58	82.64	93.48	95.71	91.31	36.16	955.36
	Biogenic	1.93	3.65	2.98	6.26	14.47	5.95	4.19	6.69	5.16	11.05	0.26	3.86
	Total	358.01	1830.68	280.36	128.03	89.98	41.53	86.83	100.17	100.87	102.36	36.42	959.21
Monday, August 16	Area	10.36	26.59	6.32	2.42	2.75	2.08	1.67	1.76	1.73	7.53	0.63	12.99
	Non-road	186.28	817.42	103.69	16.13	14.19	6.18	14.34	23.65	13.36	13.62	10.31	400.89
	On-road	203.05	1003.21	207.73	77.95	41.68	17.85	59.05	62.91	72.76	61.33	30.57	628.81
	Points	2.75	16.53	1.30	17.06	5.10	5.10	0.15	1.23	0.07	1.43	0.00	12.98
	Subtotal	402.44	1863.74	319.03	113.54	63.73	31.21	75.21	89.54	87.93	83.91	41.50	1055.67
	Biogenic	1.87	3.53	2.91	5.98	13.63	5.73	4.04	6.42	4.94	10.69	0.26	3.72
	Total	404.31	1867.27	321.94	119.52	77.36	36.94	79.26	95.96	92.87	94.61	41.76	1059.39
Tuesday, August 17	Area	10.36	26.59	6.32	2.42	2.75	2.08	1.67	1.76	1.73	7.53	0.63	12.99
	Non-road	186.28	817.42	103.69	16.13	14.19	6.18	14.34	23.65	13.36	13.62	10.31	400.89
	On-road	210.16	1042.48	213.66	79.37	42.73	18.11	60.59	64.11	74.79	61.67	31.66	641.67

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	**Source**	**48085**	**48113**	**48121**	**48139**	**48213**	**48221**	**48231**	**48251**	**48257**	**48367**	**48397**	**48439**
Tuesday, August 17	Points	2.75	16.53	1.30	17.06	5.10	5.10	0.15	1.23	0.07	1.43	0.00	12.98
	Subtotal	409.55	1903.02	324.96	114.97	64.77	31.47	76.75	90.74	89.96	84.25	42.59	1068.53
	Biogenic	1.97	3.68	2.92	6.22	15.17	5.44	4.44	6.28	5.33	10.17	0.27	3.70
	Total	411.52	1906.70	327.88	121.19	79.94	36.91	81.19	97.02	95.29	94.42	42.87	1072.23
Wed, August 18	Area	10.36	26.59	6.32	2.42	2.75	2.08	1.67	1.76	1.73	7.53	0.63	12.99
	Non-road	186.28	817.42	103.69	16.13	14.19	6.18	14.34	23.65	13.36	13.62	10.31	400.89
	On-road	216.61	1093.65	219.95	81.80	43.72	18.94	62.06	66.77	76.74	64.28	32.87	670.99
	Points	2.75	16.53	1.30	17.06	5.10	5.10	0.04	1.23	0.07	1.36	0.00	12.98
	Subtotal	416.00	1954.19	331.25	117.40	65.76	32.30	78.11	93.40	91.91	86.80	43.81	1097.85
	Biogenic	2.22	4.19	3.27	7.08	17.31	5.92	5.00	6.98	6.07	11.03	0.31	4.17
	Total	418.22	1958.38	334.52	124.48	83.07	38.21	83.11	100.38	97.98	97.83	44.12	1102.01
Thursday, August 19	Area	10.36	26.59	6.32	2.42	2.75	2.08	1.67	1.76	1.73	7.53	0.63	12.99
	Non-road	186.28	817.42	103.69	16.13	14.19	6.18	14.34	23.65	13.36	13.62	10.31	400.89
	On-road	222.27	1094.20	224.68	84.15	43.91	18.81	62.10	68.52	76.96	64.32	33.14	668.90
	Points	2.75	16.53	1.30	17.06	5.10	5.10	0.15	1.23	0.07	1.36	0.00	12.87
	Subtotal	421.66	1954.74	335.99	119.74	65.96	32.17	78.26	95.15	92.13	86.83	44.07	1095.65
	Biogenic	2.31	4.42	3.33	7.60	18.98	5.97	5.27	7.16	6.53	10.84	0.33	4.19
	Total	423.97	1959.17	339.31	127.34	84.94	38.15	83.53	102.31	98.66	97.67	44.40	1099.84
Friday, August 20	Area	10.36	26.59	6.32	2.42	2.75	2.08	1.67	1.76	1.73	7.53	0.63	12.99
	Non-road	186.28	817.42	103.69	16.13	14.19	6.18	14.34	23.65	13.36	13.62	10.31	400.89
	On-road	222.59	1118.82	226.94	100.39	51.99	22.12	73.62	79.55	90.97	75.71	33.91	678.60
	Points	2.75	16.53	1.30	17.06	5.10	5.10	0.15	1.23	0.07	1.43	0.00	12.87
	Subtotal	421.98	1979.35	338.25	135.99	74.04	35.48	89.78	106.19	106.14	98.30	44.84	1105.35
	Biogenic	1.85	3.63	2.68	6.51	16.97	5.20	4.27	6.20	5.51	9.21	0.27	3.49
	Total	423.84	1982.99	340.93	142.50	91.01	40.68	94.05	112.39	111.65	107.51	45.11	1108.83
Sat, August 21	Area	7.23	14.98	5.16	1.78	2.44	1.98	1.42	1.25	1.12	7.33	0.41	7.46
	Non-road	219.43	1122.47	131.65	23.05	27.00	10.12	22.57	27.71	21.63	19.11	15.40	511.26
	On-road	167.49	850.92	173.05	85.14	44.47	18.79	63.48	66.83	79.04	65.21	25.59	524.65
	Points	2.60	15.84	1.27	17.04	5.17	0.06	0.15	1.22	0.07	1.43	0.00	12.04
	Subtotal	396.75	2004.20	311.12	127.01	79.08	30.95	87.62	97.00	101.86	93.08	41.40	1055.40
	Biogenic	1.83	3.51	2.74	6.07	15.00	5.19	4.10	6.02	5.12	9.48	0.26	3.49
	Total	398.59	2007.71	313.86	133.07	94.07	36.14	91.72	103.02	106.98	102.56	41.66	1058.89

		Collin	Dallas	Denton	Ellis	Henderson	Hood	Hunt	Johnson	Kaufman	Parker	Rockwall	Tarrant
Date	**Source**	**48085**	**48113**	**48121**	**48139**	**48213**	**48221**	**48231**	**48251**	**48257**	**48367**	**48397**	**48439**
Sunday, August 22	Area	4.17	3.60	4.00	1.15	2.14	1.89	1.18	0.75	0.52	7.14	0.19	2.03
	Non-road	211.97	1103.46	128.61	22.27	26.61	10.04	21.87	27.18	21.24	18.84	15.13	497.98
	On-road	142.62	717.83	147.23	82.38	42.80	18.62	61.36	64.91	76.35	64.12	21.66	444.93
	Points	2.60	15.84	1.27	17.04	5.17	5.10	0.15	1.22	0.07	1.43	0.00	12.09
	Subtotal	361.36	1840.72	281.10	122.85	76.72	35.65	84.56	94.05	98.17	91.52	36.98	957.02
	Biogenic	2.13	3.98	3.11	6.71	16.21	5.64	4.75	6.58	5.75	10.61	0.30	3.89
	Total	363.49	1844.70	284.21	129.56	92.92	41.29	89.31	100.63	103.93	102.14	37.27	960.91

Table 3-10. Tons/day NOx for facilities treated with plume in grid within the 4-km domain. These represent only the elevated point emissions at each facility.

Facility Name	Stack	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug
Lake Hubba TXU Generating Company LP Dallas	2	6.7	7.5	5.9	7.9	6.5	7.6	7	6.3	5.1	3.5
	3	5.7	5.6	5.4	5.9	4.8	5.1	6.4	5.4	5.1	4.4
Total		**12.4**	**13.1**	**11.3**	**13.8**	**11.3**	**12.7**	**13.4**	**11.7**	**10.2**	**7.9**
Mountain C G TXU Generating Company LP Dallas	3	2.8	2.7	2.6	2.7	2.7	3.1	3.1	3	3	2.9
	10	3	3.4	2.5	2.8	3.2	2.9	3.1	3.3	2.9	2.2
	11	3	3.4	2.5	2.8	3.2	2.9	3.1	3.3	2.9	2.2
	12	4.7	5.8	7.6	7.9	7.4	8.6	8.4	7.3	7.2	7.1
Total		**13.5**	**15.3**	**15.2**	**16.2**	**16.5**	**17.5**	**17.7**	**16.9**	**16**	**14.4**
North Lake TXU Generating Company LP Dallas	5	0	0	0	0	0	0	2.1	0	2.2	2.1
	6	0	0	0	0	0	0	2.1	0	2.2	2.1
	7	0	0	0	2.1	0	2.1	0	2.1	2.3	2.1
	8	0	0	0	2.1	0	0	0	2.1	2.3	2.1
	9	5.8	5.1	4.2	3.5	3.9	5.3	4.9	4.9	5.8	4.7
	10	5.8	5.1	4.2	3.5	3.9	5.3	4.9	4.9	5.8	4.7
Total		**11.6**	**10.2**	**8.4**	**11.2**	**7.8**	**12.7**	**14**	**14**	**20.6**	**17.8**
The University of Texas Southwestern Dallas	3	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Total		**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**
North Texas Cement Company Ellis Midlothian	7	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	8	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	9	3	3	3	3	3	3	3	3	3	3
Total		**8.4**	**8.4**	**8.4**	**8.4**	**8.4**	**8.4**	**8.4**	**8.4**	**8.4**	**8.4**
TXI Operations Limited Partnership Ellis Midlothian	11	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	12	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
	13	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Total		**10.6**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**	**10.6**
Holcim Texas Limited Partnership Ellis Midlothian	7	4	4	4	4	4	4	4	4	4	4
Total		**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Spencer Station Generating Co LP Denton	4	0	2.2	0	2.3	2.2	2.1	2.3	2.6	0	2.1
	5	2.4	2.2	0	2.3	2.3	2.5	2.3	2.8	2.1	2.4
Total		**2.4**	**4.4**	**0**	**4.6**	**4.5**	**4.6**	**4.6**	**5.4**	**2.1**	**4.5**
TXU Generating Company LP Fannin	1	0	2.6	2.6	2.7	2.4	2.4	2.5	2.3	2.8	2.3

Facility Name	Stack	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug
Savoy	2	0	2.6	2.6	2.7	2.4	2.4	2.5	2.3	2.8	2.3
	3	12	12.8	9.4	12.3	12.8	14.7	15.2	10.9	12.4	11
	5	3.6	4.8	4.1	6.3	4.2	4.7	4.2	2.7	0	0
Total		**15.6**	**22.8**	**18.7**	**24**	**21.8**	**24.2**	**24.4**	**18.2**	**18**	**15.6**
TXU ElectriccoFreestone Fairfield	3	0	0	0	0	0	0	0	0	2.5	3
	10	28	27.1	25.2	26	22.2	26.3	28.6	28.7	26.6	26.7
	11	27.1	17.8	0	0	19.5	20.5	28.3	31	26.7	29.9
Total		**55.1**	**44.9**	**25.2**	**26**	**41.7**	**46.8**	**56.9**	**59.7**	**55.8**	**59.6**
TXU Electricco Henderson Trinidad	3	3.9	3.9	3.7	3.6	2.5	4.3	3.6	3.8	0	0
Total		**3.9**	**3.9**	**3.7**	**3.6**	**2.5**	**4.3**	**3.6**	**3.8**	**0**	**0**
TXU Generating Company LP Hood Granbury	5	29.4	26.7	23.7	28.1	27.9	33.4	32.4	21	0	21.2
Total		**29.4**	**26.7**	**23.7**	**28.1**	**27.9**	**33.4**	**32.4**	**21**	**0**	**21.2**
Frontera Generation LTD Partnership Hidalgo Mission	60	3	3	3	3	3	3	3	3	3	3
Total		**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Reliant Energy Inc Limestone Jewett	2	42	41	38.9	37.4	43.4	40.3	39.3	44.6	48.6	49.9
	3	35.4	28.4	32.1	31.5	34.4	32.5	34.2	36.3	37.4	40.3
Total		**77.4**	**69.4**	**71**	**68.9**	**77.8**	**72.8**	**73.5**	**80.9**	**86**	**90.2**
E TXU Electricco Mclennan Waco	2	0	0	0	0	0	2.1	2.1	0	0	0
	3	3	3	2.7	2.6	2.3	2.5	2.9	2.8	2.1	2.2
	4	3	3	2.7	2.6	2.3	2.5	2.9	2.8	2.1	2.2
	5	21.1	19.3	13.9	17.5	17.4	19.9	24.4	18.5	17	16.5
	6	38.2	34.5	31	37.3	39.3	45.4	46.4	41.6	35	34.6
	34	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Total		**67.7**	**62.2**	**52.7**	**62.4**	**63.7**	**74.8**	**81.1**	**68.1**	**58.6**	**57.9**
Guardian Industries Navarro Corsicana	1	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Total		**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**
R W Miller P Brazos Electric Power Coop Inc Palo Pinto	1	2.7	2.4	2.5	2.3	2.3	2.6	2.4	0	2.2	2.9
	2	5	4.4	4.5	4.6	4.7	4.6	5.2	4.8	4.2	5
	3	4.7	4.1	4.2	4.3	4.4	4.3	4.9	4.5	4	4.7
Total		**12.4**	**10.9**	**11.2**	**11.2**	**11.4**	**11.5**	**12.5**	**9.3**	**10.4**	**12.6**
Eagle Moun P TXU Generating Company LP Tarrant Fort Worth	2	5.9	0	5	2.2	3.5	5.9	5	4.9	4.5	2.1
	4	5.6	5.9	7.3	7.2	5.8	7.5	6.5	6.2	5.8	3.9
Total		**11.5**	**5.9**	**12.3**	**9.4**	**9.3**	**13.4**	**11.5**	**11.1**	**10.3**	**6**

Facility Name	Stack	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug
Handley E TXU Generating Company Tarrant Fort Worth	4	4.8	4.2	4.1	4.8	4.8	3.9	3.6	4.1	2.6	2.1
	5	5.3	4.2	4	4.9	5	4.3	3.4	4.2	3.9	3.3
	11	2.8	3.2	2.9	2.8	3.2		2.6	2.1	0	0
	12	5.3	4.3	3.7	6.1	5.7	6.3	6.5	4.8	4.9	5
	13	5.3	4.3	3.7	6.1	5.7	6.3	6.5	4.8	4.9	5
Total		**23.5**	**20.2**	**18.4**	**24.7**	**24.4**	**20.8**	**22.6**	**20**	**16.3**	**15.4**
North Main E TXU Generating Company Tarrant Fort Worth	1	3.1	3.3	3	3.3	2.8	2.7	3.2	3.1	2.8	2.4
Total		**3.1**	**3.3**	**3**	**3.3**	**2.8**	**2.7**	**3.2**	**3.1**	**2.8**	**2.4**

Table 3-11. Total gridded Texas emissions for each episode day.

Date	Area	On-Road	Off-Road	EGUs	Non-EGU	Ship	Anthropogenic	Biogenic
Tons NOx								
Friday, August 13	625.66	1089.32	985.91	1391.18	59.03	34.85	4185.95	1150
Saturday, August 14	611.75	755.76	956.69	1323.02	60.14	34.85	3742.21	1137
Sunday, August 15	597.85	583.58	886.36	1255.37	60.14	34.85	3418.14	1161
Monday, August 16	625.66	1093.66	985.91	1310.93	59.03	34.85	4110.04	1148
Tuesday, August 17	625.66	1093.66	985.91	1285.76	59.03	34.85	4084.87	1083
Wed, August 18	625.66	1093.66	985.91	1348.70	59.03	34.85	4147.82	1098
Thursday, August 19	625.66	1093.66	985.91	1375.65	59.03	34.85	4174.76	1132
Friday, August 20	625.66	1089.32	985.91	1318.85	59.03	34.85	4113.62	1122
Sat, August 21	611.75	755.76	956.69	1223.39	60.14	34.85	3642.58	1100
Sunday, August 22	597.85	583.58	886.36	1199.57	60.14	34.85	3362.35	1053
Tons VOC								
Friday, August 13	1736.51	795.83	462.45	17.98	354.62	0.79	3368.19	22157
Saturday, August 14	1394.54	585.35	849.91	17.79	333.95	0.79	3182.33	22265
Sunday, August 15	1193.39	503.93	836.24	17.89	333.95	0.79	2886.19	20962
Monday, August 16	1736.51	670.95	462.45	17.80	354.62	0.79	3243.13	20416
Tuesday, August 17	1736.51	670.95	462.45	17.80	354.62	0.79	3243.13	20157
Wed, August 18	1736.51	670.95	462.45	17.70	354.62	0.79	3243.04	21452
Thursday, August 19	1736.51	670.95	462.45	17.70	354.62	0.79	3243.04	23320
Friday, August 20	1736.51	795.83	462.45	17.54	354.62	0.79	3367.75	22379
Sat, August 21	1394.54	585.35	849.91	17.40	333.95	0.79	3181.94	20641
Sunday, August 22	1193.39	503.93	836.24	17.64	333.95	0.79	2885.94	18867
Tons CO								
Friday, August 13	939.97	10182.78	5388.05	215.37	56.40	5.33	16787.91	2610
Saturday, August 14	804.50	7935.06	7770.70	213.93	56.27	5.33	16785.80	2560
Sunday, August 15	671.80	6912.45	7632.72	215.44	56.27	5.33	15494.02	2456
Monday, August 16	939.97	8688.21	5388.05	213.90	56.40	5.33	15291.86	2333
Tuesday, August 17	939.97	8688.21	5388.05	213.90	56.40	5.33	15291.86	2269
Wed, August 18	939.97	8688.21	5388.05	203.40	56.40	5.33	15281.36	2428
Thursday, August 19	939.97	8688.21	5388.05	203.40	56.40	5.33	15281.36	2642
Friday, August 20	939.97	10182.78	5388.05	211.78	56.40	5.33	16784.31	2571
Sat, August 21	804.50	7935.06	7770.70	207.98	56.27	5.33	16779.85	2376
Sunday, August 22	671.80	6912.45	7632.72	212.73	56.27	5.33	15491.31	2246

Table 3-12. Summary of gridded emissions by major source type for states other than Texas.

State	Area			On-Road			Off-Road			Points			Anthropogenic		
	Weekday	Sat	Sun	Weekday	Sat	Sun	Weekday	Sat	Sun	Weekday	Sat	Sun	Weekday	Sat	Sun
NOx															
Alabama	35.06	34.06	33.56	457.57	343.18	343.18	517.92	513.83	497.69	32.96	29.30	29.30	1043.51	920.37	903.73
Arkansas	116.02	106.95	102.41	282.47	211.85	211.85	209.16	204.02	192.57	31.84	31.68	31.68	639.49	554.50	538.51
Florida	6.97	60.42	126.94	116.13	87.10	87.10	35.33	39.36	34.64	5.55	5.47	5.47	163.98	192.34	254.15
Georgia	72.21	67.95	65.82	636.94	477.70	477.70	192.44	173.27	149.81	20.04	18.15	18.15	921.62	737.07	711.48
Illinois	12.87	208.38	11.89	220.50	165.37	165.37	257.17	252.56	245.26	61.60	59.81	59.81	552.14	686.12	482.33
Indiana	32.51	30.22	29.07	239.61	179.71	179.71	153.07	144.29	133.28	88.64	95.21	95.21	513.83	449.43	437.27
Kansas	33.19	30.77	29.56	252.09	189.07	189.07	314.04	302.05	287.67	173.59	75.14	75.14	772.91	597.03	581.44
Kentucky	246.12	226.71	217.01	447.92	335.94	335.94	273.26	267.35	253.91	522.87	509.03	509.03	1490.18	1339.03	1315.88
Louisiana	327.48	301.31	288.22	386.16	289.62	289.62	684.76	682.90	665.08	77.45	78.15	76.99	1475.86	1351.98	1319.91
Mississippi	6.35	6.18	6.10	354.25	265.69	265.69	220.21	216.80	206.08	273.34	272.82	272.82	854.15	761.49	750.69
Missouri	177.23	372.18	159.20	591.97	443.97	443.97	447.49	444.10	421.70	46.12	49.02	49.02	1262.81	1309.27	1073.90
Nebraska	3.94	3.64	3.49	18.12	13.59	13.59	60.08	59.58	58.94	12.83	12.82	12.82	94.97	89.63	88.83
North Carolina	0.64	0.64	0.64	21.05	15.79	15.79	2.85	2.33	1.80	10.28	10.27	10.27	34.83	29.03	28.49
Ohio	23.83	22.13	21.28	131.20	98.40	98.40	98.95	91.67	83.54	60.70	58.27	58.27	314.69	270.47	261.50
Oklahoma	71.14	65.63	62.87	390.63	400.03	397.38	327.93	324.61	314.34	52.26	51.58	51.58	841.95	841.85	826.17
South Carolina	0.28	0.27	0.27	3.07	2.31	2.31	0.39	0.36	0.30	0.00	0.00	0.00	3.74	2.93	2.87
Tennessee	62.79	59.11	57.27	555.55	416.66	416.66	274.51	264.03	242.29	9.57	8.38	8.38	902.41	748.17	724.59
Virginia	1.02	0.96	0.93	9.18	6.89	6.89	4.50	4.04	3.59	0.64	0.00	0.00	15.34	11.89	11.41
West Virginia	3.10	2.92	2.83	15.42	11.57	11.57	37.50	36.72	35.49	2.16	2.25	2.25	58.18	53.46	52.13
Grand Total	**1232.76**	**1600.42**	**1219.36**	**5129.84**	**3954.43**	**3951.78**	**4111.55**	**4023.87**	**3827.97**	**1482.43**	**1367.34**	**1366.18**	**11956.58**	**10946.06**	**10365.29**
VOC															
Alabama	490.84	490.82	490.81	344.99	258.74	258.74	139.80	344.79	342.15	136.59	102.87	102.87	1112.22	1197.21	1194.56
Arkansas	381.25	381.14	381.09	184.98	138.73	138.73	81.51	200.52	198.73	43.19	32.10	32.10	690.93	752.49	750.65
Florida	126.95	6.57	60.32	85.08	63.81	63.81	52.12	188.80	188.03	38.99	33.03	33.03	303.14	292.20	345.18
Georgia	421.23	421.13	421.09	417.33	312.99	312.99	135.60	212.34	208.18	39.35	28.67	28.67	1013.50	975.14	970.94
Illinois	208.39	37.51	208.37	135.75	101.81	101.81	62.65	114.50	113.39	64.44	55.64	55.64	471.22	309.46	479.21
Indiana	278.62	278.59	278.57	160.36	120.27	120.27	53.92	94.54	92.70	118.33	65.60	65.60	611.23	559.00	557.15
Kansas	317.57	317.31	317.18	172.50	129.37	129.37	83.65	127.85	125.53	475.59	204.96	204.96	1049.30	779.49	777.05
Kentucky	409.57	409.29	409.15	293.12	219.84	219.84	92.96	224.81	222.76	352.50	282.63	282.63	1148.15	1136.57	1134.38
Louisiana	419.79	419.43	419.26	245.93	184.45	184.45	149.90	420.97	418.12	182.27	193.86	193.86	997.89	1218.71	1215.69
Mississippi	427.40	427.39	427.39	207.09	155.32	155.32	79.77	219.48	218.03	189.78	186.94	186.94	904.03	989.13	987.67

State	Area			On-Road			Off-Road			Points			Anthropogenic		
	Weekday	Sat	Sun	Weekday	Sat	Sun	Weekday	Sat	Sun	Weekday	Sat	Sun	Weekday	Sat	Sun
Missouri	921.66	165.21	921.29	387.27	290.45	290.45	205.21	490.87	486.96	100.53	73.20	73.20	1614.67	1019.73	1771.90
Nebraska	44.27	44.26	44.26	11.17	8.38	8.38	8.78	13.02	12.98	5.49	5.49	5.49	69.72	71.16	71.11
North Carolina	16.93	16.93	16.93	11.68	8.76	8.76	4.96	10.24	10.18	9.14	6.73	6.73	42.70	42.66	42.60
Ohio	151.86	151.84	151.82	96.56	72.42	72.42	49.85	58.36	56.77	24.75	19.05	19.05	323.02	301.66	300.06
Oklahoma	310.53	310.45	310.41	424.60	402.12	414.26	96.96	219.02	217.43	71.40	65.98	65.98	903.49	997.56	1008.07
South Carolina	1.98	1.98	1.98	1.84	1.38	1.38	0.53	1.31	1.30	0.00	0.00	0.00	4.35	4.66	4.66
Tennessee	708.69	708.55	708.48	368.82	276.61	276.61	133.77	316.09	312.30	164.88	55.19	55.19	1376.15	1356.44	1352.58
Virginia	7.77	7.77	7.77	5.52	4.14	4.14	0.82	1.03	0.95	4.25	1.59	1.59	18.36	14.53	14.45
West Virginia	23.30	23.29	23.28	10.77	8.08	8.08	5.63	12.48	12.27	14.42	13.62	13.62	54.12	57.47	57.25
Grand Total	**5668.58**	**4619.45**	**5599.44**	**3565.37**	**2757.67**	**2769.81**	**1438.39**	**3271.01**	**3238.77**	**2035.88**	**1427.14**	**1427.14**	**12708.22**	**12075.27**	**13035.17**
CO															
Alabama	245.23	244.93	244.78	3592.13	2694.13	2694.13	1195.26	1963.75	1928.51	148.72	147.06	147.06	5181.33	5049.87	5014.49
Arkansas	121.23	119.87	119.18	2026.94	1520.21	1520.21	702.22	1154.07	1128.38	144.49	144.45	144.45	2994.88	2938.59	2912.21
Florida	60.42	126.94	0.00	858.90	644.16	644.16	358.14	743.90	735.71	139.16	138.97	138.97	1416.62	1653.98	1518.85
Georgia	501.86	500.54	499.88	4641.13	3480.84	3480.84	1850.89	2574.27	2523.58	4.59	4.38	4.38	6998.46	6560.03	6508.68
Illinois	37.63	11.89	37.45	1475.44	1106.60	1106.60	680.38	928.75	912.32	31.48	30.55	30.55	2224.93	2077.80	2086.92
Indiana	92.77	92.02	91.64	1667.16	1250.36	1250.36	685.19	903.16	879.02	159.01	129.97	129.97	2604.13	2375.51	2351.00
Kansas	86.62	83.94	82.61	1870.29	1402.73	1402.73	1016.82	1345.99	1316.77	91.49	53.83	53.83	3065.22	2886.50	2855.93
Kentucky	200.33	197.00	195.33	3074.57	2305.92	2305.92	896.63	1442.42	1412.86	462.49	446.81	446.81	4634.03	4392.15	4360.92
Louisiana	182.28	178.46	176.56	2741.57	2056.18	2056.18	1180.51	2097.15	2064.07	352.64	352.46	352.46	4456.99	4684.25	4649.26
Mississippi	124.89	124.86	124.84	2091.65	1568.74	1568.74	647.41	1125.98	1103.11	174.21	173.39	173.39	3038.16	2992.97	2970.09
Missouri	372.18	921.42	367.60	4002.19	3001.64	3001.64	2087.06	3230.89	3179.69	72.85	70.48	70.48	6534.28	7224.42	6619.42
Nebraska	3.39	3.34	3.31	121.69	91.27	91.27	94.16	125.56	124.03	3.27	3.27	3.27	222.51	223.43	221.88
North Carolina	17.30	17.30	17.30	133.86	100.40	100.40	43.82	62.00	60.90	10.34	10.34	10.34	205.32	190.04	188.94
Ohio	63.20	62.93	62.79	980.38	735.28	735.28	754.60	901.28	883.39	107.72	98.54	98.54	1905.90	1798.03	1780.00
Oklahoma	84.02	83.20	82.79	2910.79	2810.04	2847.75	964.35	1487.97	1466.44	40.51	39.78	39.78	3999.66	4420.99	4436.76
South Carolina	3.15	3.15	3.15	20.48	15.36	15.36	4.35	6.67	6.58	0.00	0.00	0.00	27.98	25.18	25.09
Tennessee	267.00	265.46	264.68	3903.54	2927.65	2927.65	1374.46	2160.54	2111.82	6.75	6.44	6.44	5551.75	5360.09	5310.59
Virginia	4.72	4.65	4.62	60.57	45.43	45.43	10.88	14.44	13.89	0.14	0.00	0.00	76.32	64.52	63.94
West Virginia	12.13	11.89	11.77	114.15	85.61	85.61	48.61	76.51	74.35	33.52	32.98	32.98	208.41	206.99	204.71
Grand Total	**2480.36**	**3053.78**	**2390.29**	**36287.44**	**27842.56**	**27880.27**	**14595.74**	**22345.30**	**21925.43**	**1983.36**	**1883.69**	**1883.69**	**55346.89**	**55125.35**	**54079.68**

Table 3-13. Gridded biogenic emissions for states other than Texas.

	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug
NOx										
Alabama	85	74	65	74	79	82	80	73	69	73
Arkansas	137	101	95	110	125	133	134	106	104	115
Florida	11	10	9	10	10	10	10	10	10	10
Georgia	52	54	47	51	54	56	54	46	47	48
Illinois	336	275	279	344	378	330	311	292	295	329
Indiana	161	115	123	142	163	146	140	126	131	142
Kansas	433	477	641	713	671	581	494	468	549	548
Kentucky	173	111	115	139	164	155	151	122	124	133
Louisiana	118	110	91	98	106	115	121	110	103	105
Mississippi	141	111	98	111	124	128	137	119	112	119
Missouri	242	216	240	294	290	282	245	232	246	263
Nebraska	146	171	229	232	214	191	167	173	195	189
North Carolina	2	2	2	2	2	2	2	1	1	1
Ohio	25	17	18	21	26	22	19	18	19	20
Oklahoma	197	190	230	246	238	229	204	187	208	237
South Carolina	0	0	0	0	0	0	0	0	0	0
Tennessee	135	89	88	107	120	123	122	93	95	102
Virginia	1	1	0	1	1	1	1	0	0	0
West Virginia	0	0	0	0	1	0	0	0	0	0
Total	2396	2124	2373	2693	2767	2585	2392	2178	2308	2435
VOC										
Alabama	15629	12994	9764	12476	14017	14973	14720	12458	10971	11808
Arkansas	12062	8025	7596	9437	11983	12996	12615	8389	8181	10093
Florida	2685	2332	1958	2286	2523	2267	2327	2116	2232	2227
Georgia	6775	7393	5654	6513	7363	8137	7583	5301	5280	5530
Illinois	1551	931	1101	1715	1933	1201	1167	1146	1290	1578
Indiana	1499	548	857	1190	1573	1120	933	819	980	1143
Kansas	814	979	1687	2103	1886	1650	1143	944	1326	1088
Kentucky	5696	1729	2672	4286	5791	4751	4081	2324	3214	3686
Louisiana	9805	9146	6853	7888	8938	9978	10747	8994	8080	8639
Mississippi	14659	11134	8864	11526	13261	13903	14794	12234	11243	12388
Missouri	6962	5435	6819	10159	10468	9264	7077	6149	7273	8395
Nebraska	124	200	339	353	298	241	192	199	255	190

	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug
North Carolina	806	774	576	732	881	921	809	519	504	544
Ohio	640	167	329	531	793	526	334	318	412	452
Oklahoma	6990	5479	6171	6457	7271	7616	6820	5198	5184	6564
South Carolina	142	157	106	131	152	169	154	93	92	101
Tennessee	9104	4025	4682	7004	8586	8444	8236	4275	5189	6099
Virginia	180	108	87	157	192	164	152	82	91	106
West Virginia	155	52	80	144	211	149	118	67	102	109
Total	96278	71608	66196	85087	98120	98470	94004	71626	71898	80740
CO										
Alabama	1593	1342	1044	1270	1427	1520	1498	1319	1165	1268
Arkansas	1238	861	774	904	1125	1250	1255	885	843	990
Florida	372	340	290	335	355	332	327	310	316	323
Georgia	705	731	594	674	743	811	768	569	555	592
Illinois	167	112	115	160	186	157	142	125	127	152
Indiana	176	98	114	145	182	151	138	116	126	144
Kansas	132	145	228	287	260	226	163	147	187	184
Kentucky	652	327	358	499	647	558	498	361	392	431
Louisiana	1153	1063	801	882	1009	1139	1249	1057	954	990
Mississippi	1474	1139	916	1098	1272	1338	1438	1247	1137	1203
Missouri	602	487	550	755	800	781	602	532	582	659
Nebraska	21	26	41	44	39	32	26	27	33	30
North Carolina	74	68	58	69	78	79	76	53	50	53
Ohio	92	50	57	73	105	77	61	57	61	65
Oklahoma	658	529	585	606	650	685	609	486	518	650
South Carolina	14	15	12	14	15	16	16	10	10	11
Tennessee	881	491	492	663	783	785	780	517	517	572
Virginia	20	14	12	17	20	18	17	12	12	13
West Virginia	18	11	12	17	23	18	14	12	13	13
Total	10041	7848	7050	8511	9718	9973	9679	7843	7598	8342

4. METEOROLOGY

CAMx requires meteorological input data for the parameters described in Table 4-1.

Table 4-1. CAMx meteorological input data requirements.

CAMx Input Parameter	Description
Layer interface height (m)	3-D gridded time-varying layer heights for the start and end of each hour
Winds (m/s)	3-D gridded wind vectors (u,v) for the start and end of each hour
Temperature (K)	3-D gridded temperature and 2-D gridded surface temperature for the start and end of each hour
Pressure (mb)	3-D gridded pressure for the start and end of each hour
Vertical Diffusivity (m^2/s)	3-D gridded vertical exchange coefficients for each hour
Water Vapor (ppm)	3-D gridded water vapor mixing ratio for each hour
Cloud Cover	3-D gridded cloud cover for each hour
Rainfall Rate (in/hr)	2-D gridded rainfall rate for each hour

MM5 MODELING

All of the CAMx meteorological input data were derived from the Fifth Generation Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5; Duhdia, 1993). The MM5 modeling used nested 108-km, 36-km, 12-km and 4-km grids and the grid configuration for the final MM5 run (Run3) is shown in Figure 4-1. The MM5 modeling used 28 layers as described below.

ENVIRON has conducted a series of meteorological modeling runs of an August 1999 episode for northeast Texas (Emery et al., 2002, 2003) using the 5th Generation PSU/NCAR Mesoscale Model (MM5). From this MM5 meteorological modeling we have learned that:

1. The use of three-hourly EDAS (NCEP Eta Data Assimilation System) Analysis data instead of the Initialization data for developing initial/boundary conditions and inputs for the MM5 Four-Dimensional Data Assimilation (FDDA) package has proven to be more beneficial to the MM5 modeling. Although the EDAS Initialization data may be more dynamically balanced via pre-forecast spinup cycles of the Eta model, they can deviate from observed conditions due to the numerical errors of Eta model simulation. The EDAS Analysis data are generated strictly by diagnostic objective analysis procedures so they more faithfully reflect the meteorological observations. Currently, the EDAS Analysis data are widely used by the MM5 community and are recommended for use by the NCAR Data Support Section.

2. An expanded regional-scale 36-km grid can better simulate the dominant synoptic scale flow and pressure patterns and eliminate boundary effects in the finer resolution domains (12/4-km grids). This results in improved meteorological fields for the 12-km and 4-km grids.

3. Incorporation of routine surface and upper air station observation data obtained from NCAR archives can improve the EDAS analysis fields by better characterizing the mesoscale and local meteorological features.

4. A more sophisticated Pleim-Xiu Land Surface Model, which replaces the simple Five-layer Soil model, results in MM5 meteorological model estimates that better match the observed values.

The knowledge we have gained from these previous studies were applied to the Dallas/Fort Worth (DFW) August 1999 episode and resulted in the model configurations described below. The meteorological modeling report for this study (ENVIRON, 2003c) presents the performance evaluation methodology and results for several different runs, both graphically and statistically, and recommends a final set of meteorological fields for use in CAMx. These results are summarized briefly below.

MODEL PHYSICS CONFIGURATION

Since the revised MM5 meteorological modeling for the northeast Texas (Emery et al., 2003) has proved to be successful for the air quality simulations (for example, the use of RRTM radiation scheme dramatically improved the nighttime and morning minimum temperature), we adopted most of the configurations from that study. The MM5 model physics configuration for the Texas DFW August 1999 episode application is summarized as follows:

- Simple-ice microphysics is employed for all domains
- Kain-Fritsch cumulus parameterization scheme is invoked for 108/36/12-km grids. No cumulus parameterization scheme is invoked for the 4-km domain as convection is explicitly fully resolved at this resolution scale.
- The RRTM radiation scheme is used for all the grids.
- Two-way interactive 108/36/12/4-km grids are used.

It was realized in the MM5 meteorological modeling study of the August 1999 episode for northeast Texas (Emery et al., 2002, 2003) that the relatively simple MM5 "Five-Layer Soil Model" used previously does not adequately handle complex land-surface interaction processes, and that a more sophisticated Land-Surface Model (LSM) may be important for mesoscale meteorology modeling. Land-surface processes control the surface sensible and latent heat fluxes, which in turn strongly influence ground level air temperature, humidity and planetary boundary layer (PBL) development. As these parameters are especially critical for successful air pollution modeling, a more sophisticated LSM is used in this application. Currently, two new LSM models are available in MM5, the Oregon State University LSM and Pleim-Xiu LSM models, are available in the MM5 version 3.5. In the revised MM5 meteorological modeling for the northeast Texas (Emery et al., 2003), the use of Pleim-Xiu LSM coupled with its own PBL scheme is proved to have the impact of dramatically different PBL depths, thus result in noticeable improvements in the air quality simulations. Therefore,

- The Pleim-Xiu LSM, coupled with its own (mandatory) Planetary Boundary Layer (PBL) scheme, was employed in this work. In the sensitivity Run1 and Run1a, the soil moisture nudging techniques in this scheme were also tested and the soil moisture was initialized by the EDAS data through REGRID program.

As mentioned previously, FDDA has proven to be a powerful tool to limit the growth of numerical errors in MM5 and its benefits are widely recognized in the air pollution modeling community. In order to compare the effects of different FDDA configurations and find the best performance simulation, 4 MM5 runs were designed to have the same physics but different FDDA configurations. The major differences between each run are summarized in Table 4-2.

Table 4-2. The major configuration differences between each run.

		Analysis Nudging (3D & SFC) Coefficient (*E-04)				Obs Nudging Coefficient (*E-04)		Modified Obs Nudging File	Soil Moisture Nudging
Run		**108**	**36**	**12**	**4**	**12**	**4**		
1	Wind	4.0	2.5	1.0	1.0	10.0	10.0	No	Yes
	Temp	4.0	2.5	1.0	1.0	4.0	4.0		
	Humi	0.1	0.1	0.1	0.1	4.0	4.0		
1a	Wind	4.0	2.5	1.0	---	4.0	4.0	Yes	Yes
	Temp	4.0	2.5	1.0	---	---	4.0		
	Humi	0.2	0.2	0.2	---	---	4.0		
2	Wind	4.0	2.5	1.0	---	5.0	5.0	No	No
	Temp	4.0	2.5	1.0	---	5.0	5.0		
	Humi	0.1	0.1	0.1	---	5.0	5.0		
3	Wind	4.0	2.5	1.0	---	10.0	10.0	No	No
	Temp	4.0	2.5	1.0	---	---	---		
	Humi	0.1	0.1	0.1	---	---	---		

Starting with Run1, the strongest FDDA configuration is designed. The surface and 3D analysis nudging of wind, temperature and humidity are employed on all four domains. The observation nudging of wind, temperature and humidity are turned on for the 12-km and 4-km grids with very strong nudging coefficient for wind. Soil moisture nudging is also used. Compared to Run1, a relative weaker FDDA design is applied in Run1a, with no surface and 3D analysis nudging on the 4-km domain, no observation nudging of temperature and humidity on 12-km grid, and weaker wind nudging on 12-km and 4-km domains. Also, part of the data (surface observations from AIRS stations) in the observation nudging file are withheld since a dense cluster of the observations in a small area (here DFW) might have disadvantageous effects on the FDDA nudging. The method of withholding (or "sequestering") portions of an observation data set for model verification is a common practice in model simulations with FDDA. In Run2, no surface or 3D analysis nudging is used on the 4-km grid, nor is there any soil moisture nudging.

After reviewing the MM5 results of the first three runs, we found that the wind fields were relatively noisy. The observational nudging of moisture and temperature on the 4-km grid might have caused a surface heat budget imbalance, thus resulting in the abnormal fluctuations in wind performance. Therefore, observational nudging of moisture and temperature were removed in the Run3 configuration. Following are the configurations of FDDA technique used in Run3:

- FDDA analysis nudging on the 108/36/12-km grids:
    - 3D analysis nudging above the boundary layer -- MM5 is nudged toward 3-hourly EDAS analysis of wind, temperature, and humidity, which are improved by the surface and upper-air station observation data.

- o Surface analysis nudging within the boundary layer -- MM5 is nudged toward 3-hourly gridded surface analysis data generated by RAWINS program
- FDDA observation nudging of wind on the 12-km and 4-km grids from routine and special measurement data set available from NCAR that includes data from NOAA profiler, NWS Surface and Upper Air stations over most of the 12-km domain.

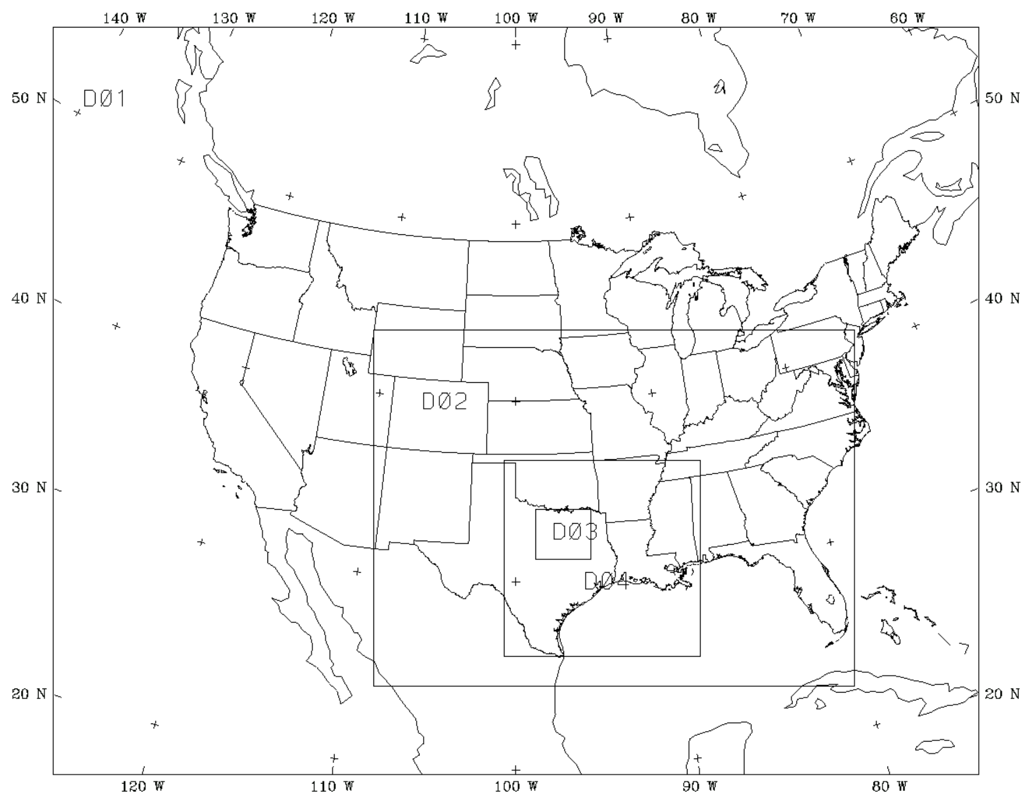


Figure 4-1. The MM5 grid system (108/36/12/4-km) for the DFW 1999 episode.

MM5 MODEL RUNS

The results of the MM5 runs performed for this study (Table 4-2) were analyzed and evaluated in full in ENVIRON, 2003. The results of these analyses are summarized below.

Four MM5 runs were configured with the same physics but different FDDA techniques. The quality of meteorological simulations plays a crucial role in determining the accuracy of air quality modeling. Thus, the statistical and qualitative evaluations were conducted to carefully assess the performance of MM5 model results. The results from four configured MM5 runs focusing on the DFW 4-km domain during August 13-22, 1999 are presented below and in ENVIRON, 2003. The MM5 model results of wind, temperature and humidity from all runs in this study showed rather good performance in replicating the large- and meso-scale meteorology in the DFW area. The overall pressure and flow patterns covering south central

U.S. and the placement of clouds and precipitations were replicated well. Some noted features about the results of the four runs are summarized as follows:

- The performance for wind speed and direction is rather good in all four runs with the best performance in Run3. The hourly and daily statistical results for wind show that smaller prediction-observation bias, no "spike" abnormity during August 15-16, and overall better performance parameters (such as RMSE and IOA) in Run3. The simulated vertical wind profiles from Run3 are also better matched with the 12-hourly sounding at Dallas/Fort Worth.

- A slight under-prediction of humidity on the 4-km grid during almost the whole episode remains throughout all runs. But the humidity bias in Run1a is much smaller comparing to those of other runs. In fact, Run1a is the only one that meets benchmark standard in all three categories (RMSE, Bias, and IOA) for the daily statistics at 4-km grid.

- The temperature performances on the 4-km and 12-km grid for all runs fairly well replicate the observed diurnal variation. The amplitude of diurnal change of Run3 and Run1 on the 4-km domain are well reproduced, while the daytime maximum temperatures in Run2 are slightly over predicted. The strength of the diurnal variation in Run1a is relatively weaker, that is, the daytime maximum temperatures are relative lower than the observed and the nighttime minimum temperatures are slightly over estimated.

Table 4-3 summarizes the episode-mean daily statistics determined for MM5 Run3, Run1, Run1a, and Run2 in the entire 12-km grid over August 13-22, 1999. Similar statistics are shown in Table 4-4 for the 4-km DFW area.

Table 4-3. Episode-mean daily statistics on the 12-km grid for each run against benchmarks.

		Run3	Run1	Run1a	Run2
Parameter	**Benchmark**	**Mean**	**Mean**	**Mean**	**Mean**
Wind Spd Bias	< ±0.5	0.36	0.34	0.32	0.53
Wind Spd RMSE	< 2.0	1.28	1.42	1.40	1.55
Wind Spd IOA	≥ 0.60	0.80	0.75	0.74	0.72
Wind Dir Bias	< ±10	-2.43	-2.26	-3.12	-1.58
Wind Dir Gross Error	< 30	29.87	33.64	35.47	37.23
Temp Bias	< ±0.5	-0.36	-0.81	-0.80	-0.35
Temp Gross Error	< 2.0	1.64	1.74	1.76	1.72
Temp IOA	≥ 0.80	0.94	0.91	0.90	0.93
Humidity Bias	< ±1.0	-1.83	-0.26	0.66	-2.44
Humidity Gross Error	< 2.0	2.45	1.98	1.81	3.04
Humidity IOA	≥ 0.60	0.83	0.84	0.86	0.74

Table 4-4. Episode-mean daily statistics on the 4-km grid for each run against benchmarks.

		Run3	Run1	Run1a	Run2
Parameter	**Benchmark**	**Mean**	**Mean**	**Mean**	**Mean**
Wind Spd Bias	< ±0.5	0.69	0.50	0.37	0.79
Wind Spd RMSE	< 2.0	1.55	1.49	1.47	1.73
Wind Spd IOA	≥ 0.60	0.59	0.57	0.54	0.52
Wind Dir Bias	< ±10	-0.56	0.35	2.17	2.66
Wind Dir Gross Error	< 30	27.61	28.49	34.60	33.35
Temp Bias	< ±0.5	0.01	-0.20	-0.35	-0.04
Temp Gross Error	< 2.0	1.74	1.67	1.65	1.82
Temp IOA	≥ 0.80	0.90	0.91	0.87	0.90
Humidity Bias	< ±1.0	-2.87	-1.57	-0.52	-3.70
Humidity Gross Error	< 2.0	3.22	2.41	1.52	3.79
Humidity IOA	≥ 0.60	0.52	0.54	0.69	0.46

A graphical presentation of the performance statistics for all four runs on the DFW 4-km domain is shown in Figure 4-2. Figure 4-3 presents the statistical performance measures on the DFW 4-km modeling domain for Run3.

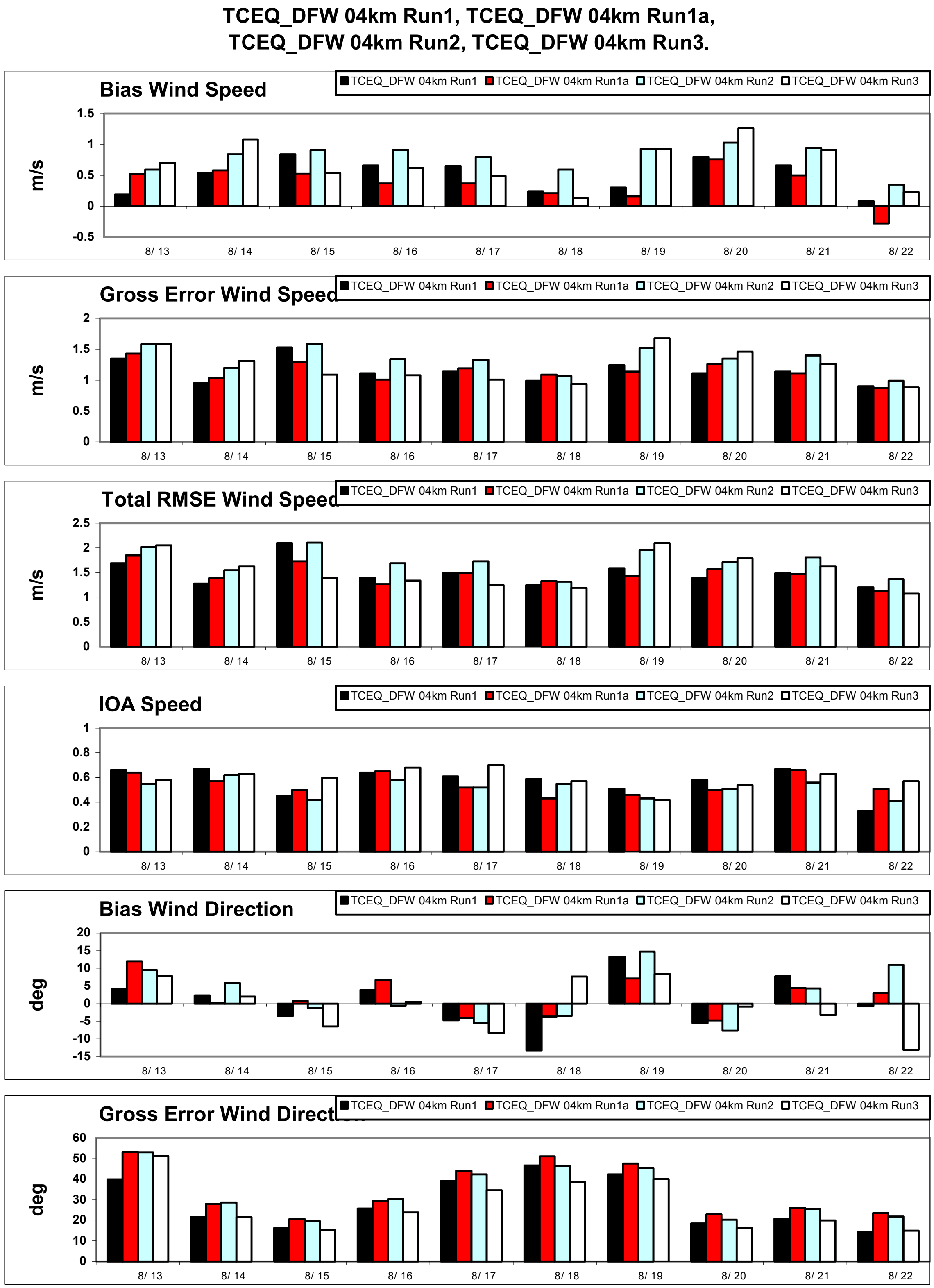


Figure 4-2a. Comparison of Run1, Run1a, Run2, and Run3 daily regional-average performance statistics for wind in the 4-km MM5 domain.

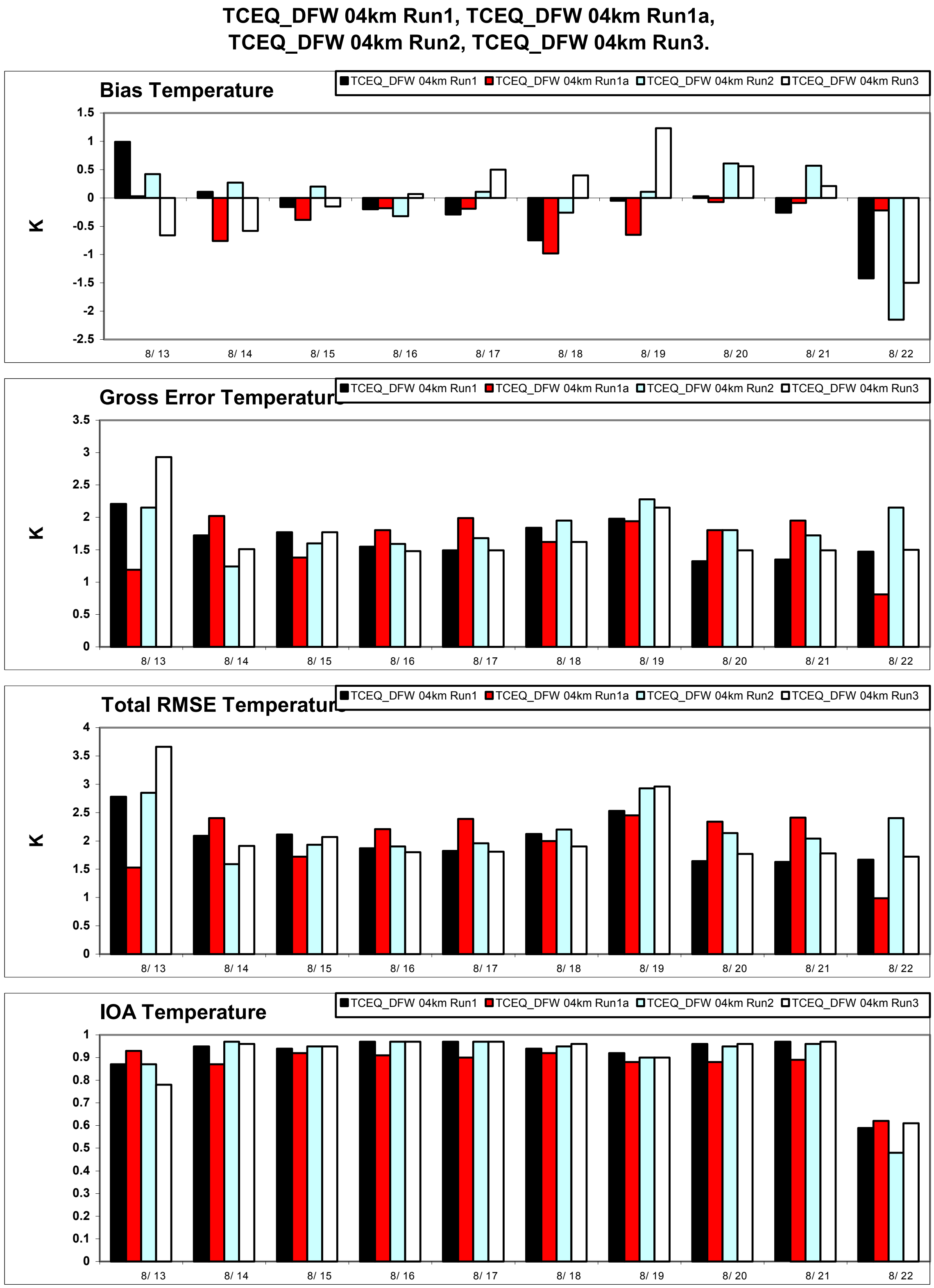


Figure 4-2b. Comparison of Run1, Run1a, Run2, and Run3 daily regional-average performance statistics for temperature in the 4-km MM5 domain.

TCEQ_DFW 04km Run1, TCEQ_DFW 04km Run1a,
TCEQ_DFW 04km Run2, TCEQ_DFW 04km Run3.

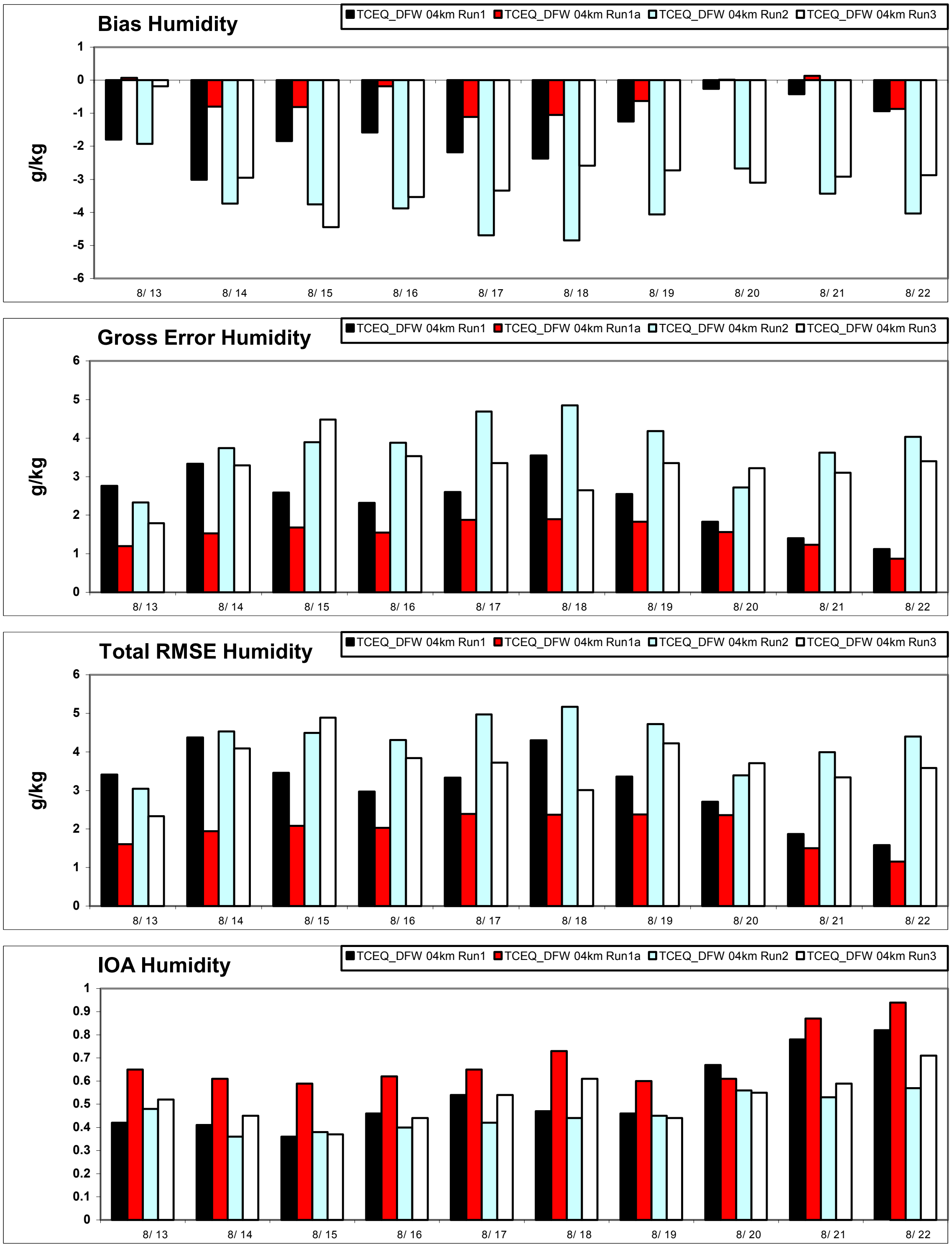


Figure 4-2c. Comparison of Run1, Run1a, Run2, and Run3 daily regional-average performance statistics for humidity in the 4-km MM5 domain.

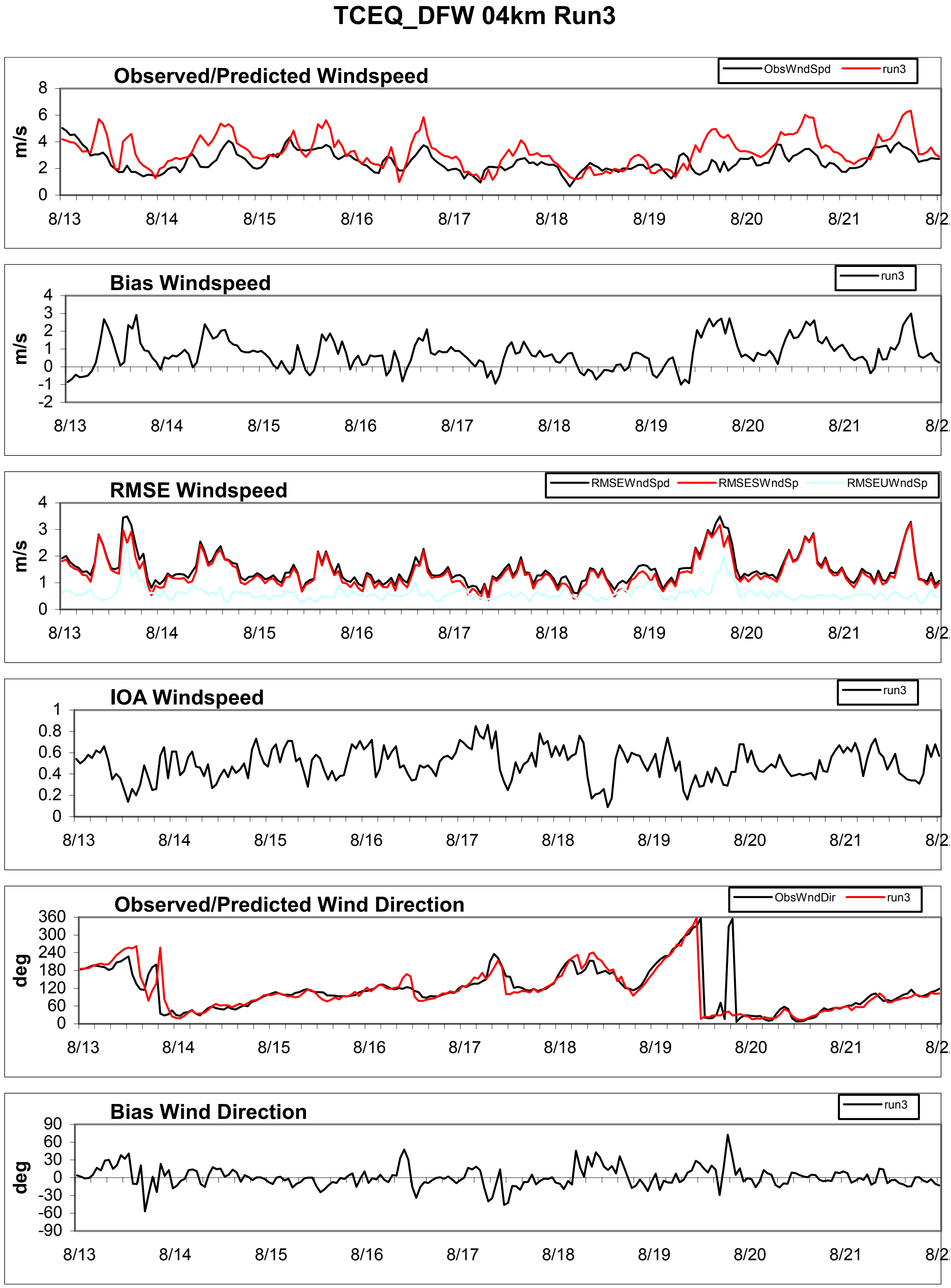


Figure 4-3a. Hourly time series of region-average observed and predicted (Run3) surface-layer winds and performance statistics in the 4-km MM5 domain. RMSE is shown for total, systematic (RMSES) and unsystematic (RMSEU) components.

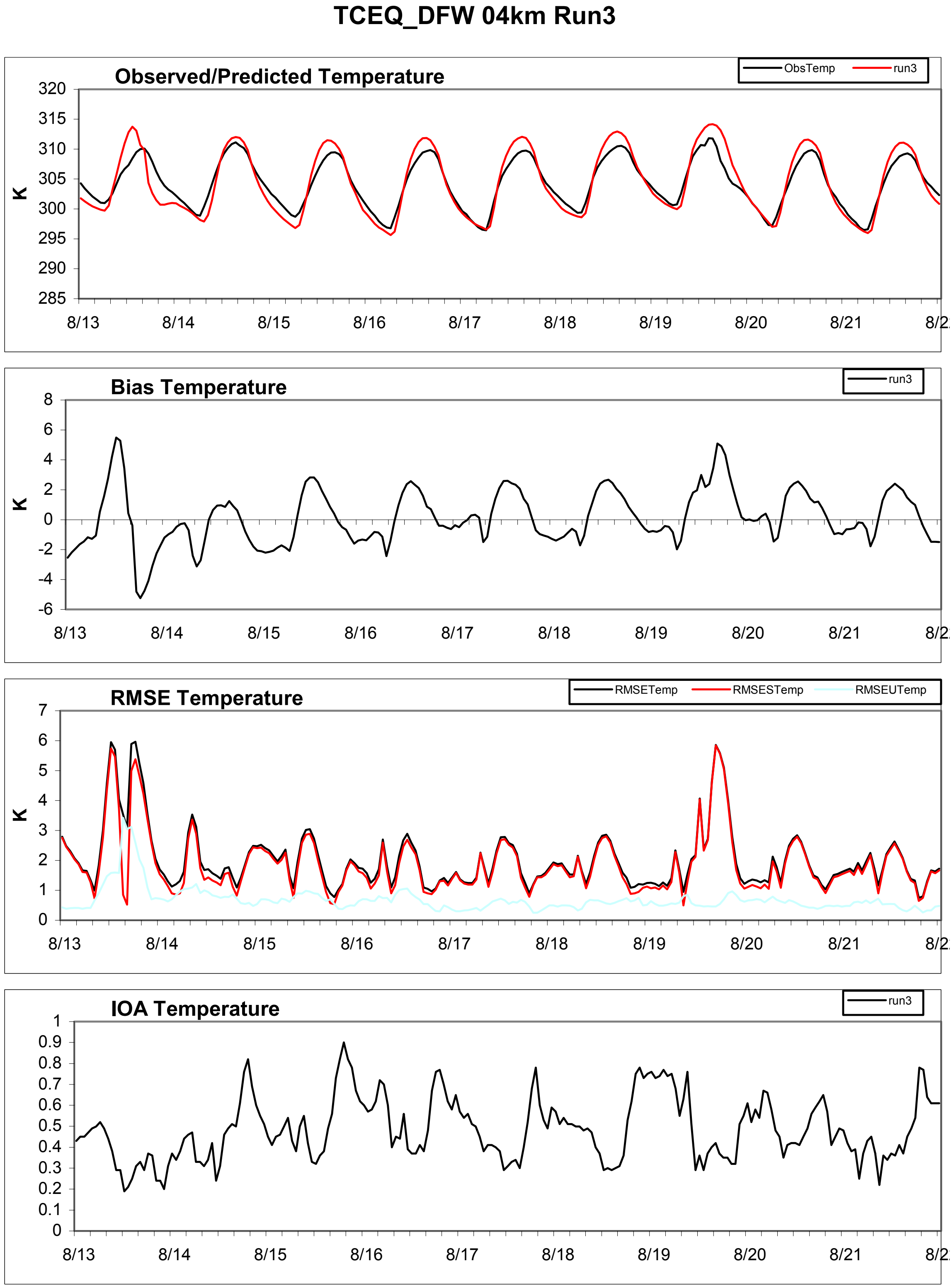


Figure 4-3b. Hourly time series of region-average observed and predicted (Run3) surface-layer temperature and performance statistics in the 4-km MM5 domain. RMSE is shown for total, systematic (RMSES) and unsystematic (RMSEU) components.

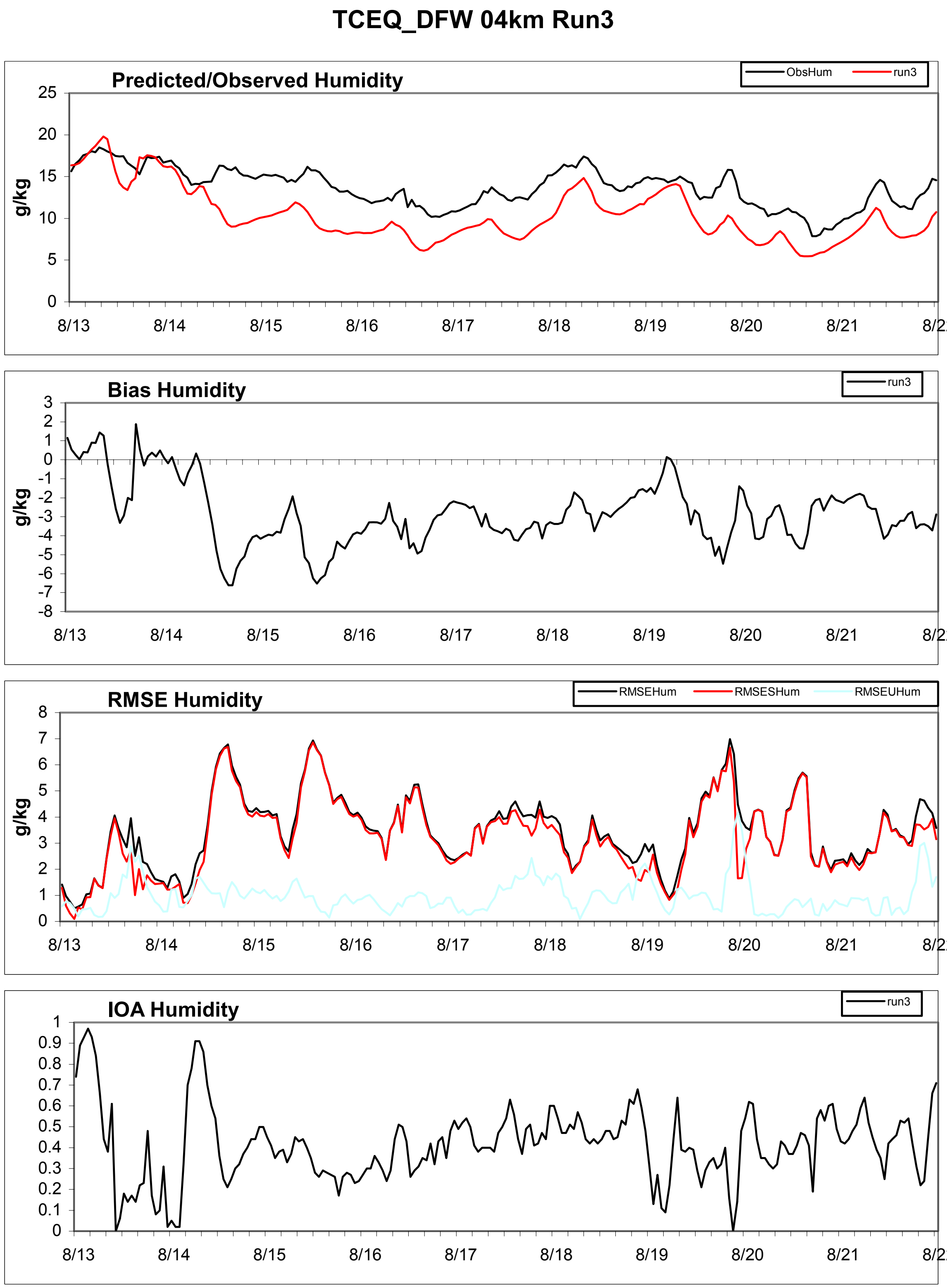


Figure 4-3c. Hourly time series of region-average observed and predicted (Run3) surface-layer humidity and performance statistics in the 4-km MM5 domain. RMSE is shown for total, systematic (RMSES) and unsystematic (RMSEU) components.

Evaluating the results from all four runs, the MM5 Run3 is recommended for the photochemical modeling of the Dallas/Forth Worth Area. In Run3, the wind performance is the best among all four runs. From previous CAMx and other photochemical modeling experience, the performance of wind direction and speed is proved to be essential to the air quality modeling. The overall performance of temperature and humidity in Run3 is comparable or better than the other runs, except that the humidity performance of Run1a is the best among all runs. Therefore, we believe that Run3 is our best choice and Run1a is also usable given its best performance in humidity and acceptable performance in wind and temperature.

PRELIMINARY CAMx MODELING RUNS

While model performance of the meteorological model is an important consideration in determining the applicability of the meteorological fields for use in air quality modeling, it is important to validate the data through application within the air quality model itself. For this reason a number of preliminary CAMx model simulations were undertaken with the meteorological runs that provided the best performance. CAMx meteorological input files were prepared (using the procedures described below) based on Run3 and Run1a. Emissions data were based on the existing East Texas inventories for the 36- and 12-km modeling domains as these were the same for both modeling studies. The flex-nesting capabilities of the CAMx model were used to provide emissions data for the DFW 4-km modeling domain. The results of these simulations were evaluated with respect to models performance in the 4-km DFW domain and are summarized below.

Table 4-5 presents the 1-hour ozone model performance statistics in the 4-km DFW domain for CAMx model runs using the meteorology from MM5 Run3 and Run1a. While in both cases the model exhibits similar statistical performance a negative bias is seen. However, the results from MM5 Run3 (CAMx tst_run1) are seen to give slightly better performance. Time series of hourly 1-hour ozone at the monitor locations within the 4-km grid are presented in Figure 4-4. In both cases, the model appears to predict the daily peaks at about the right time when compared to observed 1-hour ozone concentrations. Spatial distributions of the daily maximum 1-hour ozone concentrations are presented in Figure 4-5 and Figure 4-6 for tst_run1 and tst_run2 (MM5 Run1a), respectively. In general, the model predicts the peaks in approximately the right place in both cases, although the results from tst_run1 appear to better replicate the overall spatial patterns. Based on these preliminary CAMx model simulations, the meteorology provided by MM5 Run3 was determined to be more appropriate for use in the air quality modeling for this study.

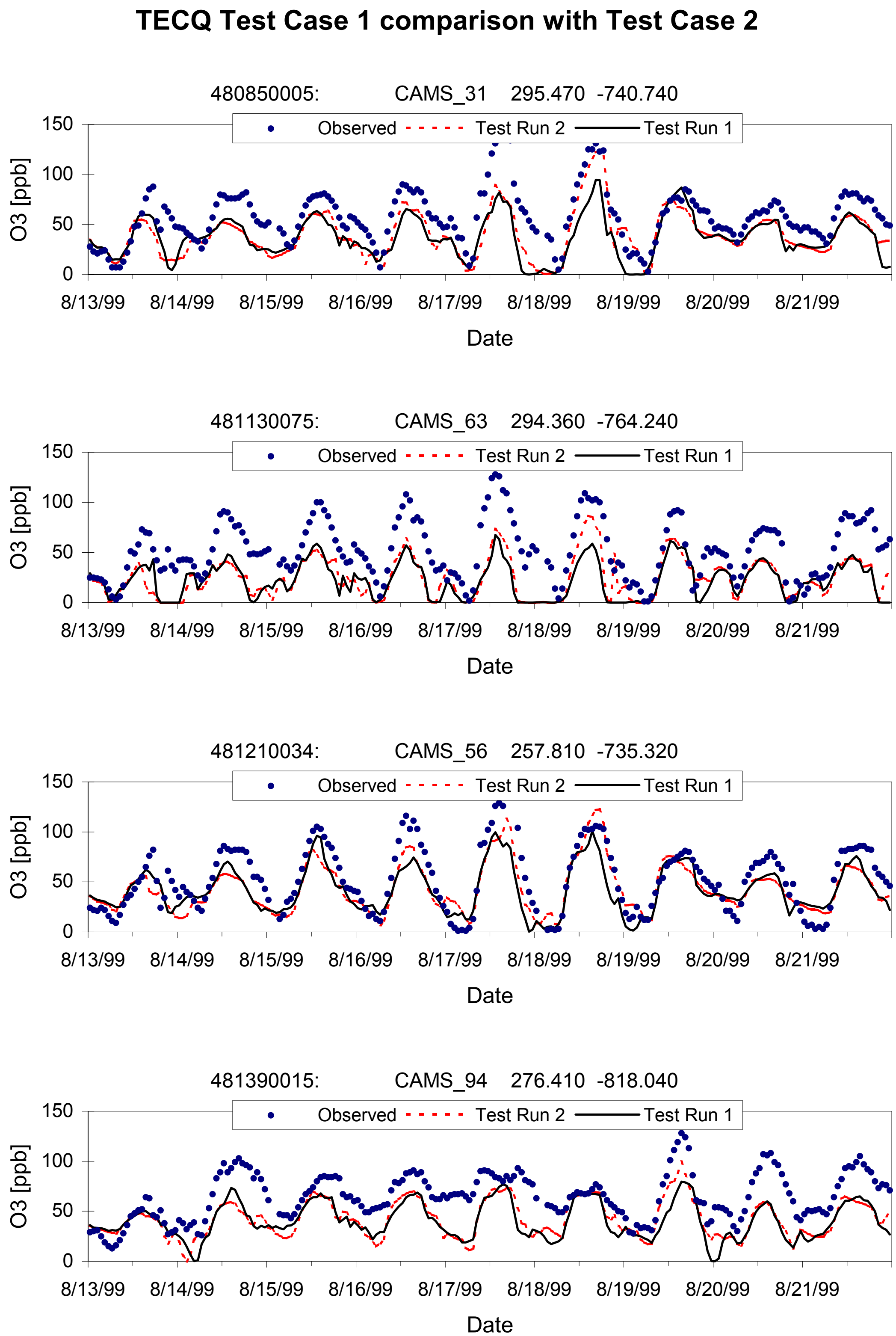


Figure 4-4. Time series of observed and predicted ozone concentrations in the DFW 4-km domain.

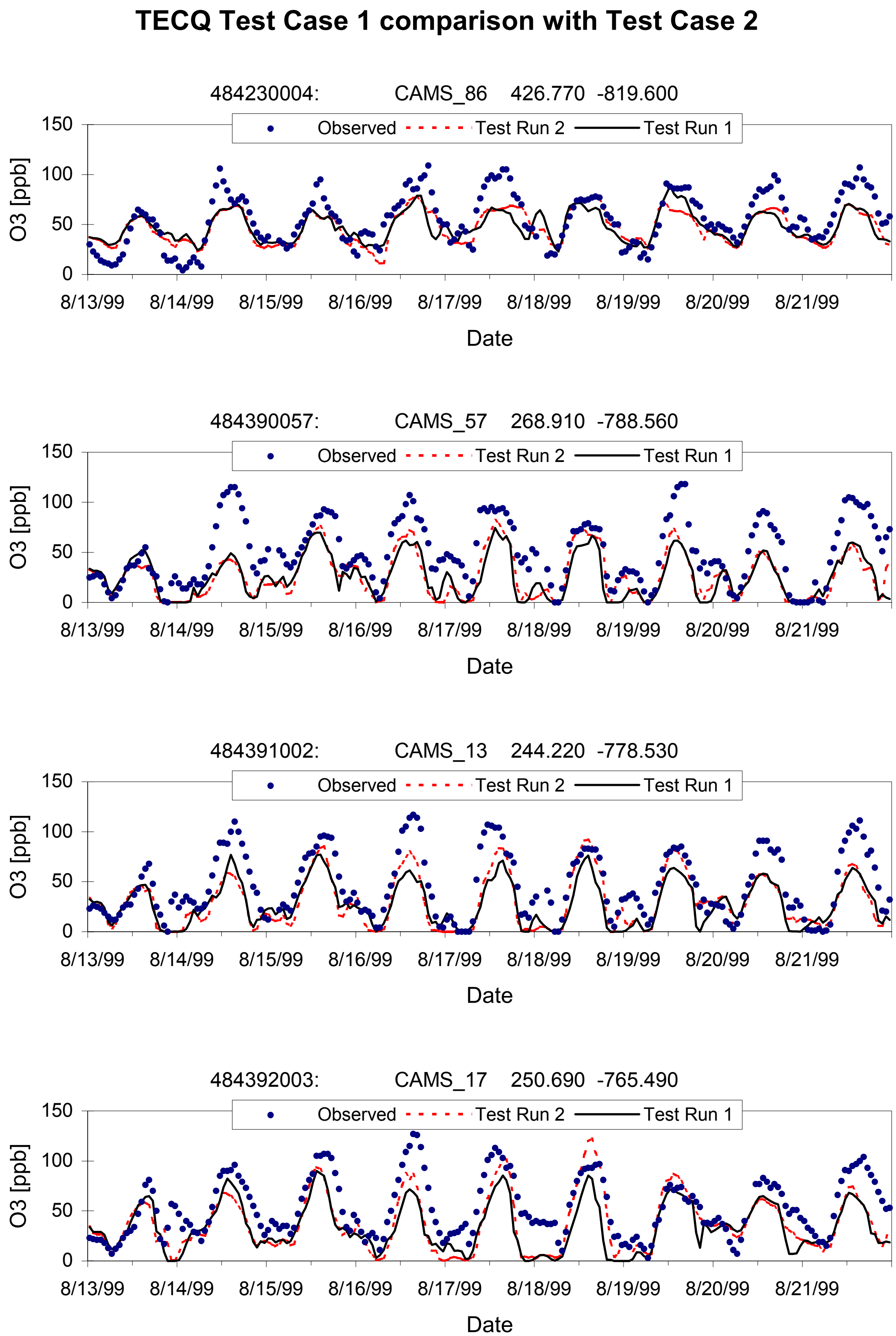


Figure 4-4. Continued. Time series of observed and predicted ozone concentrations in the DFW 4-km domain.

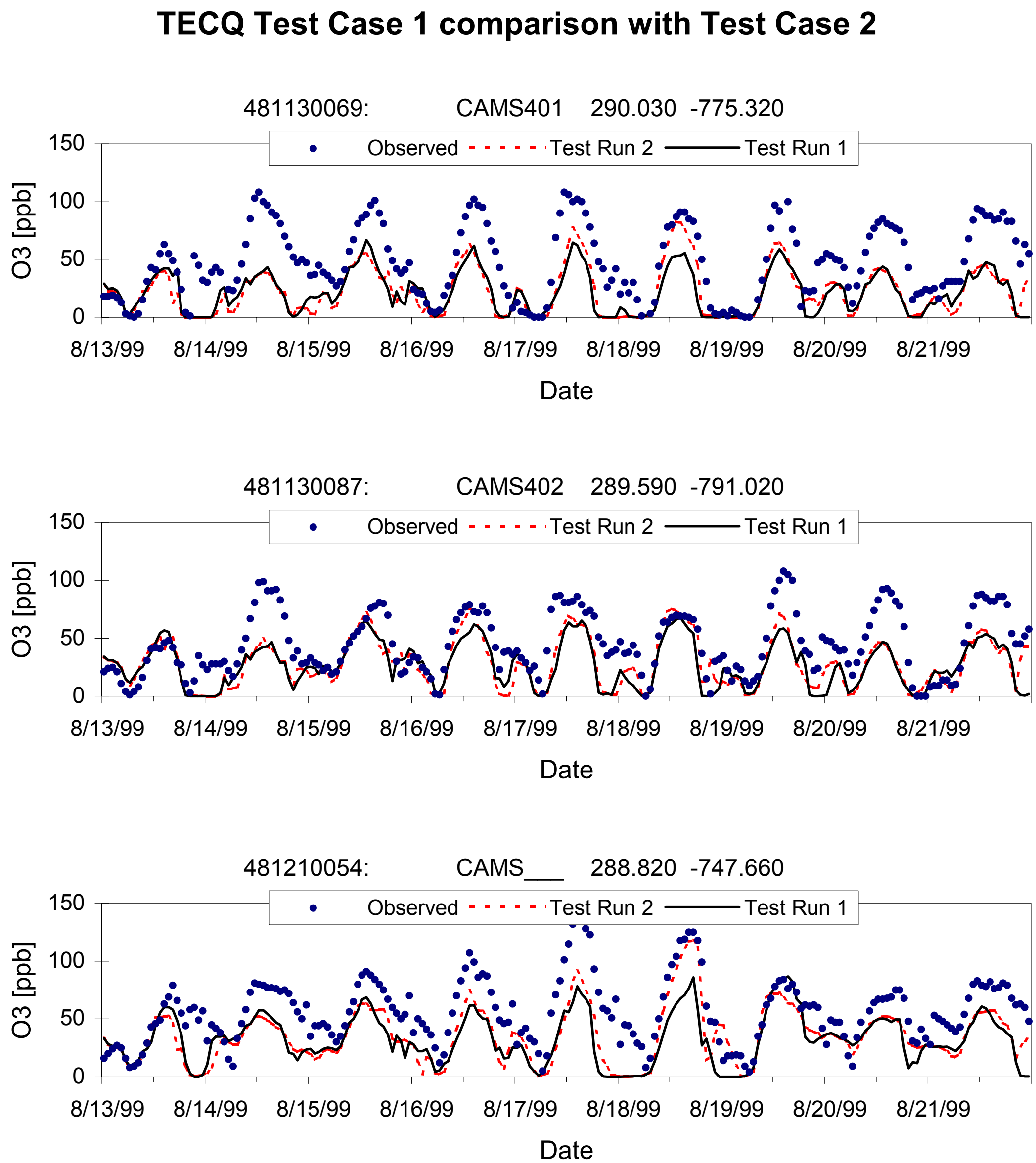
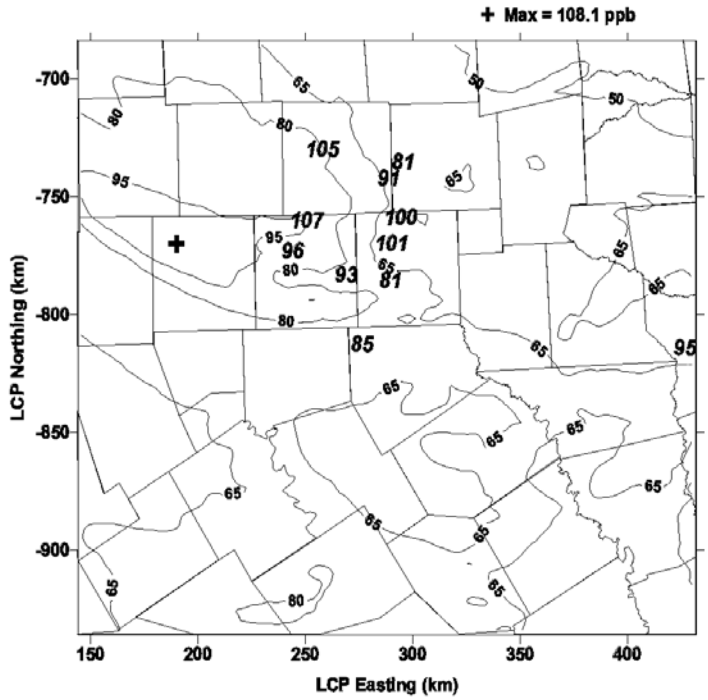
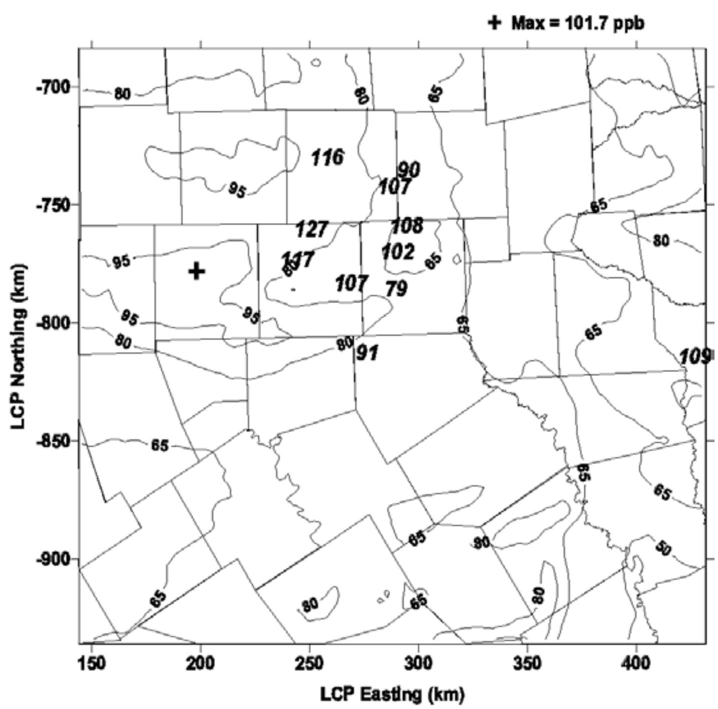


Figure 4-4. Concluded. Time series of observed and predicted ozone concentrations in the DFW 4-km domain.

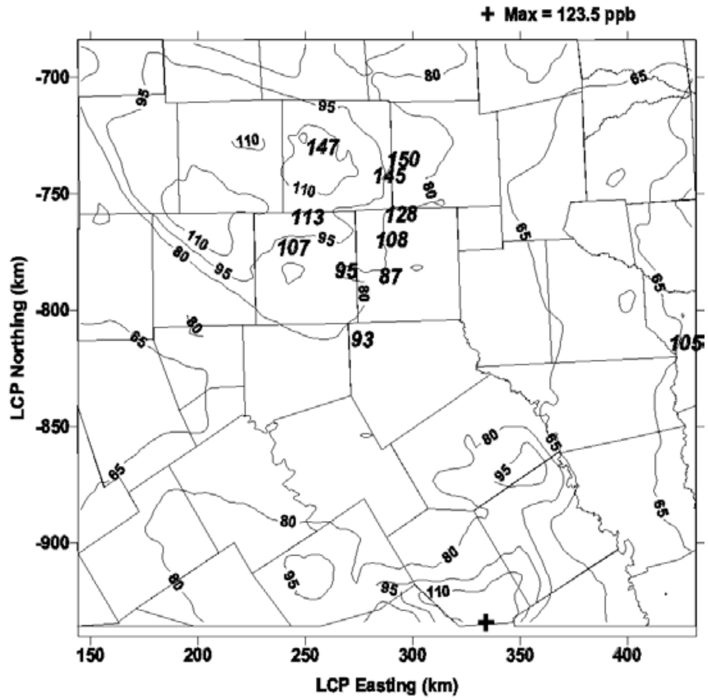


Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run1
August 15, 1999

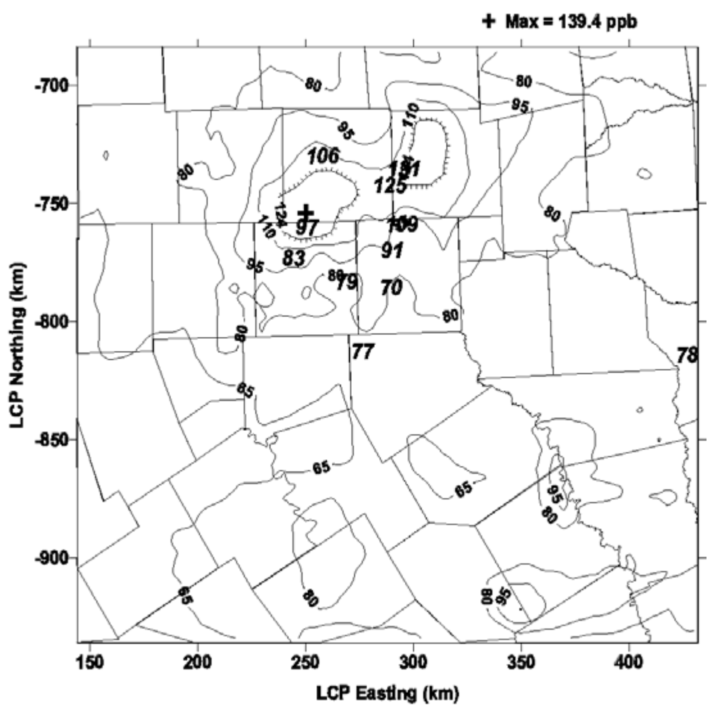


Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run1
August 16, 1999

Figure 4-5. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run3.

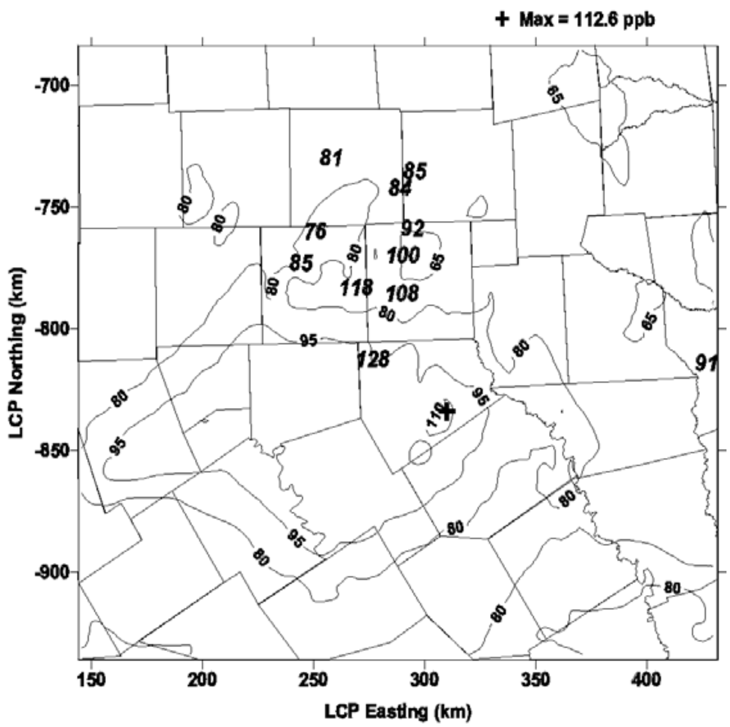


Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run1
August 17, 1999

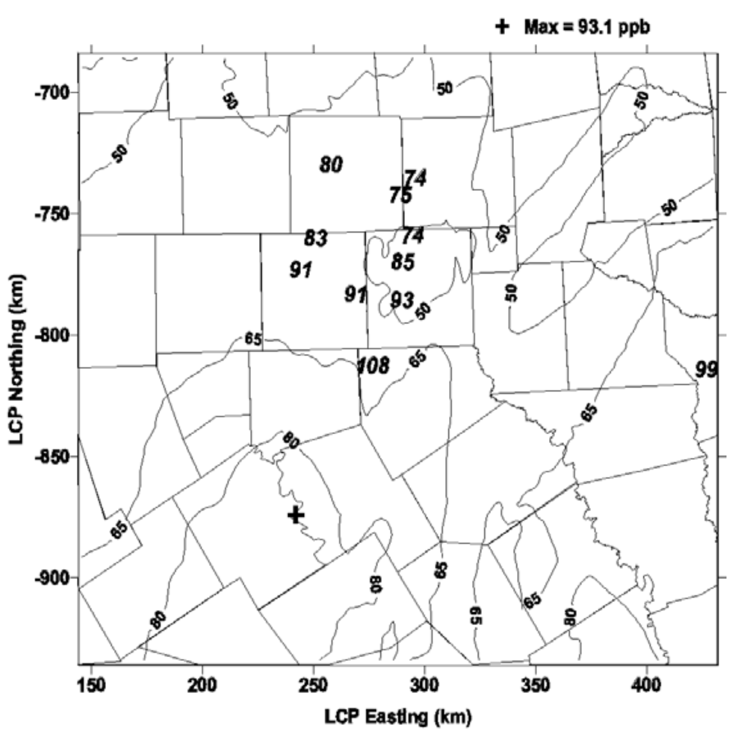


Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run1
August 18, 1999

Figure 4-5. Continued. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run3.



Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run1
August 19, 1999



Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run1
August 20, 1999

Figure 4-5. continued. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run3.

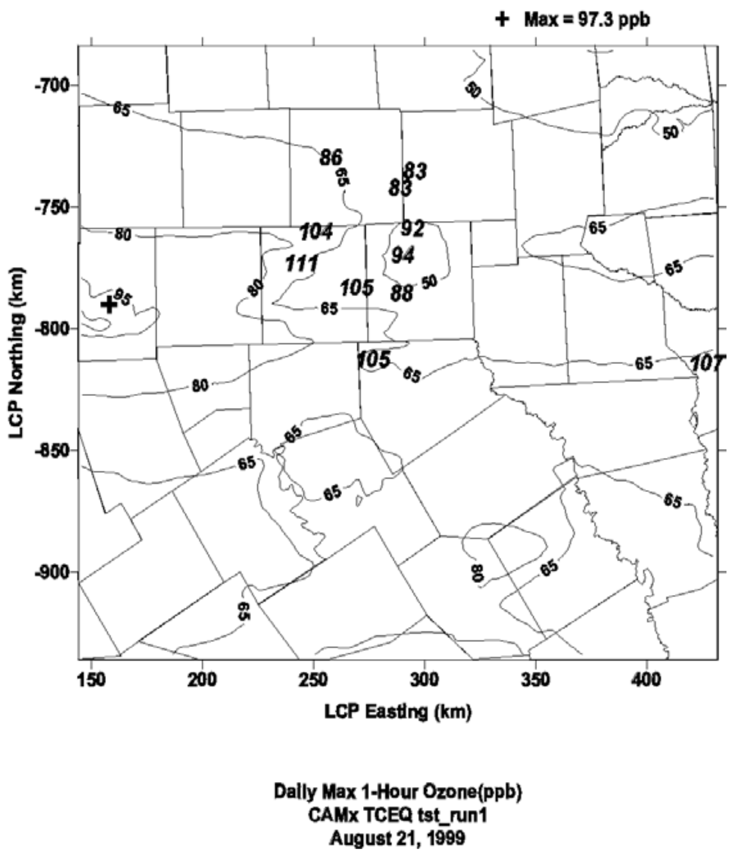
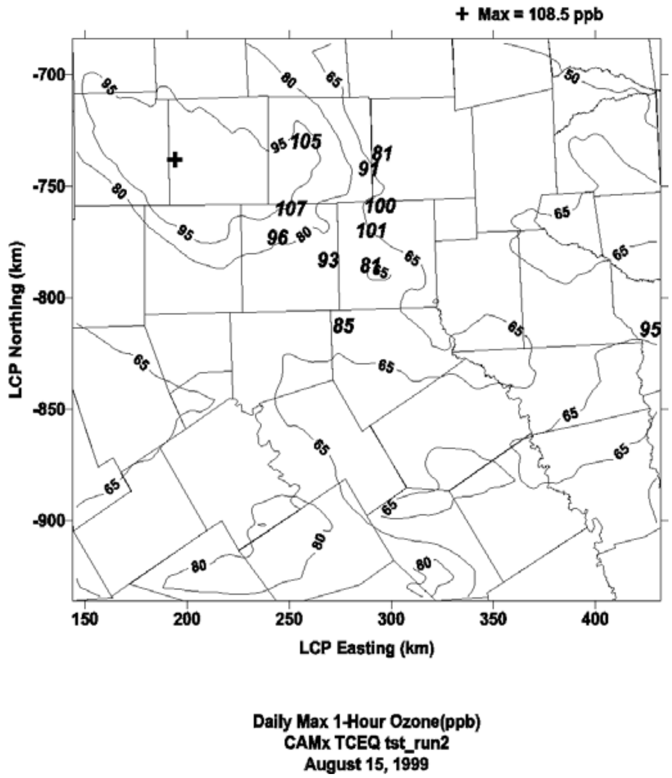


Figure 4-5. Concluded. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run3.



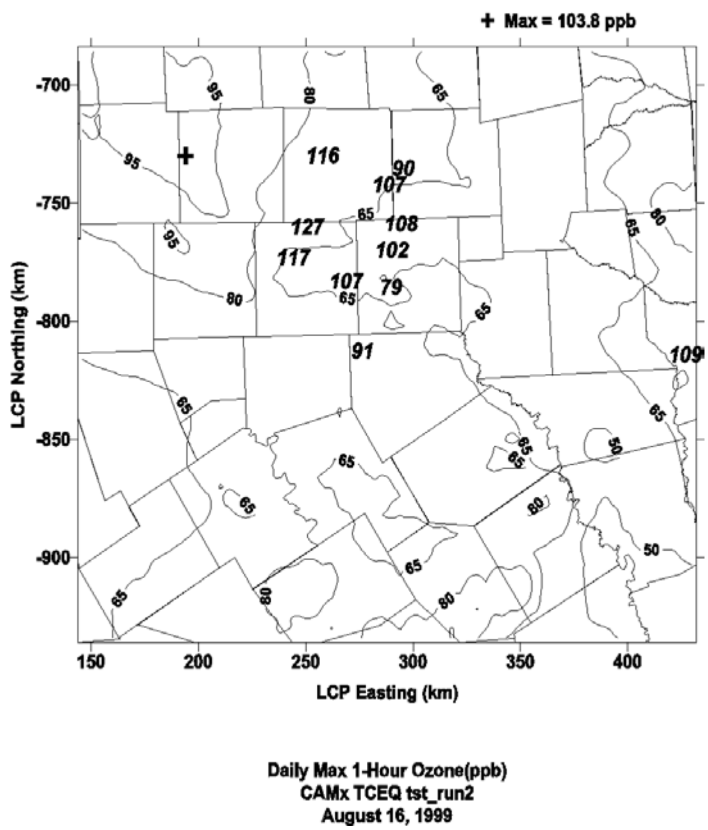
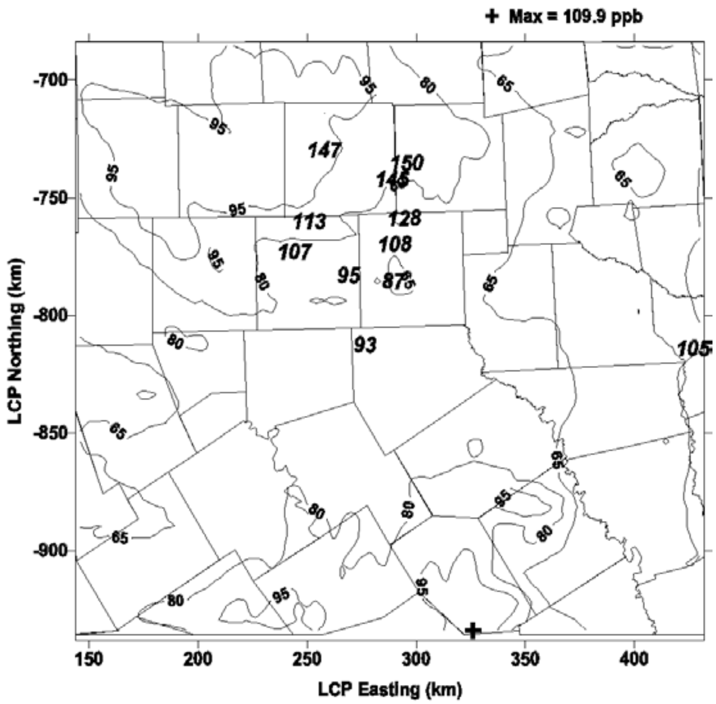
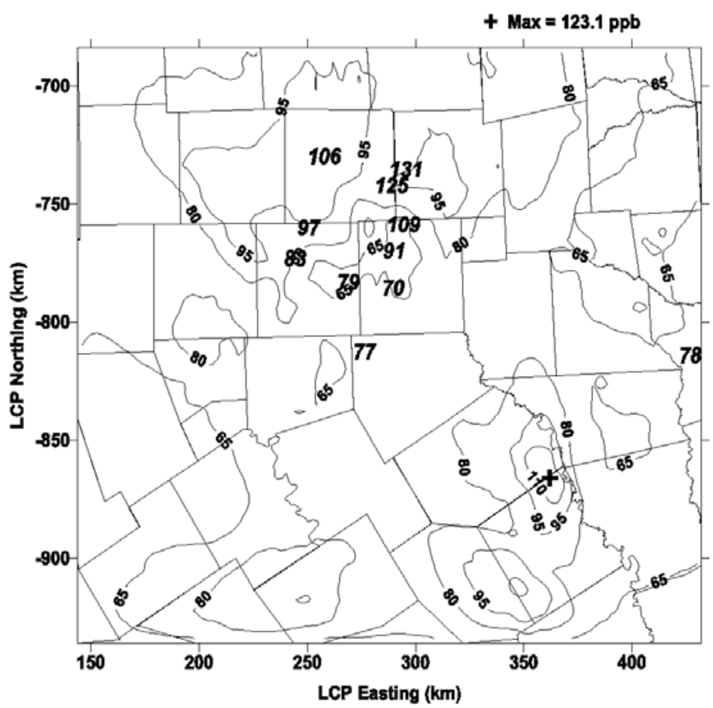


Figure 4-6. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run1a.

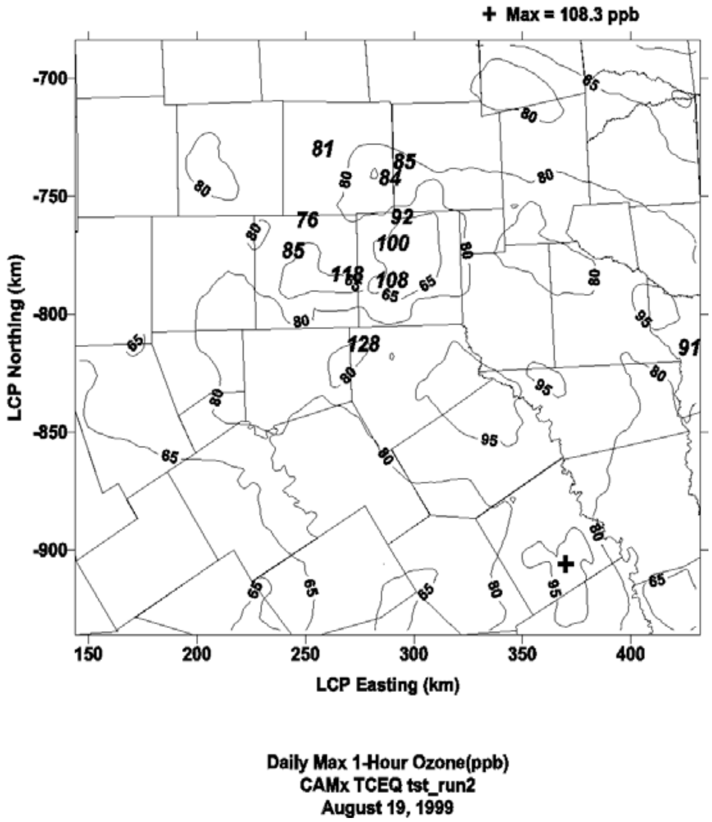


Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run2
August 17, 1999



Daily Max 1-Hour Ozone(ppb)
CAMx TCEQ tst_run2
August 18, 1999

Figure 4-6. Continued. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run1a.



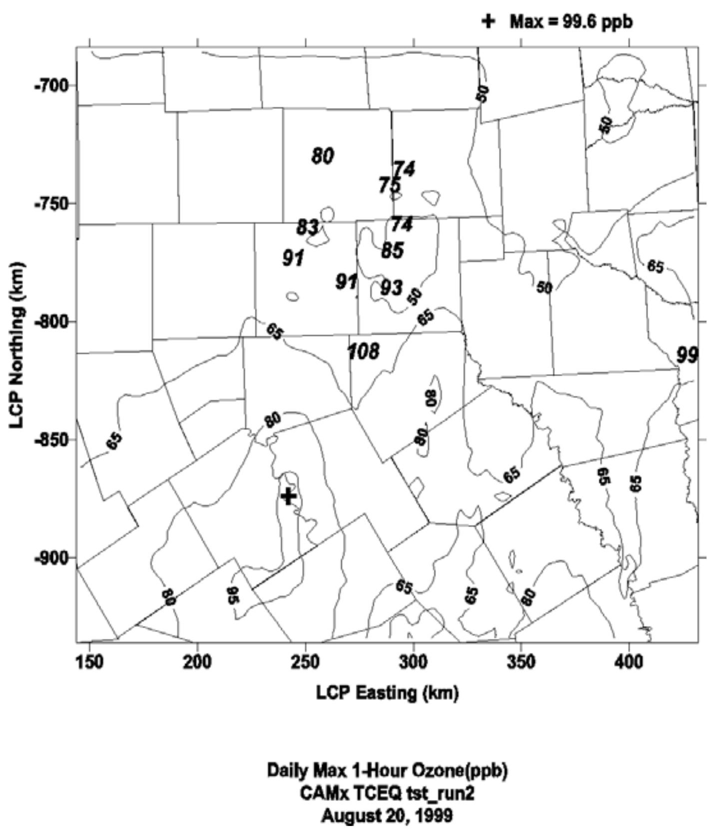


Figure 4-6. Continued. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run1a.

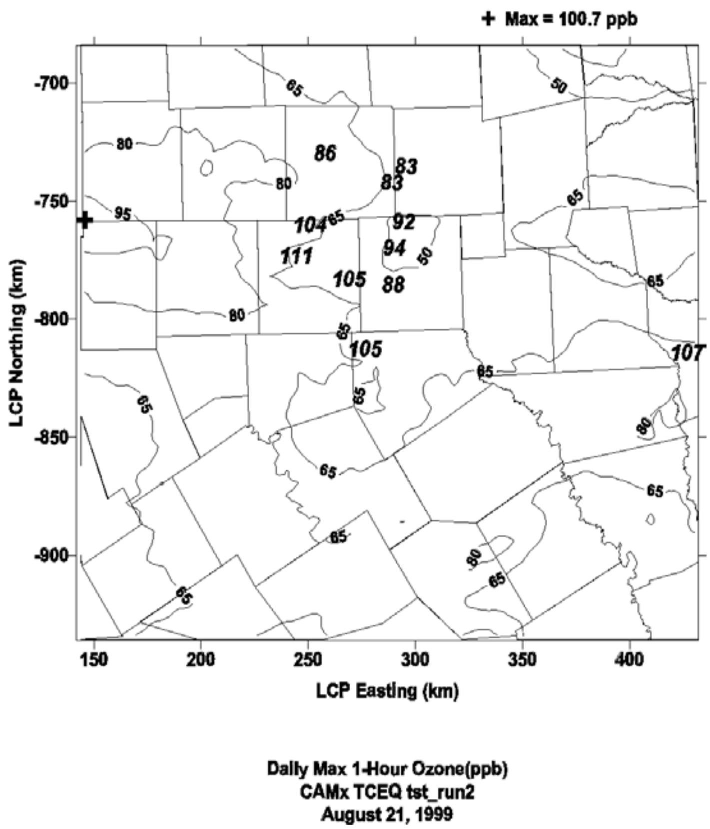


Figure 4-6. Concluded. Spatial distribution of maximum 1-hour ozone concentrations in the DFW 4-km grid for MM4 Run1a.

Table 4-5. CAMx model evaluation statistics for the 13-22, August 1999 episode on 12-km domain.

Performance Attribute	EPA Goal	15 Aug	16 Aug	17 Aug	18 Aug	19 Aug	20 Aug	21 Aug
Maximum Observed Concentration (ppb)		185.0	144.0	150.0	131.0	136.0	127.0	161.0
Maximum Modeled Conc. (ppb)								
tst_run1 (Run3 Met)		116.7	114.1	120.6	132.3	151.0	118.1	114.6
tst_run2 (Run1a Met)		116.7	114.1	120.5	129.0	150.9	118.2	114.4
Accuracy of Unpaired Peak (%)	<"20%							
tst_run1 (Run3 Met)		-36.9	-20.8	-19.6	1.0	11.0	-7.0	-28.8
tst_run2 (Run1a Met)		-36.9	-20.8	-19.6	-1.5	11.0	-7.0	-28.9
Mean Normalized Bias (%)	<"15%							
tst_run1 (Run3 Met)		-16.0	-12.8	-20.5	-16.4	-12.6	-24.0	-27.4
tst_run2 (Run1a Met)		-16.1	-14.2	-22.6	-20.6	-13.1	-24.0	-27.8
Mean Normalized Gross Error (%)	<"35%							
tst_run1 (Run3 Met)		21.9	20.9	26.3	22.7	24.6	28.6	29.6
tst_run2 (Run1a Met)		22.0	22.2	28.3	26.0	24.9	28.7	29.9

CAMx INPUT DATA PREPARATION

MM5 output fields were translated to CAMx-ready inputs using ENVIRON's MM5CAMx translation software. This program performs several functions:

1. Extracts wind, temperature, pressure, humidity, cloud, and rain fields from each MM5 grid that matches the corresponding CAMx grid.
2. Performs mass-weighted vertical aggregation of data for CAMx layers that span multiple MM5 layers.
3. Diagnoses fields of vertical diffusion coefficient (Kv), which are not directly output by MM5.
4. Outputs the meteorological data into CAMx-ready input files.

The MM5CAMx program has been written to carefully preserve the consistency of the predicted wind, temperature and pressure fields output by MM5. This is the key to preparing mass-consistent inputs, and therefore for obtaining the best possible performance from CAMx.

The data prepared by MM5CAMx were directly input to CAMx. Meteorological inputs were developed for a 15-layer CAMx application (Figure 4-7). This results in a 20m deep CAMx surface layer.

Vertical diffusivities are an important input to the CAMx simulation since they determine the rate and depth of mixing in the planetary boundary layer (PBL) and above. In general, diffusivities directly output from meteorological models, or diffusivities diagnosed from other output variables, require careful examination before they are used in air quality modeling. This may be because the air quality model results are much more sensitive to diffusivities than the meteorological model results. Vertical diffusivities are preferably calculated from output fields of turbulent kinetic energy predicted by the MM5 Gayno-Seaman boundary layer model. For the MM5 runs performed for the DFW 1999 modeling episode, the MM5 boundary layer (mixing) depths were used to define a profile of vertical diffusivity values in each grid column, depending on surface layer stability and the underlying surface characteristics. The methodology follows from O'Brien (1970). This method was necessary because the Blackadar and Pleim-Xiu PBL schemes do not generate fields of turbulent kinetic energy.

Layer	sigma	pressure	height	thickness	CAMx Layers
28	0.0000	50.00	18874.41	1706.76	
27	0.0250	73.75	17167.65	1362.47	
26	0.0500	97.50	15805.17	2133.42	
25	0.1000	145.00	13671.75	1664.35	
24	0.1500	192.50	12007.40	1376.75	
23	0.2000	240.00	10630.65	1180.35	
22	0.2500	287.50	9450.30	1036.79	
21	0.3000	335.00	8413.52	926.80	
20	0.3500	382.50	7486.72	839.57	
19	0.4000	430.00	6647.15	768.53	
18	0.4500	477.50	5878.62	709.45	
17	0.5000	525.00	5169.17	659.47	
16	0.5500	572.50	4509.70	616.58	
15	0.6000	620.00	**3893.12**	579.34	--15---
14	0.6500	667.50	**3313.78**	546.67	--14---
13	0.7000	715.00	**2767.11**	517.77	--13---
12	0.7500	762.50	**2249.35**	491.99	--12---
11	0.8000	810.00	**1757.36**	376.81	--11---
10	0.8400	848.00	**1380.55**	273.60	--10---
9	0.8700	876.50	**1106.95**	266.37	---9---
8	0.9000	905.00	**840.58**	259.54	---8---
7	0.9300	933.50	**581.04**	169.41	---7---
6	0.9500	952.50	**411.63**	166.65	---6---
5	0.9700	971.50	**244.98**	82.31	---5---
4	0.9800	981.00	**162.67**	65.38	---4---
3	0.9880	988.60	**97.29**	56.87	---3---
2	0.9950	995.25	**40.43**	20.23	---2---
1	0.9975	997.62	**20.19**	20.19	---1---
0	1.0000	1000.00	**0.00**		=============Surface======

Figure 4-7. MM5 and CAMx vertical grid structures based on 28 sigma-p levels. Heights (m) are above sea level according to a standard atmosphere; pressure is in millibars.

5. OTHER CAMx INPUT DATA

The emissions and meteorological input data for the CAMx ozone modeling were described in Sections 3 and 4, respectively. The other input data and model options are described in the section of the report.

CHEMISTRY DATA

The CAMx "chemistry parameters" file determines which photochemical mechanism is used to model ozone formation. CAMx was run with an updated version of the Carbon Bond 4 mechanism (CB4), referred to as mechanism 3 in CAMx, which is described in the CAMx User's Guide (ENVIRON, 2002). Mechanism 3 is the CB4 mechanism with updated radical-radical termination reactions and updated isoprene mechanism as used for the OTAG modeling and other TCEQ modeling studies.

The chemistry parameters file specifies the rates for all of the "thermochemical" reactions in the CB4 mechanism. The CB4 mechanism also includes several "photolysis" reactions that depend upon the presence of sunlight. The photolysis rates input file determines the rates for chemical reactions in the mechanism that are driven by sunlight. Photolysis rates were calculated using the Tropospheric visible Ultra-Violet (TUV) model developed by the National Center for Atmospheric Research (Madronich, 1993 and 2002). TUV is a state-of-the-science solar radiation model that is designed for photolysis rate calculations. TUV accounts for environmental parameters that influence photolysis rates including solar zenith angle, altitude above the ground, surface UV albedo, aerosols (haze), and stratospheric ozone column.

The albedo/haze/ozone input file is used in conjunction with the photolysis rates input file to specify several of the environmental factors that influence photoloysis rates. The photolysis rates and albedo/haze/ozone files must be coordinated to function together correctly. The surface UV albedo was calculated based on the gridded land use data using the landuse specific UV albedo values given in Table 5-1. The albedo is varies spatially according to the land cover distribution, but does not vary with time. The total ozone column was based on satellite data from the Total Ozone Mapping Spectrometer (TOMS), which are available from a web site maintained by the NASA Goddard Space Flight Center (http://jwocky.gsfc.nasa.gov). Daily ozone column are available at 1.25°longitude by 1° latitude resolution and were mapped to the CAMx grid. The haze optical depth was assumed to be 0.1.

INITIAL AND BOUNDARY CONDITIONS

The initial conditions (ICs) are the pollutant concentrations specified throughout the modeling domain at the start of the simulation. Boundary conditions (BCs) are the pollutant concentrations specified at the perimeter of the modeling domain. Conventional wisdom dictates that the boundary conditions should little or no impact on the model results for North Central Texas in this study because regional modeling is being performed. One of the reasons for performing regional scale modeling rather than urban scale modeling is to minimize the importance of ICs and BCs. Using a large regional domain moves the boundaries far away (in distance and transport time) from the study area. However, as will be seen, the boundary conditions do exhibit a significant influence on the modeling results for DFW non-attainment area. Including several "spin-up" days prior to the episode period allows time for the influence of initial conditions to be removed.

Initial CAMx simulations used clean background values were used for the ICs and BCs similar to the clean values used by the Ozone Transport Assessment Group (OTAG) for regional scale modeling of the Eastern US (OTAG, 1996). Changes from the OTAG values are the use of constant values of 40 ppb for ozone and 100 ppb for CO. The initial and boundary concentrations are shown in Table 5-1.

Table 5-1. Clean values to be used for the initial and boundary concentrations.

Species	Concentration (ppb)
O3	40.0
NO	0.000049
NO2	0.08555
CO	100.0
PAR	3.078
HCHO	1.068
ETH	0.005315
ALD2	0.1051
TOL	0.006043
PAN	0.03834
HNO2	0.000728
HNO3	1.525
H2O2	2.263

SURFACE CHARACTERISTICS (LANDUSE)

CAMx requires gridded landuse data to characterize surface boundary conditions, such as surface roughness, deposition parameters, vegetative distribution, and water/land boundaries. CAMx land use files provide the fractional contribution (0 to 1) of eleven land use categories (Table 5-2) to the surface area of grid cell.

Gridded land cover data were developed from the same landuse databases that were used in the generation of spatial emission surrogates for the 36-km and 12-km grids. A program was written to re-cast the raw spatial surrogate data into the eleven CAMx land use categories, to grid the data to the 36, 12, and 4-km CAMx grids, and to write the results to a model-ready format. Figures 5-1, 5-2 and 5-3 show the dominant land use category in each grid cell for the 36-km, 12-km and 4-km grids, respectively. The dominant land use comprises the majority of surface cover in each cell and the "Forest" category is the sum of the three CAMx categories 4 to 6.

Table 5-2. CAMx land use categories and the default surface roughness values (m) and UV albedo assigned to each category within CAMx.

Category Number	Land Cover Category	Surface Roughness (meters)	UV Albedo
1	Urban	3.00	0.08
2	Agricultural	0.25	0.05
3	Rangeland	0.05	0.05
4	Deciduous forest	1.00	0.05
5	Coniferous forest including wetland	1.00	0.05
6	Mixed forest	1.00	0.05
7	Water	0.0001	0.04
8	Barren land	0.002	0.08
9	Non-forested wetlands	0.15	0.05
10	Mixed agricultural and range	0.10	0.05
11	Rocky (with low shrubs)	0.10	0.05

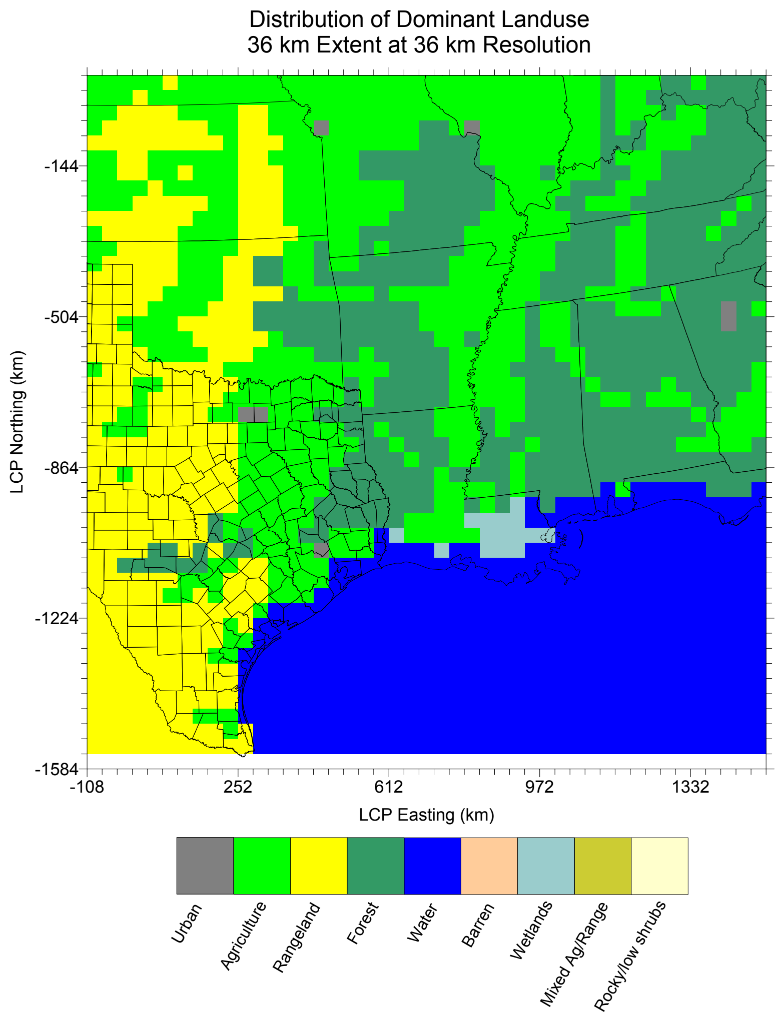


Figure 5-1. Distribution of the dominant land cover type in each grid cell of the 36-km CAMx grid.

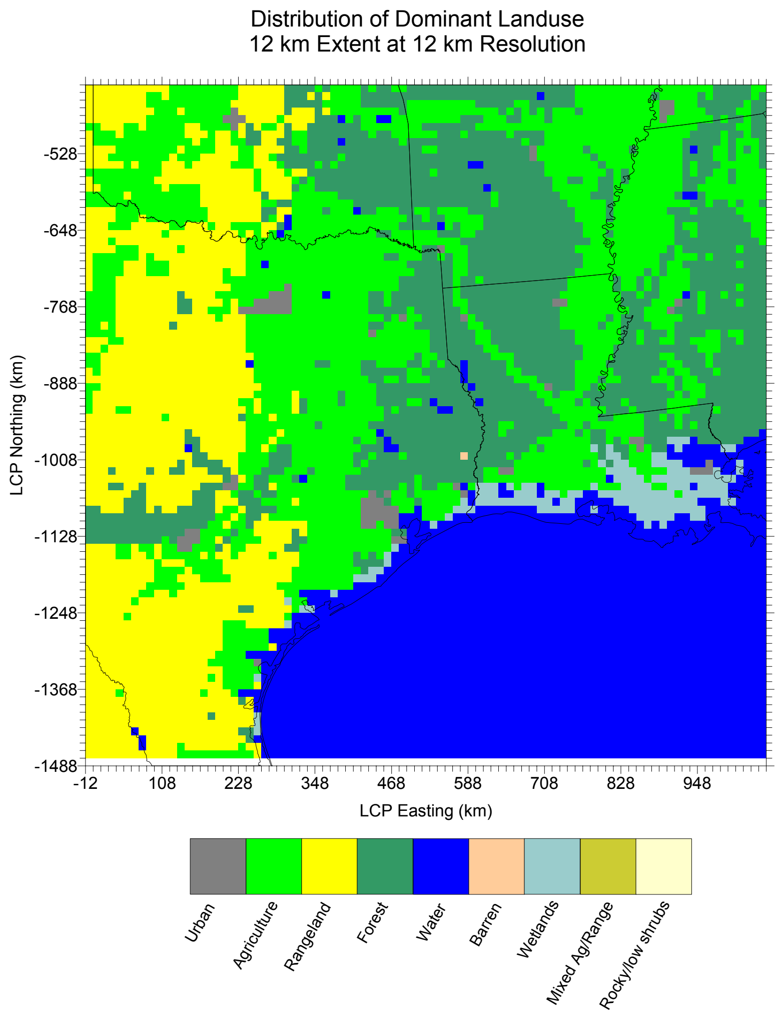


Figure 5-2. Distribution of the dominant land cover type in each grid cell of the 12-km CAMx grid.

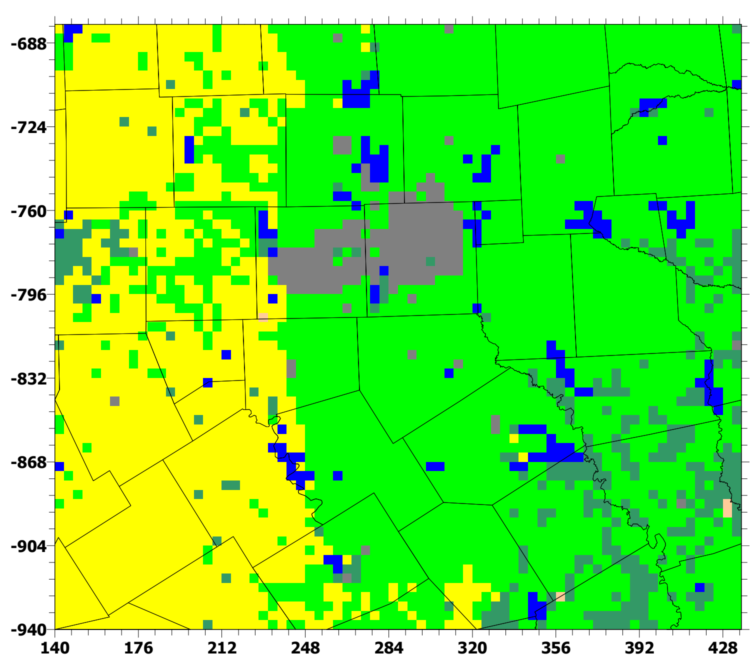


Figure 5-3. Distribution of the dominant land cover type in each grid cell of the 4-km CAMx grid.

CAMx MODEL OPTIONS

CAMx has several user-selectable options that are specified for each simulation through the CAMx control file. Most of these options follow naturally from other choices about model inputs. An example CAMx control script is shown in Figure 5-4. There are four model options that must be decided for each project: the choice of advection scheme, the plume-in-grid scheme, the chemical mechanism and the chemistry solver. The selection for each option is decided at the stage of the base case model performance evaluation and then held fixed for the evaluation of any future year emission scenarios. The recommended choices for these options are discussed below. See the CAMx User's Guide (ENVIRON, 2000) for more details on these options.

Advection Scheme

CAMx version 4.02 has three optional methods for calculating horizontal advection (the movement of pollutants due to resolved horizontal winds) called Smolarkiewicz, Bott and Piecewise Parabolic Method (PPM). The Smolarkiewicz scheme has been used for many years, and was used in the previous modeling for Northeast Texas (ENVIRON, 1999). The Smolarkiewicz scheme has been criticized for causing too much artificial diffusion of pollutants, tending to "smear out" features and artificially overstate transport. The Bott and PPM schemes are newer and have less artificial diffusion than the Smolarkiewicz scheme. The PPM scheme was used for this study as it has been determined to be the least numerically diffusive, runs at speeds similar to Smolarkiewicz, and does not exhibit certain "noisy" features near sharp gradients that are apparent with the Bott approach.

Plume-in-Grid

CAMx includes an optional sub-grid scale plume model that can be used to represent the dispersion and chemistry of major NOx point source plumes close to the source. We used the Plume-in-Grid (PiG) sub-model for major NOx sources (i.e., point sources with episode average NOx emissions greater than 2 tons per day in the 4-km grid). Selection of PiG sources was discussed in Section 3.

Chemical Mechanism

CAMx provides several two main alternatives for the chemical mechanisms used to describe the gas-phase chemistry of ozone formation, namely the Carbon Bond 4 (CB4) and SAPRC99 mechanisms. The most widely used mechanism for regional applications is CB4 with the updated isoprene and radical termination reactions, and CB4 was used for this study.

Chemistry Solver

CAMx has two options for the numerical scheme used to solve the chemical mechanism. The first option is the CMC fast solver that has been used in every prior version of CAMx. The second option is an IEH solver. The CMC solver is faster and more accurate than most chemistry solvers used for ozone modeling. The IEH solver is even more accurate than the CMC solver, but slower. The CMC solver was used for this study.

```
CAMx Version        |VERSION4.0
Run Message         |CAMx v4.02 run6 Aug 13-22 1999
Root output name    |/disk40/tceq_ut/camx/output/run6/camx_v4.02.990816.run6
Start yr/mo/dy/hr   |1999 08 16    0.
End   yr/mo/dy/hr   |1999 08 16 2400.
dtmx,dtin,dtem,dtou|15. 60. 60. 60.
nx,ny,nz            |45  46  15
Coordinate ID       |LAMBERT
xorg,yorg,dx,dy     |-108. -1584. 36. 36. -100. 40. 60. 30.
time zone           |6
PiG parameters      |2000. 12.
Avg output species  |16
                    |NO        NO2       O3        PAR       TOL       ETH
                    |OLE       PAN       ISOP      XYL       FORM      ALD2
                    |HNO3      NXOY      NTR       CO
# nested grids      |2
nest grid params    | 4 32  4 32 15 3
nest grid params    | 8 15 19 25 15 9
SMOLAR,BOTT, PPM?   |PPM
Chemistry solver    |CMC
Restart             |true
Chemistry           |true
Dry dep             |true
Wet dep             |true
PiG submodel        |true
Staggered winds     |true
Treat area emiss    |true
Treat point emiss   |true
1-day emiss inputs  |true
3-D average file    |false
Source Apportion    |false
Chemparam           |../../input/other/CAMx4.chemparam.3
Photolysis rates    |../../input/other/camx.dfw.rates.do
Landuse             |../../input/other/CAMx.landuse.36km.lcp
Height/pressure     |../../preproc/mm5v3_camxv4/36km/camx.zp.tceq36km.990816.run3.bin
Wind                |../../preproc/mm5v3_camxv4/36km/camx.uv.tceq36km.990816.run3.bin
Temperature         |../../preproc/mm5v3_camxv4/36km/camx.tp.tceq36km.990816.run3.bin
Water vapor         |../../preproc/mm5v3_camxv4/36km/camx.qa.tceq36km.990816.run3.bin
Cloud/Rain          |../../preproc/mm5v3_camxv4/36km/camx.cr.tceq36km.990816.run3.bin
Verticaldiffsvty|../../preproc/kvpatch/output/camx.kv.tceq36km.990816.run3.kvpatch1.bin
Initial conditions  |
Boundary conditions|../../input/ic-bc-tc/bc.36km.4km15.const.bin
Top concentration   |../../input/ic-bc-tc/tc.36km.const
Albedo/haze/ozone   |../../input/other/ahomap.dfw.aug99.dat
Point emiss         |../../input/emiss/ptsrce.dfw_reg.pig.990816
Area emiss          |/disk27/dfw/eps2x/emiss/emiss.surface.DFW_reg_36km.biogenic3.990816
Landuse          #1 |../../input/other/CAMx.landuse.12km.lcp
Landuse          #2 |../../input/other/CAMx.landuse.dfw.4km.lcp
Height/pressure #1 |../../preproc/mm5v3_camxv4/12km/camx.zp.tceq12km.990816.run3.bin
Height/pressure #2 |../../preproc/mm5v3_camxv4/04km/camx.zp.tceq04km.990816.run3.bin
Wind             #1 |../../preproc/mm5v3_camxv4/12km/camx.uv.tceq12km.990816.run3.bin
Wind             #2 |../../preproc/mm5v3_camxv4/04km/camx.uv.tceq04km.990816.run3.bin
Temperature      #1 |../../preproc/mm5v3_camxv4/12km/camx.tp.tceq12km.990816.run3.bin
Temperature      #2 |../../preproc/mm5v3_camxv4/04km/camx.tp.tceq04km.990816.run3.bin
Water vapor      #1 |../../preproc/mm5v3_camxv4/12km/camx.qa.tceq12km.990816.run3.bin
Water vapor      #2 |../../preproc/mm5v3_camxv4/04km/camx.qa.tceq04km.990816.run3.bin
```

Figure 5-4. Example CAMx control script for August 16th, 1999 of Base Case 6.

```
Cloud/Rain      #1 |../../preproc/mm5v3_camxv4/12km/camx.cr.tceq12km.990816.run3.bin
Cloud/Rain      #2 |../../preproc/mm5v3_camxv4/04km/camx.cr.tceq04km.990816.run3.bin
Vertical diff  1|../../preproc/kvpatch/output/camx.kv.tceq12km.990816.run3.kvpatch1.bin
Vertical diff#2 |../../preproc/kvpatch/output/camx.kv.tceq04km.990816.run3.kvpatch1.bin
Area emiss      #1 |/disk27/dfw/eps2x/emiss/emiss.surface.DFW_reg_12km.biogenic3.990816
Area emiss      #2 |/disk27/dfw/eps2x/emiss/emiss.surface.DFW_4km.biogenic3.990816
coarse restart     |/disk40/tceq_ut/camx/output/run6/camx_v4.02.990815.run6.inst.2
fine   restart     |/disk40/tceq_ut/camx/output/run6/camx_v4.02.990815.run6.finst.2
PiG    restart     |/disk40/tceq_ut/camx/output/run6/camx_v4.02.990815.run6.pig
```

Figure 5-4. Concluded. Example CAMx control script for August 16th, 1999 of Base Case 6.

6. OZONE MODELING

This section describes the ozone modeling results for the August 1999 regional scale model (RSM) developed for the Dallas/Fort Worth (DFW) non-attainment area in North Central Texas. The August 13-22, 1999 period was selected because it was a period when region experienced an extended period of high 8-hour and 1-hour ozone values. The episode selection and conceptual model were presented in Section 2 and the maximum observed ozone levels are summarized in (Table 6-1). The main episode days were August 15th through August 22nd. Two additional days (August 13th and 14th) were modeled as "spin-up" days.

Table 6-1. Maximum ozone levels and temperatures for the August 1999 episode days.

Max 1-hour O3	**Day**								
Monitor	**990814**	**990815**	**990816**	**990817**	**990818**	**990819**	**990820**	**990821**	**990822**
CAMS_31	82	81	90	150	131	85	74	83	96
CAMS401	108	101	102	108	91	100	85	94	85
CAMS_63	91	100	108	128	109	92	74	92	94
CAMS402	99	81	79	87	70	108	93	88	74
CAMS_56	86	105	116	147	106	81	80	86	97
481210054	81	91	107	145	125	84	75	83	100
CAMS_94	103	85	91	93	77	128	108	105	85
CAMS_86	106	95	109	105	78	91	99	107	78
CAMS_57	115	93	107	95	79	118	91	105	85
CAMS_13	110	96	117	107	83	85	91	111	77
CAMS_17	96	107	127	113	97	76	83	104	85
Max 8-hour O3	**Day**								
Monitor	**990814**	**990815**	**990816**	**990817**	**990818**	**990819**	**990820**	**990821**	**990822**
CAMS_31	78	77	84	126	116	77	66	79	88
CAMS401	94	87	87	97	83	79	78	88	79
CAMS_63	81	87	89	111	99	73	70	86	84
CAMS402	88	71	74	82	67	88	82	84	71
CAMS_56	82	93	100	126	101	74	71	84	90
481210054	77	82	90	123	113	76	69	80	90
CAMS_94	96	82	85	86	70	108	98	96	81
CAMS_86	84	73	93	98	75	86	86	93	77
CAMS_57	103	85	90	92	74	96	79	98	81
CAMS_13	92	88	100	97	77	77	83	95	72
CAMS_17	86	98	108	101	90	69	78	95	81

The preparation of the CAMx model inputs were described in Sections 3 (Emissions), 4 (Meteorology) and 5 (Other CAMx Inputs) of this report. The ozone modeling used version 4.02 of the CAMx model (ENVIRON, 2002). The CAMx modeling domain used a 2-way nested 36/12/4-km grid structure as shown in Figure 1-1. The CAMx 4-km grid covering the DFW non-attainment area is shown in Figure 6-1 with the locations of TCEQ ozone monitors operating in August 1999.

Ozone modeling was conducted for the 1999 base year. Several base cases were completed for 1999 as model performance was refined through improvements to CAMx inputs and configuration. The base case development process is summarized below culminating with base case 7c (Run7c).

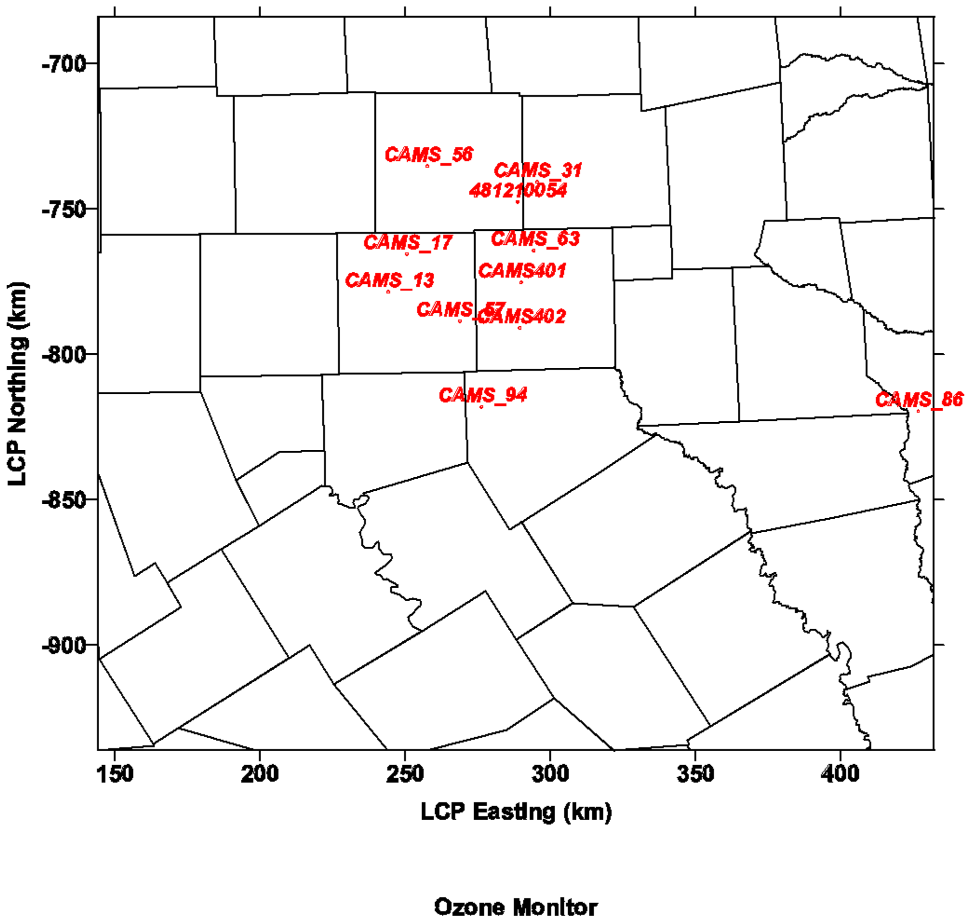


Figure 6-1. Map of the CAMx DFW 4-km grid with locations of TCEQ ozone monitors operating in August 1999.

1999 BASE CASES

All 1999 base case model simulations were run with CAMx version 4.02 using meteorology from MM5 Run3. CAMx version 3.10 was also used to investigate the sensitivity of the modeling results to CAMx model versions. The models options and configuration were adopted from the East Texas modeling study based on the experience gained through various diagnostic simulations conducted in the development of the 1999 East Texas base case. The model configuration and options are discussed in Section 5 of this report.

Model Performance Evaluation Approach

Model performance was evaluated by comparing predicted and observed hourly ozone values for all monitoring sites in the 12-km regional domain and the monitors in the DFW 4-km domain. The 1-hour ozone values were compared rather than 8-hour values because this provides a more stringent test of whether the model is describing the temporal variation in ozone at each monitor. Within an 8-hour period a model may both over- and under-estimate the observed ozone levels, so evaluating performance using 8-hour average data tends to obscure underlying performance features.

EPA established performance goals for 1-hour ozone modeling for three statistical measures (EPA, 1996):

- Accuracy of the predicted peak 1-hour ozone. The ratio of the highest predicted 1-hour ozone to the highest observed 1-hour ozone. For the 12-km grid, we limit the predicted peak to within a 50-km radius of the observed peak to avoid comparing a predicted peak in Dallas with an observed peak in Houston, for example. The EPA goal is within +/- 20% error.

- Normalized bias for observed values above 60 ppb – a measure of whether the model tends to over or under-predict high 1-hour ozone values. The EPA goal is within +/- 15% normalized bias.

$$Normalized\ Bias = 100\left(\frac{1}{N}\right)\sum \left(O_{tl} - E_{tl}\right) / O_{tl}$$

Where O_{tl} and E_{tl} are, respectively, the observed and estimated hourly ozone concentration at site l and time t (i.e., matched by time and location).

- Gross error for observed values above 60 ppb – a measure of overall agreement for high ozone values. The EPA goal is less than 35% normalized gross error.

$$Normalized\ Gross\ Error = 100\left(\frac{1}{N}\right)\sum \left|O_{tl} - E_{tl}\right| / O_{tl}$$

There are no similar statistical performance goals for 8-hour ozone performance. EPA's draft modeling guidance for 8-hour ozone (EPA, 1999) emphasizes consideration of whether model results are consistent with a conceptual understanding of what happened during the episode period.

Model performance was also evaluated using isopleth plots that compare the spatial patterns of ozone to the observed monitored values on a map, and time series plots that compare the observed and predicted ozone levels at a specific monitor over time.

Table 6-2 summarizes tine inputs and model configuration for each of the 1999 base case CAMx simulations. Model performance statistical measures for 1-hour and 8-hour ozone for 1999 base case simulations are summarized in Table 6-3 and Table 6-4, respectively. The description of each run and a discussion of the results of each are presented below.

Table 6-2. Summary of CAMx simulations of the August 1999 Dallas/Ft. Worth ozone episode.

Run	Description
run1	CAMx v4.02; No drought effects in biogenic emissions; includes PiG, cloud cover, wet deposition, clean IC/BCs
run1a	CAMx v4.02; No drought effects in biogenic emissions; correction to 12-km biogenic emissions; includes PiG, cloud cover, wet deposition, clean IC/BCs
run2	CAMx v3.10; No drought effects in biogenic emissions; includes PiG, cloud cover, wet deposition, clean IC/BCs
run3	CAMx v4.02; Drought effects in biogenic emissions; includes PiG, cloud cover, wet deposition, clean IC/BCs
run4	CAMx v4.02; No drought effects in biogenic emissions, modified CAMx code to include drought effects; includes PiG, cloud cover, wet deposition, clean IC/BCs
run6	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, clean IC/BCs
run7a	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, increase percursor IC/BCs
run7b	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, increased precursor and ozone IC/BCs
run7c	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, refined SOS precursor IC/BCs
run7d	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, refined SOS precursor and increased O3 IC/BCs
run8	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, no cloud cover or wet deposition, clean IC/BCs
run8a	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, no cloud cover or wet deposition, IC/BCs
run9	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, no wet deposition, clean IC/BCs
run9a	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, no wet deposition, IC/BCs
run10	CAMx v4.02; Drought effects in biogenic emissions and modified CAMx code to include drought effects, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, IC/BCs
run11	CAMx v4.02; Drought effects in biogenic emissions, KvPatch applied to vertical diffusivity fields; no PiG, cloud cover, wet deposition, IC/BCs
run12	CAMx v4.02; Drought effects in biogenic emissions, NCTCOG off-road emissions, KvPatch applied to vertical diffusivity fields; includes PiG, cloud cover, wet deposition, IC/BCs

Table 6-3a. One-hour performance statistics for the DFW 4-km domain.

Observed Peak	88.0	115.0	107.0	127.0	150.0	131.0	128.0	108.0	111.0	100.0
Predicted Value										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	83.7	117.9	112.4	111.8	137.1	154.0	137.2	101.6	109.4	120.3
run1a	83.0	125.3	123.8	113.9	140.9	154.0	137.9	103.7	120.4	124.9
run2	81.7	110.3	107.2	103.7	124.1	142.3	122.6	96.1	104.6	104.6
run3	82.1	119.1	120.1	109.8	134.3	146.1	132.8	100.8	116.6	120.0
run4	84.3	120.0	113.0	112.4	137.8	154.7	137.6	102.4	109.9	120.9
run6	82.1	119.0	120.0	109.9	134.9	146.3	132.7	100.8	116.6	120.3
run7a	108.6	139.0	138.4	136.9	159.0	164.3	150.0	114.7	134.1	128.4
run7b	119.6	144.8	143.9	144.8	164.6	167.4	153.8	122.2	139.6	131.6
run7c	85.1	125.7	128.8	119.1	143.5	151.1	137.5	109.1	126.1	124.0
run7e	85.1	126.9	129.4	119.2	143.9	151.1	137.6	110.8	127.1	124.3
run8	82.8	115.0	117.6	107.7	132.3	142.6	131.0	98.2	116.2	115.4
run8a	86.7	122.7	126.2	116.5	140.6	147.5	135.8	106.2	125.6	119.3
run9	82.1	118.9	120.0	109.9	134.9	146.4	132.8	100.8	116.6	119.3
run9a	85.1	125.7	128.8	119.1	143.5	151.2	137.6	109.1	126.1	123.1
run10	85.4	124.9	128.6	119.0	143.0	150.6	137.0	109.5	126.0	123.8
run12	89.5	133.1	127.2	124.8	149.9	157.9	142.6	110.0	130.4	128.8
Accuracy of Peak: EPA Goal +/-20%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	-4.9	2.5	5.0	-12.0	-8.6	17.6	7.2	-5.9	-1.4	20.3
run1a	-5.7	8.9	15.7	-10.3	-6.1	17.5	7.7	-4.0	8.5	24.9
run2	-7.2	-4.1	0.2	-18.3	-17.3	8.6	-4.2	-11.0	-5.8	4.6
run3	-6.7	3.6	12.3	-13.5	-10.4	11.5	3.7	-6.7	5.1	20.0
run4	-4.3	4.3	5.6	-11.5	-8.1	18.1	7.5	-5.2	-1.0	20.9
run6	-6.7	3.5	12.1	-13.5	-10.0	11.6	3.7	-6.7	5.0	20.3
run7a	23.4	20.9	29.4	7.8	6.0	25.4	17.2	6.2	20.8	28.4
run7b	35.9	25.9	34.5	14.0	9.7	27.8	20.2	13.2	25.8	31.6
run7c	-3.3	9.3	20.4	-6.3	-4.3	15.3	7.5	1.0	13.6	24.0
run7e	-3.3	10.4	21.0	-6.0	-4.1	15.4	7.5	2.6	14.5	24.3
run8	-5.9	0.0	9.9	-15.2	-11.8	8.9	2.3	-9.1	4.7	15.4
run8a	-1.5	6.7	18.0	-8.3	-6.3	12.6	6.1	-1.7	13.2	19.3
run9	-6.7	3.4	12.1	-13.5	-10.0	11.7	3.7	-6.7	5.0	19.3
run9a	-3.3	9.3	20.4	-6.3	-4.3	15.4	7.5	1.0	13.6	23.1
run10	-3.0	8.6	20.2	-6.3	-4.7	14.9	7.0	1.4	13.5	23.8
run12	1.7	15.7	18.9	-1.7	-0.1	20.6	11.4	1.9	17.5	28.8

Normalized Bias: EPA Goal +/-15%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	-46.4	-32.8	-18.8	-22.8	-30.4	-0.2	-10.0	-28.0	-34.1	-12.2
run1a	-46.0	-30.1	-13.0	-20.9	-28.9	0.1	-8.6	-26.4	-29.8	-9.6
run2	-38.8	-40.2	-25.5	-29.9	-37.3	-8.4	-19.0	-34.8	-41.3	-19.2
run3	-45.9	-32.5	-15.0	-23.0	-31.0	-3.6	-11.4	-28.6	-31.4	-12.2
run4	-46.1	-31.6	-17.7	-21.9	-29.7	0.6	-9.5	-27.2	-33.2	-11.3
run6	-45.4	-32.5	-15.1	-22.8	-30.5	-2.6	-11.4	-28.6	-31.3	-12.0
run7a	-28.7	-15.9	-0.6	-6.9	-18.7	9.9	1.3	-10.5	-17.3	-3.5
run7b	-16.0	-8.1	6.4	0.7	-13.2	14.6	7.6	-1.0	-10.5	1.5
run7c	-39.7	-24.1	-6.0	-14.3	-24.2	2.1	-5.4	-16.2	-21.9	-7.1
run7e	-26.6	-28.7	-9.6	-17.1	-26.0	-2.5	-2.3	-9.5	-22.0	-10.9
run8	-35.4	-35.8	-18.7	-25.8	-33.1	-5.0	-13.4	-31.6	-34.4	-14.7
run8a	-29.0	-27.9	-10.1	-17.8	-27.1	-0.5	-7.5	-19.8	-25.5	-9.8
run9	-45.5	-32.4	-15.1	-22.8	-30.5	-2.3	-11.3	-28.6	-31.3	-12.5
run9a	-28.1	-30.8	-11.1	-17.9	-26.4	-2.4	-3.0	-13.3	-23.6	-11.9
run10	-27.7	-32.0	-11.4	-18.2	-26.8	-3.1	-3.8	-13.7	-24.0	-11.4
run12	-29.2	-31.0	-12.0	-17.4	-25.9	-3.0	-3.9	-14.2	-24.4	-12.3
Normalized Gross Error: EPA Goal 35%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	46.4	33.1	23.0	23.4	32.0	12.1	16.7	28.0	34.1	21.6
run1a	46.0	30.7	23.0	21.8	30.8	12.2	16.0	26.4	30.1	21.8
run2	38.8	40.2	26.8	30.0	37.8	13.5	21.3	34.8	41.3	23.1
run3	45.9	32.9	22.8	23.6	32.4	11.9	17.0	28.6	31.5	21.3
run4	46.1	32.1	22.5	22.6	31.4	12.4	16.6	27.2	33.2	21.5
run6	45.4	32.9	22.8	23.4	31.9	11.0	17.0	28.6	31.4	21.1
run7a	31.6	18.5	18.8	13.2	24.2	15.5	13.1	13.0	19.6	19.7
run7b	24.7	13.9	18.6	12.5	21.6	18.7	13.8	10.9	16.3	19.2
run7c	39.7	25.2	19.4	16.6	27.0	11.8	14.0	17.1	22.8	19.6
run7e	37.5	30.7	22.6	20.2	31.3	17.0	15.7	15.8	23.2	24.2
run8	35.4	36.1	24.4	26.1	34.1	11.2	17.7	31.6	34.4	20.6
run8a	29.2	28.5	20.0	19.1	29.1	10.8	14.4	20.1	26.0	18.8
run9	45.5	32.9	22.8	23.4	31.9	11.0	17.0	28.6	31.4	20.9
run9a	37.6	32.0	22.9	20.8	31.6	17.0	16.1	16.9	24.6	24.1
run10	37.4	32.9	23.3	20.9	31.7	16.8	16.2	17.1	24.9	24.7
run12	38.4	32.3	23.7	20.6	31.3	17.8	17.2	18.0	25.3	25.1

Table 6-3b. One-hour performance statistics for the 12-km regional domain.

Observed Peak	88.0	129.0	185.0	144.0	150.0	131.0	136.0	127.0	161.0	107.0
Predicted Value										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	114.8	139.0	144.6	127.4	138.1	144.1	155.9	135.6	153.4	147.4
run1a	111.5	163.6	159.0	131.0	140.7	144.2	157.4	139.0	164.6	147.9
run2	95.2	135.1	114.4	113.6	125.1	134.5	155.6	123.1	113.8	109.0
run3	107.7	141.4	150.2	124.8	136.6	138.0	155.3	135.1	145.0	124.6
run4	118.0	143.0	150.0	128.6	140.7	144.7	158.8	136.6	160.4	153.6
run6	107.4	141.6	149.8	124.8	136.1	137.9	153.3	134.6	143.9	122.1
run7a	120.0	156.8	153.6	135.1	156.5	153.1	156.4	138.8	150.2	134.0
run7b	127.9	159.7	153.5	143.1	161.8	156.2	157.6	140.4	151.2	137.1
run7c	108.0	143.9	150.9	130.4	141.6	142.1	154.6	136.4	145.9	125.6
run7e	108.0	143.9	150.8	130.9	14192	142.2	154.6	136.4	146.0	125.6
run8	107.2	143.9	131.1	125.0	133.2	134.9	145.0	130.2	130.3	113.9
run8a	108.9	149.2	132.4	130.1	138.6	139.1	146.1	131.9	132.5	116.7
run9	106.0	134.7	144.4	124.8	136.2	138.0	153.3	134.4	137.9	121.1
run9a	107.4	136.8	145.9	130.4	141.6	142.3	154.5	136.1	140.6	124.8
run10	108.3	148.3	149.0	127.8	141.0	141.6	153.4	133.7	138.7	120.4
run12	108.0	143.9	150.9	130.4	144.8	147.8	154.5	136.4	145.9	125.7
Accuracy of Peak: EPA Goal +/-20%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	30.5	7.7	-21.8	-11.6	-8.0	10.0	14.6	6.8	-4.7	37.8
run1a	26.7	26.8	-14.1	-9.0	-6.2	10.0	15.7	9.4	2.3	38.3
run2	8.2	4.7	-38.2	-21.1	-16.6	2.7	14.4	-3.0	-29.3	1.9
run3	22.4	9.6	-18.8	-13.3	-8.9	5.3	14.2	6.4	-10.0	16.4
run4	34.1	10.9	-18.9	-10.7	-6.2	10.5	16.8	7.6	-0.4	43.6
run6	22.1	9.7	-19.0	-13.3	-9.3	5.3	12.7	6.0	-10.6	14.1
run7a	36.3	21.6	-17.0	-6.1	4.3	16.9	15.0	9.3	-6.7	25.3
run7b	45.3	23.8	-17.0	-0.7	7.9	19.2	15.9	10.5	-6.1	28.1
run7c	22.7	11.5	-18.5	-9.5	-5.6	8.5	13.6	7.4	-9.4	17.4
run7e	22.7	11.5	-18.5	-9.1	-5.4	8.5	13.7	7.4	-9.3	17.4
run8	21.8	11.6	-29.1	-13.2	-11.2	3.0	6.6	2.5	-19.1	6.5
run8a	23.8	15.6	-28.4	-9.7	-7.6	6.2	7.5	3.9	-17.7	9.1
run9	20.5	4.4	-21.9	-13.3	-9.2	5.4	12.7	5.8	-14.3	13.2
run9a	22.0	6.1	-21.1	-9.5	-5.6	8.6	13.6	7.2	-12.7	16.6
run10	23.1	14.9	-19.5	-11.3	-6.0	8.1	12.8	5.3	-13.9	12.6
run12	22.7	11.5	-18.4	-9.5	-3.4	12.8	13.6	7.4	-9.4	17.4

Normalized Bias: EPA Goal +/-15%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	-28.6	-12.7	-10.0	-5.3	-15.7	-11.1	-10.4	-21.7	-23.5	-11.2
run1a	-26.9	-7.5	-5.6	-2.1	-14.2	-10.0	-10.0	-19.0	-19.1	-8.3
run2	-30.1	-19.2	-16.0	-13.4	-22.3	-19.4	-14.8	-25.1	-28.6	-19.6
run3	-27.7	-11.4	-8.0	-5.5	-16.9	-15.0	-14.7	-22.0	-22.8	-11.9
run4	-27.7	-10.8	-8.4	-3.8	-14.7	-9.8	-9.0	-20.2	-22.1	-9.9
run6	-27.3	-11.1	-8.0	-5.2	-16.4	-14.2	-13.9	-21.6	-22.7	-11.8
run7a	-10.5	4.7	7.6	10.7	-2.1	-0.7	-2.7	-7.8	-7.9	1.3
run7b	1.2	12.7	15.2	17.4	4.5	5.0	2.2	-0.7	-0.8	7.4
run7c	-21.6	-3.9	2.3	4.3	-9.0	-8.4	-9.0	-13.4	-13.4	-3.5
run7e	2.3	5.4	12.6	2.9	-7.4	-6.5	-8.3	-11.9	-14.4	-2.1
run8	-23.8	-9.8	-12.1	-9.6	-19.5	-14.4	-9.3	-18.2	-22.8	-15.5
run8a	-18.1	-2.8	-2.5	-0.8	-12.6	-8.8	-4.6	-10.4	-14.0	-7.7
run9	-27.4	-13.2	-8.0	-5.4	-16.3	-15.3	-14.5	-21.8	-24.0	-12.0
run9a	0.9	1.1	9.7	1.5	-7.8	-7.5	-9.6	-14.1	-17.0	-3.5
run10	0.5	2.0	8.6	0.2	-8.6	-7.6	-10.0	-14.8	-16.8	-4.6
run12	0.9	2.4	9.7	1.7	-7.8	-6.7	-9.3	-14.1	-16.1	-3.3
Normalized Gross Error: EPA Goal 35%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	31.5	25.5	18.5	18.7	23.1	21.9	27.7	26.8	27.6	17.5
run1a	29.6	26.6	18.9	18.9	23.0	22.1	27.9	26.1	25.6	17.2
run2	32.2	26.9	21.0	20.5	26.6	25.3	26.1	28.8	30.6	22.0
run3	29.8	25.6	18.6	18.4	24.1	23.6	28.3	27.4	26.7	17.5
run4	31.0	25.4	18.4	18.7	22.8	21.7	27.5	26.0	26.9	17.2
run6	29.5	25.3	18.4	18.1	23.5	22.8	27.4	27.0	26.5	17.3
run7a	19.5	20.2	19.8	18.3	18.1	19.4	25.1	20.1	19.4	15.6
run7b	17.1	21.6	22.5	21.6	18.2	20.2	25.8	20.7	18.8	16.9
run7c	24.6	21.3	18.7	17.1	20.0	20.7	25.8	21.5	21.5	15.4
run7e	29.8	27.7	26.7	20.9	23.2	25.9	28.1	24.0	23.8	19.6
run8	27.6	23.8	19.3	19.0	24.8	22.4	24.8	24.3	27.0	19.0
run8a	23.0	20.3	17.3	16.5	20.8	19.9	23.4	18.5	21.1	15.6
run9	29.5	23.9	18.4	18.1	23.5	23.6	27.7	27.3	27.2	17.4
run9a	29.4	25.4	24.9	20.6	23.3	26.5	28.1	23.9	24.6	19.6
run10	29.4	26.9	24.5	20.3	23.4	26.2	27.8	24.2	24.4	19.8
run12	29.4	26.4	25.0	20.6	23.2	26.0	28.0	23.9	24.2	19.8

Table 6-4a. Eight-hour performance statistics for the DFW 4-km domain.

Observed Peak	**67.4**	**103.4**	**97.9**	**107.6**	**126.4**	**116.0**	**108.4**	**98.0**	**98.4**	**89.9**
Predicted Value										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	72.0	96.5	99.9	93.0	109.8	127.2	105.3	89.7	92.3	105.4
run1a	71.1	104.1	110.8	95.1	112.3	127.3	105.8	91.9	100.0	109.8
run2	69.4	89.0	94.8	84.9	100.5	115.9	95.4	84.8	86.5	95.7
run3	70.7	96.9	107.2	91.7	107.8	120.4	102.1	88.0	97.4	105.1
run4	72.7	97.4	100.7	93.7	110.4	127.9	105.6	90.4	92.9	106.3
run6	70.7	97.0	107.2	91.8	108.1	120.7	102.2	88.0	97.3	105.3
run7a	84.9	115.3	121.5	110.8	125.5	136.6	115.9	105.1	110.9	113.5
run7b	96.4	121.3	126.5	117.5	130.9	140.3	120.2	112.3	116.3	116.7
run7c	73.8	103.9	114.0	100.1	114.9	125.3	106.8	98.1	105.3	108.9
run7e	73.8	105.0	114.5	100.5	115.3	125.3	106.8	99.9	106.2	109.2
run8	69.2	94.9	104.4	89.4	105.8	117.2	100.5	85.7	95.1	102.1
run8a	72.2	101.6	110.9	97.3	112.2	121.7	105.1	95.3	102.8	105.7
run9	70.7	97.0	107.2	91.8	108.1	120.8	102.2	88.0	97.3	104.4
run9a	73.8	103.9	114.0	100.1	114.9	125.4	106.8	98.1	105.3	108.1
run10	74.1	103.3	113.9	100.0	114.6	124.7	106.4	98.3	105.4	109.1
run12	73.8	106.1	112.9	99.9	116.0	127.1	108.7	99.5	107.6	112.4
Accuracy of Peak: EPA Goal +/-20%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	6.8	-6.6	2.0	-13.6	-13.1	9.6	-2.9	-8.5	-6.2	17.3
run1a	5.6	0.7	13.2	-11.6	-11.1	9.7	-2.3	-6.3	1.7	22.1
run2	2.9	-13.9	-3.2	-21.1	-20.5	-0.1	-11.9	-13.5	-12.1	6.5
run3	4.9	-6.2	9.5	-14.8	-14.7	3.8	-5.8	-10.2	-1.0	16.9
run4	7.9	-5.8	2.8	-13.0	-12.6	10.2	-2.5	-7.8	-5.6	18.3
run6	4.9	-6.2	9.6	-14.7	-14.4	4.0	-5.7	-10.2	-1.1	17.1
run7a	25.9	11.5	24.1	3.0	-0.7	17.8	7.0	7.2	12.7	26.3
run7b	43.1	17.4	29.2	9.1	3.6	21.0	10.9	14.6	18.3	29.8
run7c	9.5	0.5	16.5	-7.0	-9.1	8.0	-1.5	0.1	7.0	21.2
run7e	9.5	1.6	17.0	-6.6	-8.8	8.0	-1.5	1.9	7.9	21.5
run8	2.7	-8.2	6.7	-16.9	-16.3	1.0	-7.3	-12.6	-3.4	13.6
run8a	7.1	-1.8	13.4	-9.6	-11.2	4.9	-3.1	-2.8	4.5	17.6
run9	4.9	-6.2	9.6	-14.7	-14.4	4.1	-5.7	-10.2	-1.1	16.2
run9a	9.5	0.5	16.5	-7.0	-9.1	8.1	-1.4	0.1	7.0	20.2
run10	10.0	-0.1	16.4	-7.1	-9.3	7.5	-1.8	0.3	7.1	21.3
run12	9.5	2.7	15.4	-7.2	-8.2	9.5	0.3	1.6	9.3	25.1

Normalized Bias: EPA Goal +/-15%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	-49.8	-34.2	-20.9	-25.4	-30.8	1.1	-10.1	-26.1	-35.7	-10.5
run1a	-48.8	-31.7	-15.6	-23.5	-29.3	1.3	-8.7	-24.7	-32.3	-7.7
run2	-45.8	-41.6	-27.7	-32.9	-37.8	-7.4	-19.3	-33.2	-43.2	-17.7
run3	-48.5	-33.9	-17.4	-25.5	-31.3	-2.4	-11.6	-26.8	-33.5	-10.4
run4	-49.5	-33.0	-19.7	-24.5	-30.1	1.8	-9.6	-25.2	-34.9	-9.6
run6	-47.8	-33.8	-17.5	-24.9	-30.4	-1.1	-11.4	-26.8	-33.1	-10.0
run7a	-31.1	-16.7	-2.4	-9.0	-18.4	11.6	1.9	-8.2	-19.1	-1.2
run7b	-17.0	-8.4	5.2	-1.3	-12.9	16.5	8.4	1.7	-12.1	4.0
run7c	-41.9	-25.1	-7.8	-16.4	-24.1	3.7	-5.1	-13.8	-23.6	-4.9
run7e	-20.1	-19.4	-4.8	-14.9	-23.4	3.5	-1.5	-8.9	-17.2	-3.4
run8	-40.9	-37.1	-21.1	-28.0	-32.9	-3.5	-13.5	-30.0	-36.0	-12.8
run8a	-34.5	-28.9	-12.0	-20.0	-26.9	1.1	-7.3	-17.8	-27.2	-7.7
run9	-47.9	-33.8	-17.5	-24.9	-30.3	-0.8	-11.3	-26.8	-33.1	-10.6
run9a	-42.0	-25.1	-7.8	-16.4	-24.0	3.9	-5.0	-13.8	-23.6	-5.5
run10	-41.4	-26.1	-7.8	-16.5	-24.3	3.3	-5.7	-13.8	-24.0	-4.8
run12	-41.9	-25.2	-8.7	-16.1	-23.5	3.1	-5.5	-14.0	-24.4	-5.3
Normalized Gross Error: EPA Goal 35%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	49.8	34.2	21.4	25.4	31.3	8.5	13.4	26.1	35.7	16.5
run1a	48.8	31.7	19.1	23.7	30.0	8.5	12.6	24.7	32.3	16.5
run2	45.8	41.6	27.7	32.9	37.8	11.4	20.5	33.2	43.2	20.3
run3	48.5	33.9	19.7	25.5	31.8	9.5	14.2	26.8	33.5	16.4
run4	49.5	33.0	20.4	24.5	30.6	8.6	13.2	25.2	34.9	16.3
run6	47.8	33.8	19.7	25.0	31.0	9.0	14.1	26.8	33.1	16.1
run7a	31.4	17.9	12.5	12.6	21.8	13.0	9.4	10.0	20.0	15.7
run7b	21.8	13.3	12.5	11.1	18.6	17.1	12.1	9.7	15.6	16.2
run7c	41.9	25.2	13.7	17.6	25.5	8.9	10.9	14.3	23.8	15.2
run7e	25.5	21.2	13.8	16.0	24.7	11.5	12.1	13.8	18.6	15.2
run8	40.9	37.1	22.4	28.0	33.2	9.5	15.5	30.0	36.0	16.6
run8a	34.5	28.9	15.9	20.4	27.8	8.4	11.5	17.8	27.2	14.7
run9	47.9	33.8	19.7	25.0	30.9	8.9	14.1	26.8	33.1	16.1
run9a	42.0	25.2	13.7	17.6	25.5	9.0	10.9	14.3	23.8	15.1
run10	41.4	26.1	13.7	17.6	25.6	8.7	11.1	14.3	24.2	15.3
run12	41.9	25.3	14.2	17.3	24.9	9.4	11.3	14.4	24.5	15.6

Table 6-4b. Eight-hour performance statistics for the 12-km regional domain.

Observed Peak	72.9	103.4	127.5	107.9	126.4	116.0	108.4	105.4	110.3	93.3
Predicted Value										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	93.7	122.3	117.0	115.4	125.0	126.9	122.1	113.7	117.8	126.3
run1a	90.7	131.2	125.3	119.3	129.5	129.5	126.3	116.1	127.4	132.4
run2	87.8	104.4	103.8	101.0	111.4	121.1	116.7	104.3	96.5	93.7
run3	86.9	124.5	118.4	112.7	124.1	126.5	122.9	112.3	115.7	107.9
run4	96.4	125.6	118.5	117.2	126.6	127.9	123.8	114.8	121.9	130.9
run6	86.8	124.6	118.3	112.7	123.3	126.4	121.1	111.7	114.3	108.8
run7a	102.6	132.8	125.8	122.9	132.9	132.6	126.2	115.9	116.6	120.9
run7b	111.7	134.8	128.7	125.8	135.9	135.9	128.7	117.7	117.5	124.4
run7c	88.7	126.5	120.9	118.3	128.6	129.7	123.5	113.6	115.3	111.9
run7e	88.7	126.8	121.0	118.9	129.1	129.9	123.6	113.6	115.5	111.9
run8	91.2	124.2	110.5	108.4	118.8	123.2	116.0	113.4	103.1	100.2
run8a	92.9	126.0	114.5	113.6	123.7	126.3	118.4	113.3	105.2	103.8
run9	86.6	117.6	115.9	112.7	123.4	126.4	120.8	111.3	112.3	106.8
run9a	88.5	120.2	119.0	118.3	128.7	129.7	123.3	113.3	113.4	110.3
run10	87.8	127.2	119.6	116.9	127.0	130.0	122.4	110.8	108.7	107.2
run12	88.7	126.5	120.9	118.3	128.6	129.7	123.6	113.6	115.3	111.9
Accuracy of Peak: EPA Goal +/-20%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	28.6	18.3	-8.3	7.0	-1.1	9.4	12.7	7.8	6.8	35.4
run1a	24.4	26.9	-1.7	10.6	2.5	11.6	16.5	10.1	15.5	42.0
run2	20.5	1.0	-18.6	-6.4	-11.8	4.4	7.7	-1.0	-12.5	0.5
run3	19.2	20.4	-7.1	4.5	-1.8	9.0	13.4	6.5	5.0	15.7
run4	32.3	21.5	-7.0	8.6	0.2	10.2	14.3	8.9	10.6	40.3
run6	19.2	20.6	-7.2	4.5	-2.4	8.9	11.7	5.9	3.7	16.7
run7a	40.7	28.5	-1.4	14.0	5.2	14.3	16.4	9.9	5.8	29.6
run7b	53.3	30.4	0.9	16.7	7.6	17.2	18.7	11.7	6.6	33.5
run7c	21.7	22.4	-5.2	9.7	1.8	11.8	14.0	7.7	4.6	20.0
run7e	21.7	22.7	-5.1	10.2	2.2	12.0	14.0	7.7	4.8	20.1
run8	25.2	20.1	-13.4	0.5	-6.0	6.2	7.0	7.5	-6.5	7.4
run8a	27.4	21.9	-10.2	5.3	-2.1	8.8	9.2	7.5	-4.5	11.4
run9	18.8	13.7	-9.1	4.5	-2.4	9.0	11.5	5.6	1.8	14.6
run9a	21.4	16.3	-6.7	9.7	1.8	11.8	13.8	7.4	2.8	18.3
run10	20.5	23.0	-6.2	8.4	0.5	12.1	13.0	5.1	-1.4	14.9
run12	21.7	22.4	-5.2	9.7	1.8	11.8	14.0	7.7	4.6	20.0

Normalized Bias: EPA Goal +/-15%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	-31.5	-20.9	-13.6	-7.9	-16.6	-11.3	-11.9	-24.1	-23.7	-10.6
run1a	-29.4	-16.6	-8.9	-4.8	-15.0	-9.9	-11.2	-21.4	-19.7	-7.7
run2	-33.6	-26.7	-19.7	-16.0	-23.8	-20.3	-16.8	-27.5	-29.0	-19.5
run3	-29.7	-19.8	-11.2	-8.0	-17.5	-14.5	-15.8	-24.5	-23.2	-11.3
run4	-30.5	-19.2	-12.2	-6.5	-15.6	-10.1	-10.5	-22.6	-22.3	-9.3
run6	-29.0	-19.1	-11.0	-7.1	-16.1	-13.0	-14.9	-23.7	-22.6	-10.6
run7a	-12.1	-2.5	4.3	8.6	-2.1	0.6	-3.6	-9.7	-7.7	2.9
run7b	-0.1	6.2	11.9	15.4	4.3	6.4	1.4	-2.5	-0.4	9.1
run7c	-23.3	-11.3	-1.0	2.4	-8.7	-7.0	-9.8	-15.4	-13.0	-1.8
run7e	0.8	9.6	15.9	7.8	-3.4	-4.0	-4.7	-9.3	-11.4	2.1
run8	-27.0	-17.4	-15.2	-11.4	-19.3	-14.1	-11.2	-20.0	-22.9	-14.6
run8a	-21.5	-9.9	-5.8	-2.6	-12.3	-8.4	-6.3	-12.1	-13.8	-6.4
run9	-29.0	-20.3	-11.1	-7.3	-16.0	-14.0	-15.5	-24.0	-23.7	-10.8
run9a	-23.3	-12.5	-1.1	2.3	-8.6	-7.9	-10.3	-15.6	-14.0	-2.0
run10	-23.7	-12.3	-1.8	1.3	-9.3	-8.0	-10.3	-15.7	-13.6	-2.8
run12	-23.3	-11.5	-1.3	2.4	-8.5	-7.0	-9.9	-15.4	-13.2	-1.8
Normalized Gross Error: EPA Goal 35%										
Run	**08/13/99**	**08/14/99**	**08/15/99**	**08/16/99**	**08/17/99**	**08/18/99**	**08/19/99**	**08/20/99**	**08/21/99**	**08/22/99**
run1	31.6	24.9	19.2	17.3	21.6	19.1	22.6	26.3	25.9	14.5
run1a	29.5	24	18.9	17	21.1	19.2	22.7	24.8	23.5	13.9
run2	33.9	28.5	22.5	19.9	25.9	23.7	23.6	28.8	30	20.6
run3	29.8	24.5	18.9	16.9	22.7	21.6	23.6	26.9	25.2	14.5
run4	30.7	24.1	19	17.1	21.3	18.7	22.3	25.3	25.1	14
run6	29.1	24	18.5	16.5	21.6	20.9	23.1	26.2	24.6	13.8
run7a	13.5	14.6	17	15.1	16.2	17.1	20.4	16.9	16.6	11.9
run7b	8.7	14.6	18.3	18.7	16.3	17.9	21.4	16.9	15.8	14
run7c	23.5	18	16.9	14.5	18.1	18.7	21.5	19.6	18.6	11.2
run7e	24.6	23	23.5	18.6	20.5	23.1	22.9	20.4	21.2	15.8
run8	29.8	23.6	19.8	17.7	22.9	20.2	20.9	23.3	25.6	16.3
run8a	25.1	18.2	16.7	14.4	18.8	17.5	19.2	16.9	18.8	11.9
run9	29.1	23.2	18.5	16.5	21.6	21.8	23.4	26.4	25.2	13.9
run9a	23.5	17.1	16.9	14.5	18.1	19.6	21.8	19.8	19.1	11.2
run10	23.8	18.5	16.6	14.1	18.4	19.2	21.5	20	18.8	11.4
run12	23.5	18.1	16.9	14.5	17.9	18.7	21.6	19.7	18.7	11.3

Base Case Runs1a and Run2

CAMx base case Run1a used meteorology from MM5 Run3, as discussed in Section 4. Biogenic emissions for this case were developed without drought stress effects using version 2.2 of the GloBEIS model. An initial Run1 simulation was conducted but an error in the emissions data was subsequently discovered. Hence, the emissions data were corrected and the model re-run, producing the first base case simulation, Run1a. CAMx version 3.10 was run with the same inputs as Run1a to investigate the effects of model version on predicted ozone concentrations. For both simulations, the modeling results exhibit a negative bias when compared with \hourly observed ozone concentrations. As shown in Table 6-2, only three of the 10 simulation days meet the EPA performance goals for normalized bias with CAMx version 4.02, while only one day meets the performance goals using version 3.10 of CAMx. While these results are clearly unacceptable, they do reflect the improvements of version 4.02 over version 3.10 of the CAMx model for this episode and modeling database.

Base Case Run3 and Run4

The modeling study of the 1999 ozone episode in East Texas (Yarwood, et al., 2003) illustrated the importance of drought stress on both the estimation of biogenic emissions and on the impacts of predicted ozone concentrations due to changes in dry deposition rates to vegetation. These effects were further investigated in this study through a number of diagnostic runs in which both the effects on biogenic emission rates and dry deposition rates were simulated. A discussion of drought stress effects is presented below. A detailed discussion and the impacts on the emissions for the DFW modeling domain were documented in Yarwood, et al, 2003.

<u>Drought Stress Change</u>

The drought stress sensitivity tests were conducted because simulated ozone levels were underpredicted within the DFW 4-km domain in the previous base case run, because dry deposition is a significant removal process for ozone at the regional scale, and because dry deposition rates to vegetation are modified by drought. The physical process by which vegetation removes ozone (dry deposition) is that ozone diffuses into leaf cuticles through the stomata and is destroyed by contact with the leaf tissue (Weseley, 1989). One response of plants to moderate drought is to partially close leaf stomata in an attempt to reduce water loss. The GloBEIS biogenic emissions model (ENVIRON, 2001) models the effects of drought stress on biogenic emissions and includes a relationship between the stomatal conductance and the Palmer drought index (SPI) calculated by the Dept. of Agriculture. Figure 6-2 presents the SPI map for August 1999 and shows that much of the CAMx domain was in drought conditions in August 1999.

The drought stress change to CAMx was to apply a 50% reduction to the stomatal conductance term in the dry deposition algorithm. This required a change to the CAMx source code and had the effect of applying the drought stress change across the whole modeling domain. A more refined drought stress adjustment could be developed in the future by enabling CAMx to read the SPI map (Figure 6-2) and adjusting the stomatal conductance using the GloBEIS algorithm (Figure 6-3).

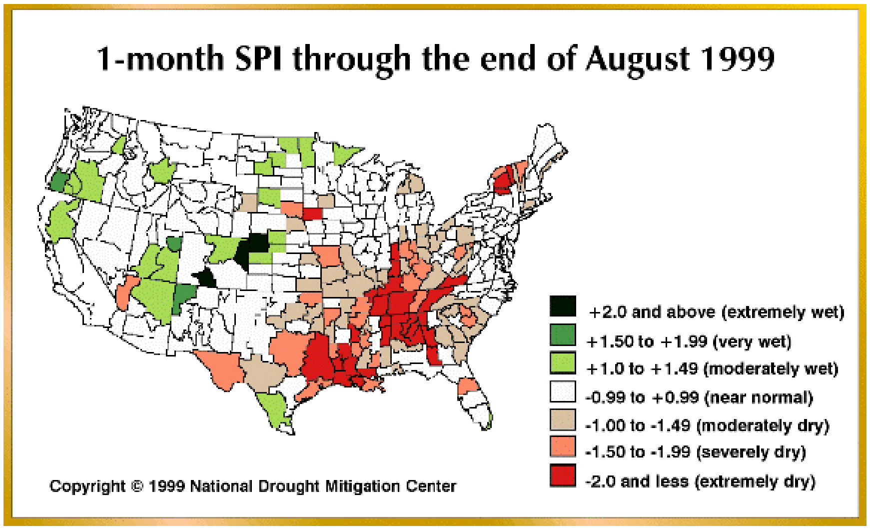


Figure 6-2. 1-month Standardized Precipitation Index ending in August 1999, indicating levels of drought relative to climatological norms in each climate zone.

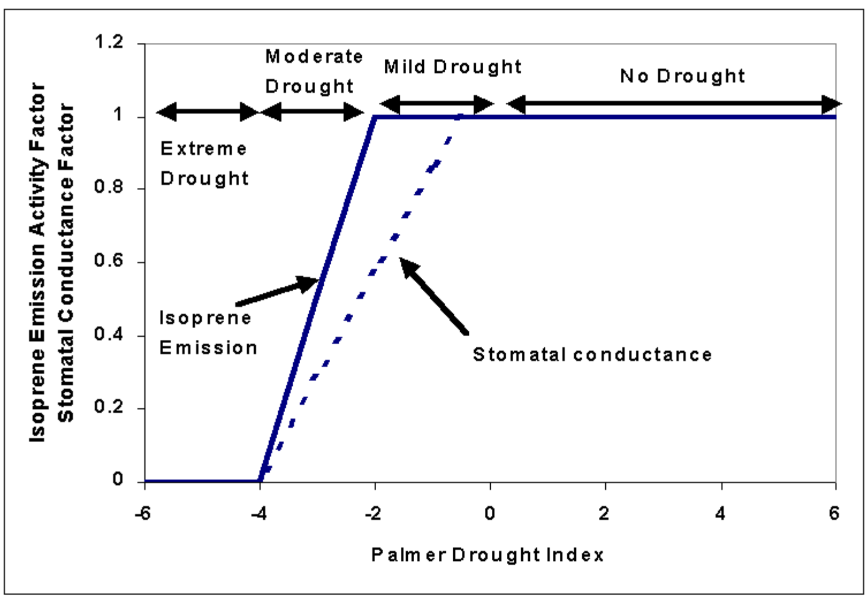


Figure 6-3. The GloBEIS3 relationship between leaf stomatal conductance and drought stress.

For Base Case Run3, biogenic emissions were developed using version 3.1 of the GloBEIS model which allows the inclusion of drought stress effects and effects due to prolonged period of high temperatures. In Base Case Run4, the changes to dry deposition rates as used in CAMx were simulated.

The peak accuracy statistical measures improved for several simulation days for Run3 as compared to Run1a, although the normalized bias statistics did not show significant improvement. CAMx Run3 utilized biogenic emissions developed with version 3.1 of GloBEIS, including drought stress and prolonged high temperatures. While model performance was not improved for this case, the effects of drought on the biogenic emissions and the impact on modeled ozone concentrations can be seen. In Base Case Run4, the modifications to the CAMx model discussed above were implemented. In this case, in order to isolate the effects of biogenic emissions from changes in the dry deposition modifications, biogenic emissions developed using version 2.2 of GloBEIS were utilized. As seen in Table 6-2, the normalized bias for Run4 did not show any improvement over Run1a, although at least three simulation days meet the EPA performance goals (only four days met the performance goal for Run1a). Run4 did, however show improvement on most days over Run3 with respect to the normalized bias and gross error, and the peak accuracy. These results illustrate the impacts of including drought stress effects in the biogenic emission. Biogenic emissions developed with version 3.1 of GloBEIS including drought stress and prolonged high temperatures were used in all remaining CAMx simulations in this study.

Base Case Run6

The results of the previous simulations have shown a tendency for the model to underpredict the observed ozone concentrations in both the 4- and 12-km modeling domains. Examination of the hourly time series of observed versus prediction hourly ozone concentrations illustrates an underprediction of ozone concentrations, particularly during nighttime hours. This may be indicative of suppressed nocturnal mixing predicted by the meteorological fields. As noted in the Modeling Protocol for the study (ENVIRON, 2003) as well as the conceptual model development, air quality modeling result can be fairly sensitive to the specification of mixing heights through the specification of the vertical diffusivity fields. Vertical diffusivities fields, Kv, are typically evaluated and adjusted to more realistically represent the level of mixing within the model simulation. For Base Case Run6, the Kv fields as generated by the MM5 pre-processors were adjusted based on the dominant landuse category in each model grid cell. Adjustments were applied to Kv from the surface vertically through the first 100m meters of the modeling domain based on land use characteristics within each grid cell. In the present case this corresponds to the first three model layers. These adjustments affect primarily only the nighttime mixing heights within the modeling domain.

The results of CAMx model simulations with these adjustments to the Kv fields have only a minimal effect on model performance statistics. Nevertheless, these adjustments are generally applied to the vertical diffusivity fields produced by the meteorological model for use in air quality modeling and were therefore adopted for all subsequent base case model runs. Displays of the spatial distribution of daily maximum 1-hour ozone concentrations are presented in Figure 6-4. Isopleth plots of daily maximum ozone concentrations within the 12-km regional modeling domain are presented in Figure 6-5, and exhibit fairly low ozone concentrations, representative of background ozone concentrations within the region. Time series plots of observed versus predicted hourly ozone concentrations are presented in Figure 6-6 for all monitors within the DFW 4-km modeling grid.

Although the performance statistics for Run6 show only minor improvements over Run3, a more detailed investigation and review of the mixing heights and the dynamics of the planetary boundary layer may provide additional insight into the persistent underpredictions of the model simulations. Due to scheduling constraints related to delayed receipt of key emission inventory inputs, this analysis was not carried for the current modeling effort. It is recommended that this investigation be completed as part of a further refinement of the 1999 base case.

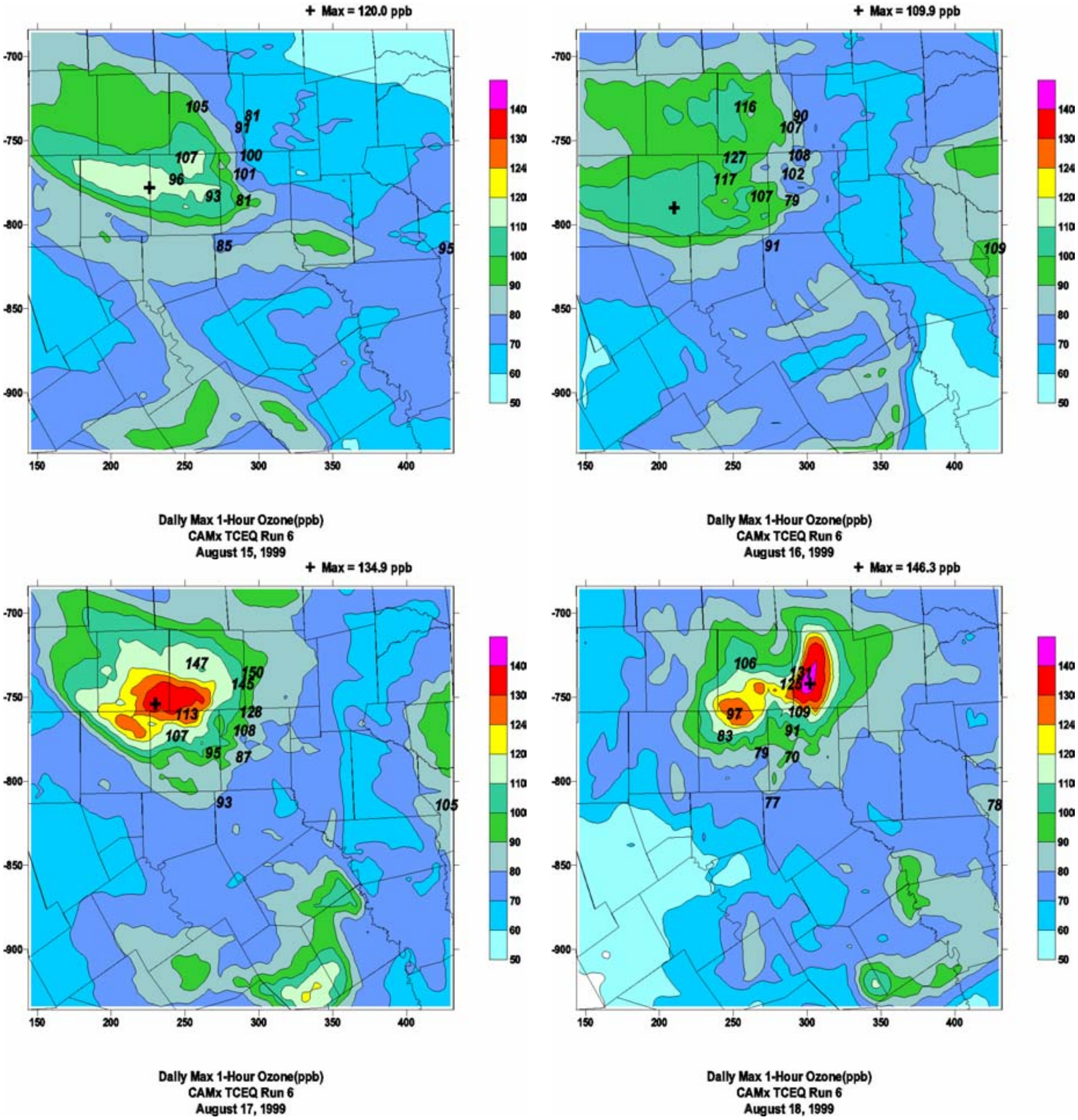


Figure 6-4. Spatial distribution of daily maximum ozone concentrations in the DFW 4-km grid for Base Case Run6.

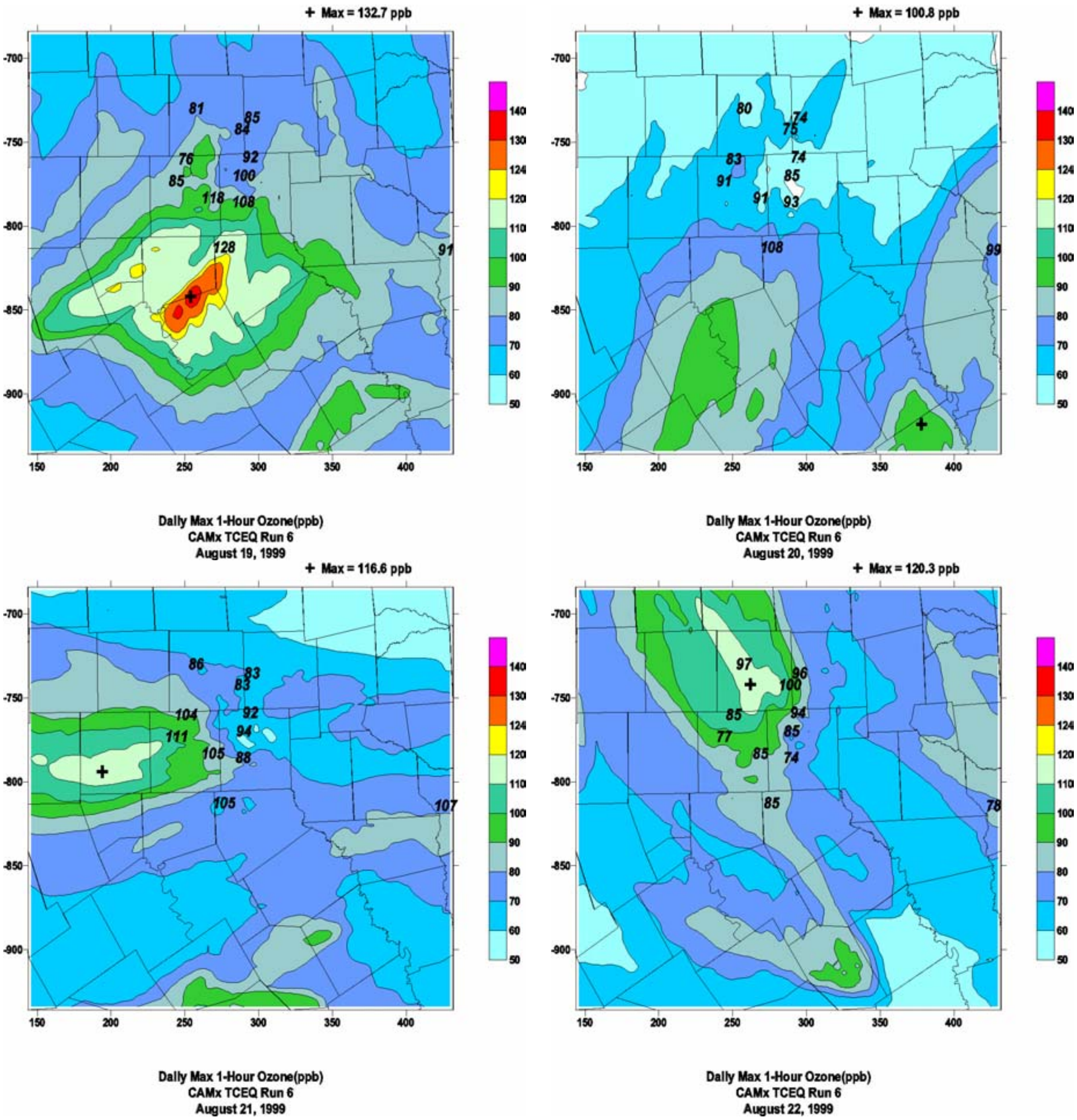


Figure 6-4. Spatial distribution of daily maximum ozone concentrations in the DFW 4-km grid for Base Case Run6. (Concluded).

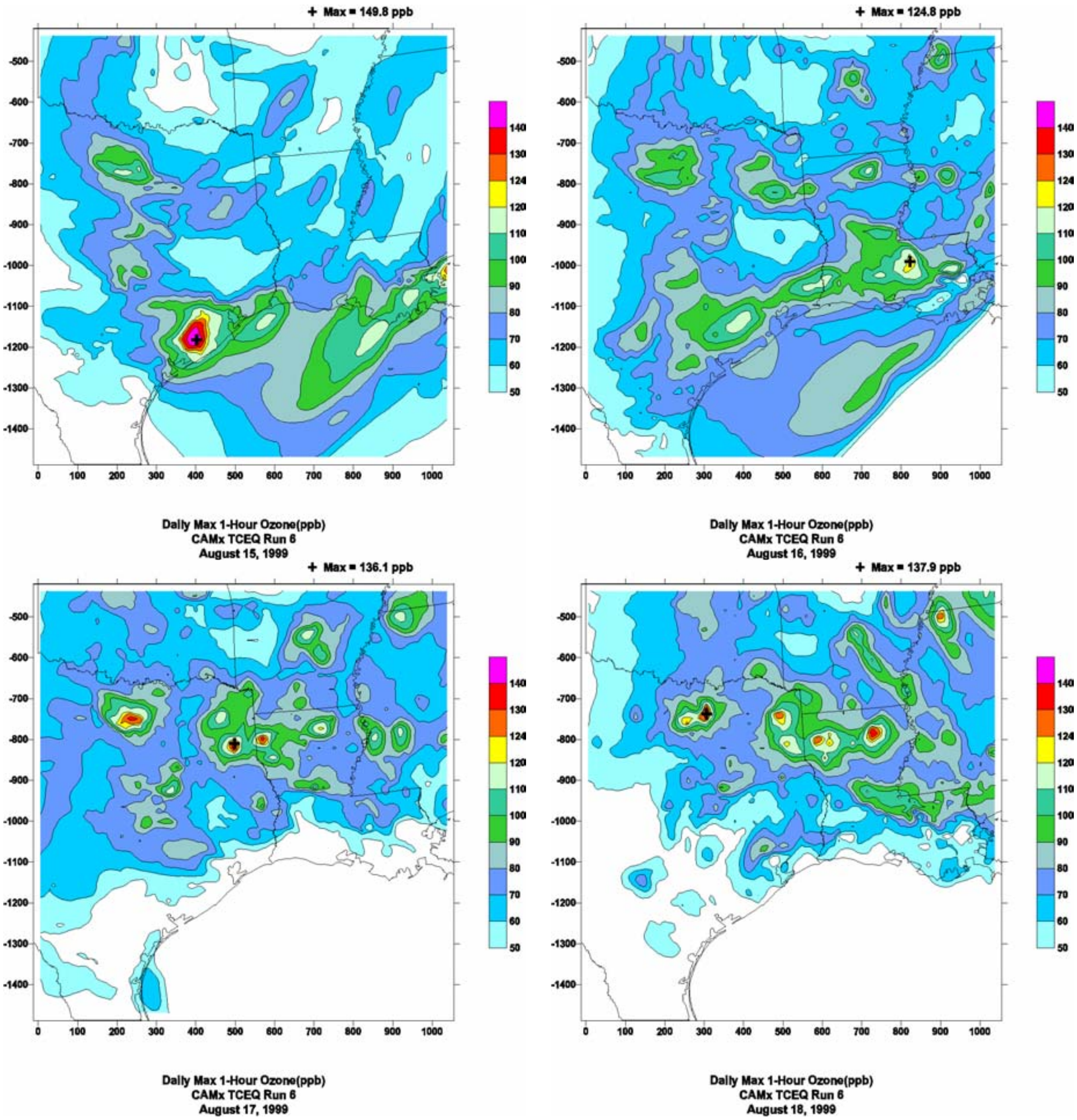


Figure 6-5. Spatial distribution of daily maximum ozone concentrations in the 12-km regional grid for Base Case Run6.

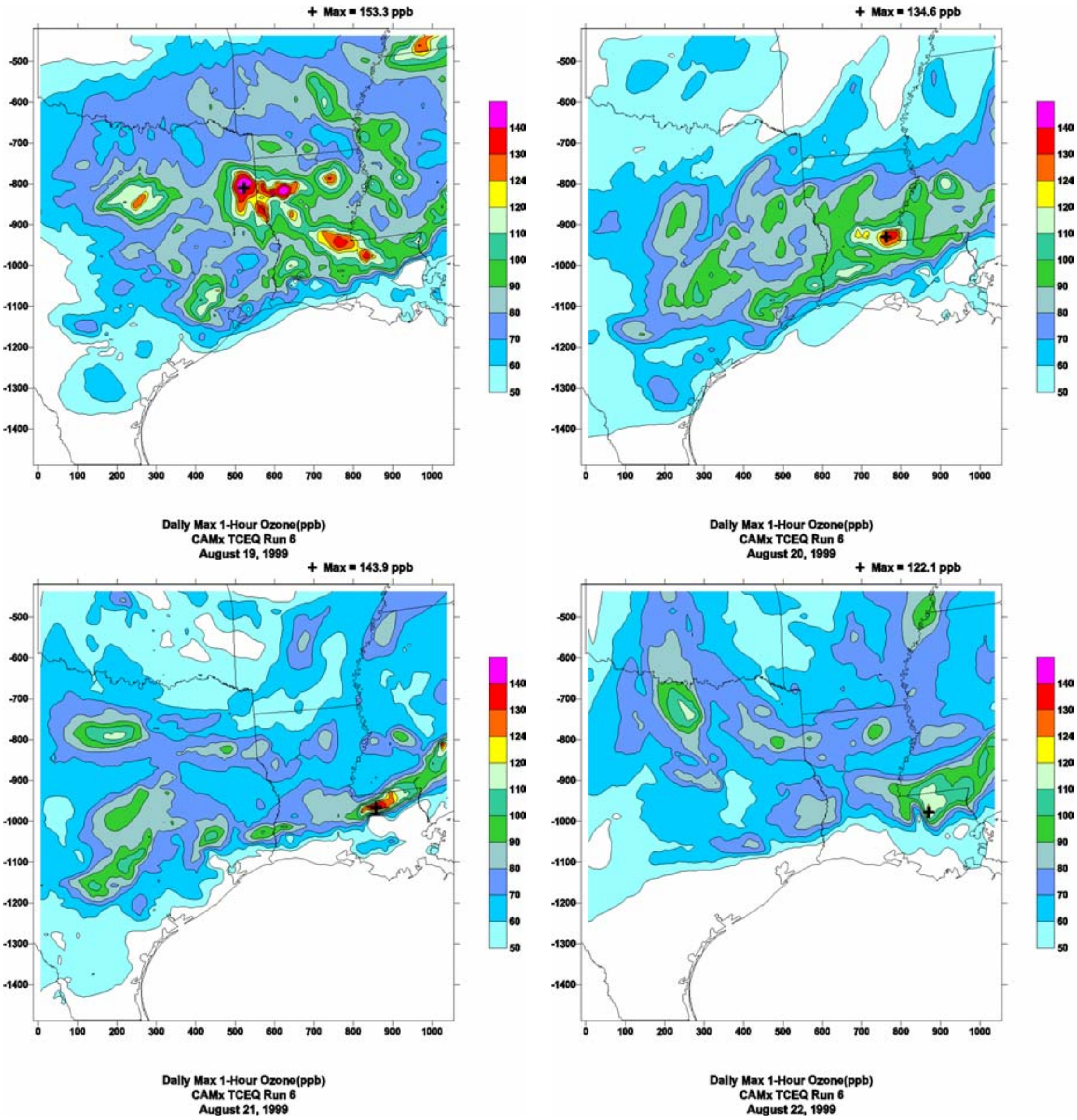


Figure 6-5. Spatial distribution of daily maximum ozone concentrations in the 12-km regional grid for Base Case Run6. (Concluded).

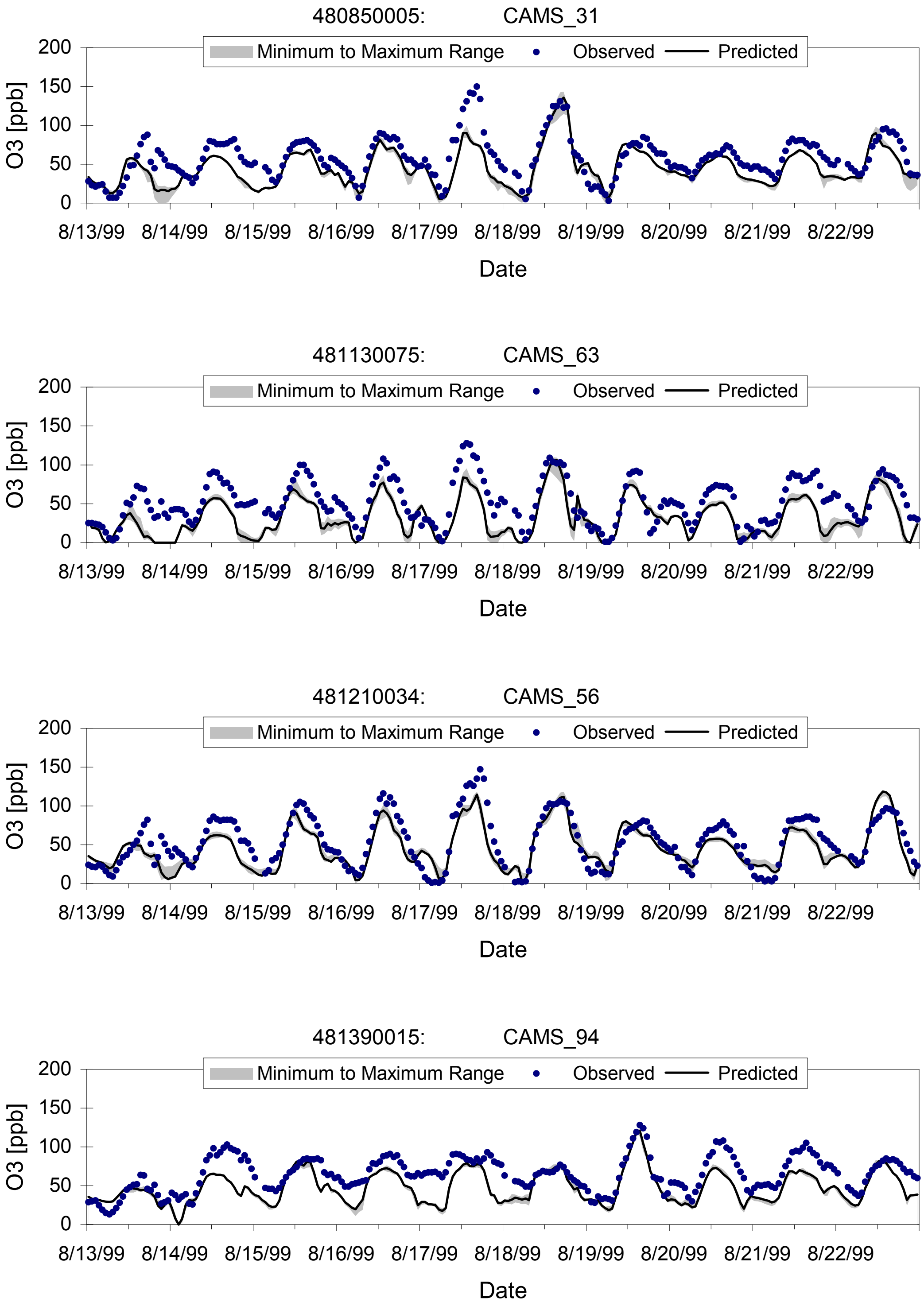


Figure 6-6. Time series of observed and predicted 1-hour ozone concentration in the DFW 4-km grid for Base Case Run6.

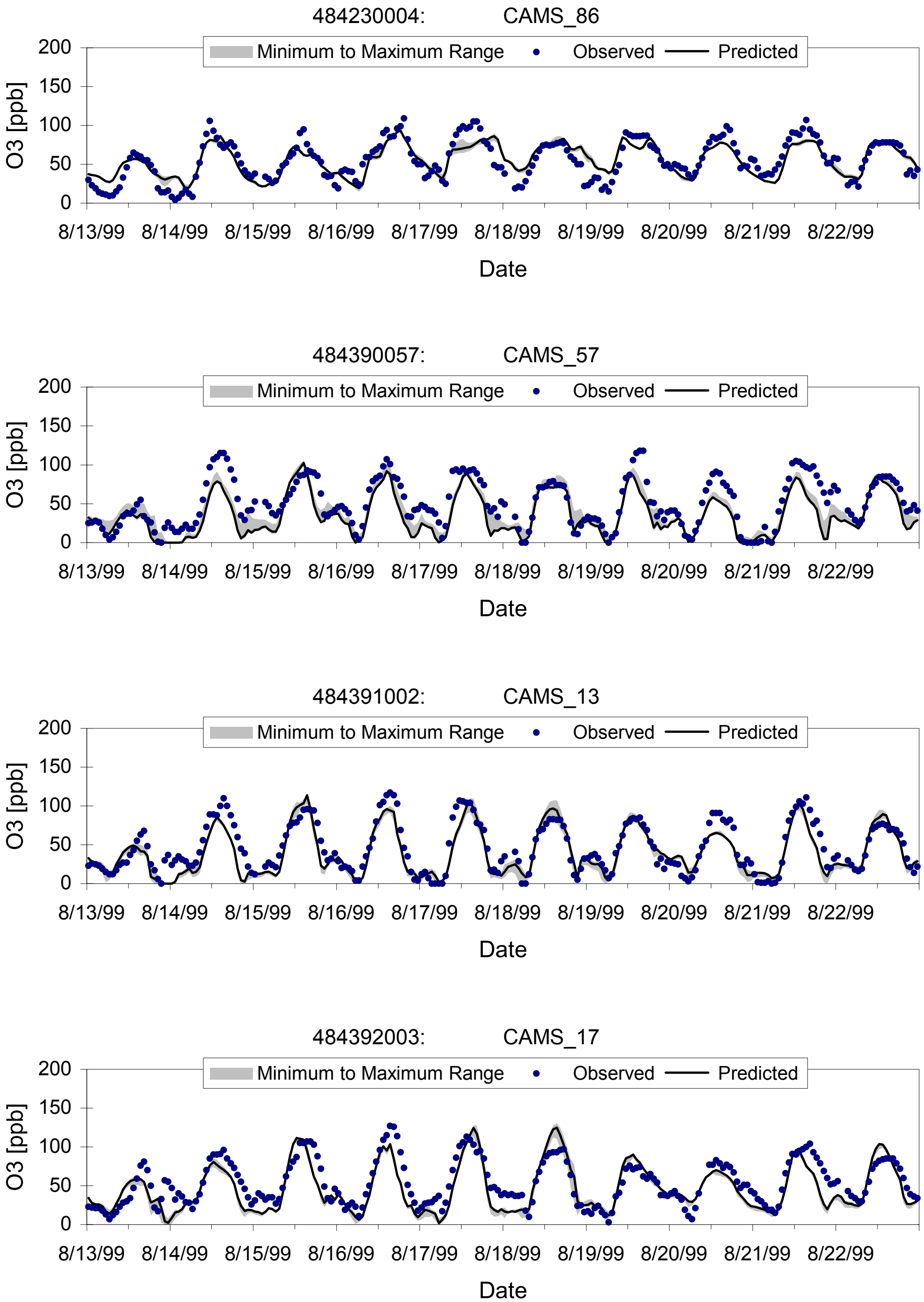


Figure 6-6. Time series of observed and predicted 1-hour ozone concentration in the DFW 4-km grid for Base Case Run6. (Continued.)

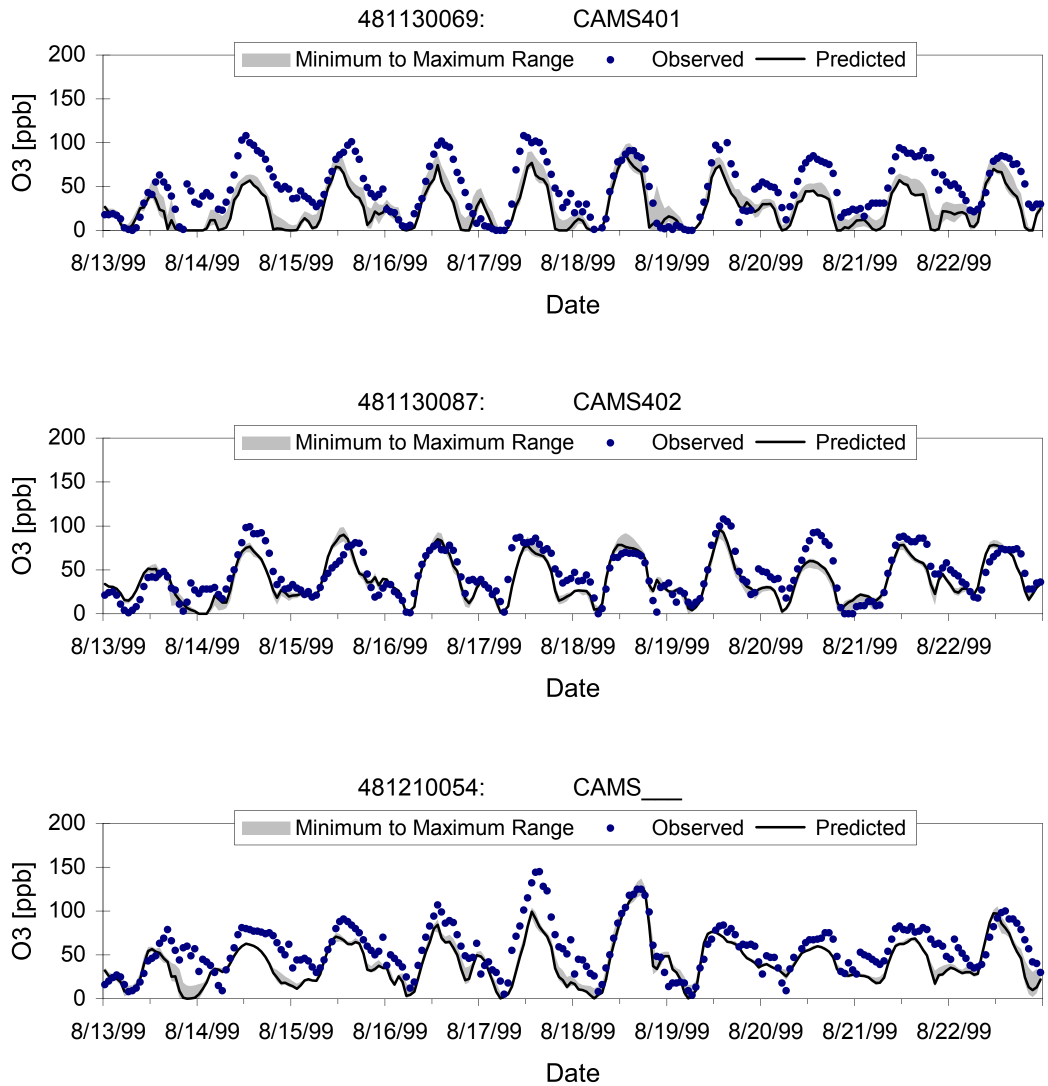


Figure 6-6. Time series of observed and predicted 1-hour ozone concentration in the DFW 4-km grid for Base Case Run6. (Concluded.)

As noted in the conceptual model of ozone formation in the DFW non-attainment area (ENVIRON, 2002), during this episode in North Central Texas fairly high background concentrations of ozone levels were measured, in the range of approximately 80 ppb. Thus, a successful simulation of the air quality in the region depends on accurately simulated these elevated background levels of ozone and precursor concentrations. For this reason, a series of diagnostic air quality simulations were undertaken to investigate the effect of varying initial and boundary conditions on the model performance for the DFW area. These simulations were designated Run7a through Run7d and are discussed below.

Base Case Run7

Given the underpredictions of the previous simulations a series of diagnostics runs were undertaken to investigate the effects of initial and boundary conditions (IC/BCs) on the predicted ozone concentrations both regionally and within the DFW 4-km modeling domains. The previous simulations utilized ICBCs representative of relatively clean background concentrations, as described in Section 5.

The initial and boundary condition data presented in Table 6-5 are similar to the values used by the Ozone Transport Assessment Group (OTAG) for regional scale modeling of the Eastern US (OTAG, 1996). Changes from the OTAG values are the use of constant values of 40 ppb for ozone and 100 ppb for CO. There was some tendency toward ozone under-prediction in these runs, for example near the end of the episode when a regional haze event with high background ozone influenced Northeast Texas. Diagnostic tests of the August 1999 episode in Northeast Texas (ENVIRON, 2003) evaluated the impact of increasing the ozone boundary condition from 40 ppb to 60 ppb. This change raised ozone levels in Northeast Texas by up to about 15 ppb, but the 60 ppb ozone boundary condition was not used further because it was considered too high to be justified. An earlier analysis of ozone data from AIRS monitors near the boundary of the regional modeling domain for the June 18-23, 1995 episode had found an average ozone boundary condition of 41 ppb (Yarwood et al., 1999), which is very close to the accepted value of 40 ppb (EPA, 1991).

Table 6-5. Clean initial and boundary concentrations used in Base Case Run6.

Species	Concentration (ppb)
O3	40.0
NO	0.000049
NO2	0.08555
CO	100.0
PAR	3.078
HCHO	1.068
ETH	0.005315
ALD2	0.1051
TOL	0.006043
PAN	0.03834
HNO2	0.000728
HNO3	1.525
H2O2	2.263
Total NOx	0.086
Total VOC (ppbC)	4.4

The current model applications for DFW also suffer from a tendency to under predict regional ozone levels and so the boundary conditions were re-considered. In particular, the total VOC level of only 4.4 ppbC in the OTAG boundary conditions may be too low in areas where the boundaries of the regional modeling domain are over land. The regional boundary conditions for the NETAC and DFW June 18-23, 1995 episode had used VOC boundary conditions that varied by boundary segment over a range from 9 to 50 ppbC (Yarwood et al., 1999). Similar boundary conditions were developed for the August 13-22, 1999 episode, as described below.

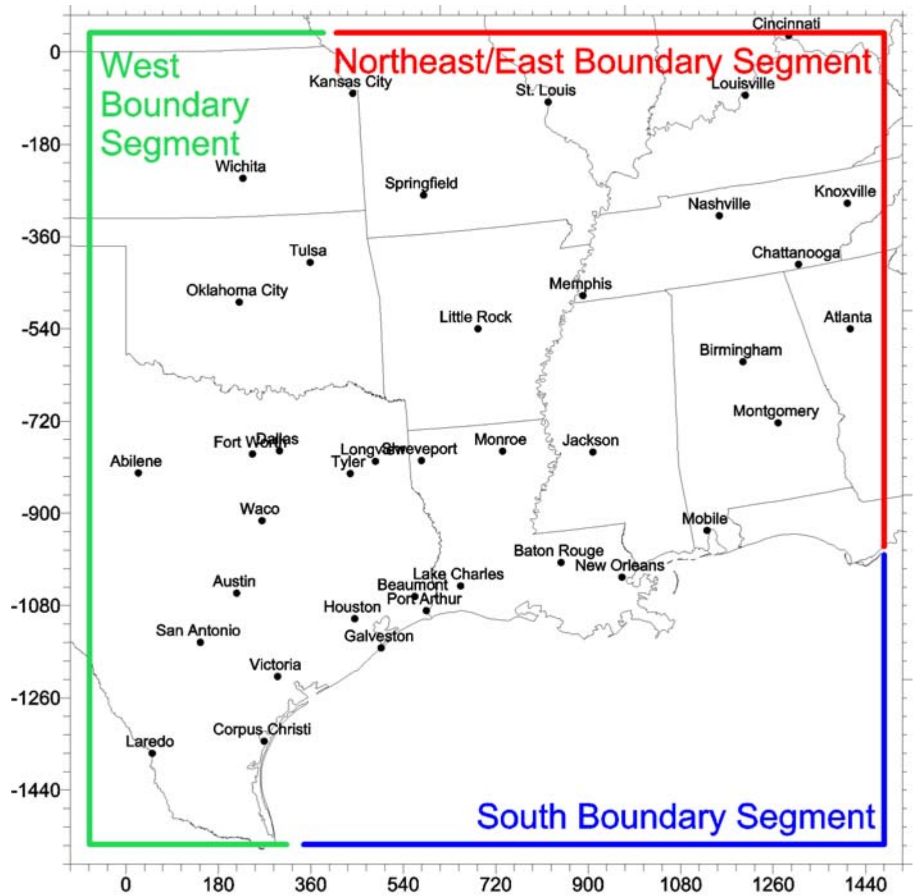


Figure 6-7. CAMx 36-km regional modeling domain showing boundary segments that are assigned different boundary conditions (BCs).

The boundary conditions that varied by segment are documented in Figure 6-7 and Table 6-6. The concentration values in column 2 of Table 6-6 were applied along the East and Northeast segment of the 36-km grid (from Florida through Missouri) from the surface through 1700m (CAMx layers 1 through 11). Values from column 3 of Table 6-6 were applied along the Western boundary segment (Nebraska through Mexico) from the surface through 1700m of the modeling domain. Values from column 4 of Table 2 were applied along the Southern boundary as well as for all boundaries above 1700m (CAMx layers 12 through 15 and the model top). The initial conditions (ICs) were set to column 4 of Table 6-6.

Table 6-6. Boundary concentrations that vary by region.

Species	East/Northeastern Boundary Below 1700 m (ppb)	Western Boundary Below 1700 m (ppb)	Southern Boundary and Above 1700 m (ppb)
O3	40.0	40.0	40.0
NO	0.1	0.1	0.1
NO2	1.0	1.0	1.0
CO	200.0	200.0	100.0
PAR	14.9	14.9	14.9
HCHO	2.1	2.1	0.05
ETH	0.51	0.51	0.15
ALD2	0.555	0.555	0.05
TOL	0.18	0.18	0.0786
PAN	0.1	0.1	0.1
HNO2	0.001	0.001	0.001
HNO3	3.0	3.0	1.0
H2O2	3.0	3.0	1.0
OLE	0.3	0.3	0.056
XYL	0.0975	0.0975	0.0688
ISOP	3.6	0.1	0.001
MEOH	8.5	0.001	0.001
ETOH	1.1	0.001	0.001
Total NOx	1.1	1.1	1.1
Total VOC (ppbC)	50.5	22.3	9.3

The boundary condition values shown in Table 6-6 were originally developed for TNRCC regional modeling of August/September 1991 (Yocke, et al., 1996) and were based on several data sources. The East/Northeastern Boundary concentrations were based on EPA's guidance for UAM modeling (EPA, 1991) with CO reduced from 350 ppb to 200 ppb and higher biogenic VOCs (ISOP, MEOH and ETOH) based on measurements at Kinterbish, AL for the Rural Oxidants in the Southern Environment study (Goldan et al., 1995). The Western boundary concentrations were based on EPA's UAM modeling guidance (EPA, 1991) with CO reduced from 350 ppb to 200 ppb and were consistent with data from Niwot Ridge, CO (Watkins et al., 1995). The Southern Boundary concentrations were based on the GMAQS (Gulf of Mexico Air Quality Study) sponsored by the Minerals Management Service (MMS, 1995).

Run7a and Run7b

A diagnostic simulation was run to investigate the effect of IC/BCs on the model performance within the 4-km DFW modeling domain. The initial diagnostic simulation, Run7a, used the values are listed in Column 1 of Table 6-6 applied to all boundary segments and for all vertical layers in the modeling domain. This run was intended to determine what effect these values would have on the overall modeling results.

Base Case Run7b also used these precursor species concentrations for IC/BCs but with initial and boundary ozone concentrations increased to 60 ppb.

The results of these diagnostic simulations were seen to reduce the negative bias in 1-hour ozone concentrations significantly. In fact, for Run7b, all simulations days, except the first spin-up day, August 13, met EPA's model performance goals for normalized bias and gross error for 1-hour ozone concentrations.

Run7c

Based on these simulation results, an additional IC/BC diagnostic run was conducted in which the application of the SOS based precursor concentrations were refined to more realistically simulate actual conditions. For Run7c the refined IC/BCs, as described above, were applied.

The 1-hour ozone concentrations from base case Run7c while still exhibiting some underpredictions, met the model performance goals for normalized bias on 5 of the 10 simulation days. One additional day, August 20, showed a negative bias only slightly outside of the EPA's goal of +-15%. While Run7b resulted in superior model performance, it was considered only a diagnostic run since the IC/BCs used were not refined in a manner that more closely replicates the observed concentrations in the atmosphere during the episode based on the Southern Oxidant Study.

The spatial distribution of daily maximum 1-hour ozone concentrations are displayed n Figures 6-8 and 6-9 for the DFW 4-km and 12-km regional modeling domains respectively. Examination of these figures illustrates the impact of the increased precursor concentrations from the boundary of the domain as well as the impacts due to long range transport on the DFW 4-km modeling domain. The results in the 4-km domain show that the magnitude of the daily maximum 1-hour ozone concentrations are well simulated although the locations of the urban plumes are slightly out of line with the observations on some of the episode days. An examination of the spatial distribution of the hourly concentrations indicate that there may be a slight bias in wind speeds and/or wind directions. This may be a possible cause for the negative bias in the model predictions as regions of elevated ozone concentrations are moved away from the monitor locations too quickly with respect to the observations. Also apparent from displays of the spatial distribution of ozone is the increase in background concentrations. Comparing the results of Run6 and Run7c, an average increase of approximately 15 ppb region-wide can be seen.

Examination of the time series plots of observed and predicted hourly ozone concentrations displayed in Figure 6-10 show considerable improvement in the model's ability to replicate both the elevated ozone concentrations as well as the lower concentrations levels during the early morning and late evening hours. Evaluation of the time series displays reveals that at some monitors the model predicts the peaks earlier than observed, so that when the observed peaks occur, the model is already predicted a downward trend in hourly ozone leading to a negative bias. In a few cases, the opposite is true, i.e., the predicted peaks occur after the observed peaks.

Given the increase in region-wide predicted ozone levels it is instructive to evaluate the model performance for monitor in upwind regions of the domain as well as some of the more predominantly rural sites within the 12-km modeling domain. Examination of the model performance in the 12-km domain shown in Table 6-3b shows that with respect to EPA performance goals the model is replicating the observed ozone concentrations fairly well.

Model performance in the 12-km grid is acceptable for characterizing ozone levels in the areas around the 4-km grid.

Figures 6-11 and 6-12 display time series of 1-hour ozone concentrations for upwind monitors in Louisiana, Arkansas and East Texas for Run6 and Run7c, respectively. As seen, the model is replicating the ozone levels at these rural monitor sites better in Run7c as compared to Run6, illustrating the appropriateness of the increased precursor boundary concentrations. AIRS monitor 050970001 is located at a Forest Ranger Station in Montgomery County, Arkansas; monitor 220170001 is located in Caddo Parish, Louisiana, north of Shreveport and outside of the urbanized area; CAMS_50 is located in Marion County, Texas and is the most rural monitor in East Texas. At these sites, the model better replicates the low nighttime and morning ozone concentrations in Run7c than in Run6 for several episode days. Daytime ozone concentrations are also better represented at many of these rural sites for several episode days illustrating the overall improvement in background regional ozone levels due to the incr4eased precursor boundary conditions.

Based on the results of these IC/BC diagnostic runs, although Run7b gives the best model performance of all the simulations conducted, Base Case Run7c is considered more technically defensible in that the initial and boundary conditions are applied in a way that more closely replicates the findings of the SOS Boundary Condition study. A final IC/BC diagnostic simulation was undertaken which increased the ozone concentrations on the boundaries to 60 ppb (Run7d). This simulation did not significantly improve the model performance and in addition, it was not felt to be a technically defensible simulation as there is not sufficient evidence to support the increased ozone concentrations.

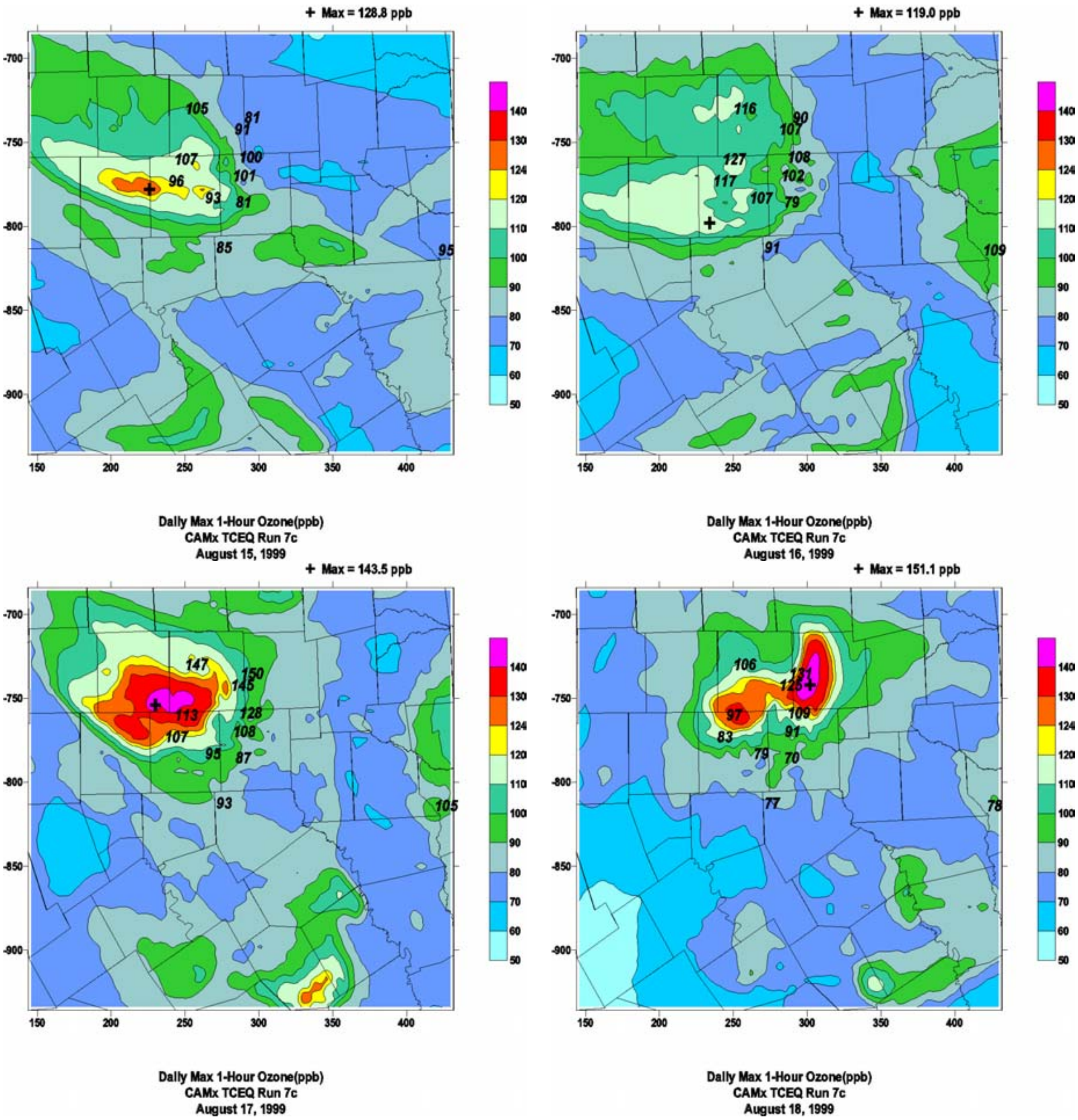


Figure 6-8. Spatial distribution of daily maximum ozone concentrations in the DFW 4-km grid for Base Case Run7c.

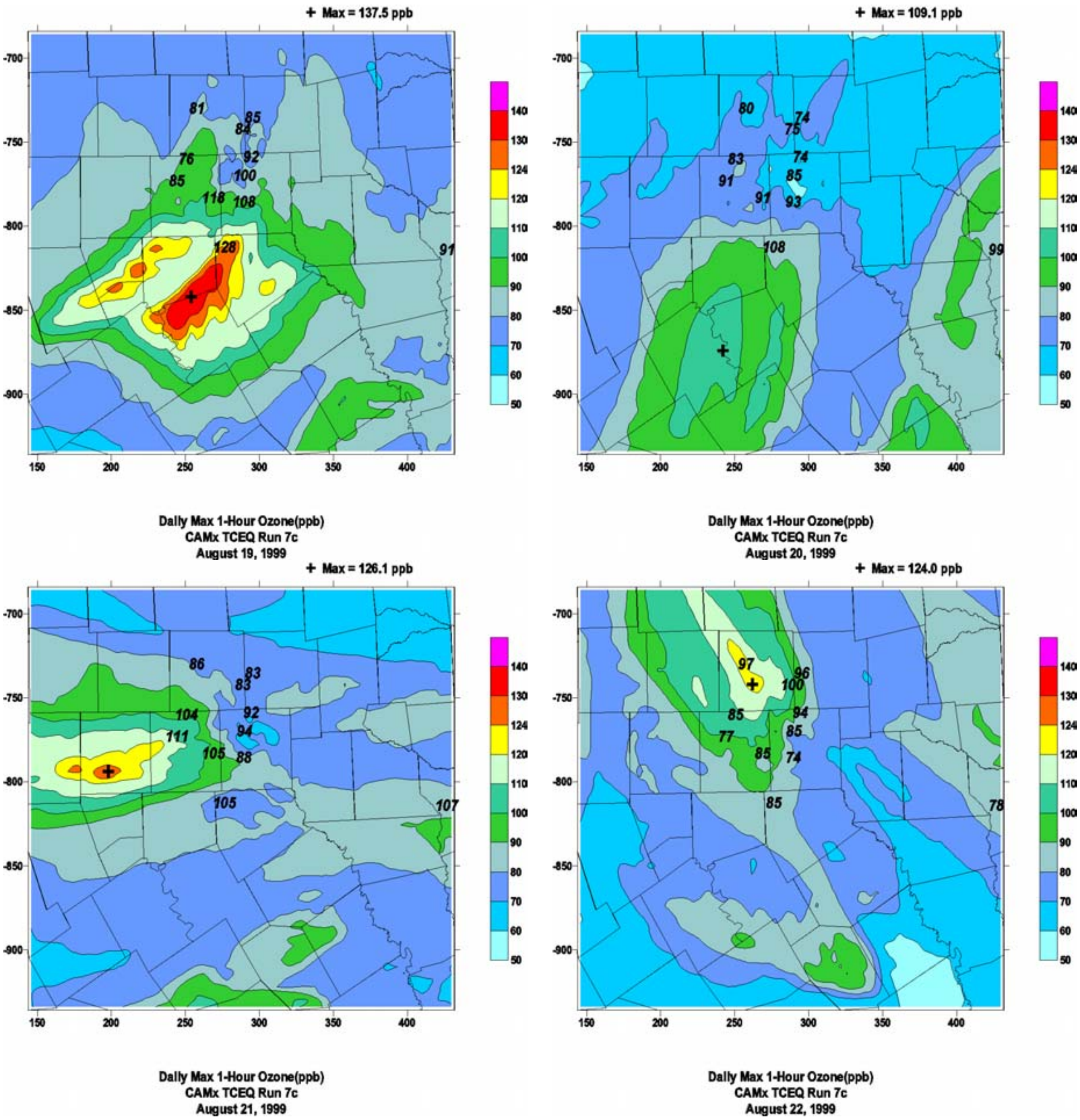


Figure 6-8. Spatial distribution of daily maximum ozone concentrations in the DFW 4-km grid for Base Case Run7c. (Concluded.)

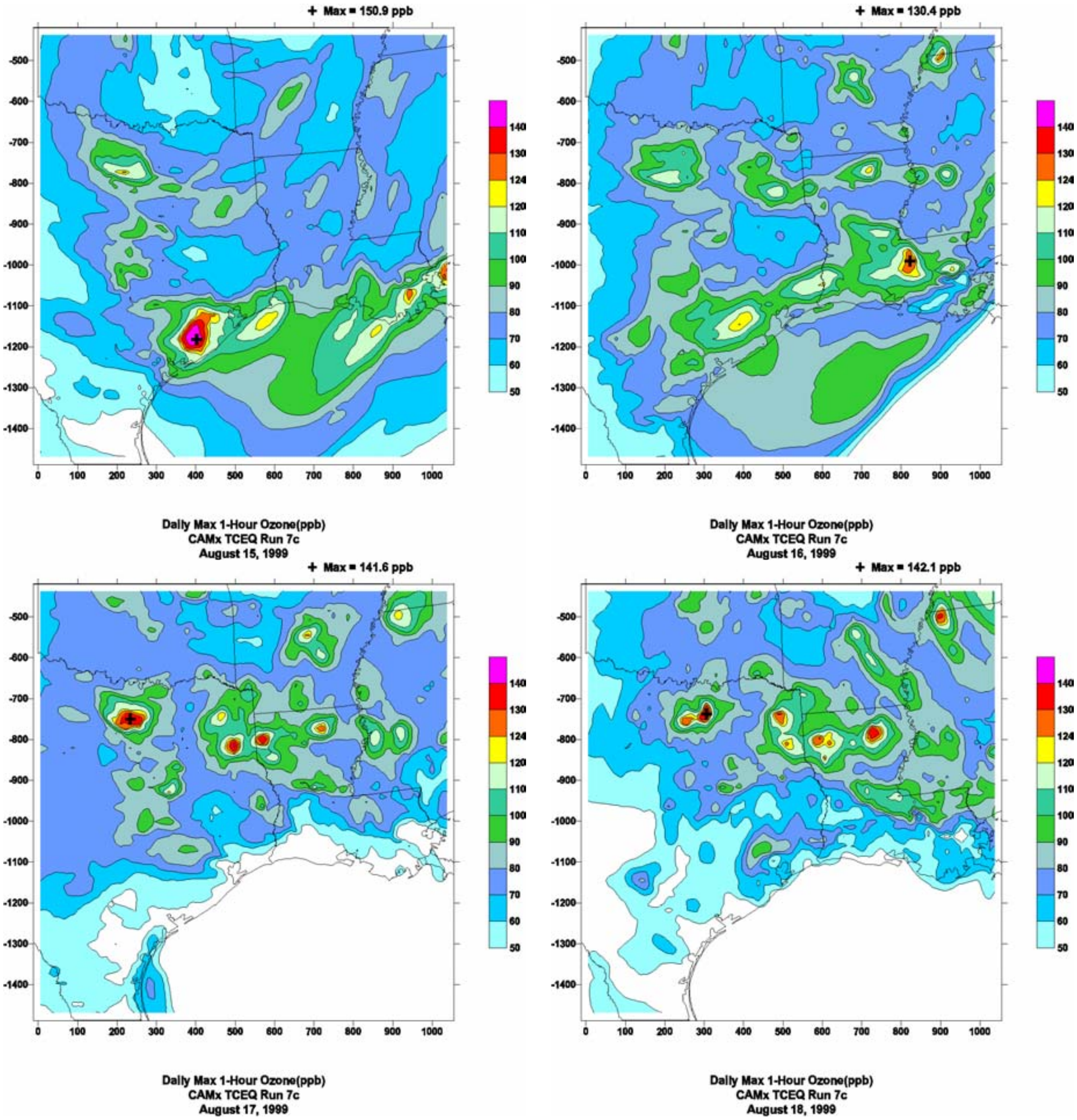


Figure 6-9. Spatial distribution of daily maximum ozone concentrations in the 12-km regional grid for Base Case Run7c.

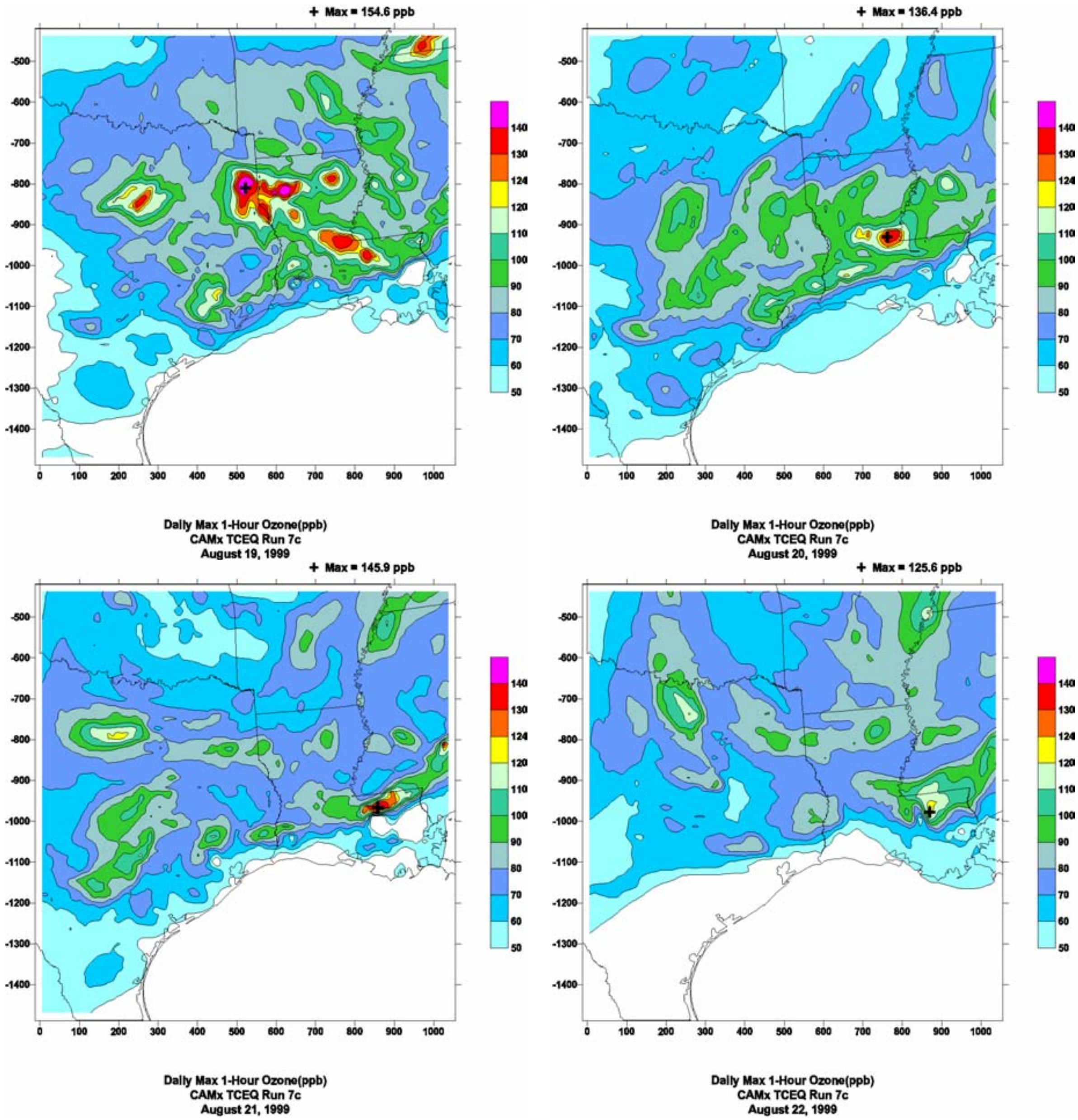


Figure 6-9. Spatial distribution of daily maximum ozone concentrations in the 12-km regional grid for Base Case Run7c. (Concluded.)

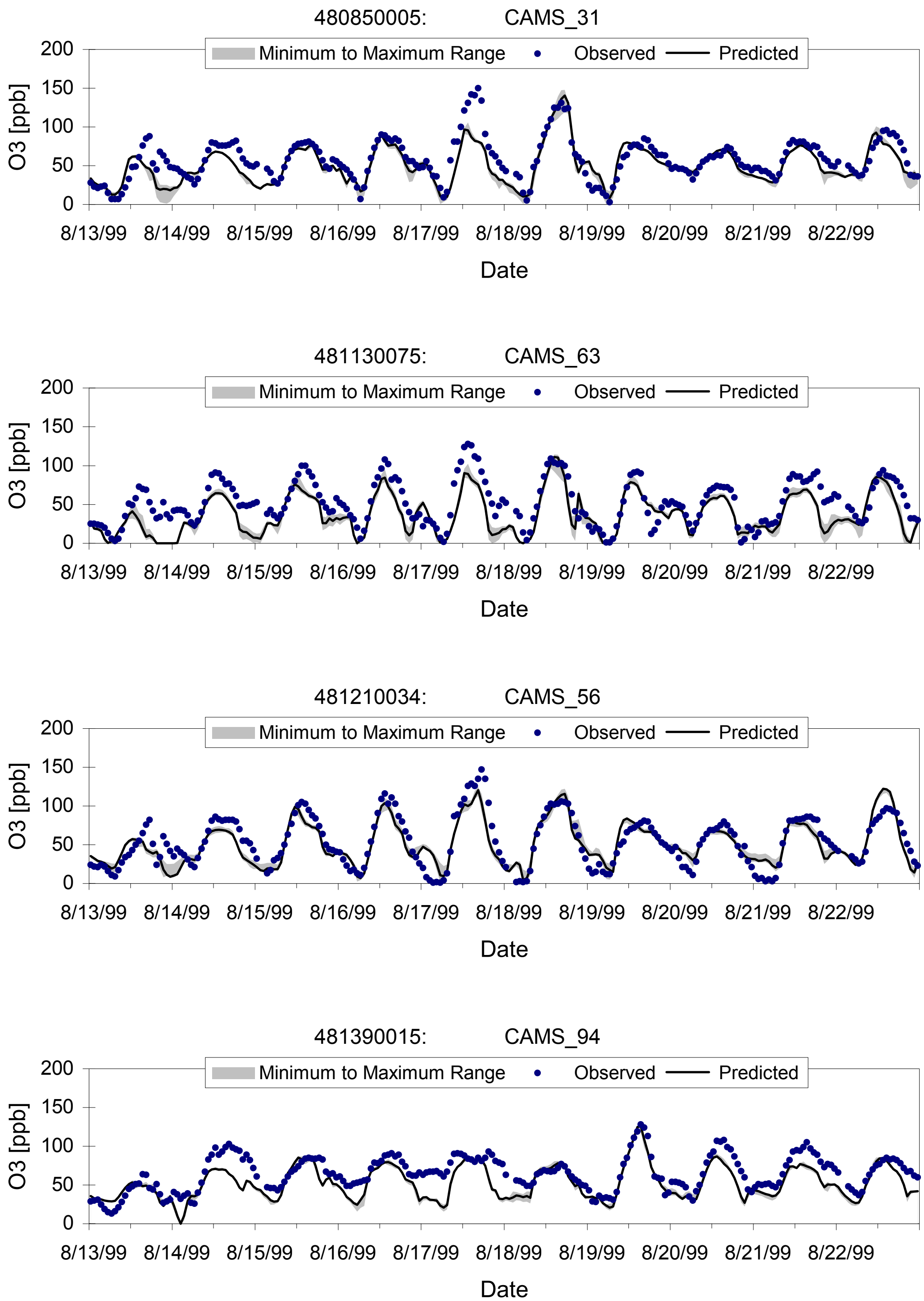


Figure 6-10. Time series of observed and predicted 1-hour ozone concentration in the DFW 4-km grid for Base Case Run7c.

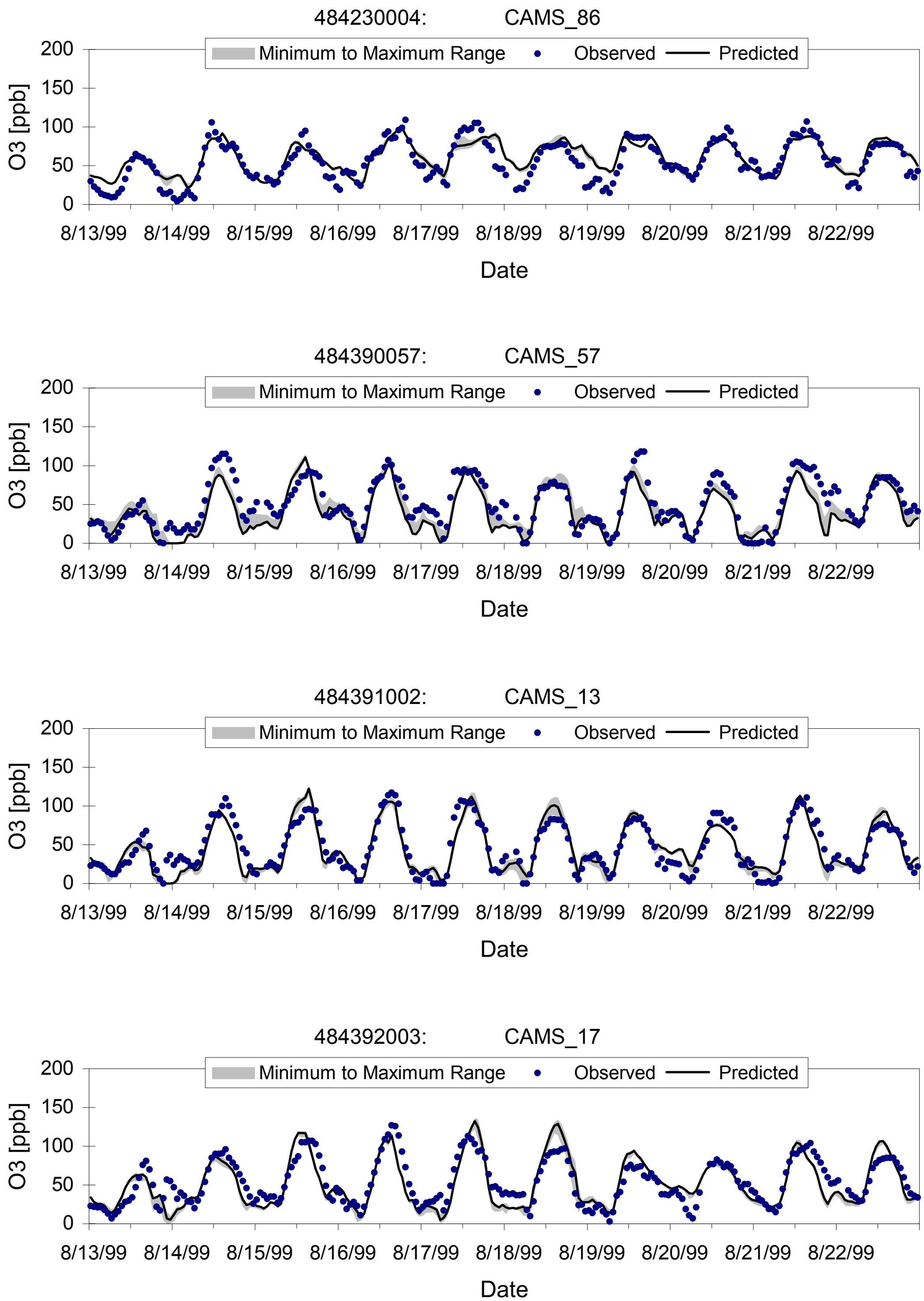


Figure 6-10. Time series of observed and predicted 1-hour ozone concentration in the DFW 4-km grid for Base Case Run7c. (Continued).

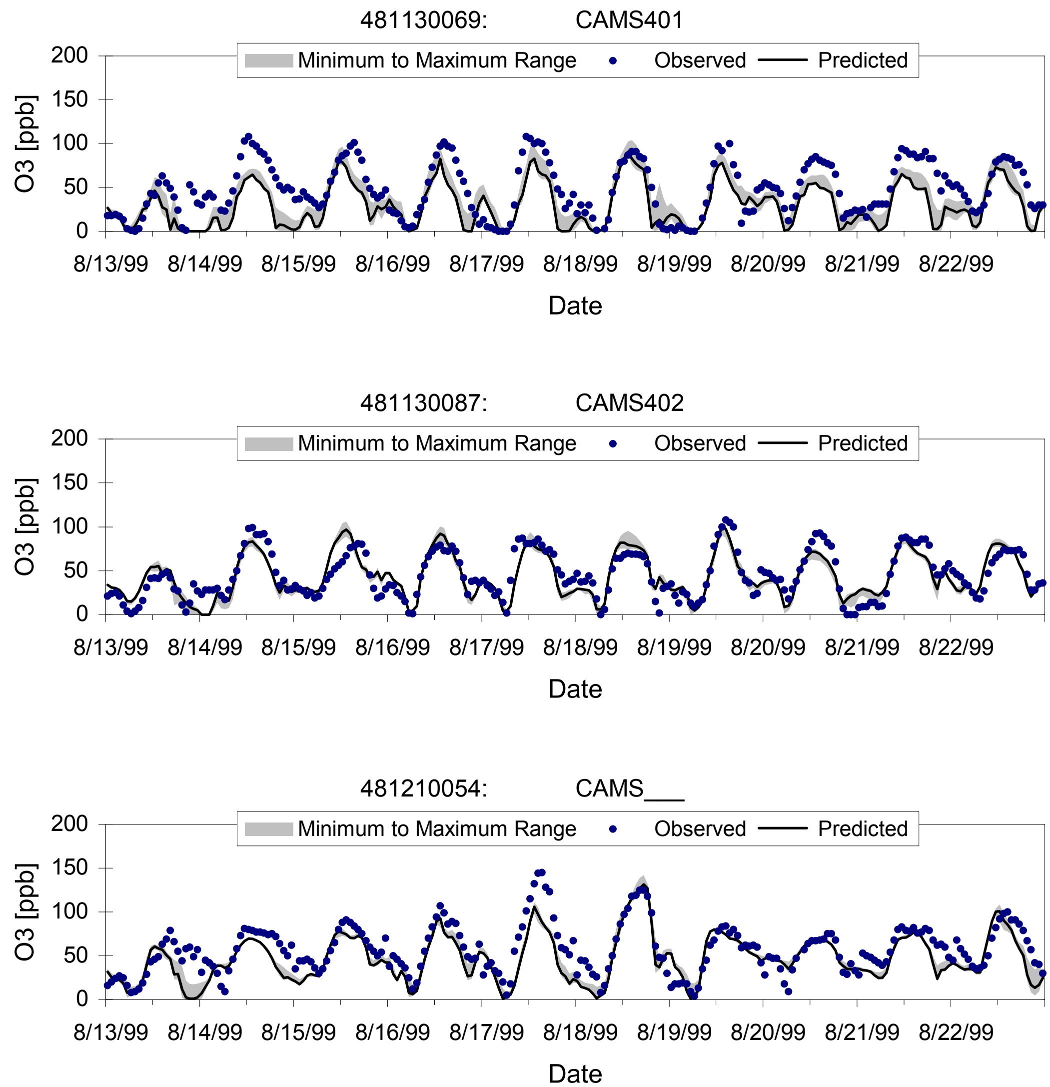
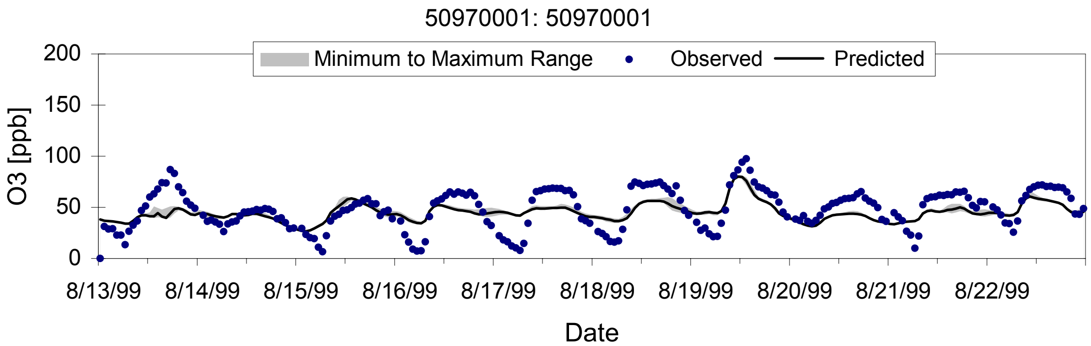
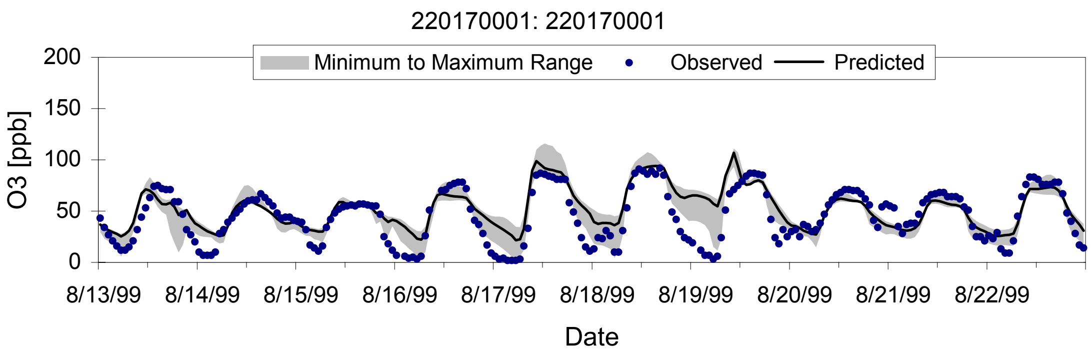


Figure 6-10. Time series of observed and predicted 1-hour ozone concentration in the DFW 4-km grid for Base Case Run7c. (Concluded).





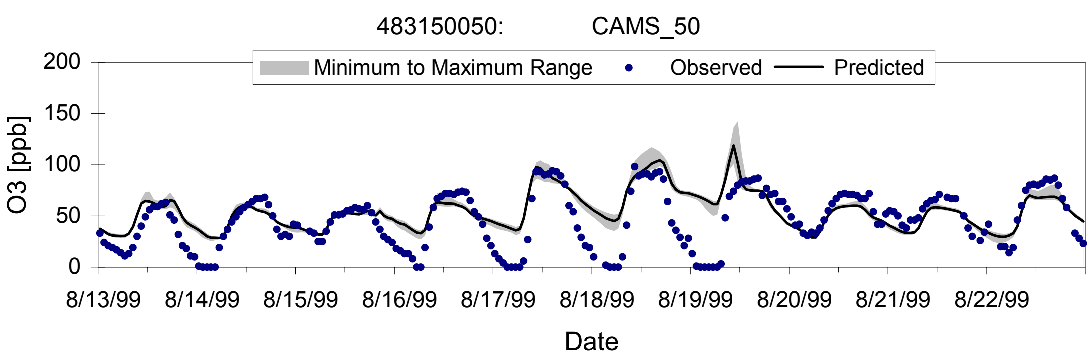
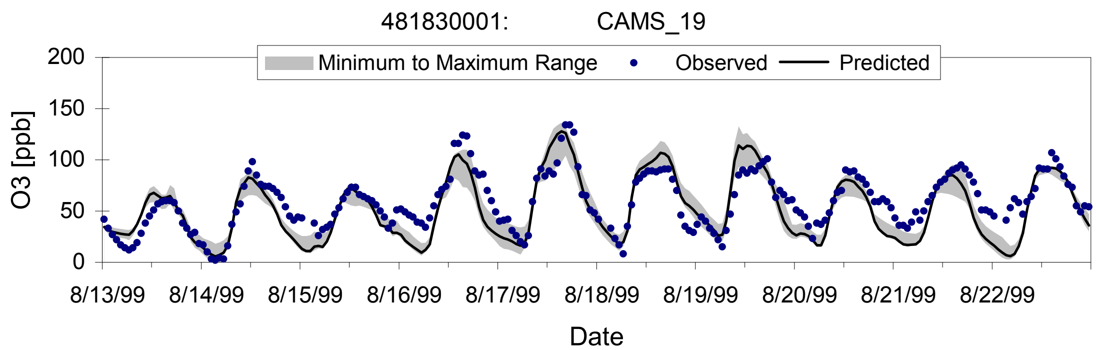
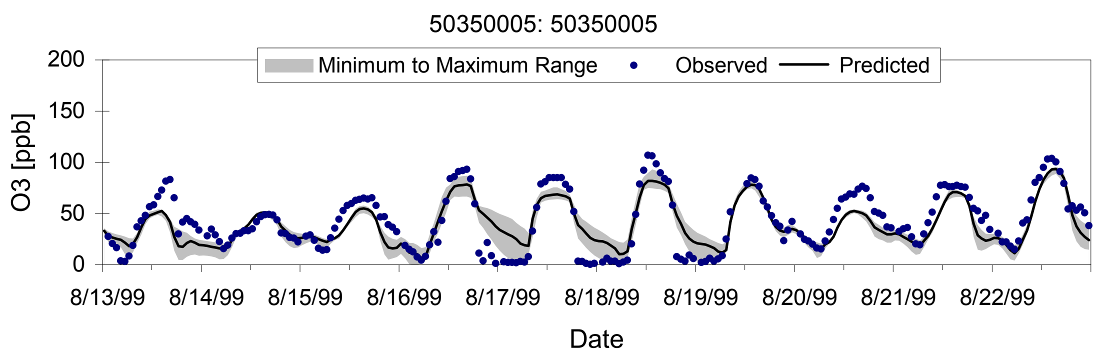


Figure 6-11. Time series of observed and predicted 1-hour ozone concentrations for upwind monitors for Base Case Run6.





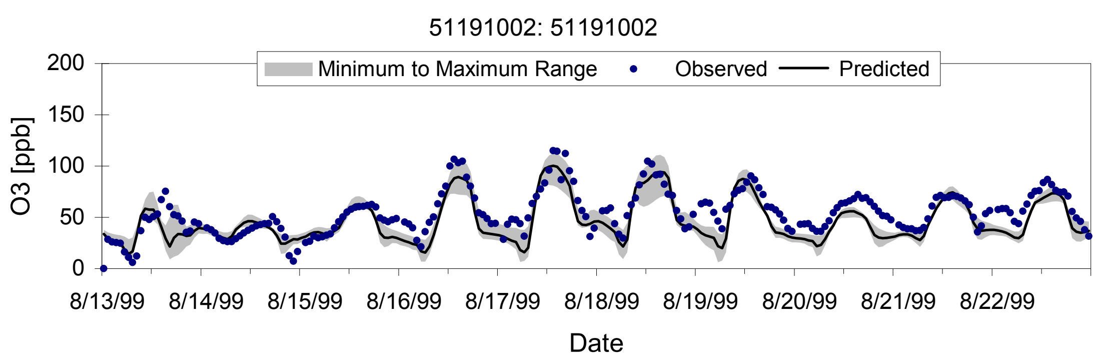
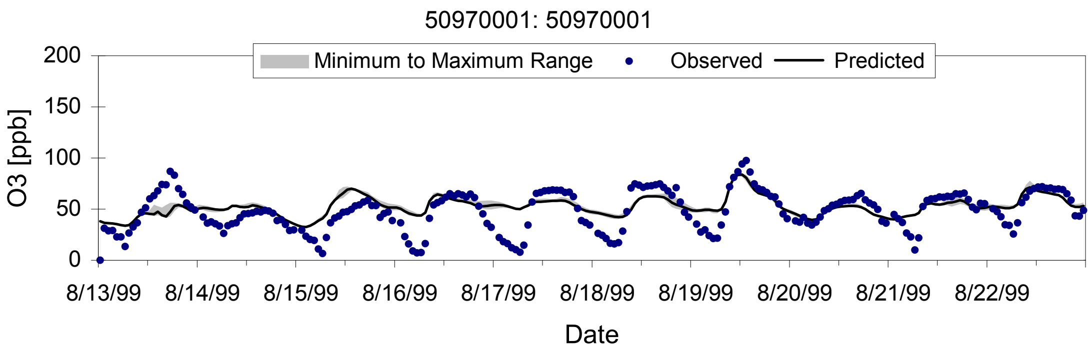
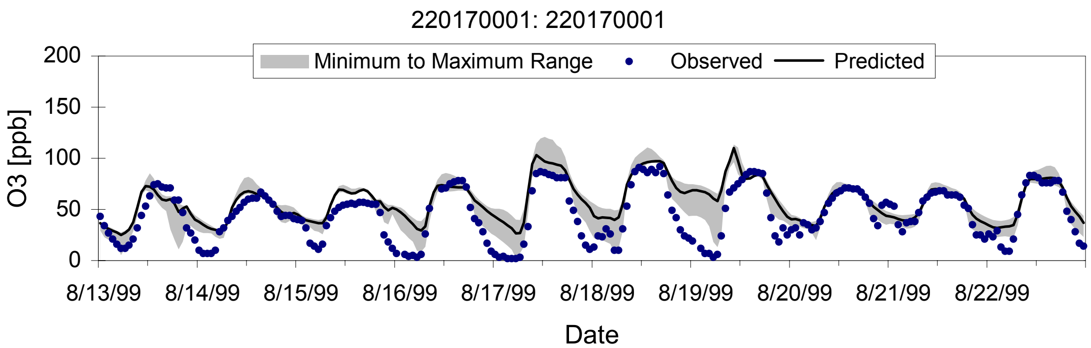


Figure 6-11. Time series of observed and predicted 1-hour ozone concentrations for upwind monitors for Base Case Run6. (Concluded).





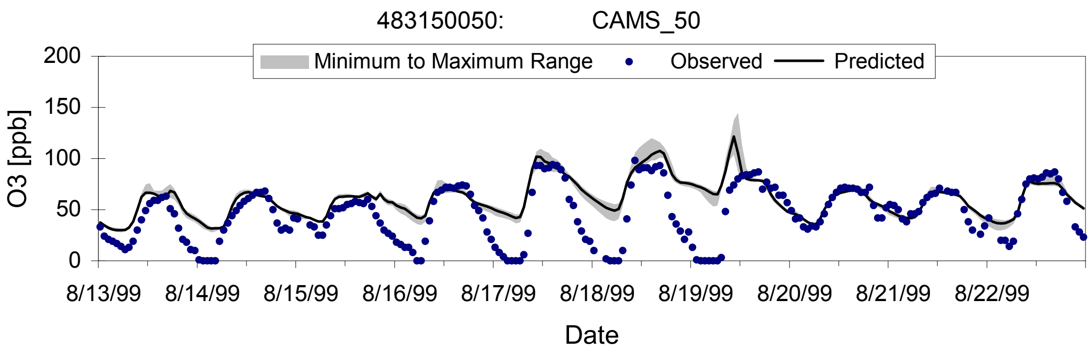


Figure 6-12. Time series of observed and predicted 1-hour ozone concentrations for upwind monitors for Base Case Run7c.

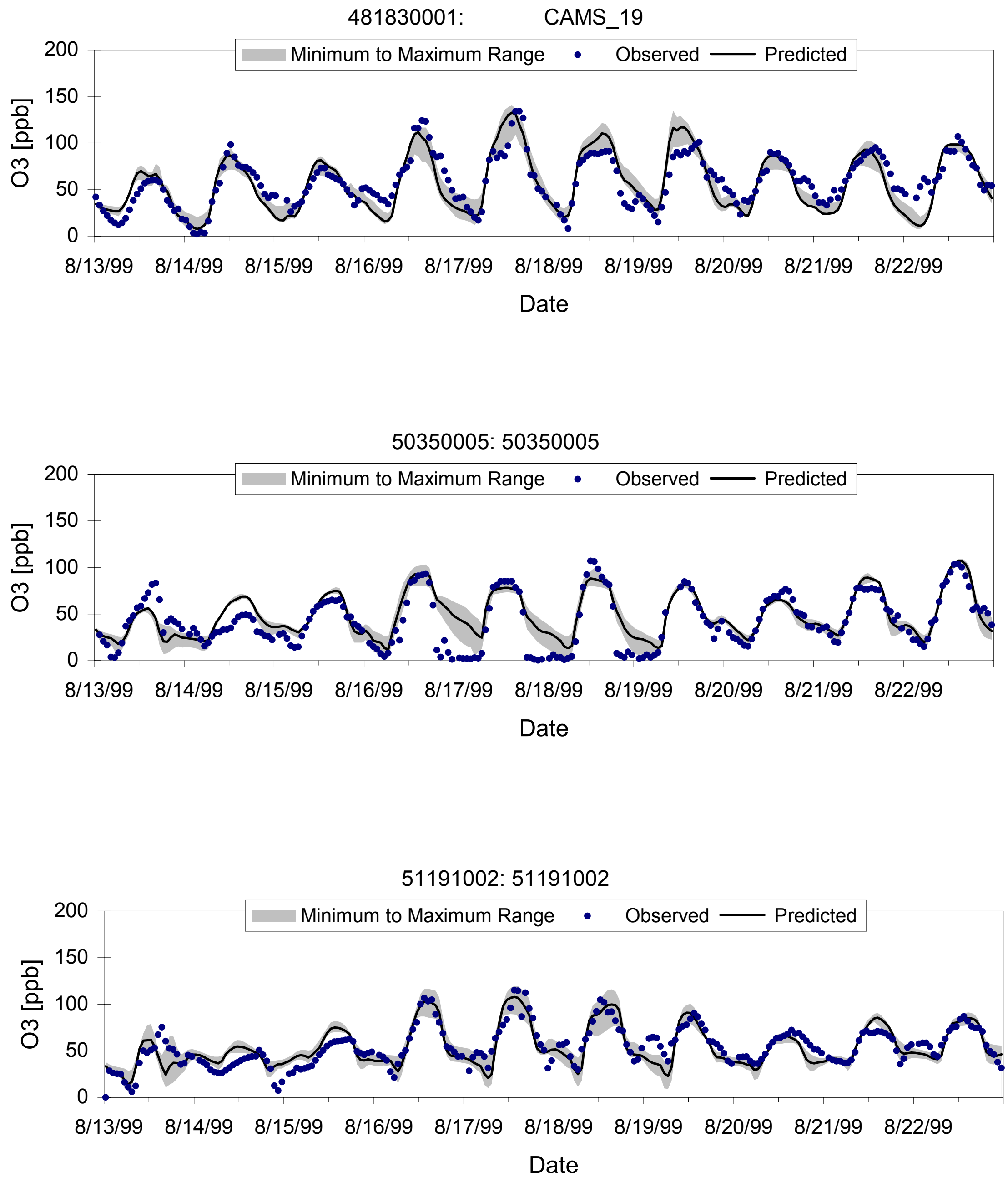


Figure 6-12. Time series of observed and predicted 1-hour ozone concentrations for upwind monitors for Base Case Run7c. (Concluded).

The spatial distribution of daily maximum 8-hour ozone concentrations in the DFW 4-km modeling grid are shown in Figure 6-13 for Run7c. In general the spatial patterns 8-hour ozone match the observed concentrations in terms of the extent and direction of the urban plumes. The model tends to over-predict the observed peaks although overall there is still a tendency to under-predict the hourly ozone concentrations. While EPA guidance for 8-hour model performance goals is not yet finalized, the normalized bias in the 4-km grid is within 15% on 6 of the 8 episode days (excluding the two spin-up days). Normalized error statistics are also within the performance goals (for 1-hour ozone) of 35% on all but the first spin-up day. Eight-hour model performance statistics for all 1999 model simulations are presented in Table 6-3.

Figure 6-14 displays the daily maximum 8-hour ozone concentrations for the 12-km regional modeling domain for Run7c. The model predicts a general background level of 8-hour concentrations in the 70-80 ppb range, with elevated 8-hour ozone levels in and around the urban areas of the domain. These results illustrate the model is performing fairly well in replicating the observed concentration levels during the 1999 episode which was characterized by high regional concentration levels for 8-hour ozone.

Time series plots of observed and predicted 8-hour ozone for the DFW 4-km modeling grid are displayed in Figure 6-15. While the model predicts the daily variation of 8-hour ozone fairly well at many monitors, the under-prediction bias is still apparent, particularly on the August 17th episode day. These results are reflected in the statistical performance measures presented in Table 6-3.

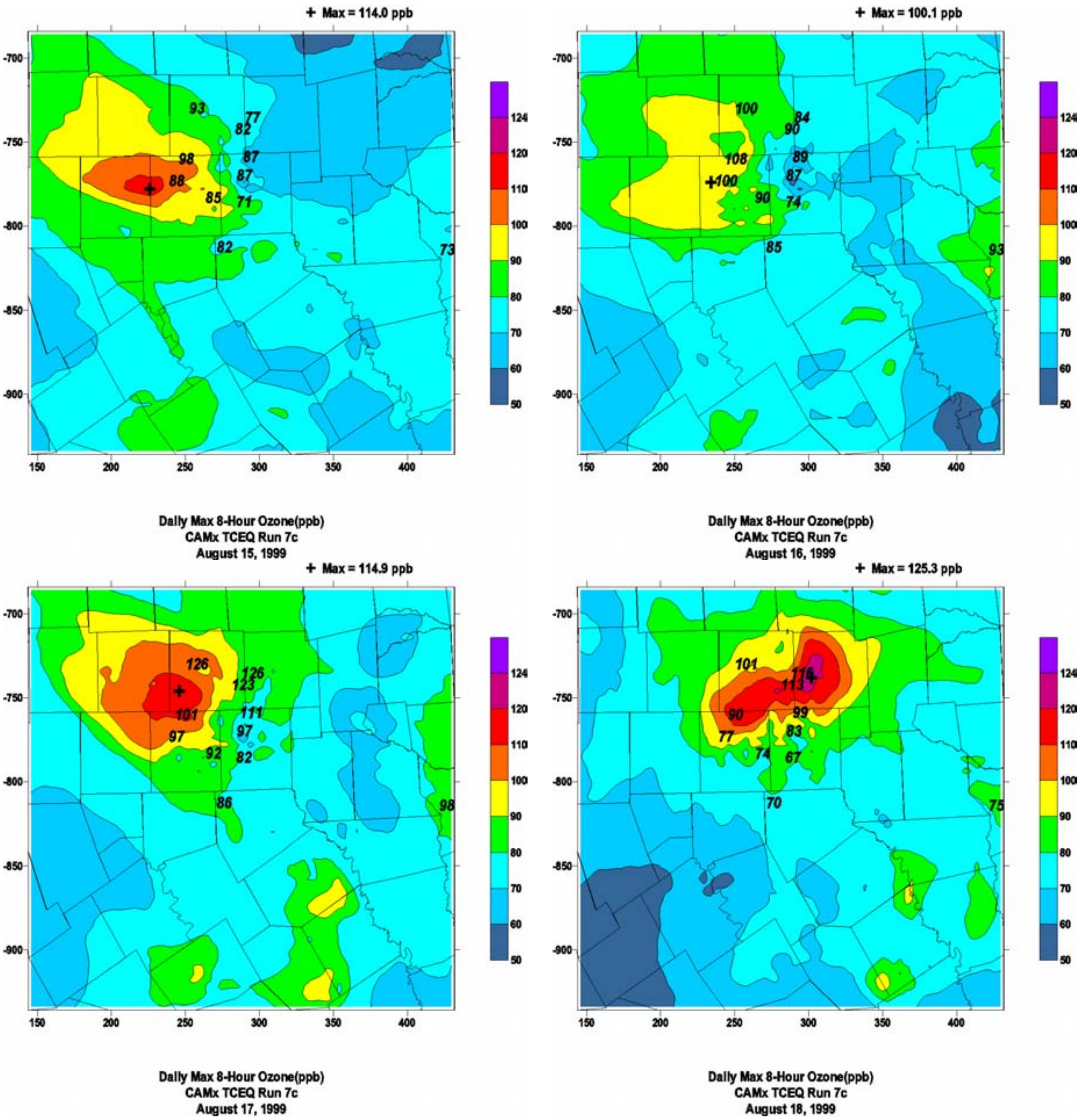


Figure 6-13. Spatial distribution of daily maximum 8-hr ozone concentrations in the DFW 4-km grid for Base Case Run7c.

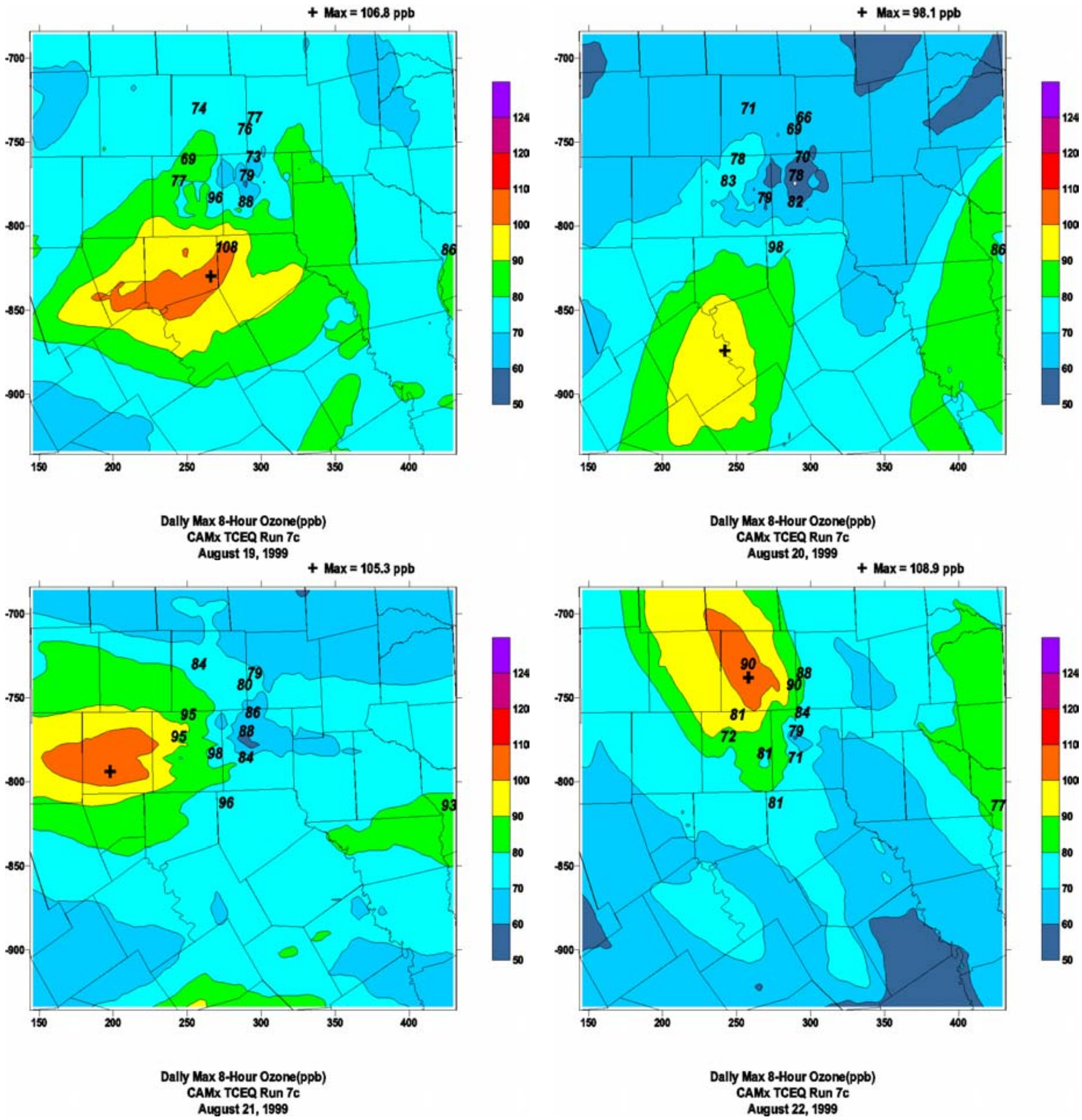


Figure 6-13. Spatial distribution of daily maximum 8-hr ozone concentrations in the DFW 4-km grid for Base Case Run7c. (Concluded.)

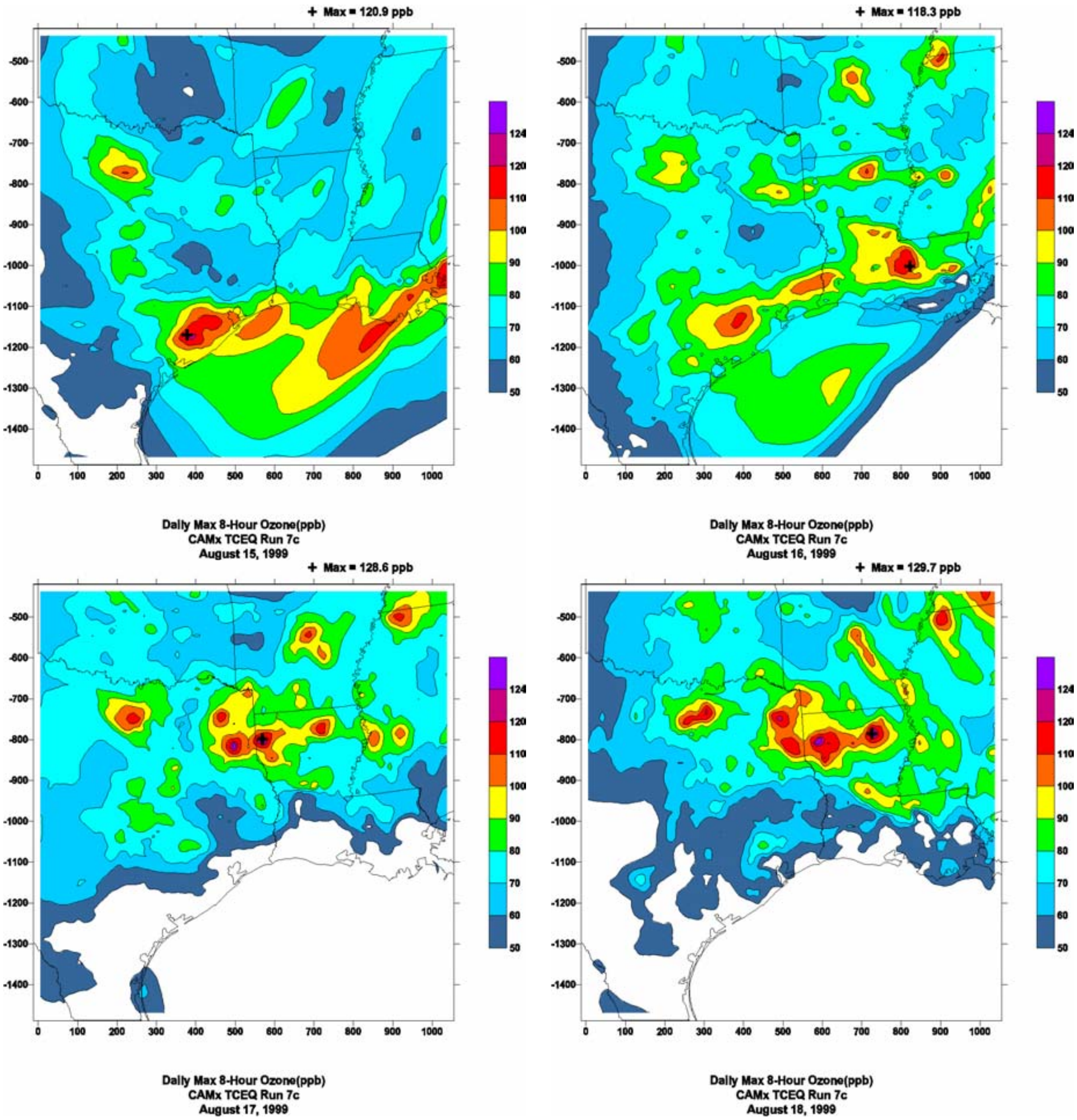


Figure 6-14. Spatial distribution of daily maximum 8-hr ozone concentrations in the 12-km regional grid for Base Case Run7c.

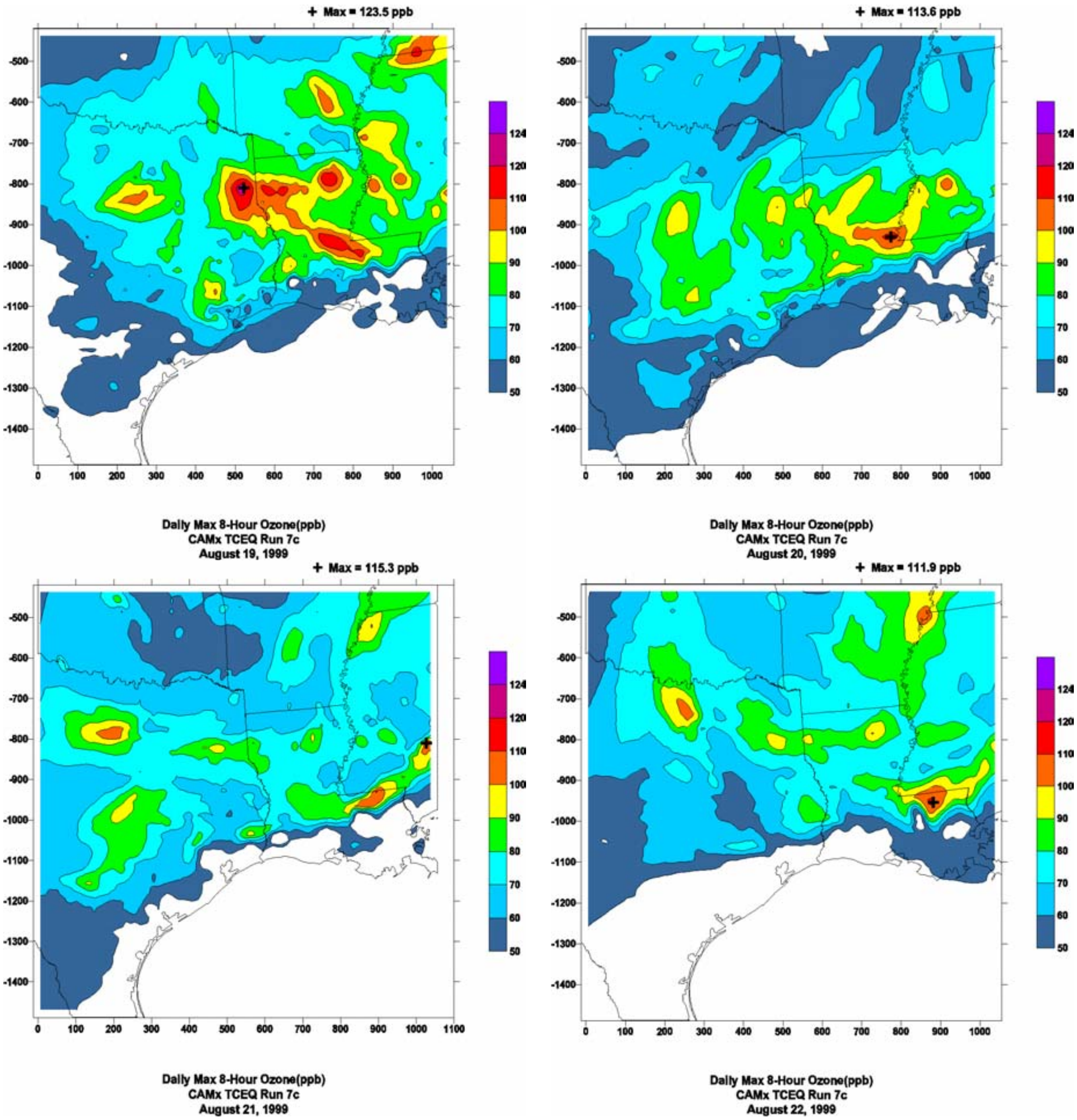


Figure 6-14. Spatial distribution of daily maximum 8-hr ozone concentrations in the 12-km regional grid for Base Case Run7c. (Concluded.)

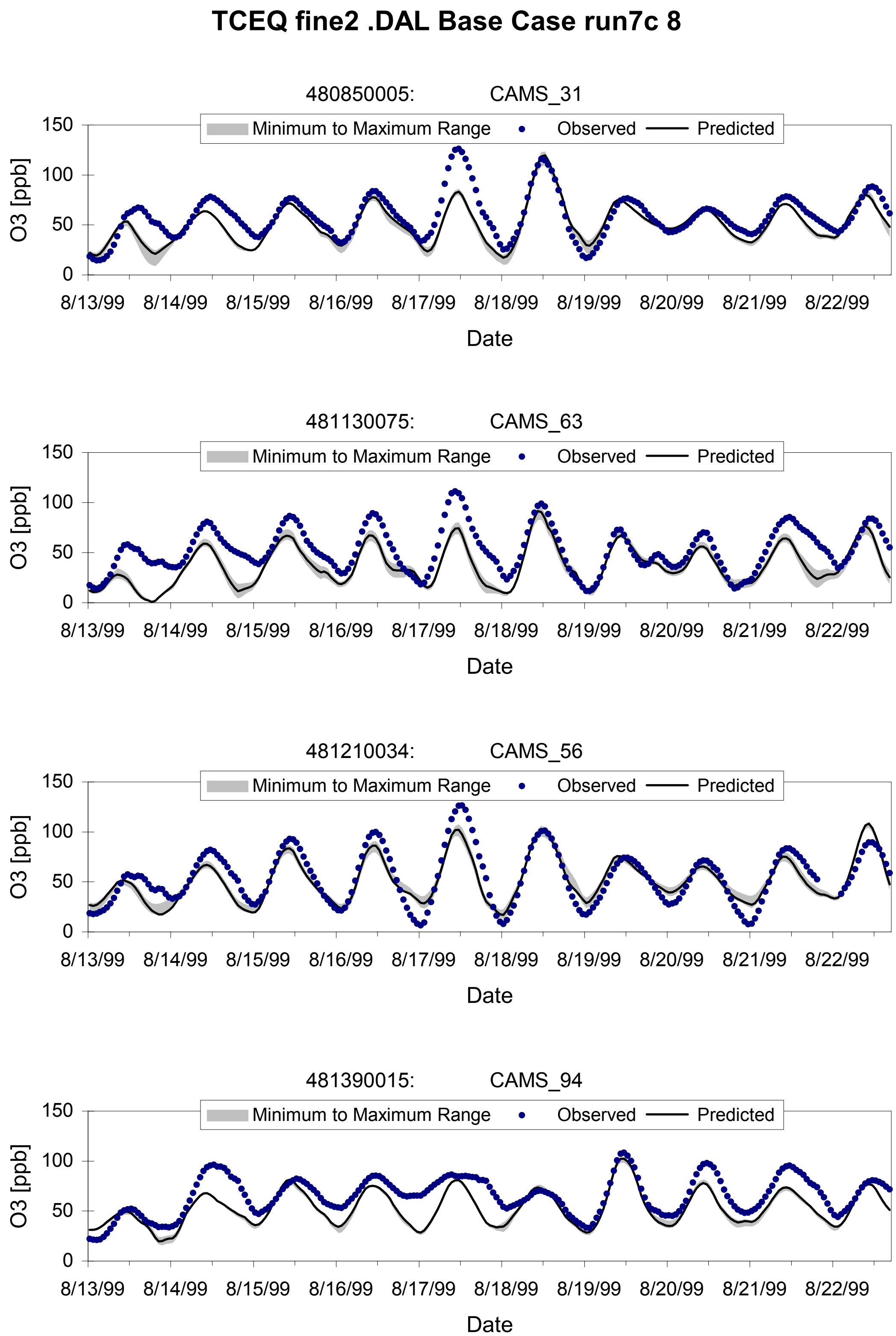


Figure 6-15. Times series of observed and predicted 8-hour ozone concentrations in the DFW 4-km grid for Run7c.

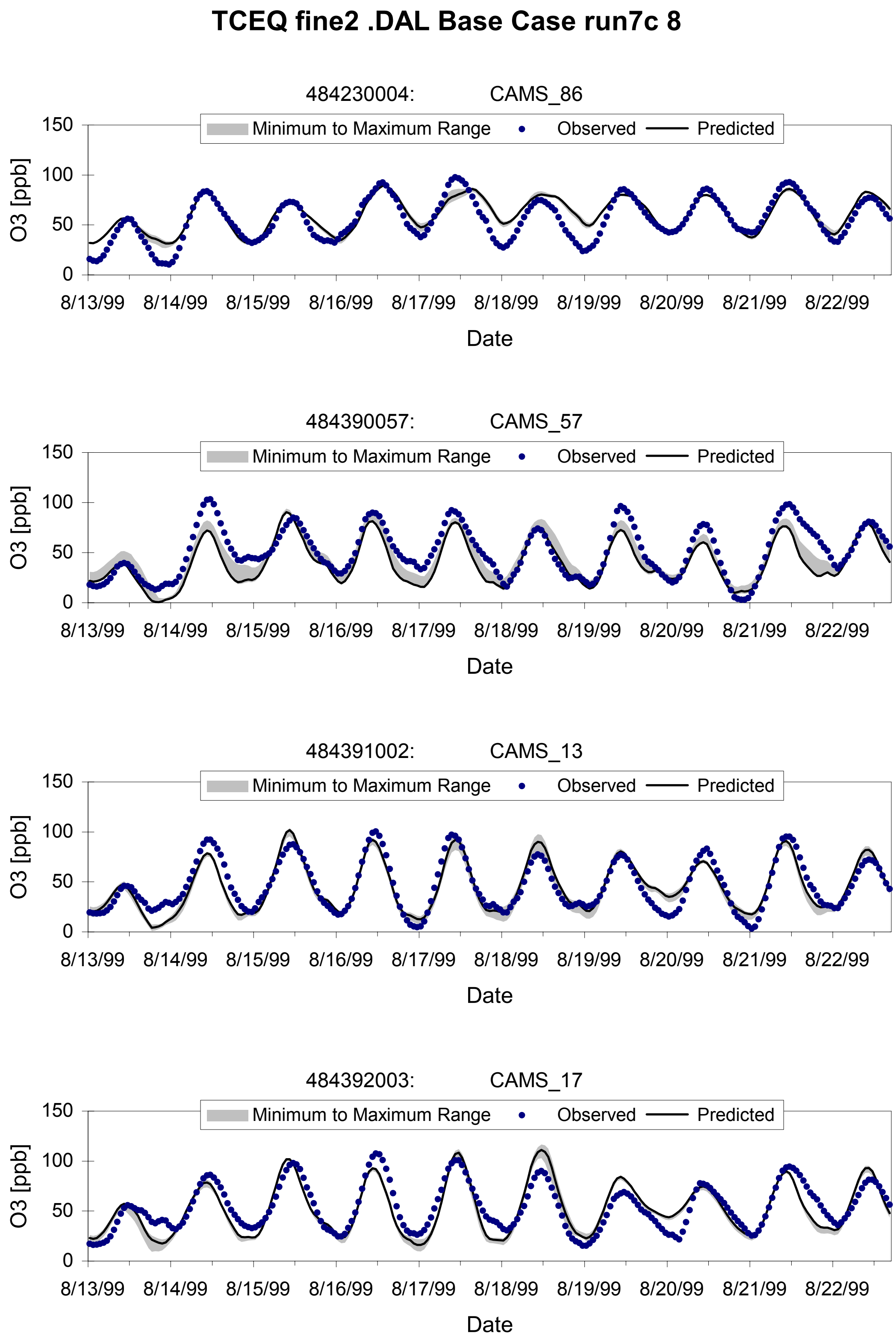


Figure 6-15. Times series of observed and predicted 8-hour ozone concentrations in the DFW 4-km grid for Run7c. (Continued).

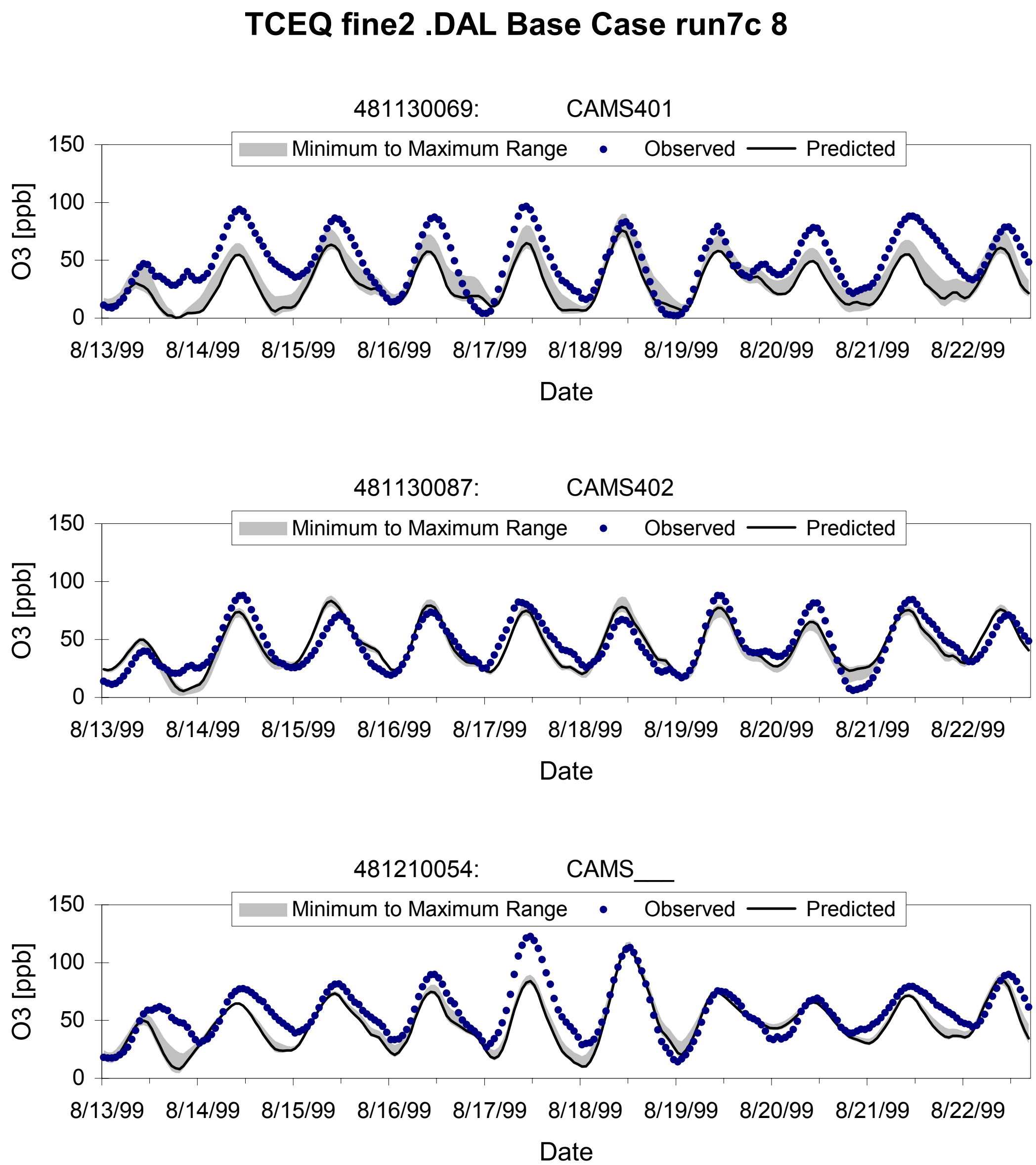


Figure 6-15. Times series of observed and predicted 8-hour ozone concentrations in the DFW 4-km grid for Run7c. (Concluded).

Base Case Sensitivity Runs

A series of sensitivity runs were conducted in order to evaluate the sensitivity of the model to various inputs and configuration options. These simulations were considered sensitivity runs, as opposed to diagnostic runs, as they involved the inclusion or omission of various inputs and run options that were not necessarily intended as a means of improving the performance of the model but rather to assess the response of the model to varying inputs and model configuration. A brief description and discussion of these simulations is presented below.

Run8 and Run9

The sensitivity of the modeled ozone concentrations to clouds and wet deposition were evaluated in Run8 and Run9. In Run8 and Run8a clouds were not included in the simulation. Run8 used the clean initial and boundary condition values as discussed in Section 5, while Run8a used the refined IC/BC as in Run7c. It was expected that this simulation would show somewhat higher ozone concentrations overall as the presences of clouds has the affect of reducing the photolysis rates within the model. An examination of the results of these simulations were somewhat unexpected as the negative bias in the DFW 4-km grid was not significantly alleviated. In fact the performance statistics exhibited an even greater negative bias on several episode days. However, due to the inclusion of the rainfall rates and cloud cover in the same meteorological input files for CAMx, this simulation also necessarily included no wet deposition. Therefore the impacts are more complicated to evaluate since the removal of cloud cover increases photolysis rates while the removal of precipitation in the simulation may result in more precursor pollutants which otherwise may have been removed through washout and wet deposition.

Run9 involved to turning off the wet deposition within the simulation. As with Run8, simulations with the clean IC/BCs (Run9) and the refined application of the SOS precursor IC/BCs (Run9a) were conducted. The removal of wet deposition in the model affects both the predicted ozone concentrations and the amount of precursor pollutants in the simulation. The CAMx uses a run option to implement wet deposition, so in this case clouds were still present in the simulation. Photolysis rates are attenuated by the presence of cloud cover, while ozone and precursor concentrations are affected by the absence of wet removal processes. As in Run8, the results showed no significant improvement in the overall model performance.

Both Run8 and Run9 warrant further investigation to understand the somewhat counterintuitive results of these simulations.

Run10

In CAMx Run10, the effects of drought on predicted ozone levels were evaluated through an implementation with\in the air quality model. Here, adjustments are made to deposition rates based on the Palmer Drought Index. A discussion of the effects of drought stress on biogenic emissions and deposition rates was presented above. The results of this simulation showed slight improvements over Run7c for some episode days, but overall the performance statistics were not significantly improved.

Run11

The effect of treating large elevated NOx sources with Plume in Grid (PiG) algorithms were investigated in Run11. The PiG treatment of the CAMx model provides a means of tracking large NOx plumes with a spatial higher resolution than possible within the grid model framework. Plume in Grid sources are tracked as distinct plumes for a portion of the simulation until various criteria are met. These include, among others, the age and size of the plumes with respect to the size of the grid cells. When the plumes reach these criteria the mass is added to the grid cell mass. Pollutants from sources not treated with PiG, are injected into the grid cell and are immediately diffused throughout the model grid cell. The overall affect of the PiG treatment is to delay the mixing of NOx with other pollutants, and the subsequent ozone formation and scavenging, and provides a more refined and realistic treatment of NOx plumes.

This simulation was intended to evaluate the effects of the PiG treatment. The results were not unexpected and model performance was not improved. In general, it is recommended that the PiG treatment be used for large elevated NOx sources. No further analysis of this simulation was conducted.

Run12

As discussed in Section 3, the North Central Texas Council of Governments provided updated emission estimates for several off-road mobile source categories. Due to the aggressive project schedule and the late receipt of these data, they were not incorporated into the initial modeling inventory. Subsequent to the initial CAMx model simulations, these data were replaced in the inventory and a sensitivity simulation was conducted. CAMx simulation Run12 included these emission estimates provided by NCTCOG. The model performance statistics for this simulation are presented in Tables 6-3 and 6-4. Overall, the model exhibited a greater under-prediction bias than Run7c. A more rigorous assessment of the accuracy and representativeness of these emissions data would be warranted before inclusion in the final inventory for CAMx modeling. In addition, the NCTCOG provided some emissions data that could not be included due to the lack of detail required for correct speciation and spatial allocation. A final assessment of this simulation should be revisited once these data can be properly included in the modeling inventory.

Anthropogenic Emissions Sensitivity Runs

An investigation of the impact on the predicted ozone concentrations within the DFW modeling domain and the contributions of the DFW area emissions on the regional background ozone levels was undertaken through the application of an emissions sensitivity simulation. For this simulation, all anthropogenic emissions within the 4-county Dallas/Fort Worth area were set to zero.

The anthropogenic emissions within the DFW 4-km domain were set to zero based on the model-ready gridded emissions files using a processor which applies adjustments by grid cell. The anthropogenic emissions within the DFW 4-county region were approximately 508 tpd

NOx, 318 tpd VOC and 2752 tpd CO, based on the August 17th episode day. Adjustments were made for all days of the simulation.

Figure 6-16 displays the results of the zero-out emissions sensitivity simulation for the DFW 4-km domain in terms of the difference in daily maximum 1-hour ozone concentrations from Run7c. The displays illustrate the influence of the Dallas core area emissions on the predicted daily maximum ozone concentrations. The location and evolution of the Dallas urban plume can be seen. The impacts range from an approximate increase of 18 ppb to a reduction of approximately 78 ppb. In general the Dallas emissions are seen to contribute from approximately 20 to 50 ppb ozone to the core region. The results also illustrate the impact on the regional background ozone concentrations due to emissions within the DFW counties. Dallas/Ft Worth area emissions contribute approximately 5 to 10 ppb to the background concentrations within the 4-km modeling domain. Small, localized increases in ozone concentrations are also apparent.

While this sensitivity simulation illustrates, in general, the impact of local emissions sources on the predicted ozone levels in the region, it provides only limited information regarding the contribution of emissions source categories and source regions on predicted elevated ozone concentration levels. A series of similar sensitivities simulation could be devised to investigate in more detail the relative contributions of different regions and emissions source categories to the predicted ozone concentrations within the DFW non-attainment area.

The CAMx air quality model includes the capability to investigate these questions in a more refined manor without the need to run numerous simulations where individual regions and emission source categories are artificially modified. The Ozone Source Apportionment Technology (OSAT) was developed in CAMx to specifically address these issues. Nonetheless, it is instructive and fairly straightforward to develop a matrix of runs using this simplified approach, as the OSAT simulations can be extremely resource intensive. Evaluation of zero-out sensitivity simulations may provide a starting point from which more refined analyses using OSAT can be developed.

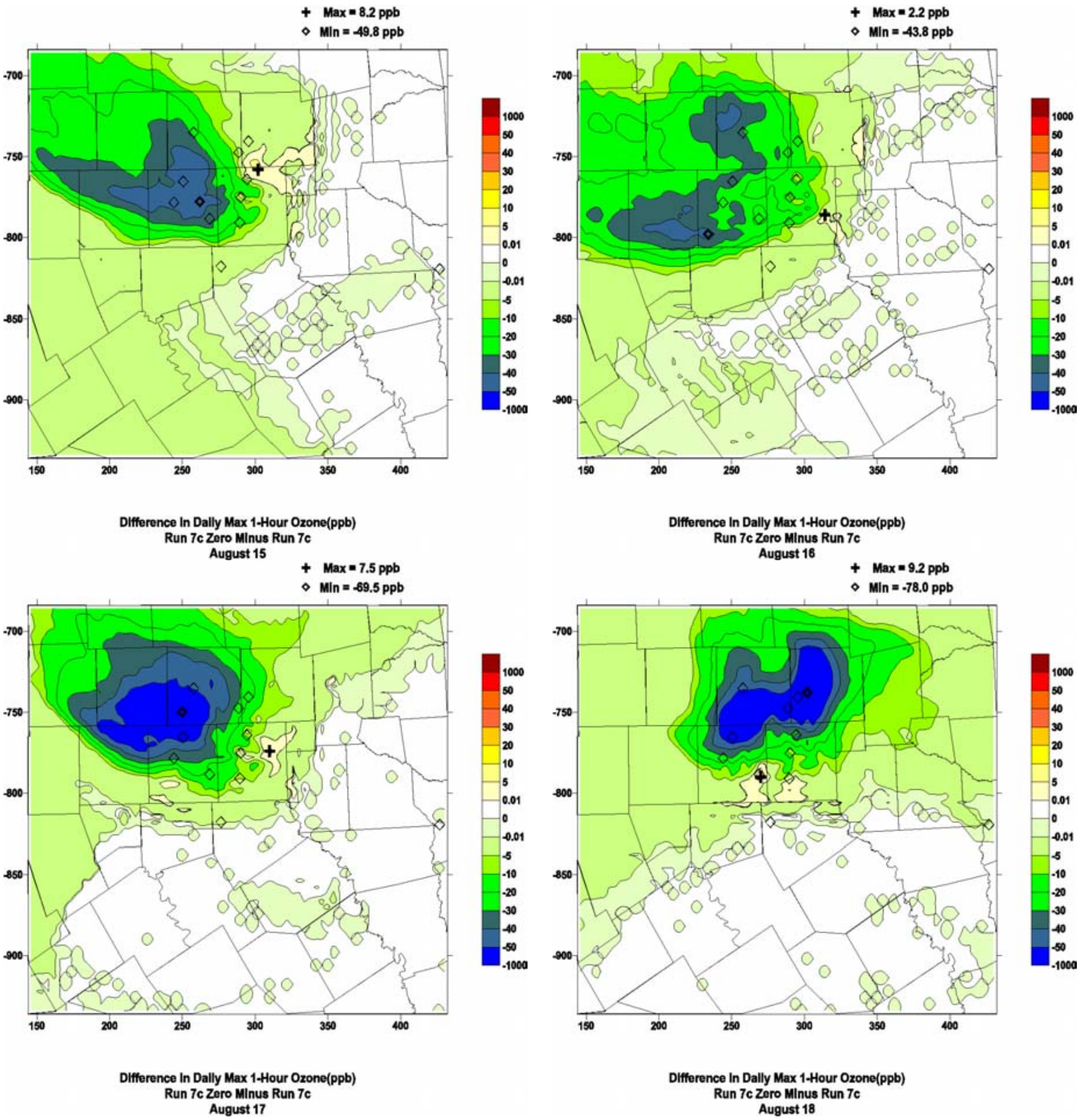


Figure 6-16. Difference in daily maximum 1-hour ozone between Run7c and Run7c_zero in the DFW.

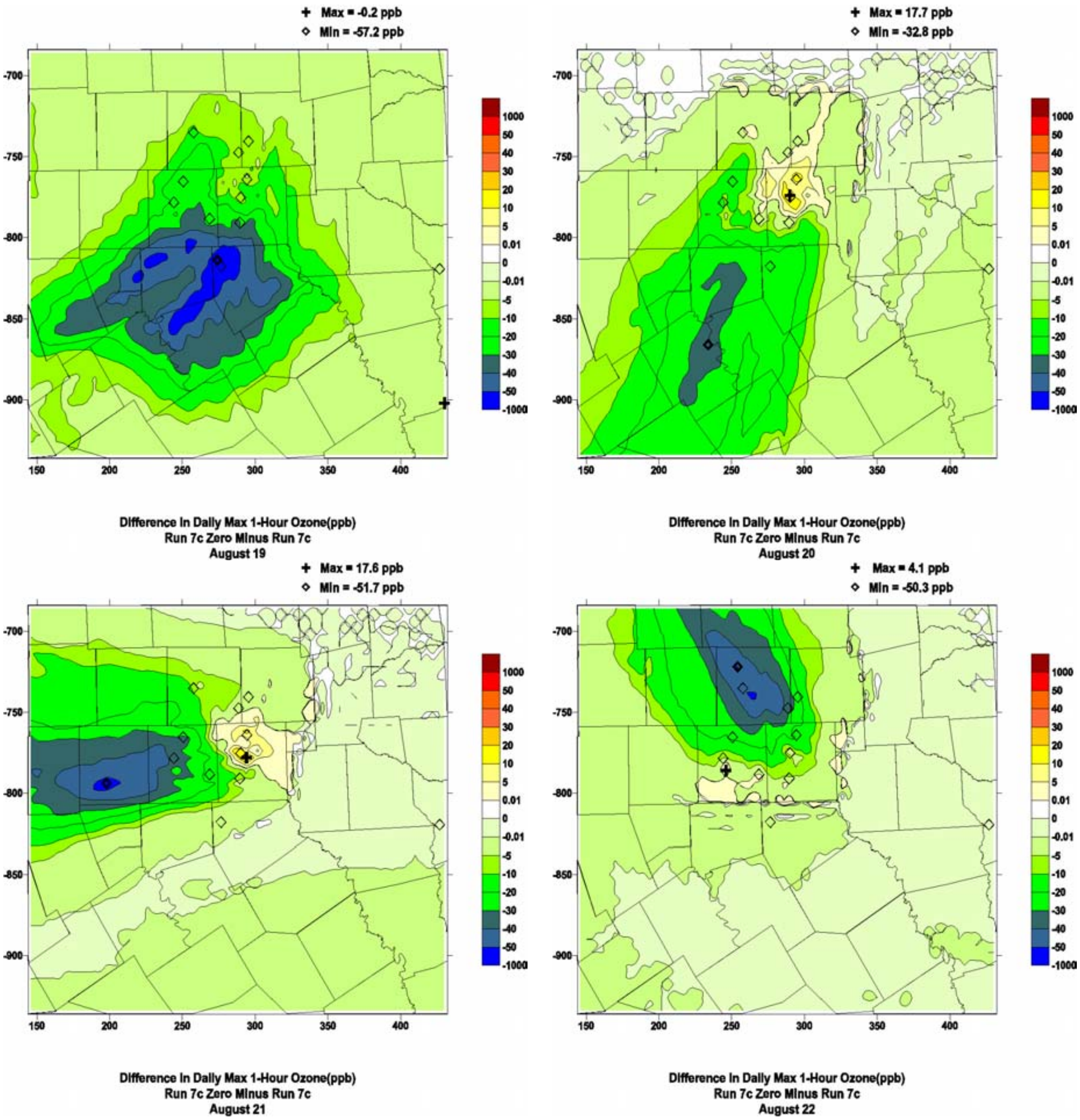


Figure 6-16. Difference in daily maximum 1-hour ozone between Run7c and Run7c_zero in the DFW. (Concluded).

7. SUMMARY AND RECOMMENDATIONS

The US Environmental Protection Agency (EPA) currently has a 1-hour ozone National Ambient Air Quality Standard (NAAQS) that, simply stated, says no monitor can measure more than three exceedances (0.12 ppm or 124 ppb) in a three-year period. With complete data capture, compliance with the 1-hour ozone NAAQS requires that the fourth highest daily maximum 1-hour ozone concentration in three years at every ozone monitor in the area be less than or equal to 0.12 ppm. Areas that have more than three exceedances violate the 1-hour ozone NAAQS and are classified as ozone nonattainment areas. Ozone nonattainment areas must develop an ozone emissions control plan and demonstrate that they will attain the ozone NAAQS by the date specified in the Clean Air Act Amendments (CAAA) in a State Implementation Plan (SIP). The SIP ozone attainment demonstration is usually accomplished using air quality modeling.

Given the short time available until a new SIP must be submitted, the state of Texas has had to move quickly to develop the emissions and photochemical modeling databases needed to develop 1-hour and 8-hour ozone plans by 2004. The key objectives in developing an all-new photochemical modeling database for the DFW area were summarized in Section 1 of this report.

It should be noted that the current modeling activities undertaken as part of this project do not include future case control strategy evaluation. However, the current air quality modeling assumed that all planned regional controls in effect at the time of the August 1999 episode (e.g., Tier 2/Low Sulfur and Heavy Duty Diesel on-road mobile source rules) and local Texas controls (e.g., DFW, HGA, Northeast Texas ozone control plans) will be included in the base case modeling.

The high 1-hour and 8-hour ozone period selected for modeling was August 15th-22nd, 1999. After including 2 additional days to "spin up" the ozone model, this results in modeling the 10 day period August 13th-22nd, 1999. This period was selected based on a conceptual model and episode selection for Dallas/Fort Worth (ENVIRON, 2003b), which is summarized in Section 2 of this report. The modeling procedures and modeling domain were developed in an ozone modeling protocol for the August 1999 episode (ENVIRON, 2003a). The Comprehensive Air Quality Model with extensions (CAMx) was selected for ozone modeling and the modeling domain is shown in Figure 1-2 and 1-3.

The preparation of ozone model inputs was described in Sections 3 through 5 of this report. Section 3 described the emission inventory development for the 1999 base year. Section 4 summarized the meteorological modeling and extensive details are given in a supporting meteorological modeling report (ENVIRON, 2003c). Section 5 described the preparation of other CAMx inputs.

Section 6 described the development of the 1999 base case including model evaluation procedures, diagnostic tests and sensitivity tests. The 1999 base case was refined through a series of improvements to the meteorology, emissions and CAMx inputs. The final 1999 base case was designated "Run7c".

As discussed in Section 6, there was a general tendency of the model to under-predict the 1-hour and 8-hour ozone concentrations in the DFW non-attainment area. A series of diagnostic simulations were undertaken in an attempt to improve model performance. The diagnostic simulations involved modification of various model inputs and configuration options. It was determined that the modeling results within the DFW non-attainment region were particularly sensitive to the specification of boundary conditions, highlighting the influence and importance of long-range transport. It was also noted that, while the peak ozone levels were generally well represented, biases in the location and timing of the predicted ozone levels resulted in a general negative bias in the predicted ozone concentrations within the DFW 4-km modeling domain.

Based on the results of the simulations conducted as part of the project, the following recommendations are made regarding further analysis and refinement of the air quality modeling databases and model configurations:

- The evaluation of the final base case simulation, Run7c, revealed a possible deficiency in the estimated mixing heights in the model, as well as possible biases in wind speeds and directions. Analysis of the movement and magnitudes of the predicted hourly ozone concentrations indicated that, while the magnitude of the Dallas plumes were well simulated, their locations tended to be slightly skewed with respect to monitored ozone concentrations. The evaluation of the MM5 modeling results showed a slight bias in wind speed and direction, and although, overall the meteorological fields were acceptable, a slight error in either wind speed or direction can have a significant effect on the modeled ozone levels, particularly within high resolution modeling domain, such as the DFW 4-km grid. As noted in Section 4, the model configuration and simulation options have already been optimized based on previous modeling efforts for Texas and Oklahoma. Therefore, it is recommended that the meteorological fields be further review for possible refinements only if additional data are available.

- The specification of initial and boundary conditions for the regional modeling domain are not usually expected to have a significant influence on fine grid modeling domains well away from the boundaries. In fact, the purpose of running nested-grid model simulations with a large, coarse modeling grid and fine resolution grids over regions of particular interest within the interior of the modeling domain is to minimize the influence of the boundary conditions. The influence of initial conditions can be eliminated by running the model for one to two days prior to the episode of interest, i.e., "spin-up" days. Given the impact that specification of boundary conditions was seen to have on the results within the DFW 4-km modeling grid, it is recommended that the specification of ozone and precursors along the boundaries of the regional domain be further investigated and refined. The diagnostic simulations run to investigate these influences applied a constant ozone concentration of 40 ppb along all segments of the domain. This magnitude seems appropriate, however, there may be evidence that possibly higher values along certain segments of the domain may be justified. Results within the 12-km modeling domain showed that the model was replicating the observed elevated background levels of 1-hour and 8-hour ozone fairly well. Nevertheless, given the significant impact that the boundary conditions have on the DFW area, a more detailed investigation into these issues is warranted.

- As noted above, the model appears to replicate the background ozone concentrations within the 12-km regional modeling domain fairly well. However, these results do not seem to be reflected very well within the DFW 4-km domain. This may indicate some inconsistencies between the input fields within the 12-km and 4-km grids. It would be instructive to consider a more urban-scale simulation using only the 4-km modeling domain. Boundary and initial conditions for this simulation could be derived from the 12-km regional domain modeling results.

- The purpose of the 1999 model efforts is to establish a baseline from which future year control strategies can be developed. It is important to establish acceptable model performance in the base case simulation in order to provide a level of confidence that the model is predicting the right answers for the right reasons. However, the fact that the performance in the base case simulation is not perfect does not preclude the use of the modeling databases in establishing acceptable control strategies. What is important is that the model responds in the correct and appropriate way to changes in emission levels. Thus, to validate the 1999 base case simulation and to build confidence in its use to develop future year control strategies, a series of emission sensitivity simulations should be conducted. Adjustments to NOx and VOC, both separately and in combination with each other, would provide an indication of whether or not the model responds appropriately to these changes in emission levels, regardless of the performance in the base case simulation. For future year base case and control strategy simulations, the same base year 1999 meteorology is used, so that any biases in the 1999 model attributed to biases in the meteorology, will also be present in these control strategy simulations. The more important issue is whether the model is correctly responding to emission controls for the purposes of evaluating potential control strategies. These types of simulations can also provide an indication of whether NOx and/or VOC controls are more effective in reducing both high 1-hour and 8-hour ozone concentrations in the future.

- The zero-out simulation described in Section 6 provided some limited information concerning the impact of the DFW emissions on the DFW 4-county area as well as on the predicted background ozone concentration levels. While these simulations are not realistic, they can provide valuable information that can be used in the development of control strategies. A series of similar simulations could be conducted to aid in the determination of which areas and which emissions source categories are most likely to contribute to effective control strategies.

- The Ozone Source Apportionment Technology (OSAT) and the Anthropogenic Precursor Culpability Assessment (APCA) are very powerful tools within the CAMx air quality model. As seen in the analyses of Appendix A, the use of OSAT and APCA can provide a great deal of information concerning source regions and emission source categories which are contributing to elevated ozone levels in an air quality simulation. It would be useful to further evaluate the use of these technologies both in the investigation of model performance of the 1999 base case and in the development of future year control strategies.

REFERENCES

Dudhia, J., 1993. "A Non-hydrostatic Version of the Penn State/NCAR Mesoscale Model: Validation Tests and Simulation of an Atlantic Cyclone and Cold Front", *Mon. Wea. Rev.*, Vol. 121. pp. 1493-1513.

Emery, Tai and Jia, 2003. "Revised Meteorological Modeling of the August 13-22, 1999 East Texas Ozone Episode." Prepared for the East Texas Council of Governments by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. January 23.

Emery and Tai, 2002. "Meteorological Modeling and Performance Evaluation of the August 13-22, 1999 Ozone Episode." Prepared for the East Texas Council of Governments by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. August.

ENVIRON. 2003a. "Modeling Protocol. Development of Base Case Photochemical Modeling to Address 1-Hour and 8-Hour Ozone Attainment in the Dallas/Ft Worth Area." Prepared for the Texas Commission on Environmental Quality by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. 22 May 2003.

ENVIRON. 2003a. "Meteorological Modeling. Development of Base Case Photochemical Modeling to Address 1-Hour and 8-Hour Ozone Attainment in the Dallas/Ft Worth Area." Prepared for the Texas Commission on Environmental Quality by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. 30 June 2003.

ENVIRON. 2003c. "Modeling a 1999 Ozone Episode in Northeast Texas" Prepared for the East Texas Council of Governments by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. 5 May 2003.

ENVIRON. 2002a."User's Guide to the Comprehensive Air Quality model with extentsions, version 3.10" available from www.camx.com. April.

ENVIRON. 2001b. "User's Guide to the extended Emissions Processing Systems version 2 (EPS2x)." ENVIRON International Corporation, 101 Rowland Way, Novato, CA. 94945. August.

ENVIRON. 2002b. "Conceptual Model of Ozone Formation on the Dallas/Fort Worth Ozone Nonattainment Area." Prepared for the Texas Commission on Environmental Quality by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. 16 October 2002.

ENVIRON. 1999a. "Ozone Modeling for the Tyler-Longview-Marshall Area of East Texas." Prepared for the East Texas Council of Governments by ENVIRON International Corporation, 101 Rowland Way, Novato, CA 94945. 12 November 1999 and revised for errata 3 August 2001.

EPA. 1999. "Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS". EPA-454/R-99-004. EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711. May.

EPA. 1996. "Guidance on Use of Modeled Results to Demonstrate Attainment of the Ozone NAAQS". EPA-454/B-95-007, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, N.C.

EPA. 1991. "Guideline for Regulatory Application of the Urban Airshed Model". EPA-450/4-91-013, U.S. Environmental Protection Agency Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711. July 1991.

Goldan, P.D., W.C. Kuster, and F.C. Fehsenfeld, 1995. "Hydrocarbon Measurements in the Southeastern United States: The Rural Oxidants in the Southern Environment (ROSE) Program 1990." *J. Geophysical Research*, vol. 100, No.D12, pp. 25945-25963.

Guenther, A., C. Wiedinmyer, B. Baugh, S. Shepard, U. Ganesh, and G. Yarwood. 2002. "Biogenic VOC Emission Estimates for the TexAQS 2000 Emission Inventory: Estimating Emissions During Periods of Drought and Prolonged High Temperatures and Developing GloBEIS3". Prepared for Texas Natural Resource Conservation Commission, Austin, TX. April.

Hoats, A., Coulter-Burke, S., Yarwood, G., and Mansell, G. Comparison of GloBEIS results for Dallas Fort Worth Biogenic Emissions Modeling Technical Memorandum prepared for Pete Breitenbach, Texas Commission on Environmental Quality. August 13.

Madronich, S. 2002. The Tropospheric visible Ultra-violet (TUV) model web page. http://www.acd.ucar.edu/TUV/.

Madronich, S. 1993. "UV radiation in the natural and perturbed atmosphere", in Environmental Effects of UV (Ultraviolet) Radiation (M. Tevini, ed.), Lewis Publisher, Boca Raton, pp. 17-69.

MMS. 1995. "Gulf of Mexico Air Quality Study, Final Report, Volume 1: Summary of Data Analysis and Modeling." U.S. Department of the Interior, Minerals management Service Gulf of Mexico OCS Region (MMS 95-0038).

NCTCOG. 2003. "Dallas/Fort Worth 1999 Episodic Emission Inventory." Prepared by the North Central Texas Council of Governments. July 2003.

Watkins, B.A., D.D. Parrish, S. Buhr, R.B. Norton, M. Trainer, J.E. Yee, and F.C. Fehsenfeld. 1995. "Factors Influencing the Concentration of Gas Phase Hydrogen Peroxide During the Summer at Kinterbish, Alabama. *J. Geophysical Research,* vol. 100, No. 311, pp. 22841-22851.

Yarwood, G. G. Mansell, G. McGauhey, and W. Vizuete. 2001. "Biogenic Emission Inventories For Regional Modeling of 1999 Ozone Episodes In Texas". Final Report to the Texas Natural Resource Conservation Commission, Austin, TX. April.

Yarwood, G., G. Wilson, C. Emery, and A. Guenther. 1999b. "Development of GLOBEIS - A State of the Science Biogenic Emissions Modeling System". Final Report to the Texas Natural Resource Conservation Commission, Austin, TX. Available from http://www.globeis.com.

Yarwood, G., G. Wilson, S. Shepard, and A. Guenther. 1999a. User's Guide to the Global Biosphere Emissions and Interactions System - Version 2.0. Available from http://www.globeis.com.

Yocke, M.A., G. Yarwood , C. A. Emery, J. G. Heiken, T. E. Stoeckenius, L. Chinkin, P. Roberts, C. Tremback and R. Hertenstein. 1996. "Future-Year Boundary Conditions for Urban Airshed Modeling for the State of Texas." Prepared for the Texas Natural Resources Conservation Commission, Austin, Texas.

APPENDIX A

SOURCE CONTRIBUTIONS TO OZONE

SOURCE CONTRIBUTIONS TO OZONE

One of the unique features of CAMx is the availability of several "probing tools" to provide additional diagnostic and sensitivity information for an ozone simulation. The probing tools can be used to answer questions such as:

- Which emissions cause high ozone?
- How will ozone levels respond to emission changes?
- How important are the initial and boundary conditions?
- What are the influences of different model processes (chemistry, deposition, etc.) on ozone levels at a specific location?

The probing tools can also provide information for ozone precursors. The tools that are available have differing capabilities and uses. This section briefly describes the available probing tools and then presents results from the application of ozone source apportionment to the 1999 base case simulation for the Dallas/Fort Worth non-attainment area.

SUMMARY OF CAMx PROBING TOOLS

The probing tools available in version 4.02 of CAMx are:

- Ozone Source Apportionment Technology (OSAT) and related methods (APCA).
- The Decoupled Direct Method (DDM) for sensitivity analysis.
- Process Analysis.

OSAT provides information about the relationships between ozone concentrations and sources of precursors in the form of ozone source apportionments. Source apportionment means that the sum of the source contributions adds up to exactly 100% of the total ozone and so all of the ozone is accounted for. OSAT attributes ozone among all of the potential sources of ozone in the simulation, namely emissions, boundary conditions and initial conditions. Ozone formation from VOC and NOx precursors is tracked separately. The emissions contributions can be broken down by geographic area and/or source category. The OSAT methods are described in the CAMx User's Guide (ENVIRON, 2002) and in Dunker et al., (2002b).

Because ozone formation chemistry is a non-linear process, there is no unique way of apportioning ozone back to precursor sources. The OSAT methods attribute ozone formation to precursors that were present at the time the ozone was formed. There are two schemes for doing this called OSAT and APCA. The OSAT or APCA results are just like any other ozone source apportionment in that they are not exact. However, OSAT and APCA are very helpful for estimating the relative importance of different sources and guiding control strategy development.

The difference between the OSAT and APCA schemes can be summarized as follows. OSAT apportions ozone formation based solely on what precursors were present when the ozone is formed. OSAT determines whether ozone formation is NOx or VOC limited in each grid cell at each time step, and attributes ozone production according to the relative contributions of the limiting precursor (VOC or NOx) from different sources present at that time. APCA modifies the OSAT method to account for the fact that biogenic emissions are not considered to be controllable, and therefore attributes ozone to controllable (anthropogenic) emissions whenever possible. The differences between OSAT and APCA are discussed in more detail below.

The DDM provides similar types of information to OSAT, but in terms of sensitivity coefficients rather than source apportionments. Sensitivity coefficients describe how ozone will change if a precursor source is changed and thus are useful for predicting the effects of control strategies. CAMx can calculate “first-order” sensitivity coefficients, which are the likely to be the most important sensitivities, and are somewhat similar to source apportionments. There are two major differences between DDM sensitivities and OSAT source apportionments: (1) Sensitivity coefficients can be negative, meaning that reducing emissions will increase ozone, whereas as source apportionments are never negative. An example would be an area with high NOx emissions where reducing NOx emissions will increase ozone and DDM will obtain negative ozone sensitivities to local NOx whereas OSAT will have zero or small ozone apportionments to local NOx. (2) Adding up all the first-order sensitivities over all sources of ozone and precursors usually explains only about 60% of the total ozone. The modeled ozone that is “unexplained” by the first-order sensitivity coefficients can be explained by higher-order sensitivities, but they are more difficult to calculate and difficult to interpret. An advantage of DDM sensitivity coefficients is that they are rigorously defined (mathematically) and so are unique. The value of this uniqueness is weakened if the sensitivities are interpreted as source apportionments because of the significant portion of the ozone that is “unexplained” by the first-order sensitivities. Further information on DDM is provided in Dunker et al. (2002 a and b) and the CAMx User’s Guide (ENVIRON, 2002).

Process analysis (PA) is a method for obtaining more information on how CAMx predicted concentrations at a specific place and time. The CAMx concentrations are determined by numerous model processes (such as emissions, transport, chemistry, deposition) but the separate contribution of each process is hidden within the final concentration output. Process analysis allows the contribution of each process to be output and used in diagnostic analyses. This is useful for explaining “how the model got the answer it got” and thus understanding model performance issues. Process analysis is not well suited for understanding source contributions to ozone or predicting responses to emissions changes. Further information on process analysis is provided in the CAMx User’s Guide (ENVIRON, 2002) and references therein.

Anthropogenic Precursor Culpability Assessment (APCA)

Applications of OSAT to the Eastern US consistently identify biogenic emissions as a major contributor to ozone formation. This is not surprising as biogenic VOC emissions are very reactive and dominate regional VOC emissions in the Eastern US, but this finding is not “policy relevant” for designing anthropogenic emissions ozone control plans. The APCA methodology was developed from OSAT to address this issue. APCA stands for Anthropogenic Precursor Culpability Assessment, and differs from OSAT in recognizing that certain emission groups are not controllable (i.e., biogenic emissions) and that apportioning ozone production to these emissions does not provide control strategy relevant information. To address this, in situations where OSAT attributes ozone formation to a non-controllable source category when it was due to the interaction of ozone precursors from a non-controllable (i.e., biogenic) and controllable emissions source, APCA re-directs the ozone attribution to the controllable precursor. In practice, biogenic emissions are the uncontrollable source category and APCA only attributes ozone production to biogenic emissions when ozone formation is due to the interaction of biogenic VOC with biogenic NOx. When ozone formation is due to biogenic VOC interacting with anthropogenic NOx under VOC-limited conditions (where OSAT would attribute ozone production to biogenic VOC's), APCA directs the attribution to the anthropogenic NOx precursors present. The result of using APCA instead of OSAT is that more ozone formation is attributed to anthropogenic NOx sources and little ozone formation is attributed to biogenic sources. APCA is not called a "source apportionment" technique because it expresses biases as to which sources should be implicated (i.e., those that are controllable), hence it is referred to as a "culpability assessment."

STRENGTHS AND LIMITATIONS OF OSAT AND APCA

The main advantage of OSAT and APCA is providing a clear apportionment of ozone concentrations among all of the sources of ozone precursors in CAMx. These precursor sources (emissions, boundary conditions and initial conditions) can be sub-divided into categories to provide refined analyses. For example the emissions can be sub-divided based on emissions category and/or geographic area. This information provides a clear understanding of which sources are involved in forming the ozone present at a specific place and time. The apportionments are based on the participation of precursor emissions in the ozone formation process.

The main limitation of OSAT and APCA is that, because ozone formation is not a linear process, the source contributions cannot be used to exactly calculate what emission reductions are needed to achieve a specific target ozone level. As ozone precursor emissions are reduced, the efficiency of ozone formation changes and controls may become more or less effective than expected. Thus, OSAT and APCA should be used as a guide for designing control strategies, but can not provide an exact control strategy solution.

SOURCE APPORTIONMENT ANALYSIS DESIGN

The OSAT and APCA probing tools were used for the source apportionment analyses. The APCA results are expected to be more useful because of the high contribution biogenic emissions in Northeast Texas. Emissions were divided into 4 source categories and 25 geographic areas as defined in Tables A-1 and A-2, respectively. The source areas are also shown as maps for the 12-km and 4-km CAMx grids in Figure A-1. This means that ozone was attributed back to VOC and NOx emissions from 100 source groups, in addition to the initial and boundary conditions. Source contributions were analyzed for all grid cells in each of the 4 Dallas non-attainment counties separately and for all grid cells in the Dallas 4-county area combined.

CAMx 4.02, the APCA source areas may be defined separately at each grid resolution. This means that the finest resolution information takes precedence and, for example, the Dallas Core County area was defined a 4-km resolution whereas East Texas and Houston were defined at 12-km resolution, etc. This feature in CAMx allows for a more accurate assessment of source and receptors regions with respect to ozone contributions to high 1-hr and 8-hr ozone levels.

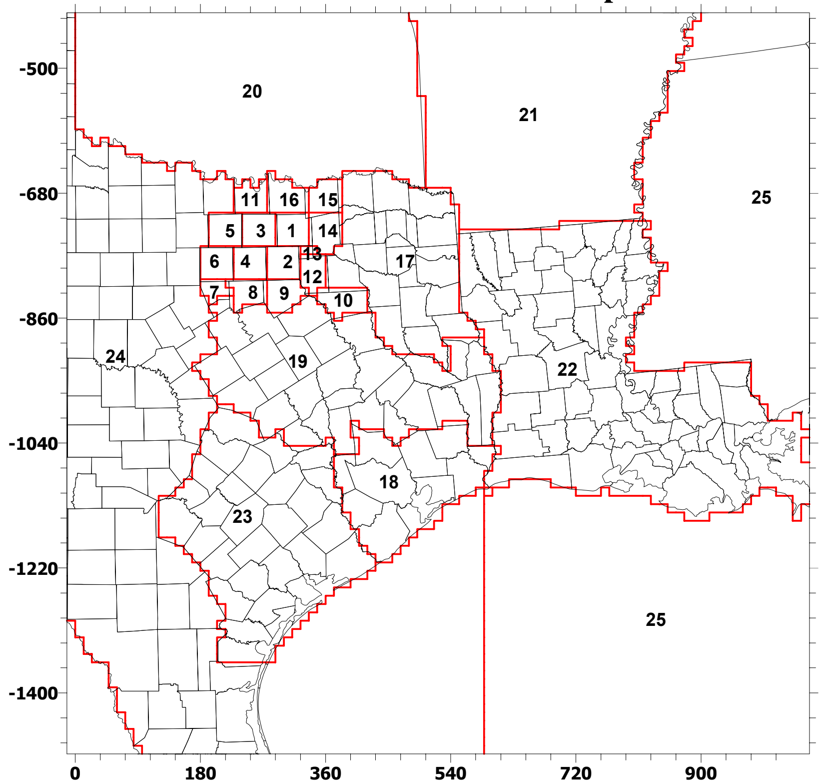
Table A-1. Emissions source category definitions for the OSAT and APCA analysis.

Source Category	Category Definition
BIO	Biogenic emissions
MV	On-road motor vehicle emissions
EPT	Elevated point source emissions
OAN	Other anthropogenic emissions (area, off-road mobile, low level point)

Table A-2. Emissions source area definitions for the OSAT and APCA analysis.

Area Number	Area Abbreviation	Area Definition
1-4	Core	Dallas Core Counties (Collin, Dallas, Denton, Tarrant)
5-16	Perimeter12	12 Counties surrounding Dallas Core (Wise, Parker, Hood Johnson, Ellis, Henderson, Cooke, Kaufman, Rockwall, Hunt, Fannin, Grayson)
17	East Texas	Northeast Texas
18	HGBPA	Houston/Galveston/Beaumont/Port-Arthur (11 Counties)
19	Central Texas	East Central Texas
20	OK	Oklahoma
21	AR	Arkansas
22	LA	Louisiana
23	South Texas	Near Non-attainment areas (Austin, San Antonio, Victoria, Corpus Christi)
24	West Texas	Texas (excluding area 1-19 and 23
25	Other STates	Other areas

12-km Grid Source Area Map



4-km Grid Source Area Map

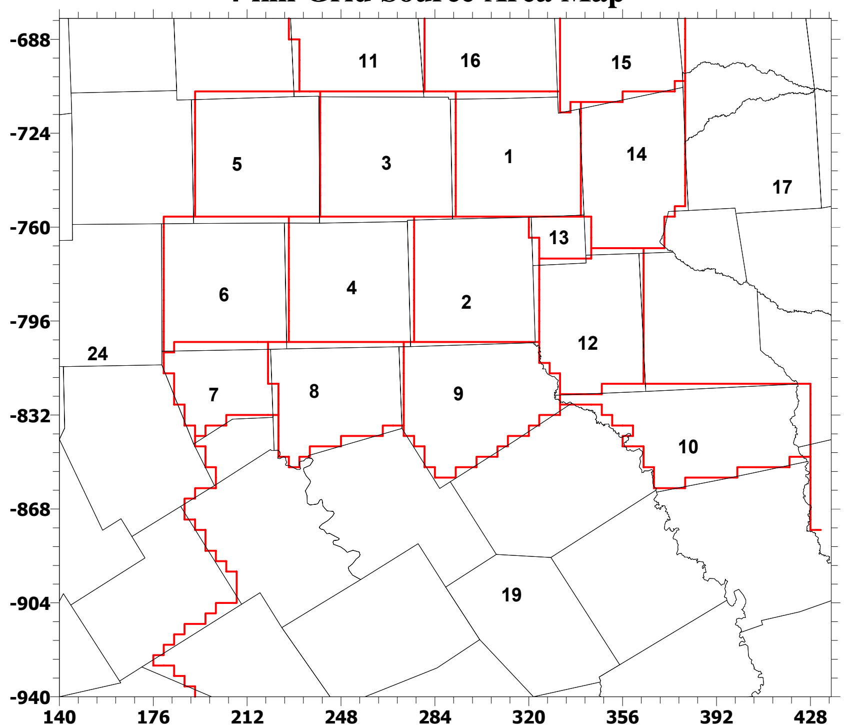


Figure A-1. Maps showing the emissions source areas for the APCA analysis.

OZONE CONTRIBUTIONS FOR 1999

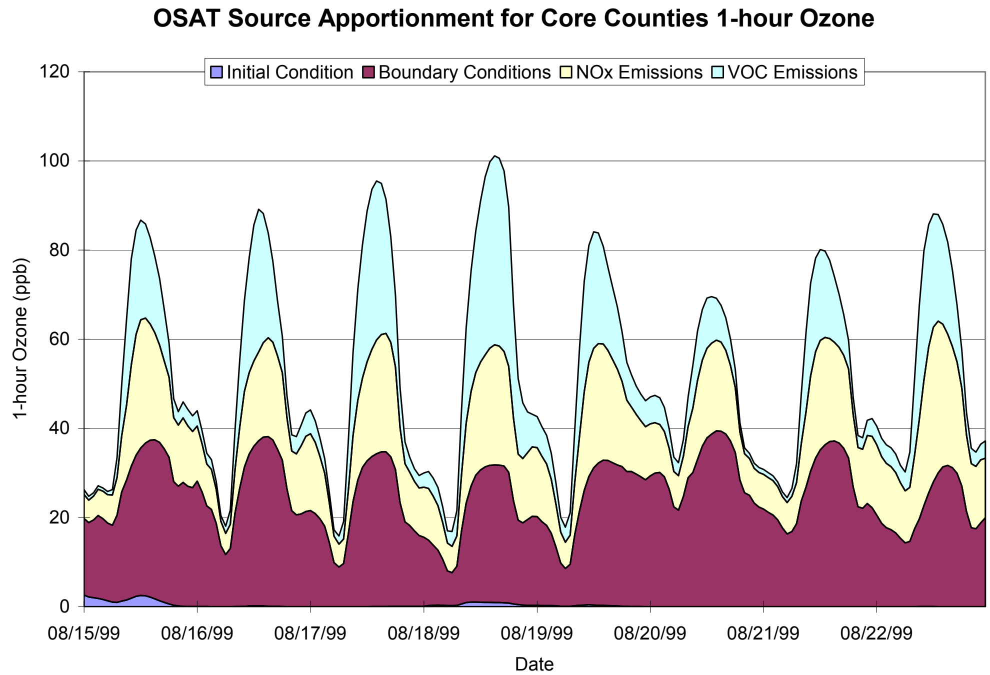
The 1999 base case (Run7c) was analyzed using both the OSAT and APCA algorithms in order to compare the resulting ozone source apportionments. The 1999 OSAT and APCA simulations used exactly the same model inputs and the only difference was the source apportionment algorithm in CAMx. As discussed above, APCA is designed to minimize attribution of ozone to biogenic emissions because they are not controllable.

Comparing OSAT and APCA

Figure A-2 (top) shows the OSAT source apportionment for 1-hour ozone for the Dallas non-attainment area to initial conditions, boundary conditions, VOC emissions and NOx emissions. The contribution of initial conditions is negligible because the spin-up days have removed the influence of the initial conditions by August 15th. The contribution of the boundary conditions ranges from about 10 ppb to 40 ppb throughout the episode. Contributions of the boundary conditions to 8-hour ozone (Figure A-4) range from about 15 ppb to 35 ppb. An ozone boundary condition of 40 ppb was used for the 1999 Run 7c base case, and the contribution of the boundary conditions in the DFW area is lower than 40 ppb because some ozone is lost to chemical reactions and deposition between the boundaries and DFW. Emissions are the main contributor to ozone in the DFW region, especially at times of high 1-hour and 8-hour ozone. NOx emissions contribute slightly more to ozone than VOC emissions on some high ozone days, but the relative contributions of NOx and VOC emissions are comparable. Comparing the OSAT and APCA results shows that the VOCs involved in forming ozone under VOC limited conditions are predominantly from biogenic sources.

Figure A-2 (bottom) shows the APCA source apportionment for 1-hour ozone in the DFW region to initial conditions, boundary conditions, VOC emissions and NOx emissions. Similar results for 8-hour ozone are displayed in Figure A-4. The contributions of initial and boundary conditions are essentially the same as in the OSAT analysis. APCA attributes almost all of the remaining ozone formation to NOx emissions. This shows that the ozone attributed to VOCs by OSAT was in fact due to biogenic VOCs. Since biogenic VOCs are not controllable, APCA redirects this ozone attribution to biogenic VOCs to the NOx emissions that were present. The small amount of ozone attributed to VOC emissions by APCA was formed under VOC limited conditions and was either (1) formed by anthropogenic VOCs, or (2) formed by biogenic VOCs and biogenic NOx. Figure A-3 will show that the second explanation applies in this case.

Figure A-3 compares the OSAT and APCA apportionments for 1-hour ozone in the DFW area to the four emissions categories (biogenic, motor vehicle, area/off-road/low points, and point source) plus boundary and initial conditions. Similar results for 8-hour ozone are displayed in Figure A-5. The initial and boundary conditions were discussed above. Biogenic emissions are identified by OSAT as a major contributor to ozone formation reflecting the high contribution of biogenic emissions to VOC emissions. APCA reduces the apportionment of ozone to biogenic emissions to almost zero and increases the apportionments to anthropogenic emissions to compensate. The small APCA contribution for biogenic emissions is from biogenic VOCs interacting with biogenic NOx, and is limited by the small contribution of biogenics to total NOx. The relative contributions of the anthropogenic emission categories will be discussed in more detail below. The remaining discussion uses just the APCA results.



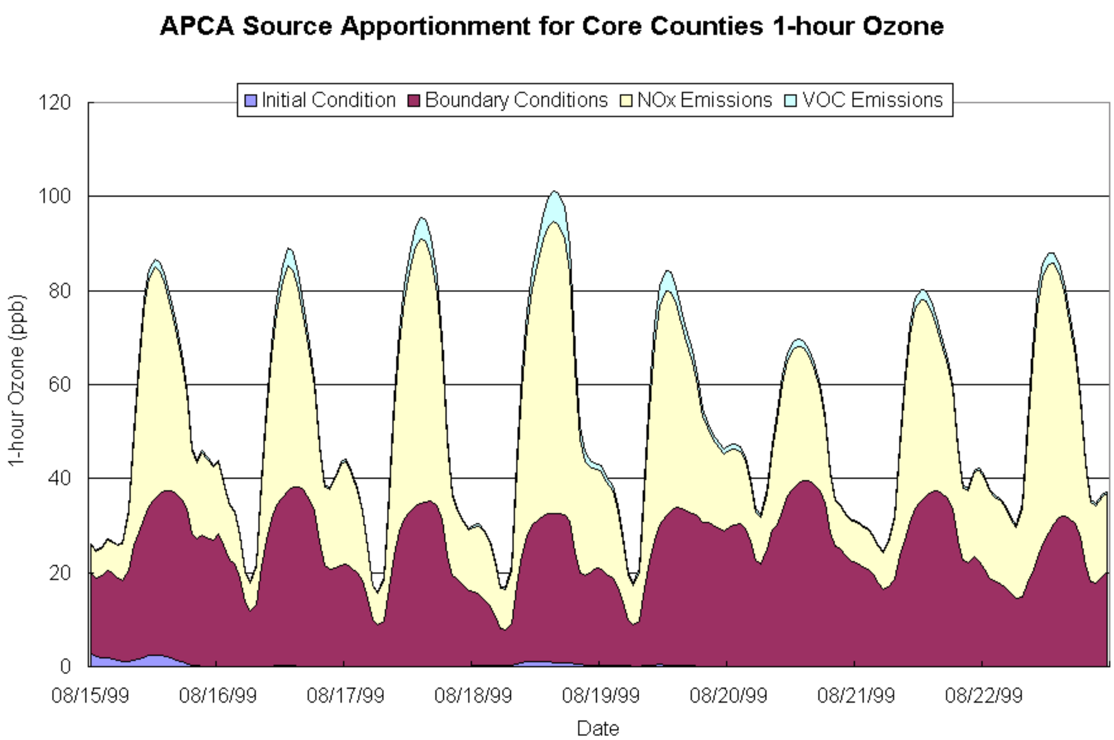


Figure A-2. Source apportionment of Dallas Core Counties 1-hour ozone to VOC and NOx emissions using OSAT (top) and APCA (bottom).

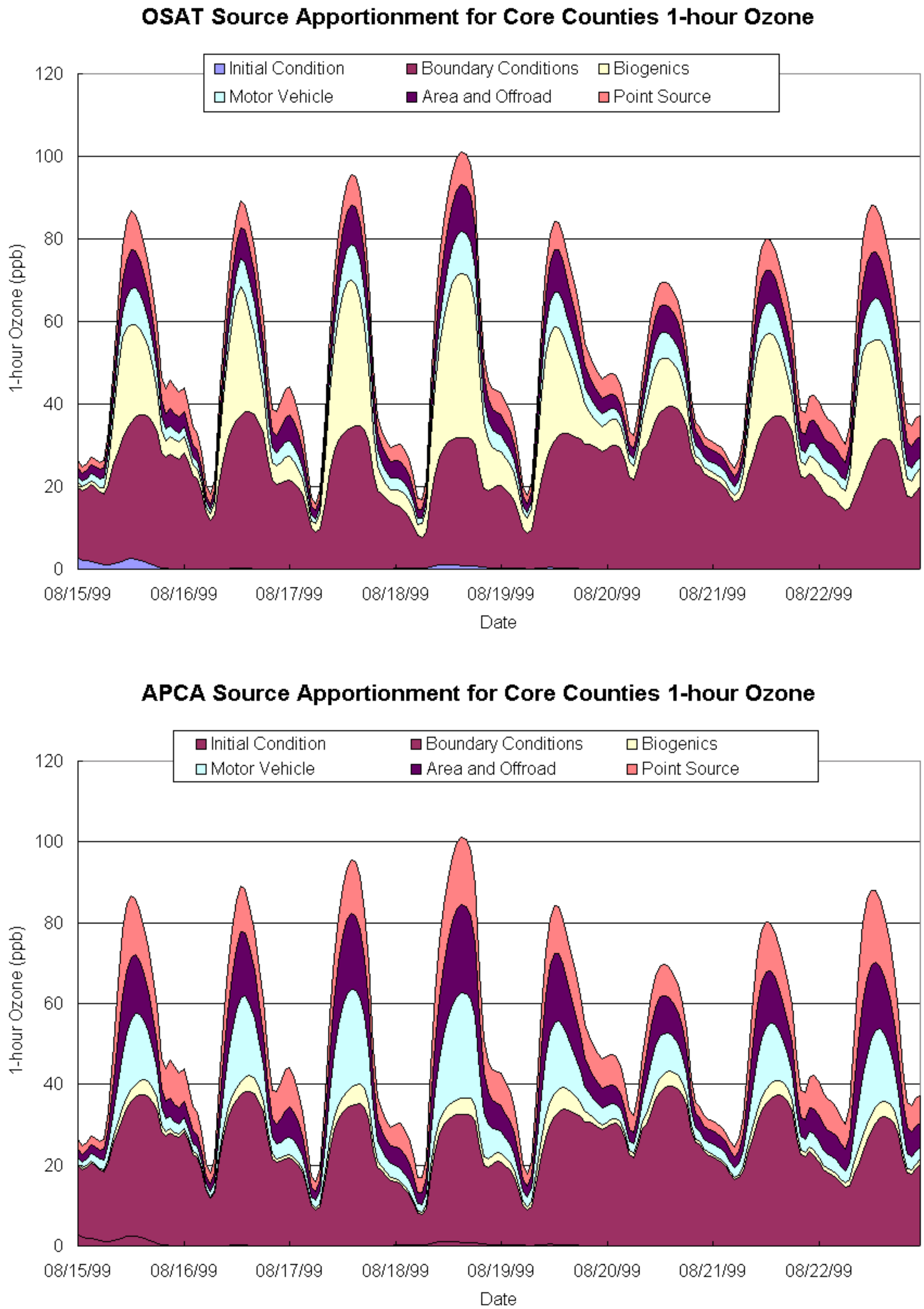
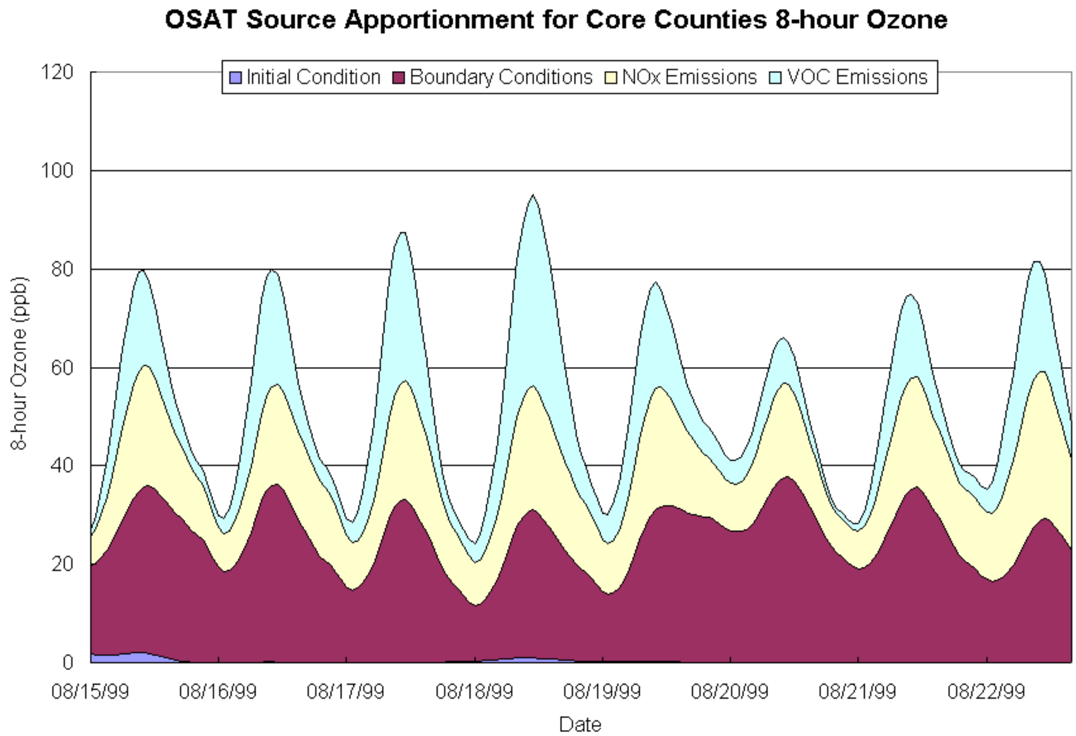


Figure A-3. Source apportionment of Dallas Core Counties 1-hour ozone to source categories using OSAT (top) and APCA (bottom).



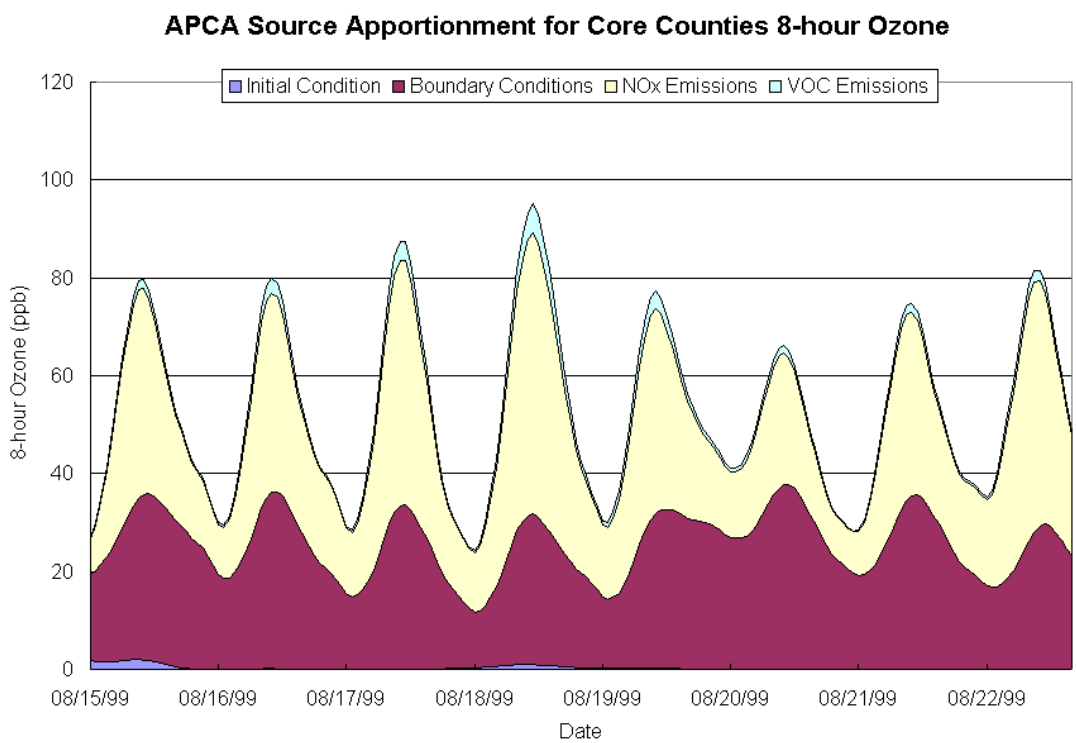
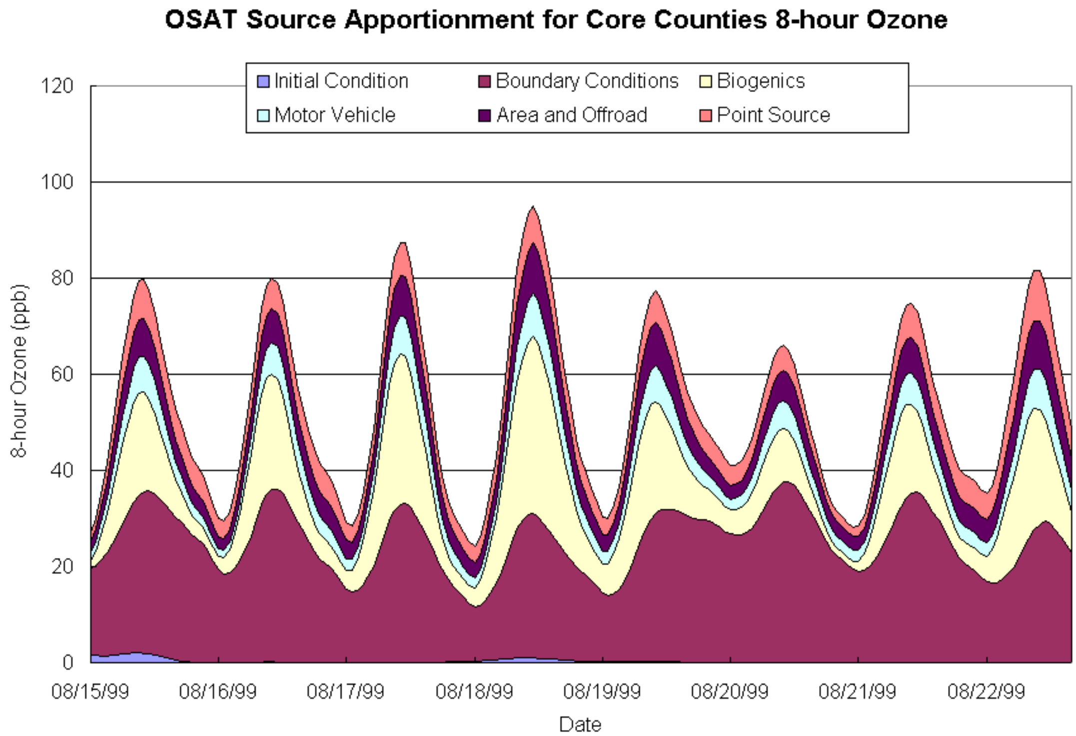


Figure A-4. Source apportionment of Dallas Core Counties 8-hour ozone to VOC and NOx emissions using OSAT (top) and APCA (bottom).



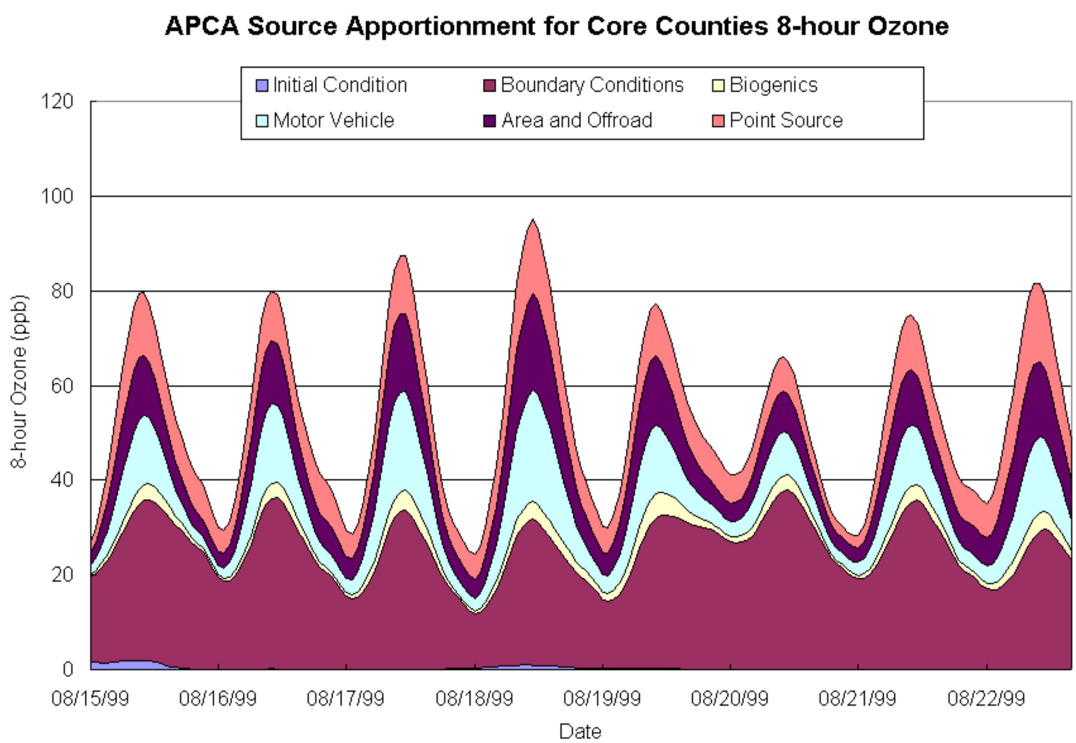


Figure A-5. Source apportionment of Dallas Core Counties 8-hour ozone to source categories using OSAT (top) and APCA (bottom).

APCA Ozone Contributions for 1999

The analysis focused on identifying the contribution of anthropogenic emissions to ozone levels exceeding the level of the 1-hour and 8-hour ozone standards. The analysis was restricted to hours when 1-hour or 8-hour ozone was 85 ppb or higher in the 1999 base case. The analysis was conducted for the grid cells containing the Core Dallas counties (Dallas, Denton, Collin, Tarrant), and for all grid cells in the 4 county DFW treated together (Figure A-1). The APCA source contributions were averaged over all grid cells and hours matching this criterion. The contributions for the whole 4 county DFW area are probably more representative because they include a larger number of grid cells and hours than for each county considered separately (Table A-3). Table A-4 summarize the emission totals (tons/day) by source area and are discussed in more detail below. The contributions of NOx and VOC to high 1-hour and 8-hour ozone are summarized in Tables A-5 and A-6 (these contributions are dominated by NOx rather than VOC, as discussed above). These results are summarized graphically in Figures A-6 to A-9

Table A-3. Number of grid cells and hours with modeled 8-hour ozone of 85 ppb or higher in 1999.

Receptor	Number of grid cell hours
Dallas Core Counties	11635
Collin Co.	1566
Dallas Co.	1549
Denton Co.	4110
Tarrant Co.	4410

The total ozone amounts shown in Tables A-5 and A-6 should not be confused with ozone design values. The total ozone in these tables is just the average over those grid cells and hours when ozone was greater than 85 ppb in the 1999 modeling. Whether or not this value exceeds 85 ppb does not indicate whether the receptor is projected to attain the 8-hour ozone standard. The results shown in Table A-5 and A-6 do indicate which sources contribute to high 1-hour and 8-hour ozone levels in the modeling, and are helpful for designing ozone control strategies. These tables and graphs are intended to illustrate any large differences between contributions among each of the individual counties and the 4-county region as a whole. As can be seen, the contributions based on the 4-county area does not vary significantly from that of each of the counties individual. The remainder of the analysis presented here is based on the 4-county DFW non-attainment area in aggregate.

Table A-4. Emission totals for August 17th summarized for the source categories and source areas used in the OSAT and APCA analyses.

Source	BIO		MV		OAN		EPT	
Region	NOx	VOC	NOx	VOC	NOx	VOC	NOx	VOC
Collin Co.	11.2	29.0	29.2	13.7	24.1	24.4	5.2	0.2
Dallas Co.	4.2	56.2	179.3	76.0	83.5	125.1	60.1	4.6
Denton Co.	8.1	66.4	36.0	15.0	18.8	21.3	5.2	1.3
Tarrant Co.	2.9	65.5	118.2	47.6	64.8	90.2	39.7	4.6
Core	**26.4**	**217.2**	**362.7**	**152.4**	**191.1**	**261.0**	**110.3**	**10.8**
Wise Co.	2.3	149.5	4.9	3.1	34.3	21.6	10.3	0.6
Parker Co.	0.6	130.9	13.5	4.3	16.7	12.3	3.9	0.3
Hood Co.	0.2	34.5	2.1	1.2	3.8	4.6	30.1	0.3
Johnson Co.	4.8	108.3	11.6	4.7	9.2	11.2	6.0	0.4
Ellis Co.	14.3	89.7	19.5	4.7	7.9	12.1	29.8	4.1
Henderson Co.	0.7	275.5	5.8	3.5	9.1	12.4	5.3	0.2
Cooke Co.	3.7	88.5	4.2	2.7	3.2	11.8	0.0	0.0
Kaufman Co.	5.0	105.8	12.6	4.6	5.0	10.8	0.0	0.2
Rockwall Co.	1.6	3.6	4.4	1.7	0.9	2.9	0.0	0.0
Hunt Co.	6.8	77.2	11.1	4.0	3.3	10.3	0.6	0.1
Fannin Co.	7.1	120.9	1.6	1.1	1.9	4.7	0.0	0.0
Grayson Co.	9.1	144.8	11.5	7.3	10.0	14.4	23.3	0.3
Perimeter12	**56.3**	**1329.3**	**102.7**	**42.9**	**105.4**	**129.1**	**109.3**	**6.5**
NE Texas	**16.4**	**4348.6**	**103.8**	**63.2**	**150.0**	**204.1**	**348.9**	**21.6**
HGBPA	**19.6**	**1548.8**	**269.0**	**173.8**	**272.7**	**479.7**	**684.0**	**70.9**
East Central TX	**111.2**	**5430.8**	**113.6**	**67.7**	**150.1**	**194.8**	**331.3**	**26.5**
OK	**224.1**	**6866.5**	**392.9**	**427.6**	**447.6**	**487.1**	**617.7**	**30.8**
AR	**133.6**	**12293.3**	**288.3**	**197.1**	**376.0**	**518.1**	**391.4**	**53.4**
LA	**108.3**	**8378.3**	**389.6**	**257.8**	**1101.0**	**748.0**	**1642.6**	**135.3**
NNA	**220.4**	**1851.7**	**101.8**	**63.9**	**267.2**	**470.6**	**445.0**	**25.1**
Other TX	**508.4**	**5370.8**	**171.1**	**126.7**	**439.4**	**623.8**	**273.8**	**13.9**
Other	**1977.8**	**64264.8**	**3691.0**	**2558.7**	**4437.2**	**6666.1**	**10682.4**	**651.6**
Total	**3485.0**	**113446.6**	**6452.3**	**4327.2**	**8234.2**	**11172.5**	**15856.4**	**1063.4**

Table A-5. Average contributions to high 1-hour ozone for 1999 for each of the 4 Dallas counties and for the DFW 4-county region as a whole.

1 Hr Ozone	by Source Area				
Source Area	**Collin County**	**Dallas County**	**Denton County**	**Tarrant County**	**DFW Core**
ICBC	32.13	32.55	33.12	34.49	33.44
Other States	5.25	4.26	4.13	3.86	4.20
West Texas	0.02	0.20	0.08	0.18	0.13
South Texas	0.31	0.58	0.39	0.44	0.42
LA	7.26	4.92	4.43	3.23	4.42
AR	0.82	2.43	2.16	3.35	2.47
OK	0.15	1.16	0.47	0.93	0.69
Central Texas	4.67	3.92	4.29	3.68	4.07
HGBPA	2.78	2.73	2.67	1.97	2.43
East Texas	3.74	4.83	3.95	4.46	4.23
Perimeter12	5.72	7.53	3.06	6.36	5.29
Core	38.50	27.88	41.92	36.13	37.40
1 Hr Ozone	**by Source Type**				
Source Area	**Collin County**	**Dallas County**	**Denton County**	**Tarrant County**	**DFW Core**
ICBC	0.64	0.76	0.52	0.86	0.70
BC	31.49	31.79	32.60	33.63	32.74
OAN	22.28	18.19	22.74	20.21	21.12
MV	27.04	22.88	27.19	25.69	26.06
EPT	15.21	15.70	14.31	15.66	15.13
BIO	4.69	3.67	3.31	3.03	3.44

Table A-6. Average contributions to high 8-hour ozone for 1999 for each of the 4 Dallas counties and for the DFW 4-county region as a whole.

8 Hr Ozone	by Source Area				
Source Area	**Collin County**	**Dallas County**	**Denton County**	**Tarrant County**	**DFW Core**
ICBC	30.31	30.09	31.72	33.35	32.01
Other States	5.04	4.26	4.14	3.69	4.13
West Texas	0.01	0.15	0.07	0.14	0.09
South Texas	0.38	0.93	0.44	0.42	0.44
LA	7.87	6.15	4.67	3.10	4.69
AR	0.44	1.29	1.69	3.36	2.08
OK	0.09	0.60	0.34	0.59	0.41
Central Texas	4.03	3.71	4.43	3.14	3.88
HGBPA	3.23	4.01	2.72	1.74	2.52
East Texas	3.28	2.77	3.53	4.36	3.75
Perimeter12	4.73	7.59	3.40	5.65	4.66
Core	39.60	28.33	37.38	33.34	35.85
8 Hr Ozone	**by Source Type**				
Source Area	**Collin County**	**Dallas County**	**Denton County**	**Tarrant County**	**DFW Core**
ICBC	0.78	0.95	0.44	0.95	0.70
BC	29.53	29.14	31.28	32.40	31.31
OAN	22.52	17.89	20.81	18.84	20.27
MV	27.07	22.46	24.85	23.65	24.69
EPT	14.91	16.16	13.91	14.37	14.35
BIO	4.20	3.28	3.24	2.67	3.19

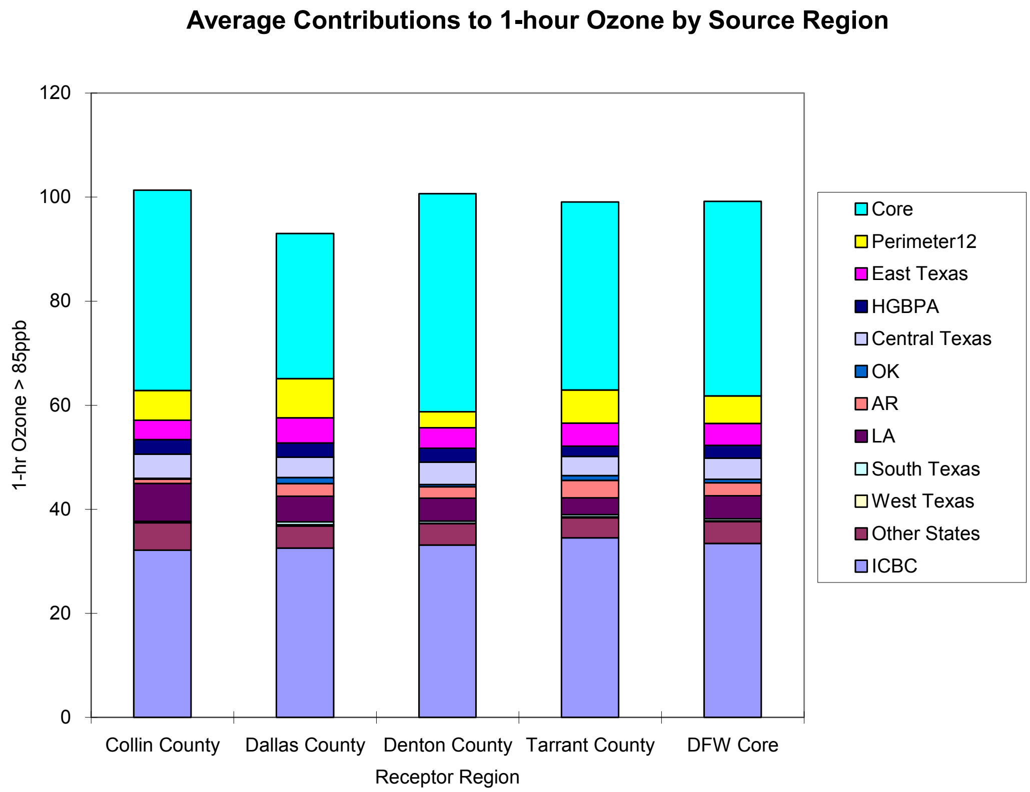


Figure A-6. Average contributions to 1-hour ozone by source region for the DFW non-attainment area.

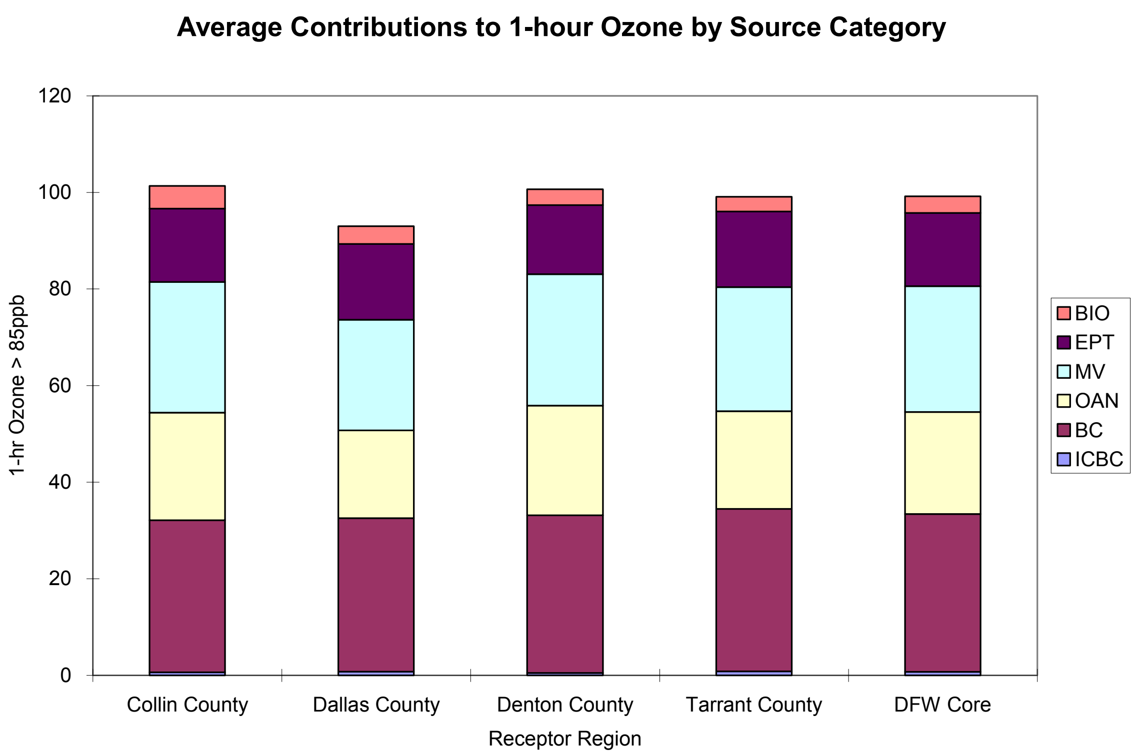


Figure A-7. Average contributions to 1-hour ozone by emission source category for the DFW non-attainment area.

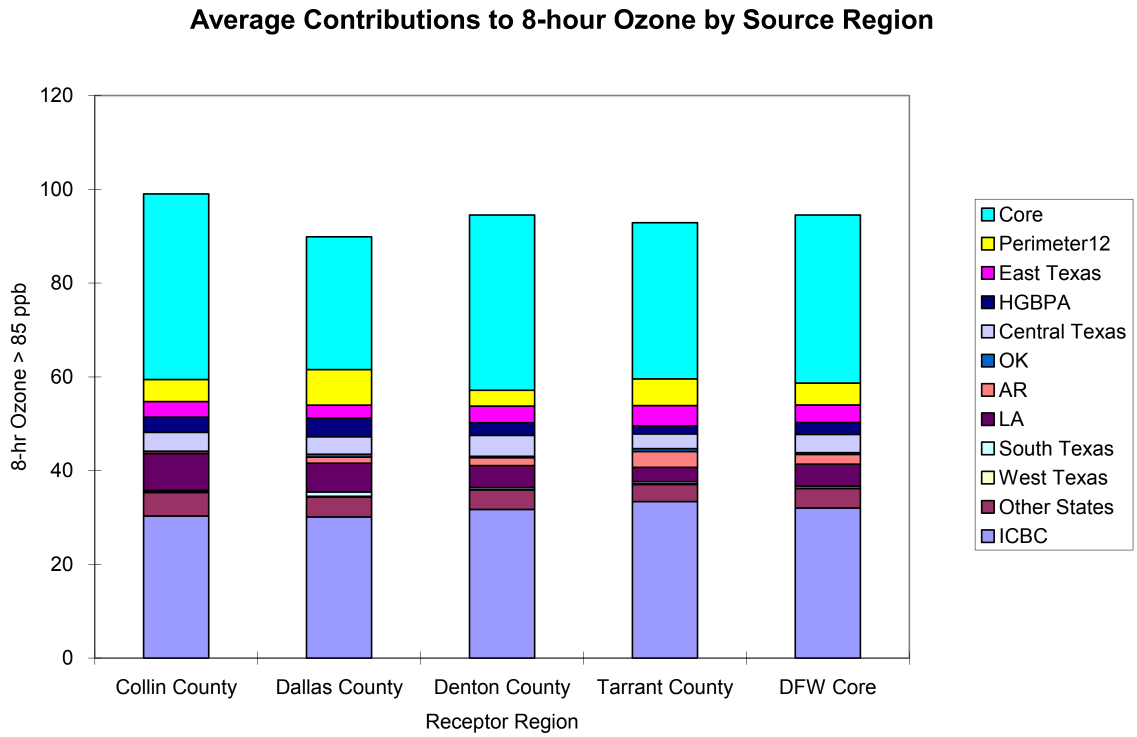


Figure A-8. Average contributions to 8-hour ozone by source region for the DFW non-attainment area.

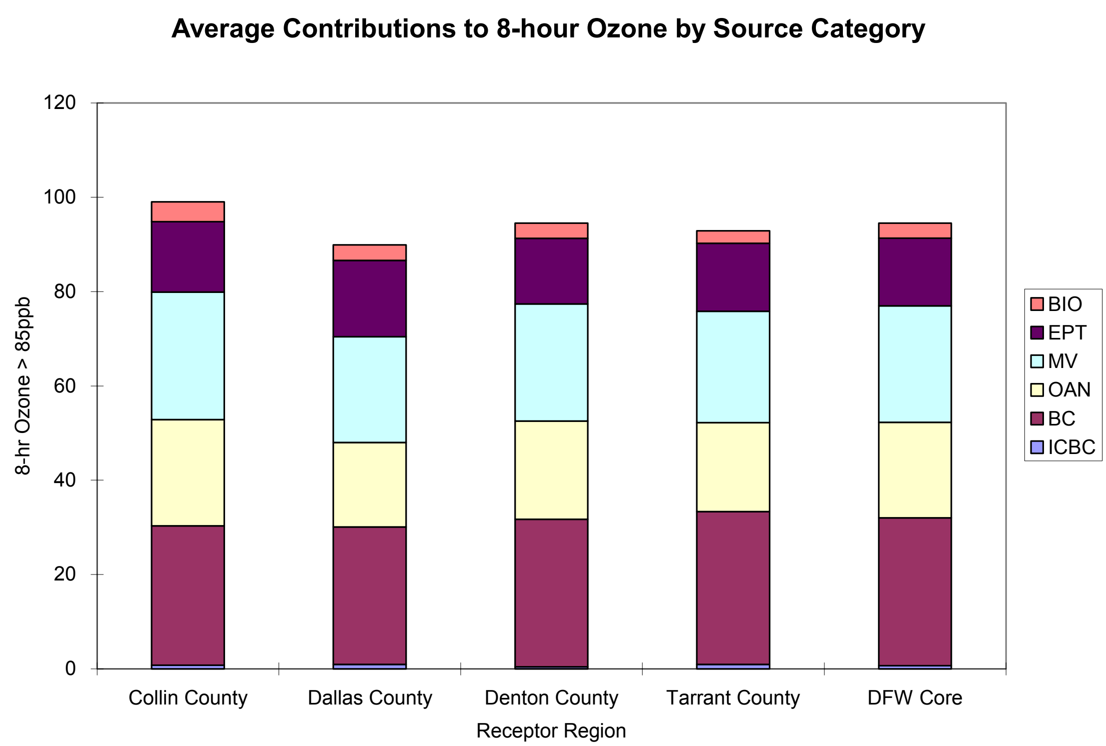


Figure A-9. Average contributions to 8-hour ozone by emission source category for the DFW non-attainment area.

Table A-7 shows the average contributions to high 1-hour ozone in 1999 broken out to 100 emissions groups (25 areas by 4 categories) plus the initial and boundary conditions. The average contribution of initial conditions was 0.1 ppb or less and the average contribution of boundary conditions was approximately 33 ppb. This shows that the contribution of initial conditions is unimportant, and the contribution of boundary conditions is significant for the DFW area. The majority of the high 1-hour ozone (nearly 62 percent) was attributed to anthropogenic emissions, with on-road mobile sources making up the majority, followed by other anthropogenic sources.

The largest emissions contributors to high 1-hour ozone in the DFW 4 county area (Table A-7) was from nearby NOx sources. Nearby means emissions from within the 4 county DFW area, followed by emissions in the surrounding 12 counties. NOx emissions within the 4 county area contributed 37% of the high 1-hour ozone and NOx emissions in the surrounding 12 county area contributed another 5%. The contribution from the remaining portions of Texas NOx emissions was 11%, with the closer regions (East and Central Texas) contributing about equally. Within the 12-county perimeter region, NOx emissions from Ellis County contribute the majority to the 1-hour ozone. NOx emissions from the remaining areas in the domain are also presented in Table A-7. The results for 8-hour ozone contributions are presented in Table A-8. The relative contributions of NOx emissions from the different source regions are essentially the same as for the 1-hour ozone contributions.

The contribution of NOx emissions was broken out between 3 sources of anthropogenic emissions: point sources, mobile sources and other sources (i.e., area, off-road mobile and low points). For the DFW 4-county area (Table A-7) the ranking of these source categories was mobile sources (26%) followed by other anthropogenic (21%) followed by elevated point sources (15%). This ranking is approximately same for the 8-hour contributions (Table A-8)

The analysis considered above is based on all grid cells and hours meeting the criteria (> 85 ppb) across all episode days mo0deled for the August 1999 ozone episode. There was some interest to determine if the resulting contributions to high 1-hour and 8-hour ozone would vary considerably day by day. An analysis was therefore undertaken which considered each day individually. Tables A-9 and A-10 present results for the August 18th episode day for 1-hour and 8-hour ozone in the DFW area, respectively.

Table A-7. Average contributions to high 1-hour ozone for 1999 (Run 7c).

Sum of Ozone	Source Category											
Region	**IC**	**BC East**	**BC North**	**BC South**	**BC Top**	**BC West**	**Biogenics**	**Elev Pts**	**On Road**	**OAN**	**Grand Total**	**Area Totals**
Collin							0.24	0.29	1.60	1.58	**3.71**	
Dallas							0.14	2.29	9.92	5.93	**18.28**	
Denton							0.21	0.26	2.41	1.46	**4.34**	
Tarrant							0.09	0.97	5.96	4.05	**11.07**	**37.40**
Wise							0.00	0.01	0.01	0.06	**0.08**	
Parker							0.00	0.00	0.06	0.05	**0.11**	
Hood							0.00	0.17	0.01	0.01	**0.19**	
Johnson							0.05	0.05	0.26	0.24	**0.60**	
Ellis							0.19	1.12	0.64	0.32	**2.27**	
Henderson							0.02	0.05	0.06	0.10	**0.23**	
Cooke							0.02	0.00	0.02	0.02	**0.06**	
Kaufman							0.13	0.00	0.51	0.22	**0.86**	
Rockwall							0.04	0.00	0.24	0.07	**0.35**	
Hunt							0.06	0.01	0.17	0.06	**0.30**	
Fannin							0.02	0.00	0.01	0.01	**0.04**	
Grayson							0.04	0.05	0.05	0.06	**0.20**	**5.29**
Central Texas							0.77	1.70	0.65	0.95	**4.07**	
East Texas							0.29	2.08	0.65	1.21	**4.23**	
South Texas							0.10	0.13	0.05	0.14	**0.42**	
HGBPA							0.10	1.12	0.50	0.71	**2.43**	
West Texas							0.03	0.03	0.02	0.05	**0.13**	**11.28**
AR							0.25	0.77	0.60	0.85	**2.47**	
LA							0.23	2.00	0.68	1.51	**4.42**	
OK							0.07	0.18	0.21	0.23	**0.69**	
Other States							0.35	1.85	0.77	1.23	**4.20**	
Boundary Conditions		1.77	11.53	0.90	17.24	1.30					**32.74**	
Initial Conditions	0.70										**0.70**	**11.78**
Grand Total	**0.70**	**1.77**	**11.53**	**0.90**	**17.24**	**1.30**	**3.44**	**15.13**	**26.06**	**21.12**	**99.19**	**99.19**

Table A-8. Average contributions to high 8-hour ozone for 1999 (Run 7c).

Sum of Ozone	Source Category											
Region	**IC**	**BC East**	**BC North**	**BC South**	**BC Top**	**BC West**	**Biogenics**	**Elev Pts**	**On Road**	**OAN**	**Grand Total**	**Area Totals**
Collin							0.24	0.31	1.51	1.46	**3.52**	
Dallas							0.11	2.16	8.55	5.18	**16.00**	
Denton							0.21	0.26	2.38	1.42	**4.27**	
Tarrant							0.09	1.10	6.46	4.41	**12.06**	**35.85**
Wise							0.00	0.00	0.01	0.08	**0.09**	
Parker							0.00	0.01	0.10	0.07	**0.18**	
Hood							0.00	0.20	0.01	0.01	**0.22**	
Johnson							0.05	0.06	0.25	0.24	**0.60**	
Ellis							0.14	0.89	0.46	0.24	**1.73**	
Henderson							0.03	0.05	0.07	0.11	**0.26**	
Cooke							0.00	0.00	0.01	0.01	**0.02**	
Kaufman							0.13	0.00	0.46	0.20	**0.79**	
Rockwall							0.04		0.22	0.06	**0.32**	
Hunt							0.07	0.01	0.18	0.06	**0.32**	
Fannin							0.02		0.01	0.01	**0.04**	
Grayson							0.02	0.03	0.02	0.02	**0.09**	**4.66**
Central Texas							0.74	1.51	0.67	0.96	**3.88**	
East Texas							0.27	1.72	0.63	1.13	**3.75**	
South Texas							0.10	0.13	0.06	0.15	**0.44**	
HGBPA							0.10	1.16	0.52	0.74	**2.52**	
West Texas							0.02	0.02	0.01	0.04	**0.09**	**10.68**
AR							0.21	0.65	0.50	0.72	**2.08**	
LA							0.23	2.15	0.72	1.59	**4.69**	
OK							0.04	0.11	0.12	0.14	**0.41**	
Other States							0.33	1.82	0.76	1.22	**4.13**	
Boundary Conditions		1.90	10.56	0.94	16.66	1.25					**31.31**	
Initial Conditions	0.70										**0.70**	**11.31**
Grand Total	**0.70**	**1.90**	**10.56**	**0.94**	**16.66**	**1.25**	**3.19**	**14.35**	**24.69**	**20.27**	**94.51**	**94.51**

Table A-9. Average contributions to high 1-hour ozone for August 18, 1999 (Run 7c).

Sum of Ozone	**Source Category**											
Region	**IC**	**BC East**	**BC North**	**BC South**	**BC Top**	**BC West**	**Biogenics**	**Elev Pts**	**On Road**	**OAN**	**Grand Total**	**Area Totals**
Collin							0.53	0.45	2.78	2.73	**6.49**	
Dallas							0.13	2.03	10.90	5.99	**19.05**	
Denton							0.21	0.21	2.21	1.31	**3.94**	
Tarrant							0.06	0.77	5.02	3.12	**8.97**	**38.45**
Wise							0.00	0.00	0.00	0.02	**0.02**	
Parker							0.00	0.00	0.03	0.02	**0.05**	
Hood							0.00	0.08	0.00	0.00	**0.08**	
Johnson							0.05	0.06	0.29	0.26	**0.66**	
Ellis							0.17	1.38	0.69	0.33	**2.57**	
Henderson							0.01	0.02	0.02	0.03	**0.08**	
Cooke							0.00		0.00	0.00	**0.00**	
Kaufman							0.11	0.00	0.49	0.20	**0.80**	
Rockwall							0.06		0.45	0.11	**0.62**	
Hunt							0.18	0.02	0.47	0.16	**0.83**	
Fannin							0.02		0.01	0.01	**0.04**	
Grayson							0.02	0.00	0.02	0.01	**0.05**	**5.80**
Central Texas							1.21	1.58	1.15	1.25	**5.19**	
East Texas							0.28	1.48	0.89	1.51	**4.16**	
South Texas							0.01	0.00	0.00	0.01	**0.02**	
HGBPA							0.12	0.31	0.24	0.30	**0.97**	
West Texas							0.00	0.00	0.00	0.00	**0.00**	**10.34**
AR							0.19	0.48	0.28	0.63	**1.58**	
LA							0.32	1.59	0.59	1.32	**3.82**	
OK							0.00	0.00	0.00	0.00	**0.00**	
Other States							0.47	2.55	0.72	1.39	**5.13**	
Boundary Conditions		0.01	14.51	0.00	19.82	0.02					**34.36**	
Initial Conditions	0.02										**0.02**	**10.53**
Grand Total	**0.02**	**0.01**	**14.51**	**0.00**	**19.82**	**0.02**	**4.15**	**13.01**	**27.25**	**20.71**	**99.50**	**99.50**

Table A-10. Average contributions to high 8-hour ozone for August 18, 1999 (Run 7c).

Sum of Ozone	Source Category											
Region	**IC**	**BC East**	**BC North**	**BC South**	**BC Top**	**BC West**	**Biogenics**	**Elev Pts**	**On Road**	**OAN**	**Grand Total**	**Area Totals**
Collin							0.32	0.41	1.88	1.86	**4.47**	
Dallas							0.10	1.99	8.02	4.70	**14.81**	
Denton							0.26	0.33	2.91	1.73	**5.23**	
Tarrant							0.09	1.34	7.35	4.88	**13.66**	**38.17**
Wise							0.00	0.00	0.02	0.12	**0.14**	
Parker							0.01	0.01	0.15	0.10	**0.27**	
Hood							0.00	0.32	0.01	0.02	**0.35**	
Johnson							0.05	0.09	0.28	0.26	**0.68**	
Ellis							0.12	0.85	0.39	0.19	**1.55**	
Henderson							0.03	0.04	0.06	0.09	**0.22**	
Cooke							0.00		0.00	0.00	**0.00**	
Kaufman							0.11	0.00	0.35	0.15	**0.61**	
Rockwall							0.04		0.25	0.07	**0.36**	
Hunt							0.07	0.01	0.16	0.06	**0.30**	
Fannin							0.02		0.01	0.01	**0.04**	
Grayson							0.01	0.02	0.02	0.01	**0.06**	**4.58**
Central Texas							0.93	1.23	0.92	1.17	**4.25**	
East Texas							0.24	0.88	0.66	0.99	**2.77**	
South Texas							0.14	0.19	0.09	0.21	**0.63**	
HGBPA							0.11	1.30	0.66	0.90	**2.97**	
West Texas							0.01	0.01	0.01	0.02	**0.05**	**10.67**
AR							0.09	0.22	0.13	0.28	**0.72**	
LA							0.26	2.88	0.92	2.02	**6.08**	
OK							0.00	0.01	0.01	0.01	**0.03**	
Other States							0.35	2.14	0.85	1.42	**4.76**	
Boundary Conditions		2.52	8.98	1.43	17.89	0.08					**30.90**	
Initial Conditions	0.57										**0.57**	**11.59**
Grand Total	0.57	2.52	8.98	1.43	17.89	0.08	3.36	14.27	26.11	21.27	**96.48**	**96.48**

SUMMARY AND CONCLUSIONS

The ozone source apportionment analysis provides insight into the sensitivity of modeled ozone levels to emissions, boundary conditions and initial conditions in 1999. This information leads to the following conclusions about the model configuration, the sources that contribute to high ozone and the effectiveness of emissions reductions.

Model Configuration

- Initial conditions were unimportant. This shows that the model spin-up period was sufficient.

- Boundary conditions contributed about 30 ppb to 35 ppb to 1-hour and 8-hour ozone levels above 85 ppb in DFW non-attainment area in 1999. Since the boundary condition for ozone was set to 40 ppb, about 25% of the boundary ozone was destroyed by chemistry and deposition before reaching North Central Texas.

- Emissions in states outside of Texas, Louisiana, Arkansas and Oklahoma contributed about 4 to 5 ppb to 1-hour and 8-hour ozone above 85 ppb in North Central Texas. This contribution is less than 10% of the high ozone which shows that:

    - High 8-hour ozone levels in North Central Texas are primarily due to emissions from within a "1-state" distance upwind.

    - The 36-km regional modeling domain is large enough to capture virtually all of the influence from upwind emissions.

    - The 12-km modeling domain captures most of the important upwind emissions influence from the states of Texas, Louisiana, Arkansas and Oklahoma.

- Emissions from North Central Texas (DFW 4 counties plus surrounding 12 counties) contributed about 42 ppb of 1-hour ozone above 85 ppb, and about 40 ppb of 8-hour above 85 ppb in the DFW non-attainment area in 1999. This shows that the 4-km modeling domain is large enough to capture more than 50% of the important emissions influences.

Ozone Sensitivity to Emissions

- The majority (more than 65%) of high 1-hour and 8-hour ozone in the DFW 4-county area in 1999 was attributed to anthropogenic emissions sources. This means that 1-hour and 8-hour ozone can be reduced by controlling the appropriate emissions sources.

- Controlling NOx emissions is the only effective strategy for reducing high 1-hour and 8-hour ozone. Ozone formation is predominantly NOx sensitive on high ozone days, but on some high ozone days, ozone is sensitive to both NOx and VOCs. However, because the

VOCs are dominated by biogenic emissions, NOx control is the only effective strategy on all days.

Source Contributions

- The largest emissions contributions to high 1-hour and 8-hour ozone in the DFW 4-county area come from nearby NOx emissions. Nearby means primarily emissions from within the 4-county DFW area, followed by emissions in surrounding counties (12 perimeter counties, East Texas and Central Texas).

- The relative importance of different source categories of NOx emission varies by region. For the 4 county region as a whole, on-road mobile sources are the largest contributor followed by other anthropogenic sources followed by point sources. The emission source contributions to high ozone in the DFW region varies by individual source region.

- The contribution to high 8-hour ozone in the DFW 4-county area from emissions in the 4 Counties was 30.7 ppb and from the surrounding 11 Counties was 13.5 ppb.

- The contribution to high 8-hour ozone in the DFW 4-county area from the surrounding 12 counties was 4.66 ppb, from East Texas was 3.75 ppb, from Central Texas was 3.88 ppb, from Houston/Galveston/Beaumont/Port Arthur was 2.52 ppb and from the rest of Texas was 0.54 ppb.

- The contribution to high 8-hour ozone in the DFW 4-county area from Louisiana was 4.7 ppb, Arkansas was 2.1 ppb and Oklahoma was 0.4 ppb.

- The contribution to high 8-hour ozone in the DFW 4-county area from states outside Texas, Louisiana, Arkansas and Oklahoma was 4.1 ppb.