ENVIRON

MEMORANDUM

To: Jim Smith, TNRCC

From: Gerard Mansell and Greg Yarwood

Date: May 29, 2002

Subject: Additional Sensitivity Analyses of the September 8-11, 1993 Ozone Episode Using SAIMM Meteorology

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This memorandum documents the CAMx modeling performed in support of the TNRCC's current SIP development efforts in the Houston/Galveston and Beaumont/Port Arthur (HGBPA) ozone nonattainment areas (the Houston area). Recent studies evaluated new features of the CAMx air quality modeling system for the September 8-11, 1993 ozone episode and evaluated model performance under alternative emission scenarios (ENVIRON, 2002a). In addition, modeling efforts focused on the determination of alternative VOC emission reductions that would be required to compensate for modifying the NOx reductions currently implemented in the future year 2007 Strategy I8a scenarios (ENVIRON, 2002b; 2002c; 2002c). These studies evaluated the CAMx modeling results using various meteorological data fields developed with the MM5 and RAMS meteorological modeling systems and included a high-resolution (1.33-km) nested grid modeling domain over the Houston/Galveston Bay area. In the case of SAIMM meteorology, the flexi-nesting capabilities of the CAMx model were implemented to obtain modeling results on the 1.33-km Houston/Galveston Bay domain as no high resolution meteorology was developed with the SAIMM model.

The current study furthers the previous analyses and investigations through implementation of the CAMx modeling system for alternative industrial olefin emission reduction scenarios in the future year 2007 utilizing the SAIMM meteorological fields. The development of the modeling databases, including the model configuration and preparation of the alternative emission scenarios has been documented previously (ENVIRON, 2002a; 2002b).

Based on the results of earlier studies, and through consultation with the TNRCC, an alternative emission scenario corresponding to a 6x increase in the industrial olefin (IOLE) emissions within the eight-county Houston/Galveston Bay region was selected for the current analysis. Version 3.01 of the CAMx air quality model was applied to the September 8-11, 1993 ozone episode using the enhanced olefin emission scenario for both the 1993 base year as well as the 2007 future year. A series of simulations were then conducted wherein the industrial NOx emissions were first increased to reflect a less stringent NOx control strategy in the future year, followed by incremental reductions of the industrial olefin emissions. The results of these simulation were evaluated to determine whether less stringent NOx reductions could be compensated by greater reductions in 2007 industrial VOC emissions.

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For reference, Figure 1 displays the daily maximum ozone concentrations for the 1993 base case within the 4-km HGBPA modeling domain. Corresponding displays for the 6xIOLE scenario are presented in Figure 2. Performance statistics for both scenarios are presented in Table 1. With respect to EPA's model performance goals, the 1993 base case modeling results with the SAIMM meteorology exhibit acceptable model performance for all episode days. The 6xIOLE emission scenario also results in acceptable model performance with the exception of the unpaired peak accuracy metric. The effects of increasing industrial olefin emission on the peak ozone concentrations in the 1993 base year are seen to be an overall increase in the magnitude of the concentrations while the spatial distribution of elevated ozone concentrations are similar.

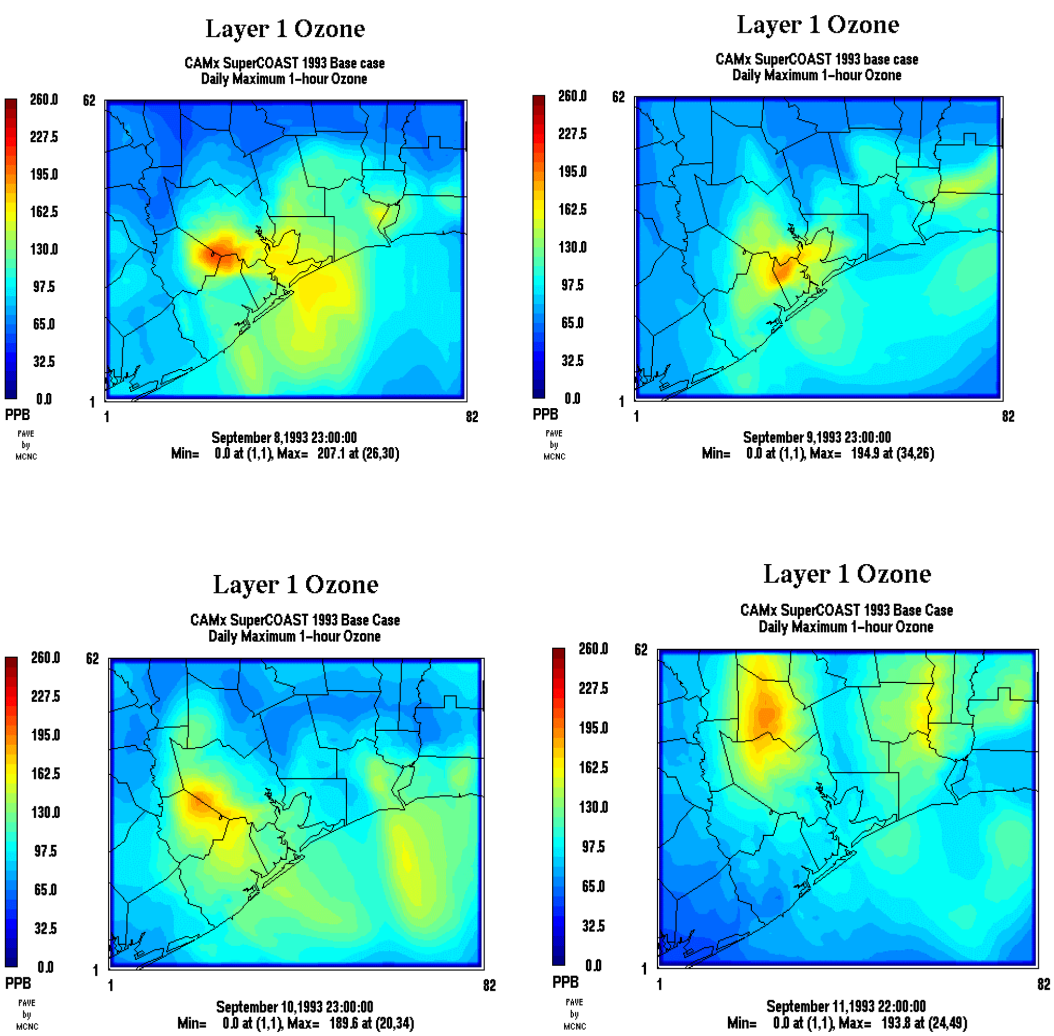


Figure 1. Daily maximum ozone concentrations for 1993 Base Case (scale max = 260 ppb).

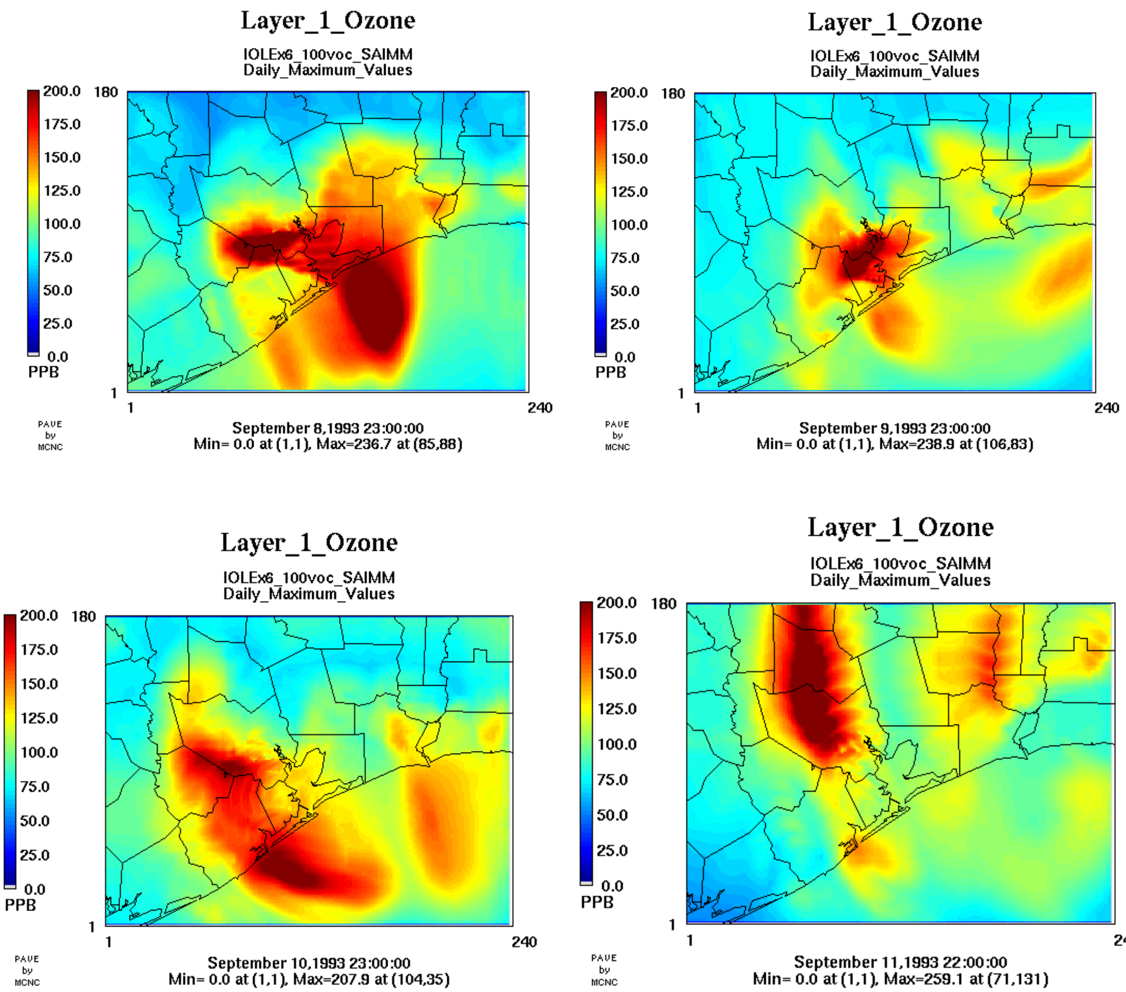


Figure 2. Daily maximum ozone concentrations for 1993 6xIOLE emission scenario (scale max = 200 ppb).

Table 1. Performance Statistics for CAMx SuperCOAST Simulations

Performance Attribute	EPA Goal	8 Sept	9 Sept	10 Sept	11 Sept
Maximum Observed Concentration (ppb)		214.0	195.0	162.0	189.0
Maximum Modeled Conc. (ppb)					
CAMx v3.01 Base Case		207.1	198.0	189.6	193.8
600ole.100voc		236.7	238.9	207.9	259.1
Accuracy of Unpaired Peak (%)	<=20%				
CAMx v3.01 Base Case		-3.2	1.5	17.1	2.5
600ole.100voc		10.6	22.5	28.3	37.1
Mean Normalized Bias (%)	<=15%				
CAMx v3.01 Base Case		7.1	5.3	-10.1	0.7
600ole.100voc		14.6	10.5	-1.5	12.1
Mean Normalized Gross Error (%)	<=35%				
CAMx v3.01 Base Case		25.4	27.4	25.7	21.4
600ole.100voc		27.7	28.5	24.7	22.3

Figures 3 and 4 display the modeled peak ozone concentrations in the 4-km HGBPA modeling domain for the 2007 Strategy I8a and the 2007 6xIOLE simulations, respectively. Similar to the 1993 scenarios, increasing industrial olefin emissions results in increased peak ozone concentrations with roughly the same spatial distribution as the 2007 Strategy I8a simulation..

Table 2 presents the predicted daily maximum 1-hour ozone concentrations for the future year emission scenarios considered in the current analysis. Corresponding spatial displays of the predicted peak ozone concentrations for each scenario are presented in Figures 5 through 7 and Figures 11 through 13 for the 80% and 85% industrial NOx emission reductions series of simulations, respectively.

Table 2. Daily maximum ozone concentrations (ppb) in the 4-km HGBPA domain

Scenario	9/8	9/9	9/10	9/11
90nox 600ole	159.8	185.5	150.1	164.4
80nox 600ole	169.4	200.6	151.5	175.0
80nox 500ole	167.7	192.2	151.3	175.0
80nox 400ole	165.9	182.1	151.1	168.7
80nox 300ole	164.1	169.9	150.9	165.3
80nox 200ole	162.7	155.3	150.7	161.5
80nox 100ole	161.3	151.4	150.5	157.3
80nox 0ole	160.3	149.4	150.3	152.7
85nox 600ole	164.6	193.9	150.8	170.3

85nox 500ole	163.1	185.8	150.6	167.7
85nox 400ole	161.9	178.3	150.4	164.8
85nox 300ole	160.8	169.3	150.2	161.6
85nox 200ole	159.8	158.1	150.0	158.2
85nox 100ole	159.0	148.3	149.8	154.5
85nox 0ole	158.2	147.4	149.6	150.6

The effects of doubled industrial NOx emissions and enhanced industrial olefin emission levels on the 2007 future year scenario are displayed in Figure 8. Increasing the industrial NOx emissions within the Houston/Galveston Bay area has the effect of increasing the ozone concentrations in a broad region over the Houston Ship Channel, Galveston Bay and offshore on the Sept. 8th and 9th episode days. Smaller regions of increased ozone levels are obtained on the 10th and 11th and tend to be downwind of the Houston area. The magnitude of the increases ranges from approximately 12 to 20 ppb. Small, localized ozone decreases are also realized due to increasing industrial NOx emissions.

Figure 9 illustrates the effects of "doubled" industrial NOx emission and a 50% reduction of industrial olefin emissions. In general, broad regions of ozone increases within and downwind of the Houston Ship Channel are the result of increases in industrial NOx emissions. The increases in peak ozone concentrations range from approximately 8 ppb to 10 ppb, depending on the simulation day. Decreases in daily maximum ozone concentrations are also realized, due to decreased industrial olefin emissions. These decreases tend to be somewhat localized on the 8th and 9th ranging from approximately 39 ppb on Sept. 8th to approximately 42 ppb on the 9th of September. The Sept. 10th and 11th simulation days show larger regions of ozone decreases due to the decreased IOLE emissions in the Houston urban region and southwest of Galveston Bay extending offshore into the Gulf. These results serve to illustrate the trade-off between doubling industrial NOx emissions and halving industrial VOC emissions within the 8-county Houston-Galveston area and can be seen to vary considerably depending on the episode day. The maximum potential ozone reductions achievable for the 80% NOx emission reduction levels are displayed in Figure 10. As seen in these displays, the regions of reduced ozone concentrations are larger than the 50% IOLE reduction scenario with approximately the same spatial distribution. The maximum ozone reductions range from approximately 32 ppb on the 10th to over 70 ppb on the 9th of September. Qualitatively similar results are obtained for other VOC reduction levels as well as for the 85% industrial NOx series of simulations as shown in Figure 14 through Figure 16.

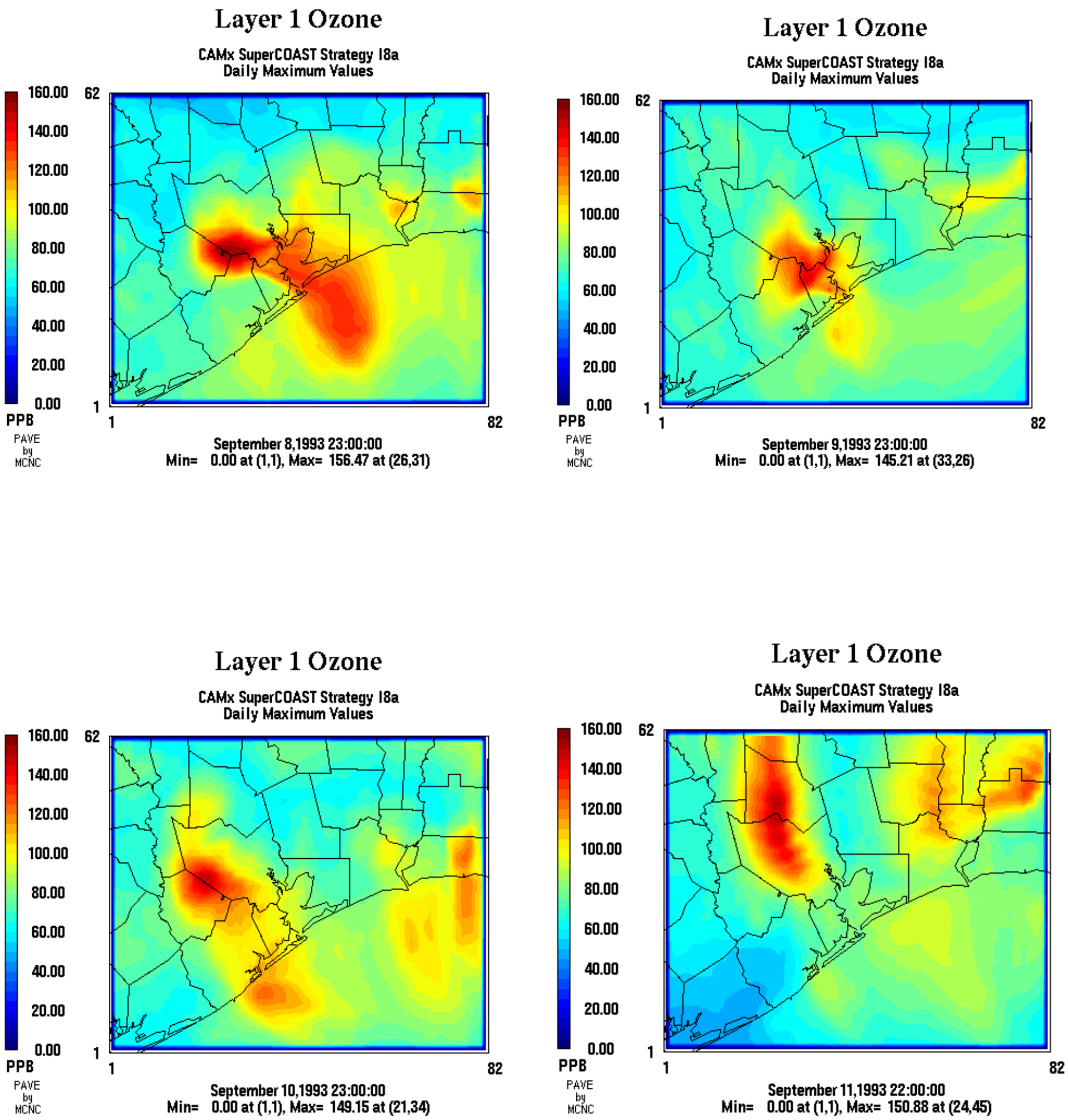


Figure 3. Daily maximum ozone concentrations for 2007 Strategy I8a scenario (scale max = 160 ppb).

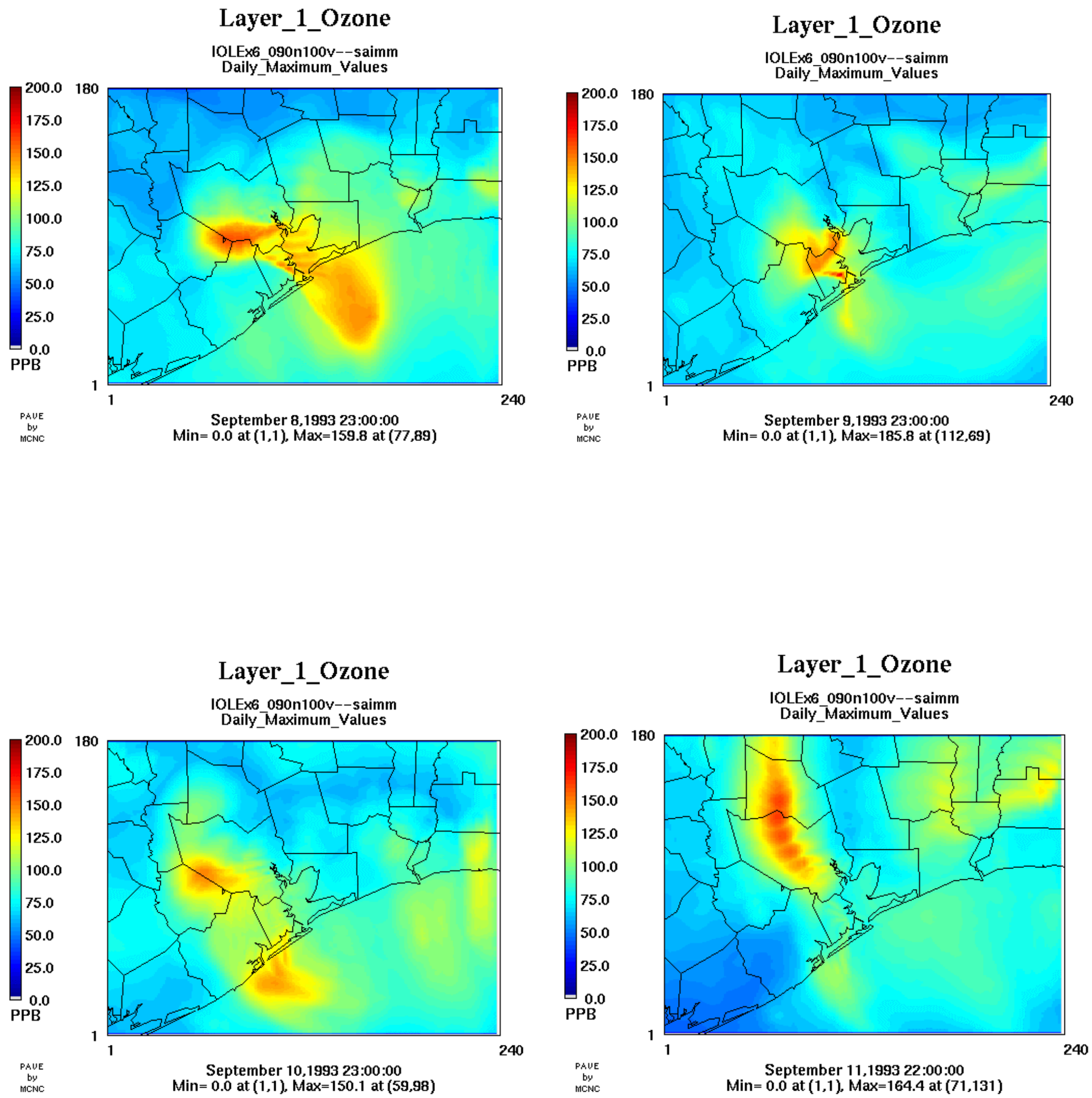


Figure 4. Daily maximum ozone concentrations for 2007 6xIOLE emission scenario at Strategy I8a NOx emission levels (90% NOx reduction) (scale max = 200 ppb).

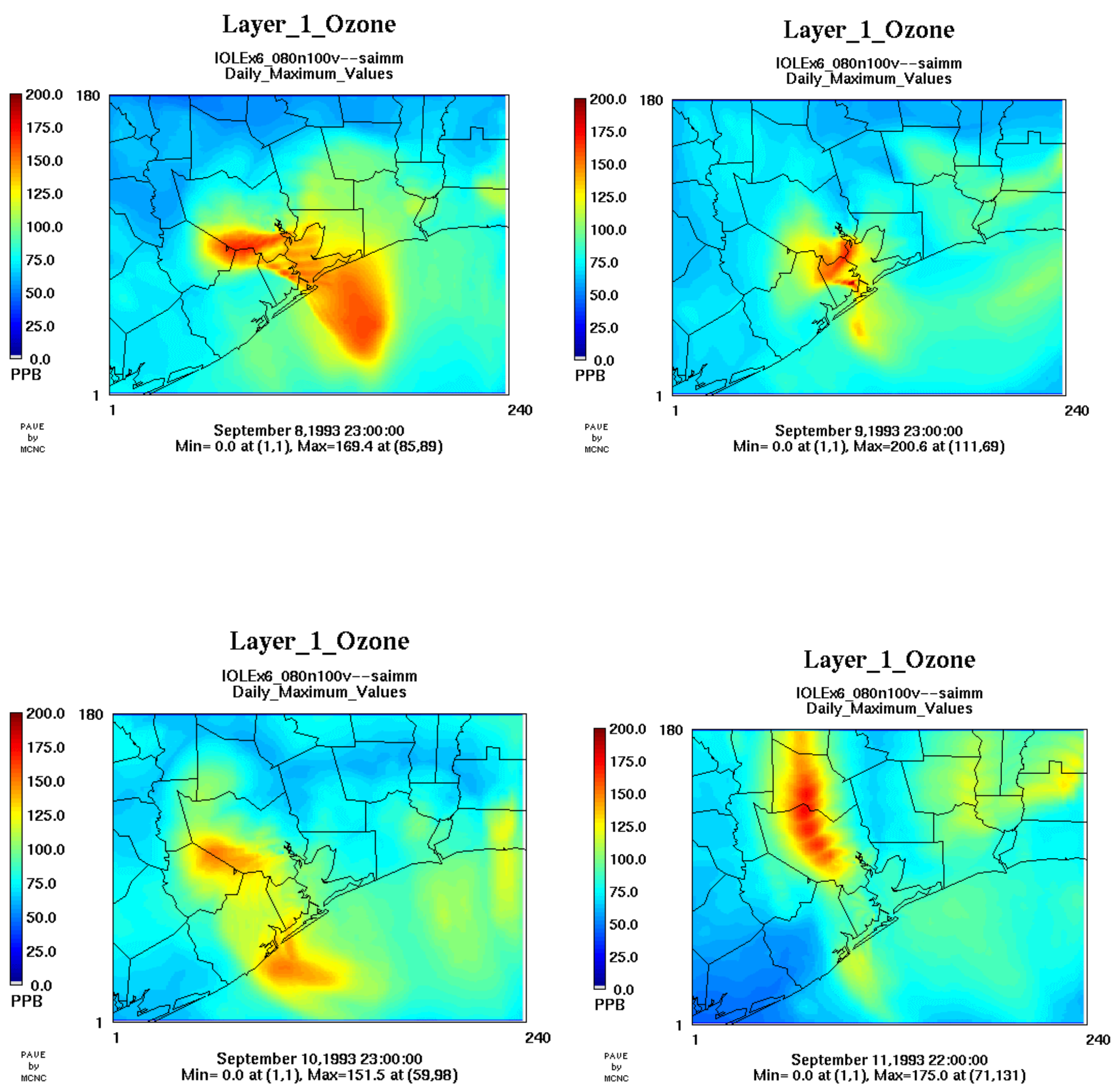


Figure 5. Daily maximum ozone concentrations for 2007 6xIOLE emission scenario at doubled Strategy I8a industrial NOx emission levels (80% NOx reduction).

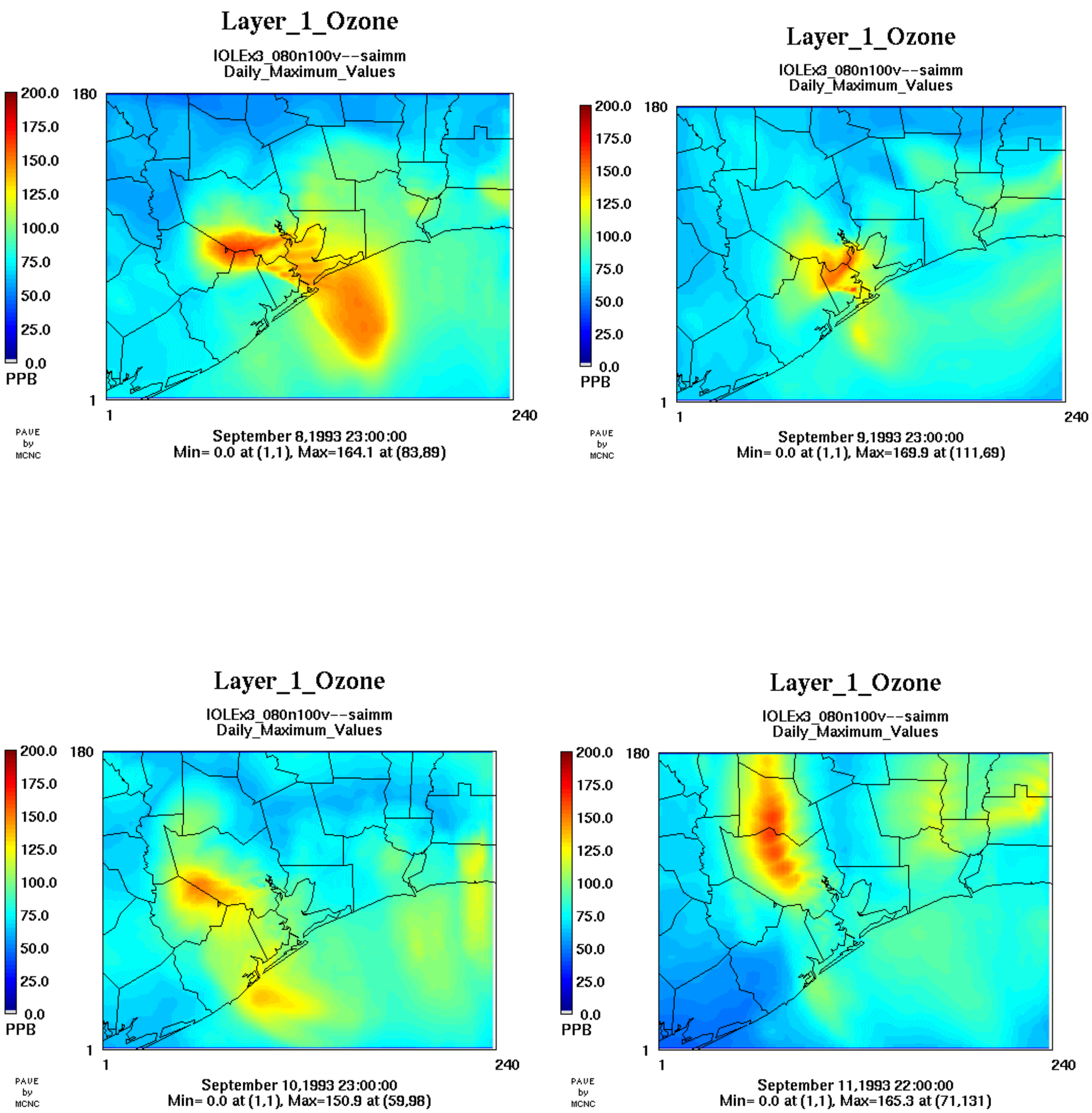


Figure 6. Daily maximum ozone concentrations for future year 2007 at 50% industrial olefin emission reduction and doubled Strategy I8a industrial NOx emission levels (80% NOx reduction).

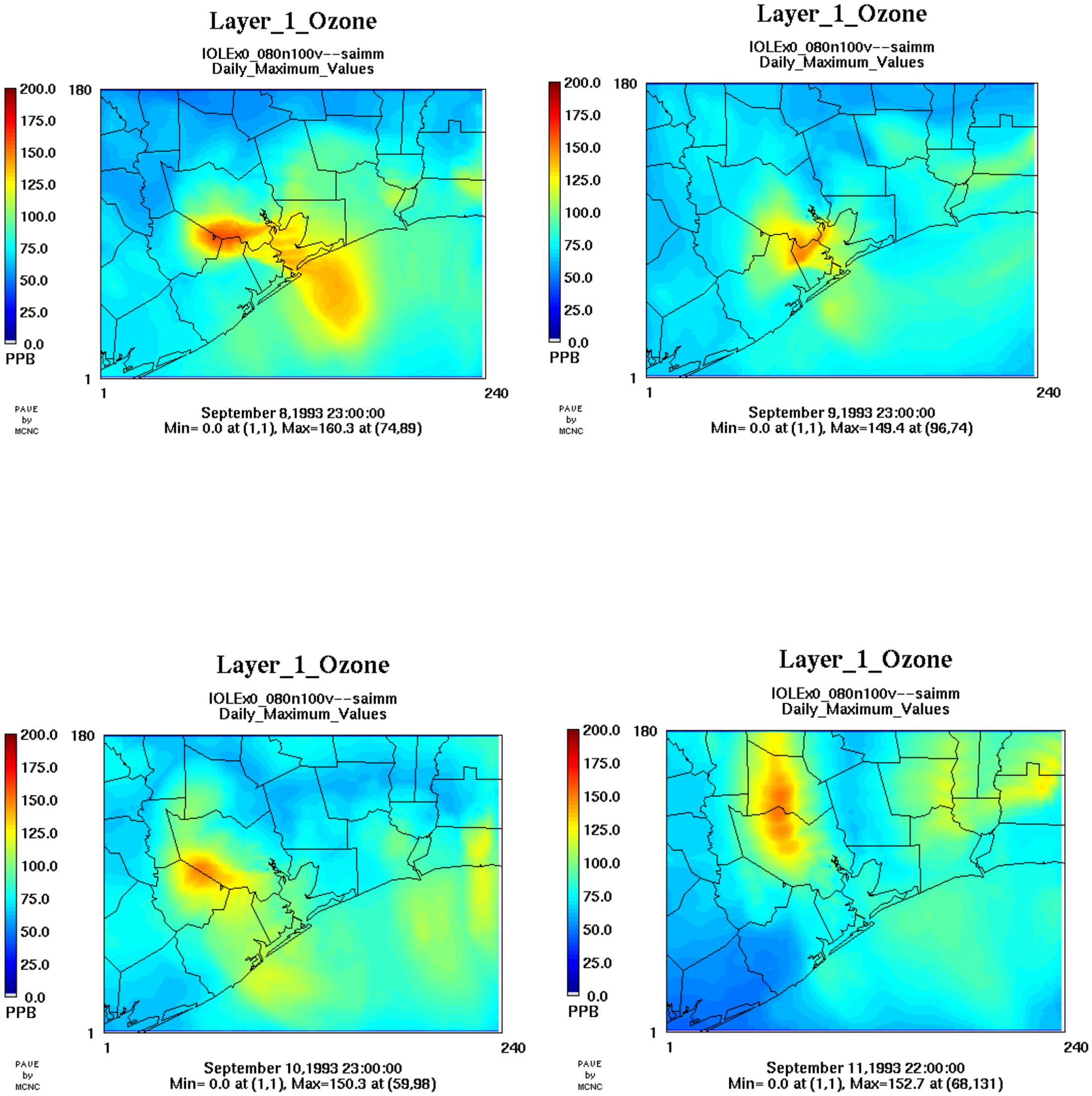


Figure 7. Daily maximum ozone concentrations for future year 2007 at 100% industrial olefin emission reduction and doubled Strategy I8a industrial NOx emission levels (80% NOx reduction).

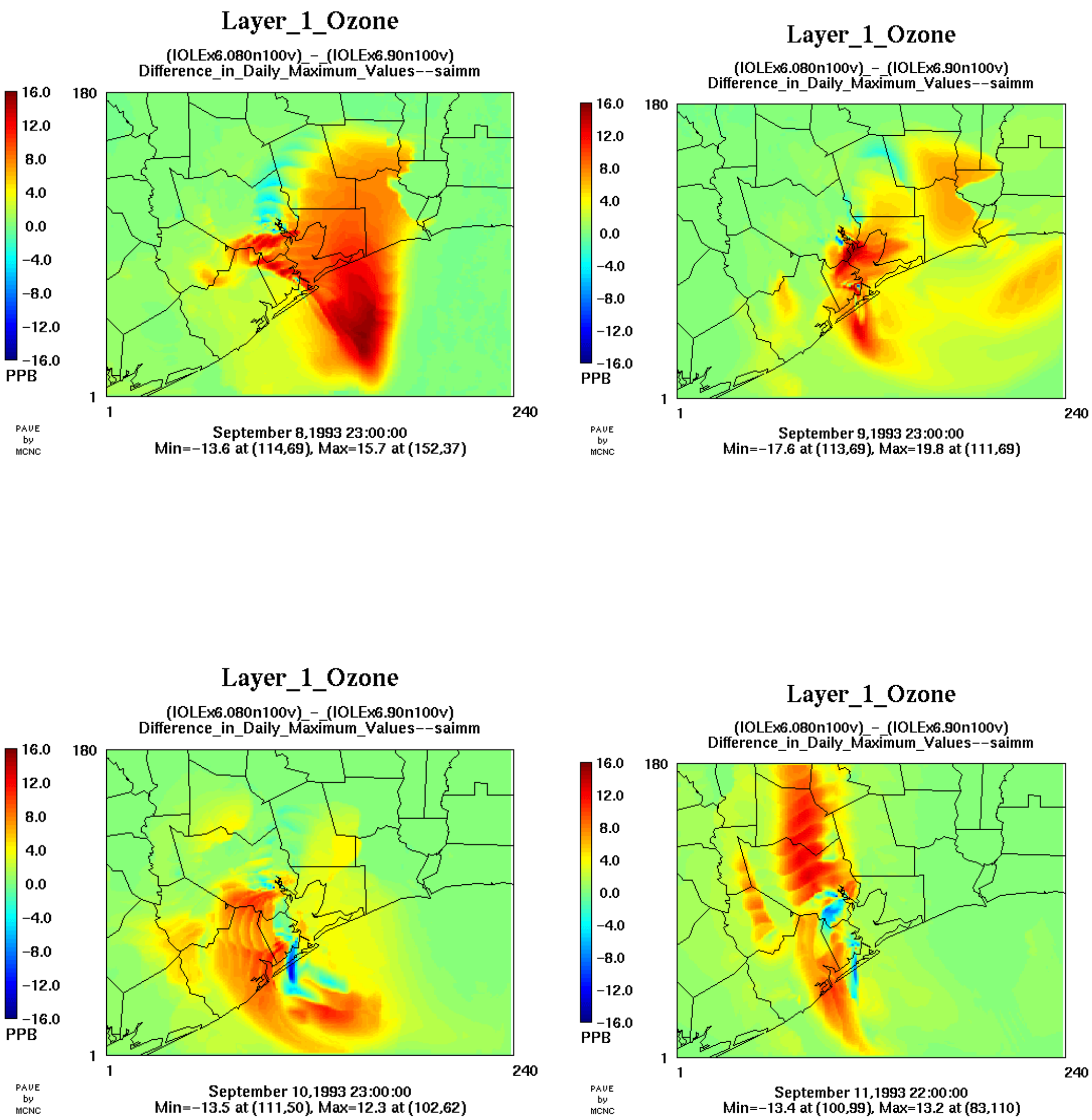


Figure 8. Effects on daily peak ozone concentrations of doubled industrial NOx emissions from 2007 I8a base case levels with 6x industrial olefins

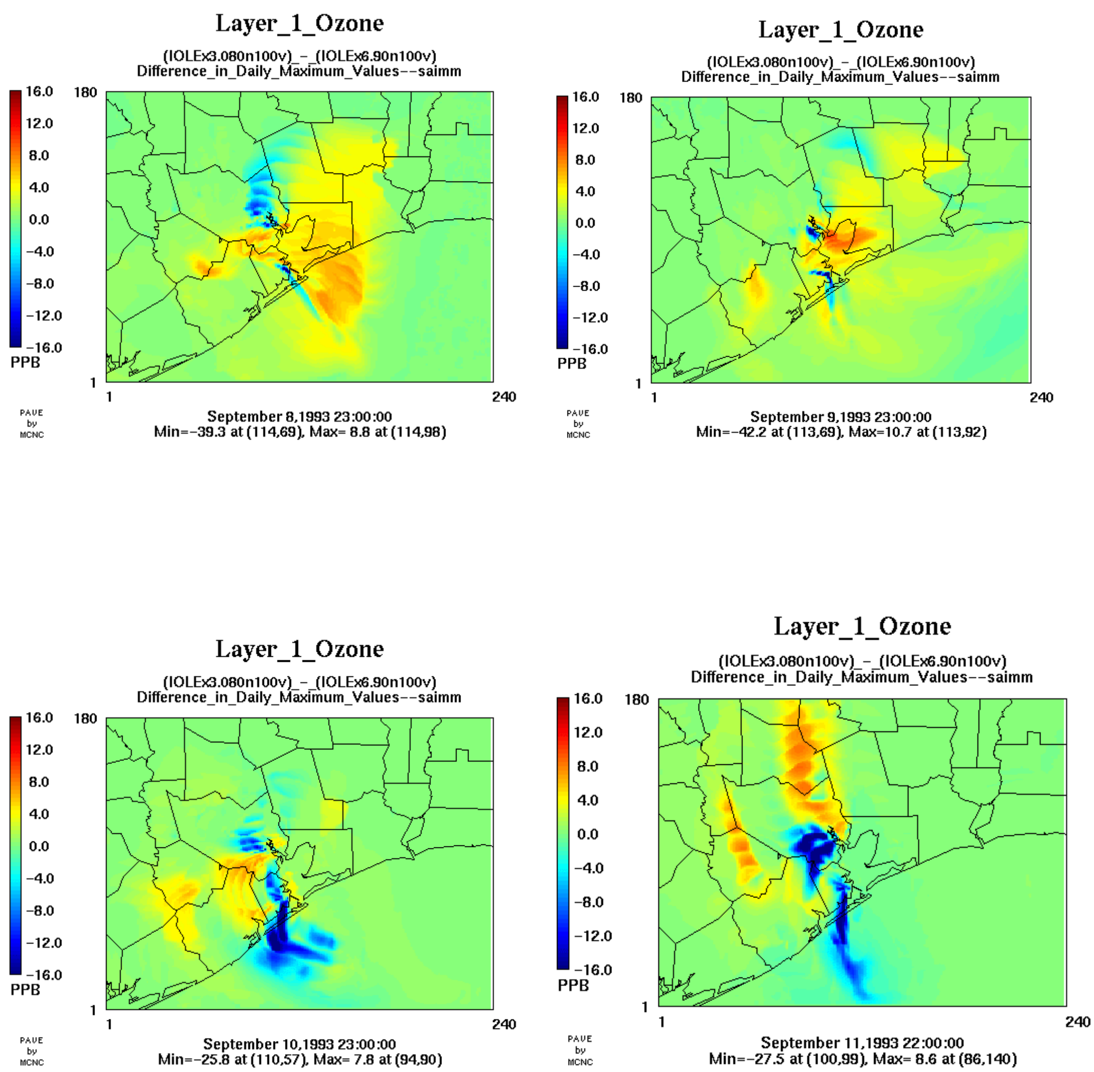


Figure 9. Effects of doubled industrial NOx emissions and 50% reduction of industrial olefin emissions on daily peak ozone concentrations.

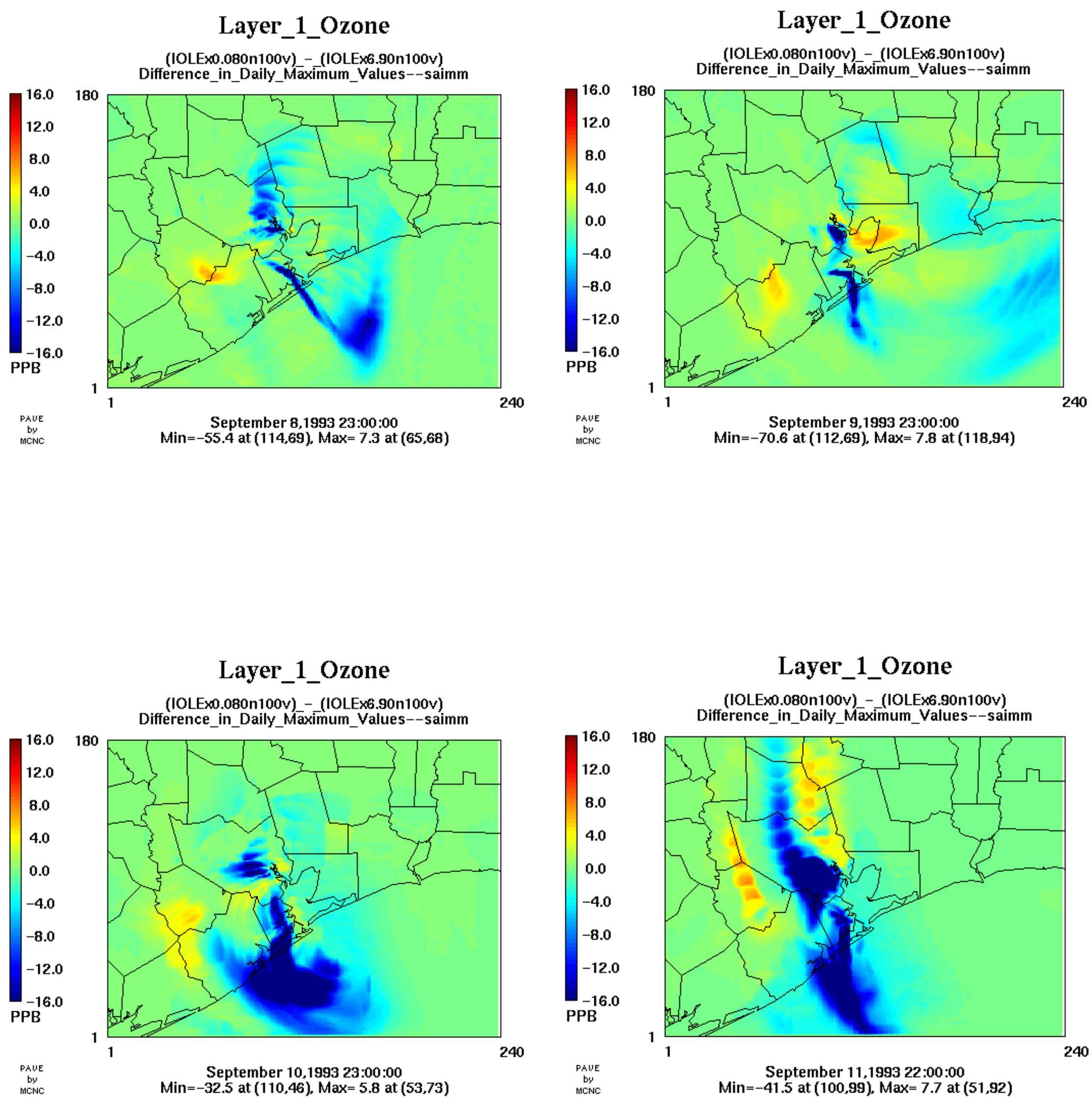


Figure 10. Maximum potential ozone reductions from the 200% I8a NOx emission levels (80% reduction) resulting from 100% reductions of IOLE emissions.

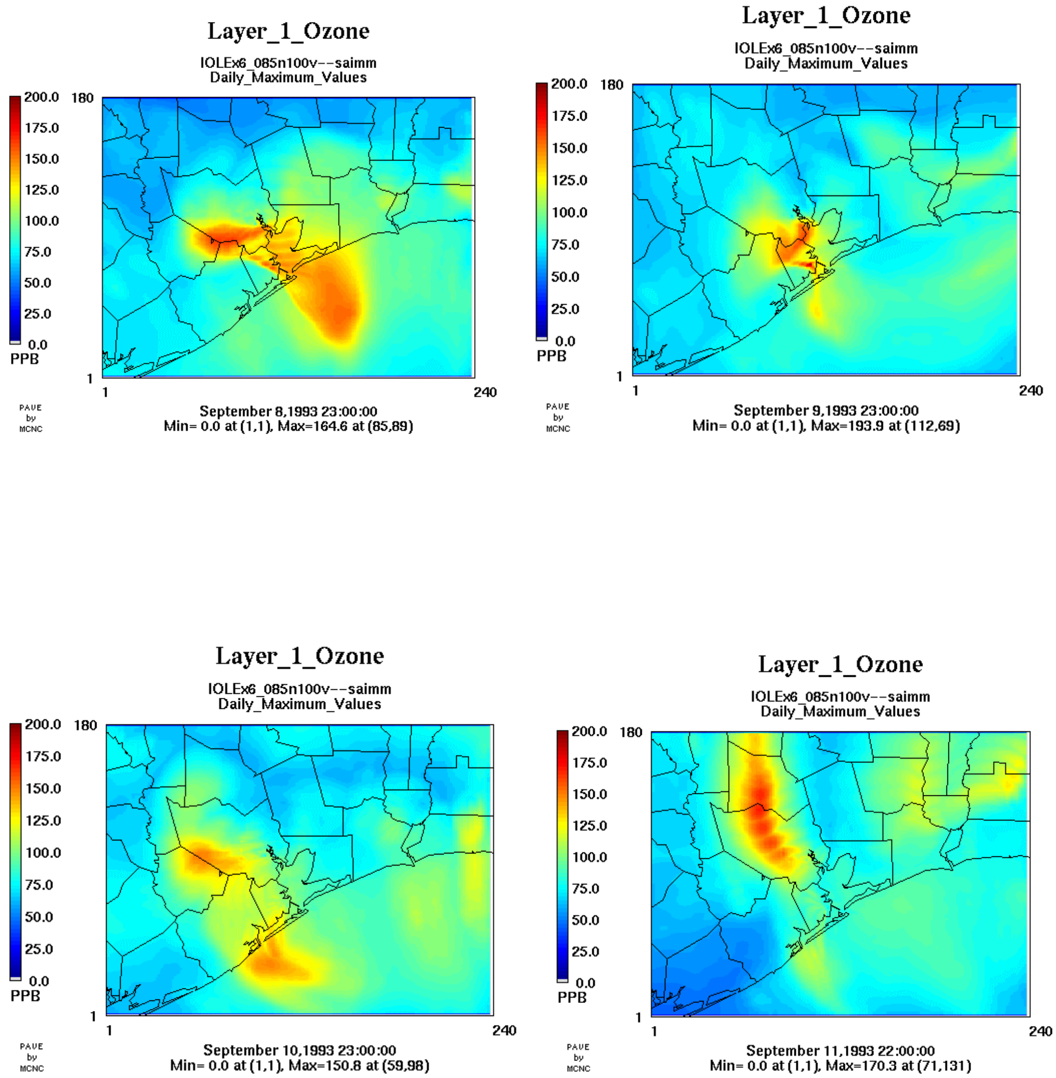


Figure 11. Daily maximum ozone concentrations for 2007 6xIOLE emission scenario at 150% Strategy I8a industrial NOx emission levels (85% NOx reduction).

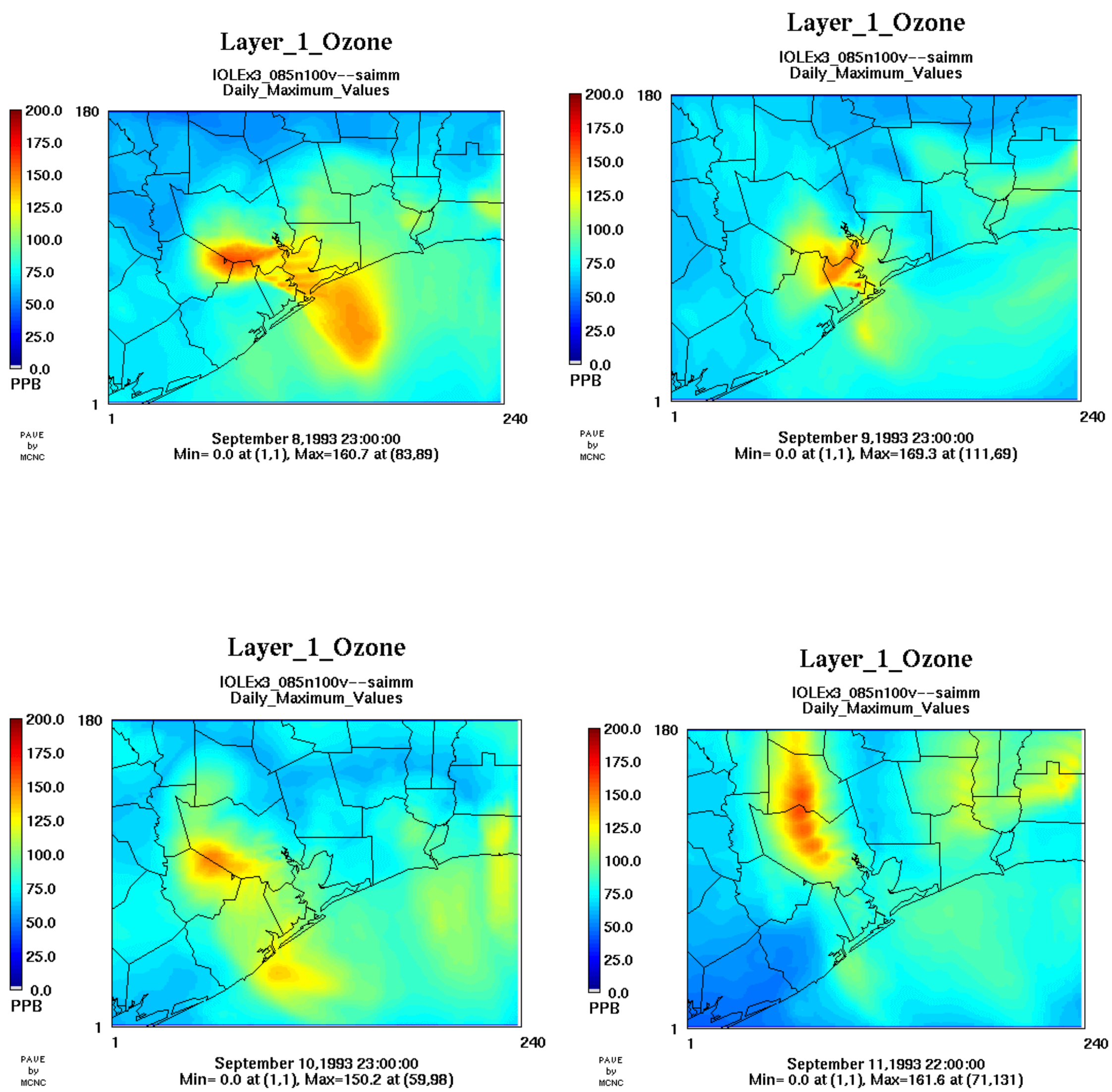


Figure 12. Daily maximum ozone concentrations for future year 2007 at 50% industrial olefin emission reduction and 150% Strategy I8a industrial NOx emission levels (85% NOx reduction).

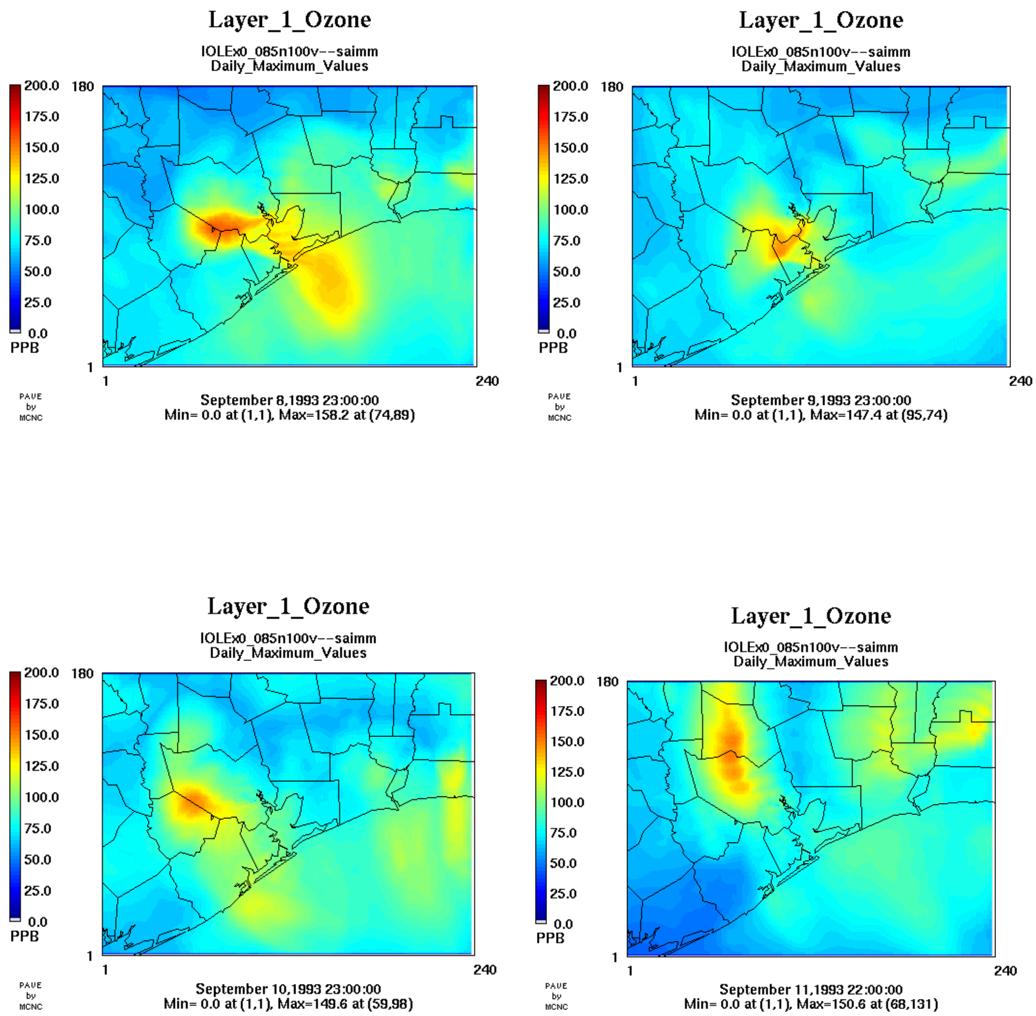


Figure 13. Daily maximum ozone concentrations for future year 2007 at 100% industrial olefin emission reduction and 150% Strategy I8a industrial NOx emission levels (85% NOx reduction).

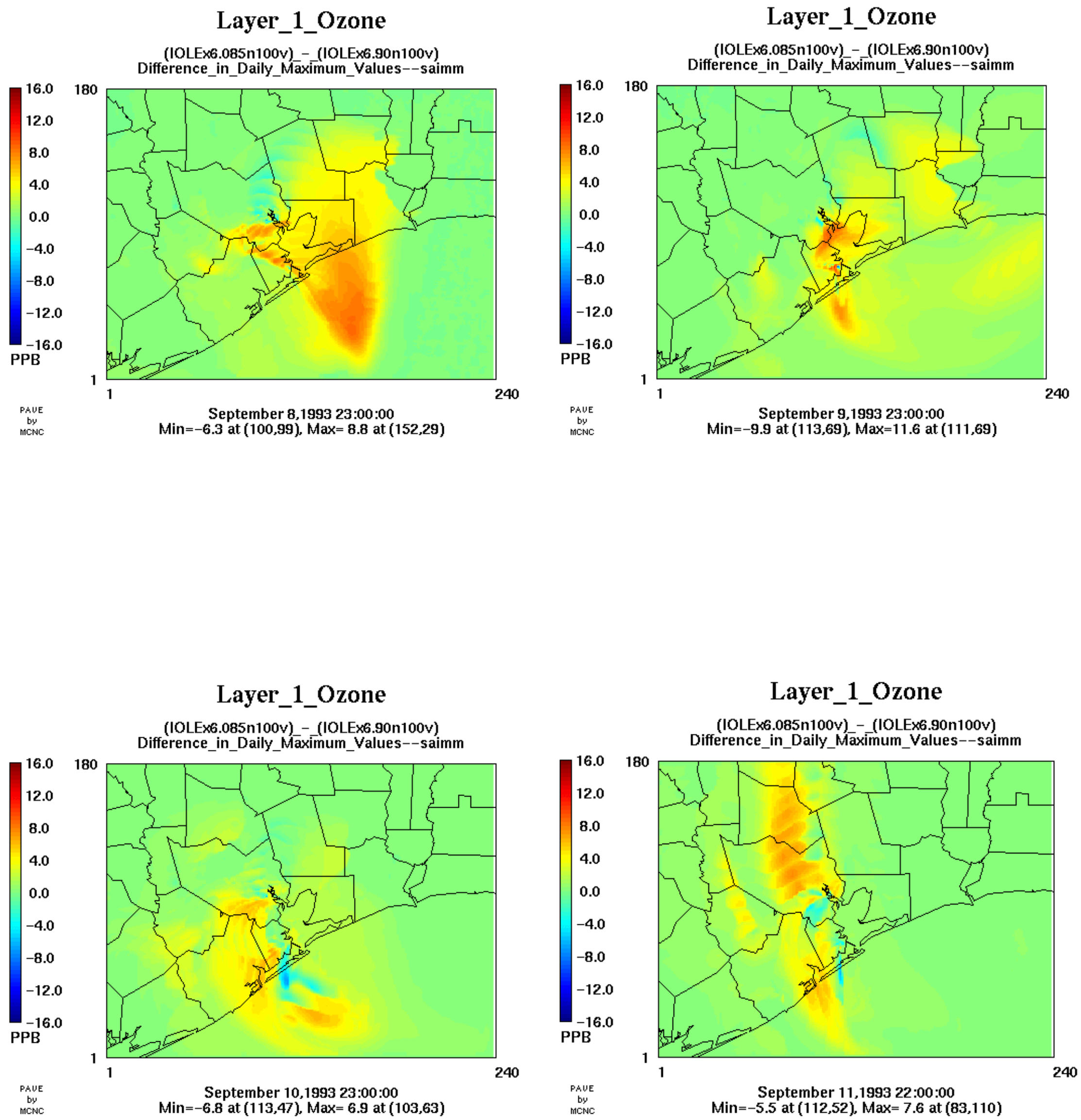


Figure 14. Effects of 150% industrial NOx emissions (85% reduction) on daily peak ozone concentrations.

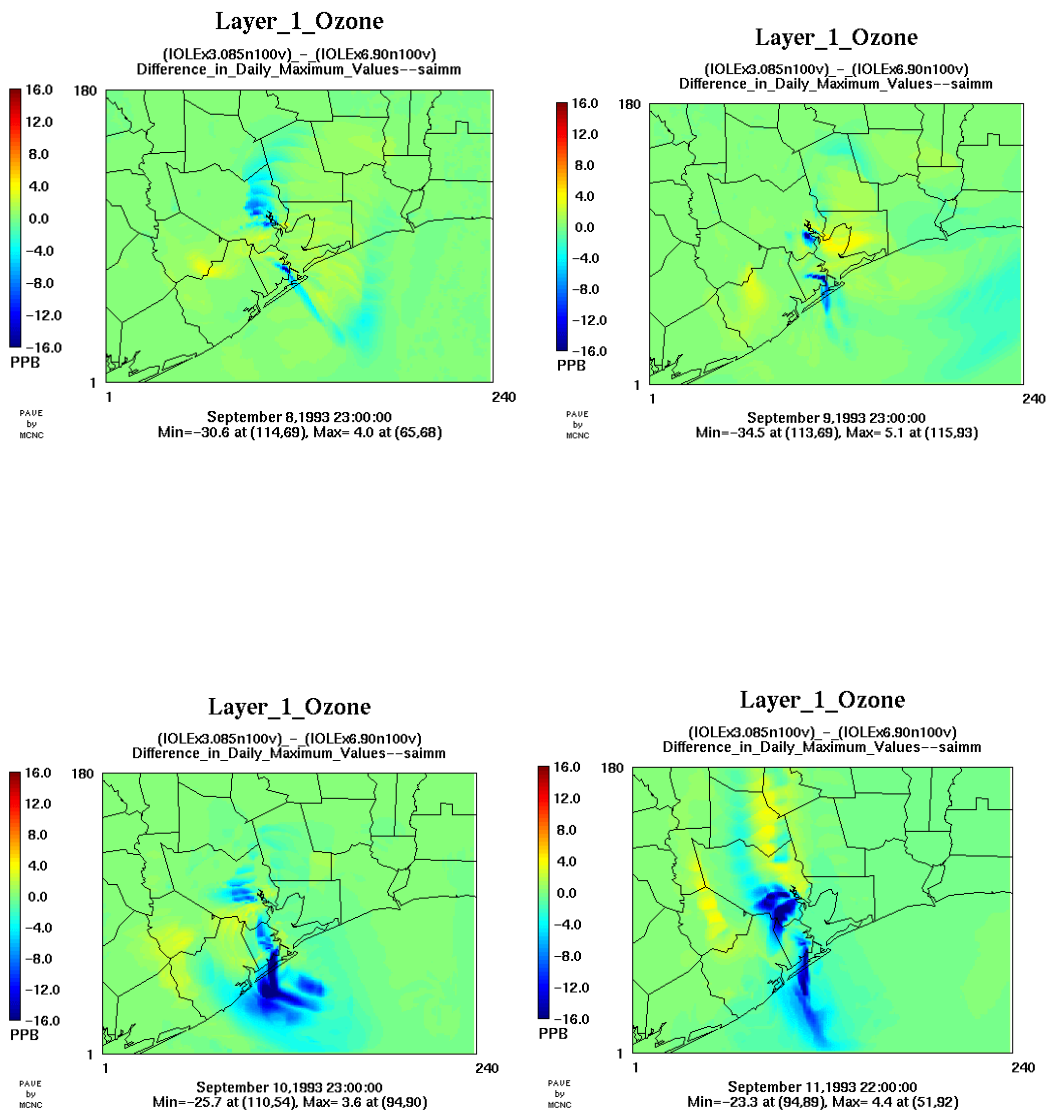


Figure 15. Effects of 150% industrial NOx emissions (85% reduction) and 50% reduction of industrial olefin emissions on daily peak ozone concentrations.

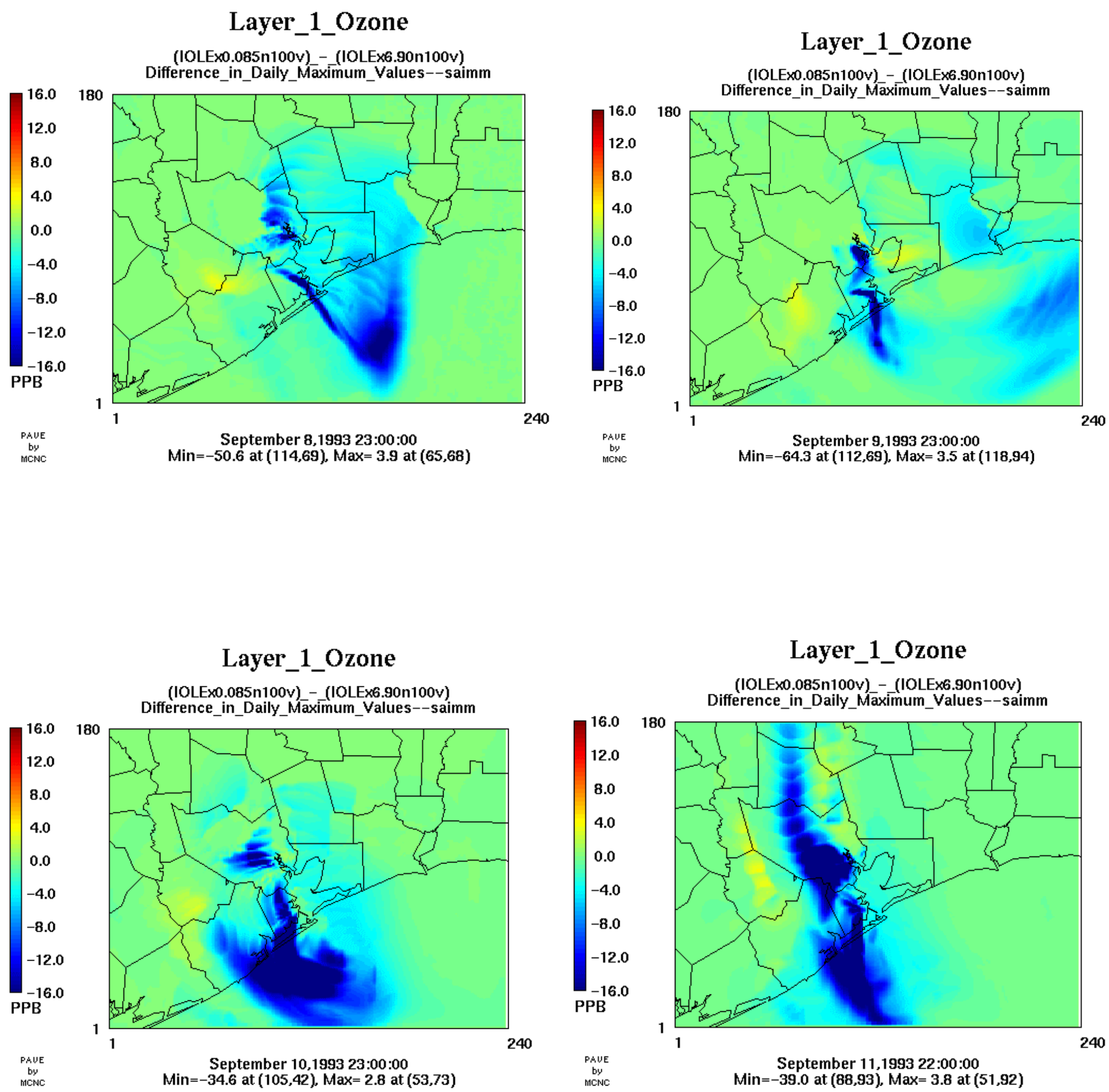


Figure 16. Maximum potential ozone reductions from the 150% I8a industrial NOx emissions (85% reduction) resulting from 100% reduction of industrial olefin emissions.

A quantitative analysis of the sensitivity scenarios investigated is presented in Table 3 and Table 4 for the 80% and 85% NOx emissions reduction series, respectively. A graphical representation of the analysis is displayed in Figure 17 and Figure 18. In Tables 3 and 4 the 90nox.600ole simulation represents the peak ozone concentration value which must be matched through reductions on industrial olefin emission levels. The 80nox.600ole simulation values provide the starting point for IOLE emission reductions. The highlighted values in the Tables give the closest match obtained for the reduction scenarios considered. As seen in previous studies, the necessary levels of industrial olefin emission reductions required to compensate for industrial NOx emission reductions varies depending on the episode day.

As an example, on the September 8th episode day, doubling the industrial NOx emissions increases the peak ozone concentration in the 4-km HGBPA domain from 159.8 ppb to 169.4 ppb. Subsequent reduction of IOLE emission levels to zero brings the peak ozone level down to 160.3 ppb, slightly above the target level of 159.8 ppb. Therefore, for this day, NOx emission reductions in the future year control case can only be compensated for with a 100% reduction in industrial olefin emissions. The analysis for the other simulation days is similar resulting in the following IOLE emission reduction levels required to compensate for doubling industrial NOx emissions: 100% on September 8th; ~35% on September 9th; 100% on September 10th; and, ~50% on September 11th.

Table 3. INOx/IOLE Equivalence at the 80% NOx emissions level.

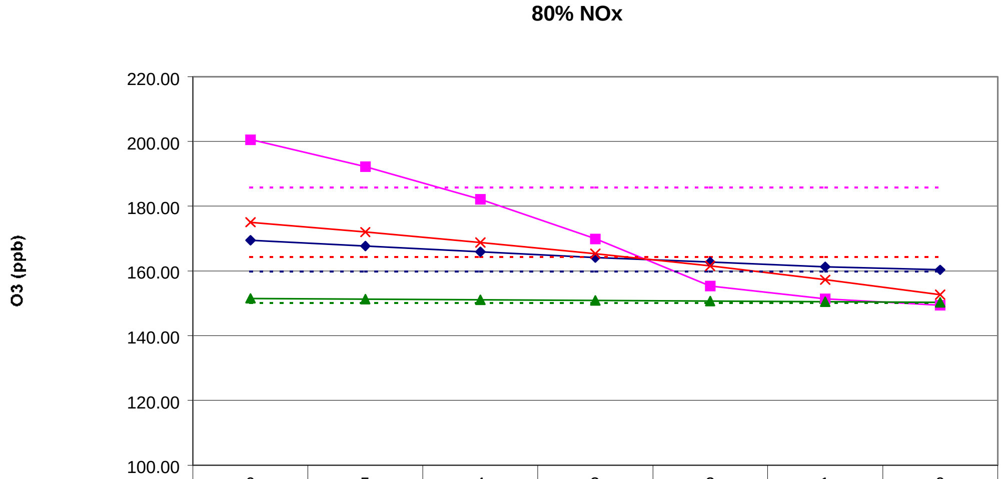
Date	90nox 6ole	80nox 6ole	80nox 5ole	80nox 4ole	80nox 3ole	80nox 2ole	80nox 1ole	80nox 0ole
9/8 Max	159.8	169.4	167.7	165.9	164.1	162.7	161.3	160.3
9/9 Max	185.8	200.6	192.2	182.1	169.9	155.3	151.4	149.4
9/10 Max	150.1	151.5	151.3	151.1	150.9	150.7	150.5	150.3
9/11 Max	164.4	175.0	172.0	168.7	165.3	161.5	157.3	152.7

Repeating the analysis for the 85% NOx emission level scenarios gives the following industrial olefin emission reductions necessary for each day: ~75% on September 8th; ~15% on September 9th; ~75% on September 10th; and, ~35% on September 11th.

Table 4. INOx/IOLE Equivalence at the 80% NOx emissions level.

Date	90nox 6ole	80nox 6ole	80nox 5ole	80nox 4ole	80nox 3ole	80nox 2ole	80nox 1ole	80nox 0ole
9/8 Max	159.8	164.6	163.1	161.9	160.8	159.8	159.0	158.2
9/9 Max	185.8	193.9	185.8	178.3	169.3	158.1	148.3	147.4
9/10 Max	150.1	150.8	150.6	150.4	150.2	150.0	149.8	149.6
9/11 Max	164,4	170.3	167.7	164.8	161.6	158.2	154.5	150.6

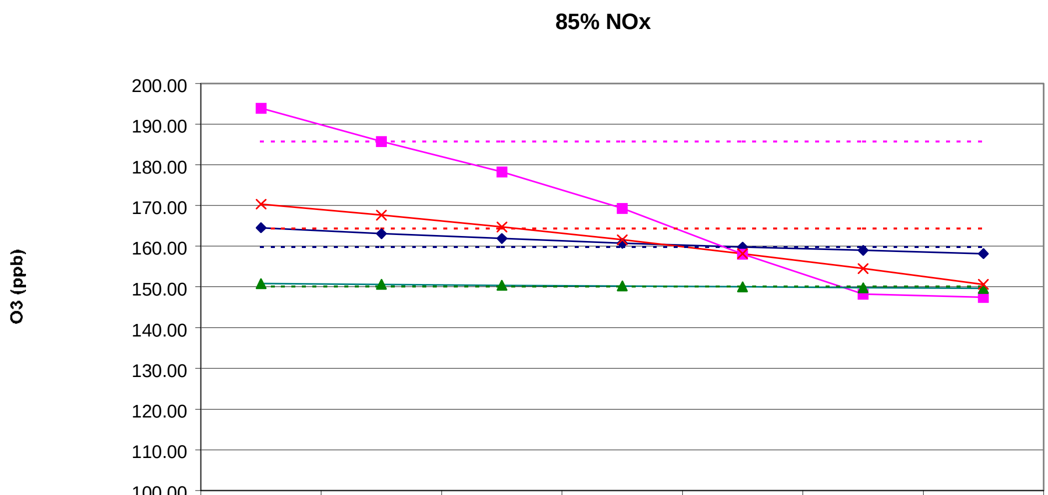
Figures 17 and 18 display these relations graphically and provide a means for interpolating the results to other IOLE emission reduction levels. These figures display the modeled peak ozone concentration as a function of the industrial olefin emission reduction levels for each day of the simulation. Also shown are the target peak ozone levels, i.e., the peak ozone concentrations resulting from the model simulations with 90% NOx emission reduction and six fold increase in industrial olefin emissions. The intersection of the curves gives the required level of IOLE emission reductions to compensate for the industrial NOx emission reductions for each day of the episode. The response of the modeled ozone peaks due to industrial olefin emission reductions can be seen and varies depending on the episode day.



OLE	6	5	4	3	2	1	0
8-Sep	169.43	167.73	165.91	164.11	162.72	161.27	160.31
9-Sep	200.59	192.19	182.08	169.89	155.33	151.38	149.43
10-Sep	151.49	151.28	151.07	150.87	150.66	150.45	150.25
11-Sep	175.03	172.00	168.74	165.30	161.52	157.29	152.67
9/8 Target	159.79	159.79	159.79	159.79	159.79	159.79	159.79
9/9 Target	185.76	185.76	185.76	185.76	185.76	185.76	185.76
9/10 Target	150.08	150.08	150.08	150.08	150.08	150.08	150.08
9/11 Target	164.40	164.40	164.40	164.40	164.40	164.40	164.40

OLE

Figure 17. Graphic representation of INOx/IOLE equivalency for the 80% INOx series.



OLE	6	5	4	3	2	1	0
8-Sep	164.57	163.08	161.89	160.75	159.82	159.01	158.21
9-Sep	193.88	185.75	178.30	169.32	158.09	148.25	147.41
10-Sep	150.81	150.62	150.43	150.24	150.04	149.84	149.65
11-Sep	170.33	167.65	164.75	161.58	158.20	154.54	150.62
9/8 Target	159.79	159.79	159.79	159.79	159.79	159.79	159.79
9/9 Target	185.76	185.76	185.76	185.76	185.76	185.76	185.76
9/10 Target	150.08	150.08	150.08	150.08	150.08	150.08	150.08
9/11 Target	164.40	164.40	164.40	164.40	164.40	164.40	164.40

OLE

Figure 18. Graphic representation of INOx/IOLE equivalency for the 85% INOx series.

References

ENVIRON, 2002a. “Sensitivity Analyses of the 8-11, September 1993 Ozone Episode.” Task 2 Report. Prepared for the Texas Natural Resources Conservation Commission. January 21, 2002.

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