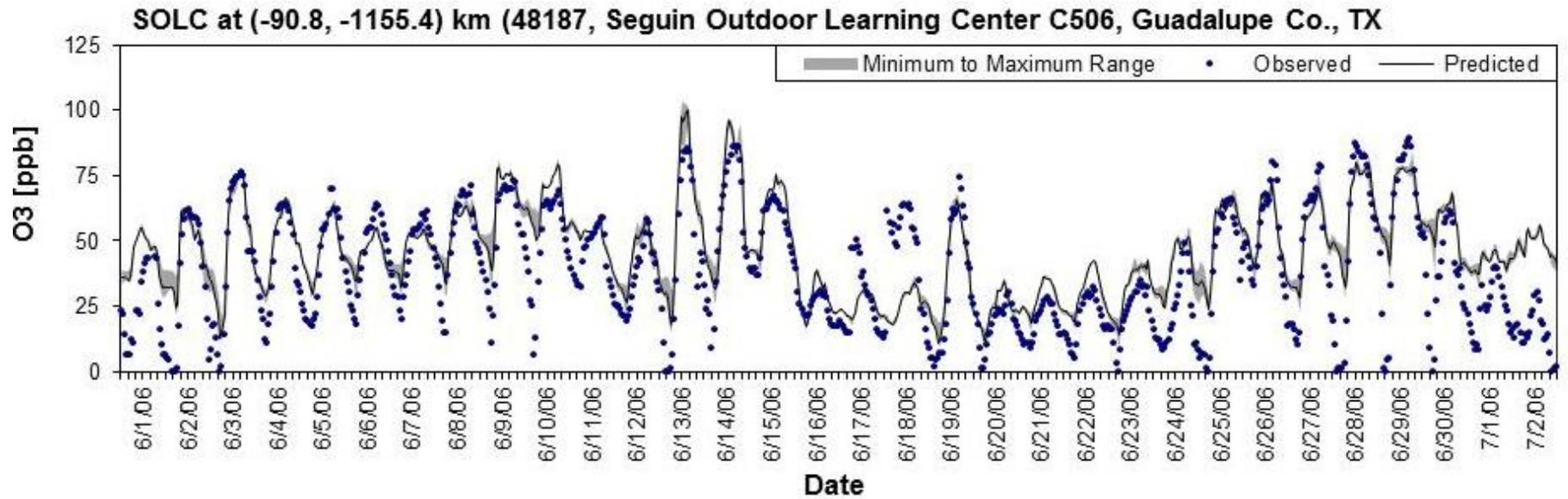


Figure 5-11: 1-Hour Ozone Time Series Observed (C506) v. Predicted (CAMx) for WRF AACOG Base Case Run 3, 2006



5.3.2 Hourly NO_x Time Series

Time series plots of modeled and predicted hourly NO_x for each monitor located in the San Antonio MSA were constructed. The model over predicted NO_x emissions at the C58 monitor on almost every day during the June 2006 episode. The average predicted hourly NO_x was 7.3 ppb, while the average observed hourly NO_x was only 3.9 ppb. Likewise, the average predicted maximum NO_x was 20.1 ppb, whereas the average observed maximum NO_x was 8.5 ppb. This over prediction of NO_x at C58 probably caused the poor model performance of predicted diurnal ozone at the monitor.

In contrast, C59 under predicted NO_x on several days including the ozone exceedance days of June 7th, 8th, 9th, 13th, and 14th. Model performance was good for most days at the C622 and C678 NO_x monitors in southeast Bexar County. However, the model over predicted ozone at the C678 monitor on several days, although most of these days were not associated with elevated ozone levels. The average predicted NO_x was higher at C678, and lower at both the C59 and C622 monitors on the southeast side of San Antonio.

Figure 5-12: 1-Hour NO_x Time Series Observed (C58) v. Predicted (CAMx) for WRF AACOG Base Case Run 3, 2006
 BOER at (-152.4, -1149.7) km (480290052, Camp Bullis C58, Bexar Co., TX)

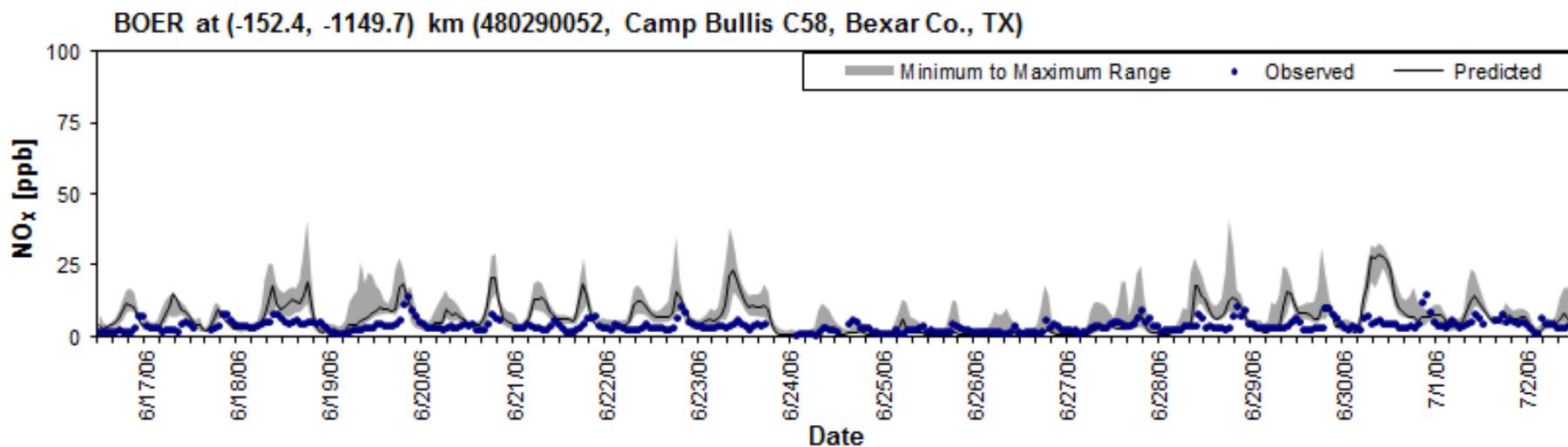
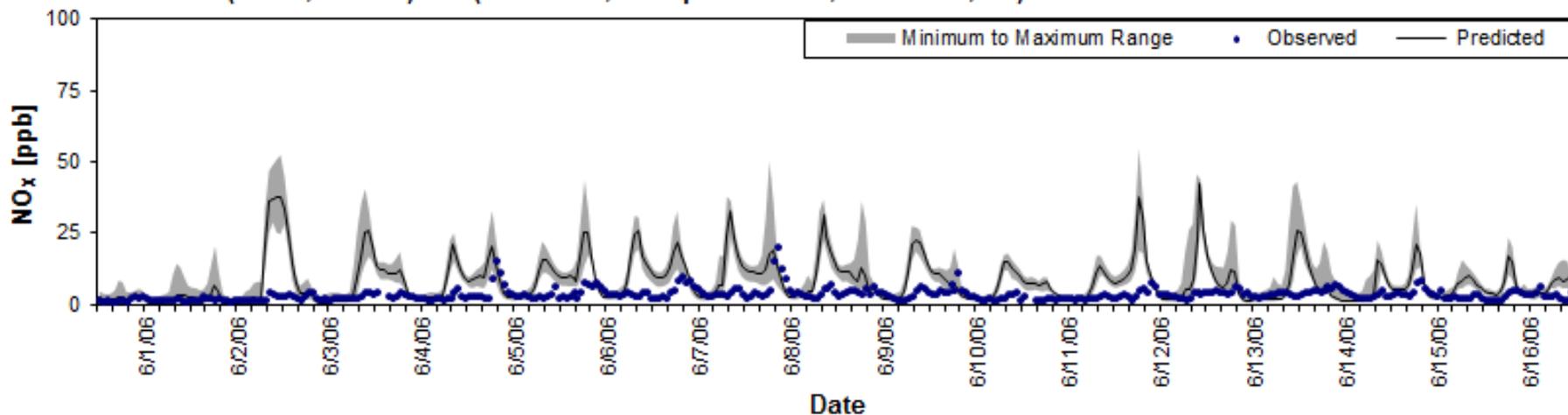


Figure 5-13: 1-Hour NO_x Time Series Observed (C59) v. Predicted (CAMx) for WRF AACOG Base Case Run 3, 2006

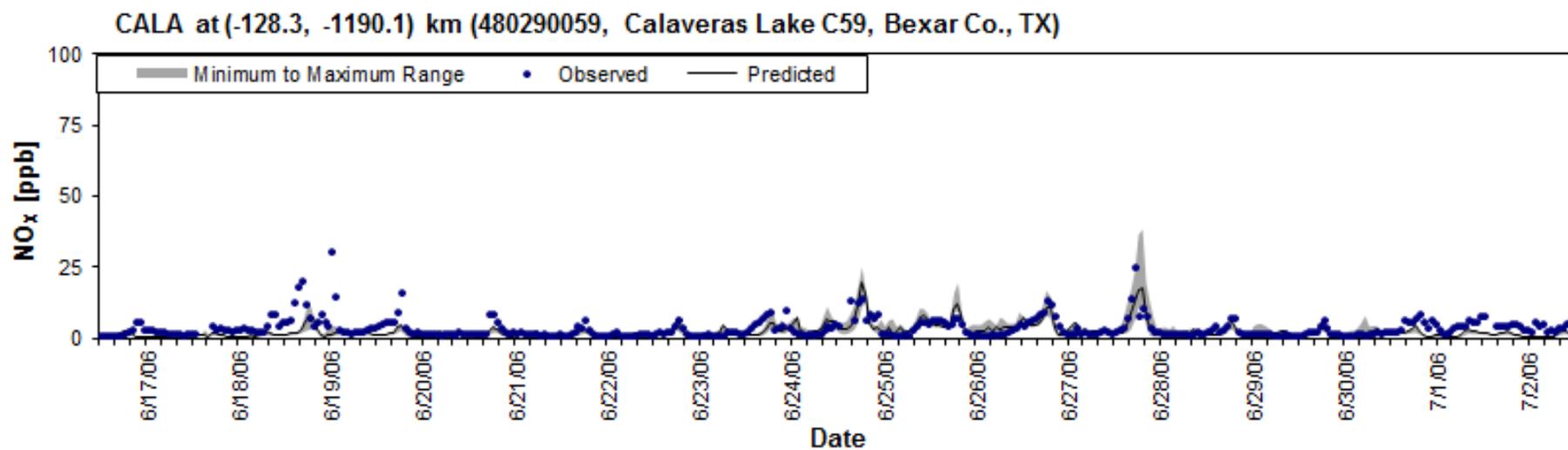
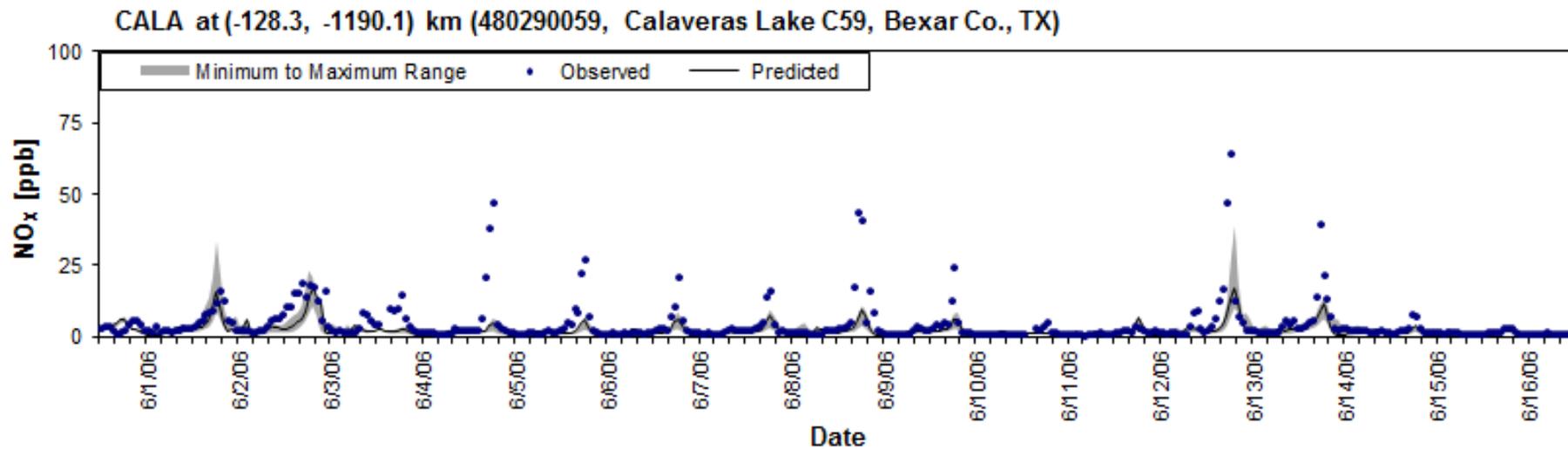


Figure 5-14: 1-Hour NO_x Time Series Observed (C622) v. Predicted (CAMx) for WRF AACOG Base Case Run 3, 2006
HTMS at (-130.2, -1181.3) km (480290622, Heritage Middle School C622, Bexar Co., TX)

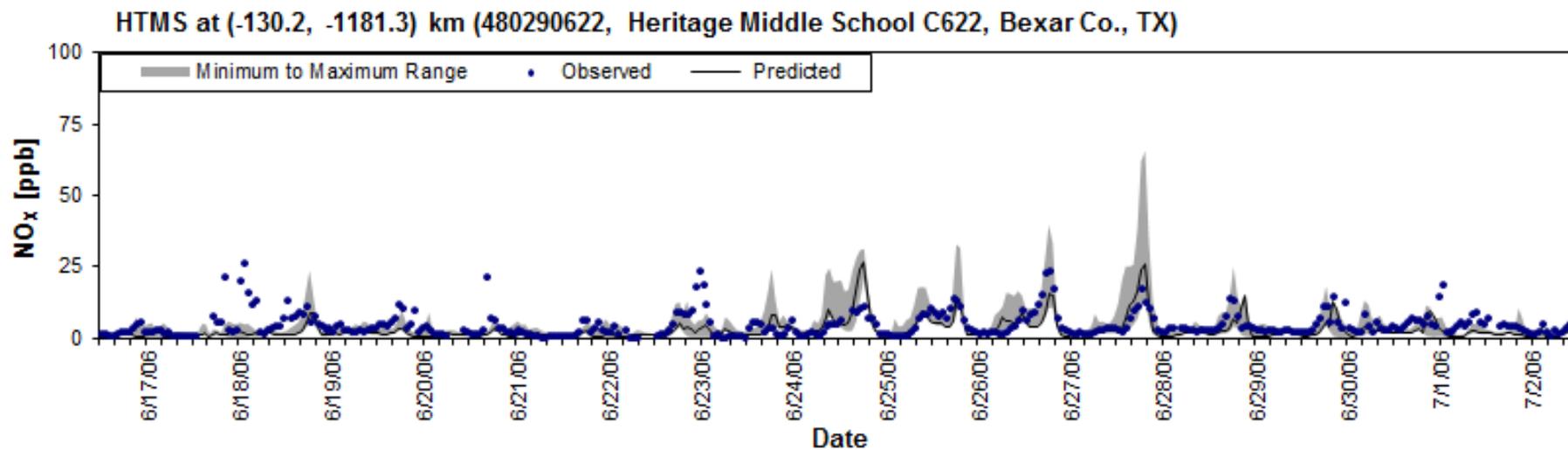
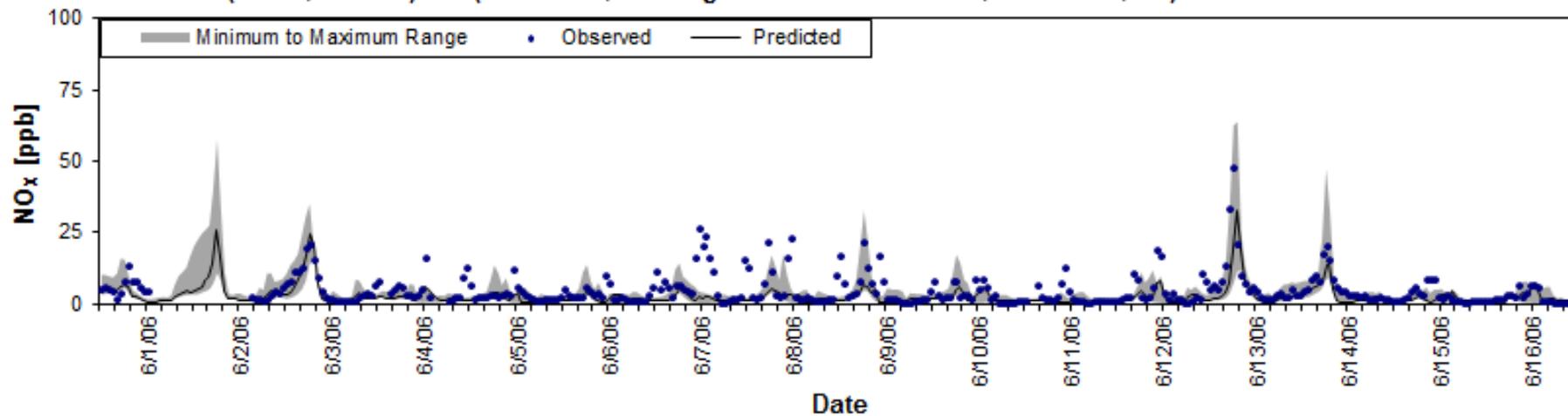
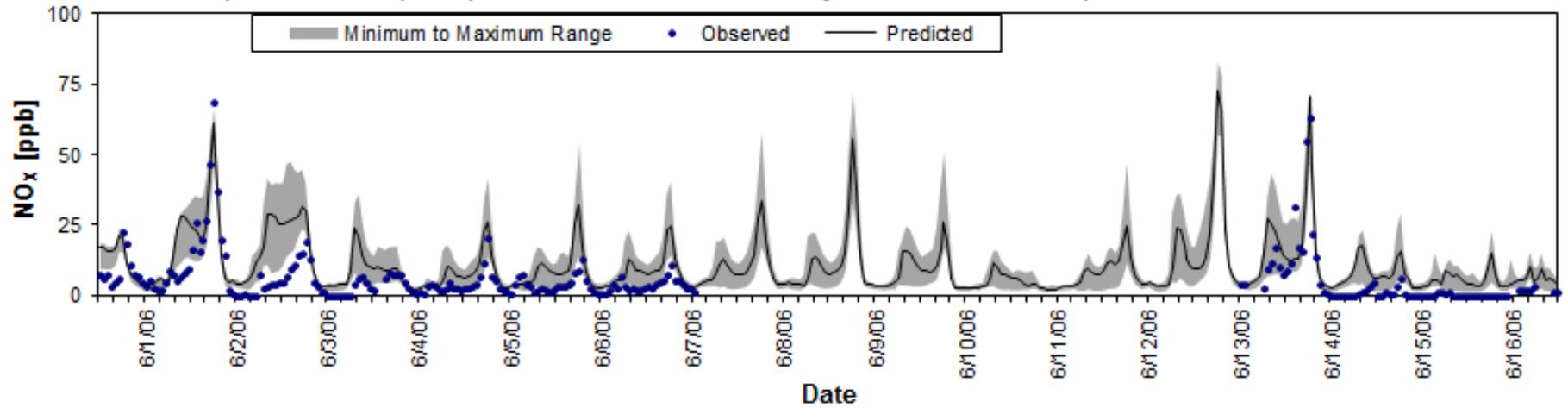
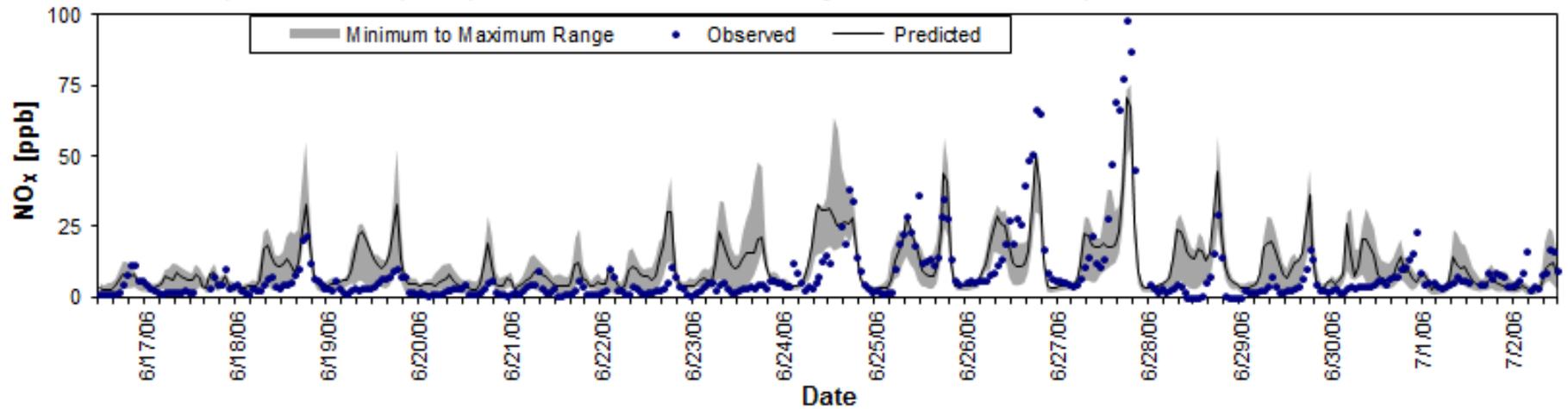


Figure 5-15: 1-Hour NO_x Time Series Observed (C678) v. Predicted (CAMx) for WRF AACOG Base Case Run 3, 2006

PECV at (-139.7, -1175.1) km (480290055, CPS Pecan Valley C678, Bexar Co., TX)



PECV at (-139.7, -1175.1) km (480290055, CPS Pecan Valley C678, Bexar Co., TX)



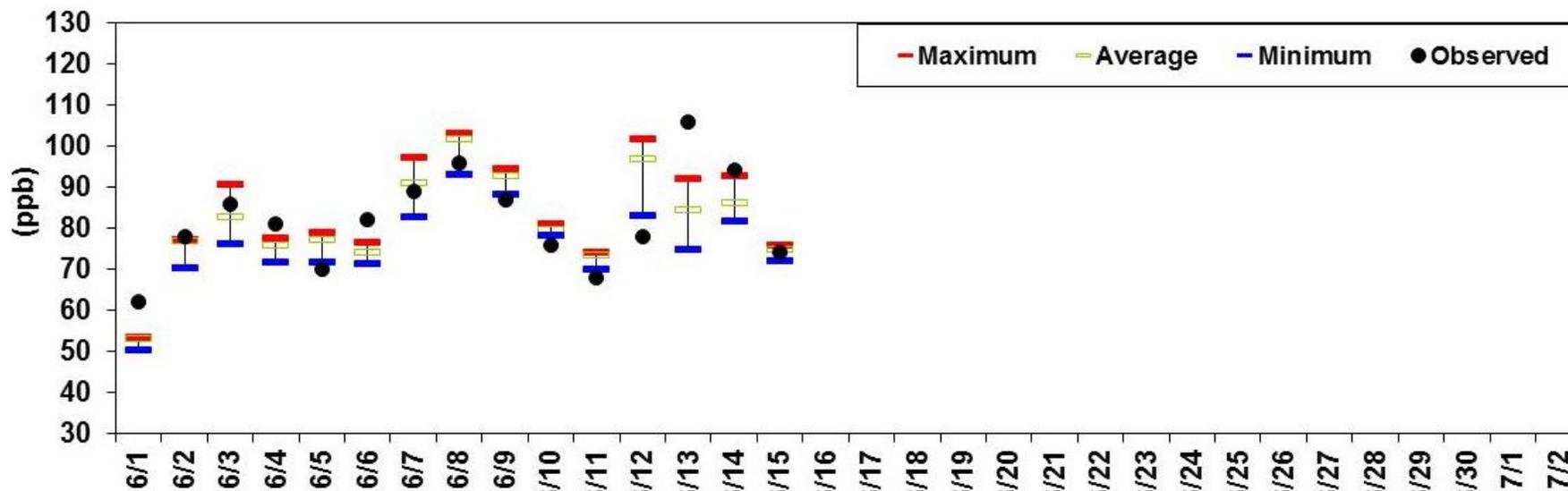
5.3.3 Daily Ozone Plots

Daily peak predicted maximum, peak average, and peak minimum ozone in a 7 x 7 4-km grid around all monitors, C23 monitor, and C58 monitor are plotted in Figure 5-16, Figure 5-17, and Figure 5-18. MM5 base case run 7 exhibited poor modeling performance when predicting ozone formation on the June 13 exceedance day. Data is not available for the second half of the episode because MM5 was only run during the May 29th to June 15th, 2006 time period.

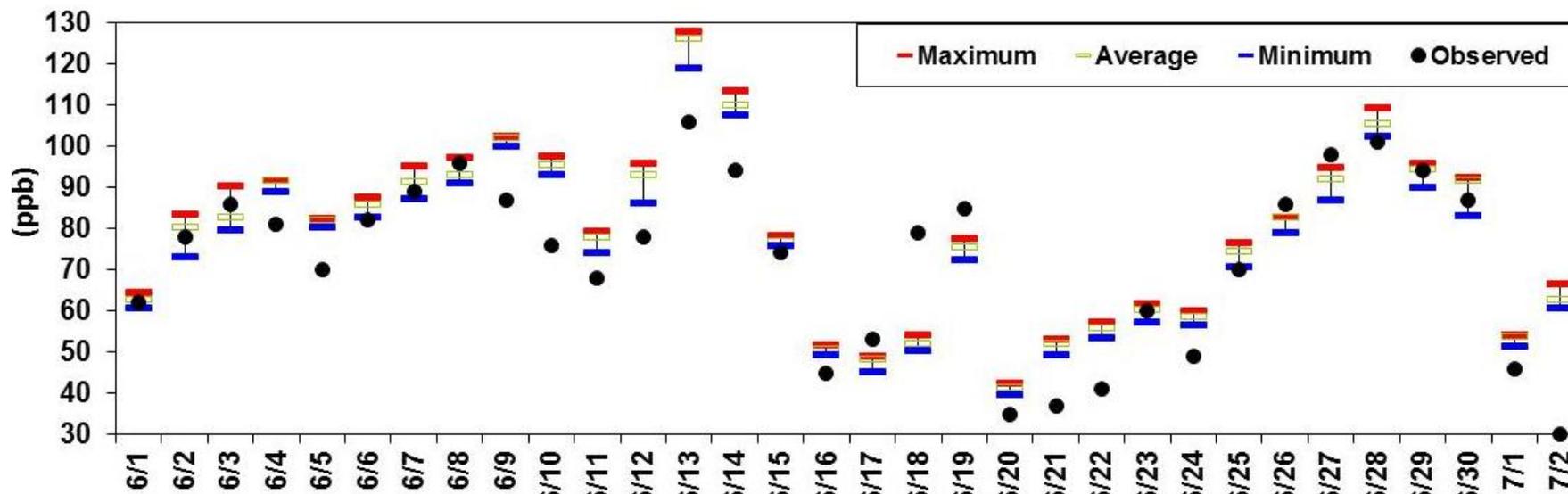
Runs using WRF over predicted hourly ozone on June 13th and June 14th. There was also a slight over prediction on the June 9th exceedance day. The WRF runs slightly under predicted ozone at C58 on June 3rd, but model performance was good overall. Modeling performance for the exceedance days in the second half of the episode, June 26th, 27th, 28th, and 29th, was good. Overall, modeling performance was improved when using WRF instead of MM5.

Although there were several significant differences in the local emission inventory, model results are similar for TCEQ run 1, TCEQ run 2, and AACOG run 3 for every monitor. Changes in meteorological conditions had a greater impact on the model's predicted ozone formation than changes to the emission inventories. For AACOG run 4 using the RPO grid, predicted ozone on some exceedance days was higher than the other 3 runs. Notably, AACOG run 4 predicted higher ozone on both the June 13th and 14th exceedance days.

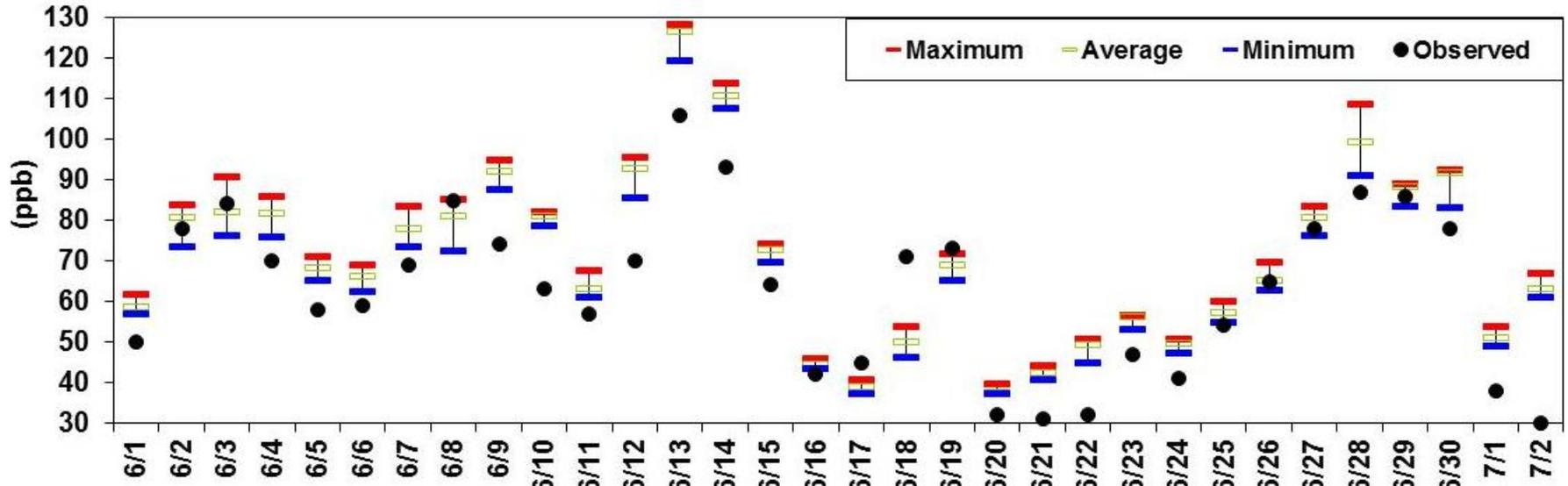
Figure 5-16: San Antonio Observed Ozone for All CAMS Daily Maximum 1-hr Average
MM5 Base Case Run 7



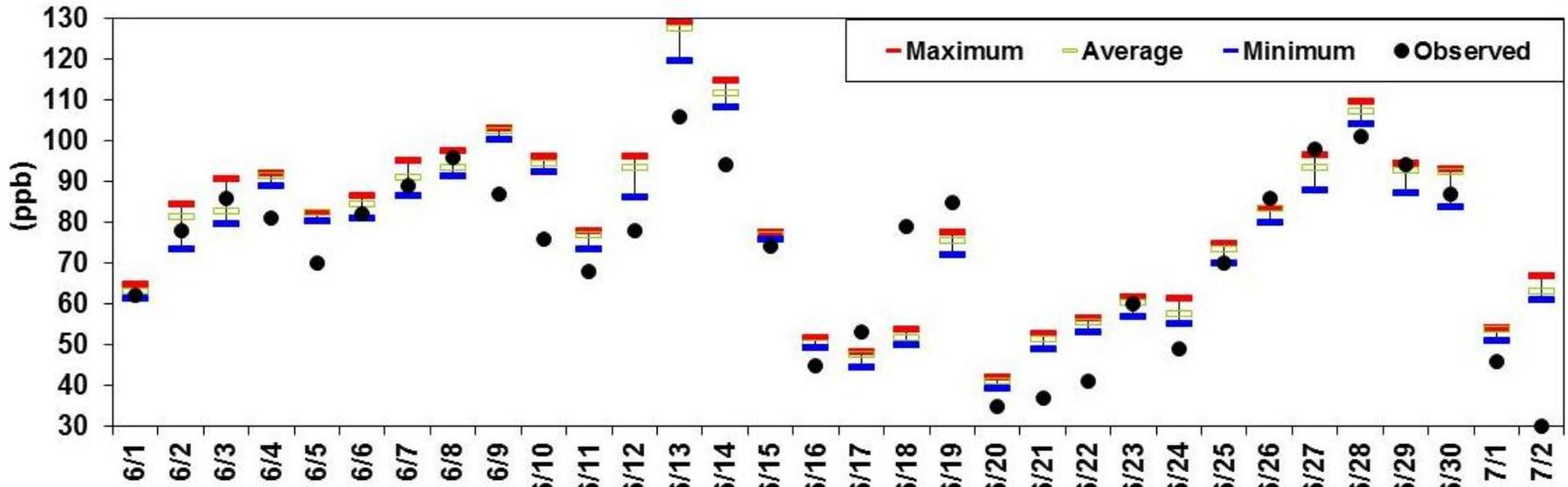
WRF TCEQ Base Case Run 1



WRF TCEQ Base Case Run 2



WRF AACOG Base Case Run 3



WRF AACOG Base Case RPO Run 4

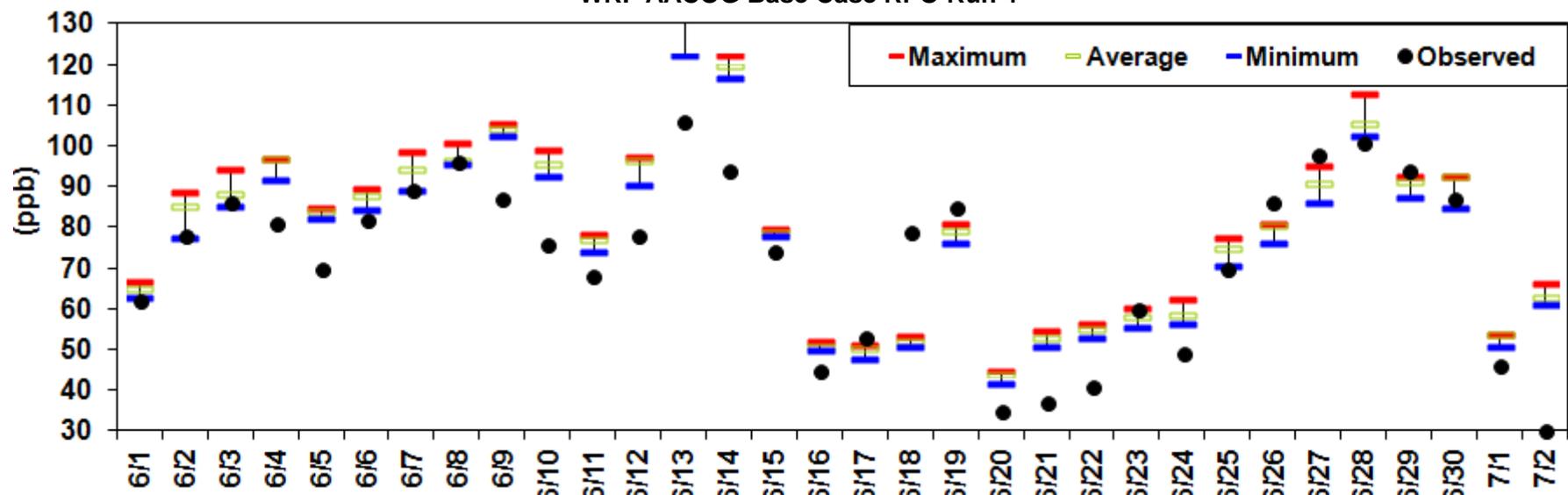
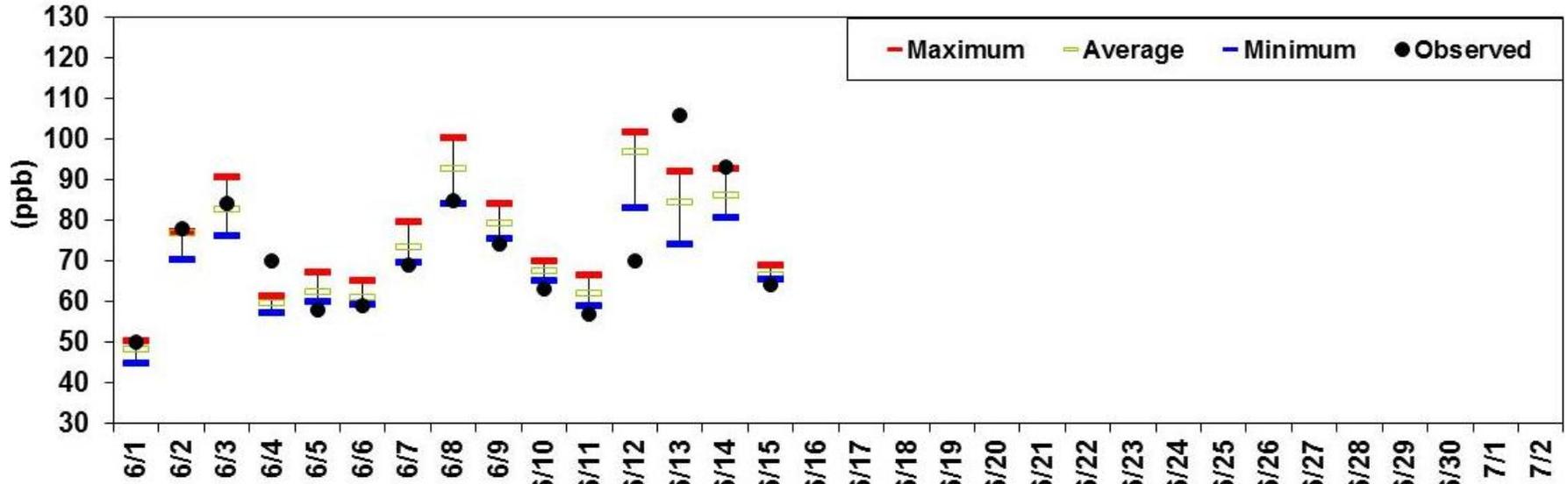
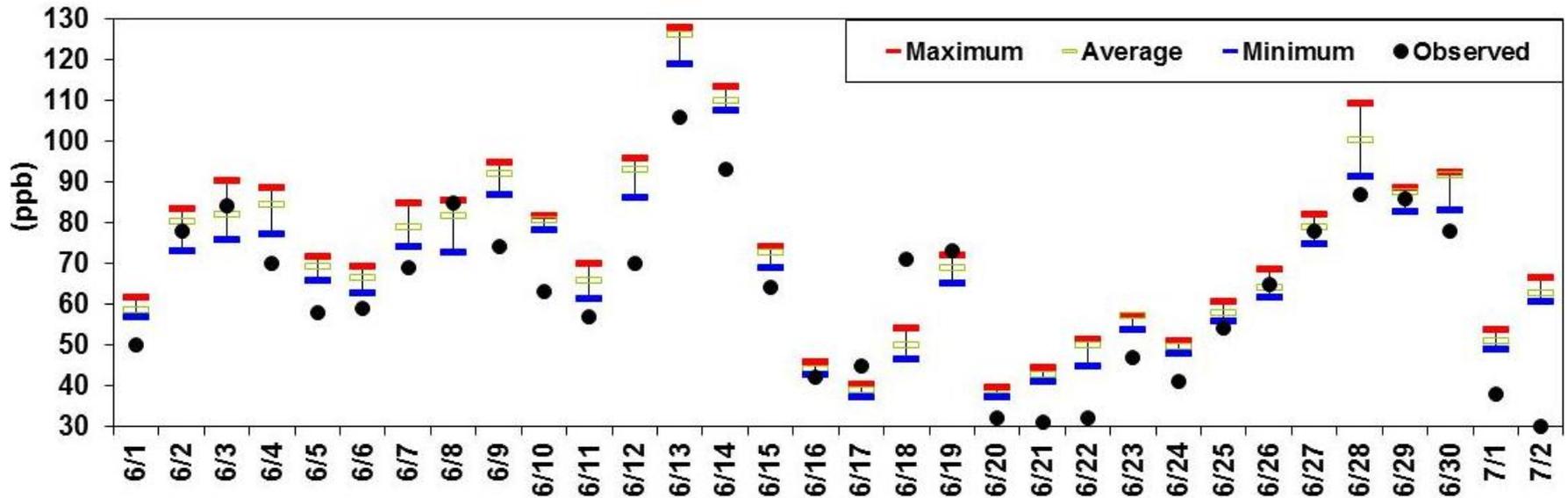


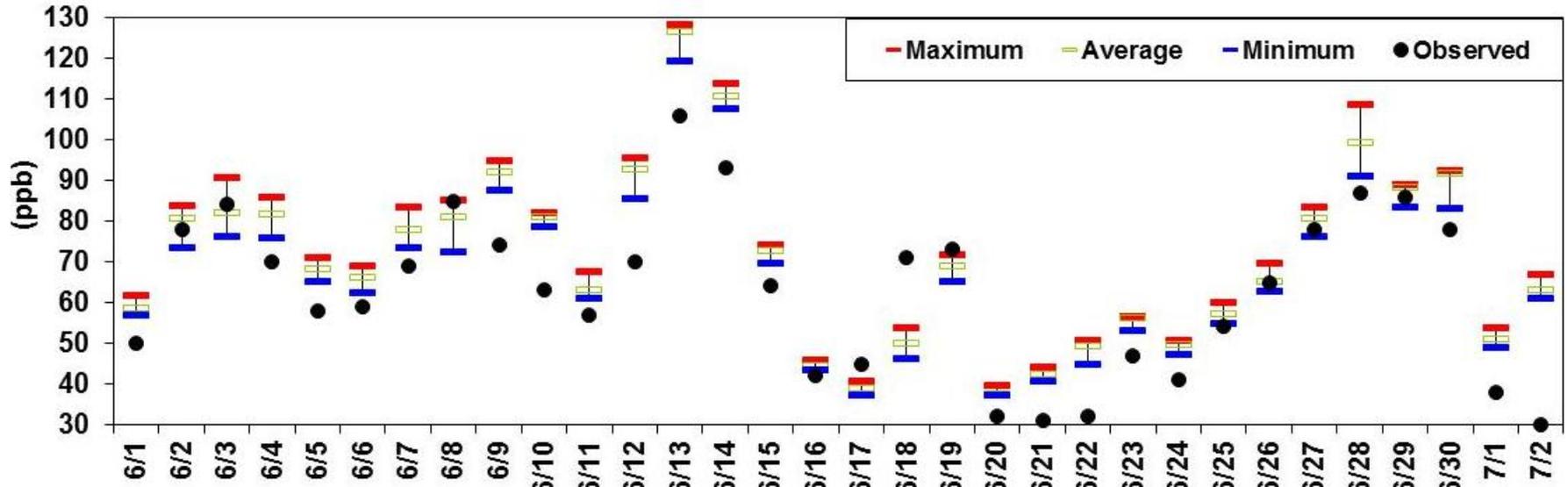
Figure 5-17: San Antonio Observed Ozone for CAMS 23 Daily Maximum 1-hr Average
MM5 Base Case Run 7



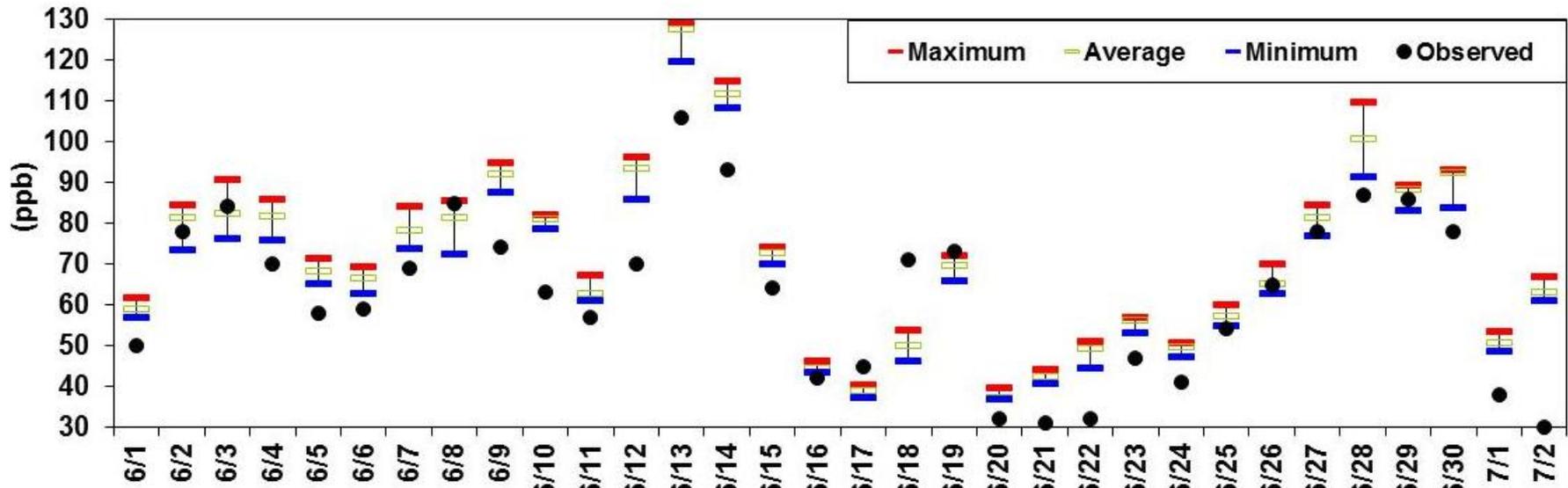
WRF TCEQ Base Case Run 1



WRF TCEQ Base Case Run 2



WRF AACOG Base Case Run 3



WRF AACOG Base Case RPO Run 4

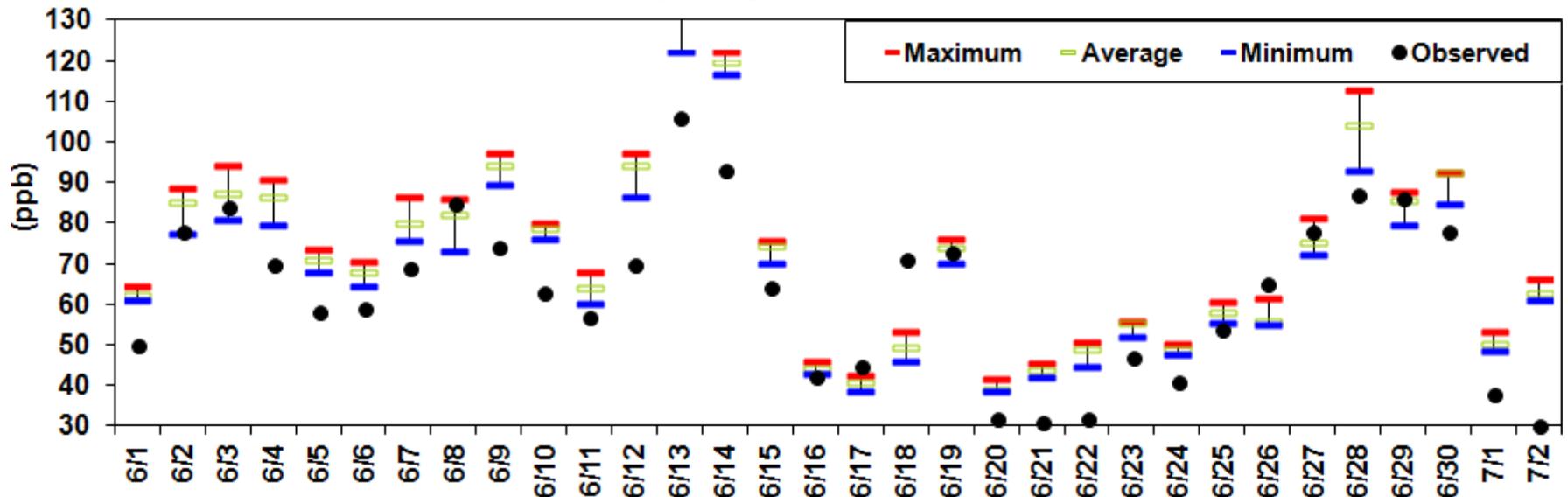
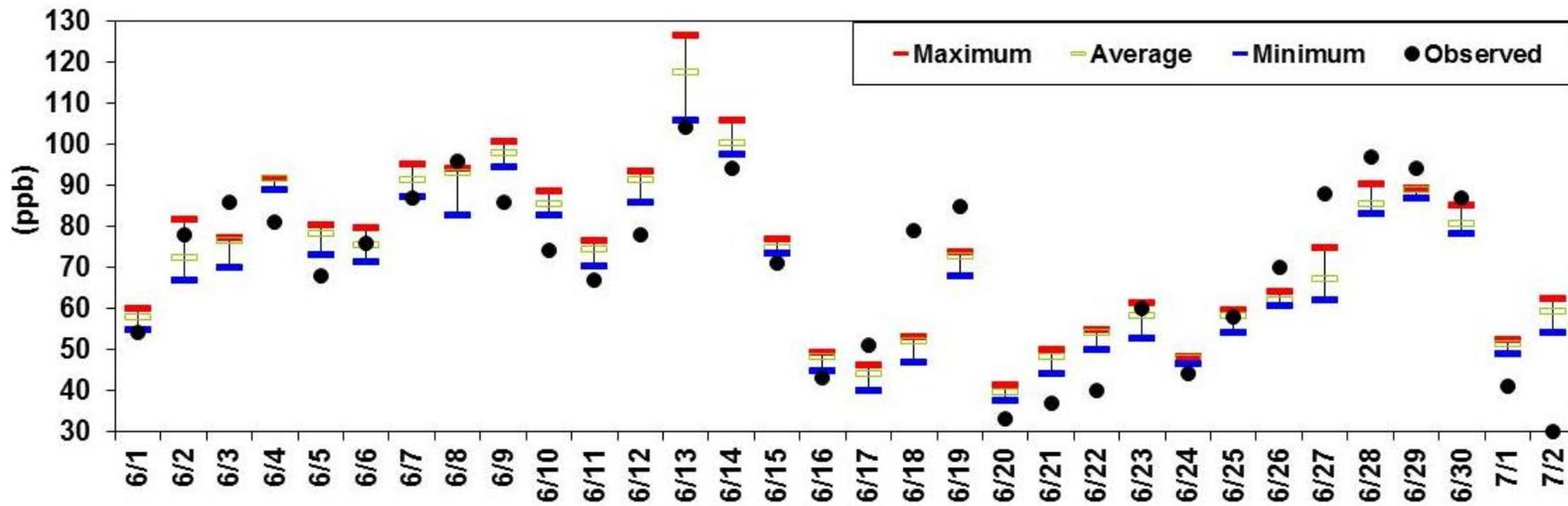
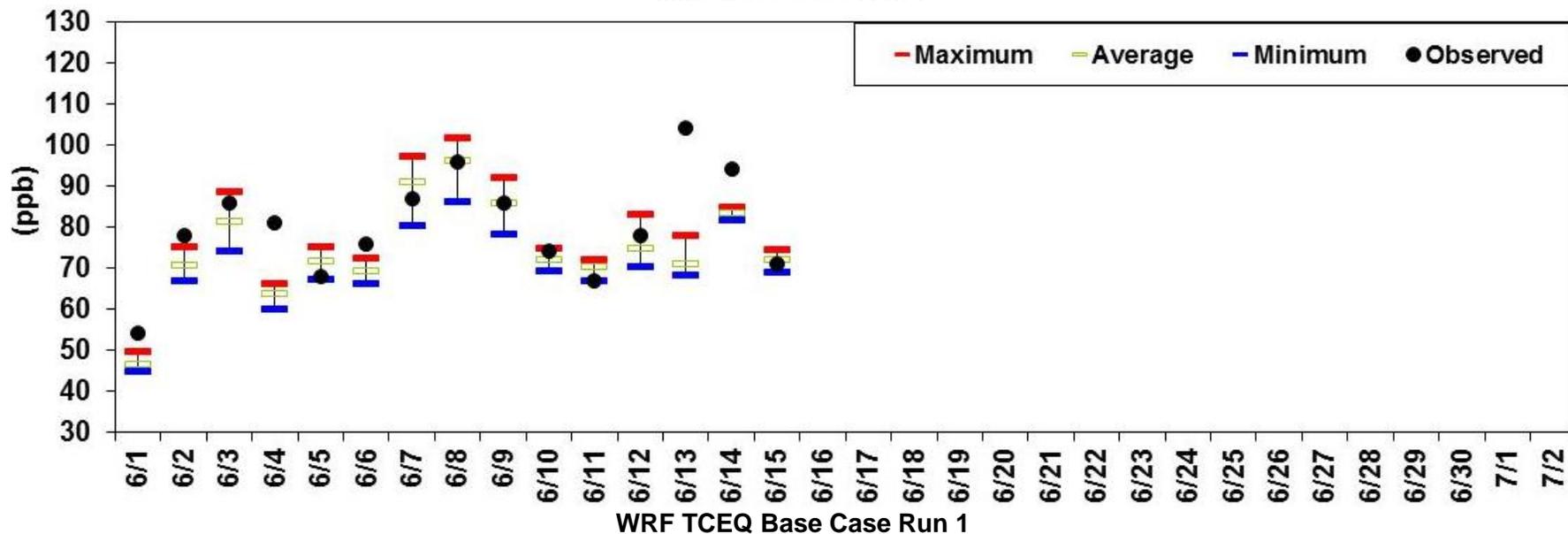
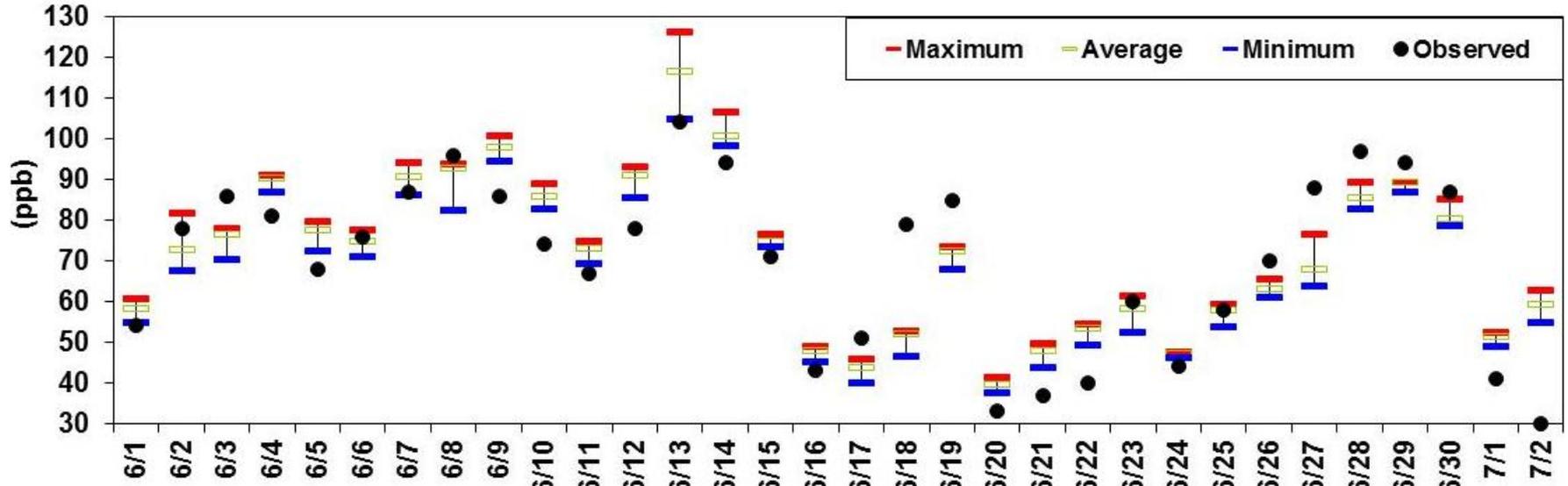


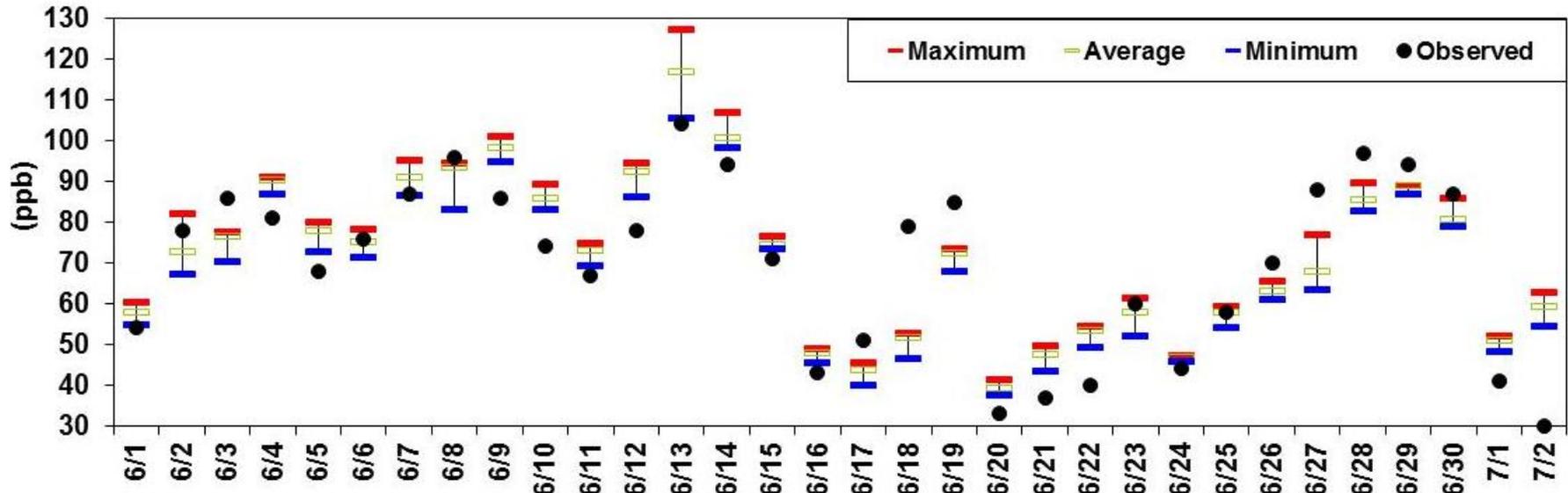
Figure 5-18: San Antonio Observed Ozone for CAMS 58 Daily Maximum 1-hr Average
MM5 Base Case Run 7



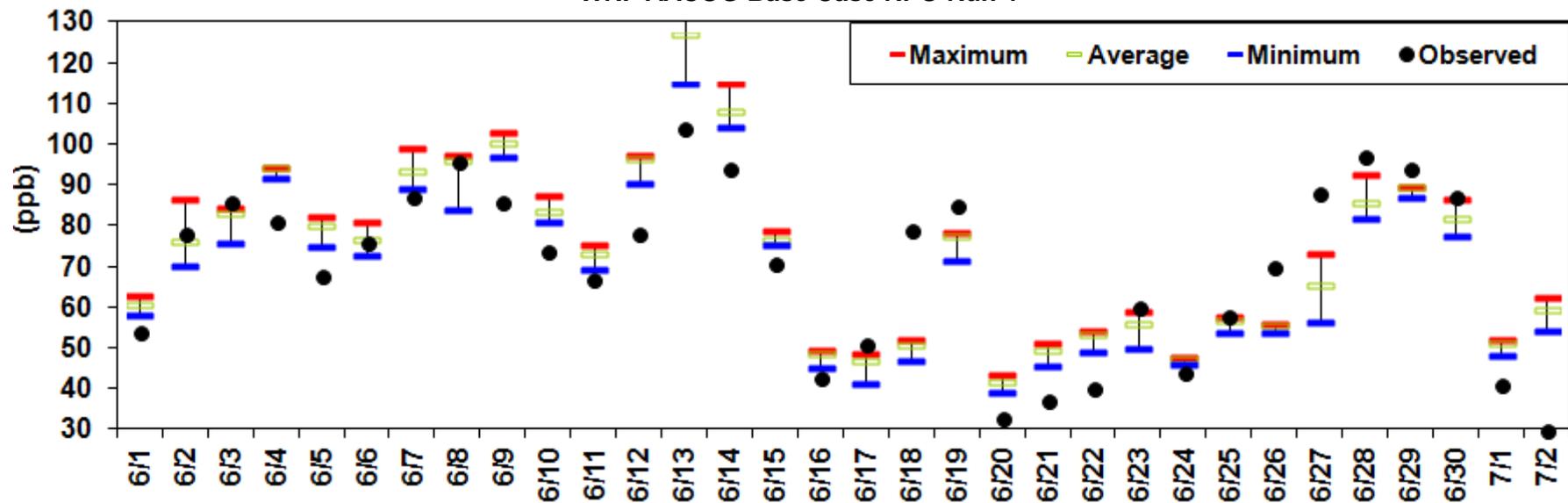
WRF TCEQ Base Case Run 2



WRF AACOG Base Case Run 3



WRF AACOG Base Case RPO Run 4



5.4 Statistical Analysis

There are several statistical measures recommended by the EPA for the purpose of evaluating performance of each base case run. This section will describe each statistical measurement, the statistical results for the modeled runs, and what the statistics indicate about overall model performance. The following six statistical measures were calculated to analyze the model's ability to predict ozone concentrations for the June 2006 episode: unpaired peak prediction accuracy, paired peak predicted accuracy, mean normalized bias, mean normalized gross error, average peak predicted bias, and average peak predicted error. All results are based on predicted hourly ozone values above 60 ppb at each monitor.

Unpaired Peak Prediction Accuracy (PPAu)

This statistical evaluation “compares the peak concentration modeled anywhere in the selected area against the peak ambient concentration anywhere in the same area. The difference of the peaks (model - observed) is then normalized by the peak observed concentration.”²⁶² EPA recommends that the unpaired peak prediction accuracy be within 20 percent of the observed hourly ozone. The main purpose of this statistical analysis is to determine if the model is under predicting ozone formation at each monitor.

Equation 5-1, Unpaired Peak Prediction Accuracy

$$PPAu = 100 \times [(peak_{pred} \div peak_{obs}) - 1]$$

Mean Normalized Bias (MB)

“This performance statistic averages the model/observation residual, paired in time, normalized by observation, over all monitor times/locations. A value of zero would indicate that the model over-predictions and model under-predictions exactly cancel each other out.”²⁶³ The calculation of this measure is shown in Equation 5-2. According to the EPA, mean normalized bias should be within 15 percent.

Equation 5-2, Mean Normalized Bias

$$MNB = 1/n \sum_1^n \left[\frac{(\text{Model} - \text{Obs.})}{\text{Obs.}} \right] \bullet 100\%$$

²⁶³ EPA, April 2007. “Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze.” EPA Office of Air Quality Planning and Standards, Air Quality Analysis Division Air Quality Modeling Group Research Triangle Park, NC. EPA - 454/B-07-002. p. 198. Accessed online: <http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf>. Last accessed 06/24/13.

Mean Normalized Gross Error (ME)

“Mean Normalized Gross Error (MNGE): This performance statistic averages the absolute value of the model/observation residual, paired in time, normalized by observation, over all monitor times/locations. A value of zero would indicate that the model exactly matches the observed values at all points in space/time.”²⁶⁴ The calculation of this measure is shown in Equation 5-3. The recommended maximum value for mean normalized gross error should be 35 percent.

Equation 5-3, Mean Normalized Gross Error

$$ME = 1/n \sum_{1}^n \left[\frac{|\text{Model} - \text{Obs.}|}{\text{Obs.}} \right] \bullet 100\%$$

Average Peak Predicted Bias and Error (APPB and APPE)

“Average Peak Prediction Bias and Error: These are measures of model performance that assesses only the ability of the model to predict daily peak 1-hour and 8-hour ozone. They are calculated essentially the same as the mean normalized bias and error ..., except that they only consider daily maxima data (predicted versus observed) at each monitoring location.”²⁶⁵ These statistical measurements use Equation 5-2 for APPB and Equation 5-3 for APPE.

Following EPA guidance, these statistical measures were calculated for all hourly ozone pairs, ozone pairs on days that the 8-hour peak observed concentrations are greater than 60 ppb, and ozone exceedance days.²⁶⁶ The statistical measures were also calculated for individual monitors averaged over all days in the June 2006 modeling episode. Days without complete observed datasets were removed from the statistics.

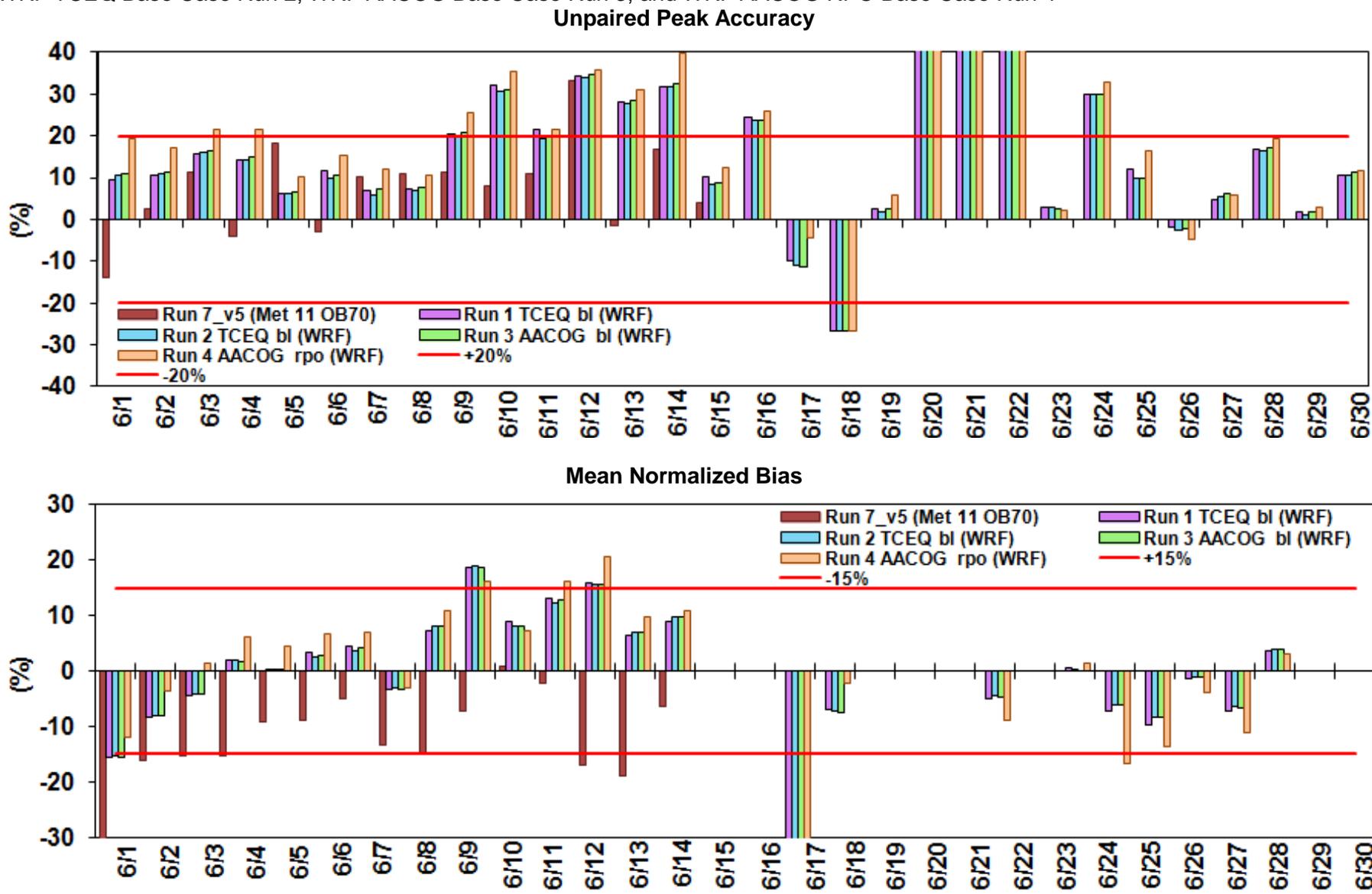
The results of these statistical analyses indicate the model over predicted peak ozone on most exceedance days except the June 26th exceedance day. Statistical results for the June 13th and 14th exceedance days were above the level recommended by EPA. Although, the statistics indicated significant over prediction on June, 20th, 21st, and 22nd, none of these days had peak ozone levels observed or predicted above 60 ppb. For model performance, over prediction of peak accuracy is considered better than under prediction because the calculations are based on the highest value in the grids cells surrounding the monitors. Figure 1-19 compares unpaired peak accuracy, mean normalized bias, and mean normalized error for each base case run.

²⁶⁴ *Ibid.*, p. 198.

²⁶⁵ *Ibid.*, pp. 198 – 199.

²⁶⁶ *Ibid.*, p. 199.

Figure 5-19: Daily performance for 1-hour Ozone in San Antonio on all Days for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4



Mean Normalized Error

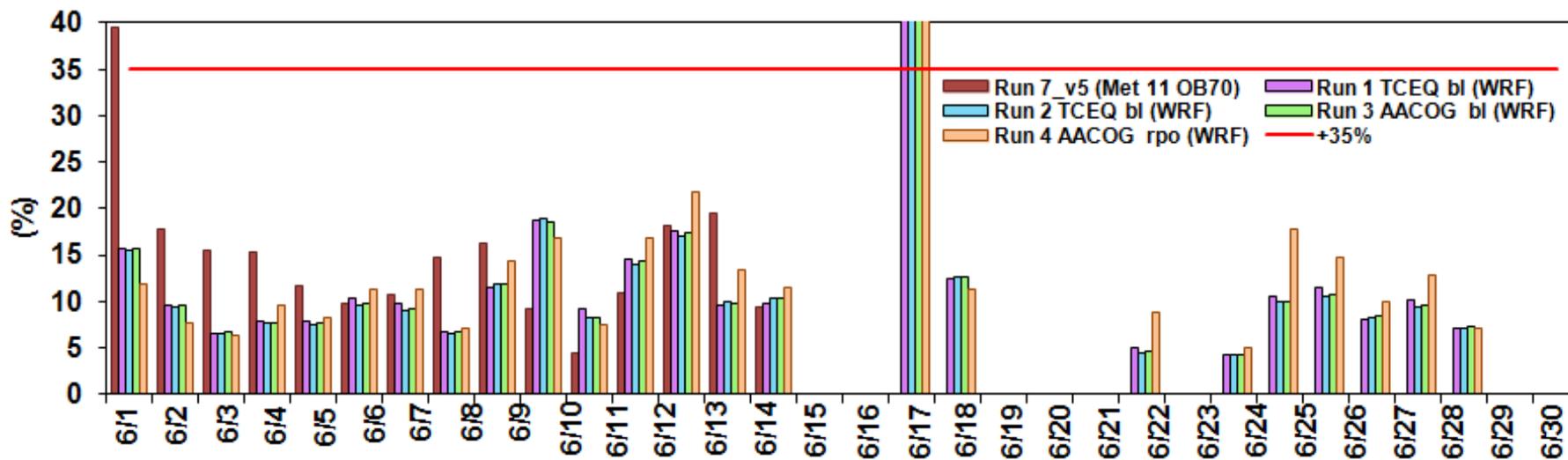


Table 5-1: Daily performance for 1-hour Ozone in San Antonio on all Days for WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4

| Statistical Analysis | Average All Days | | | | Days > 60 ppb observed | | | | Average On Exceedance Days | | | |
|-----------------------------------|------------------|----------------|-----------------|-----------------|------------------------|----------------|-----------------|-----------------|----------------------------|----------------|-----------------|-----------------|
| | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG Run 4 | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG Run 4 | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG Run 4 |
| Unpaired Peak Prediction Accuracy | 16.1 | 15.5 | 16.0 | 19.6 | 13.1 | 11.7 | 12.3 | 15.5 | 12.4 | 12.7 | 13.7 | 16.4 |
| Peak Bias (unpaired time) | <i>-0.4</i> | -0.3 | -0.4 | 0.2 | 0.1 | 0.2 | 0.1 | <i>0.8</i> | <i>0.5</i> | 0.4 | 0.3 | 0.2 |
| Peak Error (unpaired time) | 7.9 | 7.7 | 7.8 | <i>8.7</i> | 8.0 | 7.9 | 7.9 | <i>8.9</i> | 7.5 | 7.3 | 7.4 | <i>9.5</i> |
| Bias (normalized) | <i>-0.7</i> | -0.6 | -0.7 | 0.2 | 0.2 | 0.3 | 0.2 | <i>1.2</i> | <i>0.8</i> | 0.6 | 0.5 | 0.2 |
| Error (normalized) | 11.5 | 11.3 | 11.4 | <i>12.7</i> | 11.7 | 11.4 | 11.5 | <i>12.9</i> | 10.3 | 9.9 | 10.0 | <i>12.9</i> |

The performance of MM5 run 7 version 5 was degraded as indicated by mean normalized bias and mean normalized error on most modeling days. However, model performance was good on most exceedance days for every WRF run. The only exceedance day on which every run failed to meet the EPA recommended value for mean normalized bias was on June 13th. Every exceedance day exhibited normalized error within EPA recommended levels. As shown in Table 5-1, every WRF modeling runs exhibited similar performance for unpaired peak accuracy, paired peak accuracy, peak bias, peak error, normalized bias, and normalized error. Model performance on all days was improved with TCEQ run 2 and exceedance day performance was best for AACOG run 1. Performance for AACOG run 4 using the RPO grid was degraded for peak error and normalized error. This run predicted higher peak 1-hour ozone concentrations compared to the other 3 WRF runs.

The soccer-style plot in Figure 5-20 show most days are within EPA's recommendation for statistical analysis for values greater than 60 ppb for the first three WRF runs. To meet EPA's guidance for error and bias, values should be within the plots' blue squares. The one day for which measures of error and bias were near to the blue box in the graphs was June 18th (upper left hand corner of the plot). The model significantly under-predicted ozone on this day, however June 18th is not an exceedance day in the San Antonio New Braunfels MSA. June 13th was the only exceedance day for which the normalized gross error-normalized bias was just outside of the box because the model over-predicted ozone on this day. For AACOG run 4 using the RPO grid, model performance was slightly degraded and two exceedance days - June 13th and June 26th - did not fall within the blue box.

When statistical analysis was performed on data for individual monitors (Figure 5-22), model performance was significantly improved for the WRF runs compared to MM5. Results for paired peak accuracy were very good for C58, C622, C501, C502, C503, and C506 and paired peak accuracy for the remaining monitors also met EPA recommended guidelines. Normalized error on exceedance days was between 8.64% and 17.37% for every monitor in the AACOG region: these values are well below EPA's recommendation of 35%. TCEQ run 2 with WRF demonstrated the best modeling performance overall, with the best performance for normalized error at every monitor except C505 on exceedance days (Table 5-3). WRF run 4 with the RPO grid had degraded performance for normalized error. Additionally, peak prediction accuracy was higher for most monitors.

Figure 5-20: Soccer-style Plot of Normalized Gross Error and Normalized Bias by Day, WRF AACOG Base Case Run 3

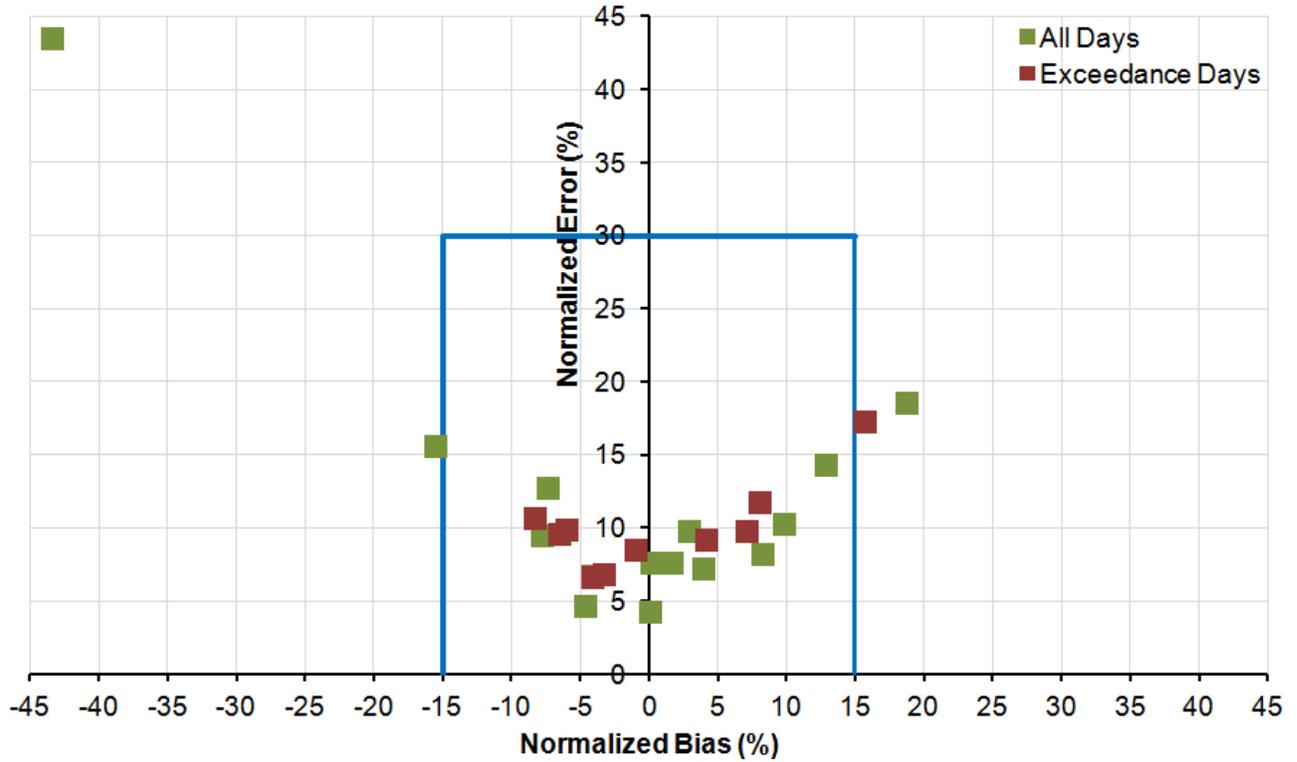


Figure 5-21: Soccer-style Plot of Normalized Gross Error and Normalized Bias by Exceedance Days, WRF AACOG RPO Base Case Run 4

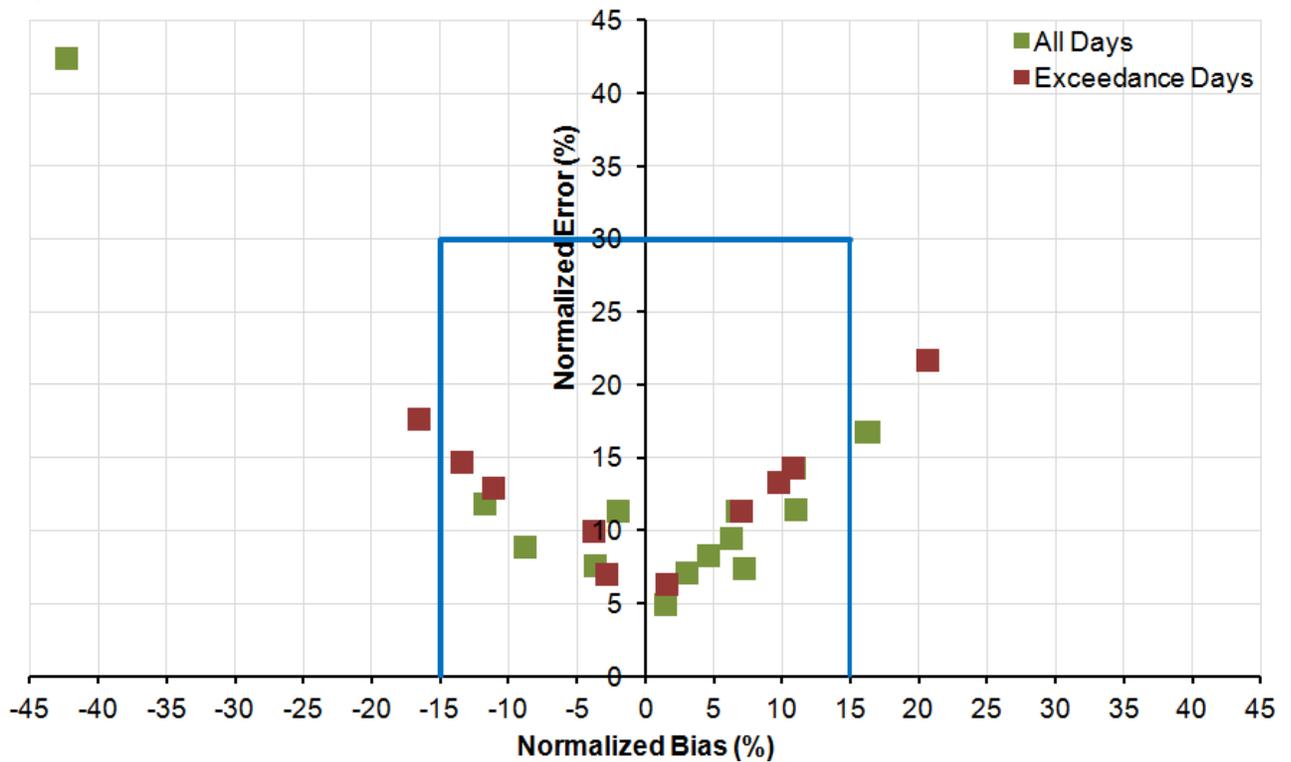
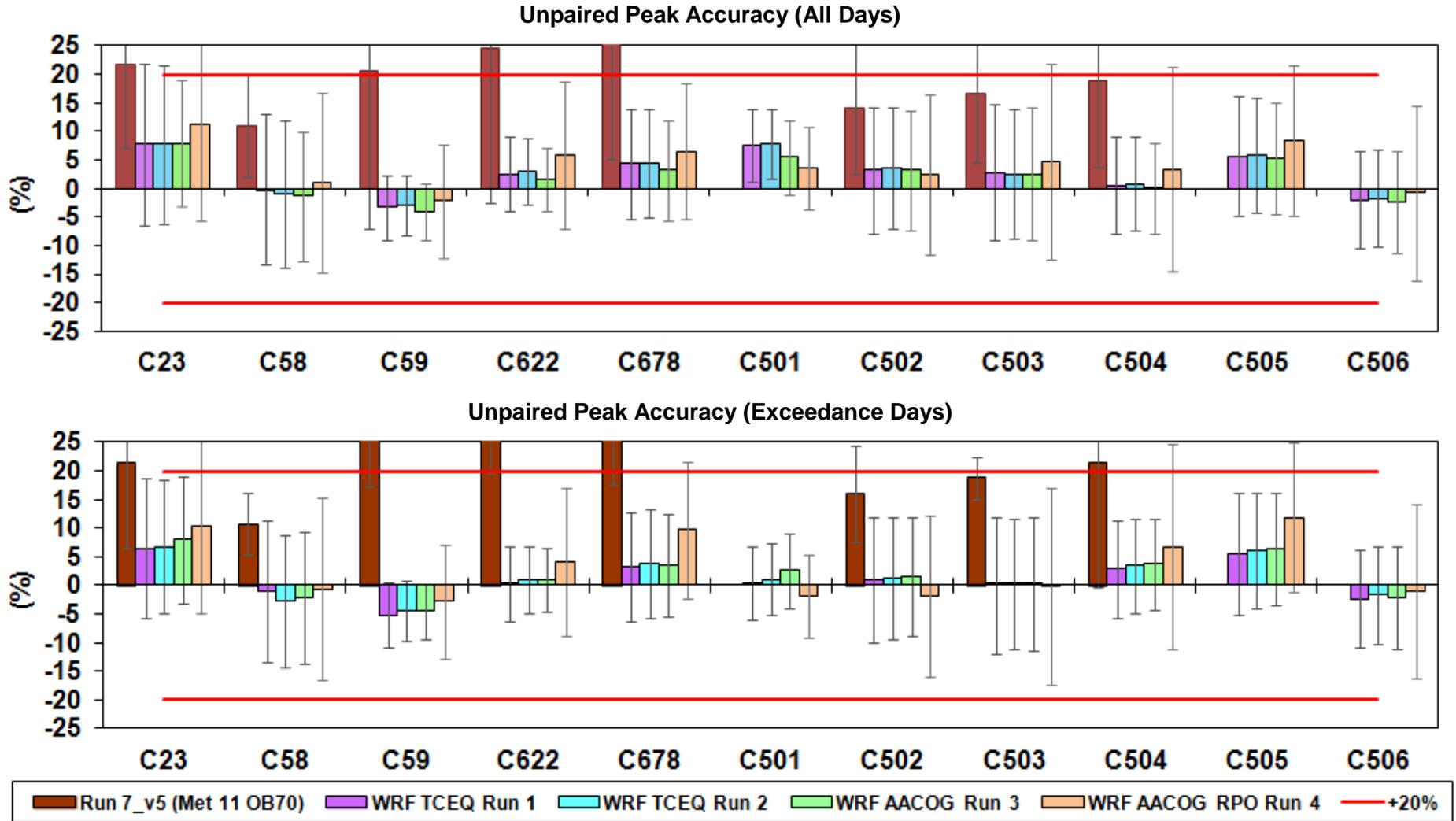
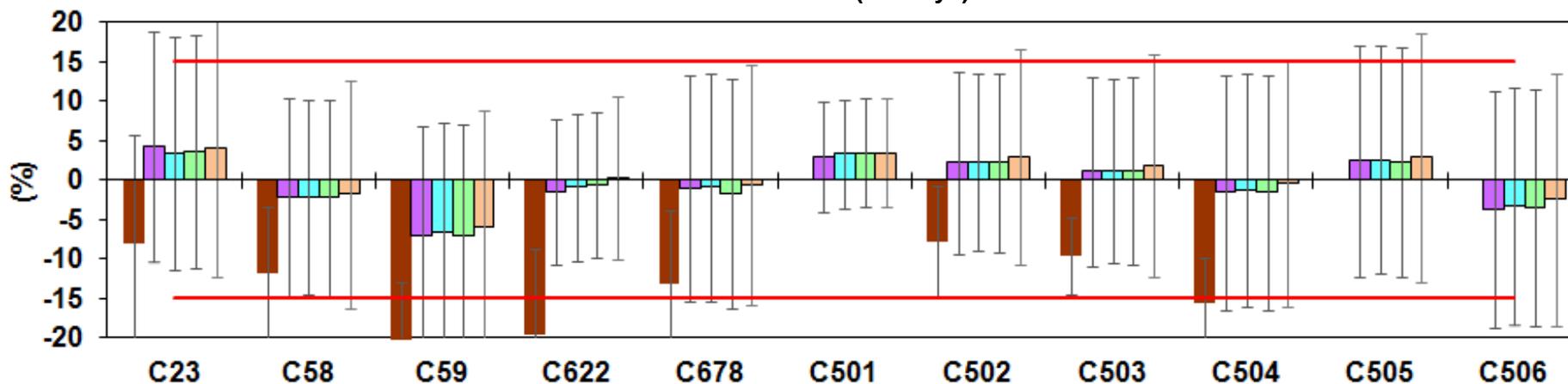


Figure 5-22: San Antonio CAMs performance for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4

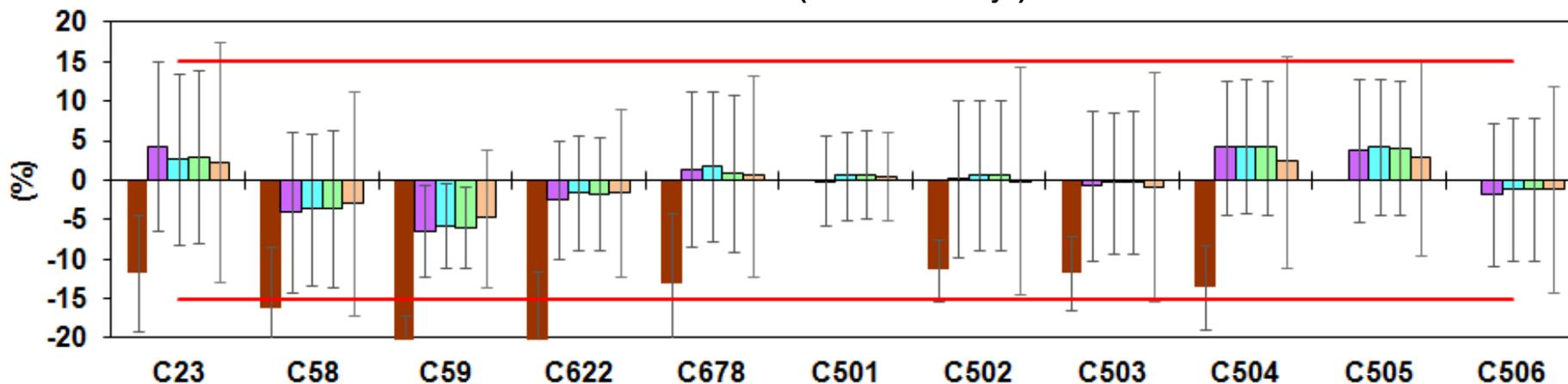


Note: Data for C501, C505, and C506 is not available for run MM5 Base Case Run 7

Mean Normalized Bias (All Days)

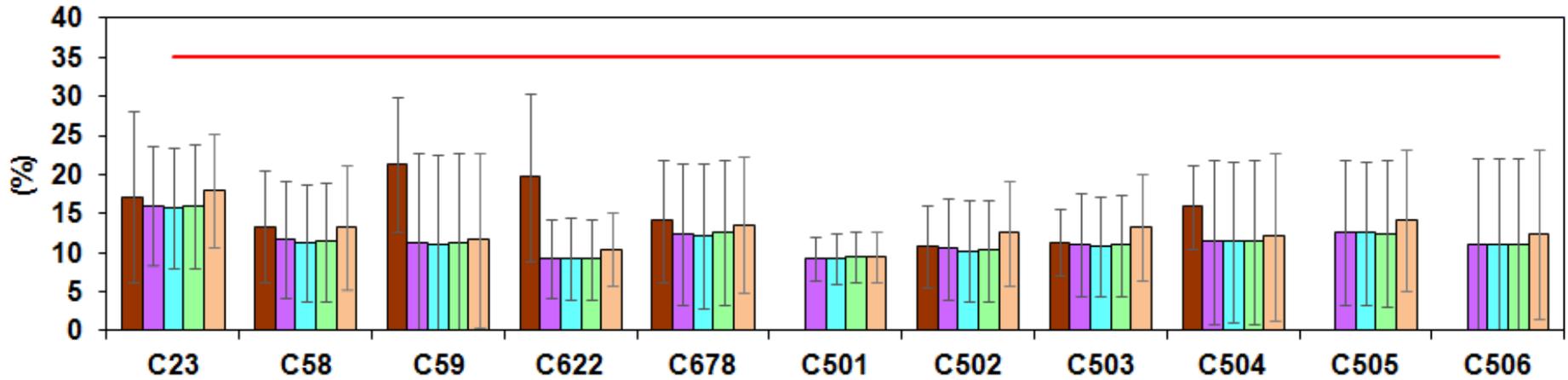


Mean Normalized Bias (Exceedance Days)

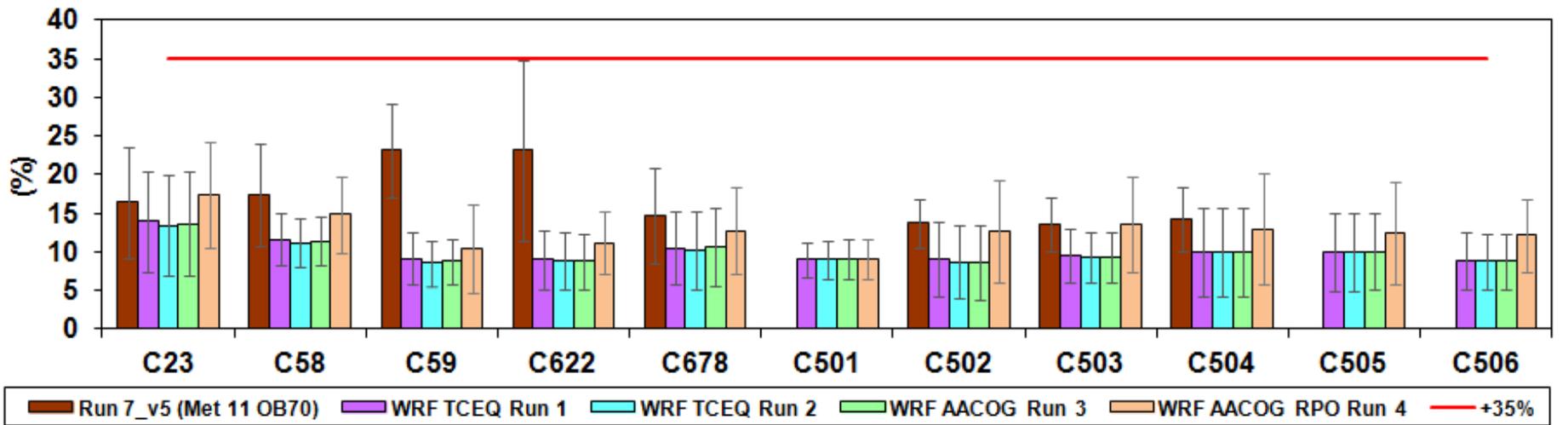


Note: Data for C501, C505, and C506 is not available for run MM5 Base Case Run 7

Mean Normalized Error (All Days)



Mean Normalized Error (Exceedance Days)



Note: Data for C501, C505, and C506 is not available for run MM5 Base Case Run 7

Figure 5-23: Soccer-style Plot of Normalized Gross Error and Normalized Bias by Monitor for Every Day, WRF AACOG Base Case Run 3

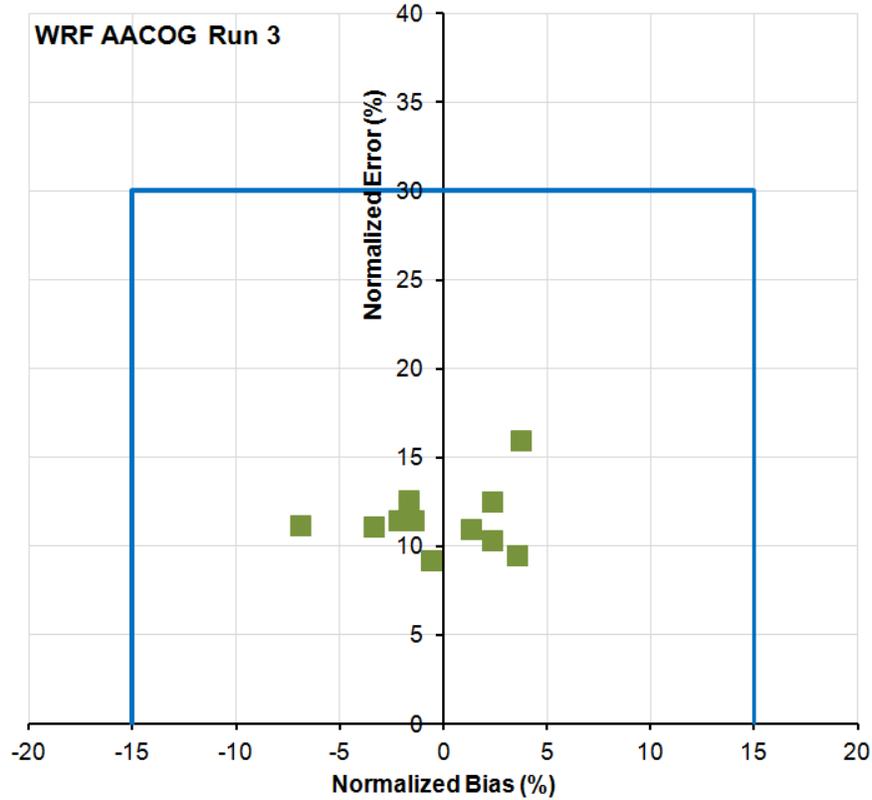


Figure 5-24: Soccer-style Plot of Normalized Gross Error and Normalized Bias by Monitor for Every Day, WRF AACOG RPO Base Case Run 4

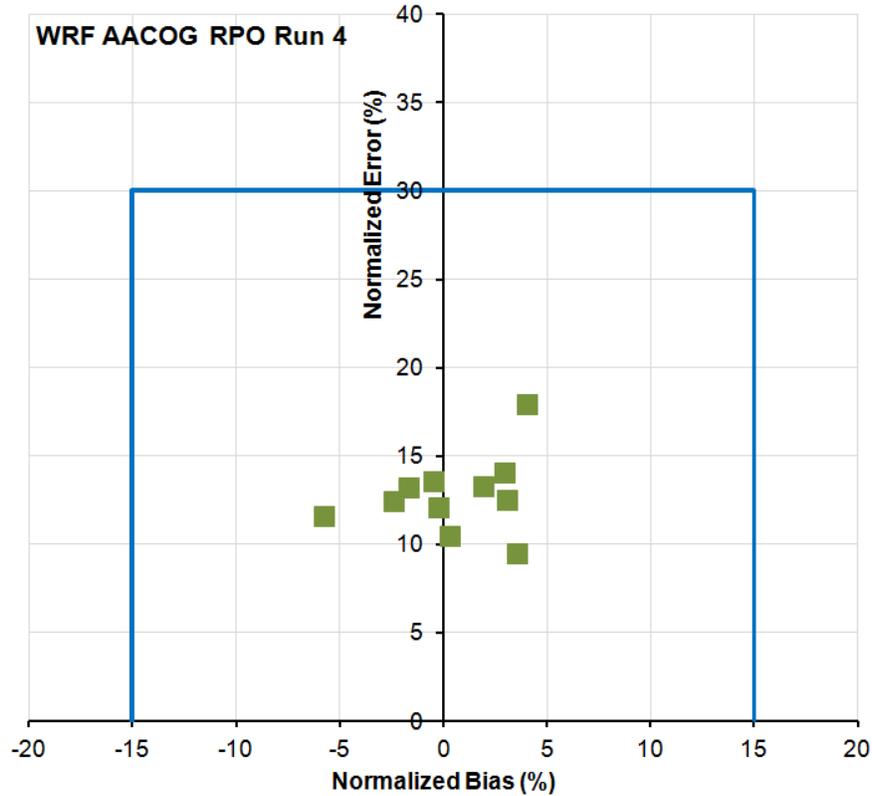


Figure 5-25: Soccer-style Plot of Normalized Gross Error and Normalized Bias by Monitor for Exceedance Days, WRF AACOG Base Case Run 3

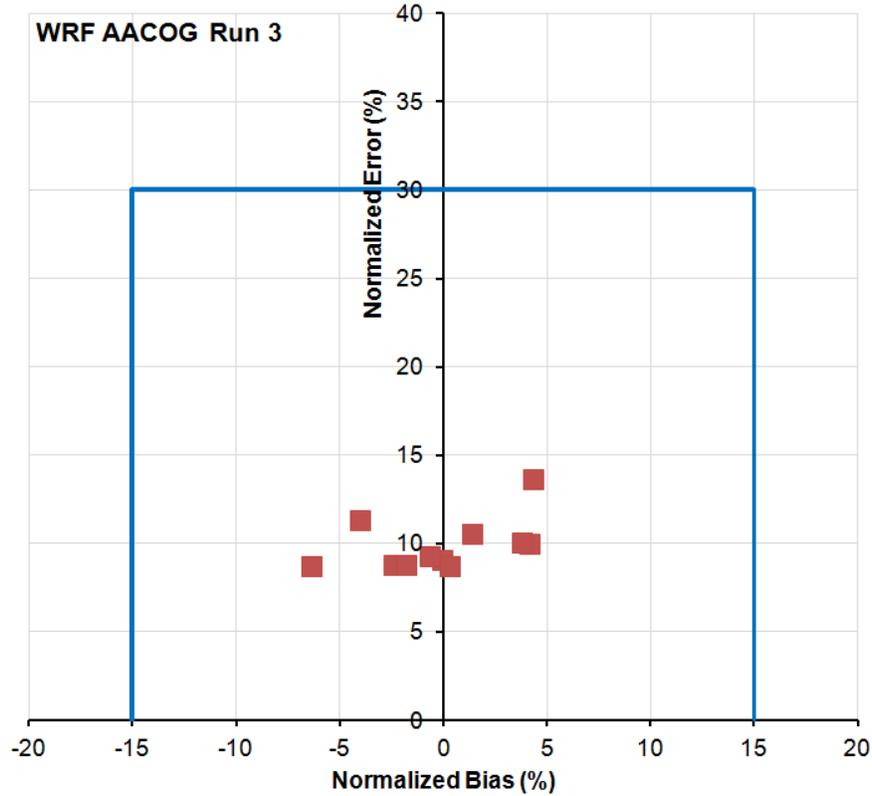


Figure 5-26: Soccer-style Plot of Normalized Gross Error and Normalized Bias by Monitor for Exceedance Days, WRF AACOG RPO Base Case Run 4

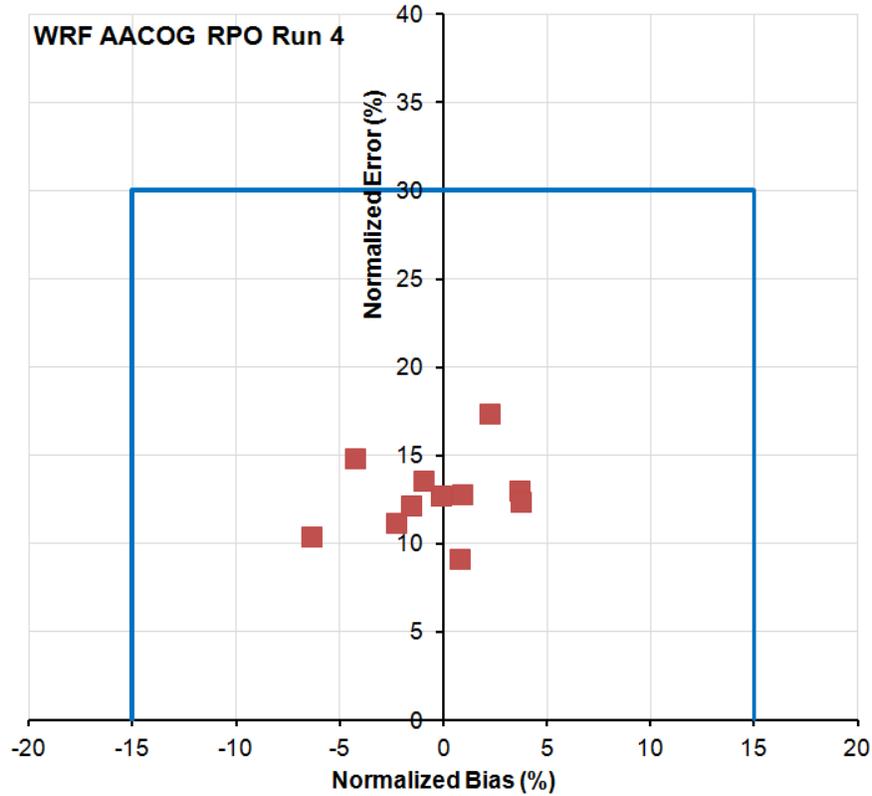


Table 5-2: San Antonio 8-hour Ozone CAMs performance in San Antonio, All Days average for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4

| Statistical | CAMS Station | Average All Days | | | | |
|-----------------------------------|--------------|------------------------|----------------|----------------|-----------------|---------------------|
| | | Run 7_v5 (Met 11 OB70) | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG RPO Run 4 |
| Unpaired Peak Prediction Accuracy | C23 | 21.87 | 7.73 | 7.77 | 7.93 | 11.33 |
| | C58 | 11.04 | -0.10 | -0.94 | -1.33 | 1.04 |
| | C59 | 20.55 | -3.29 | -2.86 | -4.02 | -2.17 |
| | C622 | 24.63 | 2.57 | 3.03 | 1.53 | 5.81 |
| | C678 | 28.56 | 4.36 | 4.48 | 3.17 | 6.51 |
| | C501 | | 7.57 | 7.85 | 5.48 | 3.52 |
| | C502 | 14.14 | 3.22 | 3.47 | 3.23 | 2.49 |
| | C503 | 16.76 | 2.85 | 2.57 | 2.48 | 4.64 |
| | C504 | 18.83 | 0.50 | 0.81 | 0.10 | 3.45 |
| | C505 | | 5.67 | 5.86 | 5.32 | 8.35 |
| | C506 | | -2.04 | -1.68 | -2.35 | -0.73 |
| Peak Bias (unpaired time) | C23 | 2.45 | 3.22 | 2.52 | 2.71 | 3.06 |
| | C58 | -5.56 | -1.70 | -1.69 | -1.68 | -1.22 |
| | C59 | -15.27 | -4.90 | -4.59 | -4.80 | -4.06 |
| | C622 | -11.83 | -0.97 | -0.54 | -0.43 | 0.24 |
| | C678 | -6.31 | -0.66 | -0.47 | -1.04 | -0.31 |
| | C501 | | 1.82 | 2.07 | 2.23 | 0.32 |
| | C502 | -3.68 | 1.44 | 1.44 | 1.49 | 2.07 |
| | C503 | -3.24 | 0.69 | 0.75 | 0.81 | 1.27 |
| | C504 | -7.99 | -0.91 | -0.77 | -0.91 | -0.14 |
| | C505 | | 1.76 | 1.92 | 1.72 | 2.11 |
| | C506 | | -2.43 | -2.14 | -2.21 | -1.60 |
| Peak Error (unpaired time) | C23 | 10.74 | 11.24 | 11.04 | 11.19 | 12.67 |
| | C58 | 7.92 | 8.67 | 8.37 | 8.47 | 9.84 |
| | C59 | 15.27 | 7.61 | 7.48 | 7.56 | 7.90 |
| | C622 | 11.83 | 6.18 | 6.15 | 6.11 | 7.16 |
| | C678 | 7.67 | 8.38 | 8.24 | 8.49 | 9.26 |
| | C501 | | 6.70 | 6.67 | 6.80 | 7.18 |
| | C502 | 10.09 | 7.28 | 7.09 | 7.15 | 8.66 |
| | C503 | 5.63 | 7.65 | 7.46 | 7.56 | 9.22 |
| | C504 | 9.46 | 7.67 | 7.66 | 7.67 | 8.21 |
| | C505 | | 8.70 | 8.64 | 8.63 | 9.76 |
| | C506 | | 7.47 | 7.43 | 7.43 | 8.44 |

| Statistical | CAMS Station | Average All Days | | | | |
|-----------------------|--------------|------------------------------|-------------------|-------------------|-----------------------|---------------------------|
| | | Run 7_v5 (Met 11 OB70) | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG RPO Run 4 |
| Bias (normalized) | C23 | -8.08 | 4.34 | 3.47 | 3.71 | 4.01 |
| | C58 | -11.71 | -2.15 | -2.15 | -2.16 | -1.70 |
| | C59 | -21.32 | -7.10 | -6.65 | -6.93 | -5.80 |
| | C622 | -19.59 | -1.45 | -0.82 | -0.62 | 0.25 |
| | C678 | -13.03 | -1.04 | -0.86 | -1.68 | -0.52 |
| | C501 | | 3.02 | 3.37 | 3.55 | 0.97 |
| | C502 | -7.79 | 2.25 | 2.26 | 2.30 | 3.04 |
| | C503 | -9.55 | 1.15 | 1.24 | 1.30 | 1.92 |
| | C504 | -15.60 | -1.47 | -1.25 | -1.47 | -0.26 |
| | C505 | | 2.45 | 2.64 | 2.34 | 2.89 |
| | C506 | | -3.69 | -3.29 | -3.39 | -2.43 |
| Error (normalized) | C23 | 17.20 | 16.06 | 15.77 | 15.97 | 17.96 |
| | C58 | 13.38 | 11.73 | 11.30 | 11.44 | 13.28 |
| | C59 | 21.32 | 11.27 | 11.07 | 11.19 | 11.63 |
| | C622 | 19.72 | 9.27 | 9.26 | 9.18 | 10.49 |
| | C678 | 14.15 | 12.46 | 12.26 | 12.62 | 13.61 |
| | C501 | | 9.33 | 9.32 | 9.50 | 10.00 |
| | C502 | 10.79 | 10.52 | 10.24 | 10.31 | 12.57 |
| | C503 | 11.33 | 11.06 | 10.80 | 10.95 | 13.28 |
| | C504 | 15.88 | 11.46 | 11.46 | 11.46 | 12.10 |
| | C505 | | 12.62 | 12.54 | 12.51 | 14.11 |
| | C506 | | 11.16 | 11.16 | 11.15 | 12.45 |

Although the results of the paired prediction accuracy analyses were similar for each of the 4 WRF runs, there were some differences for individual monitors. The first run, TCEQ run 1, exhibited the lowest paired prediction accuracy at most monitors besides C58. Peak prediction accuracy was between 6.48% and 10.23% at C23 and between -0.57% and -2.81% at C58 on exceedance days. As shown in Figure 5-23 to Figure 5-26, these analyses were well within the criteria area (“goal box”) on the soccer plots for all monitors and on all days.

Table 5-3: San Antonio 8-hour Ozone CAMs performance in San Antonio, Exceedance Days average for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4

| Statistical | CAMS Station | Average All Days | | | | |
|---|--------------|------------------------------|-------------------|-------------------|-----------------------|---------------------------|
| | | Run 7_v5 (Met 11 OB70) | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG RPO Run 4 |
| Unpaired Peak Prediction Accuracy | C23 | 21.43 | 6.48 | 6.79 | 8.06 | 10.23 |
| | C58 | 10.77 | -1.09 | -2.81 | -2.10 | -0.57 |
| | C59 | 34.42 | -5.16 | -4.45 | -4.54 | -2.72 |
| | C622 | 36.65 | 0.36 | 1.02 | 1.08 | 4.21 |
| | C678 | 35.13 | 3.27 | 3.78 | 3.66 | 9.70 |
| | C501 | | 0.55 | 1.13 | 2.63 | -1.93 |
| | C502 | 16.05 | 0.98 | 1.30 | 1.54 | -1.84 |
| | C503 | 18.77 | 0.01 | 0.37 | 0.29 | -0.21 |
| | C504 | 21.44 | 2.87 | 3.46 | 3.73 | 6.77 |
| | C505 | | 5.57 | 6.06 | 6.45 | 11.93 |
| C506 | | -2.35 | -1.64 | -2.19 | -0.99 | |
| Peak Bias (unpaired time) | C23 | -1.13 | 3.64 | 2.34 | 2.56 | 2.33 |
| | C58 | -7.25 | -2.97 | -2.71 | -2.64 | -2.88 |
| | C59 | -17.68 | -4.73 | -4.24 | -4.44 | -4.77 |
| | C622 | -14.30 | -1.63 | -1.06 | -1.19 | -1.53 |
| | C678 | -6.98 | 0.94 | 1.32 | 0.63 | 0.62 |
| | C501 | | -0.10 | 0.35 | 0.50 | -2.43 |
| | C502 | -6.17 | 0.07 | 0.29 | 0.30 | -0.04 |
| | C503 | -6.83 | -0.70 | -0.42 | -0.39 | -0.80 |
| | C504 | -6.38 | 2.77 | 2.86 | 2.77 | 2.41 |
| | C505 | | 2.87 | 3.24 | 3.12 | 2.88 |
| C506 | | -1.29 | -0.76 | -0.79 | -1.12 | |
| Peak Error (unpaired time) | C23 | 8.57 | 10.49 | 10.17 | 10.35 | 13.05 |
| | C58 | 8.82 | 9.13 | 8.83 | 8.98 | 11.62 |
| | C59 | 17.68 | 6.64 | 6.27 | 6.37 | 7.59 |
| | C622 | 14.30 | 6.32 | 6.17 | 6.17 | 7.90 |
| | C678 | 9.48 | 7.64 | 7.43 | 7.71 | 9.35 |
| | C501 | | 6.93 | 6.90 | 7.03 | 7.65 |
| | C502 | 11.10 | 6.57 | 6.32 | 6.35 | 9.05 |
| | C503 | 9.60 | 6.99 | 6.71 | 6.79 | 9.81 |
| | C504 | 9.90 | 7.17 | 7.13 | 7.17 | 9.38 |
| | C505 | | 7.37 | 7.38 | 7.43 | 9.13 |
| C506 | | 6.47 | 6.32 | 6.33 | 8.85 | |

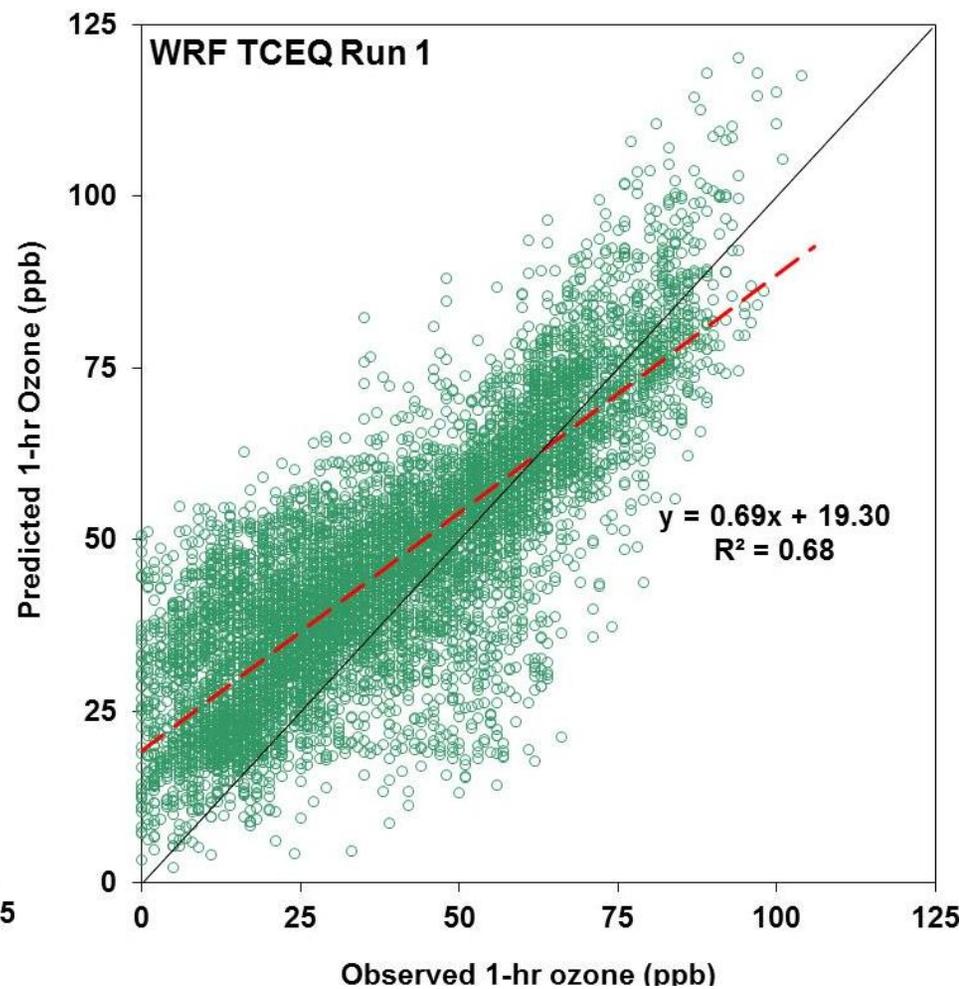
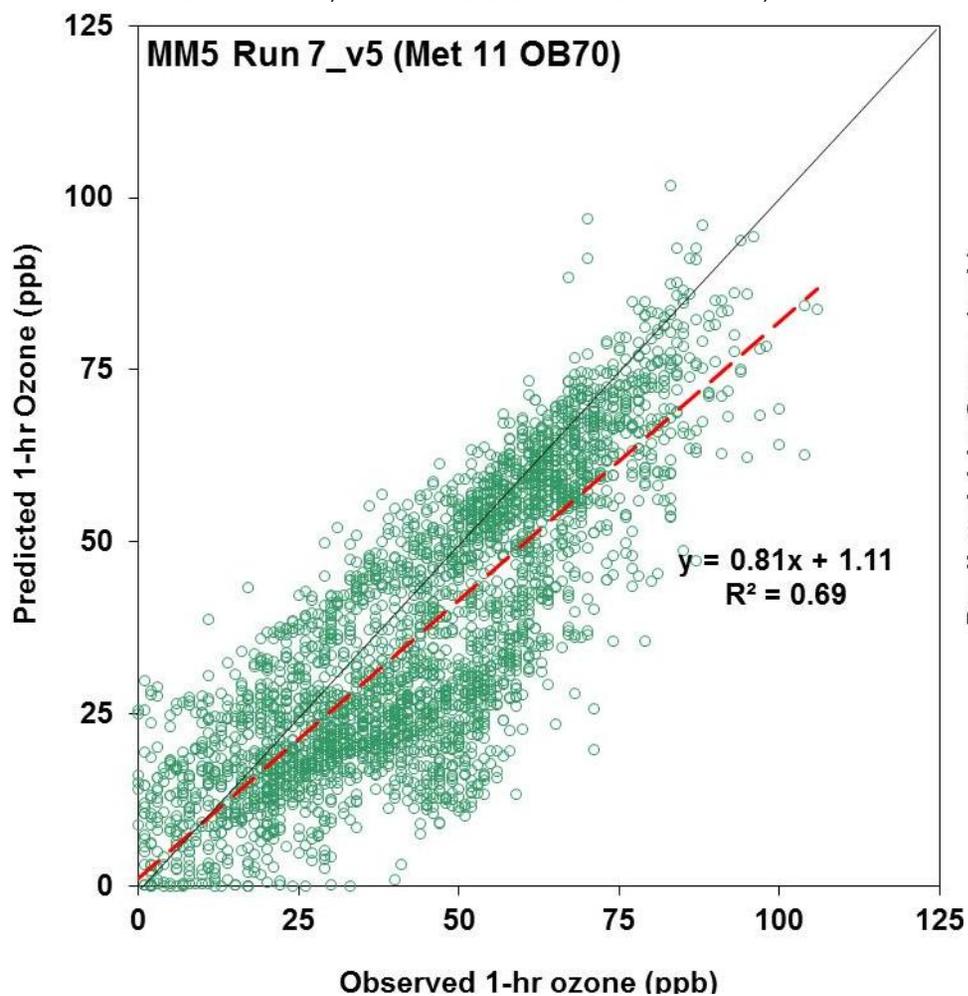
| Statistical | CAMS Station | Average All Days | | | | |
|-----------------------|--------------|------------------------------|-------------------|-------------------|-----------------------|---------------------------|
| | | Run 7_v5 (Met 11 OB70) | WRF TCEQ Run 1 | WRF TCEQ Run 2 | WRF AACOG Run 3 | WRF AACOG RPO Run 4 |
| Bias (normalized) | C23 | -11.68 | 4.33 | 2.69 | 2.96 | 2.18 |
| | C58 | -16.25 | -4.01 | -3.62 | -3.58 | -4.30 |
| | C59 | -23.15 | -6.37 | -5.70 | -5.97 | -6.40 |
| | C622 | -23.15 | -2.38 | -1.59 | -1.75 | -2.32 |
| | C678 | -13.00 | 1.41 | 1.81 | 0.86 | 0.88 |
| | C501 | | -0.05 | 0.60 | 0.75 | -3.25 |
| | C502 | -11.37 | 0.29 | 0.64 | 0.65 | -0.13 |
| | C503 | -11.78 | -0.67 | -0.28 | -0.25 | -0.98 |
| | C504 | -13.58 | 4.16 | 4.28 | 4.16 | 3.63 |
| | C505 | | 3.80 | 4.29 | 4.16 | 3.63 |
| | C506 | | -1.82 | -1.10 | -1.16 | -1.59 |
| Error (normalized) | C23 | 16.48 | 13.96 | 13.48 | 13.69 | 17.37 |
| | C58 | 17.35 | 11.60 | 11.19 | 11.40 | 14.84 |
| | C59 | 23.15 | 9.17 | 8.64 | 8.77 | 10.39 |
| | C622 | 23.18 | 9.02 | 8.81 | 8.83 | 11.19 |
| | C678 | 14.72 | 10.53 | 10.18 | 10.62 | 12.78 |
| | C501 | | 9.00 | 9.00 | 9.15 | 9.95 |
| | C502 | 13.73 | 9.09 | 8.71 | 8.73 | 12.73 |
| | C503 | 13.55 | 9.61 | 9.23 | 9.32 | 13.55 |
| | C504 | 14.24 | 10.03 | 10.02 | 10.03 | 13.01 |
| | C505 | | 10.00 | 10.03 | 10.11 | 12.37 |
| | C506 | | 8.96 | 8.77 | 8.80 | 12.15 |

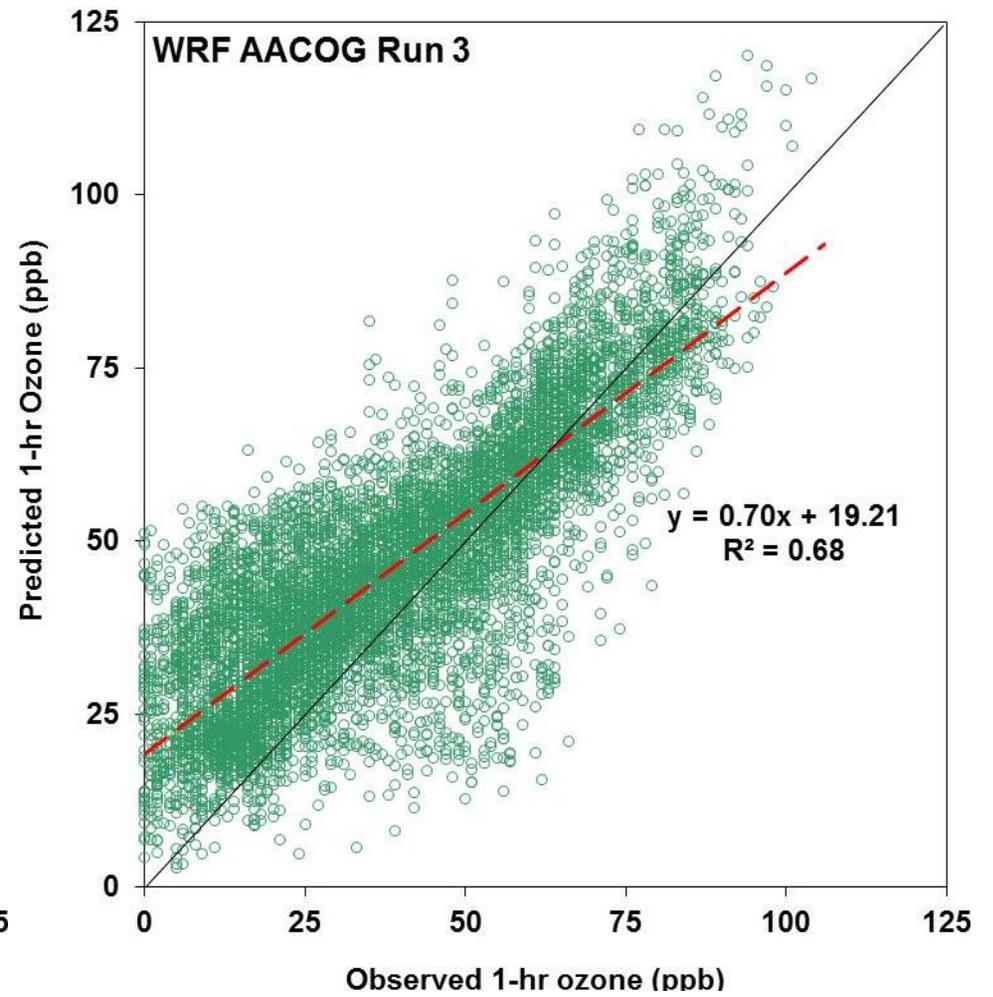
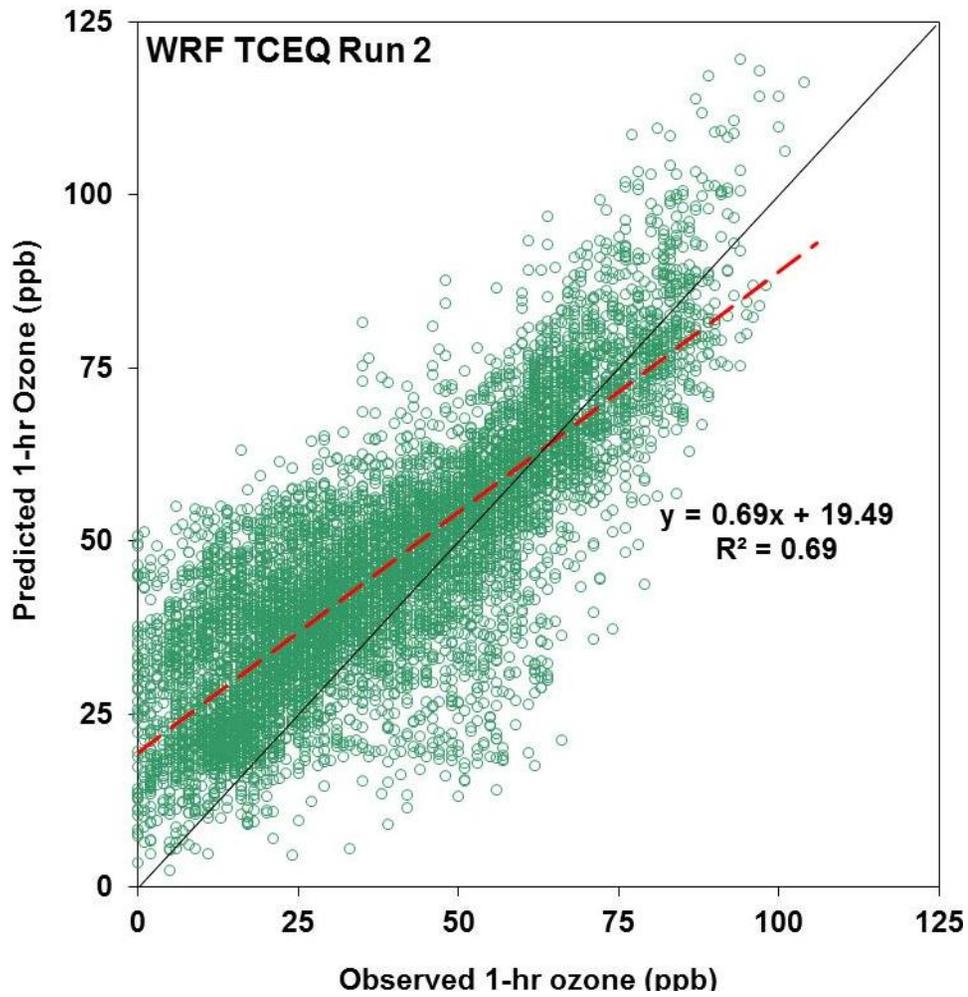
5.5 Ozone Scatter Plots

Scatter plots of hourly predicted and observed ozone readings at CAMS stations were plotted to determine how well the base case runs represented observed ozone (Figure 5-27). The scatter plots are based on hourly observed and predicted data from all the ozone monitors in the San Antonio-New Braunfels MSA. Each run tended to over predict ozone below 60 ppb, but correlated well for higher ozone values. Figure 5-28 provides the scatter plots for 8-hour daily maximum ozone for each run. Eight-hour observed and predicted ozone correlated well, although values below 60 ppb tended to be slightly over predicted.

The R^2 values for predicted 8-hour ozone ranged from 0.74 to 0.75. Correlation between predicted and observed hourly ozone was good for both C23 and C58: R^2 values ranged from 0.67 to 0.70. Overall TCEQ run 2 demonstrated the best correlation for both 1 hour and 8 hour ozone (Table 5-4). Surprisingly, performance was slightly degraded when local emission inventory inputs were included in AACOG run 3. AACOG run 4 with the RPO grid, had degraded performance for hourly ozone values for all monitors, C23 and C58. Although performance was degraded for 1 hour values and on days > 60 ppb, AACOG run 4 had the best performance for 8 hour values at C23 and C58 (R^2 was 0.75 and 0.73).

Figure 5-27: San Antonio Hourly Ozone Scatter Plots in San Antonio for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4





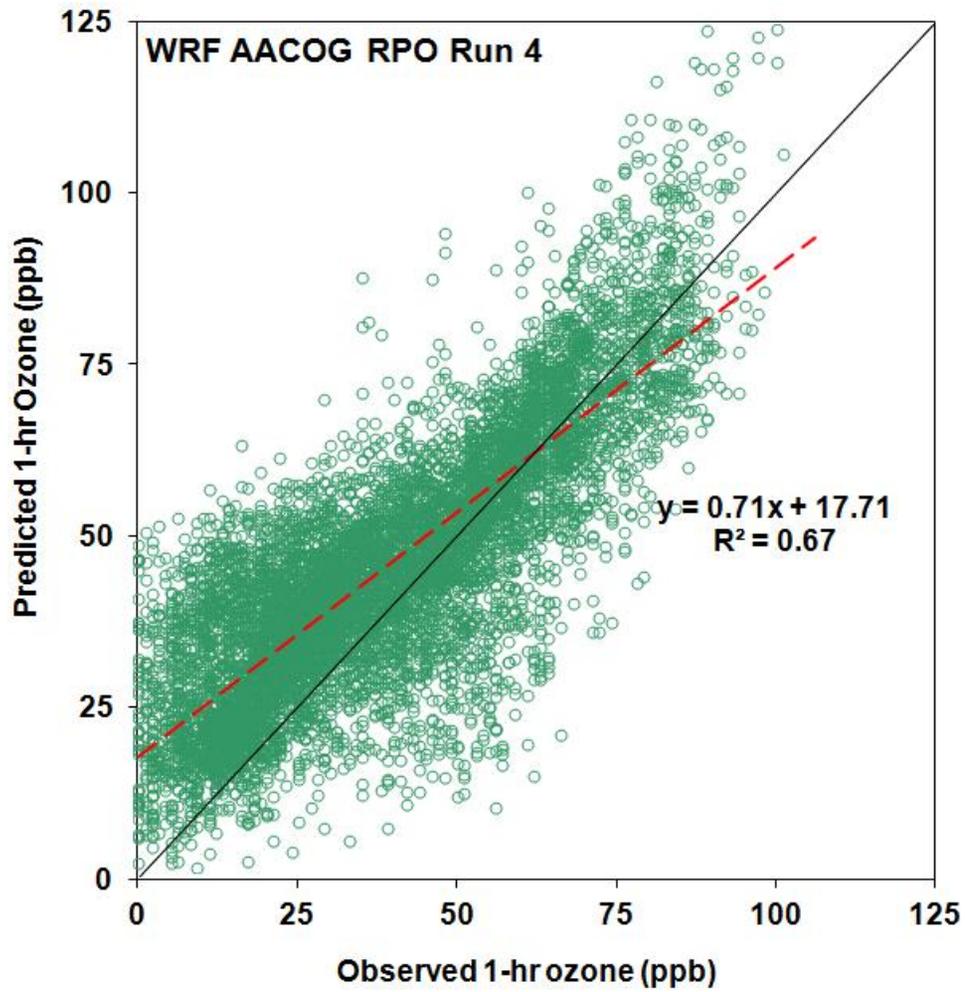
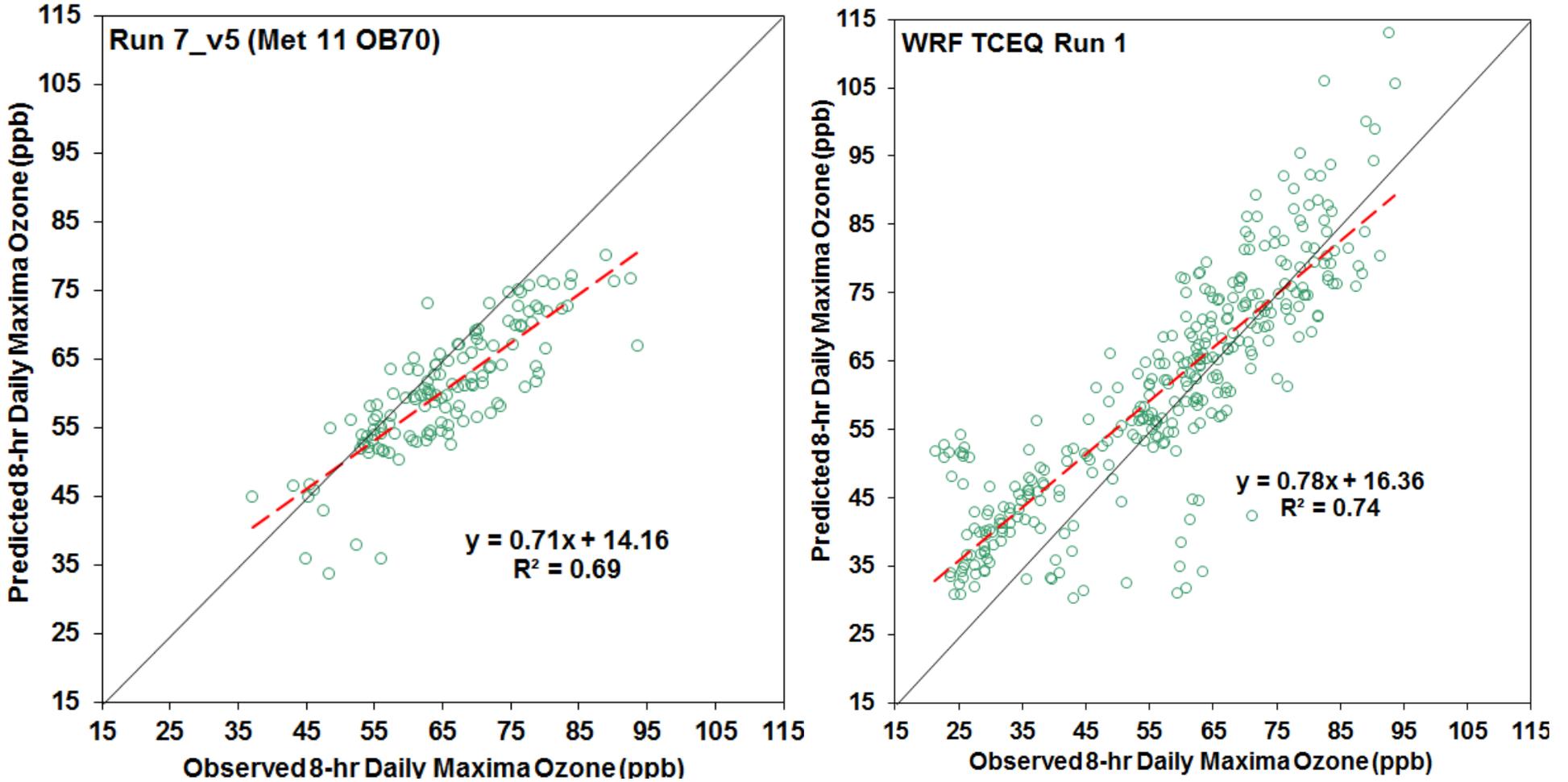
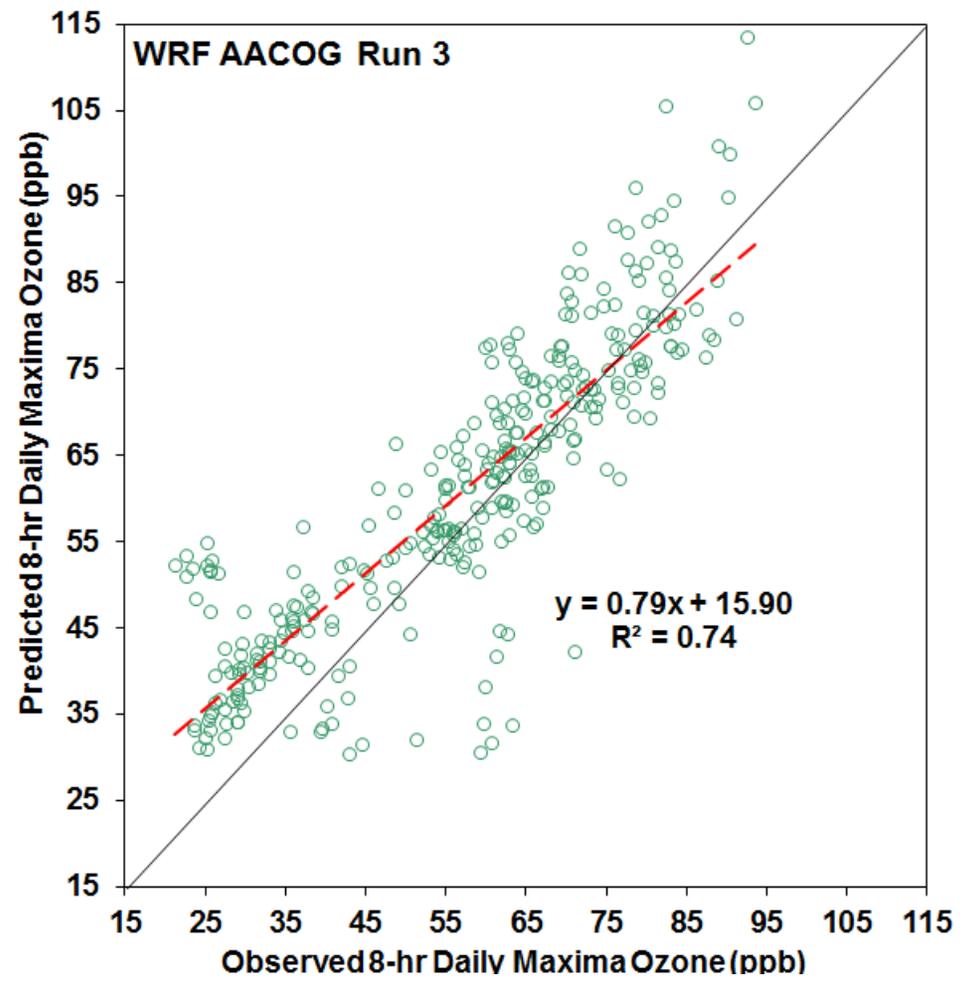
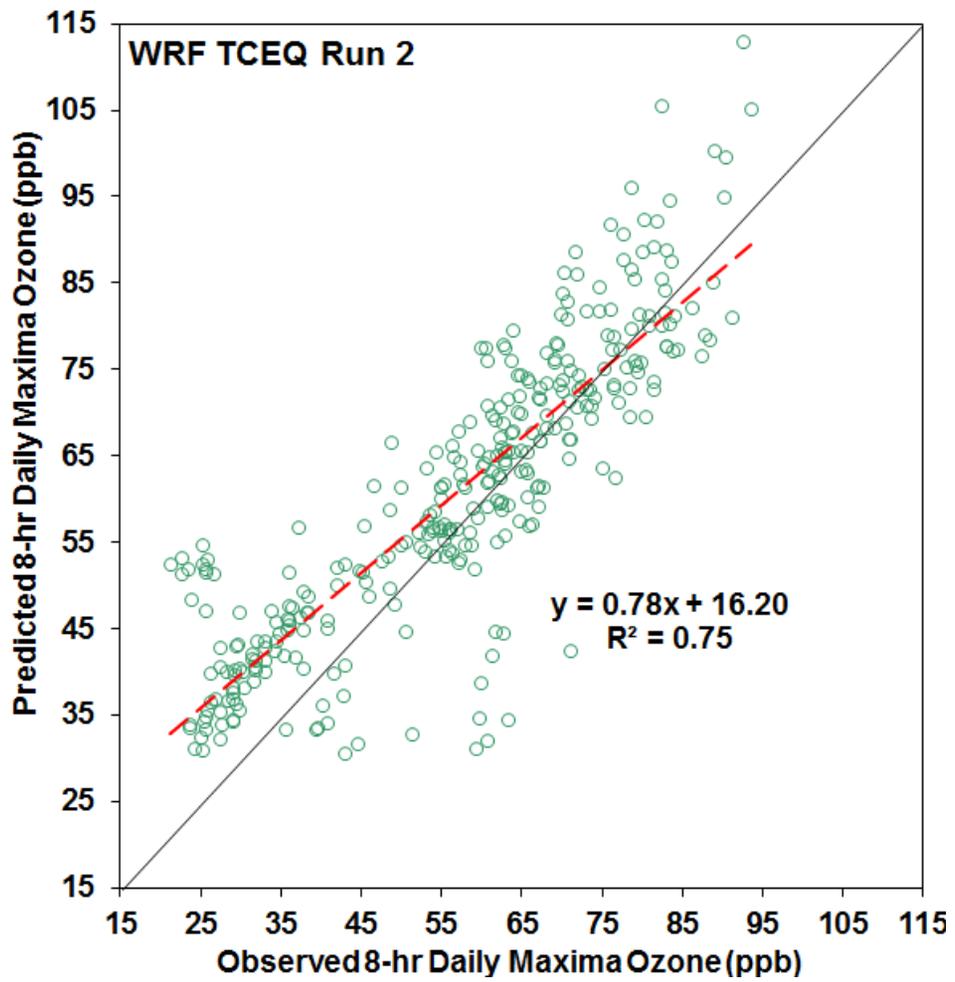


Figure 5-28: San Antonio 8-Hour Daily Maximum Ozone Scatter Plots in San Antonio for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4





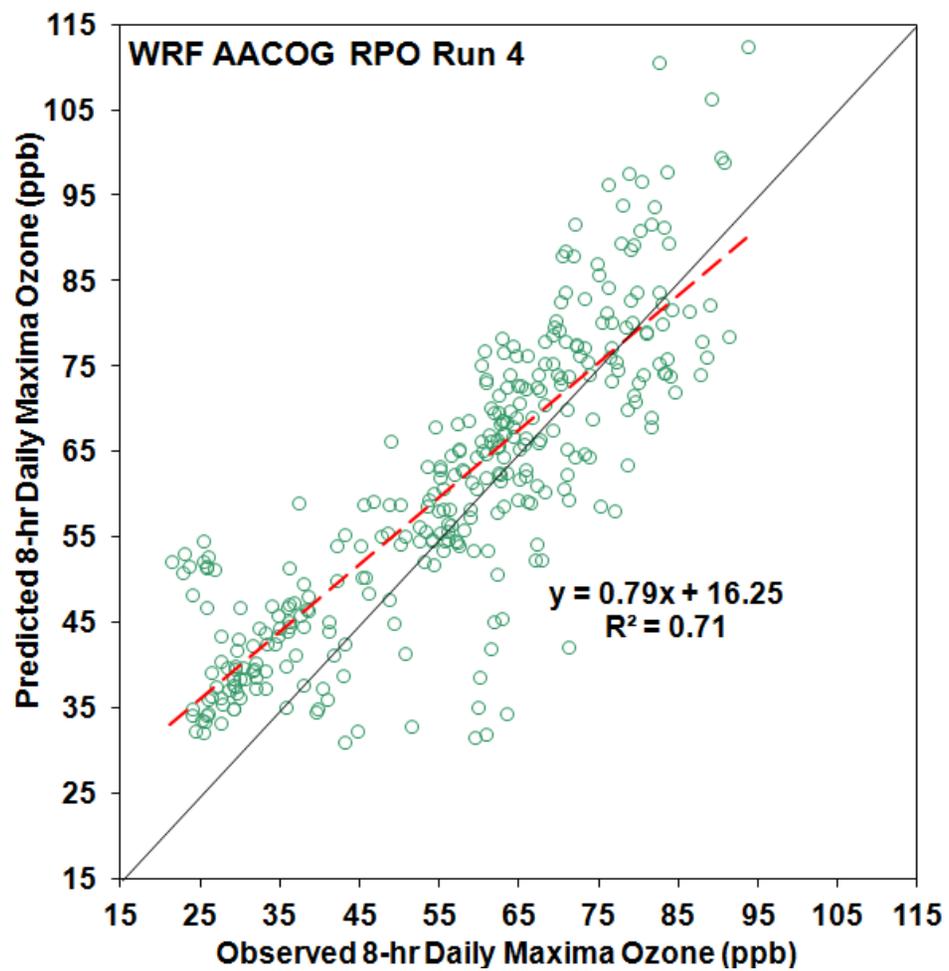


Table 5-4: R² values for San Antonio Ozone Scatter Plots: MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF AACOG Base Case Run 3, and WRF AACOG RPO Base Case Run 4

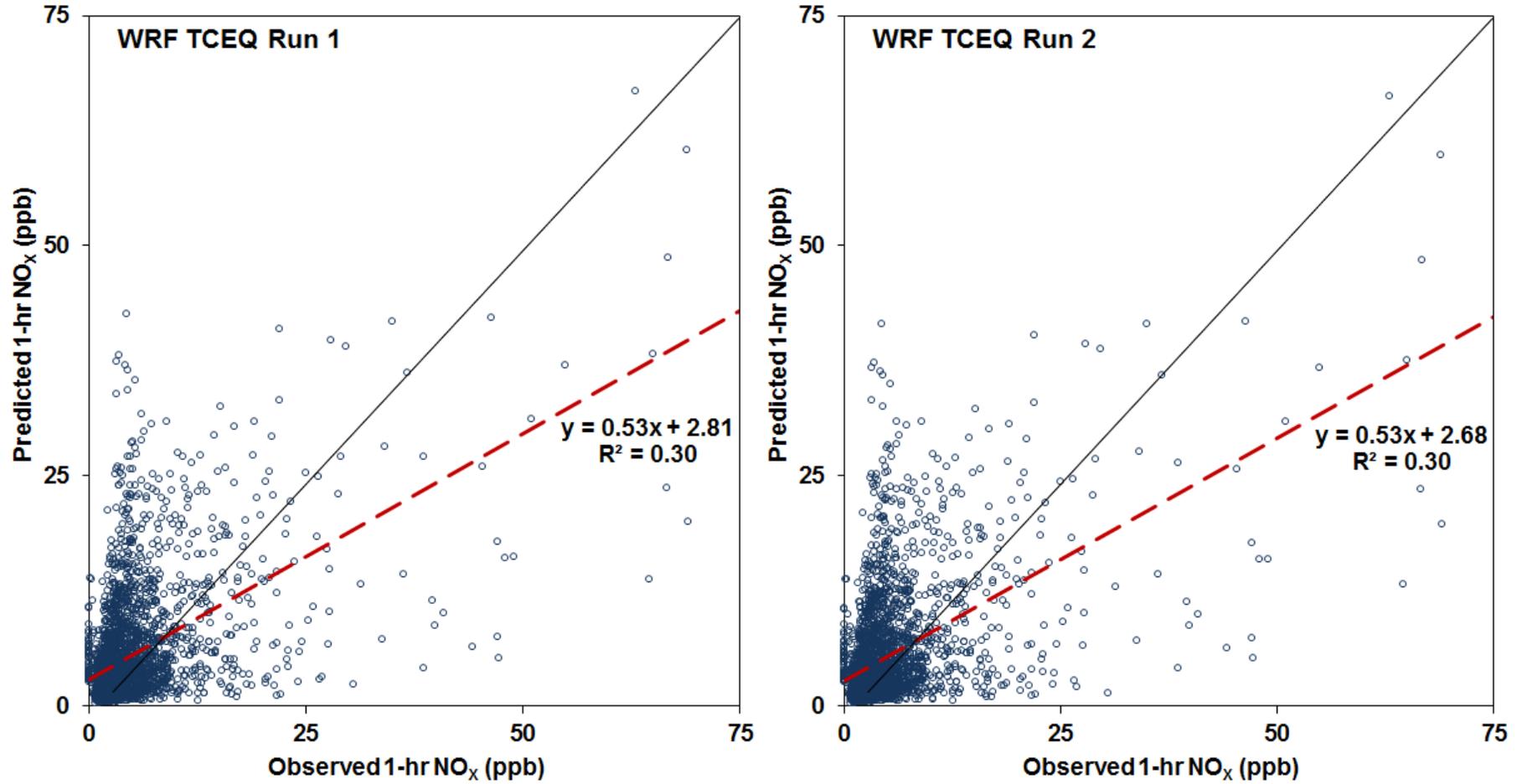
| Date | Run | Hourly Ozone R ² | | | | | | 8-hour Daily Maxima Ozone R ² | | | | | | |
|---------------------|-----------------|-----------------------------|--------------|--------------|--------------|--------------|--------------|--|--------------|--------------|--------------|--------------|--------------|--|
| | | All Hours | | | >60 ppb | | | All Hours | | | >60 ppb | | | |
| | | All CAMS | C23 | C58 | All CAMS | C23 | C58 | All CAMS | C23 | C58 | All CAMS | C23 | C58 | |
| June 1-15, 2006 | MM5 Run 7_v5 | <i>0.688</i> | <i>0.629</i> | <i>0.719</i> | <i>0.274</i> | <i>0.145</i> | <i>0.299</i> | <i>0.690</i> | | | | | | |
| | WRF TCEQ Run 1 | 0.737 | 0.742 | 0.738 | 0.436 | 0.643 | 0.498 | 0.775 | 0.777 | 0.784 | 0.469 | 0.574 | <i>0.540</i> | |
| | WRF TCEQ Run 2 | 0.737 | 0.744 | 0.741 | 0.441 | 0.648 | 0.508 | 0.774 | 0.778 | 0.785 | 0.470 | 0.574 | 0.544 | |
| | AACOG Run 3 | 0.733 | 0.738 | 0.737 | 0.439 | 0.649 | 0.502 | 0.771 | <i>0.773</i> | 0.781 | <i>0.463</i> | <i>0.569</i> | 0.541 | |
| | AACOG RPO Run 4 | 0.734 | 0.741 | 0.738 | 0.469 | 0.672 | 0.522 | 0.772 | 0.778 | <i>0.778</i> | 0.516 | 0.633 | 0.563 | |
| June 1-July 2, 2006 | WRF TCEQ Run 1 | 0.685 | 0.693 | 0.680 | 0.290 | 0.392 | 0.318 | 0.719 | 0.730 | 0.725 | 0.342 | 0.411 | 0.351 | |
| | WRF TCEQ Run 2 | 0.686 | 0.697 | 0.681 | 0.298 | 0.401 | 0.328 | 0.720 | 0.733 | 0.726 | 0.355 | 0.416 | 0.360 | |
| | AACOG Run 3 | 0.684 | 0.693 | 0.679 | 0.295 | 0.403 | 0.325 | 0.718 | <i>0.730</i> | <i>0.724</i> | 0.347 | 0.412 | 0.358 | |
| | AACOG RPO Run 4 | <i>0.672</i> | <i>0.681</i> | <i>0.668</i> | <i>0.252</i> | <i>0.371</i> | <i>0.300</i> | <i>0.702</i> | 0.753 | 0.727 | <i>0.269</i> | <i>0.395</i> | <i>0.311</i> | |

5.6 NO_x Scatter Plots

Scatter plots of hourly predicted and observed NO_x concentrations at CAMS stations were plotted to determine how well the base case runs represented observed ozone (Figure 5-29). The scatter plots are based on observed and predicted data from C58, C59, C622, and C678 NO_x monitors for June 1st – July 2nd. The model over predicted NO_x when the observed value was below 10 ppb and under predicted when higher NO_x readings were recorded. The model performance for NO_x was poorer compared to the performance for ozone.

Model performance was poor for the C58 NO_x monitor in northwest San Antonio with an R² value between 0.12 and 0.13 (Table 5-5). The model significantly over predicted NO_x at C58 during most days of the modeling episode. Model performance was slightly improved at C59 and C622 with good performance at C678. AACOG run 4 with the RPO grid had improved performance at C58 and C622, but degraded performance at C59.

Figure 5-29: San Antonio Hourly NO_x Scatter Plots in San Antonio for WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF ACOG Base Case Run 3, and WRF ACOG RPO Base Case Run 4



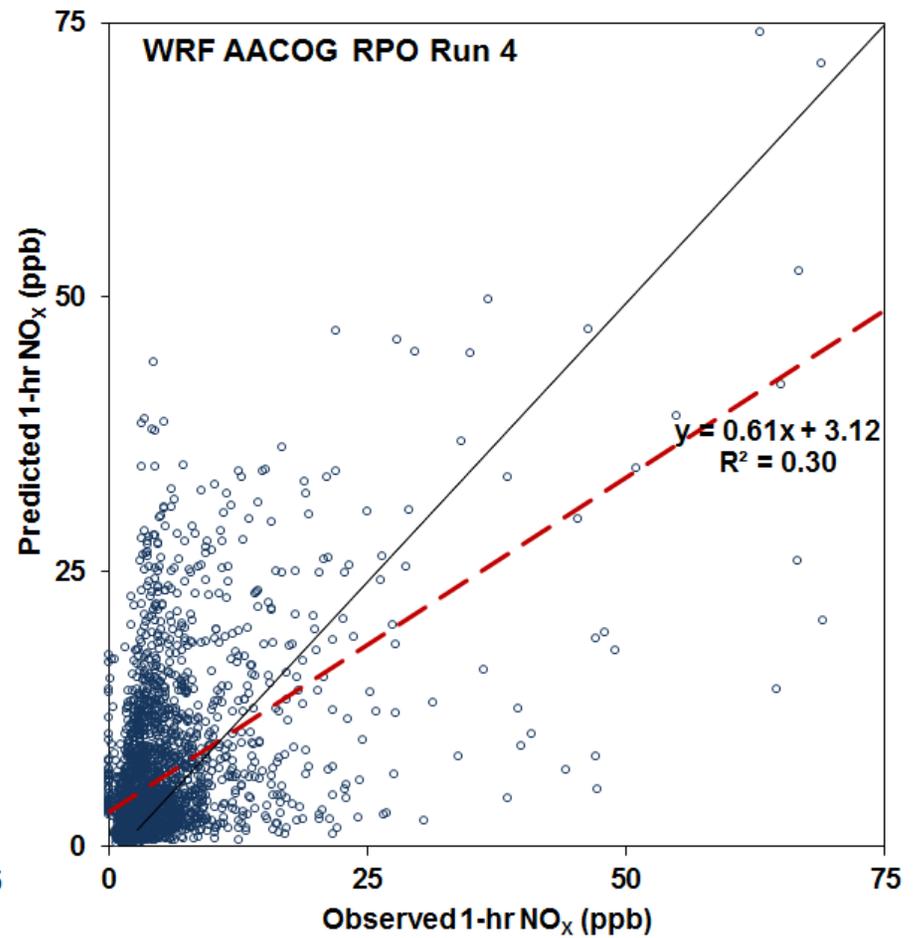
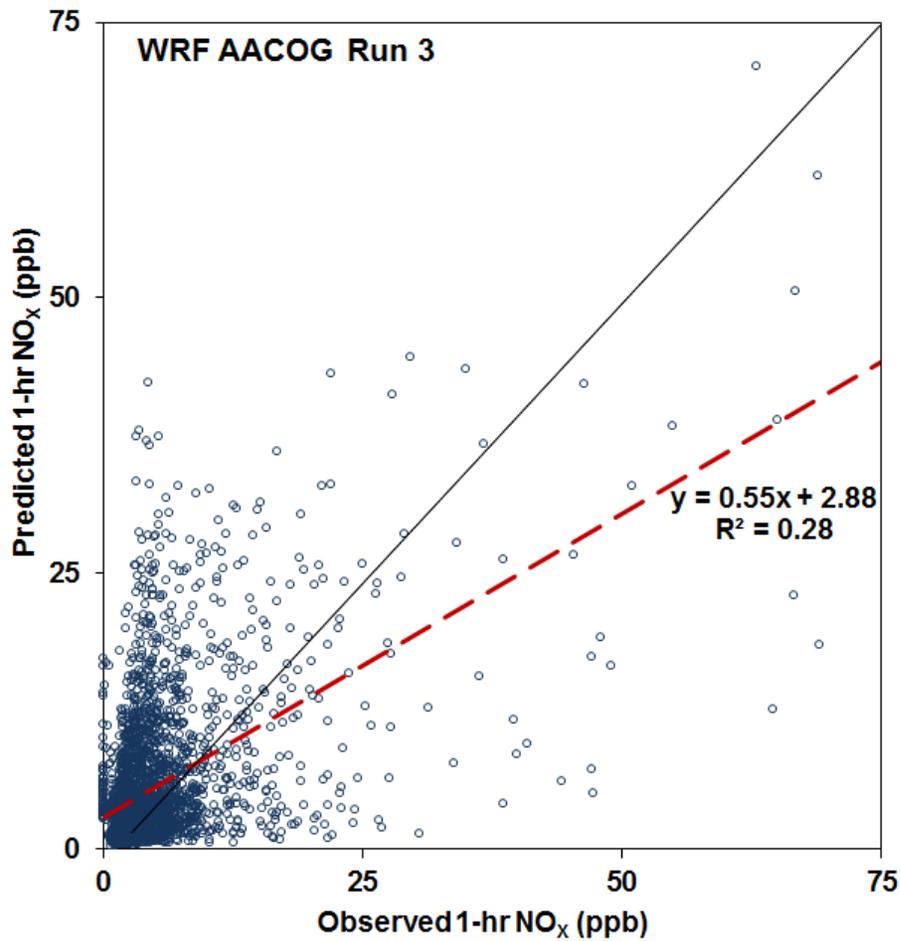


Table 5-5: R² values for San Antonio NO_x Scatter Plots, June 1-July 2, 2006: WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF ACOG Base Case Run 3, and WRF ACOG RPO Base Case Run 4

| Run | All | C58 | C59 | C622 | C678 |
|-----------------------|--------------|--------------|--------------|--------------|--------------|
| TCEQ Run 1 (WRF) | 0.298 | 0.121 | 0.270 | 0.254 | 0.573 |
| TCEQ Run 2 (WRF) | 0.301 | 0.123 | 0.286 | 0.265 | 0.573 |
| AACOG Run 3 (WRF) | 0.281 | 0.128 | 0.281 | 0.264 | 0.500 |
| AACOG RPO Run 4 (WRF) | 0.296 | 0.131 | 0.261 | 0.266 | 0.534 |

5.7 EPA Quantile-Quantile Plots

“The quantile-quantile (q-q) plot is a graphical technique for determining if two data sets come from populations with a common distribution. A q-q plot is a plot of the quantiles of the first data set against the quantiles of the second data set. By a quantile, we mean the point below which a given fraction (or percent) of points lies. That is, the 0.3 (or 30%) quantile is the point at which 30% percent of the data fall below and 70% fall above that value. A 45-degree reference line is also plotted. If the two sets come from a population with the same distribution, the points should fall approximately along this reference line. The greater the departure from this reference line, the greater the evidence for the conclusion that the two data sets have come from populations with different distributions.”²⁶⁷

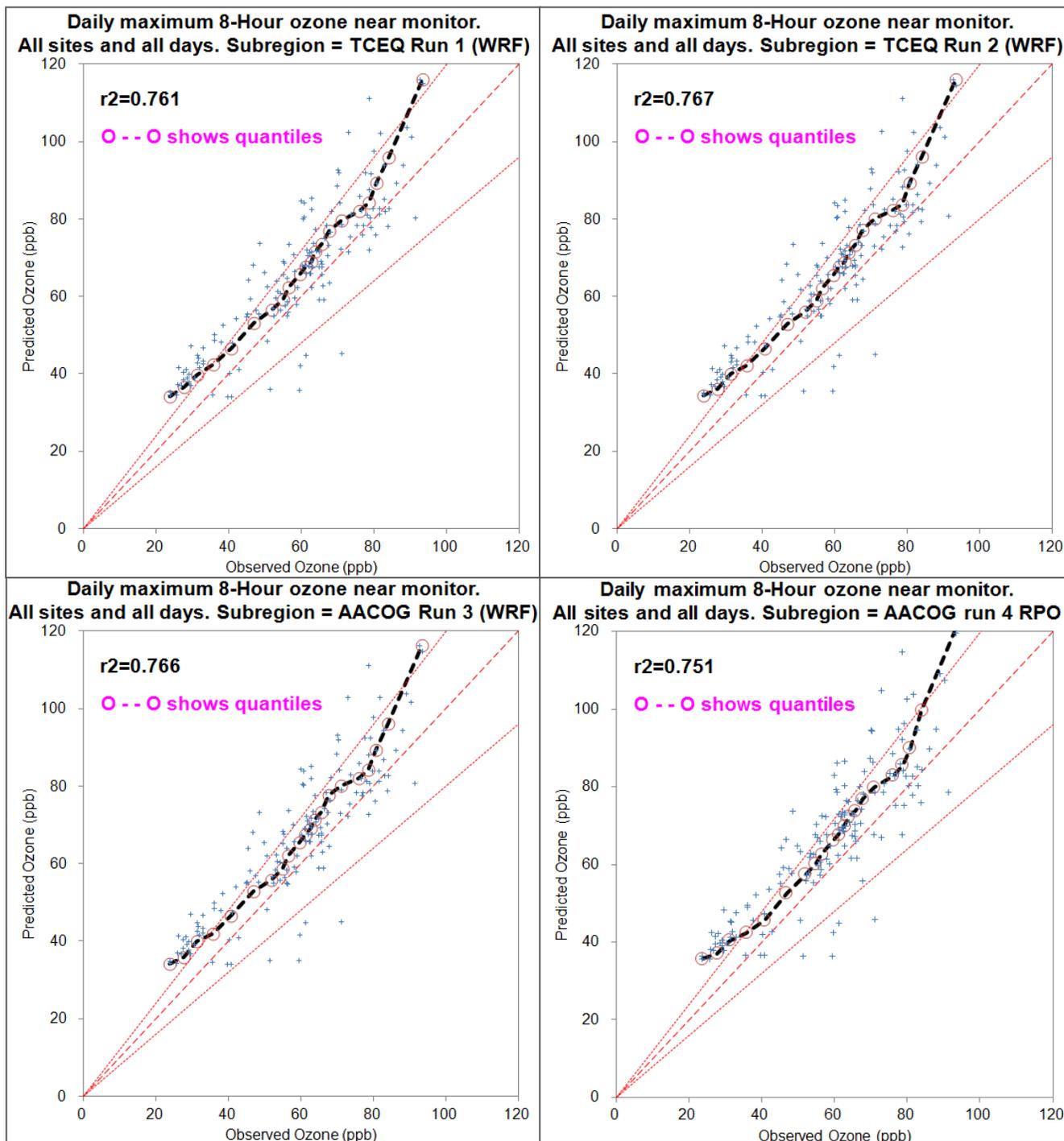
EPA quantile-quantile plots are provided in Figure 5-30 for daily maximum 8-hour ozone at each monitor, nearest daily maximum 8-hour ozone, and daily maximum 8-hour ozone near monitor. If the Q-Q plot results are close to the 1-1 line on each plot, the same number of low, medium, and high ozone values are predicted by the model as was measured at the monitor. For both 8-hour and 1-hour ozone plots, TCEQ run 2 had the best results. The R² value was similar for all 4 WRF runs and improved compared to the MM5 run 7. The R² value varied from 0.72 to 0.92 for the WRF runs which indicates good model performance with some degradation of performance for AACOG run 4 with the RPO grid.

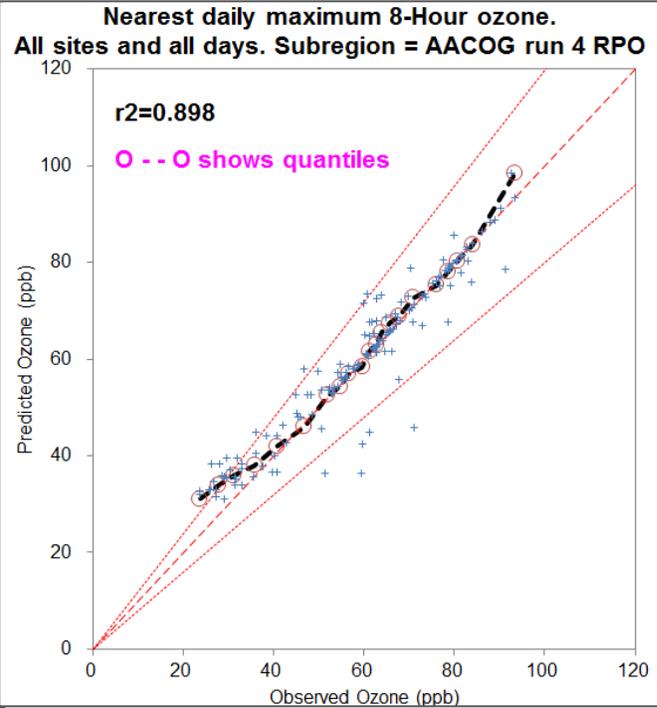
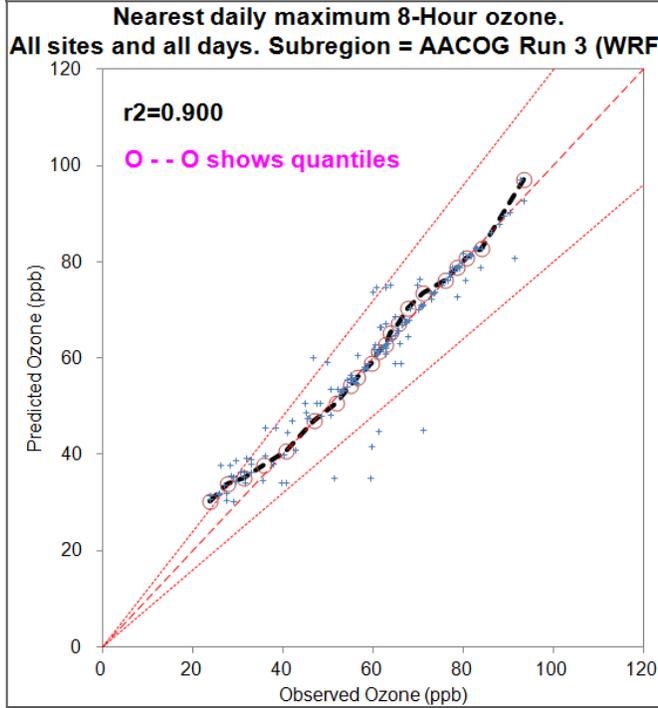
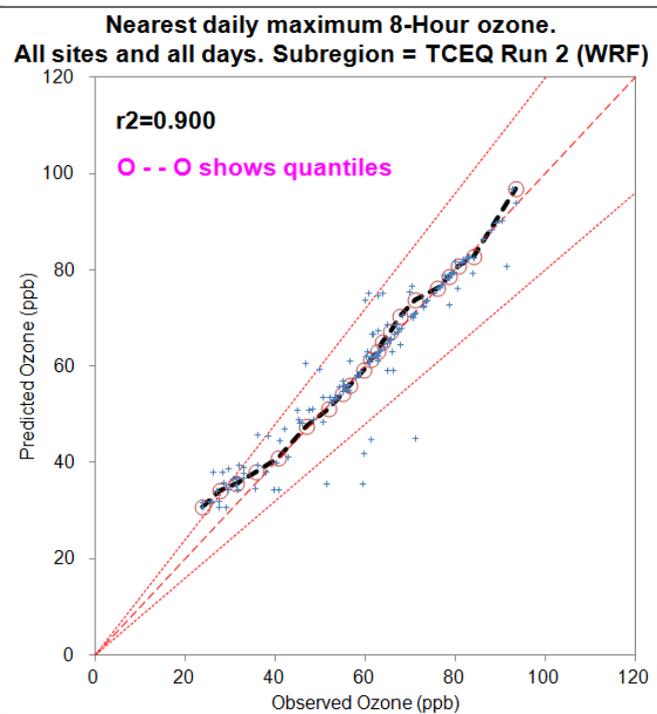
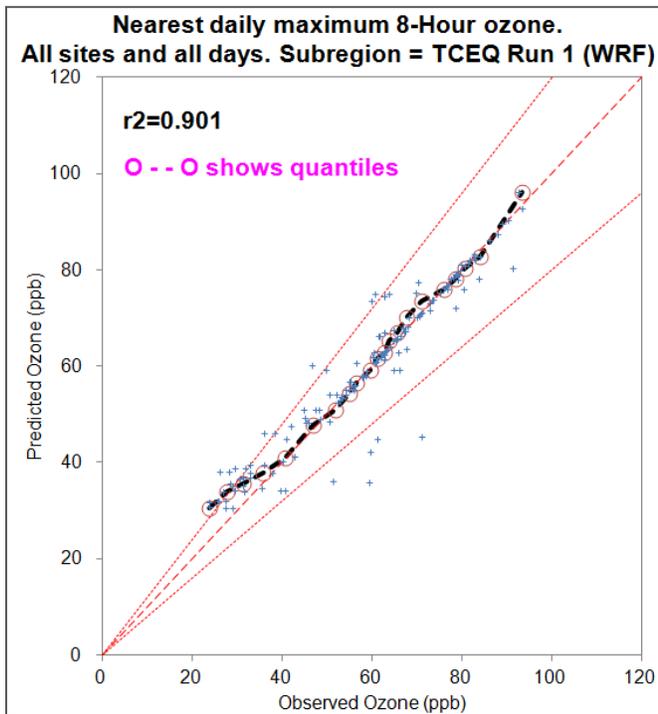
Caution should be used when elevating the results from quantile-quantile plots. According to the EPA, quantile-quantile “plots may also provide additional information with regards to the distribution of the observations vs. predictions. But due to the fact that Q-Q plots are not paired in time, they may not always provide useful information. Care should be taken in interpreting the results.”²⁶⁸

²⁶⁷ NIST/SEMATECH, April, 2012. “e-Handbook of Statistical Methods”. Available online: <http://www.itl.nist.gov/div898/handbook/eda/section3/qgplot.htm>. Accessed 06/12/13.

²⁶⁸ EPA, April 2007. “Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM_{2.5}, and Regional Haze.” EPA -454/B-07-002. Research Triangle Park, North Carolina. p. 201. Available online: <http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf>. Accessed 06/24/13.

Figure 5-30: Quantile-Quantile Plots of daily peak 8-hour ozone for San Antonio: WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF ACOG Base Case Run 3, and WRF ACOG RPO Base Case Run 4.





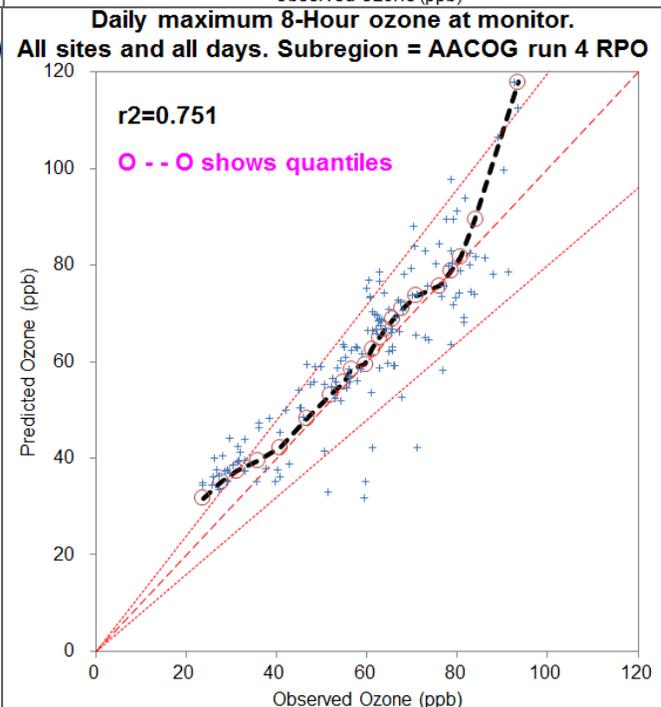
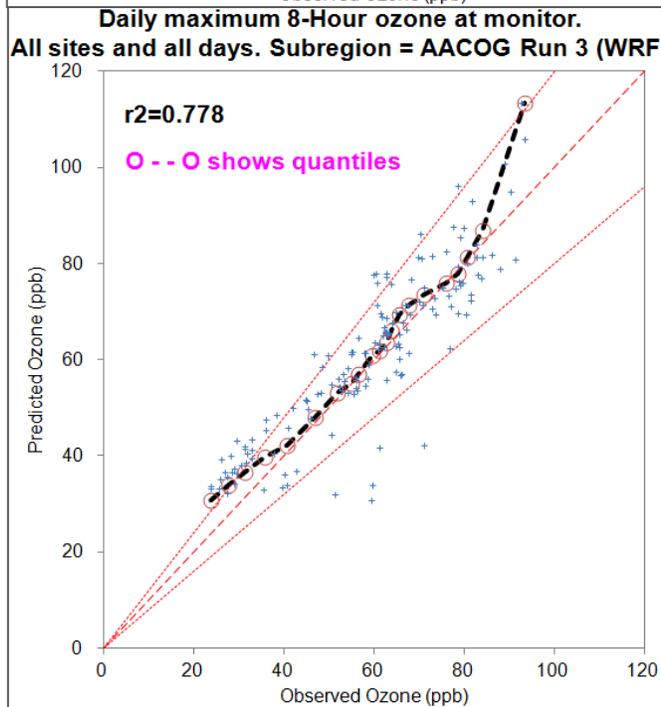
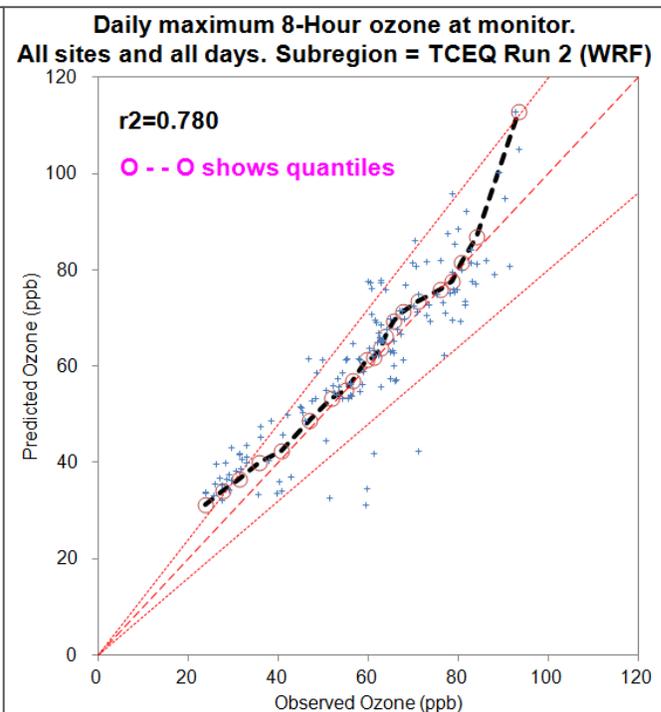
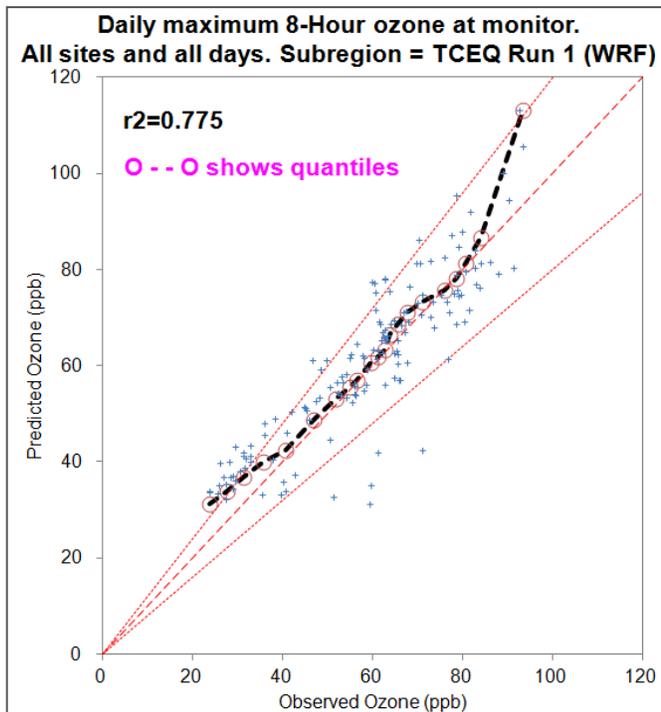


Table 5-6: R² values for San Antonio Quantile-Quantile Plots: MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, and WRF AACOG Base Case Run 3

| Run | Daily Maximum 1-Hour Ozone at Monitor R ² | Nearest Daily Maximum 1-Hour Ozone R ² | Daily Maximum 1-Hour Ozone Near Monitor R ² | Daily Maximum 8-Hour Ozone at Monitor R ² | Nearest Daily Maximum 8-Hour Ozone R ² | Daily Maximum 8-Hour Ozone Near Monitor R ² |
|---------------------------|--|---|--|--|---|--|
| Run 7_v5 (Met 11 OB70) | <i>0.582</i> | <i>0.908</i> | <i>0.585</i> | <i>0.689</i> | <i>0.881</i> | <i>0.658</i> |
| TCEQ Run 1 (WRF) | 0.745 | 0.922 | 0.737 | 0.779 | 0.901 | 0.761 |
| TCEQ Run 2 (WRF) | 0.751 | 0.919 | 0.742 | 0.780 | 0.900 | 0.767 |
| AACOG Run 3 (WRF) | 0.748 | 0.920 | 0.742 | 0.778 | 0.900 | 0.766 |
| AACOG RPO Run 4 (WRF) | 0.724 | 0.919 | 0.736 | 0.751 | 0.898 | 0.751 |

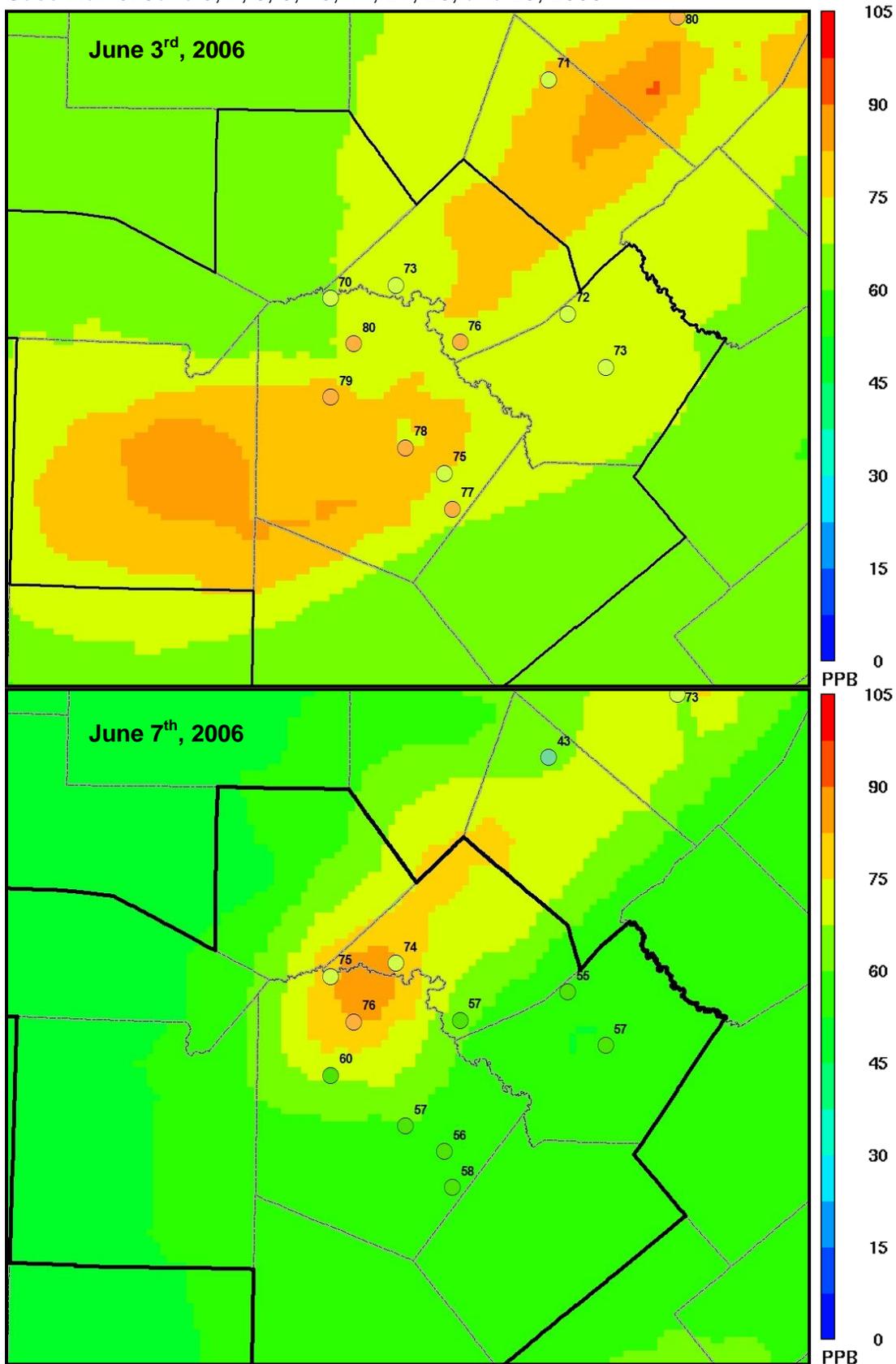
5.8 Daily Maximum 8-Hour Ozone Fields

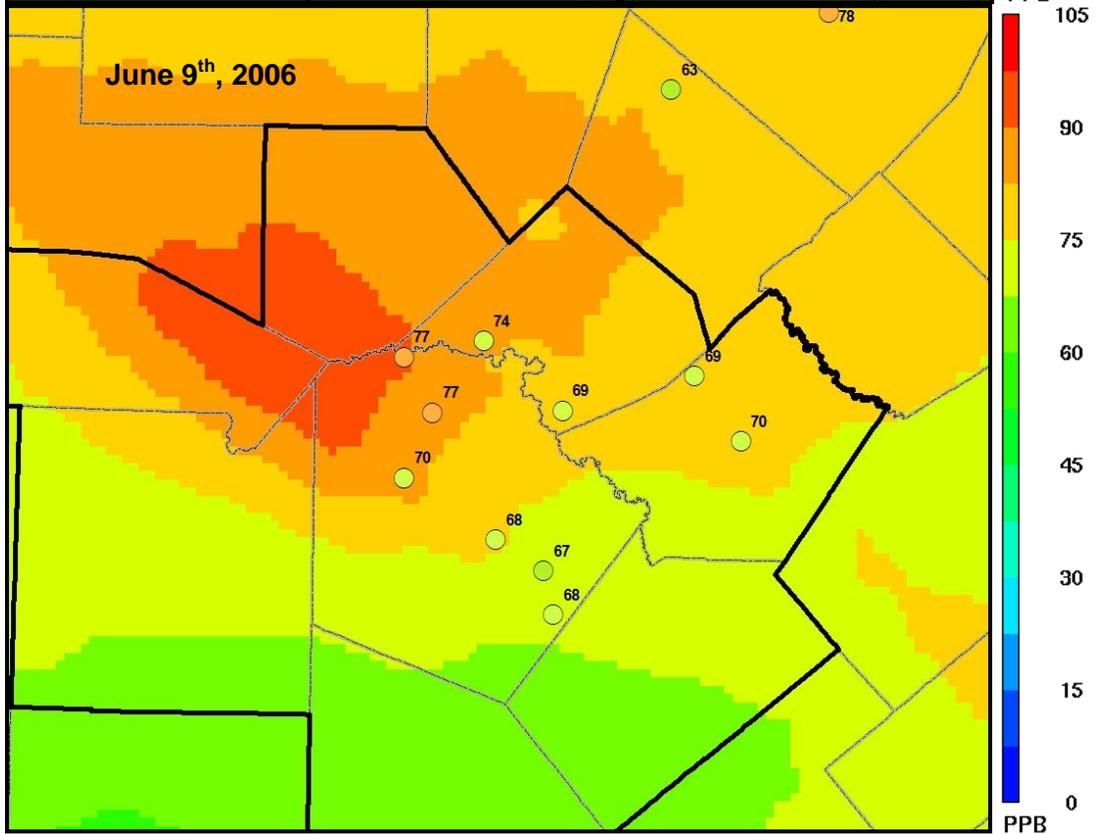
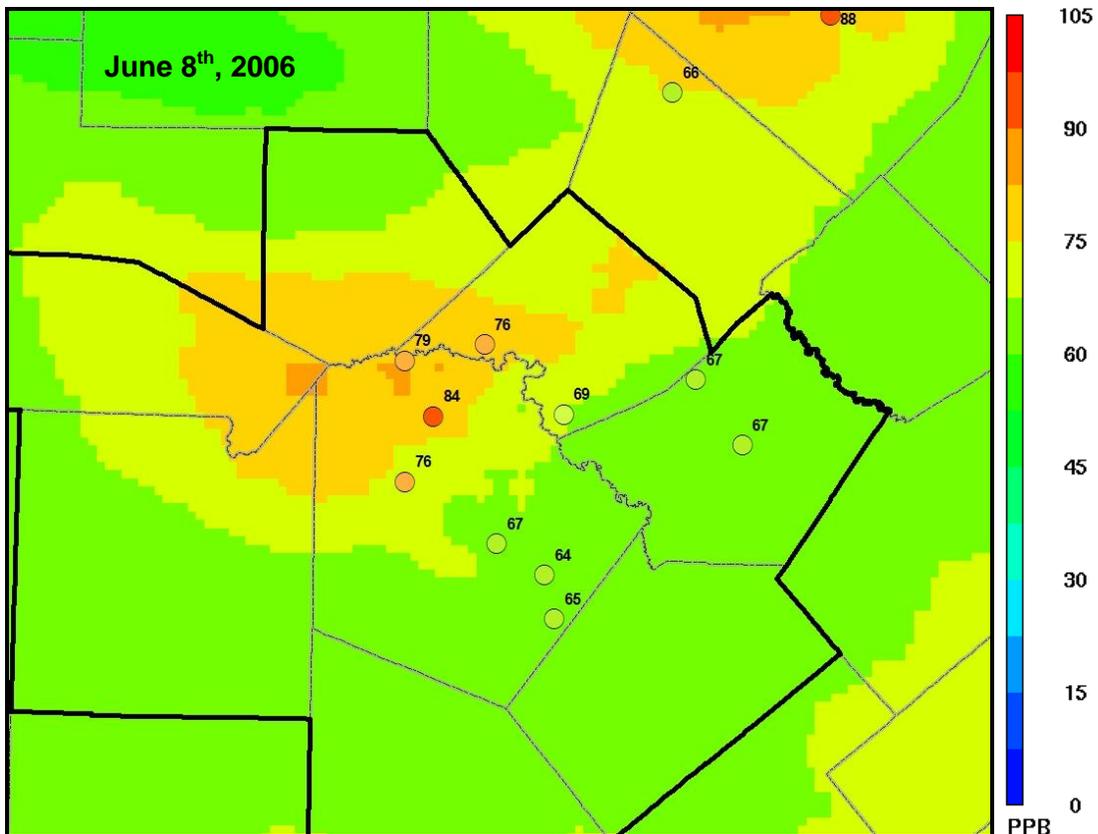
Another means of analyzing model performance recommended by the EPA is use of tile plot graphics. Figure 5-31 shows tile plots of predicted maximum ozone across the modeling domain for AACOG run 3 for each exceedance day. The plots for AACOG run 3 are similar to TCEQ run 1 and TCEQ run 2. These plots display the geographic distribution of the model's ozone predictions. Observed ozone at each monitor is plotted, color coded, and overlaid above the map of predicted ozone. The tile plots indicated that there were no unusual patterns of ozone formation. As seen on the plots for ozone exceedance days, ozone plumes were produced in the vicinity of San Antonio and Austin. These urban plumes were predicted for each urban core and downwind areas of the cities. The plots were also animated to examine the timing and location of ozone formation. The animation of the tile plots indicated that there was adequate model performance on all days.

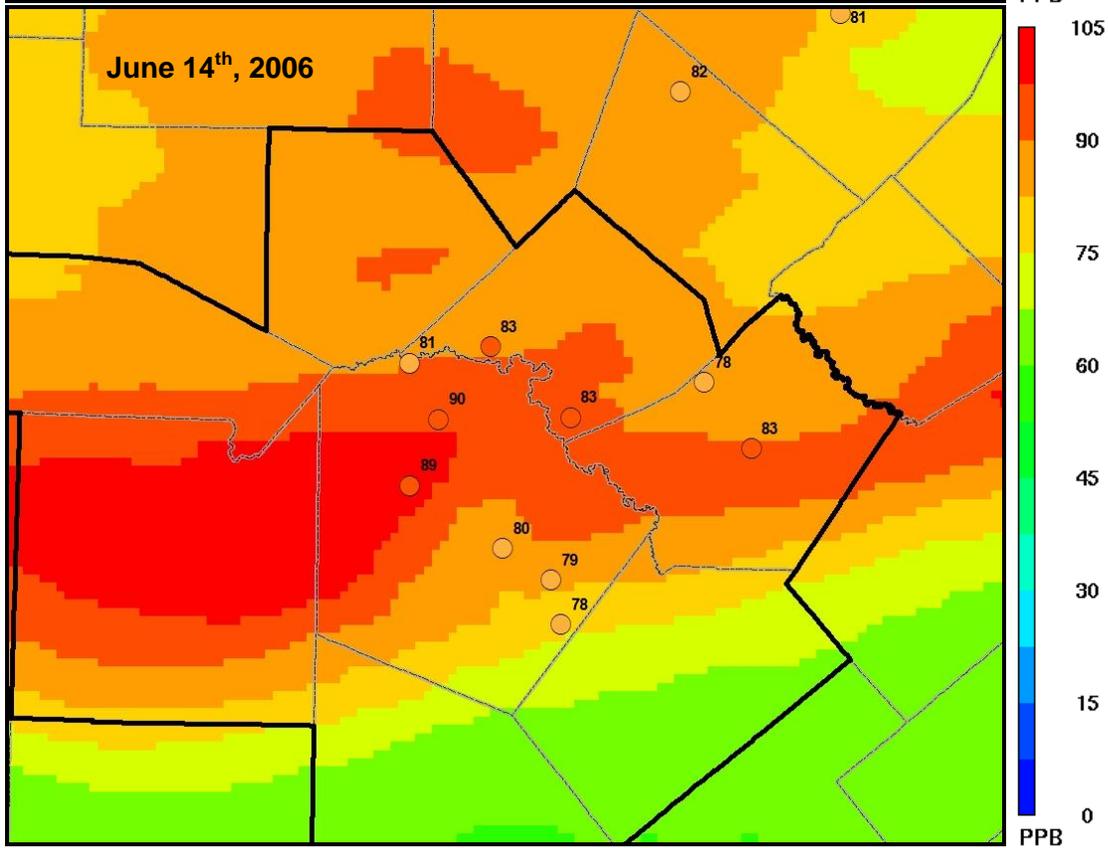
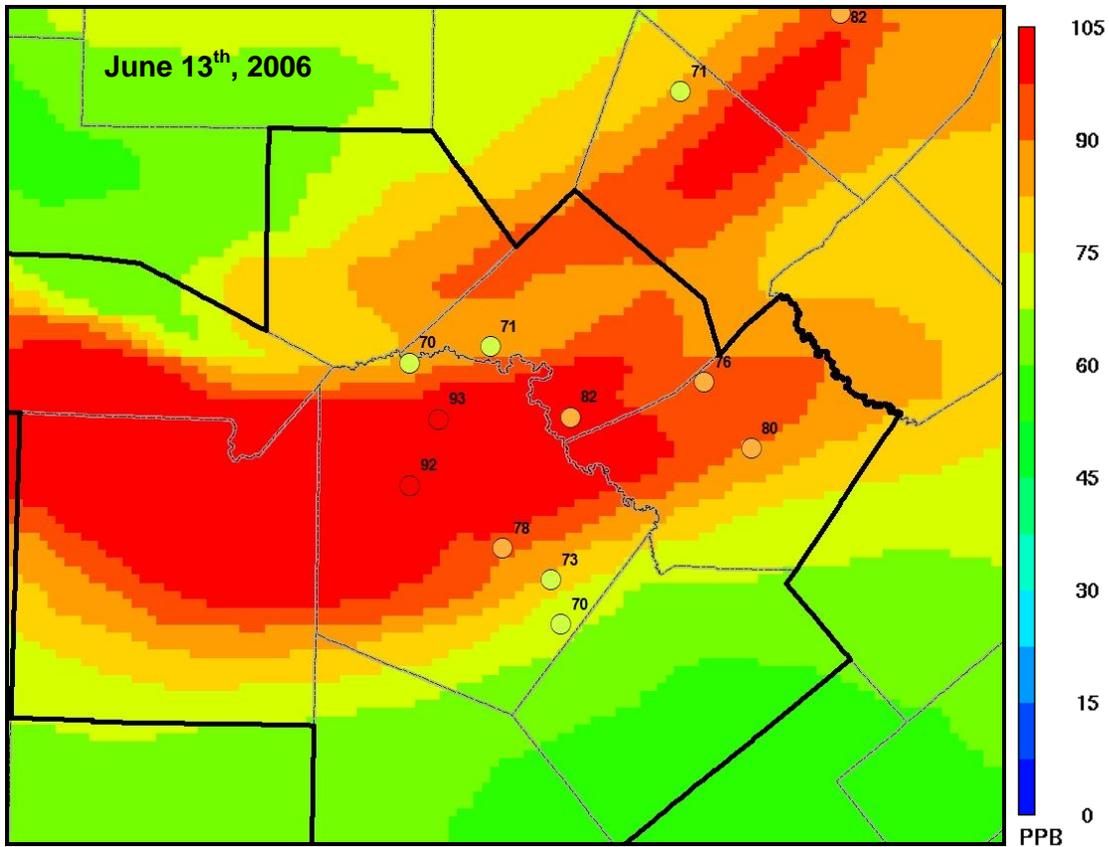
The daily tile plots for June 3rd, June 27th, and June 28th indicate good correlation between predicted and observed peak ozone. The model accurately predicted the locations of high ozone located at C58 and low ozone at C23 and the monitors southeast of San Antonio on June 7th. There was a slight over prediction of ozone in the San Antonio region on June 9th and on June 13th at C502. Ozone was over predicted at the monitors in northwest San Antonio, C23, C58, C502, and C504, on June 29th.

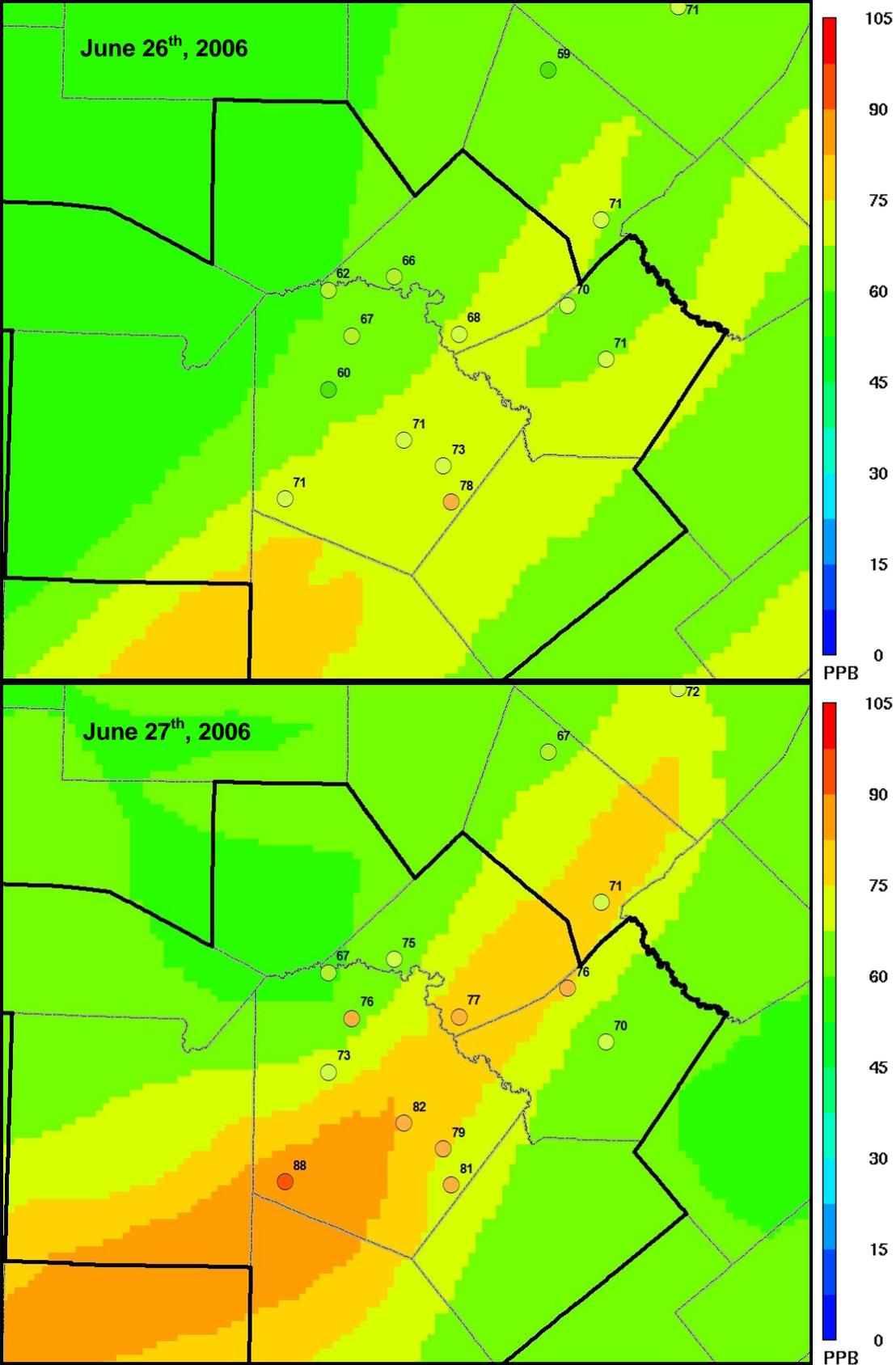
On Table 5-7, the predicted daily maximum 1-hour ozone concentrations within the San Antonio MSA are listed for each run. There was good correlation between observed and predicted ozone on the June 3rd, June 7th, June 8th, June 26th, June 27th, and June 29th exceedance days. On these days, there was only a -3.2 ppb to 6.3 ppb difference between predicted and observed hourly ozone. Every WRF run over-predicted ozone formation on the June 9th, 13th, and 14th exceedance days. Over prediction on these days ranged from 15.4 ppb to 23.0 ppb. Model performance was improved using WRF compared to MM5, especially on the exceedance days of June 7th and 8th. When comparing the WRF runs, TCEQ run 2 exhibited the best performance for all days and days greater than 74 ppb, while AACOG run 3 exhibited the best performance on days when the maximum hourly ozone was greater than 84 ppb.

Figure 5-31: Predicted Daily Maximum 8-hour Ozone Concentrations for WRF AACOG Base Case Run 3: June 3, 7, 8, 9, 13, 14, 27, 28, and 29, 2006









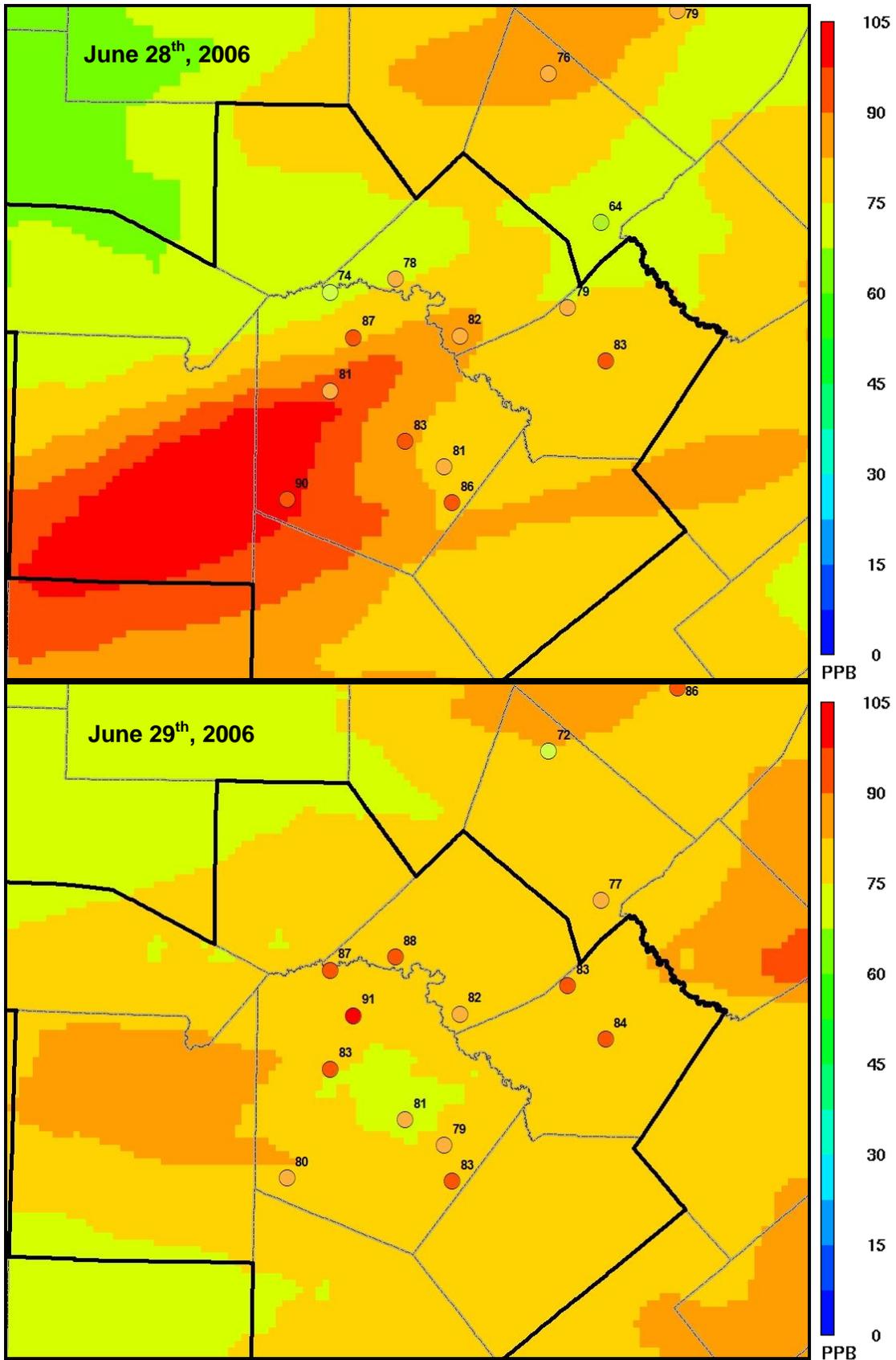


Table 5-7: Predicted Daily Maximum 1-hour Ozone Concentrations within the San Antonio MSA for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF ACOG Base Case Run 3, and WRF ACOG RPO Base Case Run 4

| Modeling Day | Peak 1-hr Monitored ozone in SA | Run 7_v5 (Met 11 OB70) | | Run 1 TCEQ bl (WRF) | | Run 2 TCEQ bl (WRF) | | Run 3 ACOG bl (WRF) | | Run 4 ACOG RPO (WRF) | |
|--------------|---------------------------------|------------------------|-------|---------------------|-------|---------------------|-------|---------------------|-------|----------------------|-------|
| | | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. |
| 1-Jun-06 | 62 | 53 | -8.6 | 64 | 2.4 | 65 | 2.9 | 65 | 2.9 | 67 | 4.9 |
| 2-Jun-06 | 78 | 77 | -0.7 | 84 | 5.6 | 84 | 5.9 | 85 | 6.5 | 89 | 11.2 |
| 3-Jun-06 | 86 | 91 | 4.5 | 90 | 4.4 | 91 | 4.7 | 91 | 4.7 | 95 | 8.5 |
| 4-Jun-06 | 81 | 78 | -3.4 | 92 | 10.8 | 92 | 10.7 | 92 | 11.1 | 97 | 16.1 |
| 5-Jun-06 | 70 | 79 | 9.0 | 82 | 12.3 | 82 | 12.0 | 83 | 12.5 | 85 | 15.3 |
| 6-Jun-06 | 82 | 76 | -5.6 | 88 | 5.7 | 86 | 3.9 | 86 | 4.5 | 90 | 7.9 |
| 7-Jun-06 | 89 | 97 | 8.2 | 95 | 6.3 | 94 | 5.1 | 95 | 6.3 | 99 | 9.9 |
| 8-Jun-06 | 96 | 103 | 7.0 | 97 | 1.1 | 97 | 0.6 | 98 | 1.5 | 101 | 5.3 |
| 9-Jun-06 | 87 | 94 | 7.4 | 102 | 15.4 | 103 | 15.5 | 103 | 16.2 | 106 | 18.9 |
| 10-Jun-06 | 76 | 81 | 5.2 | 98 | 21.7 | 96 | 20.0 | 96 | 20.2 | 99 | 23.1 |
| 11-Jun-06 | 68 | 74 | 6.0 | 79 | 11.2 | 78 | 9.8 | 78 | 10.0 | 79 | 10.5 |
| 12-Jun-06 | 78 | 102 | 23.7 | 96 | 17.7 | 95 | 17.4 | 96 | 18.2 | 97 | 19.4 |
| 13-Jun-06 | 106 | 92 | -14.0 | 128 | 22.1 | 128 | 22.3 | 129 | 23.0 | 135 | 28.7 |
| 14-Jun-06 | 94 | 93 | -1.3 | 113 | 19.4 | 114 | 19.7 | 115 | 20.7 | 122 | 28.4 |
| 15-Jun-06 | 74 | 76 | 1.8 | 78 | 4.2 | 77 | 3.4 | 77 | 3.4 | 80 | 5.9 |
| 16-Jun-06 | 45 | | | 52 | 6.8 | 52 | 6.5 | 52 | 6.6 | 52 | 7.3 |
| 17-Jun-06 | 53 | | | 49 | -4.1 | 48 | -4.8 | 48 | -4.9 | 51 | -1.6 |
| 18-Jun-06 | 79 | | | 54 | -24.9 | 54 | -25.1 | 54 | -25.1 | 54 | -25.3 |
| 19-Jun-06 | 85 | | | 77 | -7.5 | 77 | -7.8 | 78 | -7.4 | 81 | -3.7 |
| 20-Jun-06 | 35 | | | 42 | 7.3 | 42 | 7.2 | 42 | 7.1 | 45 | 10.1 |
| 21-Jun-06 | 37 | | | 53 | 16.0 | 53 | 15.5 | 53 | 15.7 | 55 | 18.0 |
| 22-Jun-06 | 41 | | | 57 | 16.2 | 56 | 15.3 | 56 | 15.5 | 56 | 15.5 |
| 23-Jun-06 | 60 | | | 62 | 1.6 | 62 | 1.7 | 62 | 1.6 | 61 | 0.5 |
| 24-Jun-06 | 49 | | | 60 | 11.2 | 61 | 12.2 | 62 | 12.5 | 63 | 13.6 |
| 25-Jun-06 | 70 | | | 76 | 6.4 | 75 | 4.6 | 75 | 4.8 | 78 | 7.7 |
| 26-Jun-06 | 86 | | | 83 | -3.2 | 83 | -2.7 | 83 | -2.6 | 81 | -4.9 |

| Modeling Day | Peak 1-hr Monitored ozone in SA | Run 7_v5 (Met 11 OB70) | | Run 1 TCEQ bl (WRF) | | Run 2 TCEQ bl (WRF) | | Run 3 AACOG bl (WRF) | | Run 4 AACOG RPO (WRF) | |
|-----------------------|---------------------------------|------------------------|-------|---------------------|-------------|---------------------|-------------|----------------------|-------------|-----------------------|-------------|
| | | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. |
| 27-Jun-06 | 98 | | | 95 | -3.1 | 96 | -2.1 | 96 | -1.6 | 95 | -2.5 |
| 28-Jun-06 | 101 | | | 109 | 8.2 | 109 | 7.7 | 110 | 8.7 | 113 | 12.2 |
| 29-Jun-06 | 94 | | | 96 | 1.7 | 94 | 0.3 | 94 | 0.3 | 93 | -1.2 |
| 30-Jun-06 | 87 | | | 92 | 5.3 | 92 | 5.5 | 93 | 6.0 | 93 | 5.8 |
| 1-Jul-06 | 46 | | | 54 | 8.3 | 54 | 8.3 | 54 | 8.1 | 54 | 8.1 |
| 2-Jul-06 | 30 | | | 66 | 36.4 | 67 | 36.9 | 67 | 36.8 | 67 | 36.8 |
| Avg. All Days | | | 2.6 | | 7.6 | | 7.3 | | 7.6 | | 9.7 |
| Avg. on Days > 74 ppb | | | 3.4 | | 6.4 | | 6.0 | | 6.2 | | 8.8 |
| Avg. on Days > 84 ppb | | | 2.0 | | 7.2 | | 7.1 | | 6.3 | | 8.8 |

Table 5-8: Predicted Daily Maximum 8-hour Ozone Concentrations within the San Antonio MSA for MM5 Base Case Run 7, WRF TCEQ Base Case Run 1, WRF TCEQ Base Case Run 2, WRF ACOG Base Case Run 3, and WRF ACOG RPO Base Case Run 4

| Modeling Day | Peak 8-hr Monitored ozone in SA | Run 7_v5 (Met 11 OB70) | | Run 1 TCEQ bl (WRF) | | Run 2 TCEQ bl (WRF) | | Run 3 ACOG bl (WRF) | | Run 4 ACOG RPO (WRF) | |
|--------------|---------------------------------|------------------------|-------------|---------------------|-------------|---------------------|-------------|---------------------|--------------|----------------------|--------------|
| | | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. |
| 1-Jun-06 | 56 | 55.8 | -0.2 | 59.1 | 3.1 | 59.6 | 3.6 | 59.6 | 3.6 | 61.8 | 5.8 |
| 2-Jun-06 | 66 | 65.0 | -1.0 | 68.3 | 2.3 | 68.5 | 2.5 | 68.8 | 2.8 | 72.1 | 6.1 |
| 3-Jun-06 | 80 | 78.9 | -1.1 | 79.3 | -0.7 | 79.5 | -0.5 | 79.4 | -0.6 | 83.5 | 3.5 |
| 4-Jun-06 | 73 | 68.5 | -4.5 | 75.5 | 2.5 | 75.3 | 2.3 | 75.4 | 2.4 | 78.7 | 5.7 |
| 5-Jun-06 | 63 | 63.1 | 0.1 | 68.2 | 5.2 | 68.1 | 5.1 | 68.0 | 5.0 | 70.4 | 7.4 |
| 6-Jun-06 | 68 | 66.6 | -1.4 | 77.5 | 9.5 | 76.5 | 8.5 | 76.9 | 8.9 | 78.9 | 10.9 |
| 7-Jun-06 | 76 | 79.2 | 3.2 | 85.3 | 9.3 | 84.6 | 8.6 | 85.4 | 9.4 | 88.6 | 12.6 |
| 8-Jun-06 | 84 | 79.1 | -4.9 | 82.8 | -1.2 | 82.6 | -1.4 | 82.8 | -1.2 | 84.5 | 0.5 |
| 9-Jun-06 | 77 | 76.9 | -0.1 | 91.2 | 14.2 | 91.5 | 14.5 | 91.8 | 14.8 | 95.0 | 18.0 |
| 10-Jun-06 | 71 | 73.8 | 2.8 | 89.6 | 18.6 | 89.1 | 18.1 | 89.3 | 18.3 | 89.2 | 18.2 |
| 11-Jun-06 | 64 | 65.8 | 1.8 | 71.8 | 7.8 | 71.2 | 7.2 | 71.3 | 7.3 | 70.8 | 6.8 |
| 12-Jun-06 | 70 | 77.2 | 7.2 | 81.5 | 11.5 | 81.0 | 11.0 | 81.5 | 11.5 | 83.8 | 13.8 |
| 13-Jun-06 | 93 | 83.3 | -9.7 | 114.0 | 21.0 | 113.8 | 20.8 | 114.3 | 21.3 | 118.9 | 25.9 |
| 14-Jun-06 | 90 | 94.9 | 4.9 | 101.0 | 11.0 | 101.0 | 11.0 | 101.5 | 11.5 | 106.9 | 16.9 |
| 15-Jun-06 | 69 | 70.5 | 1.5 | 73.7 | 4.7 | 73.7 | 4.7 | 73.8 | 4.8 | 74.7 | 5.7 |
| 16-Jun-06 | 35 | | | 47.4 | 12.4 | 47.3 | 12.3 | 47.3 | 12.3 | 48.0 | 13.0 |
| 17-Jun-06 | 44 | | | 41.7 | -2.3 | 41.6 | -2.4 | 41.4 | -2.6 | 43.2 | -0.8 |
| 18-Jun-06 | 71 | | | 45.8 | -25.2 | 45.7 | -25.3 | 45.6 | -25.4 | 46.8 | -24.2 |
| 19-Jun-06 | 65 | | | 66.0 | 1.0 | 65.9 | 0.9 | 65.7 | 0.7 | 68.7 | 3.7 |
| 20-Jun-06 | 29 | | | 36.2 | 7.2 | 36.2 | 7.2 | 36.1 | 7.1 | 37.6 | 8.6 |
| 21-Jun-06 | 32 | | | 45.2 | 13.2 | 45.1 | 13.1 | 45.0 | 13.0 | 46.1 | 14.1 |
| 22-Jun-06 | 36 | | | 48.6 | 12.6 | 48.3 | 12.3 | 48.3 | 12.3 | 48.3 | 12.3 |
| 23-Jun-06 | 50 | | | 49.8 | -0.2 | 49.6 | -0.4 | 49.6 | -0.4 | 48.0 | -2.1 |
| 24-Jun-06 | 45 | | | 53.1 | 8.1 | 52.9 | 7.9 | 53.0 | 8.0 | 52.6 | 7.6 |
| 25-Jun-06 | 65 | | | 67.0 | 2.0 | 67.6 | 2.6 | 67.6 | 2.6 | 67.9 | 2.9 |
| 26-Jun-06 | 78 | | | 72.6 | -5.4 | 73.3 | -4.8 | 73.4 | -4.6 | 68.1 | -9.9 |
| 27-Jun-06 | 88 | | | 86.5 | -1.5 | 87.5 | -0.5 | 88.0 | 0.0 | 85.5 | -2.5 |

| Modeling Day | Peak 8-hr Monitored ozone in SA | Run 7_v5 (Met 11 OB70) | | Run 1 TCEQ bl (WRF) | | Run 2 TCEQ bl (WRF) | | Run 3 AACOG bl (WRF) | | Run 4 AACOG RPO (WRF) | |
|-------------------------------|---------------------------------|------------------------|-------|---------------------|-------------|---------------------|-------------|----------------------|-------------|-----------------------|--------------|
| | | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. | ppb | Diff. |
| 28-Jun-06 | 90 | | | 102.5 | 12.5 | 103.0 | 13.0 | 103.3 | 13.3 | 102.9 | 12.9 |
| 29-Jun-06 | 91 | | | 83.1 | -8.0 | 83.2 | -7.8 | 83.1 | -7.9 | 80.5 | -10.5 |
| 30-Jun-06 | 71 | | | 77.8 | 6.8 | 78.1 | 7.1 | 78.5 | 7.5 | 77.4 | 6.4 |
| 1-Jul-06 | 38 | | | 48.1 | 10.1 | 48.5 | 10.5 | 48.5 | 10.5 | 48.5 | 10.5 |
| 2-Jul-06 | 26 | | | 56.2 | 30.2 | 56.7 | 30.7 | 56.7 | 30.7 | 56.7 | 30.7 |
| Avg. All Days | | | -0.1 | | 6.0 | | 6.0 | | 6.2 | | 7.2 |
| Avg. on Days > 60 ppb | | | -0.1 | | 4.4 | | 4.4 | | 4.7 | | 6.0 |
| Avg. on Ozone Exceedance days | | | -1.3 | | 5.1 | | 5.3 | | 5.6 | | 6.5 |

When looking at the results for maximum 8-hour ozone, there was a slight under-prediction of ozone on June 3rd, June 8th, June 26th, and June 29th. As expected, 8 hour ozone maximums were over predicted on June 9th, June 13th, June 14th, and June 28th. In the San Antonio-New Braunfels MSA, prediction of 8-hour maximums ranged from -10.5 ppb to 25.9 ppb of monitored values on exceedance days. TCEQ run 1 demonstrated the best average prediction for maximum 8-hour ozone on all days (6.0 ppb) and exceedance days (5.1 ppb). AACOG run 4 with the RPO grid had the highest average over predictions for 8-hour maximum values for all days and for exceedance days. "Since the modeled peak is taken across every grid cell in the domain and the observed peak is from only a limited number of monitoring sites, it is expected that the domain-wide peak simulated by a good-performing model will exceed the monitored peak."²⁶⁹

5.9 Summary of CAMx Base Case Runs

The CAMx model over predicted ozone concentrations at monitors on the northwest side of San Antonio, C23, C25, and C505, on two of the episode's exceedance days: June 13 and 14th. On other days of the episode, the model's ozone estimations correlated well with observed peak hourly ozone values and predicted peak hourly ozone values. For most monitors, there was an excellent correlation between observed peak hourly ozone and predicted hourly ozone in the second half of the episode, with some under prediction at C503. When examining the diurnal bias, model results for C58 over predicted diurnal ozone on most exceedance days during the episode. The model also over predicted diurnal hourly ozone in the second part of the episode at monitors located in rural areas of the San Antonio-New Braunfels MSA, C502, C503, C504, and C506. The model over predicted NO_x emissions at C58 on almost every day of the June 2006 episode. This over prediction of NO_x at C58 provides a plausible explanation for the model's poor performance regarding diurnal ozone forecasts for the monitor.

Although there were several significant differences in the local emission inventory, model results are similar for TCEQ run 1, TCEQ run 2, and AACOG run 3 for every monitor. Changes in meteorological conditions had a greater impact on the model's ozone predictions than changes to the emission inventories. For AACOG run 4 using the RPO grid, predicted ozone on some exceedance days was higher than the other 3 WRF runs.

Every WRF modeling run exhibited similar performance for unpaired peak accuracy, paired peak accuracy, peak bias, peak error, normalized bias, and normalized error. Model performance on all days was improved with TCEQ run 2 and exceedance day performance was best for AACOG run 1. Performance for AACOG run 4 using the RPO grid was degraded for

²⁶⁹ TCEQ, Dec. 7, 2011. "Appendix C: Photochemical Modeling for the DFW Attainment Demonstration Sip Revision for the 1997 Eight-Hour Ozone Standard". Austin, Texas. P. C-45. Available online: http://www.tceq.texas.gov/assets/public/implementation/air/sip/dfw/ad_2011/AppC_CAMx_ado.pdf. Accessed 06/26/13.

peak error and normalized error. This run provided higher peak 1-hour ozone predictions compared to the other 3 WRF runs. Results for paired peak accuracy were very good for C58, C622, C501, C502, C503, and C506 and paired peak accuracy for the remaining monitors also met EPA recommended guidelines.

Tile plots indicated that there were no unusual patterns of ozone formation predicted by the model runs. Ozone plumes were produced in the vicinity of San Antonio and Austin. As expected, these urban plumes were predicted for each urban core and areas downwind of the cities. AACOG run 3 was used as the 2006 base case because it has the latest and most accurate emission inventory. When the base case was completed, the emission inventory in the model was projected to 2012 and 2018. There were three different emission inventory scenarios in 2018, low, moderate, and high, based on projected activity in the Eagle Ford. Future work will include continued evaluation of using the RPO grid for the emission inventory and evaluating the newly released CAMx6.0 model performance with the extended June 2006 modeling episode.

6 Future Year Modeling

The photochemical model developed to simulate the extended June 2006 high-ozone episode was updated with 2012 and 2018 projected anthropogenic emission inventories to estimate future ozone concentrations under the same meteorological conditions as the 2006 base case. The projected emission inventories account for existing local, state, and federal air quality control strategies to determine whether such measures are sufficient to help the region meet the 2008 NAAQS 8-hour ozone standard. The 2018 projection case was compared to the 2012 projection to determine future ozone design values.

6.1 Projections Cases

A total of 6 future year scenarios were developed from the June 2006 modeling episode.

2012 Without Eagle Ford

- WRF v3.2
- CAMx 5.40
- Local 2012 San Antonio-New Braunfels MSA emission data including construction equipment, landfill equipment, quarry equipment, agricultural tractors, combines, commercial airports, point sources, and heavy duty truck idling

2012 With Eagle Ford Emission Inventory

- WRF v3.2
- CAMx 5.40
- Local 2012 San Antonio-New Braunfels MSA emission data including construction equipment, landfill equipment, quarry equipment, agricultural tractors, combines, commercial airports, point sources, and heavy duty truck idling
- Eagle Ford 2012 Emission Inventory

2018 Without Eagle Ford Emission Inventory

- WRF v3.2
- CAMx 5.40
- Local 2018 San Antonio-New Braunfels MSA emission data including construction equipment, landfill equipment, quarry equipment, agricultural tractors, combines, commercial airports, point sources, and heavy duty truck idling

2018 Low Scenario Eagle Ford Emission Inventory

- WRF v3.2
- CAMx 5.40
- Local 2018 San Antonio-New Braunfels MSA emission data including construction equipment, landfill equipment, quarry equipment, agricultural tractors, combines, commercial airports, point sources, and heavy duty truck idling
- Eagle Ford 2018 Emission Inventory Low Scenario

2018 Moderate Eagle Ford Emission Inventory

- WRF v3.2
- CAMx 5.40
- Local San Antonio-New Braunfels MSA emission data including construction equipment, landfill equipment, quarry equipment, agricultural tractors, combines, commercial airports, point sources, and heavy duty truck idling
- Eagle Ford 2018 Emission Inventory Moderate Scenario

2018 High Eagle Ford Emission Inventory

- WRF v3.2
- CAMx 5.40
- Local 2018 San Antonio-New Braunfels MSA emission data including construction equipment, landfill equipment, quarry equipment, agricultural tractors, combines, commercial airports, point sources, and heavy duty truck idling
- Eagle Ford 2018 Emission Inventory High Scenario

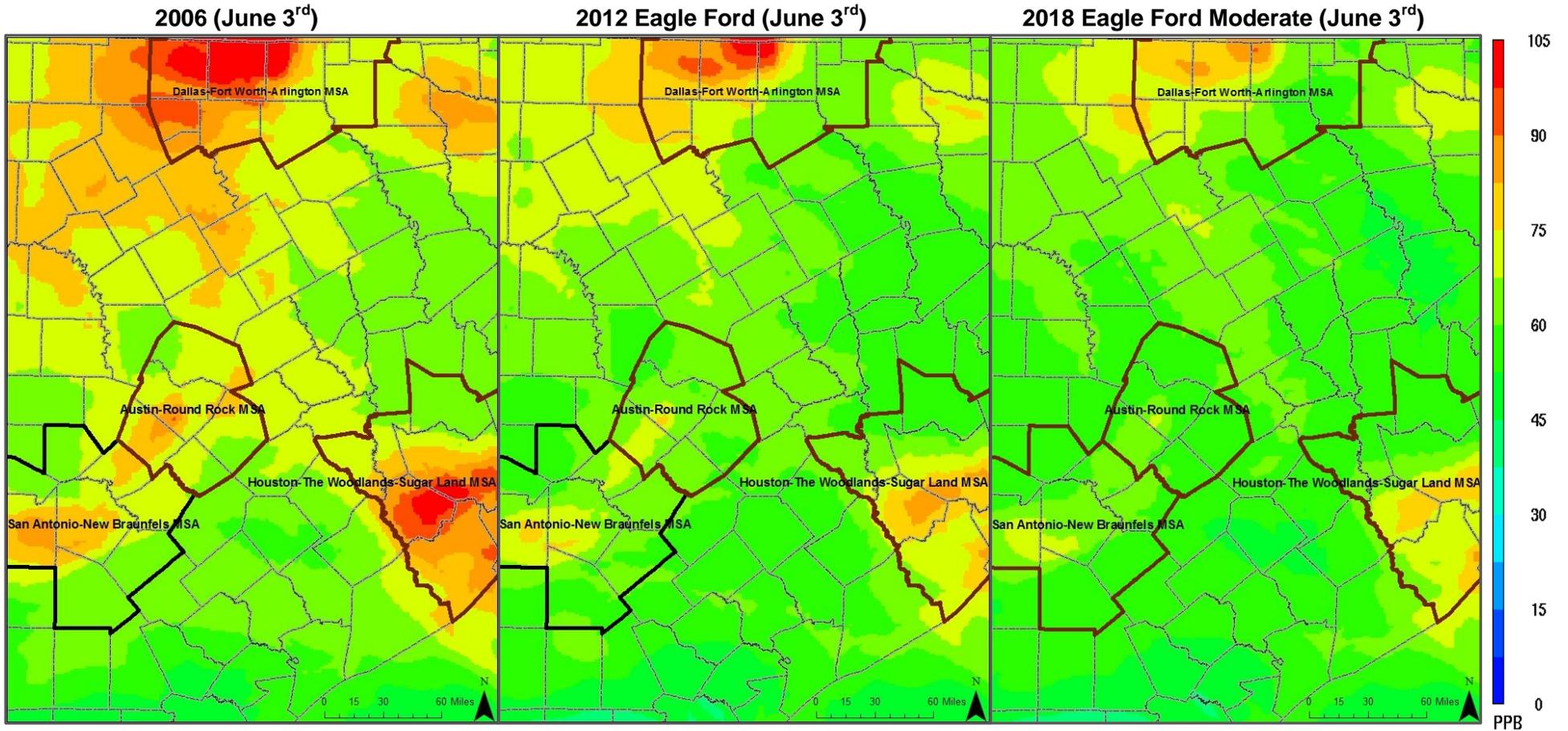
6.2 Tile Plots – Ozone Concentration: 2006, 2012, and 2018

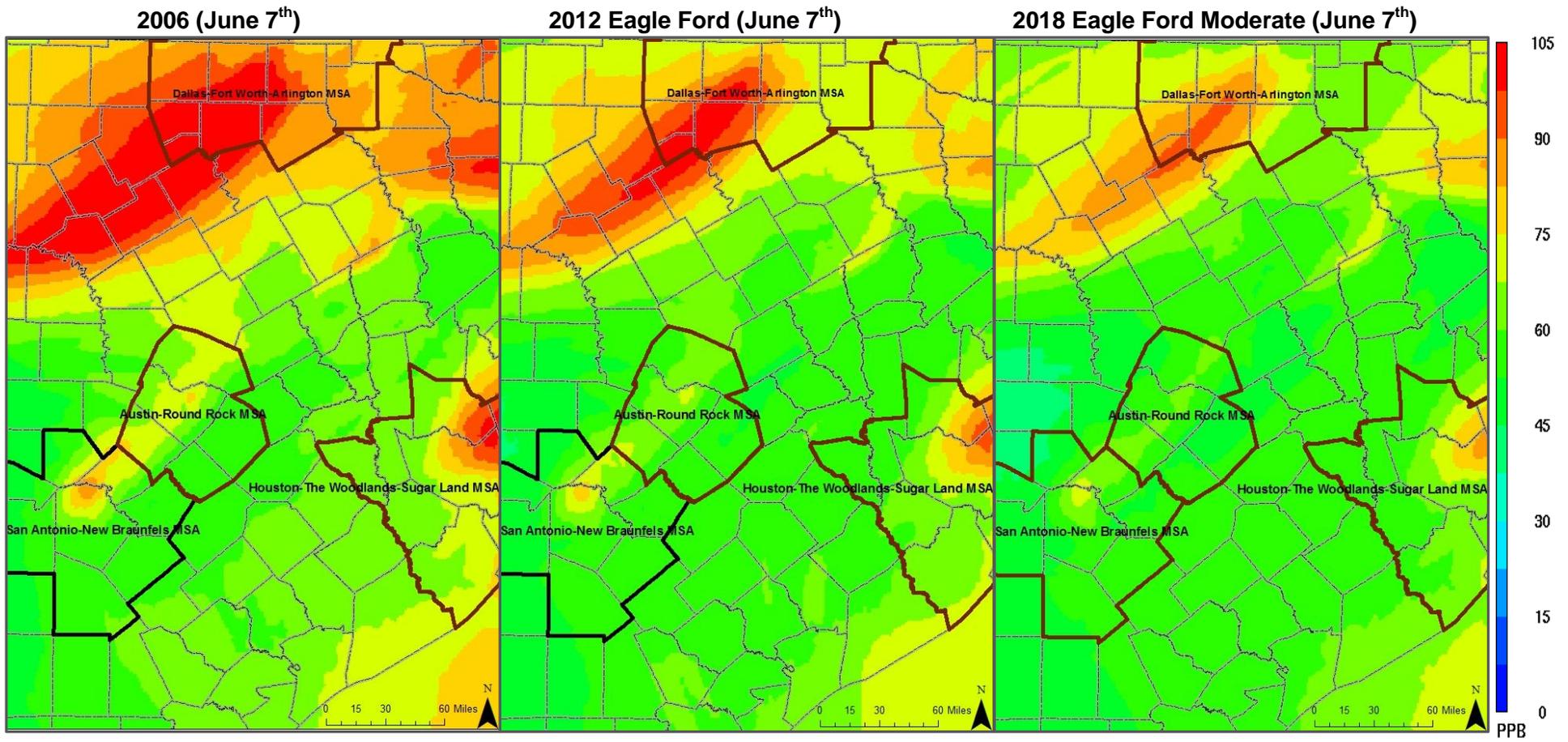
Tile plots can be used as a means of determining if there is an error in the input data or model performance. The plots are visual representations of the model output, displaying ozone concentrations by hour for the episode day or the maximum ozone by day. The following tile plots (Figure 6-1) represent comparisons between the model results for 2006, 2012 Eagle Ford, and 2018 Moderate Eagle Ford 8-hour daily maximum ozone concentrations in the 4km grid for each day.

Peak ozone concentrations are predicted downwind of city centers and major point sources in these tile plots. In addition, the overall reduction in total NO_x, VOC, and CO emissions (local and regional) between 2006 and 2018 diminishes the magnitude of the urban plumes each day of the 2018 projection compared to its 2006 counterpart. Likewise, the spatial extent of 8-hour ozone plumes greater than 75 ppb are significantly reduced for every exceedance day in the San Antonio region in 2018.

Although there is an overall reduction of ozone on every exceedance day in the San Antonio-New Braunfels MSA when comparing the 2018 simulation with the 2006 model results, significant transport still occurs. On the June 14th plots, Houston's elevated ozone plume can be observed reaching the San Antonio-New Braunfels MSA. Although the concentration of the Houston plume diminishes between the 2006 and 2018 model runs, the tile plots indicate the 8-hour ozone levels in the 2018 scenario remain above 65 ppb. A similar pattern occurs on June 27th where the Austin plume has a significant impact on ozone levels in the San Antonio-New Braunfels MSA.

Figure 6-1: Predicted Daily Maximum 8-hour Ozone Concentrations in the 4-km Subdomain, 2006, 2012 Eagle Ford, and 2018 Eagle Ford Moderate Scenario

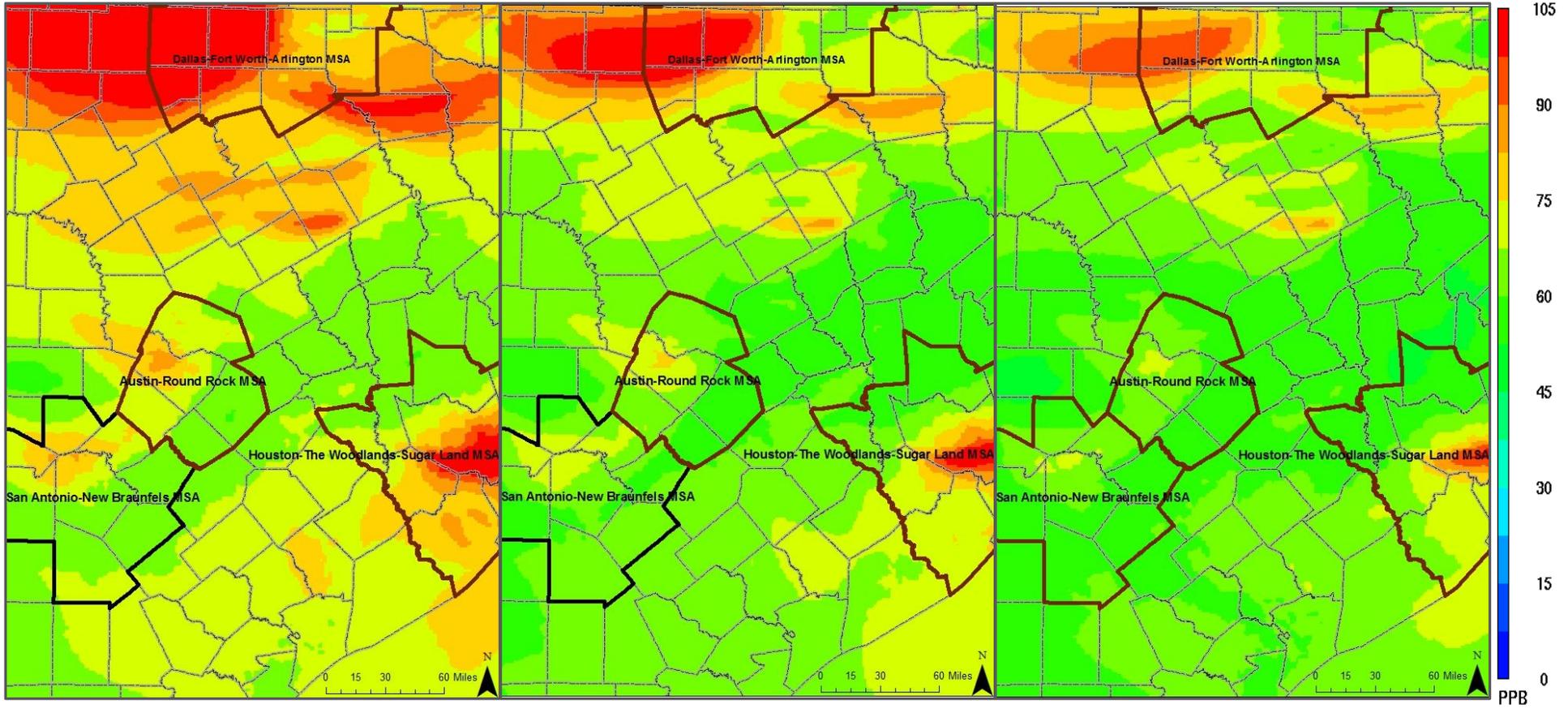




2006 (June 8th)

2012 Eagle Ford (June 8th)

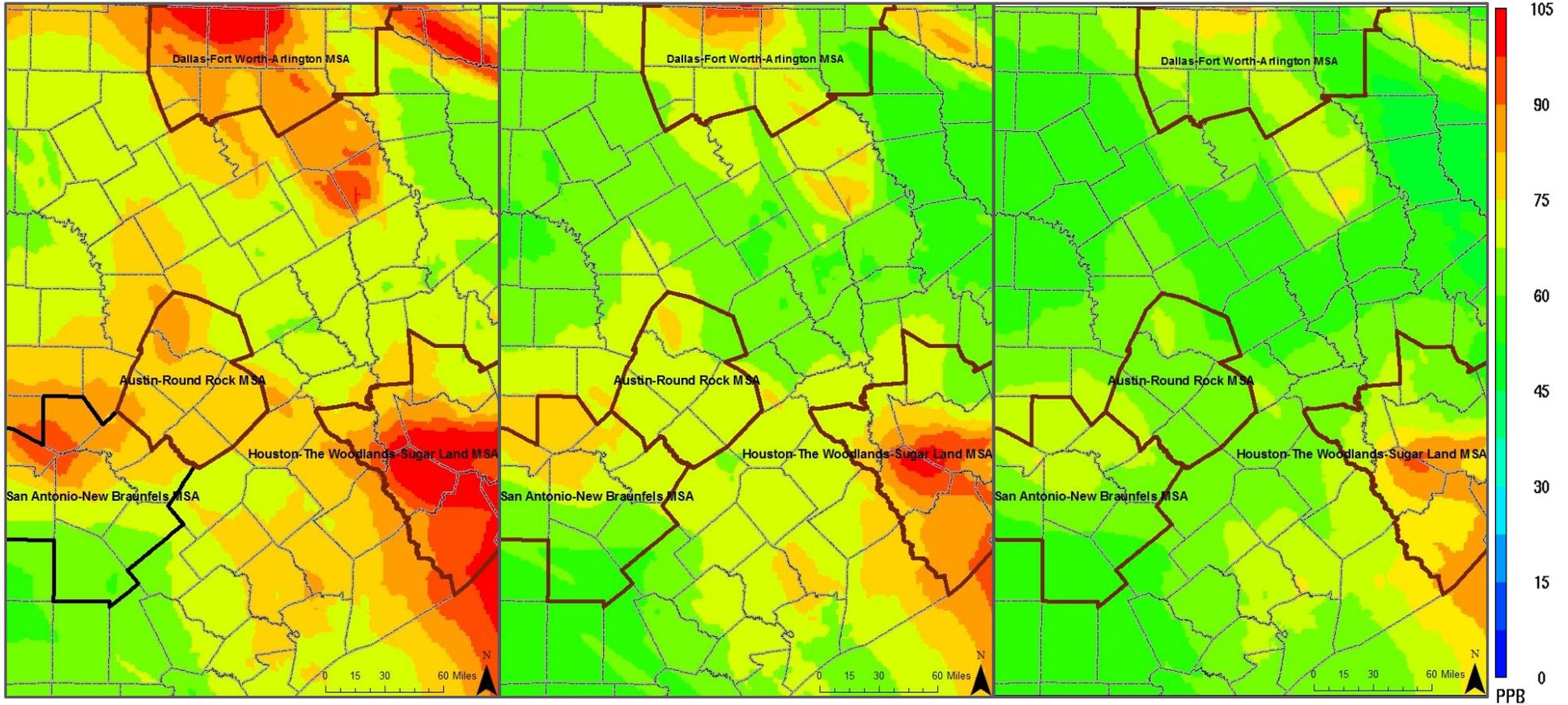
2018 Eagle Ford Moderate (June 8th)



2006 (June 9th)

2012 Eagle Ford (June 9th)

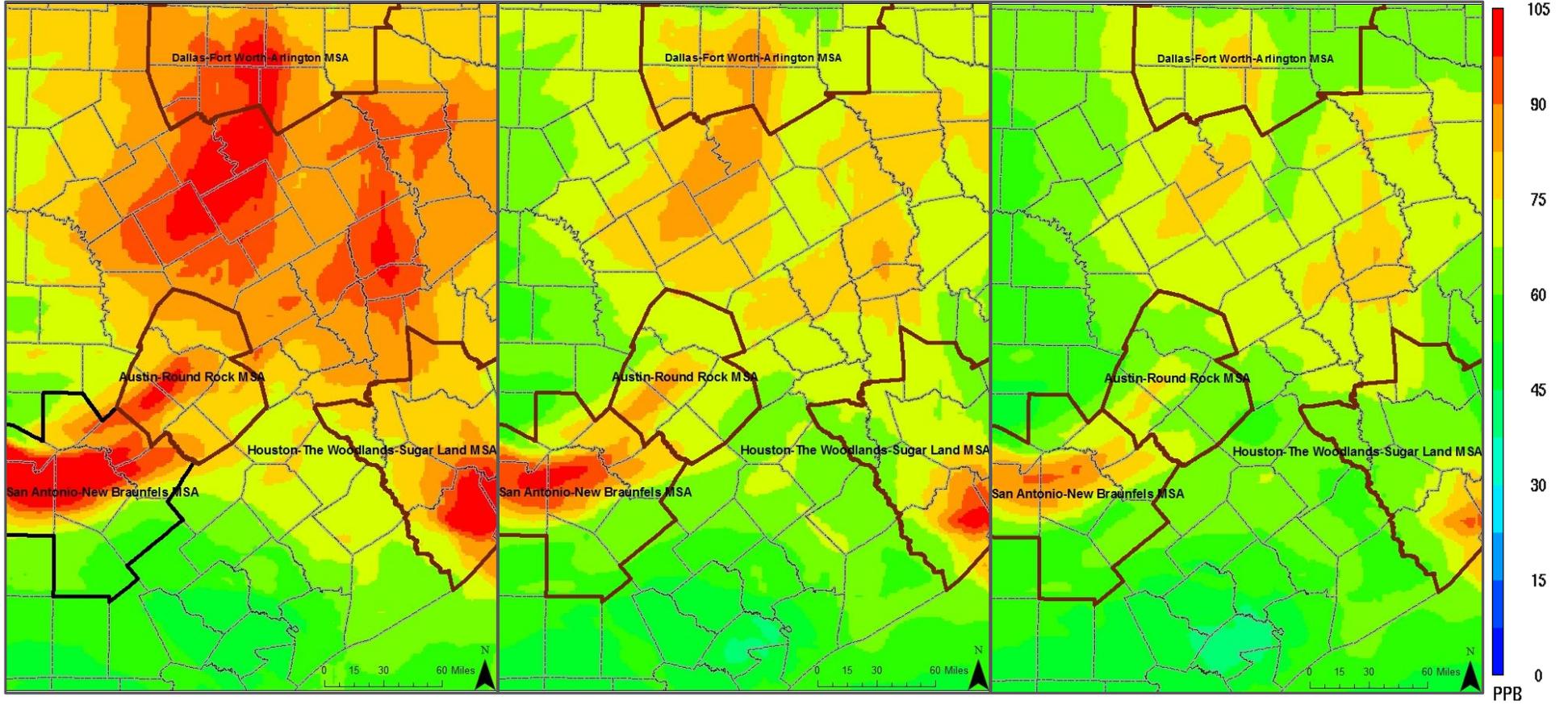
2018 Eagle Ford Moderate (June 9th)



2006 (June 13th)

2012 Eagle Ford (June 13th)

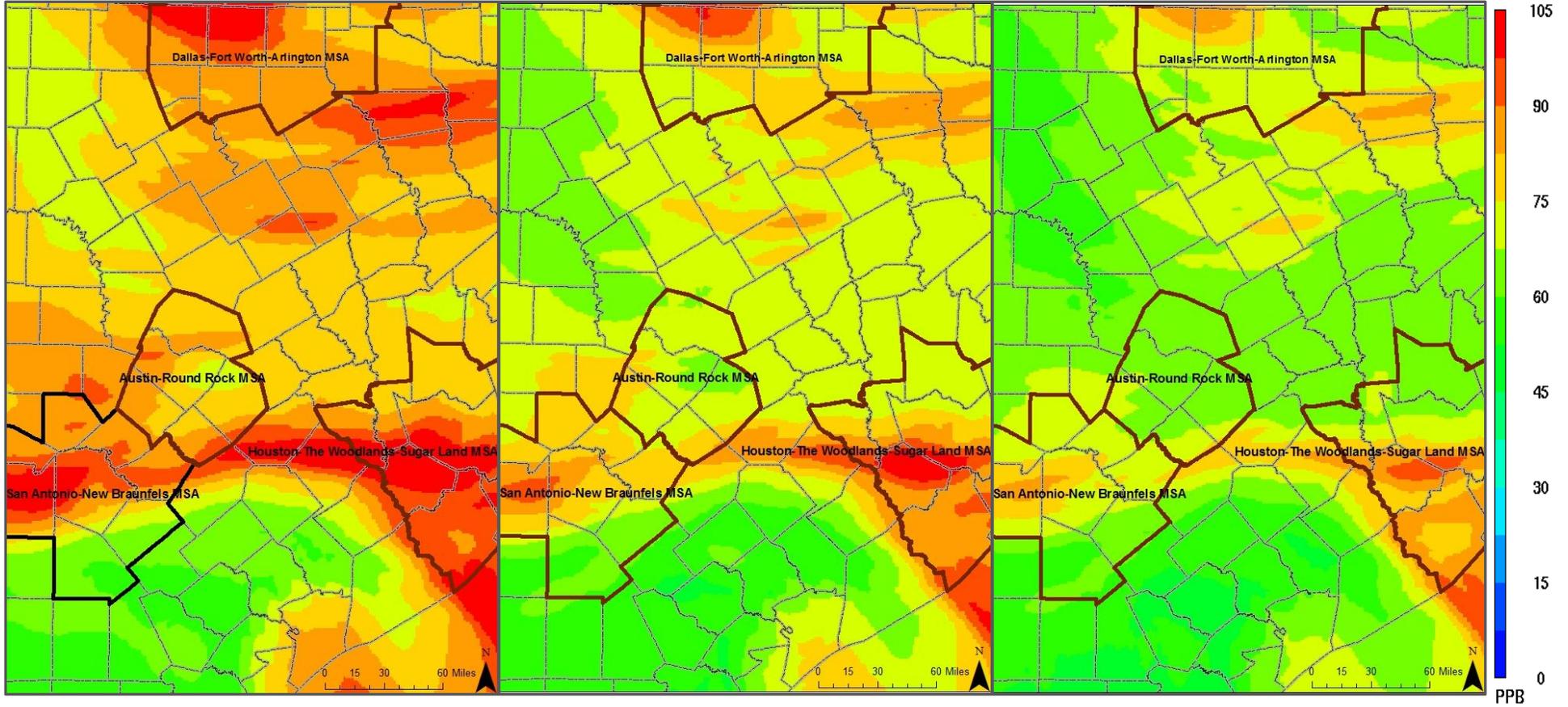
2018 Eagle Ford Moderate (June 13th)



2006 (June 14th)

2012 Eagle Ford (June 14th)

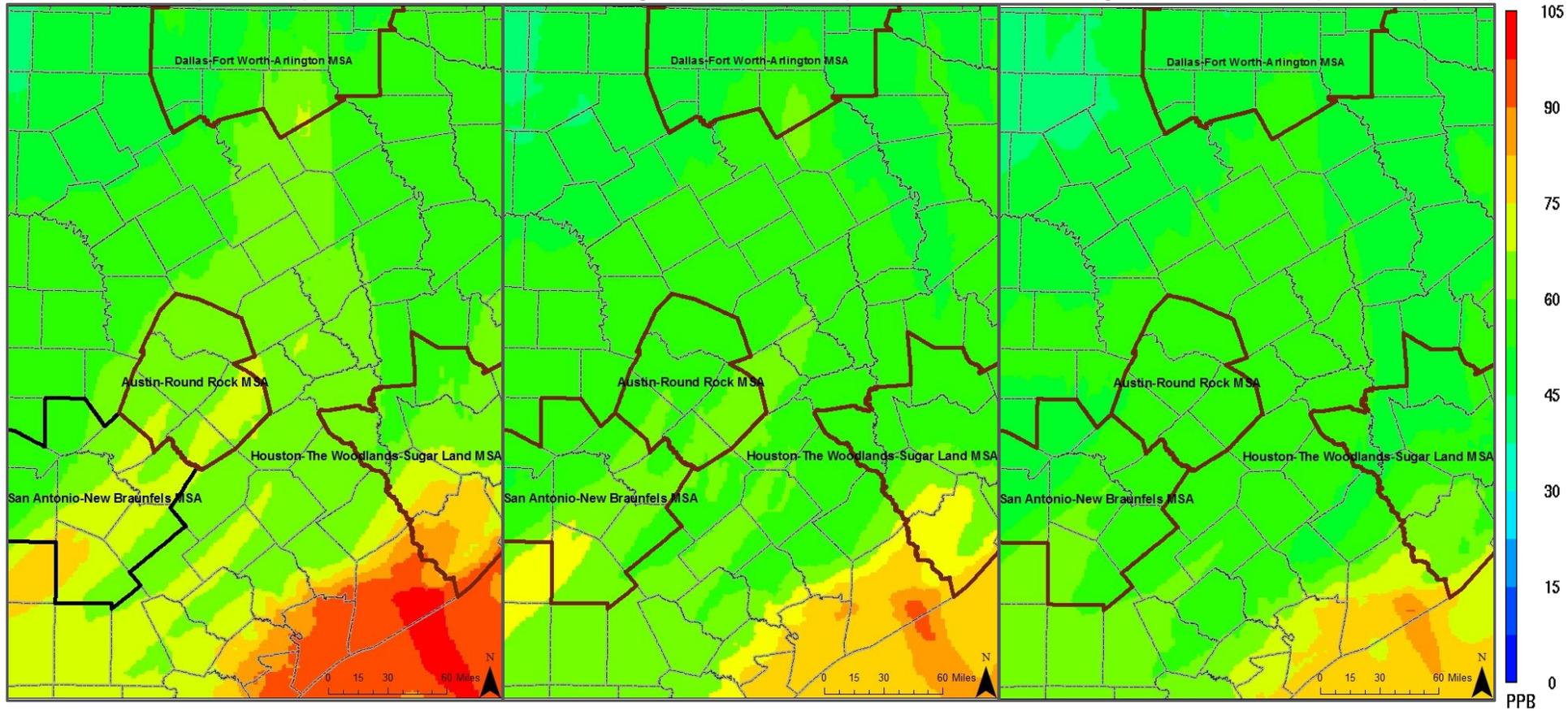
2018 Eagle Ford Moderate (June 14th)



2006 (June 26th)

2012 Eagle Ford (June 26th)

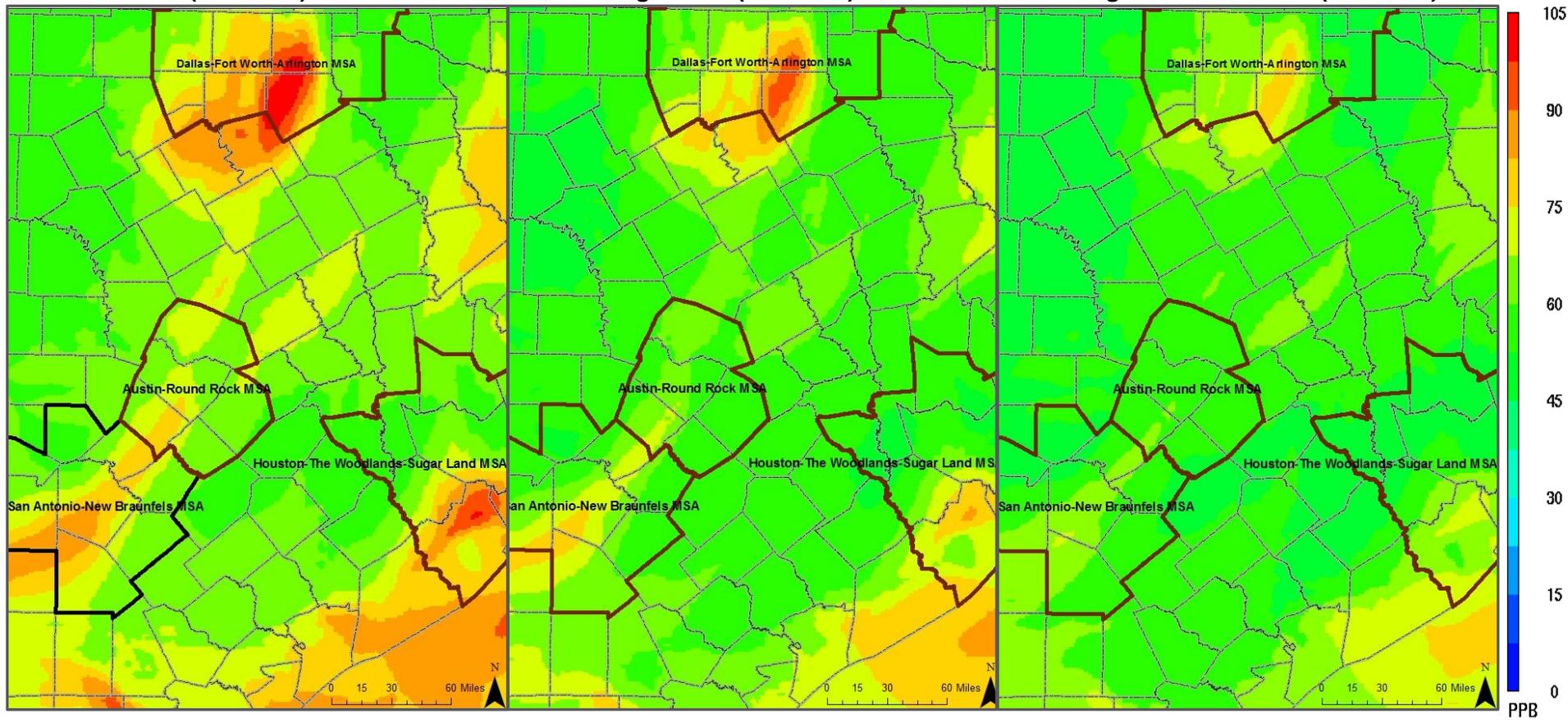
2018 Eagle Ford Moderate (June 26th)



2006 (June 27th)

2012 Eagle Ford (June 27th)

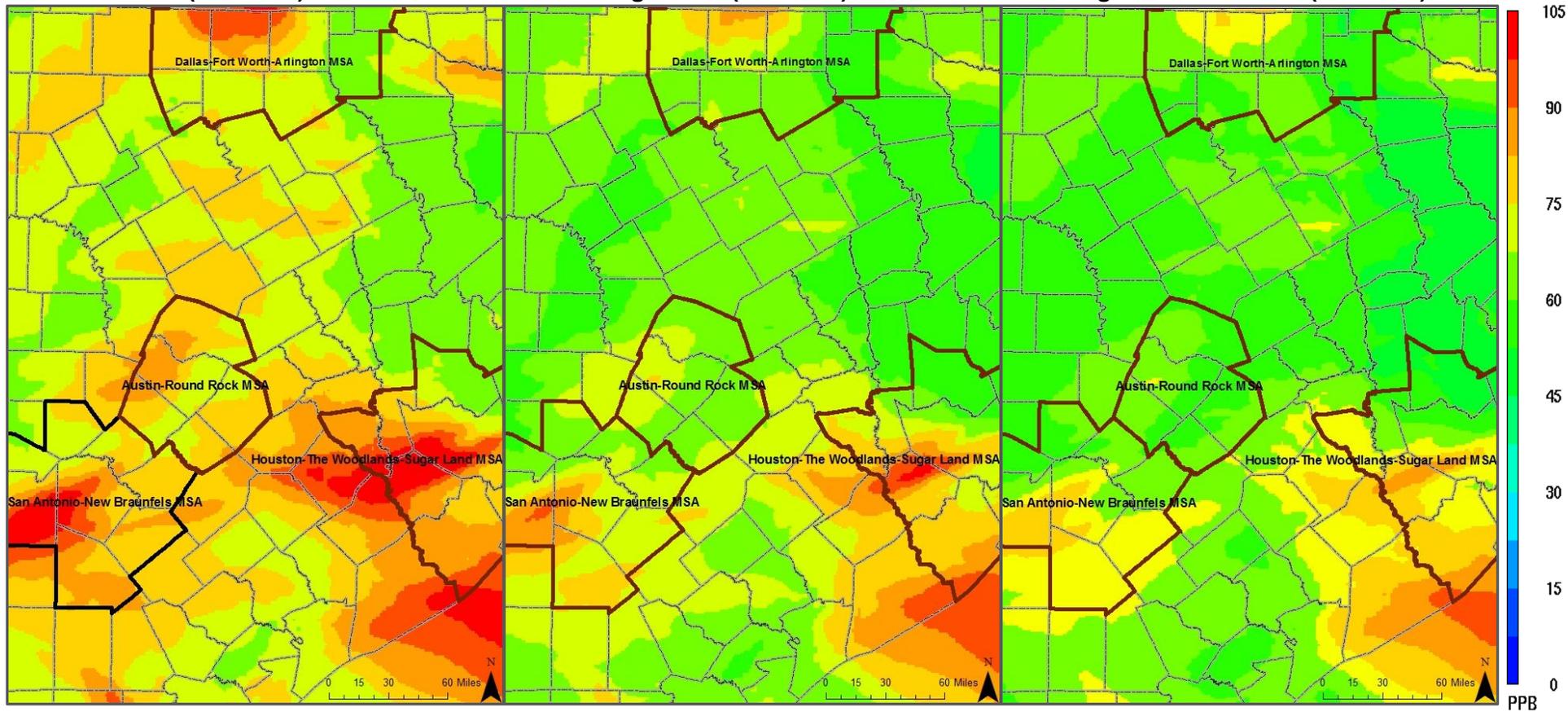
2018 Eagle Ford Moderate (June 27th)



2006 (June 28th)

2012 Eagle Ford (June 28th)

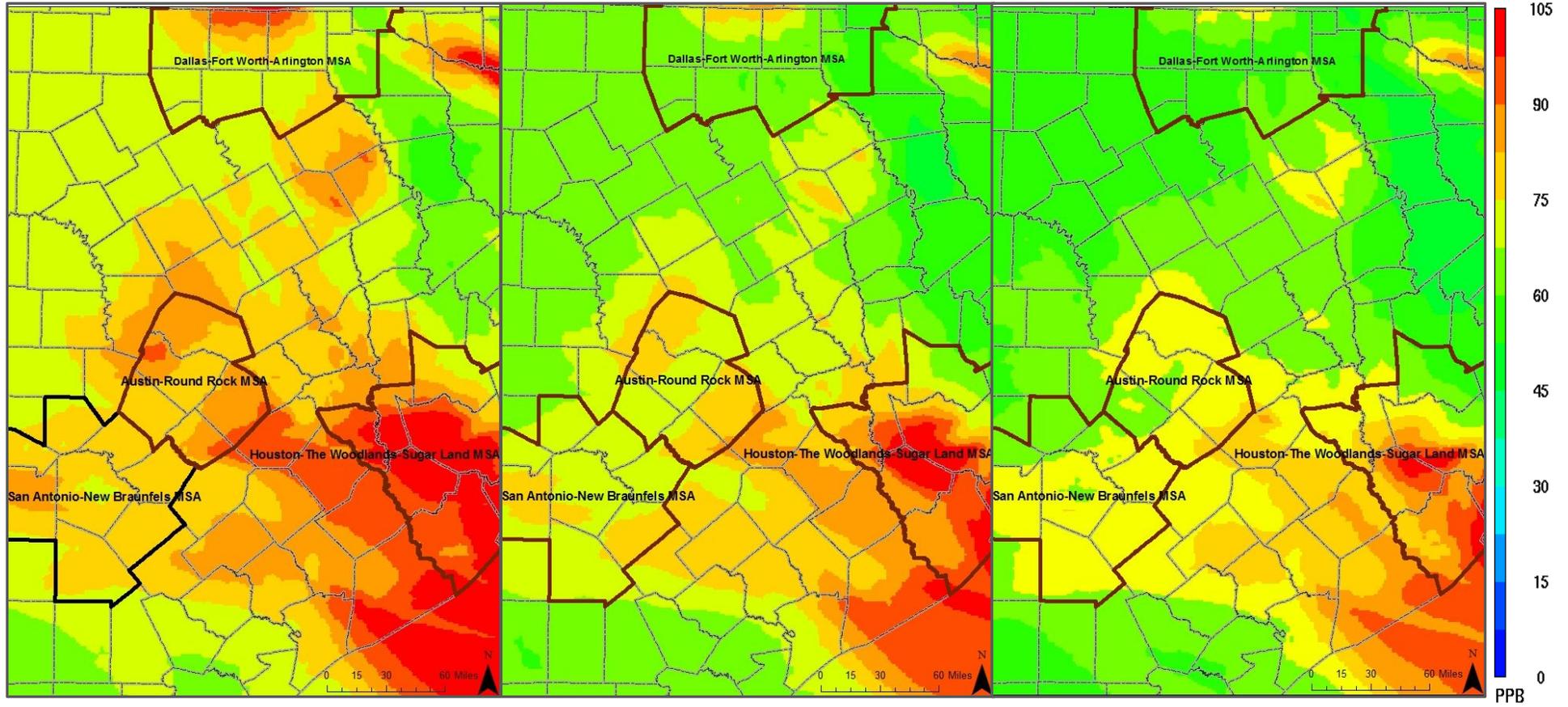
2018 Eagle Ford Moderate (June 28th)



2006 (June 29th)

2012 Eagle Ford (June 29th)

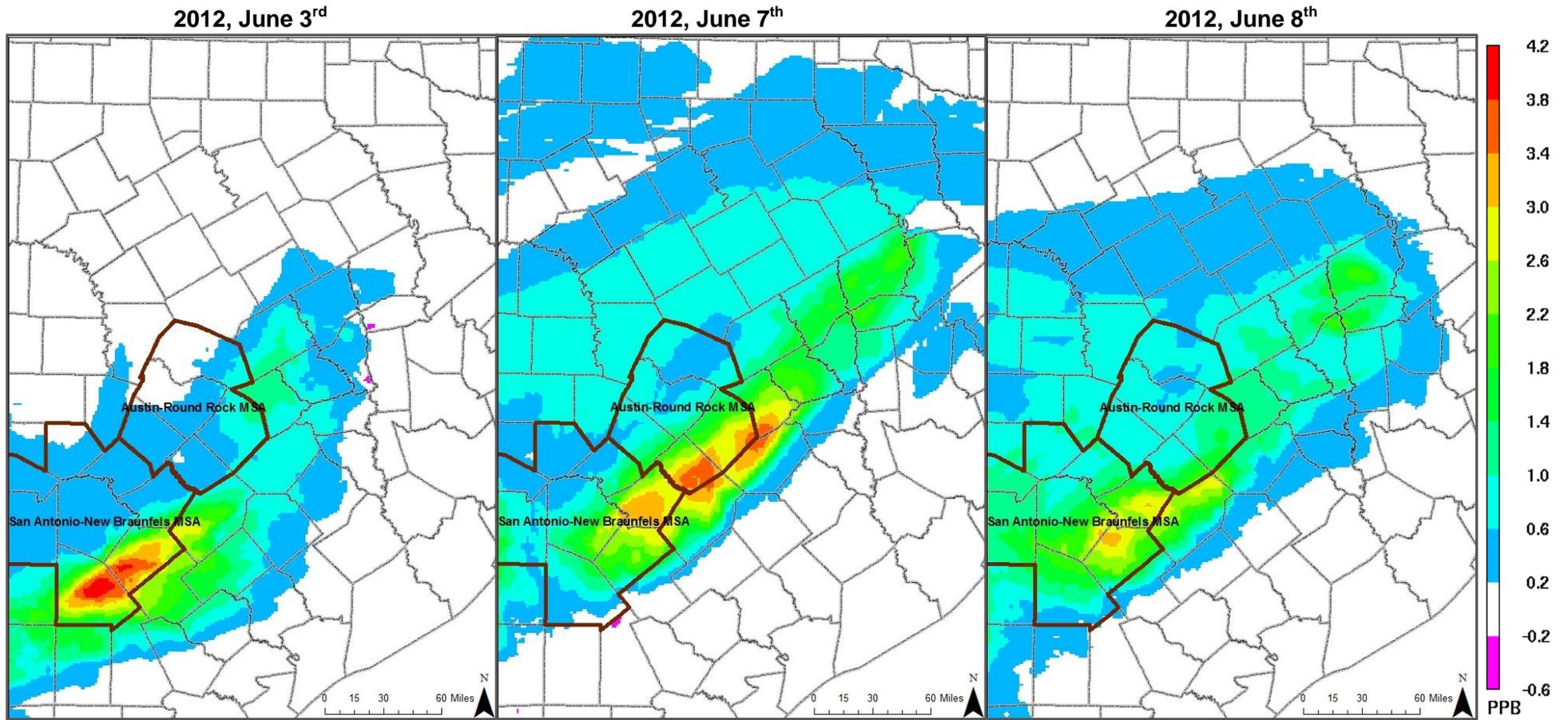
2018 Eagle Ford Moderate (June 29th)



A 2012 base case run was performed with and without the 2012 Eagle Ford emission inventory. Tile plots of the difference in predicted maximum ozone levels for these runs are provided in Figure 6-2. On most days, the model predicts that the maximum impact of the Eagle Ford is southeast of Bexar County, with ozone levels increasing from 3.1 ppb to 9.3 ppb depending on the modeling day. The greatest maximum impact occurred on June 13th (9.3 ppb) and the June 14th (8.4 ppb) exceedance days.

Although the maximum predicted impact is southeast of Bexar County, emissions from the Eagle Ford increase ozone levels in Bexar County and at the regulatory monitors in the region. Significant impacts on Bexar County ozone concentrations occurred on June 7th, 8th, 9th, 14th and June 29th of the modeled episode. The impact from the Eagle Ford development was insignificant on June 26th and 27th exceedance days because the prevailing winds were from the northeast which pushed the ozone impact of the Eagle Ford south of Bexar County. Figure 6-3 shows the difference in 2018 8-hour ozone from Eagle Ford emissions for each modeling day

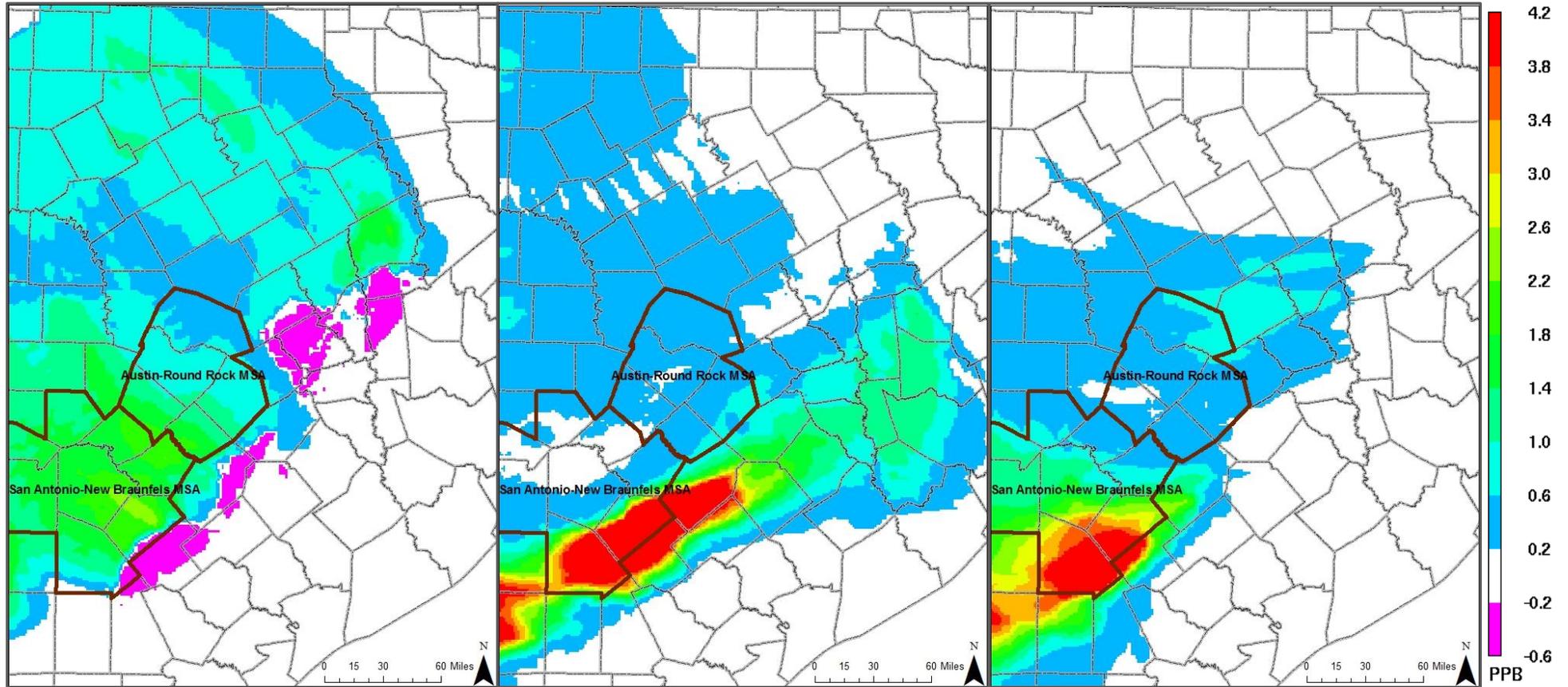
Figure 6-2: Predicted Daily Maximum Difference in 8-hour Ozone Concentrations in the 4-km Subdomain, 2012 Eagle Ford - Base Case



2012, June 9th

2012, June 13th

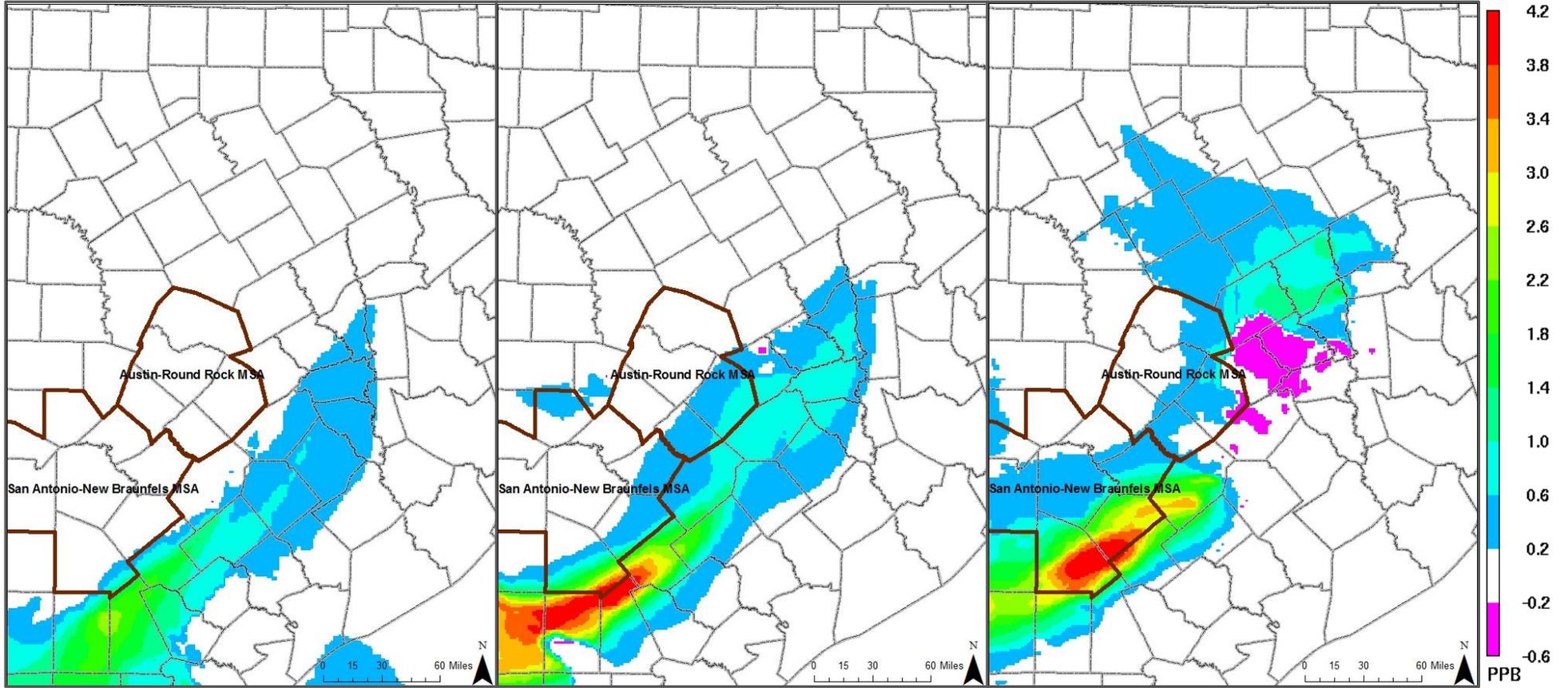
2012, June 14th



2012, June 26th

2012, June 27th

2012, June 28^h



2012, June 29th

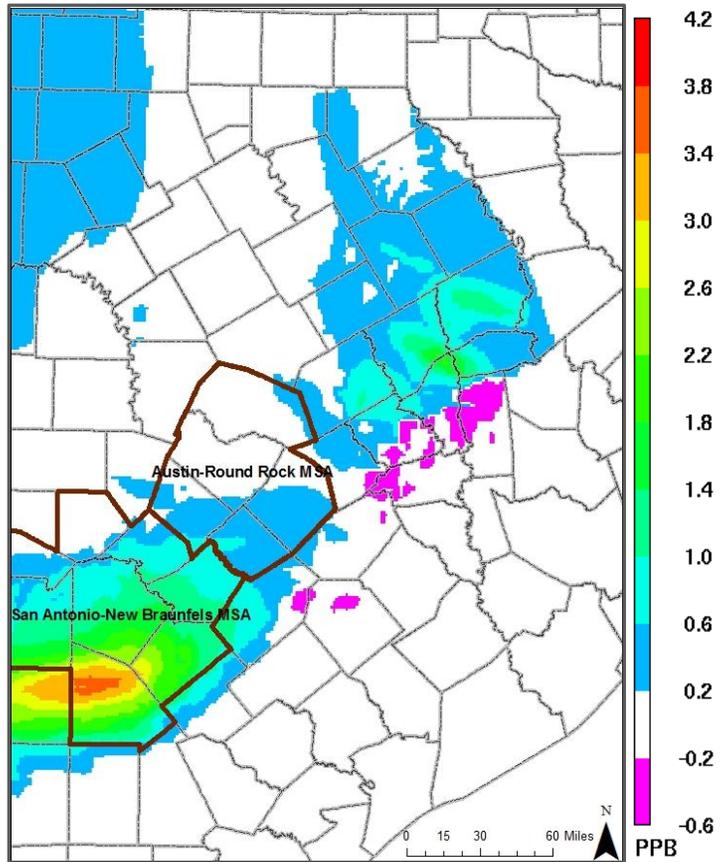
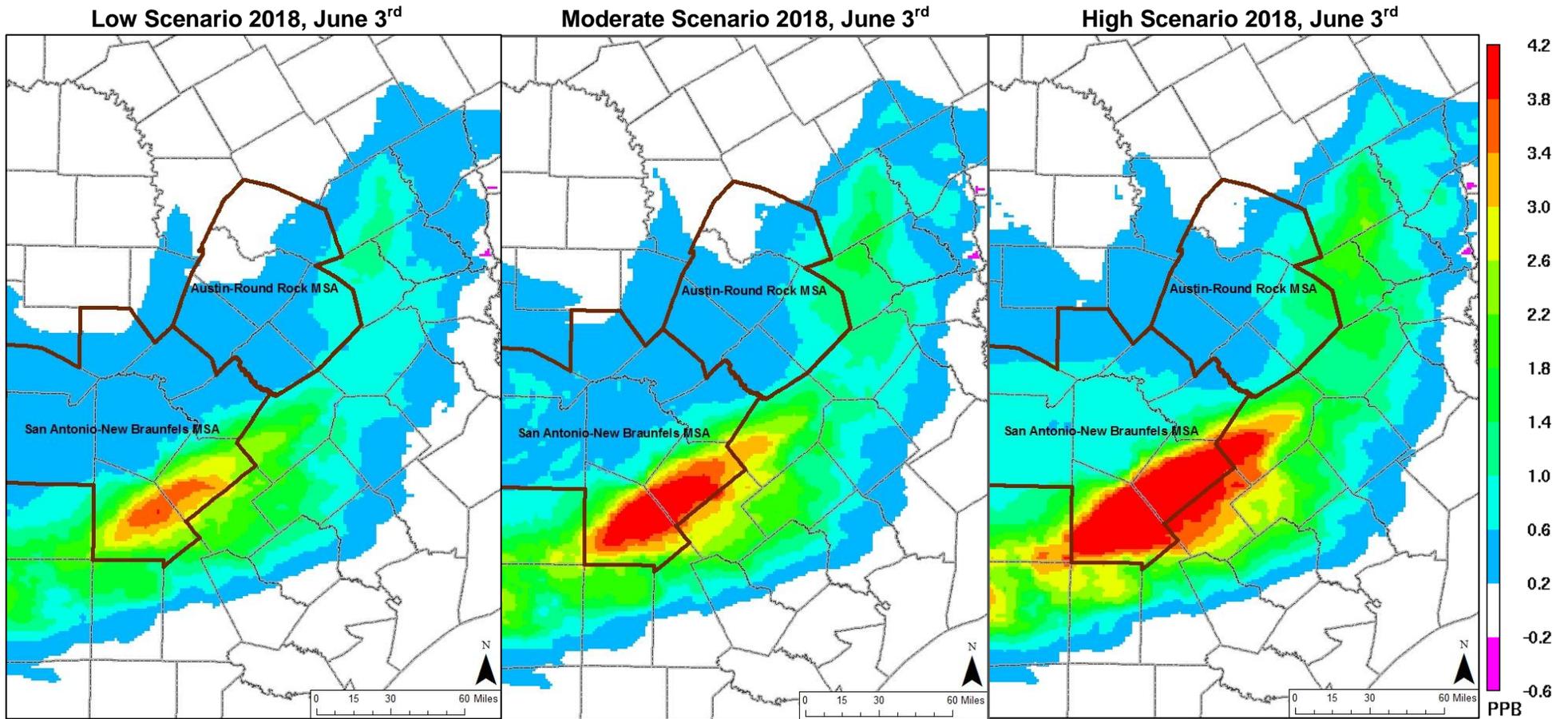


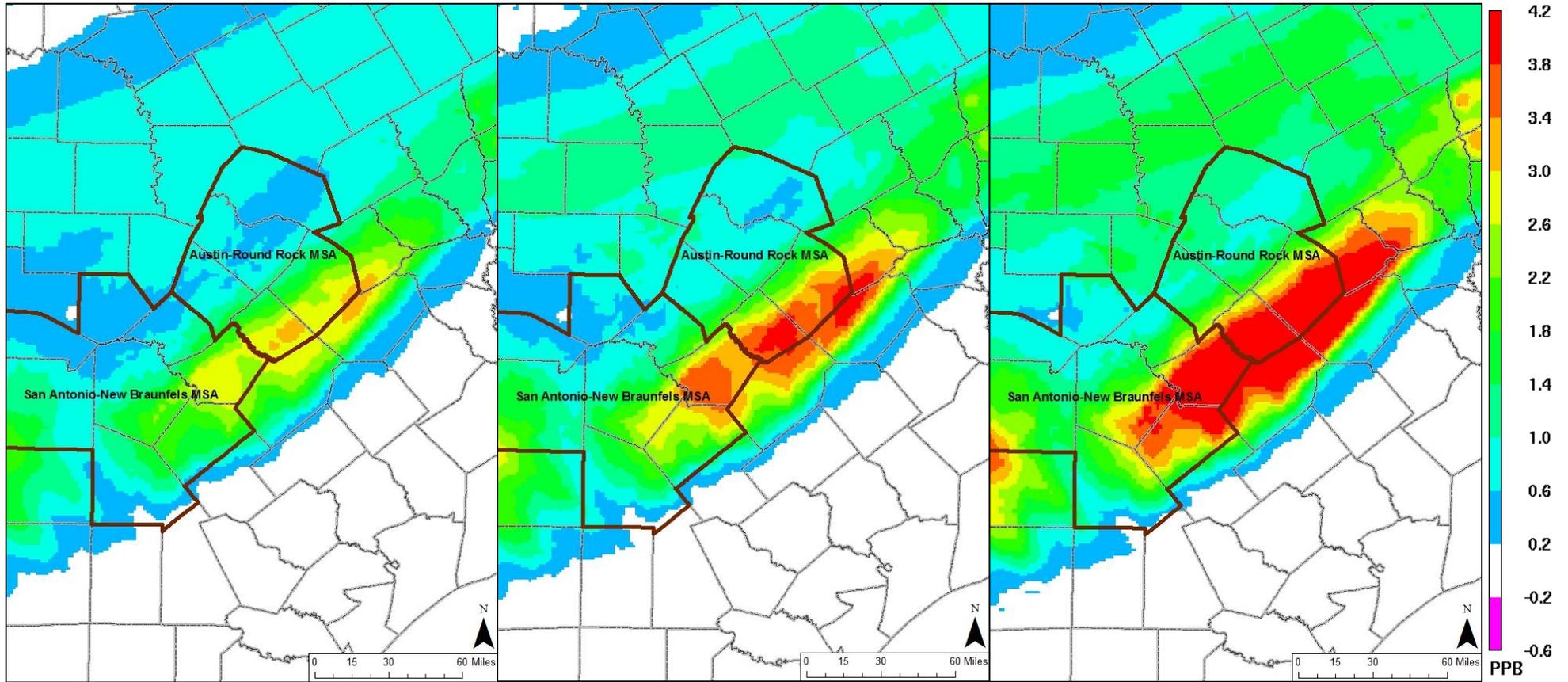
Figure 6-3: Predicted Daily Maximum Difference in 8-hour Ozone Concentrations in the 4-km Subdomain, 2018 Eagle Ford - Base Case



Low Scenario 2018, June 7th

Moderate Scenario 2018, June 7th

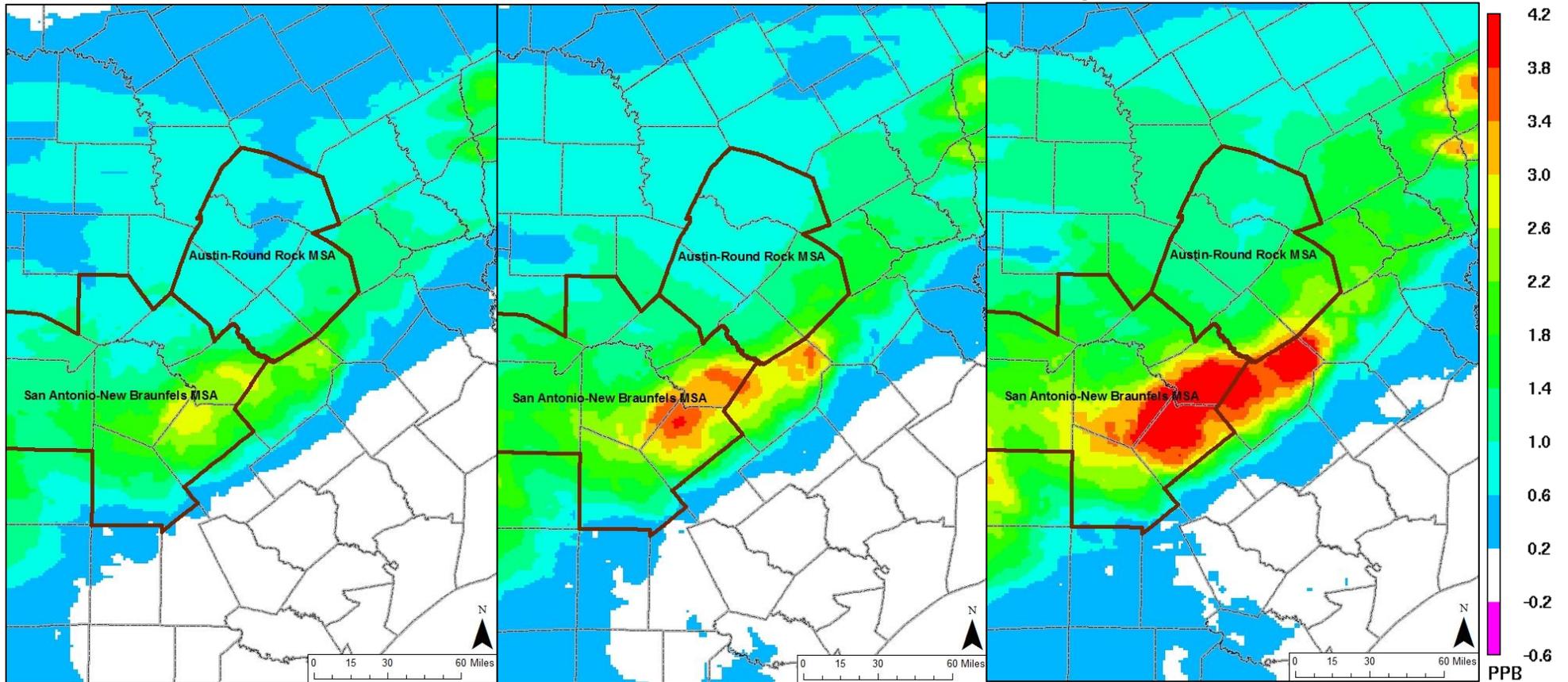
High Scenario 2018, June 7th



Low Scenario 2018, June 8th

Moderate Scenario 2018, June 8th

High Scenario 2018, June 8th



Low Scenario 2018, June 9th

Moderate Scenario 2018, June 9th

High Scenario 2018, June 9th

