C.3.4.5 EC Monthly Bias and Error

The monthly average bias and error for EC across the IMPROVE and STN monitors in the CENRAP region are shown in Figure C-26. The STN network exhibits low bias year round, whereas the IMPROVE monitoring network exhibits a large under-prediction bias in the summer months (-40% to -60%) and much lower EC bias in the winter. The errors in the IMPROVE summer EC performance are also quite high (60% to 80%), whereas during the winter the IMPROVE errors are in the 40% to 50% range which is also where the STN errors reside year round.

The Bugle Plot puts the EC performance in context (Figure C-27). The low EC concentrations put the IMPROVE EC performance in the horn of the Bugle Plot so that it achieves the proposed PM performance goal for all months of the year.

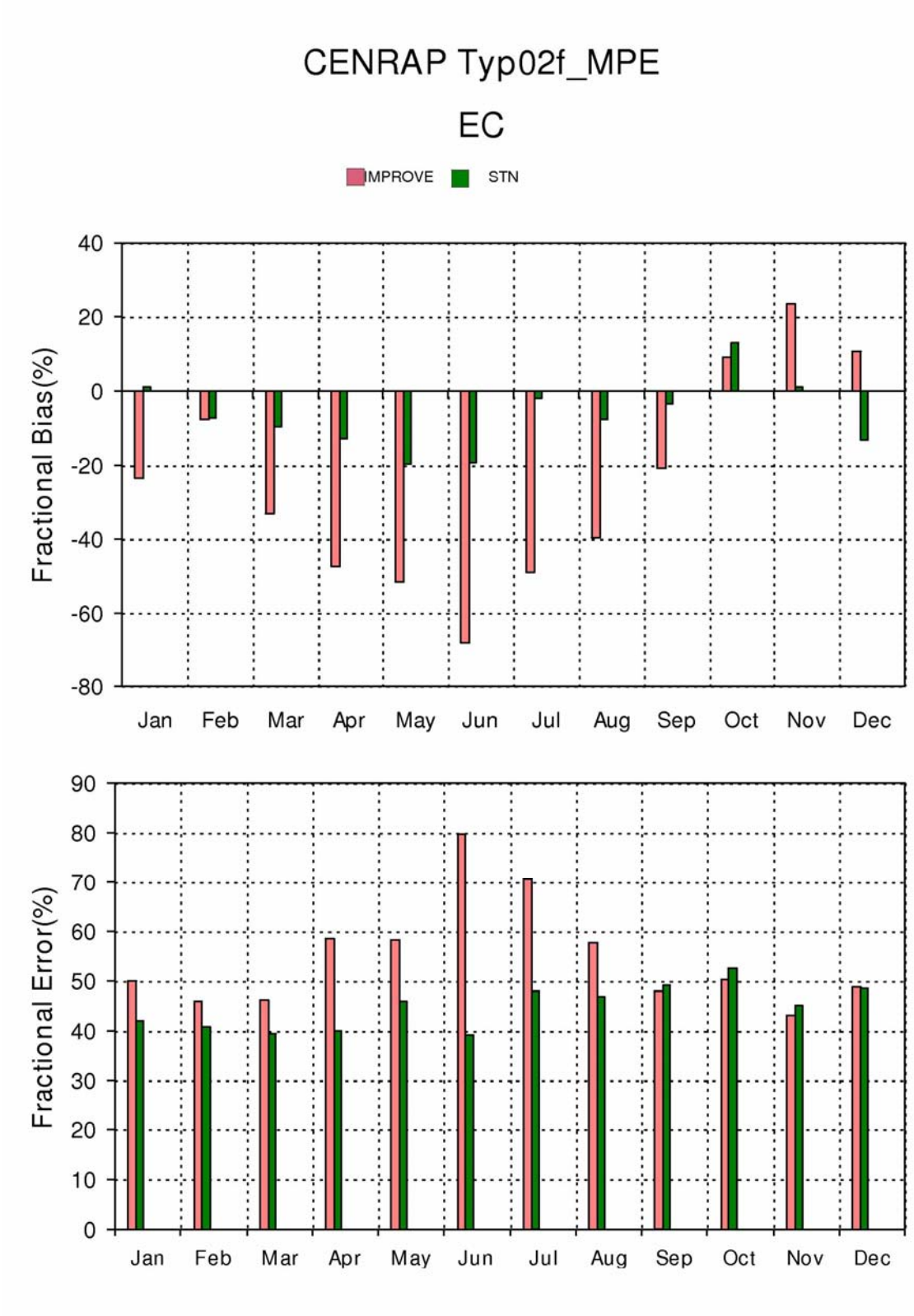


Figure C-26. Monthly EC fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE and STN monitoring sites in the CENRAP region.

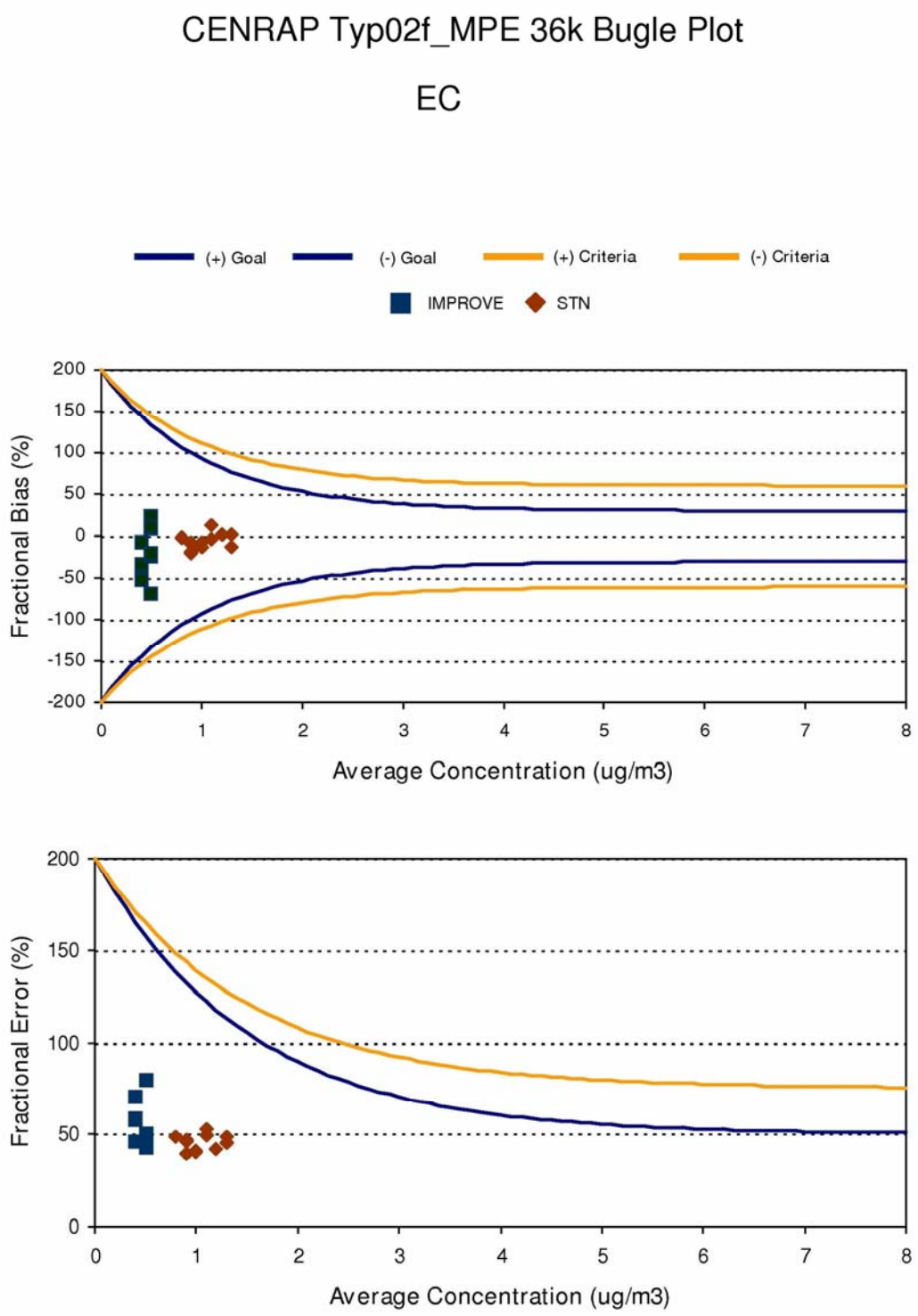


Figure C-27. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for EC and IMPROVE and STN monitoring sites in the CENRAP region.

C.3.5 Other $PM_{2.5}$ (Soil) Monthly Model Performance

There are also model-measurement incommensurability problems with the other $PM_{2.5}$ (Soil) species. Whereas the IMPROVE Soil species is built up from measure elements, the modeled other $PM_{2.5}$ concentrations are based on emissions speciation profiles that likely include other species besides just elements. Soil is only collected at the IMPROVE monitors.

C.3.5.1 Soil in January 2002

The model greatly overestimates the Soil species at IMPORVE sites in January (Figure C-28a). The fractional bias exceeds 100% with errors of almost 130%. With the possible exception of the two Texas sites, the model Soil overestimation bias occurs across all of the CENRAP Class I areas in January (Figure C-28b). The model also does a poor job in reproducing the spatial variability of the observed Soil with a general overestimation tendency except at GUMO where it fails to reproduce the high Soil events.

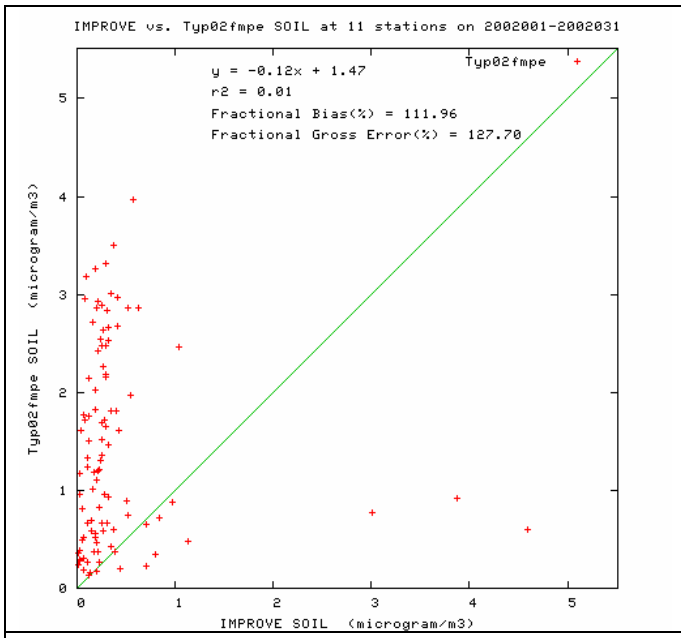
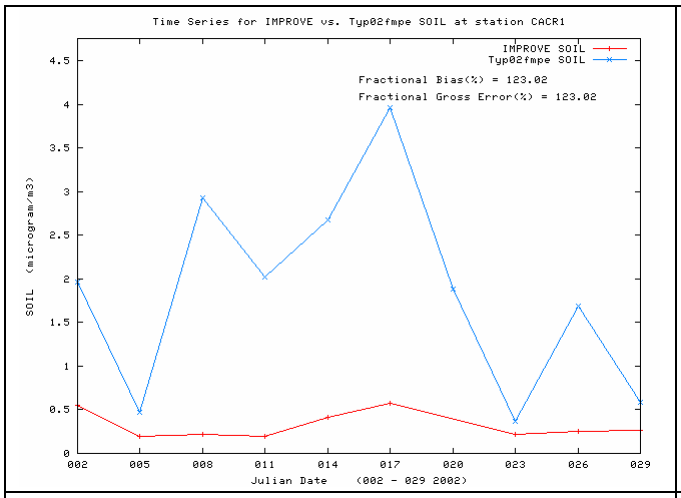
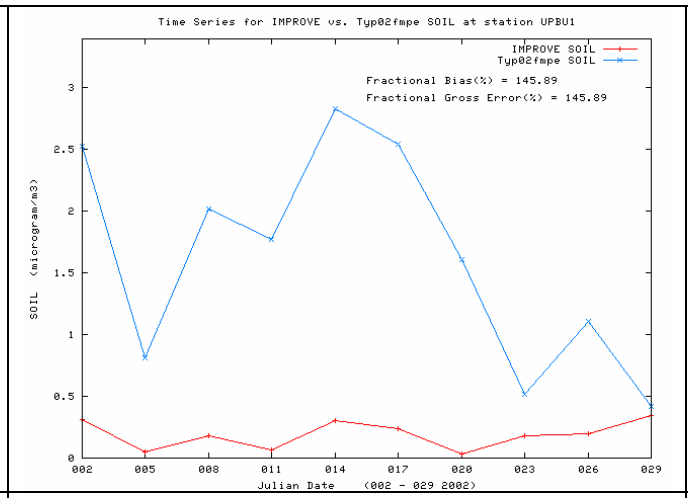
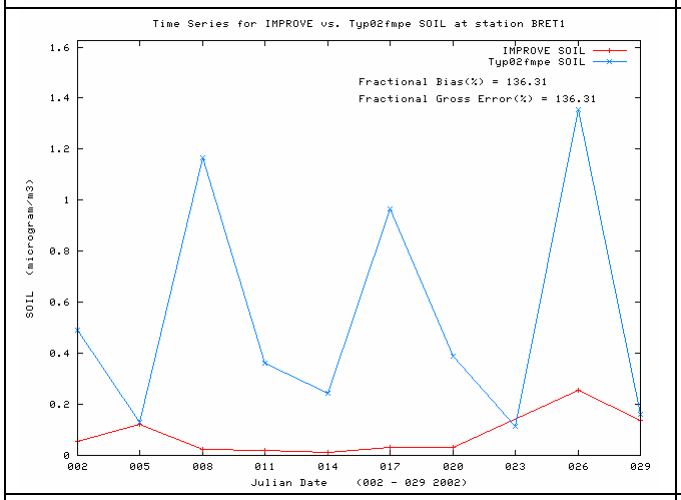
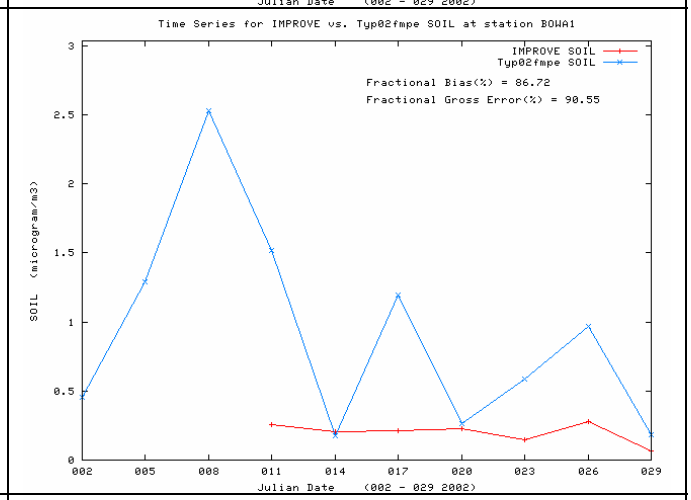


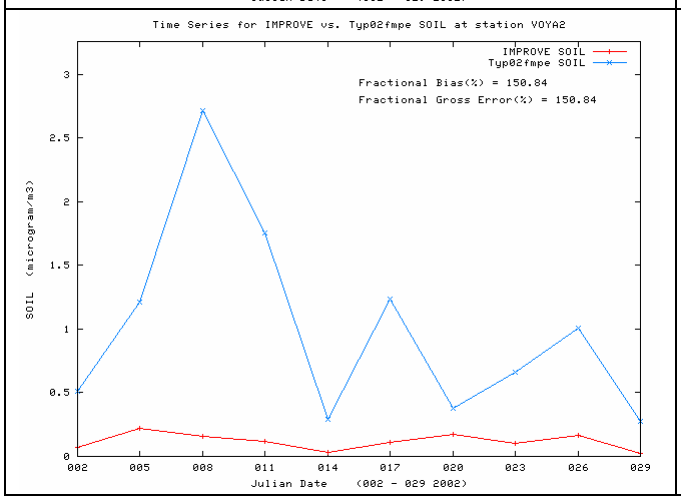
Figure C-28a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for January 2002 and sites in the CENRAP region using IMPROVE monitoring network and the CMAQ 2002 36 km Base F base case simulation.

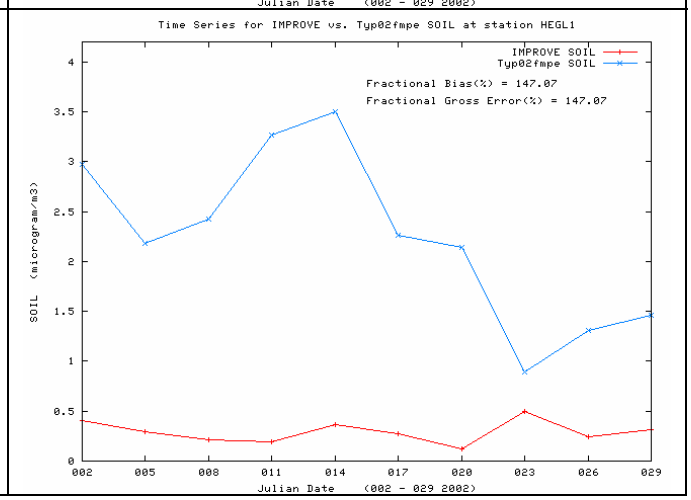

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 123.02
Fractional Gross Error(%) = 123.02
SOIL (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 145.89
Fractional Gross Error(%) = 145.89
SOIL (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 136.31
Fractional Gross Error(%) = 136.31
SOIL (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 86.72
Fractional Gross Error(%) = 90.55
SOIL (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 150.84
Fractional Gross Error(%) = 150.84
SOIL (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 147.07
Fractional Gross Error(%) = 147.07
SOIL (microgram/m3)
Julian Date (002 - 029 2002)

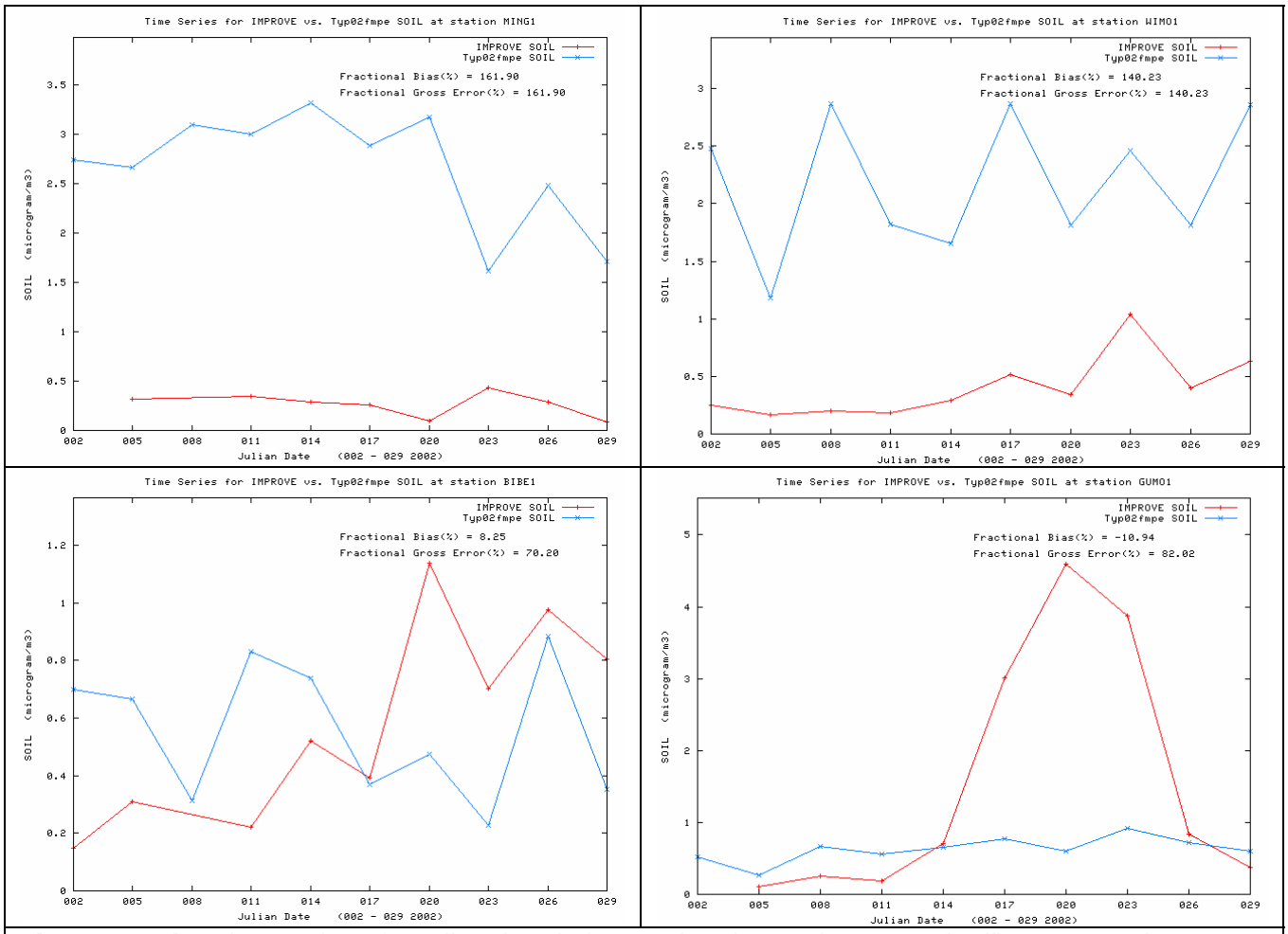


Figure C-28b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

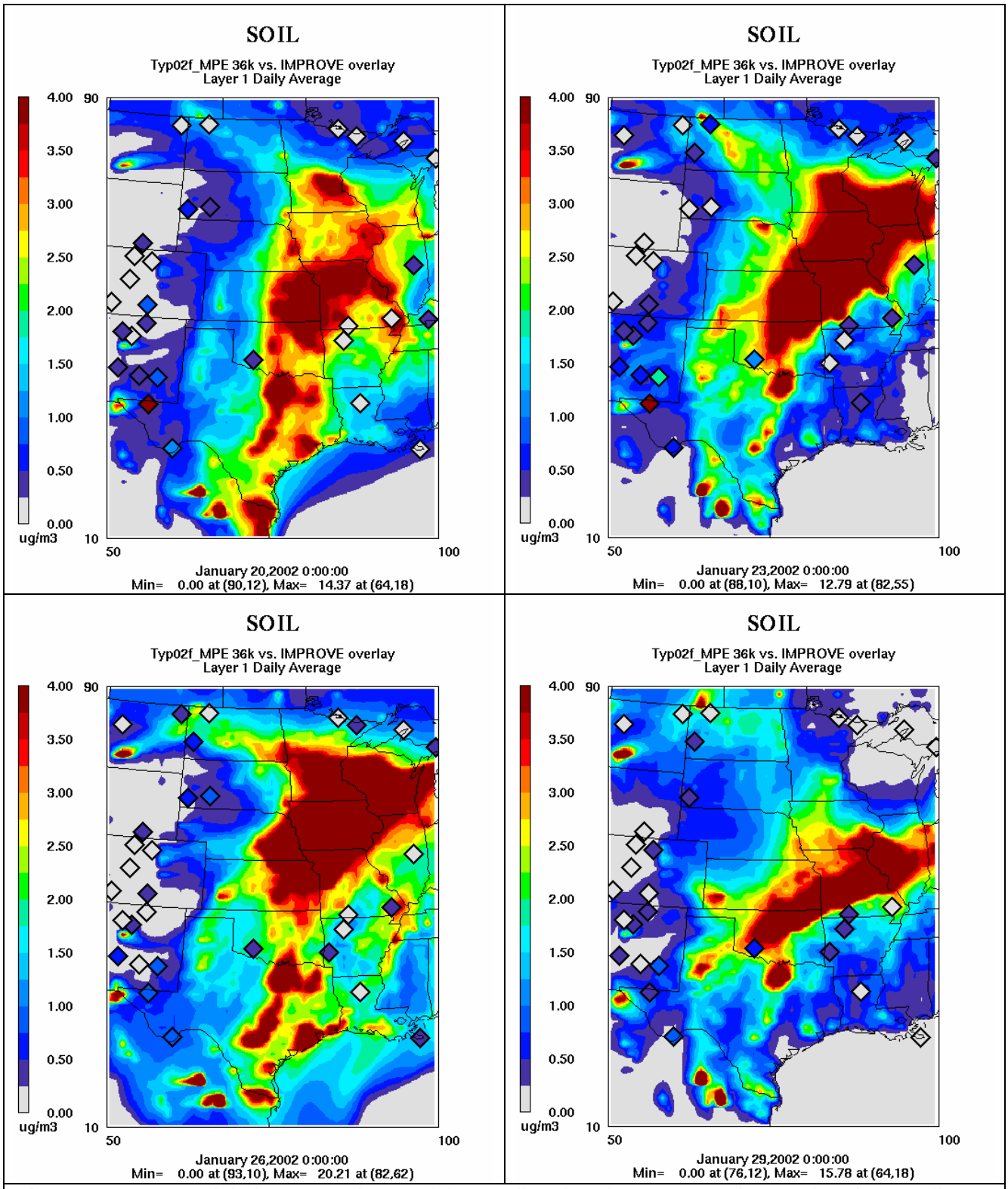


Figure C-28c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for January 20, 23, 26 and 29, 2002.

C.3.5.2 Soil in April 2002

The model does a better job in reproducing the overall magnitude of the Soil measurements in April with a bias of 13% (Figure C-29a). But it exhibits little skill with lots of scatter and an error of 81%. The model is generally exhibiting a lot more day-to-day variability than observed with the observed daily time series much flatter than the modeled values (Figure C-29b). The modeled and observed spatial variability in Soil on April 5, 8, 11 and 14 are shown in Figure C-29c. Although the model exhibits large day-to-day variability, the observations do not reflect what the model predicts.

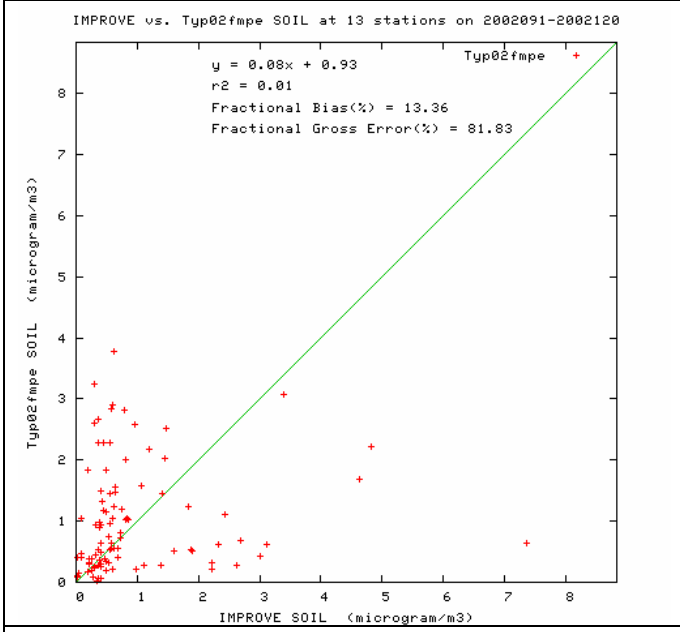
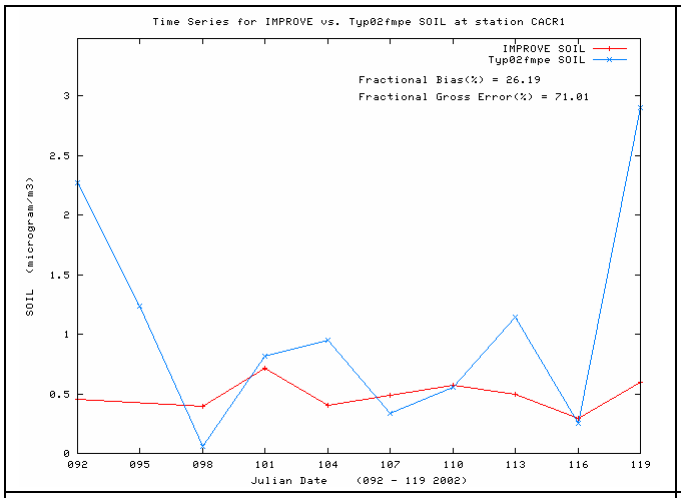
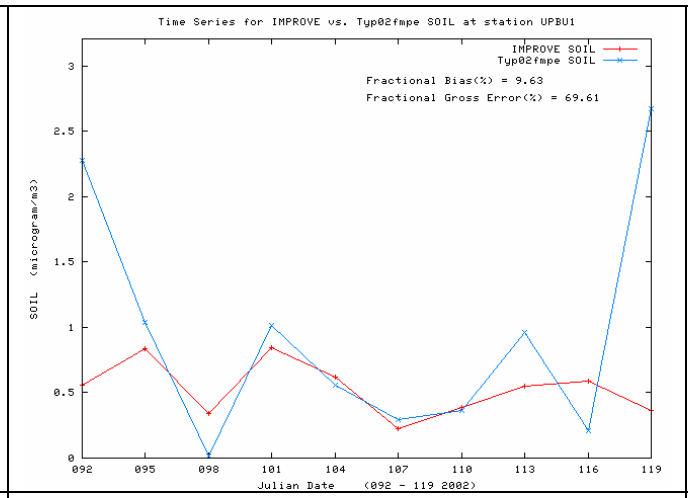
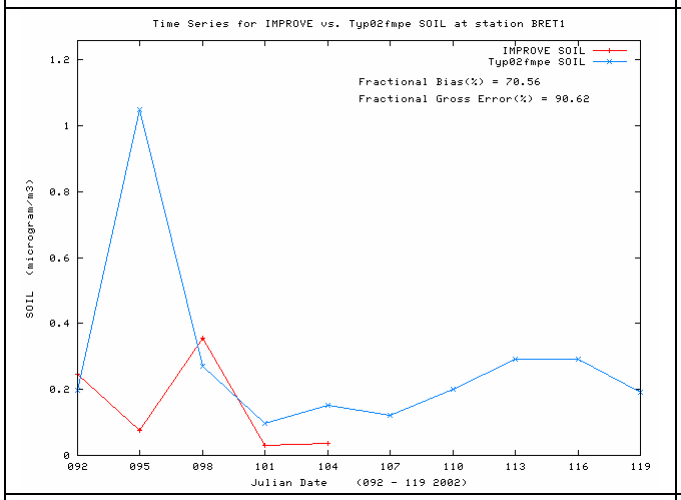
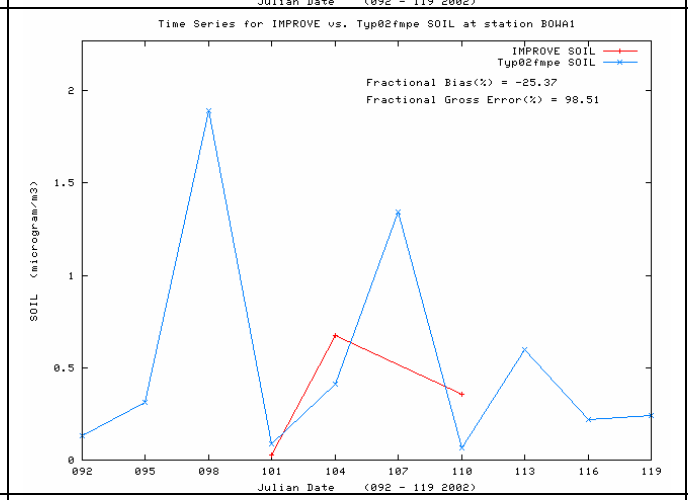


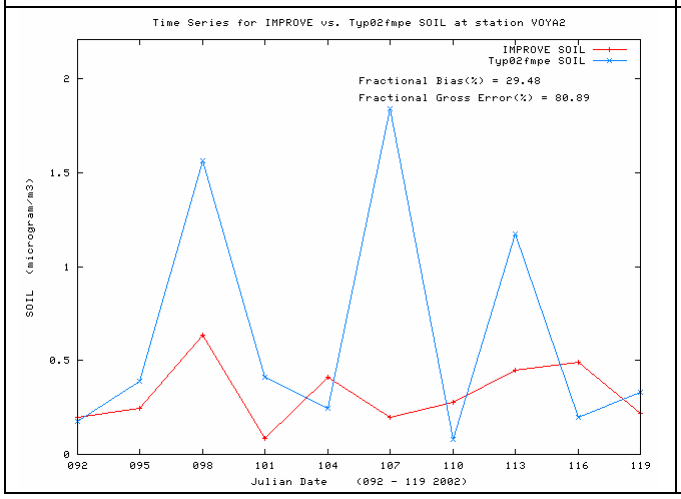
Figure C-29a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for April 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

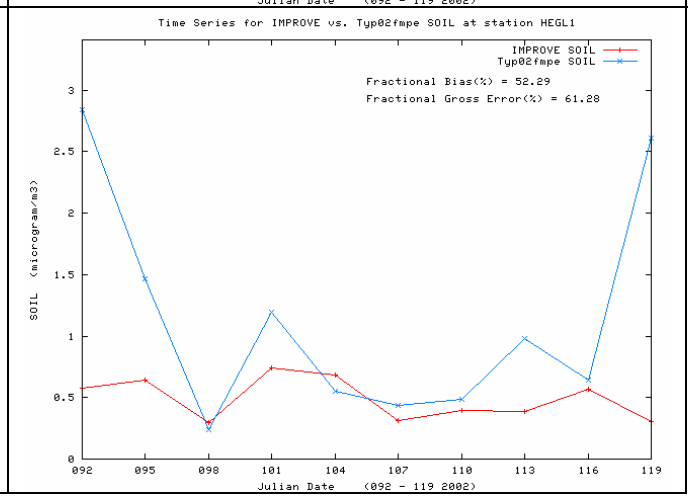

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 26.19
Fractional Gross Error(%) = 71.01
SOIL (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 9.63
Fractional Gross Error(%) = 69.61
SOIL (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 70.56
Fractional Gross Error(%) = 90.62
SOIL (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -25.37
Fractional Gross Error(%) = 98.51
SOIL (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 29.48
Fractional Gross Error(%) = 80.89
SOIL (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 52.29
Fractional Gross Error(%) = 61.28
SOIL (microgram/m3)
Julian Date (092 - 119 2002)

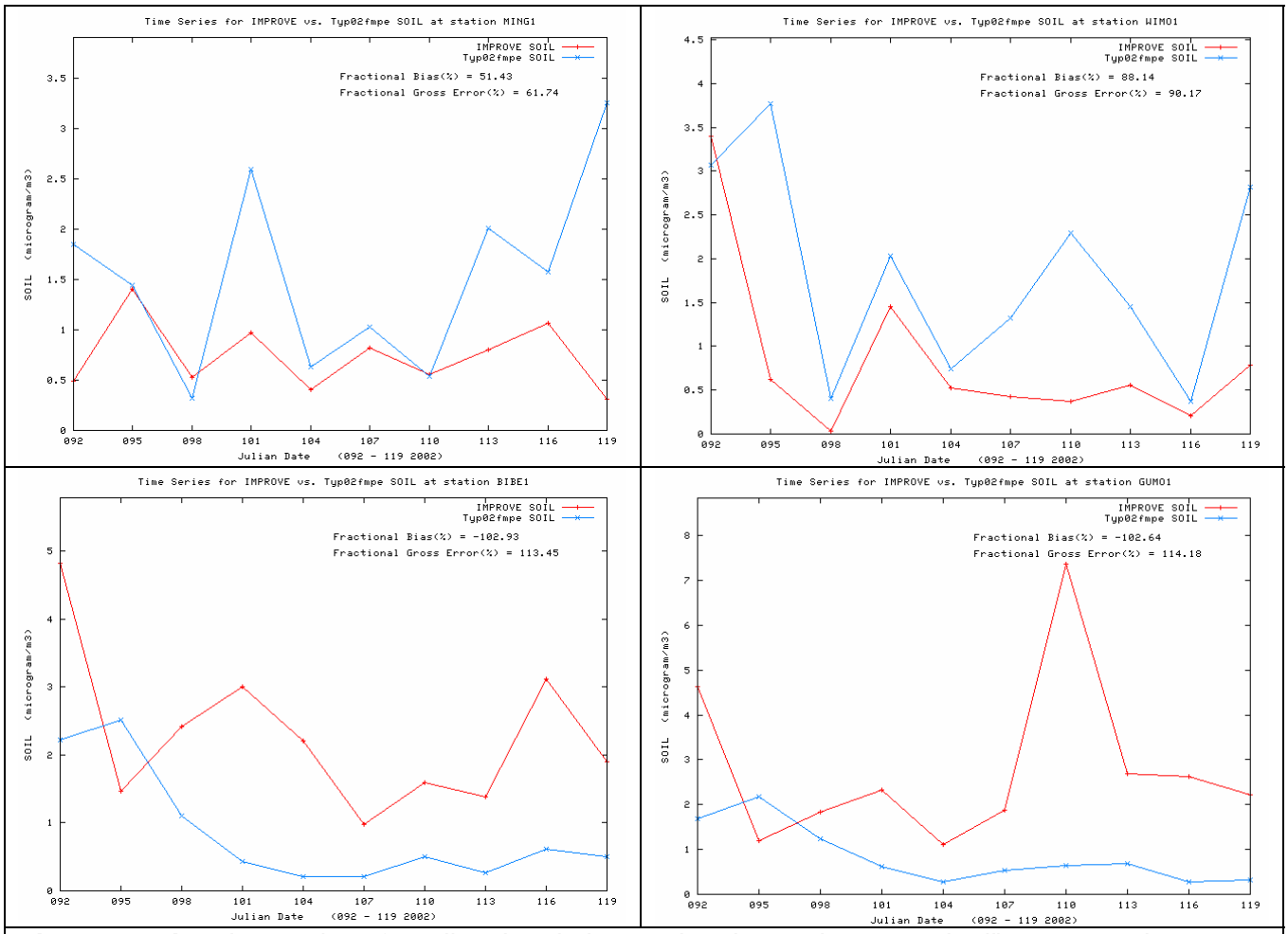


Figure C-29b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

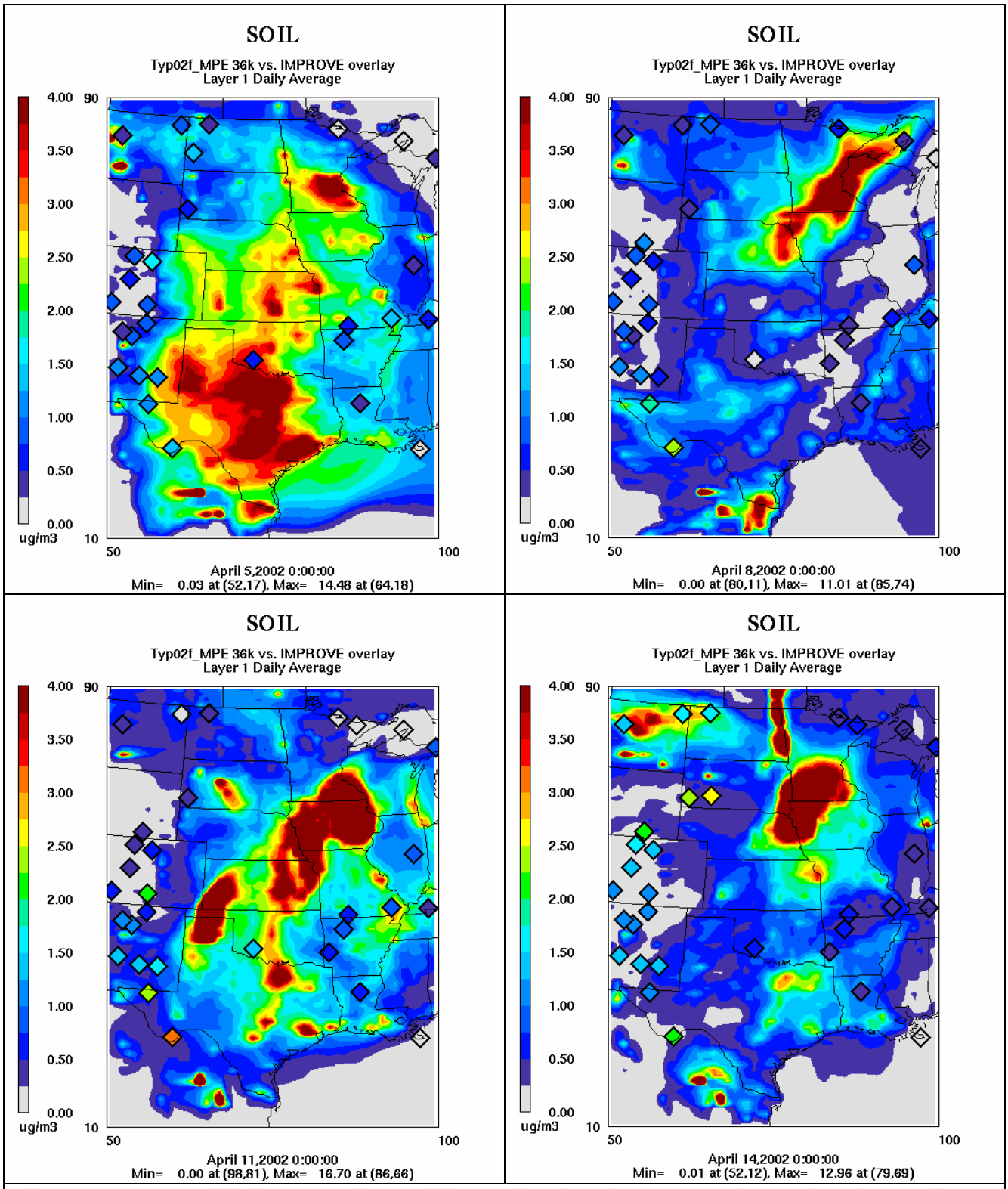


Figure C-29c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for April 5, 8, 11 and 14, 2002.

C.3.5.3 Soil in July 2002

The -50% Soil under-prediction bias seen in July appears to be driven to several high Soil measurements (Figure C-30a). An observed high Soil event took place on July 1 (Julian Day 182) across the Arkansas and Missouri Class I areas that all observed Soil values in excess of 15 µg/m^3. This event was not captured by the model. With the exception of a systematic Soil underestimation bias at the two Texas sites and missing these high Soil events, the model generally reproduces the magnitudes of the Soil observations in July.

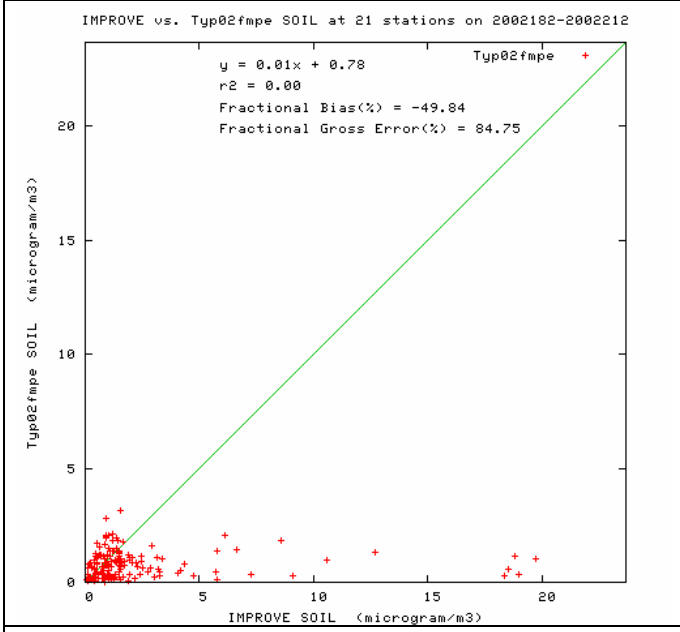
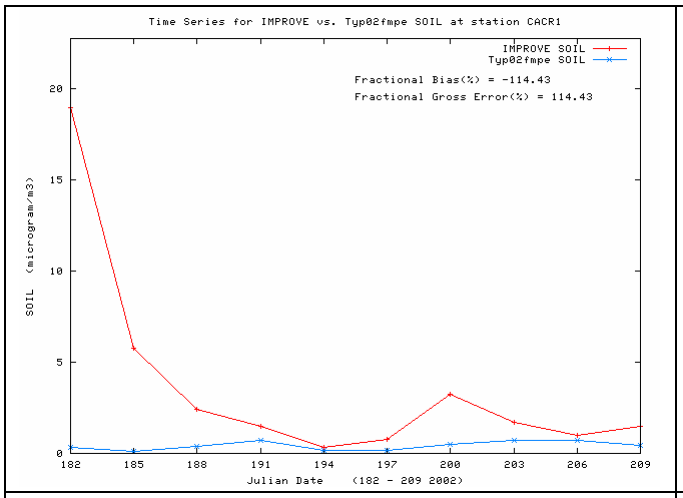
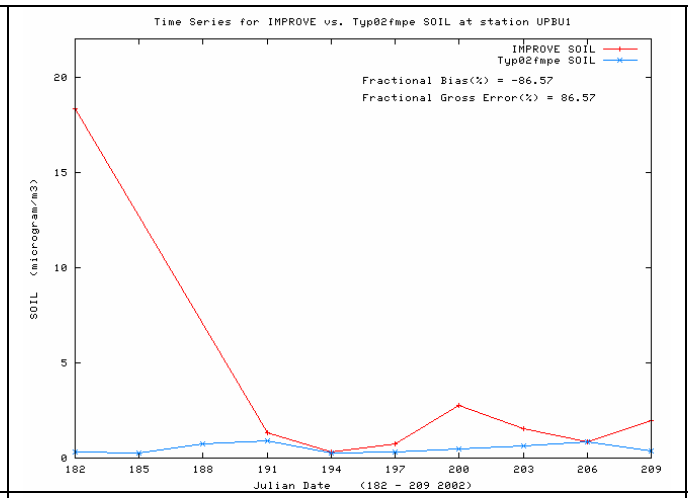
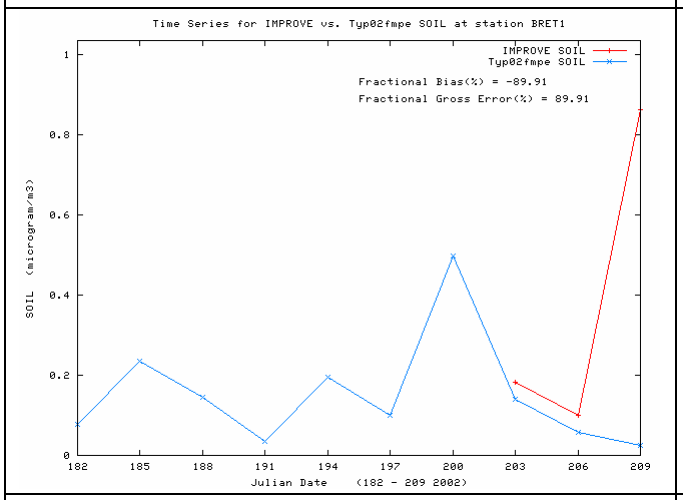
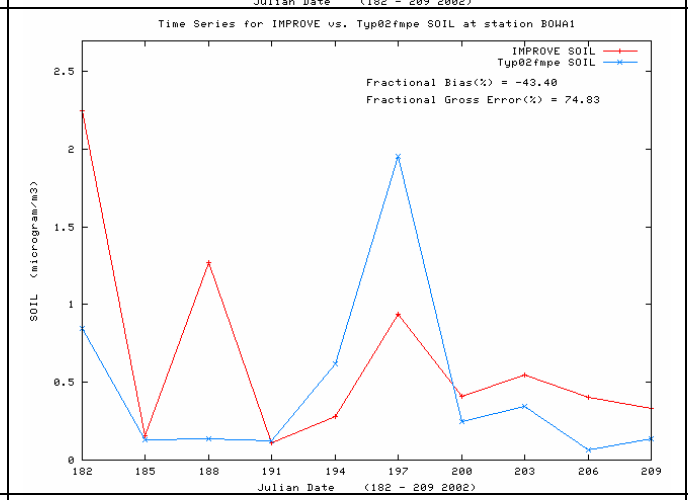


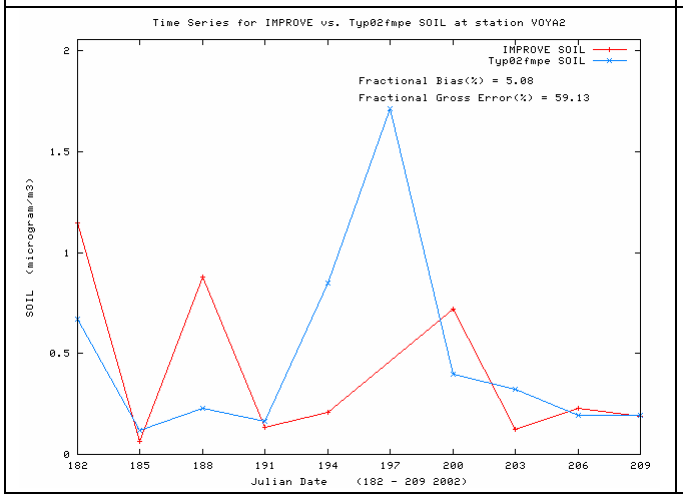
Figure C-30a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for July 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

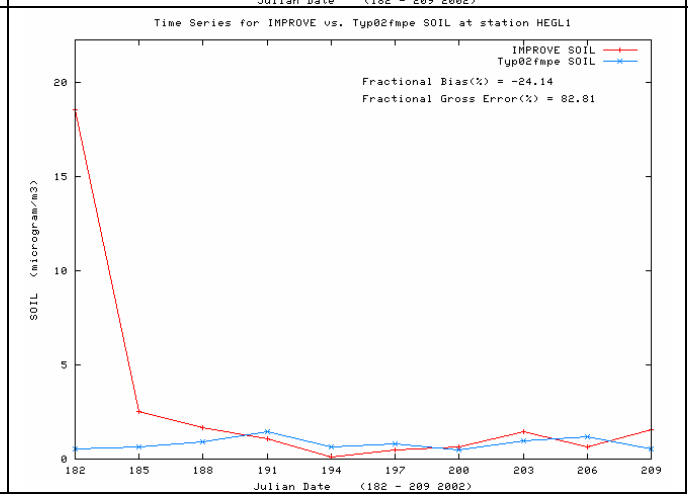

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -114.43
Fractional Gross Error(%) = 114.43
SOIL (microgram/m3)
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -86.57
Fractional Gross Error(%) = 86.57
SOIL (microgram/m3)
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -89.91
Fractional Gross Error(%) = 89.91
SOIL (microgram/m3)
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -43.40
Fractional Gross Error(%) = 74.83
SOIL (microgram/m3)
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 5.08
Fractional Gross Error(%) = 59.13
SOIL (microgram/m3)
Julian Date (182 - 209 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -24.14
Fractional Gross Error(%) = 82.81
SOIL (microgram/m3)
Julian Date (182 - 209 2002)

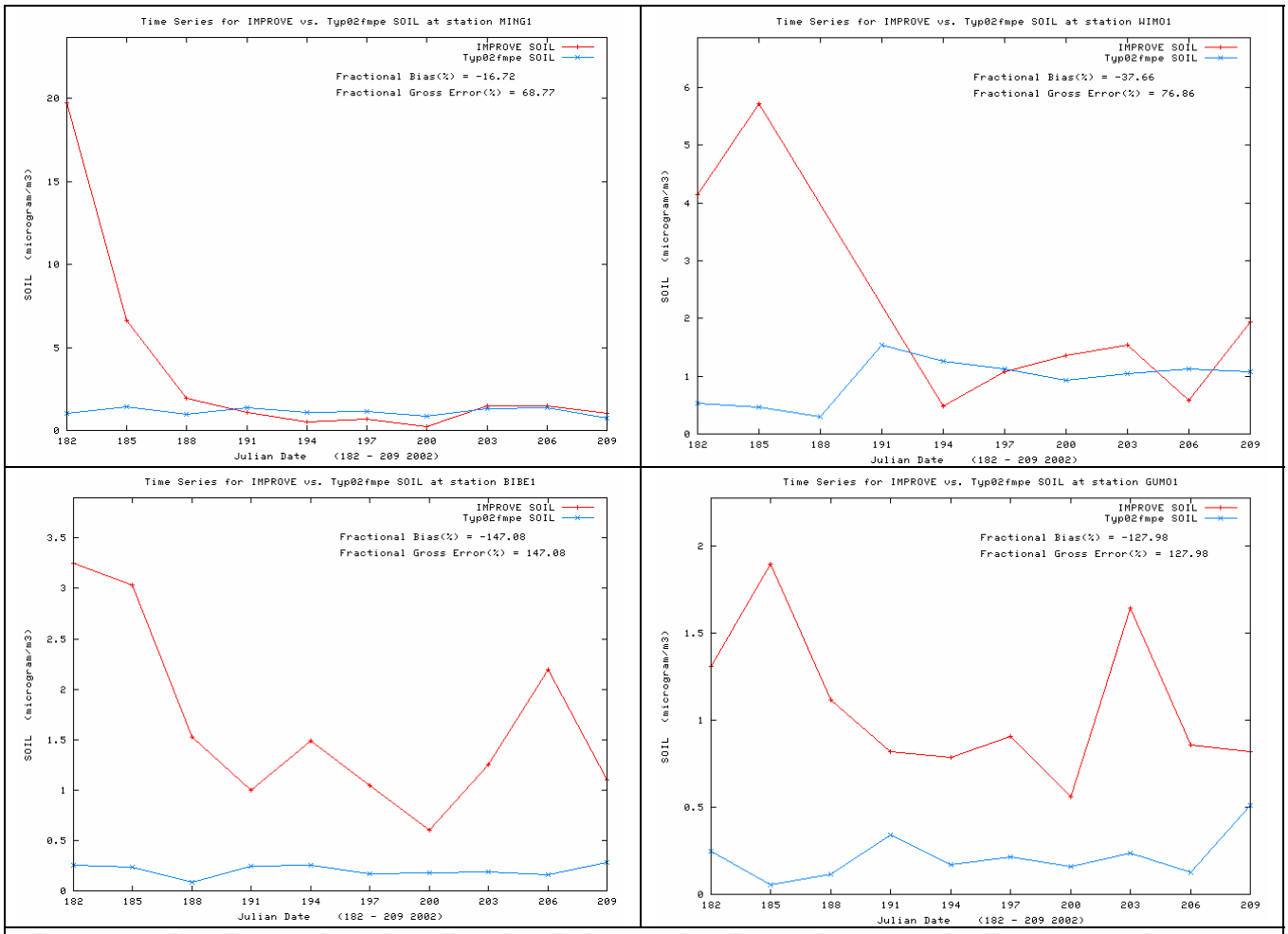


Figure C-30b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE sites in July 2002 for CMAQ 2002 36 km Base F base case simulation.

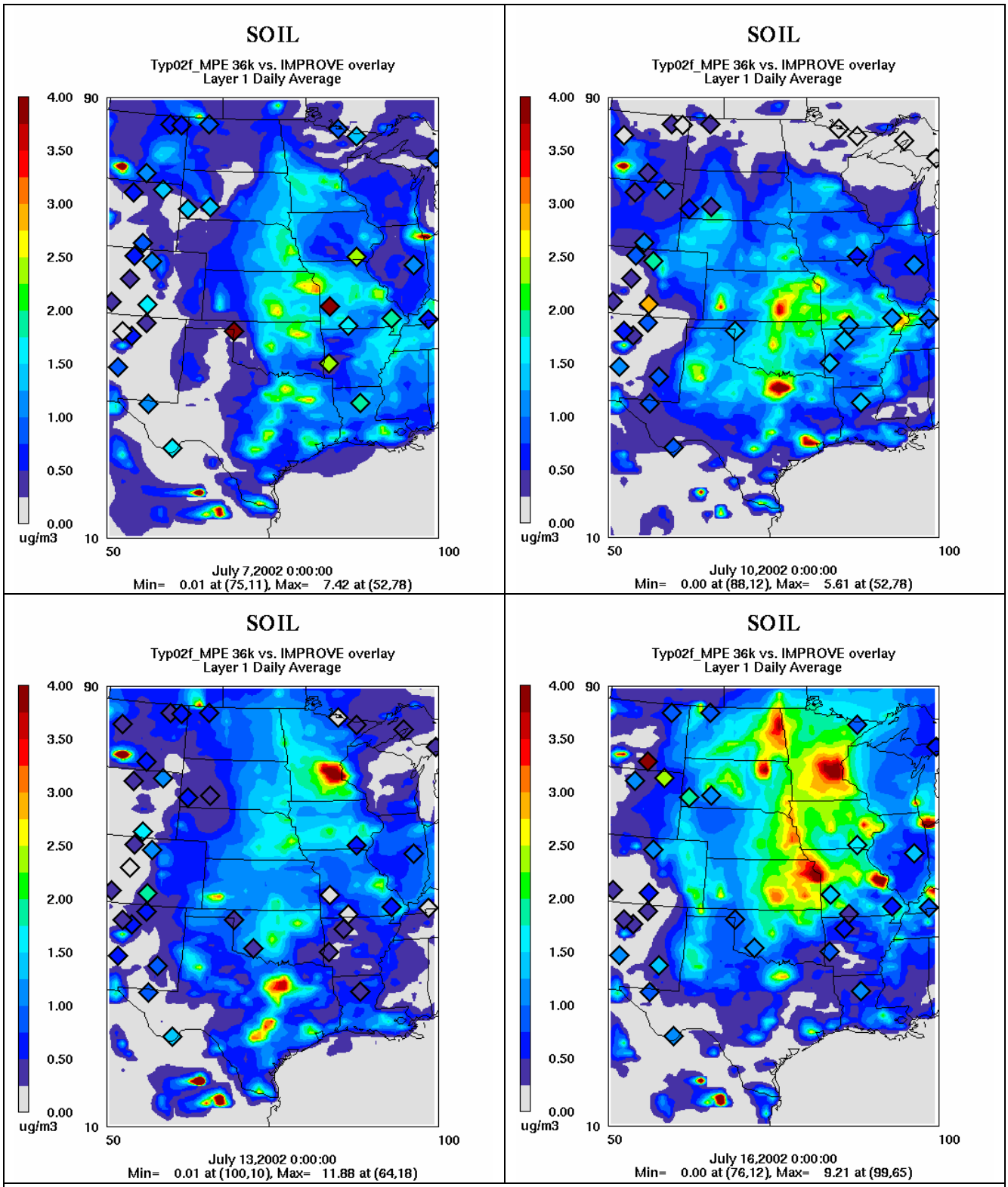


Figure C-30c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for July 7, 10, 13 and 16, 2002.

C.3.5.4 Soil in October 2002

The nearly systematic Soil over-prediction bias seen in January returns in October (Figure C-31a). Except for the two Texas sites, BRET and BOWA, the model overstates the observed Soil during all days of October at the other monitoring sites (Figure C-31b). The model is predicting elevated Soil concentrations in the OK-KS-MO-IA area that is not reflected in the measurements (Figure C-31c).

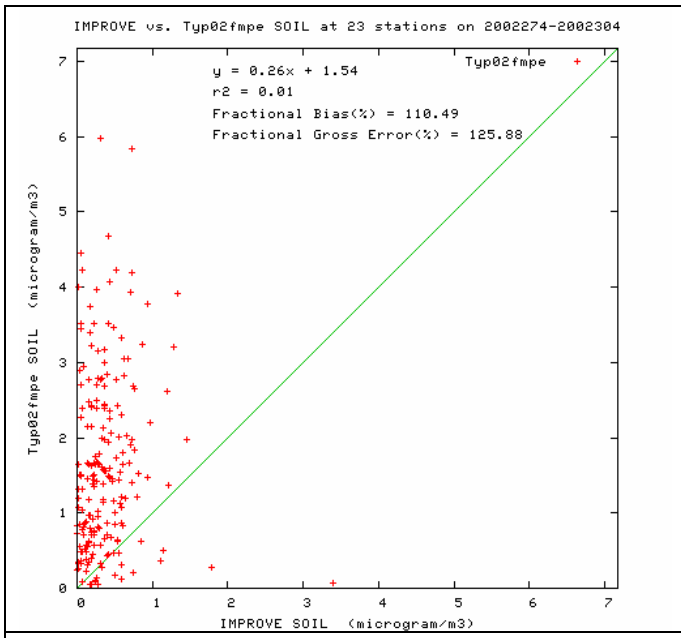
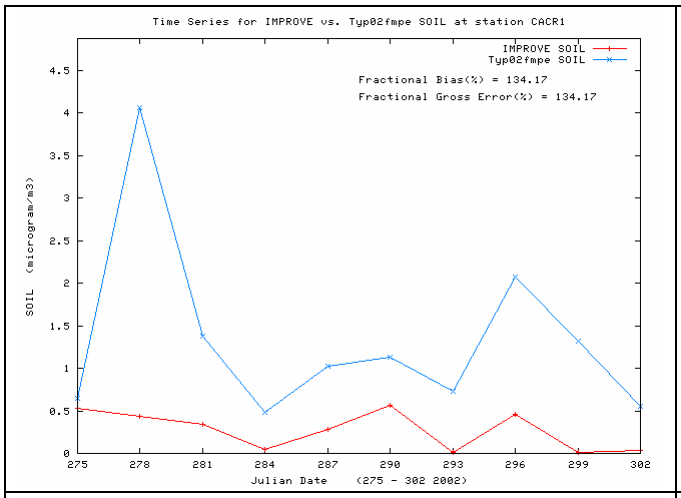
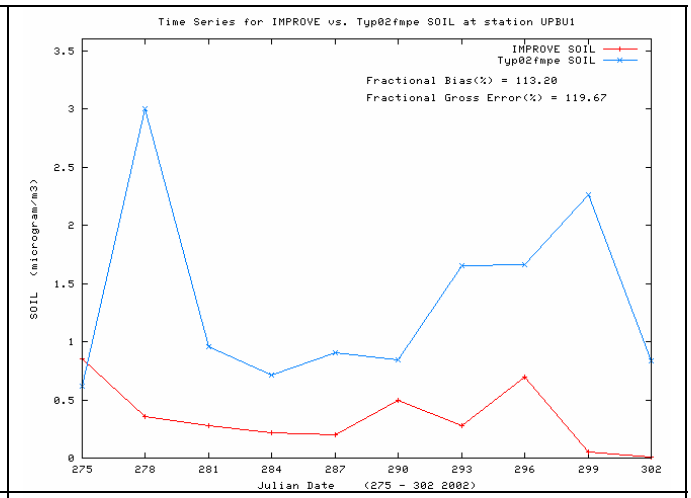
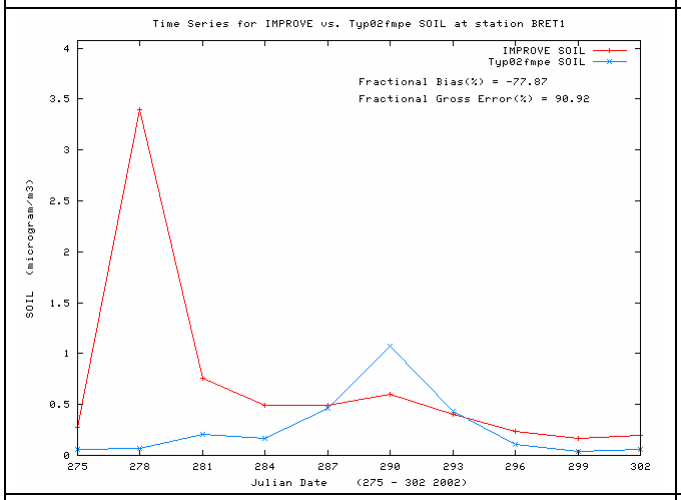
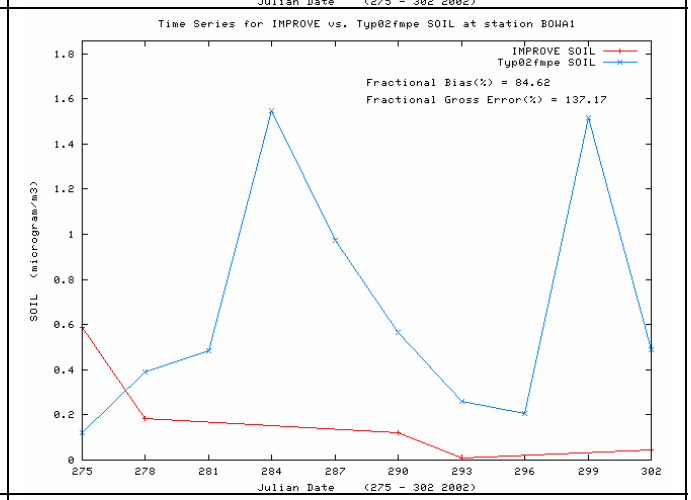


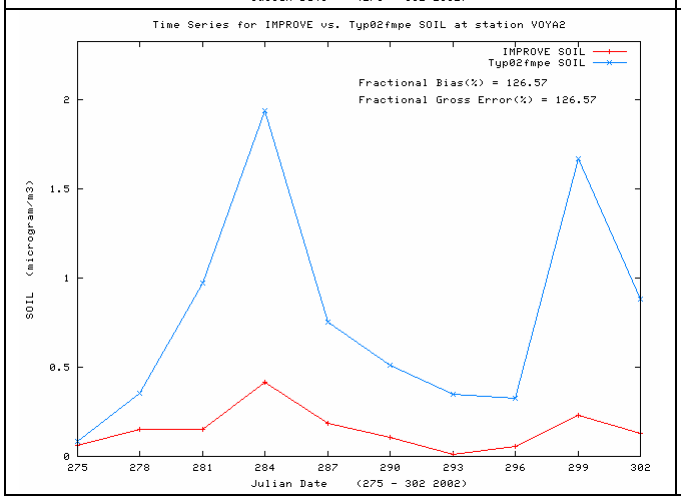
Figure C-31a. Scatter plots of predicted and observed other $PM_{2.5}$ (Soil) concentrations for October 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

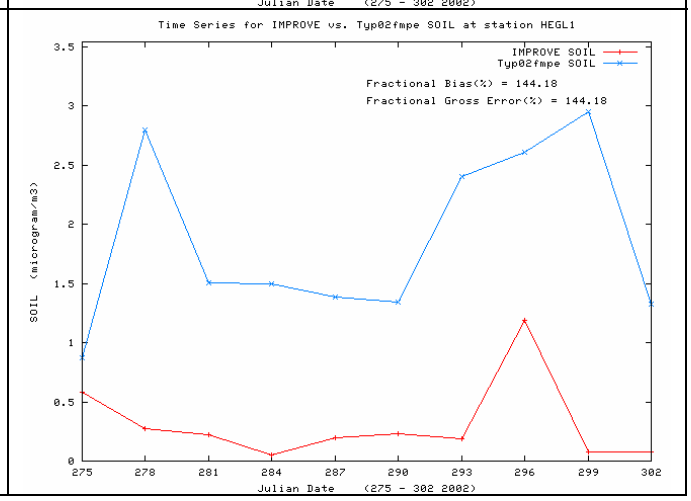

Time Series for IMPROVE vs. Typ02fmpe SOIL at station CACR1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 134.17
Fractional Gross Error(%) = 134.17
SOIL (microgram/m3)
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station UPBU1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 113.20
Fractional Gross Error(%) = 119.67
SOIL (microgram/m3)
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BRET1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = -77.87
Fractional Gross Error(%) = 90.92
SOIL (microgram/m3)
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station BOWA1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 84.62
Fractional Gross Error(%) = 137.17
SOIL (microgram/m3)
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station VOYA2
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 126.57
Fractional Gross Error(%) = 126.57
SOIL (microgram/m3)
Julian Date (275 - 302 2002)


Time Series for IMPROVE vs. Typ02fmpe SOIL at station HEGL1
IMPROVE SOIL
Typ02fmpe SOIL
Fractional Bias(%) = 144.18
Fractional Gross Error(%) = 144.18
SOIL (microgram/m3)
Julian Date (275 - 302 2002)

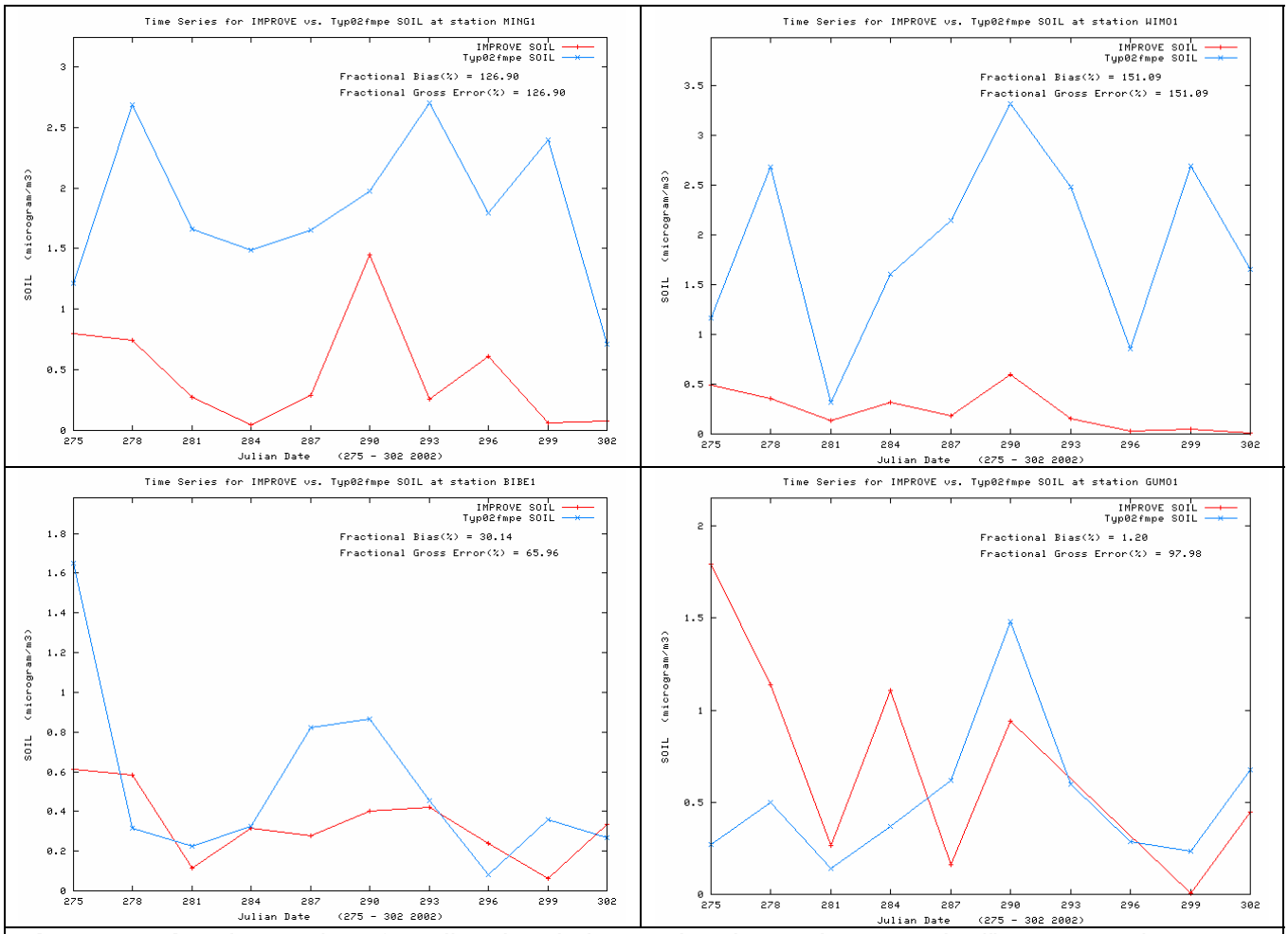


Figure C-31b. Time series of predicted and observed 24-hour other $PM_{2.5}$ (Soil) concentrations at CENRAP IMPROVE CLASS I AREA sites in October 2002 for CMAQ 2002 36 km Base F base case simulation.

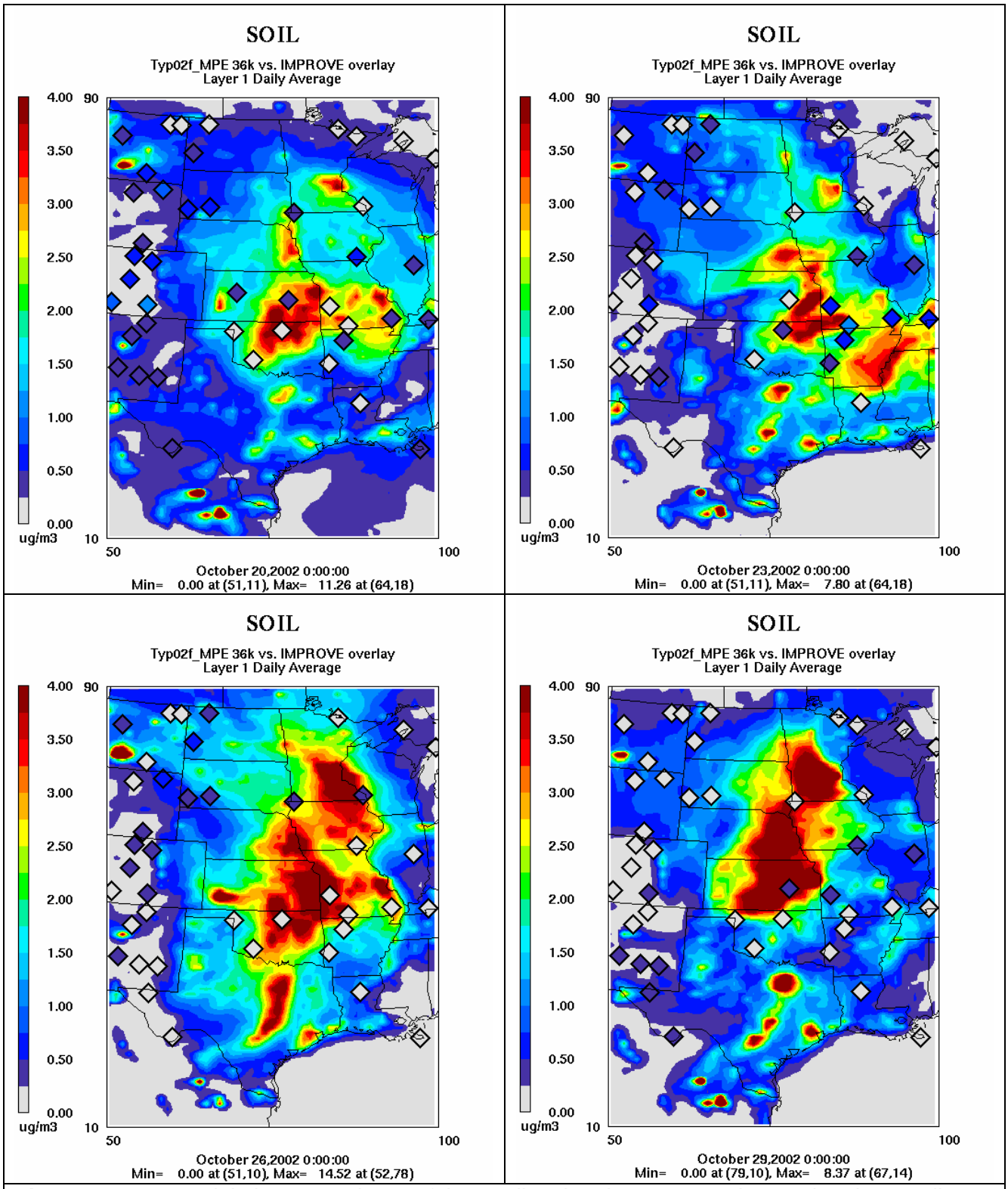


Figure C-31c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour Soil concentrations for October 20, 23, 26 and 29, 2002.

C.3.5.5 Soil Monthly Bias and Error

Figure C-32 displays the monthly variation in the Soil bias and error. During the winter months the model exhibits a very large (> 100%) overestimation bias with large errors as well. With the exception of July, in the summer the model bias is a slight over-prediction but generally less than 20% with errors of 60% to 80%. The Bugle Plot indicates that the summer Soil performance achieves the PM performance goal, a few months in the Spring/Fall period fall between the performance goal and criteria and the winter Soil performance exceeds the model performance criteria by a far margin. Thus, the Soil performance is a cause for concern.

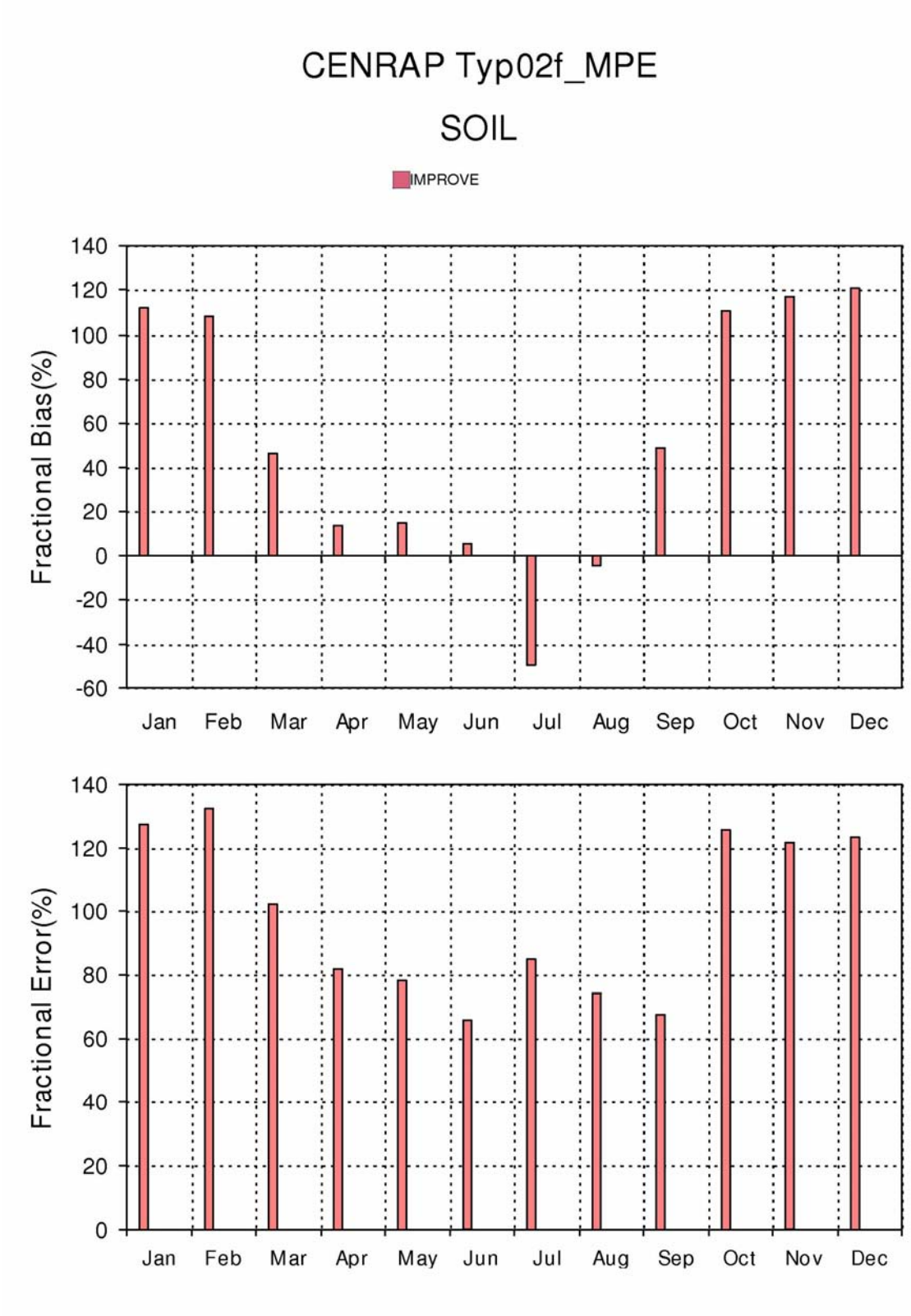


Figure C-32. Monthly Soil fractional bias (top) and fractional gross error (bottom) statistical measures for IMPROVE, STN and CASTNet monitoring sites in the CENRAP region.

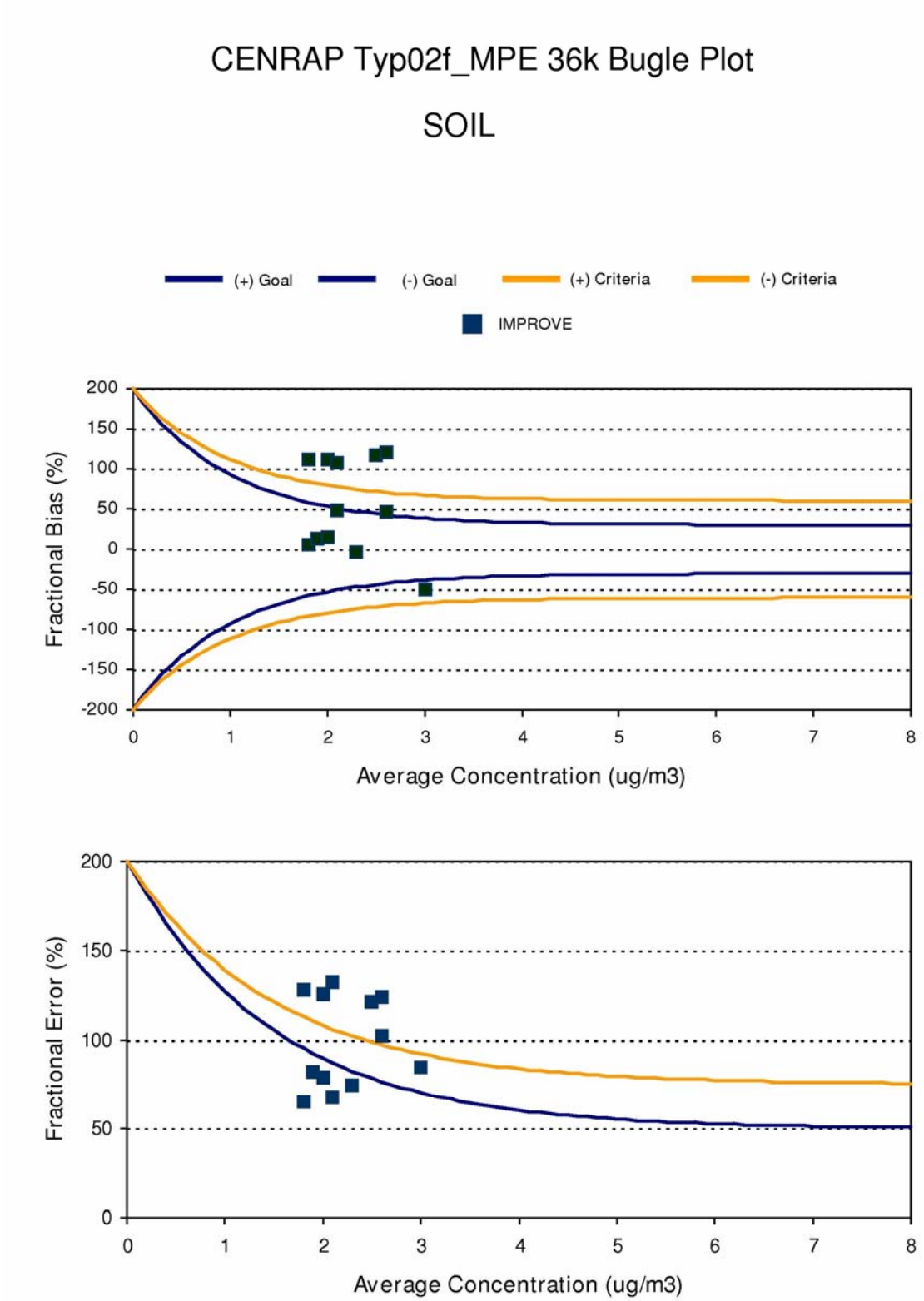


Figure C-33. Bugle Plots of monthly fractional bias (top) and fractional gross error (bottom) and comparisons with model performance goals and criteria for Soil and IMPROVE monitoring sites in the CENRAP region.

C.3.6 Coarse Mass (CM) Monthly Model Performance

The IMPROVE coarse mass (CM) measurement is taken as the difference between the PM_{10} and $PM_{2.5}$ mass measurement. Any SO4 or NO3 in the coarse mode will be in the CM measurement. The model, on the other hand, only includes primary CM. Any coarse SO4 or NO3 will be in the SO4 and NO3 modeled species.

C.3.6.1 CM in January 2002

The model underestimates the observed CM in January with a fractional bias of -83% (Figure C-34a). Although the model appears to reproduce CM at some sites (e.g., VOYA) at the two Texas sites the bias is approximately -150% (Figure C-34b). The observed spatial distribution of CM in January is not reproduced by the model at all (Figure C-34c). Whereas the observations indicate high CM concentrations in the west Texas-New Mexico area, the model estimates elevated CM in northeast Texas, through Oklahoma, Kansas, Iowa and into southern Minnesota. Although the CM measurements at WIMO in this area are also elevated, the rest of the high modeled CM values fall in between the IMPROVE monitors so can not be verified or refuted by the measurements.

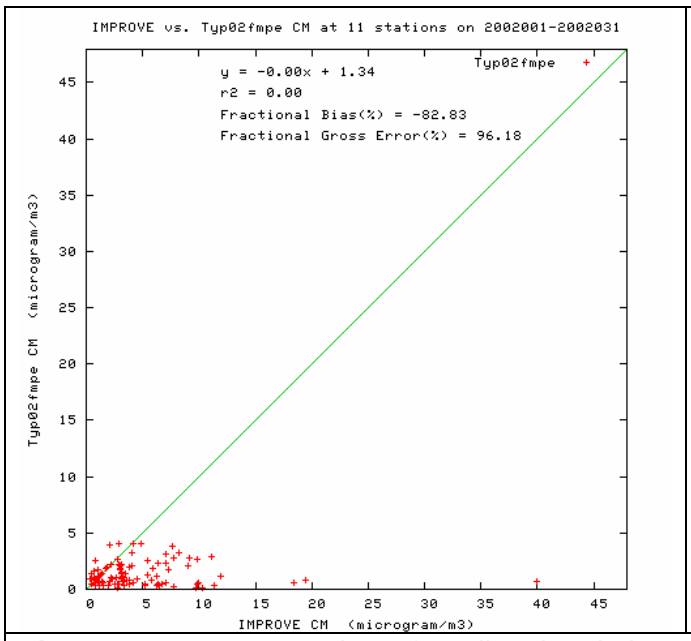
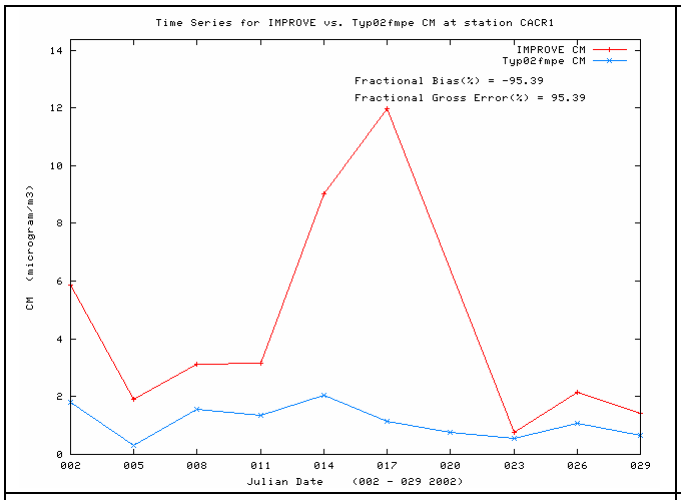
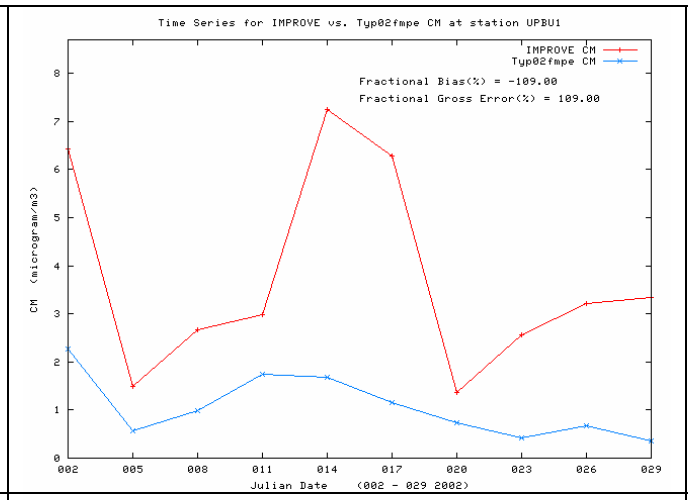
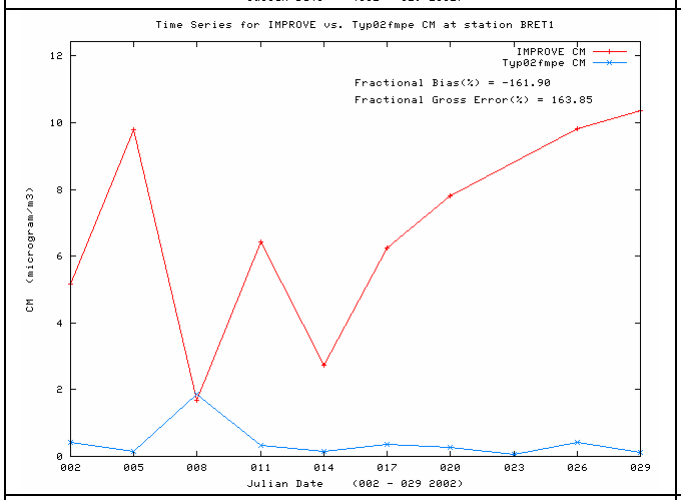
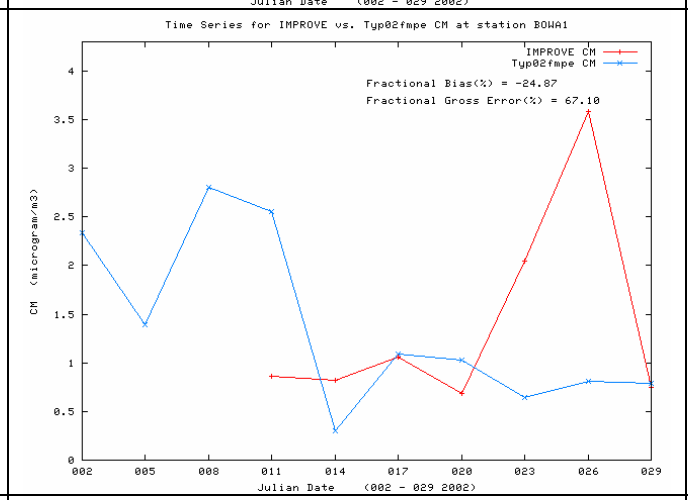


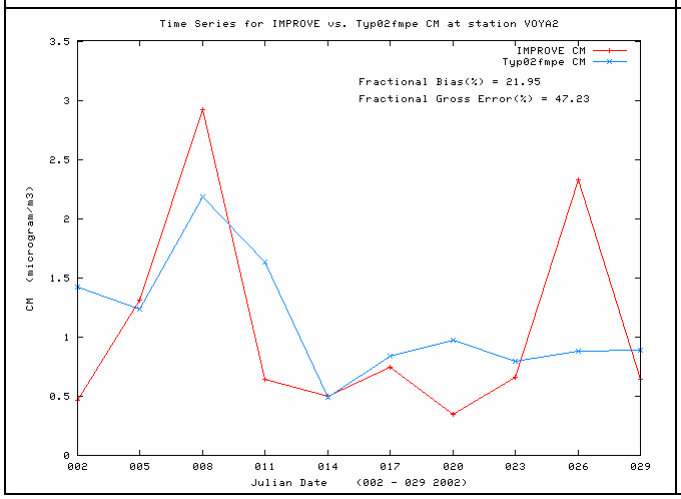
Figure C-34a. Scatter plots of predicted and observed coarse mass (CM) concentrations for January 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

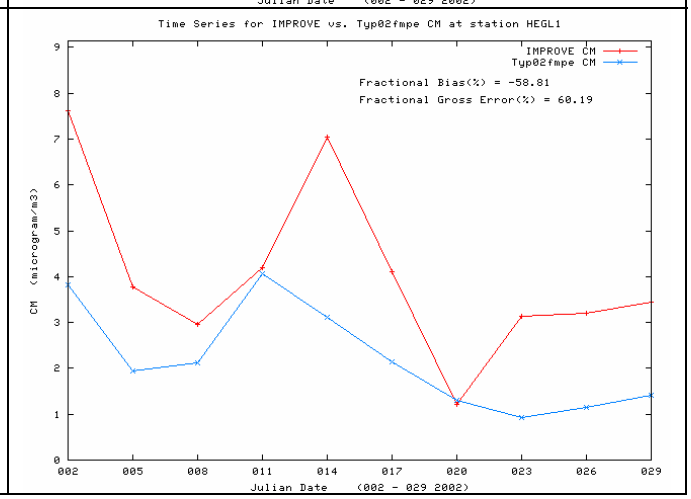

Time Series for IMPROVE vs. Typ02fmpe CM at station CACR1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -95.39
Fractional Gross Error(%) = 95.39
CM (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station UPBU1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -109.00
Fractional Gross Error(%) = 109.00
CM (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station BRET1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -161.90
Fractional Gross Error(%) = 163.85
CM (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station BOWA1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -24.87
Fractional Gross Error(%) = 67.10
CM (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station VOYA2
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = 21.95
Fractional Gross Error(%) = 47.23
CM (microgram/m3)
Julian Date (002 - 029 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station HEGL1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -58.81
Fractional Gross Error(%) = 60.19
CM (microgram/m3)
Julian Date (002 - 029 2002)

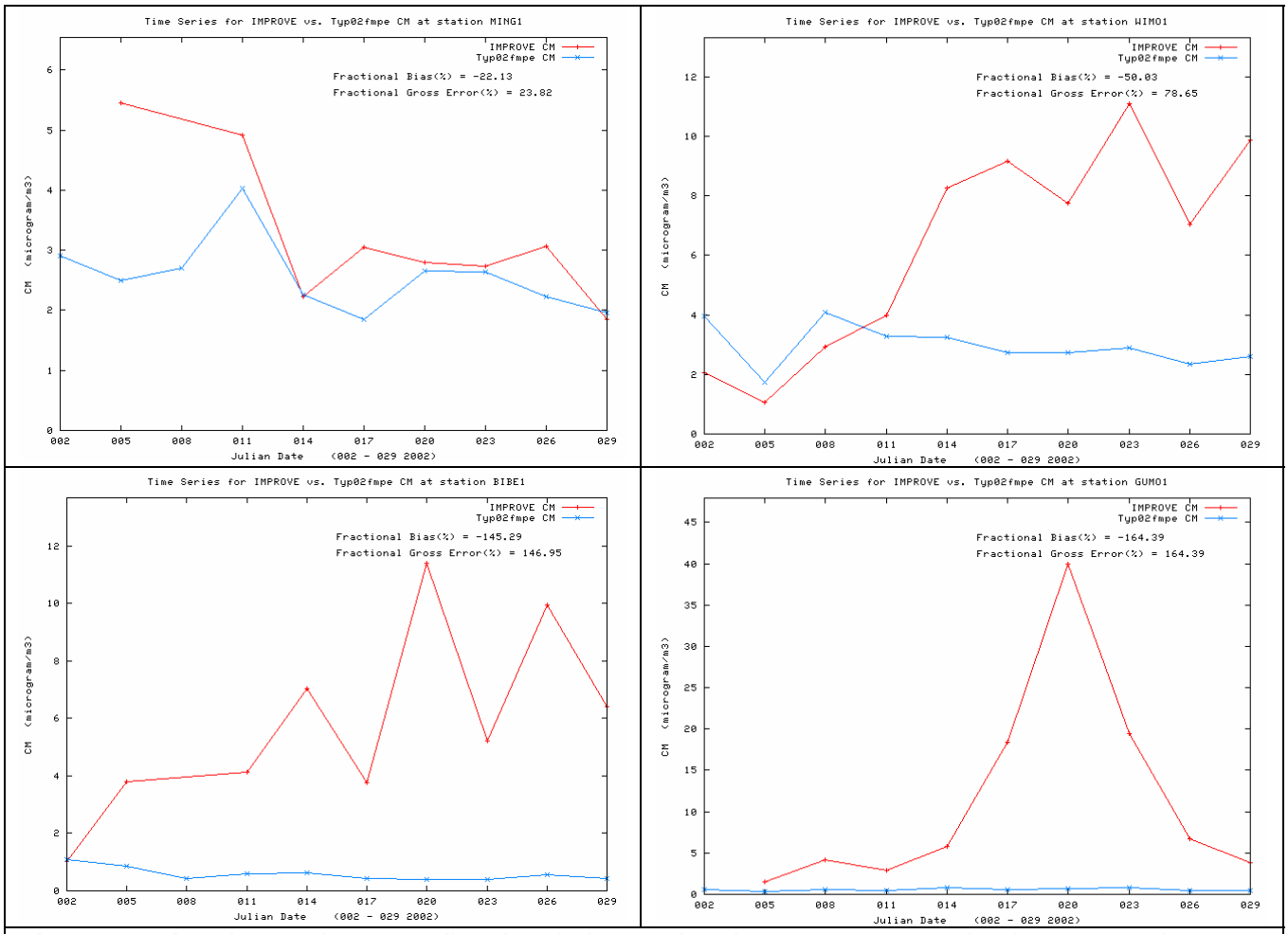


Figure C-34b. Time series of predicted and observed 24-hour coarse mass (CM) concentrations at CENRAP IMPROVE CLASS I AREA sites in January 2002 for CMAQ 2002 36 km Base F base case simulation.

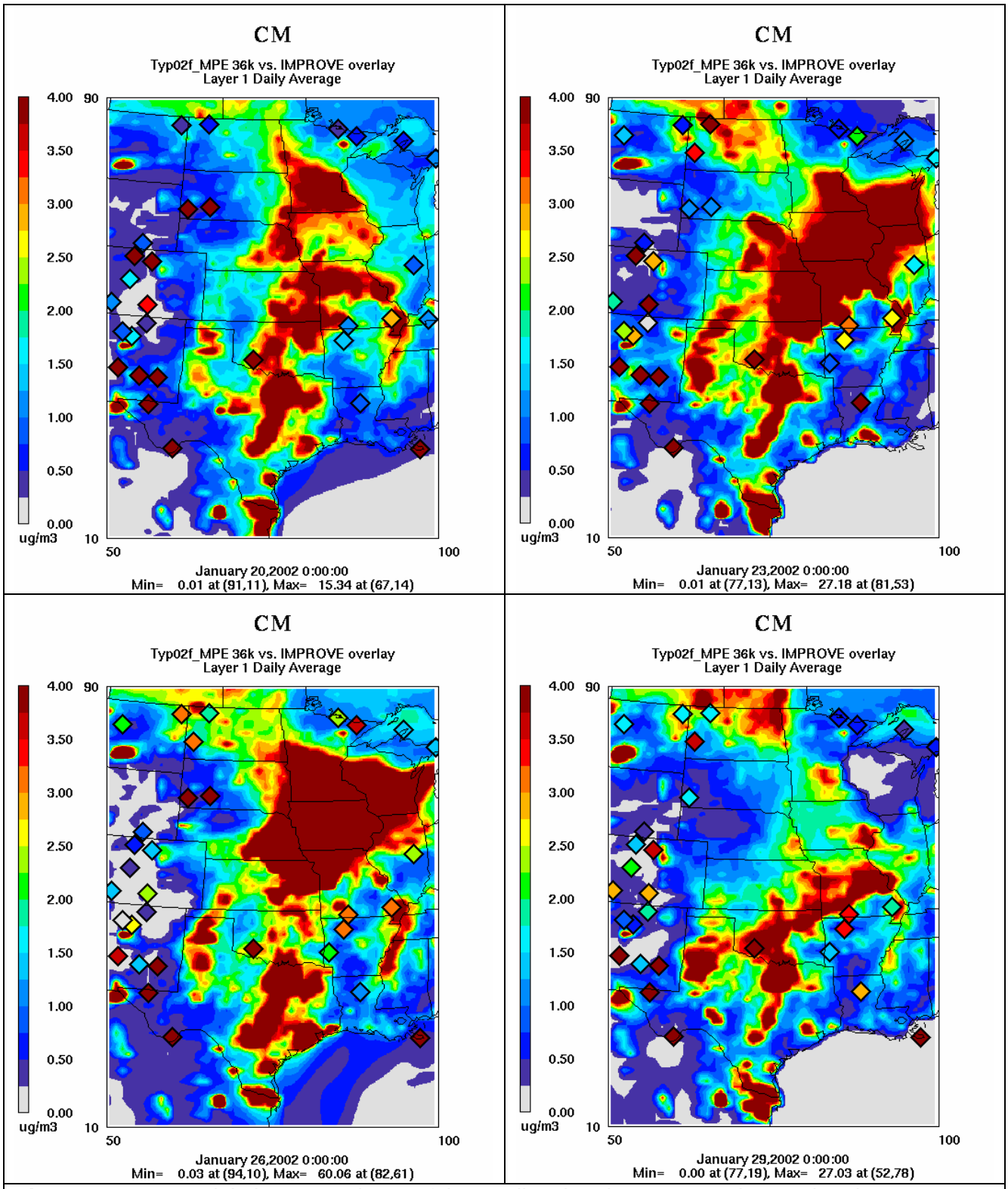


Figure C-34c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour CM concentrations for January 20, 23, 26 and 29, 2002.

C.3.6.2 CM in April 2002

The CM underestimation bias is even greater in April (-137%) and occurs at all IMPROVE sites (Figure C-35).

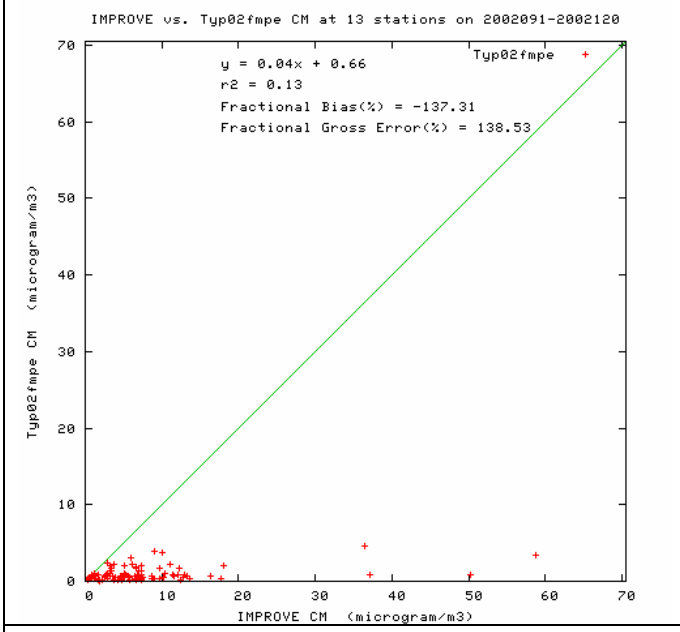
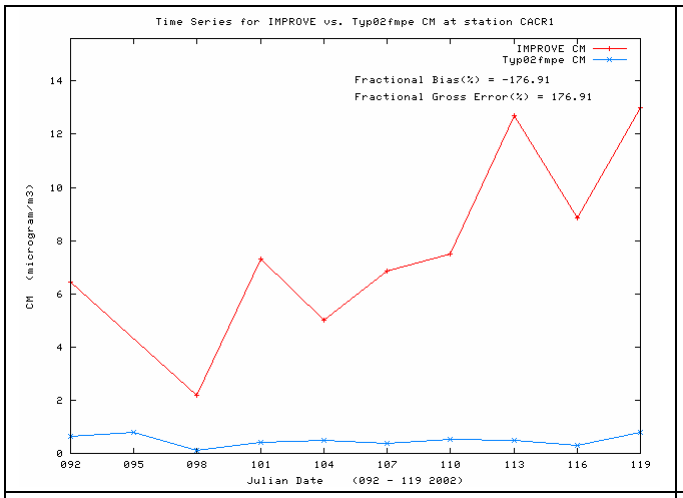
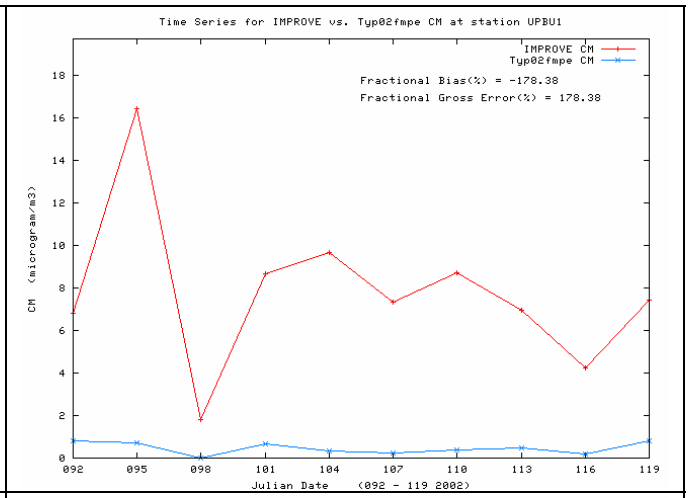
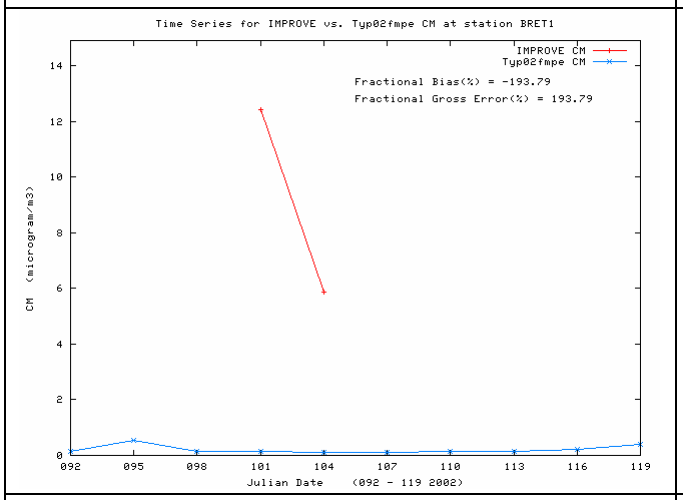
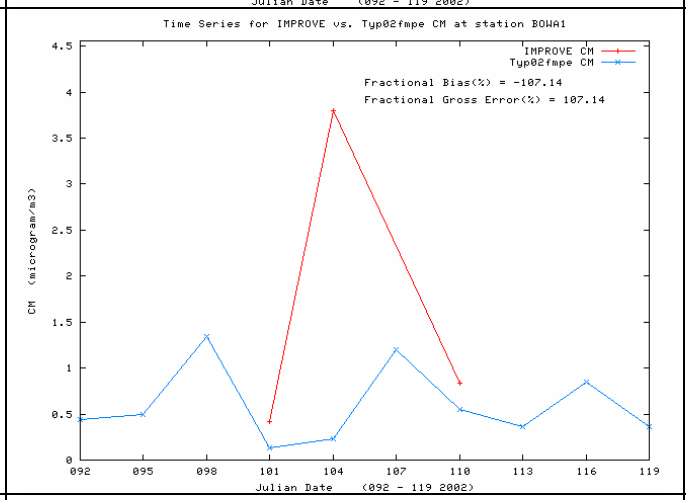


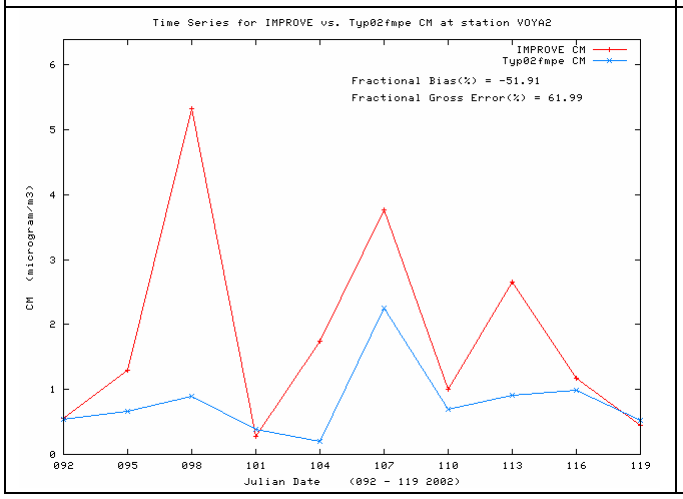
Figure C-35a. Scatter plots of predicted and observed coarse mass (CM) concentrations for April 2002 and sites in the CENRAP region using IMPROVE monitoring networks using the CMAQ 2002 36 km Base F base case simulation.

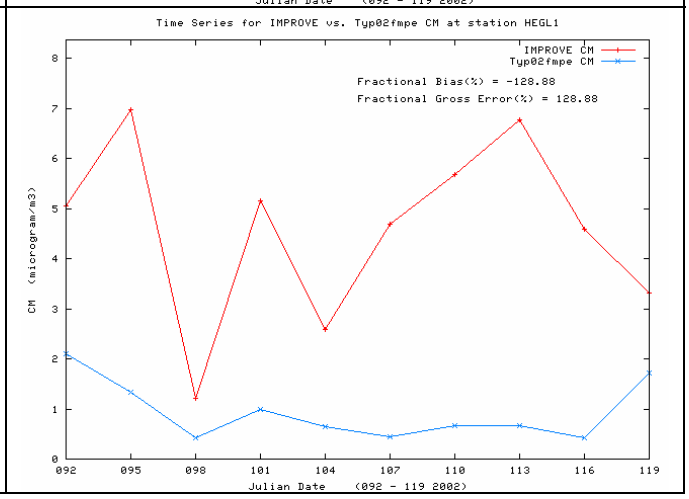

Time Series for IMPROVE vs. Typ02fmpe CM at station CACR1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -176.91
Fractional Gross Error(%) = 176.91
CM (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station UPBU1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -178.38
Fractional Gross Error(%) = 178.38
CM (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station BRET1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -193.79
Fractional Gross Error(%) = 193.79
CM (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station BOWA1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -107.14
Fractional Gross Error(%) = 107.14
CM (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station VOYA2
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -51.91
Fractional Gross Error(%) = 61.99
CM (microgram/m3)
Julian Date (092 - 119 2002)


Time Series for IMPROVE vs. Typ02fmpe CM at station HEGL1
IMPROVE CM
Typ02fmpe CM
Fractional Bias(%) = -128.88
Fractional Gross Error(%) = 128.88
CM (microgram/m3)
Julian Date (092 - 119 2002)

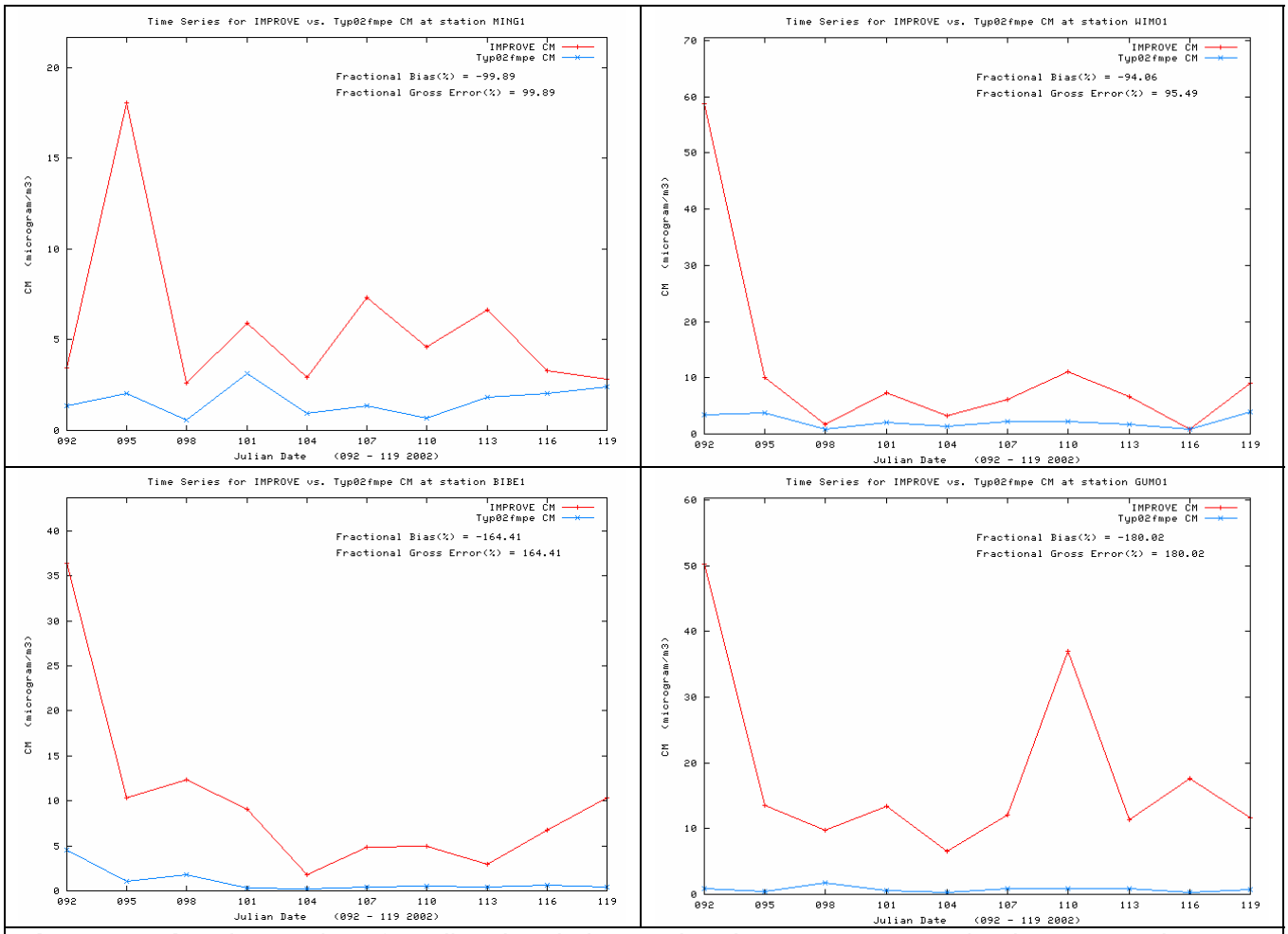


Figure C-35b. Time series of predicted and observed 24-hour coarse mass (CM) concentrations at CENRAP IMPROVE CLASS I AREA sites in April 2002 for CMAQ 2002 36 km Base F base case simulation.

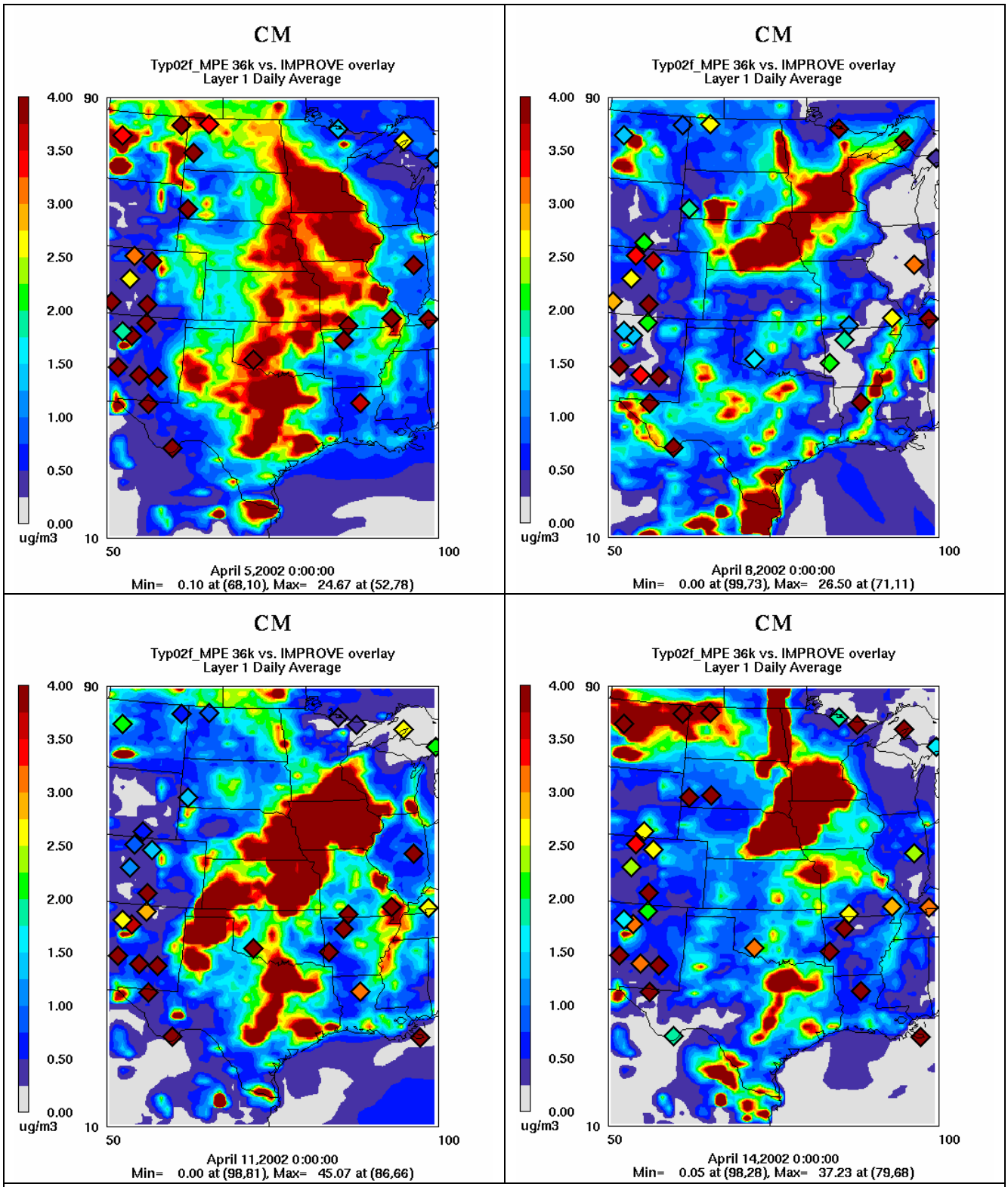


Figure C-35c. Spatial plot comparisons of the predicted and IMPROVE observed 24-hour CM concentrations for April 5, 8, 11 and 14, 2002.