PHOTOCHEMICAL MODELING IN SUPPORT OF ATTAINING THE FEDERAL 8-HOUR OZONE AIR QUALITY STANDARD IN CENTRAL CALIFORNIA

Volume 1:
Model Performance

California Air Resources Board
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For District review purposes, this document summarizes model performance procedures and results for meteorological modeling (Section 1) as well as air quality modeling (Section 2) for the July 1999 and July-August, 2000, episodes. The model performance evaluations are based on USEPA guidance (1991 and 2005) as well as recommendations from Emery (2001), Tesche (1994) and Tesche et al. (2001). The third section (Section 3) provides a summary of the performance analysis and Section 4 provides a tabular listing of complete graphical and statistical results that can downloaded via ftp from eos.arb.ca.gov.

Of note is that the two episodes have both been extended by two days at the beginning of the original episode periods in an effort to increase the number of useable days for future year design value calculations.

1 Meteorological Model Performance

1.1 Meteorological Model Performance Metrics

Meteorological model performance is assessed both quantitatively using statistical metrics as well as qualitatively against known conceptual meteorological flows and observed episodic meteorological features.

1.1.1 Quantitative Performance Evaluation

There are a number of statistical and graphical approaches for evaluating meteorological model outputs. However, none of them are independently conclusive. Most of these approaches involve comparisons between observed and simulated meteorological parameter values. These analyses pose a difficult challenge, since most of the available meteorological monitoring stations are located in urbanized areas. Thus, the majority of observations tend to represent those areas versus the full complexity of meteorology throughout the CCOS domain. Furthermore, since the use of objective analysis and observational nudging forces the meteorological modeling results towards the observations, model performance problems can increase in areas away from observation locations.

It also needs to be recognized that output from the various meteorological models must be preprocessed for input into the air quality model. This preprocessing may inadvertently perturb the meteorological fields. Therefore, meteorological model performance should be based on the air quality model input files, rather than the meteorological model outputs.

The SIP modeling domain is geographically very complex and the observational data on which meteorological model outputs were evaluated are not distributed uniformly. Therefore, it is unreasonable to evaluate model performance for the domain as a whole. For purposes of meteorological model performance analysis, the CCOS domain is divided into sub-regions, representing areas of similar meteorological features. The graphical and statistical model evaluations will be done for each of these sub-regions.

A number of standard statistical and graphical techniques are used for meteorological model performance analysis. The most widely used application is the METSTAT program (Tesche, 1994, Tesche et al, 2001). Two graphical representations of the METSTAT statistics were used in meteorological model performance analysis conducted here: a) “Root Mean Square Error (RMSE) of Wind Speed” vs. “Gross Error (E) of Wind Direction”, and b) “Bias Error (B)” vs. “Gross Error (E)” for temperature. Equations used for these comparisons were taken from the user documentation of the METSTAT program and are given below:

Bias Error (B): calculated as the mean difference in prediction-observation pairings with valid data within a given analysis region and for a given time period (hourly or daily):

$$B = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left(P_j^i - O_j^i\right)$$

Here, *P* and *O* indicate model predictions and observations, respectively. Similarly, I and J are the indices of grid points in x and y directions, respectively.

Gross Error (E): calculated as the mean *absolute* difference in prediction-observation pairings with valid data within a given analysis region and for a given time period (hourly or daily):

$$E = \frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left|P_j^i - O_j^i\right|$$

Note that the bias and gross error for winds are calculated from the predicted-observed residuals in speed and direction (not from vector components *u* and *v*). The direction error for a given prediction-observation pairing is limited to range from 0 to ±180°.

Root Mean Square Error (RMSE): calculated as the square root of the mean squared difference in prediction-observation pairings with valid data within a given analysis region and for a given time period (hourly or daily):

$$RMSE = \left[\frac{1}{IJ}\sum_{j=1}^{J}\sum_{i=1}^{I}\left(P_j^i - O_j^i\right)^2\right]^{1/2}$$

The RMSE, as is the gross error, is a good overall measure of model performance. However, since large errors are weighted heavily (due to squaring), large errors in small subregions may produce a large RMSE even though the errors may be small and quite acceptable elsewhere.

Table 1-1 shows the criteria used to decide if the results of a given model fall within acceptable performance limits.

Table 1-1 Statistical comparisons between observed and simulated meteorological parameter values. Statistical comparisons are made by model performance sub-regions.

Parameter	Abbreviation	Benchmark
Wind Speed	RMSE:	≤ 2 m/s
	Bias:	$\leq \pm 0.5$ m/s
	IOA:	≥ 0.6
Wind Direction	Gross Error:	≤ 30 deg
	Bias:	$\leq \pm 10$ deg
Temperature	Gross Error:	$\leq 2\ ^{o}K$
	Bias:	$\leq \pm 0.5\ ^{o}K$
	IOA	≥ 0.8

In an ideal situation, meteorological field evaluation would be done independent of the air quality model results. However, in practice, meteorological field evaluation is limited by the relative paucity of observational data, especially aloft. Therefore, base year air quality model performance was also considered in the selection of meteorological fields used for air quality simulations.

Table 1-2 Graphical analysis of meteorological model fields. Time series plots are made for each station and spatial plots are made over the whole modeling domain.

Time-series plots of hourly mean air temperature
Time-series plots of hourly mean wind speeds.
Spatial plots of hourly wind vectors
Spatial plots of hourly air temperatures

1.1.2 Qualitative Performance Analyses

Given episode-specific information on the meteorological features that were observed with field measurements, additional subjective analyses of observed versus predicted mesoscale features can be conducted. Examples of such qualitative analyses that will be considered are described below.

1. Determine and compare modeled and observed horizontal flow patterns over the modeling domain. Features to consider include flow splitting, the structure of the sea breeze, urban circulations, local flows such as Fresno and Schultz eddy circulations, slope and drainage flows, up/down valley flows, and the existence of cloud formations.

2. Study the 3-D spatial characteristics of the flow field by using time-height cross sections of wind profiler observations and the simulated wind field at the wind profiler location.

3. Determine the spatial and temporal characteristics of the mixing layer height using available upper air observations, and compare it with the simulated behavior of mixing layer height.

4. Perform some sensitivity tests to see the effects of certain model parameters on the model results, such as observational nudging vs. analysis nudging, the choice of soil physics, and boundary layer parameterizations.

1.2 Meteorological Model Performance Results

The following two sections present the results of meteorological model performance for the two modeling episodes, based on the criteria discussed above. For illustration purposes, a small number of the graphics that were produced are used in the subsequent discussions. However, all of the graphics that have been generated are available via ftp per the table in the Appendix.

1.2.1 July 1999 Episode (Routine Episode)

The July 1999 simulation covers the period from July 5th 12Z, 1999 to July 14th 12Z, 1999. Meteorological model performance is assessed for the 7-day period spanning July 7th through July 13th.

The July 1999 episode model performance is assessed for three MM5 runs as follows:

Table 1-3. July-1999 Episode. Three ARB simulations are considered.

Simulation Number	Abbreviation	Description
1	C108	7 day simulation; without FDDA
2	C109	7 day simulation; with FDDA; includes all the available observational data.
3	C110	7 day simulation; with FDDA; but excludes from the FDDA file all known 2-meter station height data (i.e. CIMIS and NWS stations).

The FDDA file for run C109 includes all of the available observational data that are available for this routine field measurement episode. The Bay Area Air Quality Management District and their contractors, AtMet and ENVIRON, produced FDDA data for the original ‘core’ episode days, July 9th through July 12th. For the extended episode days that fall outside of the original core days, ARB FDDA data are used. The third run (c110) has the same model setup as “c109”, except that data from sources utilizing 2-meter station heights are excluded from the C109 FDDA file. Simulation C110 is a sensitivity run to evaluate the effect of 2-meter observational station heights on MM5 performance for this episode.

To calculate model performance statistics, the results from all three MM5 simulations are processed through the METSTAT program. Performance statistics and site-averaged time series are calculated for 5 regions: Bay Area region, Sacramento region, Central San Joaquin Valley, Southern San Joaquin Valley and Northern San Joaquin Valley. The resulting statistics are presented in soccer plots, where, ideally, model performance statistics fall within the central box of the goal.

Figure 1-1 shows sites-averaged time series for winds and temperatures in the Bay Area region. There is little difference between the three simulations. Wind speeds were generally under-predicted over the entire simulation period. On the other hand, temperature performance is good, as noted by the simulated diurnal pattern. The exception to this is that temperatures were over-predicted on July 13th. In terms of model performance statistics for the Bay Area region, Figure 1-2 shows the soccer goal plots of daily performance for winds and temperature. There was little difference between c109 and c110.

Figure 1-3 shows sites-averaged time series for winds and temperatures in the Sacramento region. In general, there is little difference between the three simulations. Wind speeds are over-predicted on July 7th and July 12th. Otherwise, the wind speed performance is good over the simulation period. On the other hand, temperatures were under-predicted during the day and over-predicted in the morning. Figure 1-4 shows the soccer goal plots of daily performance for winds and temperature.

Figure 1-5 shows sites-averaged time series for winds and temperatures in the Central San Joaquin Valley. Wind speeds were generally over-predicted. Temperatures were under-predicted during the day and over-predicted in the morning. There was little difference between the three simulations. Figure 1-6 shows the soccer goal plots of daily performance for winds and temperature.

Figure 1-7 shows sites-averaged time series for winds and temperatures in the Southern San Joaquin Valley. Wind speeds were generally over-predicted. Temperatures were under-predicted during the day and over-predicted in the morning. There was little difference between the three simulations. Figure 1-8 shows the soccer goal plots of daily performance for winds and temperature.

Figure 1-9 shows sites-averaged time series for winds and temperatures in the Northern San Joaquin Valley. Wind speeds were generally over-predicted. Temperatures were under-predicted during the day and over-predicted in the morning. There was little difference between the three simulations. Figure 1-10 shows the soccer goal plots of daily performance for winds and temperature.

It should be noted that both the ARB and the Bay Area Air Quality Management District have done much work to improve meteorological model performance for this episode. However, little additional progress has been made over the past two years and performance statistics still remain outside of the ‘ideal’ range. Alone, however, this is not grounds to dismiss the met simulations as poor. We are hopeful that statistical performance can be improved and will continue to work closely with the districts and other stakeholders, including CCOS contractors, with this goal in mind.

Among the three July 1999 simulations, MM5 with observation nudging (c109 and c110) improves the wind speed and wind direction a little over c108, which has no observation nudging. Since there were no significant differences between c109 and c110, it is assumed that the 2-meter station data included in the FDDA file play no significant role in degrading model performance. As a result, c109 is used as input for the air quality model.

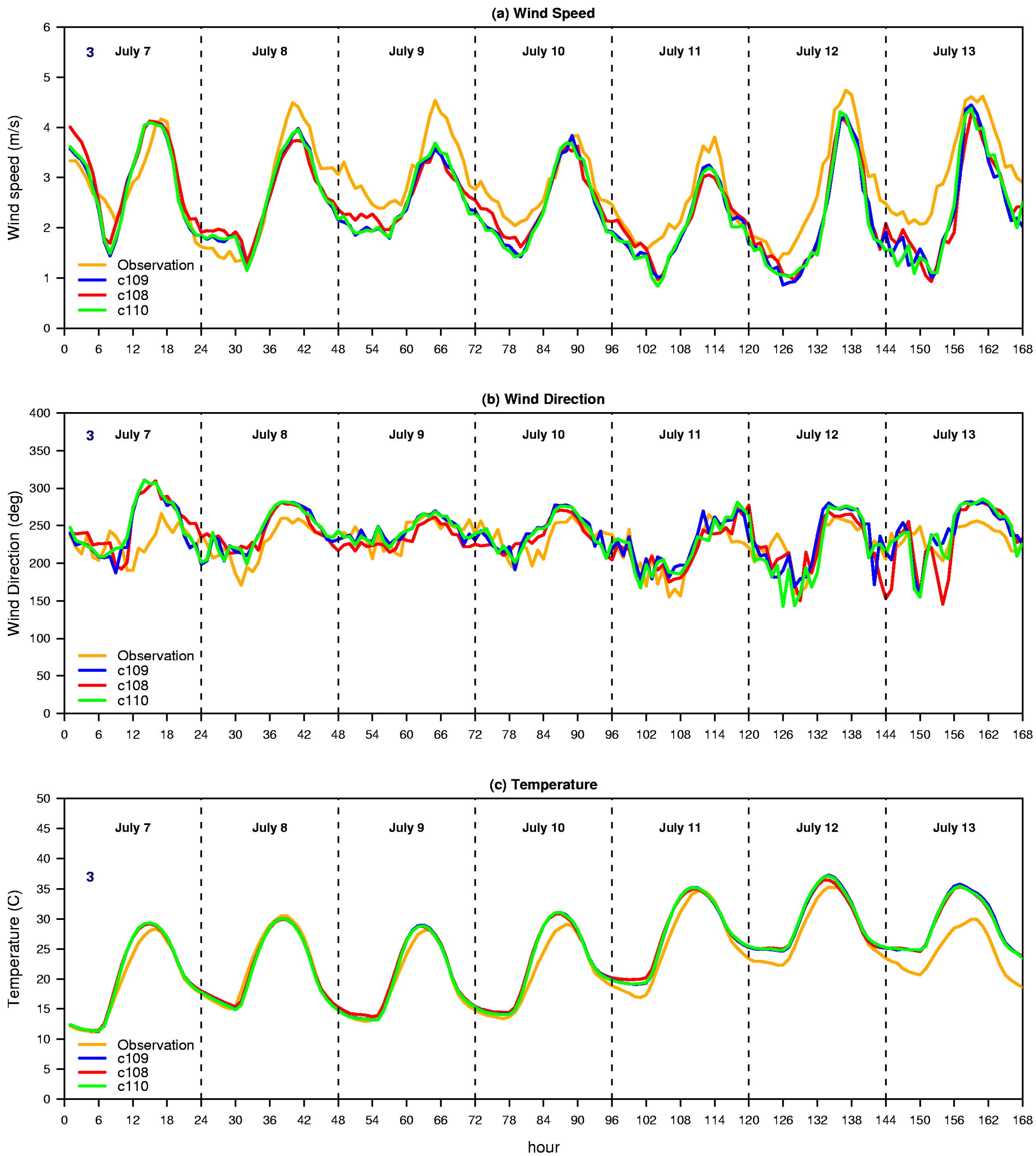
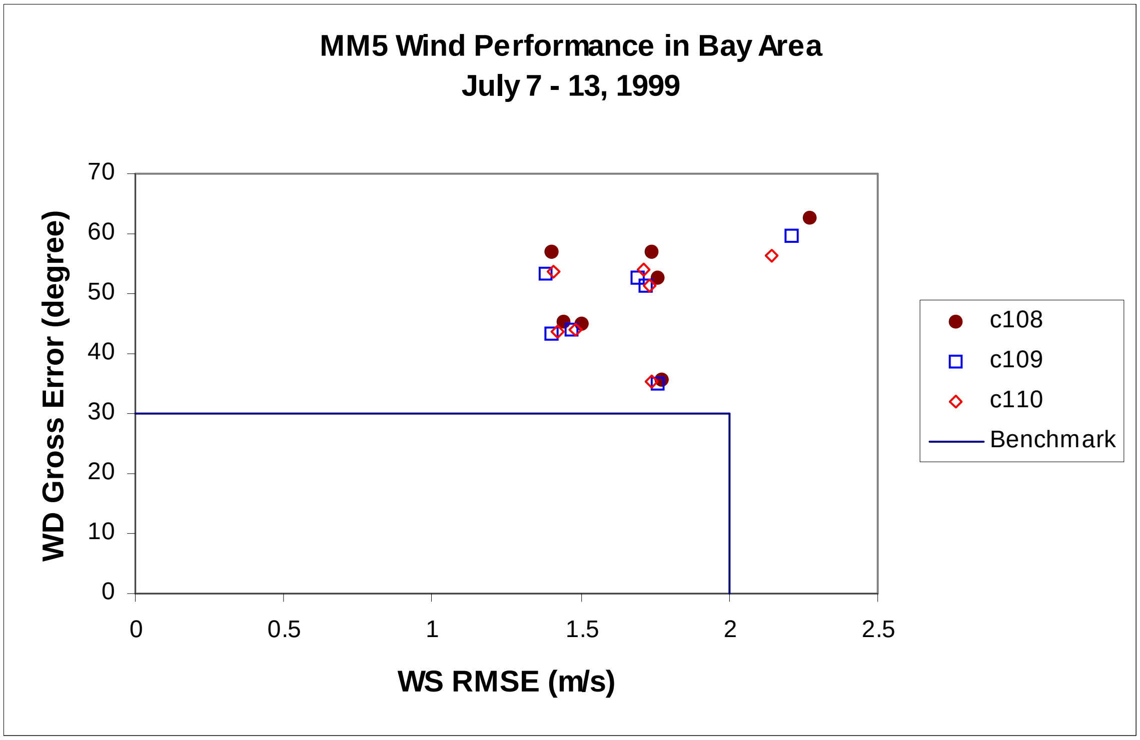


Figure 1-1. Time series of wind speed, direction, and temperature for the Bay Area region over the July 7-13, 1999 modeling period.



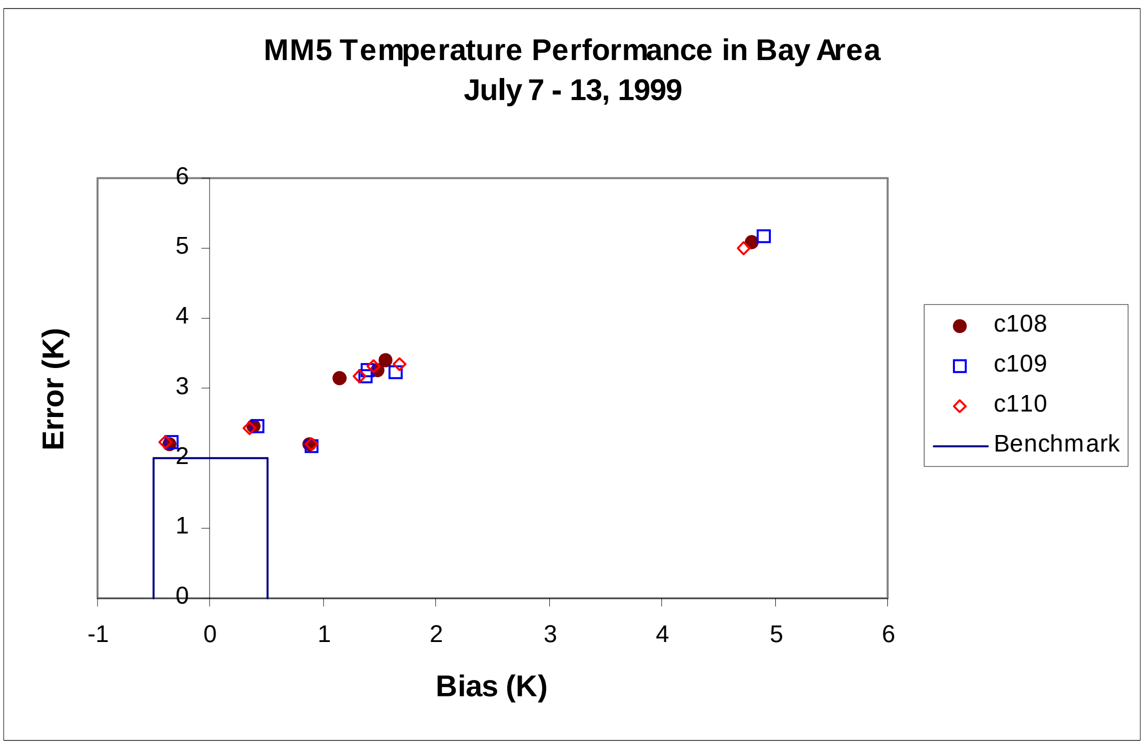


Figure 1-2. MM5 performance for winds and temperature in the Bay Area region.

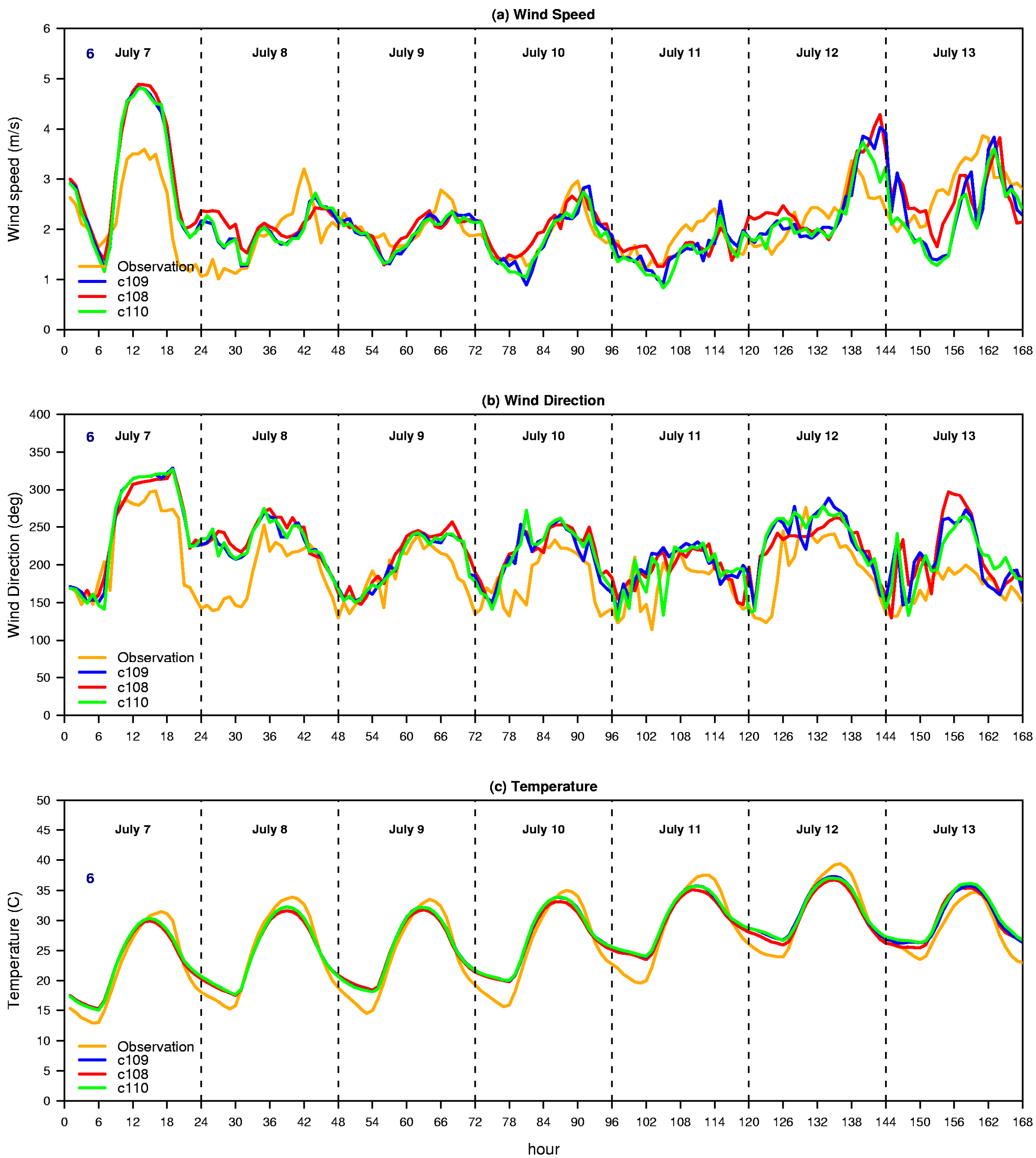
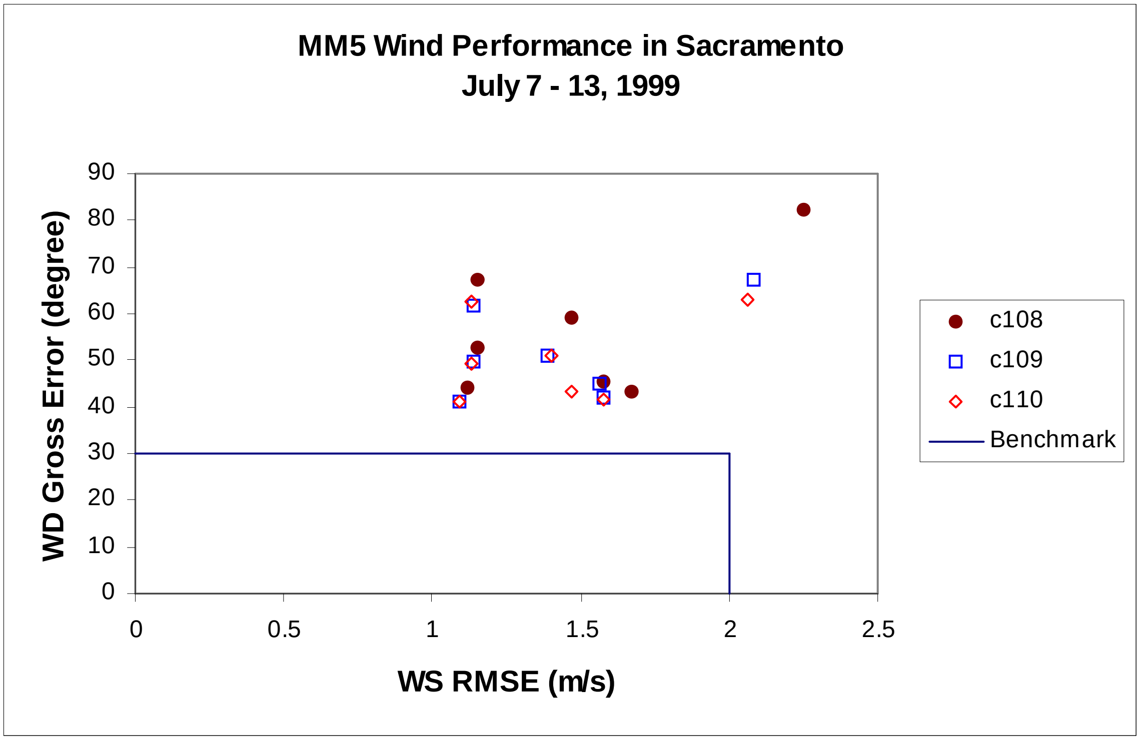


Figure 1-3. Time series of wind speed, direction, and temperature for the Sacramento region over the July 7-13, 1999 modeling period.



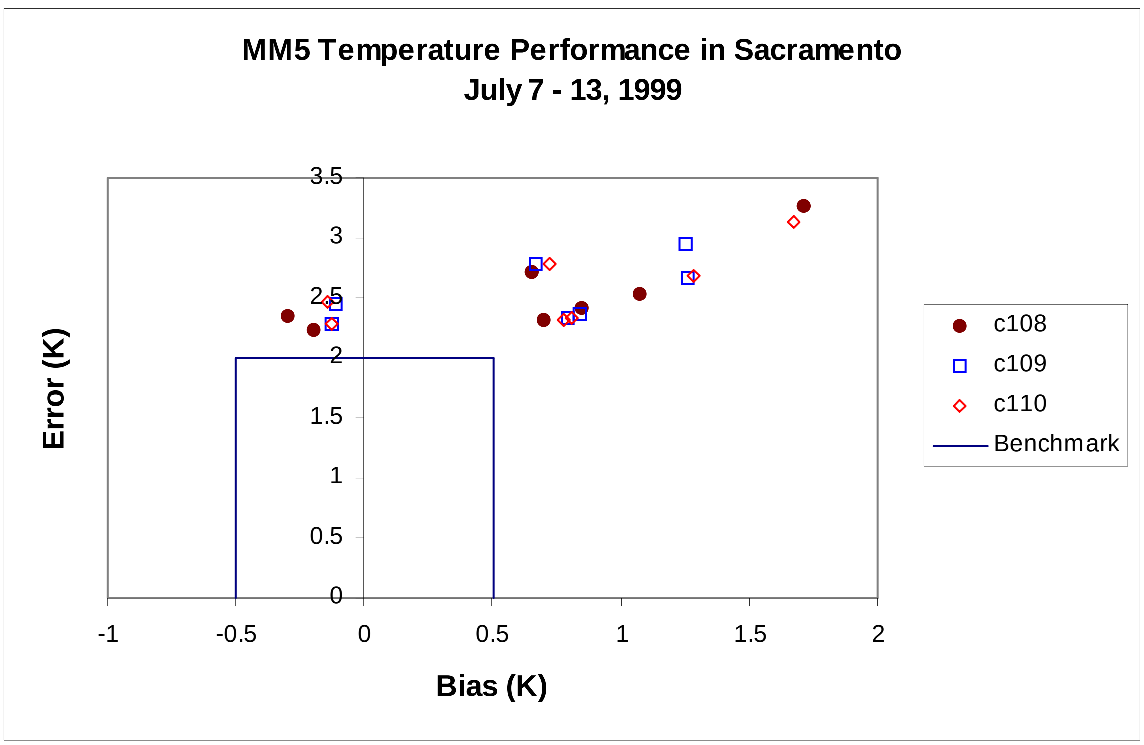


Figure 1-4. MM5 performance for winds and temperature in the Sacramento region.

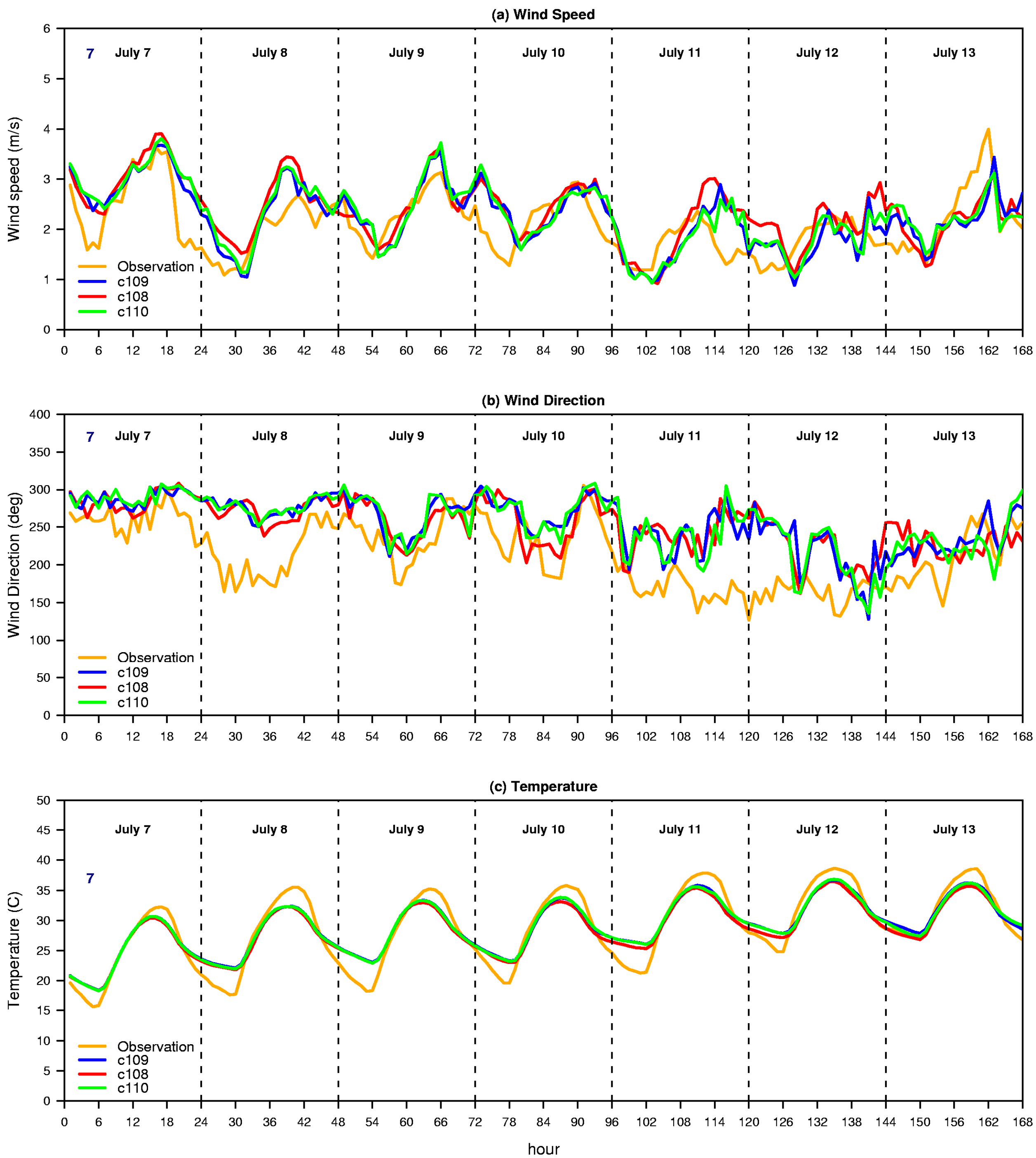
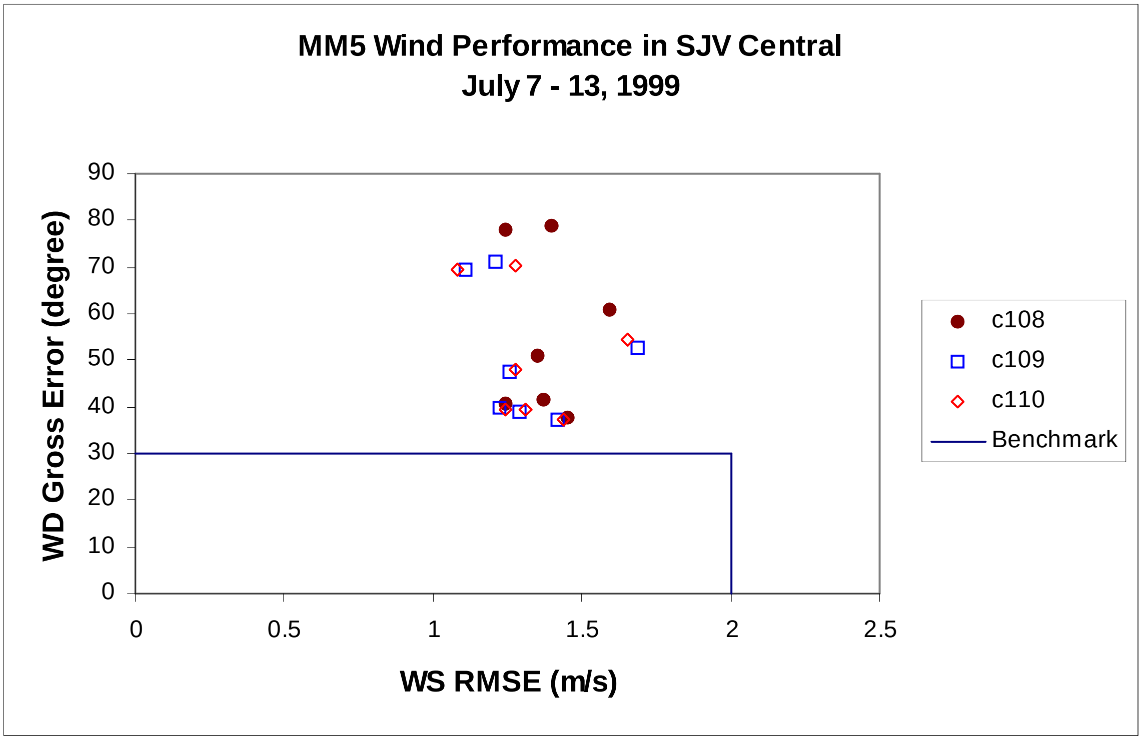


Figure 1-5. Time series of wind speed, wind direction, and temperature for the Central San Joaquin Valley over the July 7-13, 1999 modeling period.



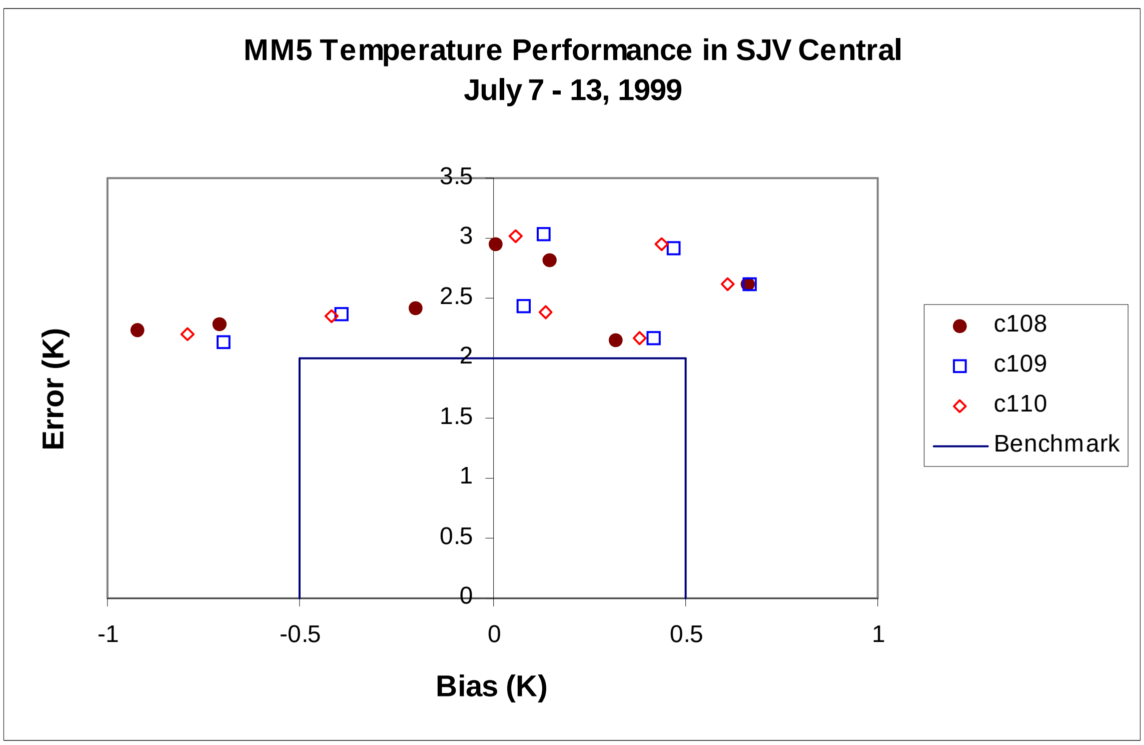


Figure 1-6. MM5 performance for winds and temperature in the Central San Joaquin Valley.

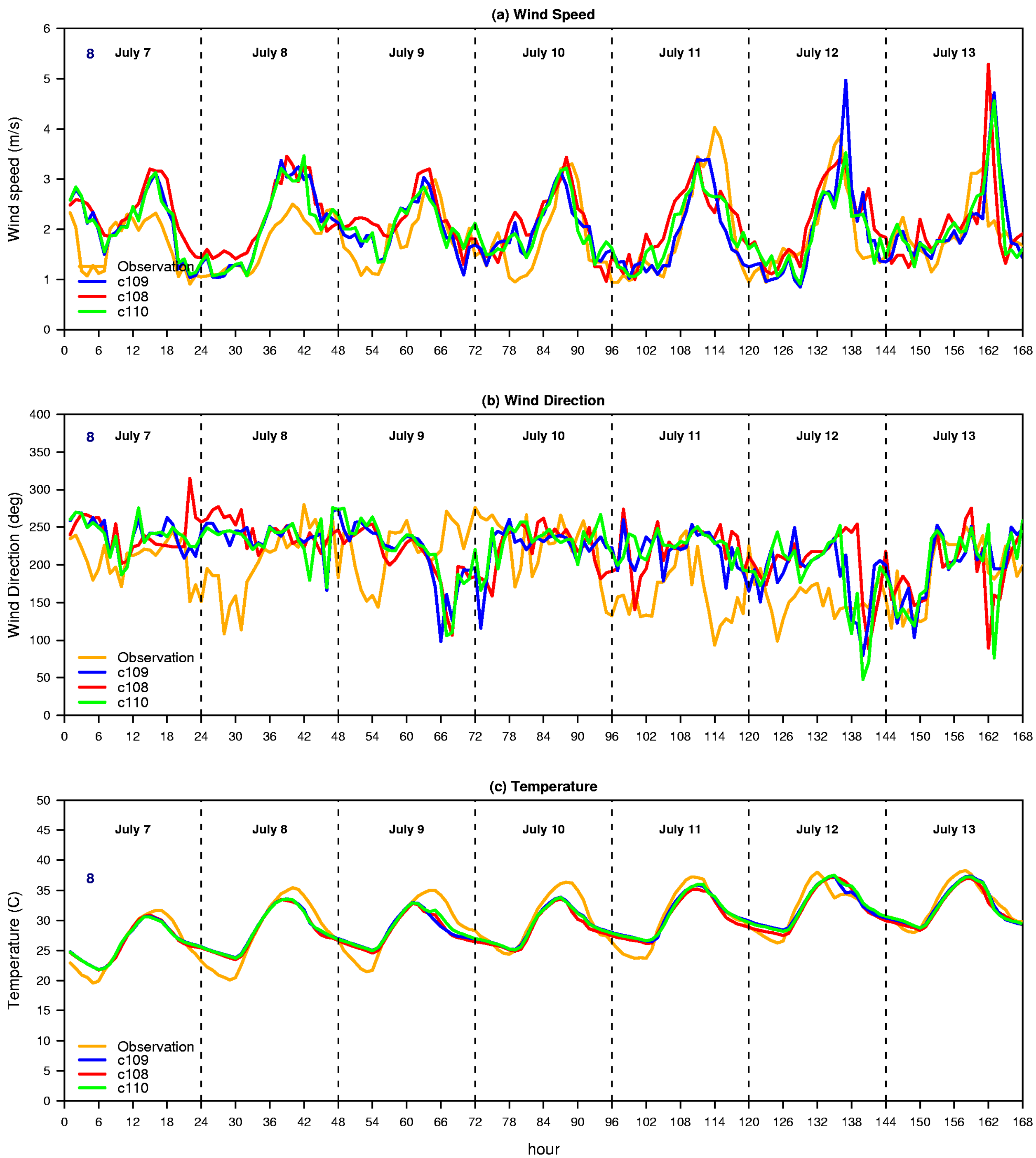
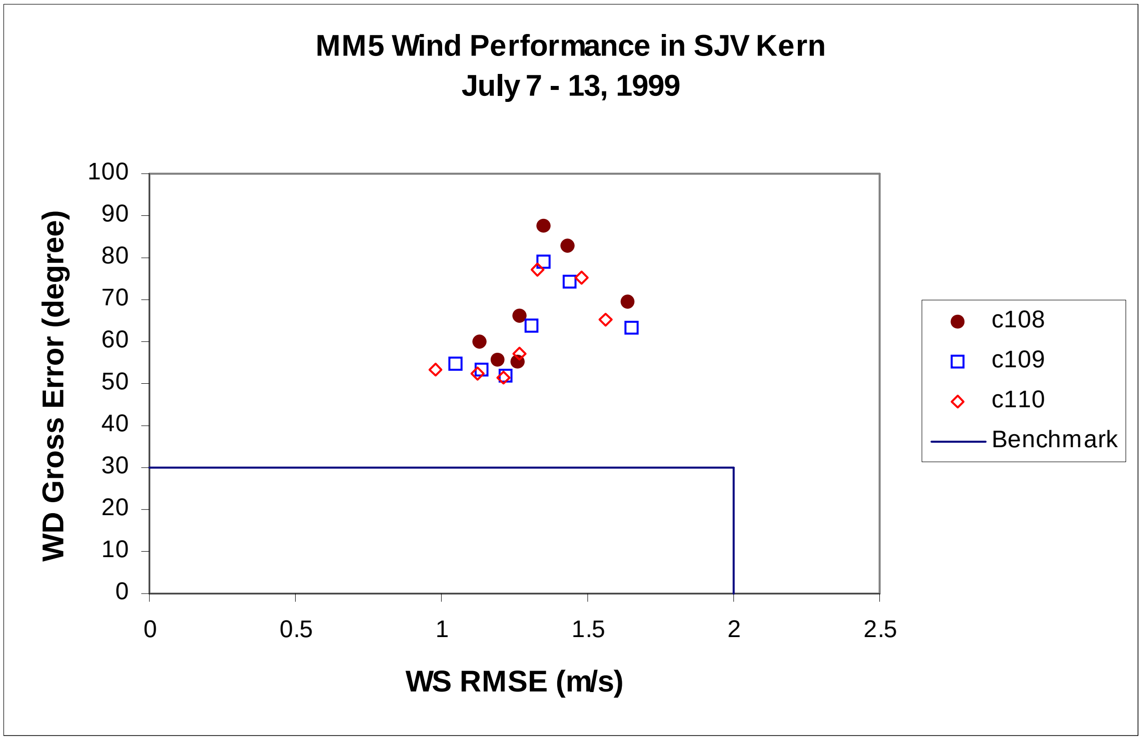


Figure 1-7. Time series of wind speed, wind direction, and temperature for the Southern San Joaquin Valley over the July 7-13, 1999 modeling period.



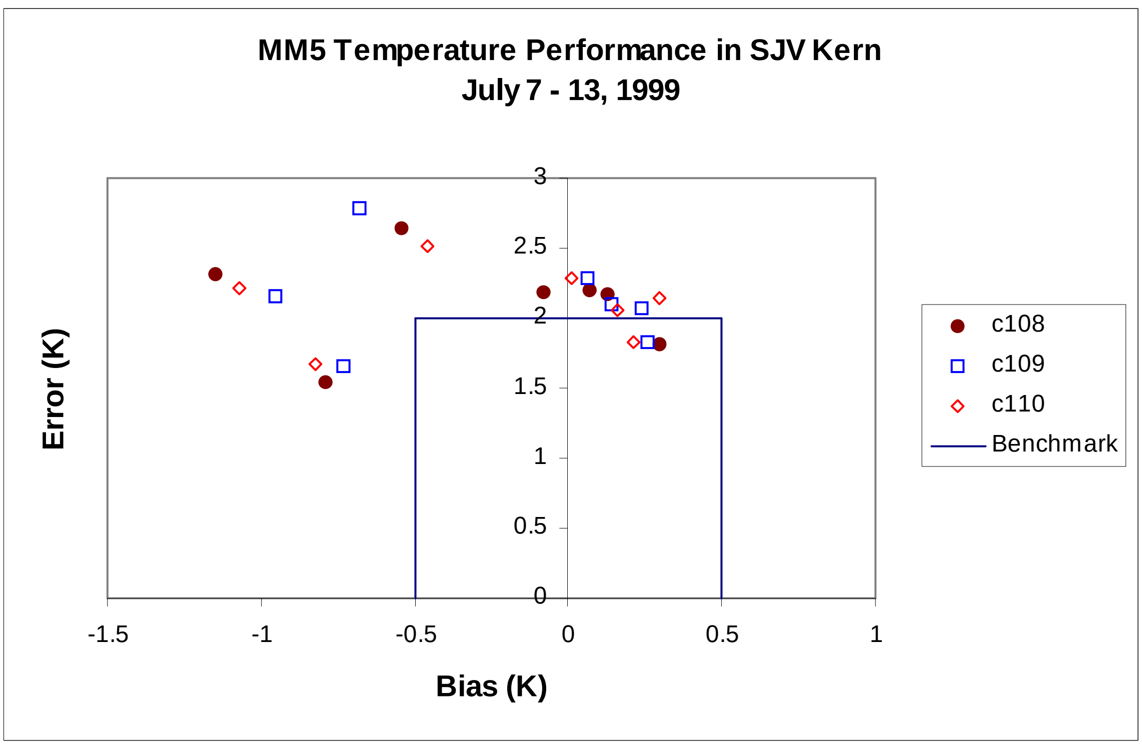


Figure 1-8. MM5 performance for winds and temperature in the Southern San Joaquin Valley.

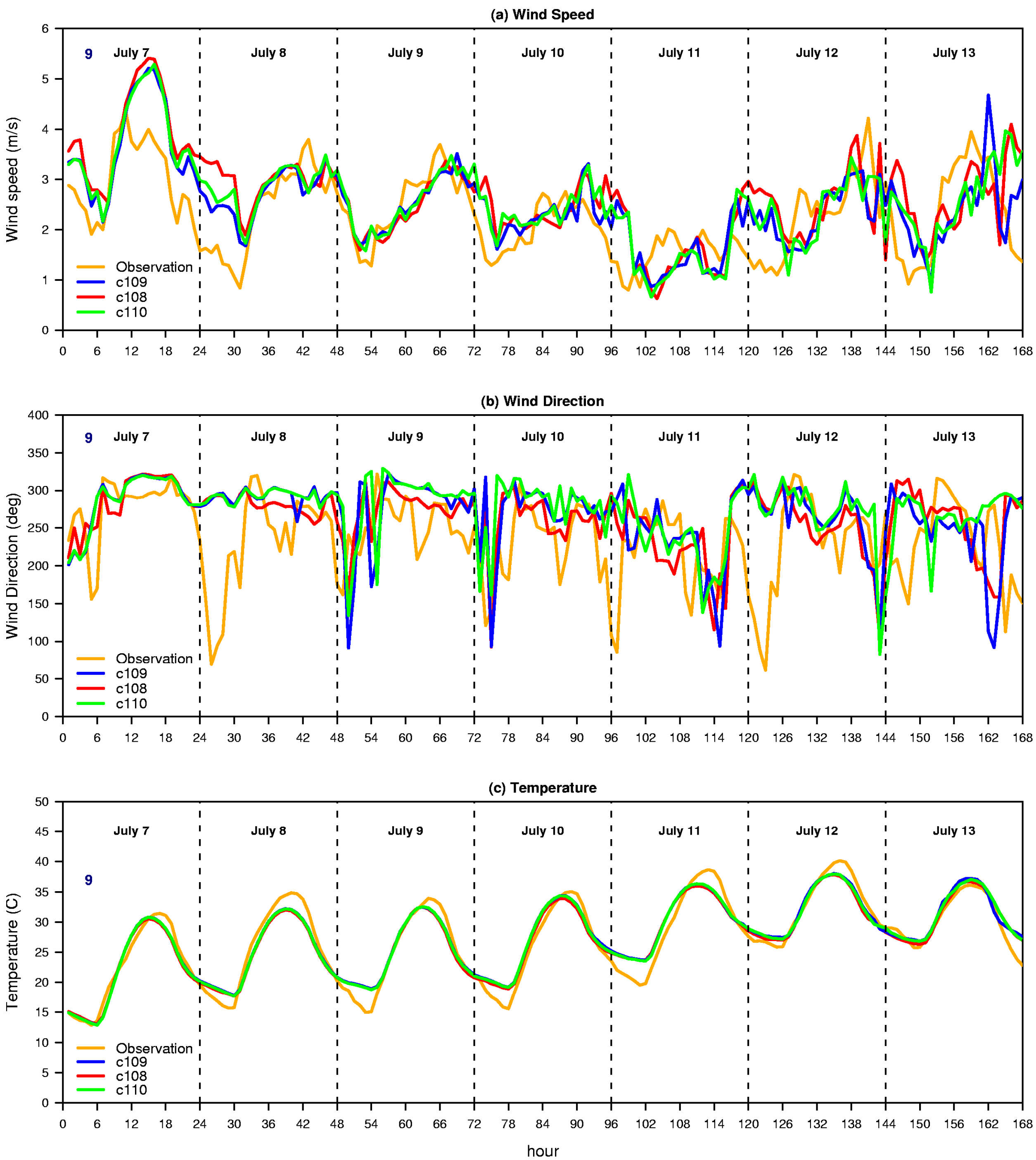
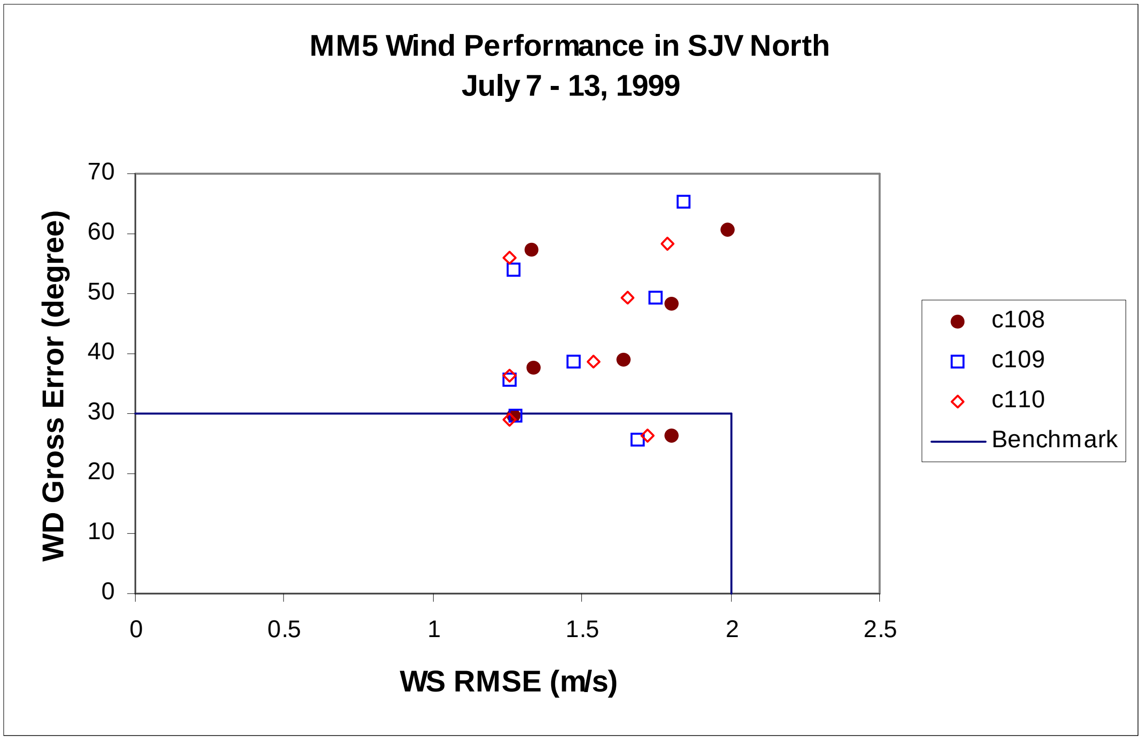


Figure 1-9. Time series of wind speed, direction, and temperature for the Northern San Joaquin Valley over the July 7-13, 1999 modeling period.



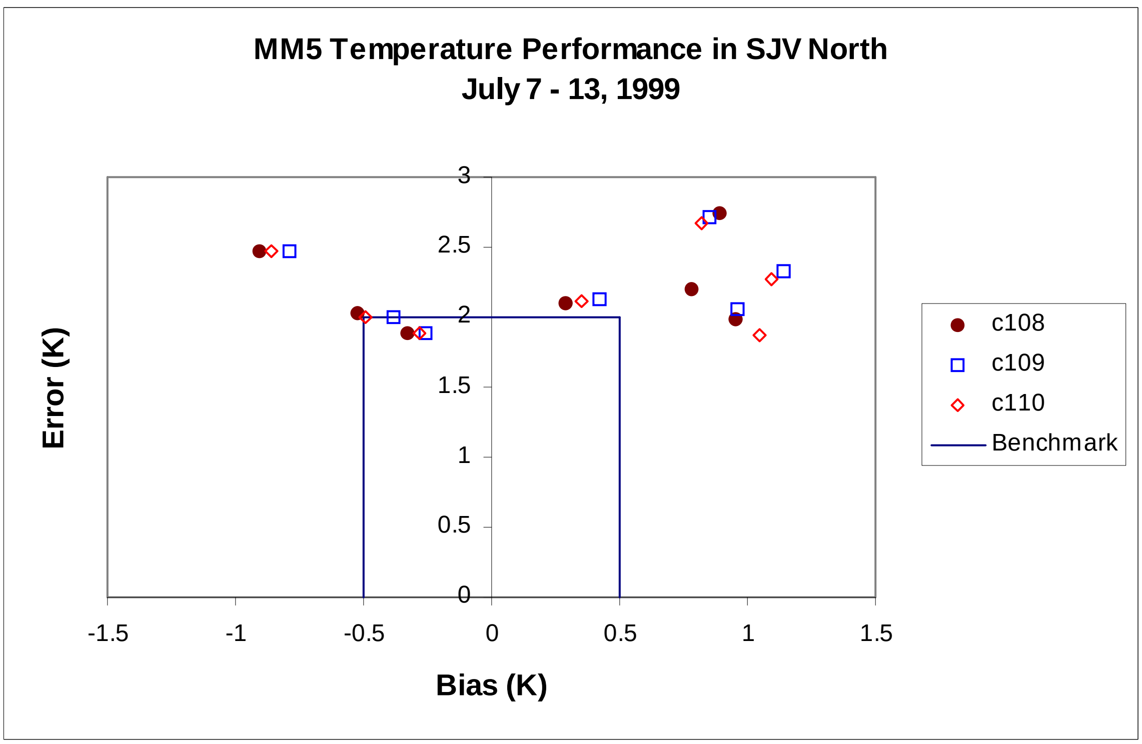


Figure 1-10. MM5 performance for winds and temperature in the Northern San Joaquin Valley.

1.2.2 July-August 2000 Episode (CCOS Episode)

Under the CCOS program, the meteorological modeling group at the National Oceanic and Atmospheric Administration (NOAA) was selected as a contractor to study the July 29, 2000 12Z – Aug 3, 2000 12Z ozone episode that occurred during CCOS. Under this CCOS contract, NOAA studied the meteorology of this episode using the MM5 numerical model with various model options and initial and boundary conditions.

After extensive internal simulations, NOAA produced and distributed an MM5 model output in 2003 that is referred to as the "NOAA placeholder" simulation. Subsequently, NOAA produced several additional MM5 outputs. Three of these other simulations as well as the placeholder simulation were selected by ARB as candidates for SIP modeling purposes. The last two of these simulations are considered by NOAA to be their 'best available' runs. The model setups in all of these simulations are identical except as noted in the first four rows of the table below (Table 1-3).

Table 1-3 July-Aug 2000 CCOS Episode. Four 5-day NOAA simulations and two 7-day ARB simulations are considered.

Simulation Number	Abbreviation	Description
1	NOAA placeholder	5 day simulation using 5 layer soil model and observational FDDA file prepared by the Bay Area AQMD
2	NOAA FDDA1	5 day simulation; Same as NOAA placeholder (#1), except using NOAH land-surface model
3	NOAA FDDA2	5 day simulation; Same as NOAA FDDA1 (#2), above, except using observational FDDA file prepared by NOAA and with roughness length doubled.
4	NOAA FDDA3	5 day simulation; Same as NOAA FDDA1 (#2), above, except using observational FDDA file prepared by NOAA and with 5 times the roughness length.
5	ARB NO FDDA	7 day simulation
6	ARB FDDA	7 day simulation

As indicated in the last two rows of the table above, model simulations were also conducted at ARB. In these two ARB simulations, different model options were used: the Gayno Seaman boundary layer scheme was used; a larger radius of influence was selected; and the model was started approximately two days earlier, on July 27, 00Z, in order to provide additional days for Relative Reduction Factor calculations performed for air quality analyses. Thus, both ARB runs are for 7 days.

The four five-day NOAA outputs along with two seven-day ARB outputs, called ARB NO FDDA and ARB FDDA, were analyzed and compared against observational data using the comparison methods discussed previously.

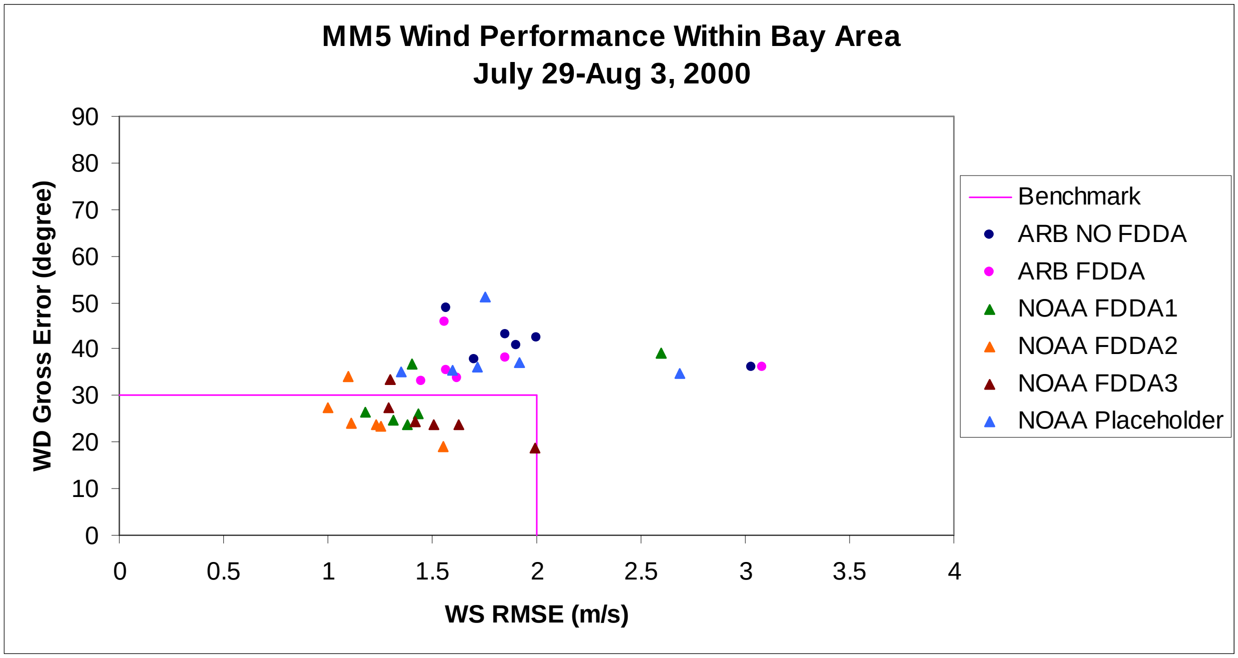
Model performance statistics provided in Figures 1-10 (a-g) and 1-11(a-g) point out that the statistical error of simulation NOAA FDDA3 are within the acceptable limits of EPA standards for wind speed and direction while temperature predictions are not very good.

The temporal comparison of model variables at the Angiola site is illustrated in Figures 1-12 (a and b). Comparisons at other stations were also made and can be made available (see the reference to other 2000 meteorology information in the Appendix). While previous figures show the station averaged model performance statistics within each subregion, these give a detailed perspective of model performance at an individual observation station. As can be seen from the examination of these temporal comparisons, model performance can vary dramatically from one station to the next. While all NOAA and ARB FDDA simulations appear to adequately produce the observed wind field, the NOAA Placeholder model appears to produce observed temperatures better than the other model runs do.

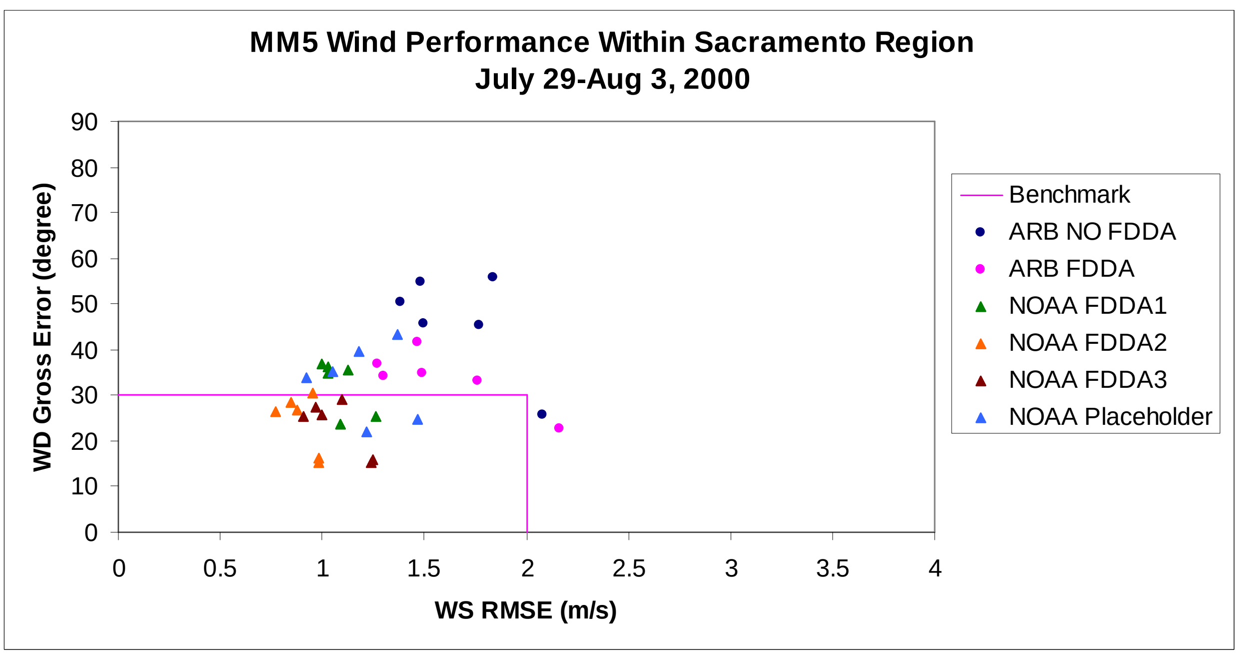
Figures 1-13(a-f) compare horizontal wind vectors against observations at 21Z on July 29, 2000 (2 PM local time) when the flow field is expected to play an important role in maximum ozone concentrations. Each model has slightly different wind flows, however the flows in the NOAA FDDA2, FDDA3 and Placeholder simulations seem to be more organized than in the other models.

Since NOAA FDDA2 and NOAA FDDA3 are sensitivity tests generated by playing with roughness length, these results will not be considered in air quality simulations until the effects of these tests are further understood and accepted. Presently, it appears that this has an adverse impact on temperature performance. ARB is currently working with NOAA to better understand these runs. The figures indicate that the overall performance of NOAA’s placeholder model for all variables is generally as acceptable as all other MM5 results that were considered. Therefore, the NOAA placeholder model output is used in air quality simulations.

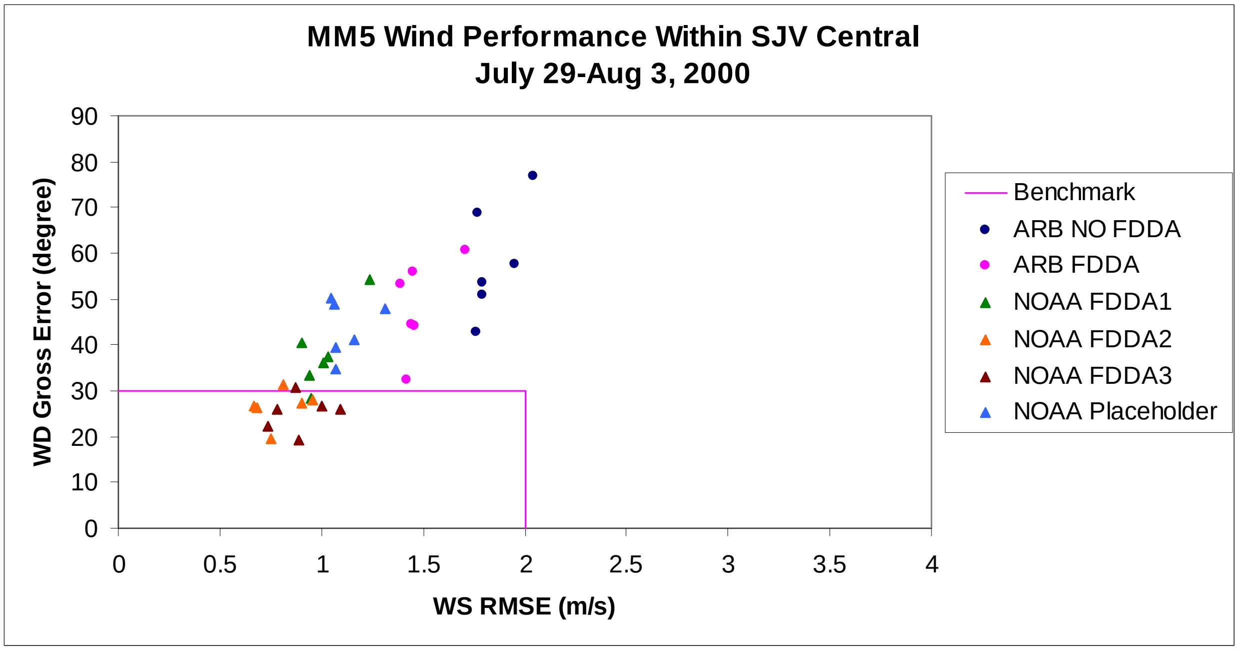
Figures 1-11 (a-g): Model performance statistics of wind speed and direction created for subregions 3, 6, 7, 8, 9, 10 and 11, respectively.



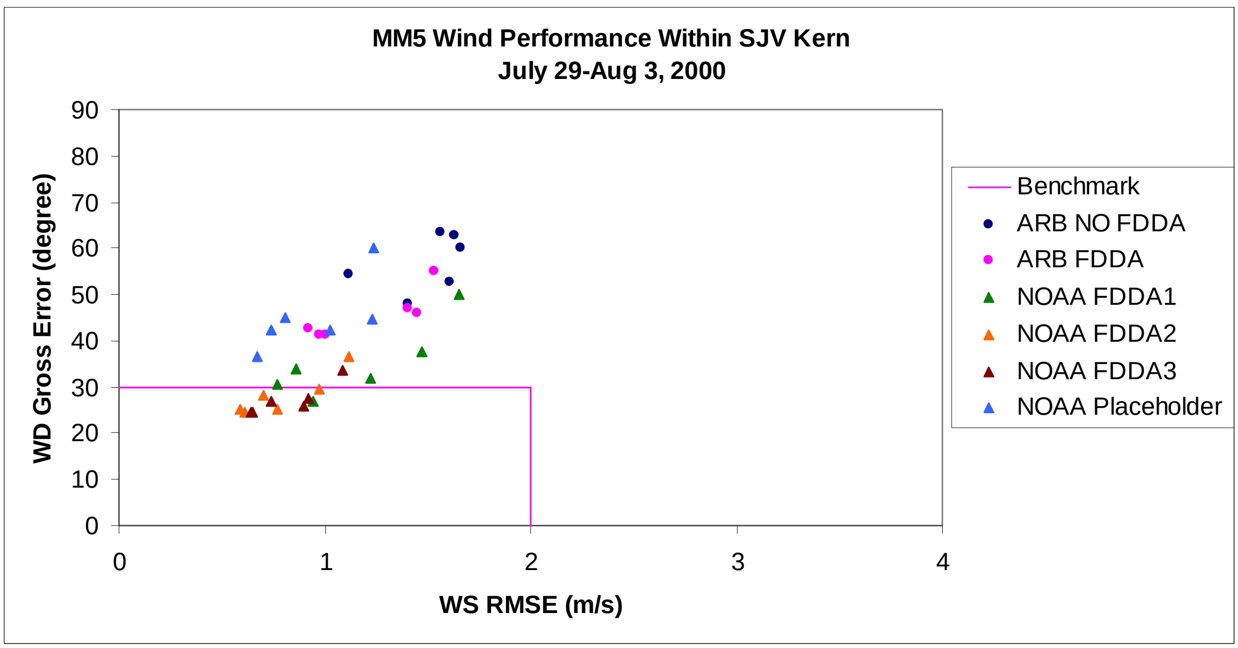
(a)



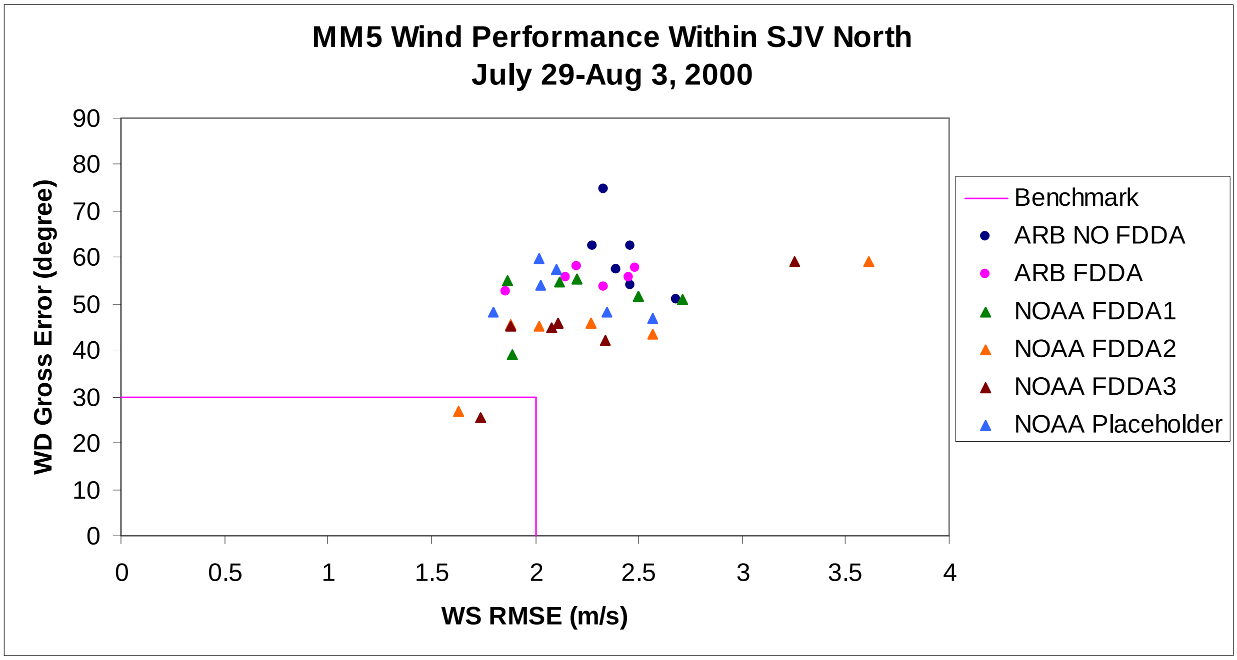
(b)


MM5 Wind Performance Within SJV Central
July 29-Aug 3, 2000
WD Gross Error (degree)
WS RMSE (m/s)
0
10
20
30
40
50
60
70
80
90
0
0.5
1
1.5
2
2.5
3
3.5
4
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

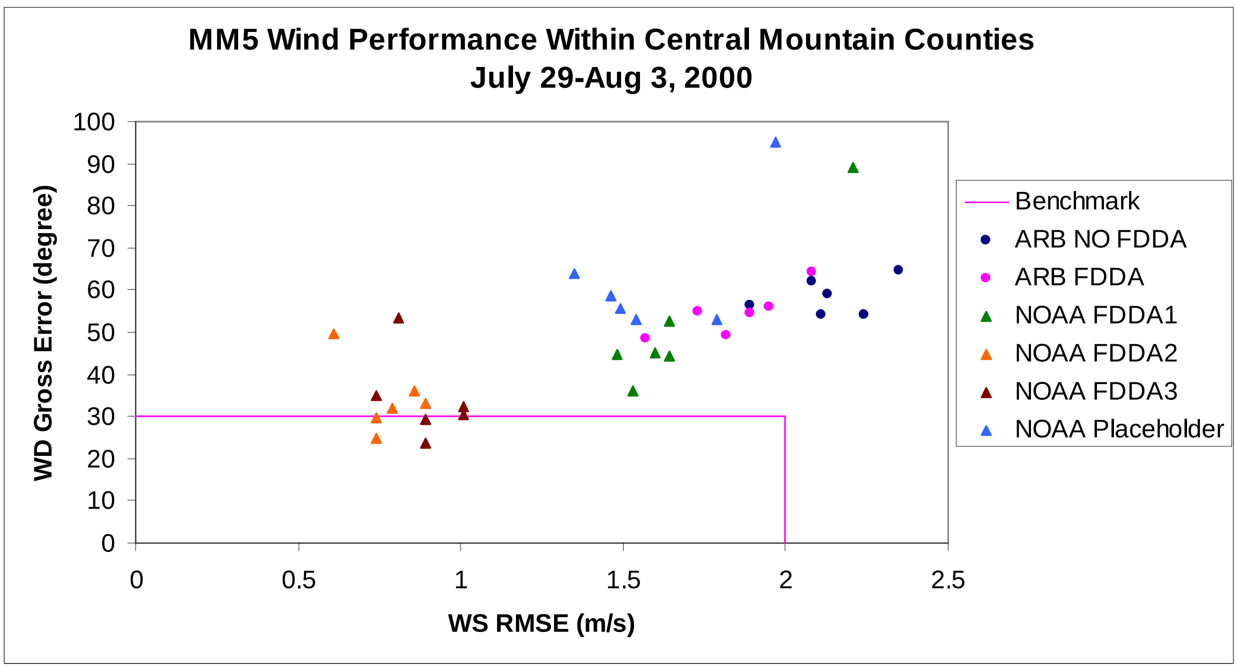
(c)


MM5 Wind Performance Within SJV Kern
July 29-Aug 3, 2000
WD Gross Error (degree)
WS RMSE (m/s)
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

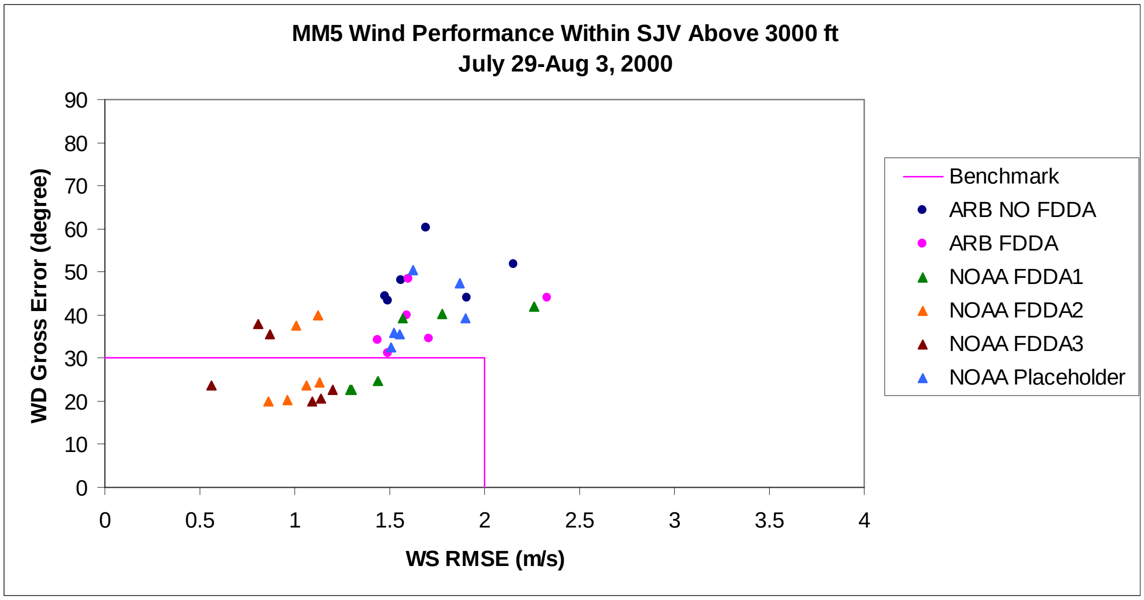
(d)


MM5 Wind Performance Within SJV North
July 29-Aug 3, 2000
WD Gross Error (degree)
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
WS RMSE (m/s)
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

(e)

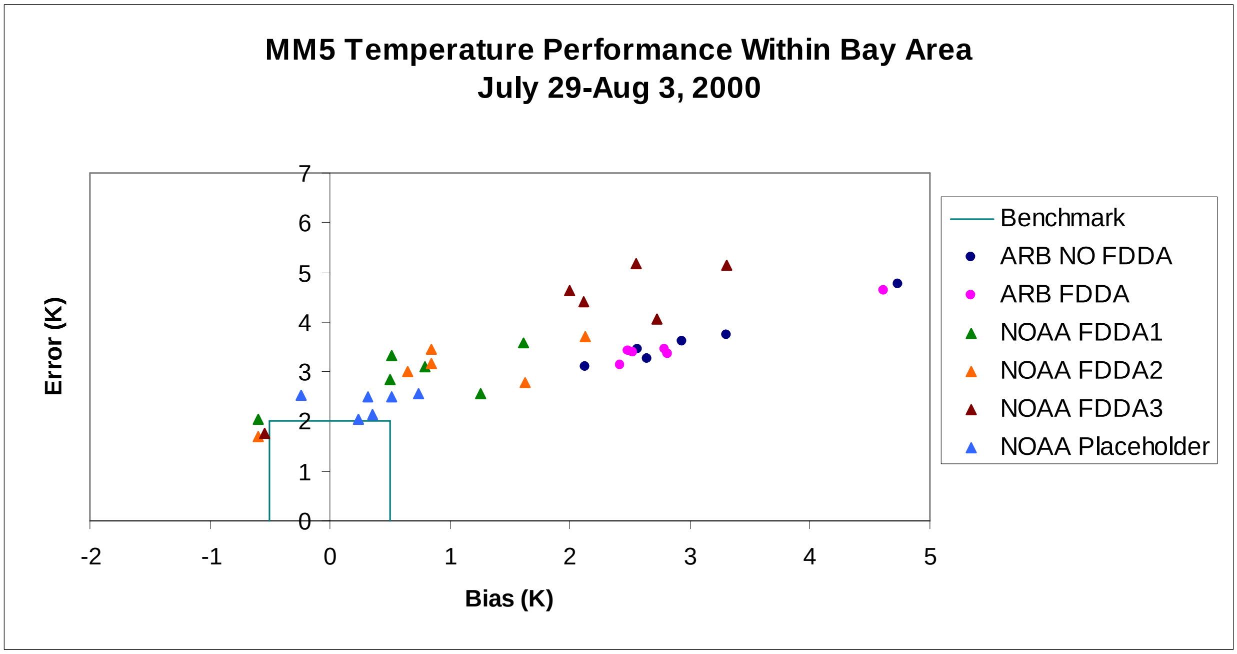

MM5 Wind Performance Within Central Mountain Counties
July 29-Aug 3, 2000
WD Gross Error (degree)
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
WS RMSE (m/s)
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

(f)

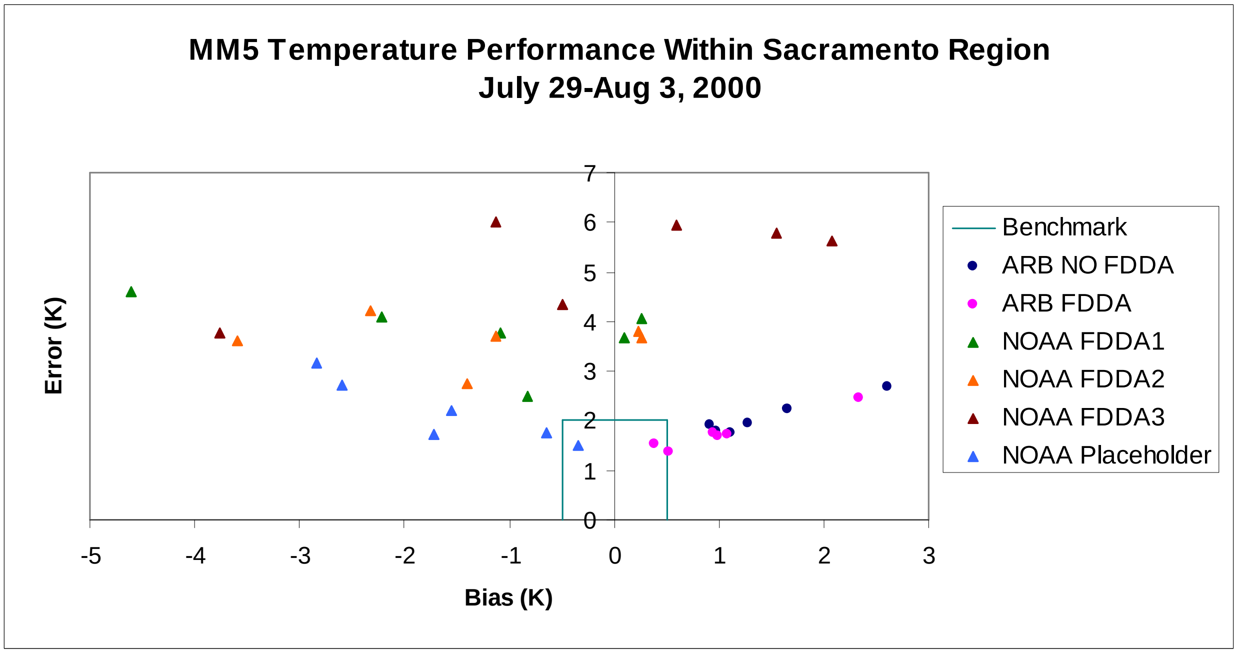

MM5 Wind Performance Within SJV Above 3000 ft
July 29-Aug 3, 2000
WD Gross Error (degree)
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
WS RMSE (m/s)
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

(g)

Figures 1-12 (a-g): Same as Figures 1-11, except for temperature.



(a)



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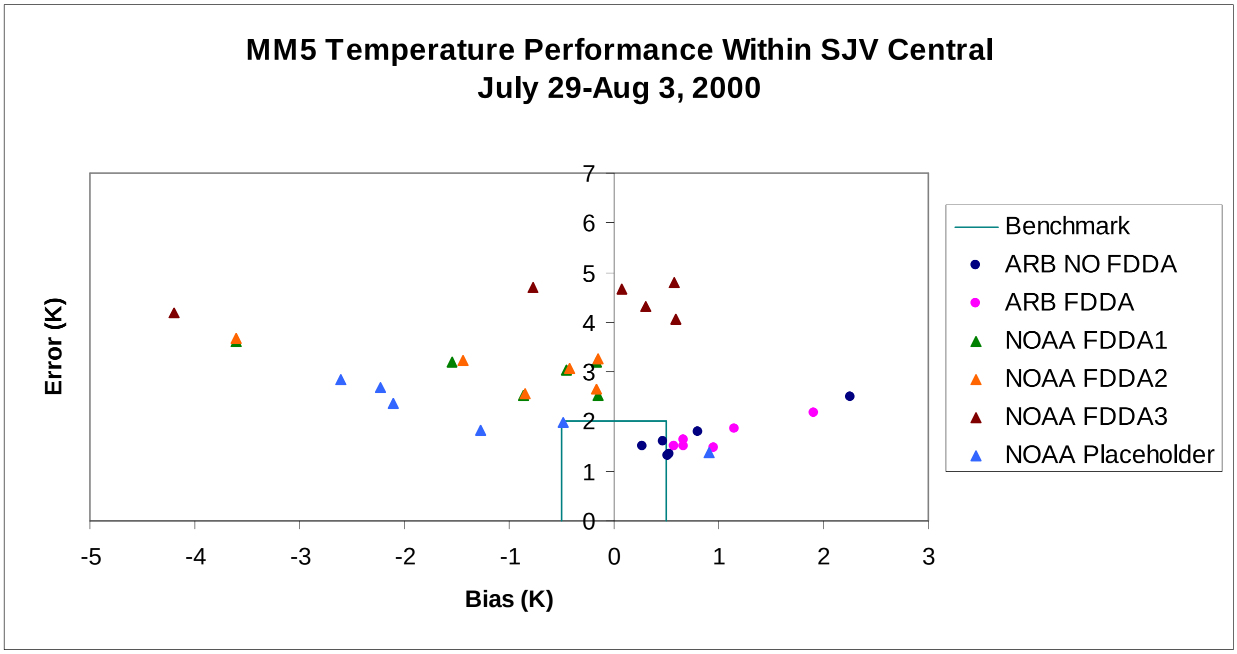
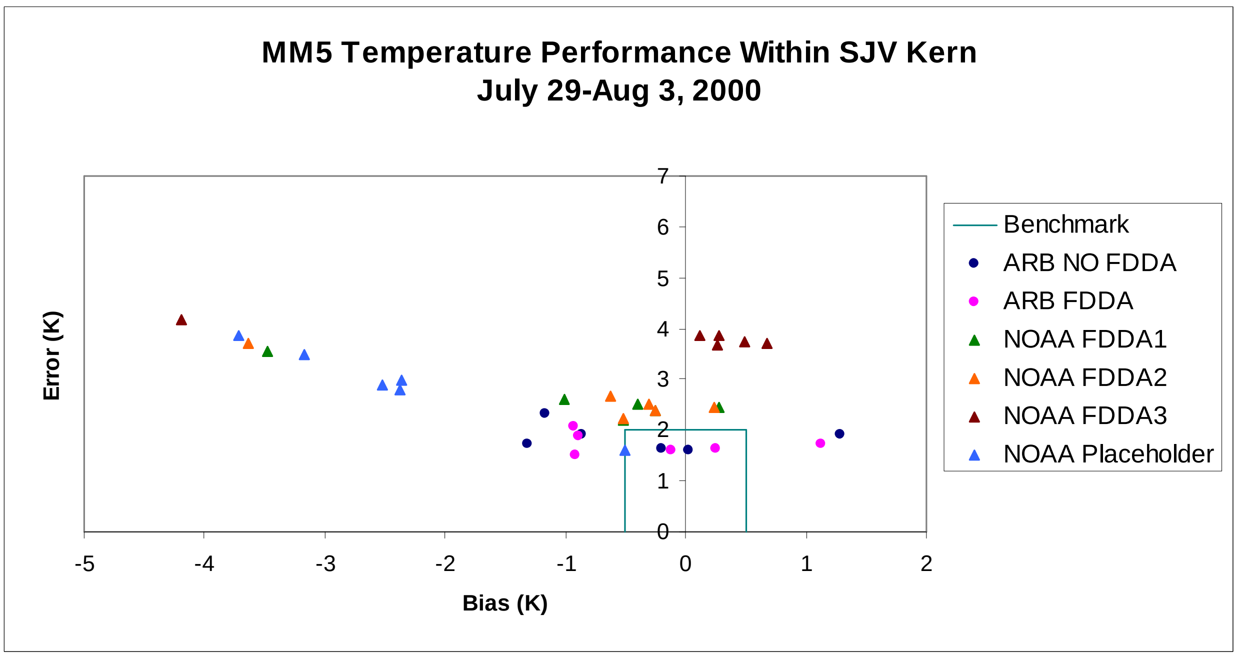
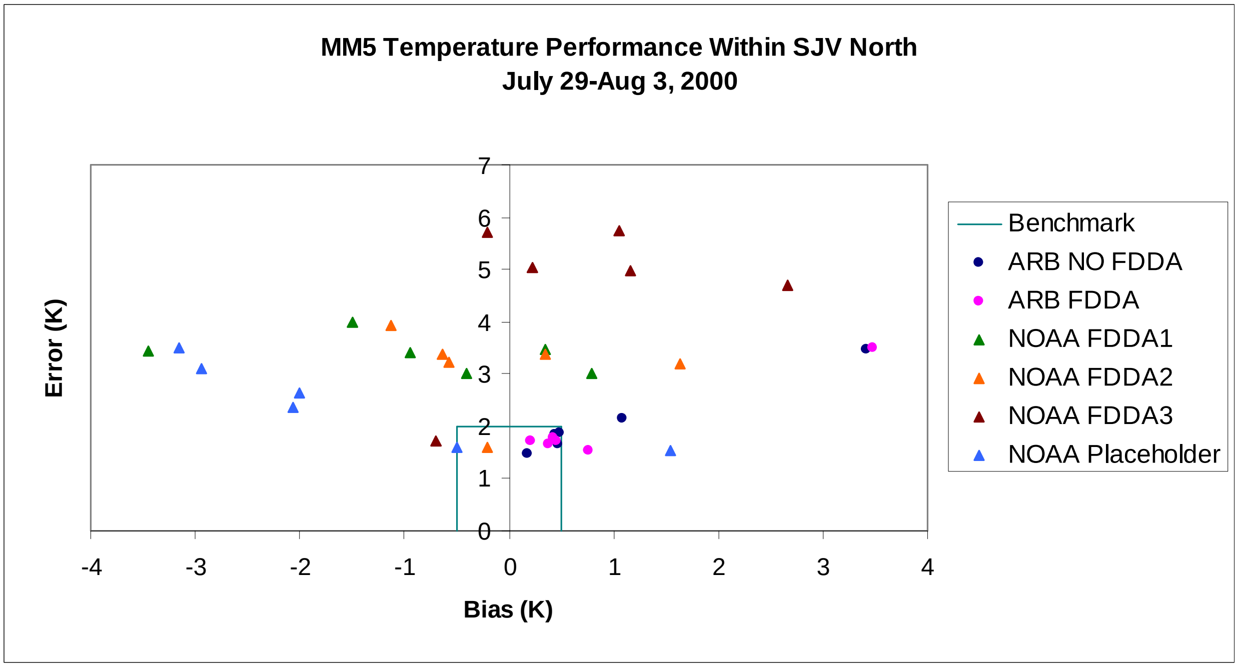

MM5 Temperature Performance Within SJV Central
July 29-Aug 3, 2000
Error (K)
Bias (K)
7
6
5
4
3
2
1
0
-5
-4
-3
-2
-1
0
1
2
3
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

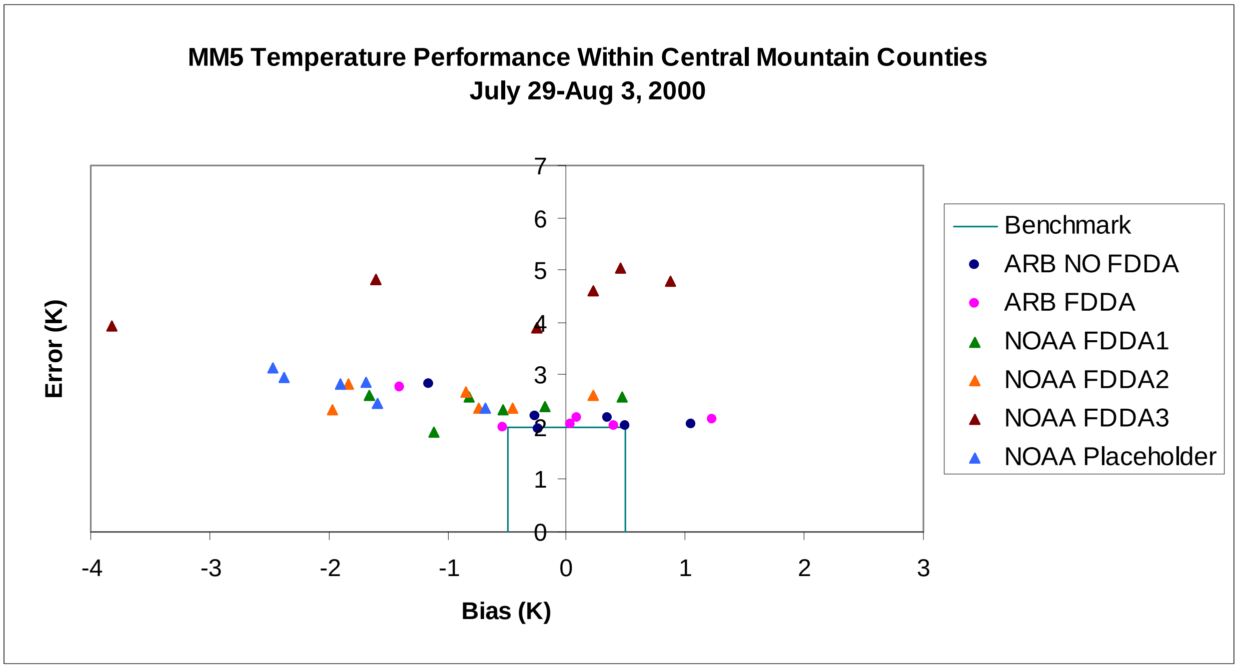
(c)


MM5 Temperature Performance Within SJV Kern
July 29-Aug 3, 2000
Error (K)
Bias (K)
7
6
5
4
3
2
1
0
-5
-4
-3
-2
-1
0
1
2
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

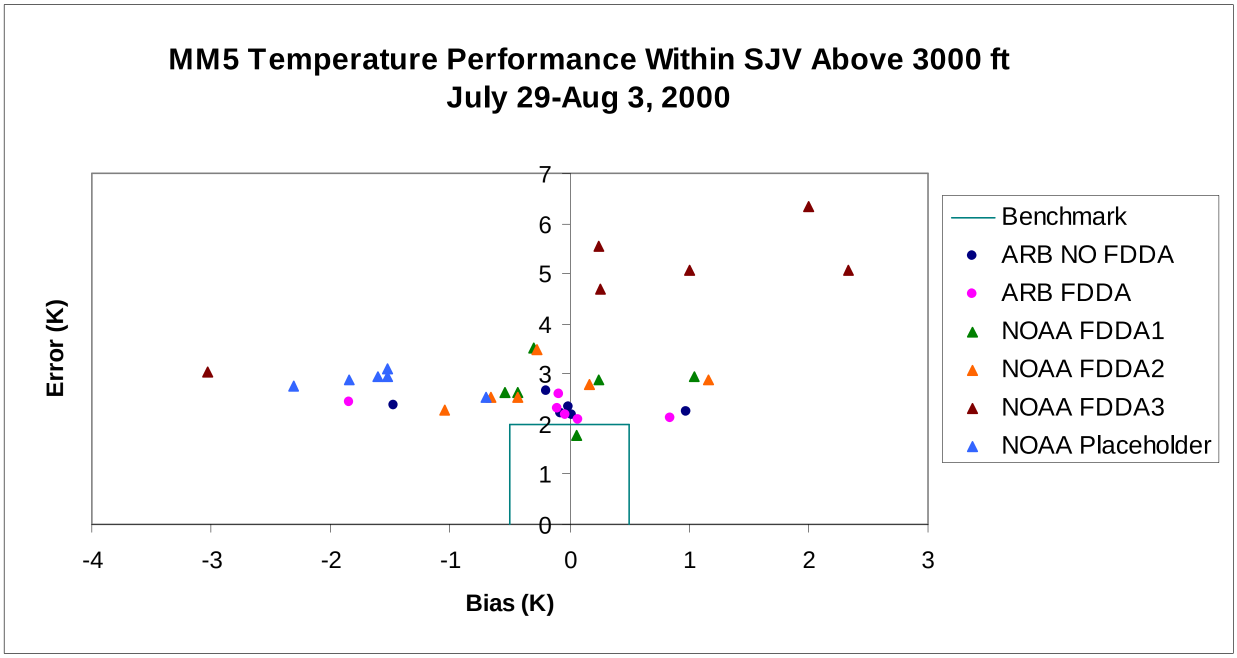
(d)


MM5 Temperature Performance Within SJV North
July 29-Aug 3, 2000
Error (K)
Bias (K)
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

(e)

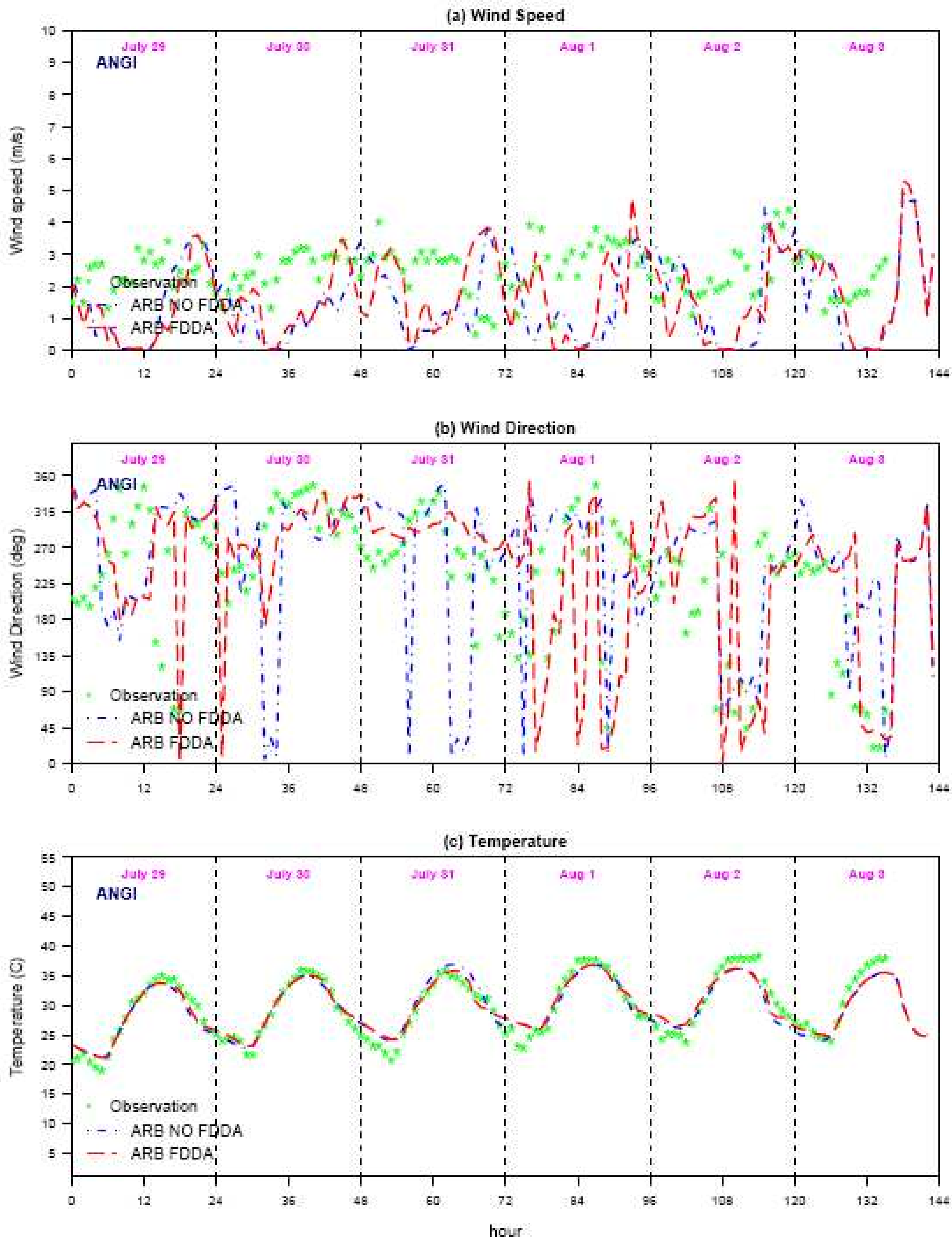

MM5 Temperature Performance Within Central Mountain Counties
July 29-Aug 3, 2000
Error (K)
Bias (K)
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

(f)

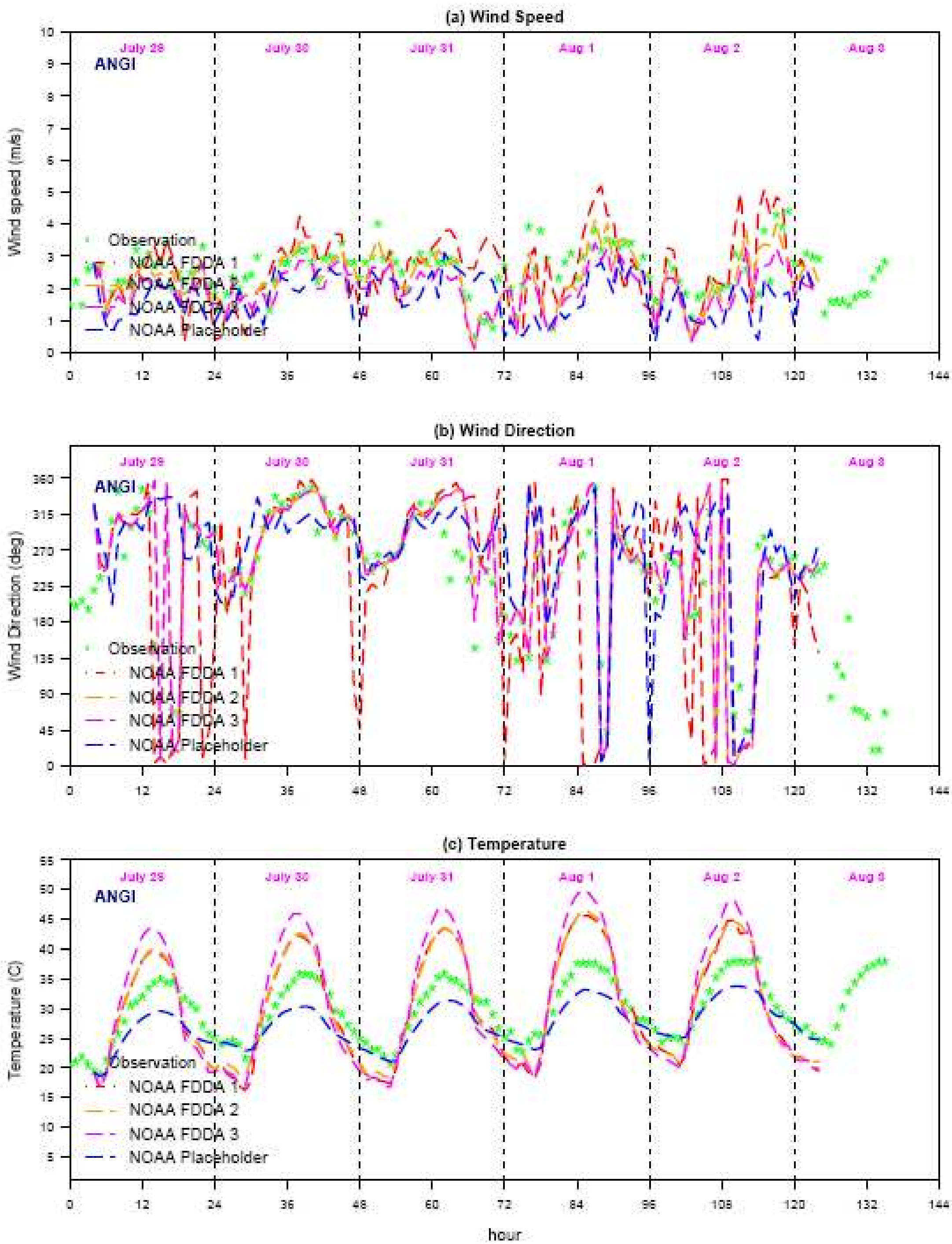

MM5 Temperature Performance Within SJV Above 3000 ft
July 29-Aug 3, 2000
Error (K)
Bias (K)
7
6
5
4
3
2
1
0
-4
-3
-2
-1
0
1
2
3
Benchmark
ARB NO FDDA
ARB FDDA
NOAA FDDA1
NOAA FDDA2
NOAA FDDA3
NOAA Placeholder

(g)

Figures 1-12 (a and b): Temporal comparisons of wind speed, direction and temperature at Angiola station for ARB (a) and NOAA (b) model results

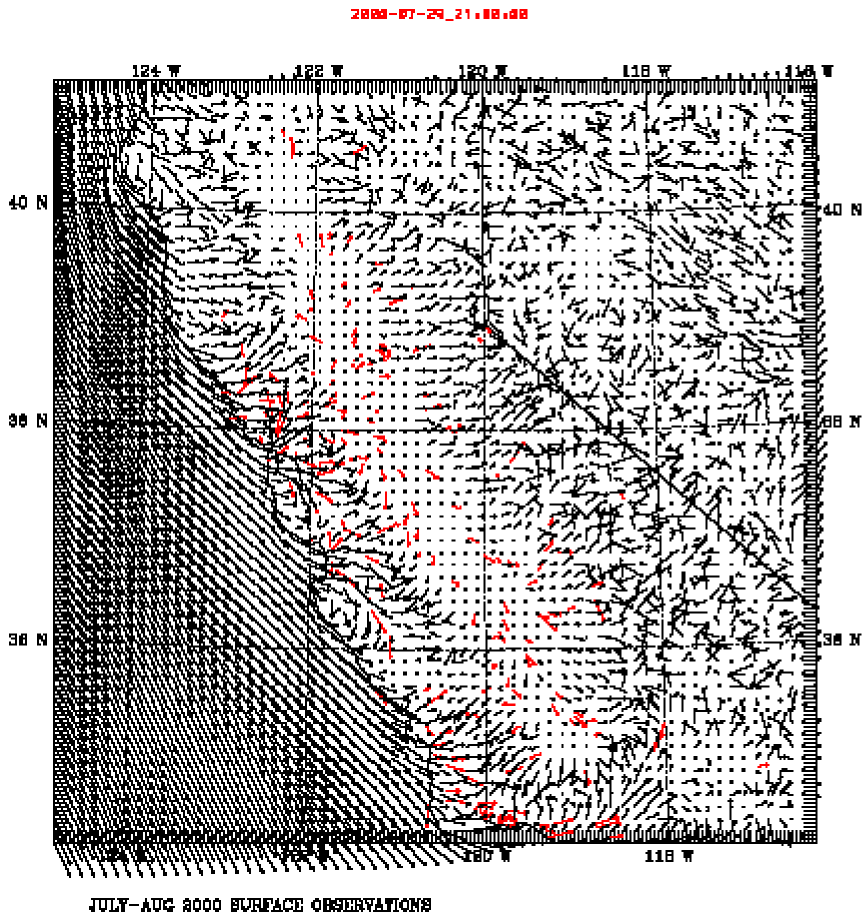


(a)

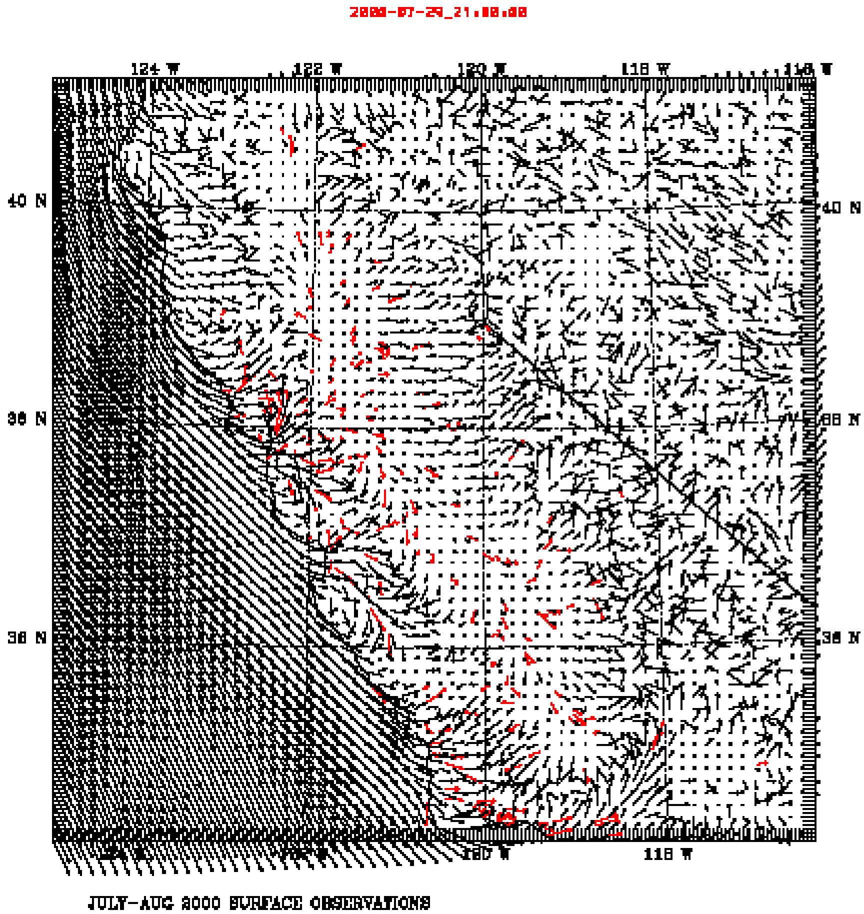

(a) Wind Speed
July 29
July 30
July 31
Aug 1
Aug 2
Aug 3
ANGI
Wind speed (m/s)
Observation
NOAA FDDA 1
NOAA FDDA 2
NOAA FDDA 3
NOAA Placeholder
(b) Wind Direction
Wind Direction (deg)
(c) Temperature
Temperature (C)
hour

(b)

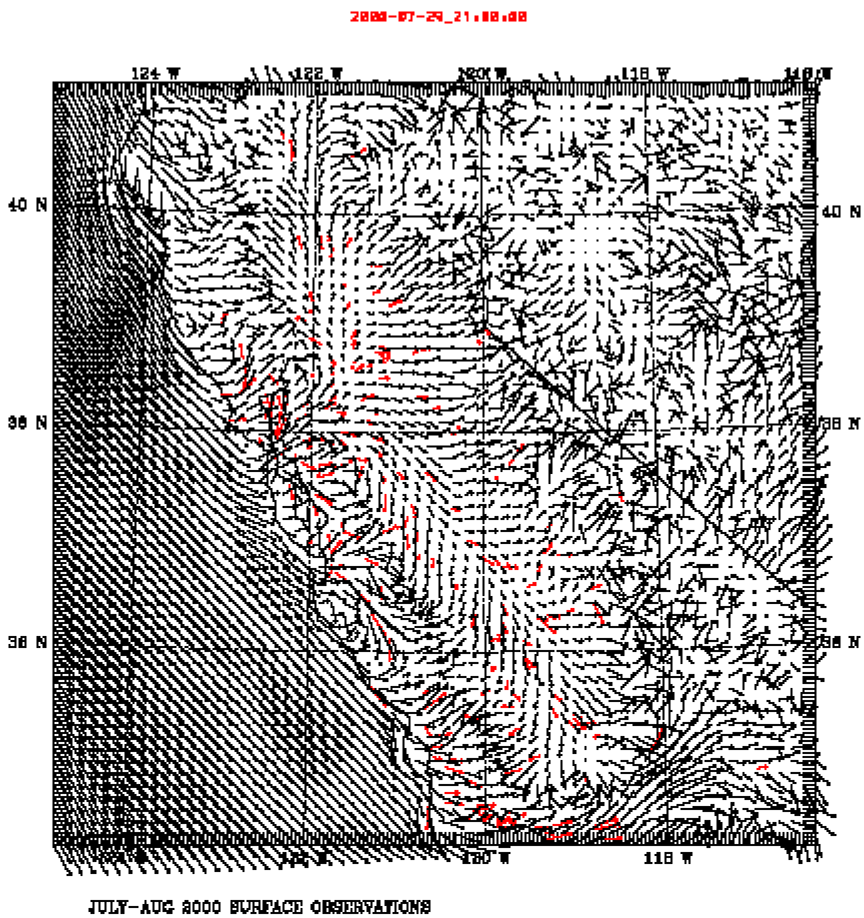
Figures 1-13(a-f): Horizontal variation of wind vectors on July 29, 2000 21Z (2 PM local time) compared to the observations for ARB NO FDDA (a), ARB FDDA (b), NOAA FDDA1 (c), NOAA FDDA2 (d), NOAA FDDA3 (e) and NOAA Placeholder models (f).



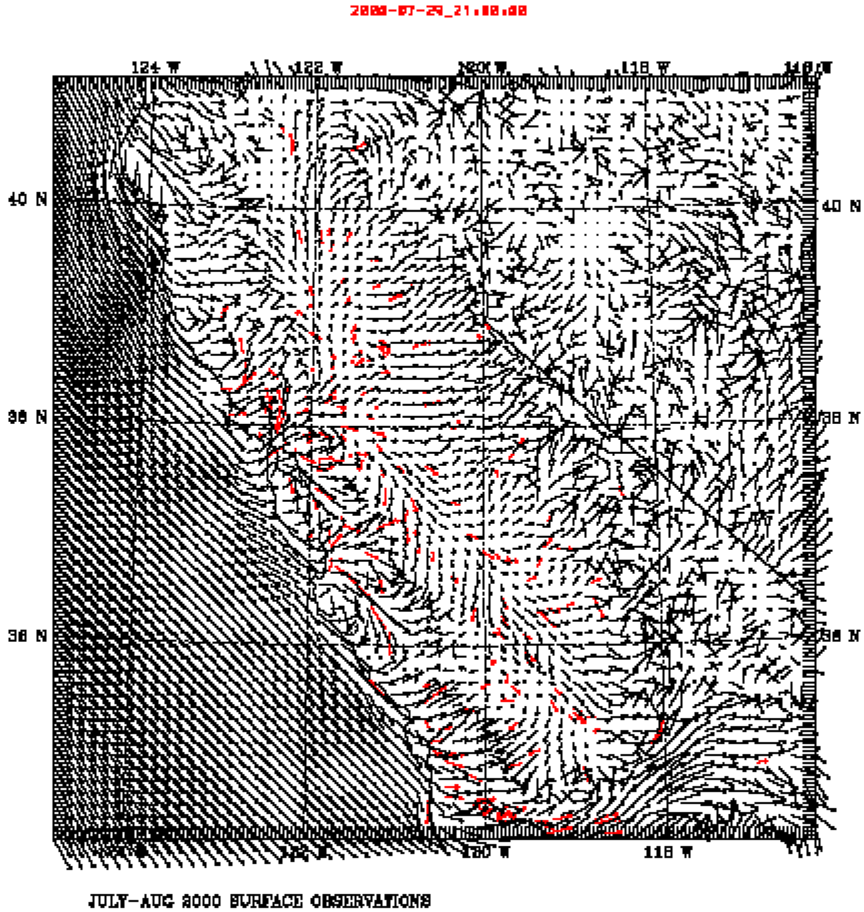
(a)


2000-07-29_21:00:00
124 W
122 W
120 W
118 W
116 W
40 N
38 N
36 N
JULY-AUG 2000 SURFACE OBSERVATIONS

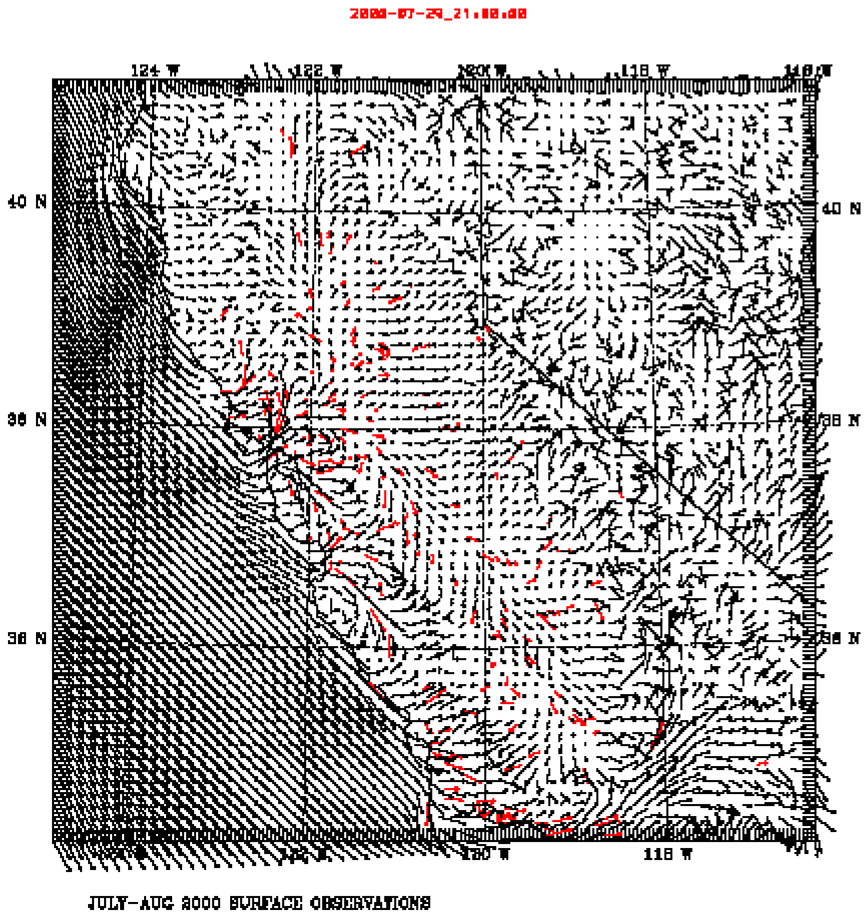
(b)


2000-07-29_21:00:00
124 W
122 W
120 W
118 W
116 W
40 N
38 N
36 N
JULY-AUG 2000 SURFACE OBSERVATIONS

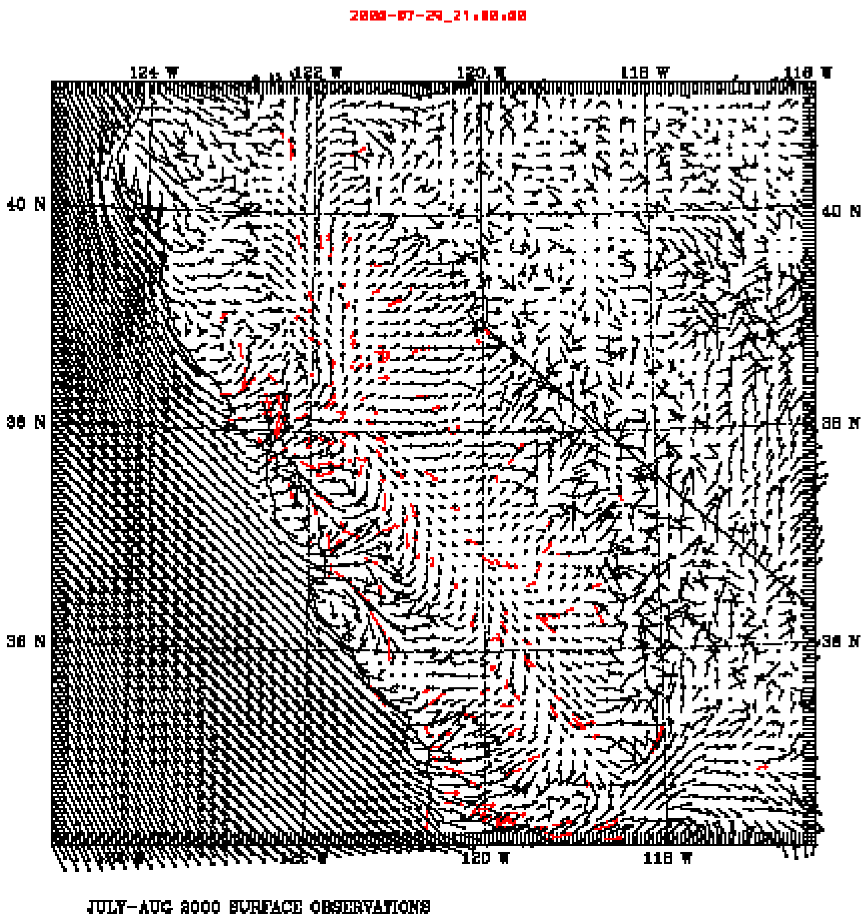
(c)


2000-07-29_21:00:00
124 W
122 W
118 W
40 N
38 N
36 N
120 W
118 W
JULY-AUG 2000 SURFACE OBSERVATIONS

(d)


2000-07-29_21:00:00
124 W
122 W
120 W
118 W
116 W
40 N
38 N
36 N
JULY-AUG 2000 SURFACE OBSERVATIONS

(e)


2000-07-29_21:00:00
124 W
122 W
120 W
118 W
116 W
40 N
38 N
36 N
JULY-AUG 2000 SURFACE OBSERVATIONS

(f)

2 Air Quality Model Performance

2.1 Air Quality Model Performance Metrics

Air quality model results are used to develop strategies for attaining the federal 8-hour ozone standard. The development of these strategies relies on the use of relative reduction factors (RRFs). More detailed discussion of RRFs is provided in other documents. However, the use of RRFs requires an evaluation of relative air quality model response at specific monitoring sites in the base year(s), a baseline year, and a future year.

Adequate model performance is a requirement for use of modeled results. The lack of acceptable performance greatly increases uncertainty in the use of the modeling results, and casts doubt on conclusions based on the modeling. Although it is desirable to include as many days as possible in the RRF calculations, our experience has demonstrated that not all modeled days meet the minimum performance standards, and are thus not suitable for use. Therefore only those days that satisfy the following model performance criteria will be utilized in subsequent RRF calculations.

The USEPA (1991) and ARB (1990) outline a number of procedures for analysis of base year, air quality model performance. These include spatial and time-series plots, and statistical analyses, comparing simulated and observed pollutant concentrations, as well as sensitivity analysis of selected input fields. The purpose of the performance analysis is to provide some confidence that the air quality simulations – which are the basis of future-year ozone concentration estimates – are performing properly.

The application of air quality modeling results to demonstrate attainment of the federal 1-hour ozone standard emphasized the simulated unpaired peak ozone concentration. Three statistical measures were recommended to evaluate model performance: unpaired peak ratio (UPR), paired mean normalized bias (NB), and paired gross error (GE). These statistical measures were calculated for the modeling domain as a whole, and the NB and GE were calculated from all hourly concentrations in excess of 60 ppb (to avoid biasing the statistical measures with low concentrations). To meet performance guidelines, recommendations were that the UPR should be within ± 20%, NB should be within ± 15%, and the GE less than 35%. However, California's geography is very complex and modeling domains have evolved to cover large geographic areas. Thus it is recommended that the domains be divided into subregions, and that the performance measures be calculated independently for each subregion. The configuration of these subregions is somewhat arbitrary; however, they should be configured to isolate "common" regions of higher ozone. Figure 2-1 illustrates the proposed subregions for the CCOS domain.

The USEPA (2005) recommends that model performance be evaluated for 8-hour concentrations as well . The recommended statistical measures to assess simulated versus observed maximum 8-hour ozone concentrations include paired (in space, but not time) peak prediction accuracy (PPPA), paired mean normalized bias (NB), and paired gross error (GE). Although limited performance analysis has been completed for 8-hour ozone modeling in California, it seems prudent at this point to carry forward the 1-hour statistical goals and apply them for the 8-hour standard (UPR within ± 20%, NB within ± 15%, and the GE less than 35%). However, these limits may need to be revised as 8-hour SIP modeling progresses and rigorous model performance evaluations are completed.

While statistical measures for 1-hour model performance were typically calculated independently for each modeled day available, the USEPA also suggests that PPPA, NB, and GE be calculated for each site over all modeled days. However, because the number of episode days available may be very limited, the statistical uncertainties in these latter calculations would be large and they are not recommended or used herein.

In order to have confidence in future year estimates from air quality models, there must be confidence in the air quality modeling for the base year. That is, days not meeting model acceptance criteria provide high uncertainty, and should not be used for the modeled attainment test.

In addition to the issue of model performance, analyses conducted by the USEPA (2005) suggest that air quality models respond more to emission reductions at higher predicted ozone values. Correspondingly, the model predicts less benefit at lower concentrations. This is consistent with preliminary modeling in support of the 8-hour ozone standard conducted by the ARB and the districts. These results imply that RRF calculations should be restricted to days with predicted high ozone concentrations. It is thus reasonable to establish a minimum threshold for predicted peak 8-hour ozone concentrations in the baseline year. Days for which the predicted daily peak 8-hour ozone concentrations at a site are less than the threshold, would not be used for calculating RRFs at that site. Consistent with USEPA's recommendation, we propose to use a value of 85 ppb for the baseline year threshold. However, USEPA guidelines allow the use of the maximum 8-hour concentrations within 15km of a site for this purpose.

Based on the above discussion, we propose the following model performance based methodology for determining sites and modeled days to be used in the RRF calculations:

Only those modeled days meeting the following criteria will be used to calculate site-specific RRFs:

1) **The modeled daily 8-hour peak ozone concentration within 15 km of the site for the base year of the modeling must be within ±20% of the observed value at the site.**
2) **The modeled daily 8-hour peak ozone concentration within 15 km of the site in the baseline year must be 85 ppb or greater.**
3) **The subregional 1-hour and 8-hour statistical measures of NB and GE must fall within the thresholds of ± 15% and 35%, respectively.**

Of these three criteria, only the third is considered in this document.

Along with the statistical measures discussed above, the graphical and statistical tests recommended by the USEPA (1991 and 2005) and shown in Tables 2-1 and 2-2 will be used to assess overall model performance. Several sensitivity tests recommended by the USEPA (1991) will also be used (Table 2-3) for qualitative evaluation. While the results of these sensitivity analyses are inherently subjective, they are designed to provide confidence that the air quality model is not only performing well, but is also properly responding to changes in inputs.

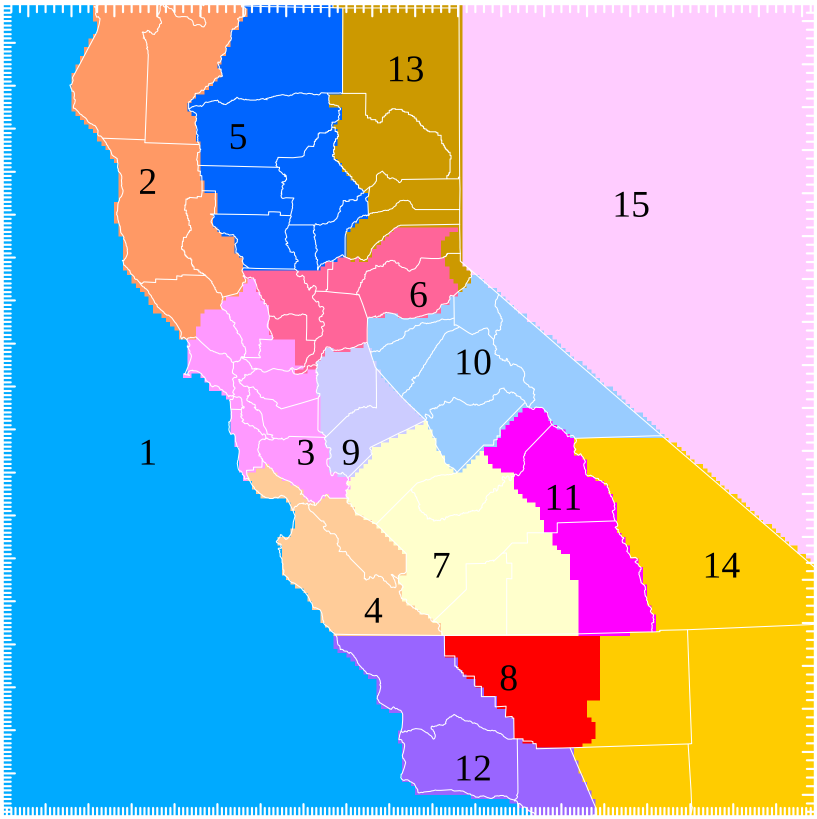


Figure 2-1 Sub-regions of air quality model performance evaluation (3: Bay area region, 6: metro Sacramento region, 7: central San Joaquin valley region , 8 southern San Joaquin valley region, 9: northern San Joaquin valley region).

Table 2-1. Statistics for evaluating base year air quality model performance for all sub-regions.

- mean normalized bias for all 1-hour ozone concentrations (60 ppb), unpaired in time and space for all sites
- mean normalized gross error for all 1-hour ozone concentrations (≥60 ppb), unpaired in time and space for all sites
- peak 1-hour ozone concentration ratio, unpaired in time and space
- mean normalized bias for all 8-hour ozone concentrations (≥60 ppb), unpaired in time for all sites
- mean normalized gross error for all 8-hour ozone concentrations (≥60 ppb), unpaired in time for all sites
- peak 8-hour ozone concentration ratio, unpaired in time and space

Table 2-2. Graphical tools for evaluating base year air quality model performance.

– time-series plots comparing 1-hour measured and simulated concentrations of ozone, NO, NO2, and CO for each site.

– hourly spatial plots of 1-hour measured and simulated concentrations of ozone, NO, NO2, and CO for the CCOS modeling domain.

– scatter plot of 1-hour ozone concentrations for each day, and for each subregion of the modeling domain.

Table 2-3. Sensitivity tests for evaluation of Base Year air quality simulations. The results of these analyses will be tabulated by subregion.

1	Minimize vertical diffusivity based on land cover
2	Zero anthropogenic emissions
3	Zero biogenic emissions
4	Set lateral ozone boundary conditions to 50 ppb
5	Set lateral ozone boundary conditions to 90 ppb
6	Set initial ozone conditions to 40 ppb everywhere
7	Set initial conditions to 0.1 ppb NO2 and 0.0 NO (run with all emissions)
8	Set initial conditions to 0.1 ppb NO2 and 0.0 NO (run with biogenic emissions only)
9	Double biogenic emissions
10	Remove wildfires
11	Zero mobile emissions
12	Set top ozone boundary conditions to 135ppb at 15km

2.2 Air Quality Model Performance Results

The following two sections present the results of air quality model performance for the two modeling episodes, based on the criteria discussed in the previous section. For illustration purposes, only a portion of the graphics that were actually produced are presented. All of the graphics that have been generated are available via ftp per the table in the Appendix.

2.2.1 July 1999 Episode (Routine Episode)

The July 1999 air quality model simulation covers the 7-day period from July 7, 1999, through July 13, 1999. However, the model performance assessment only covers the 5-day, non-spin-up period from July 9 to July 13, 1999. As discussed previously in Section 1.2.1, the ARB c109 MM5 meteorological simulation is used for these air quality simulations.

Tables 2-4 and 2-5 summarize the 1-hour and 8-hour statistical model performance assessment in terms of identifying the days for which simulated results fall within acceptable statistical performance thresholds in each model performance region (performance regions were shown in Figure 2-1). Each cell in the tables represents whether model-simulated results, on a region-wide basis, are statistically acceptable. The cell is assigned a value of 1 if the model-simulated results pass the statistical model performance criteria; while a value of 0 means that the model-simulated results for the region do not meet the criteria. If all simulated ozone concentrations in the region are below 60 ppb, then the region-day cell is assigned -99 and the modeling results cannot be used for that region. Total days for each episode day and region are provided at the bottom row and far right column of the table, respectively.

For the Bay Area region, 4 days meet the 1-hour criteria and only 1 day meets the 8-hour criteria. For the Sacramento region, all 5 days meet both the 1-hour and 8-hour criteria. For the Central San Joaquin Valley region, 5 days meet the 1-hour criteria and 3 days meet the 8-hour criteria. For the Southern San Joaquin Valley region, only 1 day meets the 1-hour criteria and 4 days meet the 8-hour criteria. For the Northern San Joaquin Valley region, 2 days meet the 1-hour criteria and 3 days meet the 8-hour criteria.

Figures 2-2 through 2-6 show the site-averaged time series of modeled versus predicted CO, ozone, NO and NO_2 for the Bay Area, Sacramento, Central San Joaquin Valley, Southern San Joaquin Valley, and Northern San Joaquin Valley regions, respectively. The orange and blue lines represent observations and model predictions, respectively. The time series for individual stations for these five regions have also been plotted and are available via the ftp site and filename indicated in the Appendix.

Figure 2-2 shows the hourly averaged CO, ozone, NO and NO_2 for the Bay Area region. Predicted CO concentrations are slightly under-predicted for most of the simulation period. However, the simulated ozone is generally over-predicted for the entire simulation period. The model captures the magnitude and diurnal variation of the NO and NO_2 reasonably well.

Figure 2-3 shows the hourly averaged CO, ozone, NO and NO_2 for the Sacramento region. Predicted CO concentrations are over-predicted for most of the simulation period. Ozone concentrations perform well for the first three days and the last day of the simulation period, but are under-predicted from July 10 to July 12. Predicted NO and NO_2 concentrations generally agree with the observations.

Figure 2-4 shows the hourly averaged CO, ozone, NO and NO_2 for the Central San Joaquin Valley region. Predicted CO concentrations are under-predicted for the entire simulation period. The simulated ozone is generally under-predicted during the day, but over-predicted in the morning. Both predicted NO and NO_2 concentrations are under-predicted for the entire simulation period.

Figure 2-5 shows the hourly averaged CO, ozone, NO and NO_2 for the Southern San Joaquin Valley region. Predicted CO concentrations are generally under-predicted in the morning, but over-predicted in the afternoon. The simulated ozone is generally under-predicted during the day, but over-predicted in the morning. NO concentrations are under-predicted for the entire simulation period. In general, NO_2 concentrations are also under-predicted. However, the NO_2 concentrations are over-predicted at night on July 9 and July 11.

Figure 2-6 shows the hourly averaged CO, ozone, NO and NO_2 for the Northern San Joaquin Valley region. Predicted CO concentrations are under-predicted for the entire simulation period. The simulated ozone is generally predicted well for all days. The model captures the diurnal variation of the NO, but predicted concentrations are generally less than the observed values. NO_2 concentrations also generally agree with the observations.

Plots of model performance statistics for each region are provided in Figures 2-7 and 2-8, which show the predicted 1-hour and 8-hour unpaired peak ratio and normalized bias in graphical format for each station in each of the five regions.

Table 2-4. 1-hour ozone performance by each region over the July 9-13, 1999 modeling period.

Region ID	Region Name	7/9/1999	7/10/1999	7/11/1999	7/12/1999	7/13/1999	Total
2	North Coast	1	0	0	1	-99	2
3	BAAQMD	1	1	1	1	0	4
4	MBAQMD	1	0	0	1	0	2
5	Sacramento Valley North	1	0	1	1	0	3
6	Sacramento Region	1	1	1	1	1	5
7	SJVAPCD Central	1	1	1	1	1	5
8	SJVAPCD Kern	0	0	0	0	1	1
9	SJVAPCD North	1	0	1	0	0	2
10	Sierra Nevada Central	0	1	0	0	0	1
11	SJVAPCD Above 3000 ft	0	0	1	1	1	3
12	South Central Coast	1	1	0	1	0	3
13	Sierra Nevada North	1	0	0	1	1	3
14	Desert	0	0	0	0	0	0
15	Nevada	1	0	-99	1	0	2
Total:		10	5	6	10	5	36

Table 2-5. 8-hour ozone performance by each region over the July 9-13, 1999 modeling period.

Region ID	Region Name	7/9/1999	7/10/1999	7/11/1999	7/12/1999	7/13/1999	Total
2	North Coast	-99	-99	0	1	-99	1
3	BAAQMD	0	0	1	0	0	1
4	MBAQMD	1	-99	0	0	-99	1
5	Sacramento Valley North	1	1	1	1	0	4
6	Sacramento Region	1	1	1	1	1	5
7	SJVAPCD Central	1	1	0	1	0	3
8	SJVAPCD Kern	1	1	1	0	1	4
9	SJVAPCD North	1	0	1	0	1	3
10	Sierra Nevada Central	1	1	0	0	0	2
11	SJVAPCD Above 3000 ft	0	0	1	1	1	3
12	South Central Coast	0	1	0	1	1	3
13	Sierra Nevada North	1	0	0	1	1	3
14	Desert	0	0	0	1	0	1
15	Nevada	1	-99	-99	1	1	3
Total:		9	6	6	9	7	37

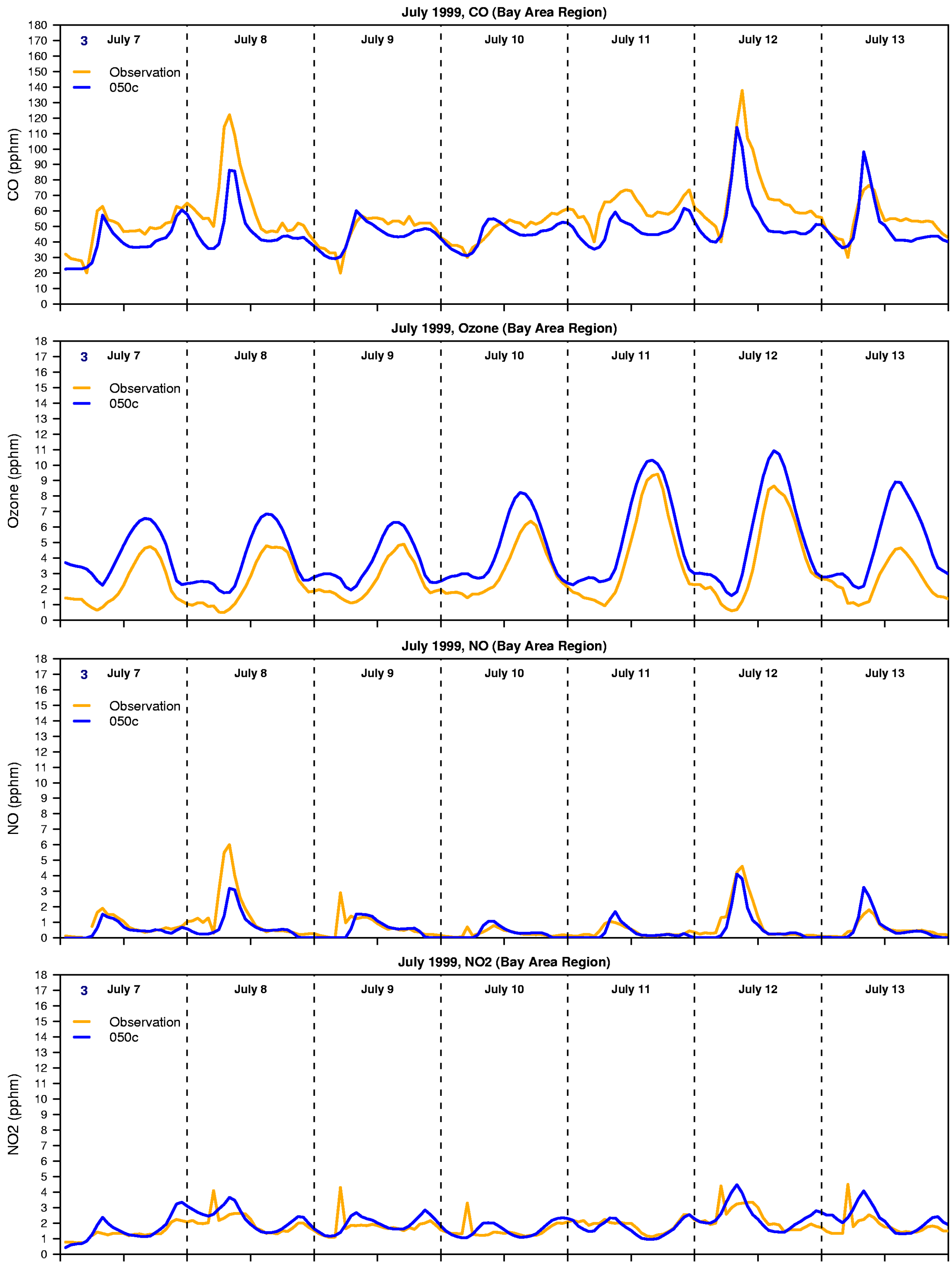


Figure 2-2. Hourly averaged of CO, ozone, NO and NO_2 for the Bay Area region over the July 7-13, 1999 modeling period.

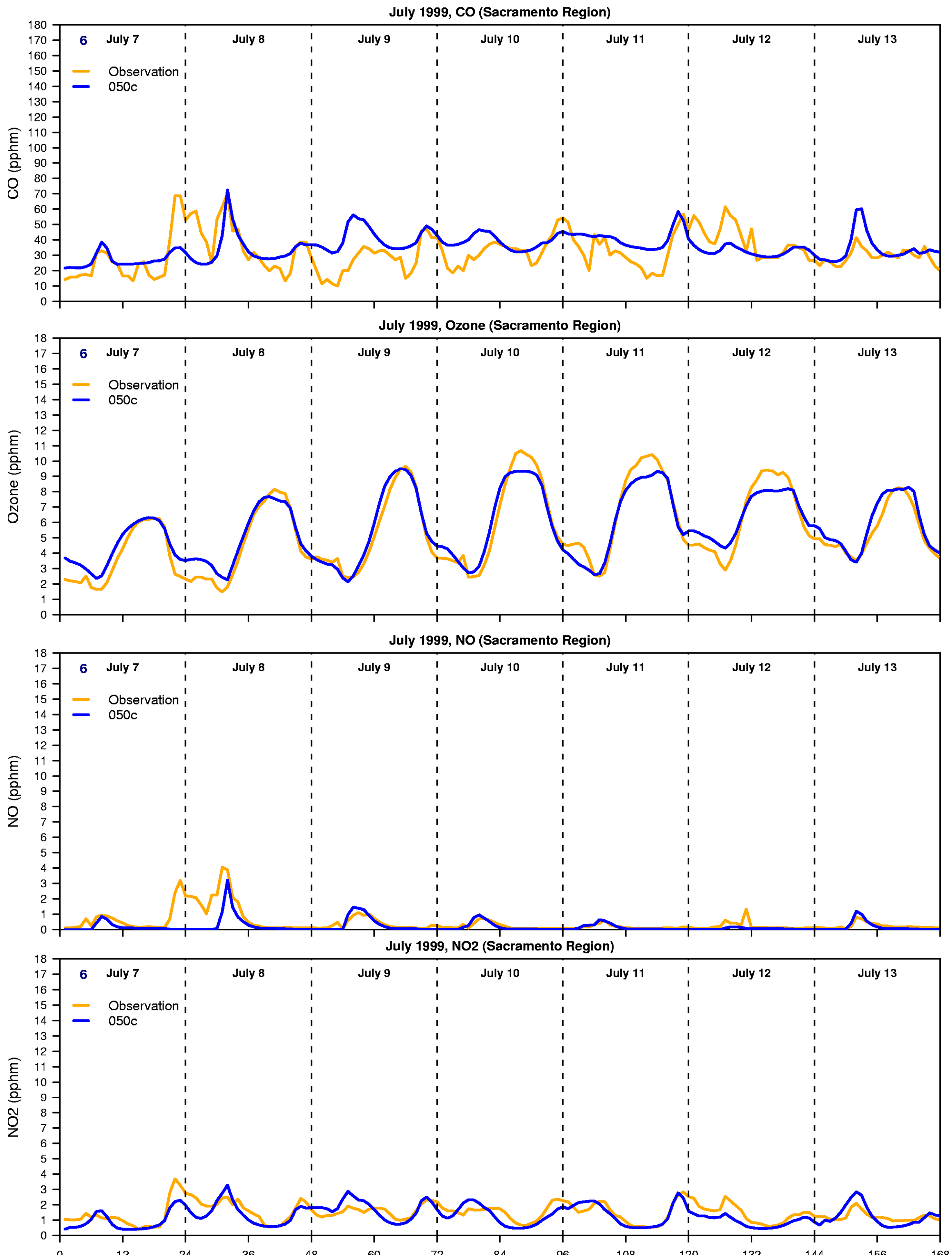


Figure 2-3. Hourly averaged CO, ozone, NO and NO_2 for the Sacramento region over the July 7-13, 1999 modeling period.

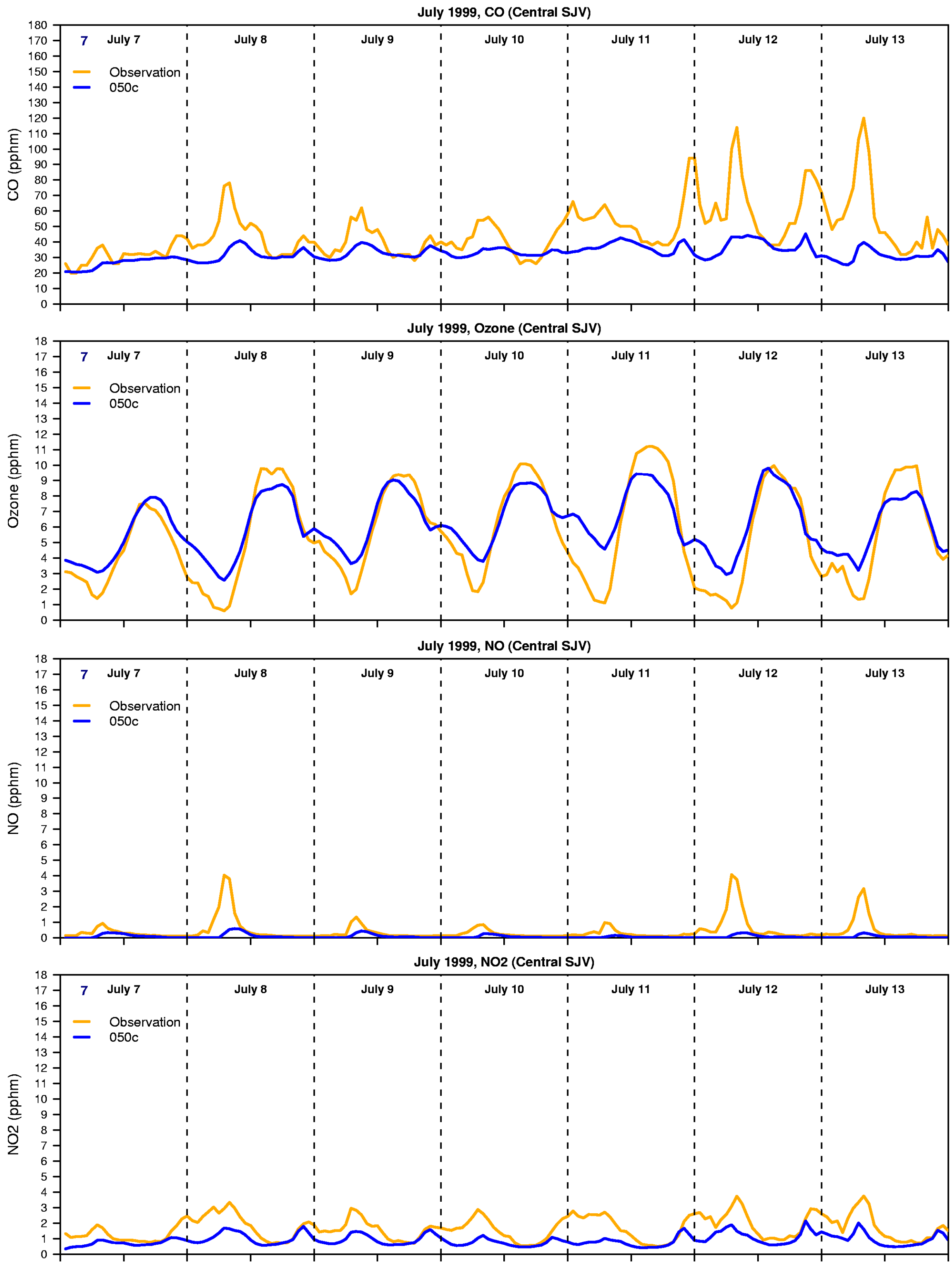


Figure 2-4. Hourly averaged CO, ozone, NO and NO_2 for the Central San Joaquin Valley over the July 7-13, 1999 modeling period.

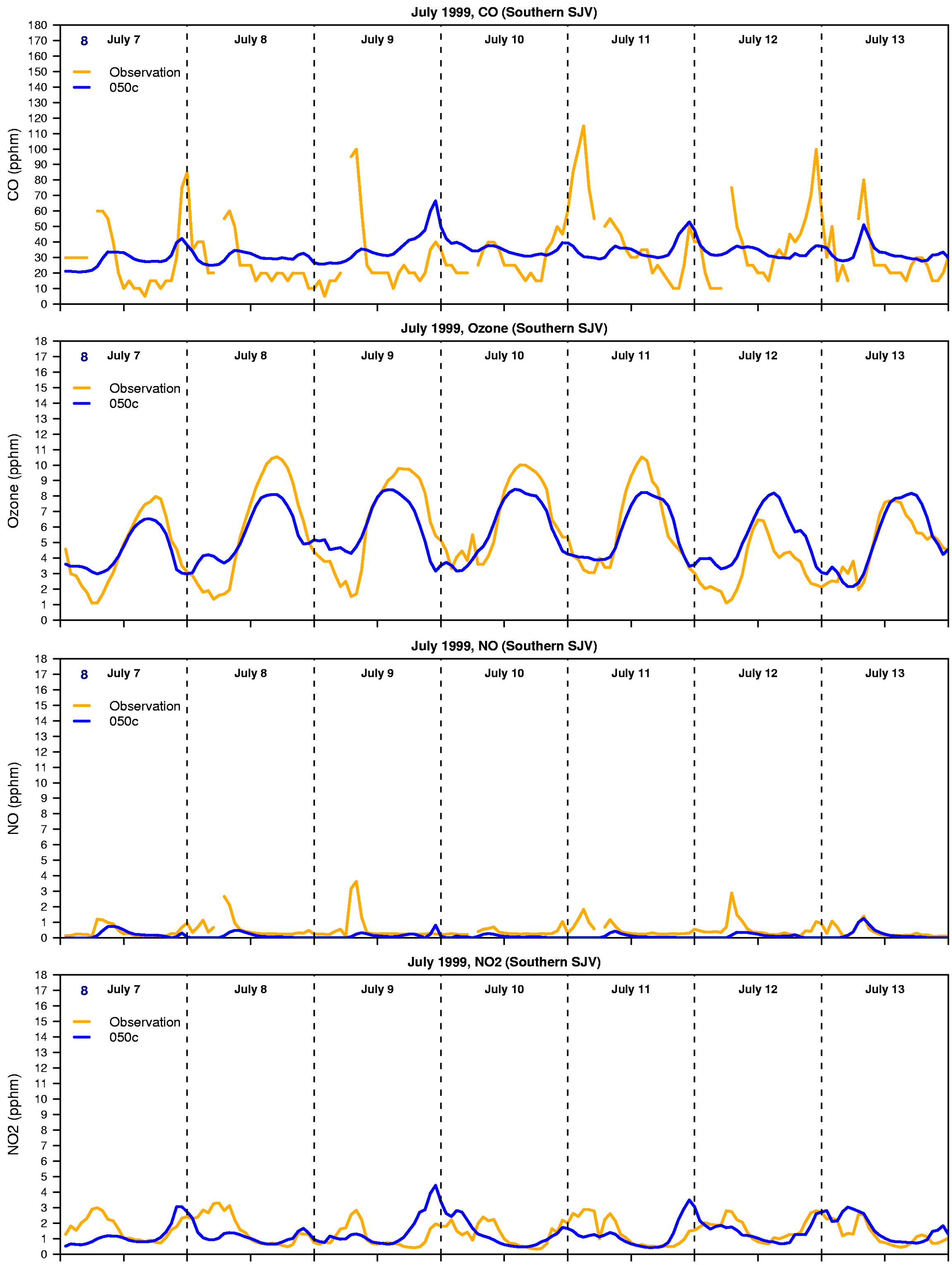


Figure 2-5. Hourly averaged CO, ozone, NO and NO_2 for the Southern San Joaquin Valley over the July 7-13, 1999 modeling period.

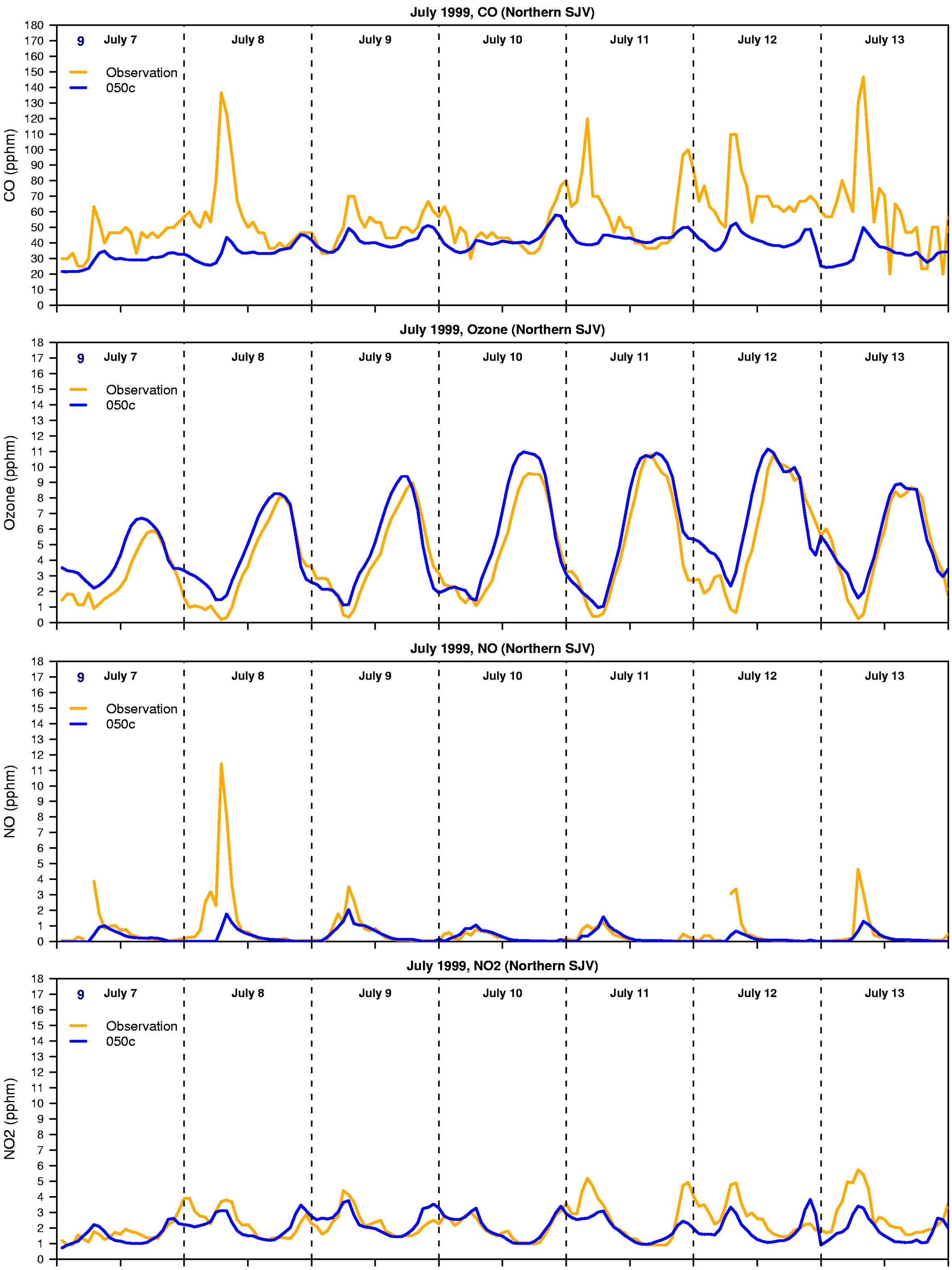
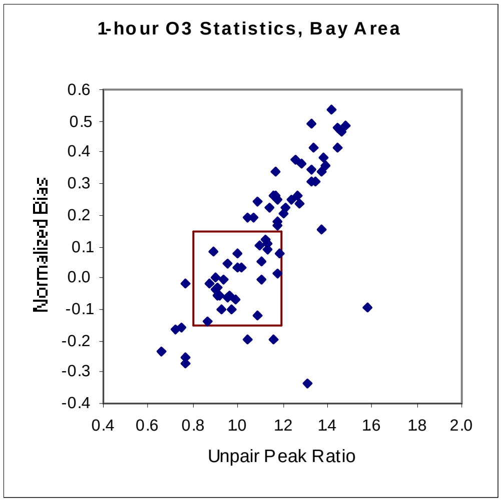
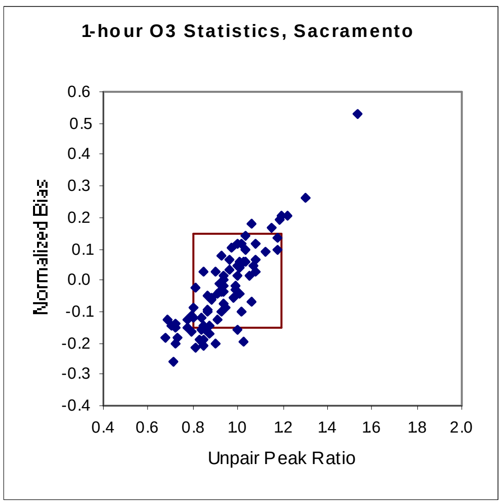
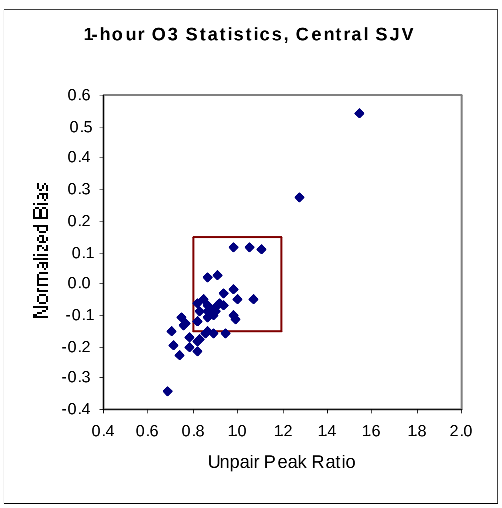


Figure 2-6. Hourly averaged CO, ozone, NO and NO_2 for the Northern San Joaquin Valley over the July 7-13, 1999 modeling period.


1-hour O3 Statistics, Bay Area
Normalized Bias
Unpair Peak Ratio
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4
0.6
0.8
10
12
14
16
18
2.0


1-hour O3 Statistics, Sacramento
Normalized Bias
Unpair Peak Ratio
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4
0.6
0.8
10
12
14
16
18
2.0


1-hour O3 Statistics, Central SJV
Normalized Bias
Unpair Peak Ratio
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4
0.6
0.8
10
12
14
16
18
2.0

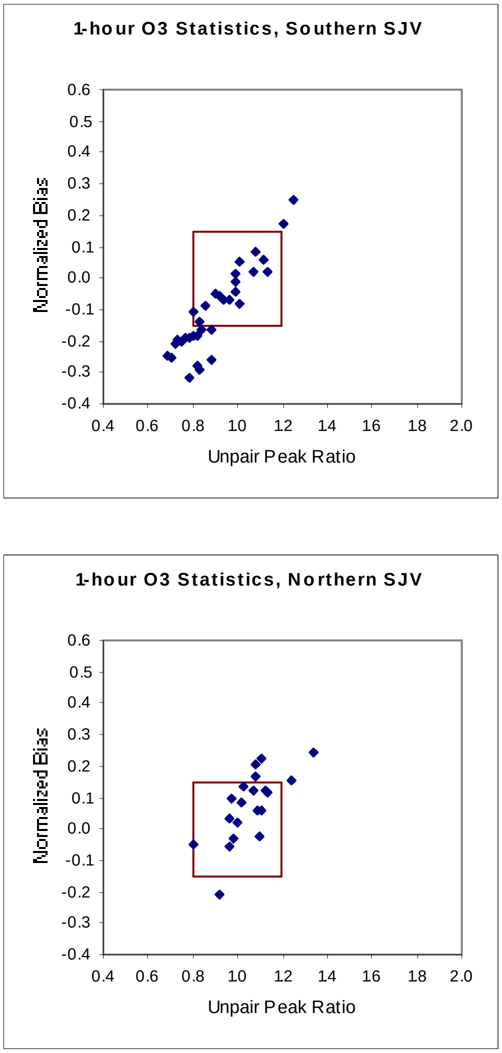
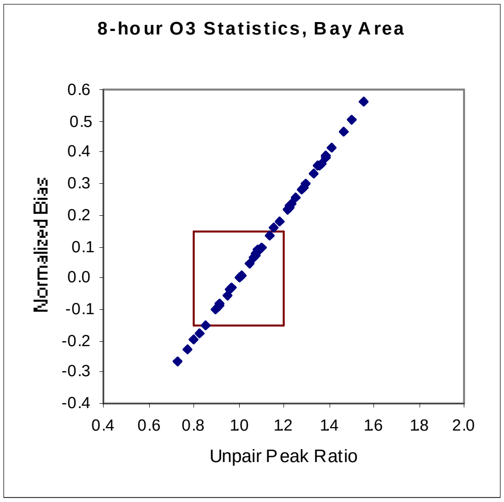
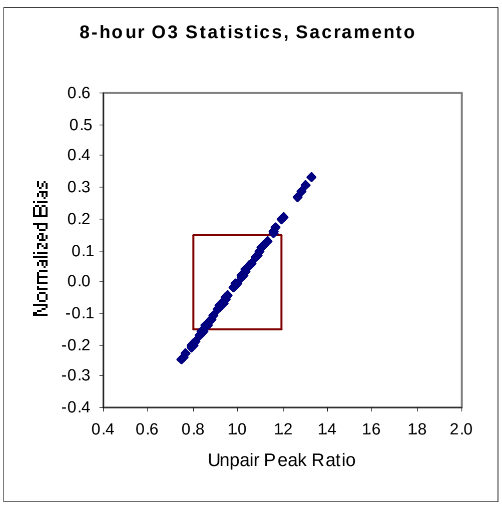
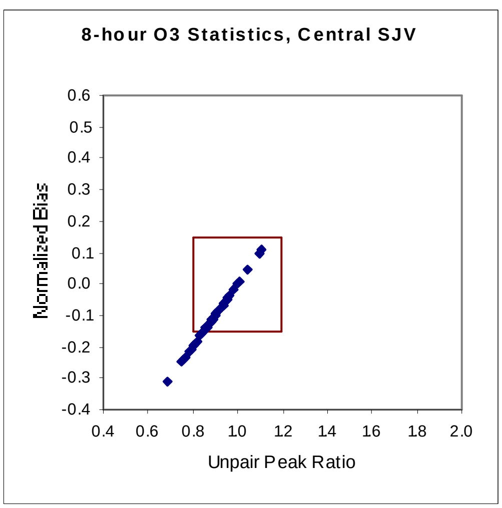
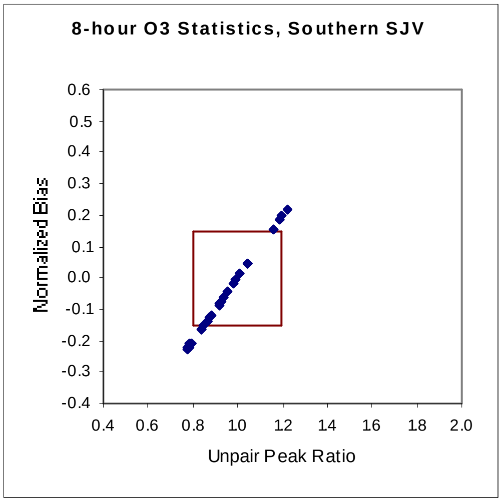


Figure 2-7. Unpaired peak ratio vs. normalized bias for 1-hour ozone for the July 9-13, 1999 modeling period. Each dot represents one-day results for an individual site.


8-hour O3 Statistics, Bay Area
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4 0.6 0.8 10 12 14 16 18 2.0
Unpair Peak Ratio


8-hour O3 Statistics, Sacramento
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4 0.6 0.8 10 12 14 16 18 2.0
Unpair Peak Ratio


8-hour O3 Statistics, Central SJV
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4 0.6 0.8 10 12 14 16 18 2.0
Unpair Peak Ratio



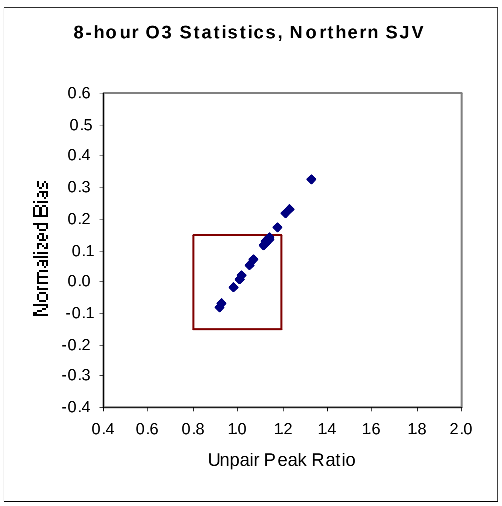


Figure 2-8. Unpaired peak ratio vs. normalized bias for 8-hour ozone for the July 9-13, 1999 modeling period. Each dot represents one-day results for an individual site.

2.2.2 July-August 2000 Episode (CCOS Episode)

The air quality model simulation covers the period from July 27, 2000, to August 2, 2000. The first two days of the simulation are treated as a model spin-up period for which model performance is not considered. As a result, the statistical model performance assessment only covers the non-spin-up period, from July 29th through August 2nd. As described previously in Section 1.2.2, the NOAA placeholder MM5 meteorological simulation is used for these air quality simulations.

Performance statistics for 1-hour and 8-hour model performance were calculated for each region and are listed in Table 2-6 and 2-7, respectively. For days that a region meets the criteria a value of 1 is assigned. A value of 0 means that region doesn't meet the criteria for the respective day and, if there is no model simulated concentrations above 60ppb, then -99 is assigned. The following paragraph summarizes the subregional statistical results.

For the Bay Area region, the model performance meets both the 1-hour and 8-hour criteria on July 29, 2000 and August 2, 2000, but fails on all the other days. For the Sacramento region, 4 days meet the 1-hour criteria and 3 days meet the 8-hour criteria. For the Central San Joaquin Valley region, all 5 days meet both the 1-hour and 8-hour criteria. For the Southern San Joaquin Valley region, 4 days meet the 1-hour criteria and all 5 days meet the 8-hour criteria. For the Northern San Joaquin Valley region, only 2 days meet both the 1-hour and 8-hour criteria.

Figures 2-9 through 2-13 show the site-averaged time series of observed versus predicted CO, ozone, NO and NO_2 for the Bay Area, Sacramento, Central San Joaquin Valley, Southern San Joaquin Valley and Northern San Joaquin Valley regions, respectively. The orange and blue lines represent observations and model predictions, respectively. Take note that the start hour of the simulation is 0600 PDT, so the first day has only 18 data points. Also, note that the 1-hour and 8-hour region-wide statistics are not directly calculated from site-averaged time series, but from the statistics of each station and then arithmetically averaged. The time series for individual stations for these five regions have also been plotted and are available via the ftp site and filename indicated in the Appendix.

Figure 2-9 shows the hourly averaged CO, ozone, NO and NO_2 for the Bay Area region. Predicted CO concentrations are over-predicted for the entire simulation period. Ozone concentrations are significantly over-predicted for the entire simulation period although predictions gradually begin to match observations by the last day. Predicted NO concentrations generally match the observed concentrations but are under-predicted for the last two days of the simulation period. The model predicts NO_2 concentrations that have a significant diurnal variation, where the NO_2 increases in the morning traffic hours and in the evening hours when the atmospheric boundary layer becomes less turbulent. However, the regional averaged observation does not exhibit this NO_2 variation.

Figure 2-10 shows the hourly averaged CO, ozone, NO and NO_2 for the Sacramento region. Predicted CO concentrations generally agree with the observations. Ozone concentrations show excellent agreement with observations for all days. The NO concentrations generally agree with the observations and clearly reproduce the early morning traffic peak. The model captures the magnitude as well as the diurnal variation of the NO_2.

Figure 2-11 shows the hourly averaged CO, ozone, NO and NO_2 for the Central San Joaquin Valley region. Predicted CO concentrations are under-predicted for the entire simulation period. Ozone concentrations show excellent agreement with observations for all the days. The NO concentrations also generally agree with the observations and clearly reproduced the early morning traffic peak. The model captures the diurnal variation of the NO_2, but predicted concentrations are generally less than the observed values.

Figure 2-12 shows the hourly averaged CO, ozone, NO and NO_2 for the Southern San Joaquin Valley region. Predicted CO concentrations are under-predicted for the entire simulation period. Ozone concentrations show excellent agreement with observations for all the days. The NO concentrations also generally agree with the observations and clearly reproduced the early morning traffic peak. The model captures the magnitude as well as the diurnal variation of the NO_2.

Figure 2-13 shows the hourly averaged CO, ozone, NO and NO_2 for the San Joaquin Valley North region. Predicted CO concentrations generally match the observed concentrations through July 29th, but, the sharp peaks in the observations later in the episode are not captured in the simulated concentrations. These sharp peaks, however, are likely from some high-emitters near the observation site and cannot be captured by a regional scale model. Ozone concentrations generally agree with the observations, but some days are over-predicted. The NO concentrations also generally agree with the observations and clearly reproduced the early morning traffic peak. The predicted NO_2 concentrations are generally higher than the observations.

Figures 2-14 and 2-15 show the correlation between the unpaired peak and the mean normalized bias for each individual site in a region. Through experience it has been observed that, if the NB statistical metric is satisfied, then the GE statistic is also satisfied. Hence, GE statistical results are not presented.

The results shown above were generated using NOAA's 'placeholder' MM5 meteorology. Since the first 'placeholder' version of the NOAA meteorology, CARB and NOAA have been working together to improve the meteorological model performance. A more recent NOAA meteorology, as described in the previous meteorology section, was developed and used as an alternative input to air quality modeling simulations. The model performance results using this alternative meteorological field are provided in Tables 2-8 and 2-9 for 1-hour and 8-hour averaging periods, respectively. Using the updated meteorology inputs slightly degrades the 1-hour model performance, but improves the 8-hour model performance. However, as mentioned in section 1.2.2, this alternative wind field as well as the associated meteorological model options and inputs are still in draft form and continue to be investigated.

Table 2-6. 1-hour ozone performance by each region over the July 29-August 2, 2000 modeling period.

Region ID	Region Name	7/29/2000	7/30/2000	7/31/2000	8/1/2000	8/2/2000	Total
2	North Coast	-99	0	-99	-99	-99	0
3	BAAQMD	1	0	0	0	1	2
4	MBAQMD	0	0	0	1	1	2
5	Sacramento Valley North	1	1	1	1	1	5
6	Sacramento Region	1	1	0	1	1	4
7	SJVAPCD Central	1	1	1	1	1	5
8	SJVAPCD Kern	1	1	1	1	0	4
9	SJVAPCD North	1	0	0	0	1	2
10	Sierra Nevada Central	0	1	0	1	1	3
11	SJVAPCD Above 3000 ft	1	1	1	1	1	5
12	South Central Coast	1	1	0	0	0	2
13	Sierra Nevada North	1	1	1	1	1	5
14	Desert	1	1	0	0	0	2
15	Nevada	-99	-99	-99	-99	-99	0
Total:		10	9	5	8	9	41

Table 2-7. 8-hour ozone performance by each region over the July 29-August 2, 2000 modeling period.

Region ID	Region Name	7/29/2000	7/30/2000	7/31/2000	8/1/2000	8/2/2000	Total
2	North Coast	-99	-99	-99	-99	-99	0
3	BAAQMD	1	0	0	0	1	2
4	MBAQMD	-99	0	0	1	1	2
5	Sacramento Valley North	1	1	1	1	0	4
6	Sacramento Region	1	0	0	1	1	3
7	SJVAPCD Central	1	1	1	1	1	5
8	SJVAPCD Kern	1	1	1	1	1	5
9	SJVAPCD North	1	0	0	0	1	2
10	Sierra Nevada Central	1	1	0	1	0	3
11	SJVAPCD Above 3000 ft	1	1	1	1	0	4
12	South Central Coast	0	0	0	0	1	1
13	Sierra Nevada North	1	1	1	1	1	5
14	Desert	1	1	1	1	1	5
15	Nevada	-99	-99	-99	-99	-99	0
Total:		10	7	6	9	9	41

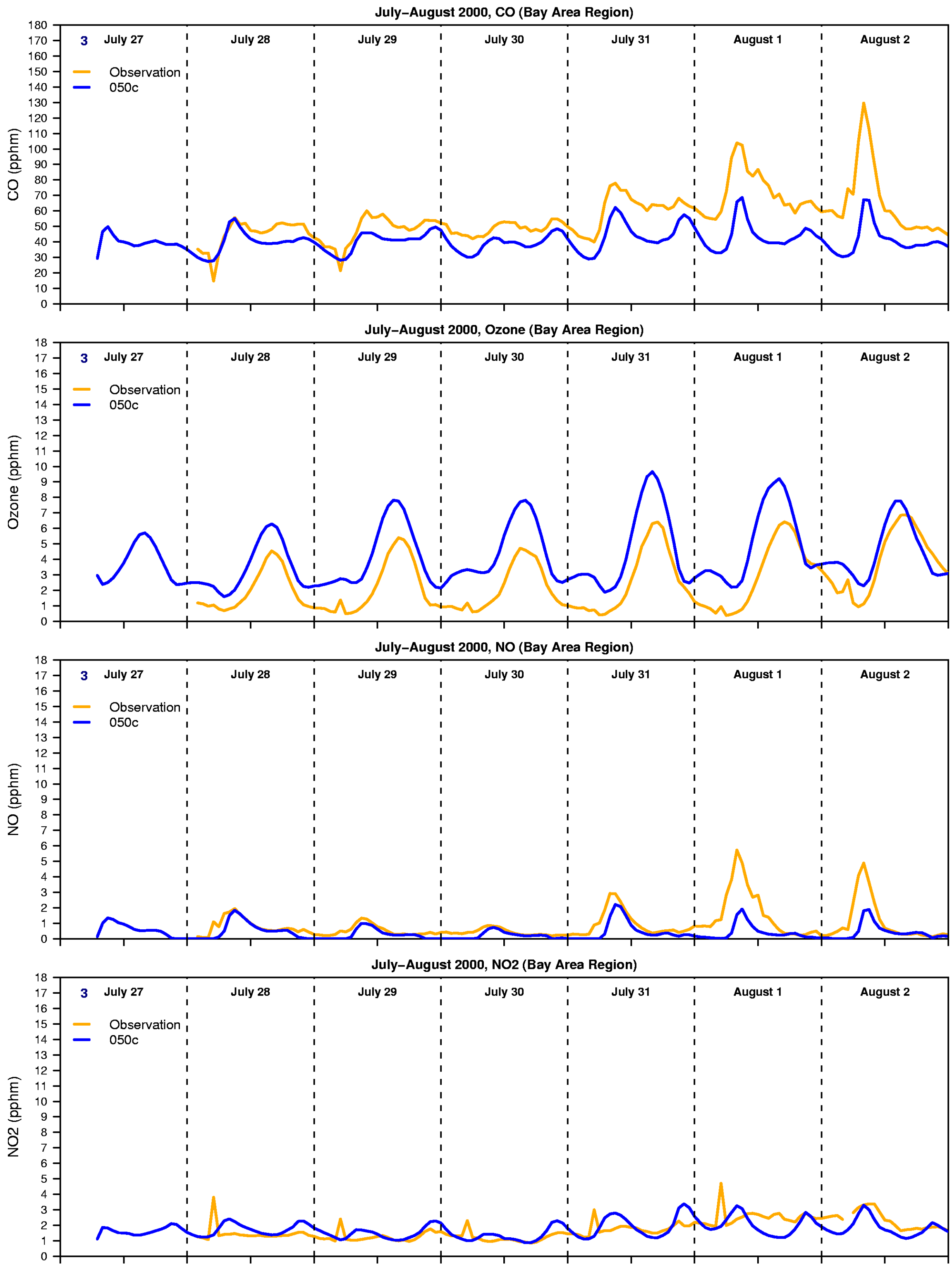


Figure 2-9. Hourly averaged CO, ozone, NO and NO_2 for the Bay Area region over the July 27 – August 2, 2000 modeling period.

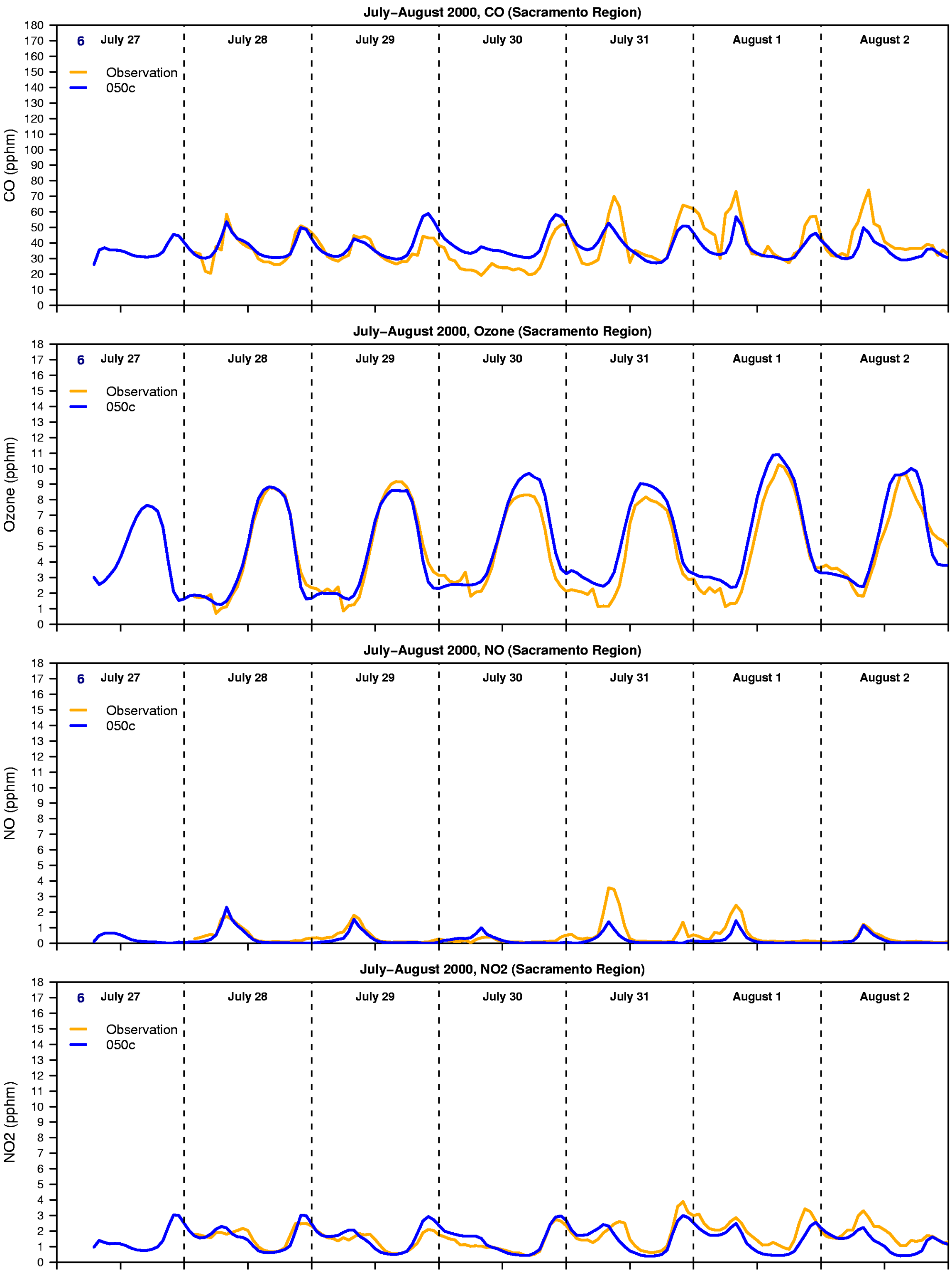


Figure 2-10. Hourly averaged CO, ozone, NO and NO_2 for the Sacramento region over the July 27 – August 2, 2000 modeling period.

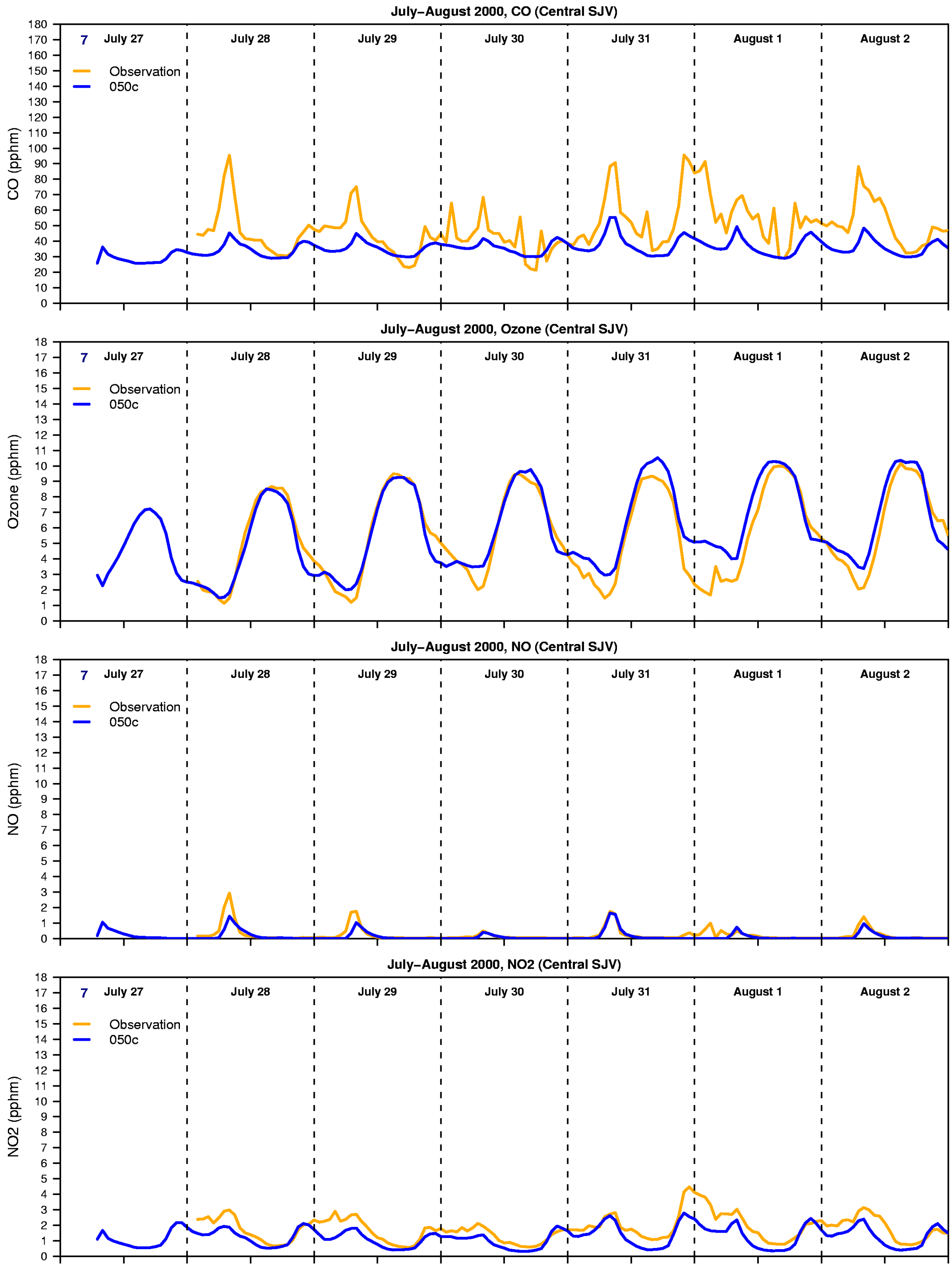


Figure 2-11. Hourly averaged CO, ozone, NO and NO_2 for the Central San Joaquin Valley region over the July 27 – August 2, 2000 modeling period.

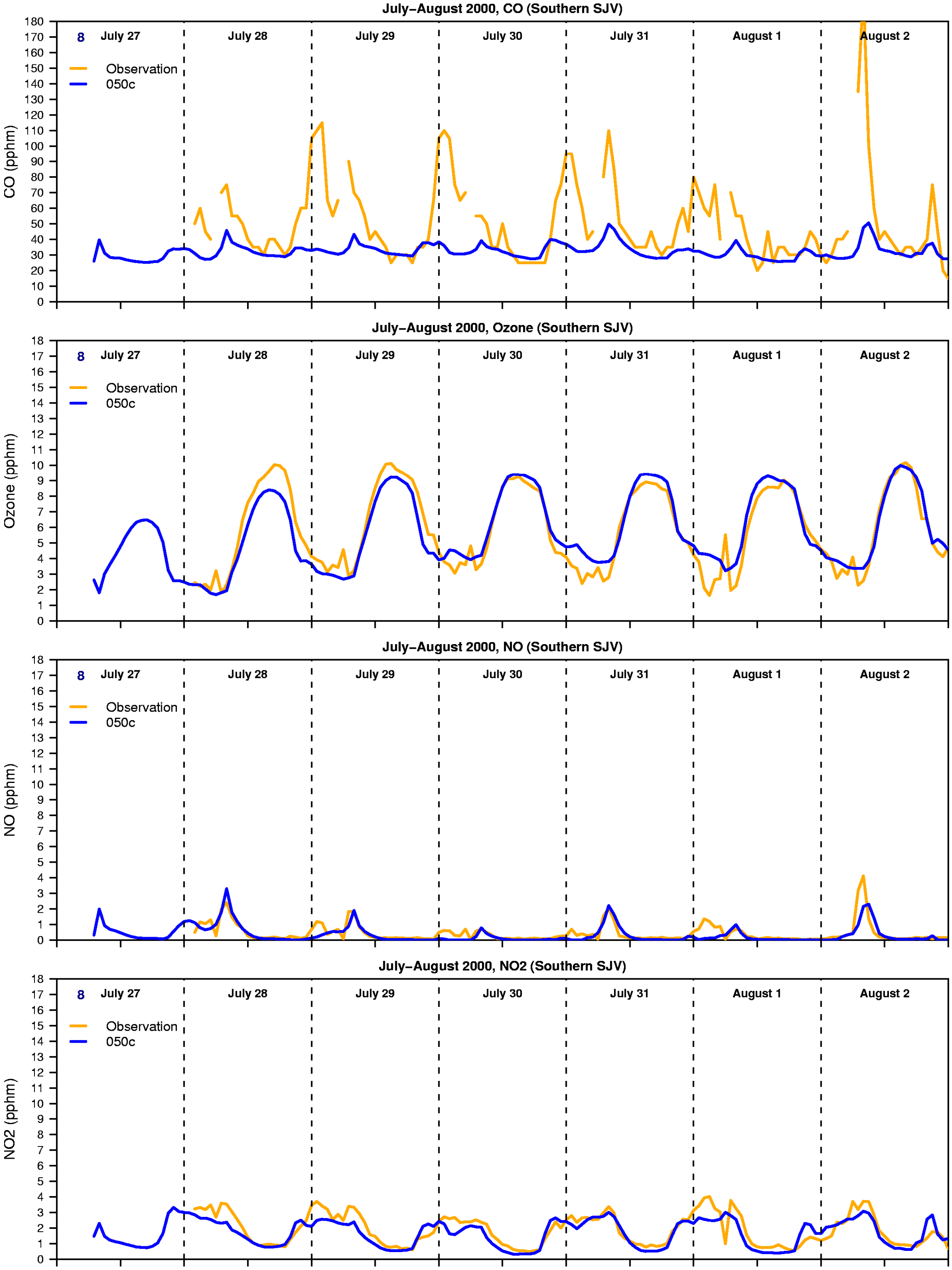


Figure 2-12. Hourly averaged CO, ozone, NO and NO_2 for the Southern San Joaquin Valley region over the July 27 – August 2, 2000 modeling period.

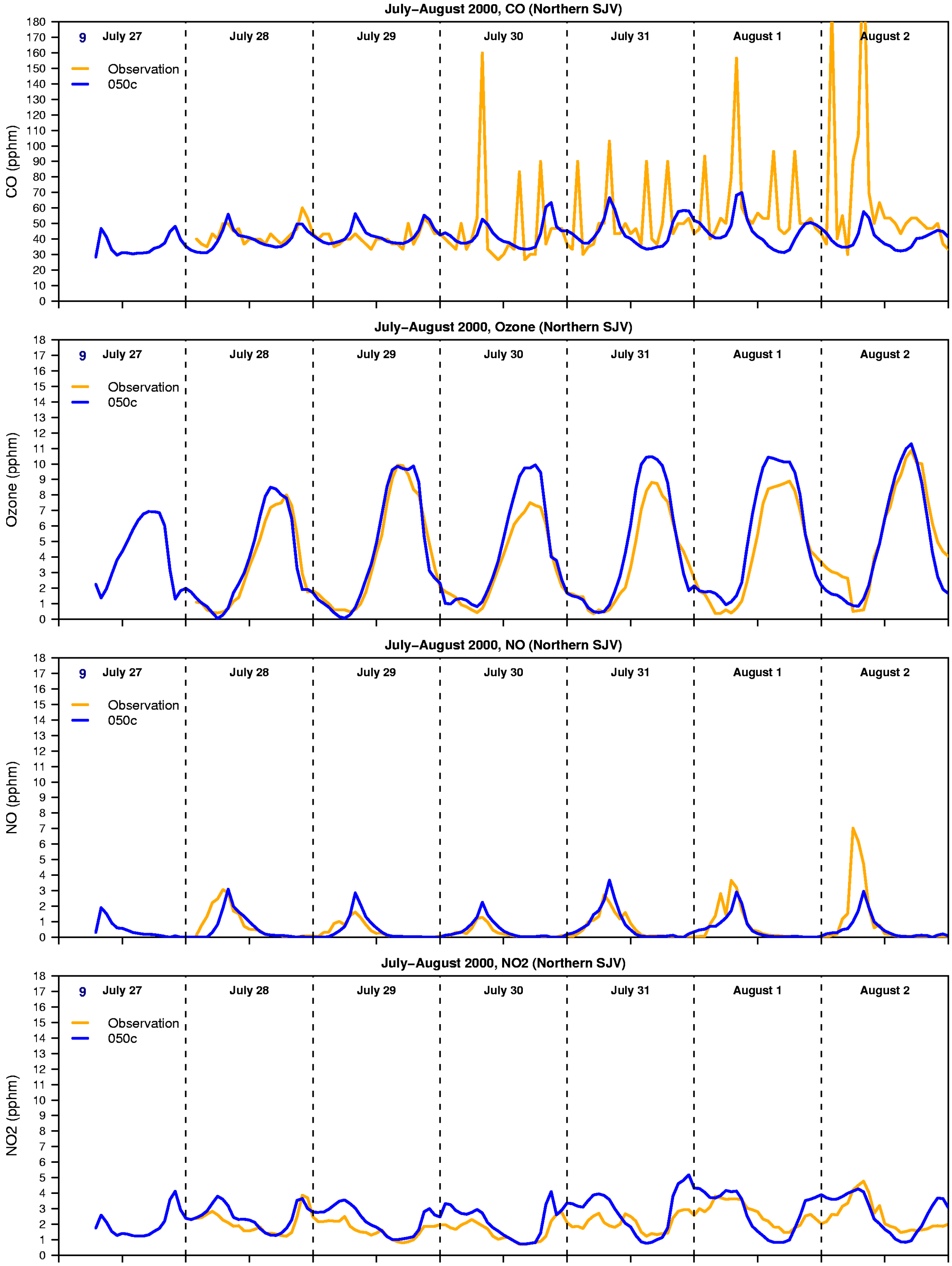
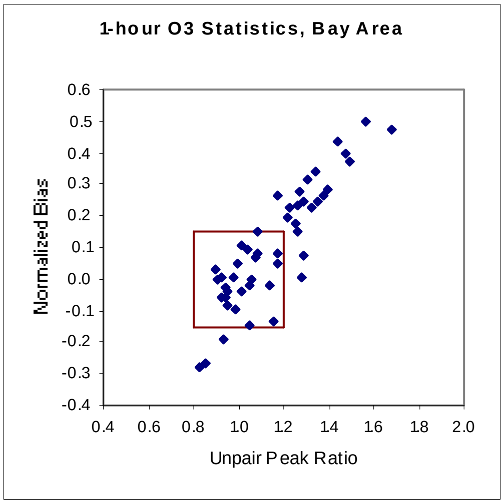
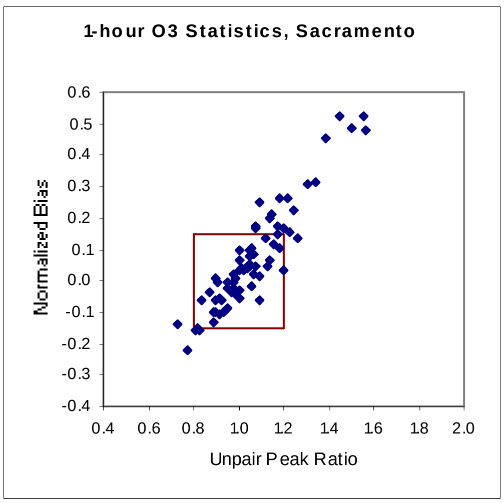
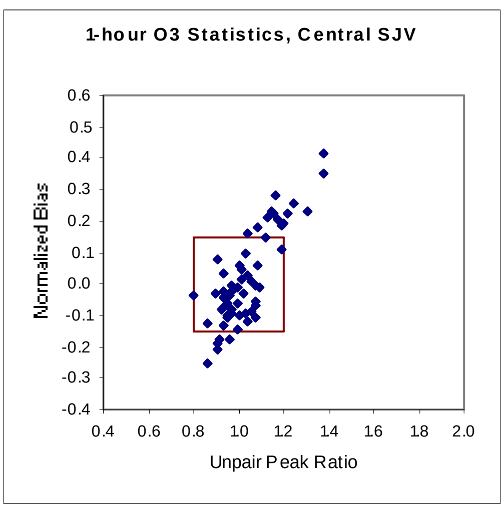


Figure 2-13. Hourly averaged CO, ozone, NO and NO_2 for the Northern San Joaquin Valley region over the July 27 – August 2, 2000 modeling period.


1-hour O3 Statistics, Bay Area
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4
0.6
0.8
10
12
14
16
18
2.0
Unpair Peak Ratio


1-hour O3 Statistics, Sacramento
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4
0.6
0.8
10
12
14
16
18
2.0
Unpair Peak Ratio


1-hour O3 Statistics, Central SJV
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4
0.6
0.8
10
12
14
16
18
2.0
Unpair Peak Ratio

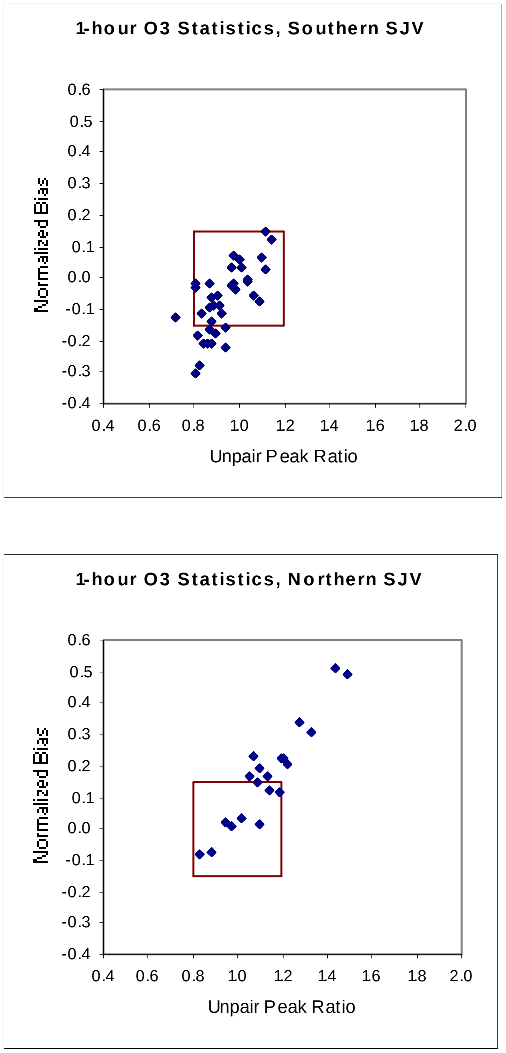
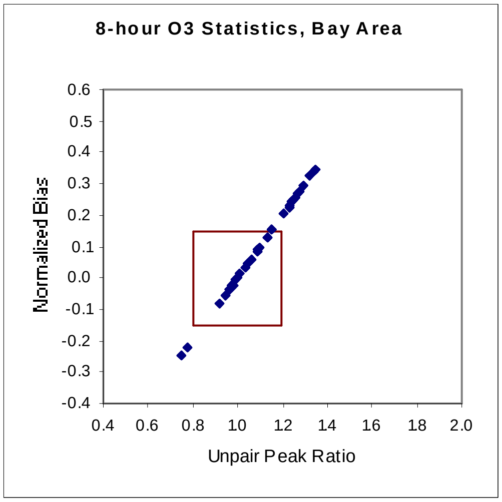
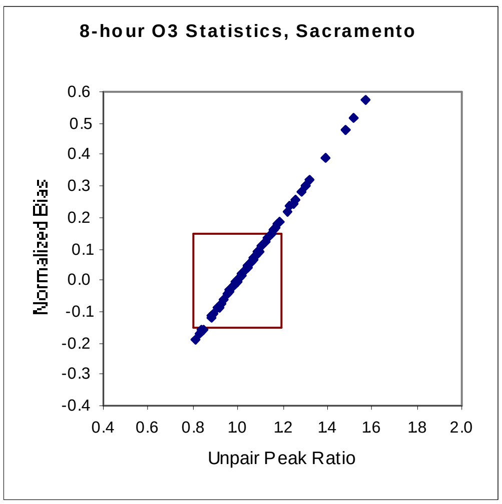
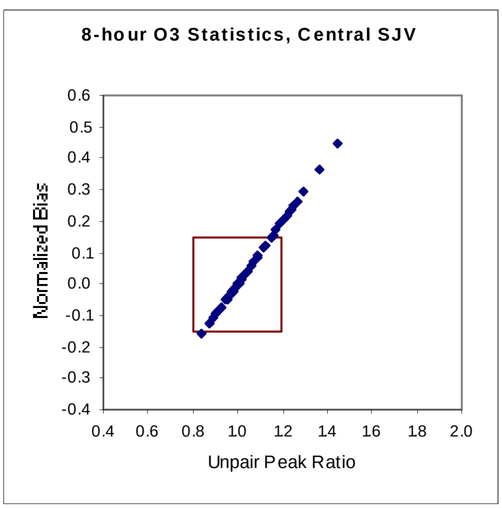
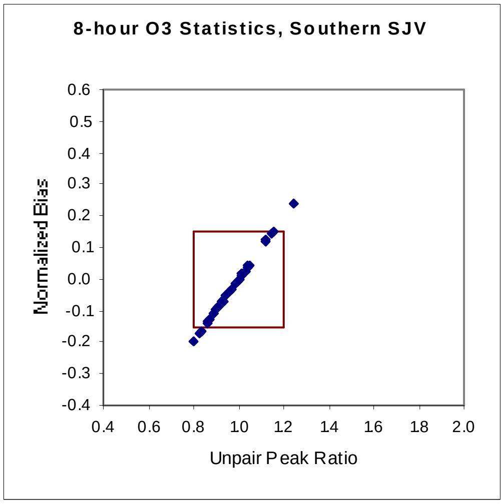


Figure 2-14. Unpaired peak ratio vs. normalized bias for 1-hour ozone for the July 29 – August 2, 2000 modeling period. Each dot represents one-day results for an individual site.


8-hour O3 Statistics, Bay Area
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4 0.6 0.8 10 12 14 16 18 2.0
Unpair Peak Ratio


8-hour O3 Statistics, Sacramento
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4 0.6 0.8 10 12 14 16 18 2.0
Unpair Peak Ratio


8-hour O3 Statistics, Central SJV
Normalized Bias
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0.4 0.6 0.8 10 12 14 16 18 2.0
Unpair Peak Ratio



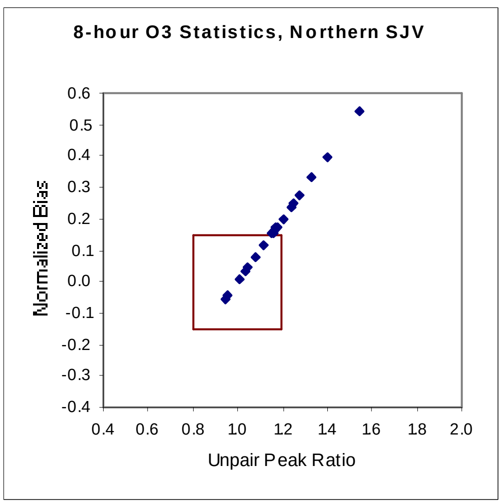


Figure 2-15. Unpaired peak ratio vs. normalized bias for 8-hour ozone for the July 29 – August 2, 2000 modeling period. Each dot represents one-day results for an individual site.

Table 2-8. 1-hour ozone performance by each region over the July 27-August 2, 2000 modeling period using the most recent NOAA meteorology (under ARB investigation)

Region ID	Region Name	7/29/2000	7/30/2000	7/31/2000	8/1/2000	8/2/2000	Total
2	North Coast	-99	0	-99	-99	-99	0
3	BAAQMD	1	1	1	1	1	5
4	MBAQMD	1	1	1	1	1	5
5	Sacramento Valley North	1	1	1	1	1	5
6	Sacramento Region	0	1	1	0	1	3
7	SJVAPCD Central	0	1	1	1	1	4
8	SJVAPCD Kern	0	0	1	0	0	1
9	SJVAPCD North	1	1	1	1	1	5
10	Sierra Nevada Central	0	1	1	0	0	2
11	SJVAPCD Above 3000 ft	0	0	0	1	1	2
12	South Central Coast	1	1	0	0	0	2
13	Sierra Nevada North	1	1	1	0	0	3
14	Desert	0	0	0	0	0	0
15	Nevada	-99	-99	-99	-99	-99	0
Total:		6	9	9	6	7	37

Table 2-9. 1-hour ozone performance by each region over the July 27-August 2, 2000 modeling period using the most recent NOAA meteorology (under ARB investigation)

Region ID	Region Name	7/29/2000	7/30/2000	7/31/2000	8/1/2000	8/2/2000	Total
2	North Coast	-99	-99	-99	-99	-99	0
3	BAAQMD	1	0	1	1	1	4
4	MBAQMD	-99	1	1	1	1	4
5	Sacramento Valley North	1	1	1	1	1	5
6	Sacramento Region	1	1	1	1	1	5
7	SJVAPCD Central	1	1	1	1	1	5
8	SJVAPCD Kern	1	1	1	1	1	5
9	SJVAPCD North	1	0	0	1	1	3
10	Sierra Nevada Central	1	1	1	0	0	3
11	SJVAPCD Above 3000 ft	0	1	1	1	1	4
12	South Central Coast	1	1	1	1	1	5
13	Sierra Nevada North	1	1	1	1	0	4
14	Desert	1	0	1	1	1	4
15	Nevada	-99	-99	-99	-99	-99	0
Total:		10	9	11	11	10	51

3 Conclusion – Cumulative 1-hour and 8-hour Days

Per the prior discussion of performance statistics and analyses of model performance, Tables 3-1 and 3-2 provide a summary of 1-hour and 8-hour episode days that meet model performance criteria for both episodes. As noted previously with regard to these types of tables, for days that a region meets the associated performance criteria a value of 1 is assigned. A value of 0 means that region doesn't meet the criteria for the respective day and, if there is no model simulated concentrations above 60ppb, then -99 is assigned.

As is illustrated in the tables, of 10 possible days per region (5 per episode), 2-10 days are available for each region based on 1-hour metrics and, with the exception of the North Coast (1 day), 1-9 days are available based on 8-hour metrics.

Table 3-1. Combined Number of Available Days Per Subregion Under 1-hour Metrics

Region Name	July 1999	July-Aug 2000	Total
North Coast	2	0	**2**
BAAQMD	4	2	**6**
MBAQMD	2	2	**4**
Sacramento Valley North	3	5	**8**
Sacramento Region	5	4	**9**
SJVAPCD Central	5	5	**10**
SJVAPCD Kern	1	4	**5**
SJVAPCD North	2	2	**4**
Sierra Nevada Central	1	3	**4**
SJVAPCD Above 3000 ft	3	5	**8**
South Central Coast	3	2	**5**
Sierra Nevada North	3	5	**8**
Desert	0	2	**2**
Nevada	2	0	**2**
Total	**36**	**41**	**77**

Table 3-2. Combined Number of Available Days Per Subregion Under 8-hour Metrics

Region Name	July 1999	July-Aug 2000	Total
North Coast	1	0	**1**
BAAQMD	1	2	**3**
MBAQMD	1	2	**3**
Sacramento Valley North	4	4	**8**
Sacramento Region	5	3	**8**
SJVAPCD Central	3	5	**8**
SJVAPCD Kern	4	5	**9**
SJVAPCD North	3	2	**5**
Sierra Nevada Central	2	3	**5**
SJVAPCD Above 3000 ft	3	4	**7**
South Central Coast	3	1	**4**
Sierra Nevada North	3	5	**8**
Desert	1	5	**6**
Nevada	3	0	**3**
Total	**37**	**41**	**78**

4 Results for Model Sensitivity Tests

(Work in Progress.)

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6 Appendix – Information Available for Downloading

Anonymous ftp to eos.arb.ca.gov, then change directories to /pub/outgoing/model_protocol2

Model	Episode	Task/Item	Complete?	File Name on eos.arb.ca.gov
AQ	1999	Regional daily tabulation of 1-hour performance results (1,0,-99)	Y	Included in document
AQ	1999	Station-specific tabulation of 1-hour performance results (1,0,-99)	Y	1999 ozone performance by each station.doc
AQ	1999	Station-specific tabulation of 1-hour performance STATISTICS	Y	1999.050c.1hO3.doc
AQ	1999	Station-specific time-series plots of 1-hour ozone	Y	1999.pdf.zip
AQ	1999	Station-specific time-series plots of 1-hour precursors (CO, NO, NO2); ok to combine w/ ozone	Y	1999.pdf.zip
AQ	1999	Regional daily tabulation of 8-hour performance results (1,0,-99)	Y	Included in document
AQ	1999	Station-specific tabulation of 8-hour performance results (1,0,-99)	Y	1999 ozone performance by each station.doc
AQ	1999	Station-specific tabulation of 8-hour performance STATISTICS	Y	1999.050c.8hO3.doc
AQ	2000	Regional daily tabulation of 1-hour performance results (1,0,-99)	Y	Included in document
AQ	2000	Station-specific tabulation of 1-hour performance results (1,0,-99)	Y	2000 ozone performance by each station.doc
AQ	2000	Station-specific tabulation of 1-hour performance STATISTICS	Y	2000.050c.1hO3.doc
AQ	2000	Station-specific time-series plots of 1-hour ozone	Y	2000.pdf.zip
AQ	2000	Station-specific time-series plots of 1-hour precursors (CO, NO, NO2); ok to combine w/ ozone	Y	2000.pdf.zip
AQ	2000	Regional daily tabulation of 8-hour performance results (1,0,-99)	Y	Included in document
AQ	2000	Station-specific tabulation of 8-hour performance results (1,0,-99)	Y	2000 ozone performance by each station.doc
AQ	2000	Station-specific tabulation of 8-hour performance STATISTICS	Y	2000.050c.8hO3.doc

MODEL PERFORMANCE EVALUATION

Anonymous ftp to eos.arb.ca.gov, then change directories to /pub/outgoing/model_protocol2

Model	**Episode**	**Task/Item**	**Complete?**	**File Name on eos.arb.ca.gov**
Met	1999	Wind Speed Statistics per Performance Region (RMSE < 2 m/s; Bias::< ±0.5 m/s; IOA:^{3} 0.6)	Y	Included in document
Met	1999	Wind Direction Statistics per Performance Region(Gross Error:< 30 deg; Bias:< ±10 deg)	Y	Included in document
Met	1999	Temperature Statistics per Performance Region(Gross Error:< 2 K; Bias:< ±0.5 K; IOA^{3} 0.8)	Y	Included in document
Met	1999	Station-specific, time-series plots of hourly mean air temperature	Y	July1999.met.regionN.pdf, where N is region number
Met	1999	Station-specific, time-series plots of hourly mean wind speeds.	Y	same as above
Met	1999	Domain-wide spatial plots of hourly wind vectors	Y	July1999_surface_hourly_wind.EEEE.pdf, where EEEE is simulation ID
Met	1999	Domain-wide, spatial plots of hourly air temperatures	N	
Met	2000	Wind Speed Statistics per Performance Region (RMSE < 2 m/s; Bias::< ±0.5 m/s; IOA:^{3} 0.6)	Y	Included in document
Met	2000	Wind Direction Statistics per Performance Region(Gross Error:< 30 deg; Bias:< ±10 deg)	Y	Included in document
Met	2000	Temperature Statistics per Performance Region(Gross Error:< 2 K; Bias:< ±0.5 K; IOA^{3} 0.8)	Y	Included in document
Met	2000	Station-specific, time-series plots of hourly mean air temperature	Y	<<to be posted>>
Met	2000	Station-specific, time-series plots of hourly mean wind speeds.	Y	<<to be posted>>
Met	2000	Domain-wide spatial plots of hourly wind vectors	Y	Included in document
Met	2000	Domain-wide, spatial plots of hourly air temperatures	N	