Appendix J
Model Performance Evaluation

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1 Air Quality Modeling

The air quality modeling for the Charlotte-Gastonia-Rock Hill, NC-SC 8-hour ozone nonattainment area (referred to as the Metrolina area) was performed in conjunction with the regional haze modeling being done by the Southeast Regional Planning Organization, Visibility Improvement State and Tribal Association of the Southeast (VISTAS) and the fine particulate matter (PM2.5) and ozone modeling being done by the Association of Southeastern Integrated Planning (ASIP). VISTAS and ASIP are run by the ten Southeast states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia. Since the regional haze and PM2.5 modeling uses annual simulations and includes an intermediate year that is the attainment year required for the Metrolina nonattainment area, the North Carolina Division of Air Quality (NCDAQ) decided to use the this modeling for its attainment demonstration.

1.1 Air Quality Model Configuration

This air quality modeling system used in this State Implementation Plan (SIP) modeling exercise was the US Environmental Protection Agency's (USEPA's) Models-3/ Community Multiscale Air Quality (CMAQ). The configuration of the CMAQ modeling system was chosen based on the results of the model sensitivity testing performed in Phase I of the VISTAS/ASIP regional haze, fine particulate, and ozone modeling efforts. This configuration of options is identical to those used in Phase II of the VISTAS/ASIP projects. The Phase II CMAQ configuration is presented in Table 1-1. The 36/12 kilometer (km) horizontal and vertical grid system used in the VISTAS/ASIP Phase II modeling is displayed in Figure 1-1.

Table 1-1 VISTAS/ASIP Phase II Initial CMAQ Model Configuration.

Model Option	Phase II CMAQ Configuration
Model Version	Version 4.5 (September 2003)
Horizontal Resolution	36/12 km
No. Vertical Layers	NZ = 19
Horizontal Advection	PPM
Vertical Advection	PPM
Horizontal Diffusion	Spatially Varying
Vertical Diffusion	K_V (Eddy Diffusion)
Minimum Vertical Diffusivity	1.0 m_2/s
MM5 Configuration	Pleim-Xiu/ACM No linkage of 5-day run segments
MM5 Processing	MCIP2.2 Pass Through
Gas-Phase Chemistry	CB4
Gas-Phase Chemistry Solver	MEBI
Secondary Organic Aerosol	SORGAM
Aqueous-Phase Chemistry	RADM
Aerosol Chemistry	AE3/ISORROPIA
Dry Deposition	Pleim-Xiu
Plume-in-Grid	Off
Initial Concentrations	Default with 13-15 day spin-up
Boundary Conditions	2001 Seasonal GEOS-CHEM
Emissions	2002 Emissions

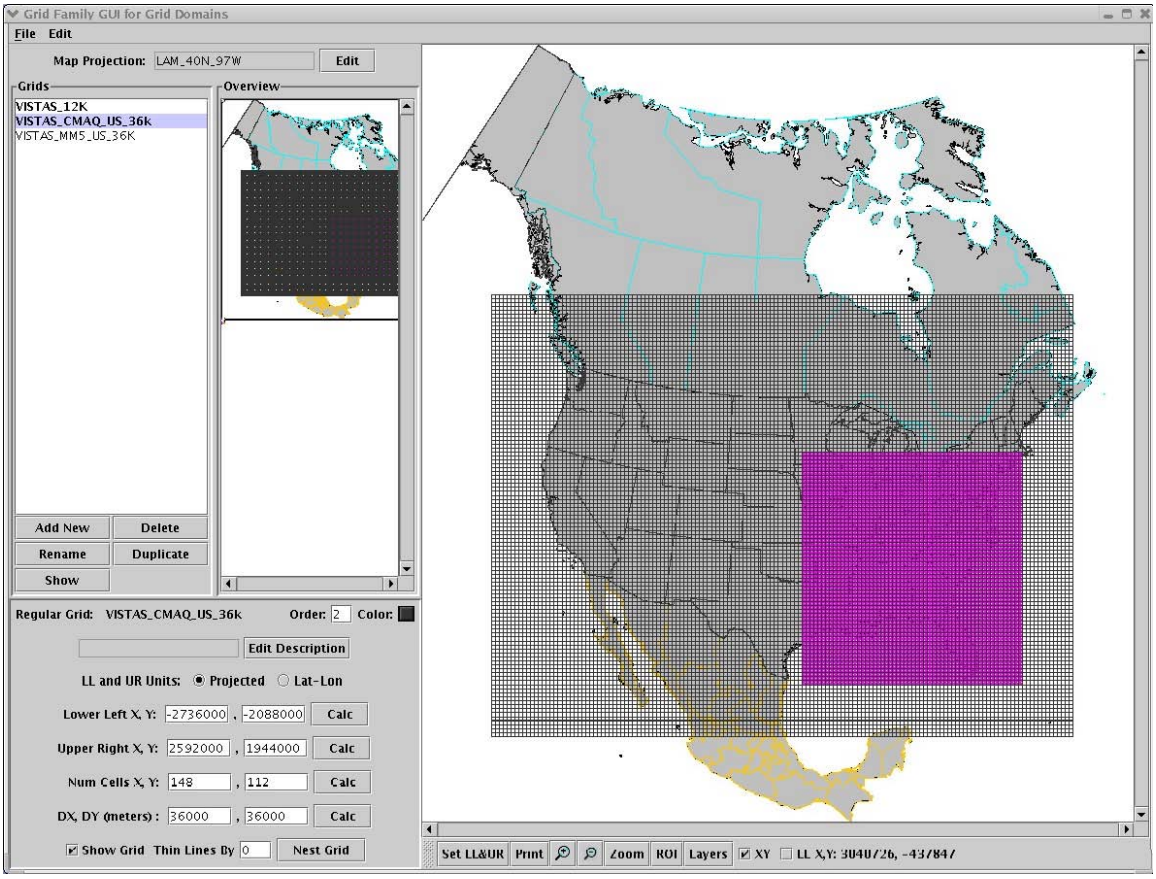


Figure 1-1 CMAQ nested 12 km grid in the CMAQ 36 km grid. Lower left x, y of the 36 km grid is at -2736000, -20880000

1.2 Secondary Organic Aerosols Modifications

As a part of the Phase II modeling project, the VISTAS/ASIP air quality modeling contractors developed modifications to the Secondary Organic Aerosols (SOA) subroutines inside of the CMAQ modeling system to improve modeled particulate matter and visibility performance. Since the modeling activities in this SIP exercise took a "one atmosphere" approach identical to that of VISTAS/ASIP, the CMAQ SOA modifications are included as part of this ozone modeling.

2 Model Performance Statistics

To quantify model performance, several statistical measures were calculated and evaluated for the VISTAS/ASIP states combined, for North Carolina, for South Carolina, and individually for each of the Metrolina area ozone monitors. The statistical measures selected were based on the recommendations outlined in section 18.4.1 of the USEPA's Guidance On The Use Of Models And Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze ("*Attainment Guidance*").

The statistical measures were calculated for both 1-hour and 8-hour ozone concentrations and based only on the respective portion of the 12km modeling domain. A customary 60 parts per billion (ppb) cutoff threshold was applied in the statistical calculations. This cutoff threshold prevents very low ozone concentrations from being included in the model performance statistics and generally prevents a widely known overnight over prediction of minimal ozone concentrations from biasing the performance evaluation of the modeling when ozone concentrations are much higher and of the most concern.

For convenience, these statistical measures or metrics along with a variety of additional statistical measures are summarized in Table 2-1.

Table 2-1 Statistical Metric Calculations

Statistical Measure	Shorthand Notation	Mathematical Expression	Notes
Accuracy of Paired Peak	A_p	$\frac{P - O_{peak}}{O_{peak}}$	
Coefficient of Determination	R^2	$\frac{\left[\sum_{i=1}^{N}(P_i - \overline{P})(O_i - \overline{O})\right]^2}{\sum_{i=1}^{N}(P_i - \overline{P})^2 \sum_{i=1}^{N}(O_i - \overline{O})^2}$	P_i= prediction at time and location i; O_i = observation at time and location i; $\overline{P}$ = arithmetic average of P_i, i = 1, 2, . . ., N; $\overline{O}$ = arithmetic average of O_i, i = 1, 2, . . ., N;
Normalized Mean Error	NME	$\frac{\sum_{i=1}^{N}\lvert P_i - O_i\rvert}{\sum_{i=1}^{N} O_i}$	Reported as %
Root Mean Square Error	RMSE	$\left[\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2\right]^{\frac{1}{2}}$	Reported as %
Fractional Gross Error	FError	$\frac{2}{N}\sum_{i=1}^{N}\left\lvert\frac{P_i - O_i}{P_i + O_i}\right\rvert$	Reported as %
Mean Absolute Gross Error	MAGE	$\frac{1}{N}\sum_{i=1}^{N}\lvert P_i - O_i\rvert$	
Mean Normalized Gross Error	MNGE	$\frac{1}{N}\sum_{i=1}^{N}\frac{\lvert P_i - O_i\rvert}{O_i}$	Reported as %
Mean Biased	MB	$\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)$	Reported as concentration
Mean Normalized Bias	MNB	$\frac{1}{N}\sum_{i=1}^{N}\frac{(P_i - O_i)}{O_i}$	Reported as %
Mean Fractionalized Bias (Fractional Bias)	MFB	$\frac{2}{N}\sum_{i=1}^{N}\left(\frac{P_i - O_i}{P_i + O_i}\right)$	Reported as %
Normalized Mean Bias	NMB	$\frac{\sum_{i=1}^{N}(P_i - O_i)}{\sum_{i=1}^{N} O_i}$	Reported as %
Bias Factor	BF	$\frac{1}{N}\sum_{i=1}^{N}\left(\frac{P_i}{O_i}\right)$	Reported as BF:1 or 1:BF or in fractional notation (BF/1 or 1/BF)

2.1 12km Domain Statistics – Selected Regions

The statistical data calculated for the VISTAS/ASIP region, the North Carolina, and the South Carolina portions of the 12-km domain are presented in Tables 2.1-1 for 1-hour ozone and Table 2.1-2 for 8-hour ozone. On the whole, all of the statistical measures or metrics were within generally accepted ranges for mean bias, mean normalized bias, and mean normalized gross error. There was a slight under prediction of 1-hour and 8-hour ozone concentrations. This under prediction was noted in all months and across the VISTAS/ASIP states as a whole and also individually across North Carolina and across South Carolina. The most noted under prediction of ozone was contained in the months of August and September. In these months, the mean normalized bias fell slightly below the suggested range of ± 5-15 percent. The NCDAQ does not believe this slight under prediction for August and September impacts the overall results for this SIP modeling exercise. In all cases, the mean normalized gross error was significantly below the 30-35 percent range at the 60 ppb threshold for all regions. These 1-hour and 8-hour statistical metrics were used as a first screening of the model performance.

Table 2.1-1 12km Domain Model Statistics for 1-Hour Ozone

1-Hour Model Performance Statistics (BaseG2A - 60 ppb Cutoff)					
Region / Month	**Modeled Mean (ppb)**	**Observed Mean (ppb)**	**Mean Bias (ppb)**	**Mean Normalized Bias (%)**	**Mean Normalized Gross Error (%)**
12km ASIP States Combined					
May	62.54	69.08	-6.53	-8.92	13.64
June	63.75	73.45	-9.7	-12.67	15.81
July	64.20	73.70	-9.5	-12.16	16.70
August	62.95	75.35	-12.4	-15.78	18.49
September	62.19	74.68	-12.49	-16.20	18.52
Mean (May-Sept)	*63.13*	*73.25*	*-10.12*	*-13.15*	*16.63*
North Carolina					
May	64.68	70.24	-5.56	-7.53	12.74
June	63.65	74.39	-10.74	-13.97	15.89
July	64.54	75.51	-10.97	-13.71	16.61
August	62.34	76.92	-14.59	-18.24	19.59
September	59.83	71.64	-11.81	-16.08	18.10
Mean (May-Sept)	*63.01*	*73.74*	*-10.73*	*-13.91*	*16.59*
South Carolina					
May	64.39	69.37	-4.98	-6.72	11.69
June	62.99	73.33	-10.34	-13.36	15.33
July	61.61	72.73	-11.12	-14.54	16.72
August	61.05	74.13	-13.08	-17.20	18.34
September	62.23	75.24	-13.01	-16.69	18.34
Mean (May-Sept)	*62.45*	*72.96*	*-10.51*	*-13.70*	*16.08*

Table 2.1-2 12km Domain Model Statistics for 8-Hour Ozone

8-Hour Model Performance Statistics (BaseG2A - 60 ppb Cutoff)					
Region / Month	**Modeled Mean (ppb)**	**Observed Mean (ppb)**	**Mean Bias (ppb)**	**Mean Normalized Bias (%)**	**Mean Normalized Gross Error (%)**
12km ASIP States Combined					
May	61.26	67.69	-6.44	-8.96	12.47
June	62.62	70.99	-8.37	-11.37	14.02
July	62.73	70.85	-8.12	-10.90	14.74
August	61.33	72.57	-11.24	-14.92	16.98
September	60.81	71.98	-11.17	-14.98	17.07
Mean (May-Sept)	*61.75*	*70.82*	*-9.07*	*-12.23*	*15.06*
North Carolina					
May	64.06	69.05	-5	-6.86	10.76
June	62.21	71.82	-9.62	-13.03	14.47
July	62.94	72.10	-9.16	-12.09	14.63
August	60.60	73.92	-13.33	-17.40	18.34
September	57.90	69.37	-11.46	-16.11	17.68
Mean (May-Sept)	*61.54*	*71.25*	*-9.71*	*-13.10*	*15.18*
South Carolina					
May	63.87	67.71	-3.85	-5.31	9.66
June	61.95	70.92	-8.97	-12.10	13.52
July	60.89	70.24	-9.35	-12.73	14.75
August	59.77	71.39	-11.62	-16.03	16.64
September	61.18	72.62	-11.44	-15.22	16.32
Mean (May-Sept)	*61.53*	*70.58*	*-9.05*	*-12.28*	*14.18*

2.2 Metrolina Nonattainment Area and Monitor Statistics

As a further exploration of modeling performance, specifically in the Metrolina region, similar 1 hour (Table 2.2-1) and 8-hour (Table 2.2-2) statistical measures were calculated for the region as a whole and for each of the ozone monitors in this region. In just the Metrolina region, the mean bias, mean normalized bias, and mean normalized gross error were all within recommended and accepted ranges. A slight under prediction of 1-hour and 8-hour ozone was also observed at this more refined level of analysis and was similar to what was seen at the larger state and VISTAS/ASIP region levels. Individual monthly statistics are not presented here due to the very limited number of modeled and observed data pairs at just the eight Metrolina ozone monitoring sites. Whole season statistics were more representative of how this air quality modeling will be applied in the modeled attainment test discussed in Appendix L. Across the whole season, the Metrolina region as a whole and all of the ozone monitoring sites had mean normalized bias statistics in the suggested ± 5-15 percent range and mean normalized gross error statistics in the suggested 30-35 percent range given a 60 ppb threshold.

Table 2.2-1 Metrolina Region and Monitor Statistics for 1-Hour Ozone

1-Hour Model Performance Statistics (BaseG2A - 60 ppb Cutoff)						
Monitor	**Site AIRS ID**	**Modeled Mean (ppb)**	**Observed Mean (ppb)**	**Mean Bias (ppb)**	**Mean Normalized Bias (%)**	**Mean Normalized Gross Error (%)**
Metrolina Region		**66.875**	**75.75**	**-8.75**	**-10.716**	**15.035**
Crouse	37-109-0004	69.0	76.0	-6.0	-7.232	12.050
Garinger	37-119-0041	66.0	76.0	-11.0	-13.777	17.861
Arrowood	37-119-1005	69.0	74.0	-5.0	-5.872	14.354
County Line	37-119-1009	69.0	77.0	-8.0	-9.248	13.835
Rockwell	37-159-0021	66.0	76.0	-10.0	-12.223	14.812
Enochville	37-159-0022	68.0	77.0	-9.0	-11.230	14.767
Monroe	37-179-0003	63.0	75.0	-12.0	-14.677	17.048
York, SC	45-091-0006	65.0	75.0	-9.0	-11.471	15.549

Table 2.2-2 Metrolina Region and Monitor Statistics for 8-Hour Ozone

8-Hour Model Performance Statistics (BaseG2A - 60 ppb Cutoff)						
Monitor	**Site AIRS ID**	**Modeled Mean (ppb)**	**Observed Mean (ppb)**	**Mean Bias (ppb)**	**Mean Normalized Bias (%)**	**Mean Normalized Gross Error (%)**
Metrolina Region		**65.25**	**73.50**	**-8.000**	**-10.346**	**13.388**
Crouse	37-109-0004	69.0	73.0	-4.0	-5.269	9.860
Garinger	37-119-0041	63.0	74.0	-11.0	-14.249	15.940
Arrowood	37-119-1005	67.0	72.0	-5.0	-5.793	12.300
County Line	37-119-1009	67.0	74.0	-7.0	-8.837	11.894
Rockwell	37-159-0021	65.0	74.0	-9.0	-11.643	13.495
Enochville	37-159-0022	65.0	75.0	-9.0	-11.933	13.774
Monroe	37-179-0003	62.0	73.0	-10.0	-13.721	15.371
York, SC	45-091-0006	64.0	73.0	-9.0	-11.326	14.472

3 Spatial Plots

The 12km domain spatial plots of modeled 1-hour and 8-hour maximum ozone concentrations for 2002, with the actual ozone observations overlaid are presented in this section. These plots are magnified or zoomed with respect to North Carolina. Only the days used in calculating the relative reduction factor (RRF) calculation at the Metrolina monitoring sites are presented here. The first plot on the page is the 1-hour maximum ozone, followed by the 8-hour maximum ozone plot. The color scale moves from lower concentrations in shade of blue to warmer colors for higher ozone concentrations. The scale loosely approximated the Air Quality Index (AQI) color scale for the 8-hour standard but was set to best demonstrate the gradient of ozone across North Carolina and Northern South Carolina, and to best highlight the range of observed ozone concentrations.

Overall, the air quality model does well with the spatial extent of the higher ozone concentrations. The model does slightly under-predict the 1-hour max and 8-hour max ozone concentration, as was seen in the model performance statistic earlier in this Appendix. The plots show North Carolina and South Carolina's higher ozone concentrations generally coincide with the major urbanized areas and with the major highways running through the states. The urban core of the city of Charlotte, North Carolina is well represented in the air quality model. This is important as the highest monitoring values occur at the urban sites (i.e. Garinger, County Line, and Enochville).

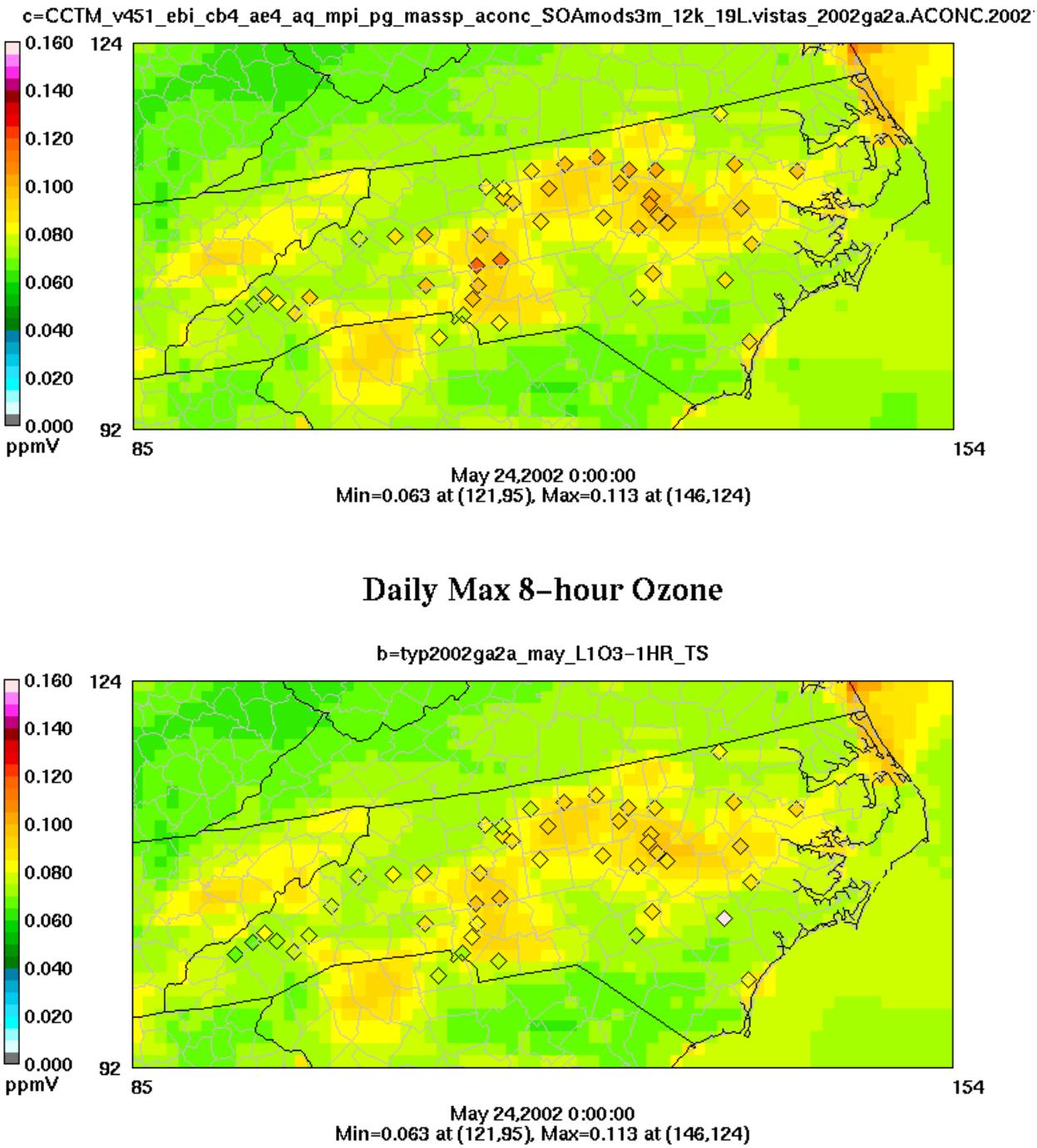


Figure 3-1 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For May 24, 2002

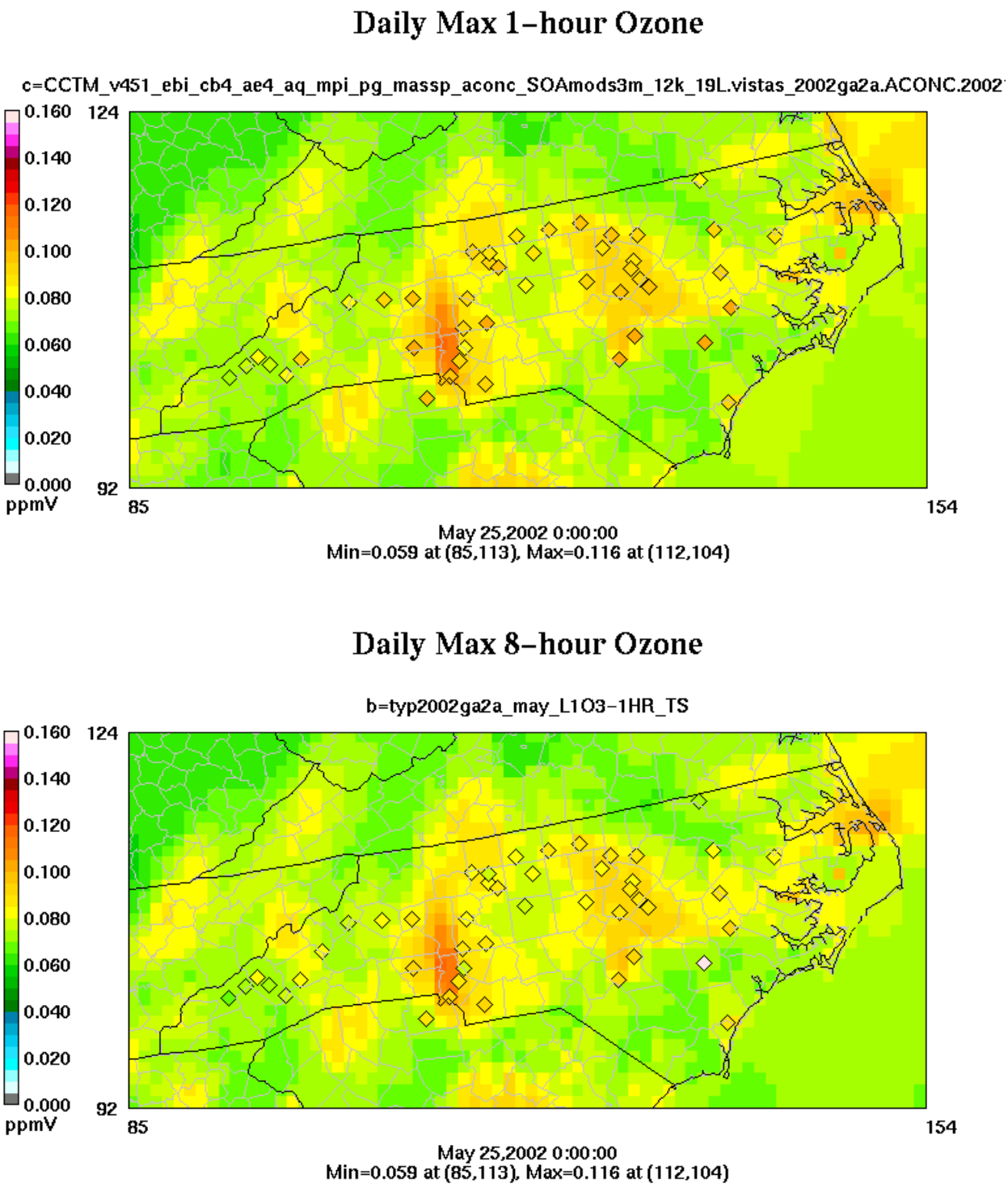


Figure 3-2 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For May 25, 2002

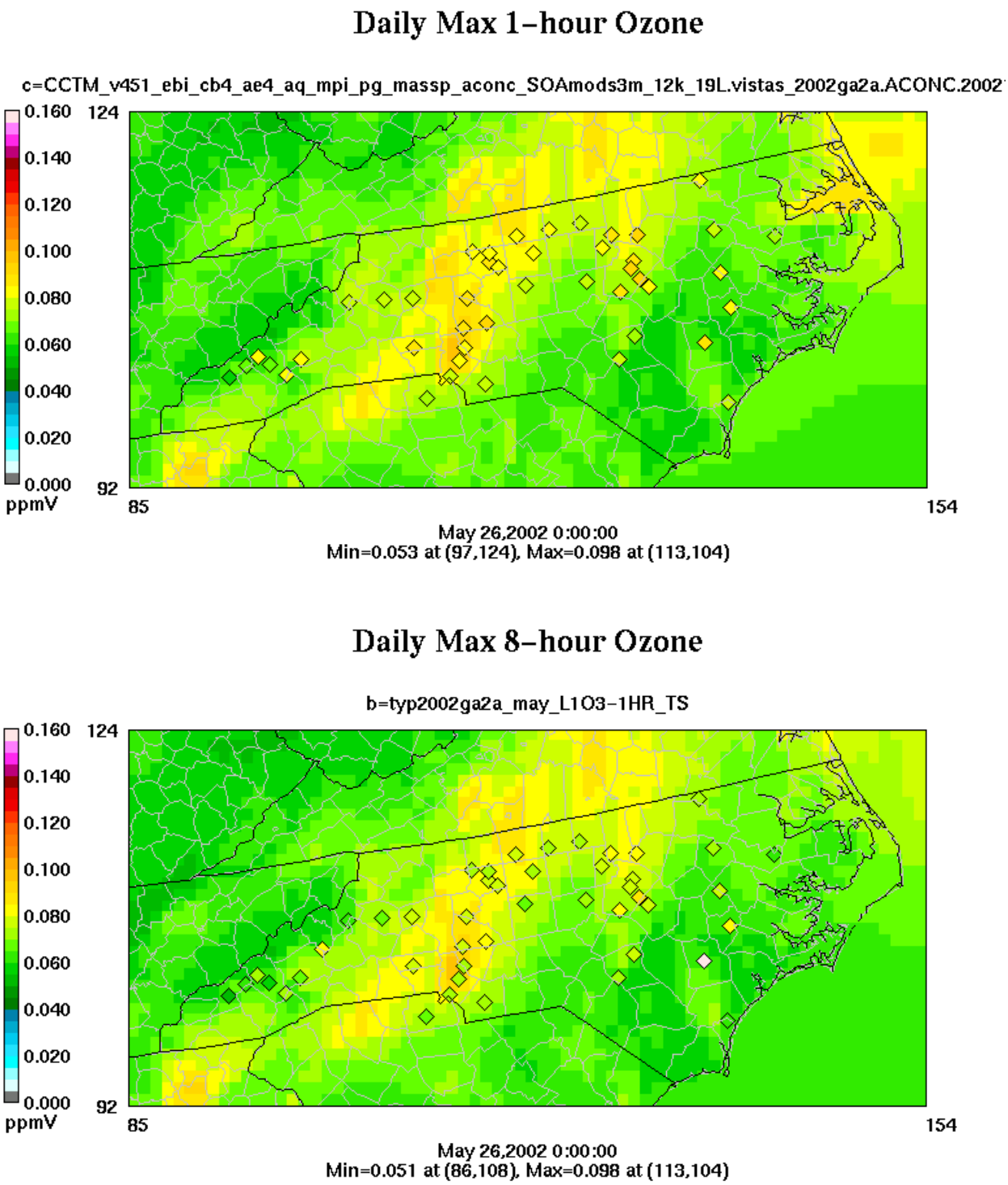


Figure 3-3 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For May 26, 2002

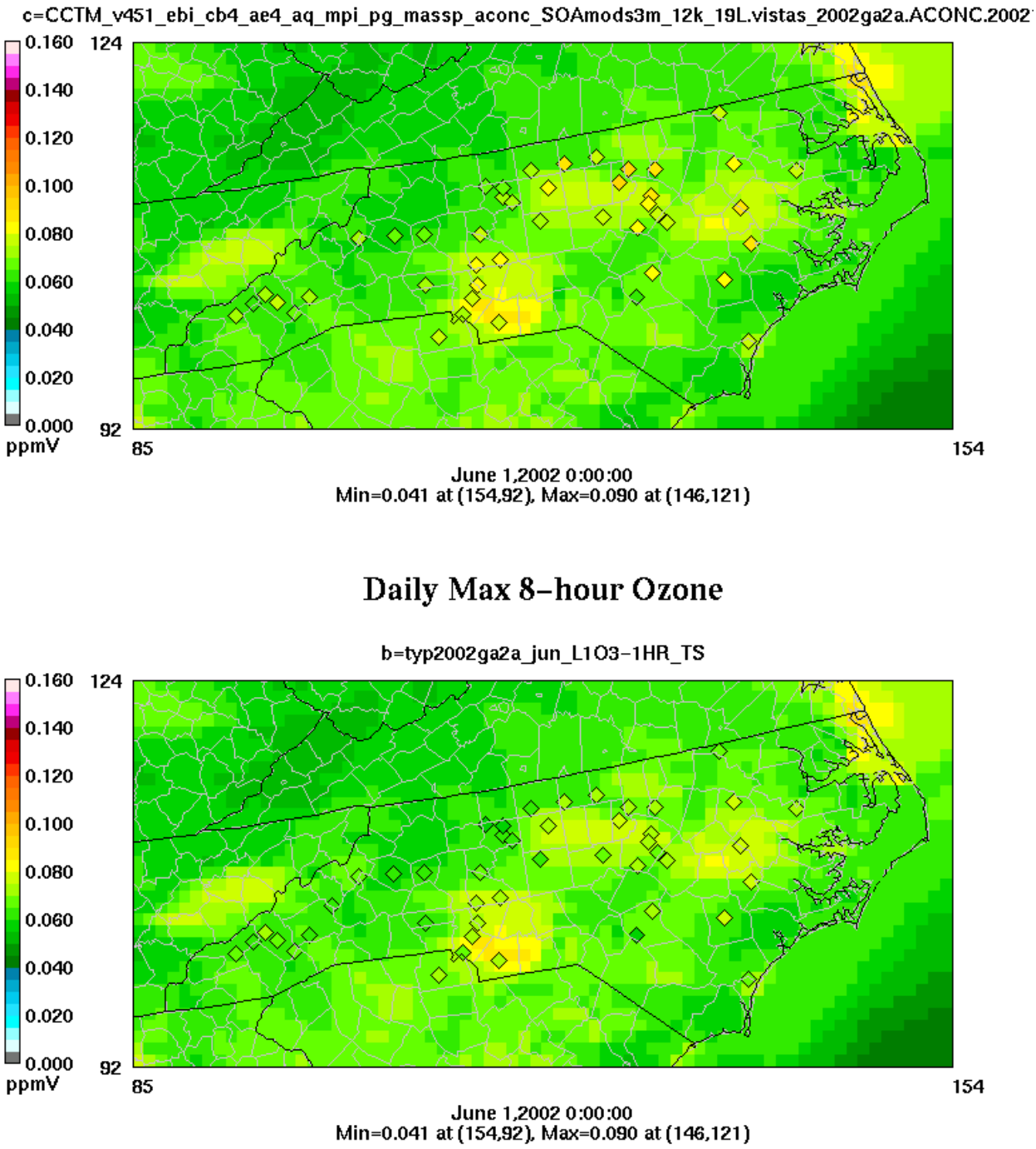


Figure 3-4 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 1, 2002

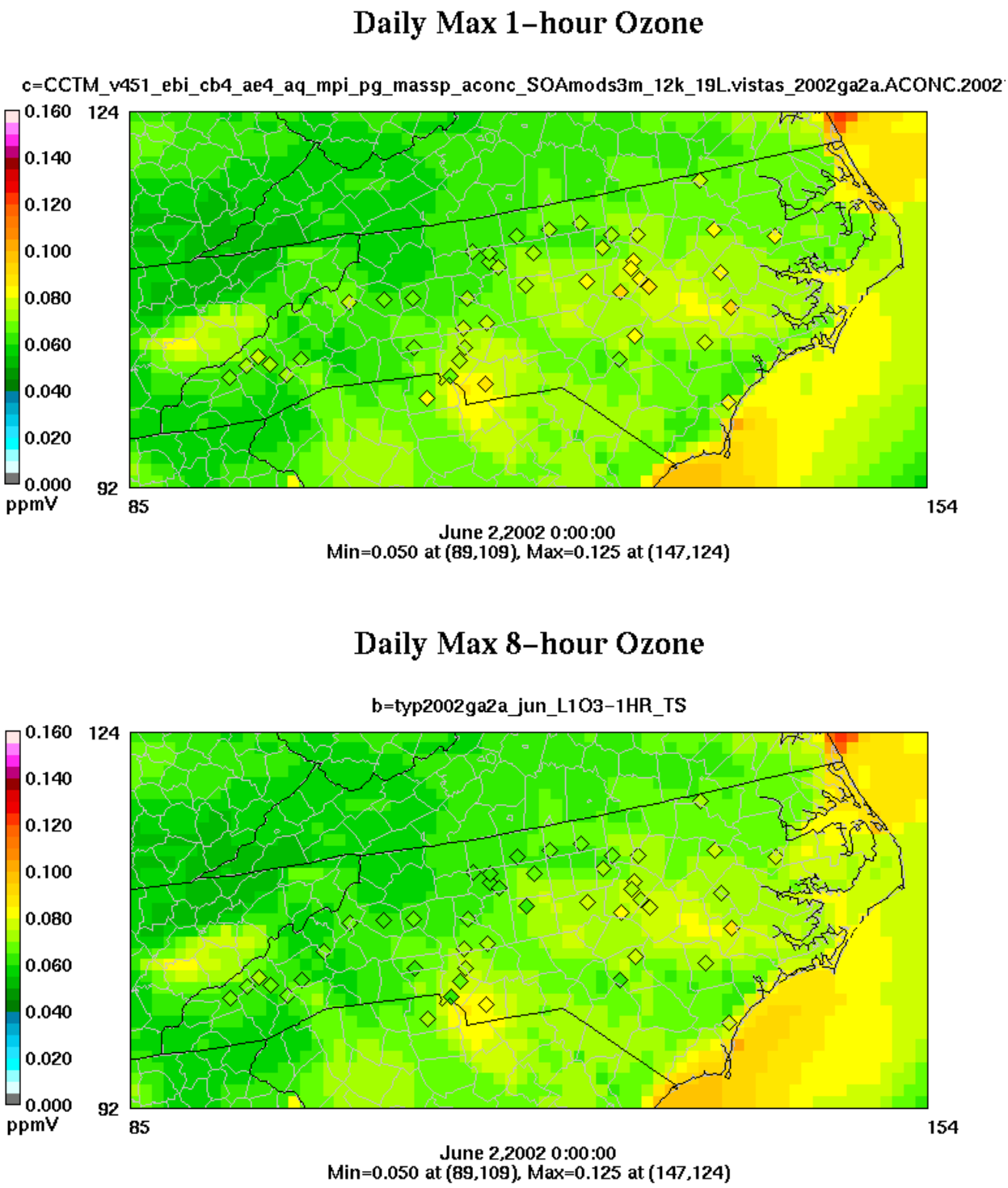


Figure 3-5 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 2, 2002

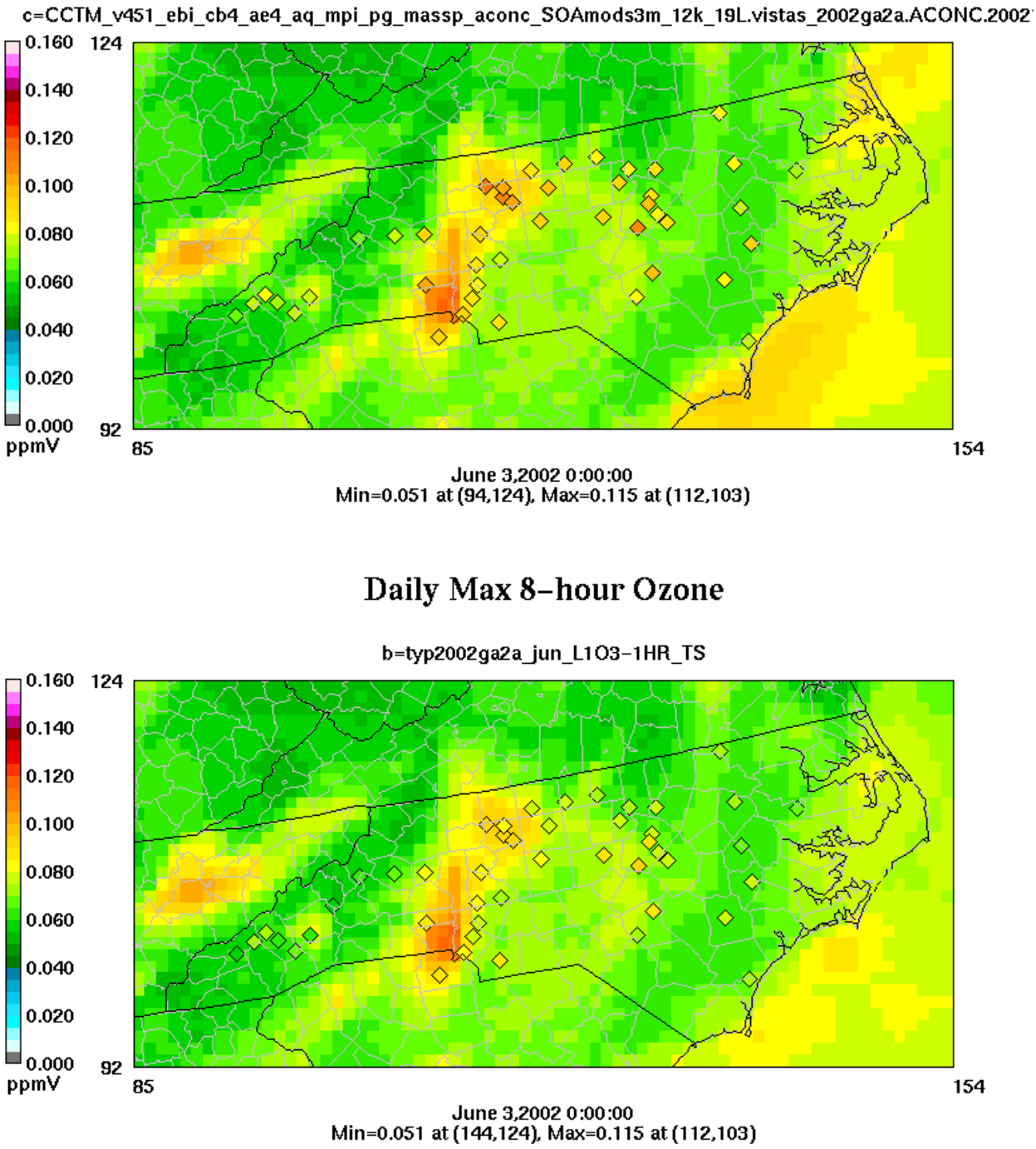


Figure 3-6 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 3, 2002

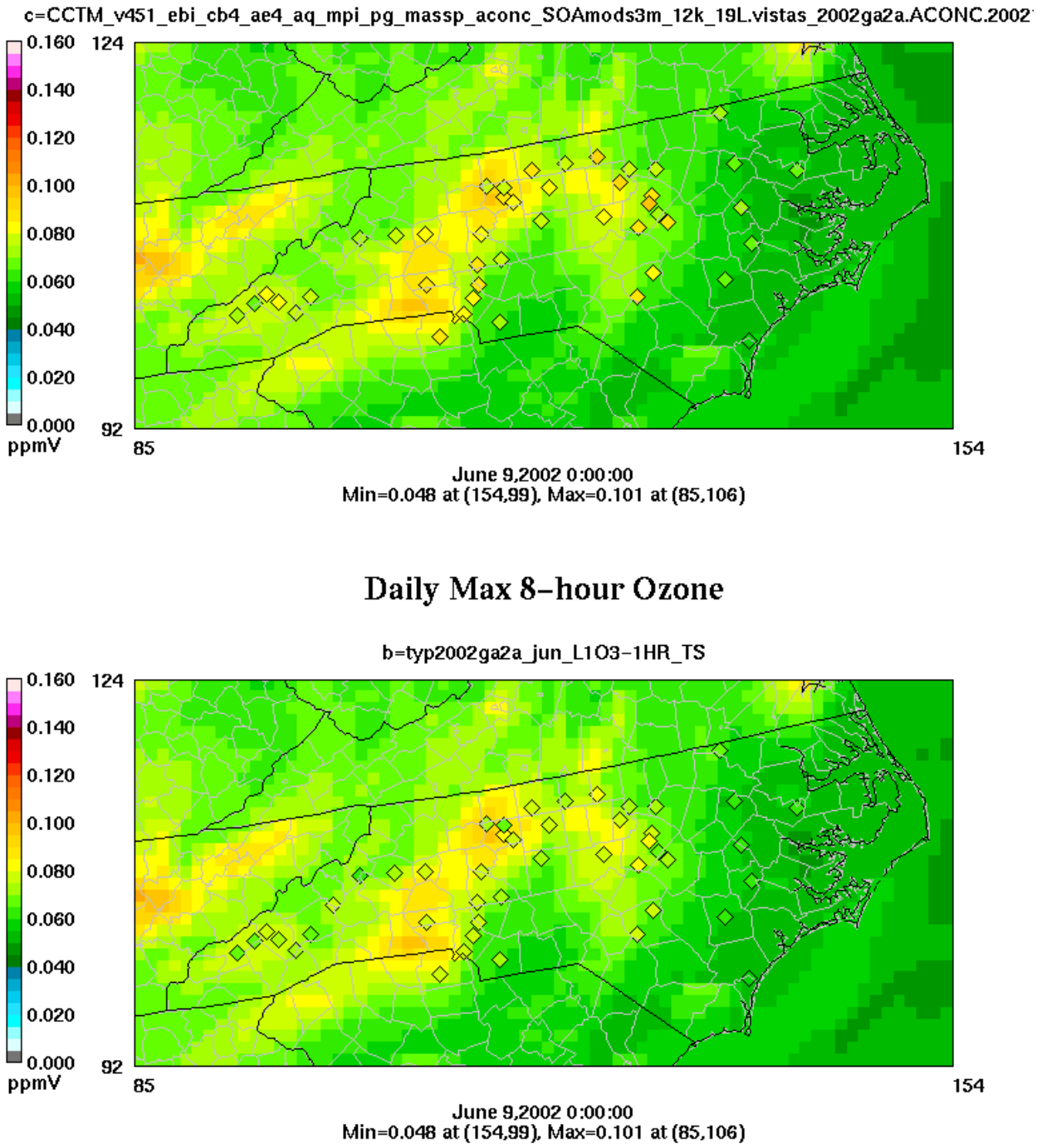


Figure 3-7 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 9, 2002

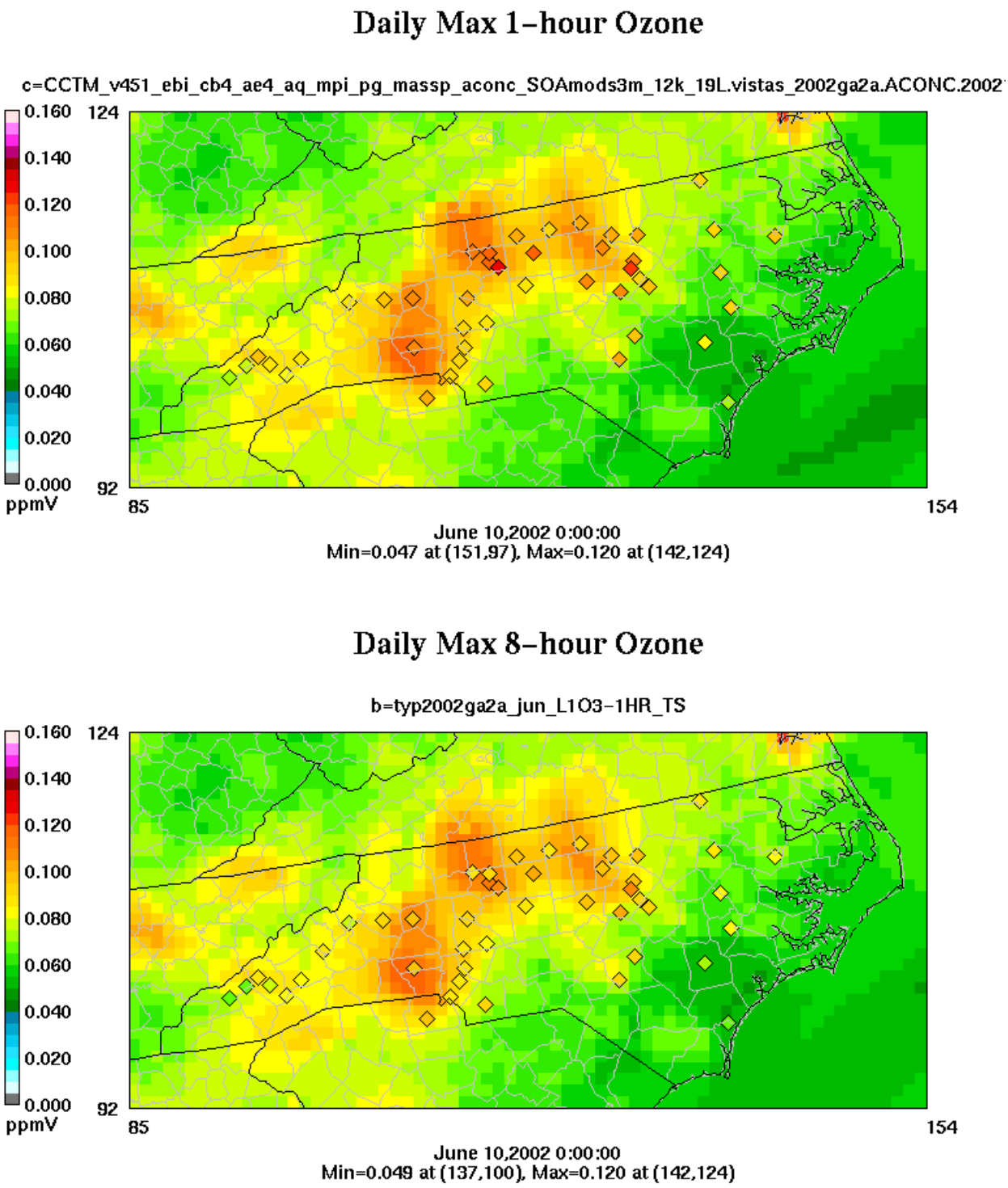


Figure 3-8 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 10, 2002

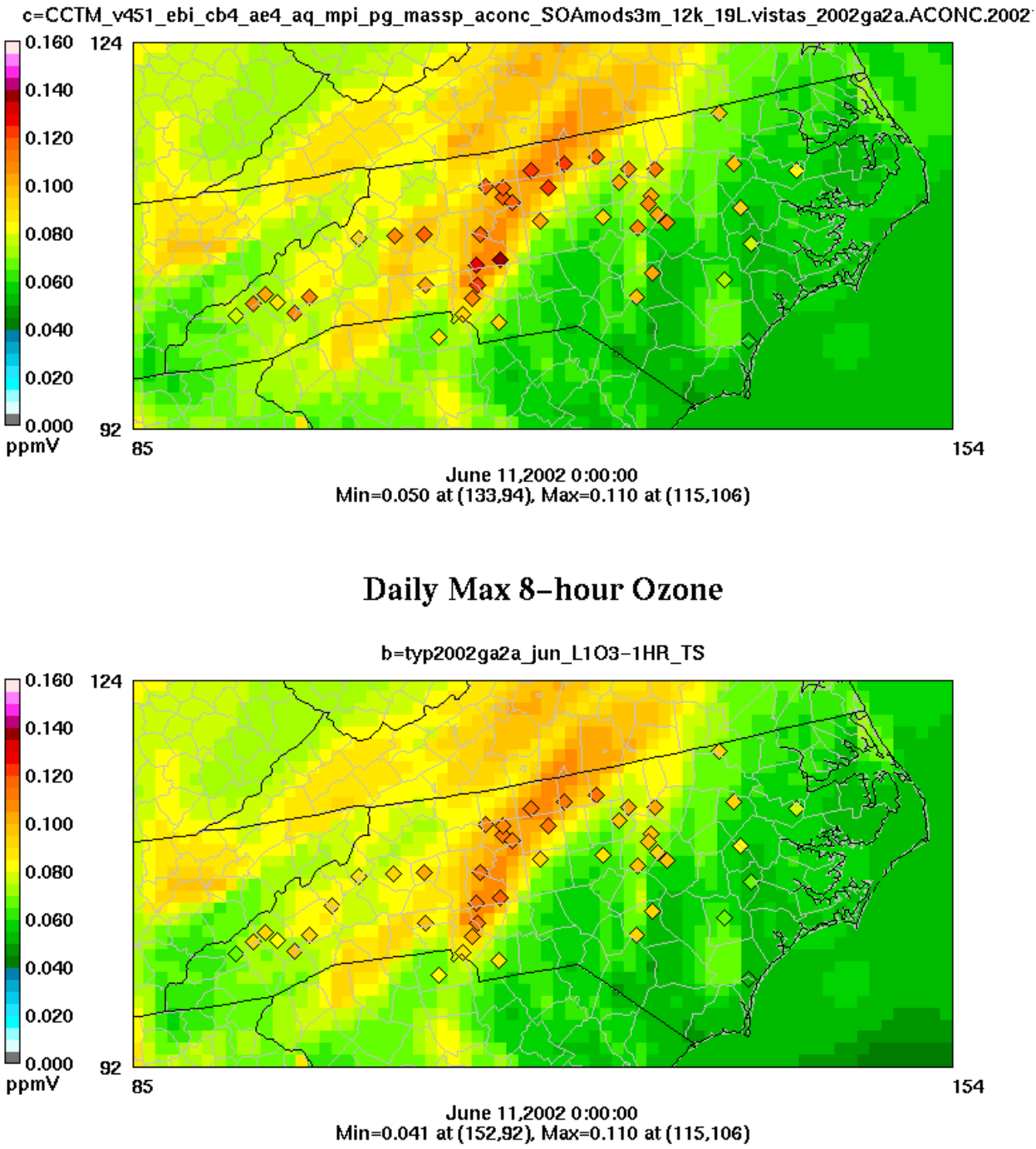


Figure 3-9 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 11, 2002

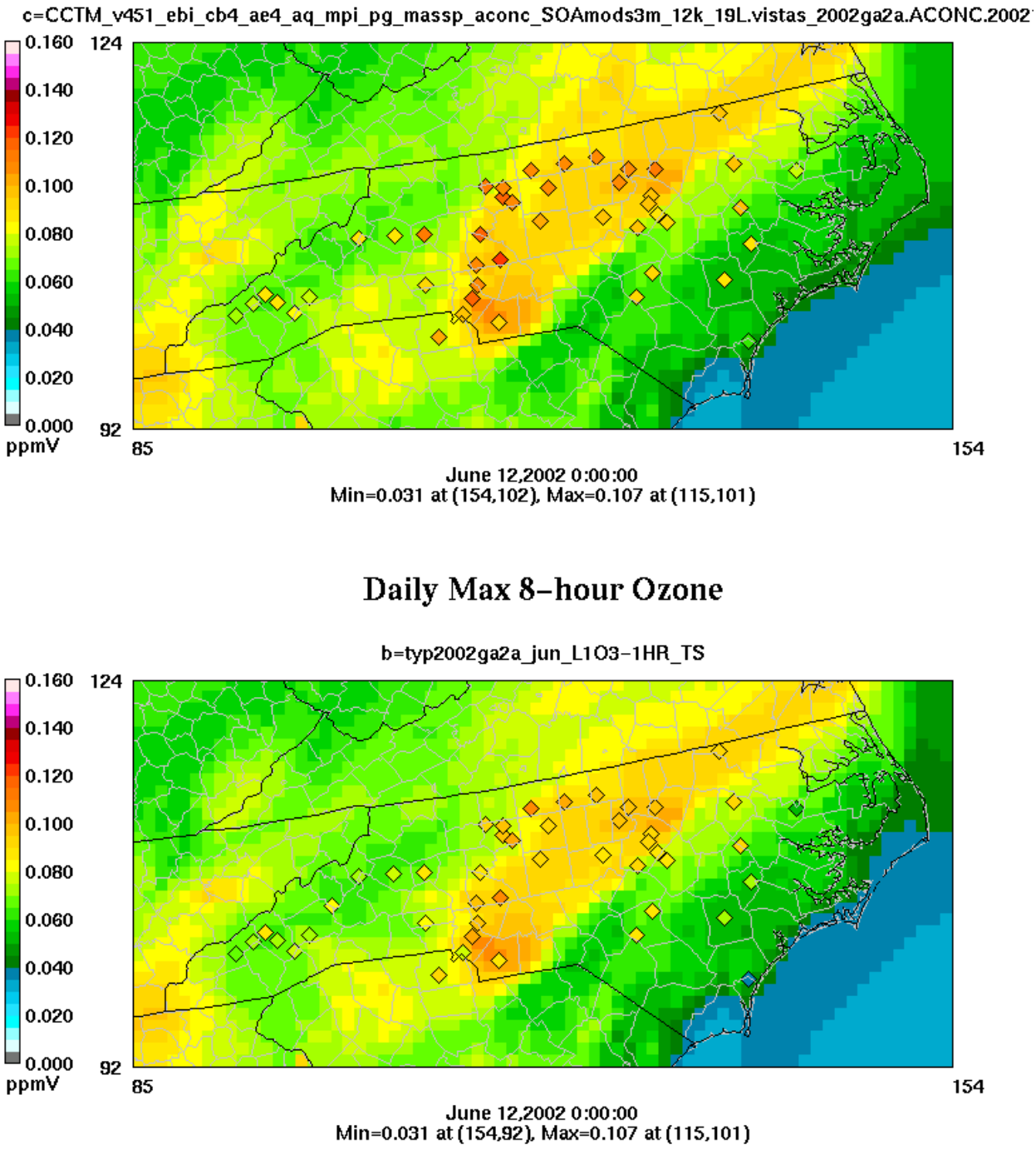


Figure 3-10 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 12, 2002

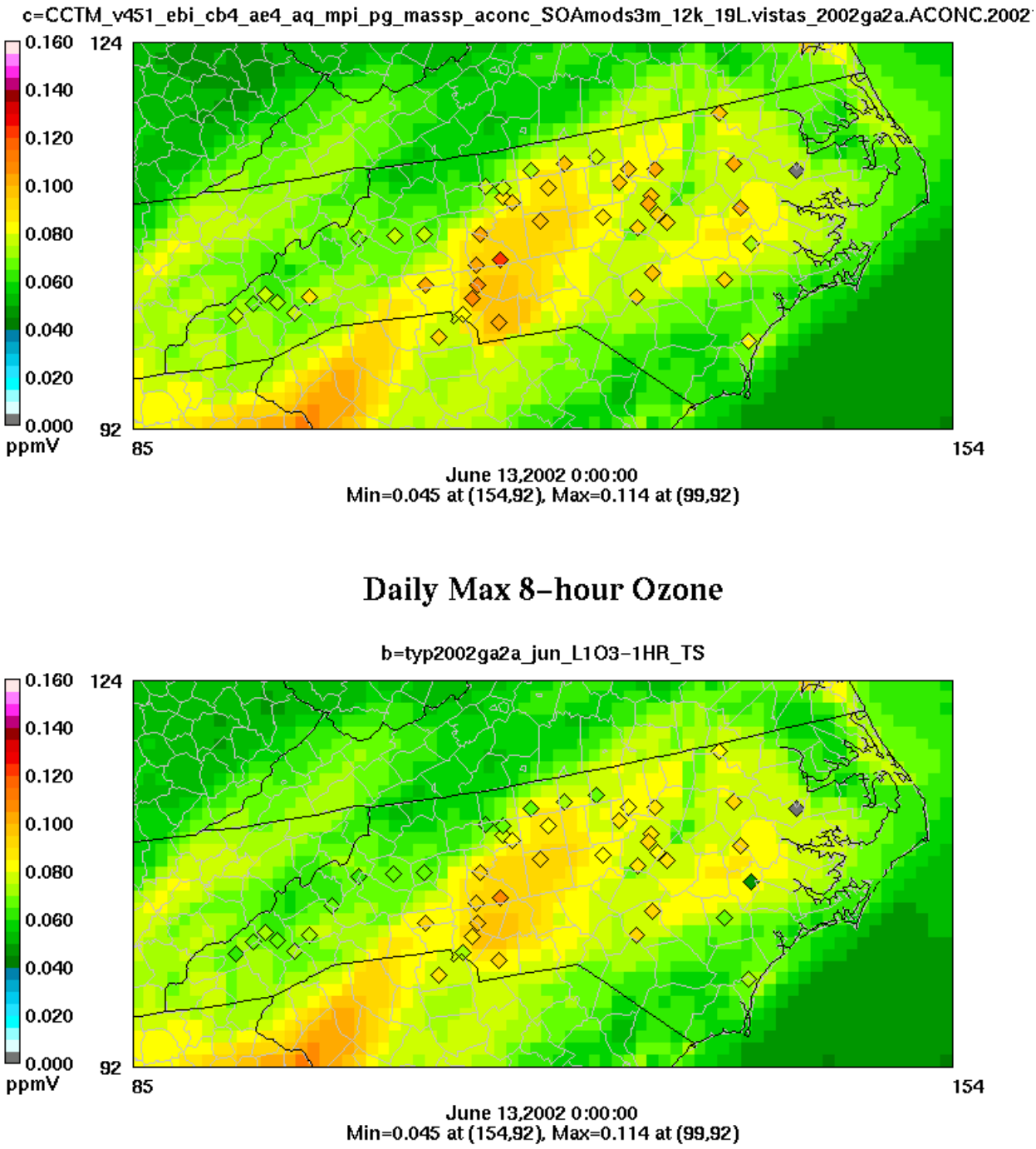


Figure 3-11 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For June 13, 2002

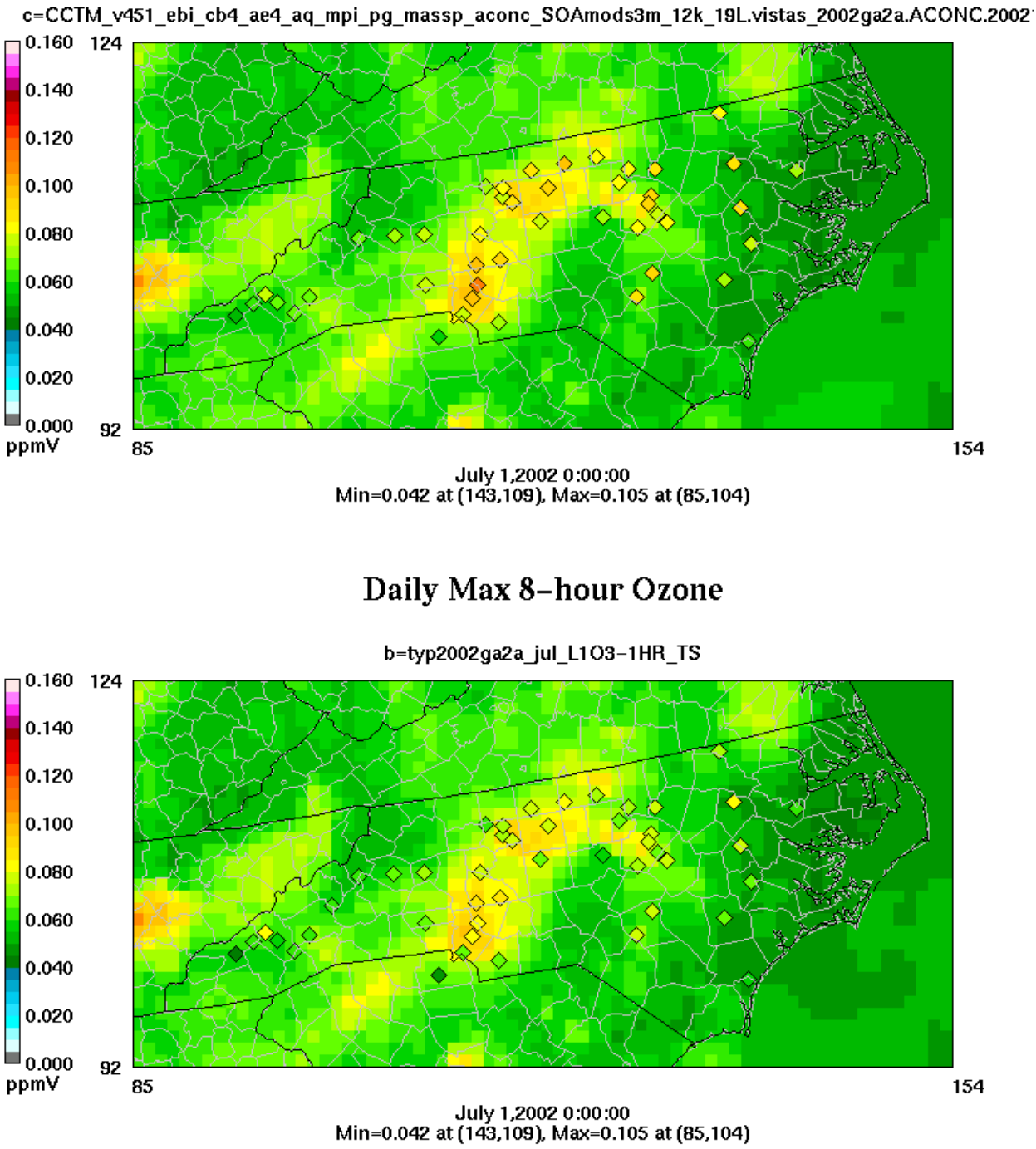


Figure 3-12 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 1, 2002

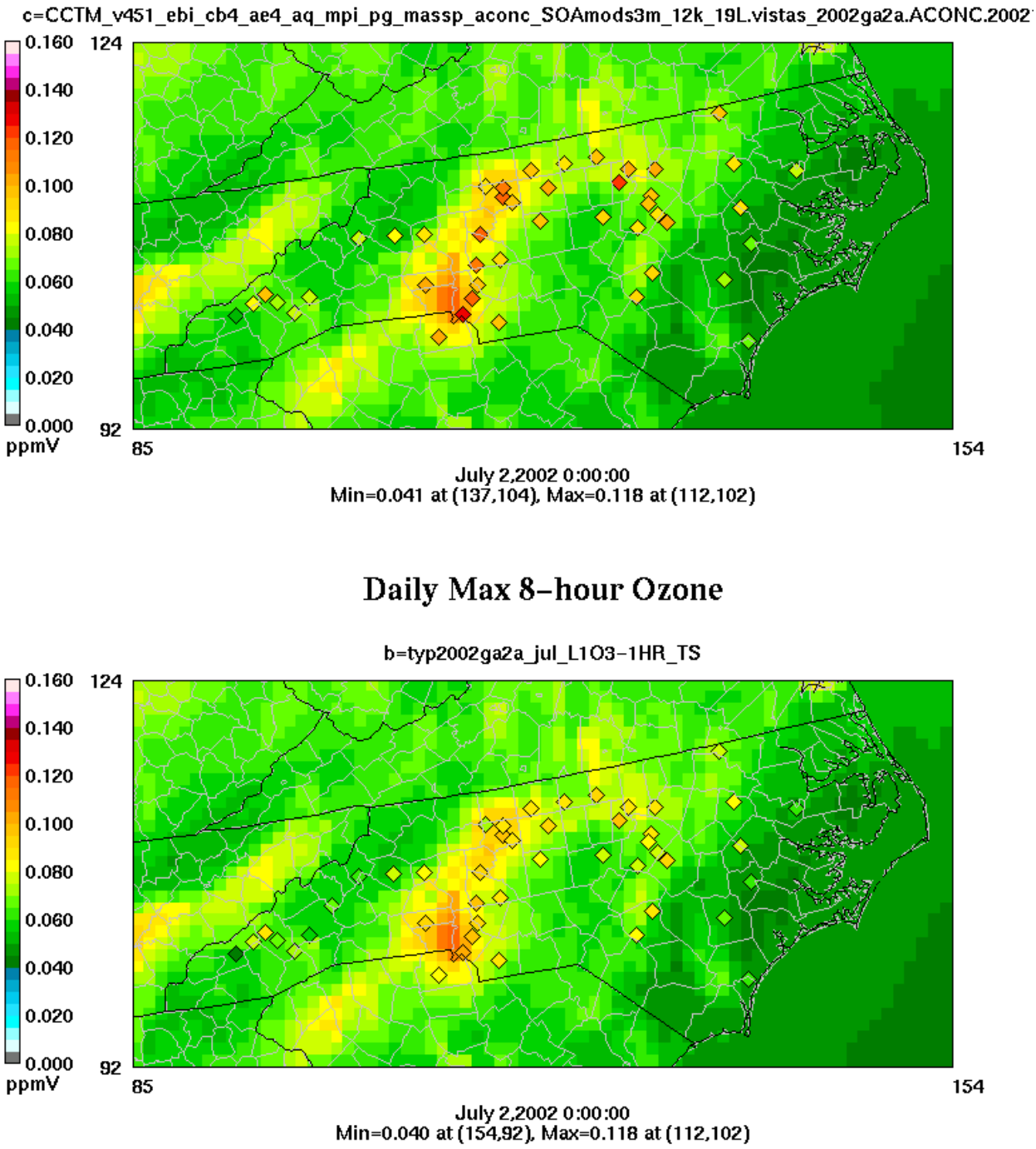


Figure 3-13 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 2, 2002

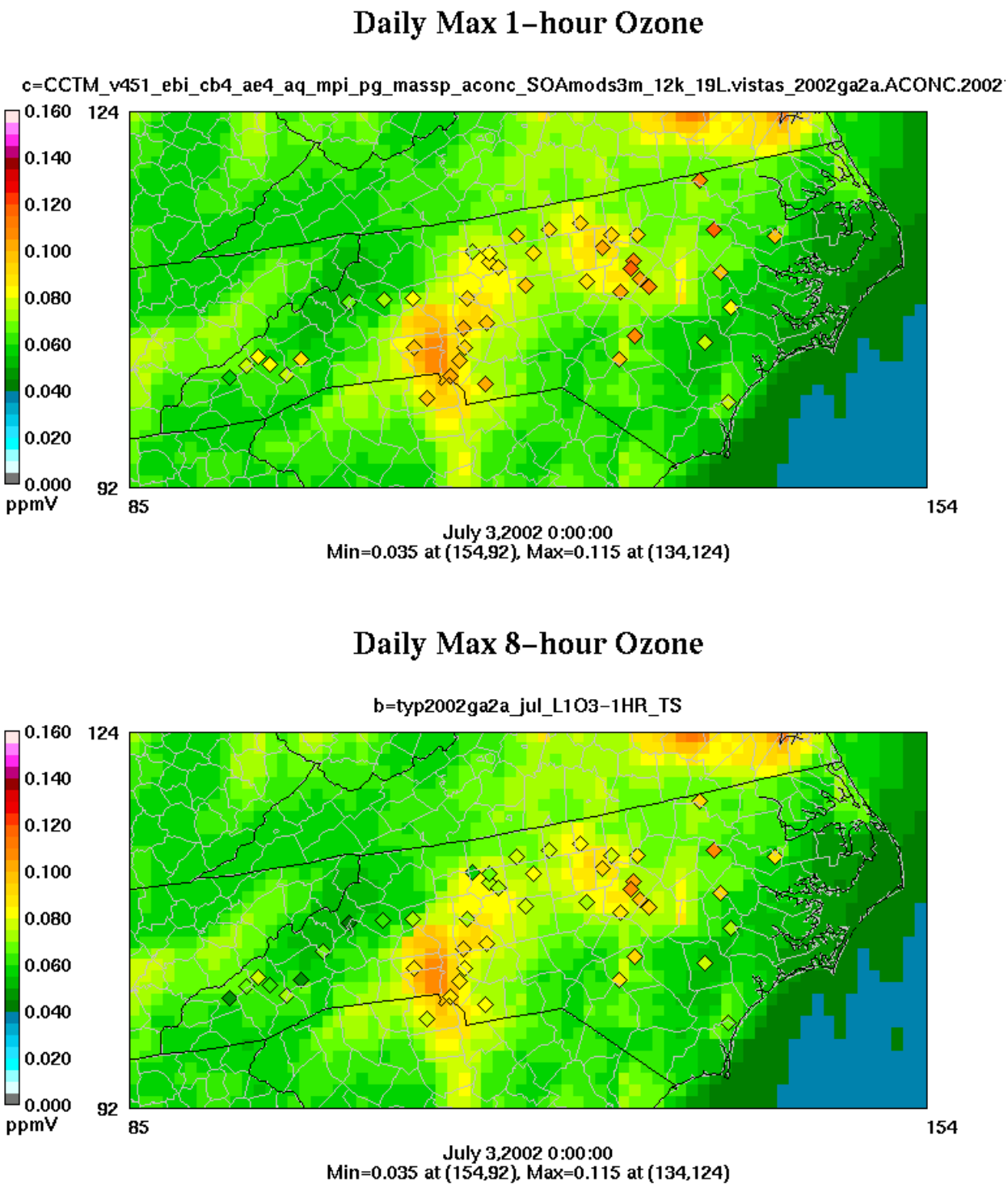


Figure 3-14 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 3, 2002

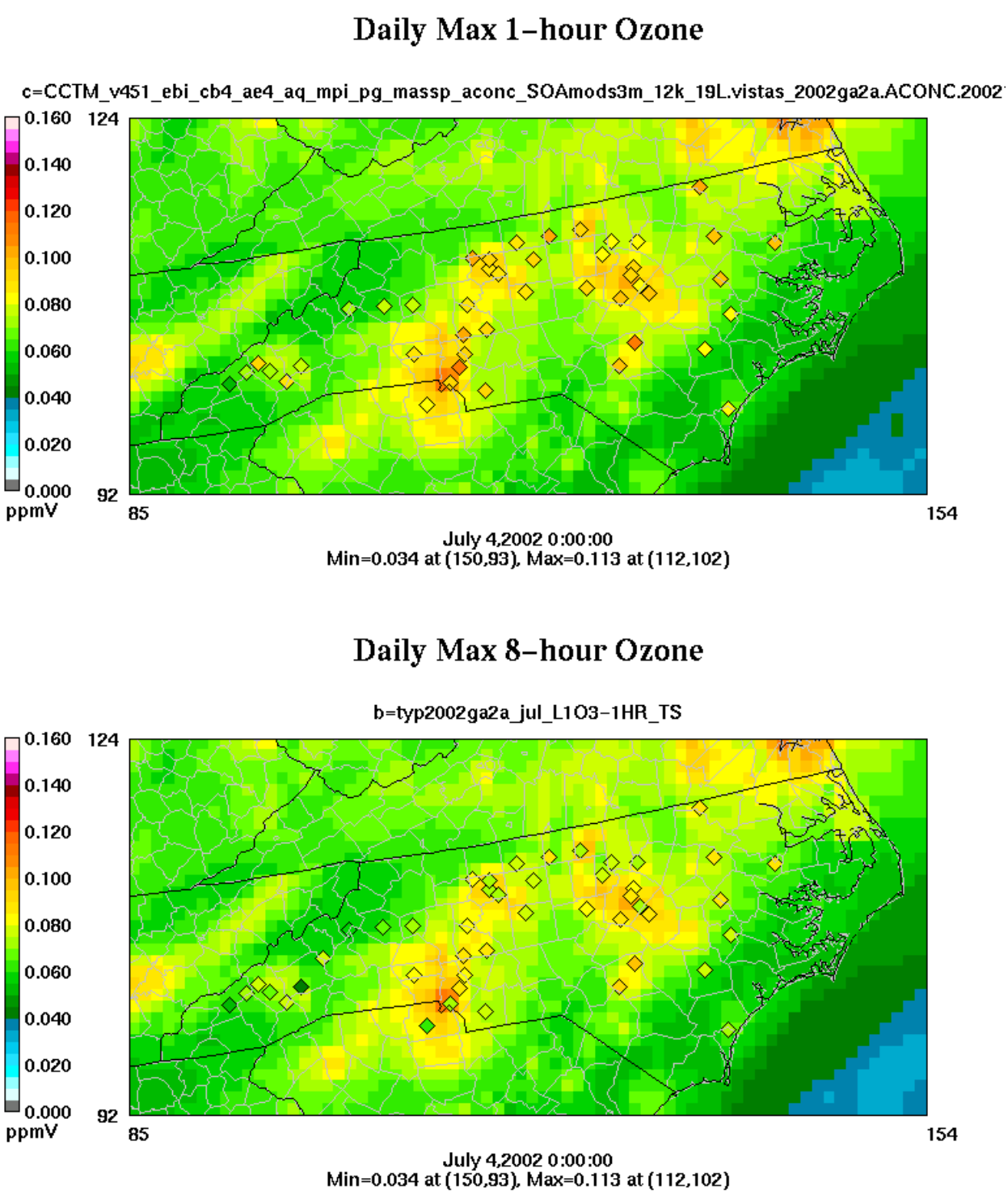
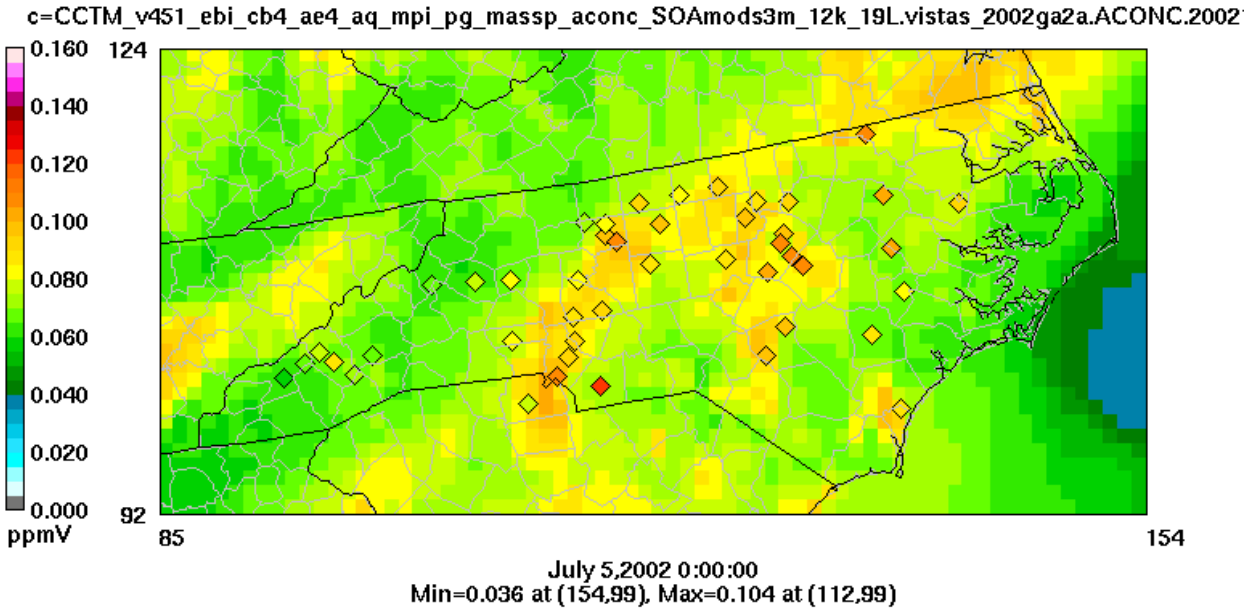


Figure 3-15 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 4, 2002

Daily Max 1-hour Ozone



Daily Max 8-hour Ozone

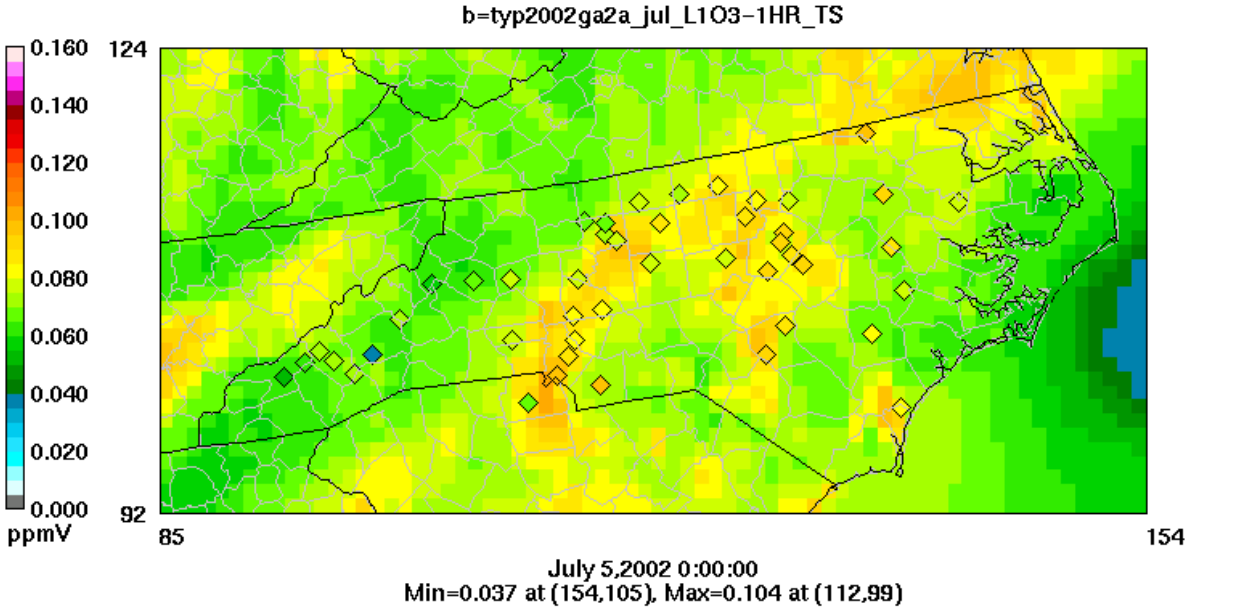


Figure 3-16 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 5, 2002

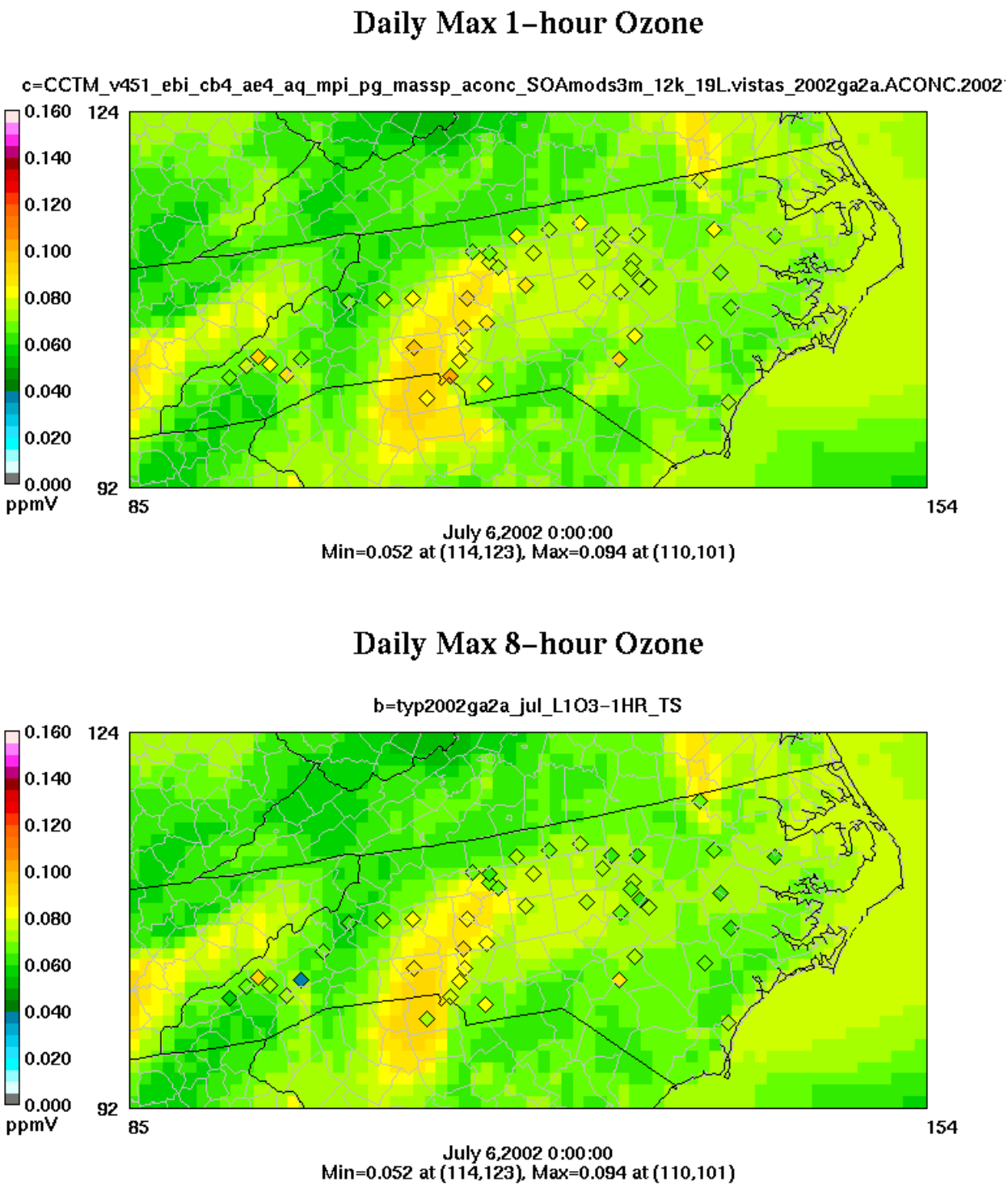


Figure 3-17 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 6, 2002

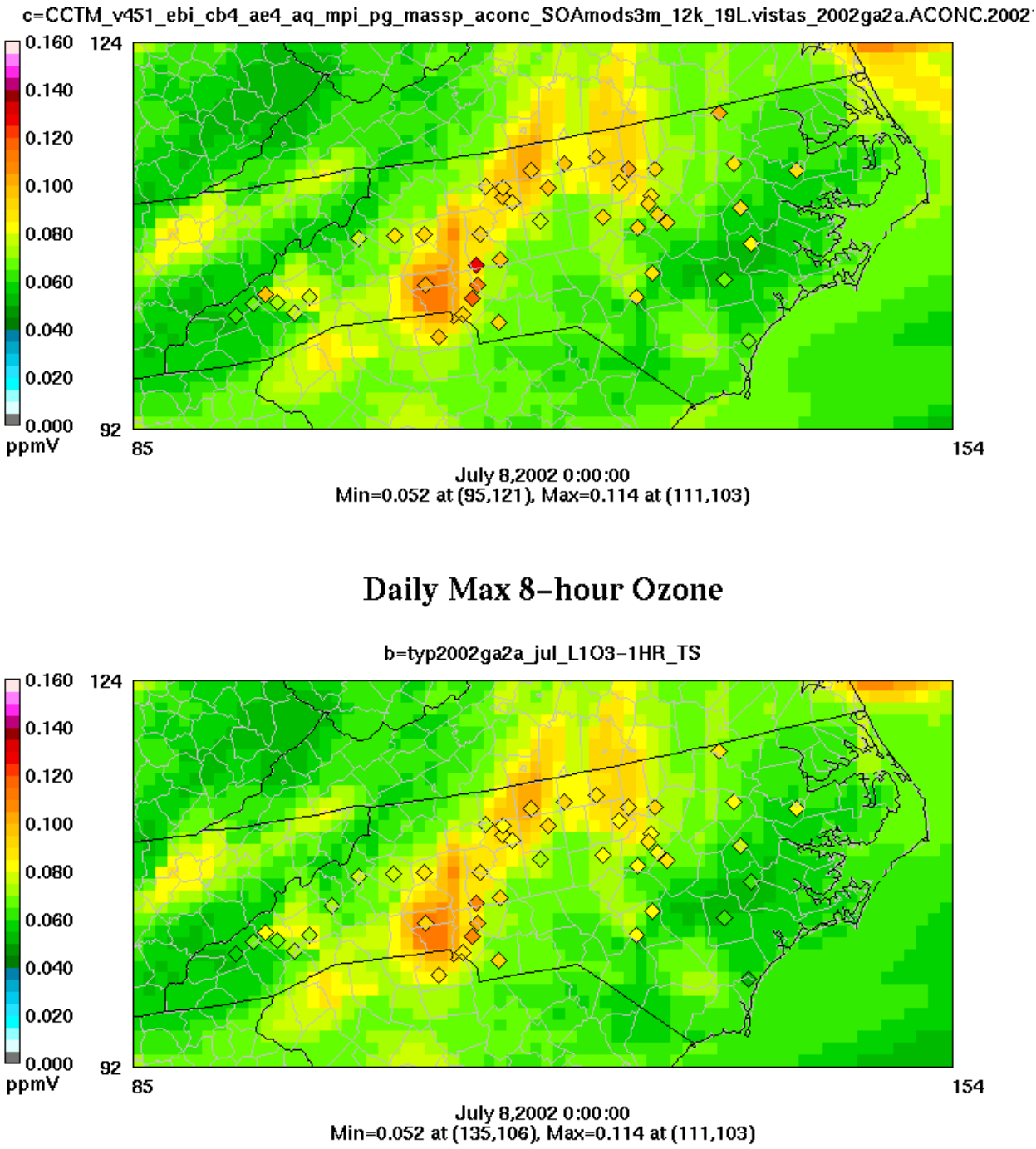


Figure 3-18 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 8, 2002

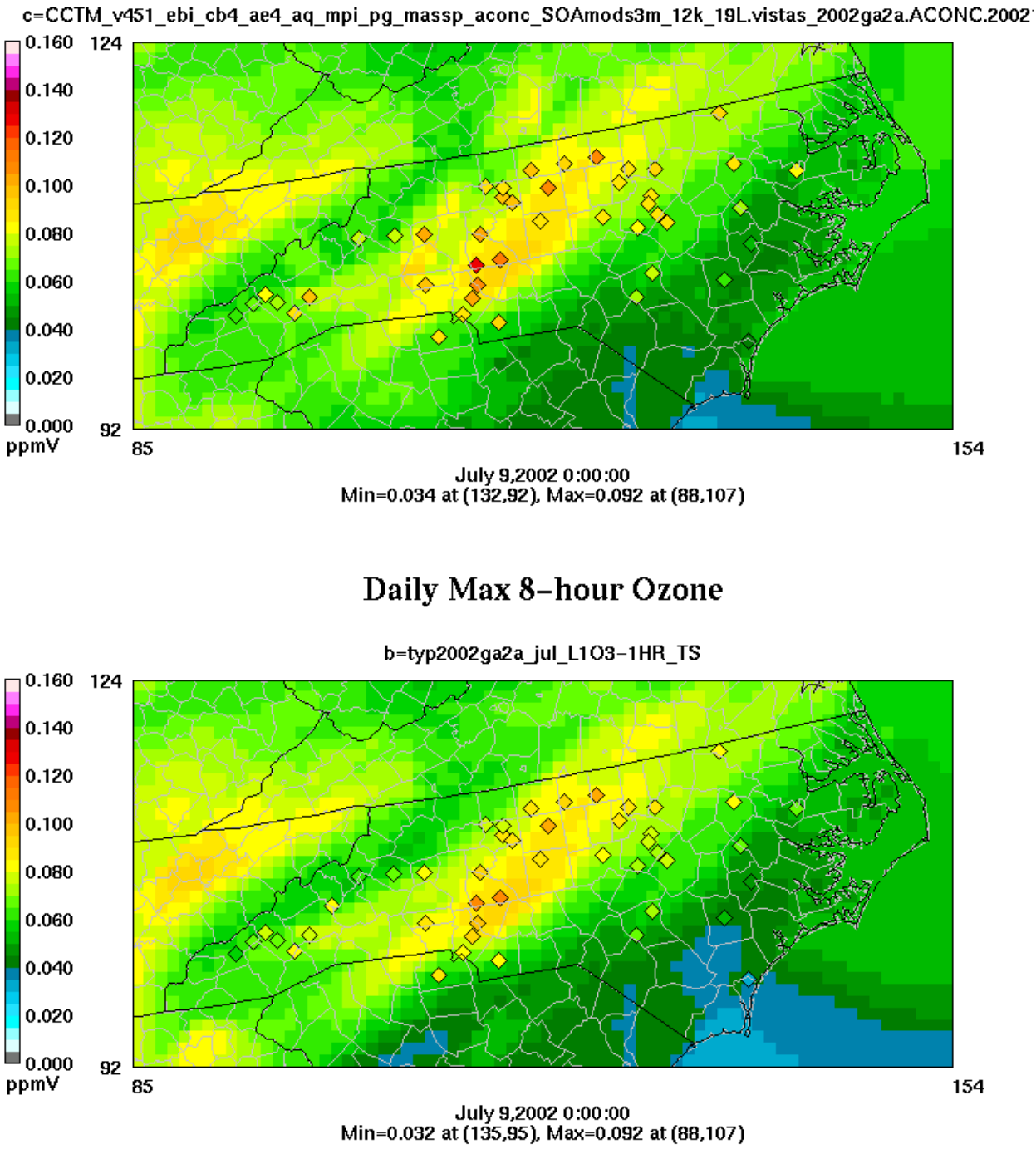


Figure 3-19 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 9, 2002

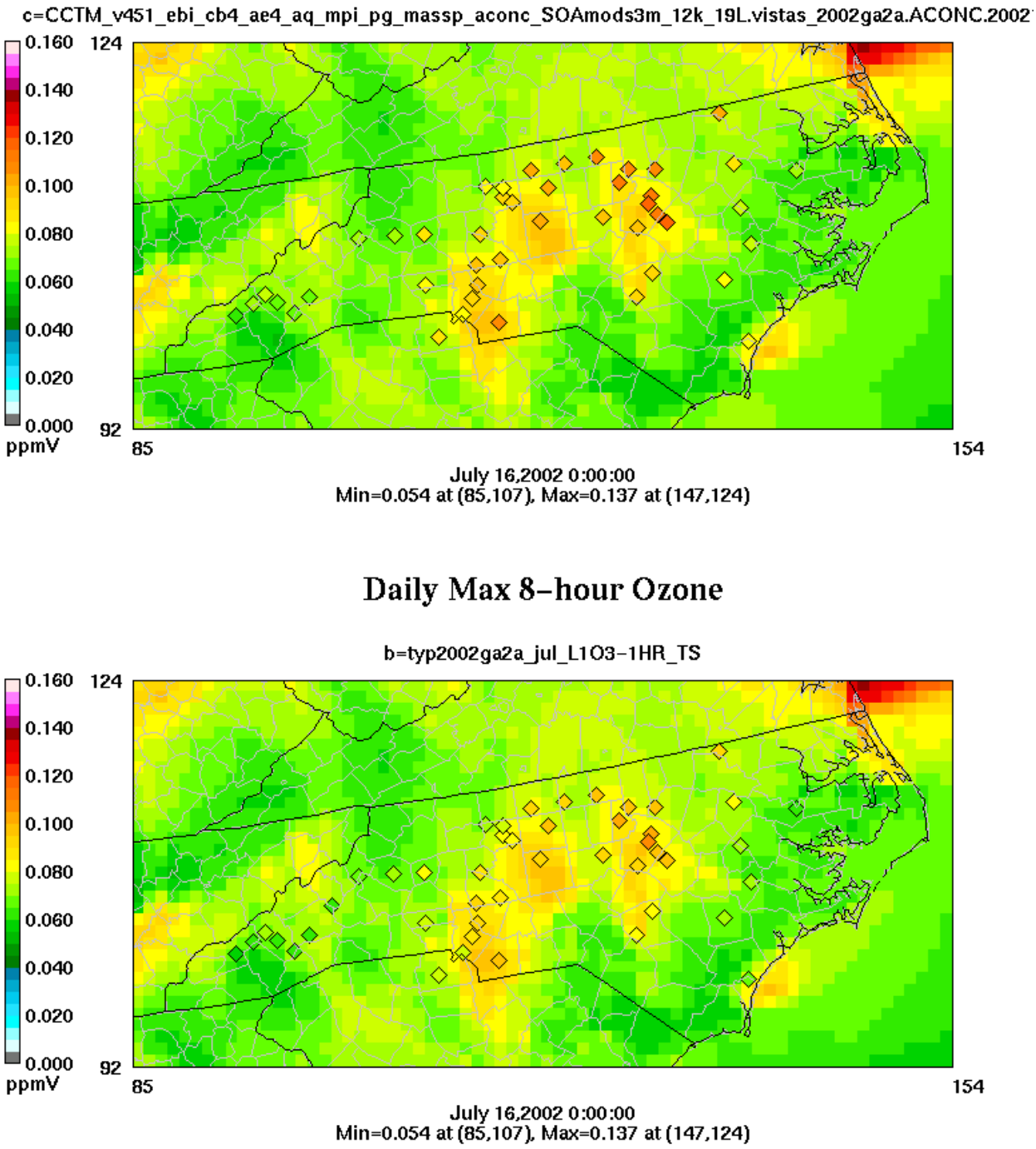


Figure 3-20 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 16, 2002

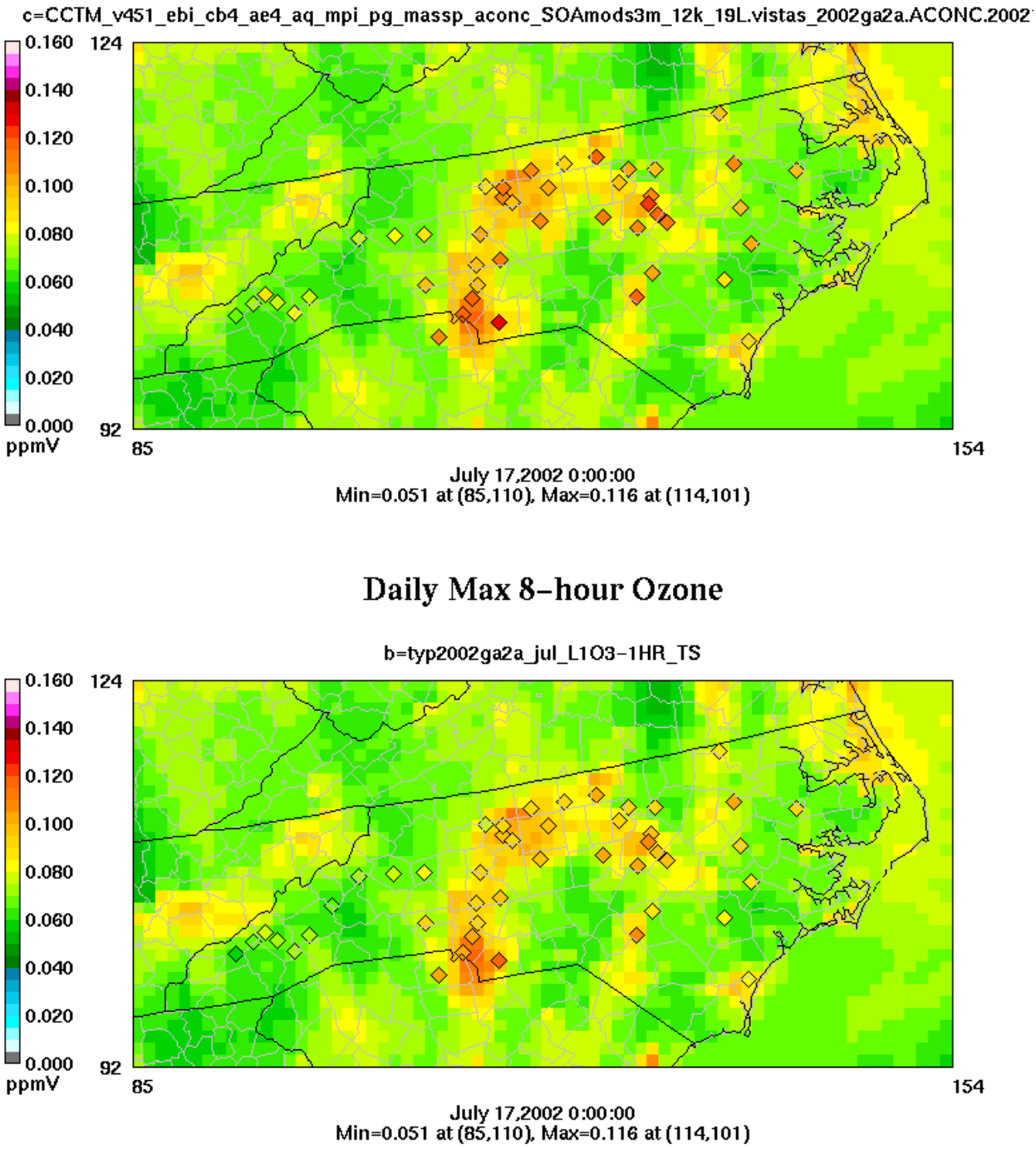


Figure 3-21 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 17, 2002

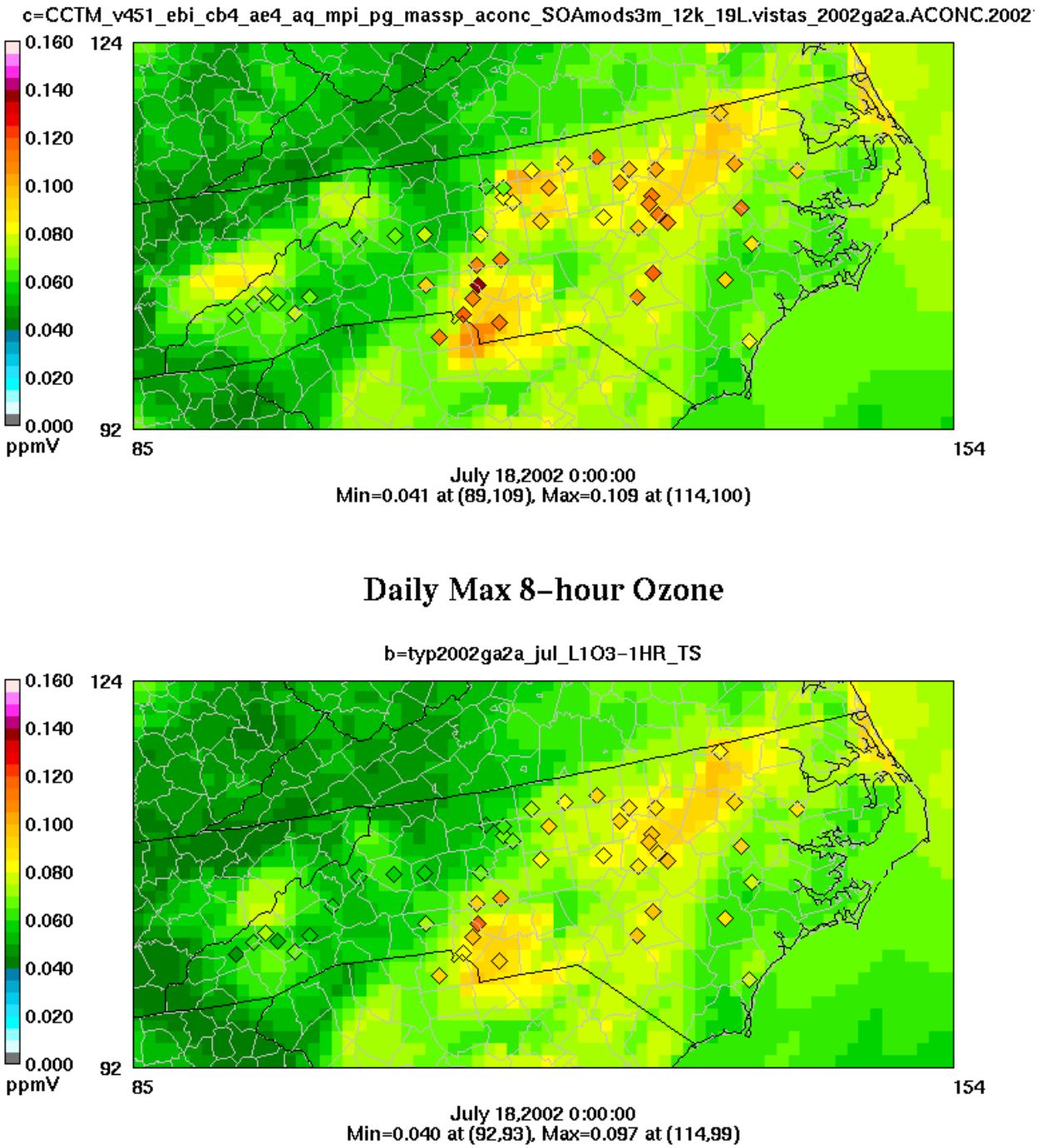


Figure 3-22 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 18, 2002

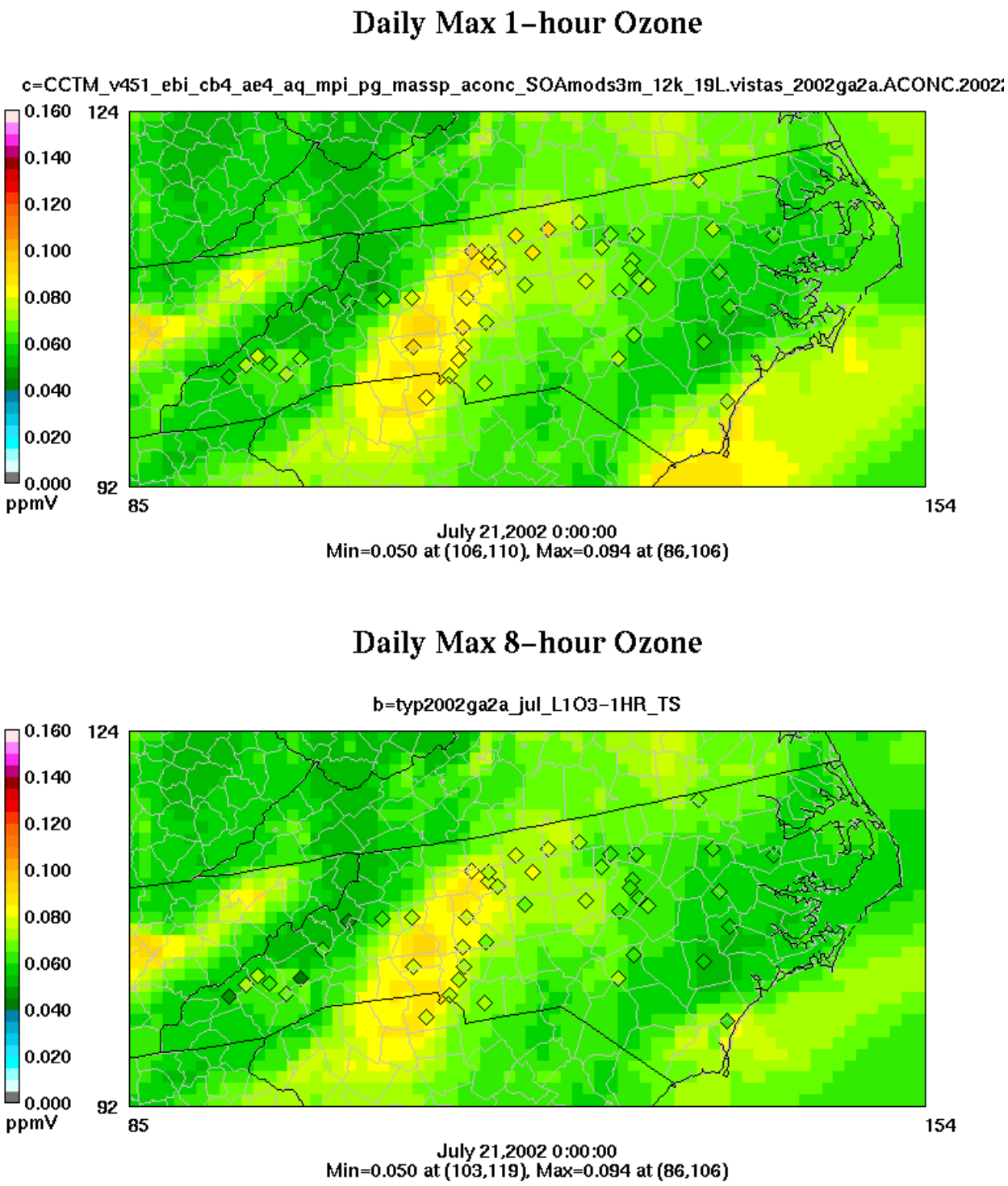


Figure 3-23 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For July 21, 2002

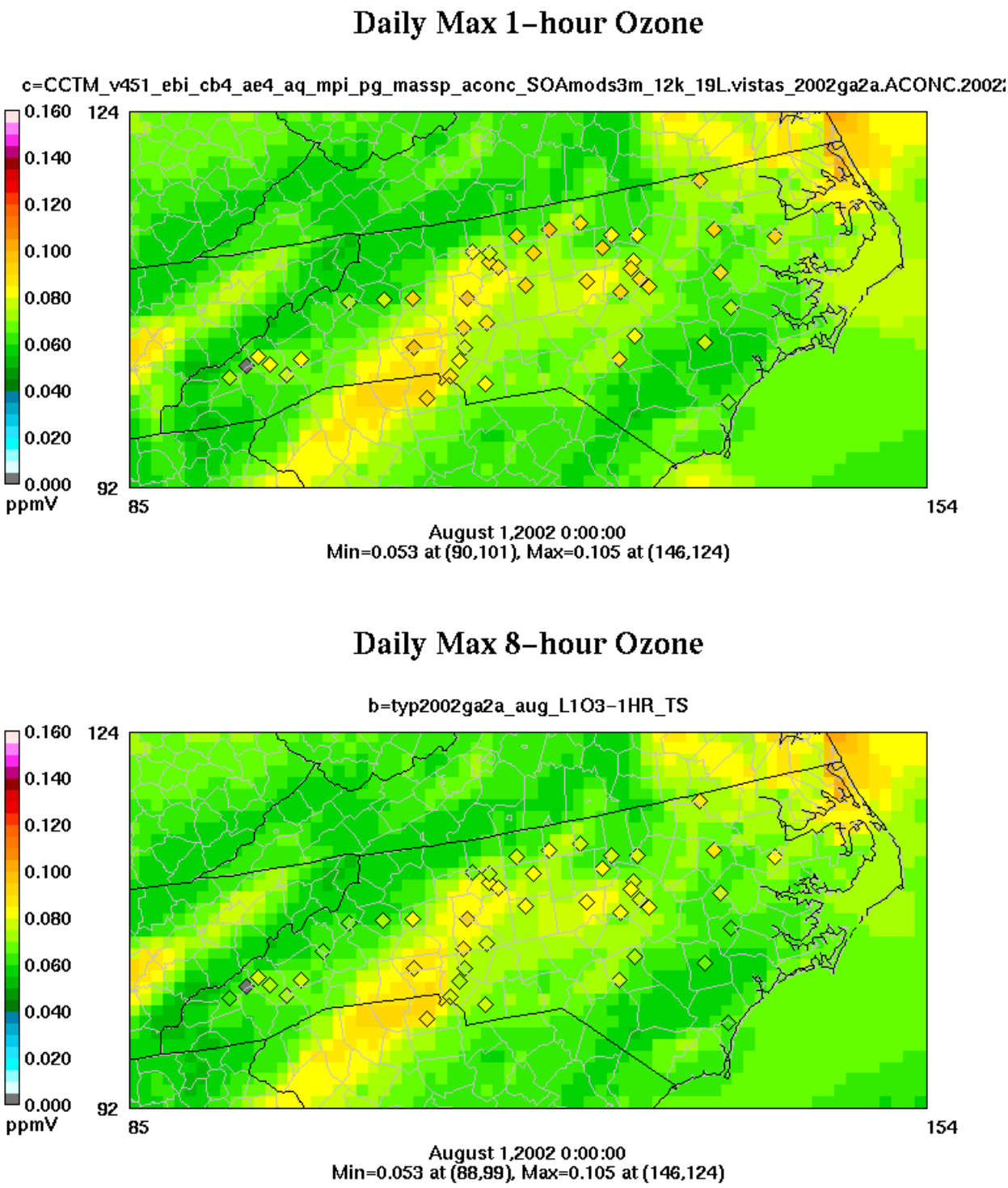


Figure 3-24 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 1, 2002

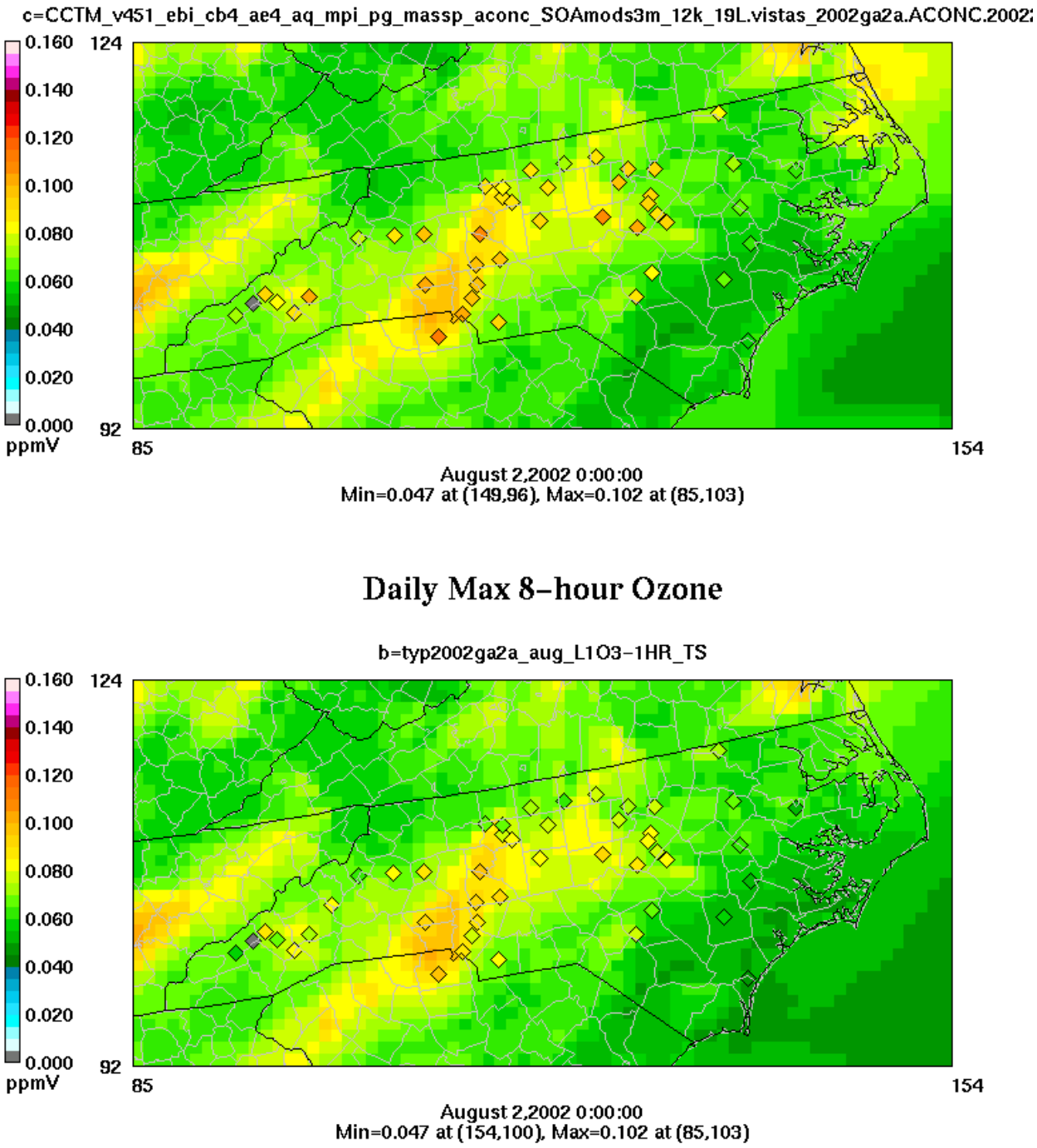


Figure 3-25 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 2, 2002

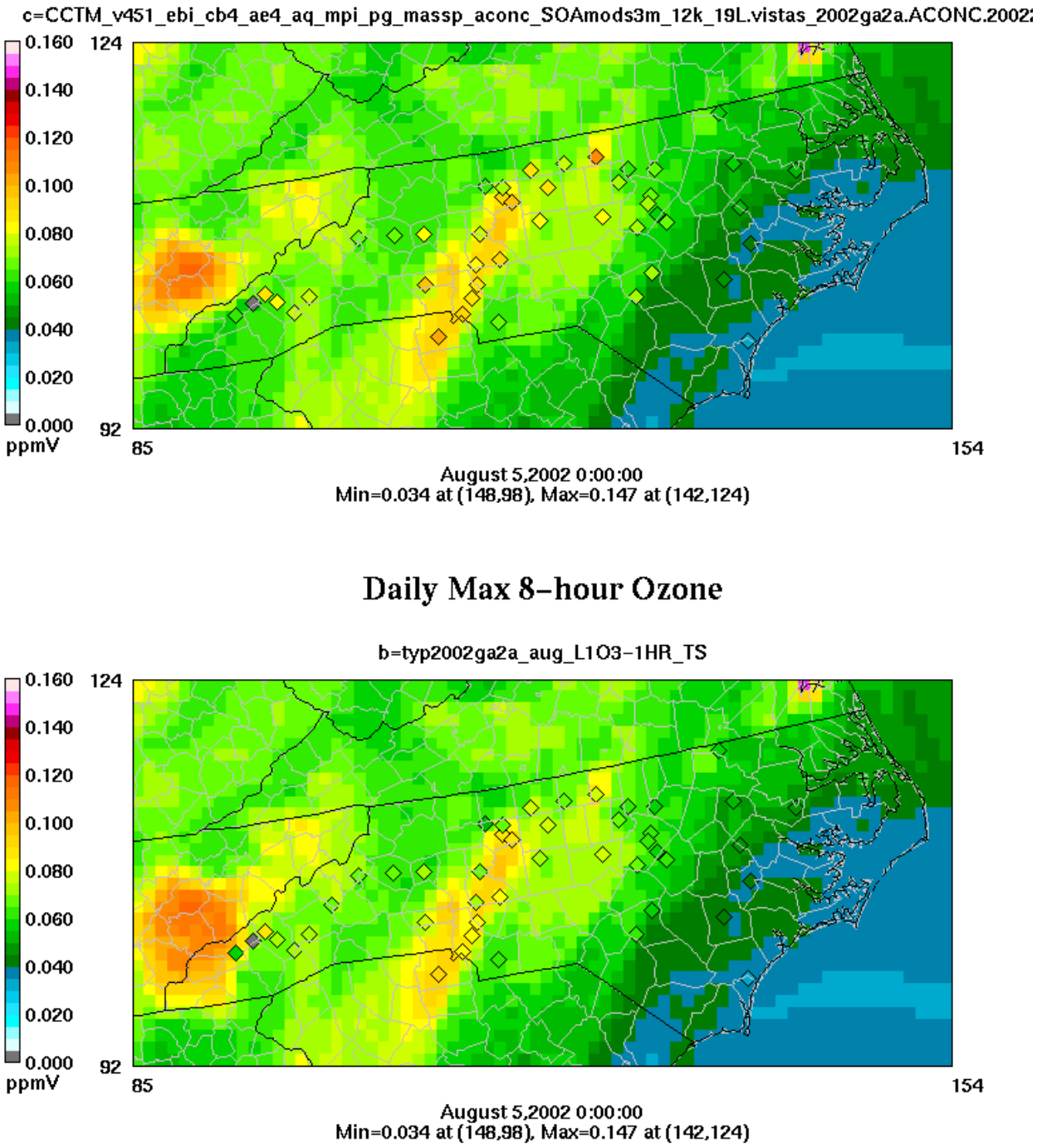


Figure 3-26 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 5, 2002

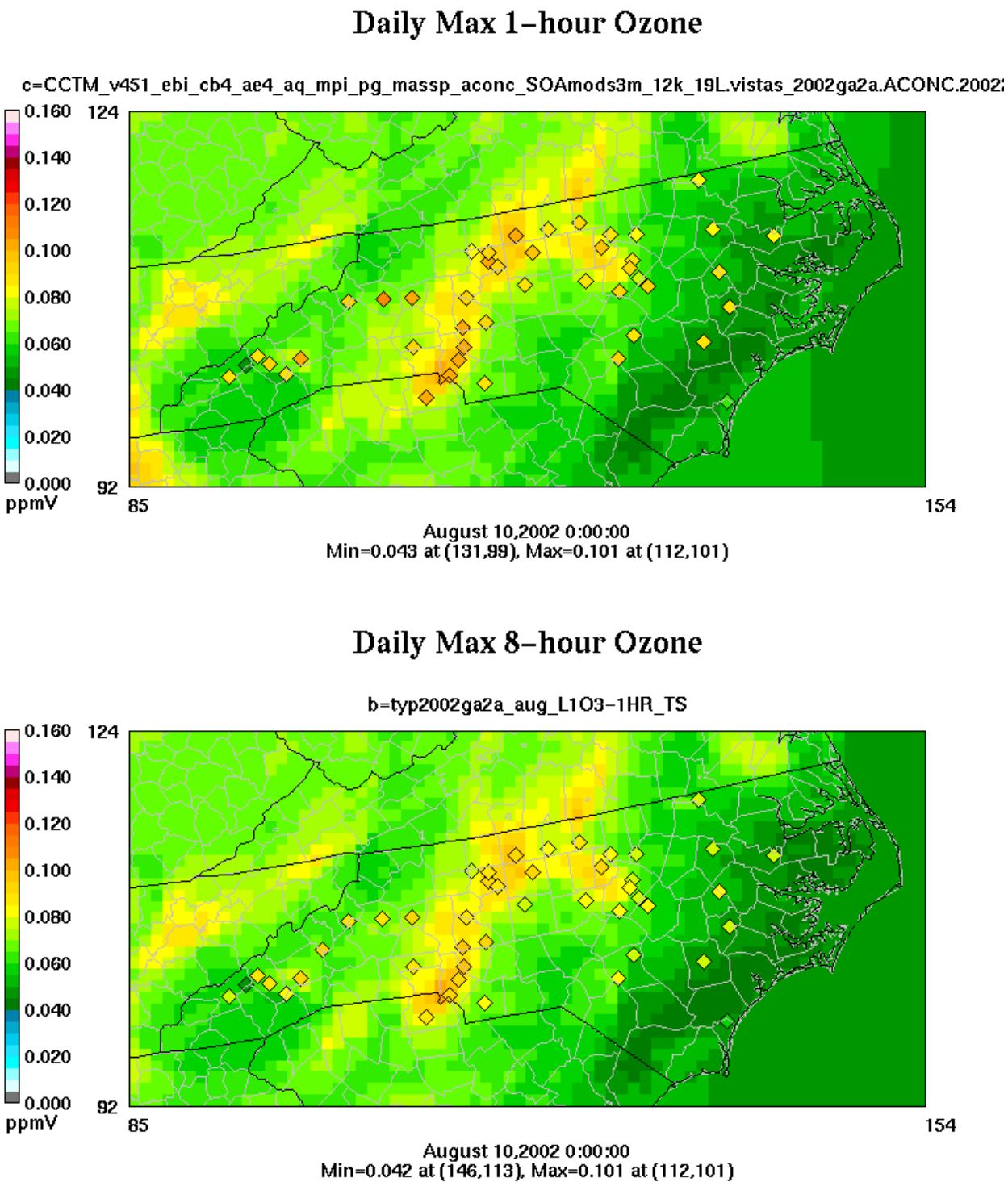


Figure 3-27 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 10, 2002

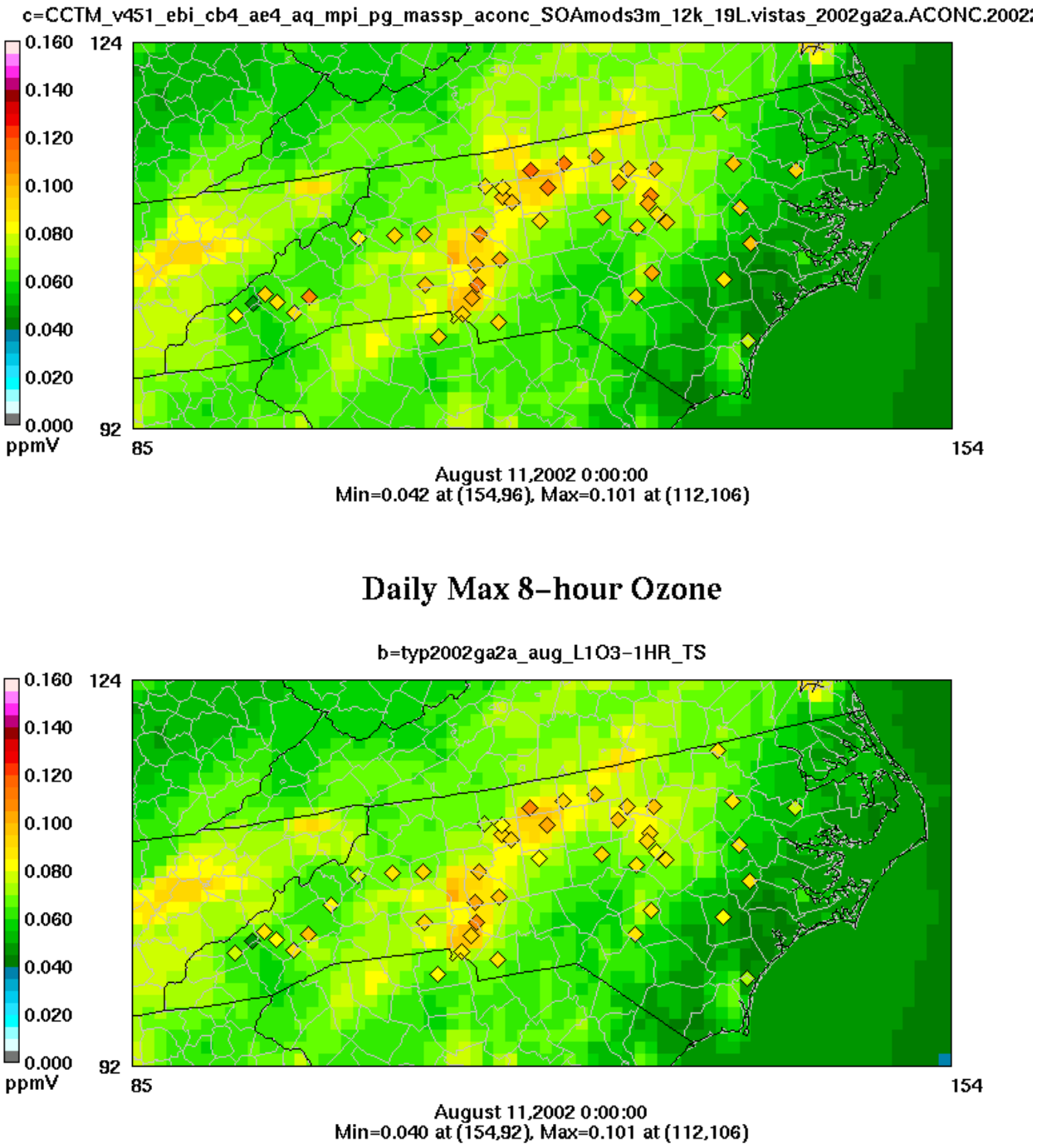


Figure 3-28 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 11, 2002

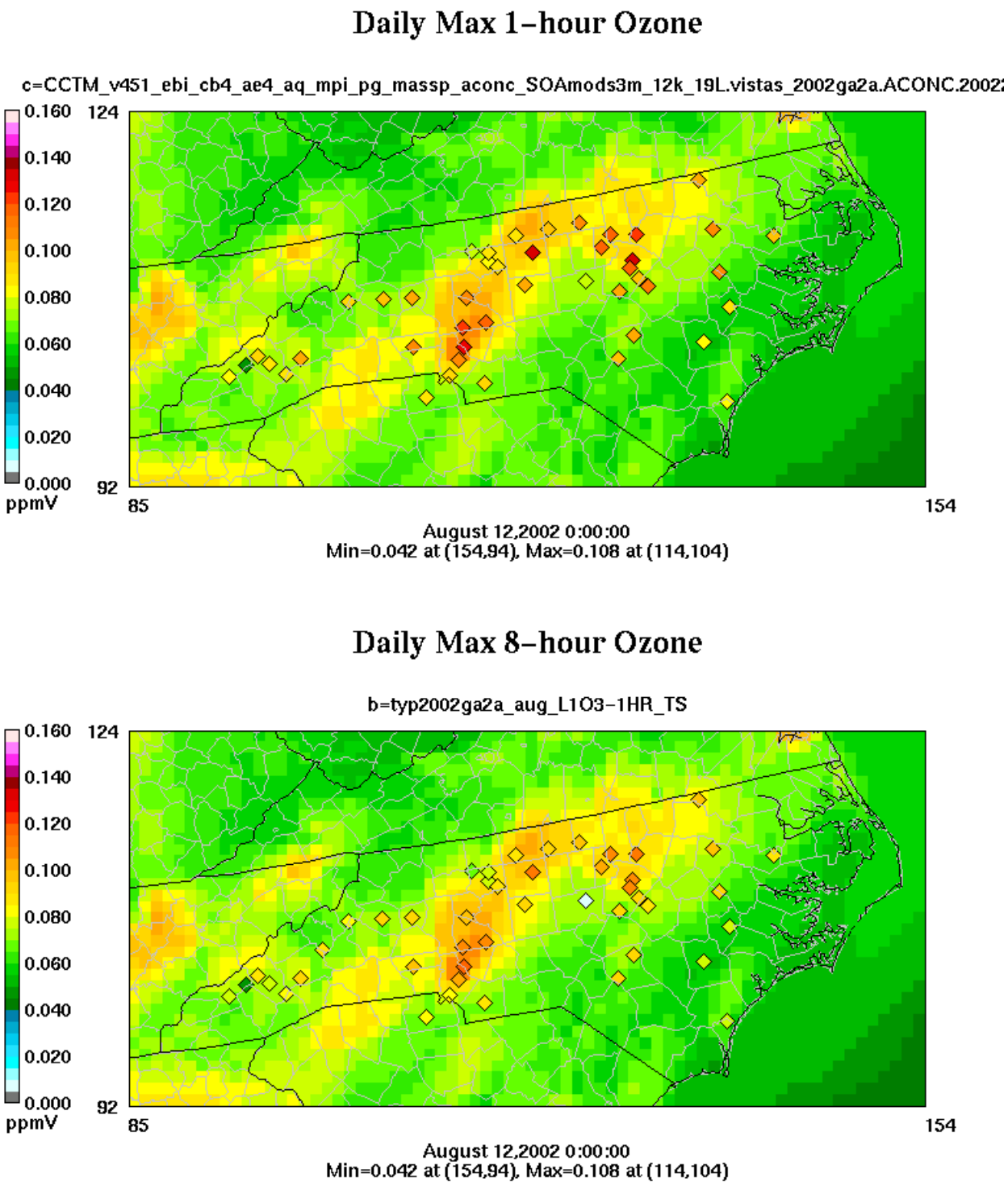


Figure 3-29 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 12, 2002

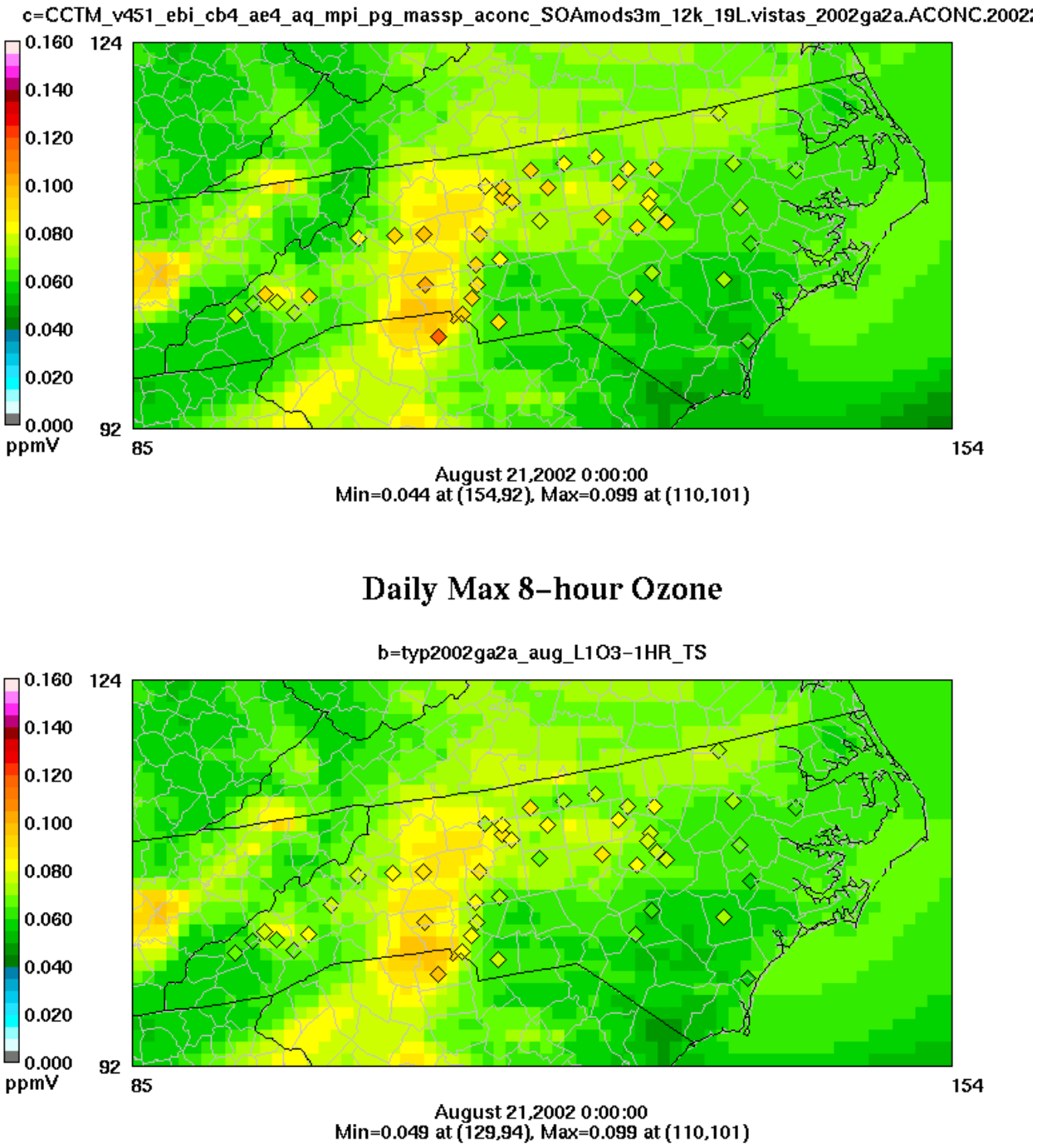


Figure 3-30 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 21, 2002

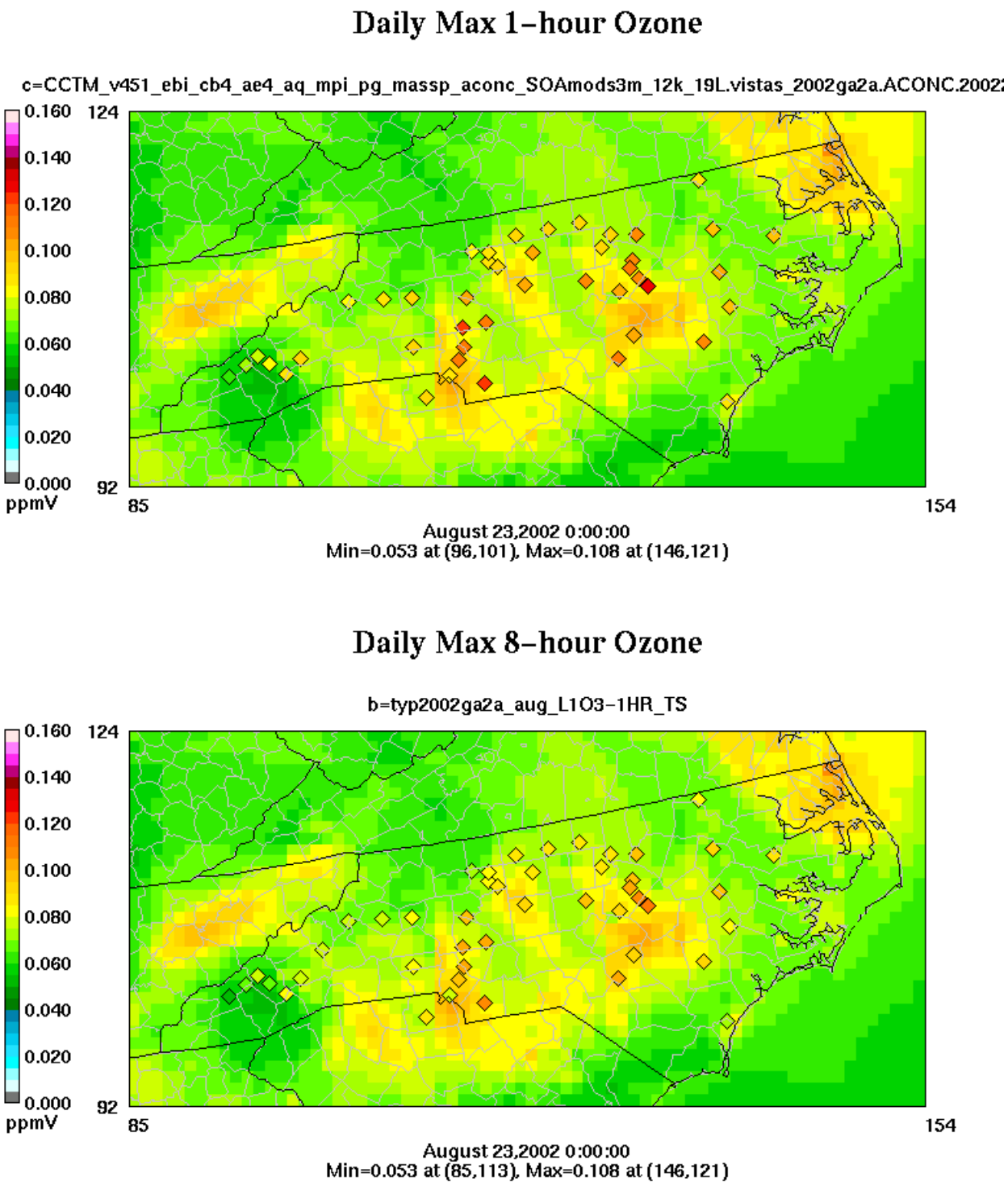


Figure 3-31 Modeled Predicted And Observed Peak 1-hour (top) And 8-hour (bottom) Ozone Concentrations Spatial Plots For August 23, 2002

4 Scatter Plots

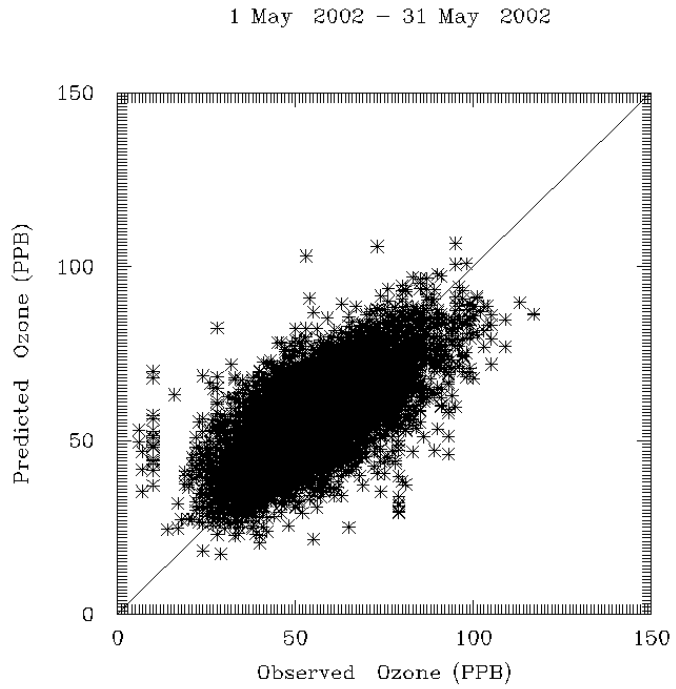
Scatter plots of modeled predicted daily maximum ozone versus observed daily maximum ozone are presented in this section. There are scatter plots for both 1-hour and 8-hour ozone concentrations. As with the previous model performance statistics, scatter plots were created for the VISTAS/ASIP region of the 12km modeling domain, for North Carolina, for South Carolina, and individually for each of the ozone monitors in the Metrolina region. At the VISTAS/ASIP regional and the two individual state levels, monthly scatter plots are presented across the entire summer season of May through September. For the individual ozone monitoring sites, only the scatter plots for the entire summer season are displayed due to the limited nature of the dataset.

On each page, the top image is the 1-hour daily maximum ozone scatter plot and the bottom image is the 8-hour daily maximum ozone scatter plot for the respective month or season and the respective region or monitoring site.

4.1 12km Domain Scatter Plots – VISTAS/ASIP States Only

From the whole VISTAS/ASIP region perspective, thousands of data points are presented in the 1-hour and 8-hour ozone scatter plots (Figure 4.1-1 through Figure 4.1-5). These data points include modeled and observed ozone concentrations at numerous urban, suburban, and rural ozone monitoring sites. Across this 10 state VISTAS/ASIP region, there are a greater frequency of urban and suburban sites represented in these scatter plots. Even with such a wide variety of monitoring site locations, the model and observed values tend to correlated reasonable well, as most of the data points are clustered along the 1:1 line across the full range of data. The under prediction of observed ozone concentrations previously discussed in this Appendix is most notable in these scatter plots when observed ozone concentrations are in excess of 120 ppb.

There are not any systematic abnormalities found in either the 1-hour or 8-hour scatter plots for the VISTAS/ASIP region of the 12km modeling domain. This confirms the acceptable model performance statistics presented earlier in this Appendix.



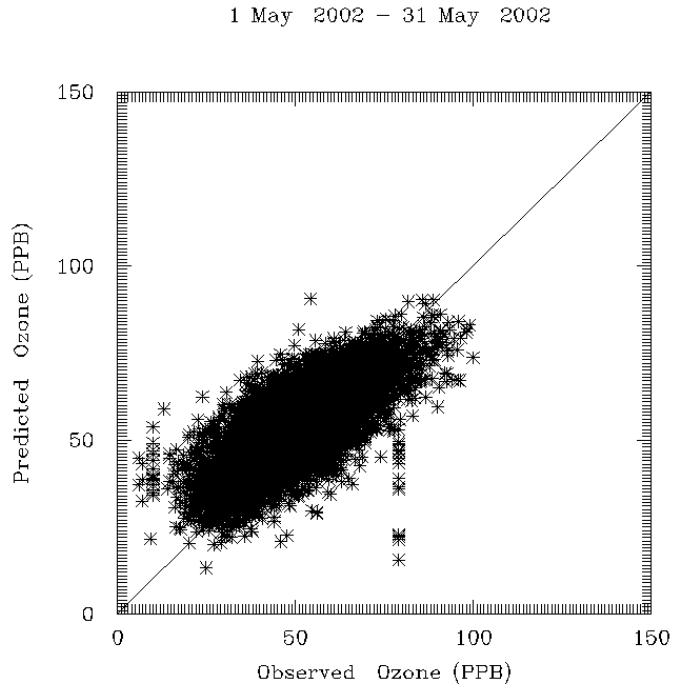
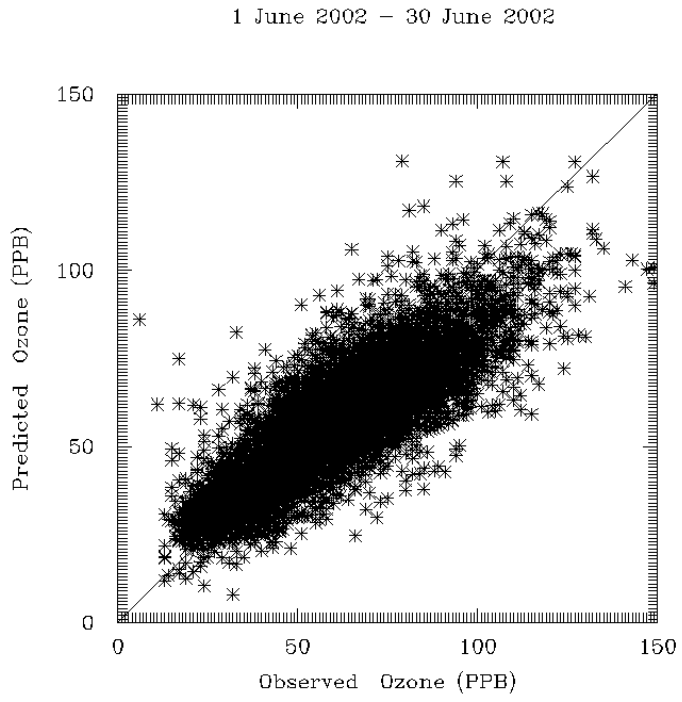


Figure 4.1-1 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Scatter Plots For May



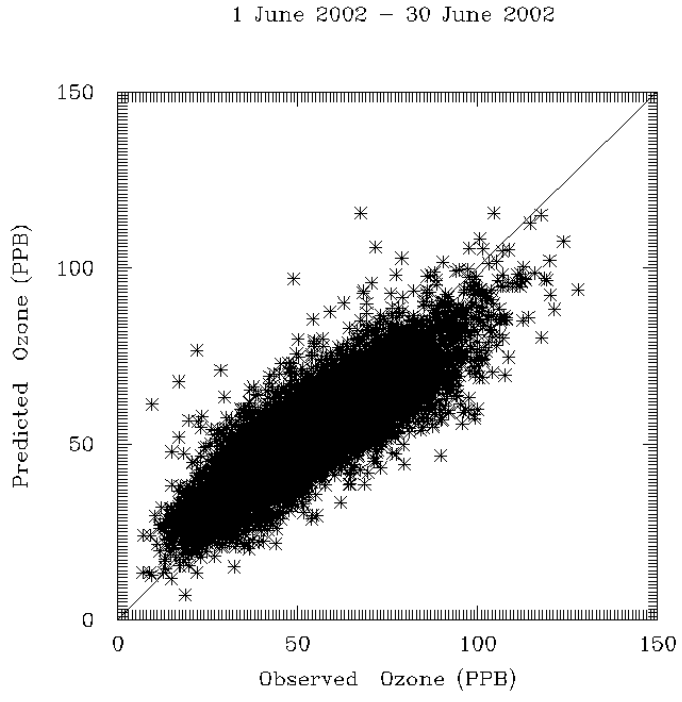
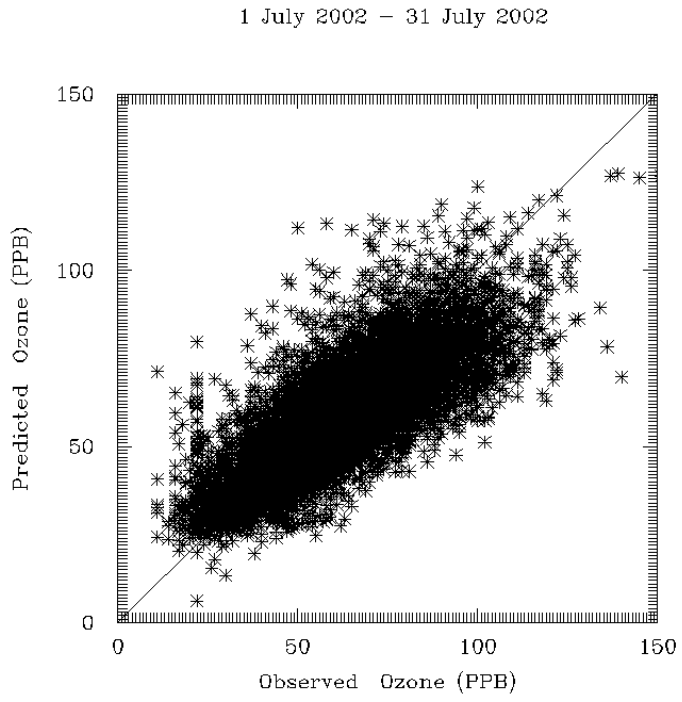


Figure 4.1-2 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Scatter Plots For June



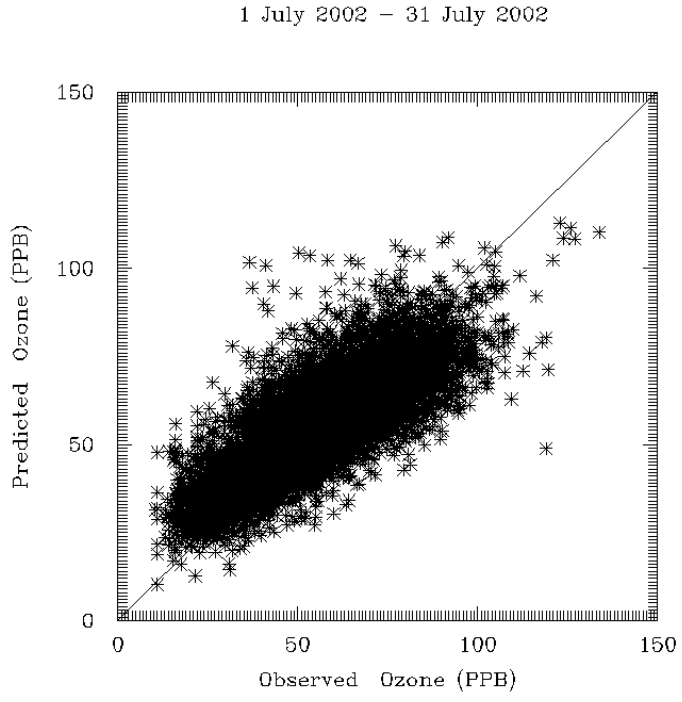
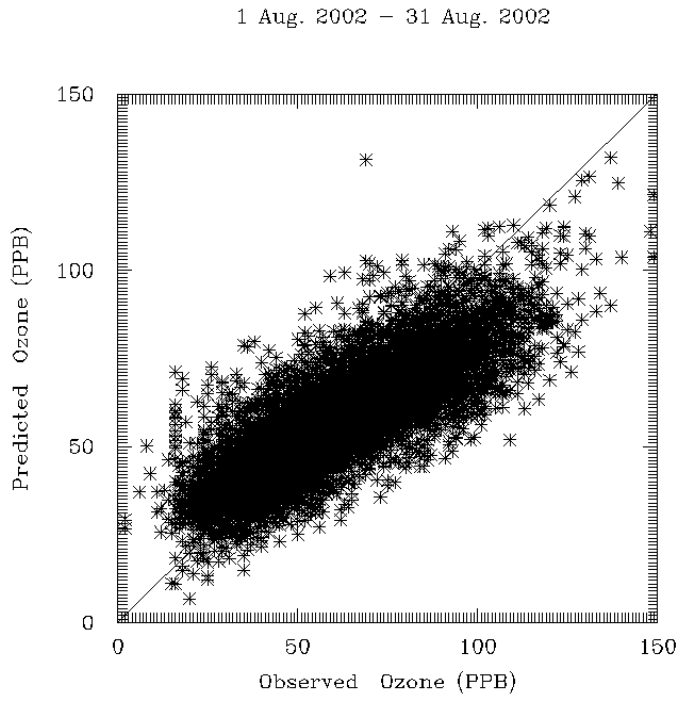


Figure 4.1-3 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Scatter Plots For July



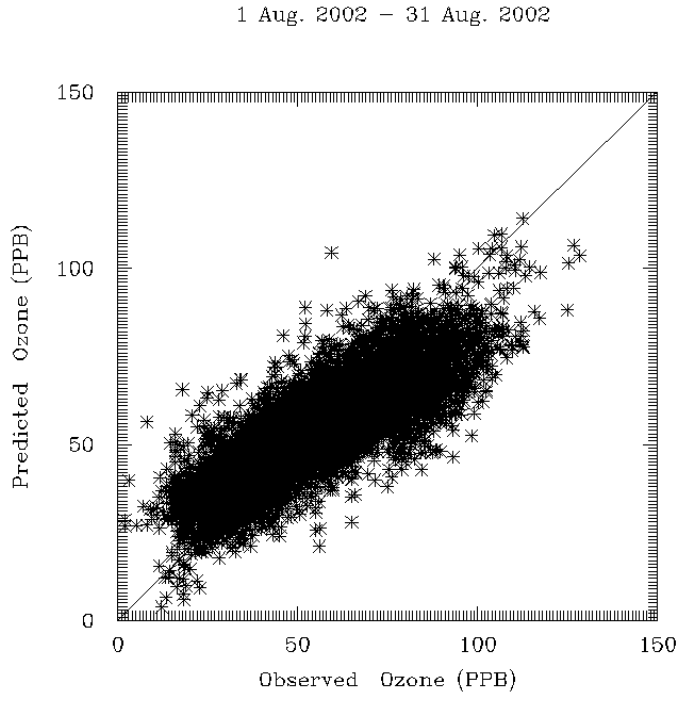
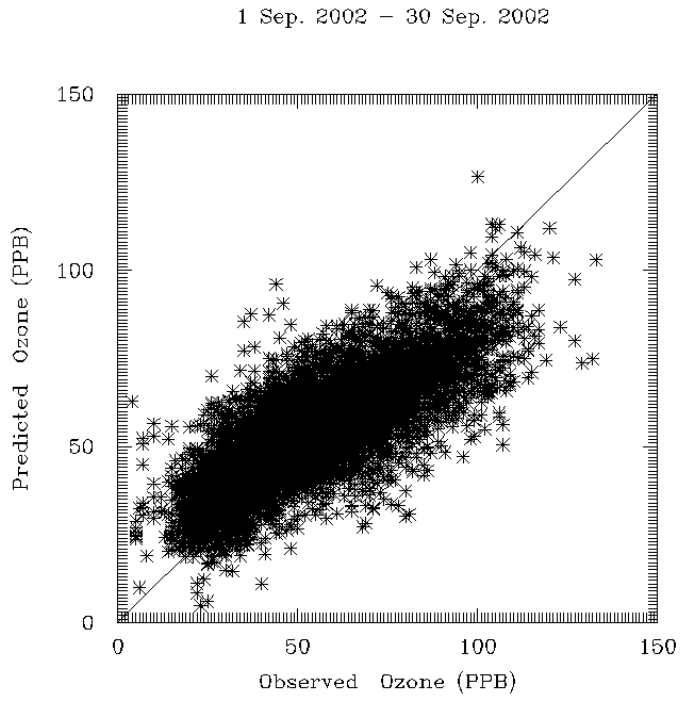


Figure 4.1-4 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Scatter Plots For August



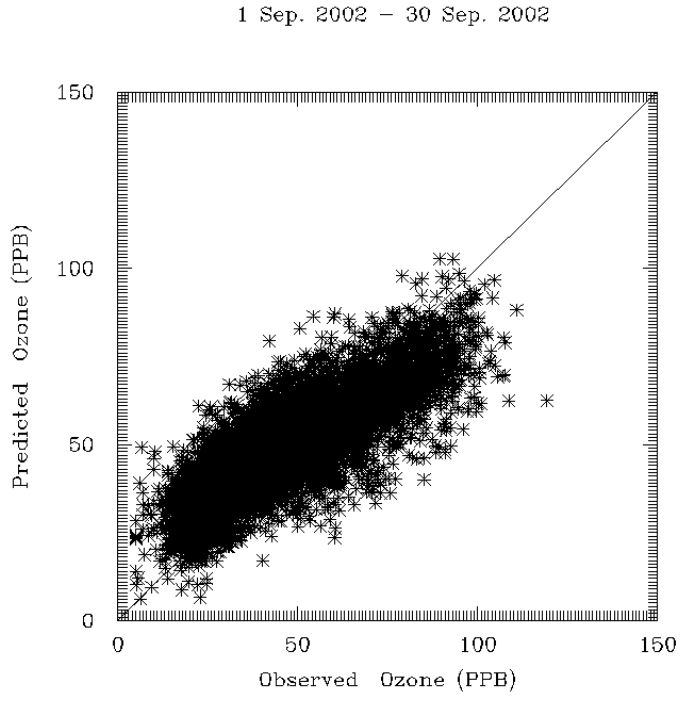
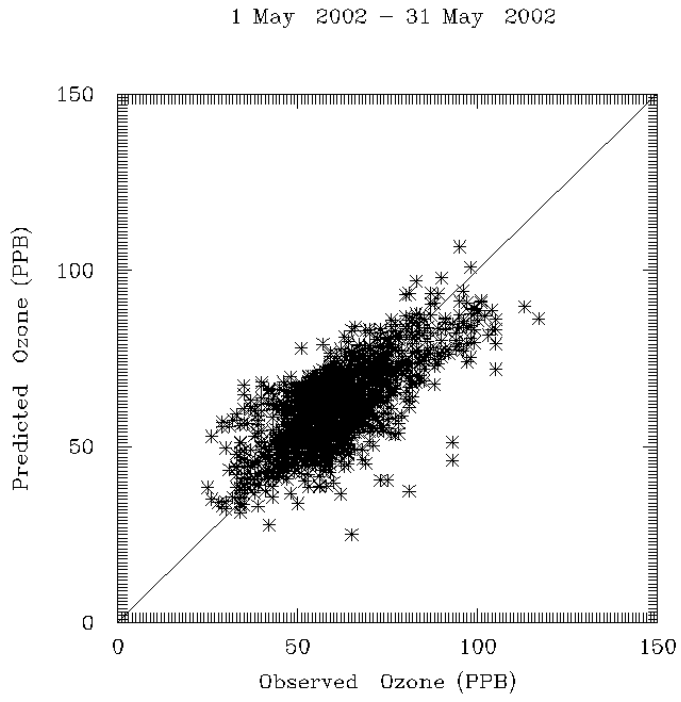


Figure 4.1-5 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Scatter Plots For September

4.2 12km Domain Scatter Plots – North Carolina

The 1-hour and 8-hour ozone scatter plots for just North Carolina are presented in this subsection. The North Carolina scatter plots for May through September are found in Figure 4.2-1 through Figure 4.2-5 on the following pages. There is a good mixture of urban, suburban, and rural ozone monitoring sites contained in these scatter plots. With this heterogeneous mixture of sites, the model and observed values are well correlated and tightly clustered along the 1:1 line across the majority of the data pairs. Under predictions of observed ozone can be seen when observed ozone concentrations are greater than 100 ppb and are most notable in the few cases that observed ozone surpasses 120 ppb.

There are not any systematic abnormalities found in either the 1-hour or 8-hour scatter plots for the North Carolina portion of the 12km modeling domain. This further confirms the reasonable model performance statistics presented earlier in this Appendix.



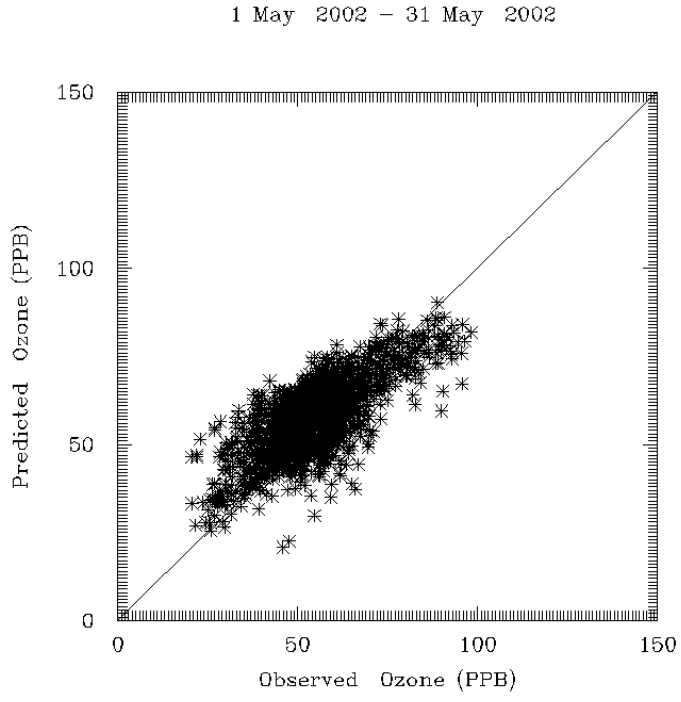
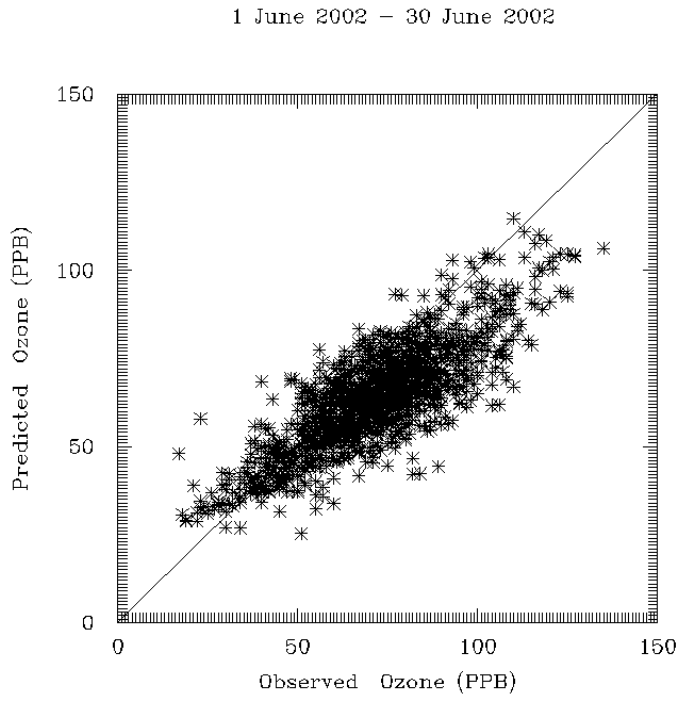


Figure 4.2-1 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For May



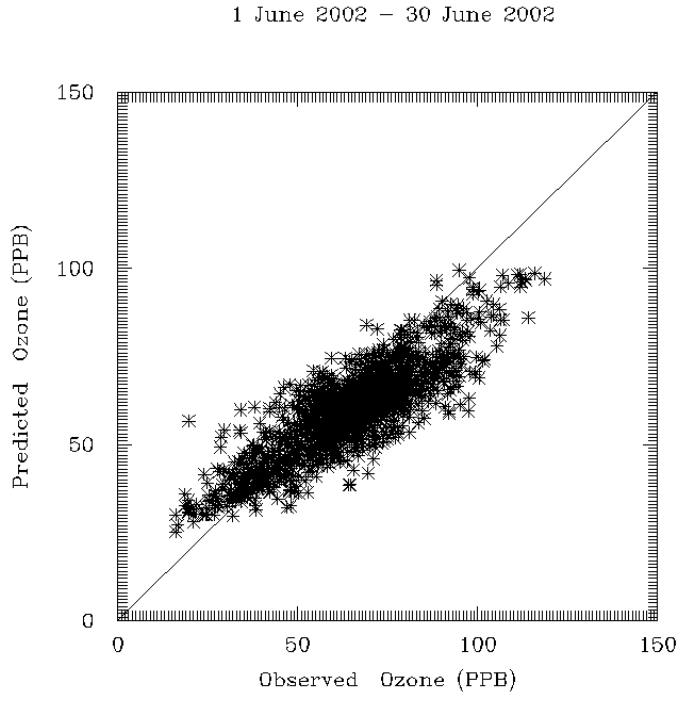
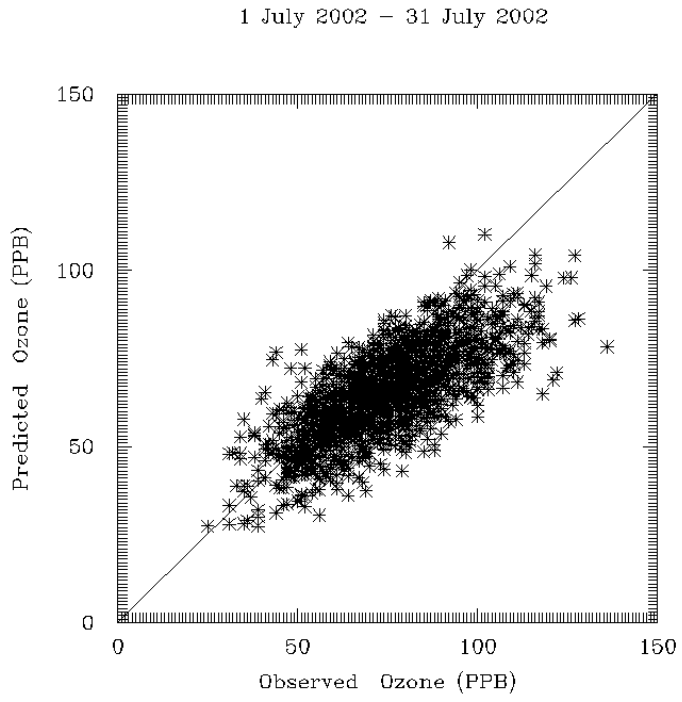


Figure 4.2-2 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For June



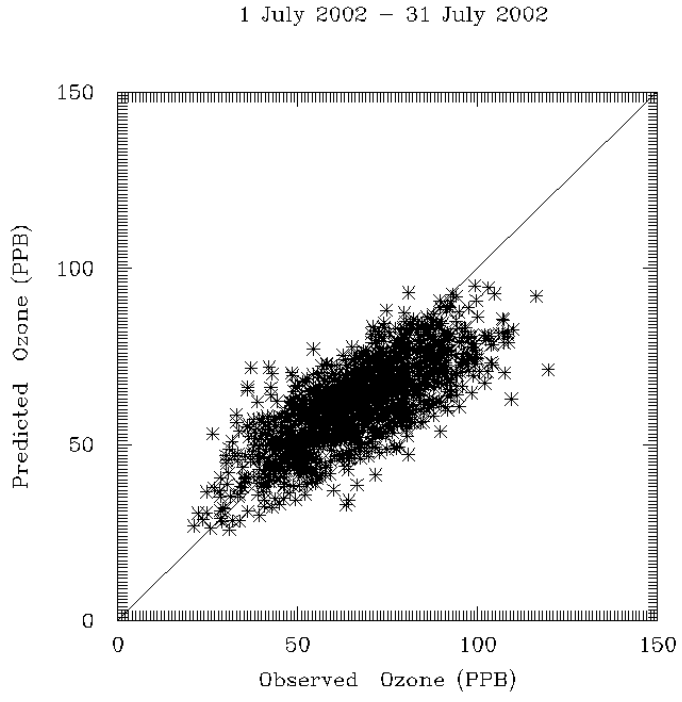
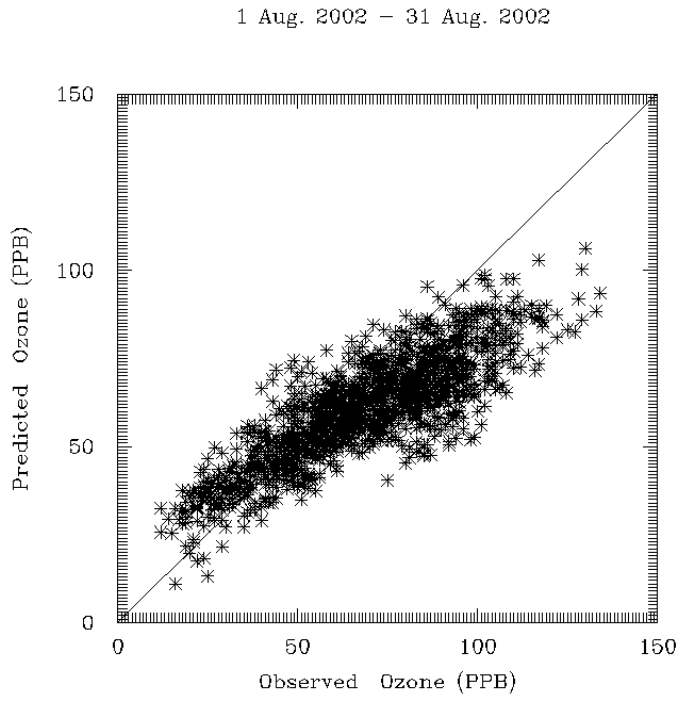


Figure 4.2-3 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For July



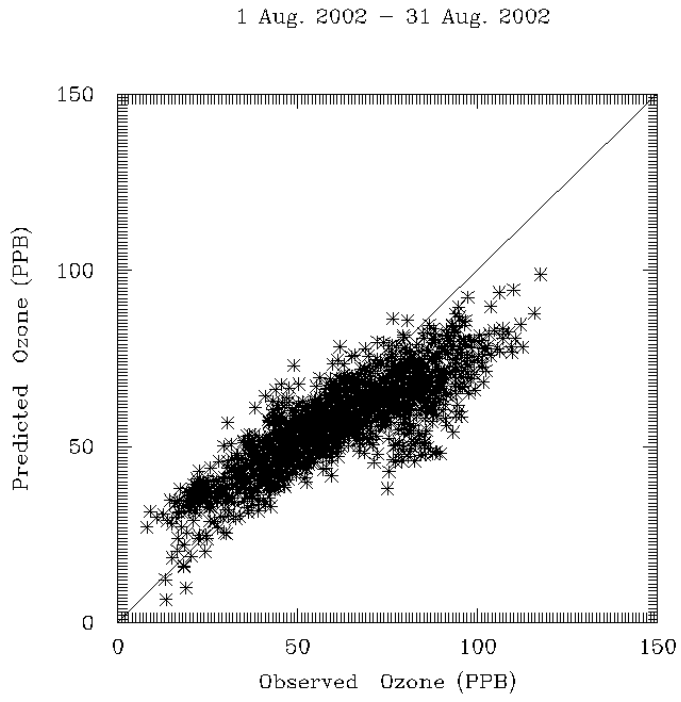
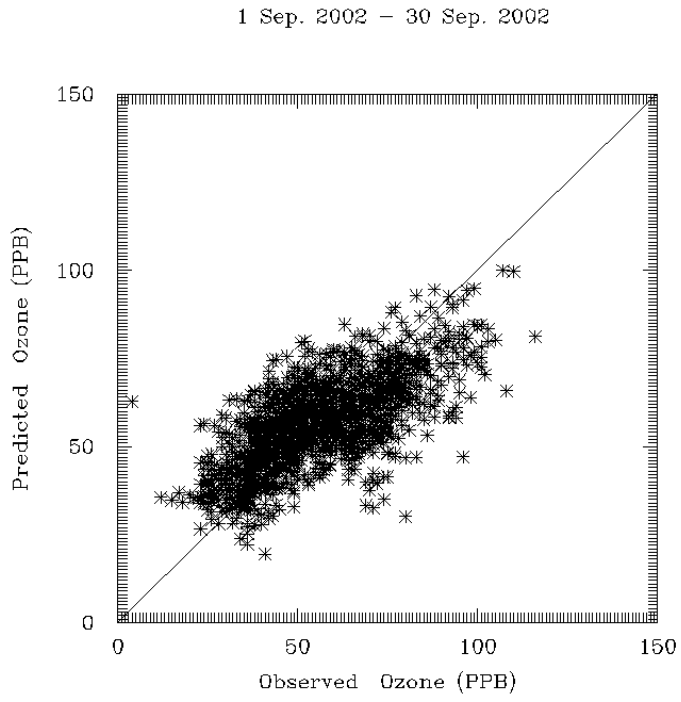


Figure 4.2-4 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For August



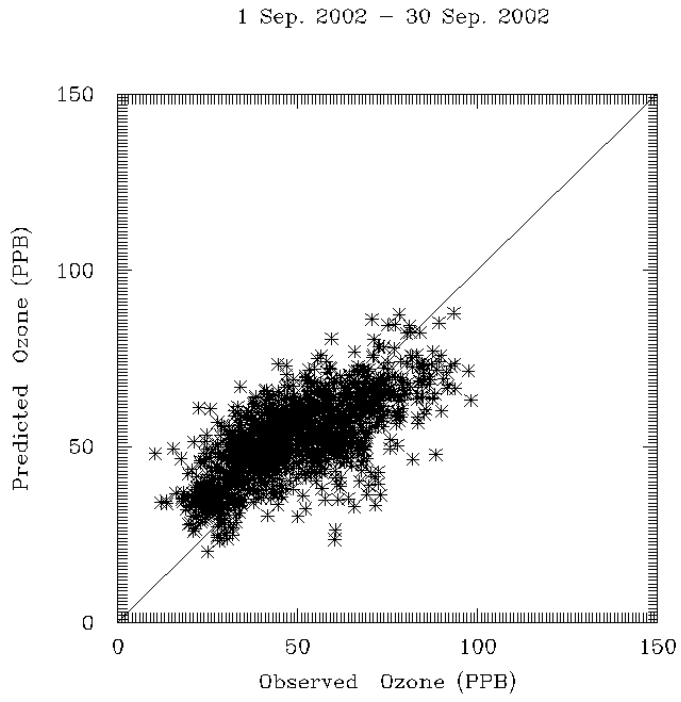
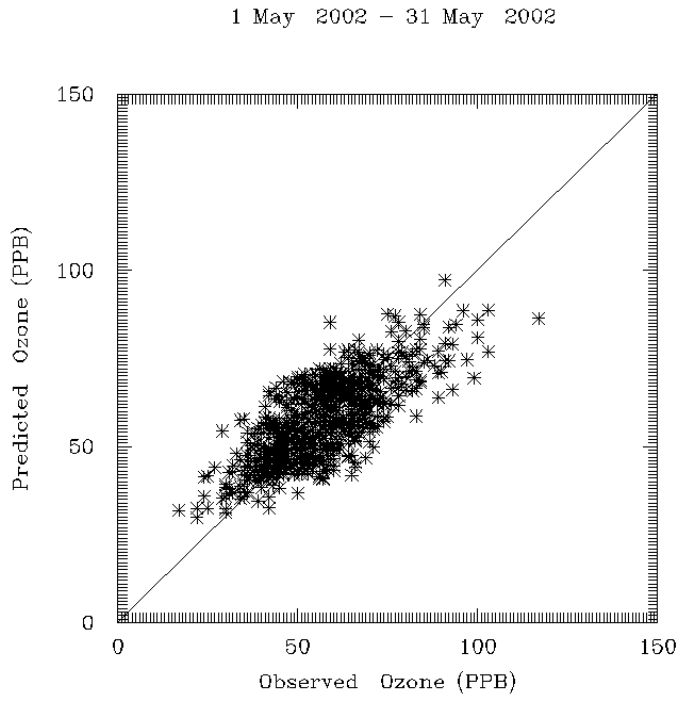


Figure 4.2-5 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For September

4.3 12km Domain Scatter Plots – South Carolina

The 1-hour and 8-hour ozone scatter plots for just South Carolina are presented in this subsection. The South Carolina scatter plots for May through September are found on the following pages (Figure 4.3-1 through Figure 4.3-5). South Carolina has a slightly higher frequency of suburban and rural ozone monitoring sites. Even with a lower frequency of urban ozone monitoring sites than across the VISTAS/ASIP region or across North Carolina, these scatter plots continue to demonstrate very reasonable correlations between model and observed ozone concentrations. Under predictions of observed ozone can be seen when observed ozone concentrations are at the higher end of the scale, but there are relatively few observations of ozone that surpass 120 ppb where more notable under predictions were seen in the previous VISTAS/ASIP and North Carolina regional scatter plots.

There are not any systematic abnormalities found in either the 1-hour or 8-hour scatter plots for the South Carolina portion of the 12km modeling domain. This further confirms the reasonable model performance statistics presented earlier in this Appendix.



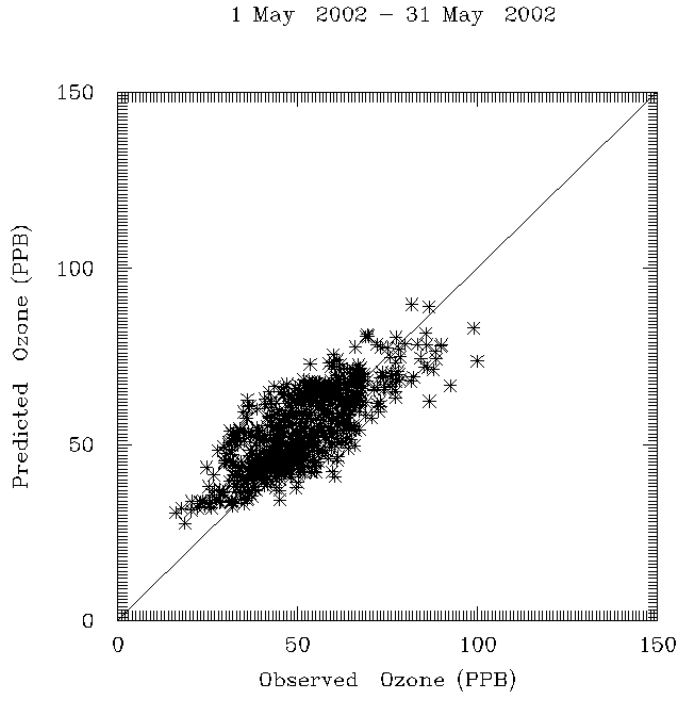


Figure 4.3-1 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For May

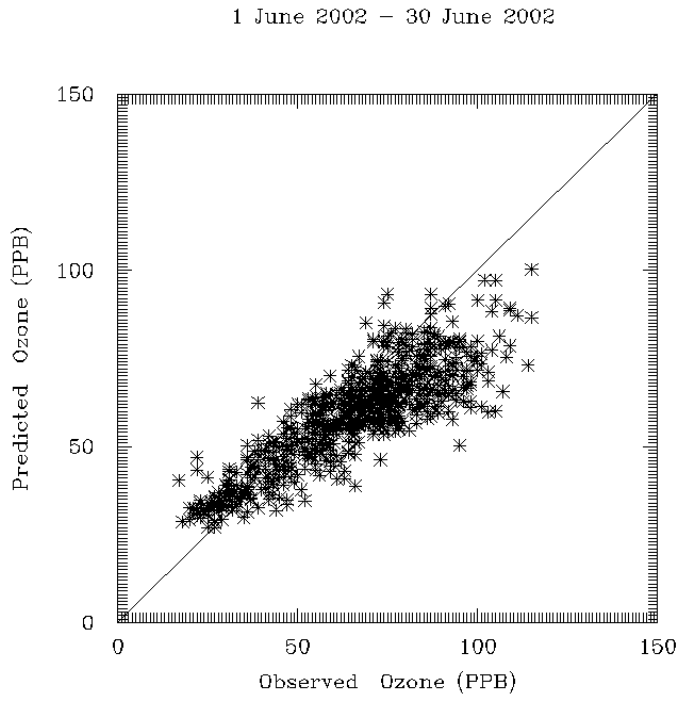
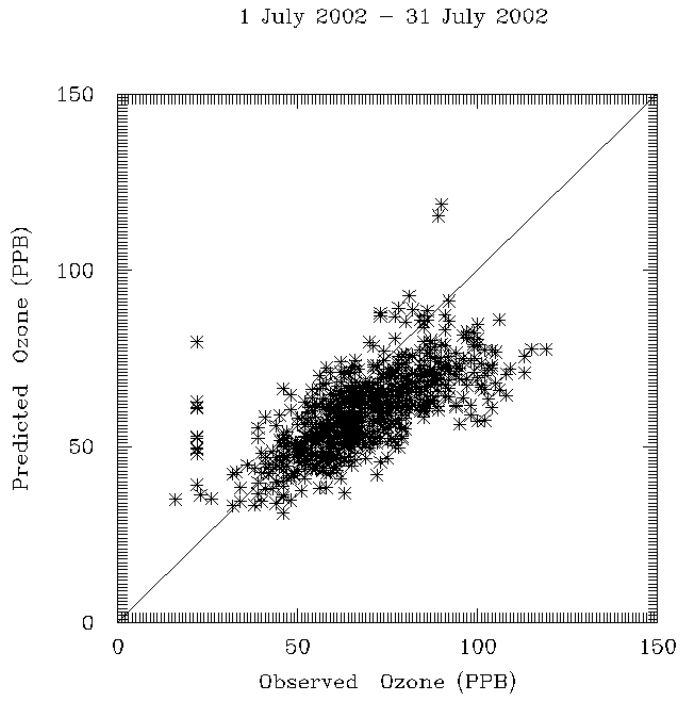


Figure 4.3-2 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For June



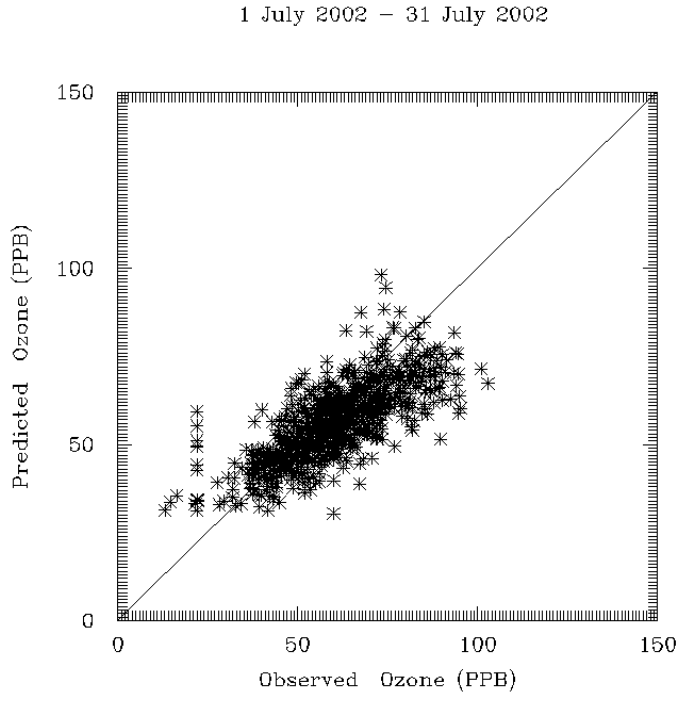
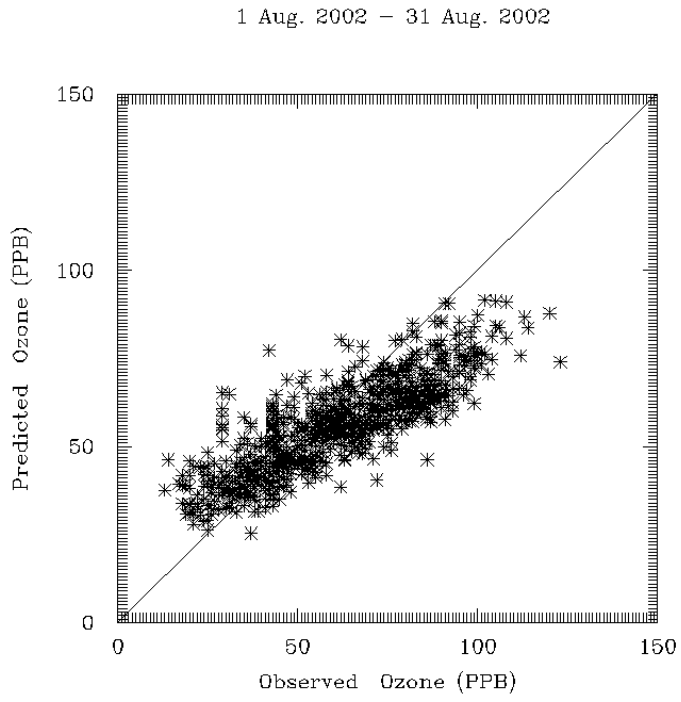


Figure 4.3-3 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For July



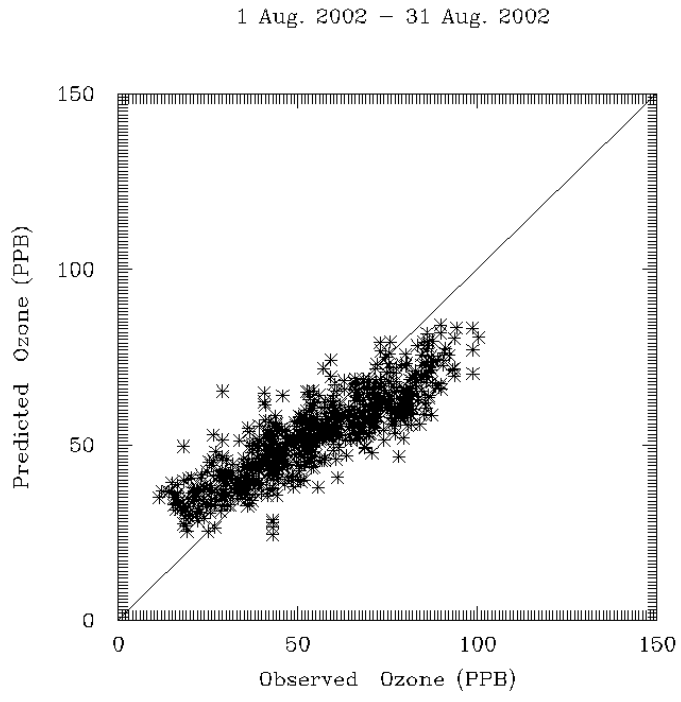
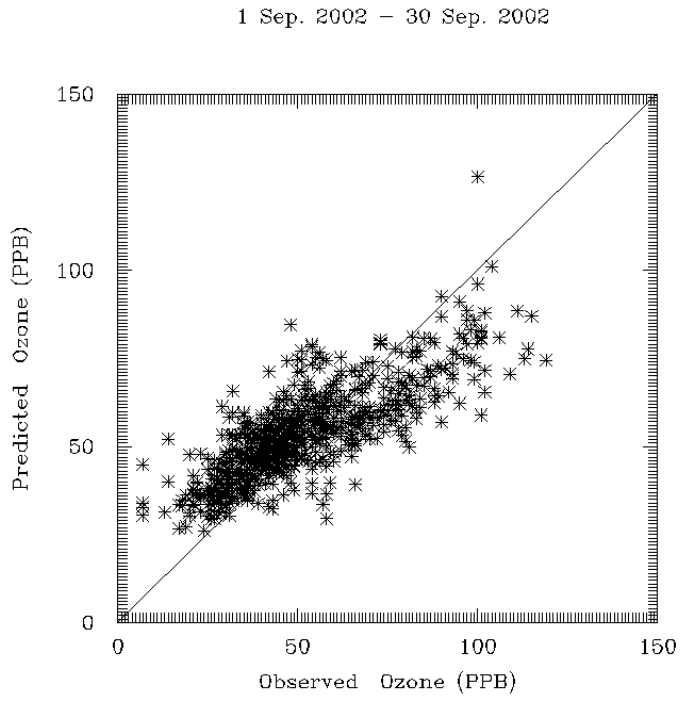


Figure 4.3-4 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For August



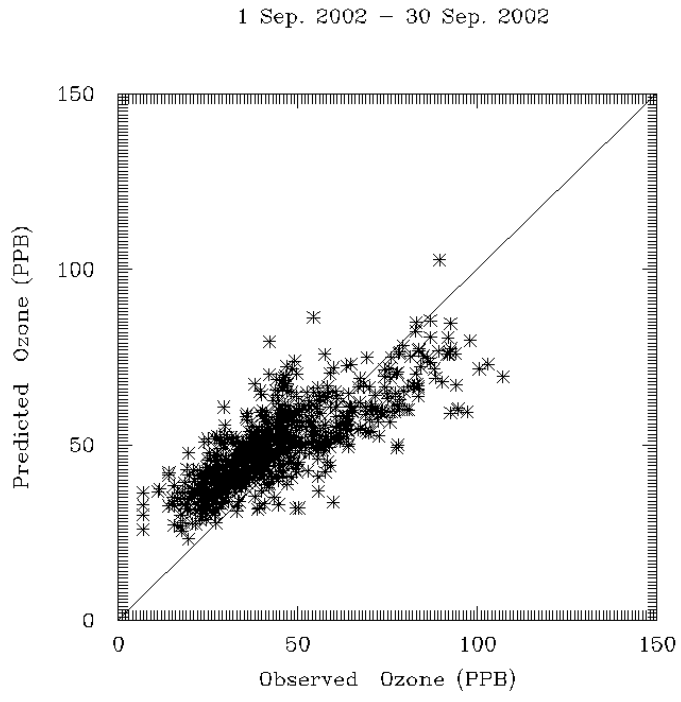


Figure 4.3-5 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Scatter Plots For September

4.4 Metrolina Monitor Specific Scatter Plots

The 1-hour and 8-hour ozone scatter plots for the individual ozone monitoring sites in the Metrolina region are presented in this subsection. The Metrolina monitor specific scatter plots for the entire summer season of May through September are found in Figure 4.4-1 through Figure 4.4-8 on the following pages. Of these 8 monitoring sites, the majority of the sites are either urban or suburban. With a more urbanized observed dataset, the respective monitor scatter plots show excellent correlation of model and observed ozone concentrations across the entire range of data. Under predictions of higher observed ozone concentrations can still be seen in these scatter plots, but these under predictions are significantly less notable than in any of the previous 1-hour or 8-hour ozone scatter plots presented in this section.

There are not any systematic abnormalities found in either the 1-hour or 8-hour scatter plots for the individual ozone monitoring sites in the Metrolina region. This is a strong indication that the model performance statistics presented earlier in this Appendix are sound and that these modeling results are appropriate for further use in the modeled attainment test.

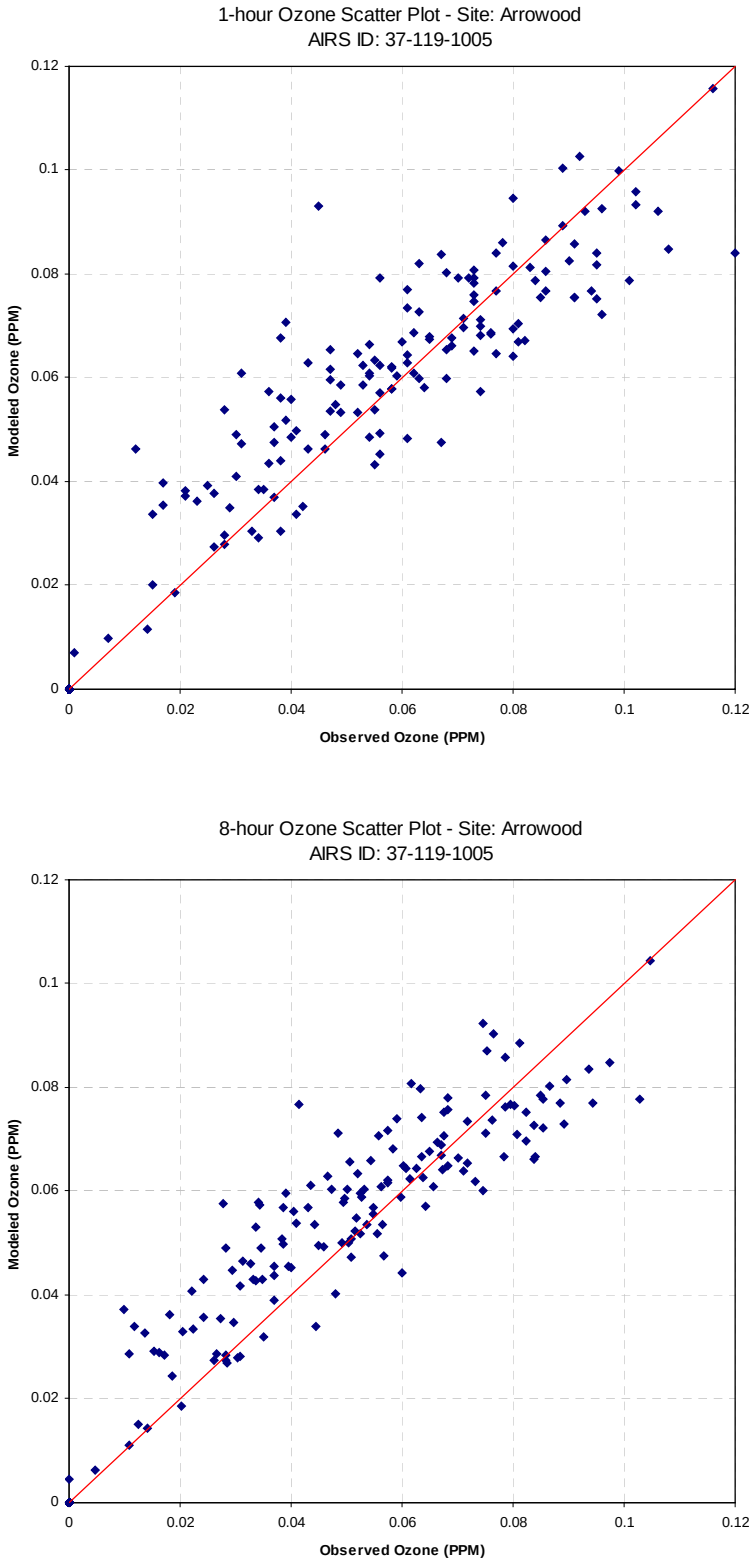


Figure 4.4-1 Arrowood 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

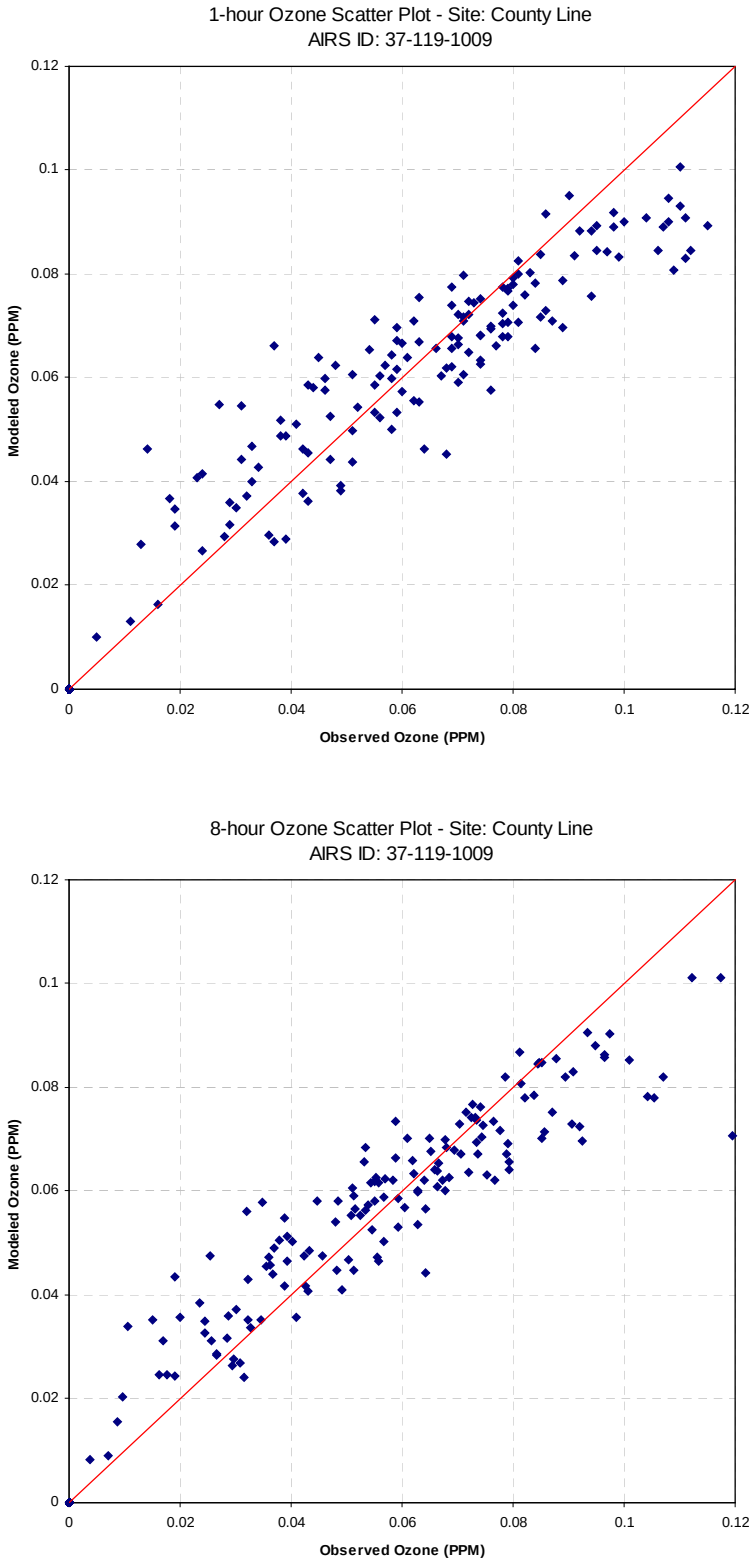


Figure 4.4-2 County Line 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

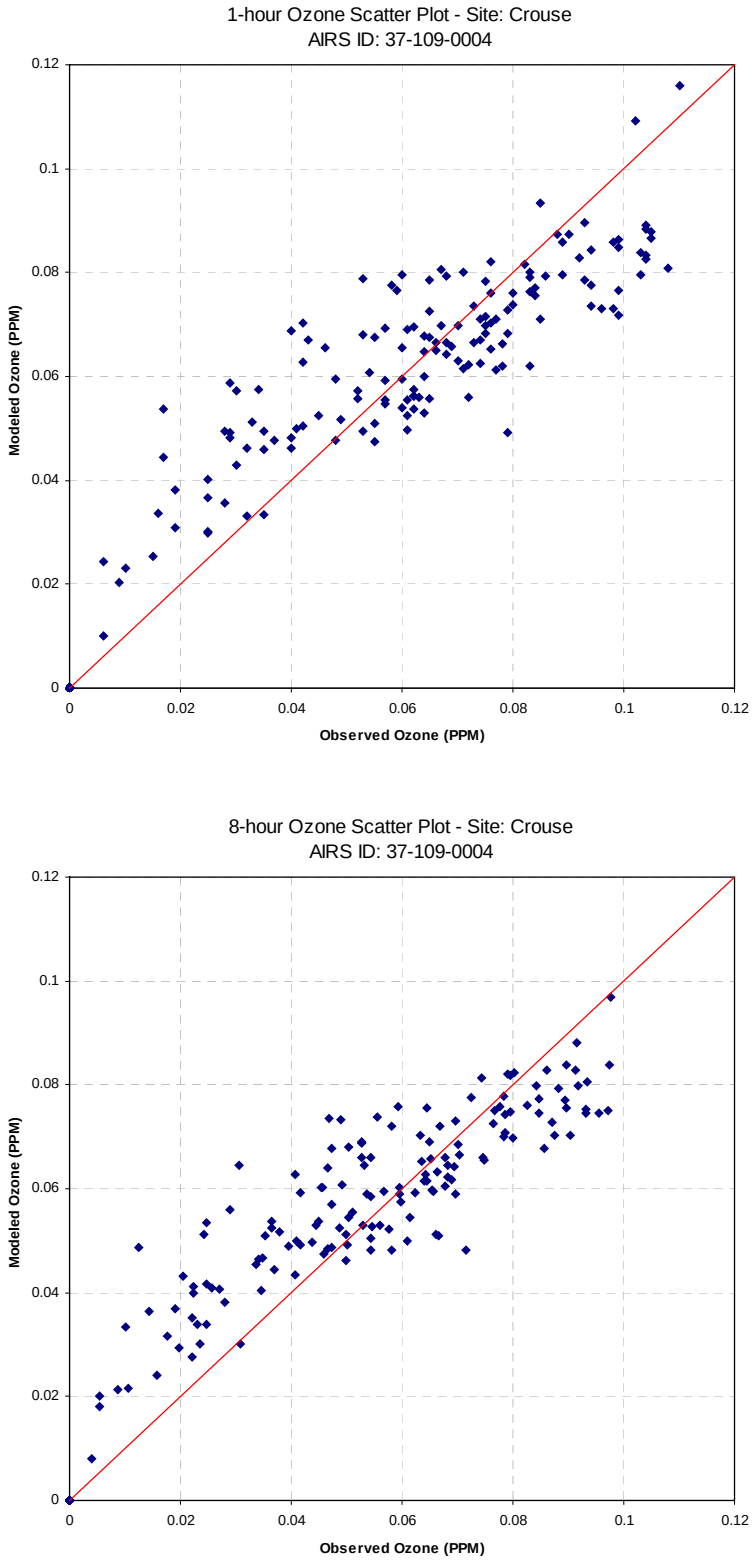


Figure 4.4-3 Crouse 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

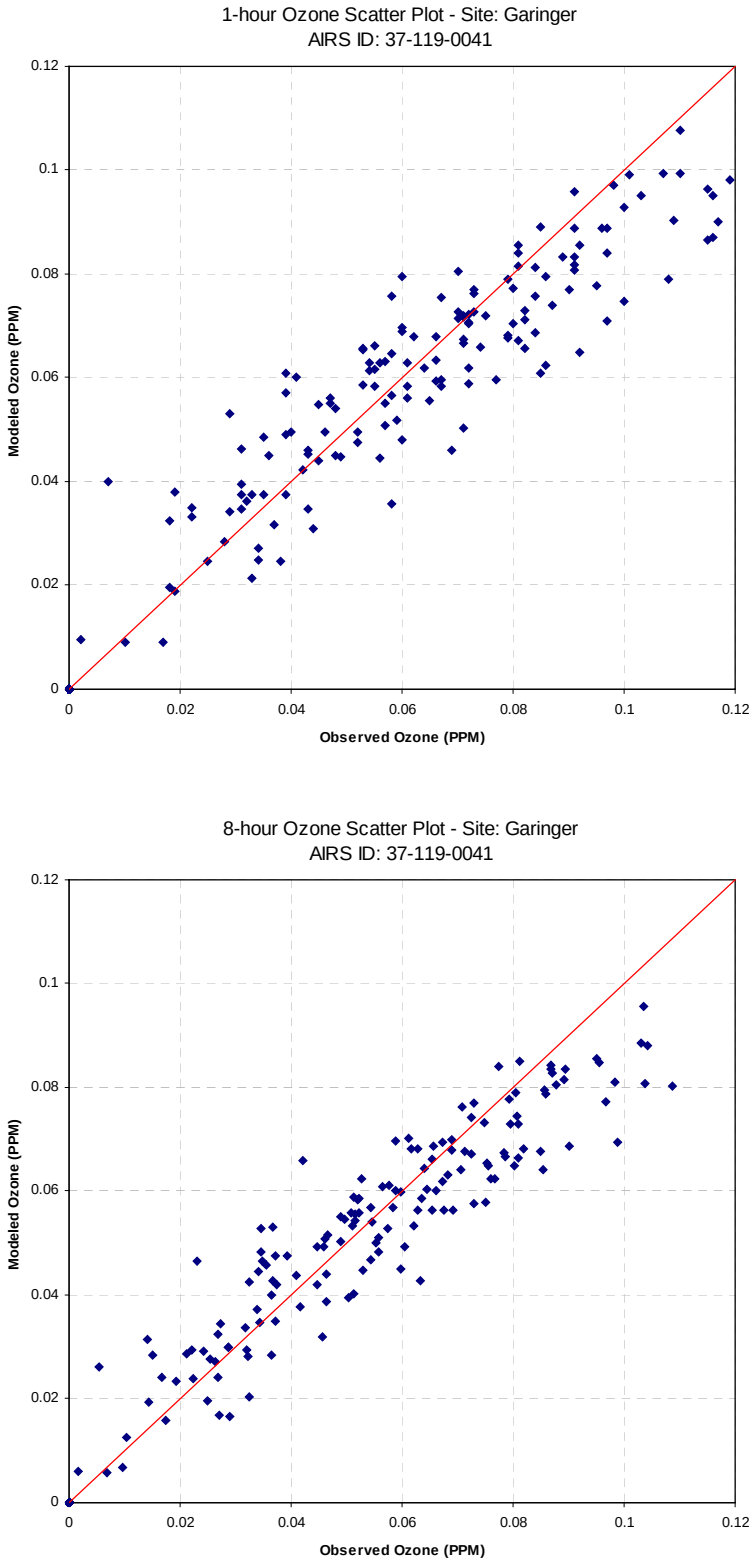


Figure 4.4-4 Garinger 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

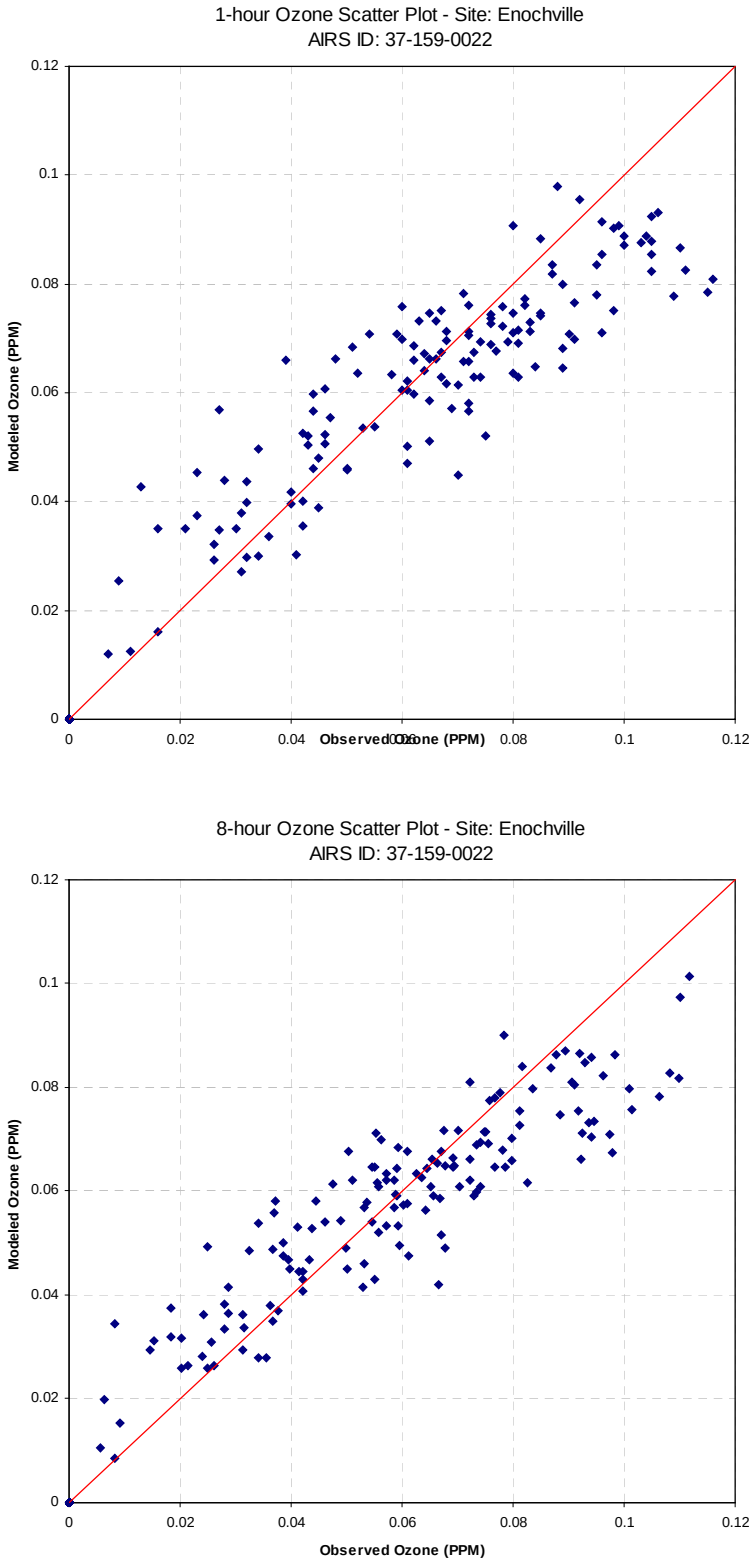


Figure 4.4-5 Enochville 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

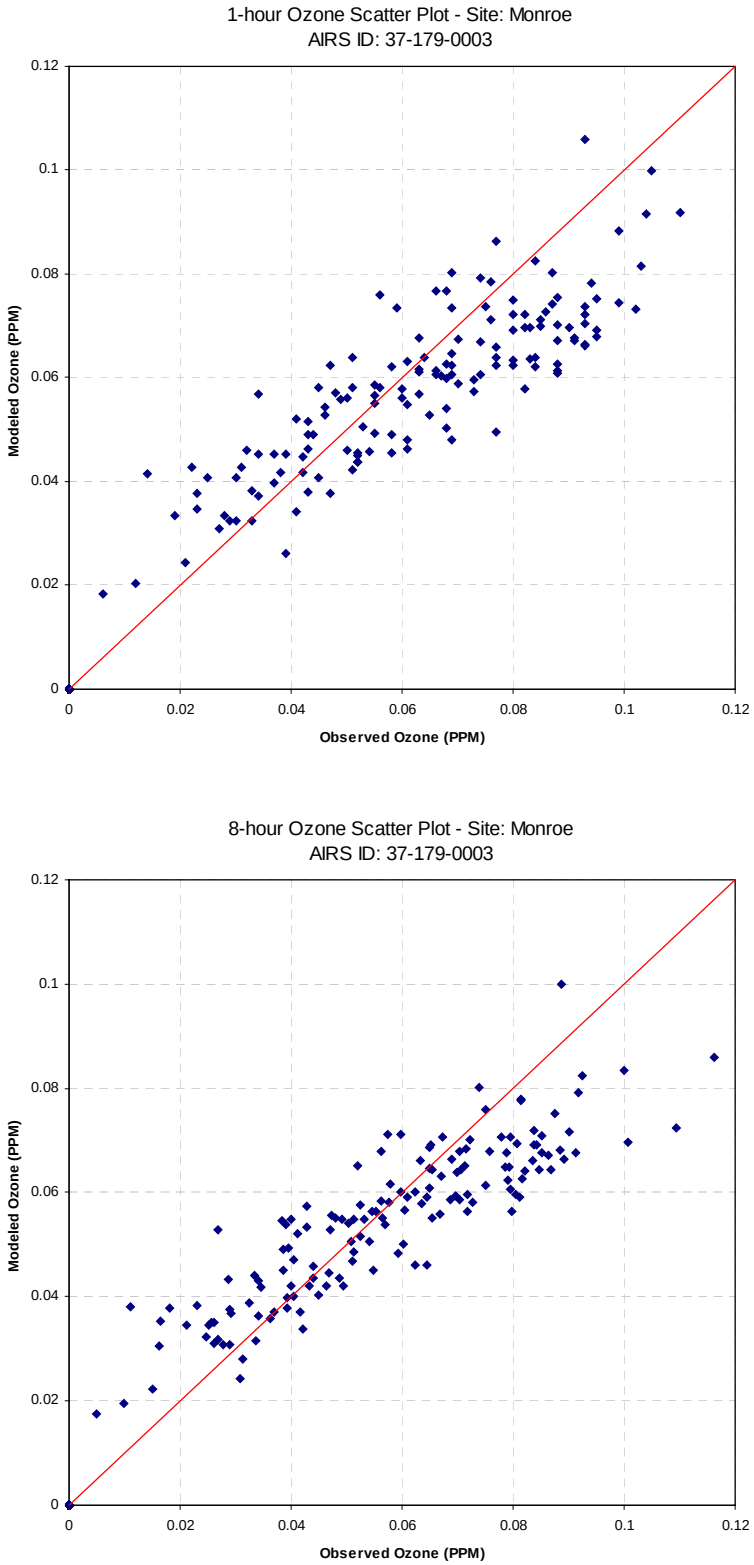


Figure 4.4-6 Monroe 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

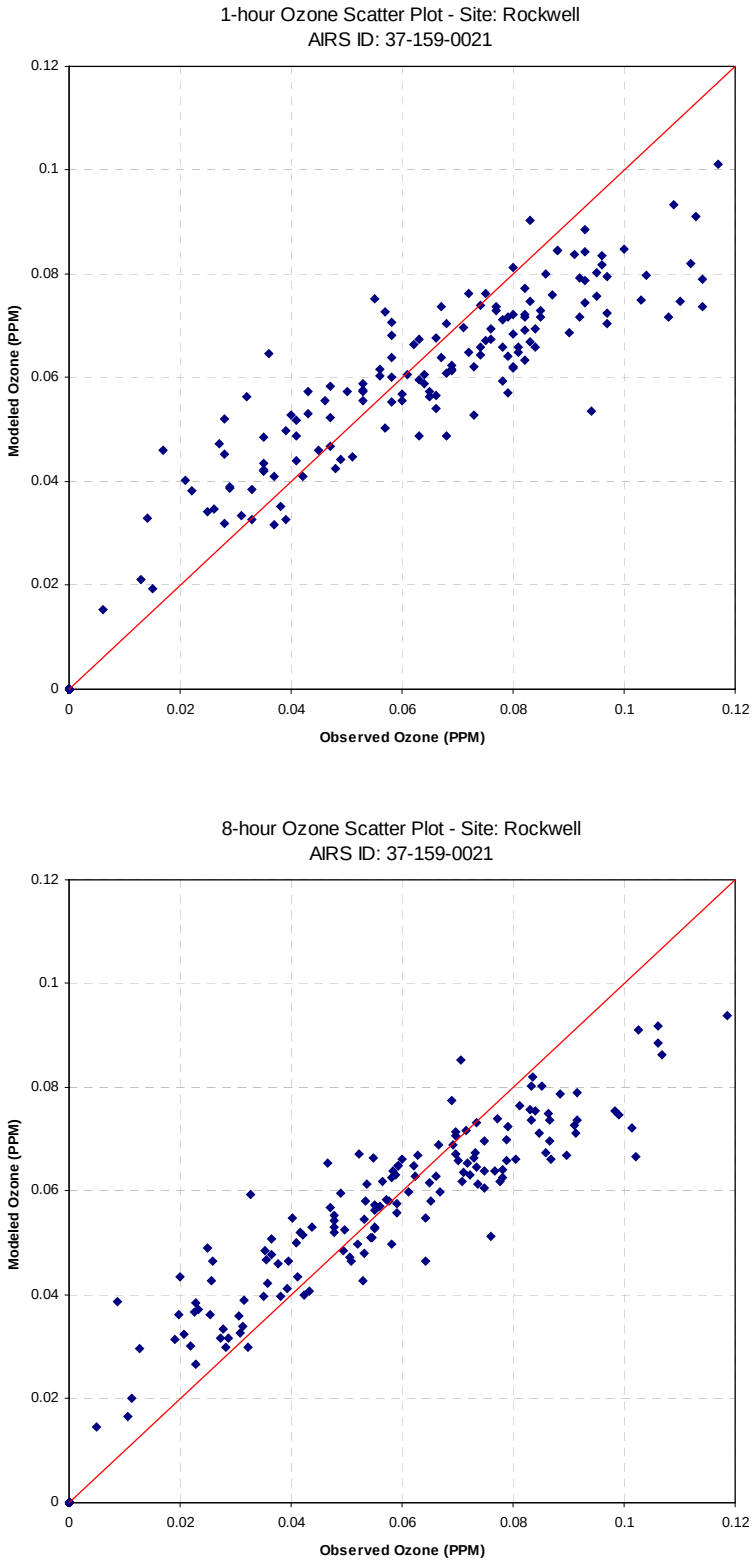


Figure 4.4-7 Rockwell 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

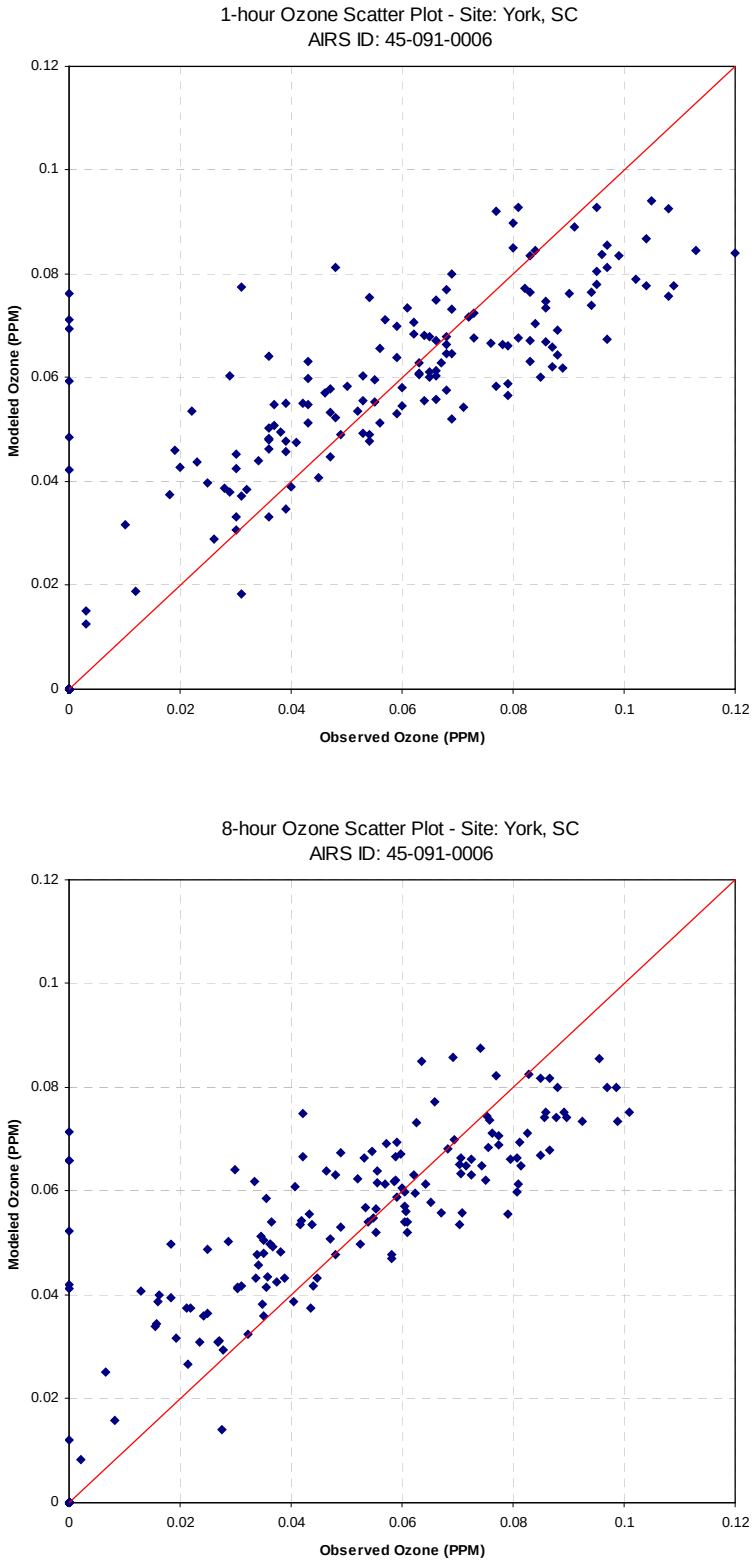


Figure 4.4-8 York, SC 1-hour (top) And 8-hour (bottom) Scatter Plots For May Through September

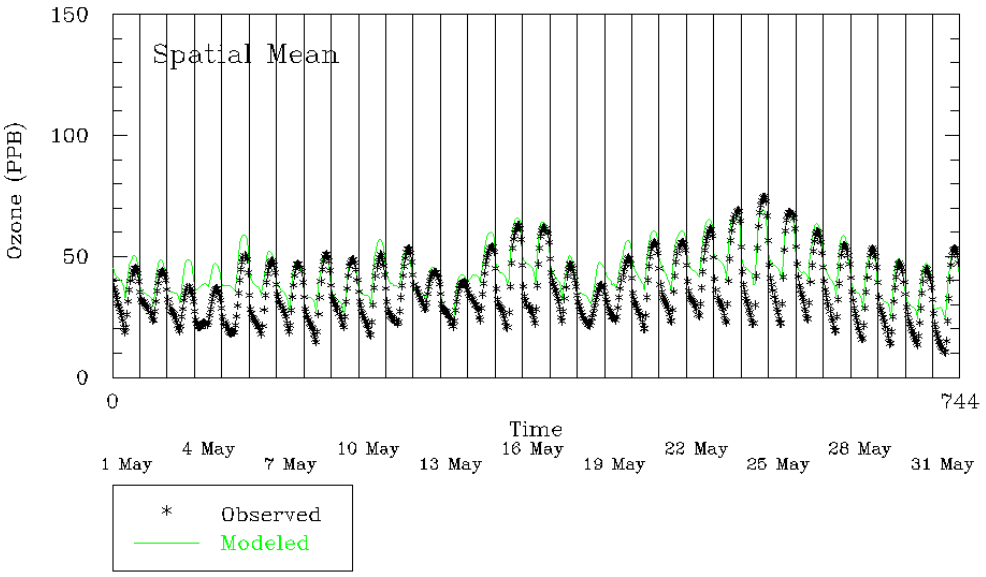
5 Time Series

The time series plots of hourly model predicted ozone (green line) and hourly observed ozone (black stars) are presented in this section. There are time series plots for both 1-hour and 8-hour ozone concentrations for each of the months from May through September. Time series plots were created for the VISTAS/ASIP region of the 12km modeling domain, for North Carolina, for South Carolina, and individually for each of the ozone monitors in the Metrolina region.

On each page, the 1-hour ozone time series plot is presented first (top) and the 8-hour ozone time series plots is present second (bottom) for the respective month and the respective region or monitoring site.

5.1 12 km Domain Time Series Plots – VISTAS/ASIP States Only

Overall the air quality model does an excellent job at capturing the diurnal pattern for both 1-hour and 8-hour ozone (Figure 5.1-1 through Figure 5.1-5). The model tends to over predict the minimum ozone values over the course of the May through September time frame, but this is expected given the well known issue of air quality models generally not capturing the absolute overnight ozone minimums very well. This overnight over prediction of ozone is not expected to cause any issues with the application of the modeled attainment test as these lower ozone concentrations are not considered in this test. There is a slight under prediction of peak ozone values once you reach the core of the ozone season (June, July, and August). Despite this slight under prediction of the ozone peaks, several high ozone episodes and the subsequent clean out events are well captured by the modeling. This is a good indication that both the meteorological and air quality models are representing the large synoptic weather and air quality patterns well throughout the duration of this summer season.



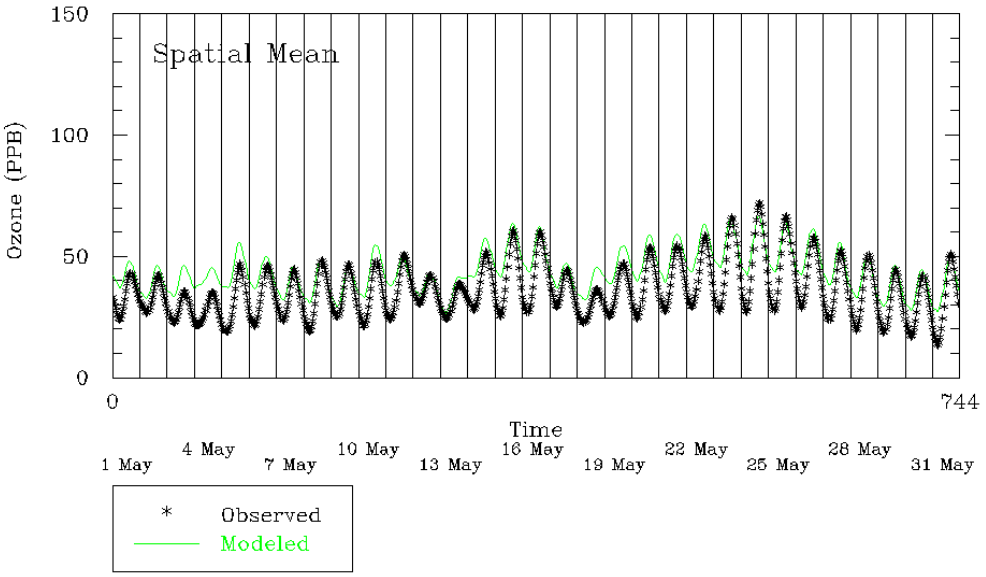
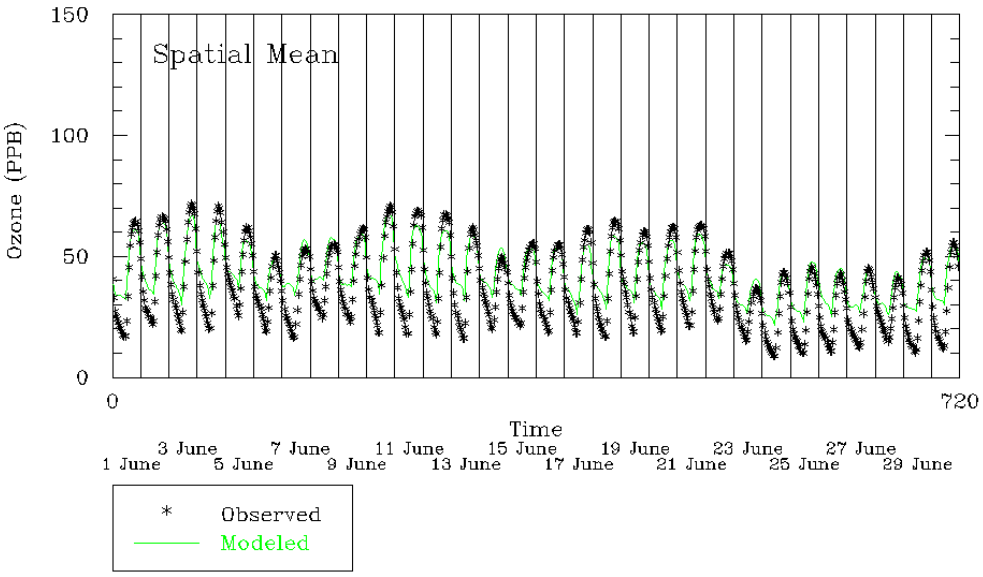


Figure 5.1-1 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Time Series Plots For May



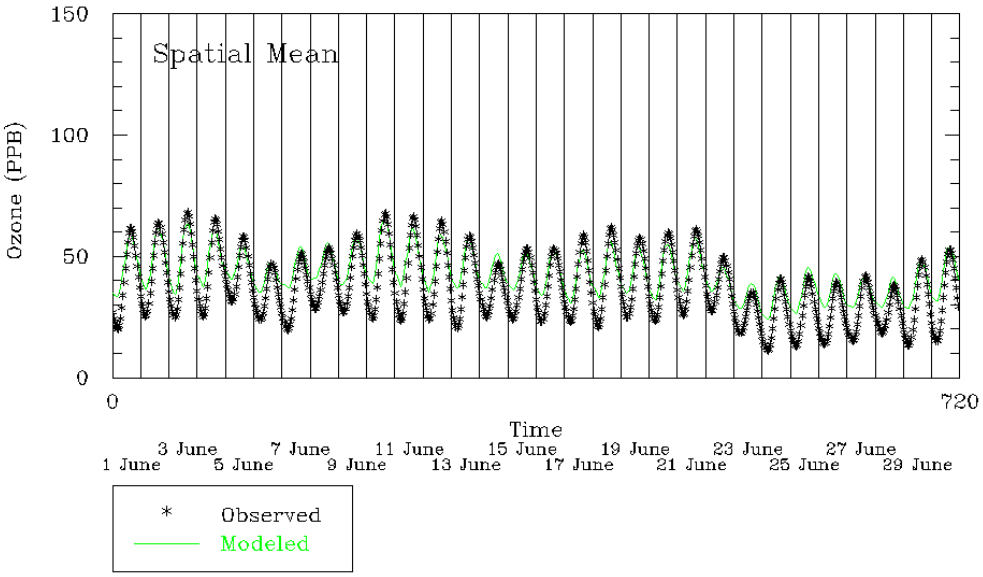
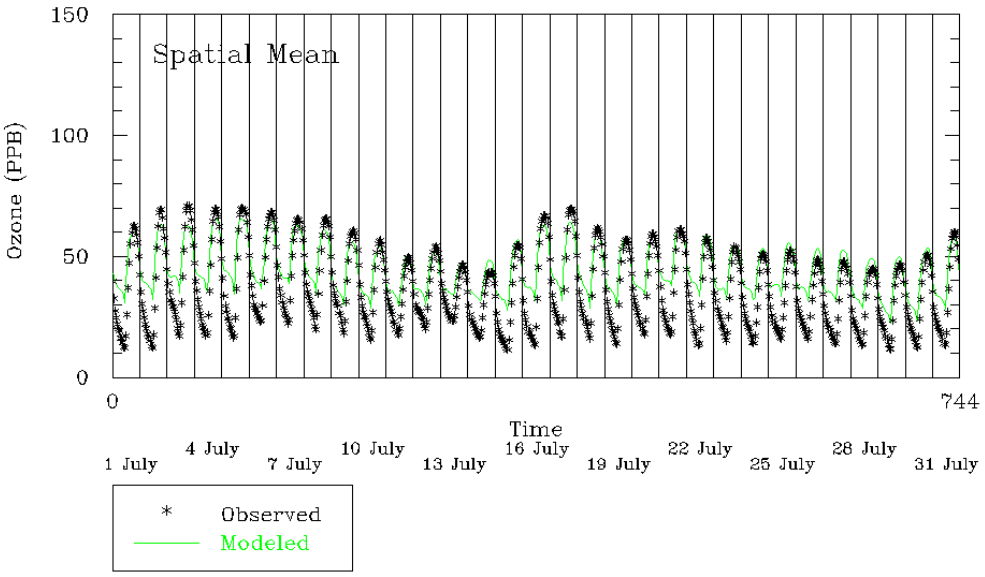


Figure 5.1-2 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Time Series Plots For June



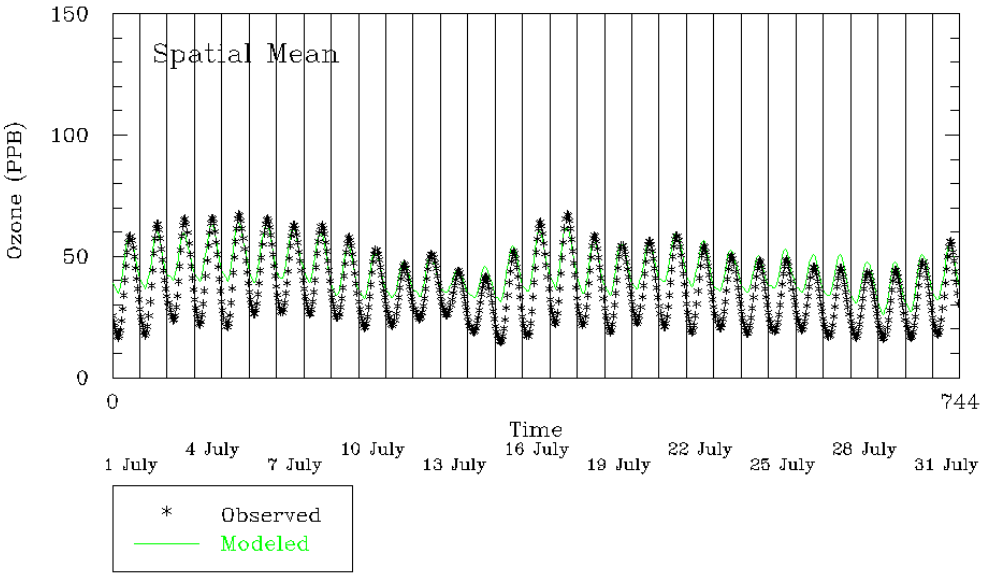
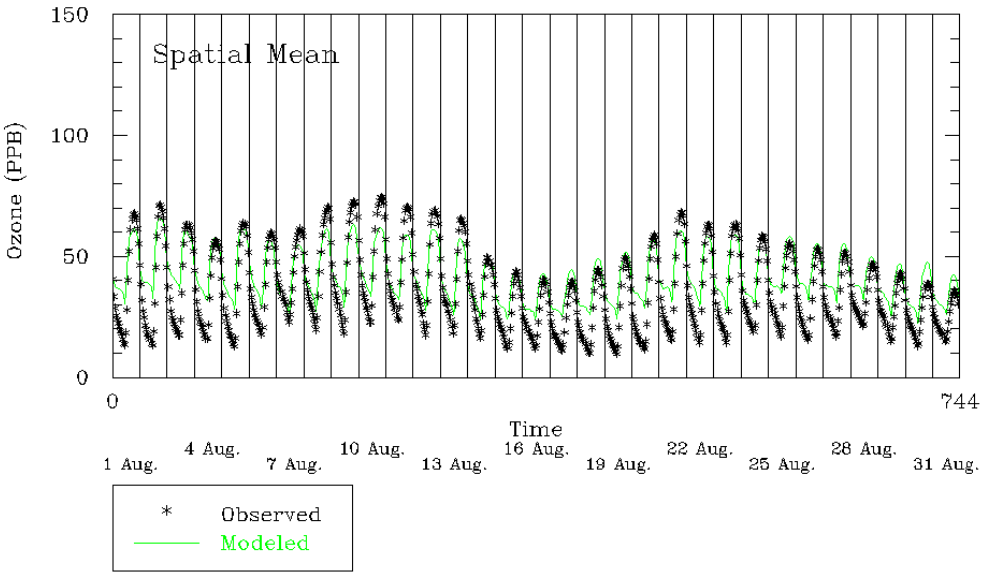


Figure 5.1-3 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Time Series Plots For July



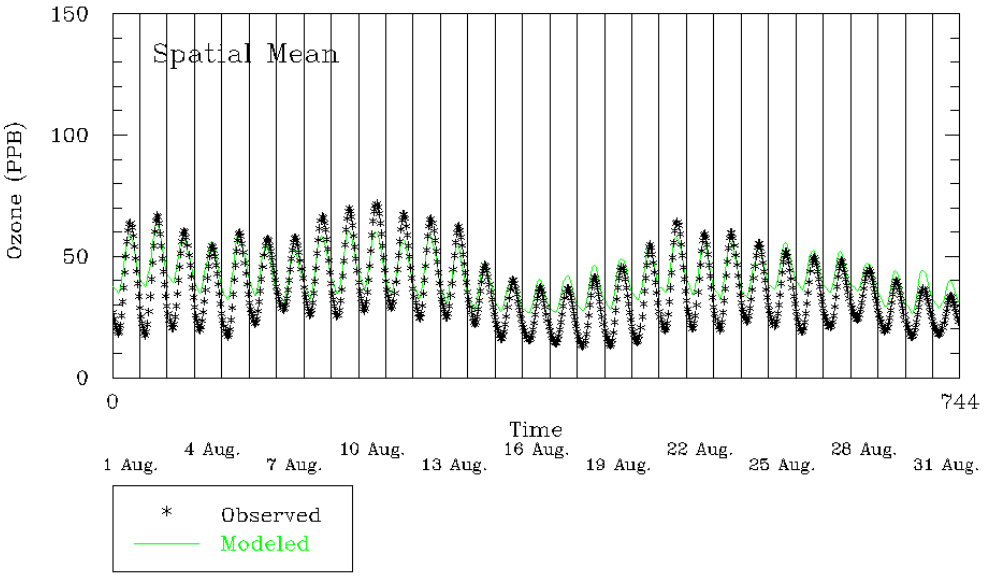
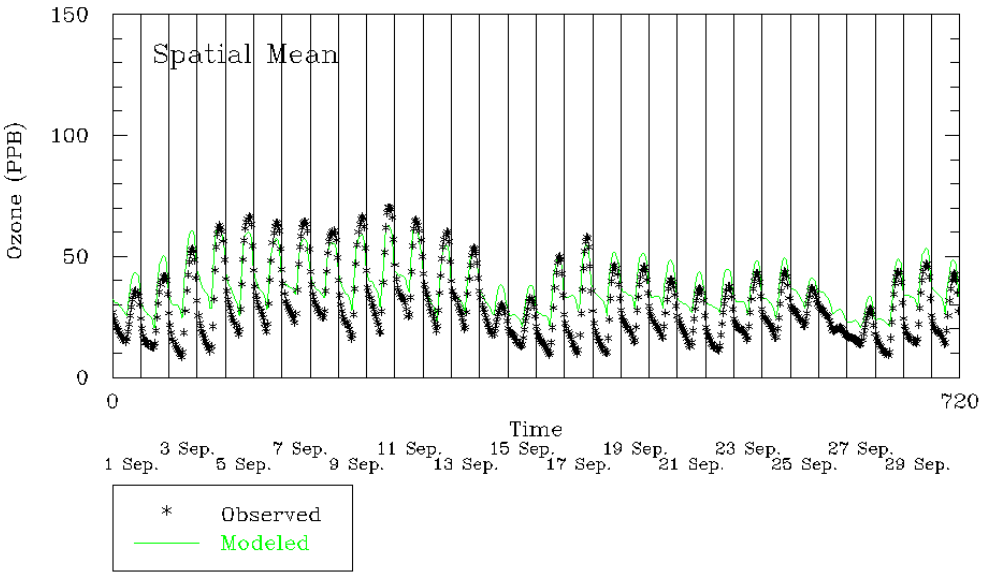


Figure 5.1-4 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Time Series Plots For August



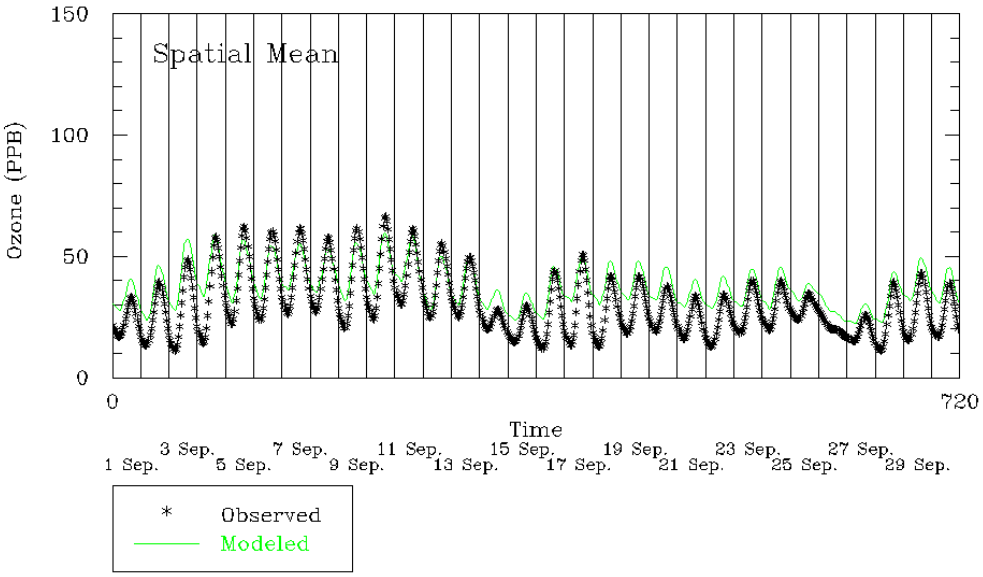
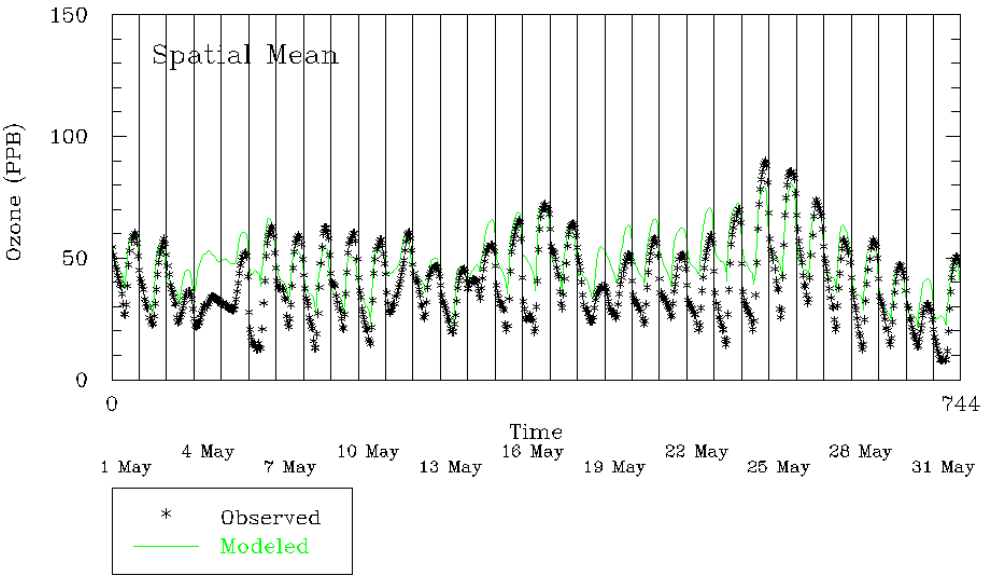


Figure 5.1-5 12km Domain – VISTAS/ASIP States Only 1-hour (top) And 8-hour (bottom) Time Series Plots For September

5.2 12 km Domain Time Series Plots – North Carolina

From just the North Carolina perspective, the air quality model continues to do an excellent job at capturing the diurnal pattern for both 1-hour and 8-hour ozone (Figures 5.2-1 through 5.2-5). As with the VISTAS/ASIP region, the model under predicts the peak ozone values at times throughout the summer season as well as the overnight over prediction issue previously discussed. In particular, a portion of the month of May and the last few days of August and September show a more notable under prediction of the afternoon peak ozone concentrations. Overall, the air quality model continues to capture the various synoptic weather and air quality cycles quite well and is within acceptable tolerances for model performance.



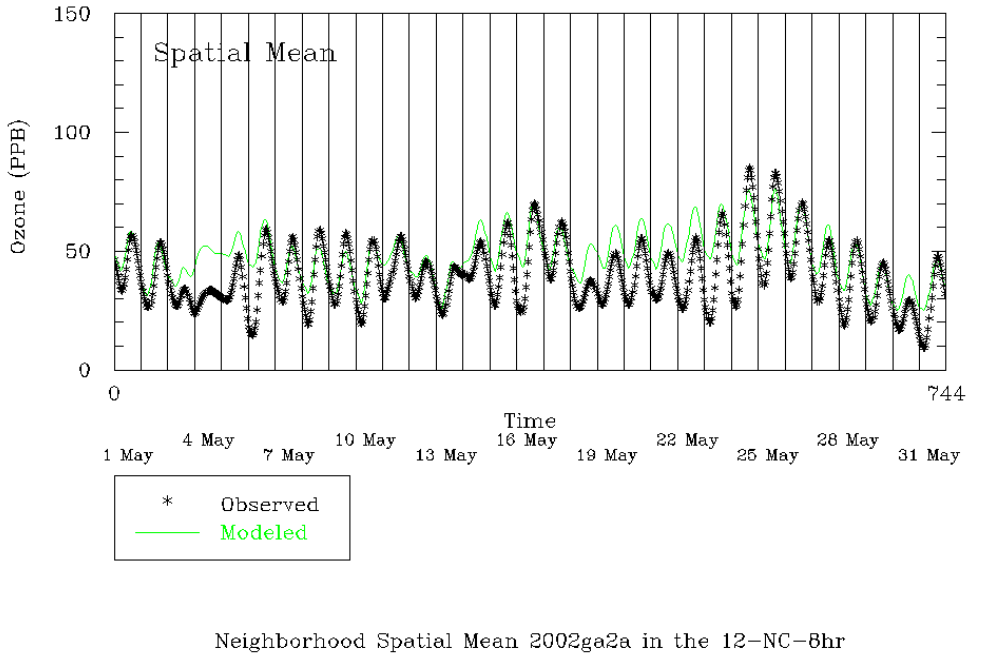
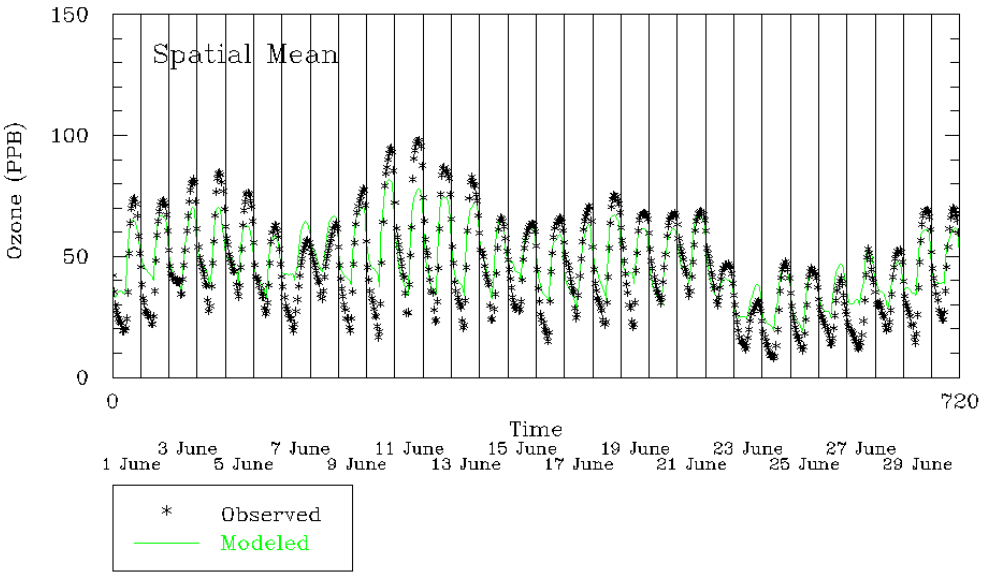


Figure 5.2-1 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For May



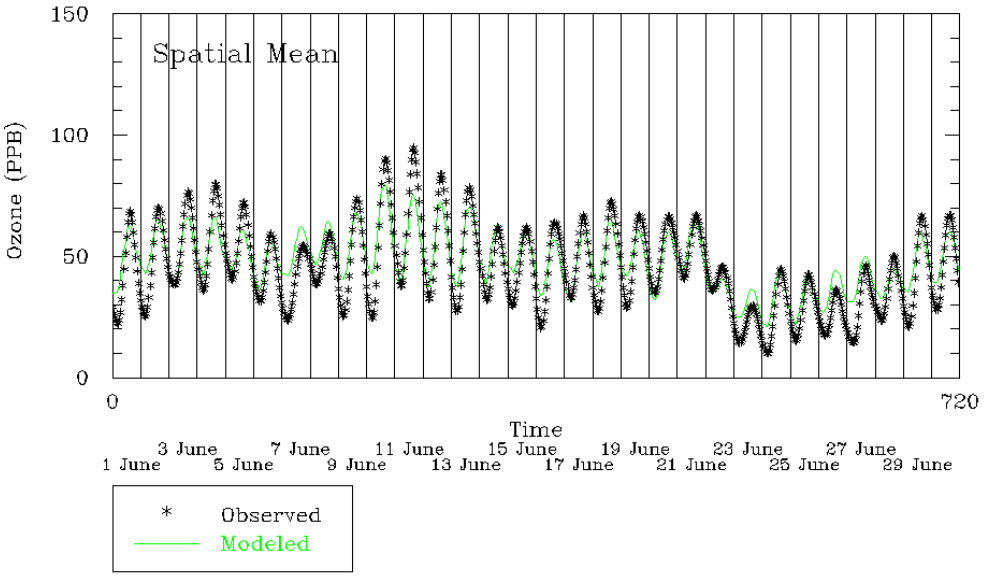
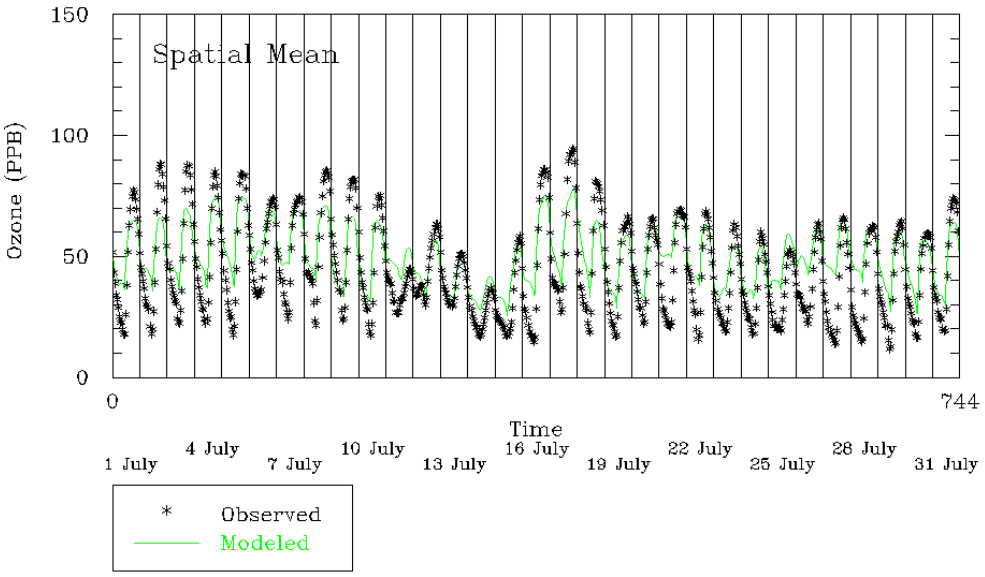


Figure 5.2-2 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For June



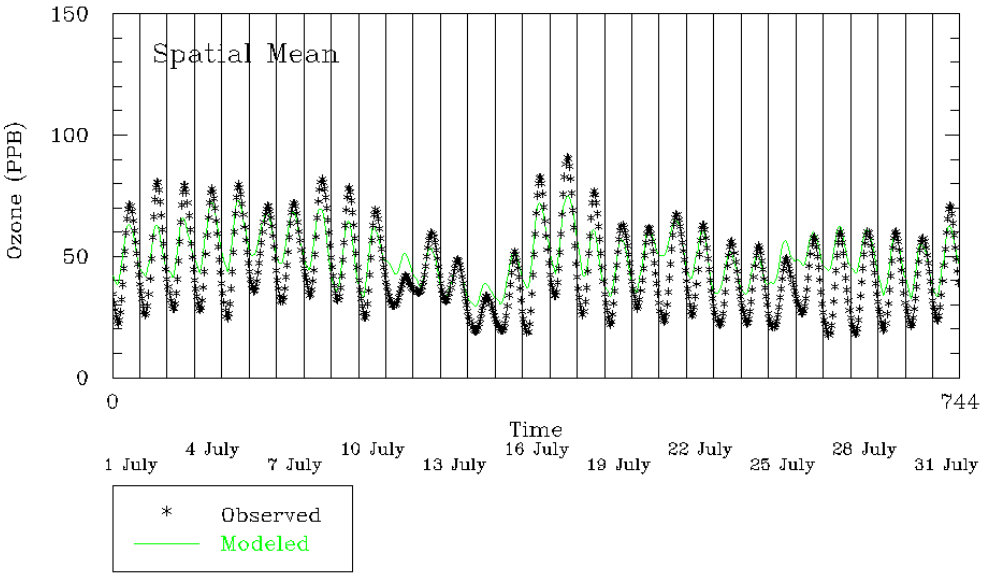
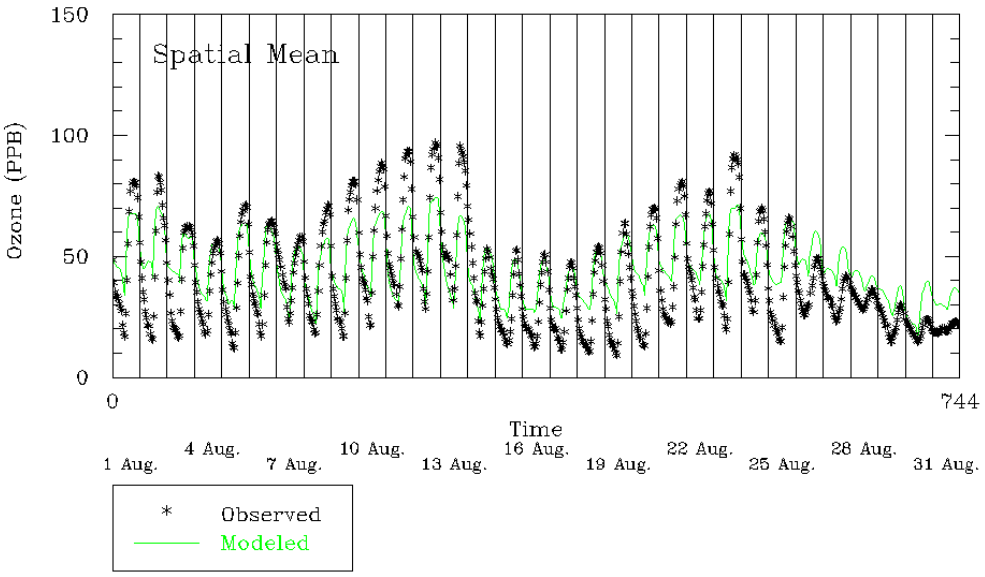
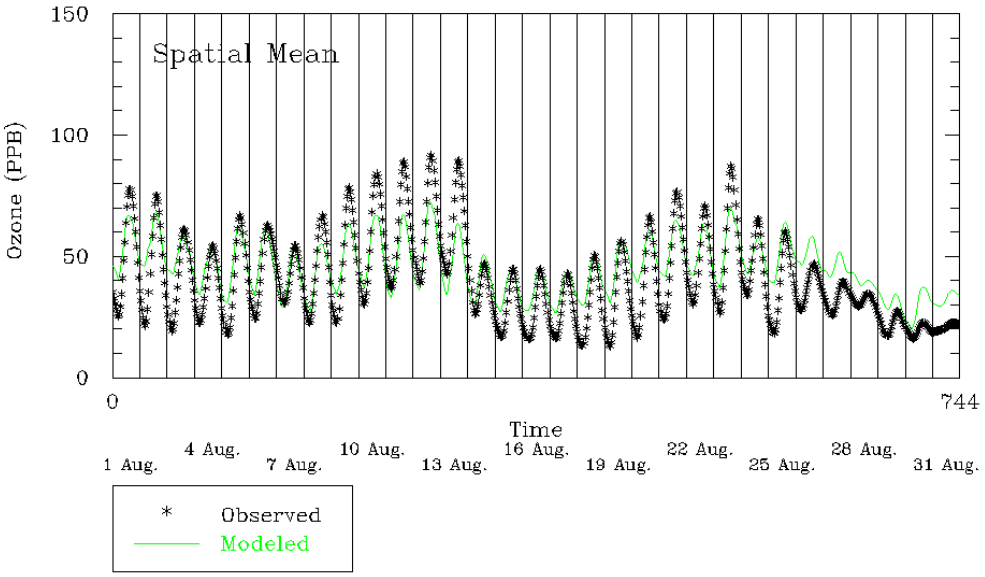


Figure 5.2-3 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For July

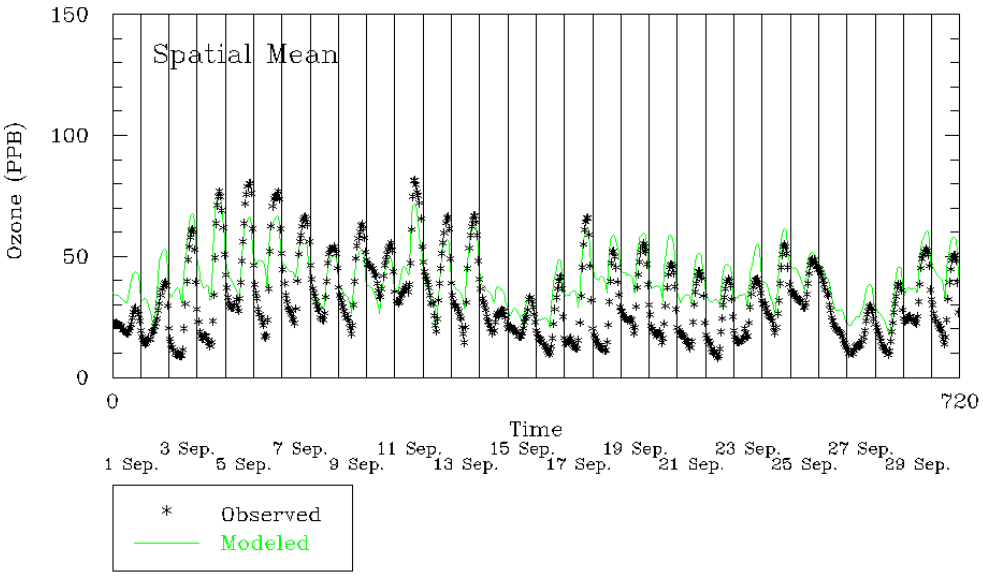


Neighborhood Spatial Mean 2002ga2a in the 12-NC-1hr



Neighborhood Spatial Mean 2002ga2a in the 12-NC-8hr

Figure 5.2-4 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For August



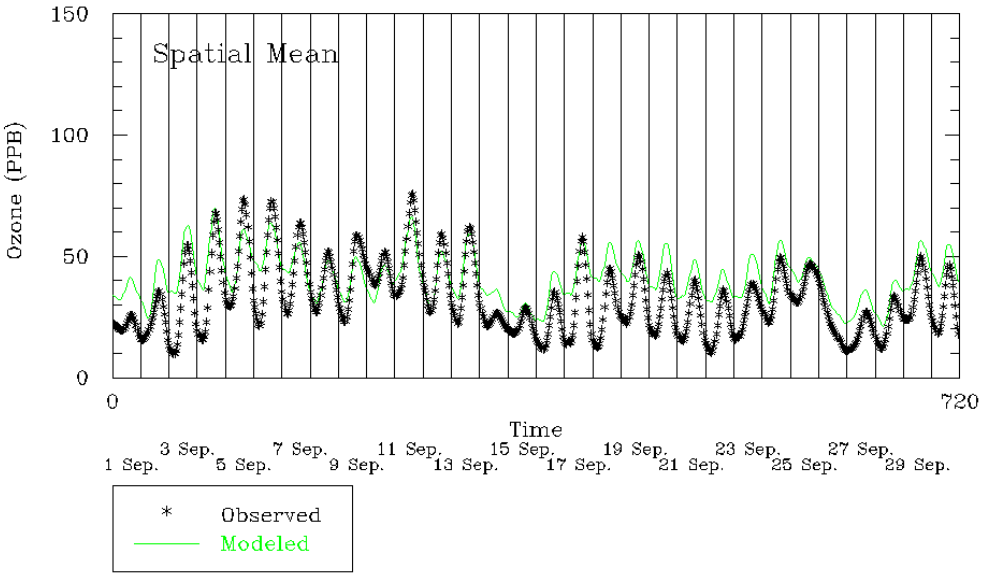
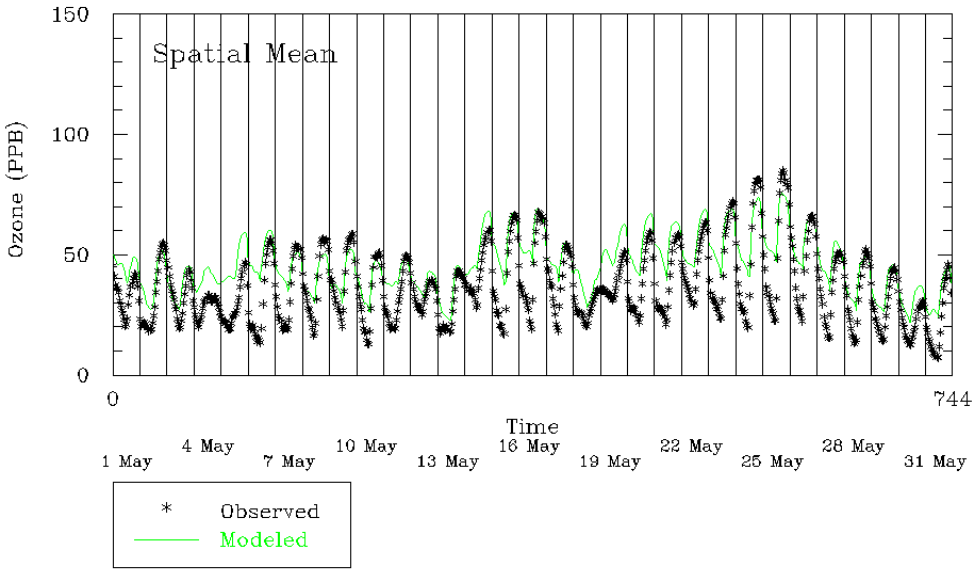


Figure 5.2-5 12km Domain – North Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For September

5.3 12 km Domain Time Series Plots – South Carolina

For South Carolina, the air quality model does an excellent job at capturing the diurnal pattern for both 1-hour and 8-hour ozone (Figures 5.3-1 through 5.3-5). The model under predicts the peak ozone values at times throughout the summer season as well as the overnight over prediction issue previously discussed. As with the North Carolina time series analysis, a portion of the month of May and the last few days of August and September show a more notable under prediction of the afternoon peak ozone concentrations. Overall, the air quality model continues to capture the various synoptic weather and air quality cycles quite well and is within acceptable tolerances for model performance.



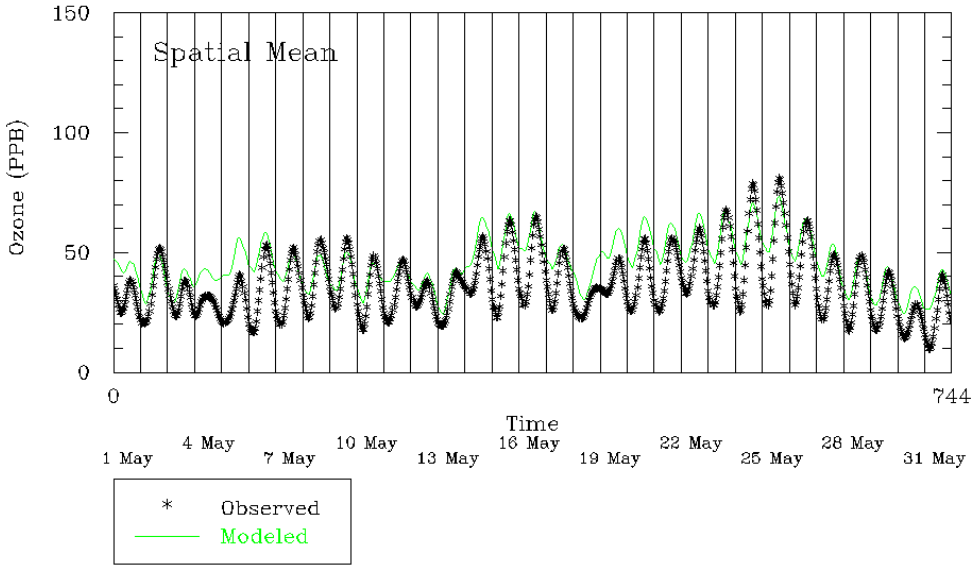
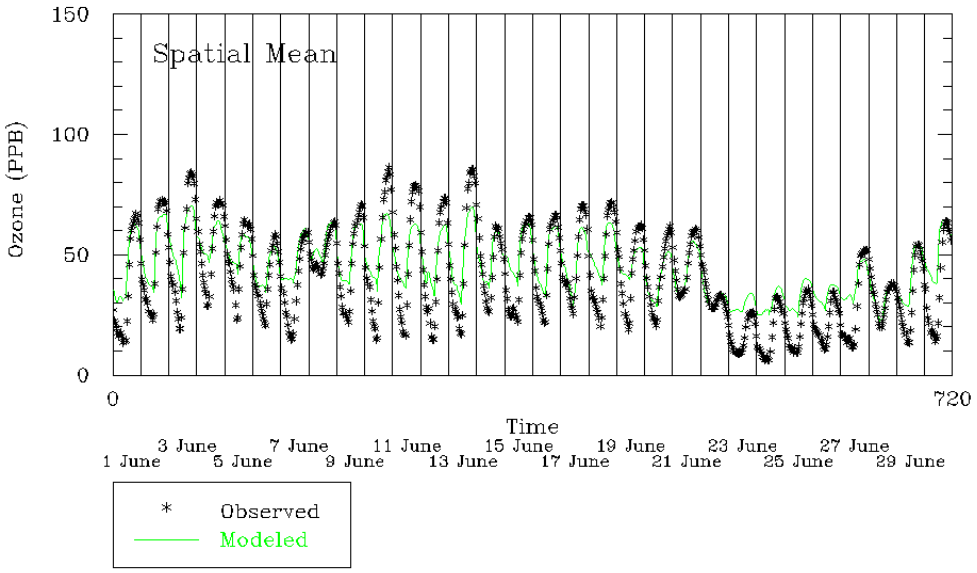


Figure 5.3-1 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For May



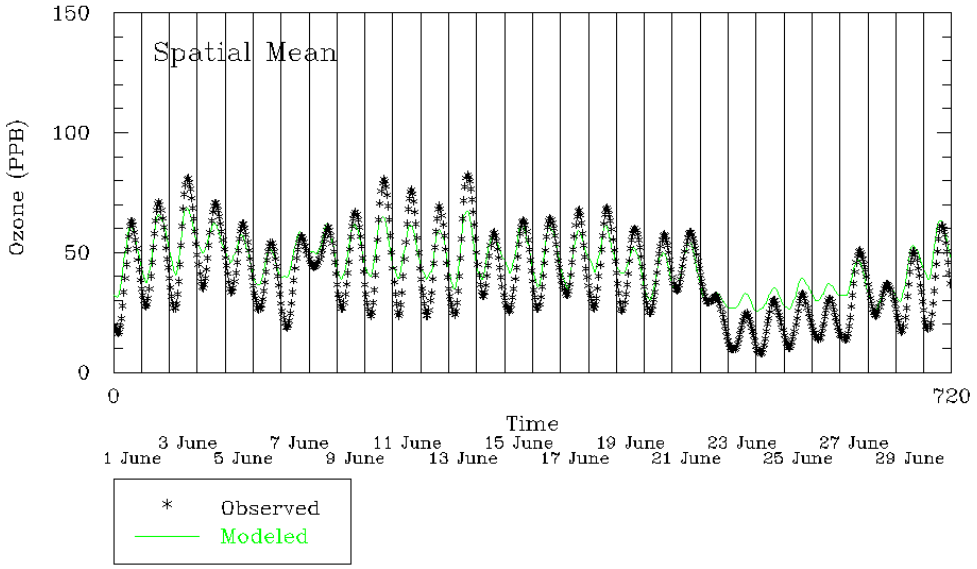
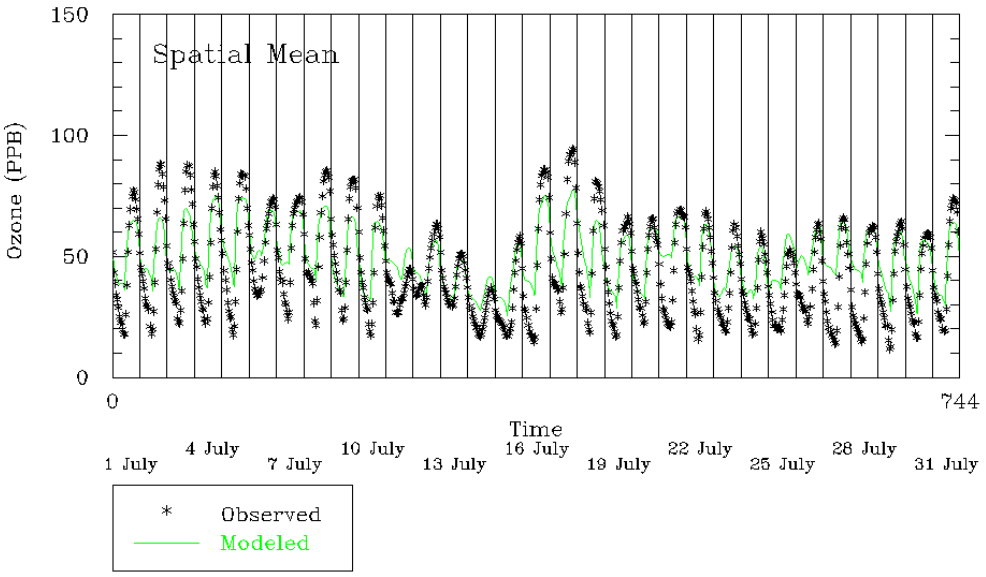


Figure 5.3-2 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For June



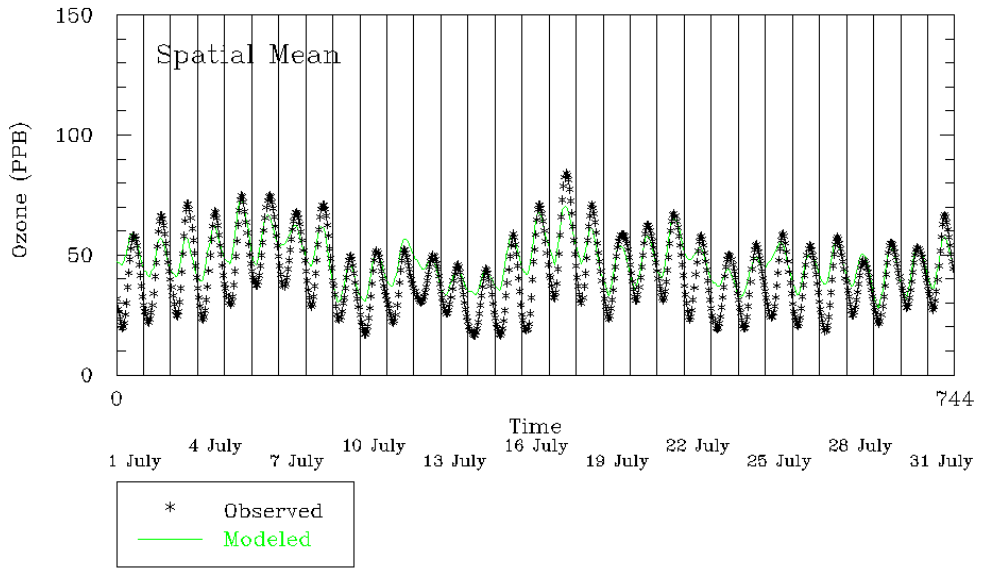
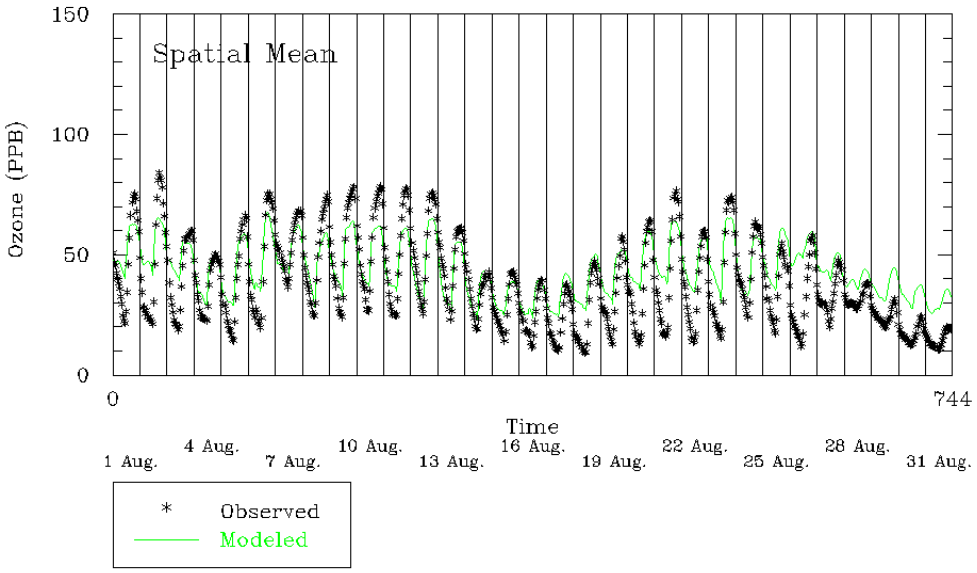


Figure 5.3-3 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For July



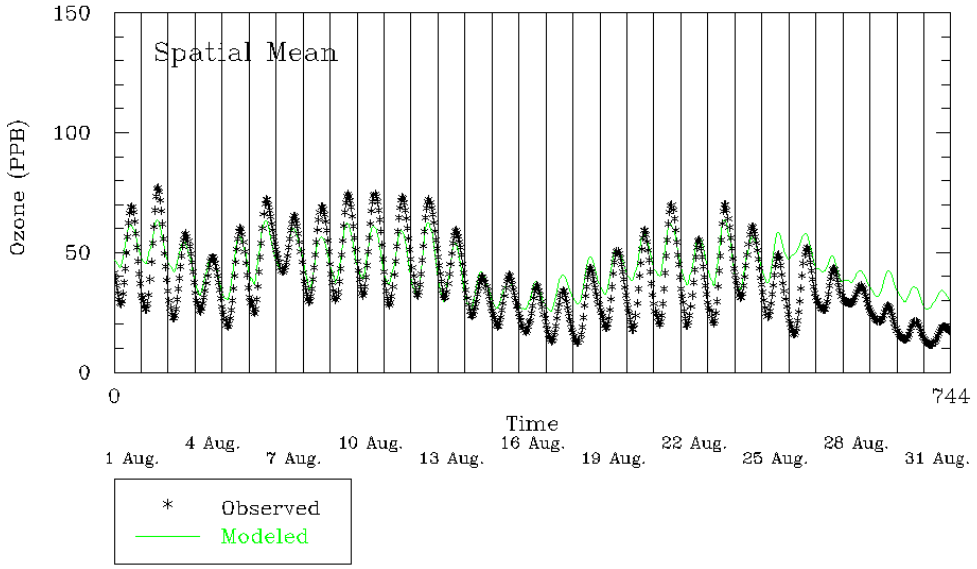
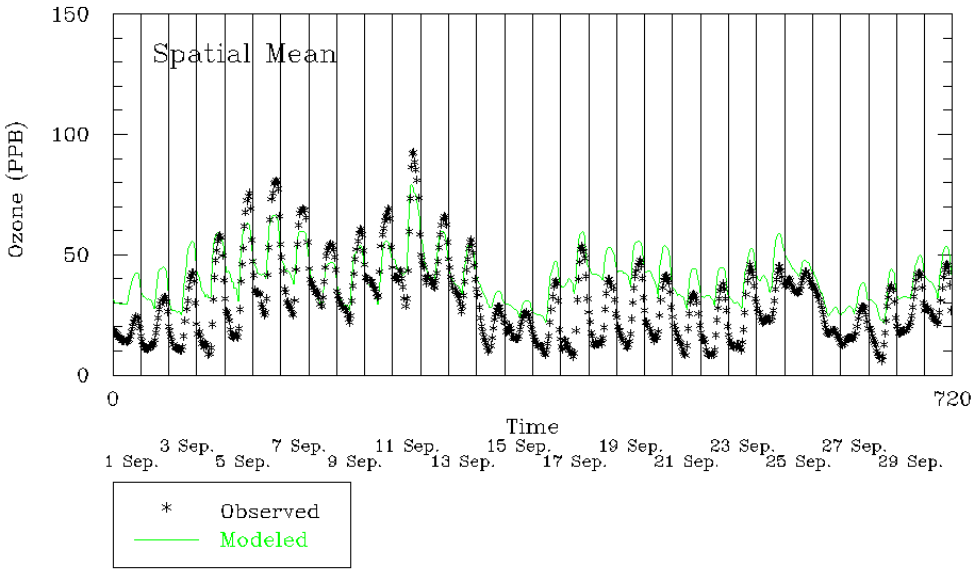


Figure 5.3-4 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For August



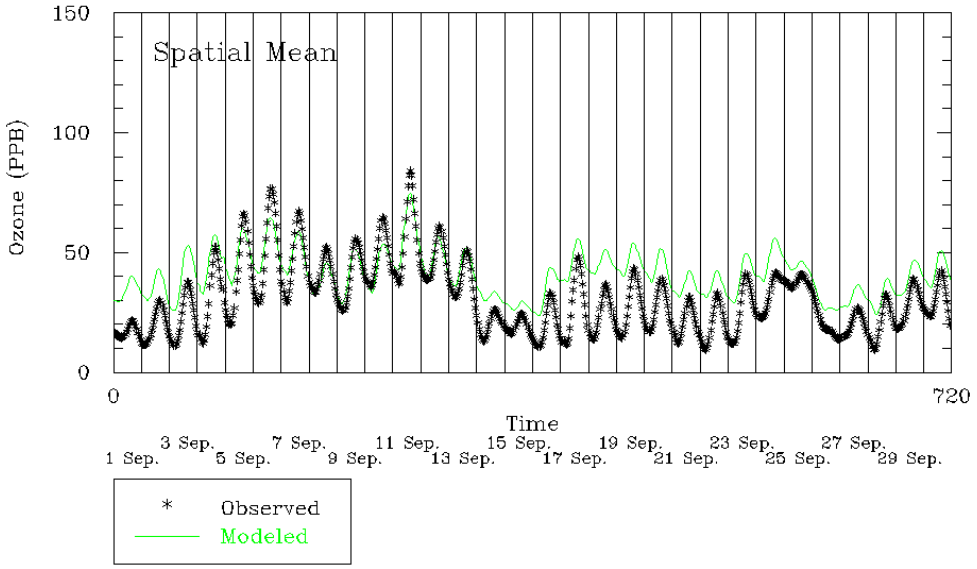


Figure 5.3-5 12km Domain – South Carolina 1-hour (top) And 8-hour (bottom) Time Series Plots For September

5.4 Metrolina Monitor Specific Time Series Plots

Finally, the time series for the individual ozone monitoring sites in the Metrolina region are present in Figures 5.4.1-1 through 5.4.8-5 on the following pages. There are 8 monitoring sites with 5 months presented for a total of 40 pages of 1-hour and 8-hour times series

As with the larger domain time series plots and analyses presented earlier in this section, the air quality model tends to slightly under predict peak 1-hour and 8-hour ozone values. The over prediction of the nighttime minimum issue is more noticeable in the individual monitoring site time series, especially this more urbanized collection of sites due to the higher night time nitrogen oxide (NOx) environment found in such a metropolitan region. The NOx emissions titrate the ozone after sunset and the ozone levels decrease dramatically. The air quality model does not replicate this type of phenomenon very well. Again, the nighttime minimum over prediction is not an issue with respect to the modeled attainment test and is not of significant concern in this modeling exercise. The ability of the air quality model to very accurately capture the synoptic cycles from high ozone episodes to very clean periods is best demonstrated in these individual monitor time series. Based on all of the data presented in these time series plots, NCDAQ concludes that the air quality modeling continues to meet all requirements for further application in the modeled attainment test.

Monitor: Arrowood (37-119-1005)
Month: May

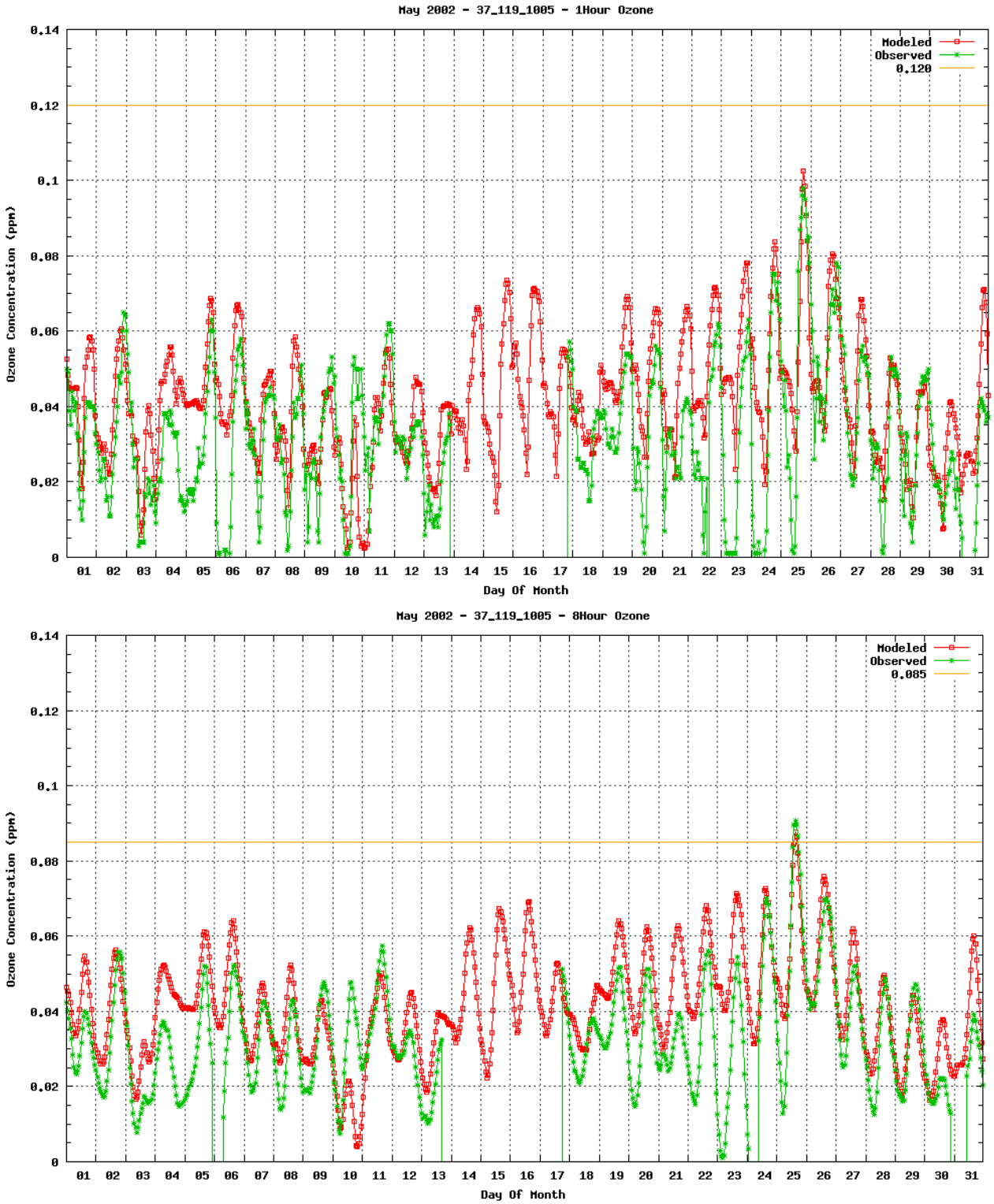


Figure 5.4.1-1 Arrowood 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: Arrowood (37-119-1005)
Month: June

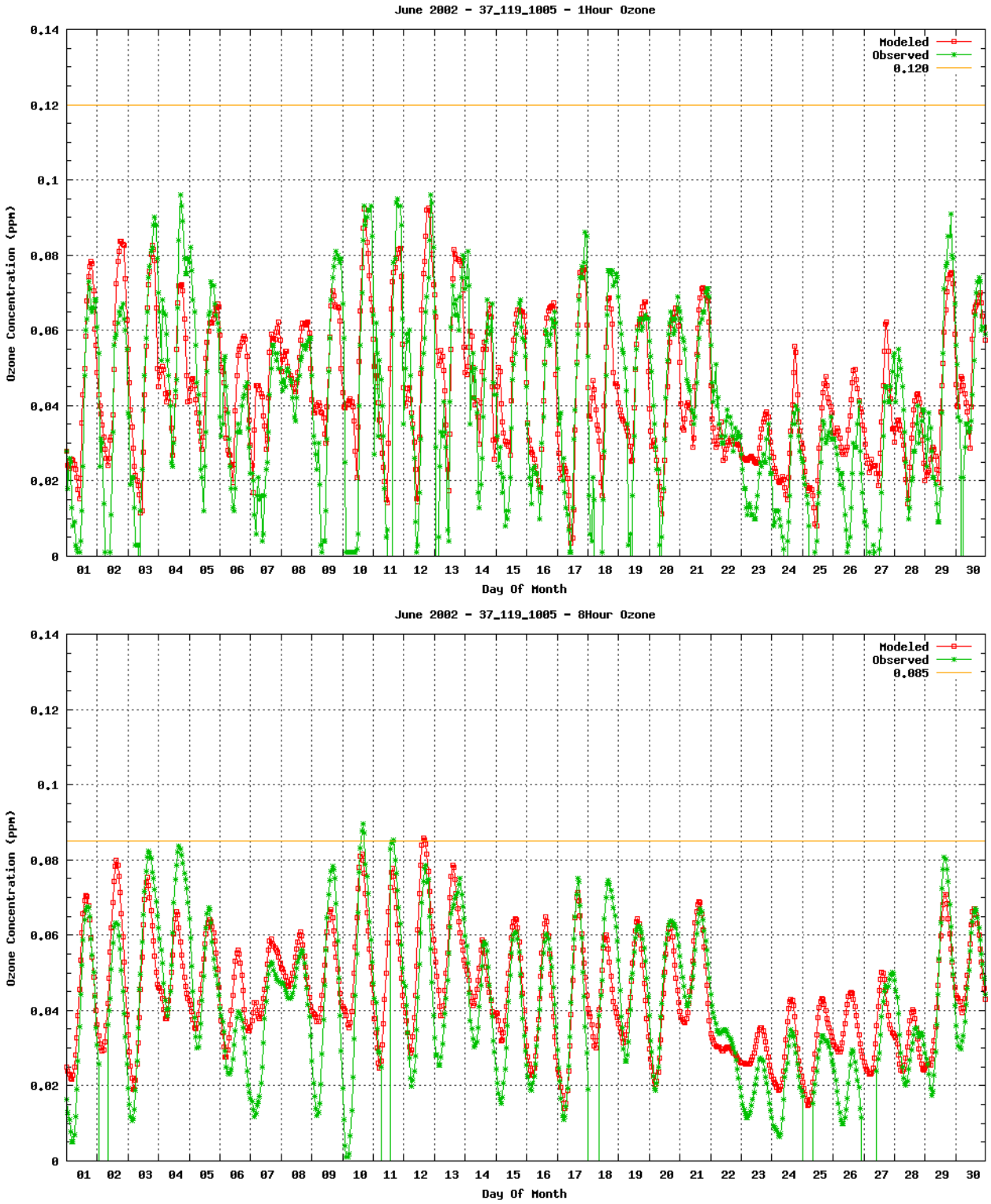


Figure 5.4.1-2 Arrowood 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: Arrowood (37-119-1005)
Month: July

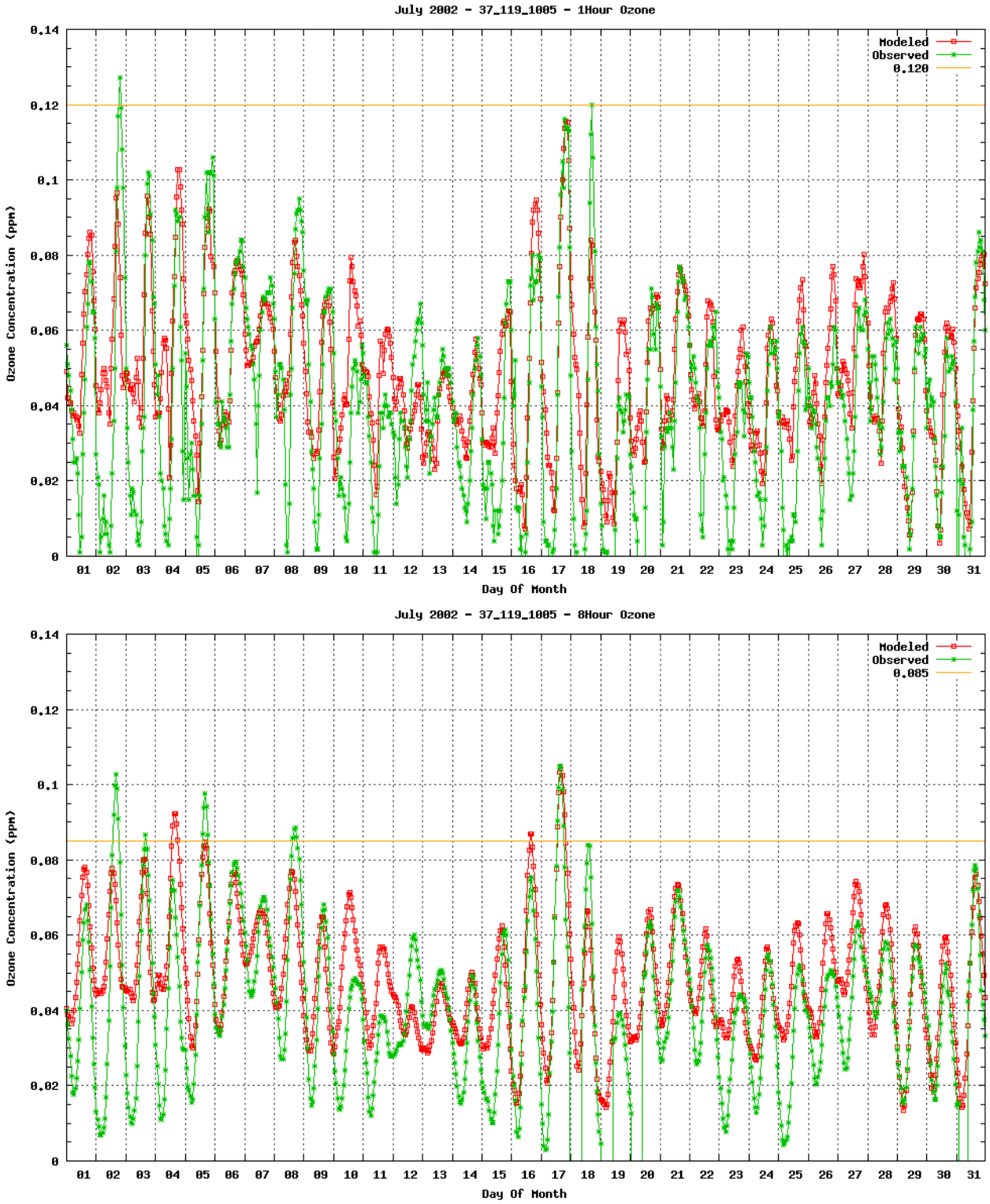


Figure 5.4.1-3 Arrowood 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: Arrowood (37-119-1005)
Month: August

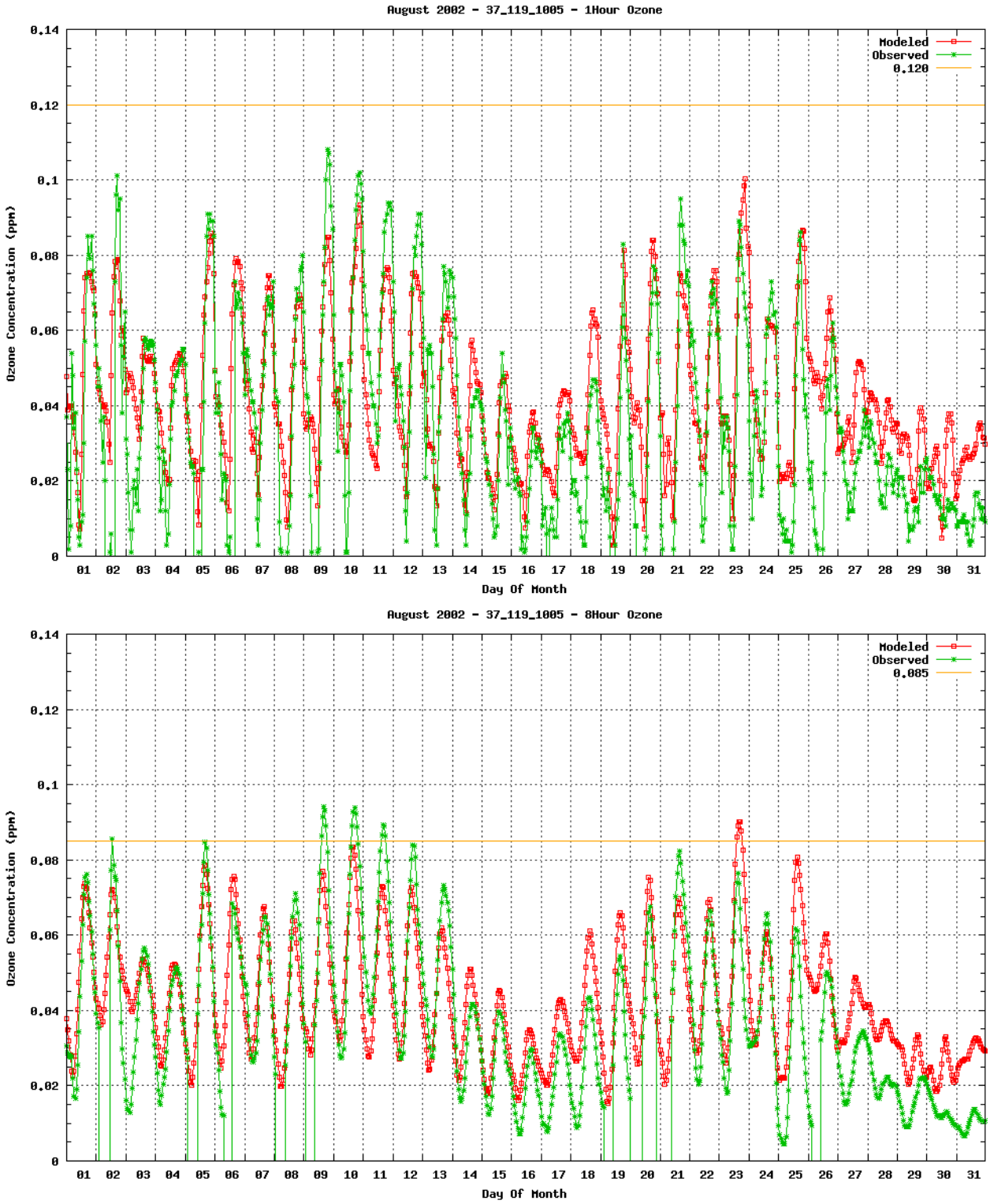


Figure 5.4.1-4 Arrowood 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: Arrowood (37-119-1005)
Month: September

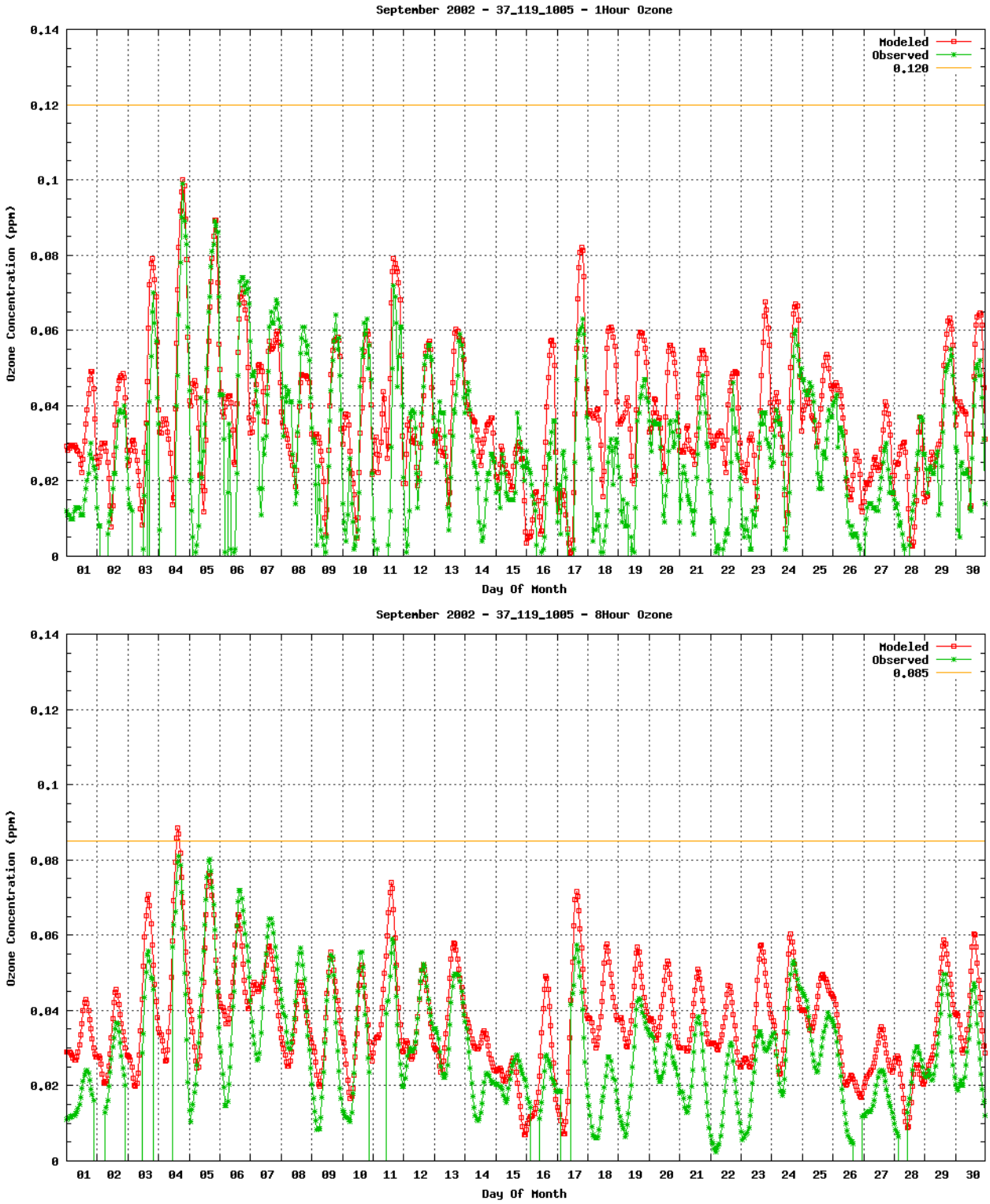


Figure 5.4.1-5 Arrowood 1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: County Line (37-119-1009)
Month: May

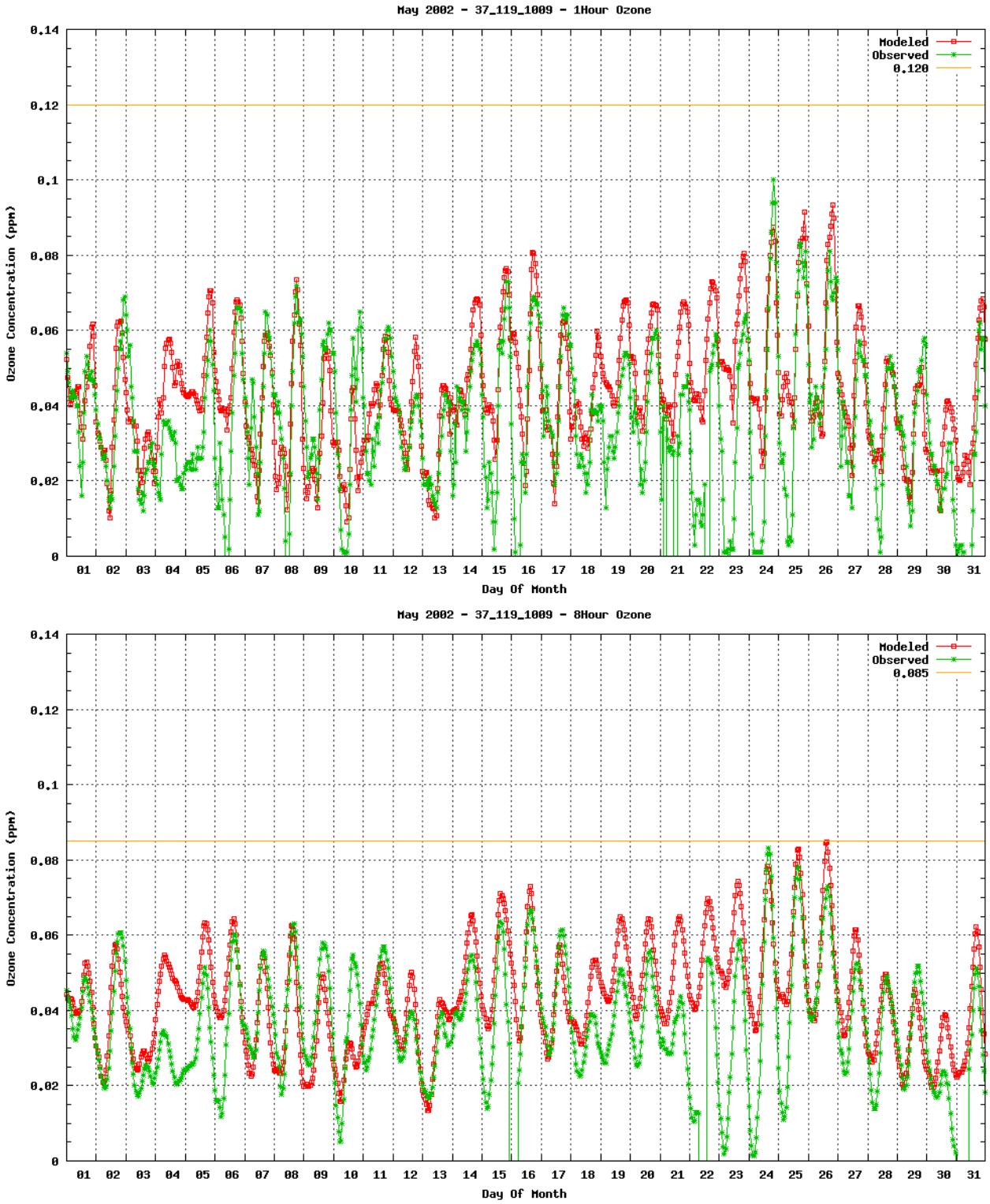


Figure 5.4.2-1 County Line 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: County Line (37-119-1009)
Month: June

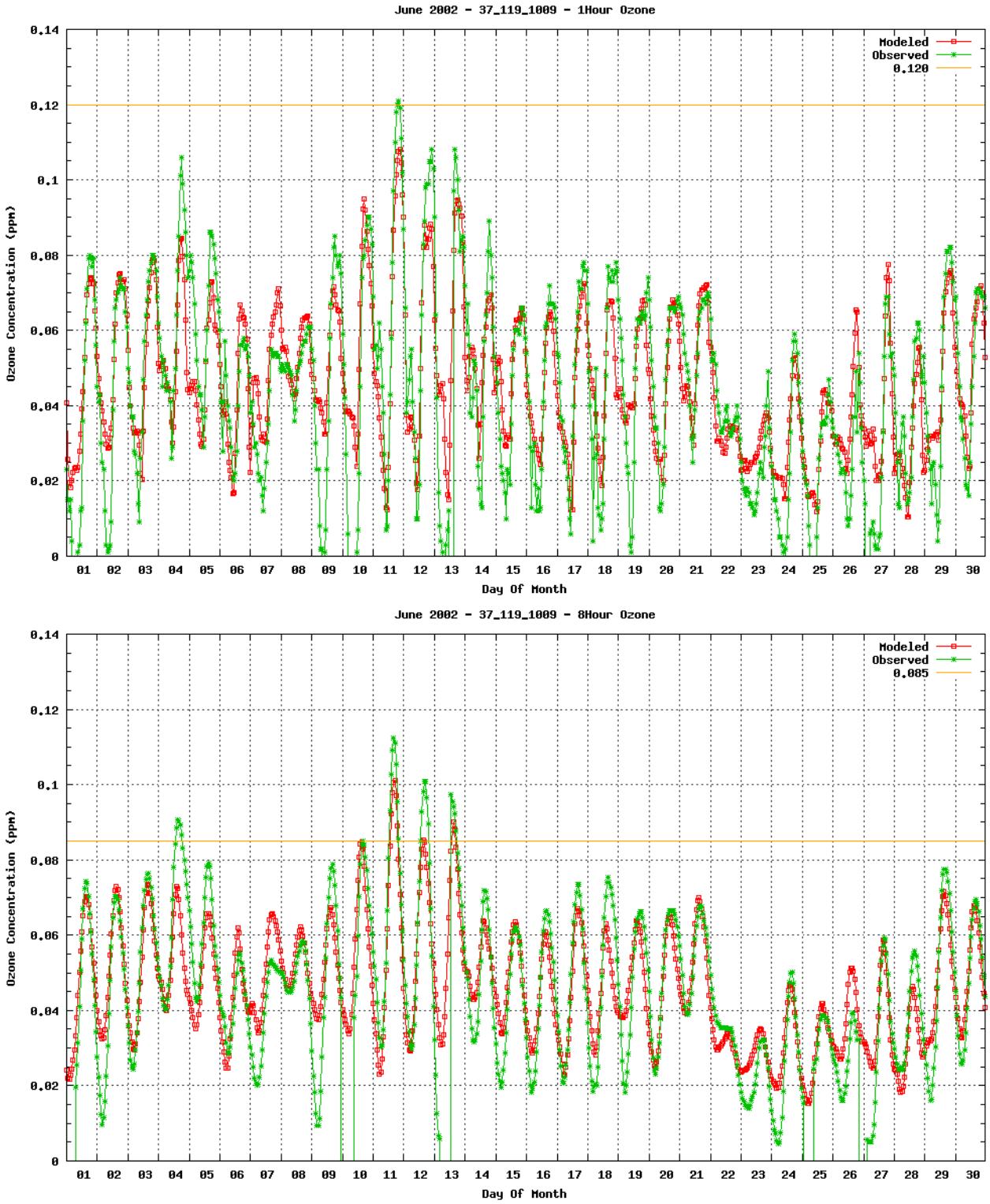


Figure 5.4.2-2 County Line 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: County Line (37-119-1009)
Month: July

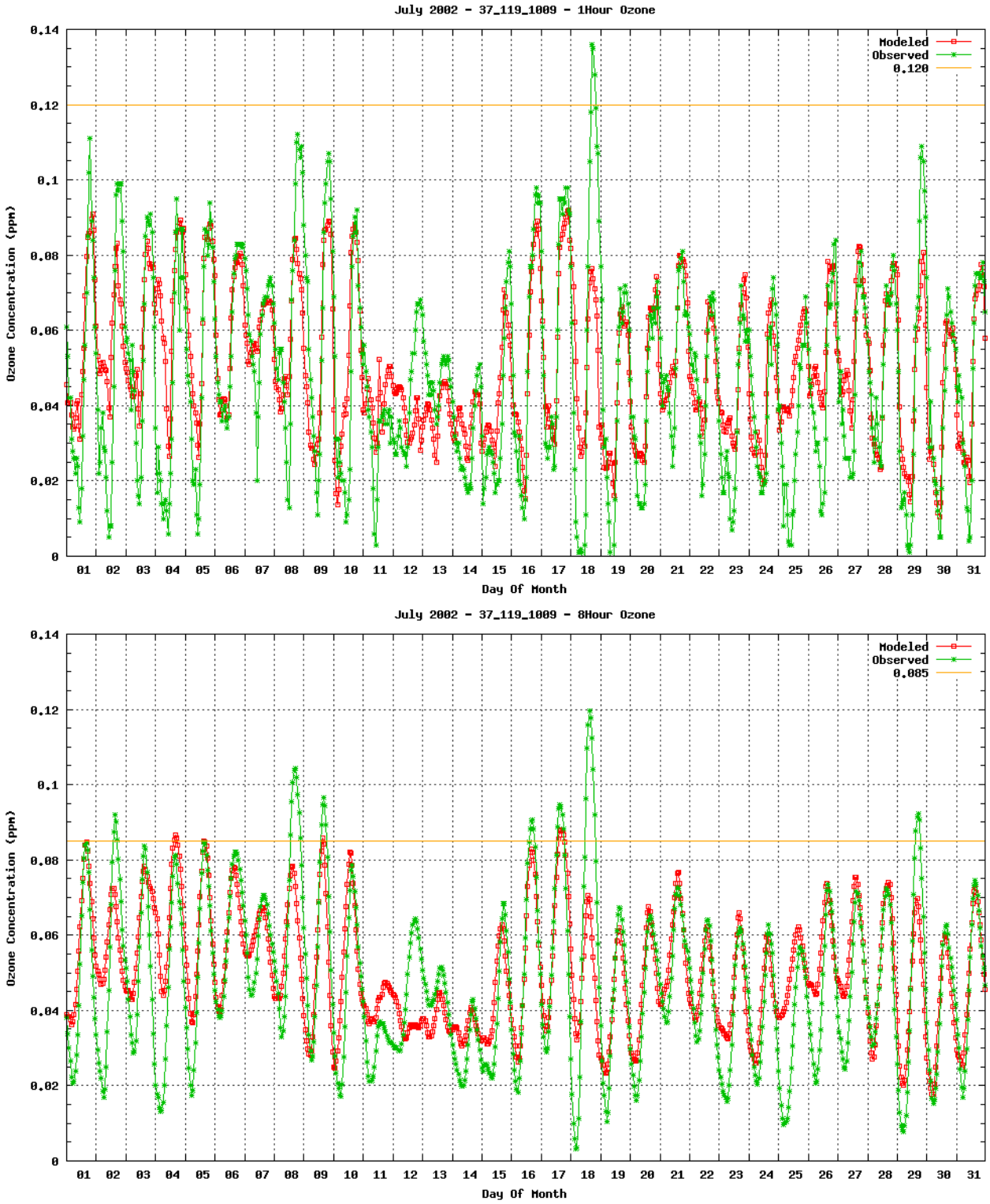


Figure 5.4.2-3 County Line 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: County Line (37-119-1009)
Month: August

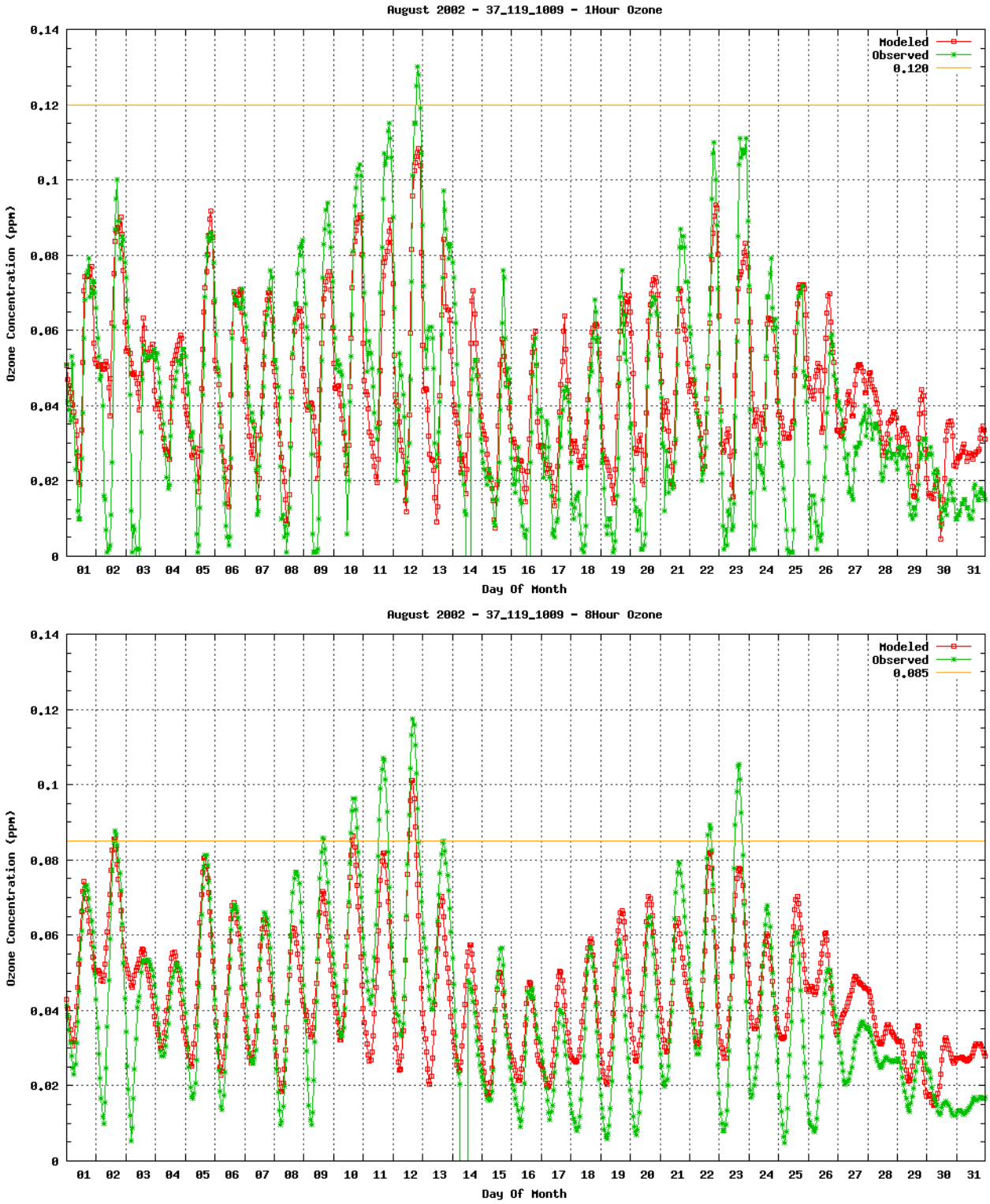


Figure 5.4.2-4 County Line 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: County Line (37-119-1009)
Month: September

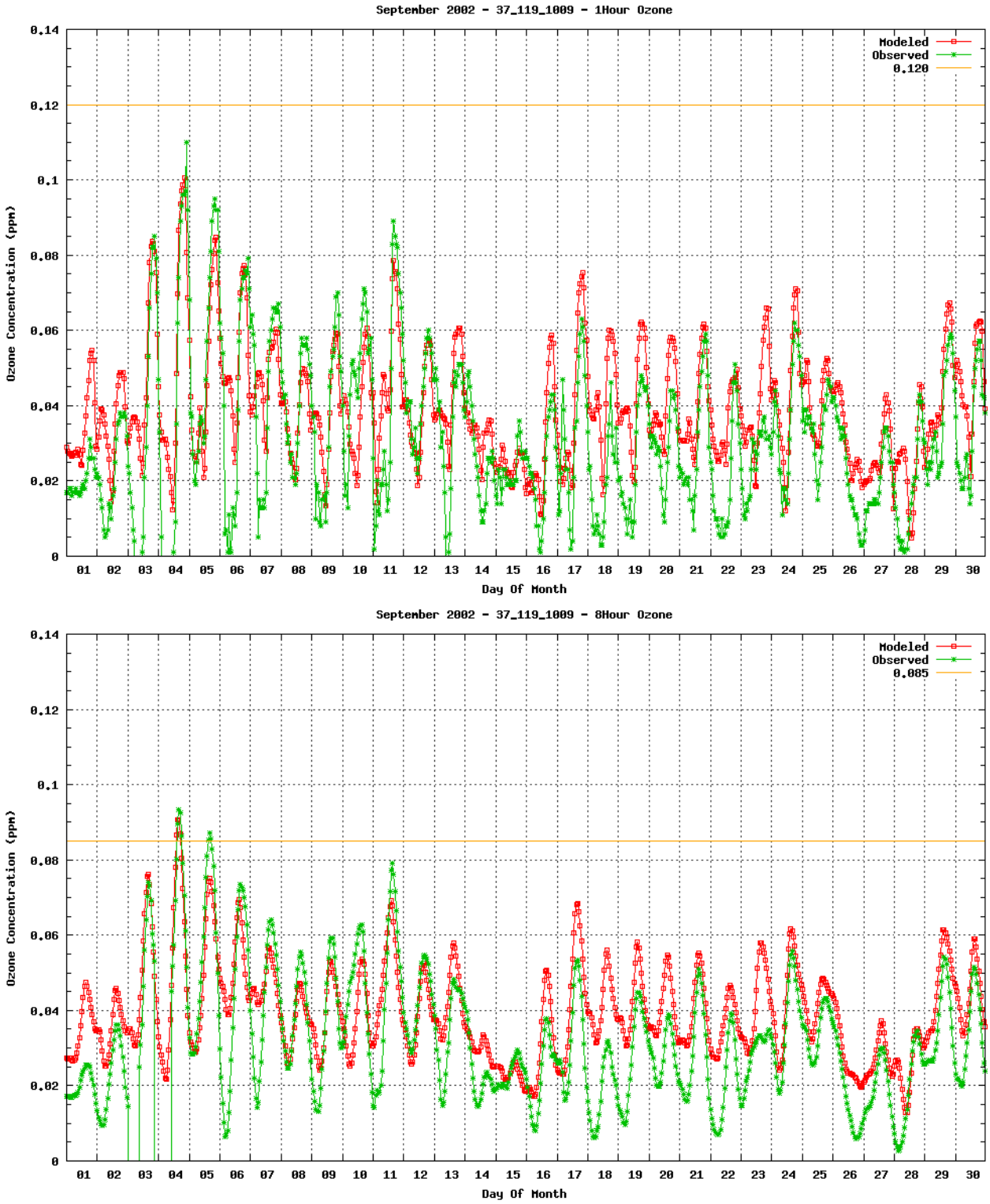


Figure 5.4.2-5 County Line1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: Crouse (37-109-0004)
Month: May

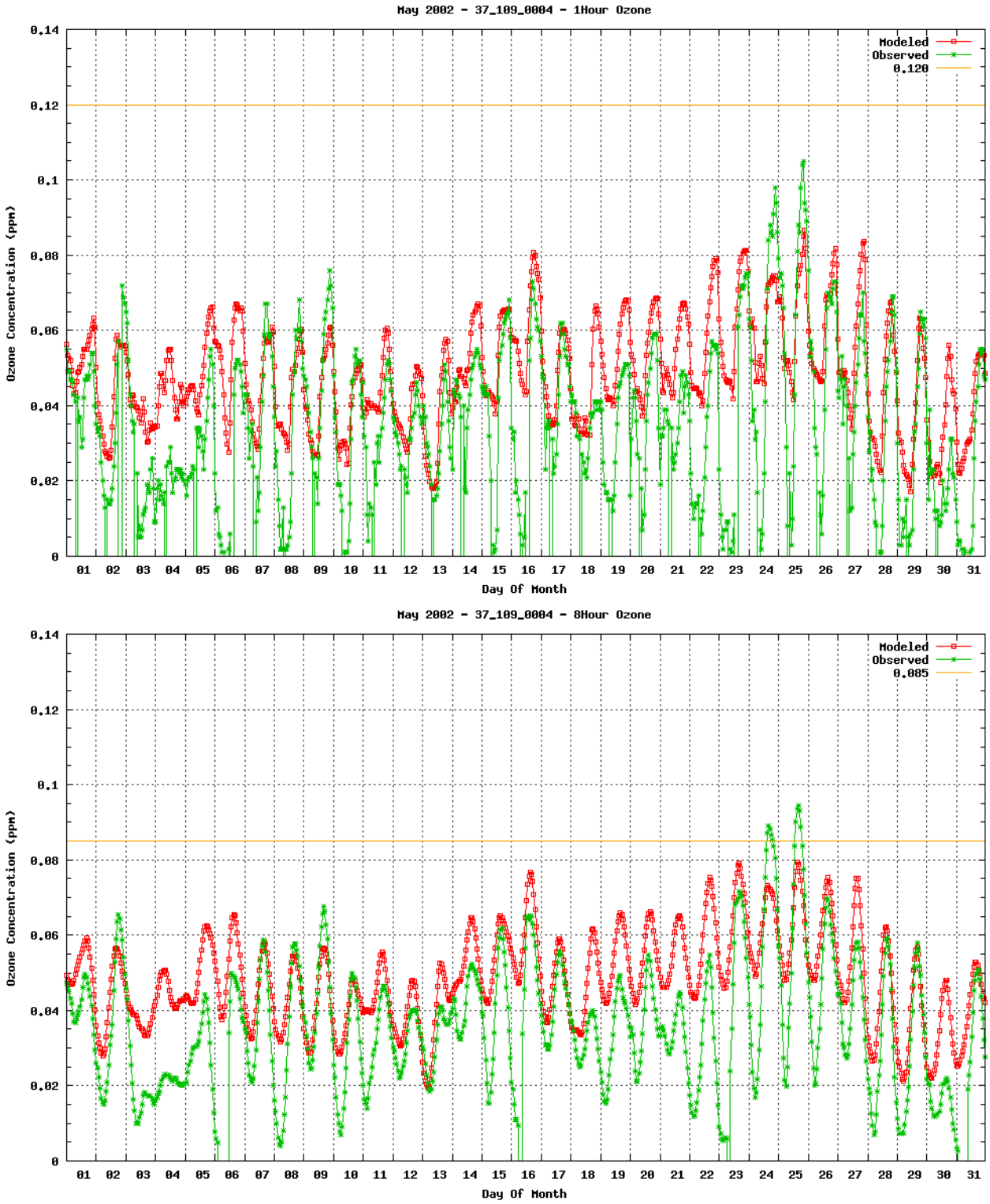


Figure 5.4.3-1 Crouse 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: Crouse (37-109-0004)
Month: June

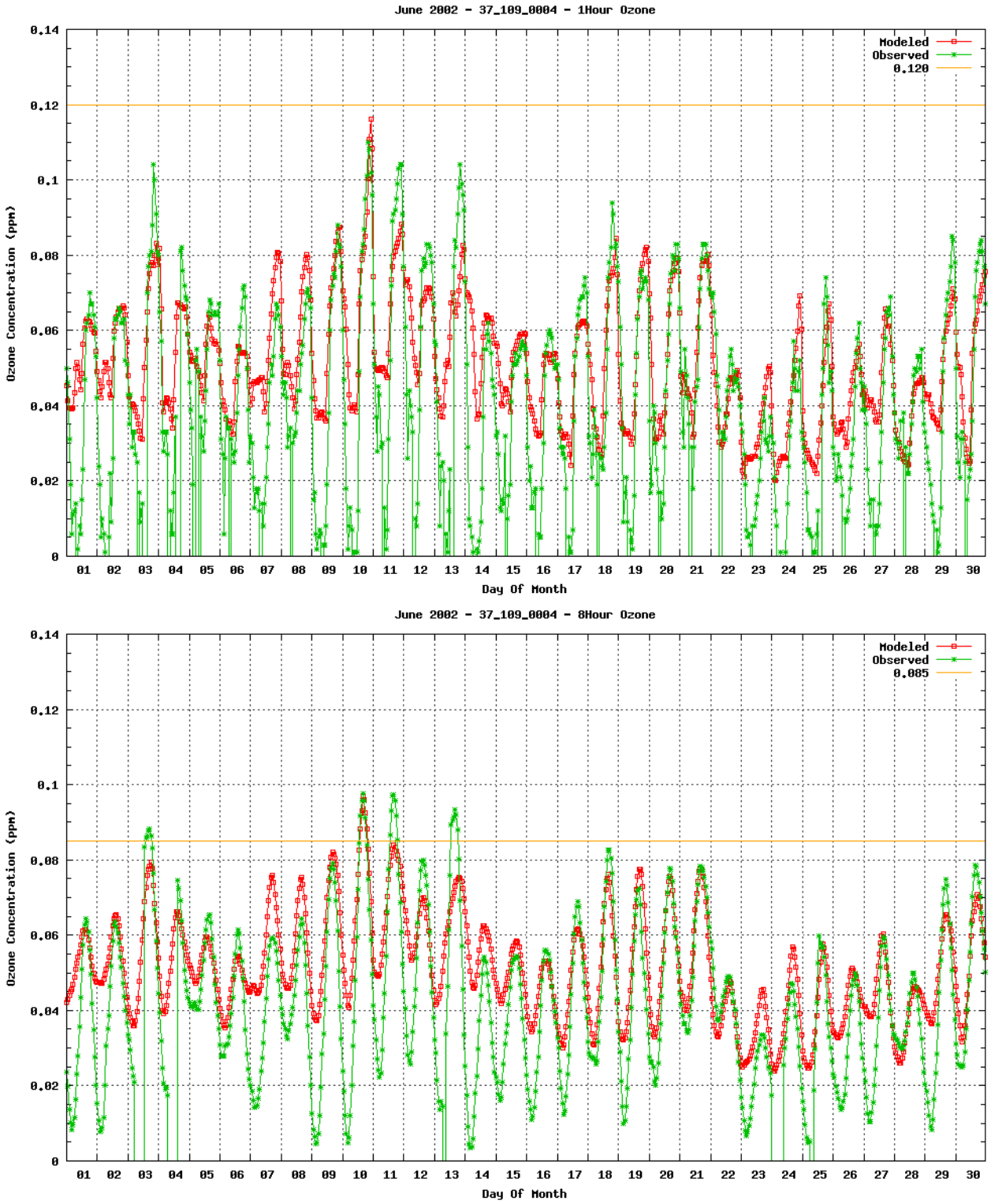


Figure 5.4.3-2 Crouse 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: Crouse (37-109-0004)
Month: July

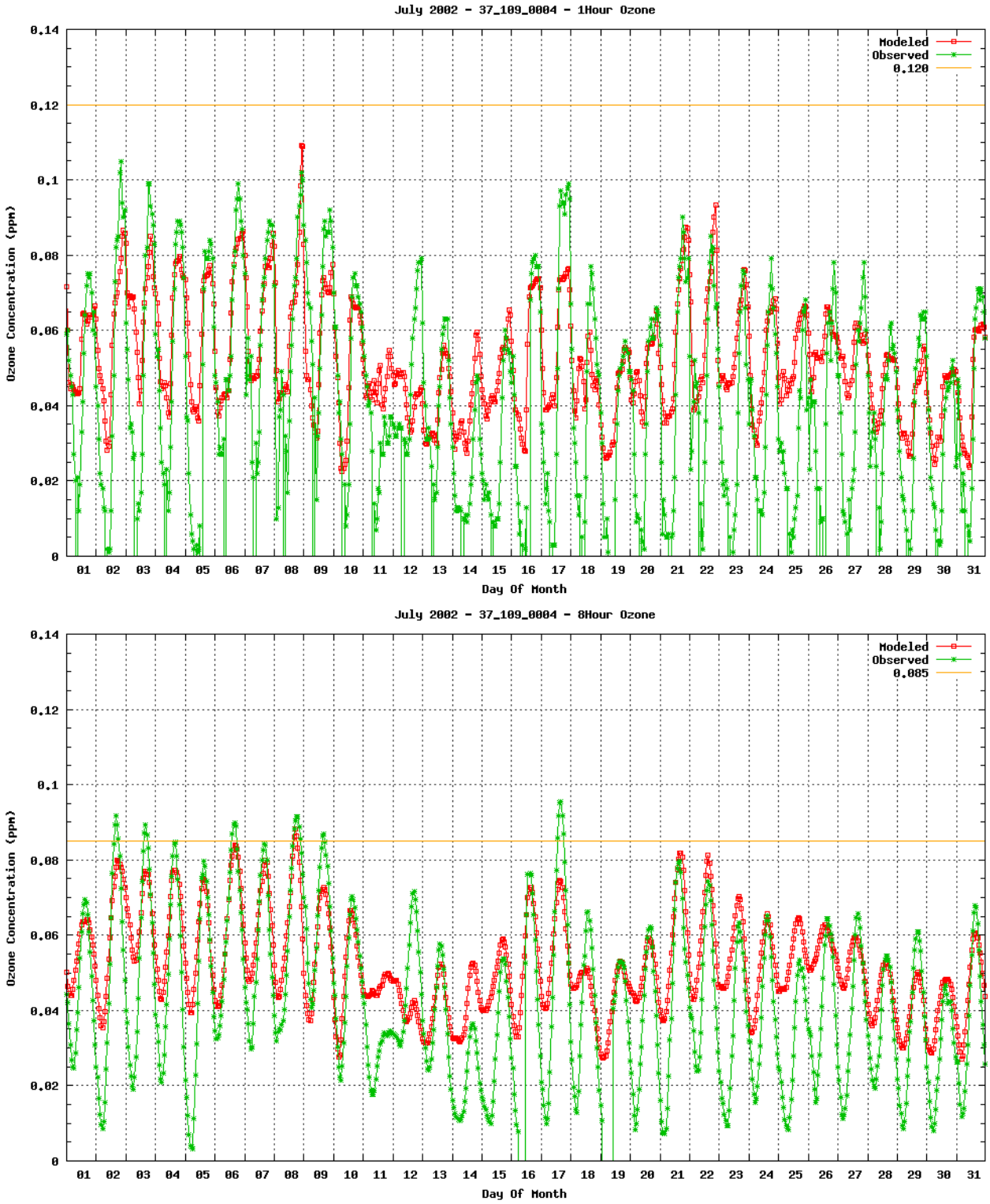


Figure 5.4.3-3 Crouse 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: Crouse (37-109-0004)
Month: August

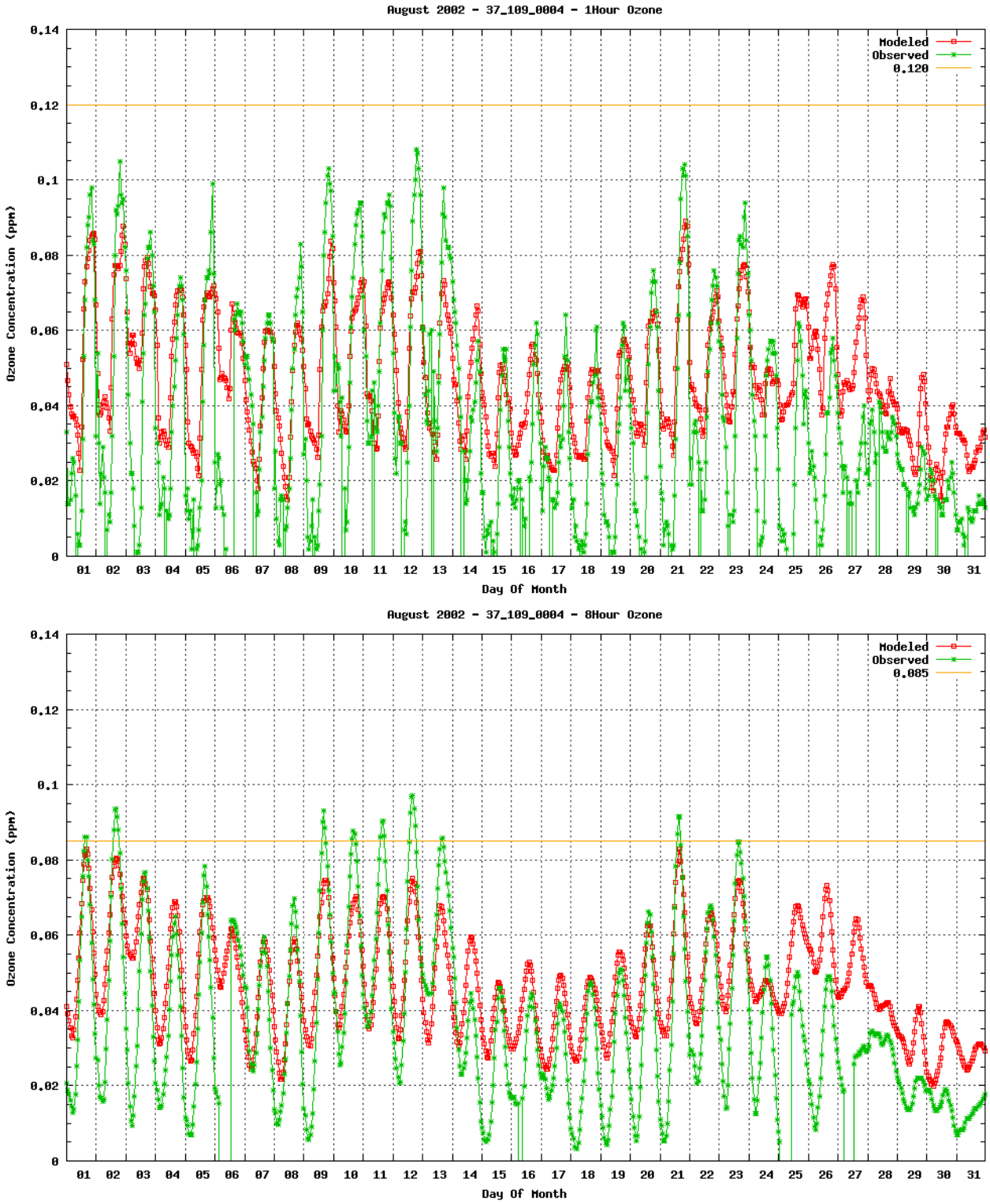


Figure 5.4.3-4 Crouse 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: Crouse (37-109-0004)
Month: September

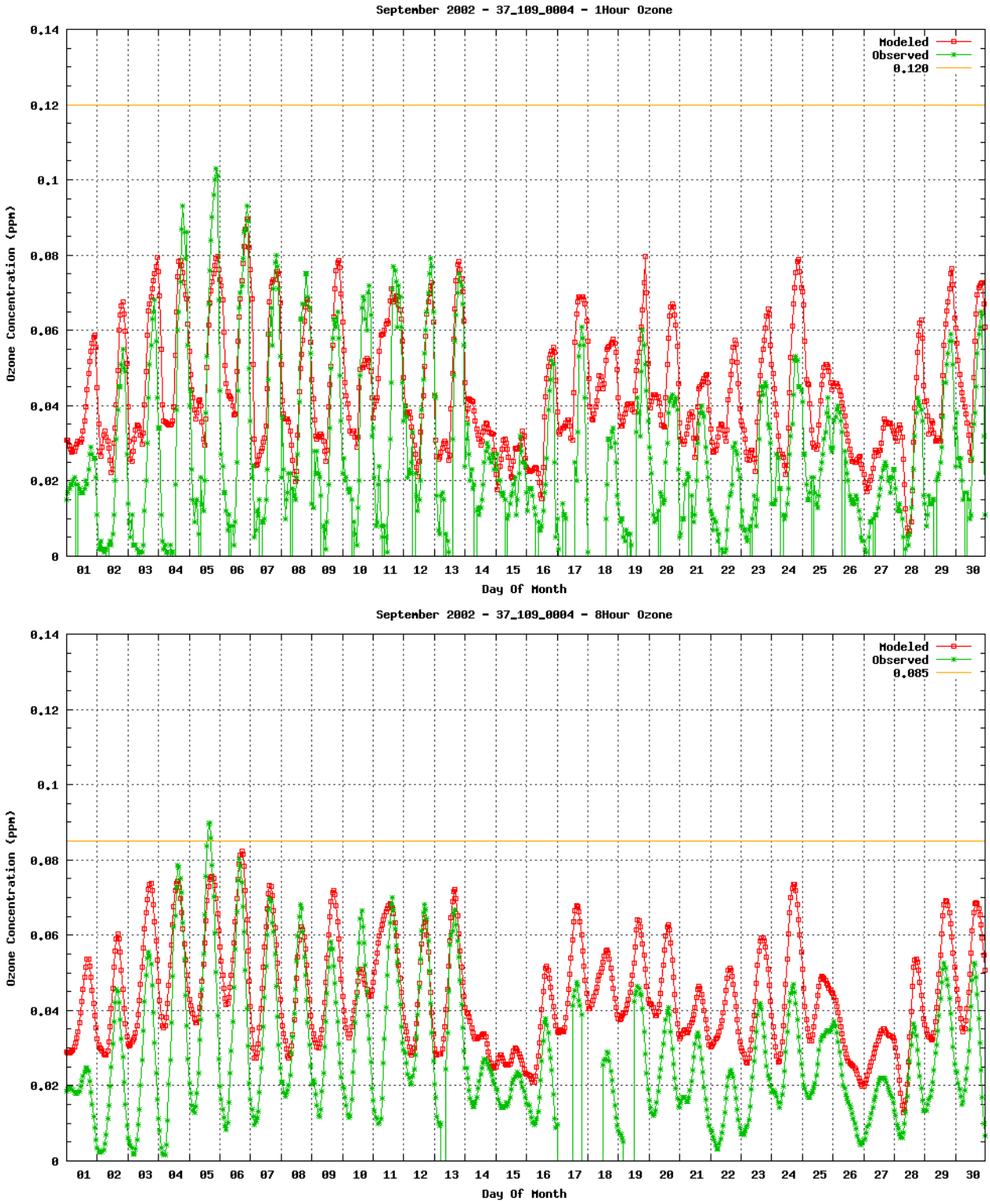


Figure 5.4.3-5 Crouse 1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: Enochville (37-159-0022)
Month: May

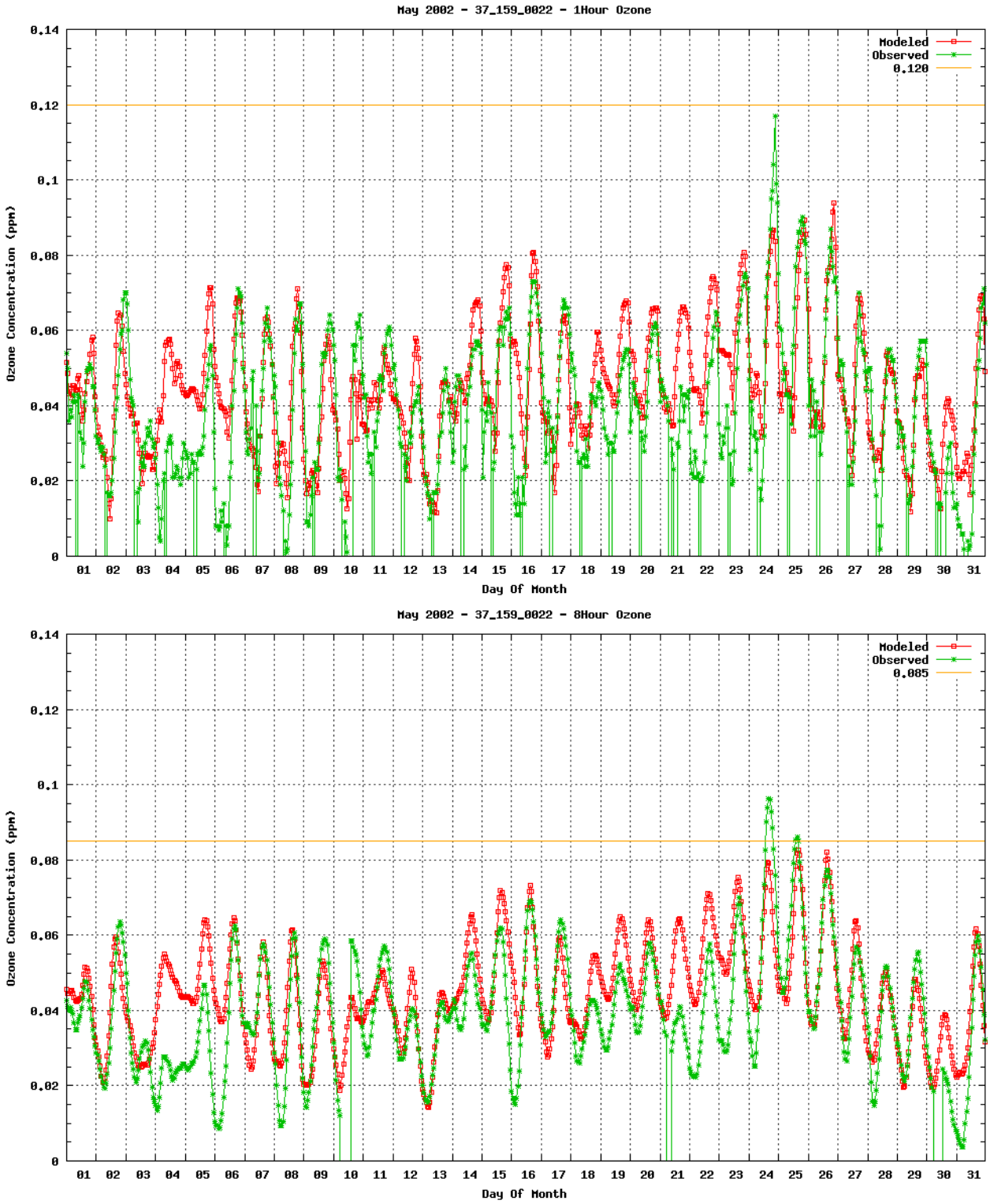


Figure 5.4.4-1 Enochville 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: Enochville (37-159-0022)
Month: June

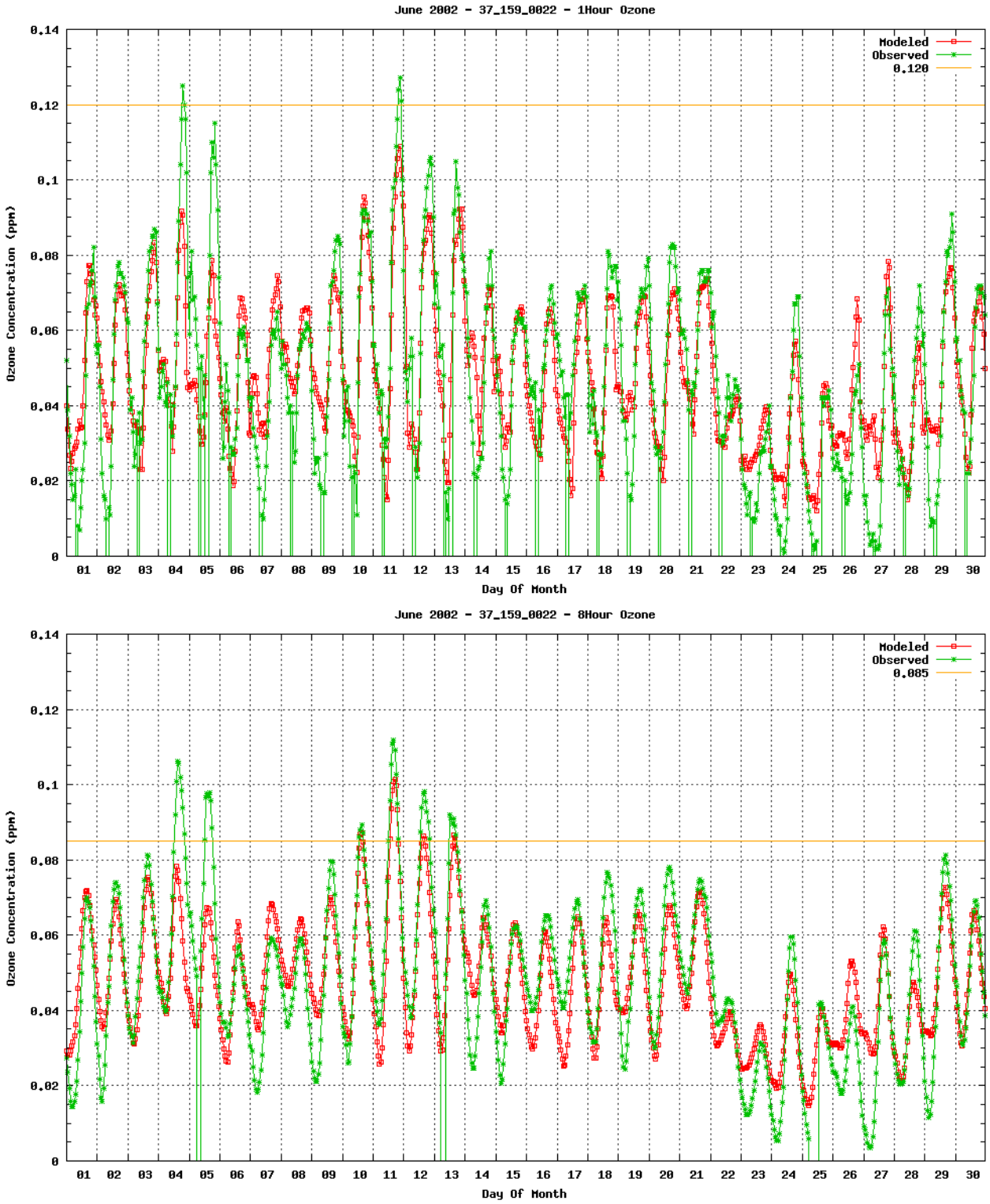


Figure 5.4.4-2 Enochville 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: Enochville (37-159-0022)
Month: July

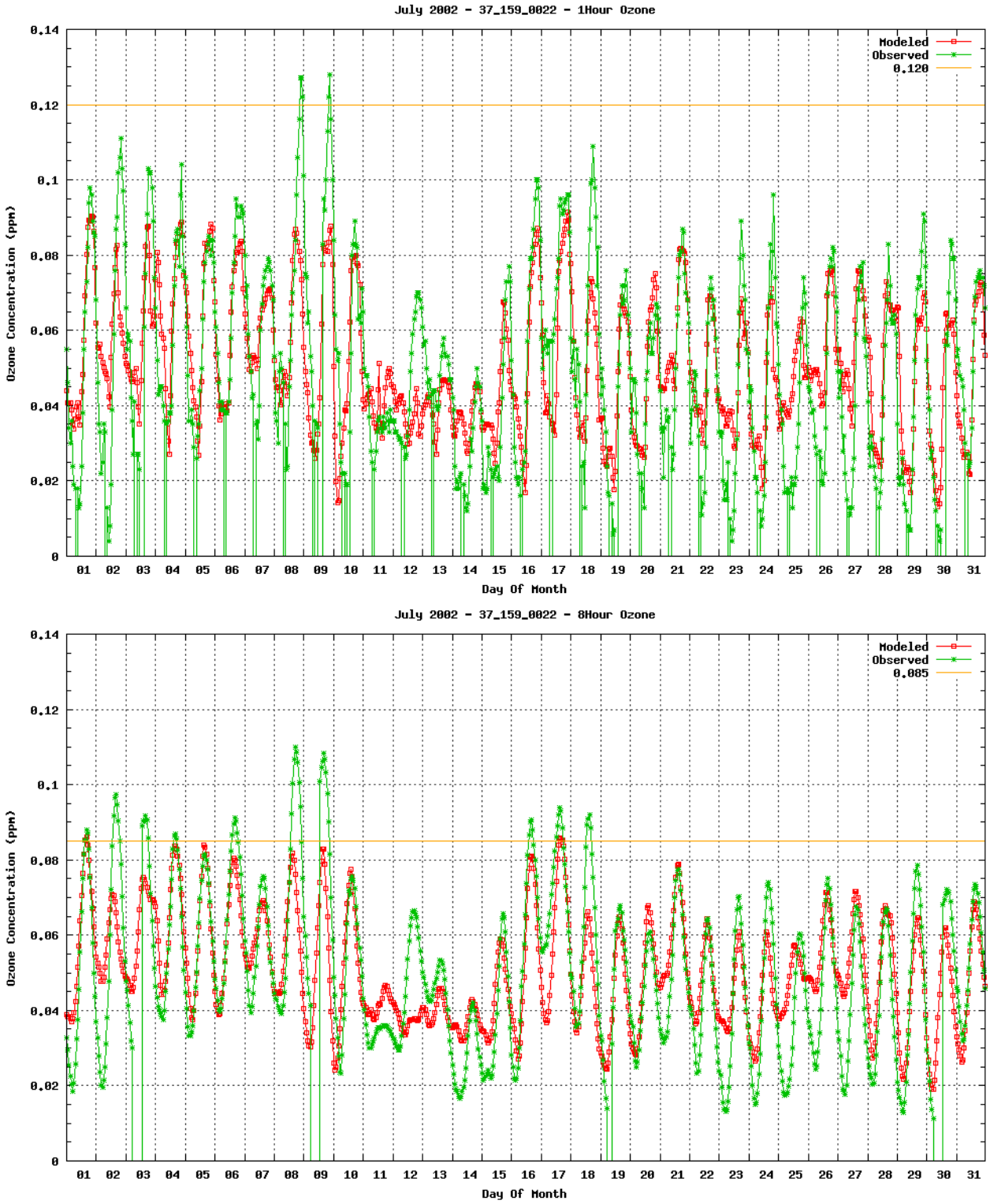


Figure 5.4.4-3 Enochville 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: Enochville (37-159-0022)
Month: August

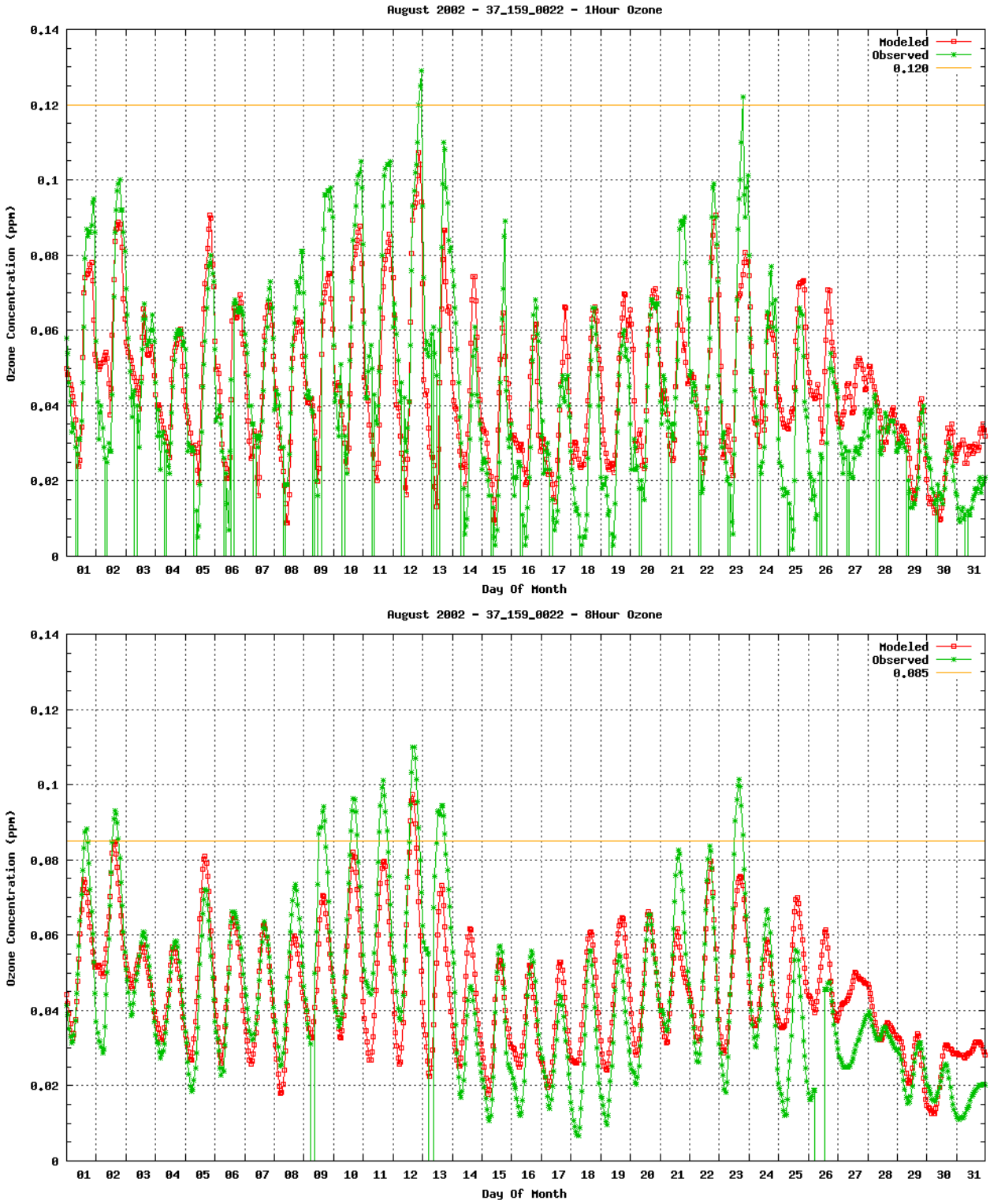


Figure 5.4.4-4 Enochville 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: Enochville (37-159-0022)
Month: September

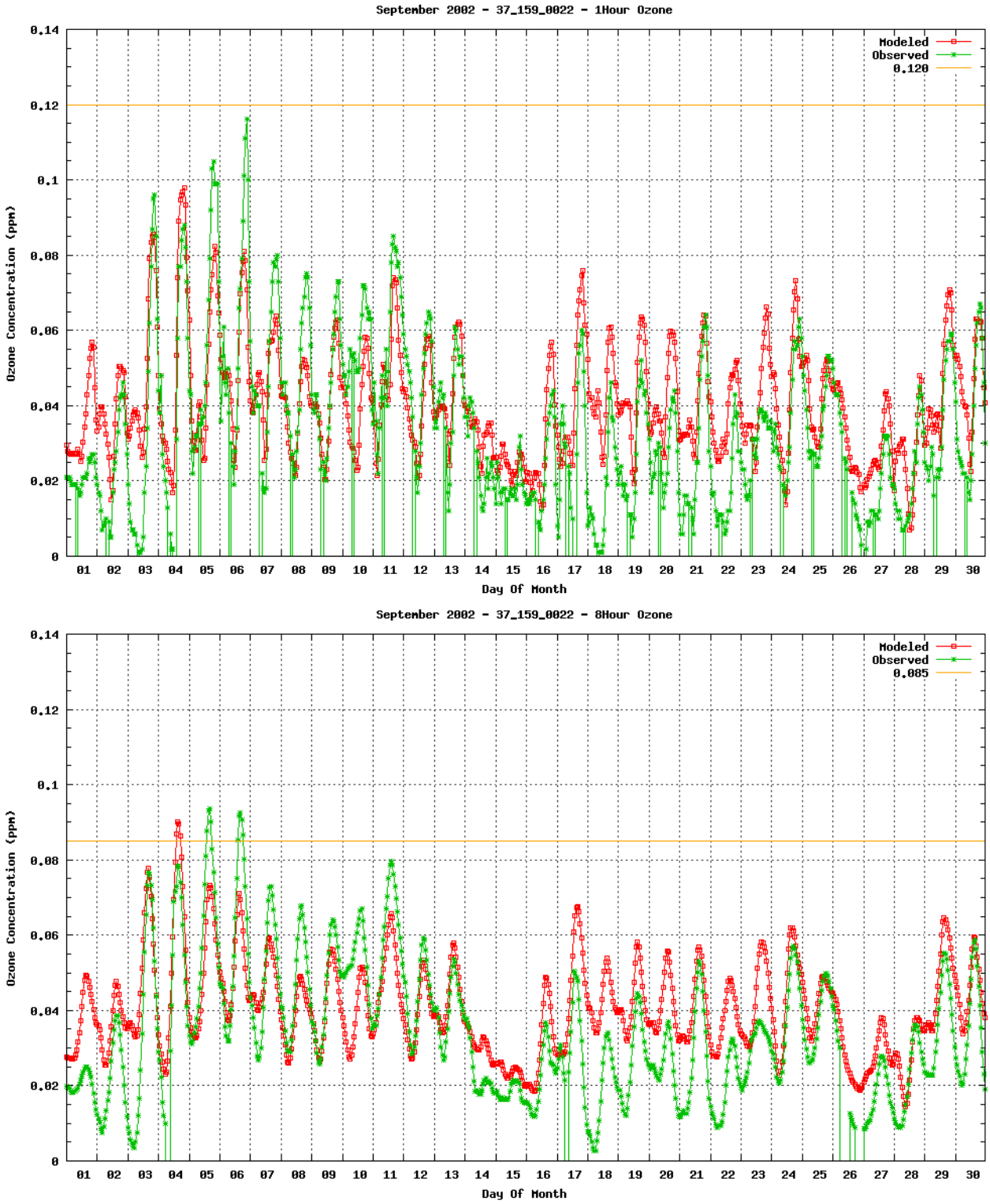


Figure 5.4.4-5 Enochville 1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: Garinger (37-119-0041)
Month: May

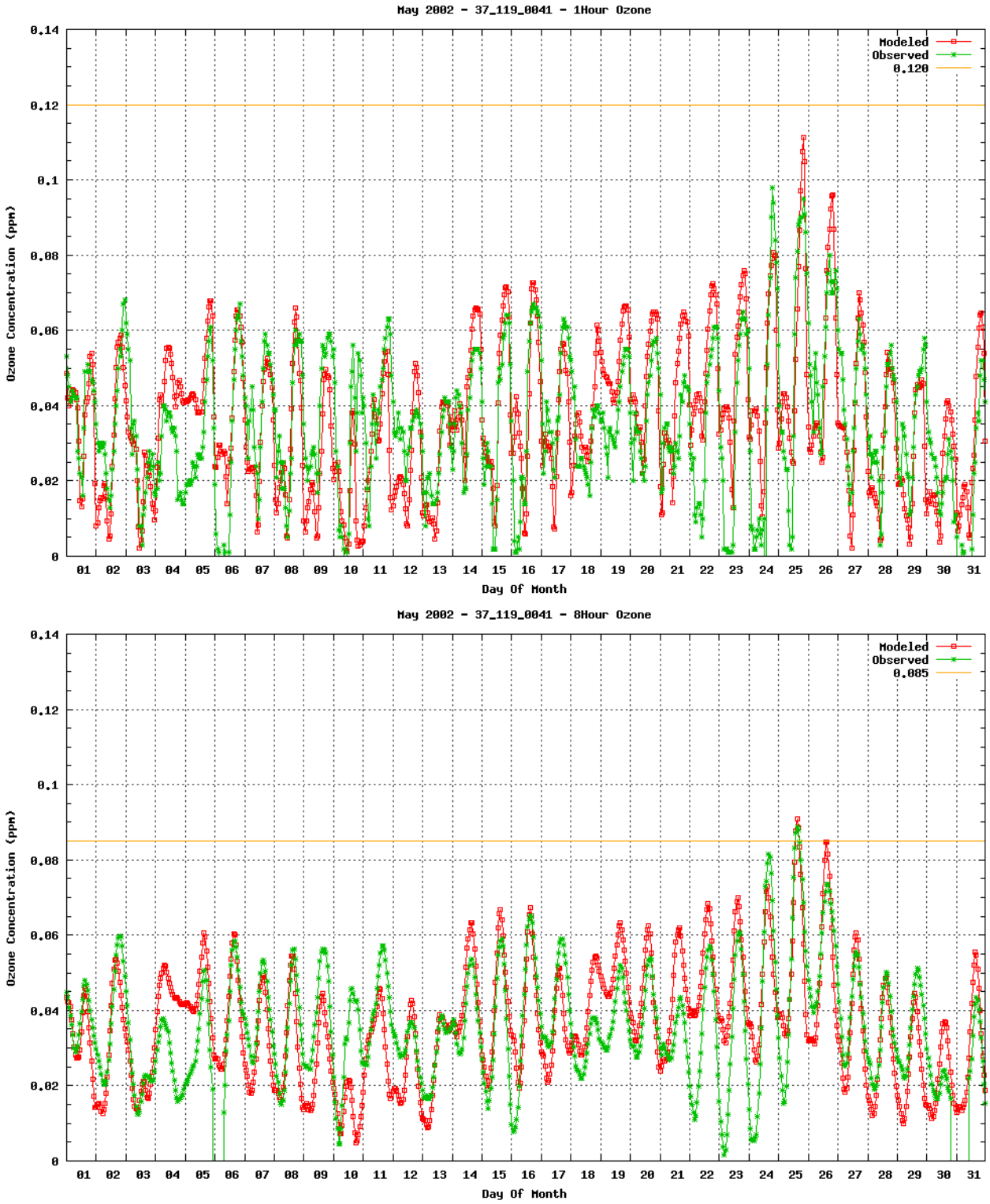


Figure 5.4.5-1 Garinger 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: Garinger (37-119-0041)
Month: June

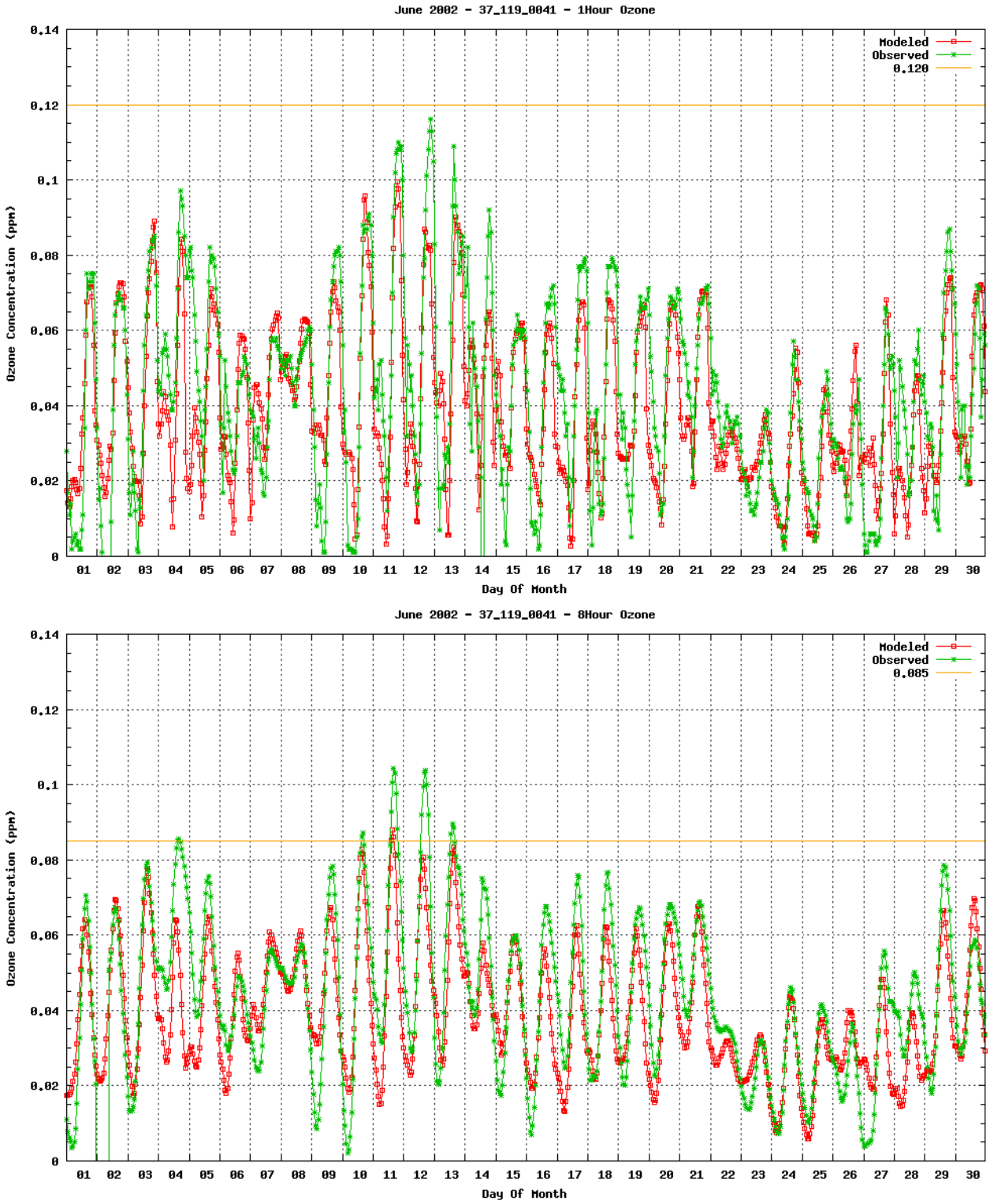


Figure 5.4.5-2 Garinger 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: Garinger (37-119-0041)
Month: July

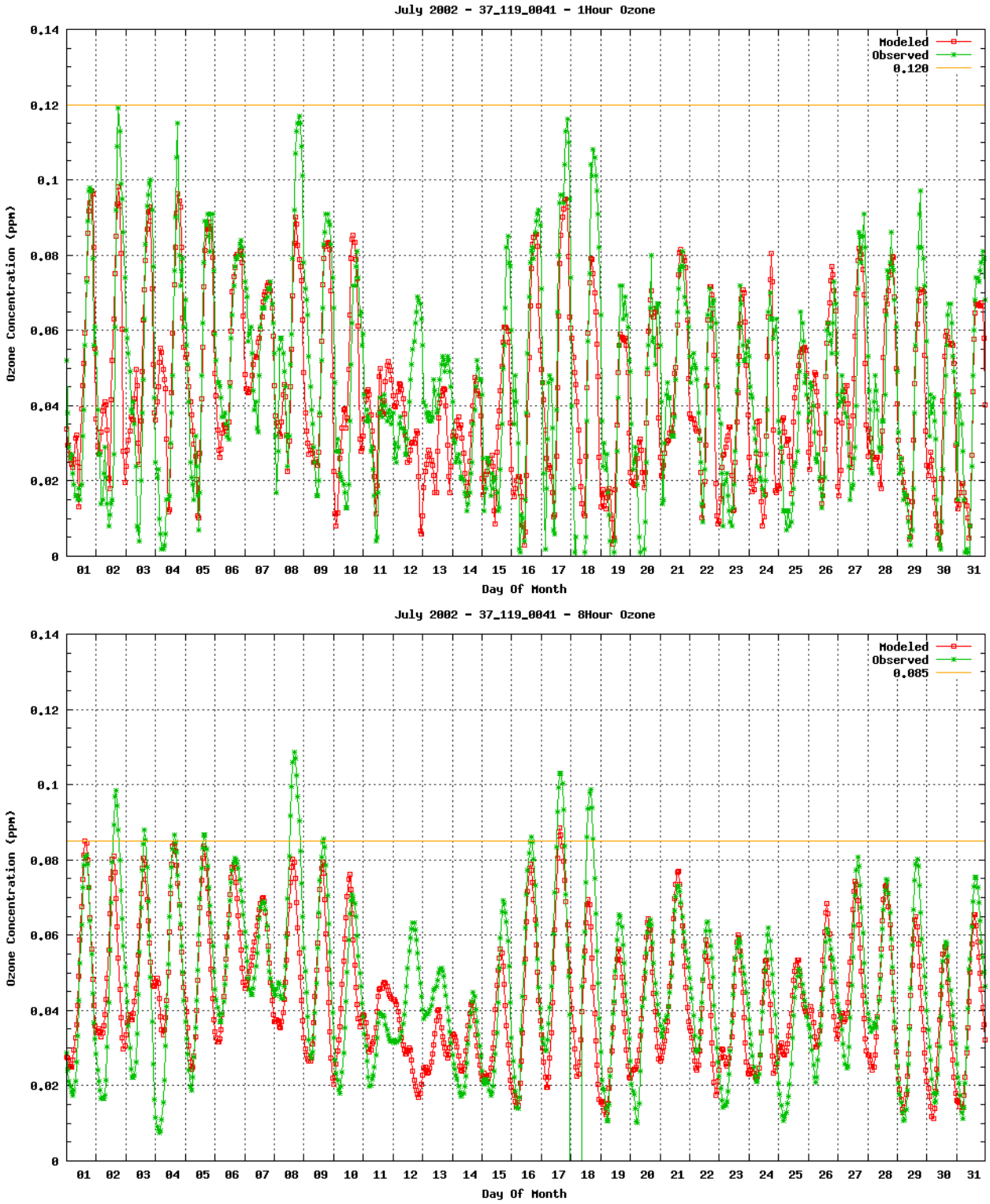


Figure 5.4.5-3 Garinger 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: Garinger (37-119-0041)
Month: August

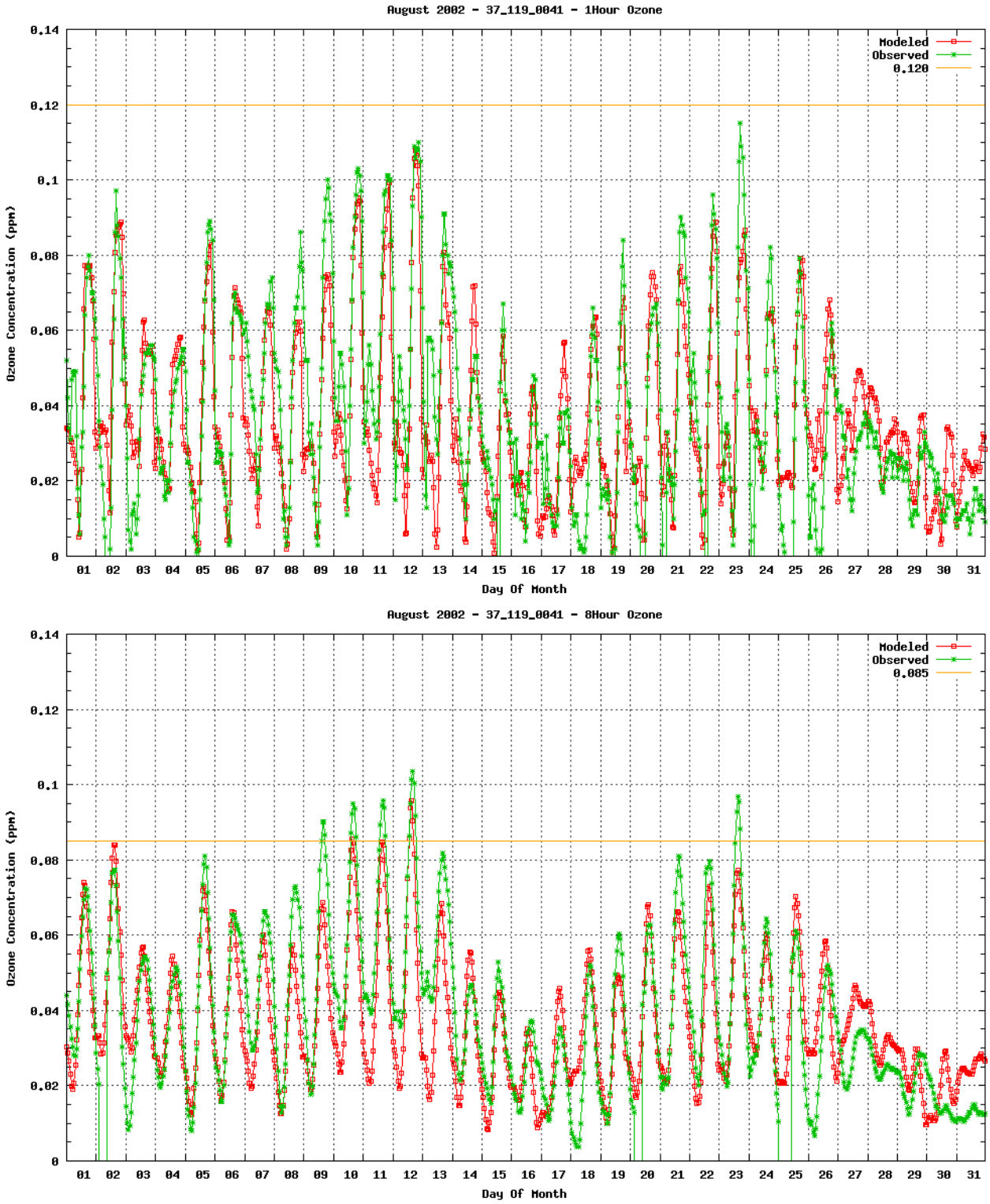


Figure 5.4.5-4 Garinger 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: Garinger (37-119-0041)
Month: September

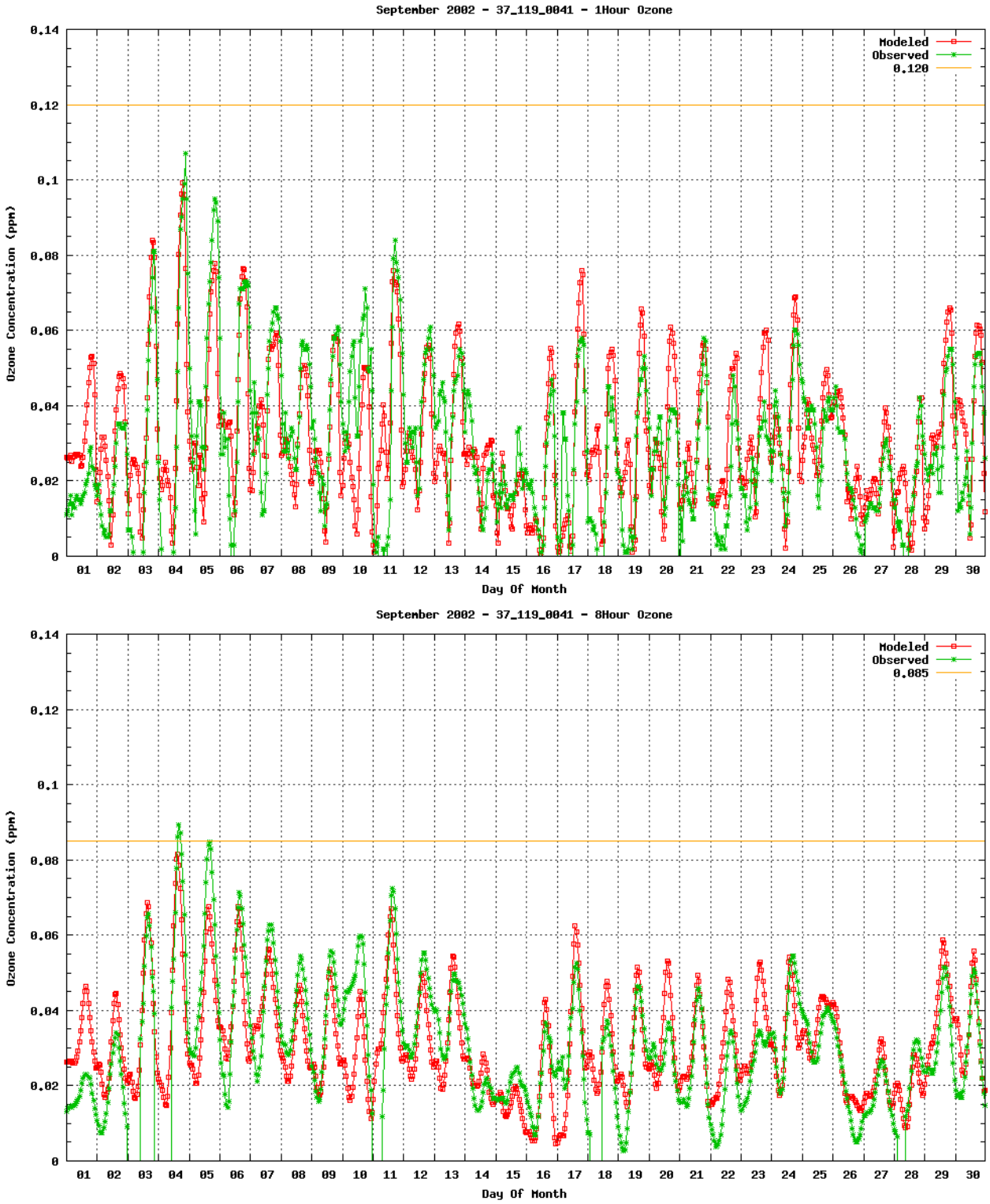


Figure 5.4.5-5 Garinger 1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: Monroe (37-179-0003)
Month: May

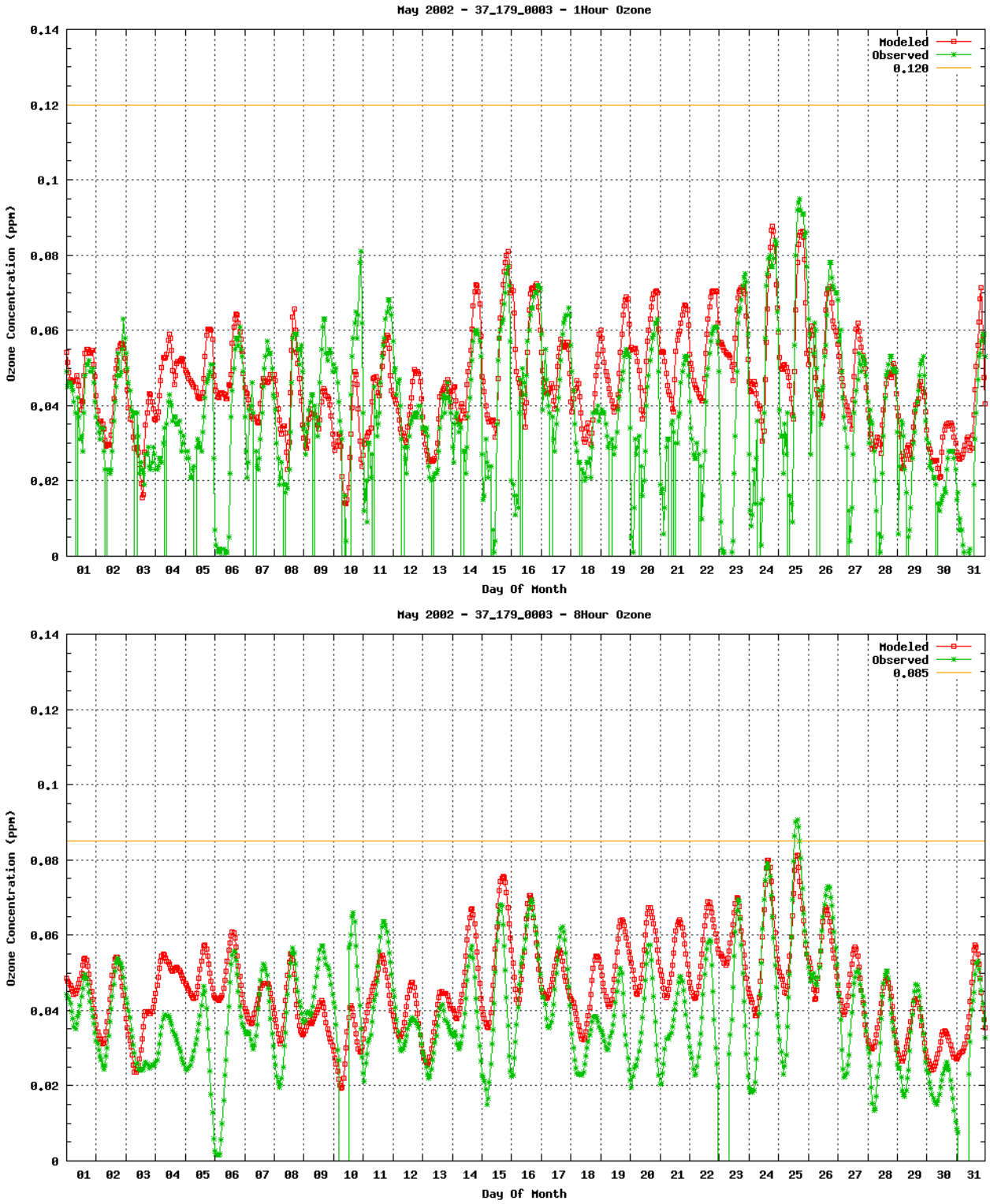


Figure 5.4.6-1 Monroe 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: Monroe (37-179-0003)
Month: June

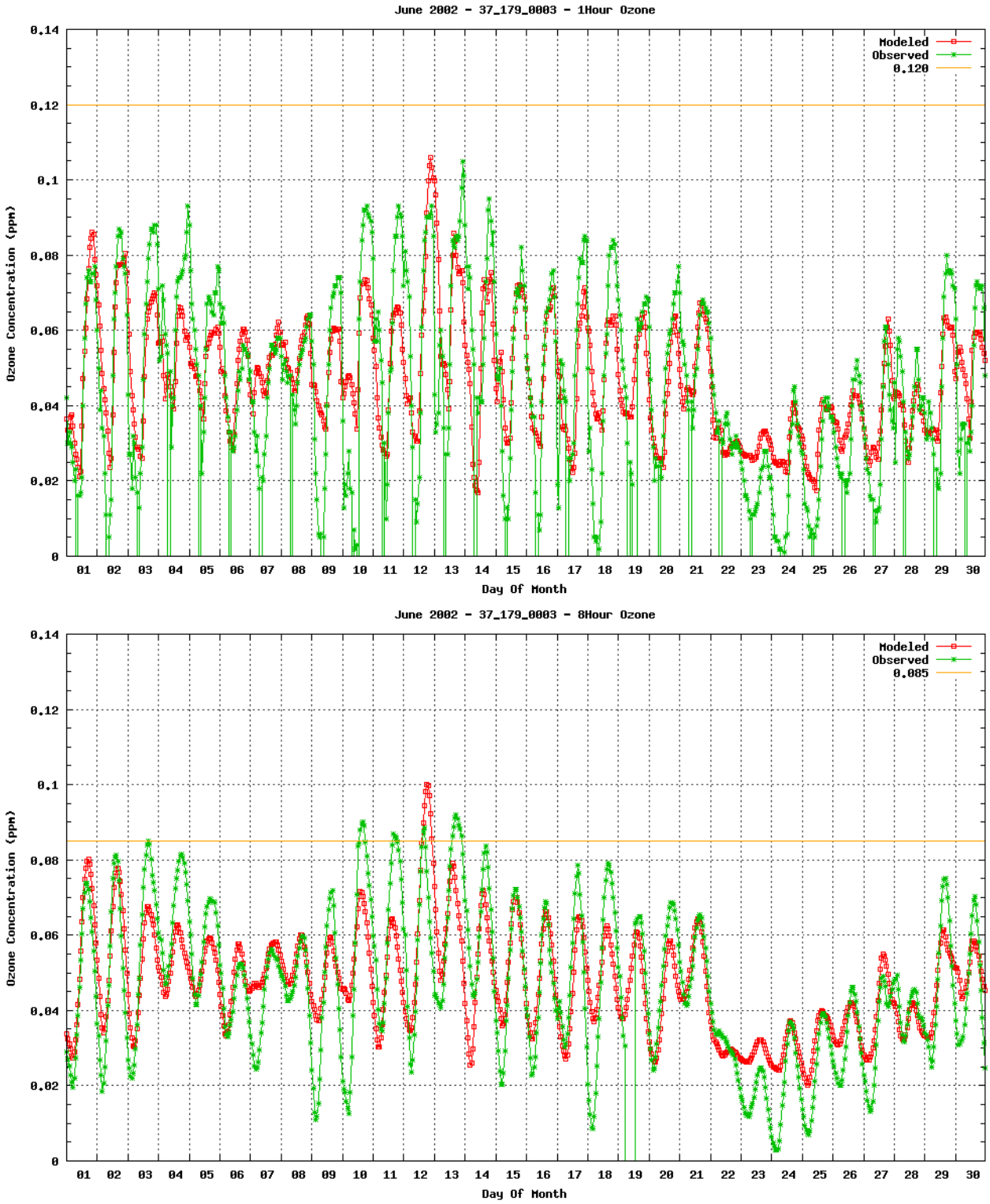


Figure 5.4.6-2 Monroe 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: Monroe (37-179-0003)
Month: July

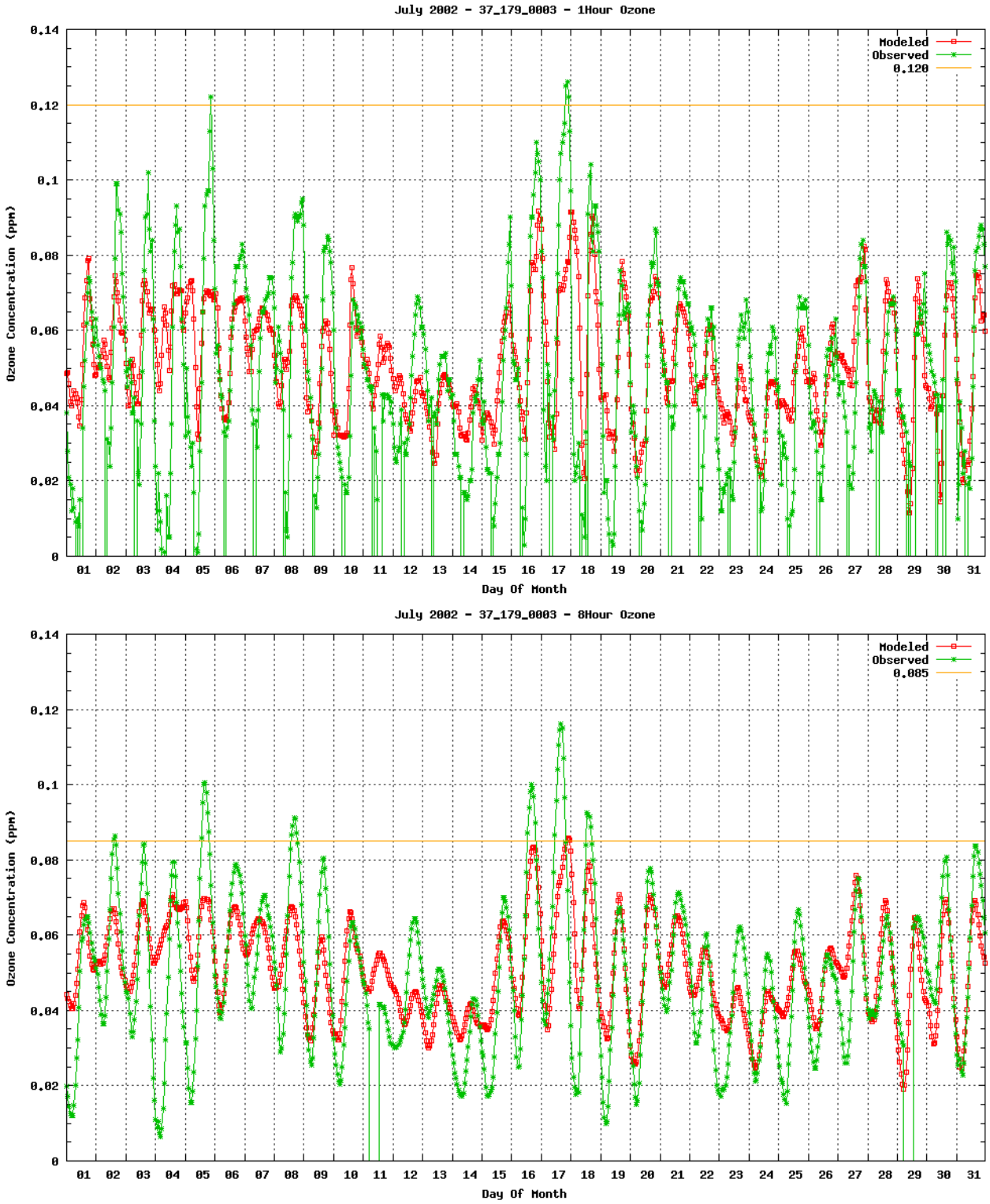


Figure 5.4.6-3 Monroe 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: Monroe (37-179-0003)
Month: August

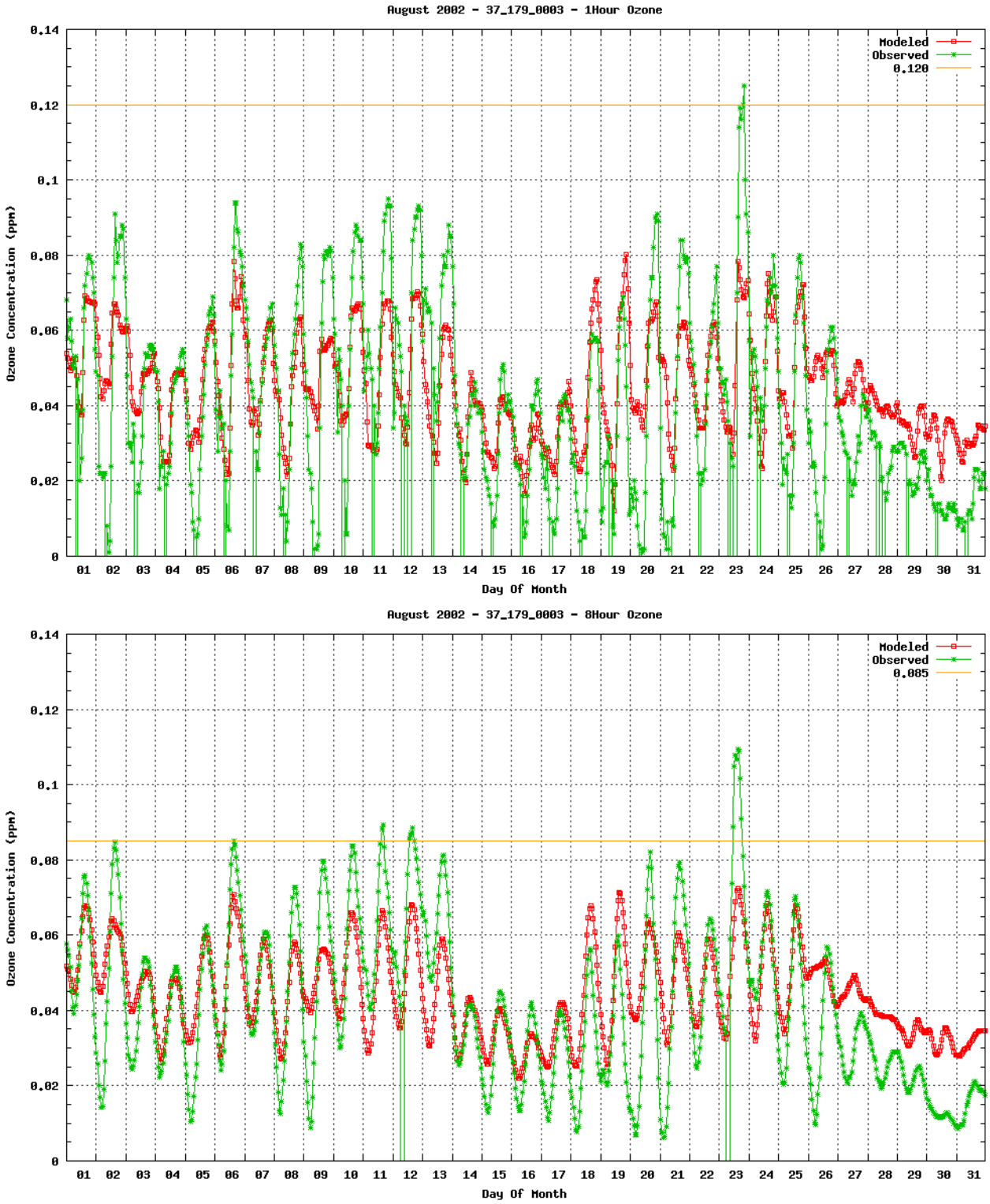


Figure 5.4.6-4 Monroe 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: Monroe (37-179-0003)
Month: September

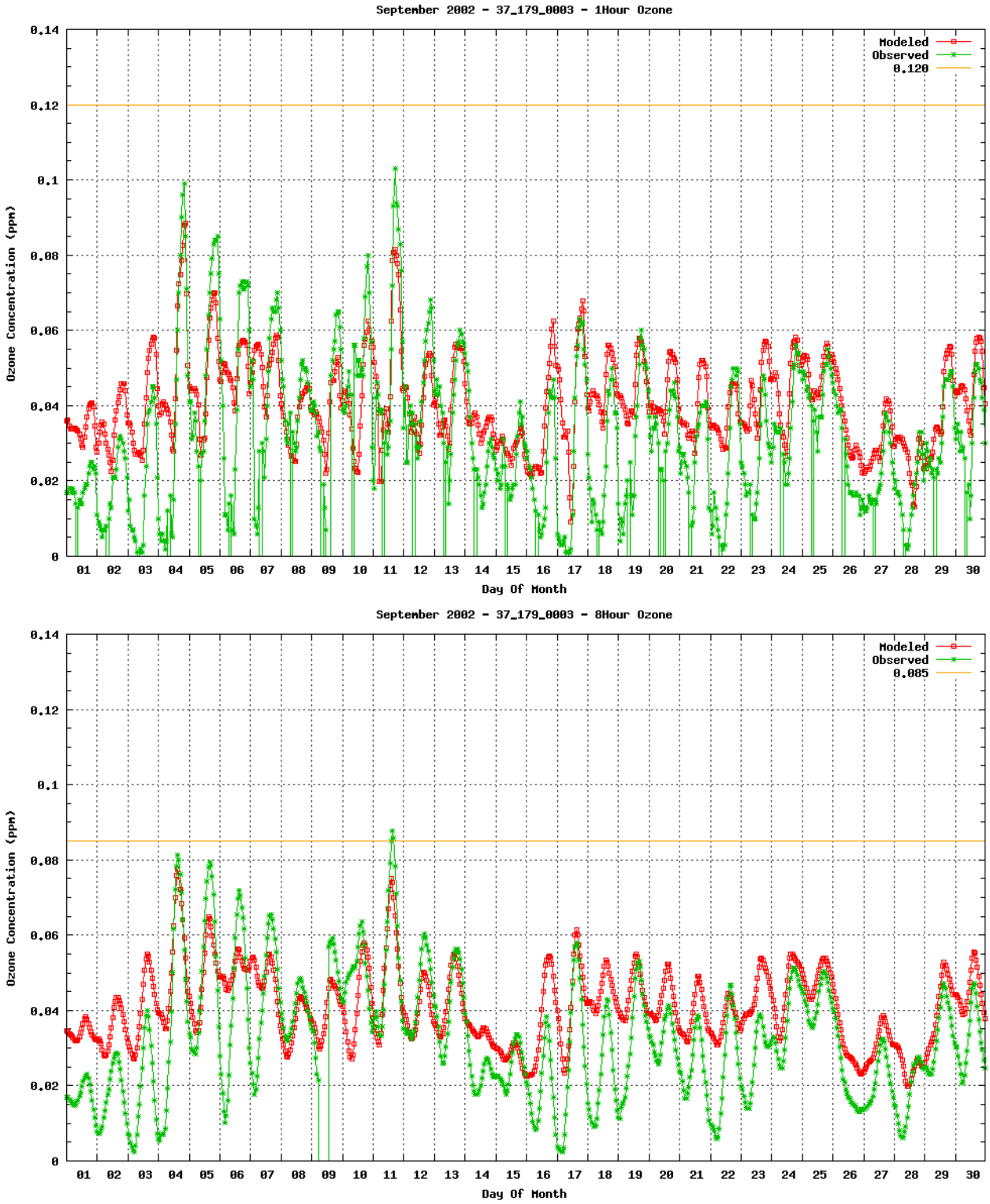


Figure 5.4.6-5 Monroe 1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: Rockwell (37-159-0021)
Month: May

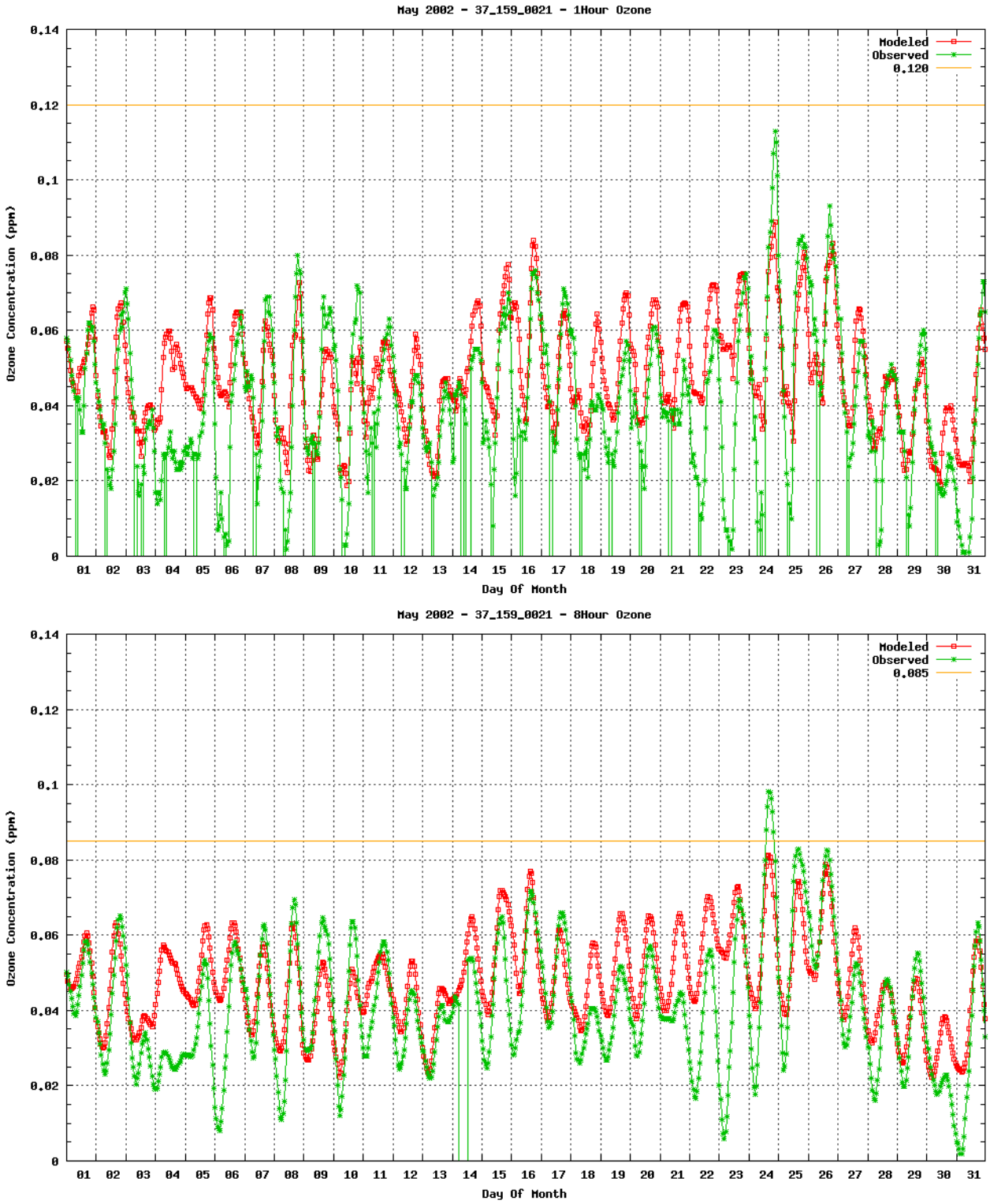


Figure 5.4.7-1 Rockwell 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: Rockwell (37-159-0021)
Month: June

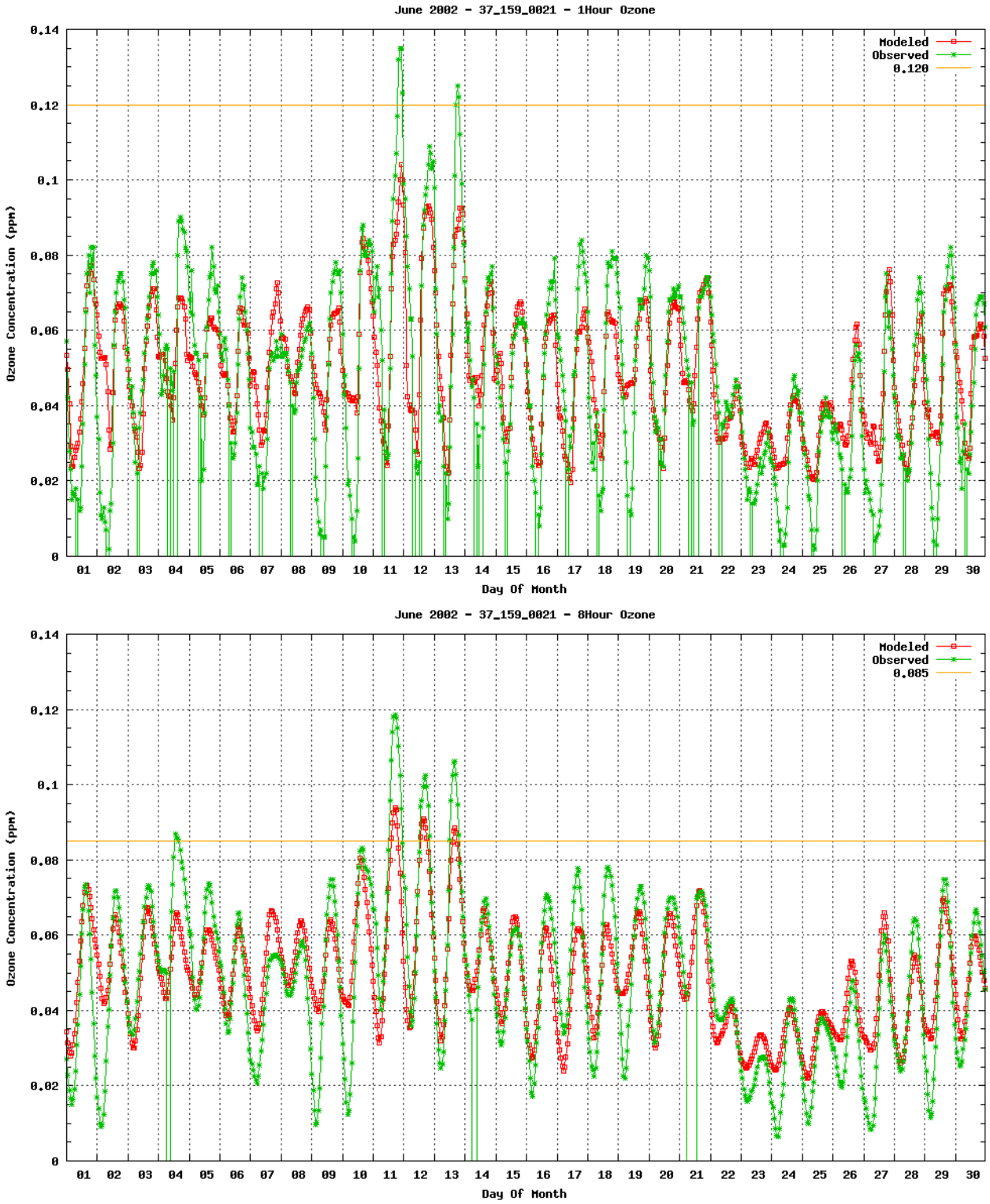


Figure 5.4.7-2 Rockwell 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: Rockwell (37-159-0021)
Month: July

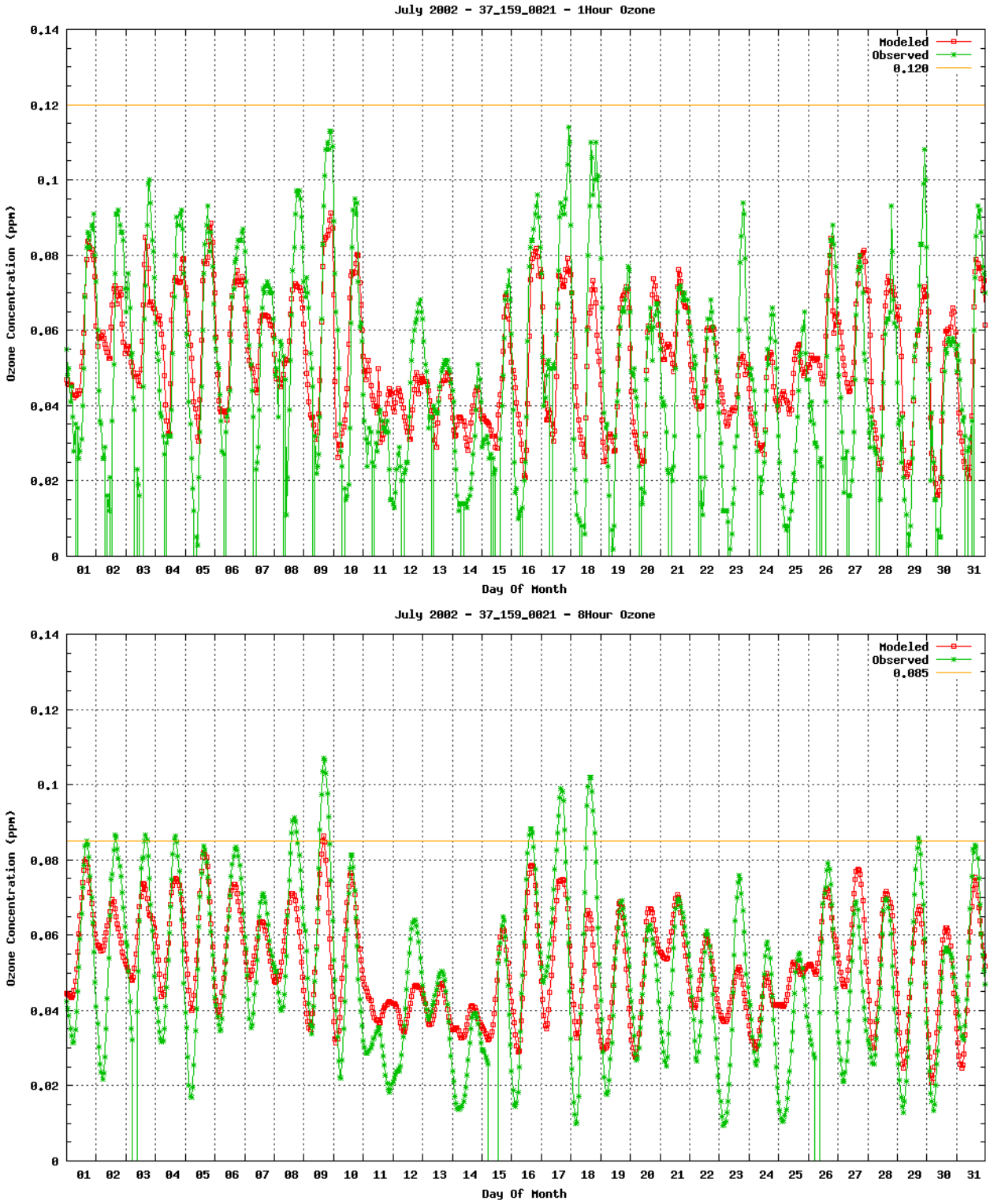


Figure 5.4.7-3 Rockwell 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: Rockwell (37-159-0021)
Month: August

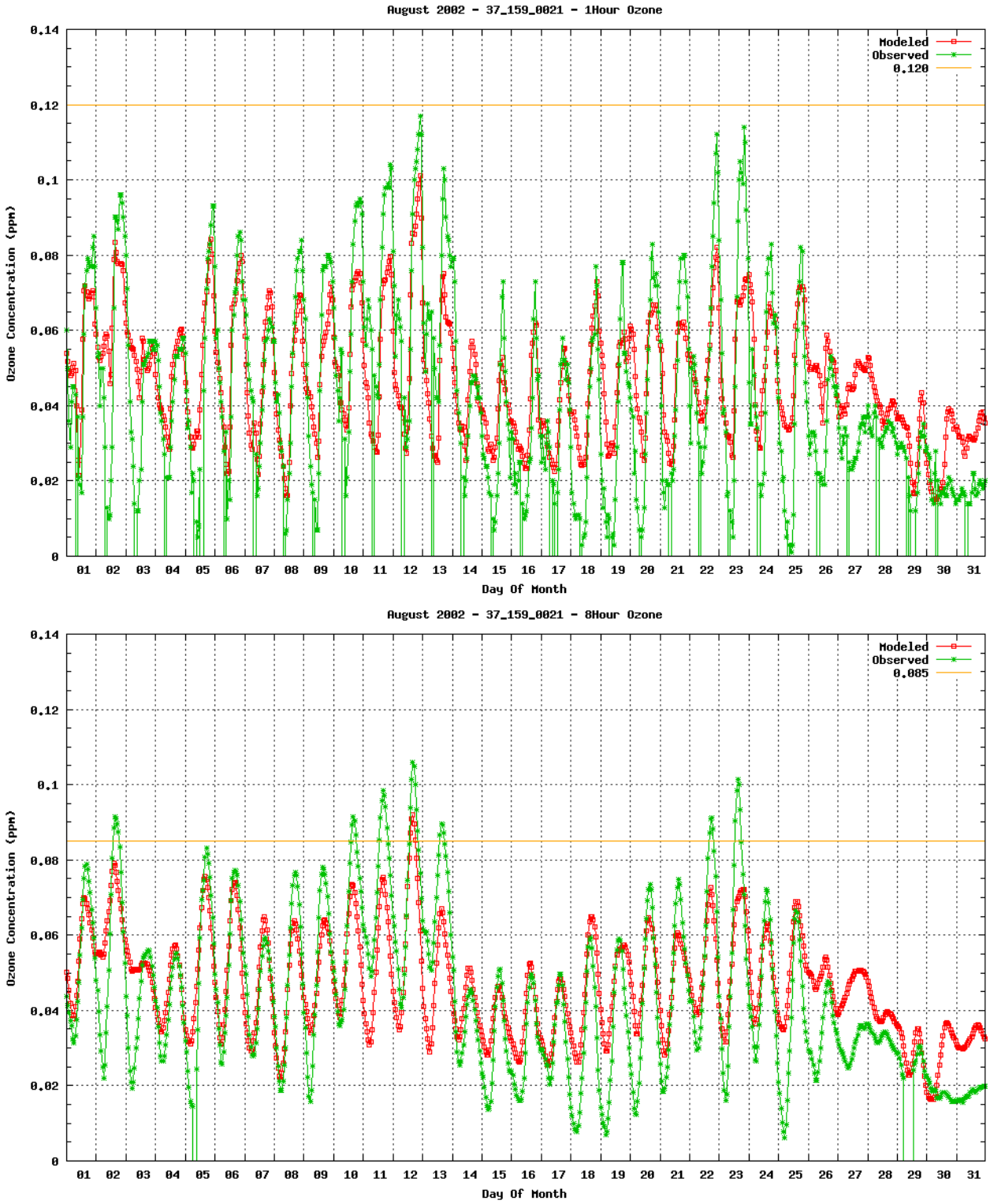


Figure 5.4.7-4 Rockwell 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: Rockwell (37-159-0021)
Month: September

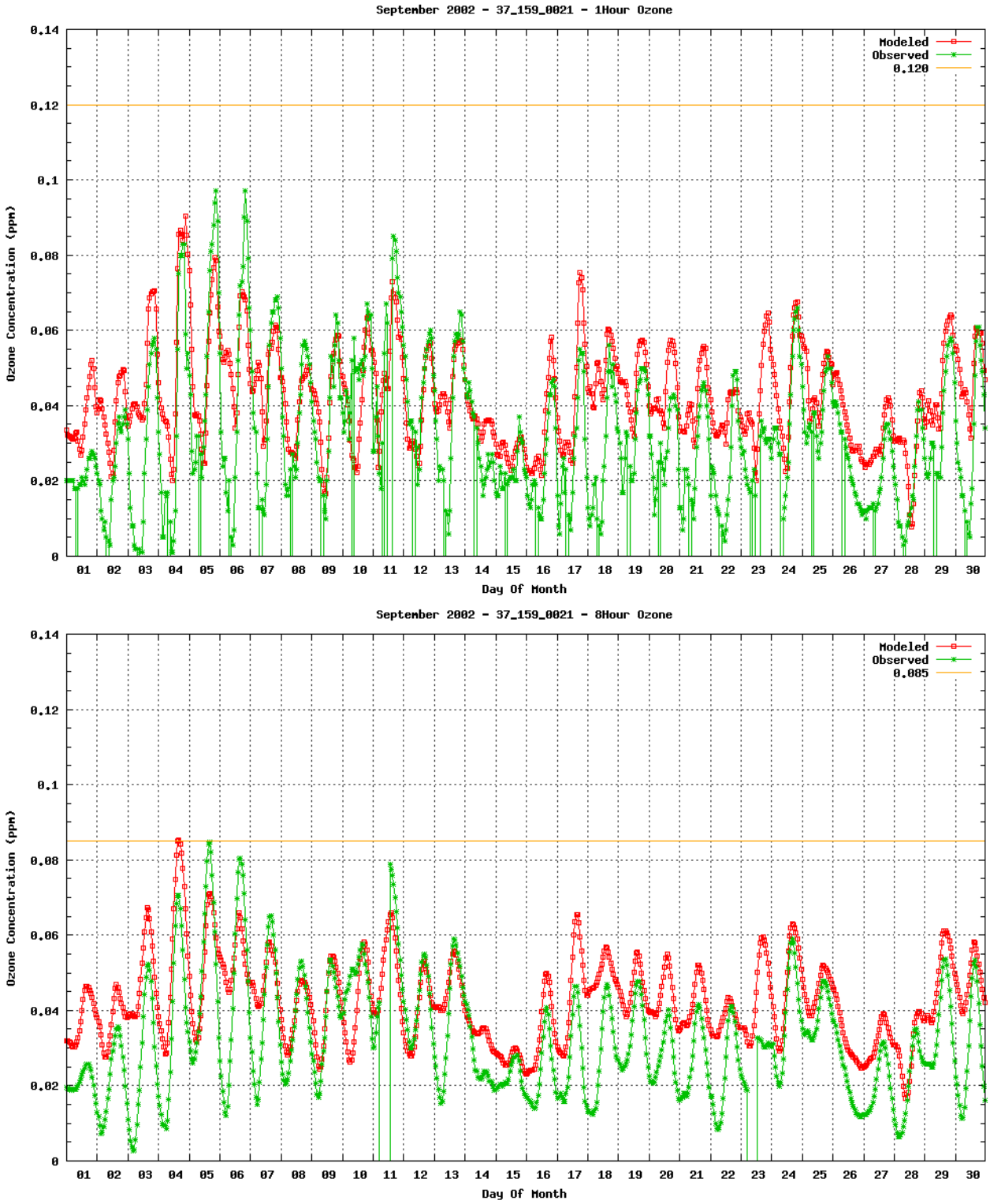


Figure 5.4.7-5 Rockwell 1-hour (top) And 8-hour (bottom) Time Series Plots For September

Monitor: York, SC (45-091-0006)
Month: May

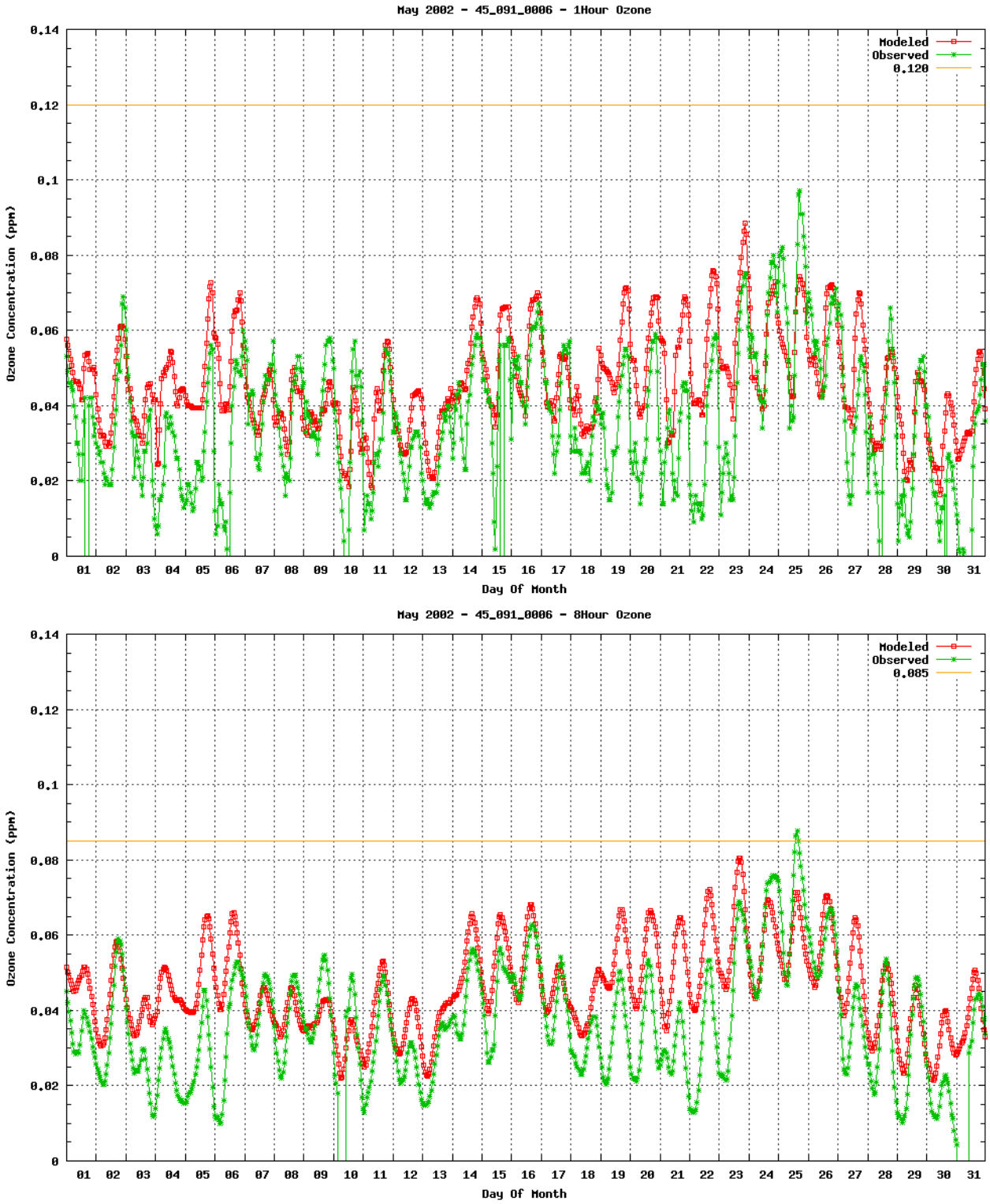


Figure 5.4.8-1 York, SC 1-hour (top) And 8-hour (bottom) Time Series Plots For May

Monitor: York, SC (45-091-0006)
Month: June

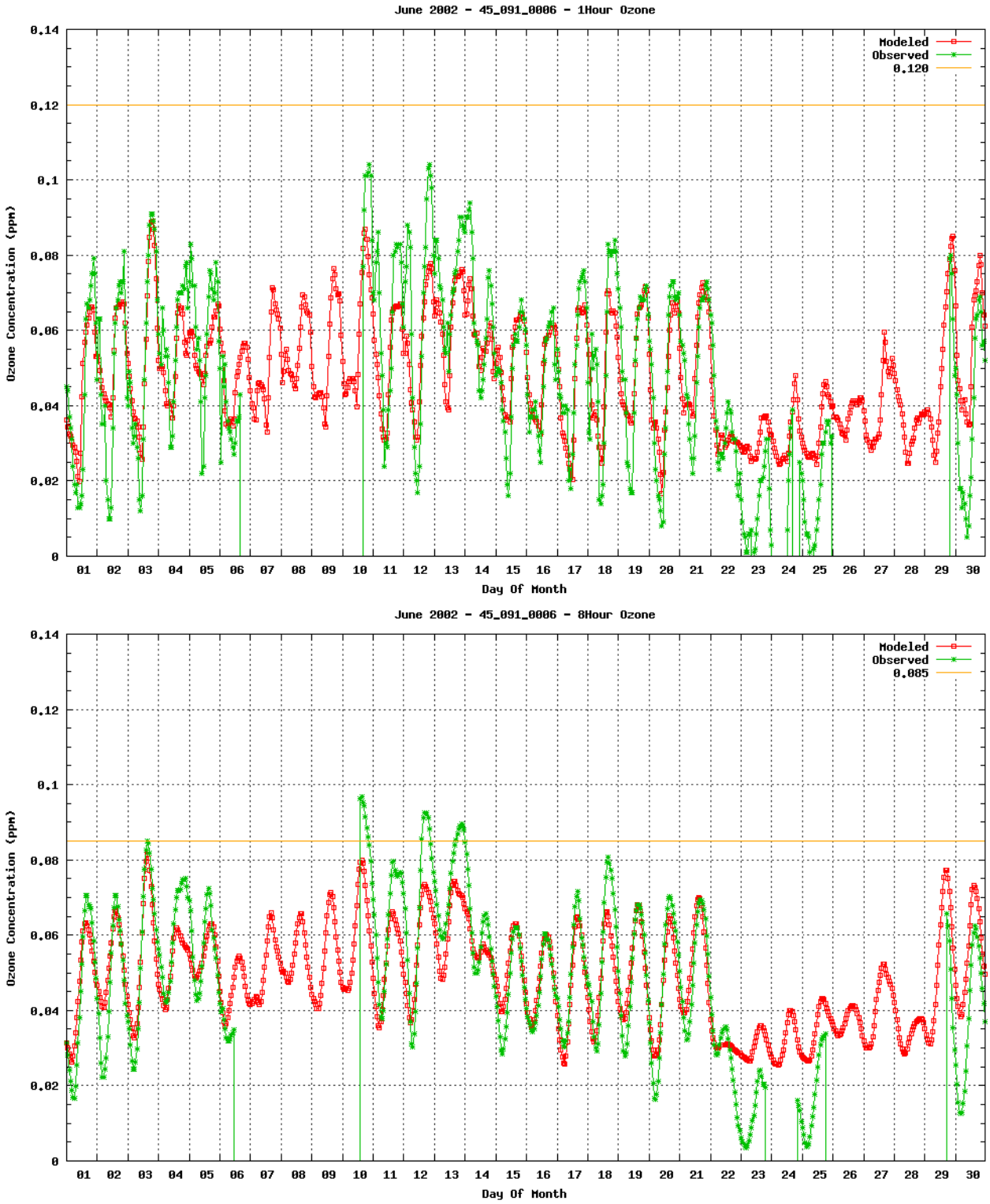


Figure 5.4.8-2 York, SC 1-hour (top) And 8-hour (bottom) Time Series Plots For June

Monitor: York, SC (45-091-0006)
Month: July

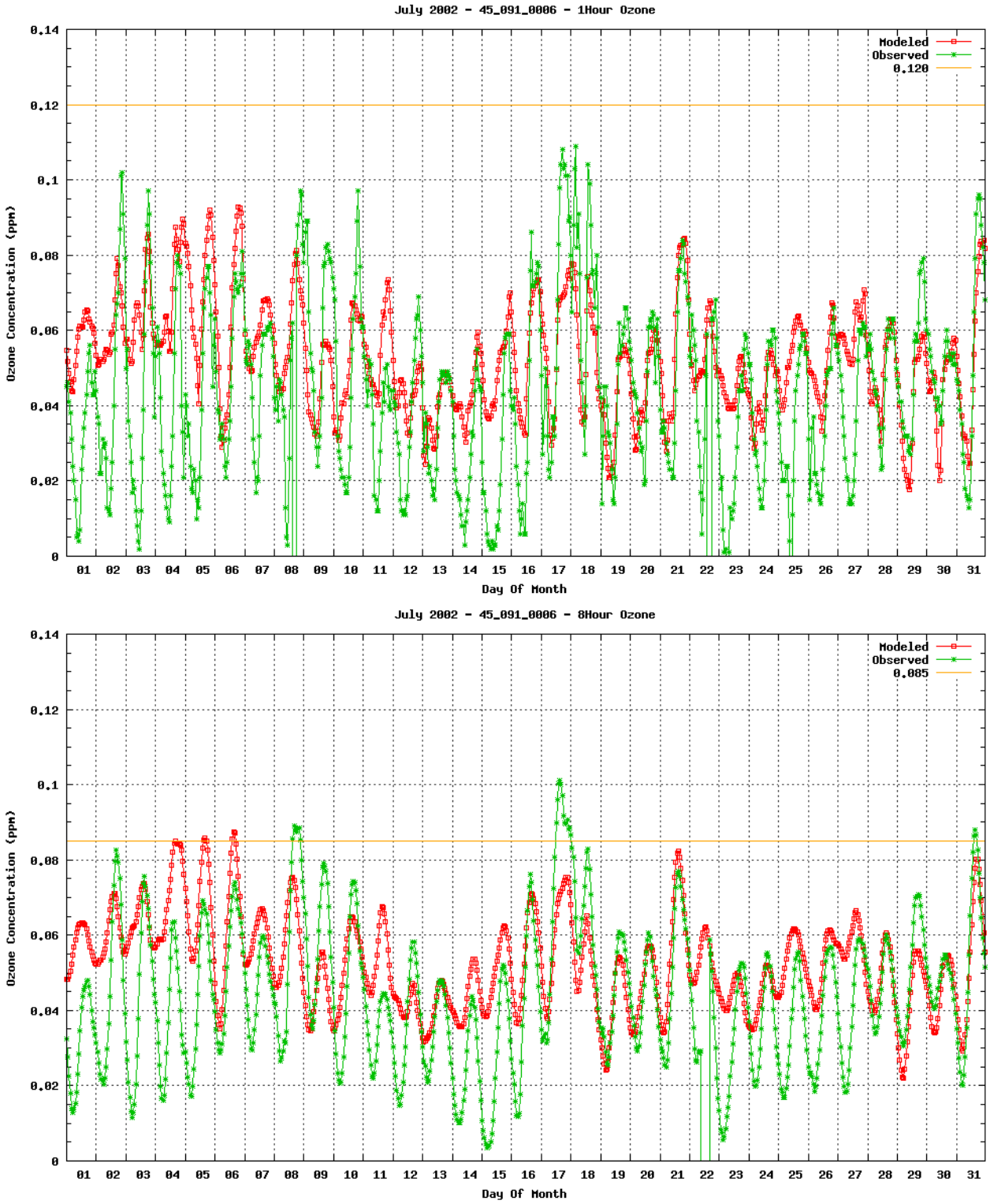


Figure 5.4.8-3 York, SC 1-hour (top) And 8-hour (bottom) Time Series Plots For July

Monitor: York, SC (45-091-0006)
Month: August

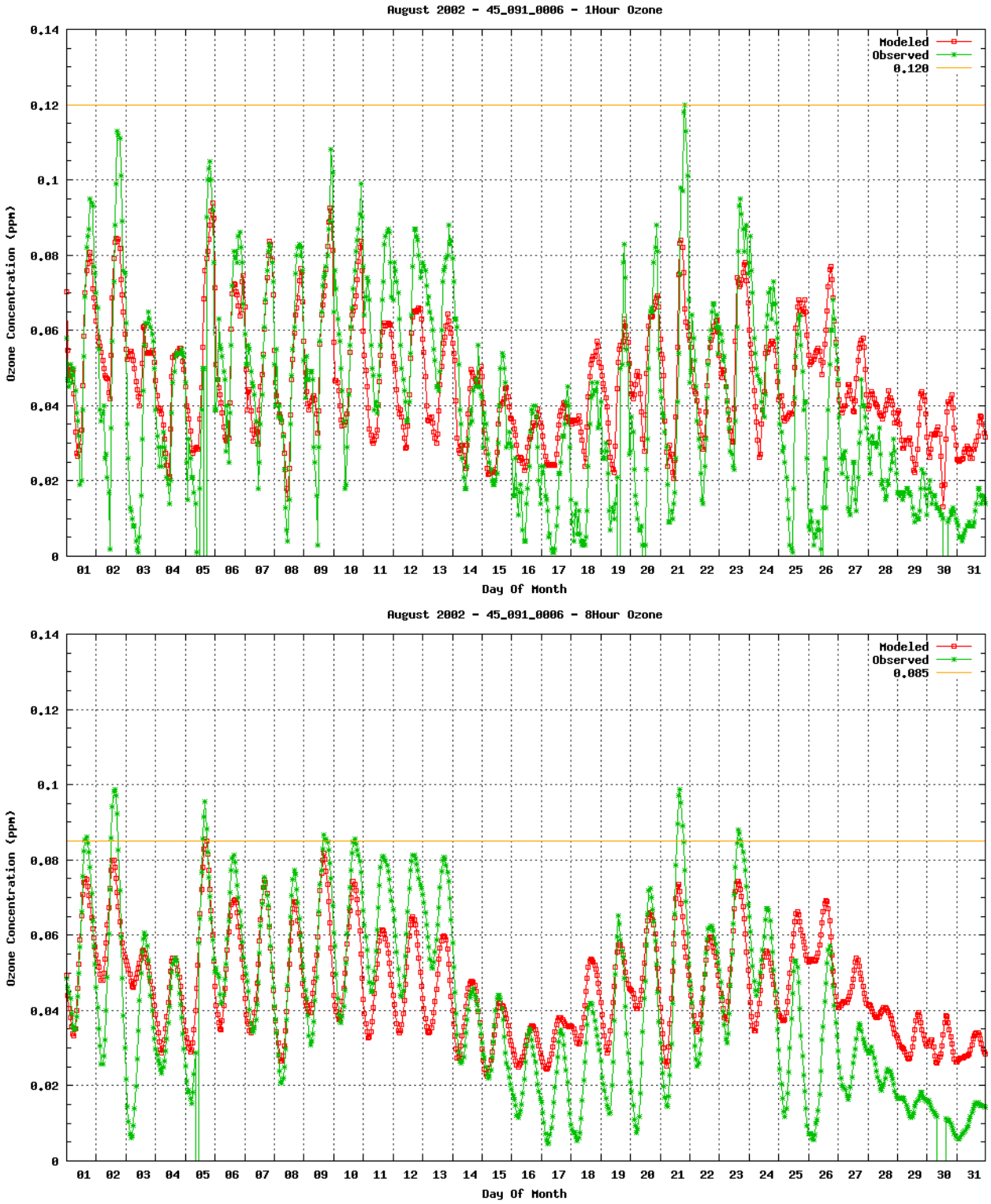


Figure 5.4.8-4 York, SC 1-hour (top) And 8-hour (bottom) Time Series Plots For August

Monitor: York, SC (45-091-0006)
Month: September

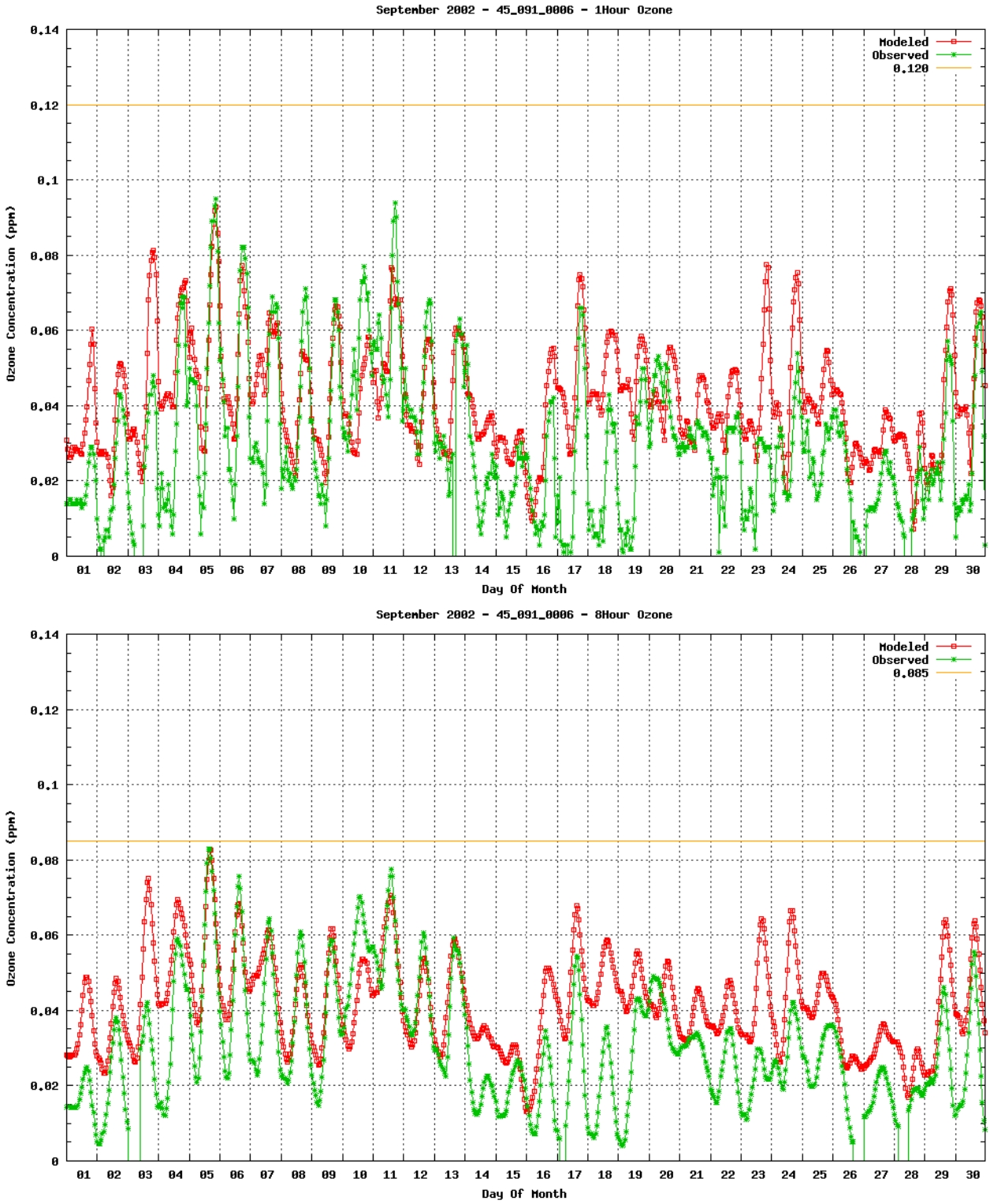


Figure 5.4.8-5 York, SC 1-hour (top) And 8-hour (bottom) Time Series Plots For September