Final Report

Dallas/Fort Worth Future Case Control Requirement Assessment

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1. INTRODUCTION

The August 13-22, 1999 period was identified as being representative of a high 8-hr and 1-hr ozone levels in the Dallas/Fort Worth (DFW) area. This episode is referred to as the "core" period. EPA's latest draft of the 8-hr ozone modeling guidance (EPA, 2005) suggests that States should model an extended period that includes a complete synoptic cycle of ozone build-up and clear-out.[1] The DFW core period includes a complete synoptic cycle, but there also were additional high ozone days in late August 1999 after the core episode period (Figure 1-1). This study models the "supplemental period" from August 23 – September 1, 1999 to pick up the additional high ozone days. Modeling results for the supplemental period may be used to corroborate the primary results obtained for the core episode. The supplemental period results are considered less reliable than the core period results because they are modeled in less detail.

Previous work for TCEQ used the Run 17b configuration to examine the level of emission controls needed to reach attainment for 8-hour ozone in 2010 during the core period by applying a matrix of VOC and NOx reductions inside the DFW 9-county non-attainment area (NAA) (Mansell et al., 2004). This study reapplies the local emission controls to both the core and supplemental periods using an improved CAMx configuration based on Run 34, which was found to yield the best model performance among several sensitivity runs performed for the Houston Advanced Research Council (HARC), project H35 (Tai, 2005). An updated method for design value scaling adopted by the EPA was also applied.

Section 2 compares the modeling inputs between Run 17b and Run 34. Section 3 evaluates the performance of MM5 Run 6 during the supplemental period. Section 4 compares the 1999 base case model performance between CAMx Run 17b and the latest run during the core and extended periods. Section 5 evaluates 2010 future year ozone for both the core and supplemental periods from 15 CAMx runs to estimate the level of controls within the DFW NAA needed to reach attainment for 8-hour ozone. An additional run evaluated the impacts from NOx reductions in Texas EGUs Section 6 applies the 1999 episode to 2002 to project more current design values to 2010.

[1] The latest draft of EPA's 8-hour ozone modeling guidance suggests that states should model episodes of at least 10-15 days durations, as follows: Page 44 says that a synoptic cycle may be anywhere from 5 to 15 days long: Page 61 states that relative reduction factor calculations are expected to be robust when they include about 10 days.

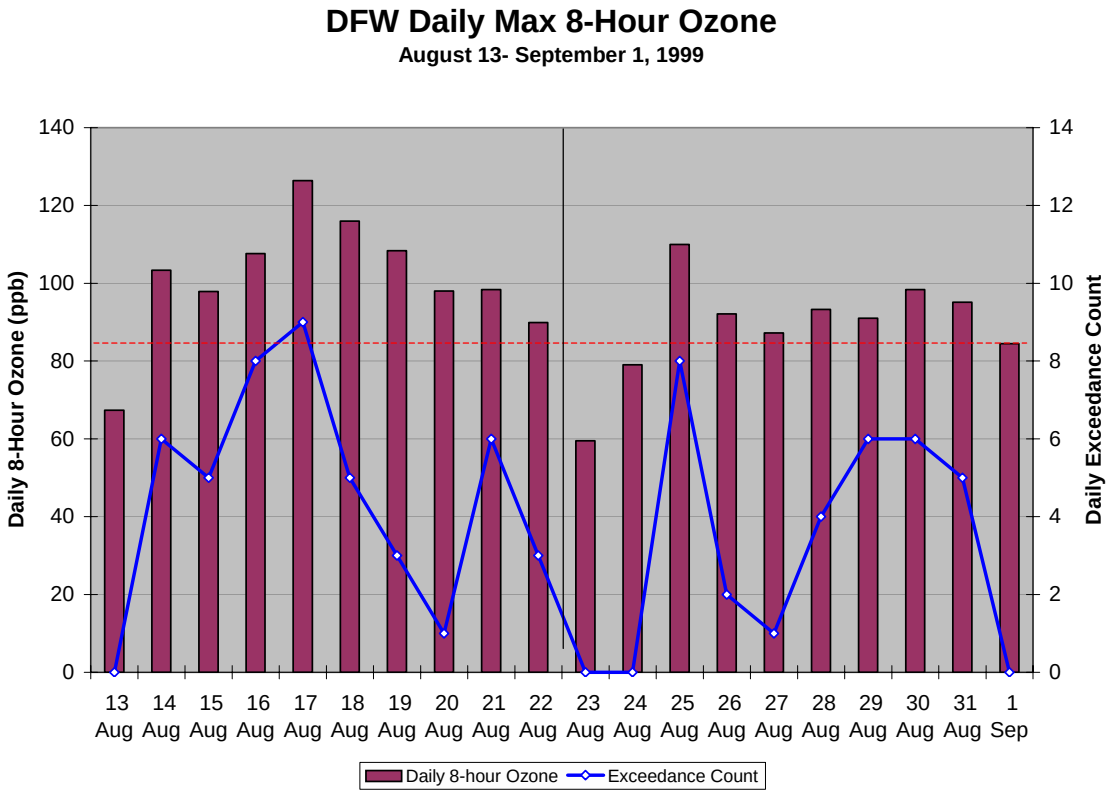


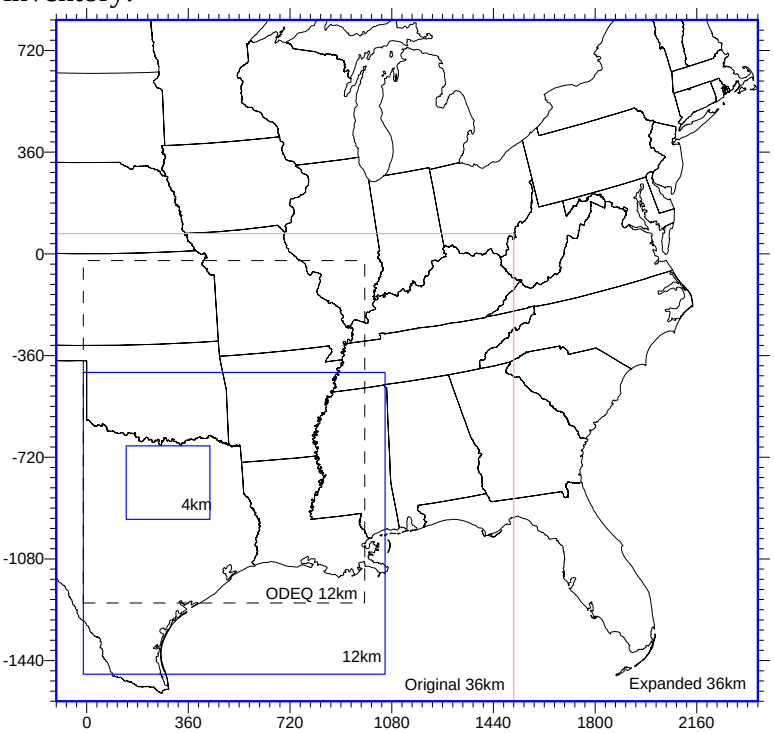
Figure 1-1. Ozone levels during the DFW core episode (August 13-22) and extension period (August 23-September 1, 1999).

2. MODELING INPUTS

Previous ozone modeling for the 2010 future year was based on the Run 17b configuration (Mansell et al., 2004), which used the standard version of CAMx 4.03. In this task, all runs were based on the Run 34 configuration, which produced better ozone performance in the core period (Tai, 2005). A modified version of CAMx 4.03 was used, in which 17 inorganic chemistry reactions, including several NOx recycling reactions, were added to the CB4 mechanism.

DOMAIN CONFIGURATION

Run 17b used the original DFW 36-km domain, which spanned 1620-km by 1656-km, extending as far north as southern Nebraska and southern Ohio, and as far east as the Florida panhandle. The Run 34 configuration extended the eastern boundary into the Atlantic to include all of the eastern states, and the northern boundary into North Dakota and parts of Canada. The southern and western boundaries were unchanged. Figure 2-1 shows the modeling domain of the original and expanded domains. The 12-km and 4-km domains were the same. Figure 2-1 also shows a 12-km grid used in modeling for the Oklahoma DEQ because this pertains to the emission inventory.



	nx x ny	SW to NE Corners
CAMx 36km (standard)	45 x 46	(-108, -1584) to (1512, 72)
CAMx 36km expanded	69 x 67	(-108, -1584) to (2376, 828)
CAMx 12km	89 x 89*	(-12, -1488) to (1056, -420)
CAMx 04km	74 x 65*	(140, -940) to (436, -680)
ODEQ 12km	86 x 101*	(-12, -1236) to (984, -24)

* includes buffer cells

Figure 2-1. CAMx 36/12/4-km nested grids for the DFW expanded domain.

Vertically, the original domain coincided with the first 15 layers from MM5, which topped out just below 4-km. The expanded domain added five more layers each spaced 2 to 3-km apart above the original model top to extend the domain up to 14-km (Tai et al., 2005). The vertical layering structures from MM5 and CAMx are listed in Table 2-1.

Table 2-1. MM5 and CAMx vertical grid structures based on 28 sigma-p levels. Heights (m) are above ground level according to a standard atmosphere; pressure is in millibars.

Layer	sigma	pressure	height	thickness	CAMx Layers	IC/BC
28	0.0000	50.00	18874.41	1706.76		
27	0.0250	73.75	17167.65	1362.47		
---------- Extended CAMx Top ----------						
26	0.0500	97.50	**15805.17**	2133.42	--20---	^
25	0.1000	145.00	**13671.75**	1664.35	--19---	|
24	0.1500	192.50	12007.40	1376.75		|
23	0.2000	240.00	**10630.65**	1180.35	--18---	|
22	0.2500	287.50	9450.30	1036.79		|
21	0.3000	335.00	**8413.52**	926.80	--17---	|
20	0.3500	382.50	7486.72	839.57		|
19	0.4000	430.00	6647.15	768.53		Clean IC/BC
18	0.4500	477.50	**5878.62**	709.45	--16---	|
17	0.5000	525.00	5169.17	659.47		|
16	0.5500	572.50	4509.70	616.58		|
---------- Original CAMx Top ----------						|
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---	v
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---	Moderate IC/BC
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---	v
0	1.0000	1000.00	**0.00**	========= Surface ======		

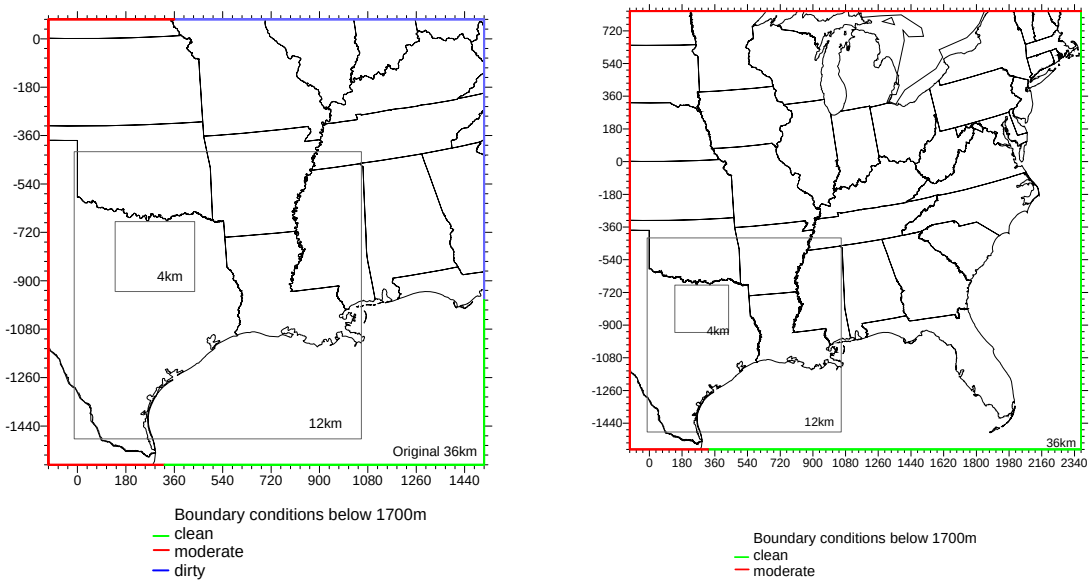
INITIAL AND BOUNDARY CONDITIONS

Initial and boundary conditions were classified into three categories: clean, moderate, and dirty. Table 2-2 lists concentrations for each species associated with each group (Mansell, 2003). In the Run 17b configuration, initial conditions were clean everywhere. Boundary conditions were clean over the Gulf of Mexico, and moderate over Mexico, Nebraska, and the entire western boundary up to 1700 m. The remaining sections of the northern and eastern boundaries were set to dirty conditions below 1700 m. All boundaries above 1700 m were considered clean.

In the latest configuration, initial conditions were moderate below 1700 m and clean aloft. The eastern boundary was assigned clean conditions because it was entirely over the ocean. The northern boundary was set to moderate up to 1700 m because most of the major urban centers were inside the expanded domain; aloft, conditions were clean. Figure 2-2 shows the categories assigned to all lateral boundaries in the original and expanded domains.

Table 2-2. Concentrations (ppb) used to define CAMx initial and boundary conditions.

Species	Dirty	Moderate	Clean
O3	40	40	40
CO	200	200	100
NO	0.1	0.1	0.1
NO2	1	1	1
HNO3	3	3	1
HNO2	0.001	0.001	0.001
ALD2	0.555	0.555	0.05
ETH	0.51	0.51	0.15
HCHO	2.1	2.1	0.05
OLE	0.3	0.3	0.05
PAR	14.9	14.9	7.6
TOL	0.18	0.18	0.0786
XYL	0.0975	0.0975	0.0688
ISOP	3.6	0.1	0.001
PAN	0.1	0.1	0.1
H2O2	3	3	1
MEOH	8.5	0.001	0.001
ETOH	1.1	0.001	0.001



Standard domain

Expanded domain

Figure 2-2. Assignment of boundary conditions in the mixed layer for the standard and expanded domains for DFW.

EMISSIONS

The emissions inventory for the August 13 – 22, 1999 core period incorporated all of the emissions from the TCEQ inventory for the standard domain, as had been used in the Run 17b (Mansell, 2004). Outside the standard 36-km domain, emissions were obtained from modeling work conducted for the Oklahoma Department of Environmental Quality (ODEQ) (Morris, 2005).

In the supplemental period (August 23 to September 1), ODEQ emissions were readily available while TCEQ emissions were not. In order to preserve the emissions inventory in Texas, anthropogenic emissions in the supplemental period were linked to dates in the core period based on the day-of-the-week. Table 2-3 lists surrogate dates used to represent the anthropogenic emissions in the supplemental period. Biogenic emissions, being more temperature dependent, were date-specific and interpolated from coarser grids from the ODEQ inventory in the extended period. The DFW 4-km biogenics were derived from the ODEQ 12-km domain, and the DFW 12-km biogenics were composed from both the ODEQ 12-km and 36-km resolution fields. Areas inside the dashed box in Figure 2-1 use 12-km resolution biogenics from ODEQ.

Table 2-3. Surrogate date emissions for the extended period.

Date	Day of Week	Surrogate Day	
		Anthro	Bio
13-Aug-99	Fri	N/A	
14-Aug-99	Sat		
15-Aug-99	Sun		
16-Aug-99	Mon		
17-Aug-99	Tue		
18-Aug-99	Wed		
19-Aug-99	Thu		
20-Aug-99	Fri		
21-Aug-99	Sat		
22-Aug-99	Sun		
23-Aug-99	Mon	16-Aug	23-Aug*
24-Aug-99	Tue	17-Aug	24-Aug*
25-Aug-99	Wed	18-Aug	25-Aug*
26-Aug-99	Thu	19-Aug	26-Aug*
27-Aug-99	Fri	20-Aug	27-Aug*
28-Aug-99	Sat	14-Aug	28-Aug*
29-Aug-99	Sun	15-Aug	29-Aug*
30-Aug-99	Mon	16-Aug	30-Aug*
31-Aug-99	Tue	17-Aug	31-Aug*
1-Sep-99	Wed	18-Aug	01-Sep*

*4-km and 12-km biogenics are interpolated from coarser grids.

The 2010 future year emissions for the core period were based on the TCEQ 2010 inventory inside the standard domain, and a projected ODEQ 2002 inventory for areas outside the standard domain. Emissions for 2010 in the expanded region were estimated by scaling the ODEQ emissions to 2010 using ratios of the 2010 and 2001 base case annual average emission rates from each state and source group, as used in the draft CAIR guidelines (EPA, 2004). Scaling factors for each state and each source group – area, off-road mobile, on-road mobile, and point

sources – are listed in Tables 2-4 to 2-7, respectively. Emissions for the supplemental period for 2010 were generated using the "surrogate day" method described for the 1999 emissions.

Table 2-4. CAIR area source emission scaling factors from 2001 to 2010 for each state inside the expanded DFW domain, but outside the original DFW domain.

State	NOx	VOC	CO	SO2
Connecticut	0.88	0.76	0.67	0.88
DC	0.95	0.89	0.99	0.95
Delaware	0.97	0.99	0.99	0.98
Florida	1.01	0.97	0.94	1.02
Georgia	1.03	0.98	0.98	1.01
Iowa	1.03	0.96	0.83	1.05
Illinois	0.93	0.90	0.82	0.98
Indiana	1.04	0.95	0.89	1.08
Kentucky	1.04	0.90	0.78	1.03
Massachusetts	0.93	0.88	0.78	0.93
Maryland	0.96	0.94	0.98	1.10
Maine	0.89	0.79	0.67	0.87
Michigan	0.95	0.87	0.73	0.95
Minnesota	1.03	0.96	0.77	0.96
Missouri	1.04	0.89	0.71	1.00
North Carolina	1.03	0.96	0.93	1.02
North Dakota	1.09	1.01	0.95	1.08
Nebraska	1.04	0.99	0.86	1.02
New Hampshire	1.02	0.88	0.74	1.01
New Jersey	0.94	0.89	0.89	0.92
New York	0.81	0.89	0.68	0.89
Ohio	0.99	0.92	0.76	1.01
Pennsylvania	0.94	0.88	0.84	0.87
Rhode Island	0.87	0.89	0.71	0.86
South Carolina	1.05	0.97	0.92	1.06
South Dakota	1.10	1.02	0.89	1.14
Tennessee	1.03	0.93	0.80	1.05
Virginia	1.01	0.95	0.81	1.01
Vermont	0.86	0.91	0.69	0.96
Wisconsin	0.97	0.91	0.81	1.03
West Virginia	0.96	0.87	0.72	0.99

Table 2-5. CAIR off-road mobile source emission scaling factors from 2001 to 2010 for each state inside the expanded DFW domain, but outside the original DFW domain.

State	NOx	VOC	CO	SO2
Connecticut	0.81	0.67	1.10	0.17
DC	0.91	1.05	1.16	0.29
Delaware	0.98	0.66	1.09	0.23
Florida	0.89	0.69	1.14	0.58
Georgia	0.83	0.72	1.12	0.28
Iowa	0.83	0.73	1.07	0.08
Illinois	0.85	0.75	1.10	0.12
Indiana	0.83	0.74	1.09	0.11
Kentucky	0.91	0.78	1.08	0.10
Massachusetts	0.83	0.70	1.09	0.15
Maryland	0.90	0.73	1.14	0.68
Maine	0.82	0.82	1.08	0.19
Michigan	0.84	0.76	1.07	0.19
Minnesota	0.86	0.79	1.06	0.14
Missouri	0.88	0.74	1.11	0.13
North Carolina	0.80	0.71	1.09	0.17
North Dakota	0.85	0.77	1.04	0.07
Nebraska	0.84	0.75	1.09	0.09
New Hampshire	0.78	0.76	1.11	0.20
New Jersey	0.86	0.68	1.13	0.77
New York	0.85	0.72	1.13	0.20
Ohio	0.84	0.73	1.10	0.35
Pennsylvania	0.81	0.76	1.11	0.28
Rhode Island	0.82	0.67	1.12	0.76
South Carolina	0.76	0.69	1.10	0.26
South Dakota	0.84	0.76	1.04	0.07
Tennessee	0.93	0.78	1.08	0.16
Virginia	0.93	0.72	1.12	0.46
Vermont	0.81	0.81	1.10	0.18
Wisconsin	0.80	0.77	1.04	0.14
West Virginia	0.74	0.85	1.14	0.68

Table 2-6. CAIR mobile source emission scaling factors from 2001 to 2010 for each state inside the expanded DFW domain, but outside the original DFW domain.

State	NOx	VOC	CO	SO2
Connecticut	0.49	0.48	0.52	0.16
DC	0.57	0.53	0.74	0.19
Delaware	0.63	0.80	1.11	0.17
Florida	0.61	0.84	1.08	0.10
Georgia	0.53	0.63	0.70	0.10
Iowa	0.56	0.79	0.95	0.10
Illinois	0.57	0.67	0.81	0.13
Indiana	0.58	0.77	0.94	0.10
Kentucky	0.57	0.79	0.96	0.11
Massachusetts	0.55	0.60	0.76	0.17
Maryland	0.53	0.61	0.75	0.16
Maine	0.57	0.73	0.98	0.09
Michigan	0.57	0.76	1.00	0.09
Minnesota	0.54	0.67	0.87	0.10
Missouri	0.56	0.75	0.88	0.11
North Carolina	0.58	0.84	1.04	0.10
North Dakota	0.58	0.80	0.98	0.10
Nebraska	0.57	0.80	0.96	0.10
New Hampshire	0.59	0.75	0.93	0.12
New Jersey	0.51	0.51	0.62	0.17
New York	0.51	0.57	0.75	0.12
Ohio	0.57	0.71	0.86	0.10
Pennsylvania	0.58	0.70	0.91	0.11
Rhode Island	0.48	0.53	0.55	0.15
South Carolina	0.57	0.89	0.95	0.09
South Dakota	0.59	0.81	1.00	0.11
Tennessee	0.58	0.84	1.01	0.10
Virginia	0.60	0.75	0.86	0.11
Vermont	0.61	0.69	0.85	0.11
Wisconsin	0.57	0.68	0.90	0.11
West Virginia	0.55	0.79	0.87	0.10

Table 2-7. CAIR point source (EGU + non-EGU) emission scaling factors from 2001 to 2010 for each state inside the expanded DFW domain, but outside the original DFW domain.

State	NOx	VOC	CO	SO2
Connecticut	0.74	0.80	1.83	0.33
DC	0.74	0.95	1.08	0.67
Delaware	0.88	0.77	1.07	1.12
Florida	0.62	0.86	1.24	0.49
Georgia	0.97	0.87	1.23	1.22
Iowa	1.05	0.66	0.90	1.13
Illinois	0.91	0.88	1.00	1.39
Indiana	0.78	0.94	1.06	0.87
Kentucky	0.87	1.00	1.13	0.70
Massachusetts	0.53	0.88	1.67	0.26
Maryland	0.85	0.94	1.02	0.92
Maine	1.02	0.89	1.09	0.87
Michigan	0.94	0.88	1.08	1.08
Minnesota	1.16	0.83	1.17	0.99
Missouri	0.95	0.96	1.06	1.16
North Carolina	0.63	0.96	1.11	0.62
North Dakota	0.98	0.76	1.04	1.00
Nebraska	1.16	0.98	0.97	1.36
New Hampshire	0.72	0.94	1.32	0.27
New Jersey	0.70	0.86	0.70	0.80
New York	0.84	0.90	1.24	0.86
Ohio	0.82	0.80	1.06	1.06
Pennsylvania	0.97	0.75	0.93	0.91
Rhode Island	2.34	0.66	1.35	0.94
South Carolina	0.87	0.77	1.12	1.01
South Dakota	0.74	1.09	0.76	2.40
Tennessee	0.73	0.89	1.09	0.86
Virginia	0.80	0.94	1.10	0.91
Vermont	0.41	0.88	0.63	0.94
Wisconsin	1.07	0.87	1.08	1.09
West Virginia	0.80	0.91	1.04	1.09

METEOROLOGY

In Run 17b, the meteorological inputs were from MM5 Run 5, which used the Pleim-Xiu PBL and land surface model (Mansell et al., 2004). The O'Brien Kv method was used to calculate the vertical diffusivity. The latest simulations favored MM5 Run 6 for the core period, based on the Eta PBL scheme coupled with the Noah land surface model. The TKE method was used to obtain the vertical diffusivity. Both sets of vertical diffusivities used the "kv100" patch, which applied the largest diffusivity value in the lowest 100 m to all layers below 100 m. Section 3 evaluates the performance of MM5 Run 6 for the extended period.

3. MODEL PERFORMANCE EVALUATION OF DFW MM5 "RUN 6"

CONFIGURATION

MM5 was run during the August 23 – September 1, 1999 "extension" period using the same configuration as previously run for the August 13 – 22 period (Tai et al., 2005), except that observational FDDA only included hourly measurements obtained from the Oklahoma Mesonet. The performance evaluation centers on hourly and daily statistics of winds, temperature, and humidity across all observation sites in both the 12-km Texas regional and 4-km DFW domains. The observational data used in the evaluation include the same Oklahoma Mesonet sites used in the FDDA, as well as NWS observations provided by NCAR dataset DS472. Furthermore, plots of layer 1 winds and PBL heights were prepared for the afternoon of each day and analyzed.

RESULTS

Figure 3-1 presents the daily plots (at 3 PM) of PBL and surface-layer winds in the 4-km DFW domain on each day between August 23 and September 1. These were generated from CAMx-ready input fields (PBL height was diagnosed from Kv fields). The period starts out as fairly quiet, with low to moderate wind speeds and moderate PBL heights. Winds remain relatively calm and unorganized up to August 27, and PBL heights gradually build to well over 2500 m as the period warms. August 27 appears to be a transition day, with an obvious convective signature in the north-central portion of the domain, complete with strong surface outflow and a directly correlated collapsed boundary layer due to surface cooling. Winds on August 28 return to a calm, unorganized pattern, and PBL heights are again moderate. Over the next four days, winds organize towards easterly, and gradually increase in strength. PBL heights remain stable with maxima mainly reaching about 2000 m. Horizontal structure of the PBL tends to align along the wind direction, which backs with time to southeasterly until September 1, when small convective areas develop in the southeast corner of the grid.

Table 3-1 displays the period-average performance statistics for the 12 and 4-km domains, along with the performance benchmarks. The performance for this simulation is not particularly good, and many measures are worse for the 4-km simulation (albeit, this has been the trend in previous MM5 modeling). The period-average statistics meet or exceed the benchmarks for wind speed error, wind direction bias, temperature IOA, and all humidity metrics. The following discussion stratifies the performance statistics by grid, time scale, and monitoring network.

Table 3-1. Summary of MM5 performance against benchmark targets for the 12-km and 4-km grids.

Parameter	Benchmark	12km	4km
Wind Speed Bias	±0.5	-1.27	-1.14
Wind Speed RMSE	2.0	1.96	1.79
Wind Speed IOA	0.60	0.56	0.46
Wind Direction Bias	±10	5.4	12.25
Wind Direction Gross Error	30	38.23	47.48
Temperature Bias	±0.5	0.72	1.99
Temperature Gross Error	2.0	2.11	2.65
Temperature IOA	0.80	0.92	0.87
Humidity Bias	±1.0	0.27	0.15
Humidity Gross Error	2.0	1.77	1.92
Humidity IOA	0.60	0.83	0.55

We begin by evaluating 12-km performance against Oklahoma Mesonet observations. MM5 was directly nudged to these data via observational FDDA. Note that these statistics reflect performance only in the area in the north-central portion of the 12-km grid. Figure 3-2 presents hourly metrics, while Figure 3-3 presents daily metrics. Figure 3-2a shows that hourly wind performance across all Oklahoma Mesonet sites is actually quite good, particularly for wind direction, which shows an astonishingly small bias throughout the period. The only periods of concern are August 23 and 26-27, which were apparently transition periods accompanied by some storm activity. MM5 under predicts wind speed during these periods by about a factor of 2. Temperature performance is rather good as well (Figure 3-2b), although there is a consistent ~2 K over prediction during most hours (morning hours excepted). Humidity is also well-simulated at these sites, with a general under-prediction bias during the middle of the period (Figure 3-2c).

The good wind performance is reflected in the daily statistics as well (Figure 3-3a), with again the exception of August 23, 26, and 27. Daily IOA is quite good on most days. Daily temperatures are over predicted by about 1 K overall, but the cool day of August 27 is not well replicated and MM5 over predicts daily mean temperature by well over 3 K (Figure 3-3b). Humidity is well simulated on a daily basis over all sites, but the generally low humidity IOA on most days suggests mismatches in time and space (Figure 3-3c).

Figures 3-4 and 3-5 present similar plots, but for all NWS sites (DS472) across the entire 12-km domain. These observations were not used in the observational FDDA. Hourly wind performance (Figure 3-4a) indicates that MM5 is dramatically under predicting speeds by factors of ~2, but maintaining very good performance for direction. Performance is very steady over the entire period, so the model does not indicate any significant drift. For temperature (Figure 3-4b), an over prediction bias is present (as seen for the Oklahoma Mesonet sites), but it appears to be slightly larger. Humidity performance (Figure 3-4c) follows the overall trends quite well, but there is a tendency for a slight over prediction.

Performance against NWS data on daily timescales reflects the hourly trends in performance. Daily wind errors are very consistent during the entire period (Figure 3-5a), with under prediction bias of 1-2 m/s (-50%); however, the directional errors are acceptable and stable. Temperatures indicate a consistent over prediction bias and error on par with the Oklahoma Mesonet results (Figure 3-5b). Humidity shows very low bias but large error (Figure 3-5c), and a much higher IOA than the Oklahoma Mesonet results. It is unclear why this occurs, except note that in the RMSE plots for both temperature and humidity, the “unsystematic” component of total error (blue bars) dominates the overall error. This is the reverse of what is normally seen (usually the “systematic” error is dominant, or the two component are roughly equivalent), and is different from the Oklahoma Mesonet results. Generally, the “unsystematic” component represents a random distribution of error, and so is regarded as the part that cannot be easily improved upon – in other words, it does not represent a model bias, or consistent error, across all hours and sites.

Effectiveness of FDDA Obs Nudging

The difference between MM5 wind performance against just Oklahoma Mesonet sites and against all NWS sites across the entire 12-km grid is significant, and could be partly the result of using the former dataset in the observational FDDA. We wanted to gauge whether good

performance over Oklahoma occurred just at the Mesonet sites (due to FDDA), or extended to the NWS sites in the area. Daily statistics were re-calculated for NWS sites over the Oklahoma area, and are compared with Mesonet statistics in Figure 3-6a-c for winds, temperature, and humidity. For winds speed, statistics continue to indicate a consistent under prediction bias across NWS sites in Oklahoma compared to the Mesonet sites. However, the performance shown in Figure 3-6a is somewhat better, especially on the worst days (e.g., August 27), than the 12-km domain-wide NWS statistics. There are two possibilities for this: (1) that observational nudging may be helping to reduce wind speed errors even at non-nudged sites on the worst performing days, and/or (2) that performance over Oklahoma is locally better for some reason (disregarding FDDA) than the performance averaged across the entire 12-km domain. Wind direction errors are on par with the Mesonet statistics, as are the temperature and humidity statistics.

Given that the wind speed performance against NWS sites in Oklahoma is consistently worse than against Mesonet sites, we conclude that the influence of observational FDDA (as configured in this run) remains mostly local and does not extend significantly to other non-nudged sites. We identify two implications from these results:

1) Lack of near-surface momentum in this simulation seems to be a broad-based PBL-deep problem that easily washes over local observational nudging effects;
2) The circular problem of using surface observations for both nudging and model performance statistics is clearly demonstrated in these unique results: i.e., better agreement between model and observations is foretold by forcing the local simulation results to the very same observations, even though the simulation on the whole is not improved in any meaningful way away from the observation sites.

These issues point to the need for a greater reliance on evaluations of wind and thermodynamic structures through the boundary layer and over wide areas. The density and availability of observational data in the vertical needs to be improved and utilized more extensively in model performance evaluations.

Figures 3-7 and 3-8 present hourly and daily performance across the 4-km domain against the NWS observations in that grid. The sites located within the 4-km grid are listed in Table 3-2. In Figure 3-7a, the hourly wind speed performance is similar to that of the 12-km domain, with large under predictions of speed during the entire period. However, the wind direction is also degraded, especially early in the period (August 23 – 27), and directional bias of 30-60 are common. The positive temperature bias is even stronger on the 4-km domain (Figure 3-7b), with midday over predictions averaging 2-4 K. Humidity is better replicated than winds or temperature, but certain periods (August 25 and 27) show large error (Figure 3-7c).

Table 3-2. "NWS" meteorological monitoring sites in the 4-km grid.

Number	Station ID	Description
1	KACT	Waco
2	KADS	Addison
3	KAFW	Alliance Airport, Ft Worth
4	KCRS	Corsicana
5	KDAL	Love Field, Dallas
6	KDFW	Dallas/Fort Worth International
7	KDTO	Denton

Number	Station ID	Description
8	KF39	Sherman-Denison, Grayson County
9	KFTW	Meacham, Fort Worth
10	KFWD	Fort Worth
11	KGKY	Arlington Municipal
12	KMWL	Mineral Wells
13	KNFW	Navy Fort Worth, Carswell
14	KPRX	Cox Field, Paris Texas
15	KPWG	McGregor Executive, Waco
16	KRBD	Dallas Executive, Redbird
17	KTKI	Collin County, McKinney
18	KTRL	Terrell Municipal, Terrell
19	KTYR	Tyler Pounds, Tyler

The daily statistics for the 4-km domain are similar (Figure 3-8a-c), showing large under predictions of wind speed, larger error for wind direction (larger than the 12-km statistics), large over predictions of temperature, and more variation in humidity error. Note that daily IOA for winds and humidity are very low, indicating very little skill for these parameters. While the systematic and unsystematic components of temperature and humidity error are more on par with expectations, the unsystematic component continues to be somewhat higher than typically seen in other MM5 simulations. Again, the cause for this is unknown.

CONCLUSION

Overall, this simulation is not adequate for use in CAMx air quality simulations. Most performance metrics are outside benchmark ranges, and are worse than performance achieved for the core period of August 13-22, 1999. Notable problems include: wind speed under predictions, and temperature over predictions. These do not seem related, as we tend to see that temperature over predictions lead to more vigorous and deeper mixing, which tend to bring higher momentum to the surface and therefore lead to wind speed over predictions. It would appear that the simulated boundary layer lacks sufficient momentum during the period. It is difficult to know the source of this consistent deficiency, since the model is being nudged toward EDAS analyses. In past evaluations of EDAS for annual 36-km and 12-km grid modeling, we have not seen any major biases or consistent errors in the EDAS wind fields.

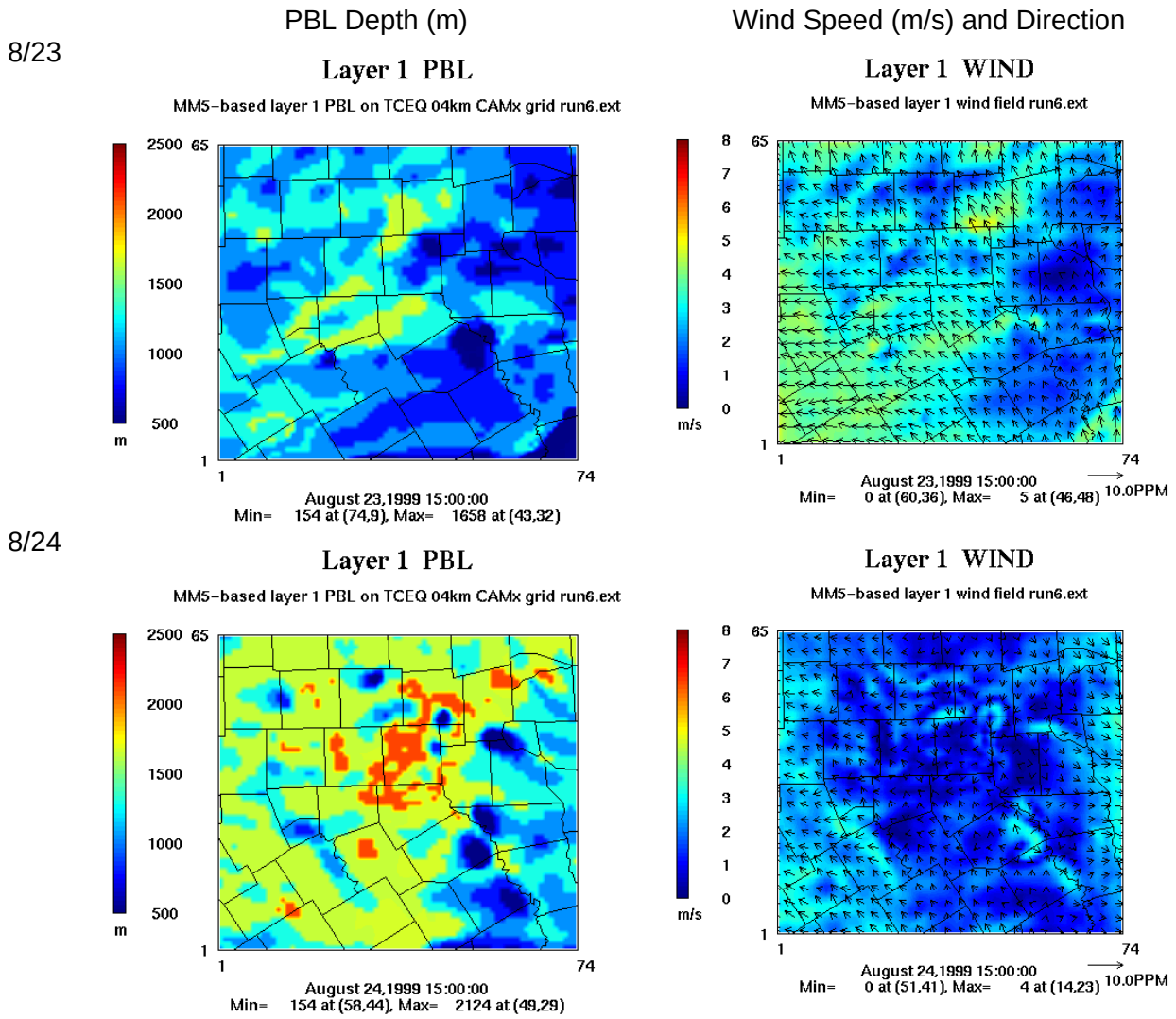
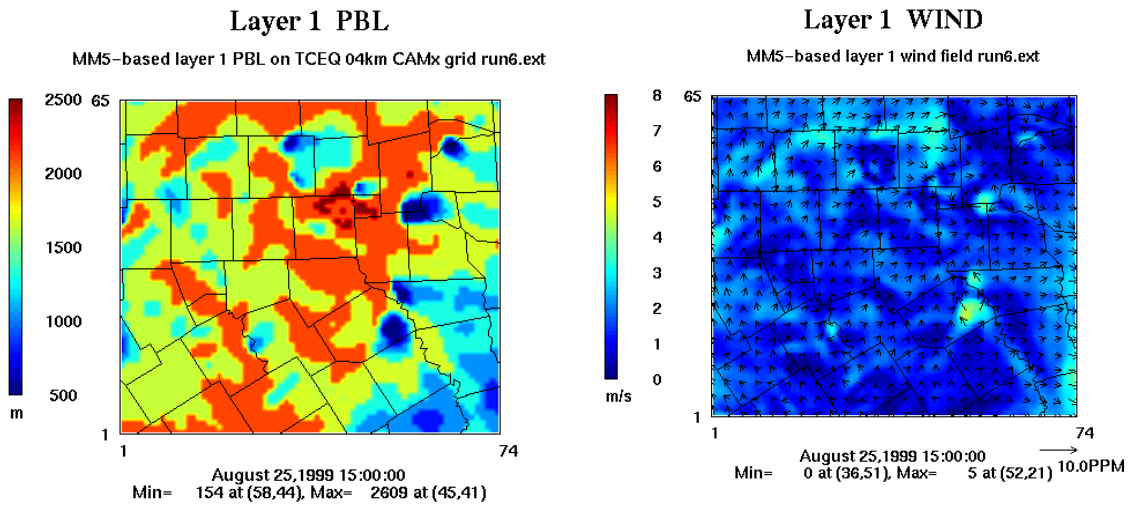


Figure 3-1. PBL depth and winds for the DFW 4-km grid at 15:00 on days in the episode extension period.

PBL Depth (m) | Wind Speed (m/s) and Direction

8/25



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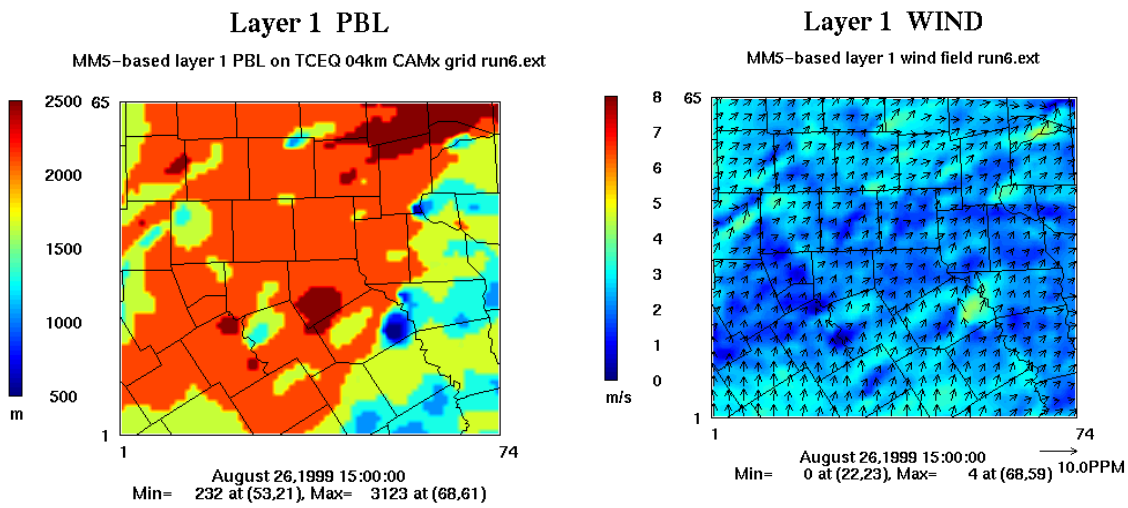
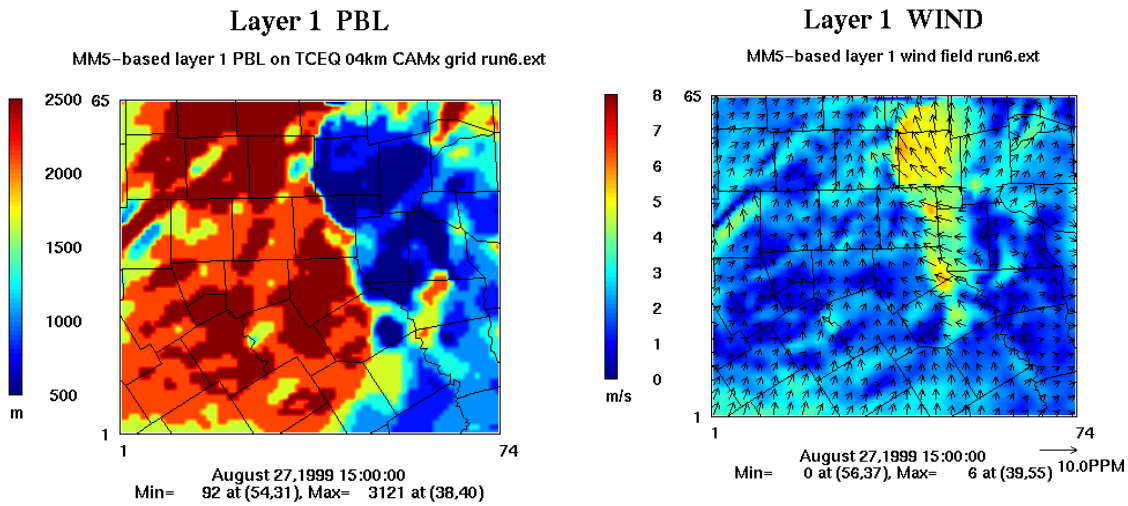


Figure 3-1 (continued). PBL depth and winds for the DFW 4-km grid at 15:00 on days in the episode extension period.

PBL Depth (m) | Wind Speed (m/s) and Direction

8/27



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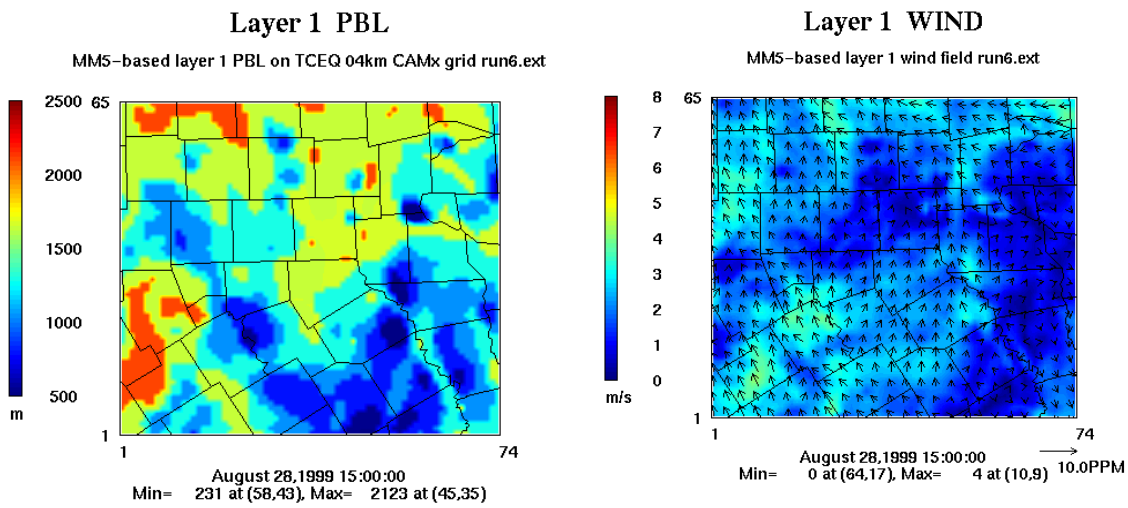
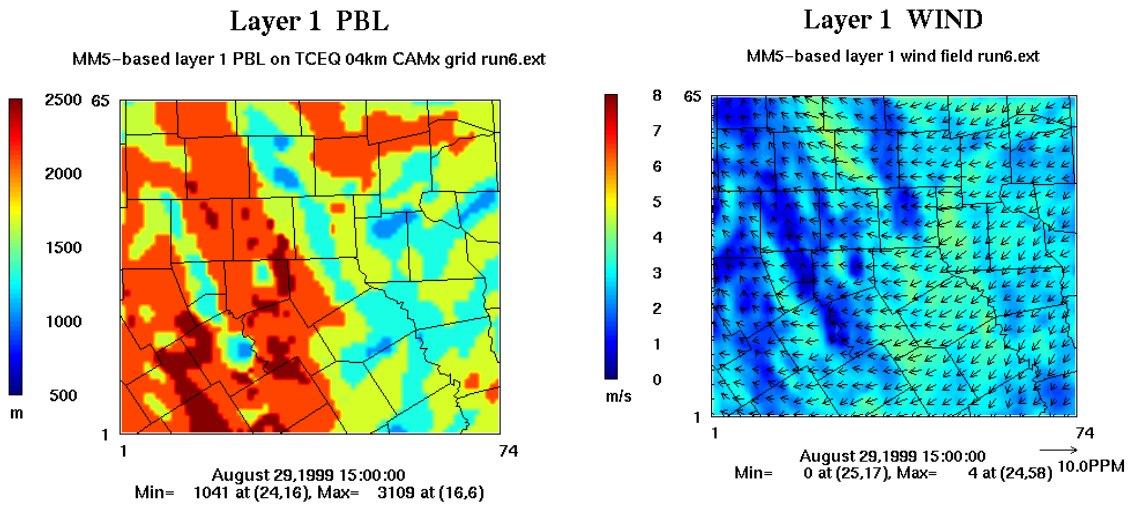


Figure 3-1 (continued). PBL depth and winds for the DFW 4-km grid at 15:00 on days in the episode extension period.

PBL Depth (m) | Wind Speed (m/s) and Direction

8/29



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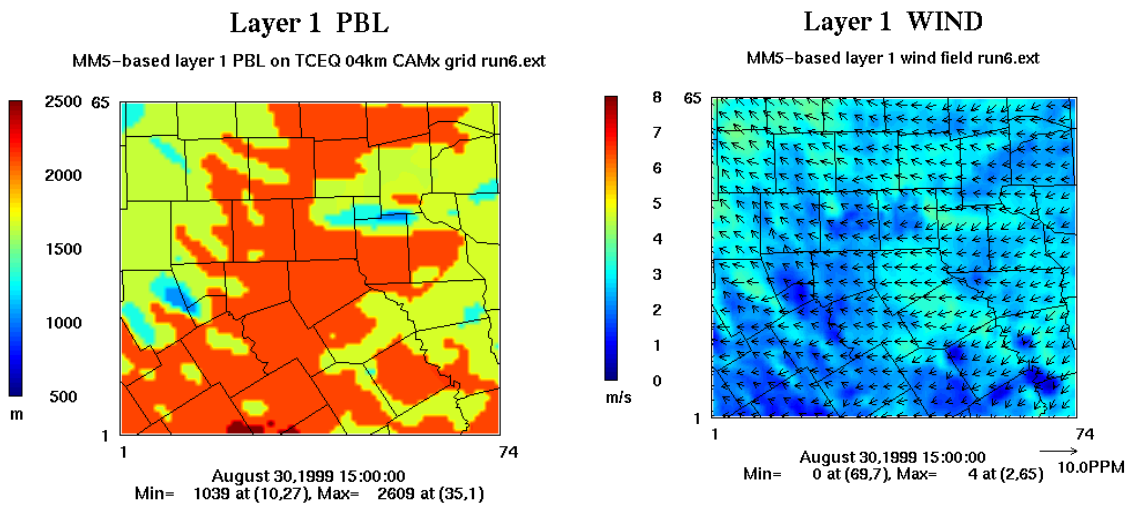
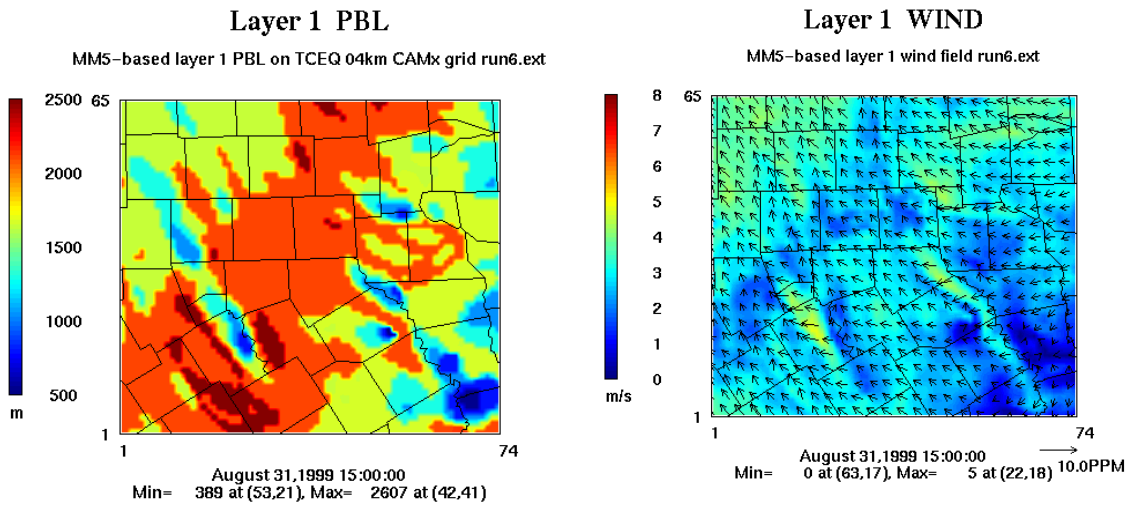


Figure 3-1 (continued). PBL depth and winds for the DFW 4-km grid at 15:00 on days in the episode extension period.

PBL Depth (m) | Wind Speed (m/s) and Direction

8/31



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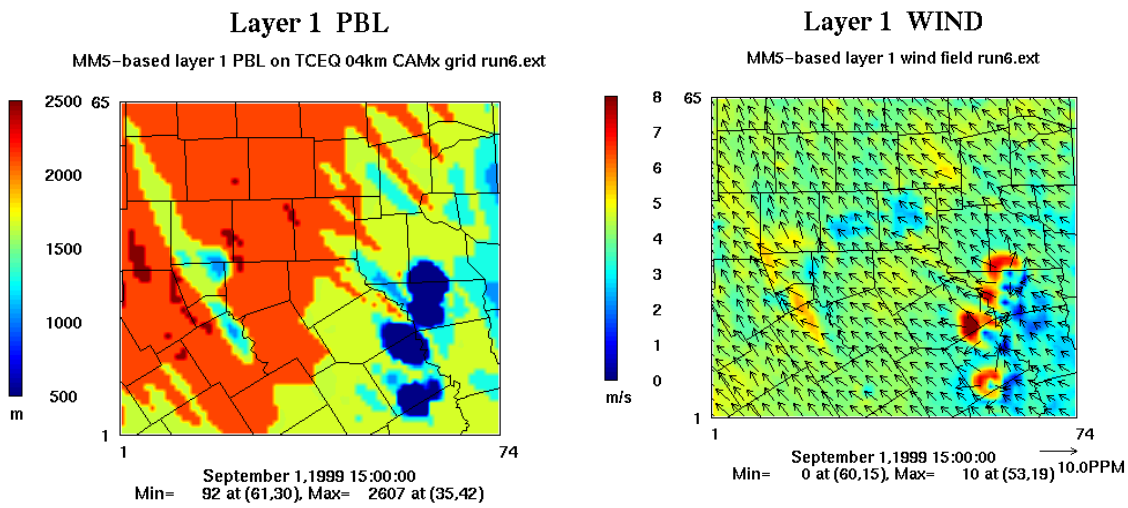


Figure 3-1 (concluded). PBL depth and winds for the DFW 4-km grid at 15:00 on days in the episode extension period.

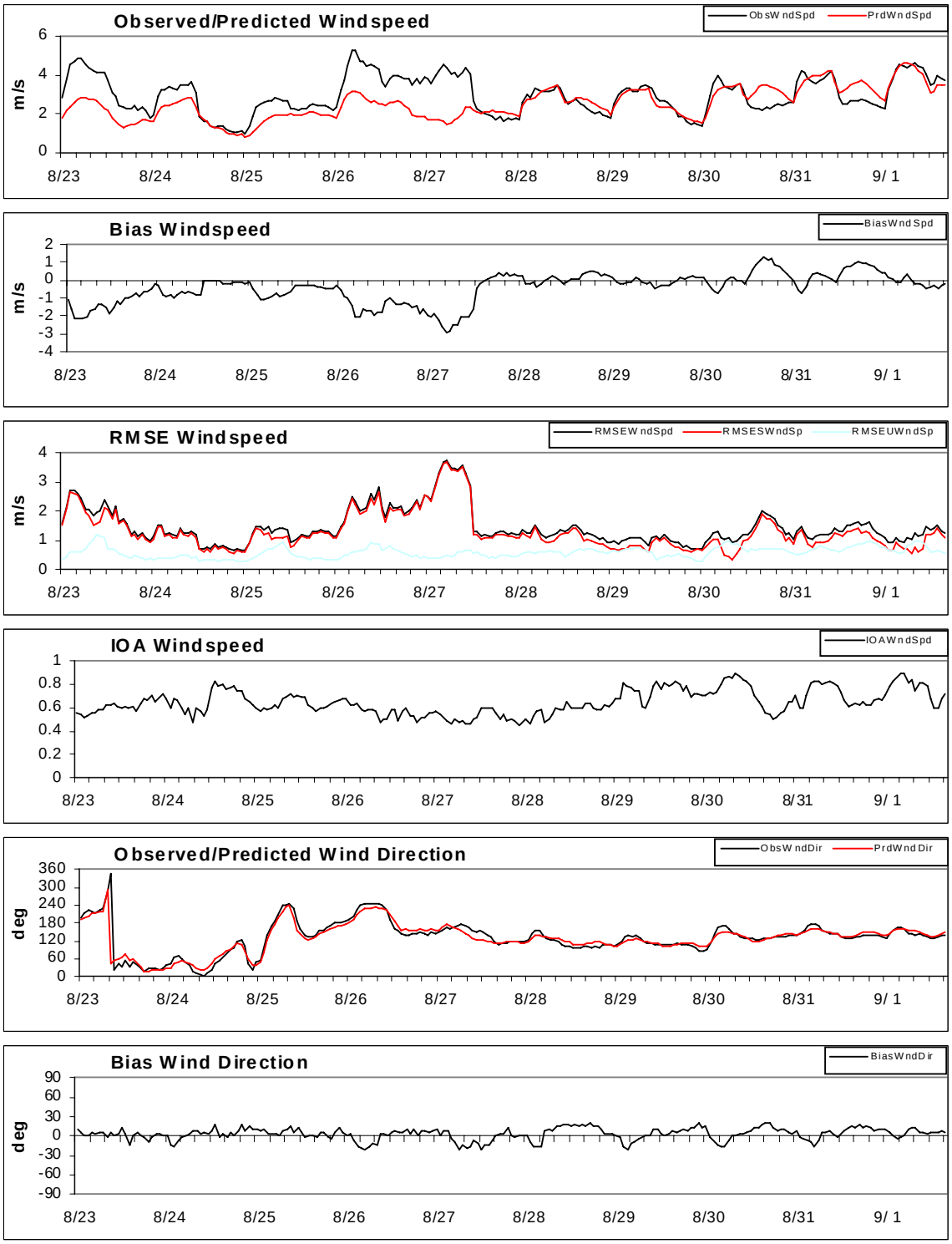


Figure 3-2a. Hourly wind performance for TCEQ run6 on the 12-km grid evaluated against Oklahoma mesonet data.

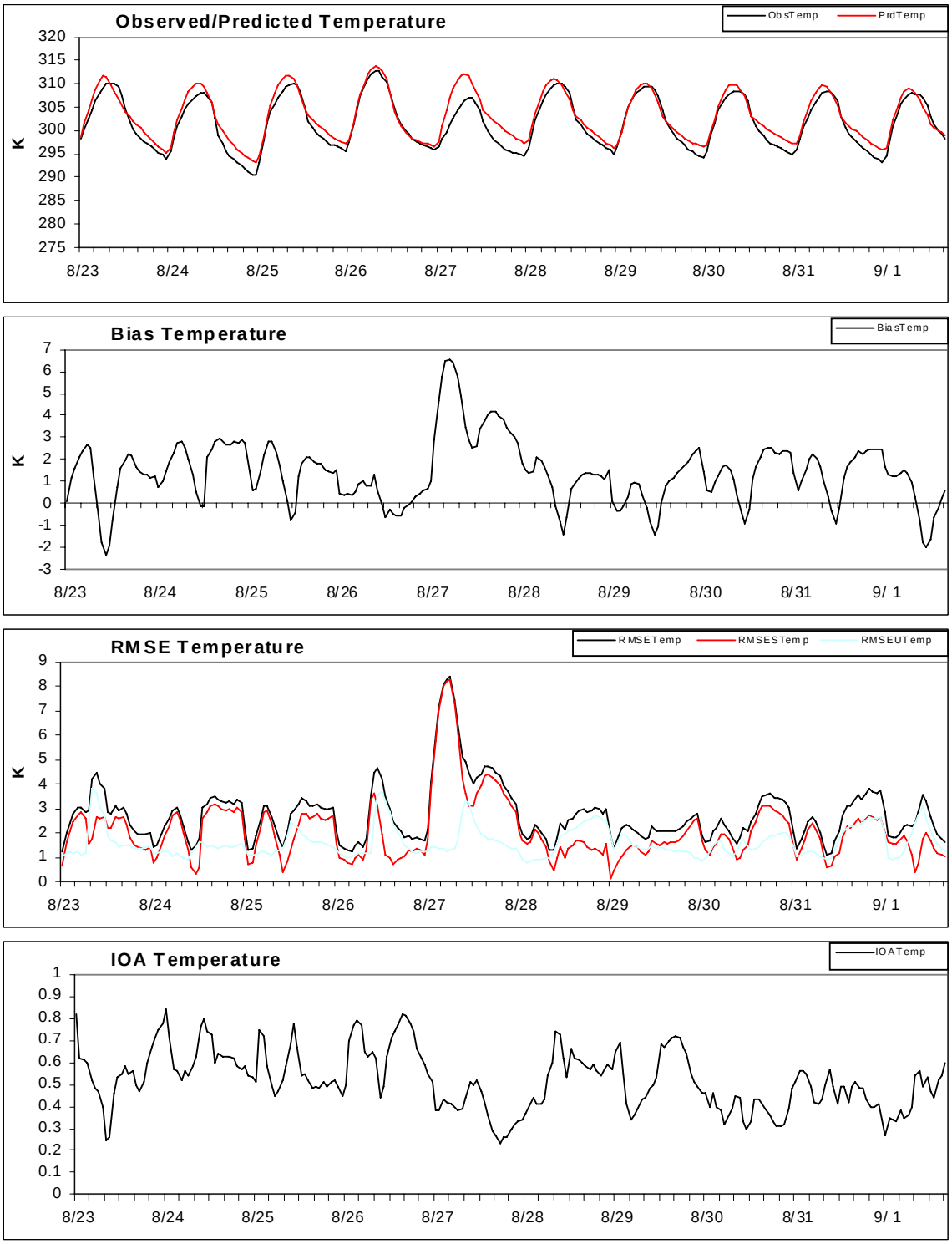


Figure 3-2b. Hourly temperature performance for TCEQ run6 on the 12-km grid evaluated against Oklahoma mesonet data.

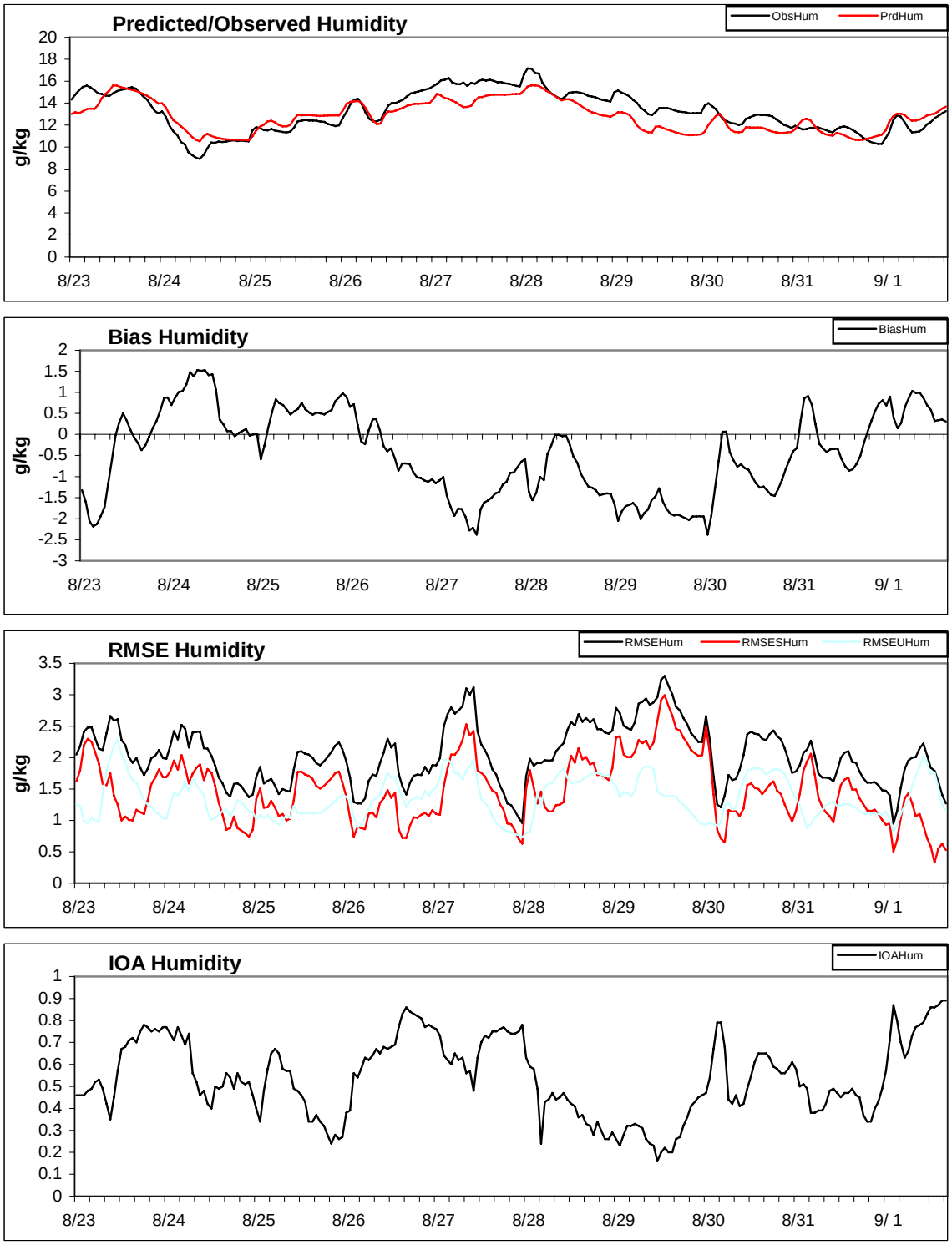


Figure 3-2c. Hourly humidity performance for TCEQ run6 on the 12-km grid evaluated against Oklahoma mesonet data.

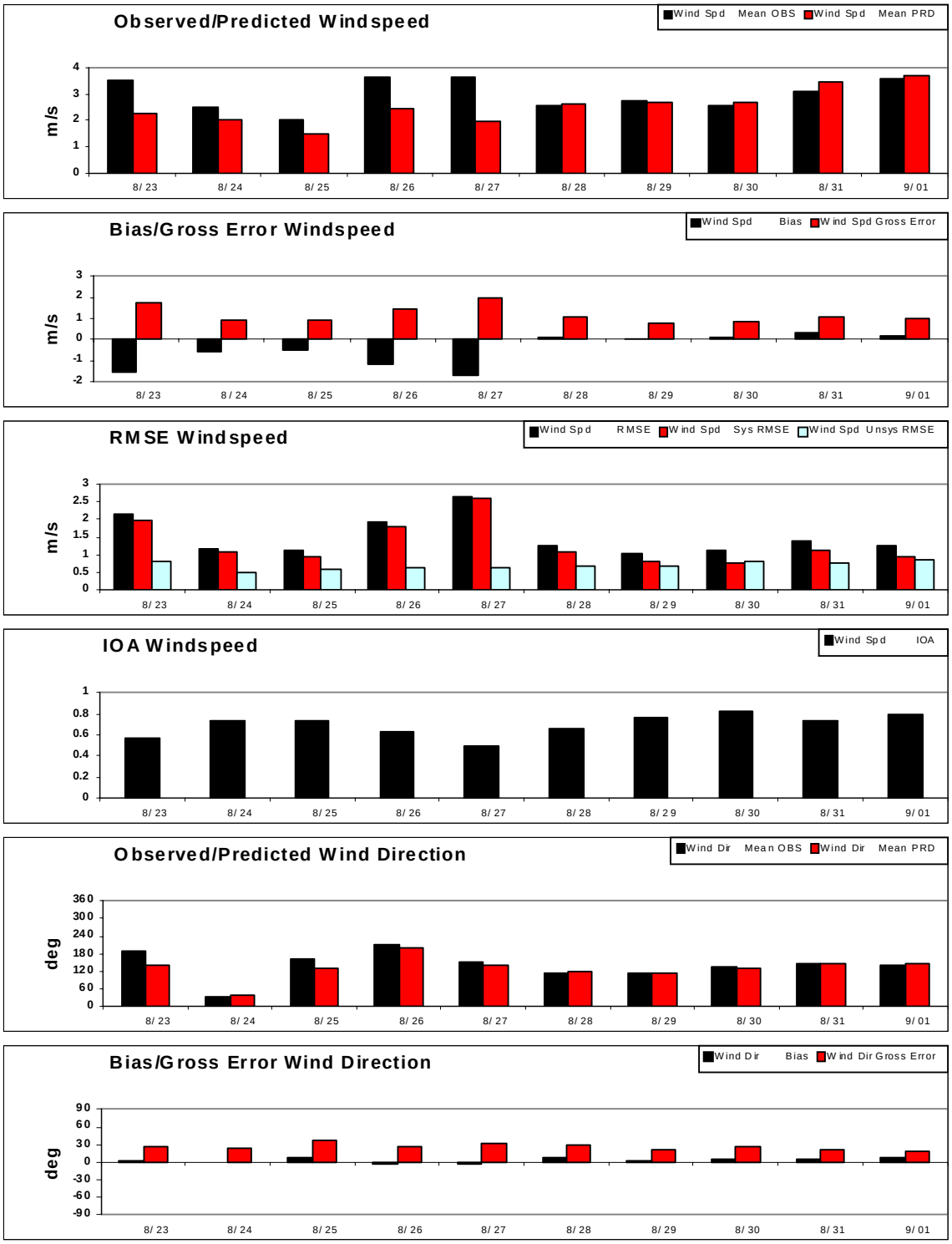


Figure 3-3a. Daily wind performance for TCEQ run6 on the 12-km grid evaluated against Oklahoma mesonet data.

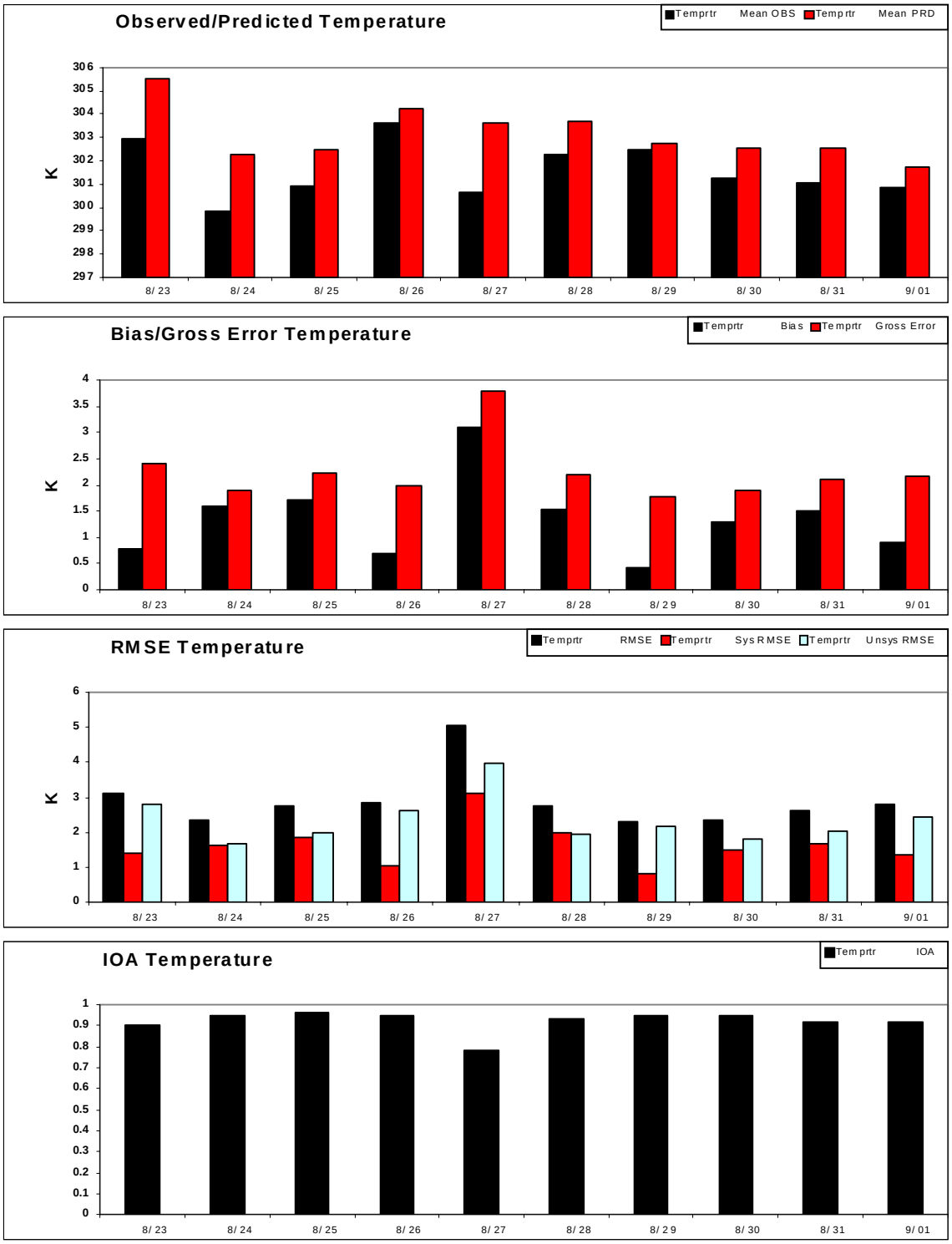


Figure 3-3b. Daily temperature performance for TCEQ run6 on the 12-km grid evaluated against Oklahoma mesonet data.

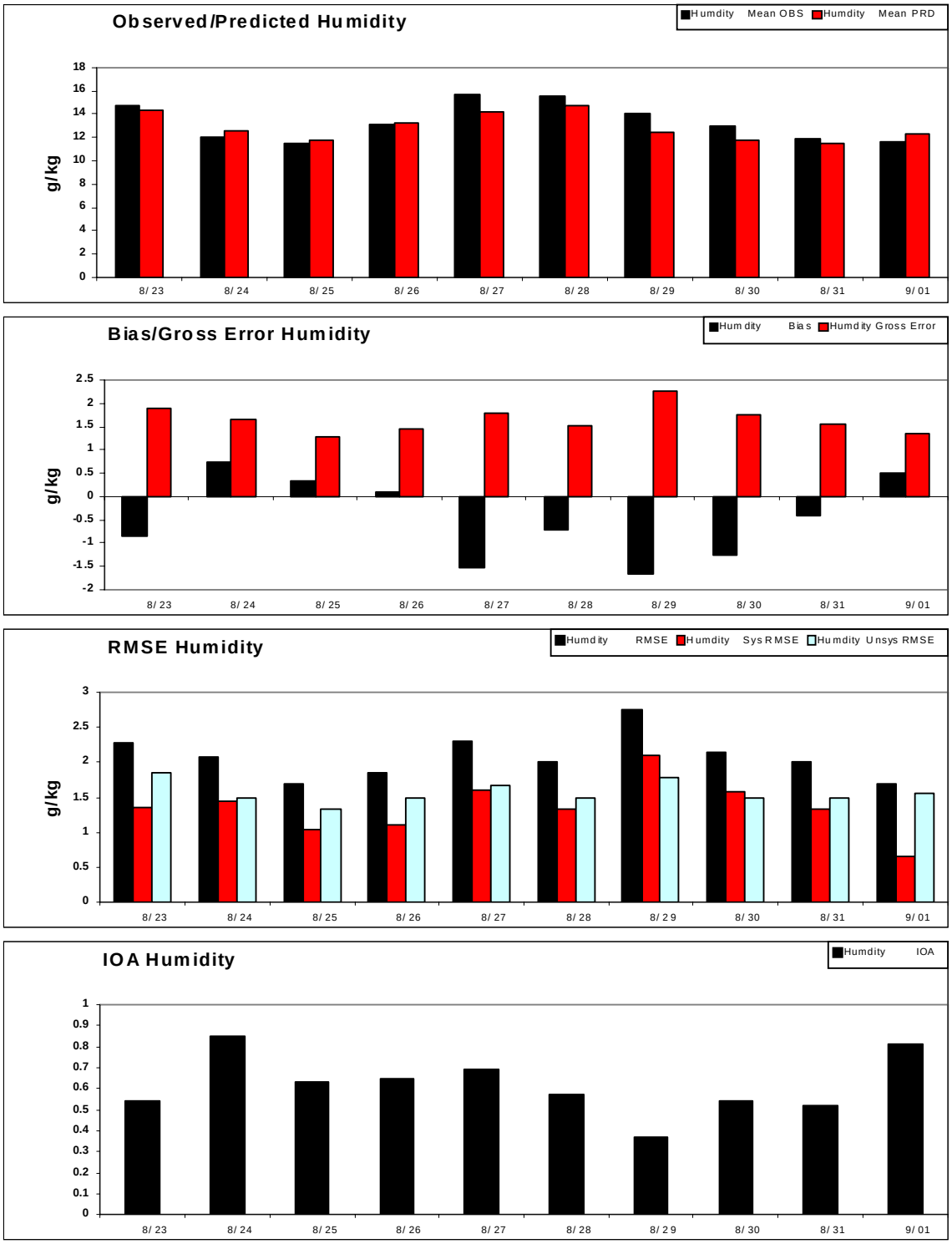


Figure 3-3c. Daily humidity performance for TCEQ run6 on the 12-km grid evaluated against Oklahoma mesonet data.

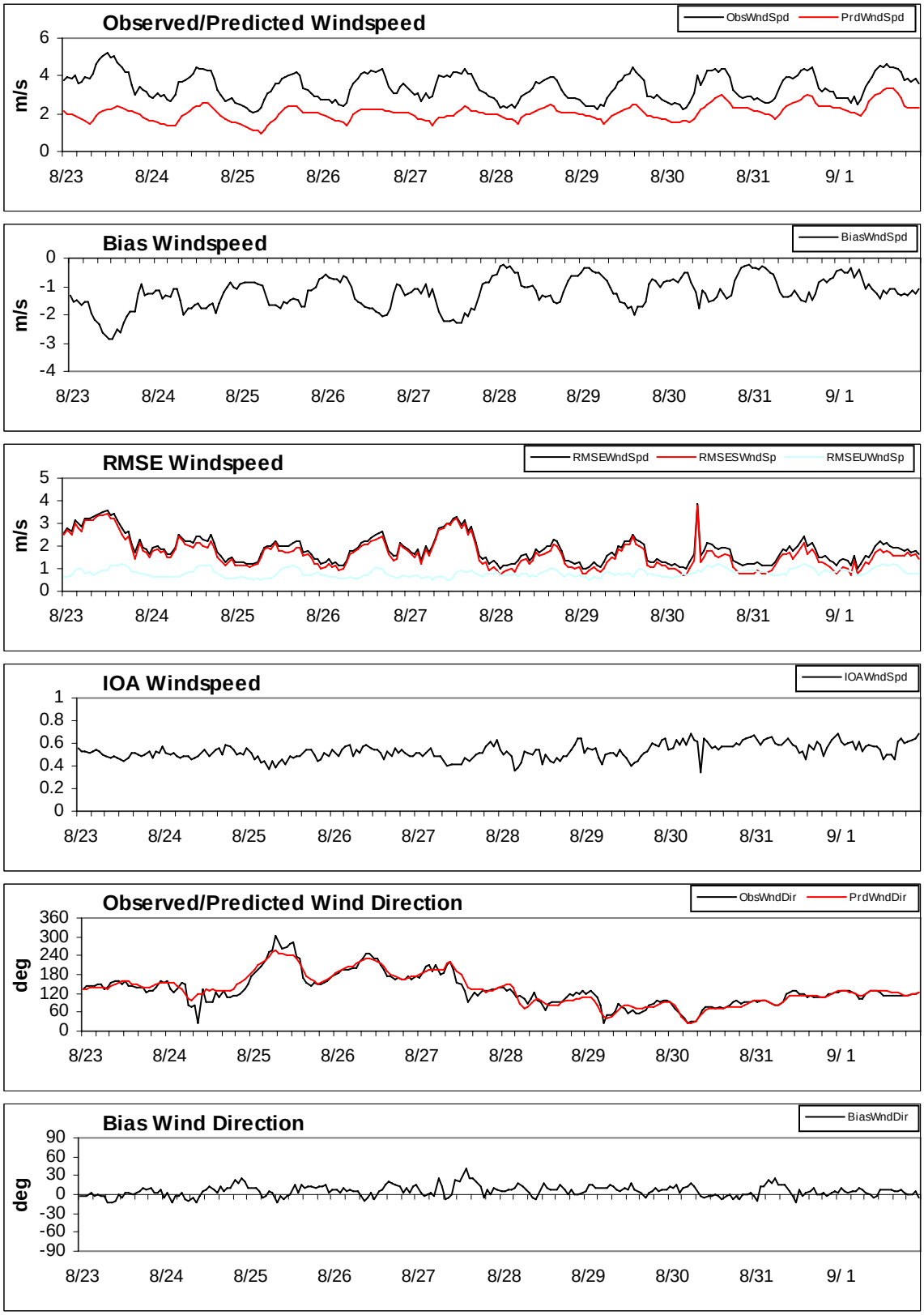


Figure 3-4a. Hourly wind performance for TCEQ run6 on the 12-km grid evaluated against NWS stations.

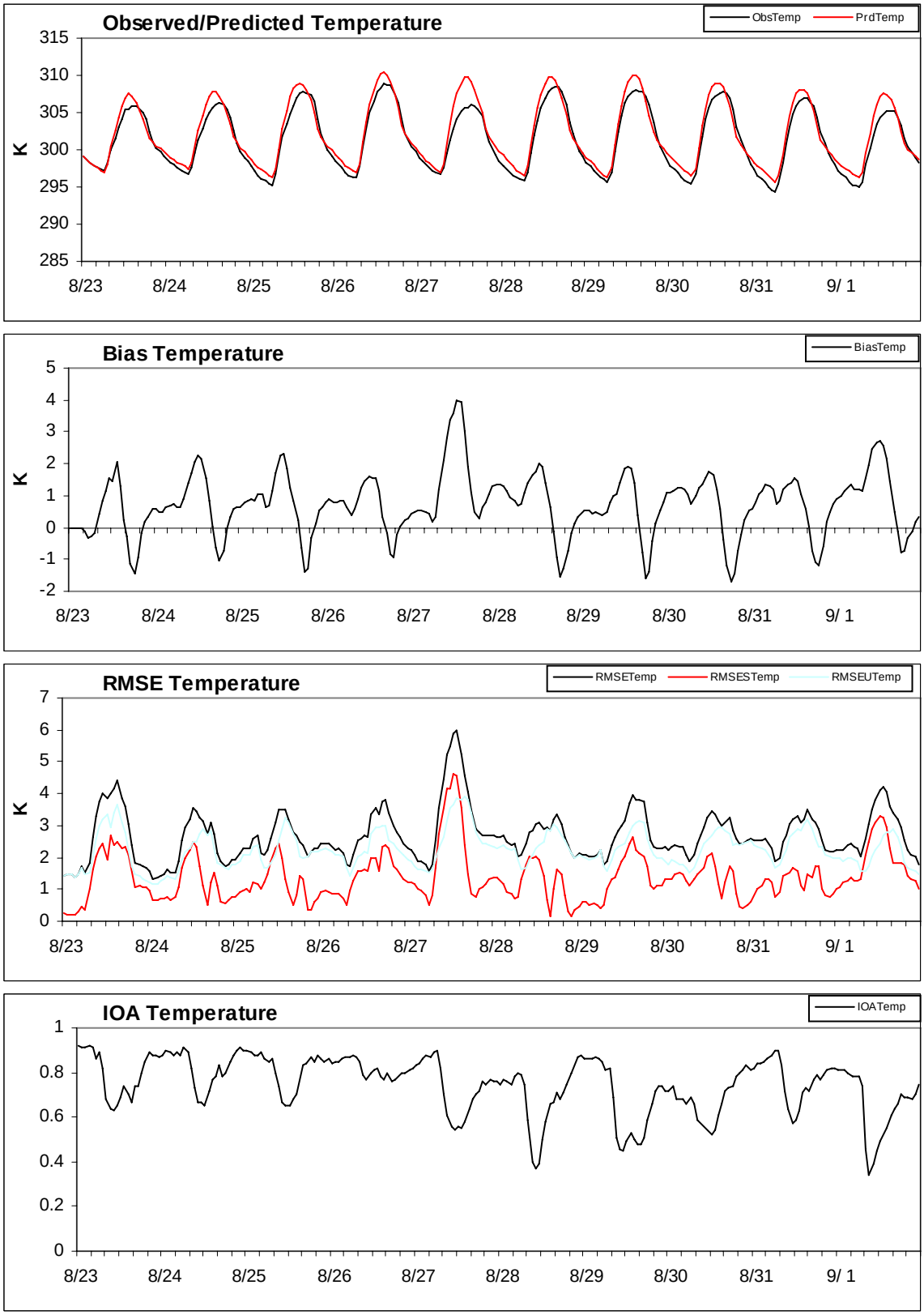


Figure 3-4b. Hourly temperature performance for TCEQ run6 on the 12-km grid evaluated against NWS stations.

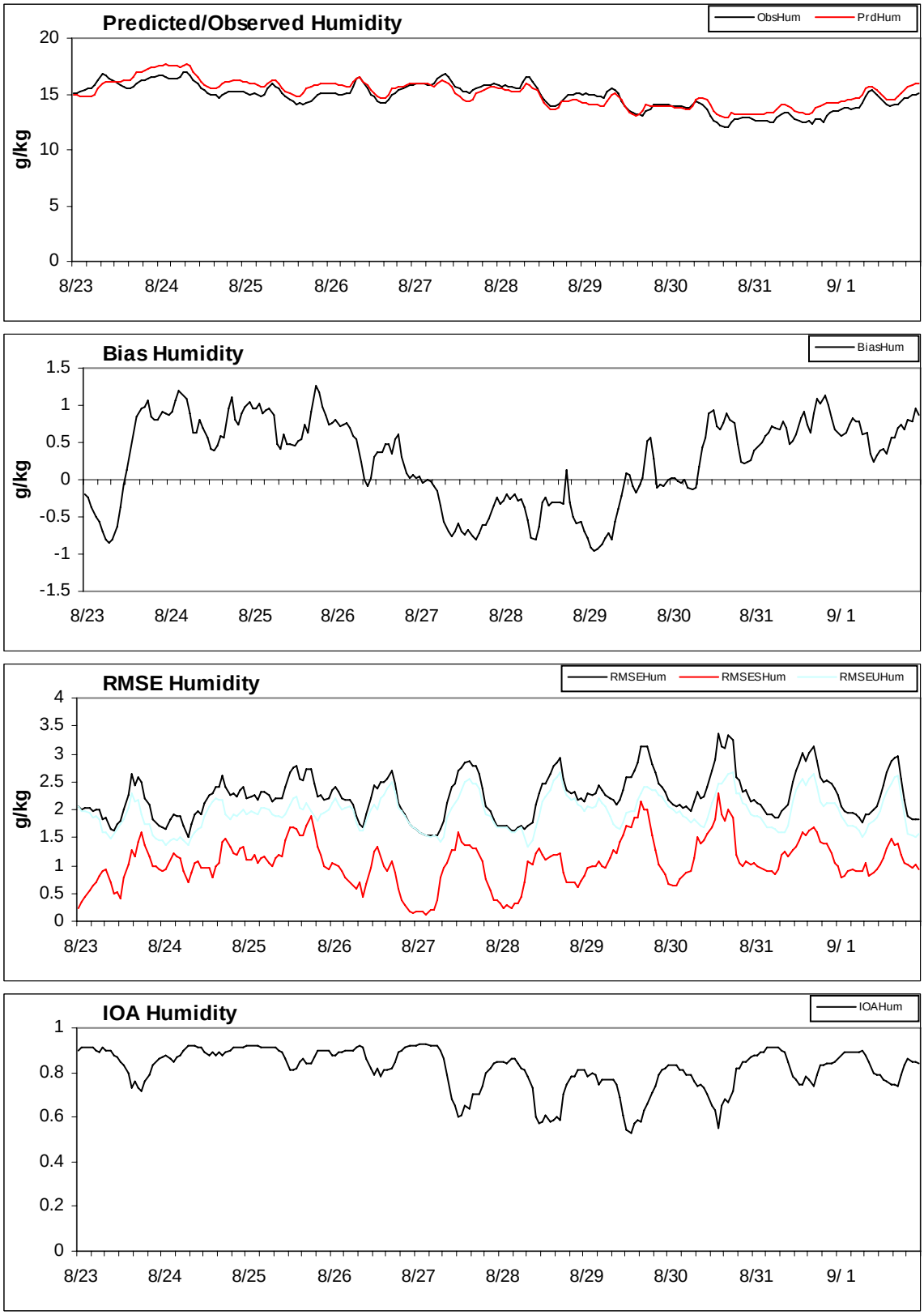


Figure 3-4c. Hourly humidity performance for TCEQ run6 on the 12-km grid evaluated against NWS stations.

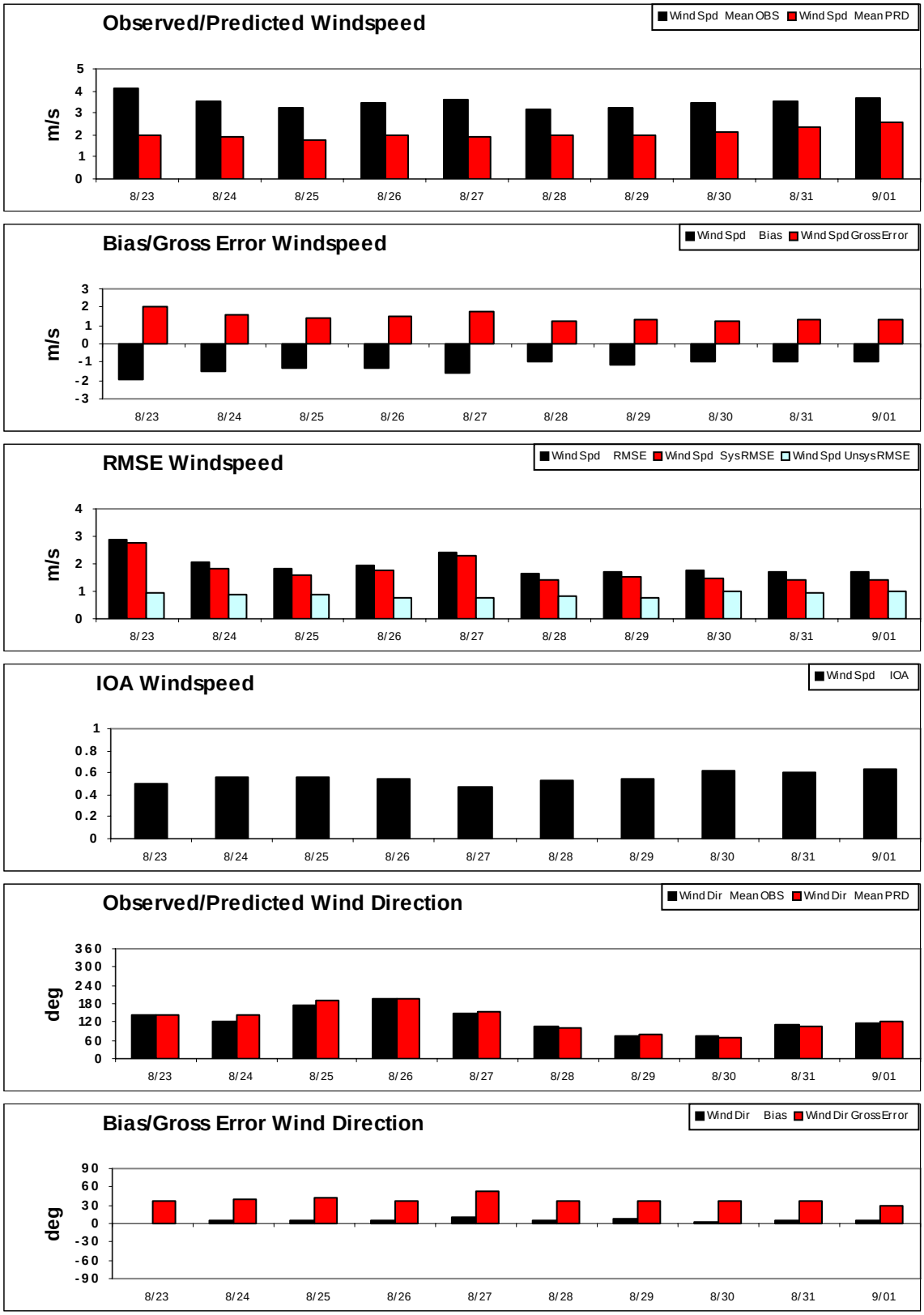


Figure 3-5a. Daily wind performance for TCEQ run6 on the 12-km grid evaluated against NWS stations.

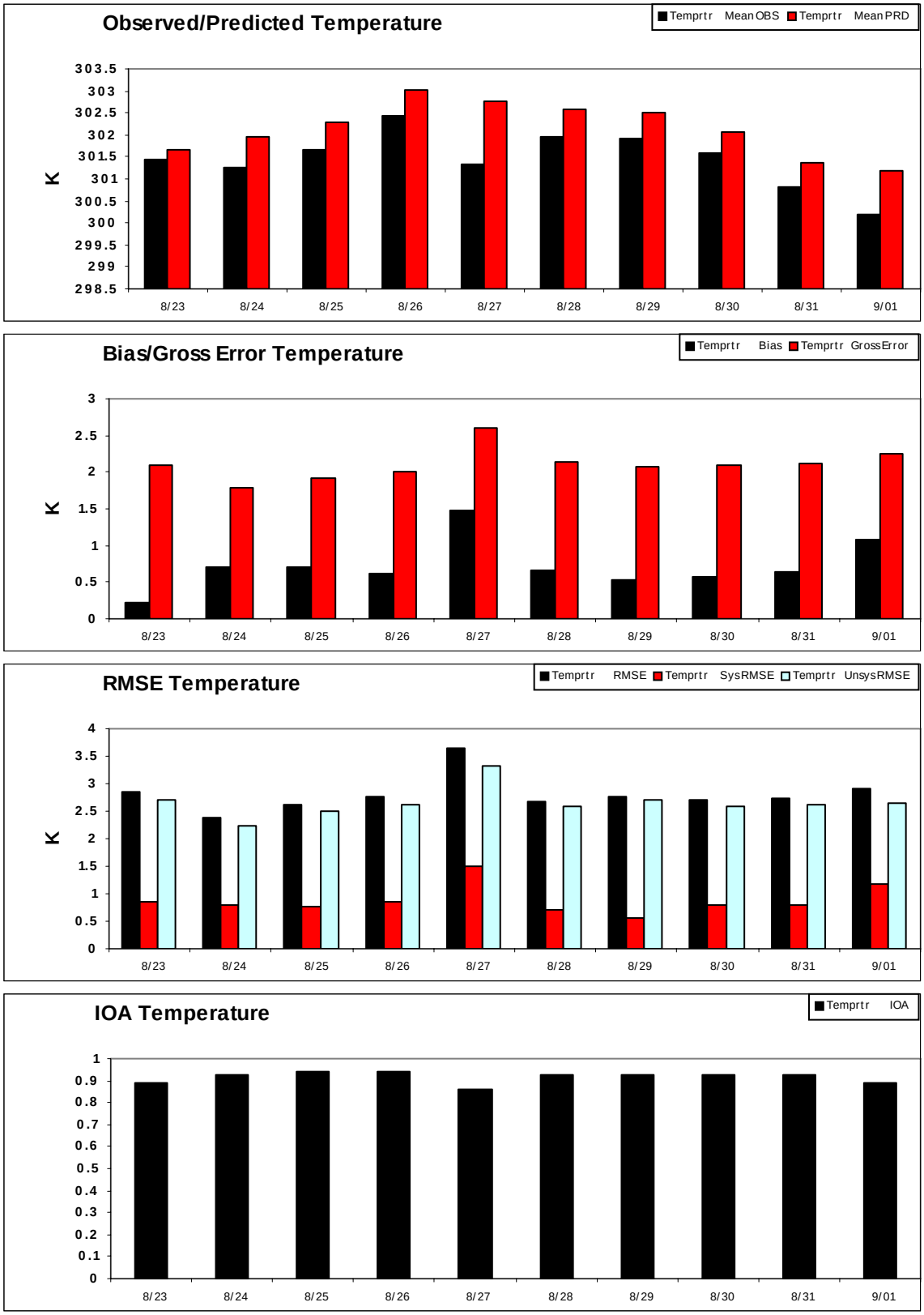


Figure 3-5b. Daily temperature performance for TCEQ run6 on the 12-km grid evaluated against NWS stations.

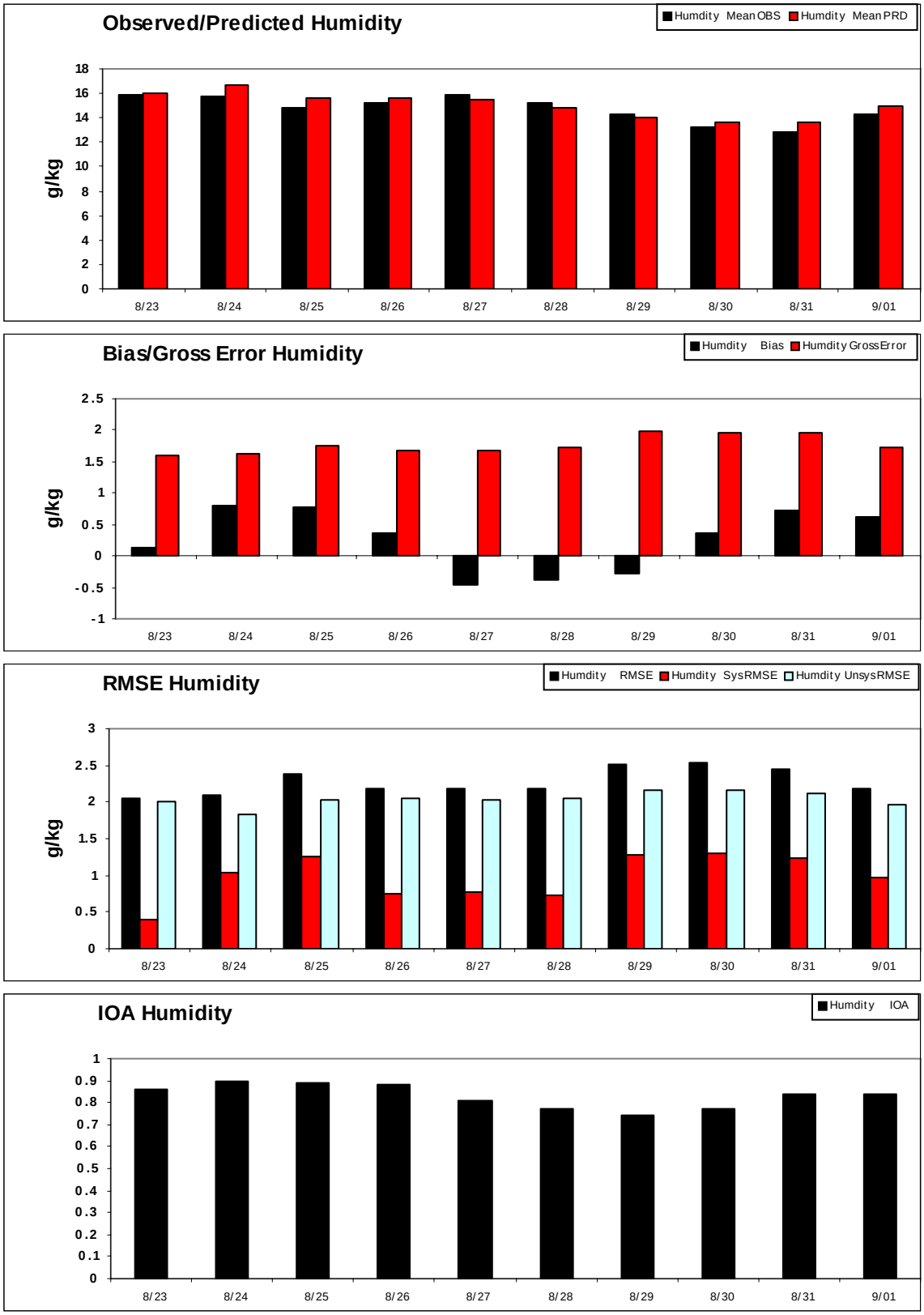


Figure 3-5c. Daily humidity performance for TCEQ run6 on the 12-km grid evaluated against NWS stations.

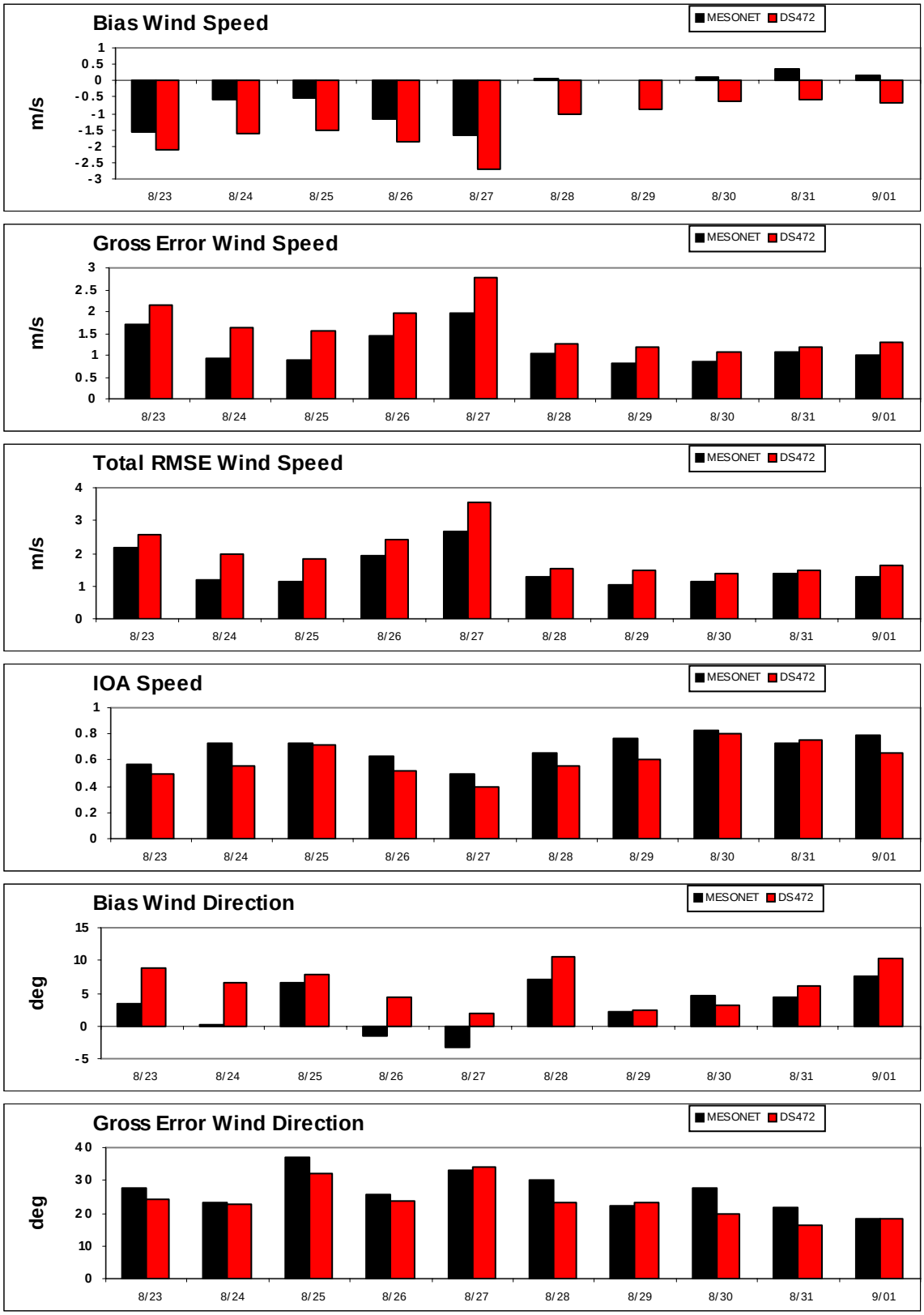


Figure 3-6a. Comparison of daily wind performance for TCEQ run6 evaluated separately against Mesonet and NWS stations over Oklahoma.

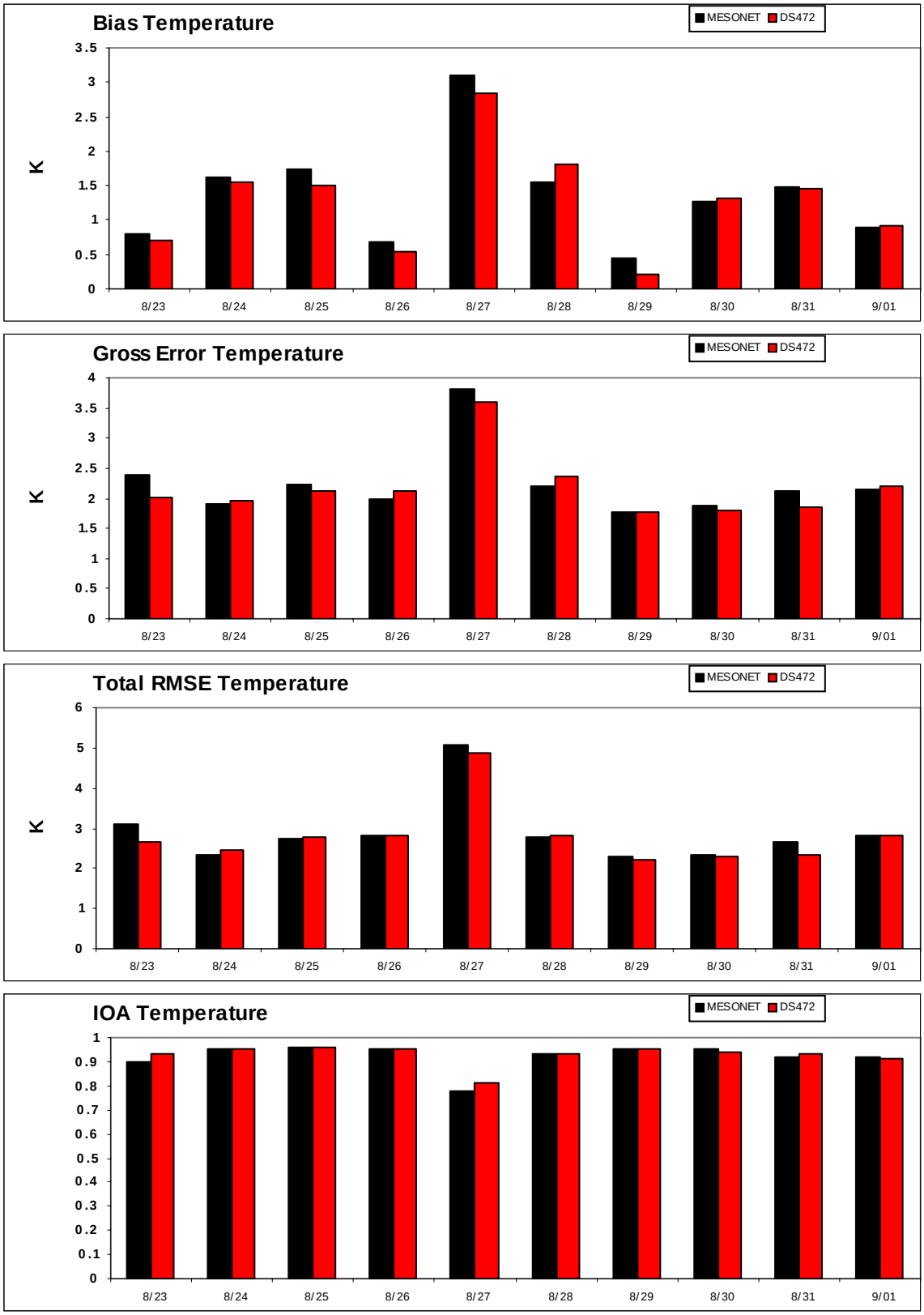


Figure 3-6b. Comparison of daily temperature performance for TCEQ run6 evaluated separately against Mesonet and NWS stations over Oklahoma.

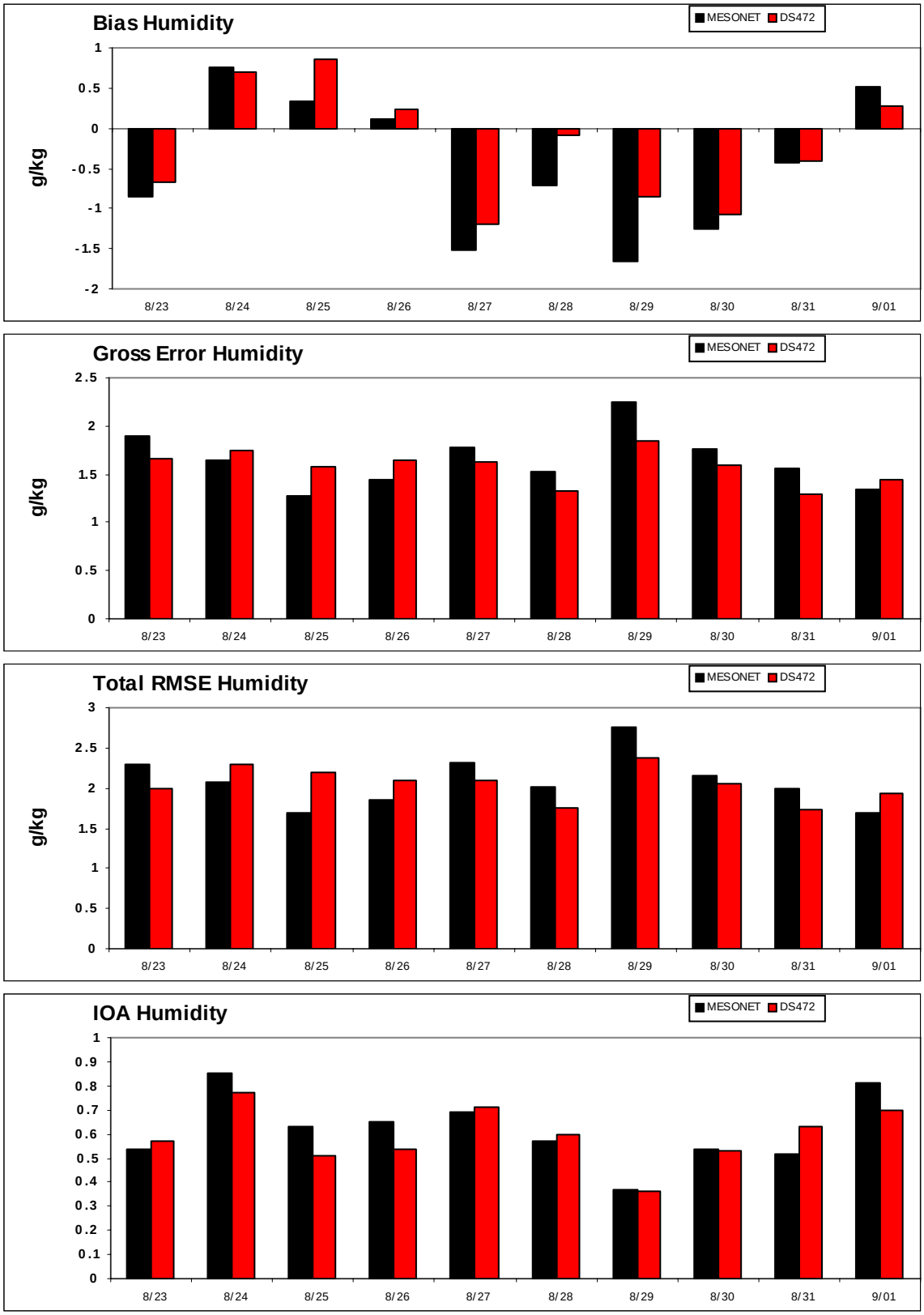


Figure 3-6c. Comparison of daily humidity performance for TCEQ run6 evaluated separately against Mesonet and NWS stations over Oklahoma.

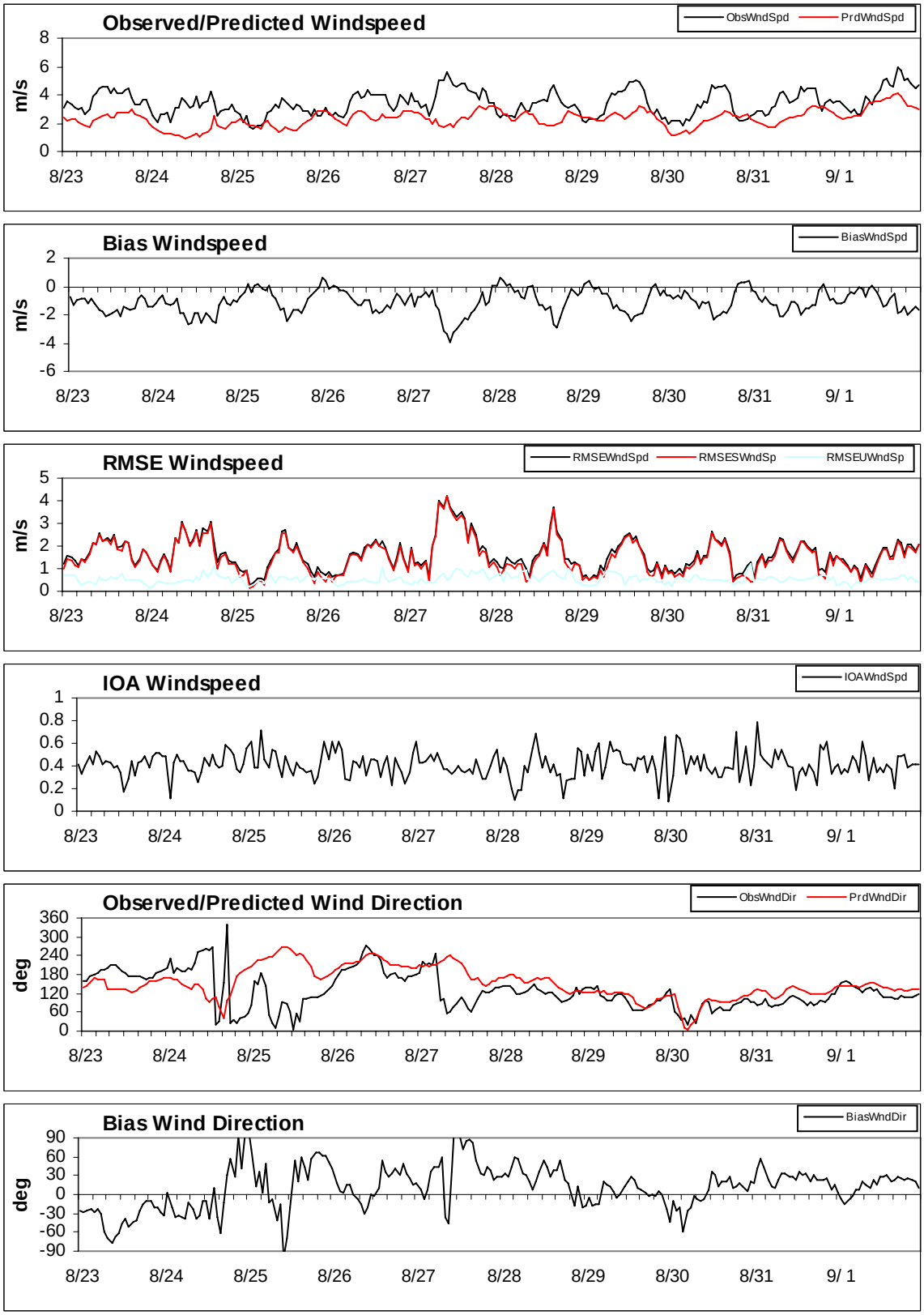


Figure 3-7a. Hourly wind performance for TCEQ run6 on the 4-km grid evaluated against NWS stations.

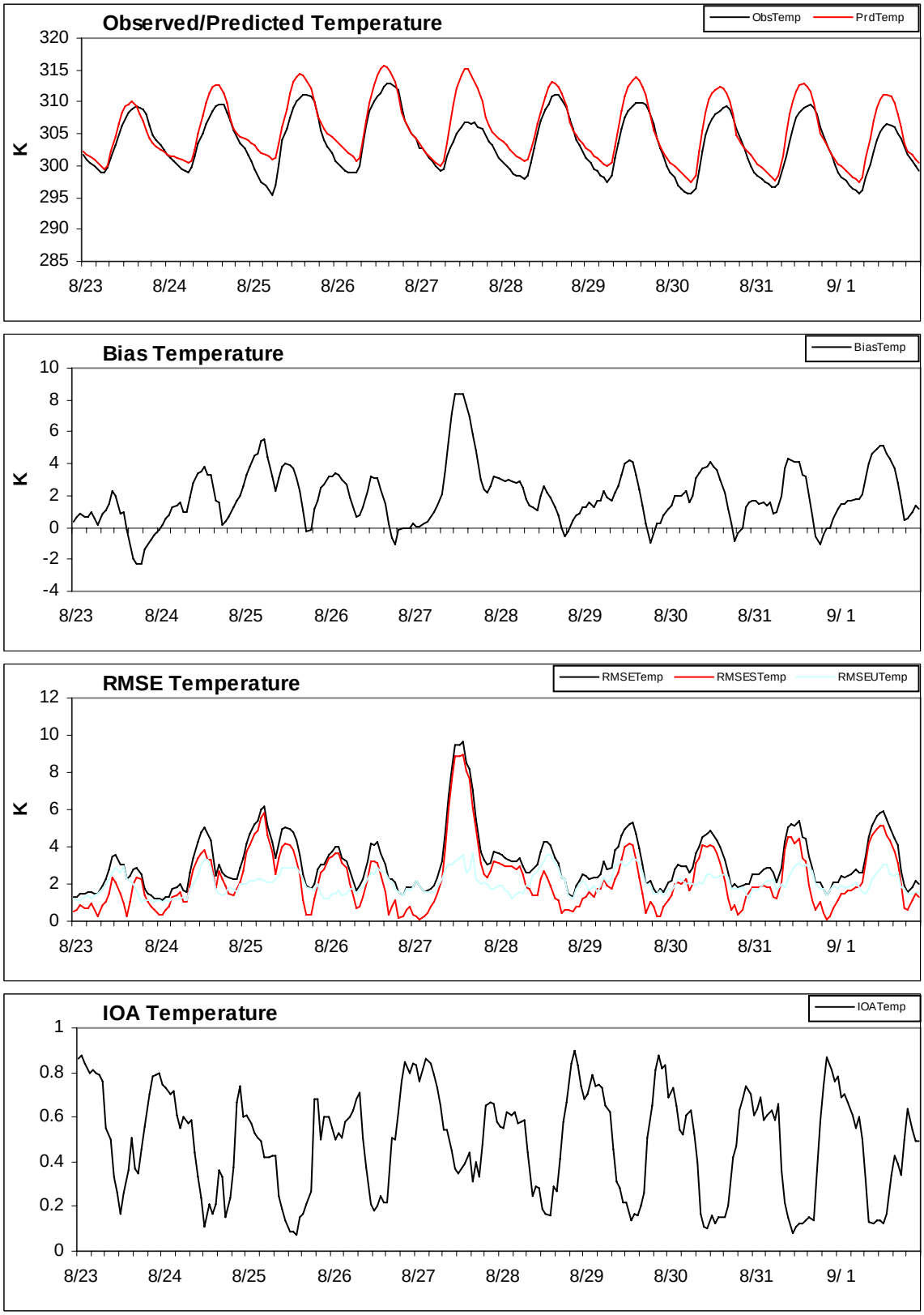


Figure 3-7b. Hourly temperature performance for TCEQ run6 on the 4-km grid evaluated against NWS stations.

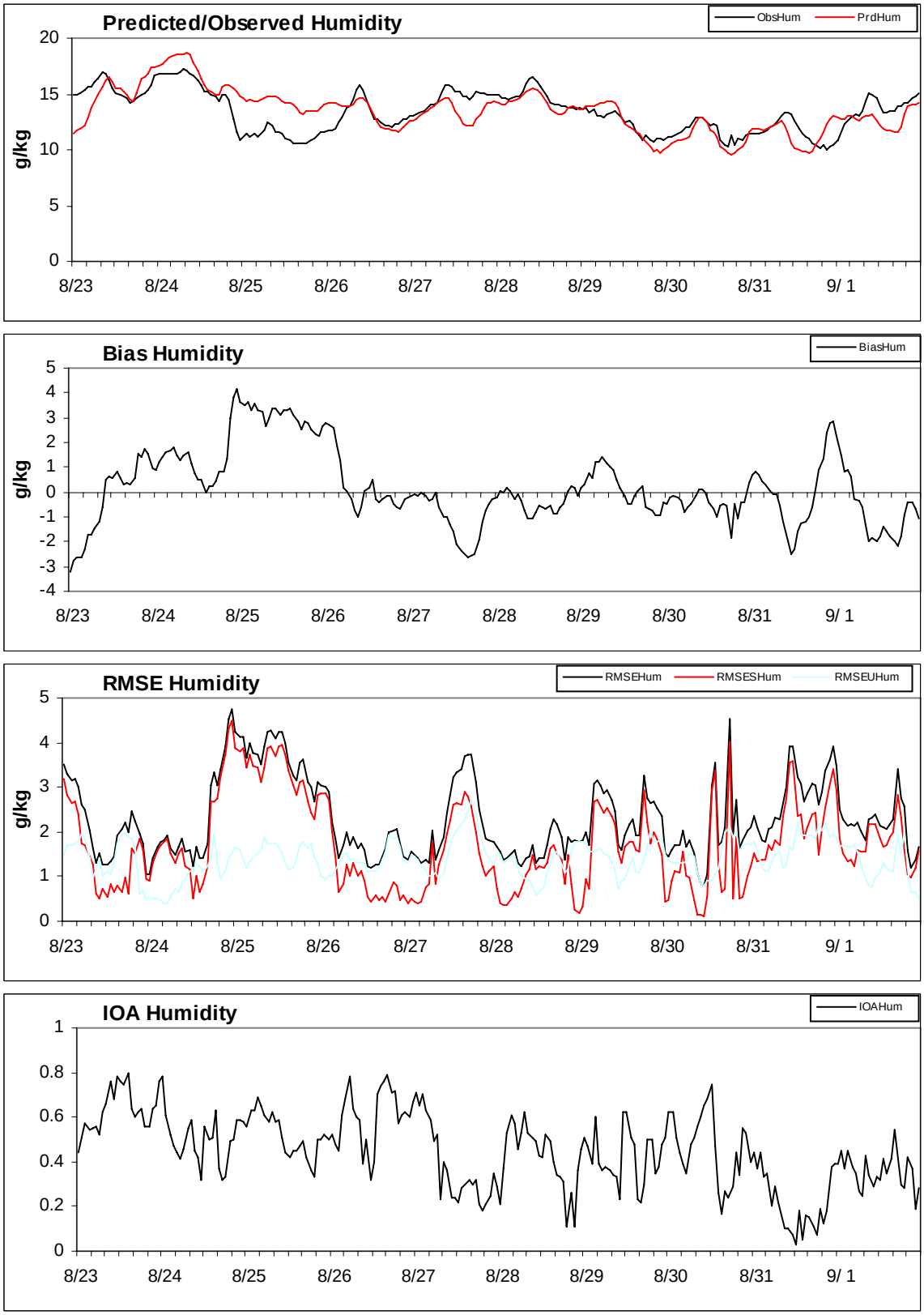


Figure 3-7c. Hourly humidity performance for TCEQ run6 on the 4-km grid evaluated against NWS stations.

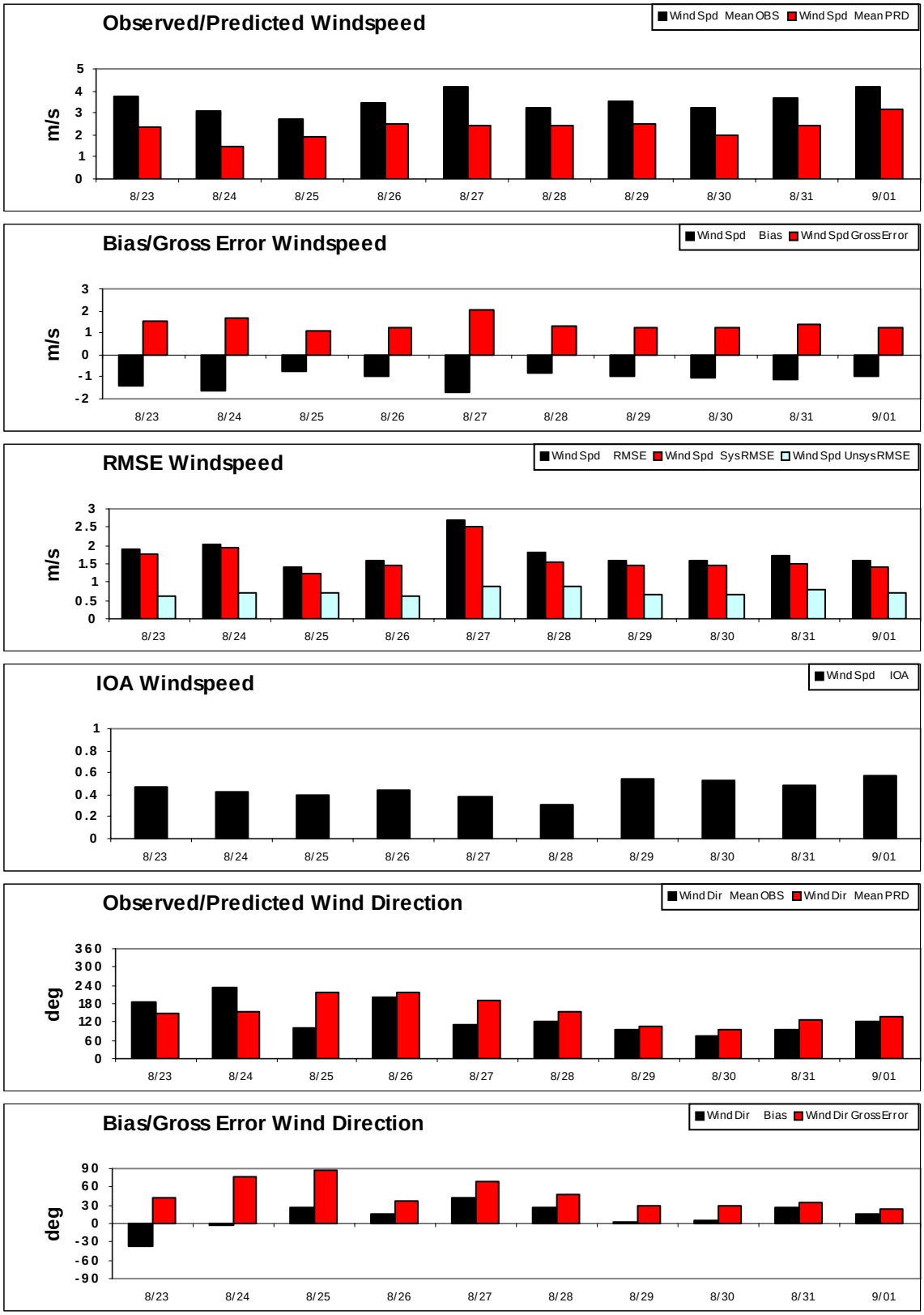


Figure 3-8a. Daily wind performance for TCEQ run6 on the 4-km grid evaluated against NWS stations.

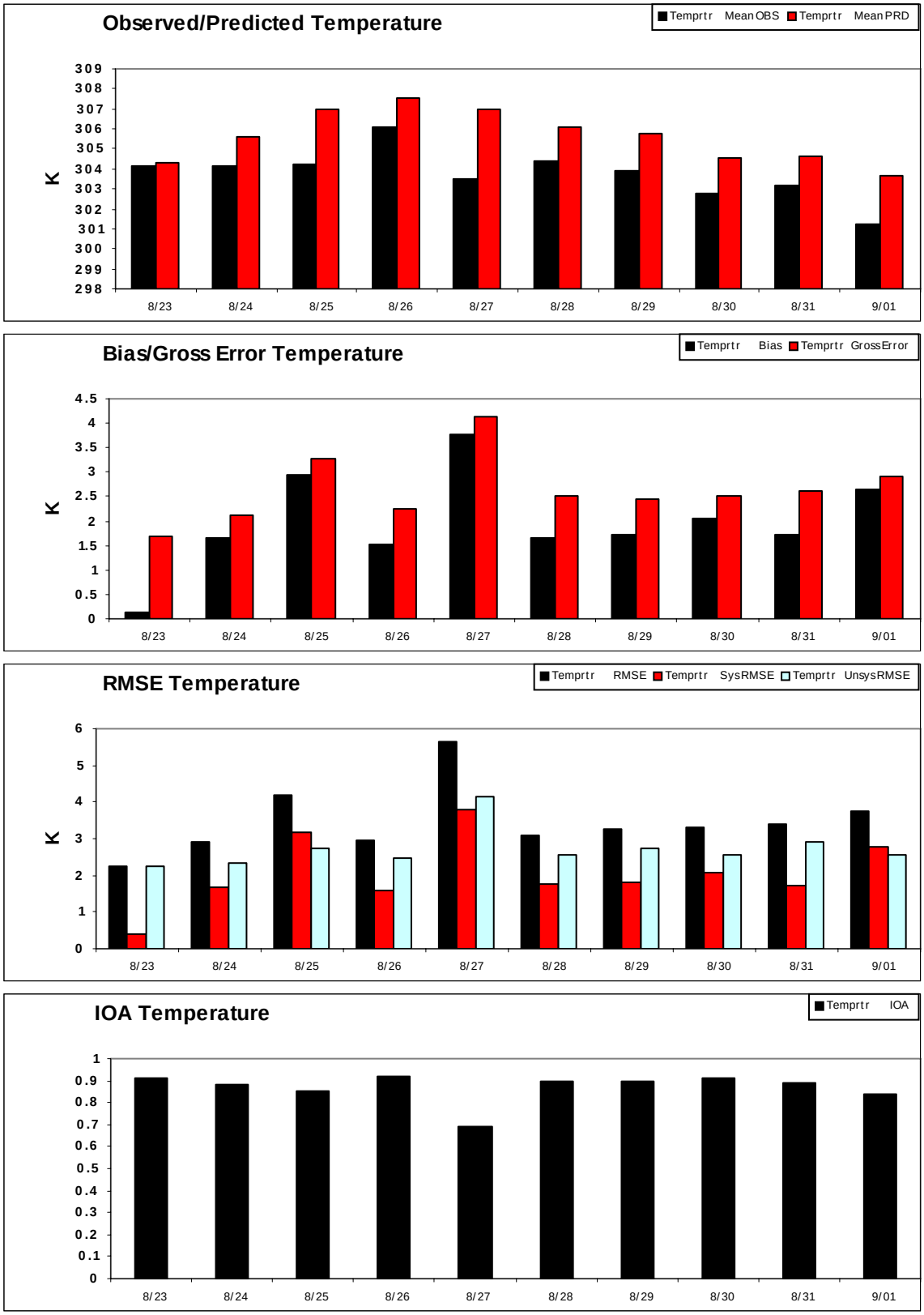


Figure 3-8b. Daily temperature performance for TCEQ run6 on the 4-km grid evaluated against NWS stations.

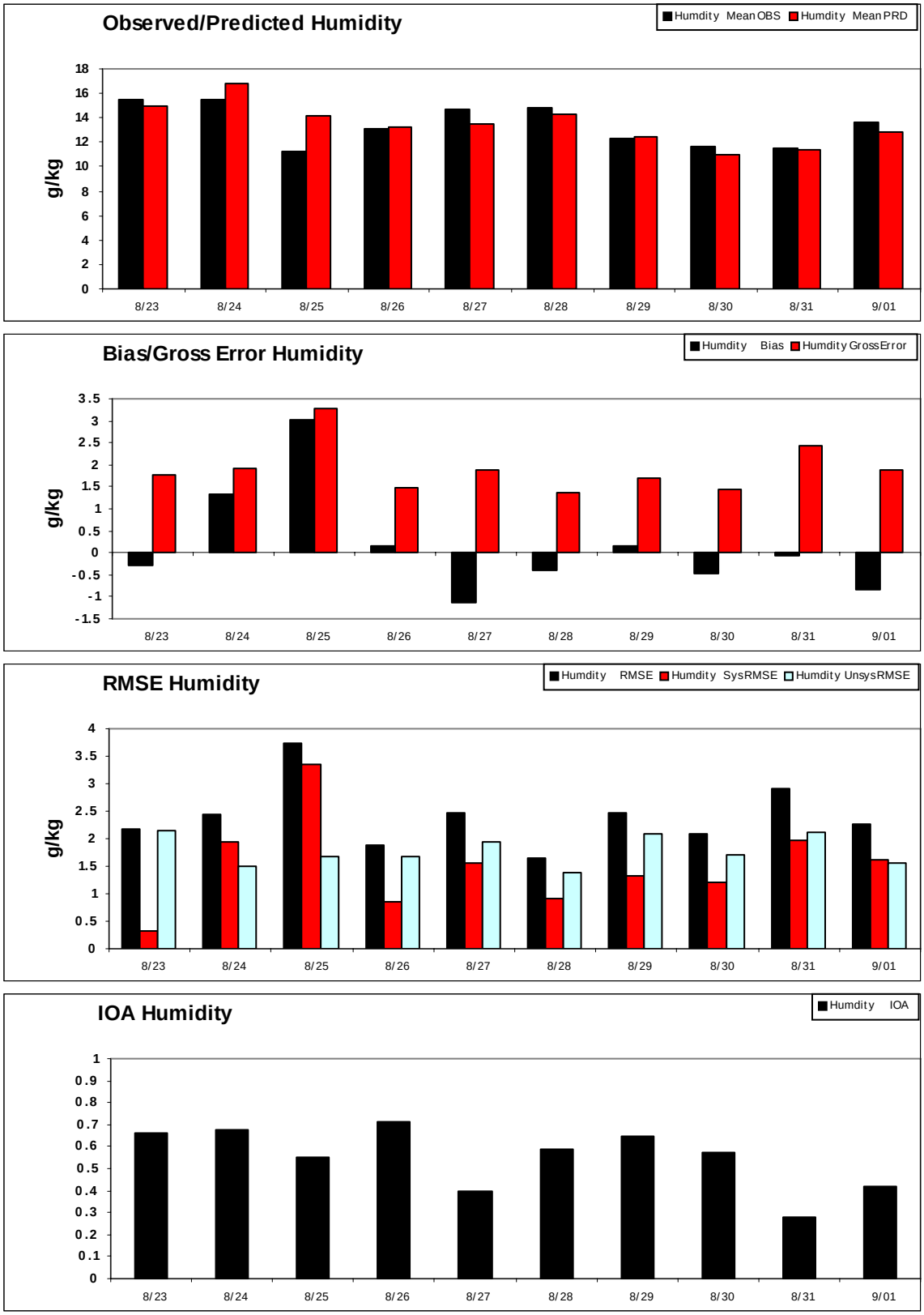


Figure 3-8c. Daily humidity performance for TCEQ run6 on the 4-km grid evaluated against NWS stations.

4. 1999 BASE CASE

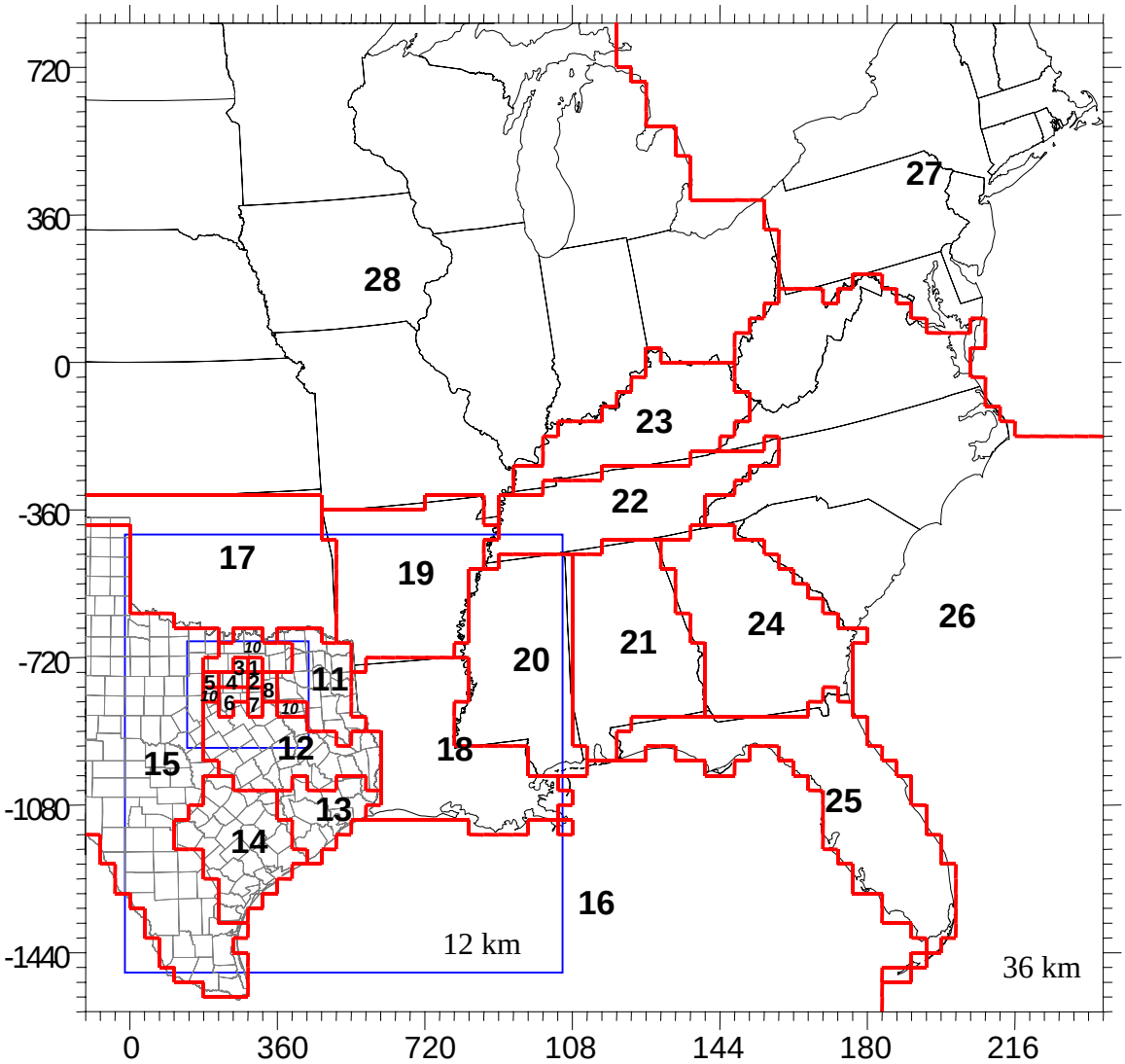
Sensitivity tests conducted for HARC project H35 (Tai, 2005) for the core period (August 13 – 22) showed that the following changes improved model performance over DFW in Run 34 compared to the previous base case Run 17b:

- Expanding the model domain northward and eastward into the Atlantic and Canada
- Extending the model top to around 14-km
- Using meteorology from MM5 Run 6, which was based on the Eta PBL scheme and Noah land-surface model
- Enhancing low-level mixing by applying the "Kv100" adjustment
- Adding NOx recycling reactions to CB4 (CB4xi)

RUN 40

CAMx Run 40 was identical to Run 34 except the modeling period was extended to include both the core period (August 13 – 22, 1999) and the supplemental period (August 23 – September 1, 1999). Minor ozone differences between Run 34 and Run 40 occurred because the categorical bins for the ozone column density differed due to the additional dates used in Run 40; thus, photolysis rates in the two runs were slightly different.

A summary of NOx and VOC emissions by source region is shown in Table 4-1 for Tuesday, August 17, 1999 – the date with the highest observed ozone in DFW. The source regions were defined from the HARC H35 project, as shown in Figure 4-1 for the 36-km expanded domain. Figure 4-2 shows the source regions and ozone monitoring sites in the DFW 4-km domain. Table 4-2 shows the daily variability in biogenic and anthropogenic emissions by listing NOx and VOC emission rates for all dates from the DFW 9-county area.



DFW Source Regions. 36 km Expanded Domain

1. Collin Co.
2. Dallas Co.
3. Denton Co.
4. Tarrant Co.
5. Parker Co.
6. Johnson Co.
7. Ellis Co.
8. Kaufman Co.
9. Rockwall Co.
10. DFW 16-County (Regions 1 - 9 plus Cooke, Fannin, Grayson, Henderson, Hood, Hunt, and Wise Counties)
11. Northeast Texas
12. Central Texas
13. Houston
14. South Texas
15. West Texas
16. Gulf of Mexico and Mexico
17. Oklahoma
18. Louisiana
19. Arkansas
20. Mississippi
21. Alabama
22. Tennessee
23. Kentucky
24. Georgia
25. Florida
26. Mid-Atlantic States (SC, NC, VA, WV)
27. Northeast US
28. Northern Plains

Figure 4-1. Source area map of the DFW 36-km expanded domain.

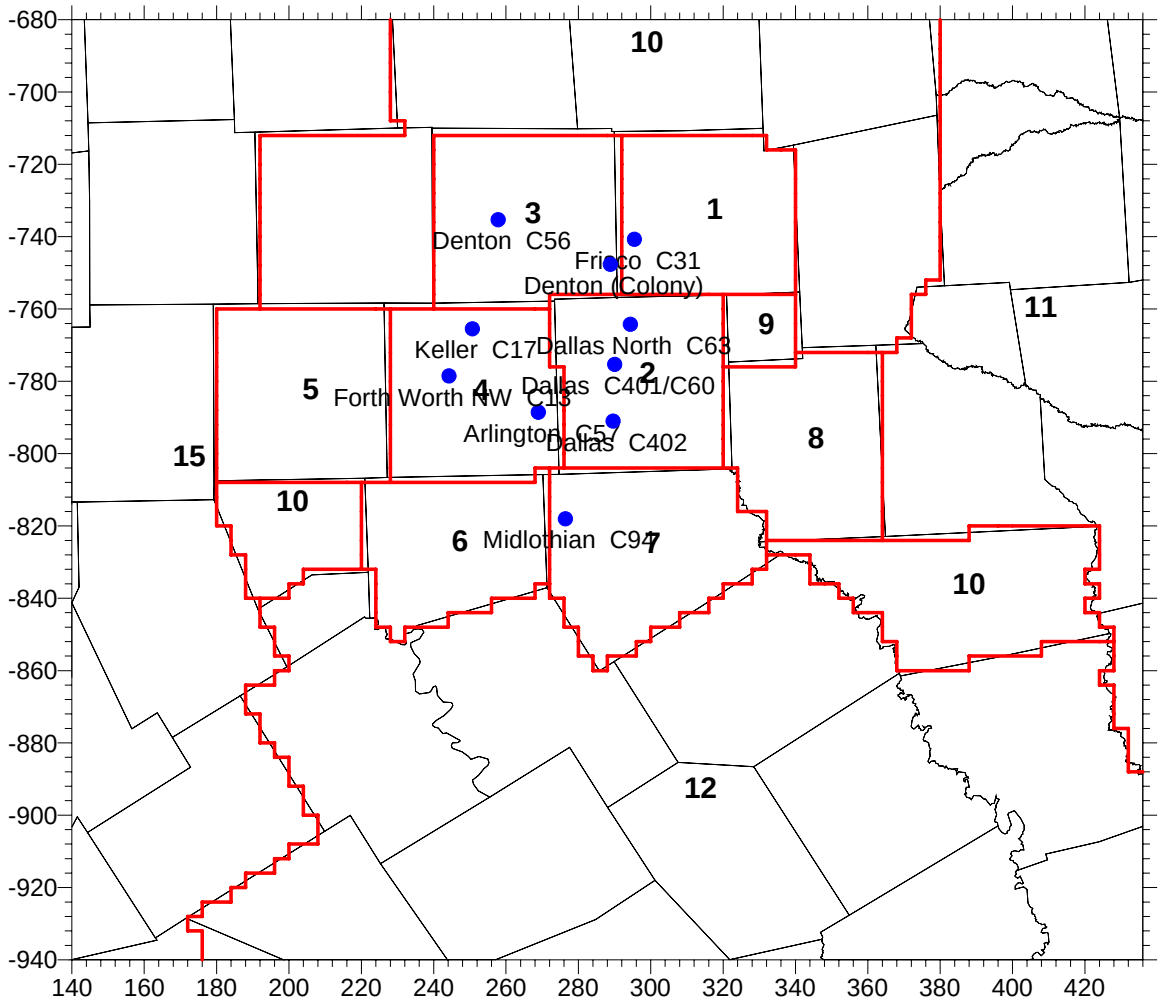


Figure 4-2. Source area map of the DFW 4-km domain and locations of ozone monitoring sites.

Table 4-1. 1999 NOx and VOC emissions by source region on Tuesday, August 17.

August 17, 1999 Emissions (tons per day)				
	NOx		VOC	
	Bio	Anthro	Bio	Anthro
Collin Co	10	58	27	38
Dallas Co	4	337	50	214
Denton Co	8	62	65	40
Tarrant Co	3	202	64	131
Parker Co	1	33	121	16
Johnson Co	5	24	111	14
Ellis Co	15	58	89	21
Kaufman Co	5	21	112	17
Rockwall Co	2	7	3	6
DFW 9-County	**52**	**802**	**642**	**497**
DFW 16-County	**83**	**991**	**1538**	**599**
NE Texas	16	666	4917	302
Central TX	113	635	6098	278
Houston	21	1340	1683	709
South TX	229	1098	2069	660
West Texas	524	981	6198	737
Gulf + Mexico	79	93	658	108
Oklahoma	227	1425	7940	760
Louisiana	106	2556	9941	1027
Arkansas	125	1014	13925	723
Mississippi	121	1063	14818	874
Alabama	75	1864	13954	1135
Tennessee	118	2163	8678	1486
Kentucky	145	3098	3753	1095
Georgia	110	2347	12198	1236
Florida	56	3928	9793	2383
Mid Atlantic States	293	6845	31294	3886
Northeast US	314	10982	20472	8749
Northern Plains	5238	21029	40144	12562
Total	**7992**	**64121**	**210073**	**39310**

Table 4-2. Daily 1999 NOx and VOC emissions inside the DFW 9-county area.

DFW 9-County Emissions (tons/day)					
		NOx		VOC	
		Bio	Anthro	Bio	Anthro
Core					
Fri	13-Aug-99	52	811	618	515
Sat	14-Aug-99	51	602	638	408
Sun	15-Aug-99	49	508	630	356
Mon	16-Aug-99	49	809	627	493
Tue	17-Aug-99	52	802	642	497
Wed	18-Aug-99	56	791	678	499
Thu	19-Aug-99	59	793	730	500
Fri	20-Aug-99	50	865	617	513
Sat	21-Aug-99	49	620	602	404
Sun	22-Aug-99	52	500	588	357
Supplemental					
Mon	23-Aug-99	50	809	561	493
Tue	24-Aug-99	50	802	558	497
Wed	25-Aug-99	50	791	566	499
Thu	26-Aug-99	52	793	556	500
Fri	27-Aug-99	47	865	480	513
Sat	28-Aug-99	44	602	522	408
Sun	29-Aug-99	48	508	539	356
Mon	30-Aug-99	45	809	456	493
Tue	31-Aug-99	49	802	532	497
Wed	1-Sep-99	43	791	424	499

PERFORMANCE EVALUATION FOR THE SUPPLEMENTAL PERIOD

Figure 4-3 shows time series of hourly ozone from Run 17b for the core period and Run 40 for the core and supplemental periods. Run 40 showed significant improvements compared to Run 17b over Dallas (CAMS 401/60) and Dallas North (CAMS 63) as daytime peaks were much higher on all dates in the core period. Run 40 also predicted a better and higher peak on August 17 in Frisco (CAMS 31) and the two Denton monitoring sites (CAMS 56 and Colony).

In the supplemental period, Run 40 under predicted daytime ozone on August 25 and 26 at most monitoring stations. Run 40 vastly over predicted the ozone on August 31 and September 1 at the three most northern stations – Frisco (CAMS 31) and Denton (CAMS 56 and Colony). Poor ozone performance in the supplemental period is primarily related to the poor meteorological model performance discussed in Section 3.

Figures 4-4 and 4-5 compare daily model performance statistics for 1-hour and 8-hour ozone, respectively, from Run 17b (core only) and Run 40 (core and extended periods). In the core period, Run 40 improved the average paired peak accuracy, and normalized bias and error on most dates. In Run 17b, four dates (August 16, 17, 20, and 21), excluding spin-up dates, were outside the EPA guideline of ±15 % for normalized bias for both 1-hour and 8-hour ozone. In Run 40, only one date in the core period was outside the threshold – August 17, when there was

a negative bias.
In the supplemental period (August 23 – September 1), the only date when the normalized bias exceeded the ±15 % range was August 23, when the statistic was too high for both 1-hour and 8-hour ozone. August 23's statistics could be misleading because ozone observations were very low on this date (the highest was 68 ppb for 1-hour ozone and 60 ppb for 8-hour ozone, both in Denton), resulting in significantly fewer predicted and observed pairings used to compute the normalized bias and error on this date. Pairings when the observed ozone was less than 60 ppb for 1-hour ozone and 40 ppb for 8-hour ozone were excluded.

Normalized error met the 35 % criteria on all dates in both runs; the supplemental period's normalized error, in general, was greater than in the core period. Unpaired peak accuracy was worst on August 23 for both 1-hour and 8-hour ozone; the statistic was also too high on the last few dates of the supplemental period. Keep in mind that the unpaired peak accuracy can be misleading because the observed peak is based on a limited number of monitoring sites, so it is better for the model to over predict ozone than under predict.

Spatial plots compare the daily maximum 1-hour ozone in the DFW 4-km domain between Run17b and Run 40 on August 17, 1999 in Figure 4-6. Due to the overwhelming number of dates in the combined core and supplemental periods, only August 17 will be shown in the core period because this date monitored the highest observed ozone. Run 40 performed better as the predicted peak was positioned more eastward and closer to the monitors with the highest observed ozone. However, the peak was still under predicted.

Daily maximum 1-hour ozone plots for each date in the supplemental period from Run 40 are shown in Figure 4-7. On August 25 and 26, the simulated peak in the 4-km domain was east of DFW, causing ozone to be under predicted at most observation sites. Run 40 predicted 1-hour ozone exceeding 124 ppb from August 29 to 31; no monitors exceeded this threshold during the supplemental period. The highest predicted value was 138 ppb on August 30, when the peak was west of DFW, where few observations were available.

The daily maximum plots of 1-hour ozone in the 12-km domain from Run 17b and Run 40 on August 17 are shown in Figure 4-8. Run 40 simulated higher local peaks near Houston and northeast Texas on this date.

The daily maximum 1-hour ozone plots in the 12-km domain for all dates in the supplemental period are shown in Figure 4-9. Run 40 shows locally higher ozone over northeast Texas between August 25 and 28. Note that the peak ozone near DFW was shifted too far to the east on August 25 and 26. High ozone was predicted near Houston from August 29 to 31. No model performance evaluations were performed to validate this.

A comparison of the August 17 daily maximum 8-hour ozone in the 4-km domain between the two runs is shown in Figure 4-10. Like 1-hour ozone, performance was better in Run 40 as the ozone peak was higher and shifted eastwards.

Plots of the daily maximum 8-hour ozone in the supplemental period are shown in Figure 4-11. On August 25, Run 40 placed the peak east of DFW when the highest observed ozone was in Tarrant and Denton Counties, where three monitors recorded 8-hour ozone exceeding 100 ppb. From August 29 to September 1, Run 40 simulated 8-hour ozone exceeding 100 ppb in parts of Denton County and areas to its northwest on each date; during this period, no monitors recorded

8-hour ozone over 100 ppb.

Despite the poor spatial distribution of ozone in the supplemental period, the coefficient of determination (R^2) when comparing the predicted and observed daily maximum 8-hour ozone from all sites in the 4-km domain on all days in the supplemental period were close to those in the core when using the maximum predicted value near each monitor and the value closest in magnitude to the observed. Scatter plots depicting the predicted and observed pairings are shown in Figure 4-12, where the left side shows the core period and the right side shows the supplemental period. The top plots use the maximum predicted value, where R^2 was 0.44 and 0.43 for the core and extended periods, respectively. The middle row uses the predicted value near each monitor making the best fit; the R^2 was 0.89 and 0.87 for the core and supplemental periods, respectively. The use of spatially paired daily maximum ozone (bottom plots in Figure 4-12) showed inferior performance in the supplemental period as the R^2 was 0.05 lower than the core.

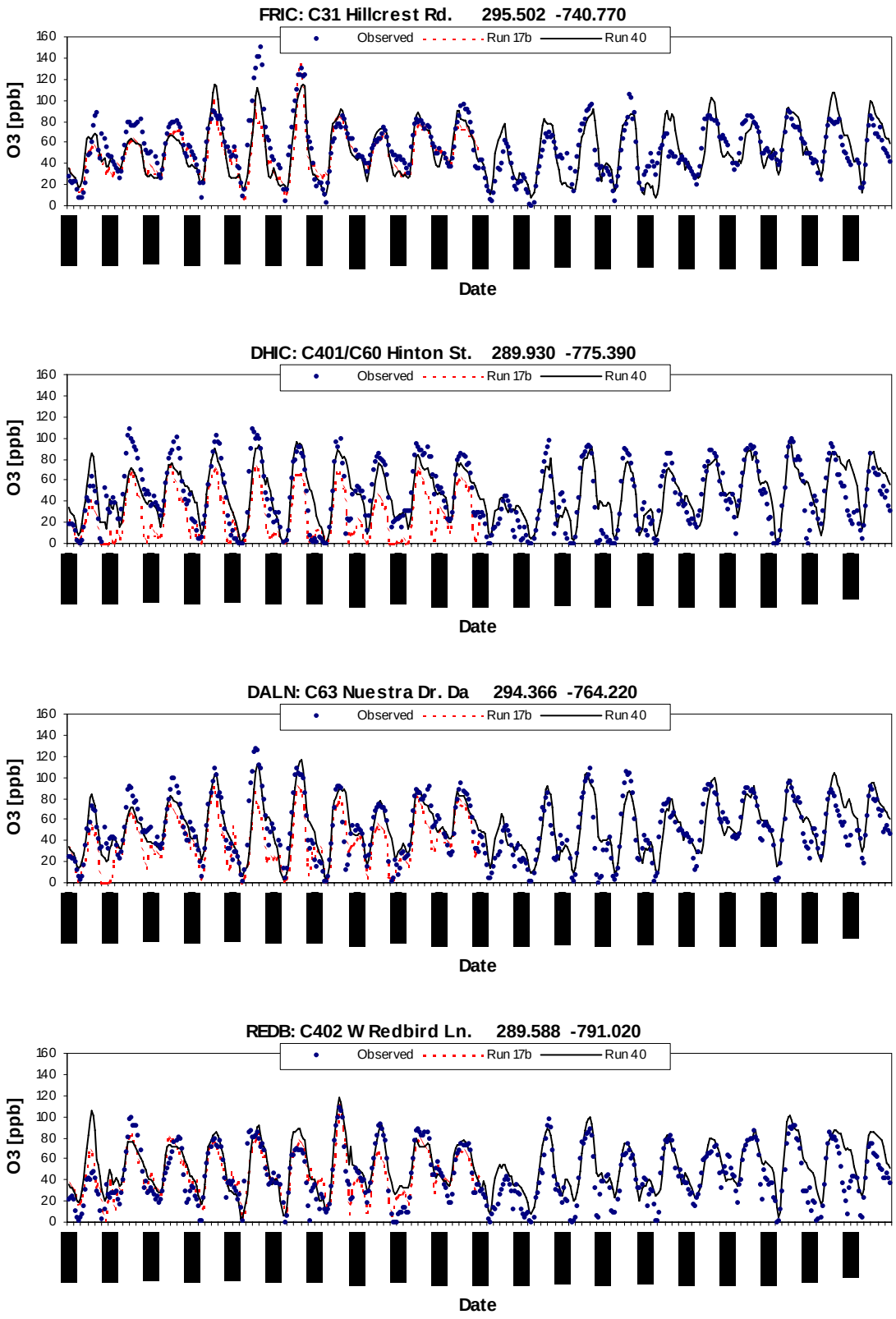


Figure 4-3. Time series of predicted and observed 1-hour ozone from Run 17b and Run 40.

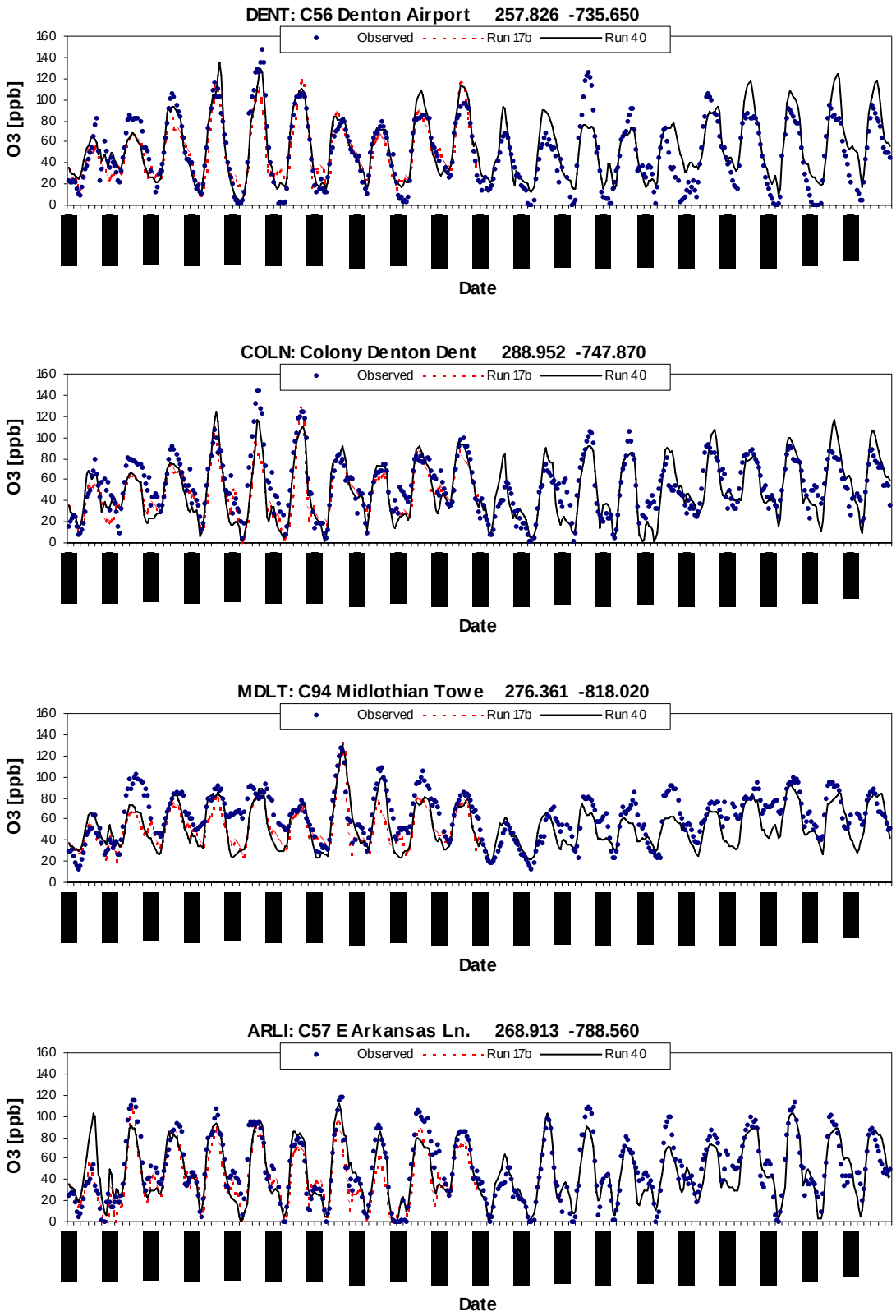


Figure 4-3 (continued). Time series of predicted and observed 1-hour ozone from Run 17b and Run 40.

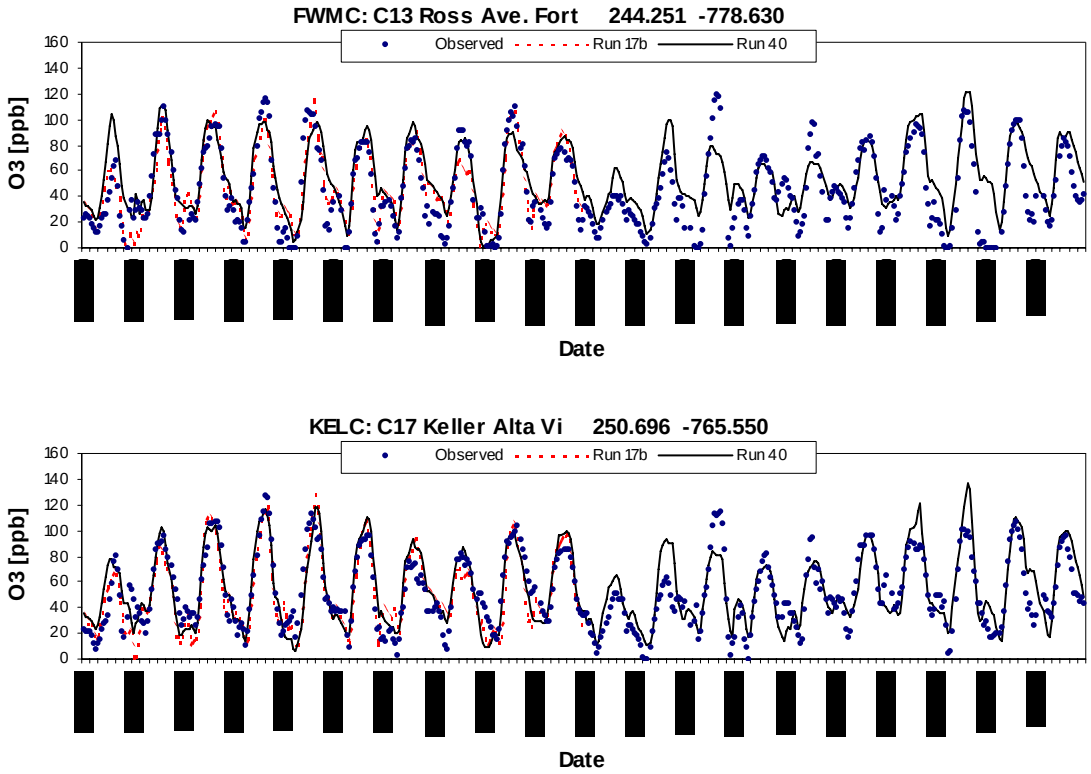


Figure 4-3 (concluded). Time series of predicted and observed 1-hour ozone from Run 17b and Run 40.

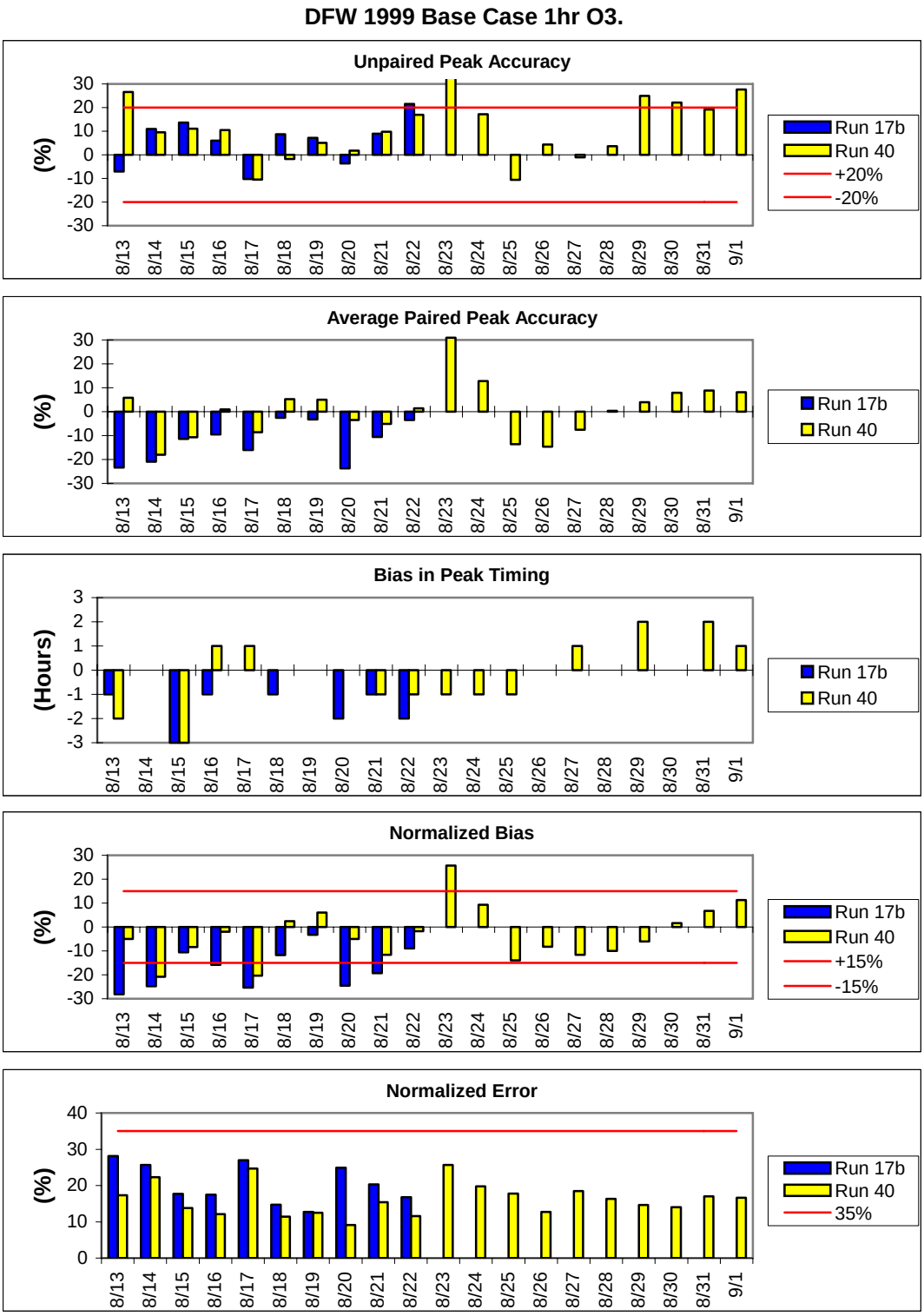


Figure 4-4. Daily performance statistics of 1-hour ozone in DFW from CAMx Runs 17b and Run 40.

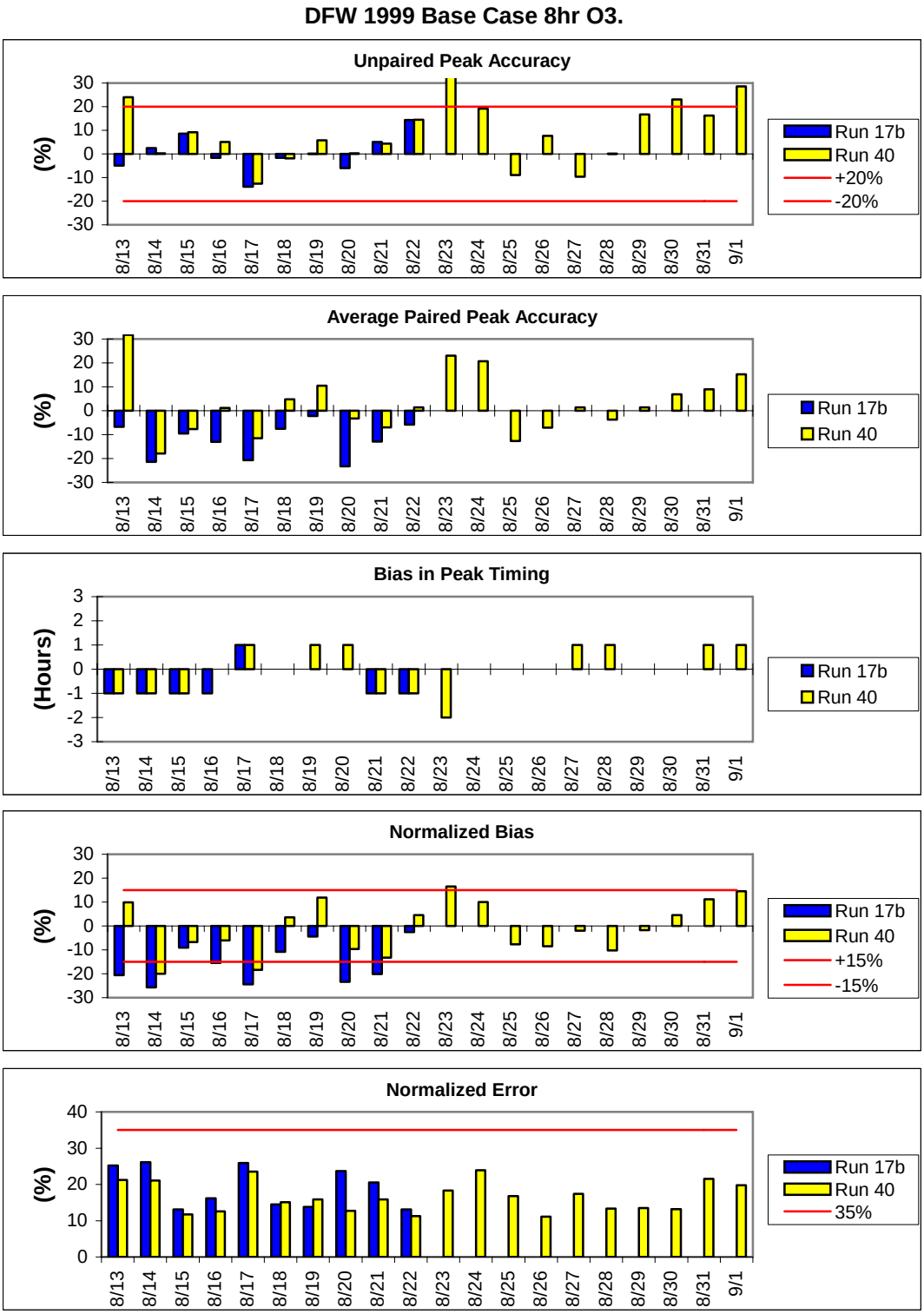
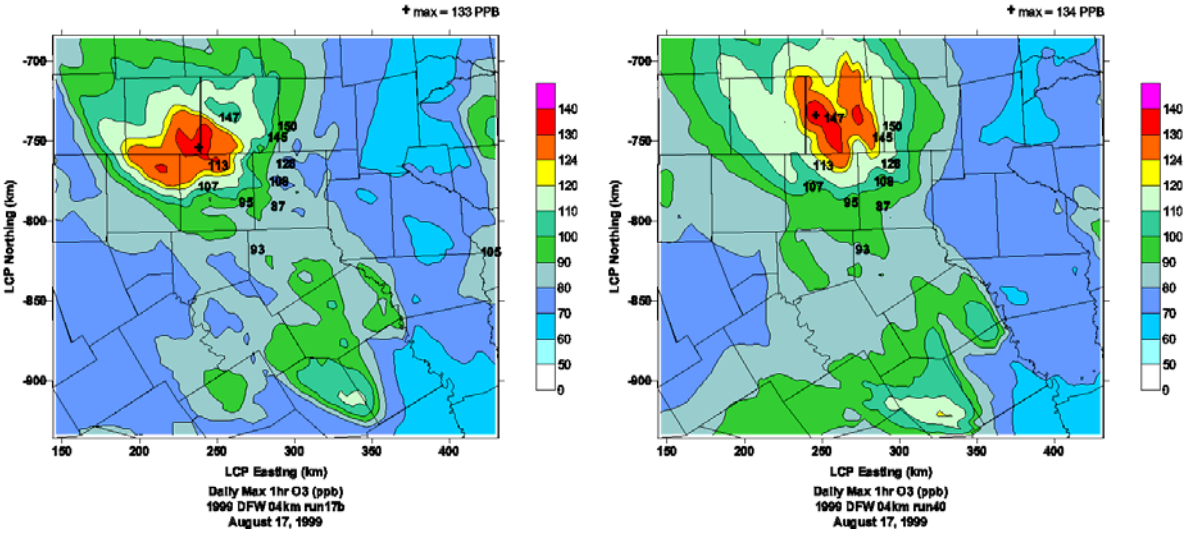


Figure 4-5. Daily performance statistics of 8-hour ozone in DFW from CAMx Runs 17b and Run 40.



Run 17b Run 40

Figure 4-6. Daily maximum 1-hour ozone of the DFW 4-km domain from Run 17b (left) and Run 40 (right) on August 17, 1999.

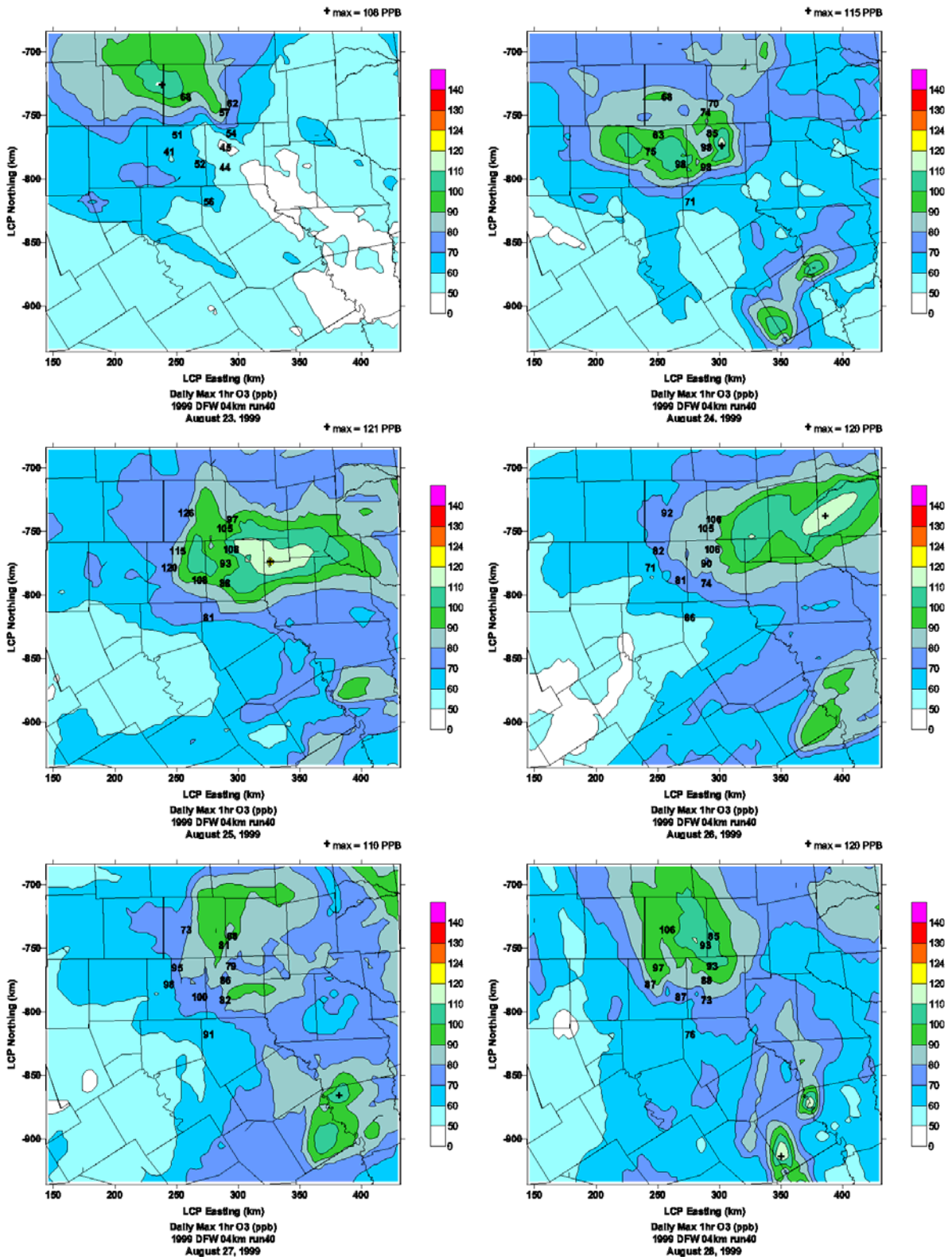


Figure 4-7. 1999 daily maximum 1-hour ozone in the DFW 4-km domain in the supplemental period.

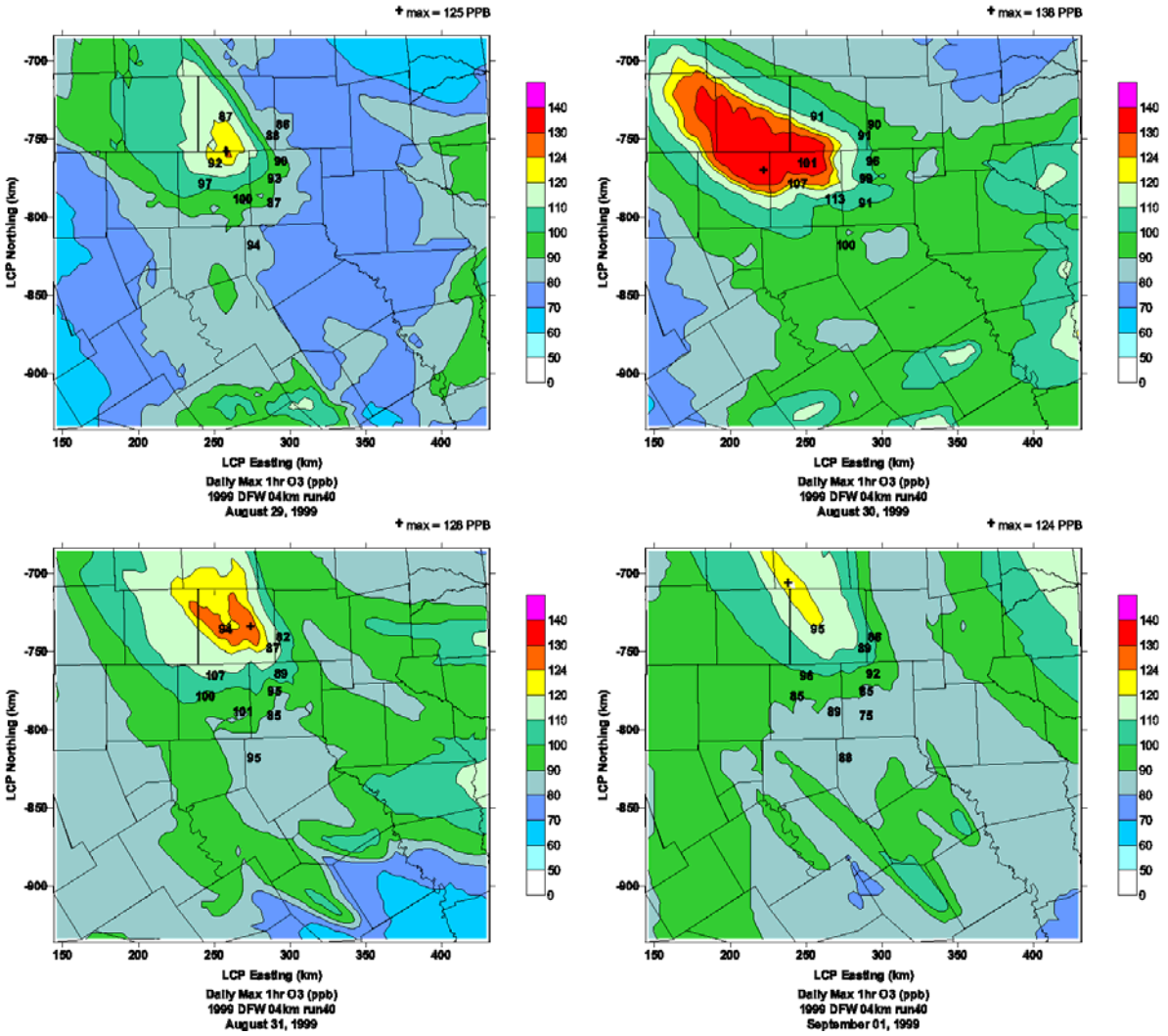
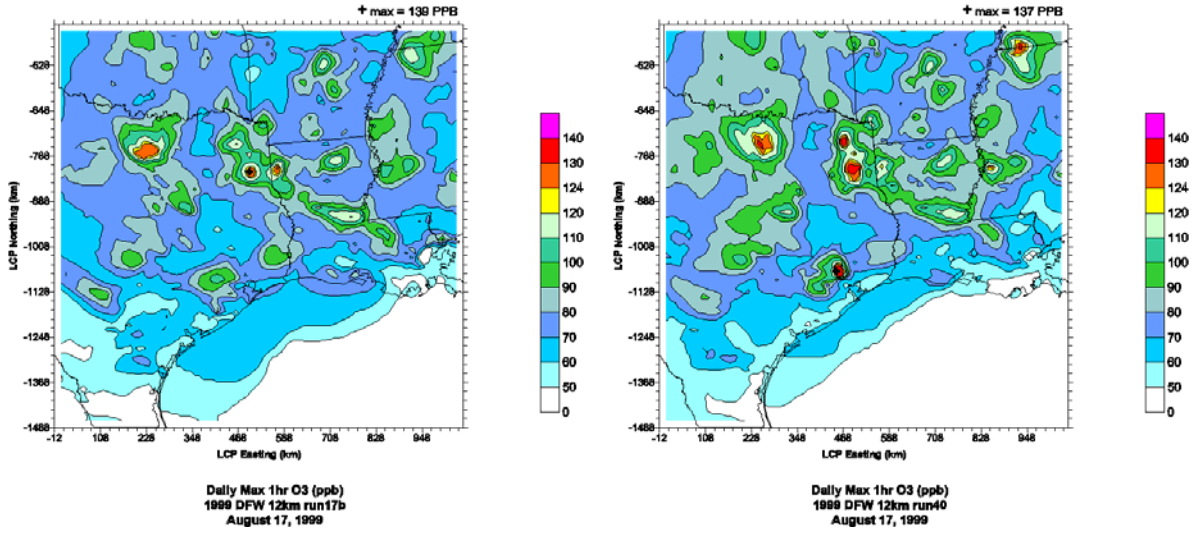


Figure 4-7 (concluded). 1999 daily maximum 1-hour ozone in the DFW 4-km domain in the supplemental period.



Run 17b Run 40

Figure 4-8. 1999 daily maximum 1-hour ozone in the DFW 12-km domain on August 17.

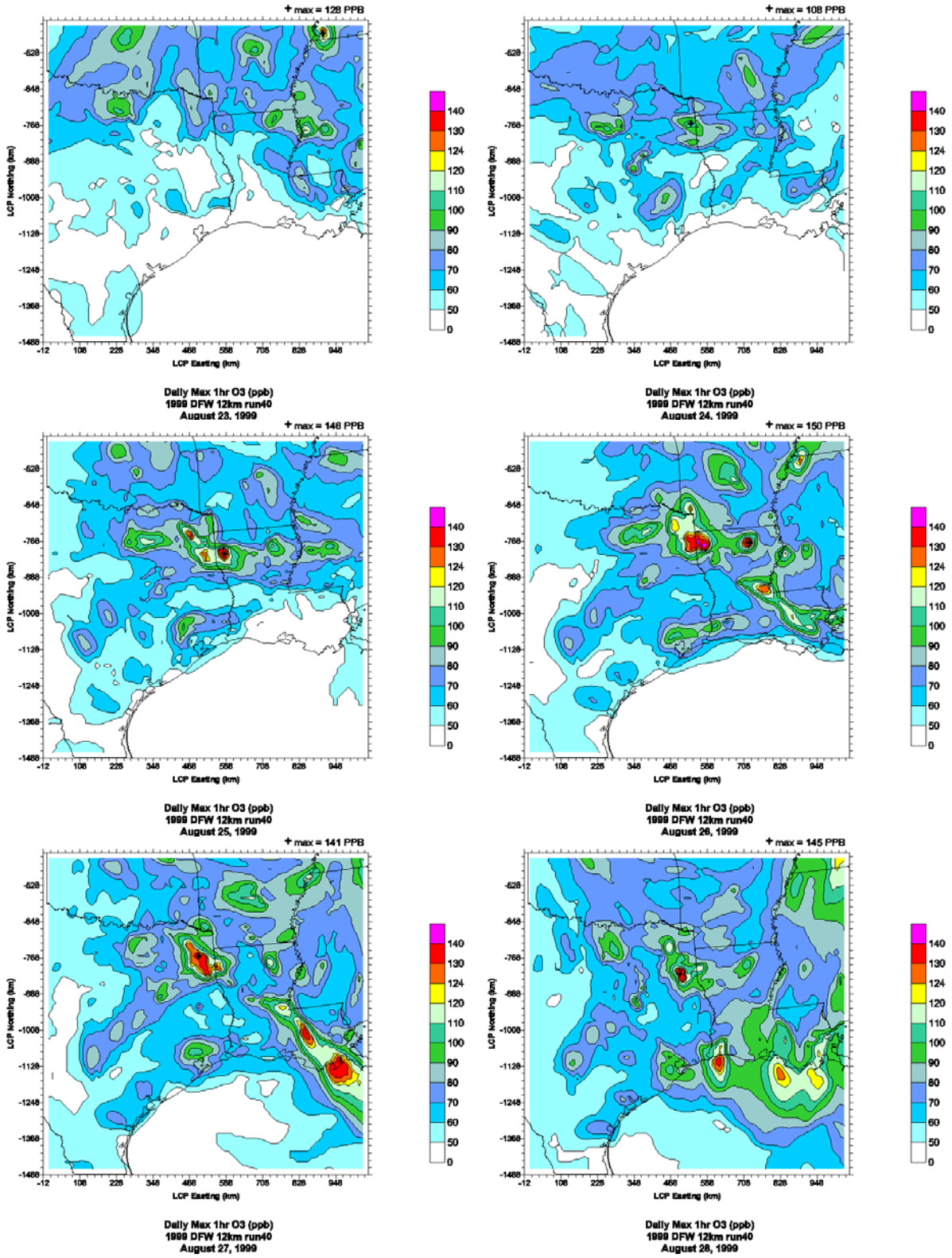


Figure 4-9. 1999 daily maximum 1-hour ozone in the DFW 12-km domain in the supplemental period.

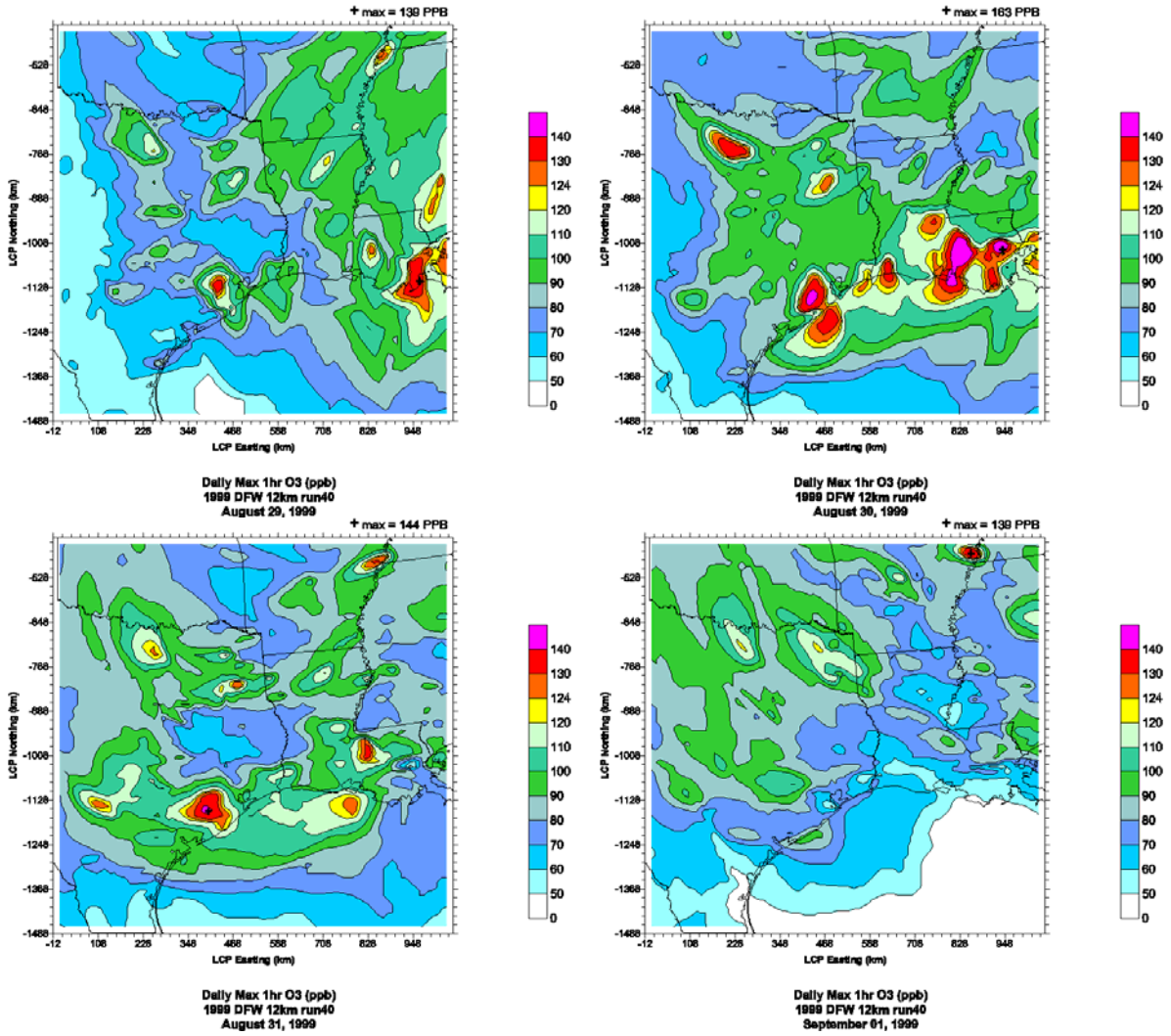
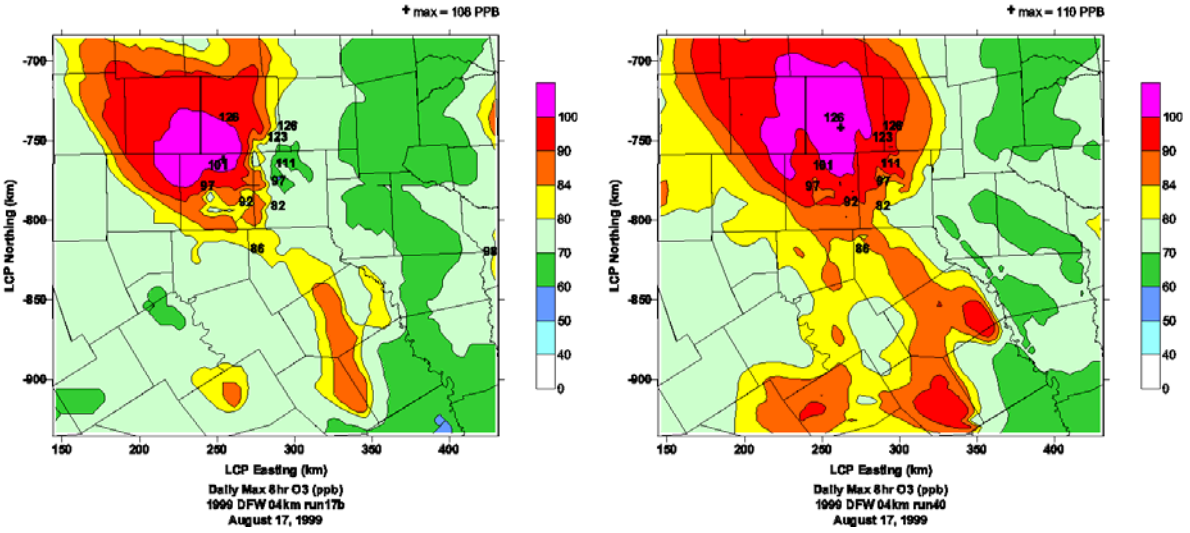


Figure 4-9 (concluded). 1999 daily maximum 1-hour ozone in the DFW 12-km domain in the supplemental period.



Run 17b Run 40

Figure 4-10. 1999 daily maximum 8-hour ozone in the DFW 4-km domain on August 17.

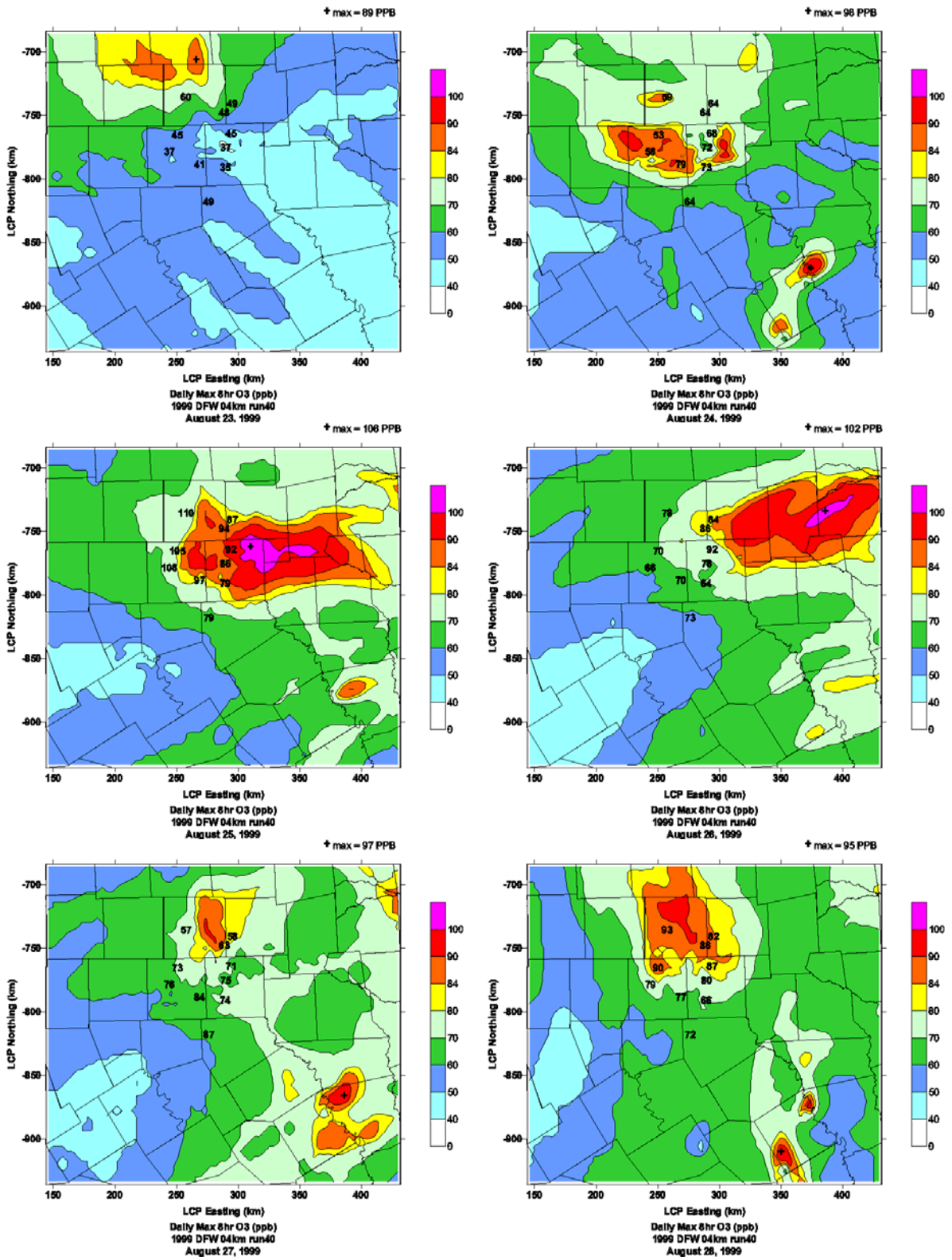


Figure 4-11. 1999 daily maximum 8-hour ozone in the DFW 4-km domain in the supplemental period.

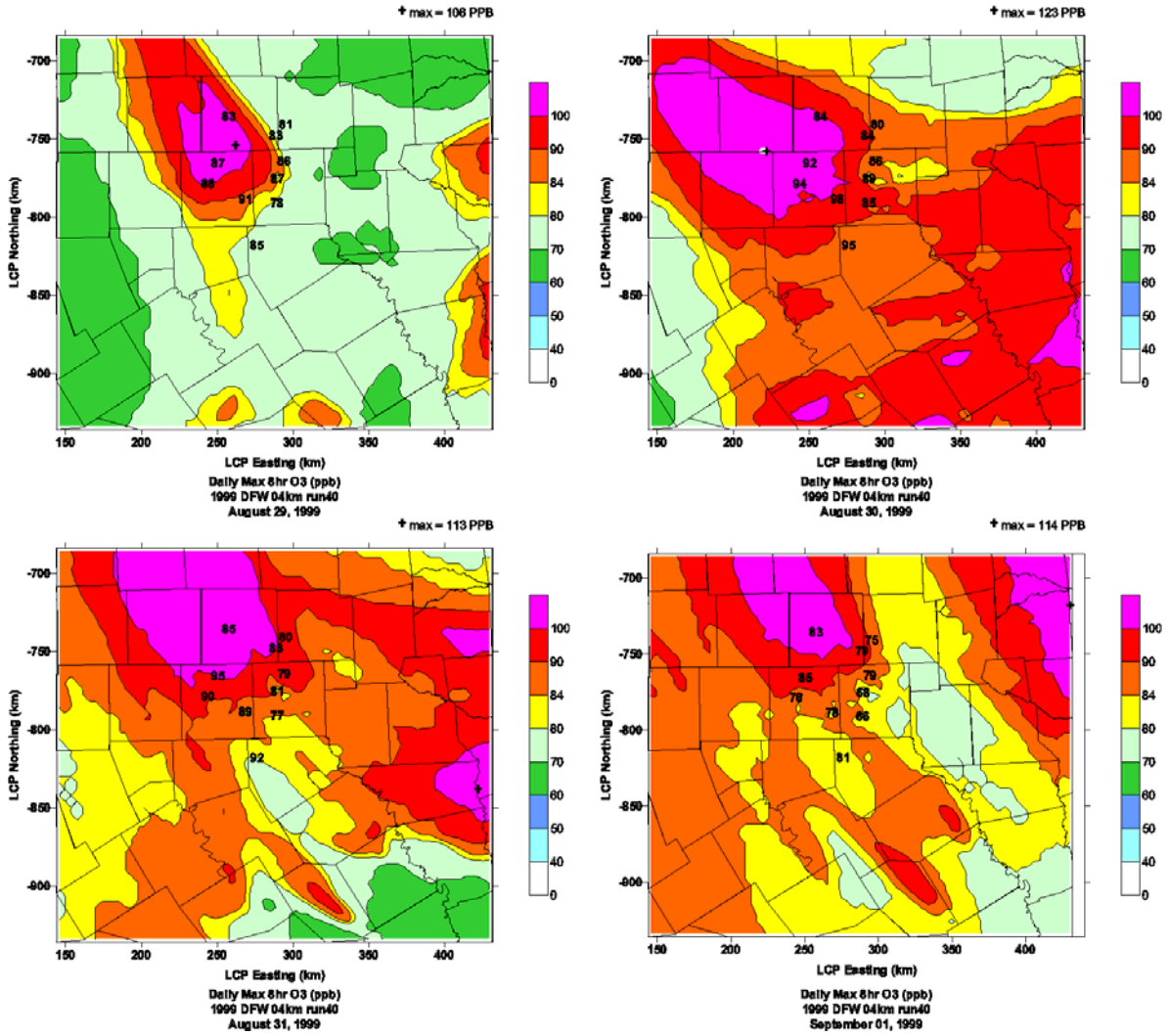
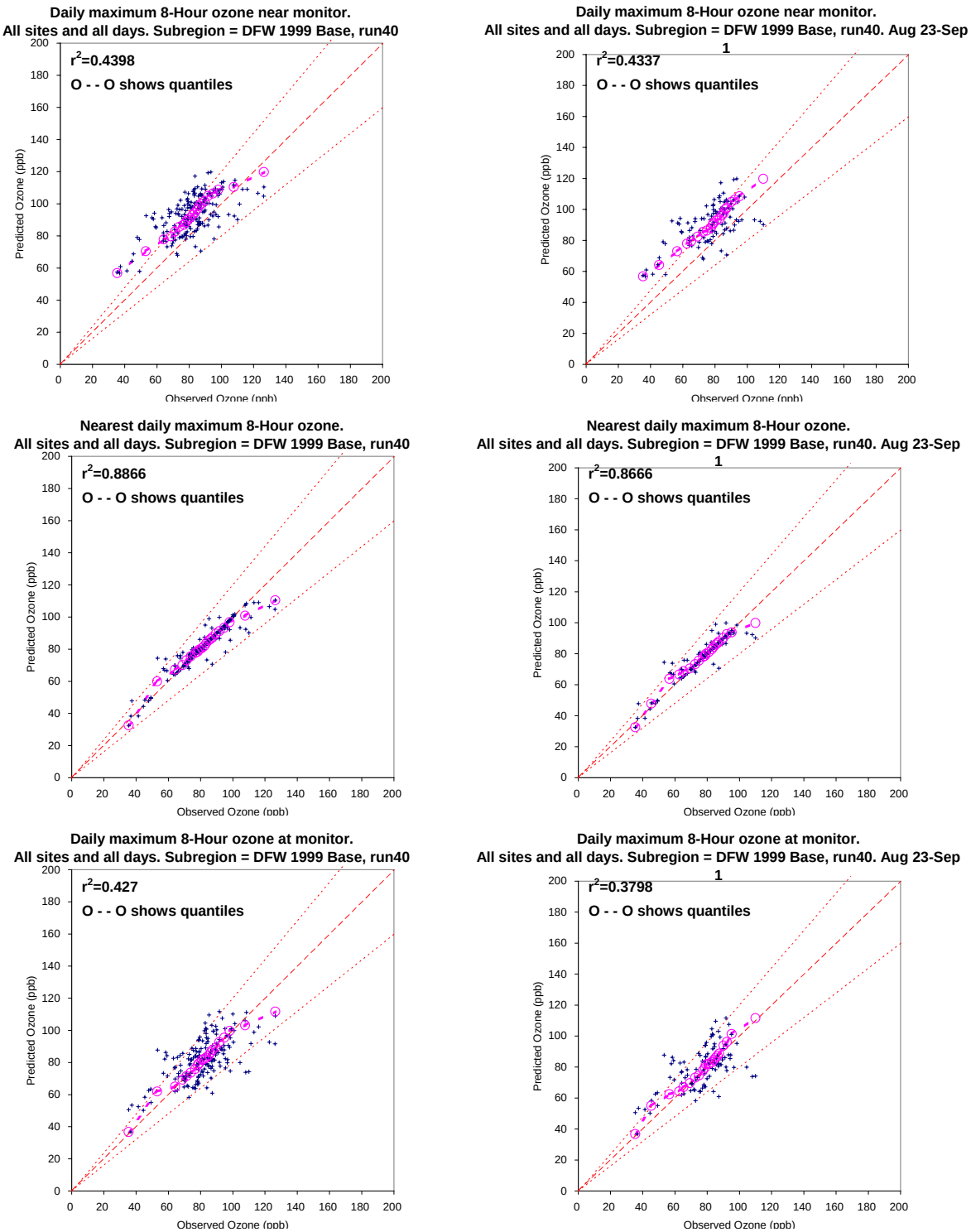


Figure 4-11 (concluded). 1999 daily maximum 8-hour ozone in the DFW 4-km domain in the supplemental period.



Run 40 Core

Run 40 Supplemental

Figure 4-12. Predicted and observed daily maximum 8-hour ozone from all monitors in the DFW 4-km domain in the core (left) and supplemental (right) periods using the maximum predicted (top), best fit (middle row), and spatially paired (bottom) values.

5. 2010 OZONE MODELING

CAMx 2010 ozone modeling was based on the Run 40 configuration using future year emissions. The 2010 emissions were obtained from TCEQ inside the standard domain and from work performed for ODEQ in the extended area, as discussed in Section 2. A matrix of NOx and VOC controls were applied to the anthropogenic emissions inside the DFW NAA to evaluate ozone reduction responsiveness at each monitoring site.

2010 BASE CASE – RUN 40

Tables 5-1 and 5-2 show the 2010 future year base case NOx and VOC emissions, respectively, from four emission categories (biogenics, on-road mobile, area and off-road mobile, and point sources) and 28 source regions, as had been used in the HARC H35 project (Tai et al., 2005), on Tuesday, August 17, 1999 – the date with the highest observed ozone. These tables also show the total 2010 anthropogenic emissions and the percent change from the 1999 base case anthropogenic emissions. The 2010 emissions include reductions due to EPA's Clean Air Interstate Rule (CAIR) estimated as described in Tai et al. (2005).

NOx was significantly reduced in 2010 compared to 1999 levels, except in Ellis County, where anthropogenic emissions increased 5%, and the Gulf of Mexico and Mexico, where emissions were almost ten times higher due to low 1999 emissions. VOC emissions were also lower in 2010, but not as strongly as NOx reductions. Johnson, Ellis, and Kaufman Counties, central Texas, and the Gulf of Mexico all emitted more anthropogenic VOCs on this date in 2010 than in 1999. Biogenics were unchanged.

Emissions from the DFW 9-county area for each emission category and date in the core and supplemental periods are shown in Tables 5-3 and 5-4 for NOx and VOC, respectively.

Figure 5-1 shows spatial plots of the daily maximum 8-hour ozone in the 4-km domain on the left side and the difference in daily maximum ozone between 1999 and 2010 on the right for each date from August 15 to September 1. Plots for 1-hour ozone in the 4-km domain can be seen in Appendix A.

The 2010 8-hour ozone was lower than in 1999 across most of the 4-km domain except in parts of the DFW 4-county core, where ozone was sometimes significantly higher. The higher ozone near DFW in 2010 was evident on August 17 and 20 during the core period, and on August 23, 24, and 27 in the supplemental period. Ozone increases in the DFW urban area from 1999 to 2010 result from NOx emission reductions in areas of high NOx emission density, i.e., "NOx disbenefits." The peak predicted ozone in the 4-km domain was lower in 2010 on all dates except August 24.

Table 5-1. 2010 NOx emissions by source region and emission category on August 17.

August 17, 1999 for FY2010 NOx Emissions (Tons per day)						
	Biogenics	**Mobile**	**Area + Off-road**	**Points**	**Anthro**	**% Change in anthro from 1999**
Collin Co	10	12	15	3	29	-49
Dallas Co	4	65	76	18	159	-53
Denton Co	8	15	19	3	37	-40
Tarrant Co	3	38	45	12	95	-53
Parker Co	1	5	5	2	12	-63
Johnson Co	5	4	7	4	15	-38
Ellis Co	15	7	9	45	61	5
Kaufman Co	5	5	4	7	16	-24
Rockwall Co	2	3	1	0	4	-43
DFW 9-County	**52**	**154**	**180**	**95**	**429**	**-47**
DFW 16-County	**83**	**176**	**222**	**151**	**548**	**-45**
NE Texas	16	80	128	217	425	-36
Central TX	113	64	144	197	405	-36
Houston	21	139	175	293	607	-55
South TX	229	159	213	325	697	-36
West Texas	524	130	310	187	626	-36
Gulf + Mexico	79	14	381	600	995	970
Oklahoma	227	175	244	690	1109	-22
Louisiana	106	179	962	918	2058	-19
Arkansas	125	119	303	305	727	-28
Mississippi	121	169	323	403	895	-16
Alabama	75	243	343	513	1099	-41
Tennessee	118	290	460	383	1133	-48
Kentucky	145	221	462	430	1113	-64
Georgia	110	416	300	356	1073	-54
Florida	56	746	460	310	1515	-61
Mid Atlantic States	293	1164	902	1268	3334	-51
Northeast US	314	2052	3231	1256	6539	-40
Northern Plains	5238	3064	4465	4375	11905	-43
Total	**7992**	**9601**	**14027**	**13177**	**36804**	**-43**

Table 5-2. 2010 VOC emissions by source region and emission category on August 17.

August 17, 1999 for FY2010 VOC Emissions (Tons per day)						
	Biogenics	**Mobile**	**Area + Off-road**	**Points**	**Anthro**	**% Change in anthro from 1999**
Collin Co	27	7	19	1	27	-29
Dallas Co	50	37	115	12	165	-23
Denton Co	65	8	25	2	35	-13
Tarrant Co	64	21	80	9	110	-16
Parker Co	121	2	13	1	15	-4
Johnson Co	111	2	13	0	15	9
Ellis Co	89	2	15	7	24	16
Kaufman Co	112	2	16	2	20	17
Rockwall Co	3	1	5	0	5	-8
DFW 9-County	**642**	**82**	**300**	**35**	**417**	**-16**
DFW 16-County	**1538**	**92**	**388**	**39**	**519**	**-13**
NE Texas	4917	34	210	21	265	-12
Central TX	6098	26	239	27	293	5
Houston	1683	74	281	107	462	-35
South TX	2069	75	458	24	558	-15
West Texas	6198	56	638	16	710	-4
Gulf + Mexico	658	11	339	48	398	268
Oklahoma	7940	101	302	168	570	-25
Louisiana	9941	95	381	235	712	-31
Arkansas	13925	61	364	131	556	-23
Mississippi	14818	80	381	163	623	-29
Alabama	13954	146	421	340	907	-20
Tennessee	8678	160	668	341	1169	-21
Kentucky	3753	123	420	221	764	-30
Georgia	12198	231	630	78	938	-24
Florida	9793	652	981	70	1703	-29
Mid Atlantic States	31294	951	1659	478	3088	-21
Northeast US	20472	1243	4737	186	6166	-30
Northern Plains	40144	2180	5428	1281	8890	-29
Total	**210073**	**6389**	**18926**	**3975**	**29290**	**-25**

Table 5-3. Daily NOx emissions by emission category in the DFW 9-county NAA.

DFW 9-county NOx emissions for 2010 (tons per day)					
Date	**Biogenics**	**On-road Mobile**	**Area + Off-road**	**Point Sources**	**Total Anthro**
Core					
13-Aug	52	157	180	95	431
14-Aug	51	104	142	93	338
15-Aug	49	81	115	93	290
16-Aug	49	155	180	95	429
17-Aug	52	154	180	95	429
18-Aug	56	148	180	95	422
19-Aug	59	149	180	95	423
20-Aug	50	177	180	95	452
21-Aug	49	107	142	93	341
22-Aug	52	80	115	93	289
Supplemental					
23-Aug	50	155	180	95	429
24-Aug	50	154	180	95	429
25-Aug	50	148	180	95	422
26-Aug	52	149	180	95	423
27-Aug	47	177	180	95	452
28-Aug	44	104	142	93	338
29-Aug	48	81	115	93	290
30-Aug	45	155	180	95	429
31-Aug	49	154	180	95	429
1-Sep	43	148	180	95	422

Table 5-4. Daily VOC emissions by emission category in the DFW 9-county NAA.

DFW 9-county VOC emissions for 2010 (tons/day)					
Date	**Biogenics**	**On-road Mobile**	**Area + Off-road**	**Point Sources**	**Total Anthro**
Core					
13-Aug	618	91	300	35	425
14-Aug	638	66	217	28	310
15-Aug	630	54	172	28	254
16-Aug	627	80	300	35	415
17-Aug	642	82	300	35	417
18-Aug	678	83	300	35	417
19-Aug	730	83	300	35	418
20-Aug	617	91	300	35	425
21-Aug	602	64	217	28	309
22-Aug	588	54	172	28	254
Supplemental					
23-Aug	561	80	300	35	415
24-Aug	558	82	300	35	417
25-Aug	566	83	300	35	417
26-Aug	556	83	300	35	418
27-Aug	480	91	300	35	425
28-Aug	522	66	217	28	310
29-Aug	539	54	172	28	254
30-Aug	456	80	300	35	415
31-Aug	532	82	300	35	417
1-Sep	424	83	300	35	417

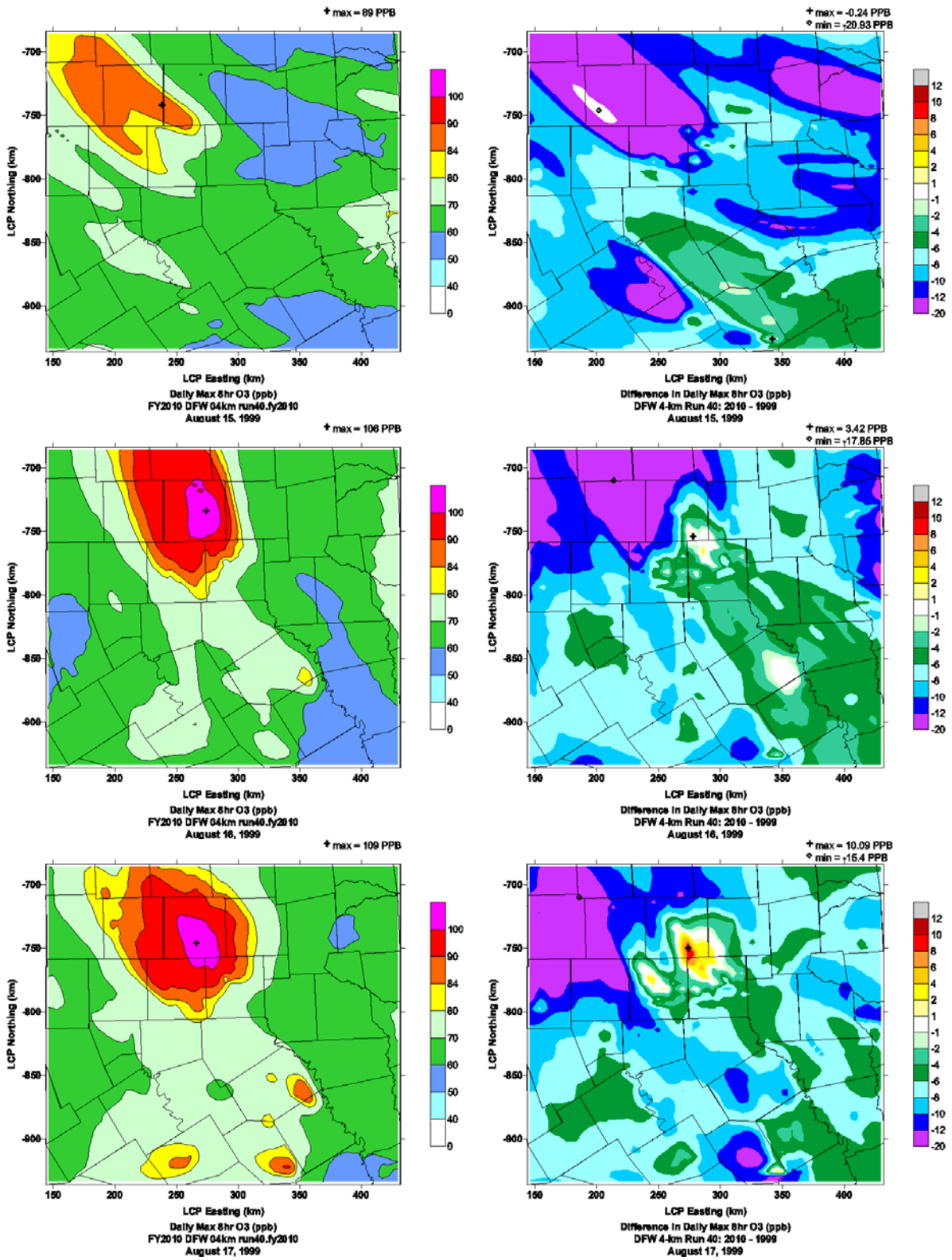


Figure 5-1. Daily maximum 8-hour ozone in the 4-km domain for 2010 (left) from Run 40 and its difference from the 1999 daily maximum (right) for each date in the core and supplemental periods.

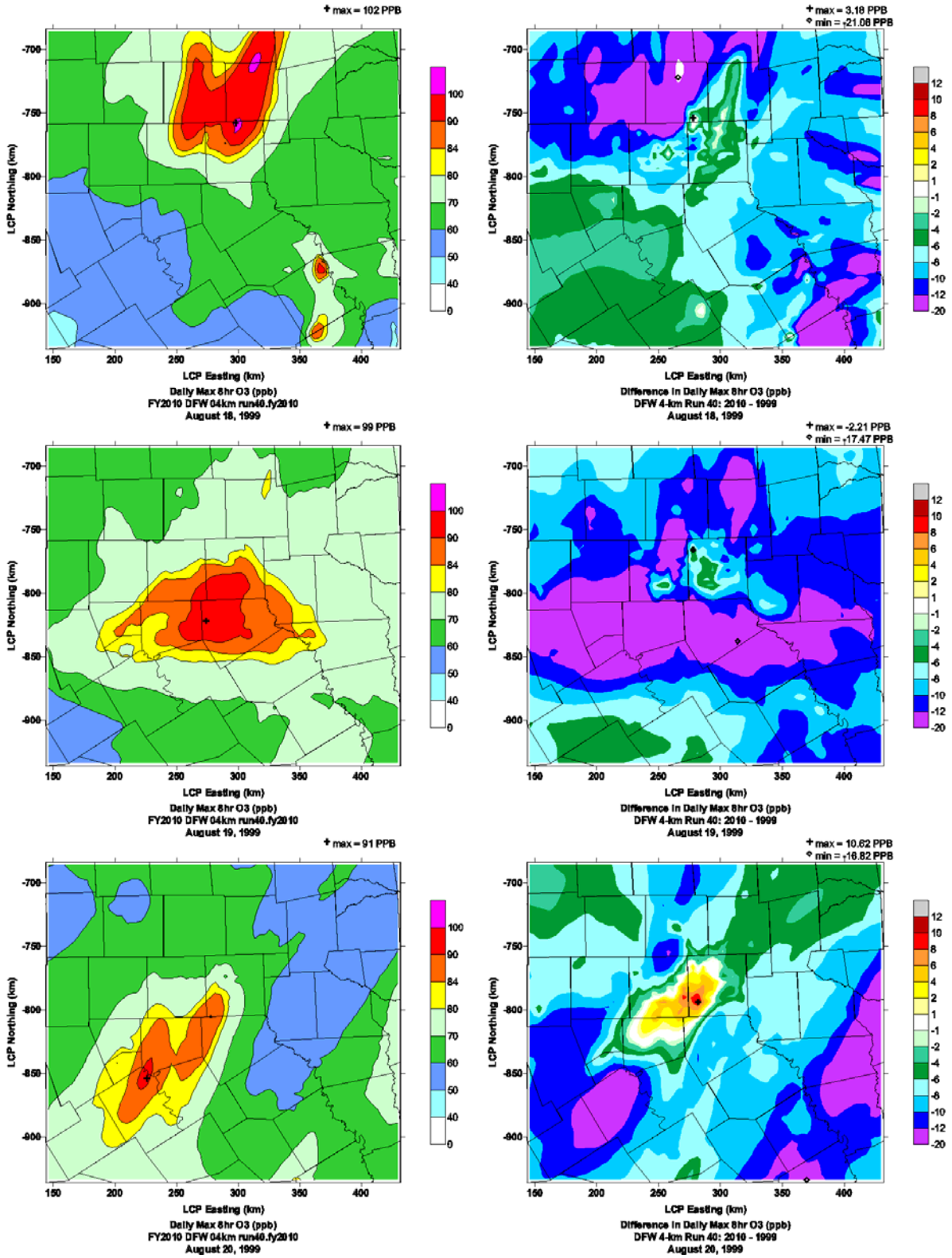


Figure 5-1. (continued). Daily maximum 8-hour ozone in the 4-km domain for 2010 (left) from Run 40 and its difference from the 1999 daily maximum (right) for each date in the core and supplemental periods.

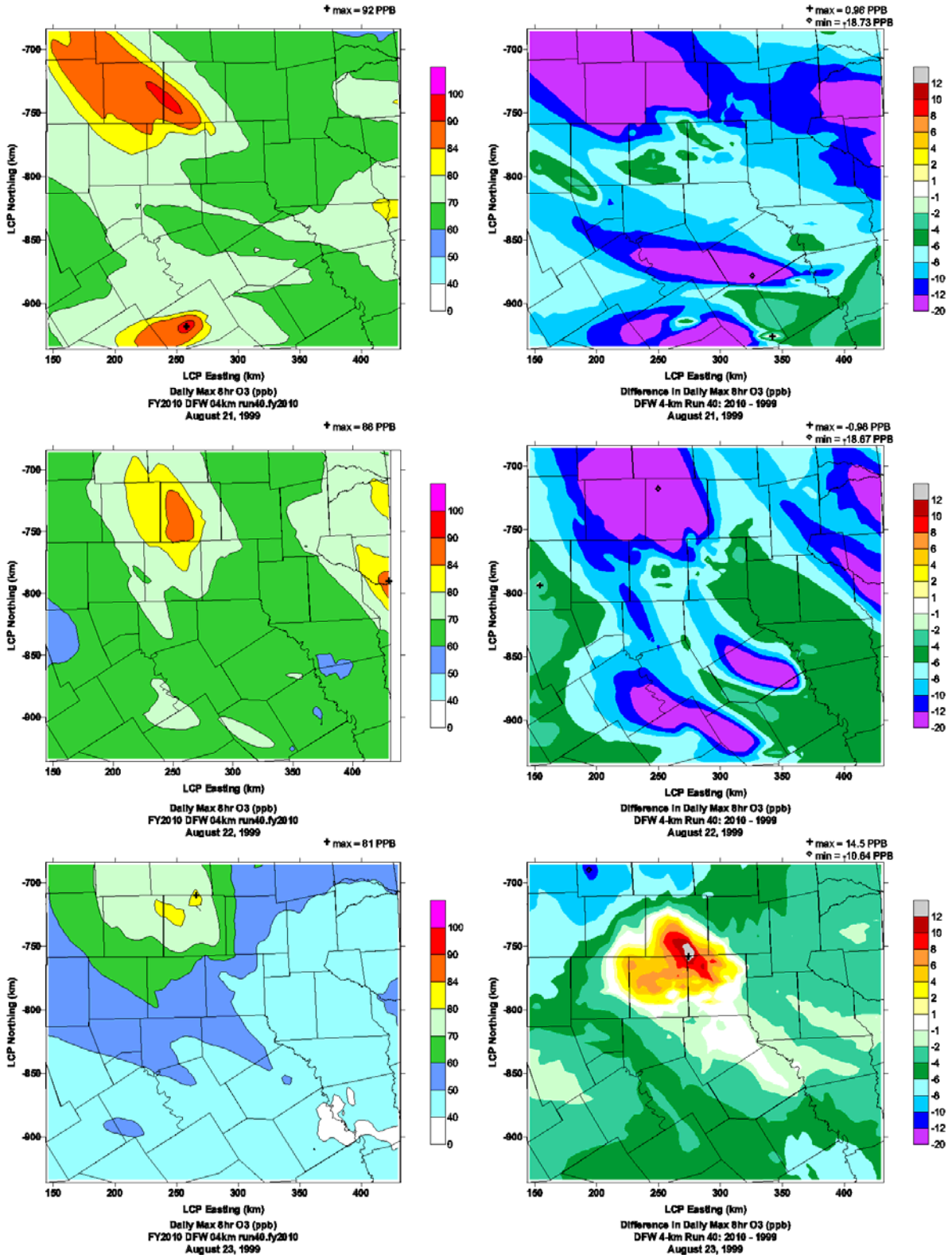


Figure 5-1. (continued). Daily maximum 8-hour ozone in the 4-km domain for 2010 (left) from Run 40 and its difference from the 1999 daily maximum (right) for each date in the core and supplemental periods.

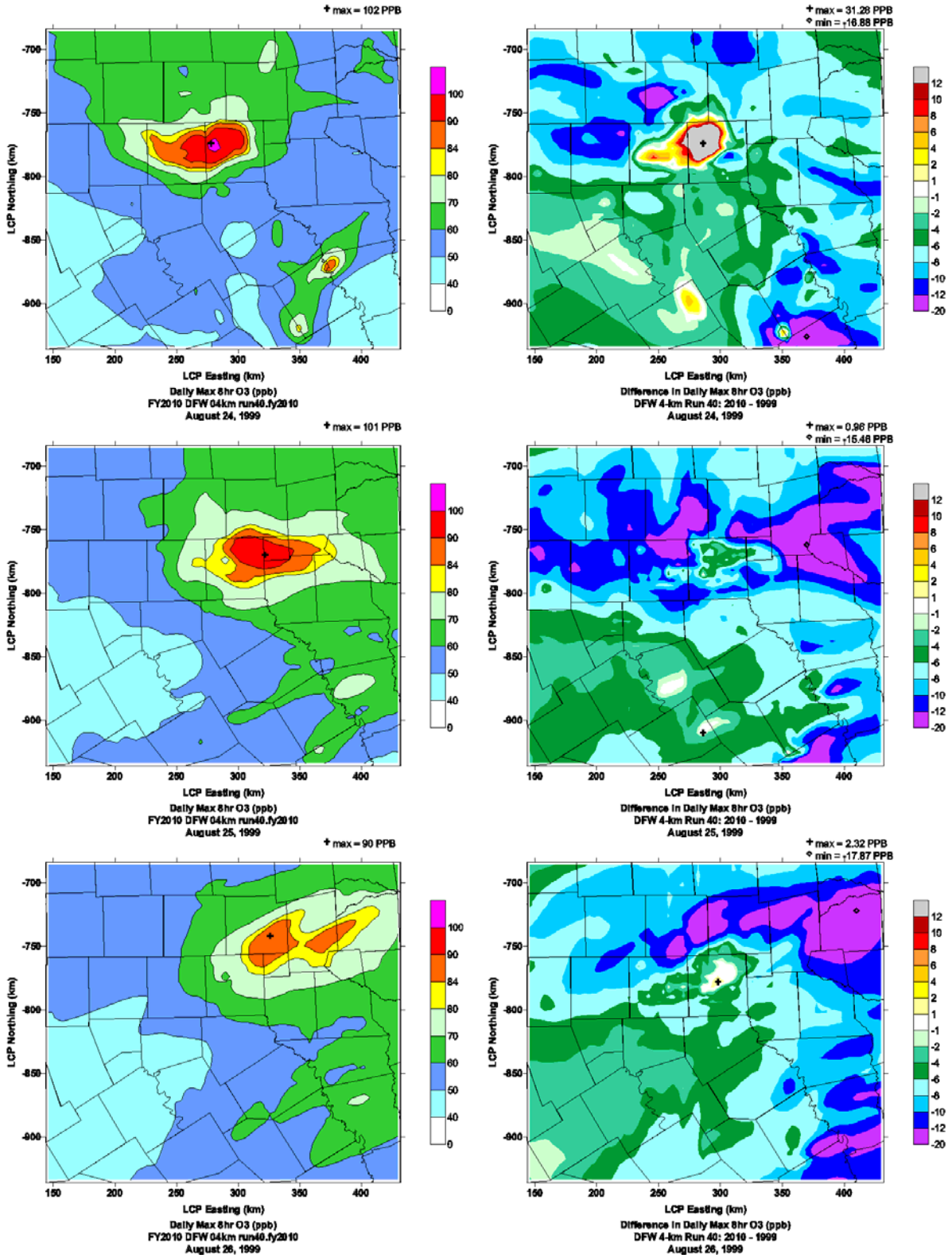


Figure 5-1. (continued). Daily maximum 8-hour ozone in the 4-km domain for 2010 (left) from Run 40 and its difference from the 1999 daily maximum (right) for each date in the core and supplemental periods.

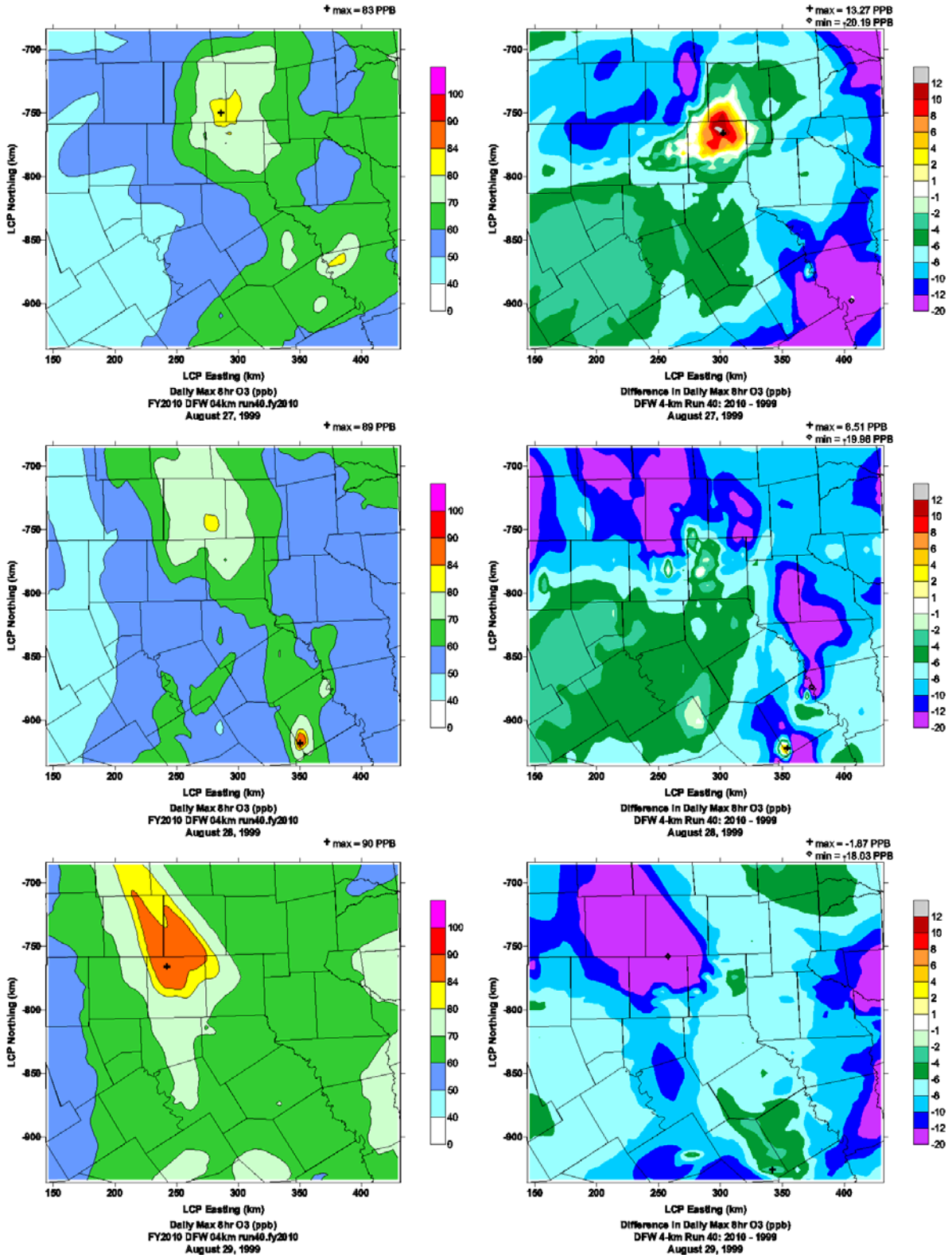


Figure 5-1. (continued). Daily maximum 8-hour ozone in the 4-km domain for 2010 (left) from Run 40 and its difference from the 1999 daily maximum (right) for each date in the core and supplemental periods.

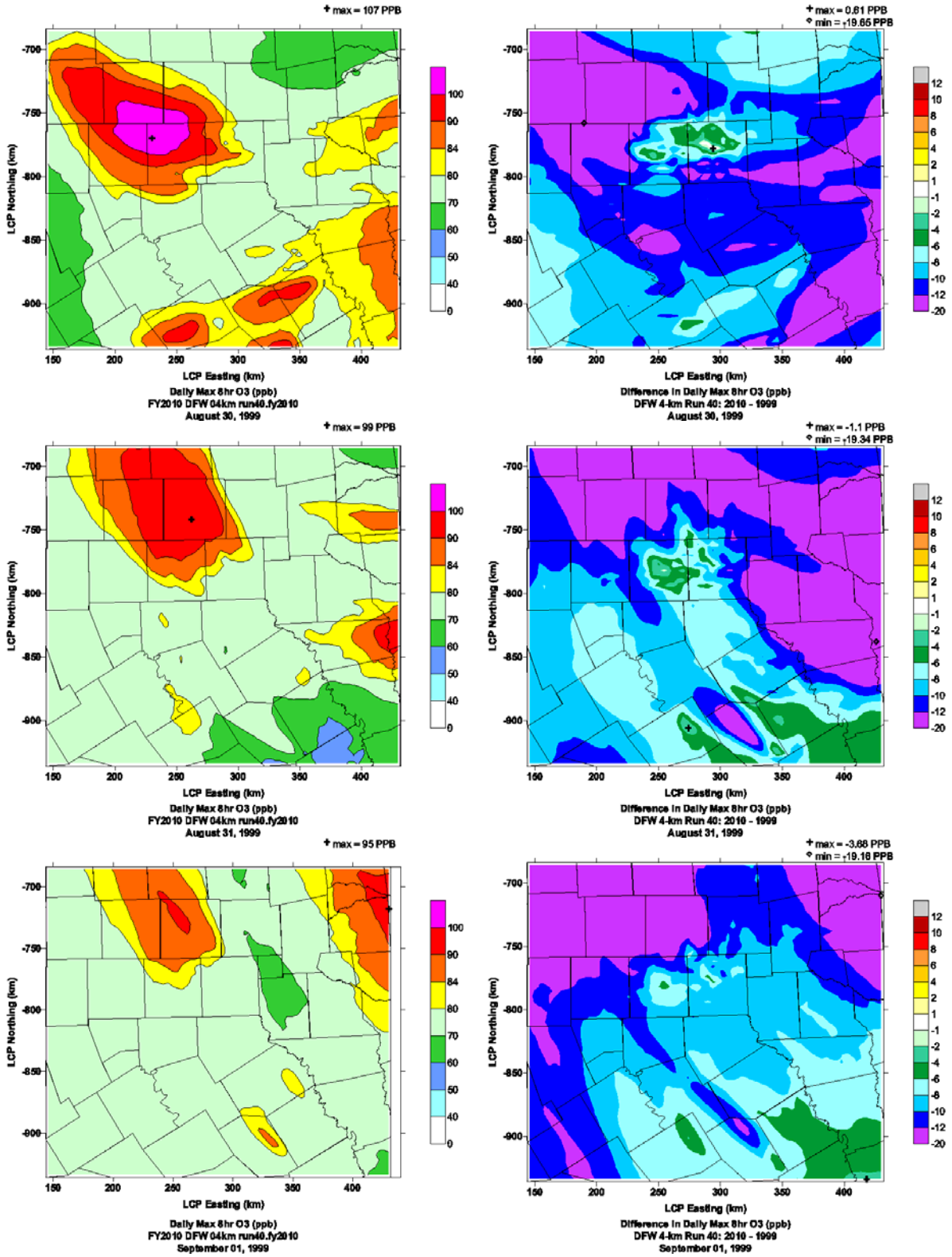


Figure 5-1. (concluded). Daily maximum 8-hour ozone in the 4-km domain for 2010 (left) from Run 40 and its difference from the 1999 daily maximum (right) for each date in the core and supplemental periods.

DESIGN VALUE SCALING

The 8-hour ozone design value (DV) at each monitoring station represents the fourth highest observed daily maximum 8-hour ozone in a 3-year period. The latest EPA guidance recommends using the average of the three design value periods that include the base year to represent the current design value (EPA, 2005). For the DFW episode, this would mean taking the average of the 1997-1999, 1998-2000, and 1999-2001 design values. If a monitor only has 3 or 4 years of ozone data, the EPA will allow the use of one or two design value periods, respectively, to represent the current DV. If a monitor has fewer than 3 years of ozone observations, the site should be excluded.

Table 5-5 shows the design values from each 3-year period containing 1999 for all monitoring stations in DFW. Based on the latest EPA guidance, half of the monitoring sites lacked sufficient data to compute a current DV for the DFW 1999 episode. Sites excluded from design value analysis include Anna, Sunnyvale, Granbury, Cleburne, Kaufman, Weatherford, Rockwall, Eagle Mountain Lake, and Grapevine. Most of the remaining sites, including the two sites with the highest current DVs (Denton and Frisco), had their values reduced when compared to the 2004 study (Mansell, 2004), where the current design value at each monitor was set to the larger of the base year design value (1998-2000) and the attainment designation (2001-2003). Dallas CAMS 63 was the only site with a higher current design value, due to insufficient observations in the 1998-2000 period. Table 5-6 shows the changes in the current design values resulting from the latest EPA recommendations.

Table 5-5. Design values at all ozone monitoring stations in the DFW NAA.

Site Name	CAMS	Design Values			Average (Current DV)
		1999	2000	2001	
		97-99	98-00	99-01	
Frisco	C31	99	101	99	**99.7**
Anna	C68	---	---	86*	---
Dallas Hinton	C60	91	93	92	**92.0**
Dallas North	C63	---	96*	93	**93.0**
Dallas Executive	C402	92	88	82	**87.3**
Sunnyvale	C74	---	---	---	---
Denton	C56	103*	102	101	**101.5**
Midlothian	C94	97*	97	88	**92.5**
Granbury	C73	---	---	---	---
Cleburne	C77	---	---	88*	---
Kaufman	C71	---	---	---	---
Weatherford	C76	---	---	---	---
Rockwall	C69	---	---	---	---
Arlington Reg Ofc	C57	100*	95	95*	**95.0**
Eagle Mt Lake	C75	---	---	---	---
FtW NW	C13	99	99	97	**98.3**
FtW Keller	C17	95	97	97	**96.3**
Grapevine	C70	---	---	---	---

*represents a 2 year average and is therefore excluded from the final average calculation.

Table 5-6. Current design values used in CAMx Run 17b and Run 40.

Design Values (ppb)	Run 17b	Run 40	% Change
Frisco C31	101	99.7	-1.3
Dallas C60	93	92.0	-1.1
Dallas C63	86	93.0	7.5
Dallas C402	88	87.3	-0.8
Denton C56	102	101.5	-0.5
Midlothian C94	97	92.5	-4.9
Arlington C57	95	95.0	0.0
Fort Worth C13	99	98.3	-0.7
Fort Worth C17	100	96.3	-3.8

The current design value is multiplied by a relative reduction factor (RRF) to compute the future year DV, where the RRF is the ratio of the future year modeled ozone averaged over all days when the base case is at least 70 ppb, and the base year modeled ozone, averaged over the same dates. The EPA recommends using the largest daily maximum 8-hour ozone within a 15-km radius of each monitor to represent the base and future year predicted ozone. In this study, a 7 by 7 block of 4-km grid cells surrounding each monitor represented the 15-km radius. The future year DV is then truncated to the nearest ppb and compared to the 84 ppb threshold for 8-hour ozone attainment.

The future year design value calculation for each monitor using Run 40 is shown in Table 5-7 for the core period and Table 5-8 for the supplemental period. All stations in the base case exceeded 70 ppb on all dates in the core period. In the supplemental period, seven of the nine stations were less than 70 ppb on August 23; three other dates near Midlothian were also below 70 ppb, and were not used to compute the RRF.

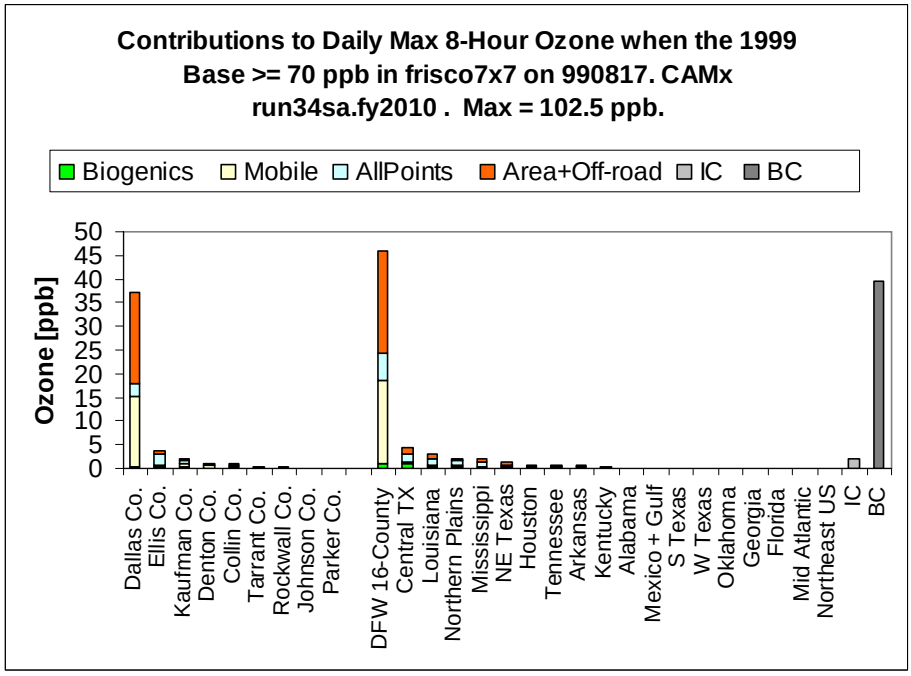
The future design value was 84 ppb or lower near Dallas (CAMS 402) and Midlothian in both the core and extended periods. The remaining seven sites were all over 84 ppb in both periods. In the core period, the RRF at each monitor did not change significantly from the RRF in Run 17b. Differences in RRFs ranged from –1.6% at Dallas CAMS 63 to +1.7% at Arlington.

The RRF in the supplemental period was within ±2% of the core period's RRF for all sites. Arlington and Dallas (CAMS 402) had the largest increases in the supplemental period, adding 2 ppb (+1.8%) to the core's 2010 design value. Denton was 1 ppb lower (-1.7%) in the supplemental period's future year design value. Frisco's future design value was the same in both the core and extended periods.

Source Contributions at High Ozone Locations

Figure 5-2 shows contributions from 28 source regions and 4 emission categories to the grid cell corresponding to the daily maximum 8-hour ozone on August 17 for 2010, as used for the future design value calculations near Frisco and Denton – the two sites with the highest 2010 DVs. Contributions were obtained from a source apportionment run from Run 34 for 2010, which was identical to Run 40 for 2010 except for slight ozone differences on the order of a few tenths of a ppb due to different photolysis rate assumptions. Contributions were analyzed for a 7 x 7 dock

of grid cells of each monitor following the DV scaling criteria. Dallas County was the largest contributor (over 30 ppb of ozone) to both sites on August 17 with the majority coming from area and off-road mobile, and on-road mobile emissions.



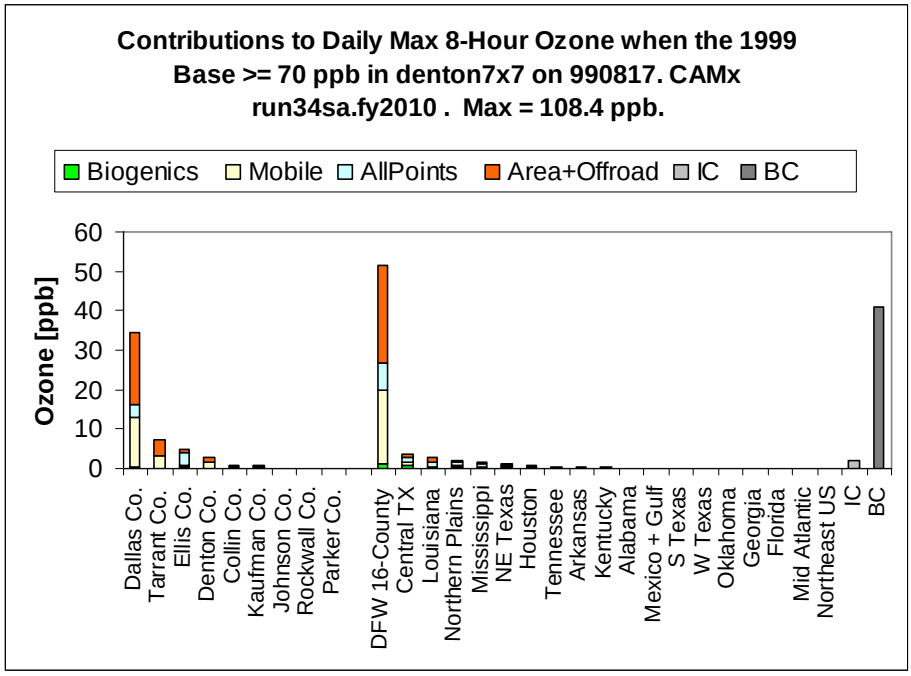
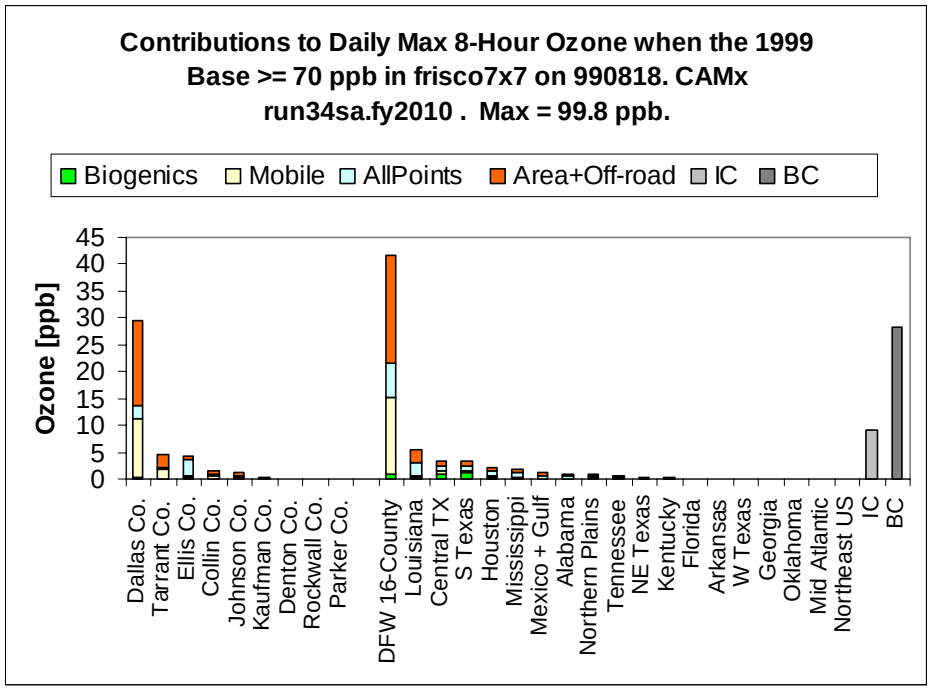


Figure 5-2. APCA analysis of contributions to the daily maximum 8-hour ozone near Frisco (top) and Denton (bottom) on August 17, 1999 for 2010.

On August 18, Dallas County continued to be the dominant contributor to the peak 8-hour ozone near Frisco. Near Denton, the peak ozone dropped 15 ppb from the previous date as a shift in wind direction placed Tarrant County upwind of Denton instead of Dallas County. Tarrant County's contribution increased to 19 ppb, while Dallas County's contribution dropped to 2 ppb.



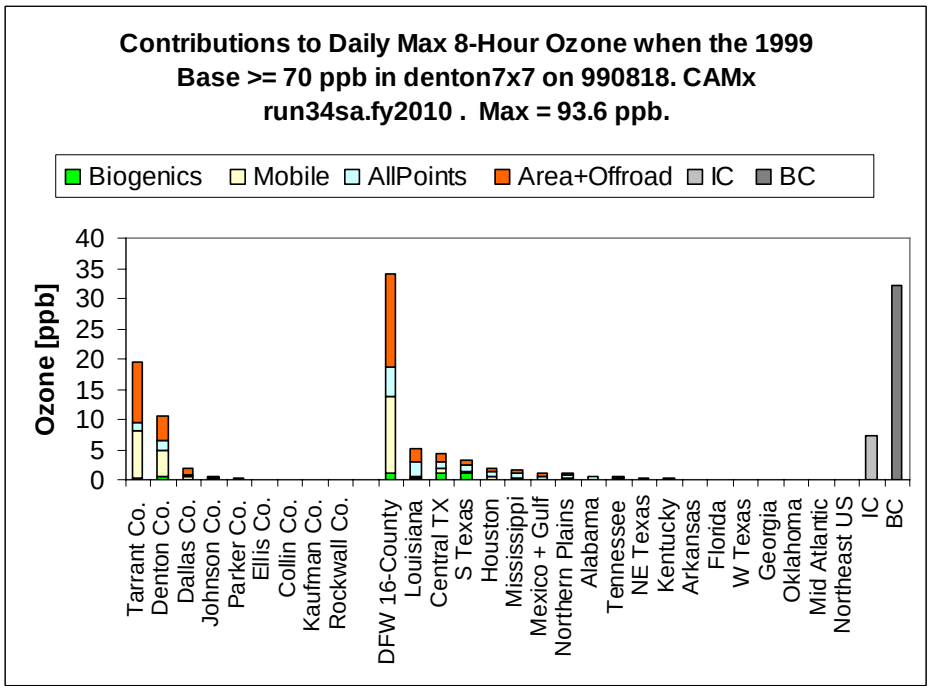


Figure 5-3. APCA analysis of contributions to the daily maximum 8-hour ozone near Frisco (top) and Denton (bottom) on August 18, 1999 for 2010.

Table 5-7. Design value calculation for the 2010 future year base case, core period.

Base Year: run40		Daily Maximum 8-hour ozone										
Site	**Current DV**	**990815**	**990816**	**990817**	**990818**	**990819**	**990820**	**990821**	**990822**	**Average**	**#Days >70**	
Run 40 Base Case												
Frisco C31	99.7	84.1	108.6	100.4	107.4	88.4	73.1	87.8	93.0	92.8	8	
Dallas C60	92.0	85.9	97.1	99.3	103.2	100.4	77.2	88.0	86.6	92.2	8	
Dallas C63	93.0	85.9	99.7	99.8	106.1	97.7	77.2	88.0	89.2	92.9	8	
Dallas C402	87.3	81.5	92.0	96.5	95.6	107.3	86.1	82.1	82.8	90.5	8	
Denton C56	101.5	105.9	113.1	110.5	113.8	87.2	76.4	105.9	102.9	102.0	8	
Midlothian C94	92.5	78.2	85.4	87.0	77.8	114.7	92.1	78.1	77.5	86.4	8	
Arlington C57	95.0	90.2	98.9	100.3	95.6	106.8	84.4	83.2	89.6	93.6	8	
Fort Worth C13	98.3	98.5	106.0	103.2	105.5	97.1	81.6	93.5	95.2	97.6	8	
Fort Worth C17	96.3	103.8	111.4	110.3	109.1	94.0	80.2	97.6	100.6	100.9	8	
Future Year: run40.fy2010		**Daily Maximum 8-hour ozone**										
Site	**Current DV**	**990815**	**990816**	**990817**	**990818**	**990819**	**990820**	**990821**	**990822**	**Average**	**RRF**	**Future DV**
Frisco C31	99.7	70.0	103.6	103.0	100.1	77.2	67.1	77.4	78.3	84.6	0.911	90
Dallas C60	92.0	75.0	95.4	103.5	100.4	91.3	83.5	81.2	77.0	88.4	0.959	88
Dallas C63	93.0	72.8	98.6	103.0	102.0	86.8	80.0	80.0	77.0	87.5	0.942	87
Dallas C402	87.3	68.6	86.7	93.3	87.9	97.5	89.8	73.9	73.4	83.9	0.927	80
Denton C56	101.5	88.6	105.2	108.8	93.6	73.0	65.6	91.1	86.1	89.0	0.873	88
Midlothian C94	92.5	70.4	78.7	81.1	72.6	98.8	90.2	70.4	69.1	78.9	0.914	84
Arlington C57	95.0	74.2	92.7	94.0	86.3	96.2	89.8	75.8	81.3	86.3	0.922	87
Fort Worth C13	98.3	82.3	97.4	95.7	91.5	84.9	77.3	82.4	83.1	86.8	0.890	87
Fort Worth C17	96.3	87.6	100.1	105.0	93.9	80.5	72.2	89.5	85.8	89.3	0.885	85

Red represents daily maximum ozone below 70 ppb in the base case. These dates are excluded from the average.

Table 5-8. Design value calculation for the 2010 future year base case, supplemental period.

Base Case: run40		Daily Maximum 8-hour Ozone												
Site	**Current DV**	**990823**	**990824**	**990825**	**990826**	**990827**	**990828**	**990829**	**990830**	**990831**	**990901**	**Average**	**#Days >70**	
Frisco C31	99.7	74.5	79.6	99.2	86.7	90.4	90.4	91.6	96.7	105.2	100.5	91.5	10	
Dallas C60	92.0	52.2	94.0	101.1	80.3	79.6	84.3	96.8	100.1	96.6	91.5	91.6	9	
Dallas C63	93.0	60.2	94.0	104.8	85.7	82.9	86.5	95.7	97.2	100.0	94.9	93.5	9	
Dallas C402	87.3	56.8	92.4	94.6	77.6	78.9	79.0	92.3	100.1	92.5	87.0	88.3	9	
Denton C56	101.5	83.7	85.8	89.0	76.9	87.9	93.3	103.9	117.2	110.5	108.0	95.6	10	
Midlothian C94	92.5	57.1	71.7	80.3	66.1	68.1	67.1	82.7	90.9	84.5	84.5	82.4	6	
Arlington C57	95.0	58.2	91.4	93.3	75.5	73.3	76.9	97.3	106.2	94.4	89.7	88.6	9	
Fort Worth C13	98.3	59.0	92.6	88.6	74.0	77.1	86.2	105.2	117.1	101.2	95.0	93.0	9	
Fort Worth C17	96.3	66.1	90.6	92.4	76.6	80.9	86.2	106.2	117.8	108.0	99.7	95.4	9	
Future Year: run40.fy2010		**Daily Maximum 8-hour Ozone**												
Site	**Current DV**	**990823**	**990824**	**990825**	**990826**	**990827**	**990828**	**990829**	**990830**	**990831**	**990901**	**Average**	**RRF**	**Future DV**
Frisco C31	99.7	73.4	78.2	87.6	81.9	83.4	81.6	78.0	86.7	93.6	86.5	83.1	0.908	90
Dallas C60	92.0	59.5	102.2	95.6	79.1	80.5	78.2	83.3	92.8	89.2	81.5	86.9	0.949	87
Dallas C63	93.0	67.5	102.2	97.2	82.5	83.2	79.3	81.7	91.2	90.7	83.5	87.9	0.940	87
Dallas C402	87.3	55.7	101.8	86.9	74.6	77.9	74.9	78.6	92.8	84.2	78.0	83.3	0.944	82
Denton C56	101.5	81.1	71.1	74.4	64.4	75.1	79.0	87.2	99.2	98.5	90.9	82.1	0.858	87
Midlothian C94	92.5	55.5	69.7	71.8	60.2	62.1	61.7	75.5	81.2	77.8	75.2	75.2	0.913	84
Arlington C57	95.0	58.9	101.8	81.4	69.8	73.1	72.6	84.2	97.1	87.8	81.4	83.2	0.939	89
Fort Worth C13	98.3	64.2	91.2	76.7	63.8	68.9	73.1	90.0	106.2	92.0	84.6	83.0	0.892	87
Fort Worth C17	96.3	70.8	93.6	79.8	66.2	71.0	73.1	90.0	105.9	97.6	86.9	84.9	0.890	85

Red represents daily maximum ozone below 70 ppb in the base case. These dates are excluded from the average.

OZONE SENSITIVITY TO LOCAL EMISSION REDUCTIONS

Nine "across-the-board" controls were applied to the 2010 anthropogenic emissions inside the DFW 9-county NAA to evaluate ozone sensitivity from each control in both the core and supplemental periods. Table 5-9 shows the matrix of NOx and VOC controls applied to the 2010 base case emissions, which were summarized for each date in Tables 5-3 and 5-4 for NOx and VOC, respectively.

Table 5-9. Emission reduction matrix for 2010 ozone sensitivity simulations.

Anthropogenic Reduction		NOx			
		0%	20%	40%	60%
VOC	0%	2010 base	X	X	X
	25%	X	X		
	50%	X		X	
	75%	X			X

Design value scaling was applied to each of the nine control runs in the matrix. A summary of the future year DVs from each monitoring site and control is shown in Table 5-10 and plotted in Figure 5-4. Ozone was unresponsive to controls in anthropogenic VOC emissions in the 9-county DFW NAA (top left plot in Figure 5-4), and was much more responsive to NOx controls (Figure 5-4, top right). The combination of VOC and NOx reductions (Figure 5-4, bottom left) had almost the same effect as NOx controls alone, as their 2010 design values were within 1 ppb of each other at all sites.

Frisco had the highest future year design value in each run. Local VOC controls up to 75% could not lower the 2010 DV below 85 ppb. Local anthropogenic NOx controls of about 45 % would be needed to bring Frisco's future year DV below 85 ppb in the core period. These results are comparable to the future design value results when using Run 17b as the 1999 base case (Mansell, 2004). In that study, Frisco needed NOx reductions inside the 9-county NAA close to 50 % to bring the 2010 8-hour ozone below 85 ppb. The level of NOx controls needed for attainment was reduced mainly because the latest EPA recommendation for computing the current design value called for an average of three periods, allowing the current DV to drop from 101 ppb to 99.7 ppb (-1.3 %). In comparison, the RRF in Frisco was 0.4 % lower in this run compared to Run 17b. .

Table 5-11 is identical to Table 5-10 except it uses model results from the supplemental period. All future design values were within 2 ppb of the core period's future design values. Frisco has the highest 2010 design value in each run, and required just over a 40 % NOx reduction to reach attainment. Arlington needed more NOx controls (near 40 %) to reach attainment in the supplemental period compared to the core. Denton could reach attainment with fewer controls (near 20 %). Ozone response curves for the supplemental period are plotted in Figure 5-5, and are similar to the core period's response curves.

Table 5-10. 2010 8-hour ozone design values at DFW monitors from the matrix of

anthropogenic emission reductions in the DFW 9-county area in the core period.

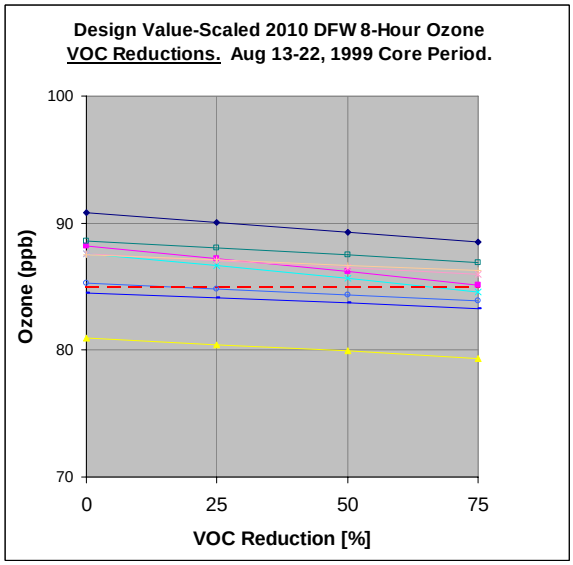
DFW Core Period	Current DV	Design Values Scaled to 2010									
NOx reduction(%)		**0**	**0**	**0**	**0**	**20**	**40**	**60**	**20**	**40**	**60**
VOC reduction(%)		**0**	**25**	**50**	**75**	**0**	**0**	**0**	**25**	**50**	**75**
Frisco C31	99.7	90.8	90.1	89.3	88.5	88.8	85.8	81.5	88.2	85.0	80.9
Dallas C60	92.0	88.2	87.2	86.2	85.1	86.5	83.5	78.9	85.7	82.4	77.9
Dallas C63	93.0	87.6	86.7	85.7	84.6	85.8	82.8	78.3	85.1	81.8	77.4
Dallas C402	87.3	80.9	80.4	79.9	79.3	79.0	76.3	72.7	78.5	75.7	72.1
Denton C56	101.5	88.6	88.1	87.5	86.9	85.6	81.9	77.0	85.2	81.4	76.8
Midlothian C94	92.5	84.5	84.1	83.7	83.3	83.0	80.9	78.0	82.7	80.5	77.7
Arlington C57	95.0	87.6	87.0	86.5	85.9	85.2	82.1	77.7	84.8	81.5	77.3
Fort Worth C13	98.3	87.5	87.1	86.7	86.3	84.8	81.5	77.0	84.5	81.0	76.7
Fort Worth C17	96.3	85.3	84.8	84.4	83.9	82.4	78.7	73.8	82.1	78.3	73.6

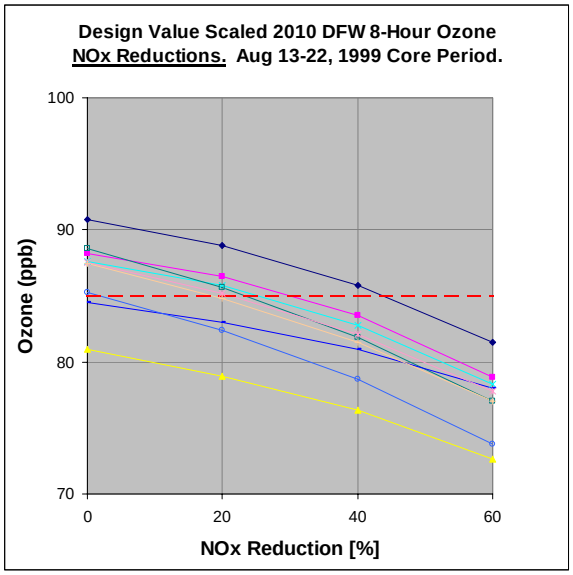
Red values represent future year design values below 85 ppb.

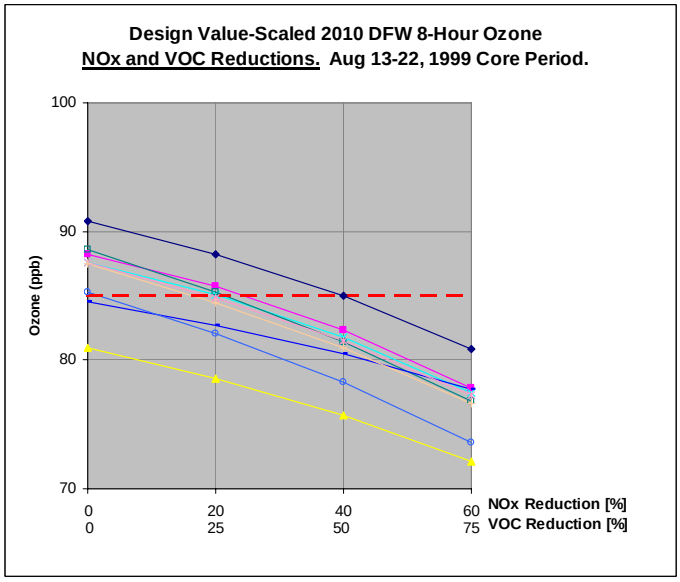
Table 5-11. 2010 8-hour ozone design values at DFW monitors from the matrix of anthropogenic emission reductions in the DFW 9-county area in the supplemental period.

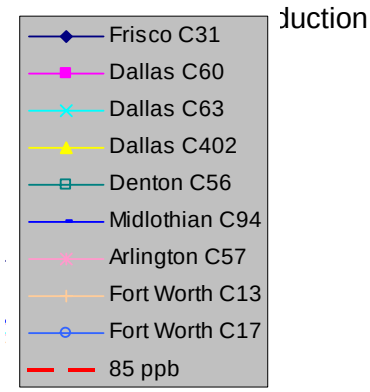
DFW Extended Period	Curren DV	Design Values Scaled to 2010									
NOx reduction (%)		**0**	**0**	**0**	**0**	**20**	**40**	**60**	**20**	**40**	**60**
VOC reduction (%)		**0**	**25**	**50**	**75**	**0**	**0**	**0**	**25**	**50**	**75**
Frisco C31	99.7	90.6	89.7	88.7	87.6	88.5	85.5	81.0	87.7	84.3	79.8
Dallas C60	92.0	87.3	86.0	84.7	83.3	85.8	83.3	79.0	84.8	81.4	77.1
Dallas C63	93.0	87.4	86.2	84.9	83.3	85.7	82.9	78.5	84.7	81.2	76.7
Dallas C402	87.3	82.4	81.4	80.4	79.3	80.9	78.5	74.7	80.1	77.2	73.5
Denton C56	101.5	87.1	86.7	86.3	85.9	84.2	80.7	76.2	83.9	80.3	75.9
Midlothian C94	92.5	84.4	84.3	84.1	83.9	83.0	81.3	79.0	82.9	81.1	78.8
Arlington C57	95.0	89.2	88.3	87.3	86.2	87.3	84.2	79.6	86.5	83.2	78.8
Fort Worth C13	98.3	87.7	87.1	86.4	85.7	84.8	81.2	76.5	84.4	80.5	76.0
Fort Worth C17	96.3	85.7	85.1	84.3	83.5	82.9	79.2	74.3	82.4	78.6	73.8

Red values represent future year design values below 85 ppb.



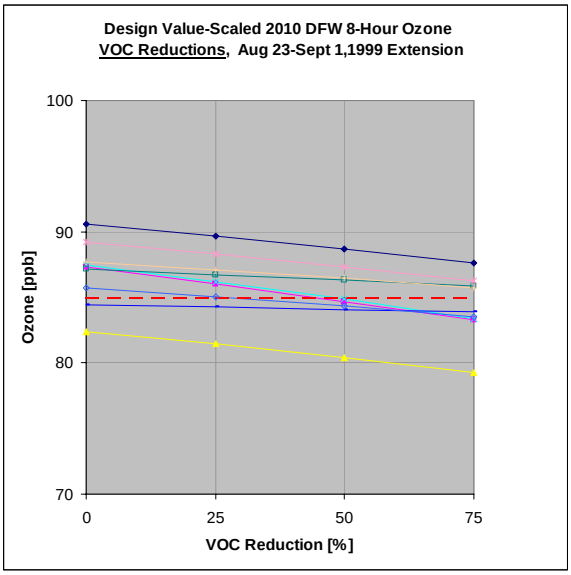




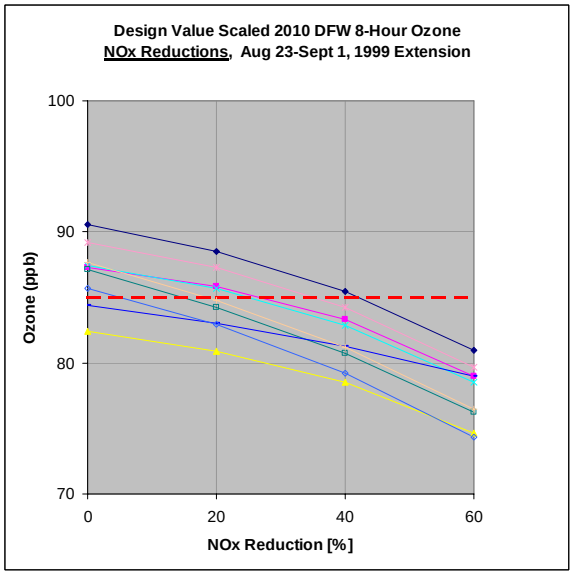


VOC and NOx Reduction

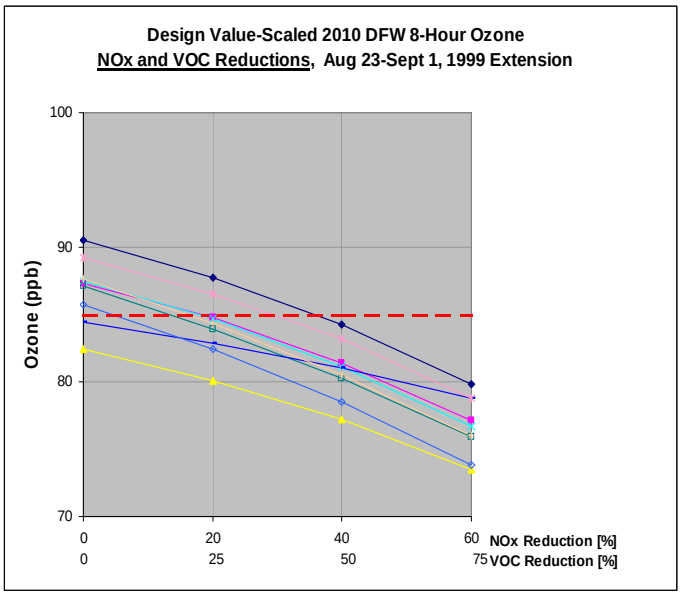
Figure 5-4. 8-hour ozone response curves for 2010 VOC and NOx anthropogenic emission reduction scenarios in the core period using a 1999 base year DV.

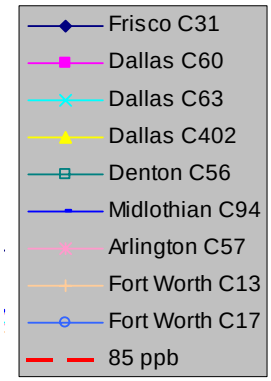


VOC Reduction



NOx Reduction





VOC and NOx Reduction

Figure 5-5. 8-hour ozone response curves for 2010 VOC and NOx anthropogenic emission reduction scenarios in the supplemental period using a 1999 base year DV.

Five additional emission reduction scenarios were examined to explore ozone sensitivity to emissions from specific source categories. A value of 40 tons per day (tpd) reduction had been selected in a previous analysis (Mansell, 2004), and was used again here. The 40 tpd reduction scenarios inside the DFW NAA were applied to the 2010 future year inventory for:

- On-road mobile source NOx
- On-road mobile source VOC
- Off-road mobile plus area source NOx
- Off-road mobile plus area source VOC
- Point source NOx

No point source VOC sensitivity test was performed because emissions inside the DFW 9-county region were less than 40 tpd, as shown in Table 5-4. Table 5-12 shows each date's percentage of NOx reduction needed to achieve the 40 tpd reduction for on-road mobile, off-road mobile plus area, and point sources in the 9-county region. Table 5-13 shows the percentages for VOC reduction.

Table 5-12. NOx controls applied to the DFW 9-county area in order to achieve a 40 tpd reduction from three source categories.

DFW 9-county NOx emission controls needed to reduce emissions by 40 TPD				
	Date	**Mobile**	**Area + Off-road**	**All Points**
Core				
Fri	13-Aug	25%	22%	42%
Sat	14-Aug	38%	28%	43%
Sun	15-Aug	49%	35%	43%
Mon	16-Aug	26%	22%	42%
Tue	17-Aug	26%	22%	42%
Wed	18-Aug	27%	22%	42%
Thu	19-Aug	27%	22%	42%
Fri	20-Aug	23%	22%	42%
Sat	21-Aug	38%	28%	43%
Sun	22-Aug	50%	35%	43%
Supplemental				
Mon	23-Aug	26%	22%	42%
Tue	24-Aug	26%	22%	42%
Wed	25-Aug	27%	22%	42%
Thu	26-Aug	27%	22%	42%
Fri	27-Aug	23%	22%	42%
Sat	28-Aug	38%	28%	43%
Sun	29-Aug	49%	35%	43%
Mon	30-Aug	26%	22%	42%
Tue	31-Aug	26%	22%	42%
Wed	1-Sep	27%	22%	42%

Table 5-13. VOC controls applied to the DFW 9-county area in order to achieve a 40 tpd reduction from three source categories.

DFW 9-county VOC emission controls needed to reduce emissions by 40 TPD			
	Date	**Mobile**	**Area + Off-road**
Core			
Fri	13-Aug	44%	13%
Sat	14-Aug	61%	18%
Sun	15-Aug	74%	23%
Mon	16-Aug	50%	13%
Tue	17-Aug	49%	13%
Wed	18-Aug	48%	13%
Thu	19-Aug	48%	13%
Fri	20-Aug	44%	13%
Sat	21-Aug	62%	18%
Sun	22-Aug	73%	23%
Supplemental			
Mon	23-Aug	50%	13%
Tue	24-Aug	49%	13%
Wed	25-Aug	48%	13%
Thu	26-Aug	48%	13%
Fri	27-Aug	44%	13%
Sat	28-Aug	61%	18%
Sun	29-Aug	74%	23%
Mon	30-Aug	50%	13%
Tue	31-Aug	49%	13%
Wed	1-Sep	48%	13%

The future year design values for each monitor and run with a 40 ton per day emission reduction inside the DFW NAA are summarized in Table 5-14 for the core period. All but Dallas CAMS 63 and 402 were over 85 ppb. Design values were not truncated to show a clearer picture of the ozone response from each emission category. Figure 5-6 displays the difference in the 2010 ozone design values between the 2010 base case and each 40 tpd control for each monitoring station in the core period. Ozone was more sensitive to NOx controls than VOC controls. On-road mobile and area plus off-road mobile NOx controls were almost equally effective in reducing 8-hour ozone at each site from 0.6 and 1.9 ppb. The two monitors in the northwest part of DFW – Denton and Fort Worth (CAMS C17) – were the most responsive, while Midlothian, in the south, was the least responsive. Ozone sensitivity to point source NOx reductions was strongest at the three stations in the southwest – Arlington, Ft. Worth (CAMS 13), and Midlothian, and weaker than either mobile or area plus off-road controls at the other monitoring sites. The largest ozone response from VOC controls was a 0.4 ppb decrease in Dallas (CAMS 60).

In the core period, Frisco and Dallas (CAMS60) were slightly more responsive (by a couple tenths of a ppb) to low-level NOx controls when compared to Run 17b (Mansell, 2004), and Midlothian was more responsive to the point source NOx reduction.

Table 5-15 and Figure 5-7 are similar to Table 5-14 and Figure 5-6, but for the supplemental period. The supplemental period was similar to the core period, but ozone was a little more

responsive to VOC controls and slightly less responsive to NOx controls, except at Fort Worth (CAMS 13).

Table 5-14. 2010 8-hour ozone design values at DFW monitors when applying 40 tons per day emission reductions in the DFW 9-county area during the core period.

DFW Core Period	Design Values Scaled to 2010					
Emission Control	**2010 Base (no control)**	**40 tpd Mobile NOx**	**40 tpd Area + Off-road NOx**	**40 tpd Point Source NOx**	**40 tpd Mobile VOC**	**40 tpd Area + Off-road VOC**
% Reduction	**0%**	**23-50%**	**22-35%**	**42-43%**	**44-74%**	**13-23%**
Frisco	92.0	90.6	90.9	91.4	91.7	91.7
Dallas C60	89.1	88.1	88.2	88.7	88.8	88.7
Dallas C63	81.0	80.0	80.1	80.4	80.7	80.7
Dallas C402	81.6	80.3	80.6	80.8	81.4	81.4
Denton	89.0	87.2	87.1	88.1	88.8	88.8
Midlothian	88.6	87.9	88.0	87.5	88.5	88.5
Arlington	87.6	86.5	86.7	86.0	87.4	87.4
Fort Worth C13	88.1	86.7	87.0	86.5	88.0	87.9
Fort Worth C17	88.5	86.7	86.7	87.7	88.4	88.3

Red values represent future year design values below 85 ppb.

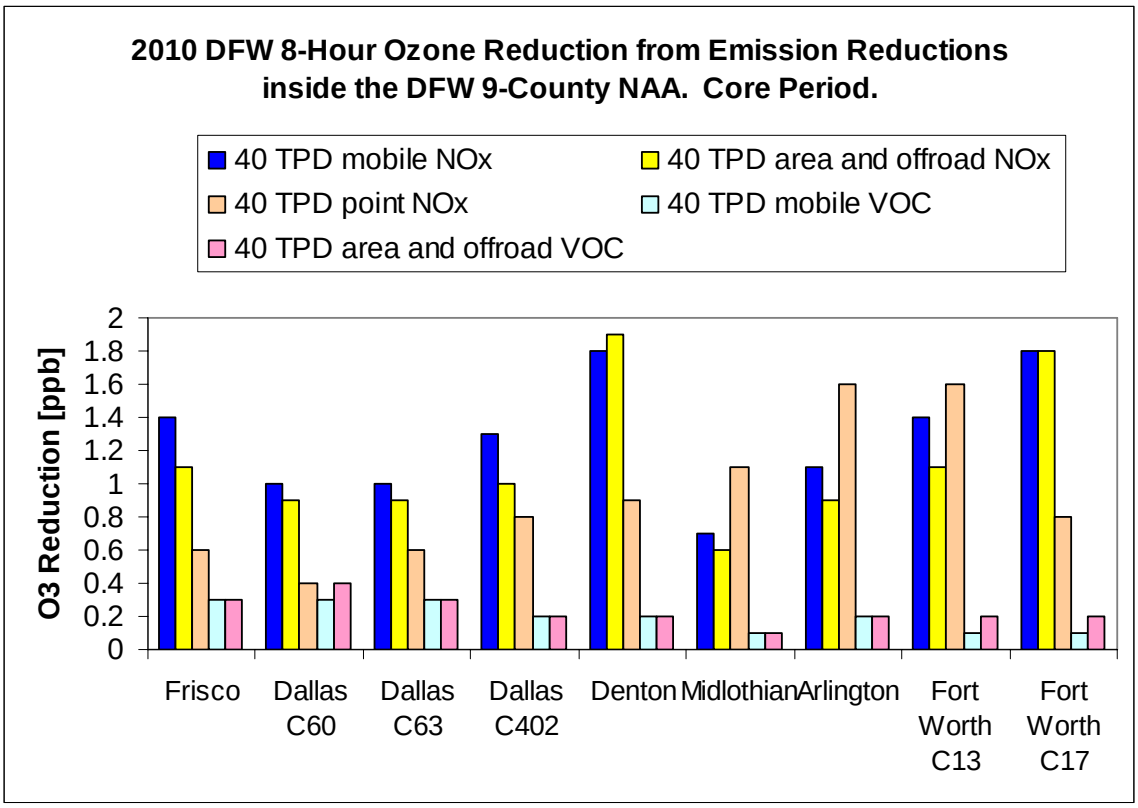


Figure 5-6. Change in the 2010 8-hour ozone design values from 40 tons per day emission reductions in the core period.

Table 5-15. 2010 8-hour ozone design values at DFW monitors when applying 40 tons per day emission reductions in the DFW 9-county area during the supplemental period.

DFW Extended Period	**Design Values Scaled to 2010**					
Emission Control	**2010 Base (no control)**	**40 tpd Mobile NOx**	**40 tpd Area + Off-road NOx**	**40 tpd Point Source NOx**	**40 tpd Mobile VOC**	**40 tpd Area + Off-road VOC**
% Reduction	**0%**	**23-50%**	**22-35%**	**42-43%**	**44-74%**	**13-23%**
Frisco	91.7	90.5	90.6	91.2	91.3	91.4
Dallas C60	88.3	87.5	87.5	87.8	87.7	87.8
Dallas C63	80.9	80.0	80.0	80.4	80.4	80.4
Dallas C402	83.1	82.2	82.3	82.3	82.7	82.7
Denton	87.6	86.0	85.9	86.7	87.4	87.4
Midlothian	88.5	88.0	88.1	86.8	88.5	88.5
Arlington	89.2	88.3	88.4	88.0	88.9	88.9
Fort Worth C13	88.3	86.8	86.9	87.1	88.1	88.1
Fort Worth C17	89.0	87.4	87.4	88.2	88.7	88.7

Red values represent future year design values below 85 ppb.

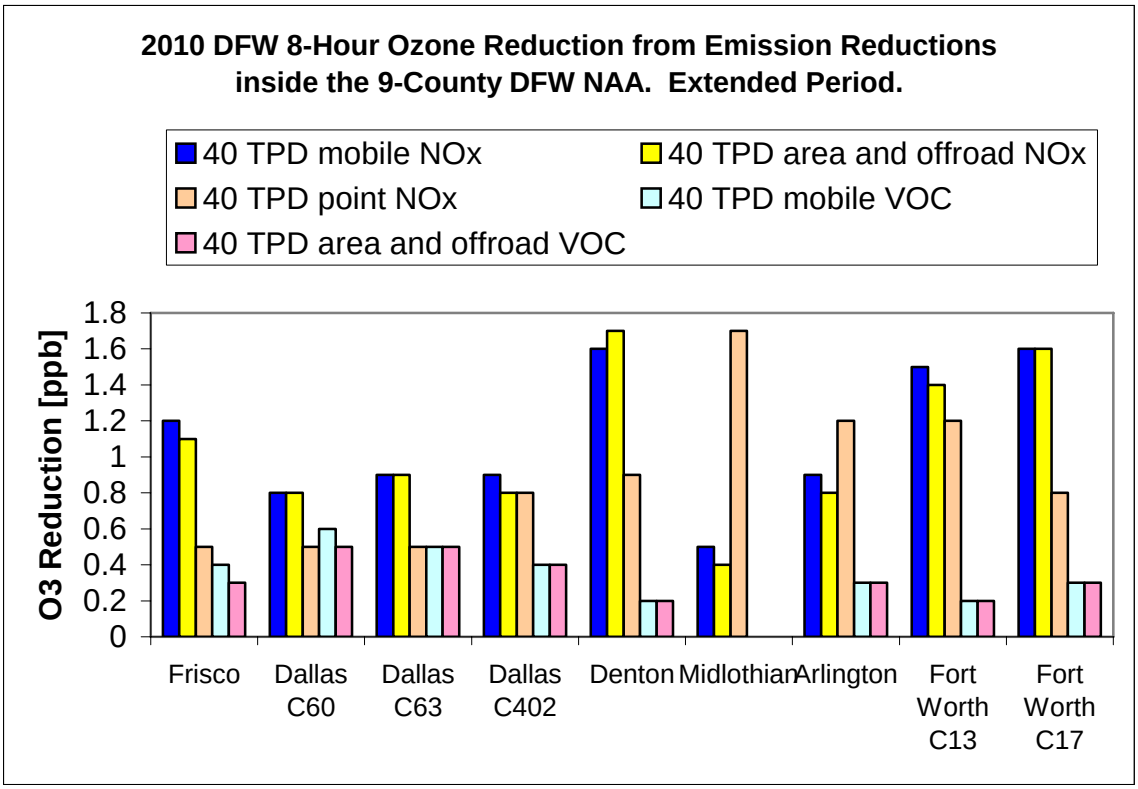


Figure 5-7. Change in the 2010 8-hour ozone design values from 40 tons per day emission reductions in the supplemental period.

TEXAS EGU NOx REDUCTION

NOx reductions were applied to approximately 100 major EGUs inside Texas, but outside of the DFW 9-county area for the 2010 future year. The EGU control scenario approximated the impact of applying the emission limits for the Houston and Dallas non-attainment areas across all of eastern Texas. Table 5-16 compares the NOx emissions with and without EGU controls by source region for the 2010 point sources on August 17. Northeast Texas and Central Texas each cut their point source NOx emissions in half.

Table 5-16. Summary of 2010 major point source NOx emissions (tons/day) by geographic area with and without "EGU NOx Reductions".

Area	2010 Base Case (TPD)	2010 "EGU NOx Reductions" (TPD)	Reduction (TPD)	% Change
DFW 9-County	95	95	0	0%
DFW 16-County	151	125	-26	-17%
NE Texas	217	107	-110	-51%
Central TX	197	94	-103	-52%
Houston	293	281	-12	-4%
South TX	325	239	-86	-27%
West Texas	187	181	-6	-3%
Total	1370	1027	-344	-25%

Emission totals are for the August 17, 1999 modeling day

The daily maximum 8-hour ozone from the EGU NOx-reduction run is shown for each date in Figures 5-8 and 5-9 for the 4-km and 12-km domains, respectively. The ozone reduction from the 2010 base case is also displayed. In the 12 km domain, significant localized reductions were evident, primarily over Northeast and Central Texas. Some of these plumes of reduced ozone spread into the DFW 9-county area, particularly on August 15 and 16. Table 5-17 shows the change in daily maximum 8-hour ozone due to the EGU NOx reductions across Texas for each monitoring site in DFW. Midlothian was the most beneficial with a 4.1 ppb reduction in ozone from the EGU controls on August 16. Frisco – the site with the highest current DV – was reduced 3.2 ppb on August 19. No site showed any disbenefits from these EGU NOx reductions.

Table 5-18 shows the design value analysis using the 1999 base case and 2010 run with EGU NOx reductions. A comparison of the 2010 8-hour ozone design values with and without the EGU NOx reduction is shown in Table 5-19. The EGU NOx reductions lowered the future design values from 0.8 ppb at Denton to 1.6 ppb at Midlothian. Fort Worth CAMS 17, whose future DV was reduced 0.9 ppb due to the EGU NOx reductions in Texas, fell into attainment. Frisco, which had the highest future DV among the DFW monitors, was reduced by 1.3 ppb.

Table 5-17. Day specific reductions in 2010 daily maximum 8-hour ozone (ppb) at DFW monitors due to "EGU NOx Reductions."

Site	990815	990816	990817	990818	990819	990820	990821	990822
Frisco C31	-1.1	-1.3	-1.0	-0.5	-3.2	-0.9	-1.4	-0.2
Dallas C60	-1.3	-1.7	-1.0	-0.5	-1.0	-0.2	-1.0	-0.3
Dallas C63	-1.3	-1.5	-1.0	-0.4	-1.8	-0.3	-1.0	-0.3
Dallas C402	-1.8	-2.4	-1.4	-0.7	-0.7	-0.1	-0.8	-0.4
Denton C56	-1.4	-1.2	-0.5	-1.3	-0.8	-0.2	-0.9	-0.3
Midlothian C94	-2.8	-4.1	-1.6	-0.4	-0.7	0.0	-2.1	-0.8
Arlington C57	-2.2	-2.6	-1.1	-1.9	-0.8	-0.1	-0.7	-0.6
Fort Worth C13	-2.0	-2.3	-0.3	-1.9	-0.6	0.0	-0.7	-0.5
Fort Worth C17	-1.4	-1.7	-0.6	-1.8	-0.8	-0.2	-0.7	-0.3

The benefits of the EGU NOx reduction may be compared to the benefits of local NOx reduction in the 9-county DFW NAA by comparing Tables 5-18 and 5-10. The comparison is not straightforward because regional vs. local reductions result in spatially different reductions. However, the EGU NOx reduction scenario appears to be roughly equivalent to a 10% local NOx reduction.

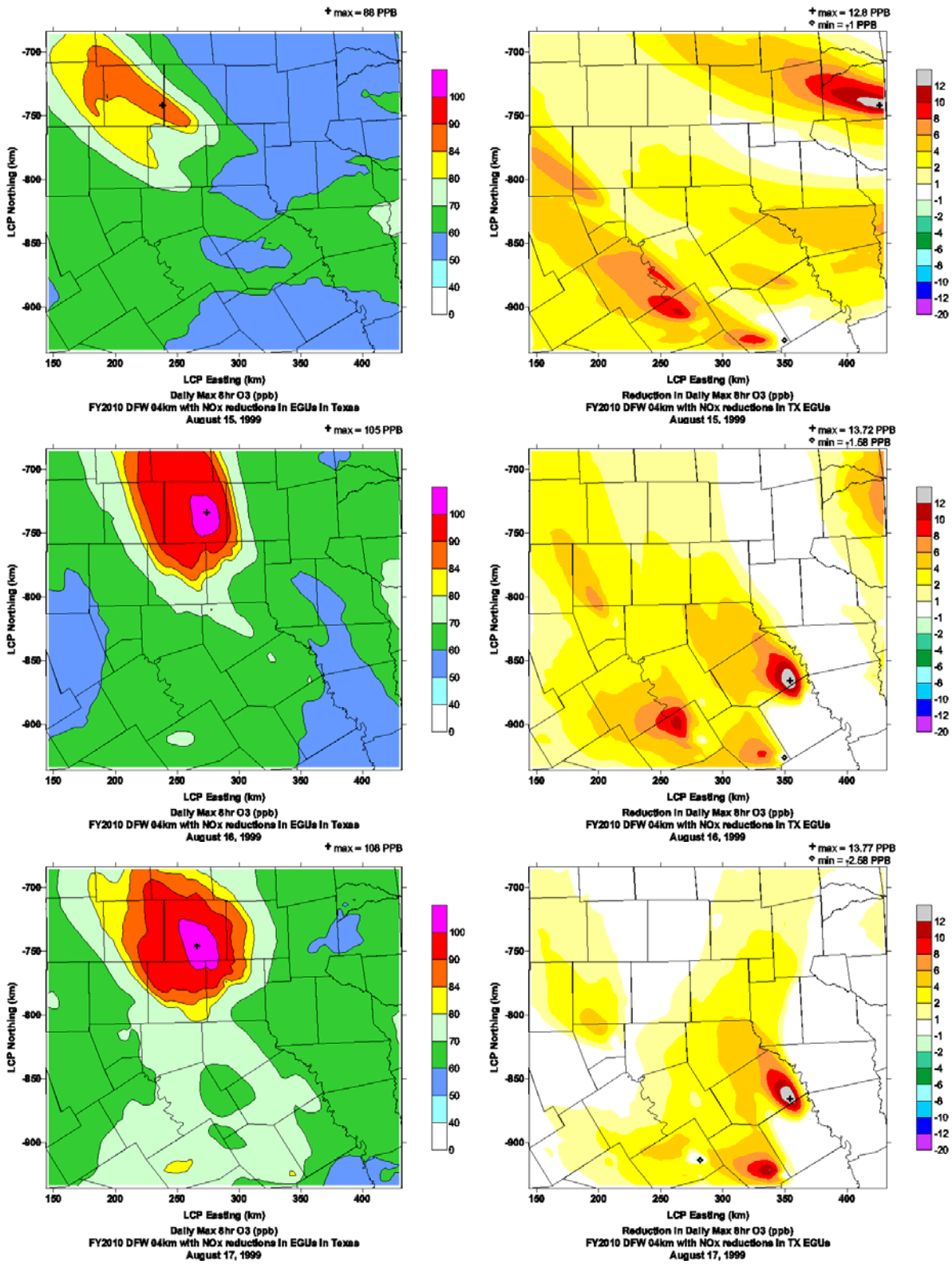


Figure 5-8. Daily maximum 8-hour ozone in the DFW 4-km grid in 2010 with "EGU NOx reductions" (left) and the difference due to the "EGU NOx reductions" (right).

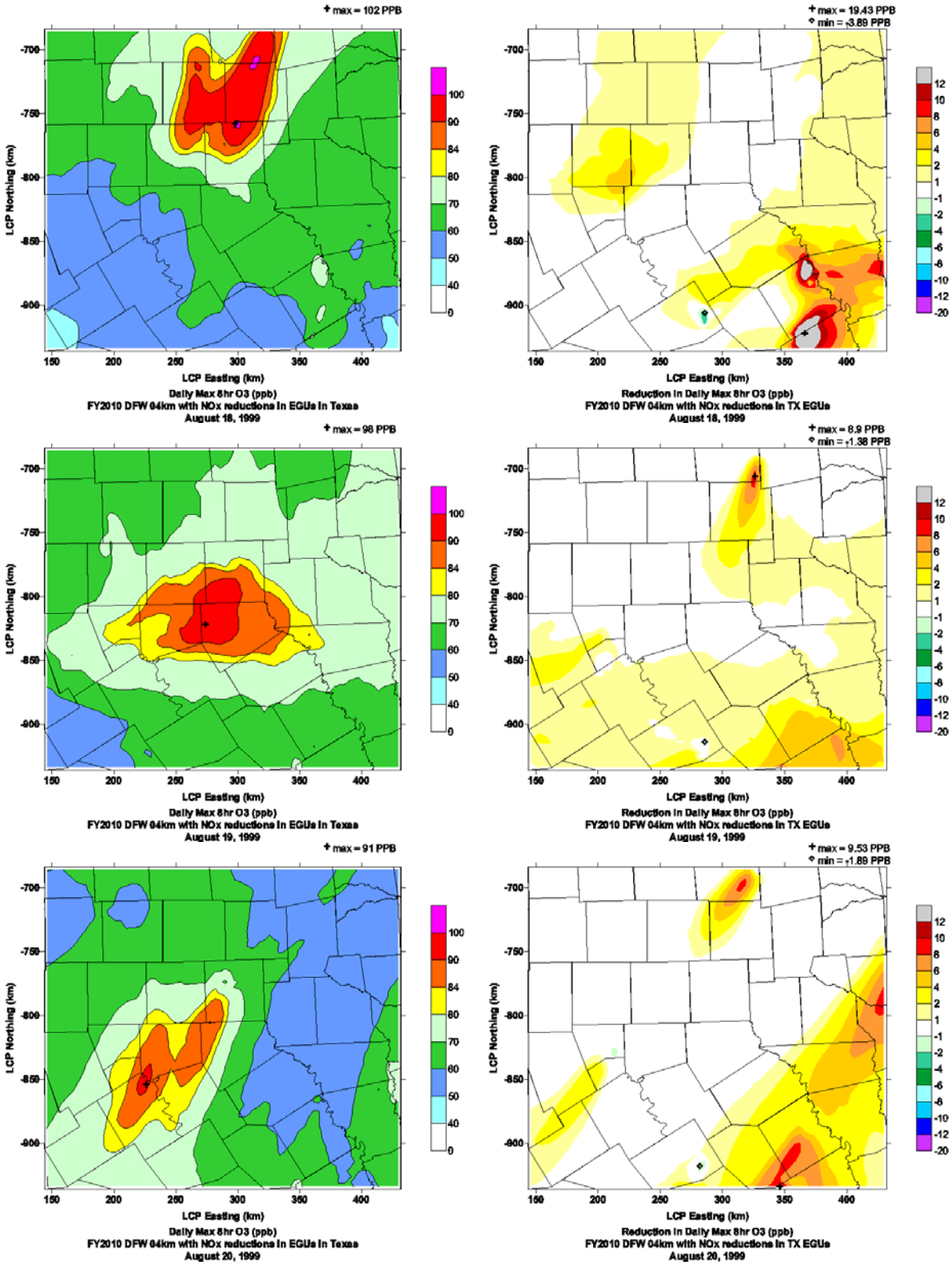


Figure 5-8. (continued) Daily maximum 8-hour ozone in the DFW 4-km grid in 2010 with "EGU NOx reductions" (left) and the difference due to the "EGU NOx reductions" (right).

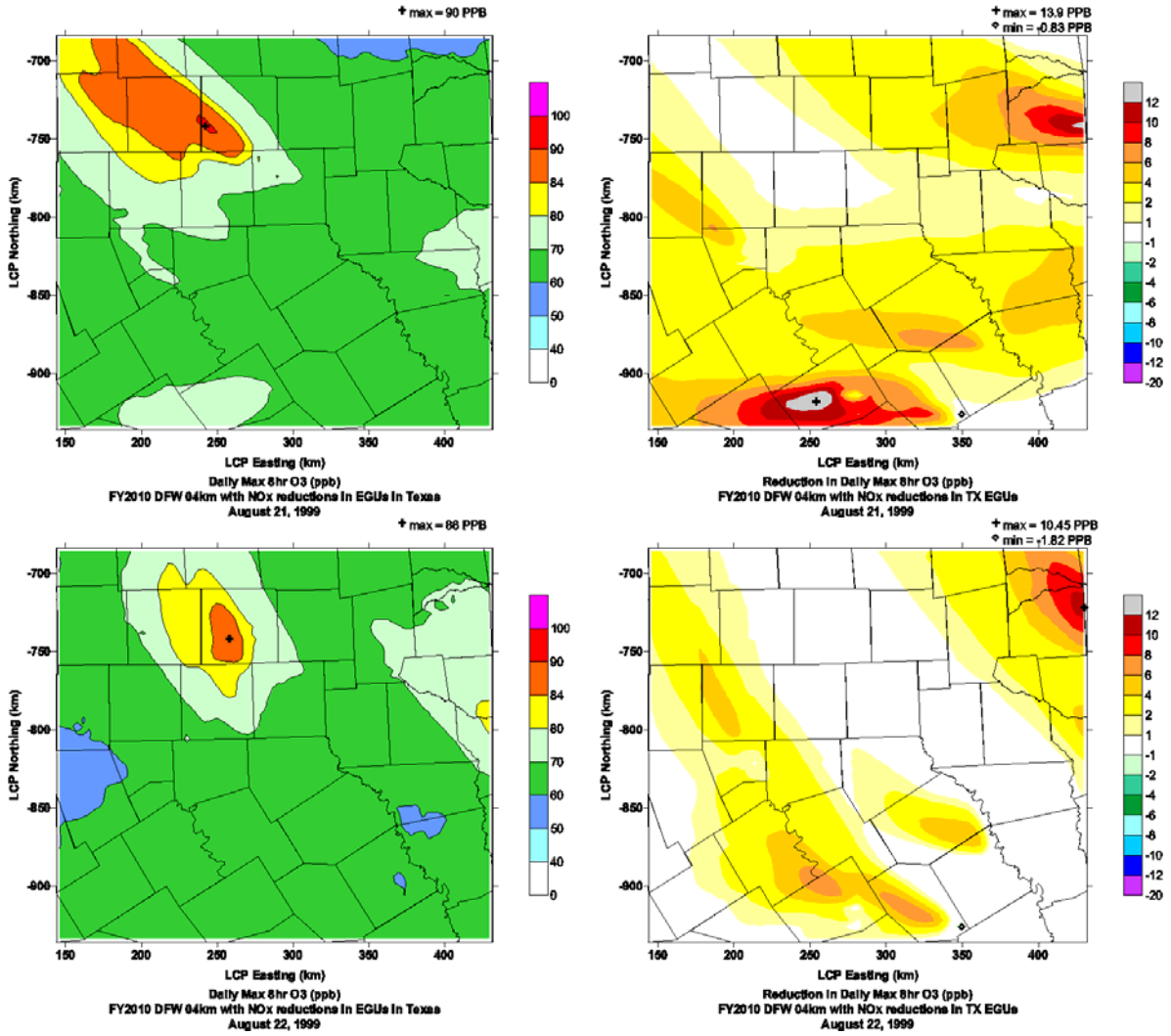


Figure 5-8. (concluded) Daily maximum 8-hour ozone in the DFW 4-km grid in 2010 with "EGU NOx reductions" (left) and the difference due to the "EGU NOx reductions" (right).

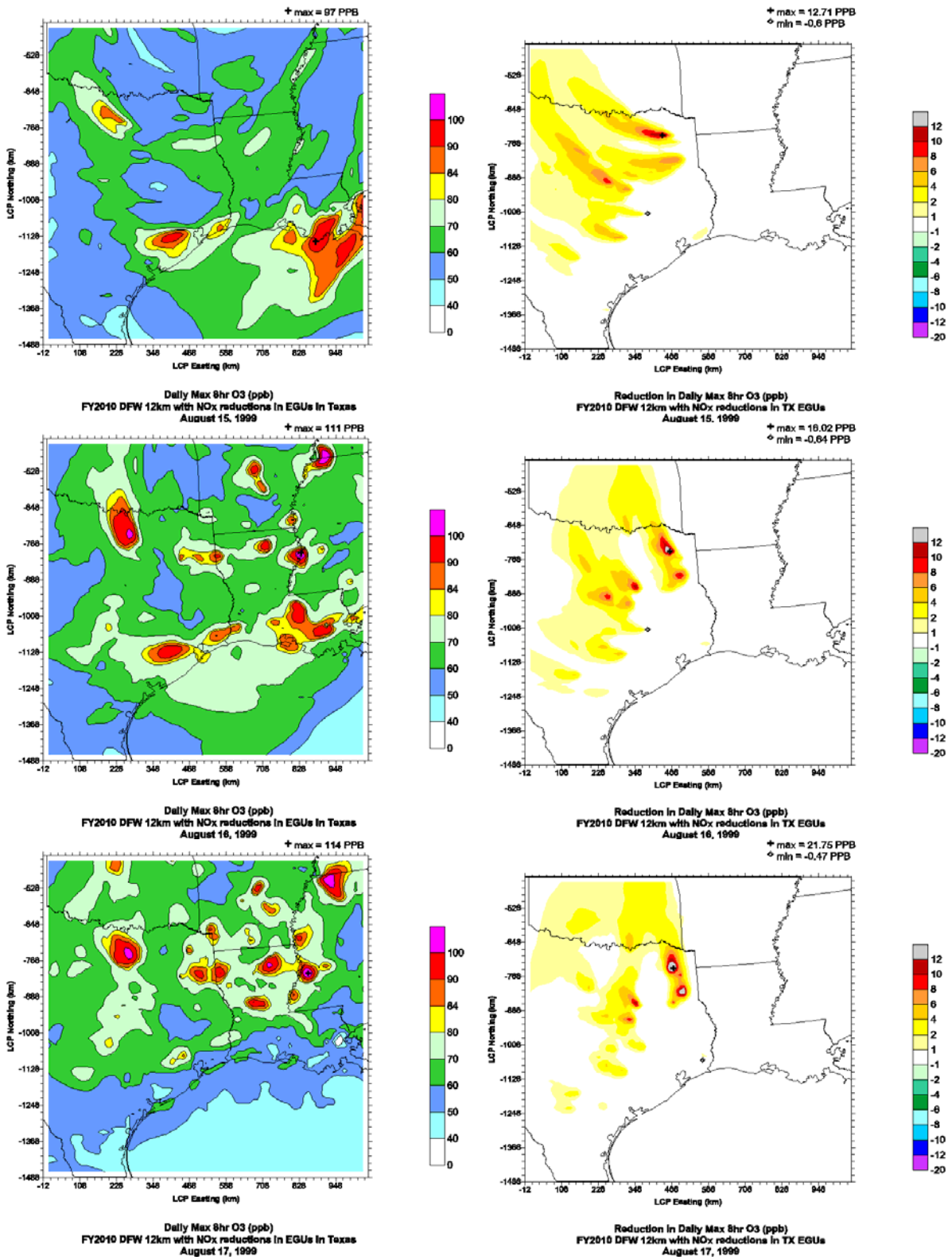


Figure 5-9. Daily maximum 8-hour ozone in the regional 12-km grid in 2010 with "EGU NOx reductions" (left) and the difference due to the "EGU NOx reductions" (right)

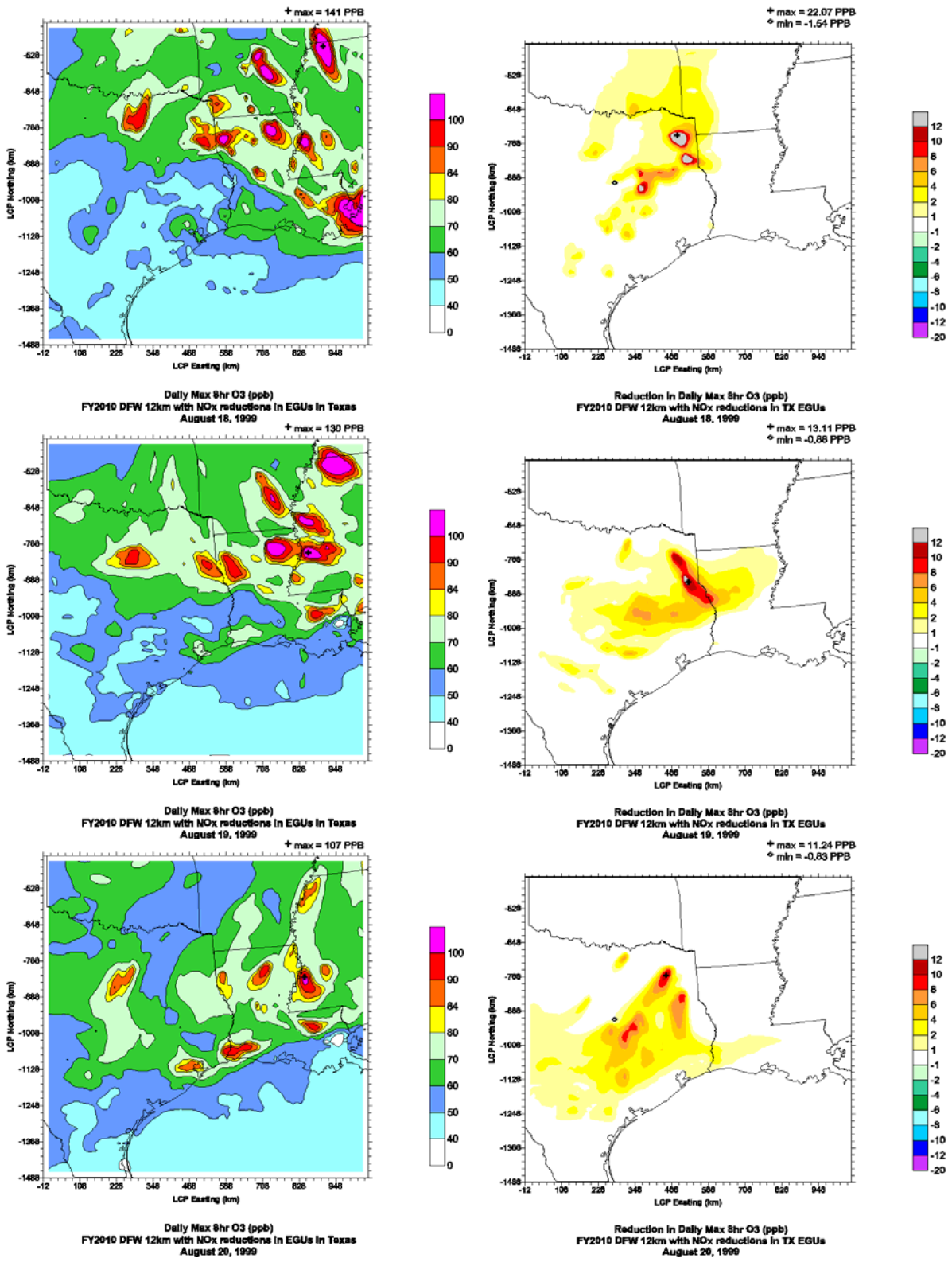


Figure 5-9. (continued) Daily maximum 8-hour ozone in the regional 12-km grid in 2010 with "EGU NOx reductions" (left) and the difference due to the "EGU NOx reductions" (right)

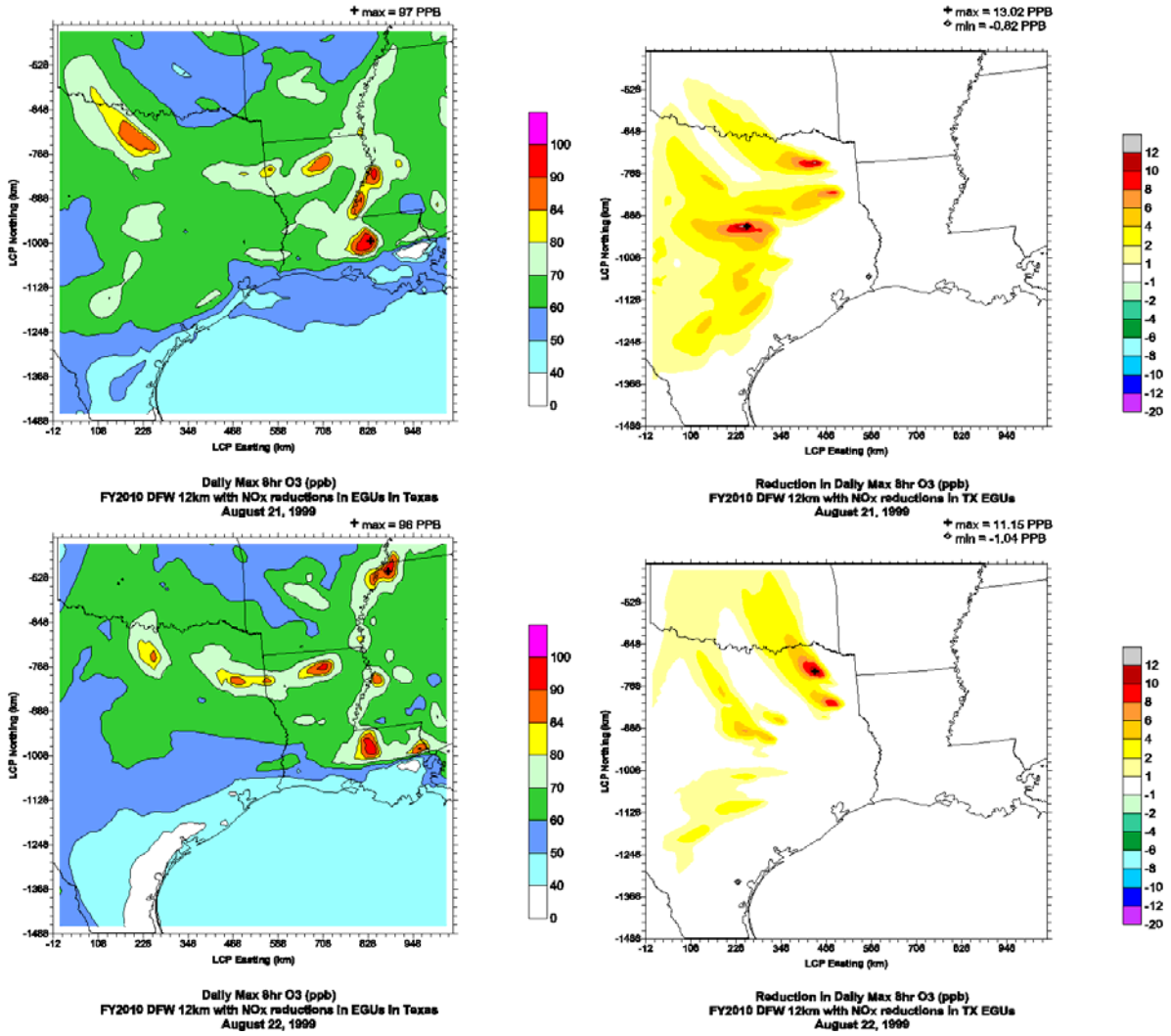


Figure 5-9. (concluded) Daily maximum 8-hour ozone in the regional 12-km grid in 2010 with "EGU NOx reductions" (left) and the difference due to the "EGU NOx reductions" (right).

Table 5-18. Calculation of projected 2010 design values for DFW monitors with "EGU NOx Reductions."

Base Year: run40		**Daily Maximum 8-hour ozone**										
Site	**Current DV**	**990815**	**990816**	**990817**	**990818**	**990819**	**990820**	**990821**	**990822**	**Average**	**#Days >70**	
Run 40 Base Case												
Frisco C31	99.7	84.1	108.6	100.4	107.4	88.4	73.1	87.8	93.0	92.8	8	
Dallas C60	92.0	85.9	97.1	99.3	103.2	100.4	77.2	88.0	86.6	92.2	8	
Dallas C63	93.0	85.9	99.7	99.8	106.1	97.7	77.2	88.0	89.2	92.9	8	
Dallas C402	87.3	81.5	92.0	96.5	95.6	107.3	86.1	82.1	82.8	90.5	8	
Denton C56	101.5	105.9	113.1	110.5	113.8	87.2	76.4	105.9	102.9	102.0	8	
Midlothian C94	92.5	78.2	85.4	87.0	77.8	114.7	92.1	78.1	77.5	86.4	8	
Arlington C57	95.0	90.2	98.9	100.3	95.6	106.8	84.4	83.2	89.6	93.6	8	
Fort Worth C13	98.3	98.5	106.0	103.2	105.5	97.1	81.6	93.5	95.2	97.6	8	
Fort Worth C17	96.3	103.8	111.4	110.3	109.1	94.0	80.2	97.6	100.6	100.9	8	
Future Year: run40.fy2010.txegu_noxredx		**Daily Maximum 8-hour ozone**										
Site	**Current DV**	**990815**	**990816**	**990817**	**990818**	**990819**	**990820**	**990821**	**990822**	**Average**	**RRF**	**Future DV**
Frisco C31	99.7	68.9	102.3	102.0	99.6	74.0	66.2	76.0	78.1	83.4	0.898	89.5
Dallas C60	92.0	73.7	93.7	102.5	99.9	90.3	83.3	80.2	76.7	87.5	0.949	87.3
Dallas C63	93.0	71.5	97.1	102.0	101.6	85.0	79.7	79.0	76.7	86.6	0.932	86.6
Dallas C402	87.3	66.8	84.3	91.9	87.2	96.8	89.7	73.1	73.0	82.9	0.916	79.9
Denton C56	101.5	87.2	104.0	108.3	92.3	72.2	65.4	90.2	85.8	88.2	0.865	87.8
Midlothian C94	92.5	67.6	74.6	79.5	72.2	98.1	90.2	68.3	68.3	77.4	0.896	82.9
Arlington C57	95.0	72.0	90.1	92.9	84.4	95.4	89.7	75.1	80.7	85.0	0.908	86.3
Fort Worth C13	98.3	80.3	95.1	95.4	89.6	84.3	77.3	81.7	82.6	85.8	0.879	86.4
Fort Worth C17	96.3	86.2	98.4	104.4	92.1	79.7	72.0	88.8	85.5	88.4	0.876	84.4

Red values represent 2010 DVs below 85 ppb

Table 5-19. Improvements in 2010 8-hour ozone design values for DFW monitors due to EGU NOx Reductions.

Site	Projected 2010 Design Value (ppb)		
	Base Case	EGU NOx Control	EGU NOx Benefit
Frisco C31	90.8	89.5	-1.3
Dallas C60	88.2	87.3	-0.9
Dallas C63	87.6	86.6	-1.0
Dallas C402	80.9	79.9	-1.0
Denton C56	88.6	87.8	-0.8
Midlothian C94	84.5	82.9	-1.6
Arlington C57	87.6	86.3	-1.3
Fort Worth C13	87.5	86.4	-1.1
Fort Worth C17	85.3	84.4	-0.9

6. 2002 OZONE MODELING

CAMx modeling of the August 13-22, 1999 episode was applied to 2002 so that more recent design values could be used to project the 8-hour ozone design values to 2010. The 2002 center-weighted design values covered ozone observations from 2000 to 2004.

2002 EMISSIONS

The 2002 emissions inventory was developed by simply applying a scaling factor to each county in Texas and source group (area, mobile, off-road, and point sources) to scale from 1999 to 2002. Although crude in assumptions, this was the most reasonable method in the short time frame allotted to develop the 2002 emissions. Scaling factors for each source group and county for NOx and VOCs are listed in Appendix B. Outside of Texas, emissions were obtained from the ODEQ 2002 inventory.

Tables 6-1 and 6-2 summarize the 2002 NOx and VOC emissions, respectively, by source region on Tuesday, August 17, and show how the emissions change from 2002 to 2010. In most regions, NOx emissions were lower in 2002 compared to 1999, and were even lower in 2010. The exception was the Gulf of Mexico, where NOx emissions increased substantially over time. From 1999 to 2002, NOx emissions inside the 9-county DFW region were 24 % lower; in comparison, the domain-wide reduction was only 17 %. From 2002 to 2010, NOx reductions inside DFW and the 36-km domain were both near 30 %.

Anthropogenic VOC emissions were 7 % lower in 2002 compared to 1999 in both the 9-county DFW area and in the 36-km domain. From 2002 to 2010, the anthropogenic VOC emissions were reduced another 20 % domain-wide, but were only 10 % lower in DFW. VOC emissions from the Gulf of Mexico increased over time, just like NOx.

Table 6-1. 2002 NOx emissions by source region on Tuesday, August 17.

	2002 NOx (tpd)		**% Change (2002 to 2010)**	
	Biogenics	Anthro	Biogenics	Anthro
Collin Co	10	40	0	-26
Dallas Co	4	229	0	-31
Denton Co	8	47	0	-21
Tarrant Co	3	154	0	-38
Parker Co	1	20	0	-39
Johnson Co	5	35	0	-57
Ellis Co	15	60	0	2
Kaufman Co	5	18	0	-12
Rockwall Co	2	6	0	-28
DFW 9-County	**52**	**609**	**0**	**-30**
DFW 16-County	**83**	**768**	**0**	**-29**
NE Texas	16	640	0	-34
Central TX	113	639	0	-37
Houston	21	981	0	-38
South TX	229	992	0	-30
West Texas	508	923	3	-32

	2002 NOx (tpd)		% Change (2002 to 2010)	
	Biogenics	Anthro	Biogenics	Anthro
Gulf + Mexico	72	650	10	53
Oklahoma	256	1311	-12	-15
Louisiana	106	2328	0	-12
Arkansas	122	929	2	-22
Mississippi	120	1139	0	-21
Alabama	72	1535	4	-28
Tennessee	109	1605	9	-29
Kentucky	131	1808	11	-38
Georgia	111	2009	-1	-47
Florida	57	2690	-2	-44
Mid Atlantic States	293	5564	0	-40
Northeast US	314	9387	0	-30
Northern Plains	5172	17296	1	-31
Total	7904	53193	1	-31

Table 6-2. 2002 VOC emissions by source region on Tuesday, August 17.

	2002 VOC (tpd)		% Change (2002 to 2010)	
	Biogenics	Anthro	Bio	Anthro
Collin Co	27	37	0	-28
Dallas Co	50	196	0	-16
Denton Co	65	44	0	-20
Tarrant Co	64	122	0	-10
Parker Co	121	15	0	0
Johnson Co	111	11	0	38
Ellis Co	89	17	0	46
Kaufman Co	112	13	0	52
Rockwall Co	3	5	0	5
DFW 9-County	**642**	**461**	**0**	**-10**
DFW 16-County	**1538**	**576**	**0**	**-10**
NE Texas	4917	263	0	1
Central TX	6098	256	0	14
Houston	1683	746	0	-38
South TX	2069	632	0	-12
West Texas	5628	939	10	-24
Gulf + Mexico	745	304	-12	31
Oklahoma	7972	739	0	-23
Louisiana	9941	872	0	-18
Arkansas	13882	635	0	-12
Mississippi	14827	787	0	-21
Alabama	13334	1160	5	-22
Tennessee	8647	1333	0	-12
Kentucky	5264	997	-29	-23
Georgia	13061	1469	-7	-36
Florida	9845	2148	-1	-21
Mid Atlantic States	31578	3573	-1	-14
Northeast US	20472	7787	0	-21
Northern Plains	39676	11246	1	-21
Total	211177	36461	-1	-20

2002 RUN 40

The Run 40 configuration was applied to the DFW episode for 2002 for the core period only. The daily maximum 8-hour ozone for each date is plotted on the left side of Figure 6-1, and the change in daily maximum from 2002 to 2010 is shown on the right. Ozone was lower in 2010 compared to 2002 on all dates inside the 4 km domain, except locally near the DFW core on August 17 and 20, where there was little change, and on August 16 near eastern Navarro County, where 8 hour ozone was 3 ppb greater in 2010 than in 2002. The daily peak 8-hour ozone in the 4 km domain was 6 to 12 ppb lower in 2010 compared to 2002.

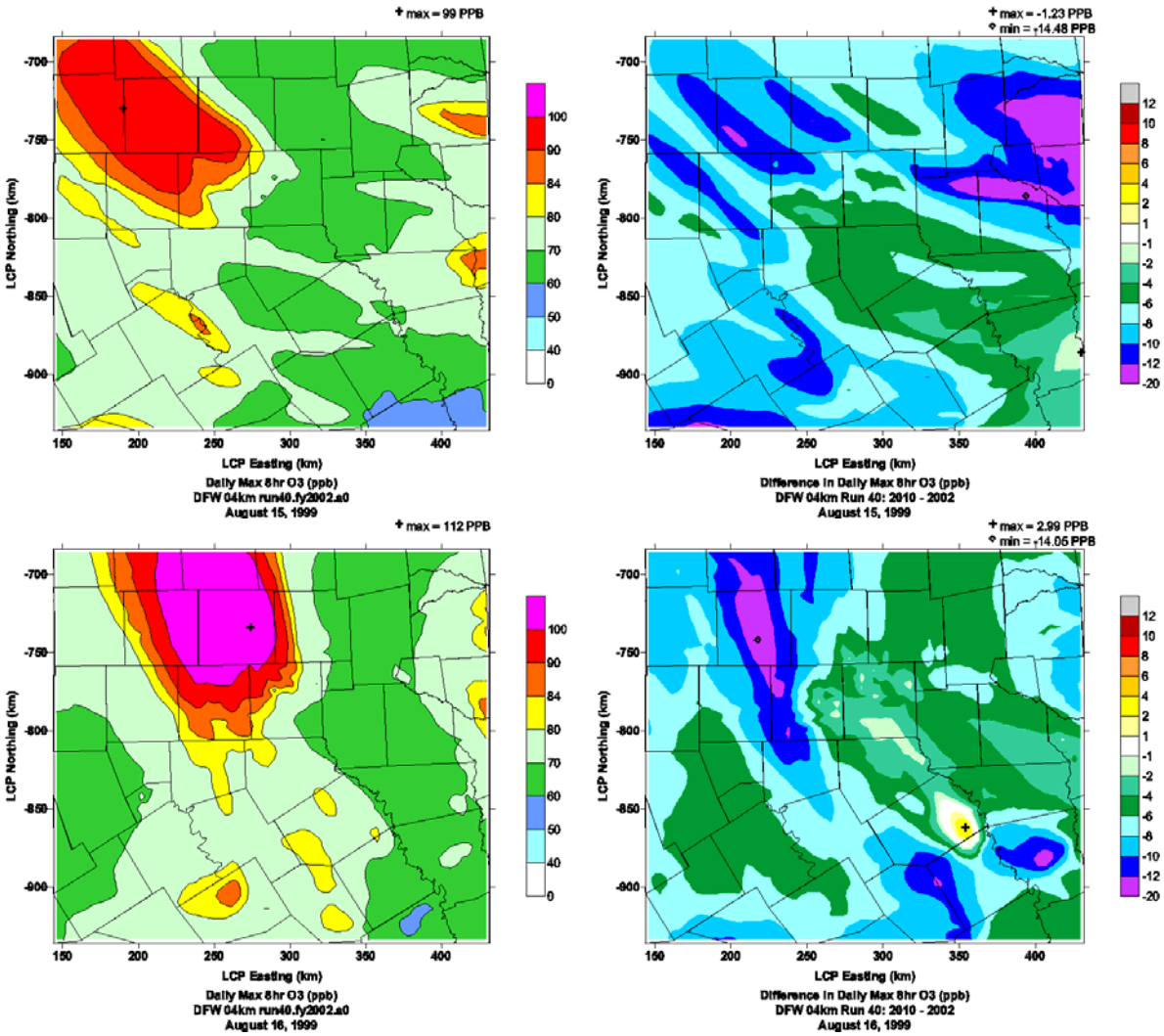


Figure 6-1. Daily maximum 8-hour ozone in the 4 km domain for 2002 (left) and the difference from 2002 to 2010 (right).

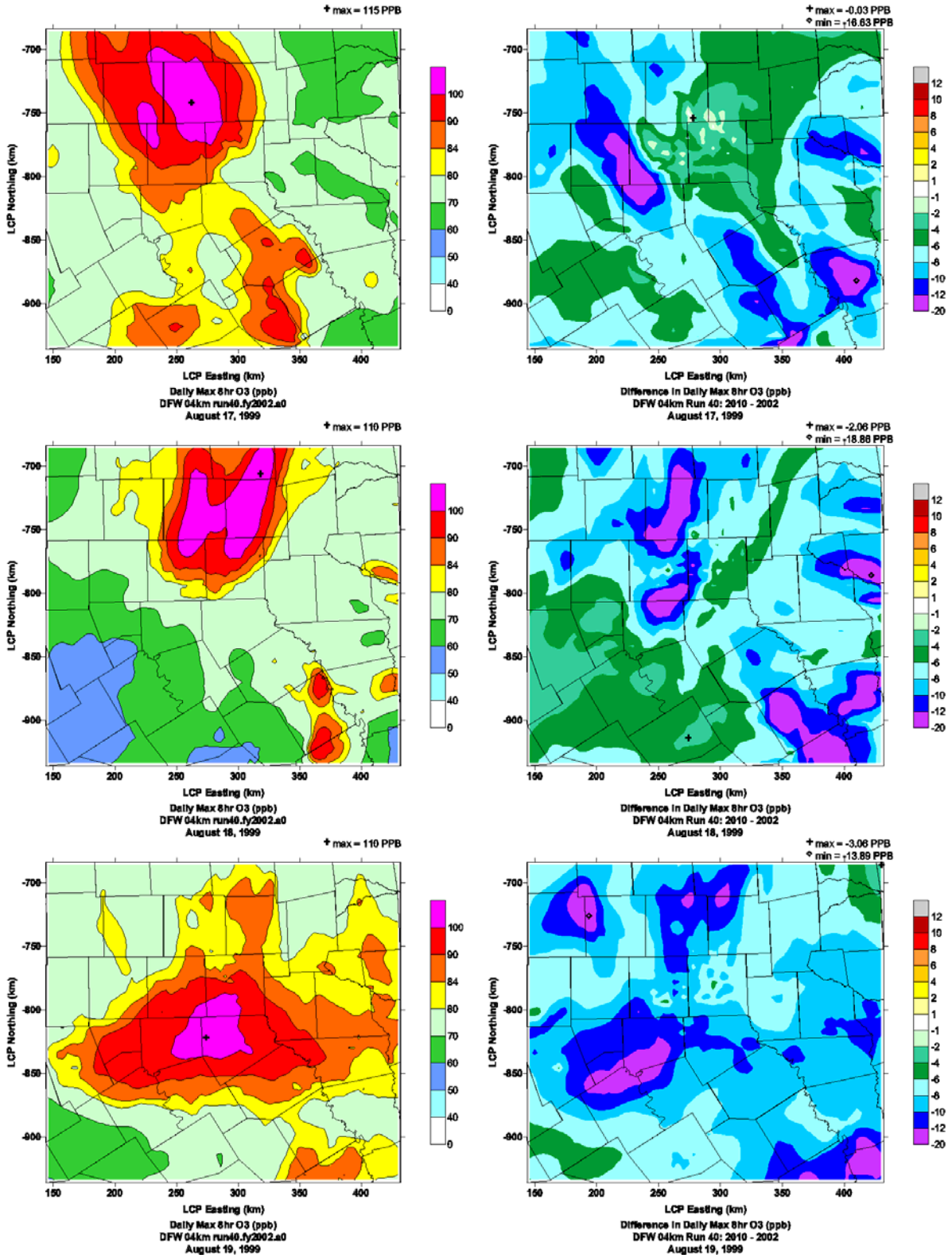


Figure 6-1. (continued) Daily maximum 8-hour ozone in the 4 km domain for 2002 (left) and the difference from 2002 to 2010 (right).

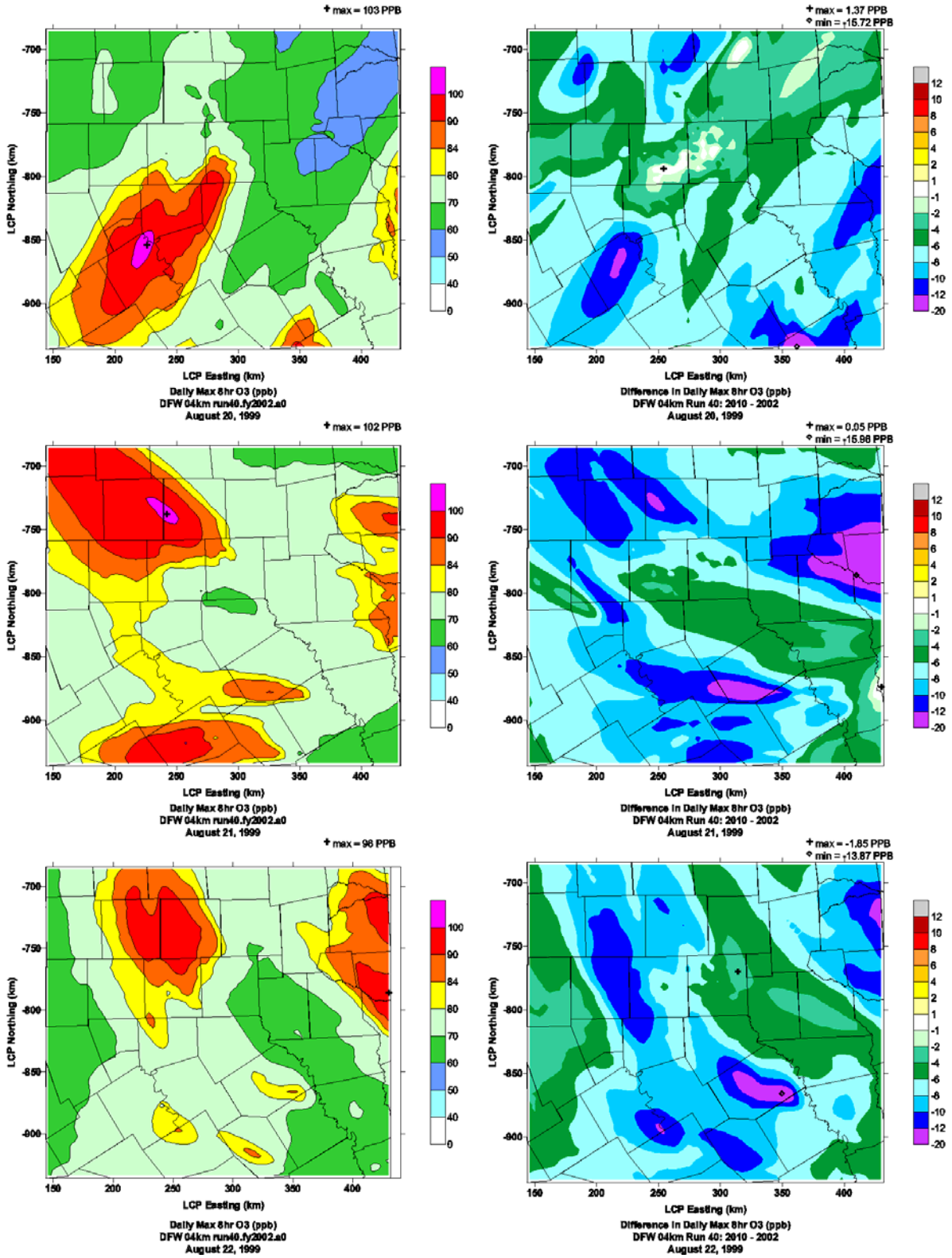


Figure 6-1. (concluded) Daily maximum 8-hour ozone in the 4 km domain for 2002 (left) and the difference from 2002 to 2010 (right).

DESIGN VALUE SCALING FROM 2002

The 8-hour ozone design values for three running three-year periods (2000-2002, 2001-2003, and 2002-2004) and the center-weighted average used to represent the current design value for 2002 were provided by TCEQ and are shown in Table 6-3. The number of observation sites available for design value analysis increased from 9 in 1999 to 18 in 2002. Figure 6-2 shows the locations of all the monitoring sites available in 2002. Blue circles represent monitors that were available for design scale analysis in 1999 and 2002; red circles represent monitors that were only available for the 2002 analysis.

Table 6-4 shows the calculation of the 2010 future design values at each monitor using the 2002 CAMx base case and 2002 current design values. Certain dates were excluded at Kaufman, Rockwall, Anna and Sunnyvale because the 2002 base case daily maximum 8-hour ozone was below 70 ppb. Five monitoring sites exceeded 85 ppb in 2010 – Denton, Eagle Mountain Lake, Fort Worth CAMS 13 and 17, and Grapevine. Frisco, which had the highest future DV when using 1999 as the base case, was in attainment when using 2002 as the base.

Differences in the RRF and current and future design values when using 2002 instead of 1999 can be seen in Table 6-5. A lower RRF when using 2002 as the base implied that the base ozone averaged over all applicable dates was higher in 2002 than 1999, and that ozone could be reduced more when using the 2002 base instead of the 1999 base. Only the three Dallas sites and Cleburne lowered their RRFs when using 2002 as the base; Dallas CAMS 60 showed the greatest reduction, dropping 1.9%. Most sites were higher, including Denton, whose RRF increased 3.7 %.

The 2002 current design values were lower at all sites that were also available in the 1999 analysis, except Fort Worth CAMS 17, which was 2.4 ppb higher. Dallas CAMS 63 and Frisco's current design values were 15 % and 10 % lower, respectively, when using 2002.

The future design value was influenced by both the current DV and RRF. At most sites, the change in current design value was more significant than the change in RRF. Of the nine sites whose future design values could be calculated from both 1999 and 2002 current DVs, seven were in exceedance with 1999 current design values; only three sites exceeded 85 ppb using the 2002 current DVs – Fort Worth CAMS 17, whose future design value increased from 85 ppb to 90 ppb, and Ft. Worth CAMS 13 and Denton, where little change occurred when switching the current base from 1999 to 2002. Frisco, Dallas CAMS 60 and 63, and Arlington's 2010 design values all fell below 85 ppb when using 2002 as the base.

Two of the nine new monitoring sites available in 2002 but not in 1999 exceeded 85 ppb in 2010 – Grapevine and Eagle Mountain Lake. Grapevine had the highest future design value among all sites at 90.5 ppb. In comparison, when the 1999 base case was used, Frisco's future design value was 90.8 ppb.

Table 6-3. 8-hour ozone design values and the current design value for 2002.

Site Name	CAMS	2002 00-02	2003 01-03	2004 02-04	**3 Yr Average**
Frisco	C31	93	88	89	**90.0**
Anna	C68	83	80	80	**81.0**
Dallas Hinton	C60	91	90	89	**90.0**
Dallas North	C63	89	86	63	**79.3**
Dallas Executive	C402	82	83	87	**84.0**
Sunnyvale	C74	65	83	83	**77.0**
Denton	C56	99	97	96	**97.3**
Midlothian	C94	86	82	87	**85.0**
Granbury	C73	84	84	81	**83.0**
Cleburne	C77	89	90	90	**89.7**
Kaufman	C71	70	73	73	**72.0**
Weatherford	C76	86	89	86	**87.0**
Rockwall	C69	83	81	82	**82.0**
Arlington Muni	C61	---	88.5*	87	**87.0**
Eagle Mt Lake	C75	95	96	94	**95.0**
FtW NW	C13	96	96	94	**95.3**
FtW Keller	C17	98	100	98	**98.7**
Grapevine	C70	95	100	98	**97.7**

* indicates a 2 year average, so not included in calculation

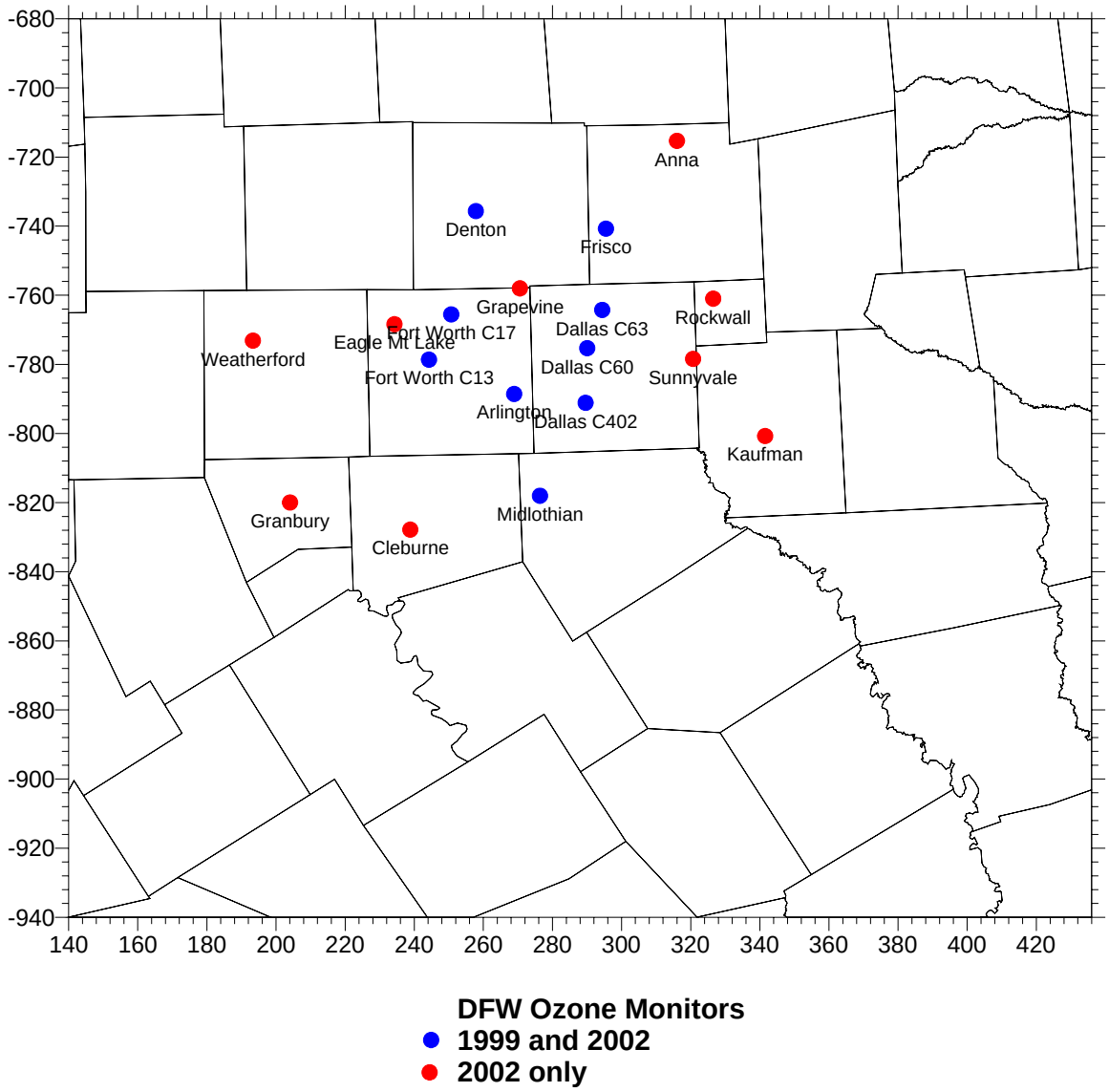


Figure 6-2. Ozone monitoring sites in DFW in 1999 and 2002.

Table 6-4. Design value calculations for the 2010 future year base case using the 2002 core period as the base case.

Design Value Scaling												
Base Case: run40.fy2002.a0												
Site	Current DV	990815	990816	990817	990818	990819	990820	990821	990822	Avg	#Days>70	
Frisco	90.0	79.5	109.5	105.9	108.1	85.4	70.7	85.8	87.5	91.6	8	
Anna	81.0	68.8	77.2	88.5	110.2	88.3	70.1	75	76.4	83.7	7	
Dallas C60	90.0	82.3	100.2	105.8	107.3	99.4	85.3	87.9	84.2	94.1	8	
Dallas C63	79.3	81.2	102.5	105.9	109.8	95	82.5	87.4	85.1	93.7	8	
Dallas C402	84.0	76.5	91.3	98.5	96.9	107.4	94.1	81.1	79.8	90.7	8	
Sunnyvale	77.0	69.9	78.2	85	96.7	96.3	70.3	76.6	72	82.1	7	
Denton	97.3	98	111.9	114.8	107.7	83.5	73.8	101.5	95.5	98.3	8	
Midlothian	85.0	74.7	82.8	85.3	79.6	109.6	95.6	75.9	76.5	85	8	
Granbury	83.0	80.9	76.8	84.7	73	97.2	90.1	83.2	79.4	83.1	8	
Cleburne	89.7	77.7	82.7	86.8	77	102.1	98.8	80.4	84.1	86.2	8	
Kaufman	72.0	68.8	68.6	72.2	74.7	96.4	64.4	74.9	69.6	79.5	4	
Weatherford	87.0	94.1	80.9	90.4	74.6	80.5	71.8	93.4	81.1	83.3	8	
Rockwall	82.0	69.2	74.8	84.6	102.8	88.7	67.9	76.3	73	83.4	6	
Arlington	87.0	83	97.4	99.3	96.6	105.9	94.1	82.4	88.6	93.4	8	
Eagle Mt Lake	95.0	94.1	107	102.7	94	89	80.1	96.3	92.1	94.4	8	
Fort Worth C13	95.3	91.1	104.1	102.4	104.2	94.5	81.3	91.4	91.8	95.1	8	
Fort Worth C17	98.7	96.3	108.5	112.1	106.3	90.7	78.2	97	94.5	97.9	8	
Grapevine	97.7	94.8	109.6	114.5	108	88	76	98.2	94.7	98	8	

Future Year: run40.fy2010												
Site	Current DV	990815	990816	990817	990818	990819	990820	990821	990822	Avg	RRF	FutureDV
Frisco	90.0	70	103.6	103	100.1	77.2	67.1	77.4	78.3	84.6	0.924	83.1
Anna	81.0	60.9	71.6	84.4	101.1	81.3	68.3	67.3	69.5	77.7	0.928	75.2
Dallas C60	90.0	75	95.4	103.5	100.4	91.3	83.5	81.2	77	88.4	0.940	84.6
Dallas C63	79.3	72.8	98.6	103	102	86.8	80	80	77	87.5	0.934	74.1
Dallas C402	84.0	68.6	86.7	93.3	87.9	97.5	89.8	73.9	73.4	83.9	0.925	77.7
Sunnyvale	77.0	62.5	74.9	82.4	90.7	88.9	67.2	69.8	69.3	77.6	0.945	72.7
Denton	97.3	88.6	105.2	108.8	93.6	73	65.6	91.1	86.1	89	0.905	88.1
Midlothian	85.0	70.4	78.7	81.1	72.6	98.8	90.2	70.4	69.1	78.9	0.928	78.9
Granbury	83.0	74.9	71.3	74.8	68.5	85.2	83.1	76.1	69.5	75.4	0.907	75.3
Cleburne	89.7	69.9	72.2	74.6	63.7	89.1	90.1	72.1	72.5	75.5	0.876	78.6
Kaufman	72.0	63.6	63.7	66.9	68	88.1	58.7	67.7	64.4	72.7	0.914	65.8
Weatherford	87.0	85.2	71.9	78.9	66.5	72.7	67.8	83.5	70.3	74.6	0.895	77.9
Rockwall	82.0	60.9	71.8	80.7	95.4	81.3	63.6	68.3	68.1	77.6	0.931	76.3
Arlington	87.0	74.2	92.7	94	86.3	96.2	89.8	75.8	81.3	86.3	0.924	80.4
Eagle Mt Lake	95.0	84.1	97.7	95.8	82.7	79.8	74.1	86.1	83.1	85.4	0.905	86.0
Fort Worth C13	95.3	82.3	97.4	95.7	91.5	84.9	77.3	82.4	83.1	86.8	0.913	87.0
Fort Worth C17	98.7	87.6	100.1	105	93.9	80.5	72.2	89.5	85.8	89.3	0.912	90.0
Grapevine	97.7	86.5	104.5	108.8	99.2	77.7	73.5	89.5	86.1	90.7	0.926	90.5
base case is below 70 ppb												
future design values >= 85 ppb												

Table 6-5. Impacts on future design values of using 1999 vs. 2002 as the current base year.

Comparison of design value scaling using the 1999 and 2002 base case for FY2010									
	RRF			Current DV			Future DV		
	Run 40: 1999 to 2010	Run 40: 2002 to 2010	% Change	1999	2002	% Change	1999 to 2010	2002 to 2010	% Change
Site									
Frisco	0.911	0.924	1.4	99.7	90.0	-9.7	90.8	83.1	-8.5
Anna	0.889	0.928	4.3		81.0			75.2	
Dallas C60	0.959	0.940	-1.9	92.0	90.0	-2.2	88.2	84.6	-4.1
Dallas C63	0.942	0.934	-0.8	93.0	79.3	-14.7	87.6	74.1	-15.4
Dallas C402	0.927	0.925	-0.2	87.3	84.0	-3.8	80.9	77.7	-4.0
Sunnyvale	0.941	0.945	0.4		77.0			72.7	
Denton	0.873	0.905	3.7	101.5	97.3	-4.1	88.6	88.1	-0.6
Midlothian	0.914	0.928	1.6	92.5	85.0	-8.1	84.5	78.9	-6.6
Granbury	0.898	0.907	1.0		83.0			75.3	
Cleburne	0.886	0.876	-1.1		89.7			78.6	
Kaufman	0.902	0.914	1.4		72.0			65.8	
Weatherford	0.868	0.895	3.1		87.0			77.9	
Rockwall	0.913	0.931	2.0		82.0			76.3	
Arlington	0.922	0.924	0.3	95.0	87.0	-8.4	87.6	80.4	-8.2
Eagle Mt Lake	0.876	0.905	3.3		95.0			86.0	
Fort Worth C13	0.890	0.913	2.6	98.3	95.3	-3.1	87.5	87.0	-0.5
Fort Worth C17	0.885	0.912	3.0	96.3	98.7	2.5	85.3	90.0	5.6
Grapevine	0.904	0.926	2.4		97.7			90.5	

Red values are future DVs >= 85 ppb.

The 2002 current design values were applied to the matrix of anthropogenic NOx and VOC reductions within the DFW 9-county region in 2010 to examine ozone responsiveness to each control. Table 6-6 summarizes the results, which were not truncated to better show ozone sensitivities. Figure 6-3 plots the response curves from VOC controls (top left), NOx controls (top right), and VOC and NOx controls (bottom left).

Ozone remains more responsive to NOx controls than VOC. The site with the highest 2010 base design value was Grapevine, which required just under a 40 % NOx reduction inside the DFW 9-county area to achieve attainment. Although still a large reduction, this is less than the 45 % NOx reduction needed to bring Frisco into attainment when the 1999 base case was used (Figure 5-4).

Table 6-6. 2010 8-hour ozone design values at DFW monitors from the matrix of anthropogenic emission reductions in the DFW 9-county area, when using the 2002 base case

2010 Future Design Values using 2002.a0 as the base case											
	Current DV (2002)	Future DV (2010) [ppb]									
Site		Base	n100v75	n100v50	n100v25	n80v100	n60v100	n40v100	n80v75	n60v50	n40v25
NOx reduction		0	0	0	0	20	40	60	20	40	60
VOC reduction		0	25	50	75	0	0	0	25	50	75
Frisco	90.0	83.1	82.4	81.7	81.0	81.3	78.5	74.6	80.8	77.8	74.0
Anna	81.0	75.2	74.8	74.4	74.0	74.1	72.7	70.9	73.8	72.3	70.5
Dallas C60	90.0	84.6	83.7	82.7	81.6	83.0	80.1	75.6	82.2	79.0	74.7
Dallas C63	79.3	74.1	73.3	72.5	71.6	72.6	70.1	66.3	72.0	69.2	65.5
Dallas C402	84.0	77.7	77.2	76.7	76.2	75.8	73.3	69.8	75.4	72.6	69.2
Sunnyvale	77.0	72.7	72.4	72.0	71.7	71.4	69.6	67.1	71.1	69.1	66.6
Denton	97.3	88.1	87.6	87.0	86.4	85.1	81.4	76.6	84.8	80.9	76.3
Midlothian	85.0	78.9	78.5	78.2	77.7	77.5	75.6	72.8	77.2	75.2	72.5
Granbury	83.0	75.3	75.1	75.0	74.8	74.3	73.2	71.8	74.2	73.1	71.8
Cleburne	89.7	78.6	78.4	78.2	78.0	77.1	75.7	74.1	77.0	75.5	73.9
Kaufman	72.0	65.8	65.6	65.4	65.2	65.1	64.3	63.2	64.9	64.0	62.9
Weatherford	87.0	77.9	77.8	77.8	77.8	75.9	73.8	71.7	75.9	73.9	71.8
Rockwall	82.0	76.3	76.0	75.6	75.2	74.9	73.3	71.0	74.6	72.8	70.5
Arlington	87.0	80.4	79.9	79.4	78.9	78.2	75.4	71.4	77.8	74.8	71.0
Eagle Mt Lake	95.0	86.0	85.7	85.4	85.0	83.1	79.5	75.1	82.9	79.3	75.0
Fort Worth C13	95.3	87.0	86.6	86.2	85.8	84.3	81.0	76.6	84.0	80.5	76.2
Fort Worth C17	98.7	90.0	89.6	89.1	88.6	87.0	83.1	77.9	86.6	82.6	77.7
Grapevine	97.7	90.5	89.7	88.9	88.0	88.1	84.6	79.4	87.4	83.7	78.7
Red = 2010 8-hour Ozone Design Values >= 85 ppb											

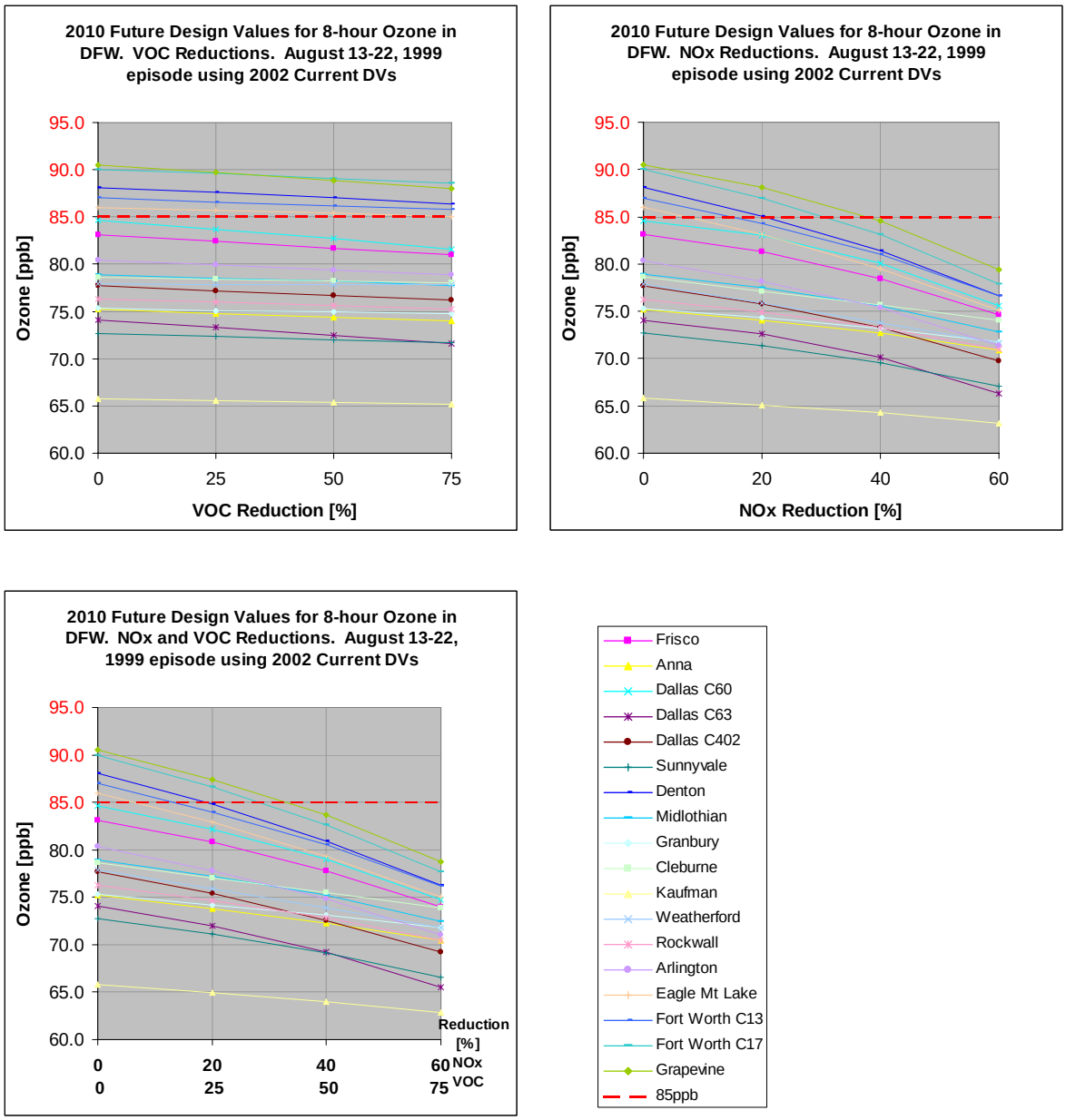


Figure 6-3. 8-hour ozone response curves for 2010 VOC and NOx anthropogenic emission reduction scenarios when using the 2002 base case.

7. SUMMARY

Revised Base Case

The 2010 future year ozone modeling for the DFW region was reexamined using an improved base case (Run 40). Improvements in Run 40 from Run 17b (Mansell et al., 2004) include:

- Expanding the model domain northward and eastward into the Atlantic and Canada
- Extending the model top to around 14-km
- Using meteorology from MM5 Run 6, which was based on the Eta PBL scheme and Noah land-surface model
- Enhancing low-level mixing by applying the "Kv100" adjustment
- Adding NOx recycling reactions to CB4 (CB4xi) in CAMx version 4.03.

Supplemental Period

CAMx Run 40 included both the core period (August 13 – 22, 1999) and the supplemental period (August 23 – September 1, 1999) to model high ozone days beyond the core period. MM5 was run for the supplemental period using the Run 6 configuration (Tai et al., 2005) but its performance was poor and falls short of the benchmarks for air quality modeling. CAMx modeling of the supplemental period showed peak ozone too far to the east of DFW on August 25 and 26, and too high and too west from August 30 to September 1. Despite these model performance flaws, the daily normalized bias and error fell within EPA's benchmarks on all dates in the supplemental period except August 23, when observed ozone concentrations were very low, resulting in significantly fewer predicted and observed pairings to compute the statistics.

2010 Response Curves

The Run 40 configuration was applied to the 2010 future year, where the base case and 14 emission control runs were simulated for both the core and extended periods. Nine runs applied various levels of NOx, VOC, or a combination of NOx and VOC controls across all anthropogenic sources inside the DFW 9-county area. Design value scaling using the latest EPA guidance was applied to each of the DFW ozone monitoring stations.

Plots of the 2010 8-hour ozone design values are shown in Figure 7-1. The top left plot shows ozone not very responsive to local VOC reductions at any DFW monitoring station. The top right plot shows ozone decreasing with increasing local NOx controls. Frisco, the station with the highest future design value, needed approximately a 45 % local NOx reduction to bring its future year design value below 85 ppb in the core period. In the supplemental period, Frisco needed around a 42 % anthropogenic NOx reduction. The combination of NOx and VOC controls (bottom left plot) showed nearly the same response as NOx controls only.

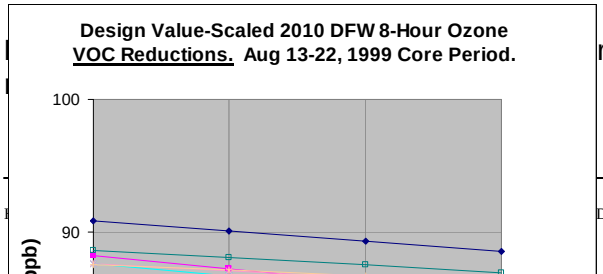
The level of DFW NOx controls needed for attainment at Frisco in the core period lowered from 50% in Run 17b (Mansell et al., 2004) to about 45% in Run 40 because of two things: the

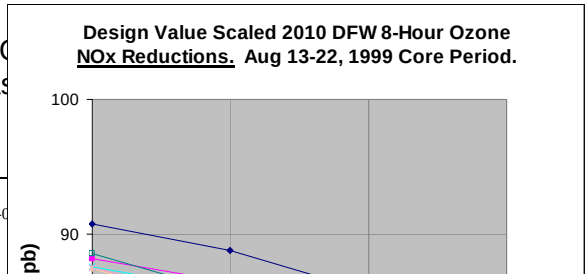
relative reduction factor (RRF) was lower and the current design value was lower. The latest EPA guidance set the current design value equal to the average of the three design values that encompassed the base year (EPA, 2005). At the time of the previous study, the current design value was equal to the higher of the base year design values from 1998-2000 and the design value for attainment designations (2001-2003). As a result, the current design value used in this task was 1.3% lower in Frisco; its RRF was 0.4% lower.

VOC Reduction

NOx Reduction

VOC and NOx Reduction





The RRFs among all stations in the Run 40 core period were comparable to the RRFs from Run 17b. Differences varied from –1.6 % to +1.8 %. The RRF between Run 40's core and supplemental periods also were similar, differing between -1.7 % and +1.8 %. In contrast, the current design values at each monitor changed from -5% to +8% when compared to the values used for the Run 17b analysis. Frisco always had the highest future design value and, despite all the improvements in the 1999 model performance, still required a significant NOx reduction in the 9-county area to achieve attainment.

2002 Base Case

A 2002 inventory was prepared by making adjustments to the existing 1999 inventory within Texas. The resulting 2002 inventory has greater uncertainties than either the 1999 or 2010 inventories. When the 2002 base case and current design values centered around 2002 were used to compute the 2010 design values, four of the seven sites whose future design values exceeded 85 ppb when using the 1999 base fell into attainment, including Frisco, whose 2002 current design value was 10 % lower than in 1999. Nine additional ozone monitoring sites were operating in 2002 that were not available in 1999. Of these, Grapevine had the highest 2010 8-hour ozone design value at 90.5 ppb; in comparison, Frisco's future design value when using 1999 as a base case was 90.8 ppb. Thus, the highest 2010 design value was almost the same with 1999 and 2002 base years but the location changed from Frisco to Grapevine.

Ozone response curves from NOx and VOC reductions inside the 9-county DFW area for the 2002 projection to 2010 at each monitoring site are shown in Figure 7-2. A NOx reduction of just under 40 % would be needed to bring Grapevine (and all DFW receptors) into attainment when using 2002 as the base case. This is less than the 45 % NOx reduction needed at Frisco to achieve attainment when using the 1999 base case.

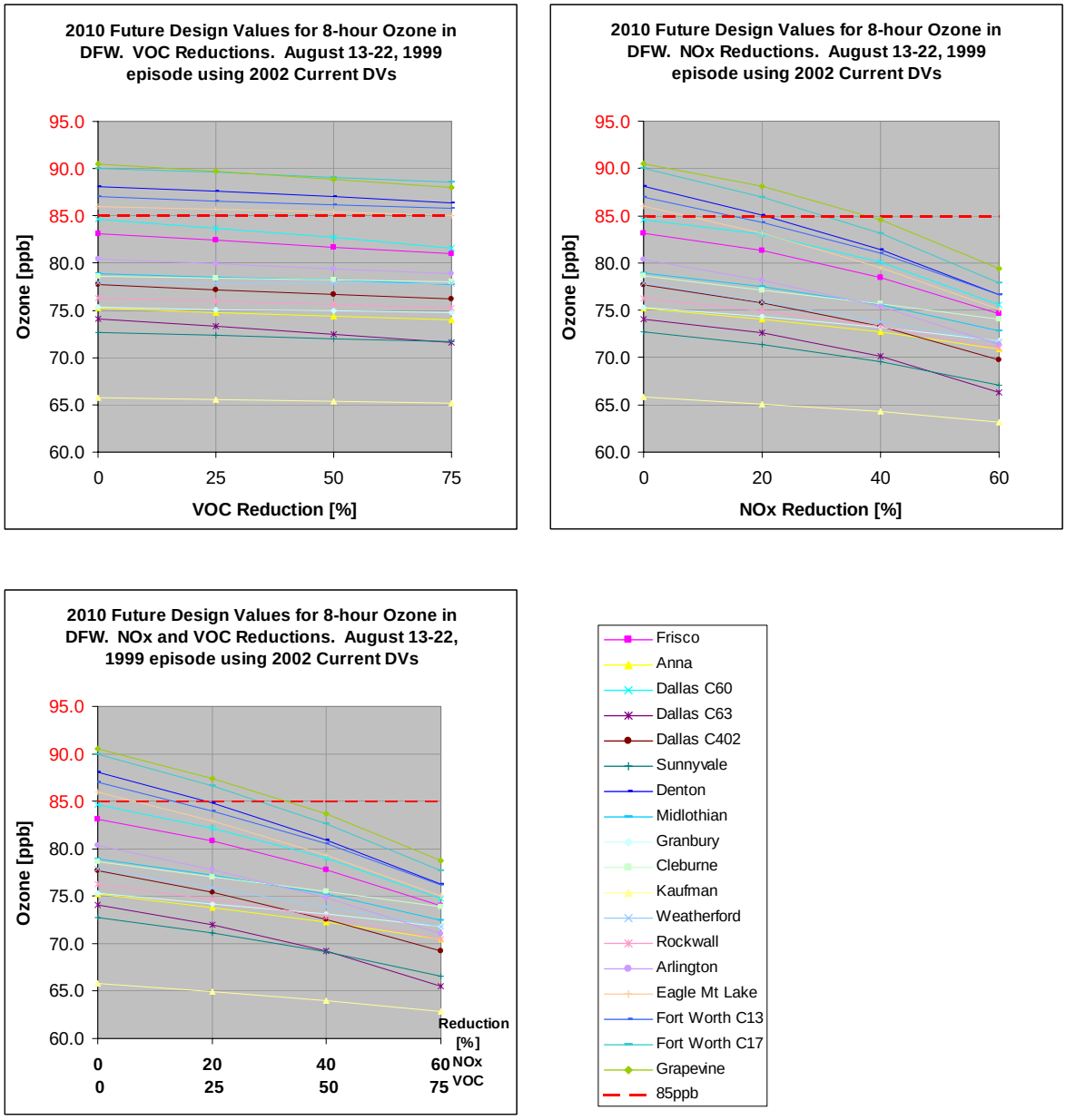


Figure 7-2. 8-hour ozone response curves for 2010 VOC and NOx anthropogenic emission reduction scenarios when using the 2002 base case.

2010 Reductions by Emissions Category

Five additional runs evaluated ozone sensitivity to controls from different anthropogenic emission categories in 2010. In each run, 40 tons of emissions per day were removed from the DFW 9-county area in the following groups:

- On-road mobile NOx
- Area + off-road mobile NOx
- Elevated and low-level point source NOx
- On-road mobile VOC
- Area + off-road mobile VOC

Figure 7-3 shows the ozone response from each run with a 40 tpd reduction using 2010 design values at the nine monitors during the core and supplemental periods. At most stations, ozone was most sensitive to on-road mobile and area plus off-road mobile NOx controls, particularly at Denton and Forth Worth (CAMS 17). In Midlothian, Arlington, and Forth Worth (CAMS 13), ozone was more responsive to the point source NOx controls, most likely due to their proximity to Ellis County, which emitted almost half of all point source NOx emissions in the DFW 9-county area.

In the core period, Frisco and Dallas (CAMS60) were slightly more responsive to low-level NOx controls when compared to the previous Run 17b, and Midlothian was more responsive to the point source NOx reduction.

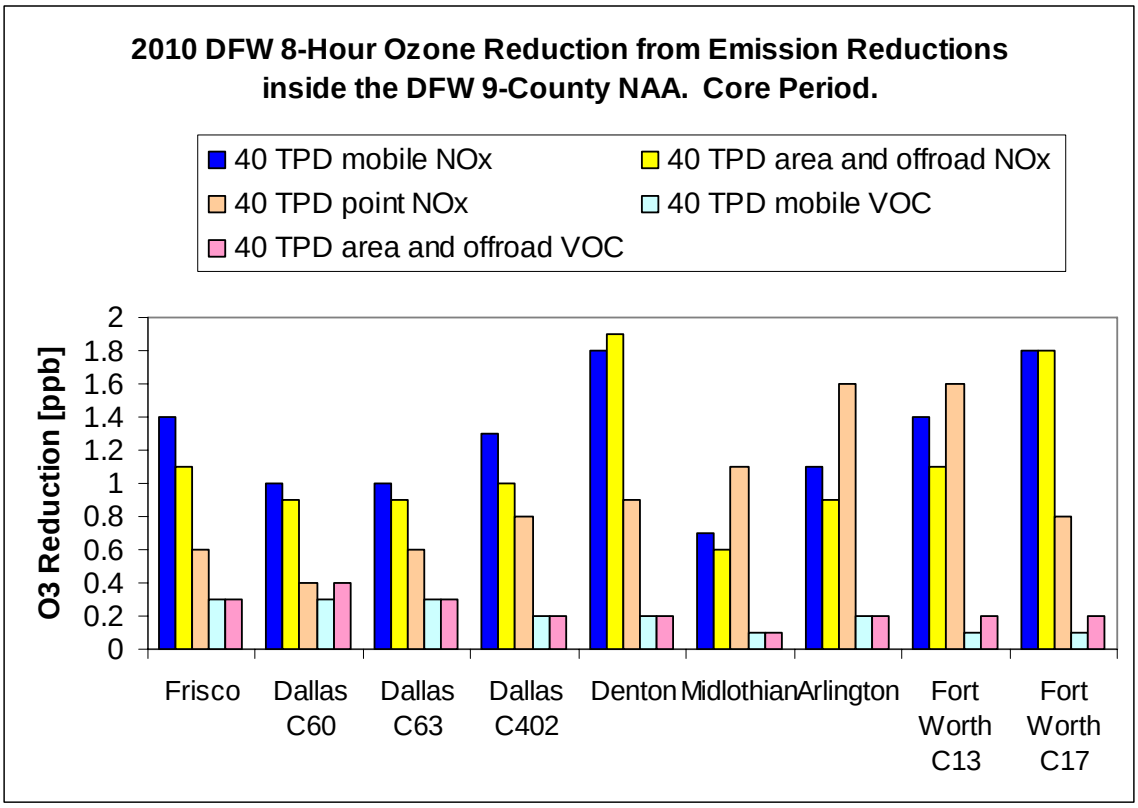
In the supplemental period, ozone was slightly less responsive to the low-level NOx controls when compared to the core period at all monitors except Fort Worth (CAMS 13). The extended period appeared to be a little more sensitive to VOC controls, but these responses were generally weaker than those from NOx controls.

In both the core and supplemental periods, Frisco was most responsive to on-road mobile NOx controls, and area plus off-road mobile NOx controls. Frisco was only about half as responsive to point source NOx reductions in the DFW 9-county area. Source apportionment analysis showed that Dallas County's on-road mobile and off-road mobile plus area emissions were the largest contributors to Frisco's peak 8-hour ozone; reductions in these emission groups in Dallas County could play a significant role in reducing 8-hour ozone near Frisco.

Texas EGU Reductions

NOx reductions from approximately 100 major EGUs across Texas, but outside of the DFW 9-county area also were evaluated. The EGU control scenario approximated the impact of applying the emission limits for the Houston and Dallas non-attainment areas across all of eastern Texas. The majority of the reductions were in Northeast Texas and Central Texas, where NOx from point sources was reduced 50 %. The EGU reduction outside of DFW benefited 8-hour ozone at all monitoring sites on all modeling dates. The greatest benefits were a 4.1 ppb reduction in 8-hour ozone at Midlothian on August 16 and a 3.2 ppb reduction at Frisco on August 19. Design value analysis using 1999 as a base case lowered the 2010 design values from 0.8 ppb at Denton to 1.6 ppb at Midlothian. A combination of NOx controls from EGUs outside of Texas and across the board NOx reductions in the DFW 9-county area was not

analyzed.



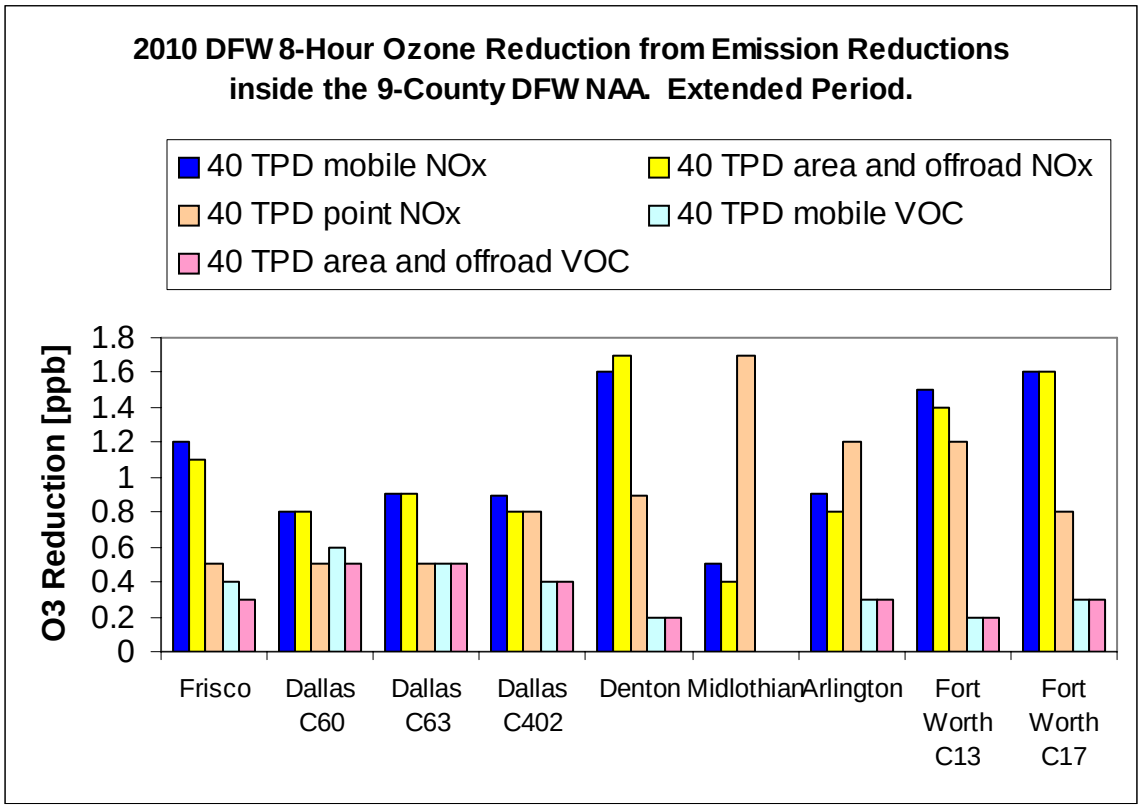


Figure 7-3. Change in the 2010 8-hour ozone design values from 40 tons per day emission reductions in the core (top) and supplemental (bottom) periods.

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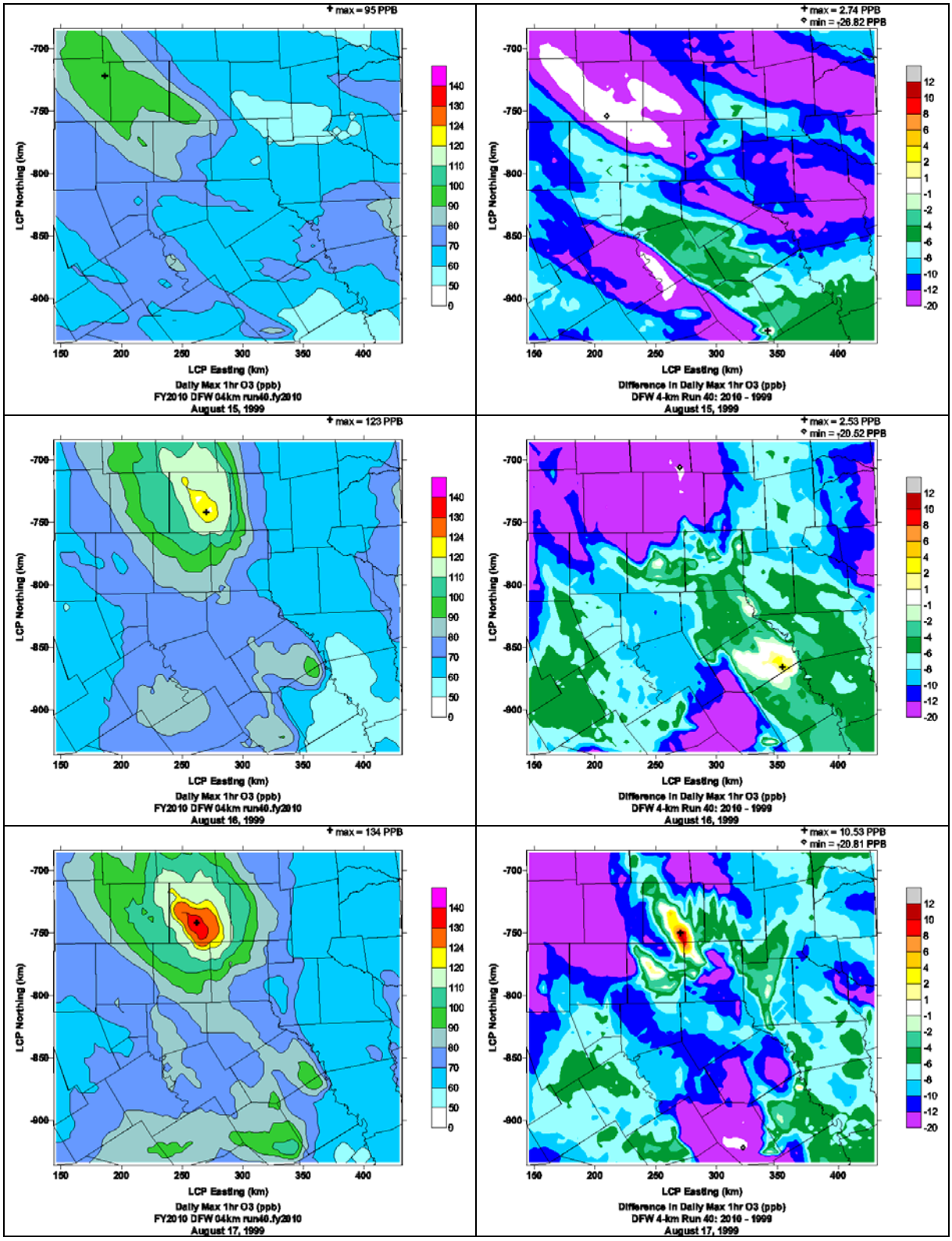
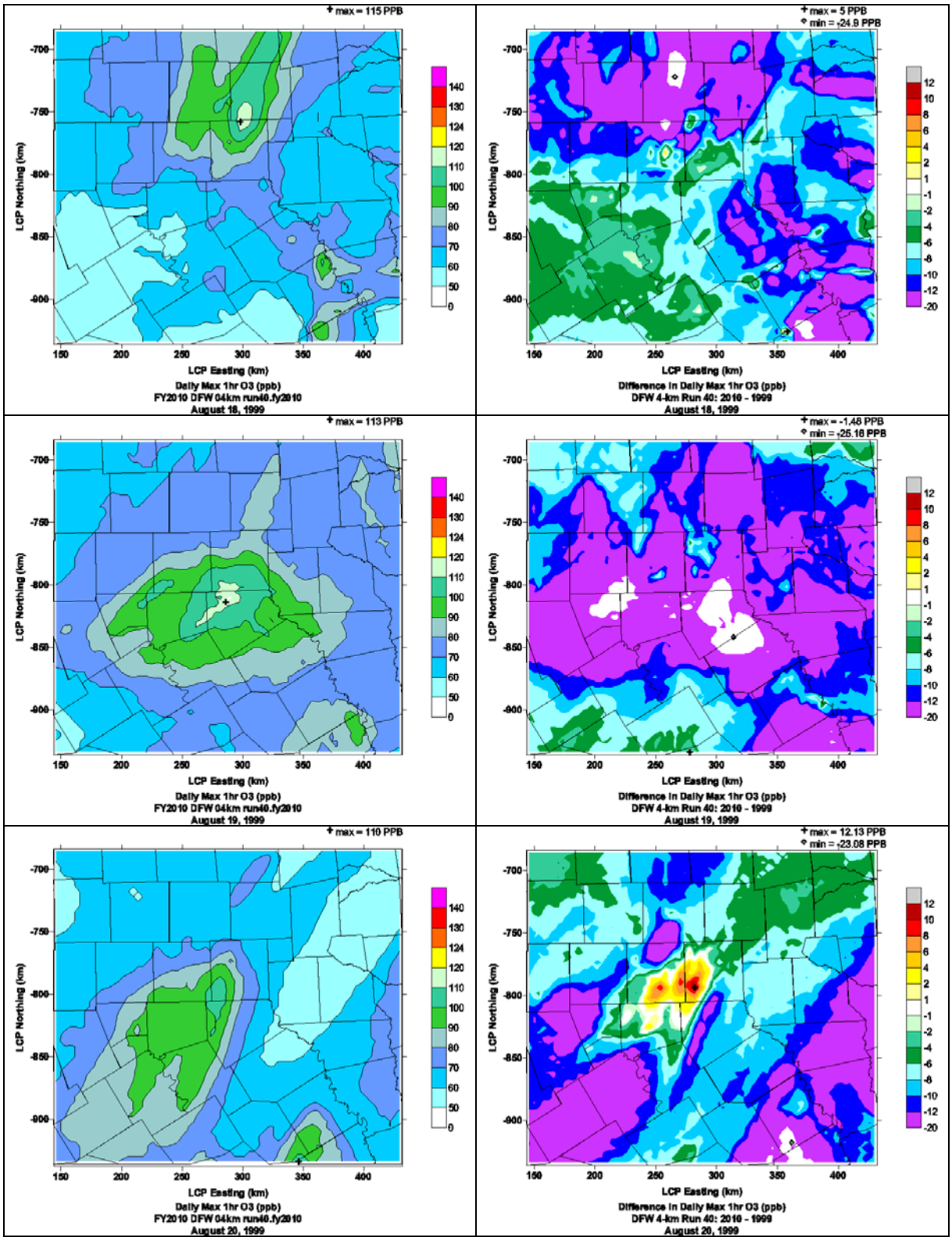
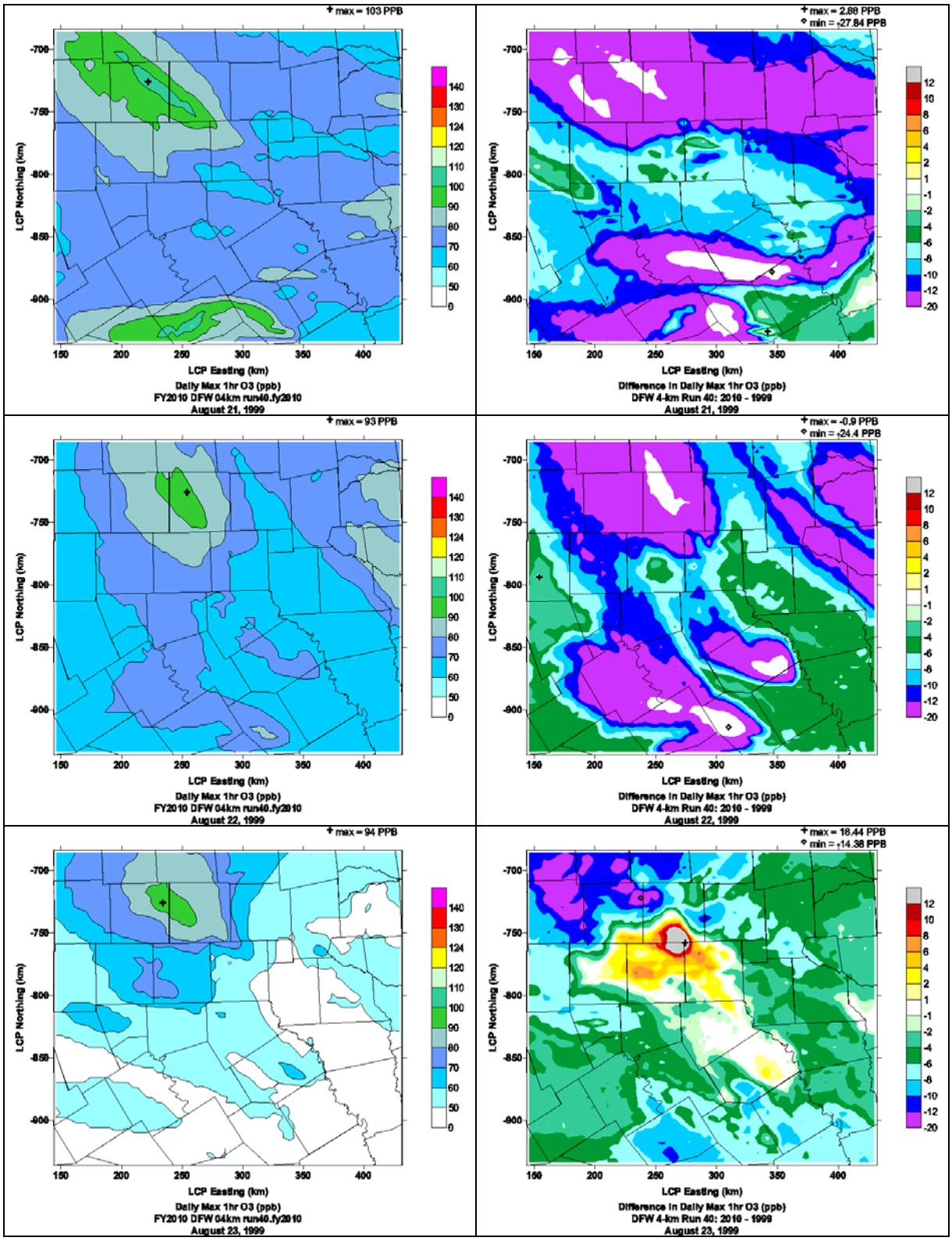
Tai, E., C. Emery, Y. Jia, and G. Yarwood. 2005. "Dallas/Fort Worth CAMx Modeling: Improved Model Performance and Transport Assessment." HARC Project H35, Phase 2. Prepared for The Houston Advanced Research Center. August.

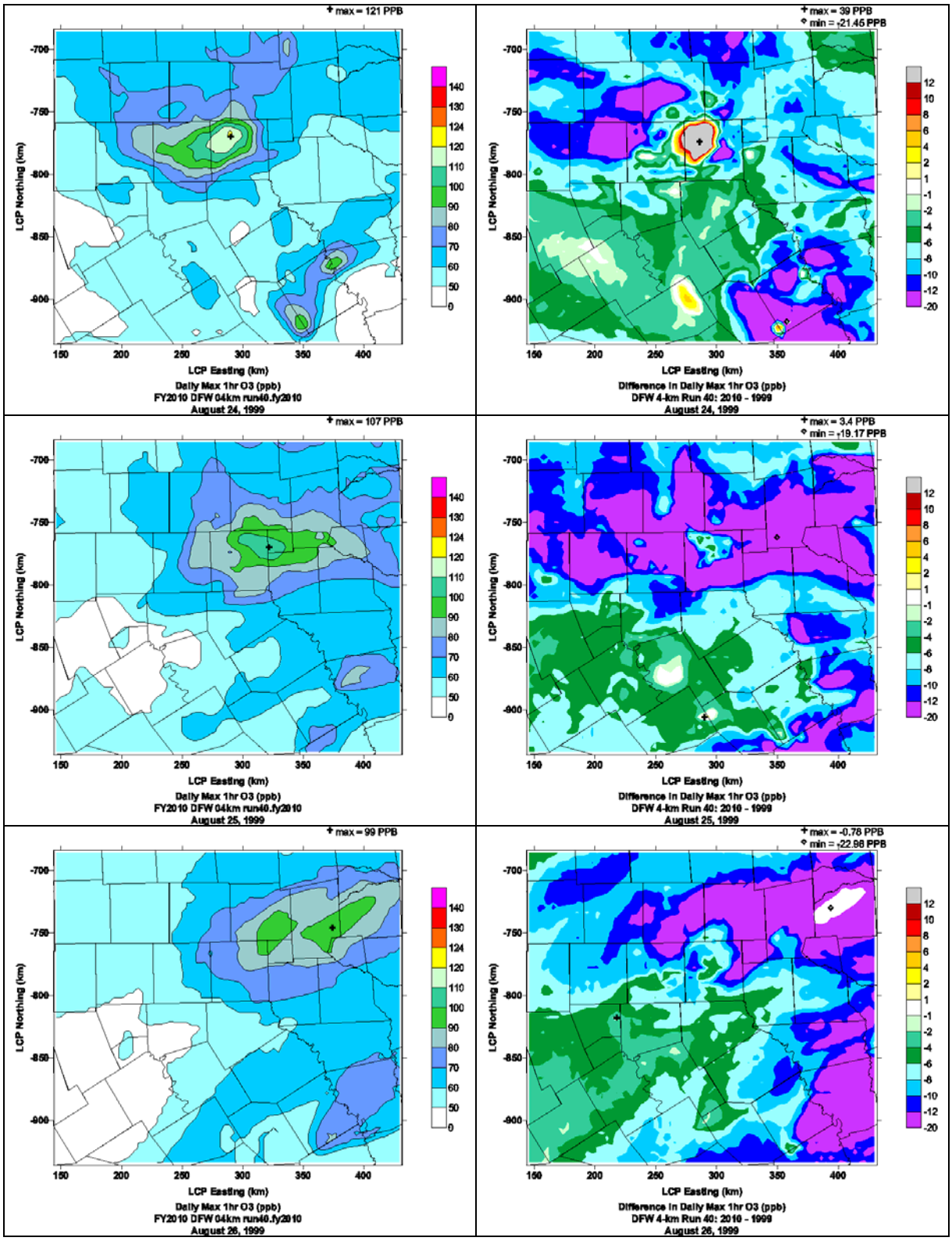
Appendix A

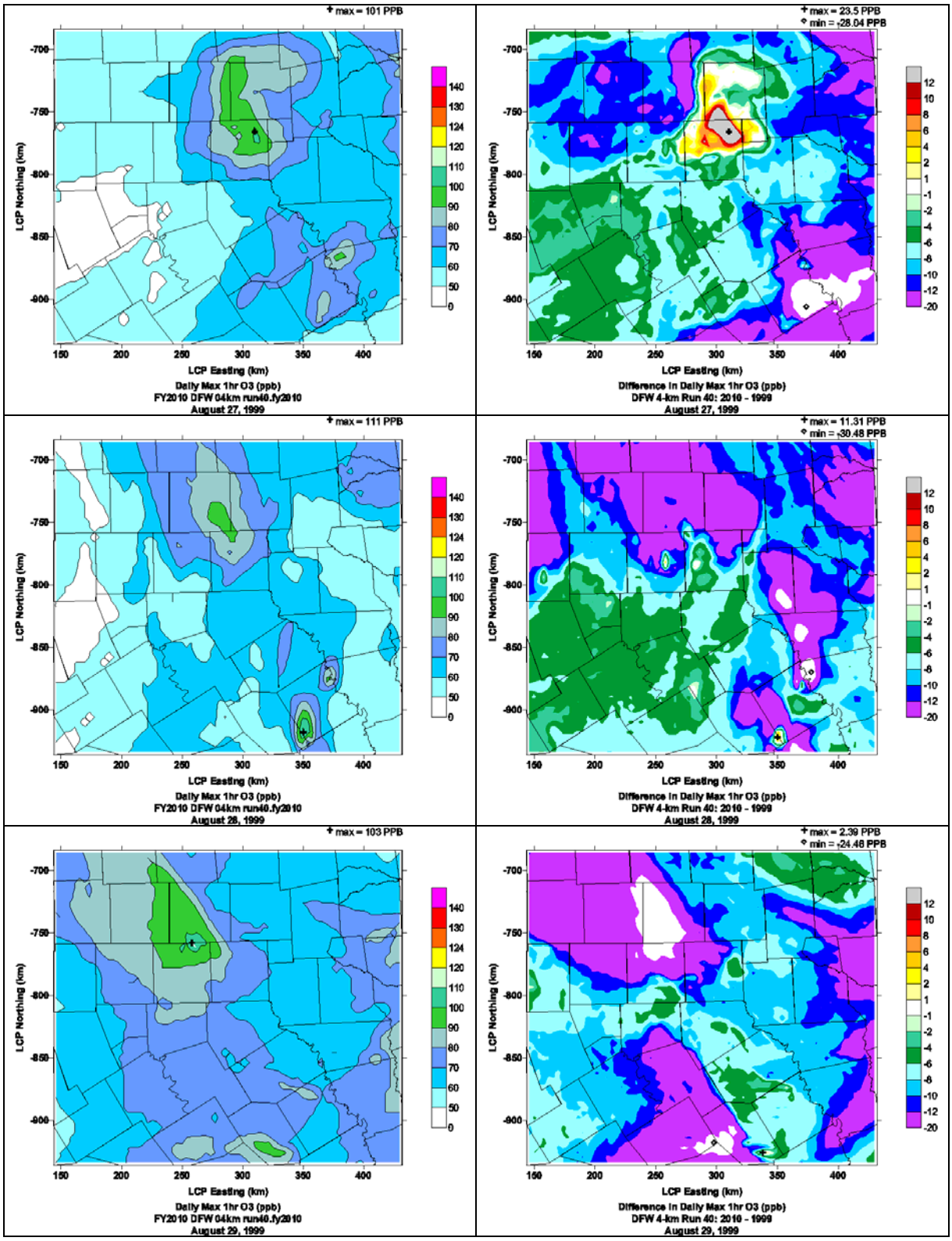
Daily maximum 1-hour ozone in the DFW 4 km domain in 2010 (left) and difference in daily maximum 1-hour ozone between 1999 and 2010 (right) for each date in the core and supplemental periods.

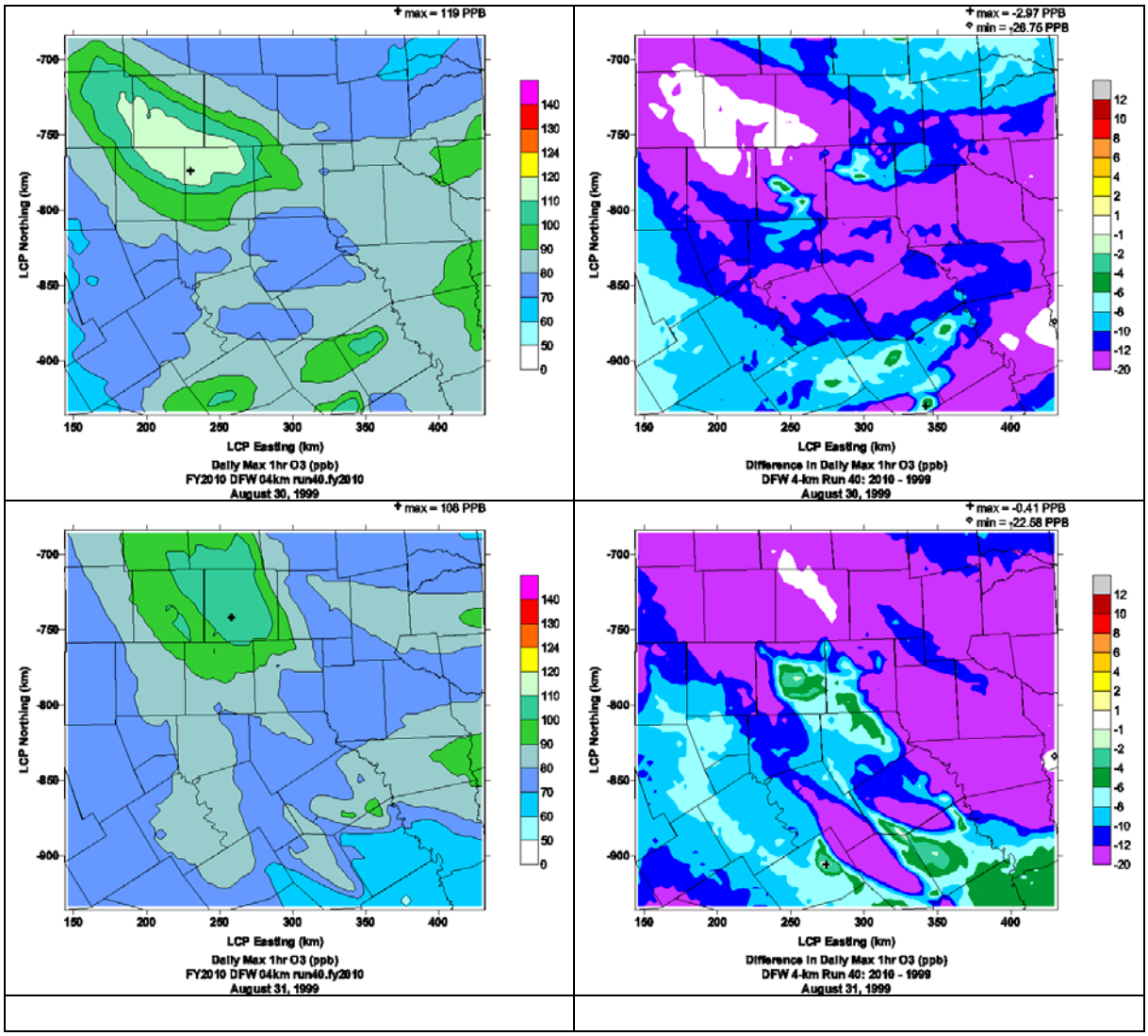

max = 95 PPB
LCP Northing (km)
LCP Easting (km)
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 15, 1999
max = 2.74 PPB
min = -26.82 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 15, 1999
max = 123 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 16, 1999
max = 2.53 PPB
min = -20.52 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 16, 1999
max = 134 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 17, 1999
max = 10.53 PPB
min = -20.81 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 17, 1999


+ max = 115 PPB
LCP Northing (km)
LCP Easting (km)
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 18, 1999
+ max = 5 PPB
min = -24.8 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 18, 1999
+ max = 113 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 19, 1999
+ max = -1.48 PPB
min = -25.16 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 19, 1999
+ max = 110 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 20, 1999
+ max = 12.13 PPB
min = -23.08 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 20, 1999


+ max = 103 PPB
LCP Northing (km)
LCP Easting (km)
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 21, 1999
+ max = 2.88 PPB
◇ min = -27.84 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 21, 1999
+ max = 93 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 22, 1999
+ max = -0.9 PPB
◇ min = -24.4 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 22, 1999
+ max = 94 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 23, 1999
+ max = 16.44 PPB
◇ min = -14.38 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 23, 1999


+ max = 121 PPB
LCP Northing (km)
LCP Easting (km)
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 24, 1999
+ max = 39 PPB
min = -21.45 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 24, 1999
+ max = 107 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 25, 1999
+ max = 3.4 PPB
min = -19.17 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 25, 1999
+ max = 99 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 26, 1999
+ max = -0.78 PPB
min = -22.98 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 26, 1999


+ max = 101 PPB
LCP Northing (km)
LCP Easting (km)
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 27, 1999
+ max = 23.5 PPB
- min = -28.04 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 27, 1999
+ max = 111 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 28, 1999
+ max = 11.31 PPB
- min = -30.48 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 28, 1999
+ max = 103 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 29, 1999
+ max = 2.39 PPB
- min = -24.48 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 29, 1999


max = 119 PPB
LCP Northing (km)
LCP Easting (km)
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 30, 1999
max = -2.97 PPB
min = -26.75 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 30, 1999
max = 108 PPB
Daily Max 1hr O3 (ppb)
FY2010 DFW 04km run40.fy2010
August 31, 1999
max = -0.41 PPB
min = -22.58 PPB
Difference in Daily Max 1hr O3 (ppb)
DFW 4-km Run 40: 2010 - 1999
August 31, 1999