

### Appendix 3. Model Performance Evaluation

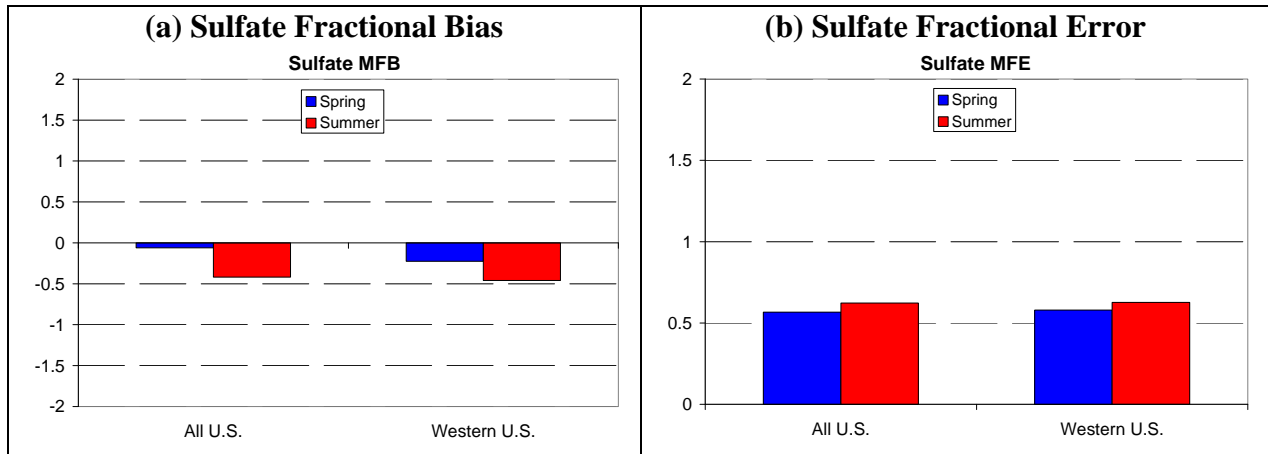


Figure 5.164. (a) Mean fractional bias and (b) mean fractional error for sulfate concentrations from the 36-km domain CAMx model predictions compared to observations from the IMPROVE network, using monitoring stations for the whole U.S. domain and monitoring stations that only fall within the western United States. Blue and red bars correspond to the spring and summer campaigns, respectively.

Table 5.21. Model performance statistics for sulfate concentrations during both the spring and summer RoMANS campaigns, using available IMPROVE monitoring stations for the entire 36-km U.S. domain and with sites that fall within the western United States alone.

Metric	Spring		Summer	
	36-km U.S. Domain	Western U.S.	36-km U.S. Domain	Western U.S.
Mean Observation ( $\mu\text{g}/\text{m}^3$ )	1.50	0.67	2.47	1.01
Mean Estimation ( $\mu\text{g}/\text{m}^3$ )	1.77	0.54	1.85	0.64
STD <sup>a</sup> Obs. ( $\mu\text{g}/\text{m}^3$ )	1.57	0.47	2.9	0.68
STD Est. ( $\mu\text{g}/\text{m}^3$ )	2.28	0.53	2.7	0.57
MFE <sup>b</sup> (%)	56.7%	58.0%	62.2%	62.7%
MFB <sup>c</sup> (%)	-6.0%	-22.5%	-41.8%	-46.0%

<sup>a</sup>Standard Deviation

<sup>b</sup>Mean Fractional Error (%)

<sup>c</sup>Mean Fractional Bias (%)

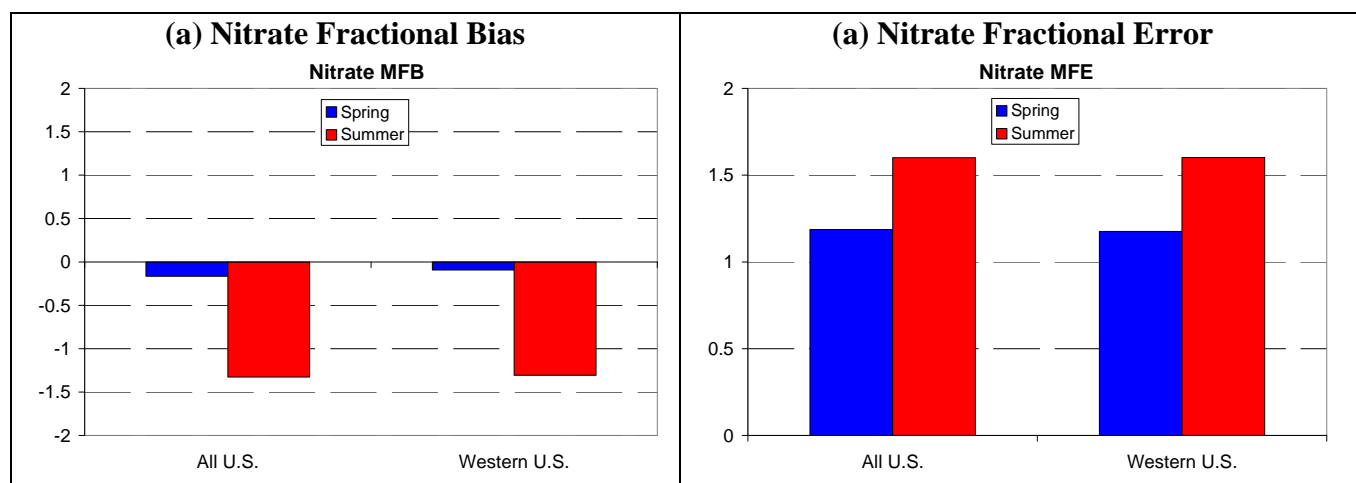


Figure 5.165. (a) Mean fractional bias and (b) mean fractional error for nitrate concentrations from the 36-km domain CAMx model predictions compared to observations from IMPROVE network, using monitoring stations for the whole U.S. domain and monitoring stations that only fall within the western United States. Blue and red bars correspond to the spring and summer campaigns, respectively.

Table 5.22. Model performance statistics for nitrate concentrations during both the spring and summer RoMANS campaigns, using available IMPROVE monitoring stations for the entire 36-km U.S. domain and with sites that fall within the western United States alone.

Metric	Spring		Summer	
	36-km U.S. Domain	Western U.S.	36-km U.S. Domain	Western U.S.
Mean Observation ( $\mu\text{g}/\text{m}^3$ )	0.45	0.27	0.21	0.19
Mean Estimation ( $\mu\text{g}/\text{m}^3$ )	0.67	0.47	0.10	0.10
STD <sup>a</sup> Obs. ( $\mu\text{g}/\text{m}^3$ )	0.70	0.47	0.27	0.28
STD Est. ( $\mu\text{g}/\text{m}^3$ )	1.04	0.75	0.33	0.35
MFE <sup>b</sup> (%)	118.7%	117.5%	160.1%	159.5%
MFB <sup>c</sup> (%)	-16.6%	-9.4%	-132.8%	-129.3%

<sup>a</sup>Standard Deviation

<sup>b</sup>Mean Fractional Error (%)

<sup>c</sup>Mean Fractional Bias (%)

**Table 5.23.** Spring campaign  $\text{NH}_4^+$  model performance statistics. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.104	0.254	0.085	0.272	0.844	-0.661
BRUS	Brush CO	0.398	0.579	0.401	0.743	0.664	-0.258
DINO	Dinosaur NM UT	0.111	0.279	0.109	0.161	1.012	-0.854
GOPA	Gore Pass CO	0.077	0.066	0.04	0.042	0.539	0.163
GRAN	Grant NE	0.398	0.802	0.496	0.623	0.895	-0.726
LYCR	Lyons Crest CO	0.346	0.463	0.434	0.474	0.853	-0.46
ROMO	Core Site	0.089	0.3	0.067	0.148	1.087	-1.087
SPRI	Springfield CO	0.146	0.434	0.164	0.463	1.049	-0.906
TICR	Timber Creek	0.089	0.306	0.046	0.237	0.961	-0.914

**Table 5.24.** Summer campaign  $\text{NH}_4^+$  model performance statistics. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	Alpine Visitor Cent.	0.138	0.321	0.054	0.093	0.782	-0.782
BEME	Beaver Meadows	0.171	0.324	0.07	0.157	0.59	-0.573
BRUS	Brush CO	0.301	0.568	0.096	0.239	0.64	-0.552
GOPA	Gore Pass CO	0.151	0.239	0.059	0.078	0.474	-0.449
LYCR	Lyons Crest CO	0.253	0.39	0.083	0.216	0.512	-0.33
ROMO	Core Site	0.165	0.31	0.068	0.153	0.649	-0.524
TICR	Timber Creek	0.154	0.216	0.064	0.093	0.536	-0.287

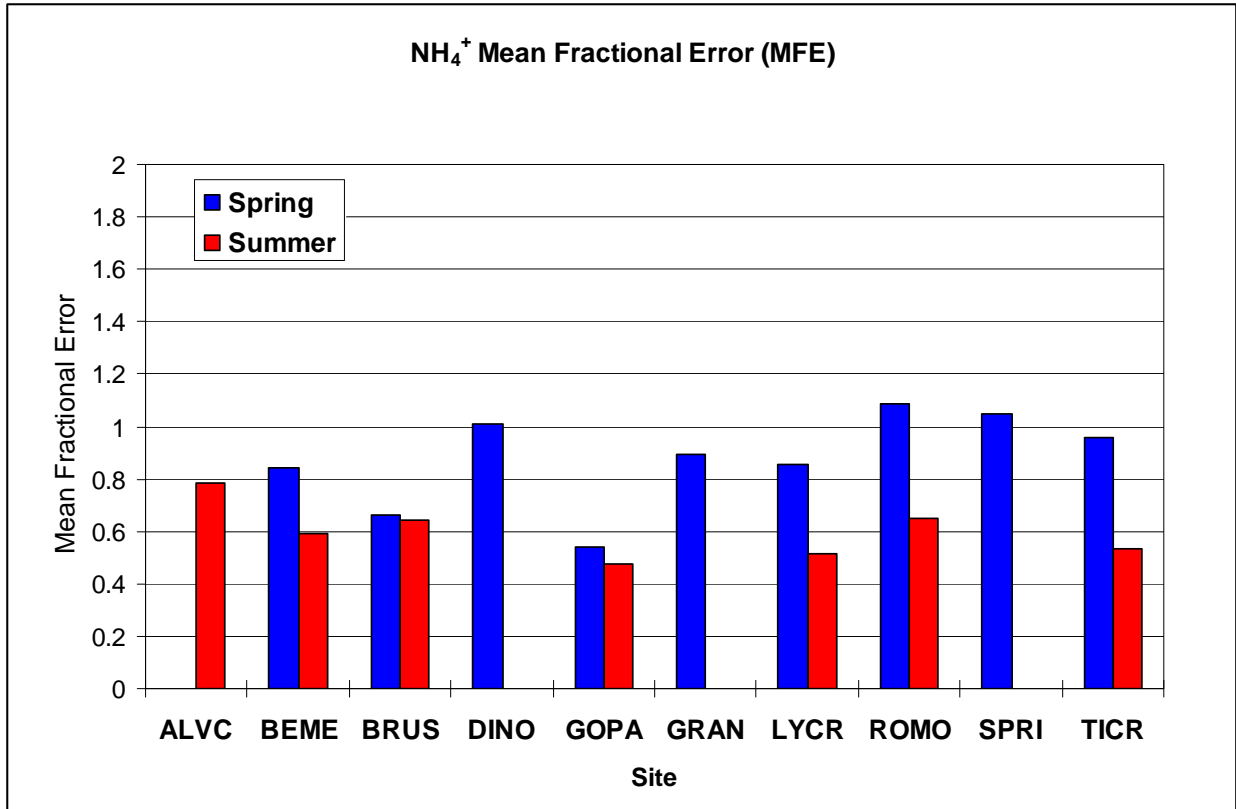


Figure 5.174. NH<sub>4</sub><sup>+</sup> mean fractional error (MFE) as a function of site for spring and summer.

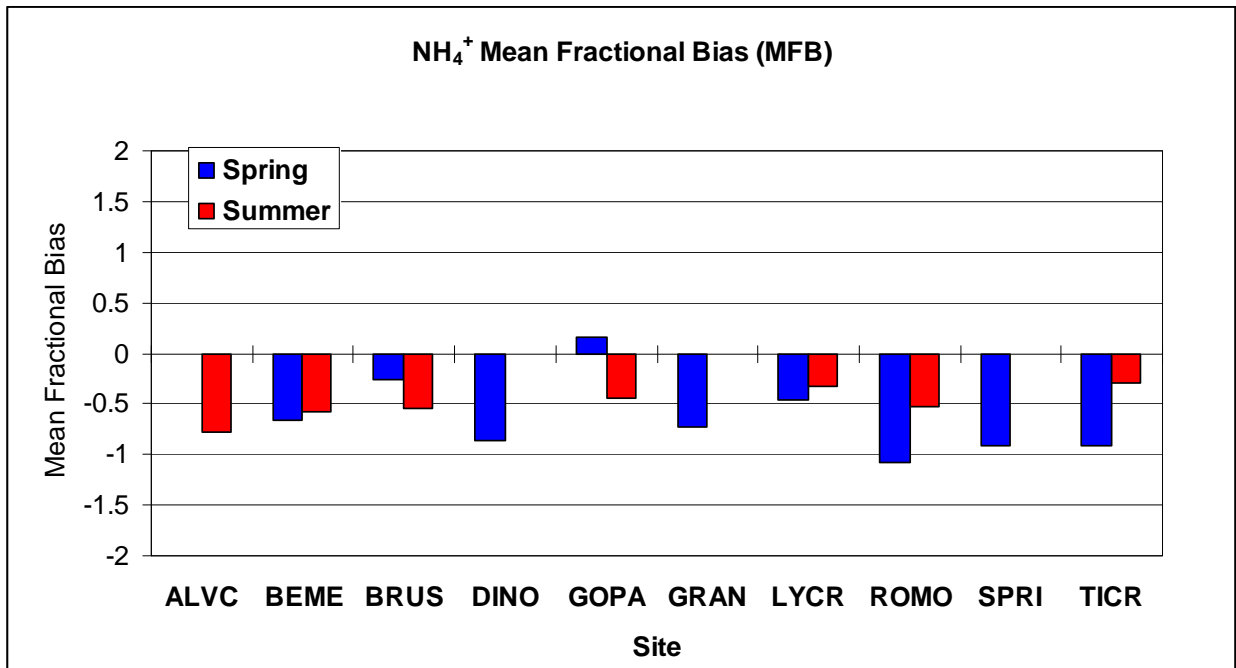


Figure 5.175. NH<sub>4</sub><sup>+</sup> mean fractional bias (MFB) as a function of site for spring and summer.

**Table 5.25.** Spring campaign NO<sub>3</sub><sup>-</sup> model performance statistics. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME, μg m<sup>-3</sup>), study mean

of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.091	0.36	0.153	0.457	1.39	-1.286
BRUS	Brush CO	0.651	0.524	1.199	0.349	1.11	-0.619
DINO	Dinosaur NM UT	0.168	0.218	0.322	0.145	1.374	-1.02
GOPA	Gore Pass CO	0.041	0.195	0.056	0.099	1.39	-1.323
GRAN	Grant NE	0.623	0.848	1.293	0.833	1.078	-0.848
LYCR	Lyons Crest CO	0.721	0.626	1.15	0.654	1.176	-0.65
ROMO	Core Site	0.076	0.32	0.105	0.353	1.342	-1.231
SPRI	Springfield CO	0.069	0.43	0.139	0.986	1.478	-1.447
TICR	Timber Creek	0.063	0.113	0.068	0.048	0.971	-0.782

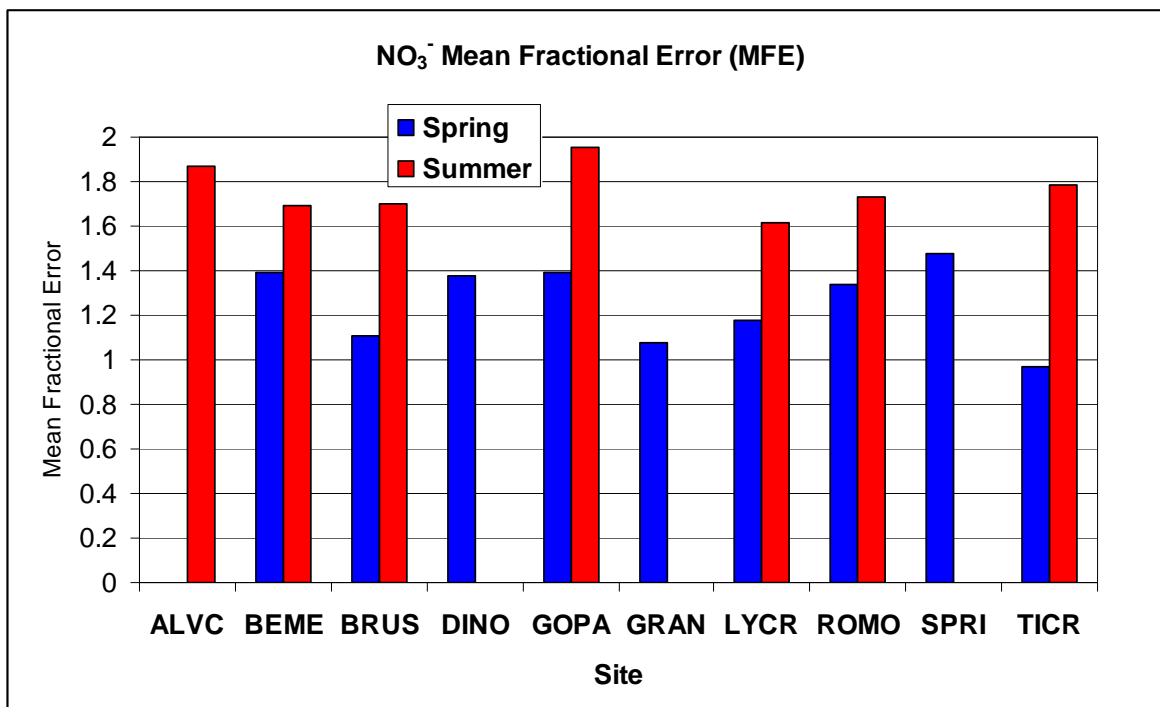


Figure 5.176. NO<sub>3</sub><sup>-</sup> mean fractional error (MFE) as a function of site location for spring and summer

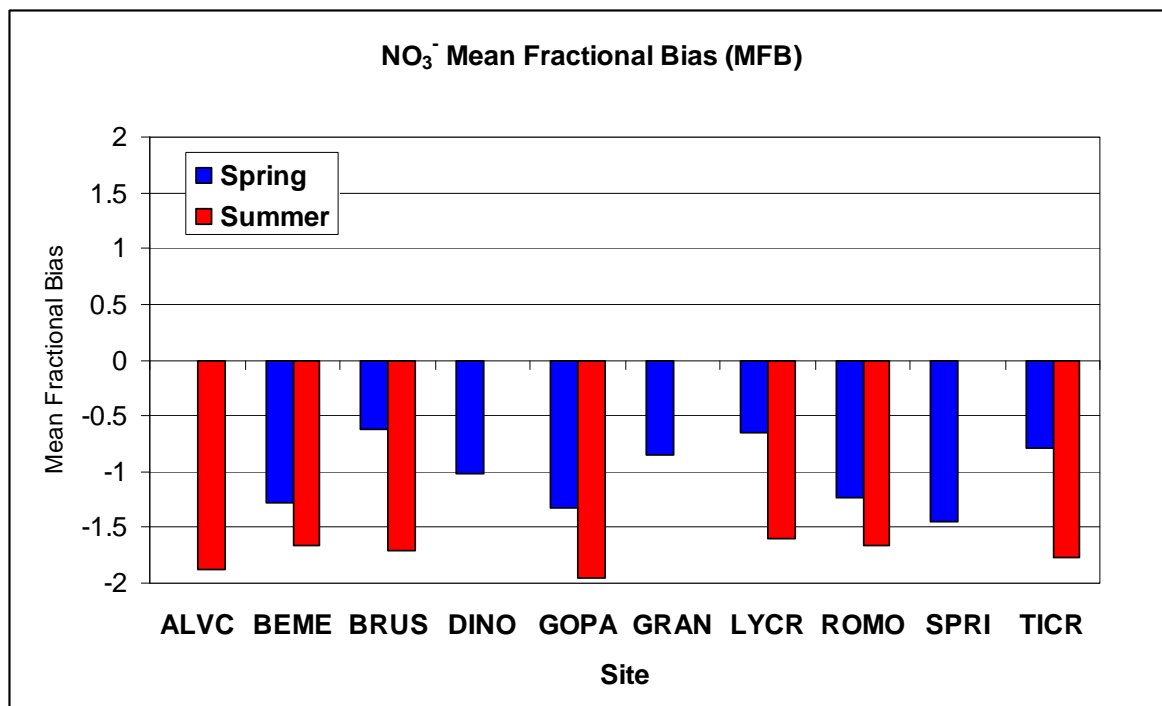


Figure 5.177. NO<sub>3</sub><sup>-</sup> mean fractional bias (MFB) as a function of site location for spring and summer.

**Table 5.26.** Summer campaign NO<sub>3</sub><sup>-</sup> model performance statistics. See text for description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME, µg m<sup>-3</sup>), study mean of the observed concentrations (MO, µg m<sup>-3</sup>), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively, µg m<sup>-3</sup>), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME (µg m <sup>-3</sup> )	MO (µg m <sup>-3</sup> )	SDE (µg m <sup>-3</sup> )	SDO (µg m <sup>-3</sup> )	MFE	MFB
ALVC	AlpineVisitorCent.	0.006	0.197	0.009	0.165	1.873	-1.873
BEME	Beaver Meadows	0.011	0.128	0.024	0.096	1.692	-1.664
BRUS	Brush CO	0.031	0.368	0.049	0.227	1.702	-1.702
GOPA	Gore Pass CO	0.001	0.093	0.002	0.032	1.955	-1.955
LYCR	Lyons Crest CO	0.026	0.27	0.048	0.275	1.612	-1.609
ROMO	Core Site	0.012	0.148	0.027	0.136	1.732	-1.667
TICR	Timber Creek	0.004	0.082	0.006	0.055	1.788	-1.763

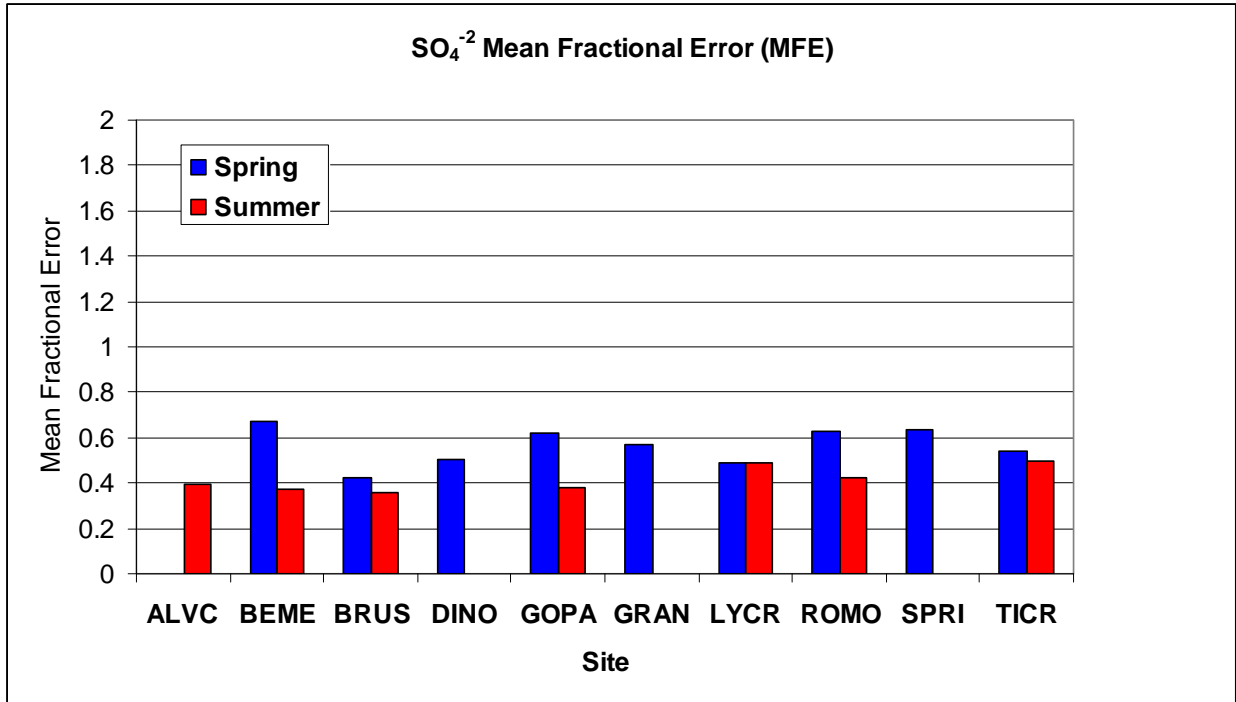


Figure 5.178. Spring and summer SO<sub>4</sub><sup>-2</sup> mean fractional error (MFE) as a function of site location.

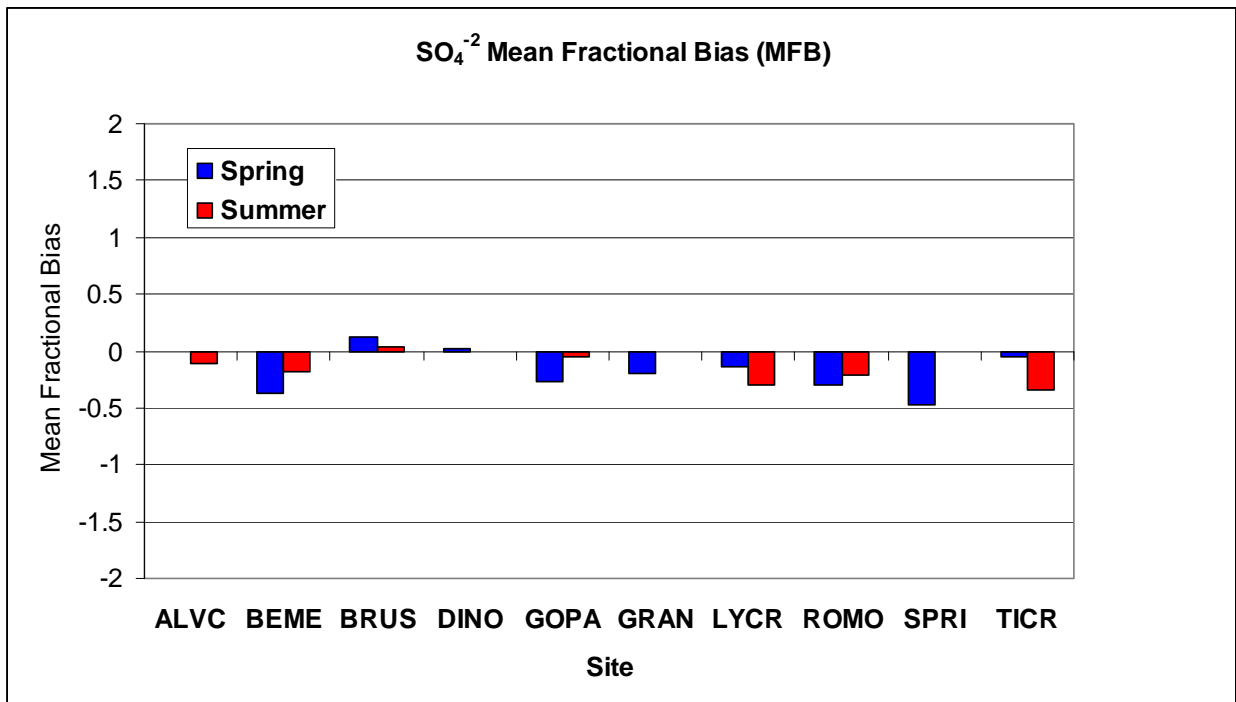


Figure 5.179. Spring and summer SO<sub>4</sub><sup>-2</sup> mean fractional bias (MFB) as a function of site location.

**Table 5.27.** Spring campaign SO<sub>4</sub><sup>-2</sup> model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the

estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.379	0.583	0.204	0.369	0.668	-0.365
BRUS	Brush CO	0.758	0.695	0.336	0.355	0.42	0.118
DINO	Dinosaur NM UT	0.379	0.423	0.167	0.308	0.502	0.028
GOPA	Gore Pass CO	0.371	0.504	0.185	0.258	0.623	-0.265
GRAN	Grant NE	0.88	0.99	0.647	0.498	0.567	-0.191
LYCR	Lyons Crest CO	0.552	0.634	0.421	0.423	0.49	-0.132
ROMO	Core Site	0.347	0.484	0.174	0.262	0.625	-0.298
SPRI	Springfield CO	0.487	0.769	0.412	0.478	0.633	-0.478
TICR	Timber Creek	0.365	0.375	0.196	0.177	0.537	-0.057

**Table 5.28.** Summer campaign  $\text{SO}_4^{-2}$  model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	Alpine Visitor Cent.	0.498	0.512	0.294	0.108	0.395	-0.116
BEME	Beaver Meadows	0.515	0.617	0.208	0.331	0.37	-0.185
BRUS	Brush CO	0.864	0.824	0.275	0.253	0.356	0.039
GOPA	Gore Pass CO	0.471	0.493	0.188	0.169	0.382	-0.048
LYCR	Lyons Crest CO	0.703	1.009	0.219	0.423	0.486	-0.3
ROMO	Core Site	0.51	0.621	0.227	0.189	0.424	-0.218
TICR	Timber Creek	0.482	0.694	0.228	0.254	0.5	-0.342



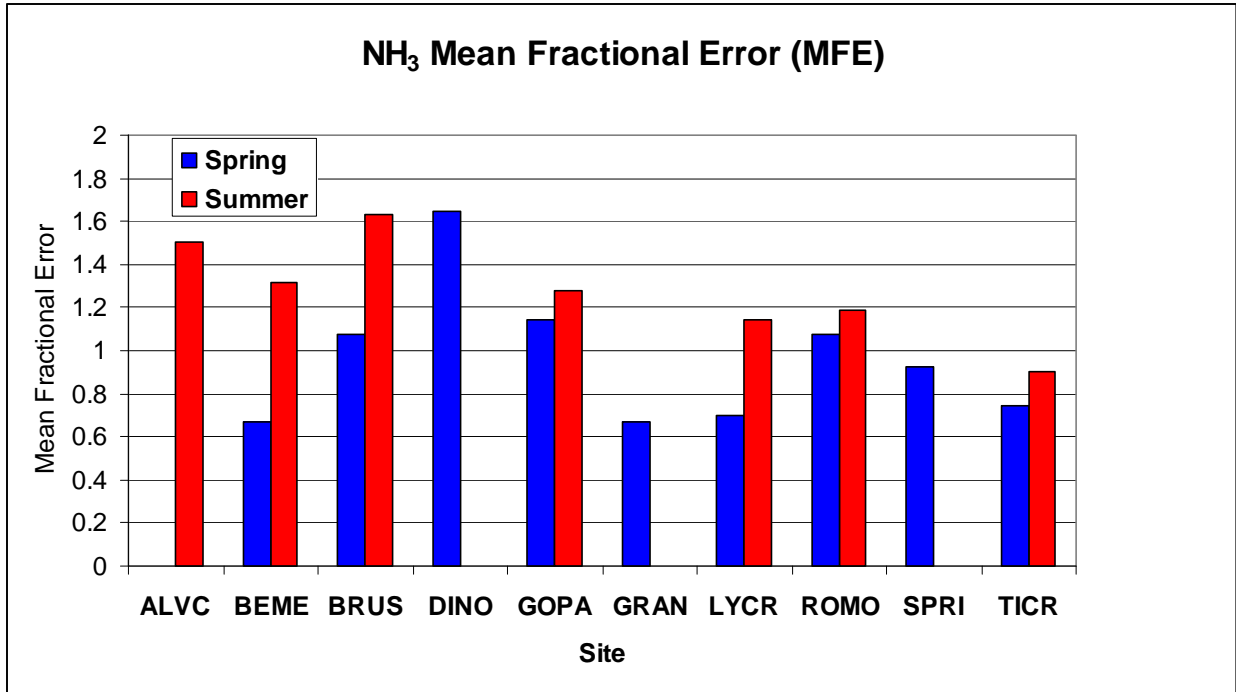


Figure 5.180. Spring and summer campaign NH<sub>3</sub> mean fractional error (MFE) as a function of site location.

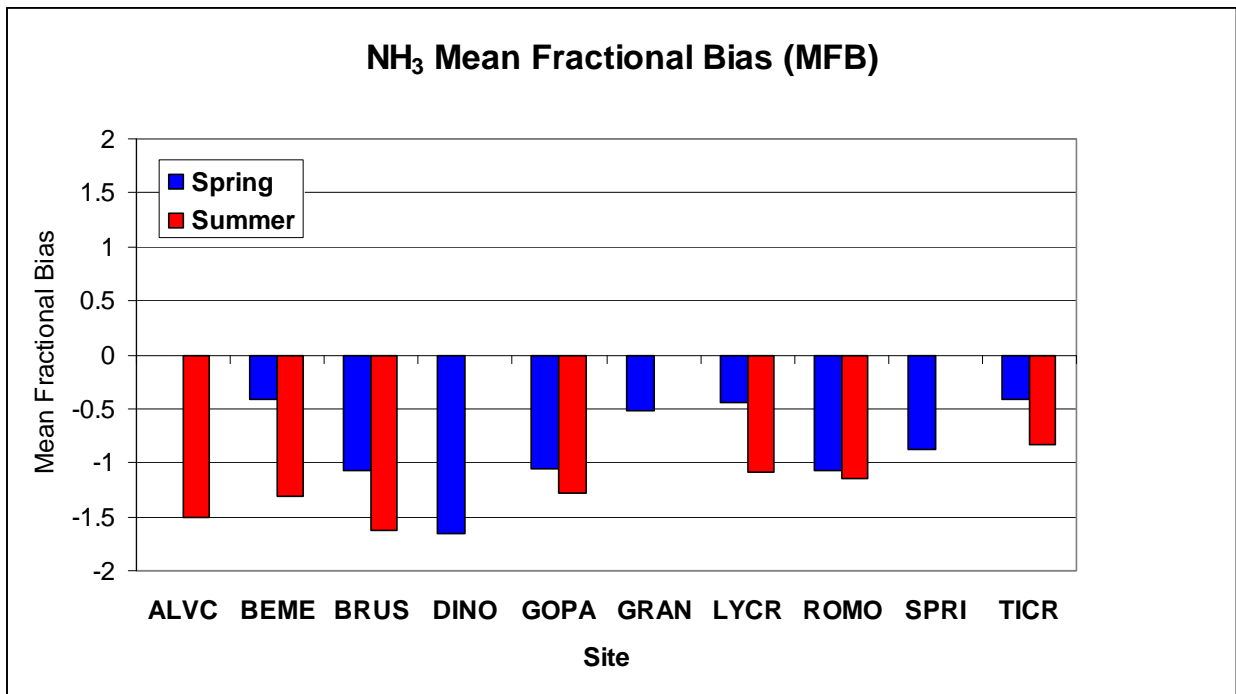


Figure 5.181. Spring and summer campaign NH<sub>3</sub> mean fractional bias (MFB) as a function of site location.

**Table 5.29.** Spring campaign NH<sub>3</sub> model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.082	0.152	0.045	0.163	0.67	-0.413
BRUS	Brush CO	1.4	5.527	0.971	4.473	1.072	-1.072
DINO	Dinosaur NM UT	0.163	1.867	0.069	0.831	1.648	-1.648
GOPA	Gore Pass	0.042	0.15	0.029	0.063	1.144	-1.052
GRAN	Grant NE	1.861	3.404	1.143	1.982	0.668	-0.514
LYCR	Lyons Crest CO	0.533	1.12	0.284	0.878	0.696	-0.447
ROMO	Core Site	0.059	0.189	0.034	0.063	1.076	-1.076
SPRI	Springfield CO	0.25	0.682	0.175	0.36	0.924	-0.874
TICR	Timber Creek	0.047	0.057	0.038	0.023	0.745	-0.416

**Table 5.30.** Summer campaign NH<sub>3</sub> model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	AlpineVisitorCent.	0.046	0.442	0.036	0.244	1.505	-1.505
BEME	Beaver Meadows	0.084	0.505	0.035	0.305	1.317	-1.317
BRUS	Brush CO	0.737	8.151	0.322	3.685	1.631	-1.631
GOPA	Gore Pass CO	0.073	0.319	0.055	0.093	1.275	-1.275
LYCR	Lyons Crest CO	0.59	2.442	0.235	1.244	1.14	-1.079
ROMO	Core Site	0.088	0.401	0.063	0.28	1.188	-1.15
TICR	Timber Creek	0.097	0.204	0.088	0.068	0.903	-0.83

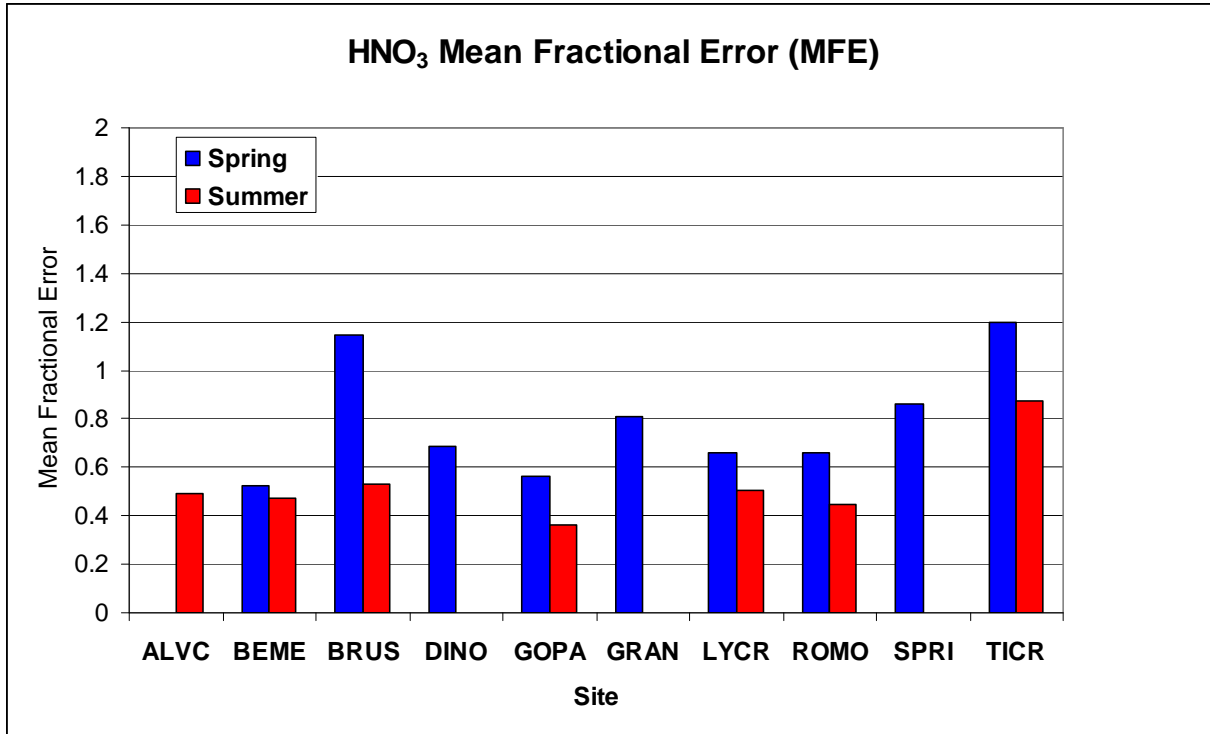


Figure 5.182. Spring and summer campaign HNO<sub>3</sub> mean fractional error (MFE) as a function of site location.

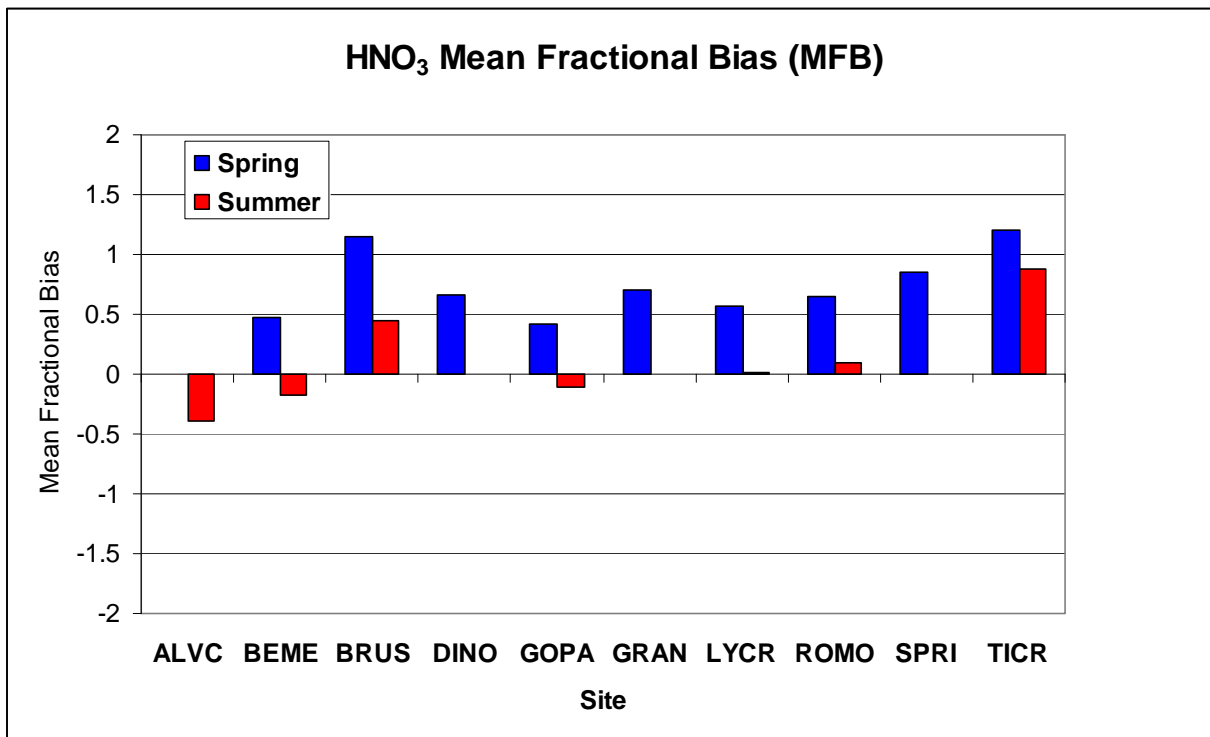


Figure 5.183. Spring and summer campaign HNO<sub>3</sub> mean fractional bias (MFB) as a function of site location.

**Table 5.31.** Spring campaign HNO<sub>3</sub> model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.43	0.271	0.196	0.151	0.527	0.471
BRUS	Brush CO	1.261	0.301	0.779	0.156	1.144	1.144
DINO	Dinosaur NM UT	0.685	0.335	0.332	0.157	0.687	0.657
GOPA	Gore Pass	0.357	0.235	0.173	0.123	0.562	0.423
GRAN	Grant NE	0.79	0.356	0.452	0.303	0.811	0.704
LYCR	Lyons Crest CO	1.119	0.582	0.696	0.34	0.663	0.572
ROMO	Core Site	0.457	0.244	0.201	0.139	0.663	0.643
SPRI	Springfield CO	0.582	0.221	0.29	0.109	0.858	0.848
TICR	Timber Creek	0.367	0.089	0.157	0.051	1.198	1.198

**Table 5.32.** Summer campaign HNO<sub>3</sub> model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	Alpine Visitor Cent.	0.395	0.554	0.191	0.123	0.491	-0.392
BEME	Beaver Meadows	0.519	0.612	0.274	0.281	0.471	-0.171
BRUS	Brush CO	1.242	0.788	0.41	0.33	0.533	0.446
GOPA	Gore Pass CO	0.461	0.474	0.297	0.195	0.363	-0.106
LYCR	Lyons Crest CO	1.455	1.613	0.651	1.079	0.506	0.017
ROMO	Core Site	0.671	0.565	0.44	0.273	0.445	0.101
TICR	Timber Creek	0.577	0.182	0.383	0.068	0.874	0.874

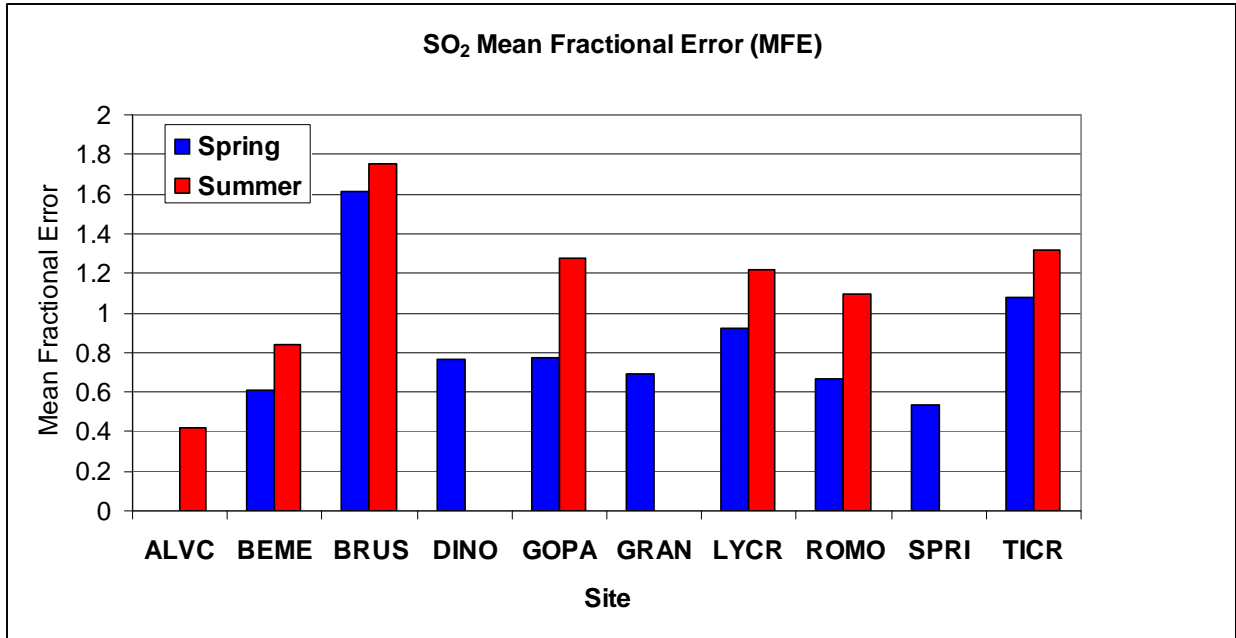


Figure 5.184. Spring and summer campaign SO<sub>2</sub> mean fractional error (MFE) as a function of site location.

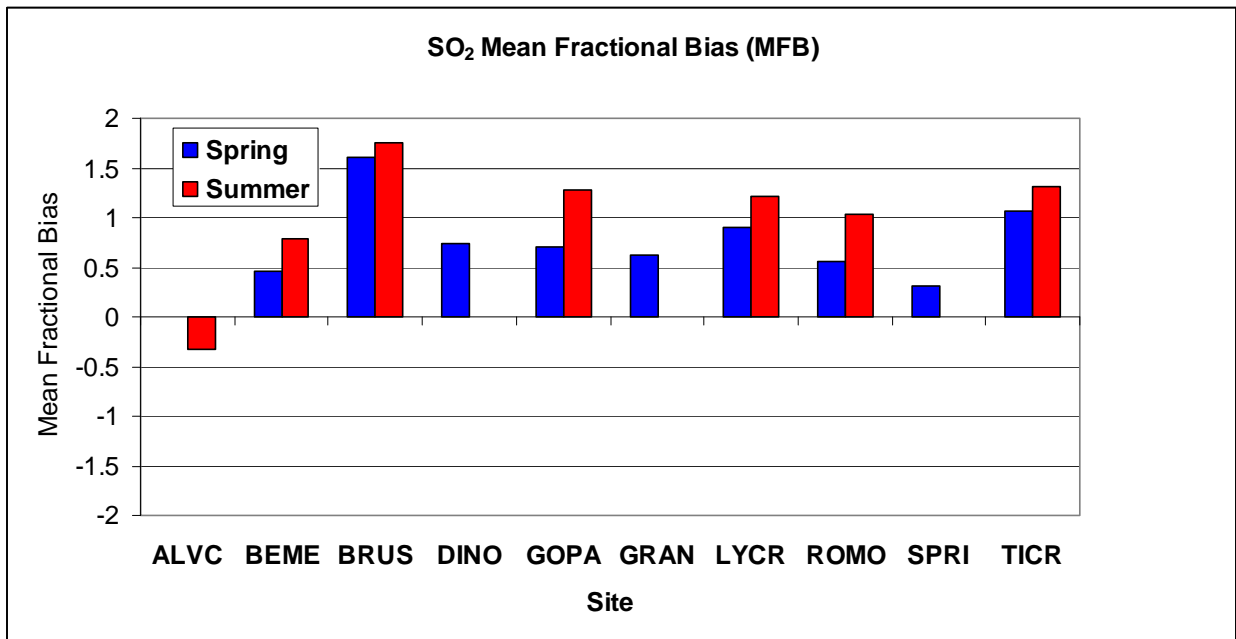


Figure 5.185. Spring and summer campaign SO<sub>2</sub> mean fractional bias (MFB) as a function of site location.

**Table 5.33.** Spring campaign SO<sub>2</sub> model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO,

respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.304	0.196	0.2	0.152	0.611	0.467
BRUS	Brush CO	7.165	0.751	4.225	0.744	1.611	1.611
DINO	Dinosaur NM UT	0.362	0.172	0.196	0.116	0.765	0.734
GOPA	Gore Pass	0.36	0.135	0.316	0.089	0.775	0.702
GRAN	Grant NE	0.649	0.331	0.532	0.23	0.692	0.63
LYCR	Lyons Crest CO	1.415	0.535	1.073	0.425	0.922	0.904
ROMO	Core Site	0.295	0.184	0.217	0.18	0.667	0.565
SPRI	Springfield CO	0.319	0.23	0.192	0.17	0.537	0.31
TICR	Timber Creek	0.216	0.061	0.11	0.039	1.075	1.059

**Table 5.34.** Summer campaign  $\text{SO}_2$  model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	Alpine Visitor Cent.	0.296	0.421	0.114	0.153	0.421	-0.334
BEME	Beaver Meadows	0.421	0.178	0.278	0.132	0.84	0.783
BRUS	Brush CO	9.045	0.598	3.422	0.616	1.749	1.749
GOPA	Gore Pass CO	0.513	0.111	0.383	0.095	1.276	1.276
LYCR	Lyons Crest CO	1.347	0.347	0.63	0.286	1.22	1.207
ROMO	Core Site	0.513	0.154	0.416	0.127	1.095	1.025
TICR	Timber Creek	0.44	0.075	0.323	0.049	1.315	1.315

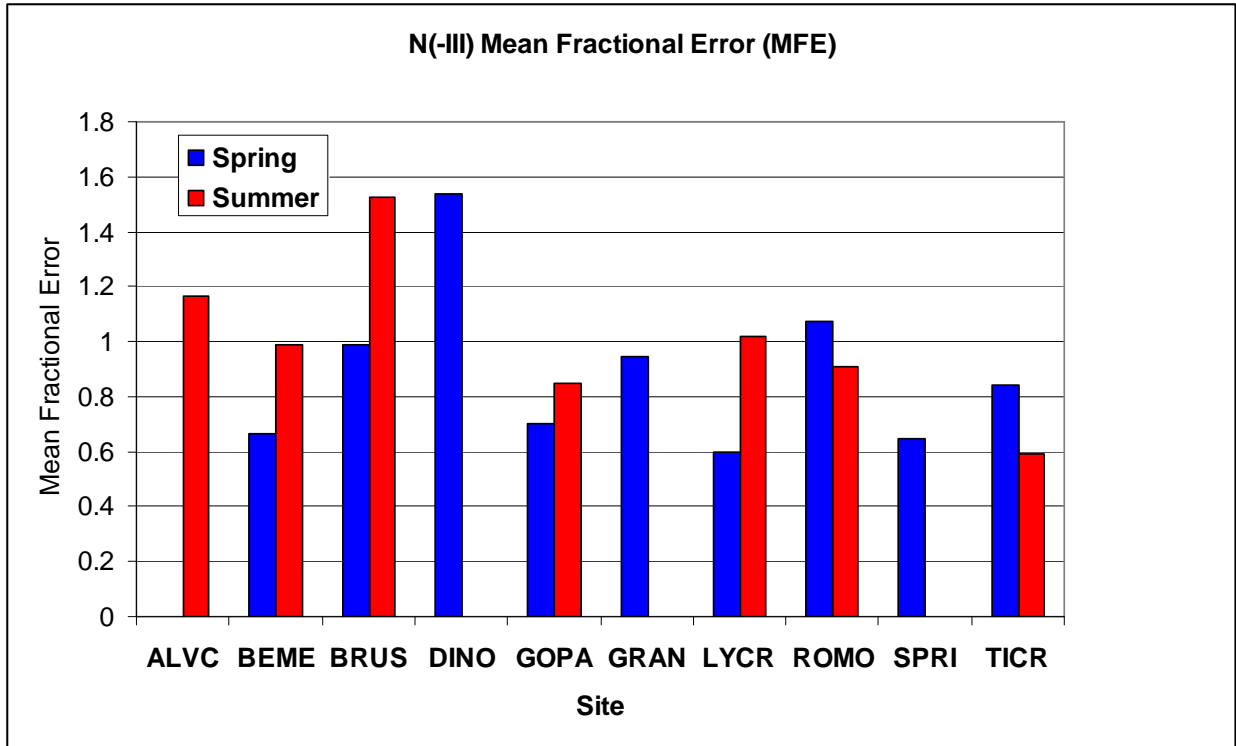


Figure 5.186. Spring and summer campaign N(-III) mean fractional error (MFE) as a function of site location.

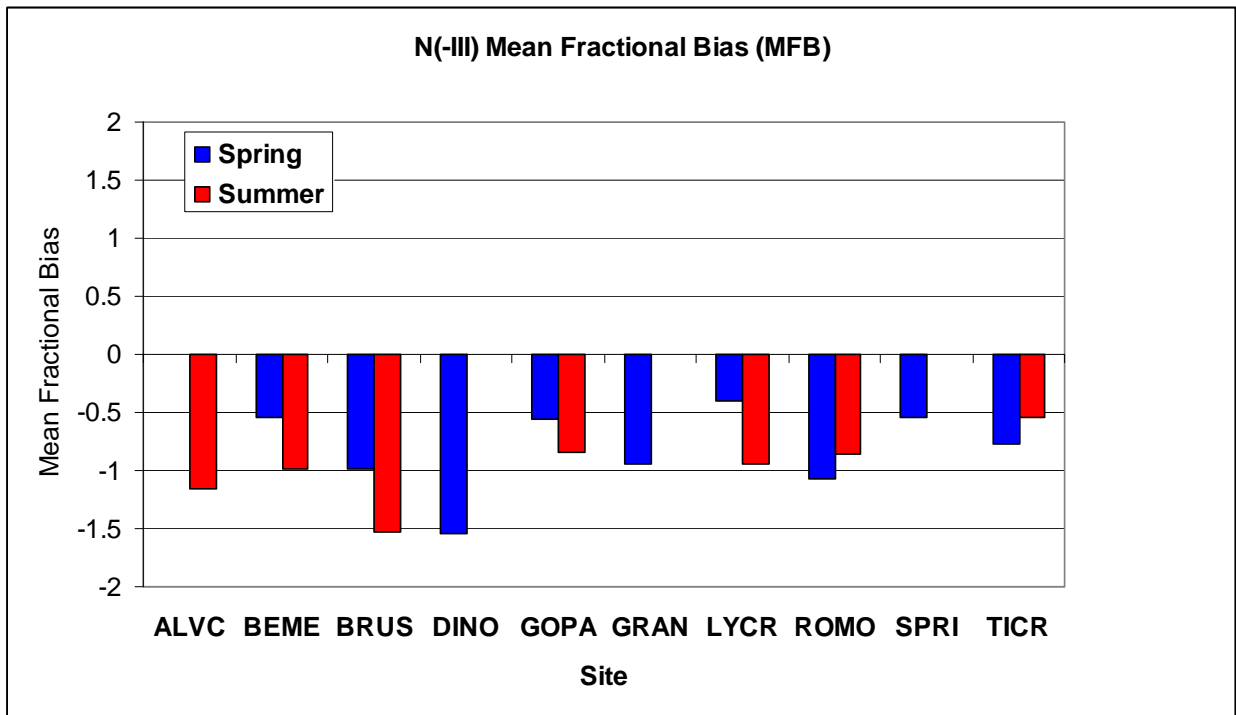


Figure 5.187. Spring and summer campaign N(-III) mean fractional bias (MFB) as a function of site location.

**Table 5.35.** Spring campaign N(-III) model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.186	0.407	0.106	0.381	0.663	-0.549
BRUS	Brush CO	1.798	6.105	1.193	4.582	0.991	-0.988
DINO	Dinosaur NM UT	0.278	2.178	0.146	0.828	1.54	-1.54
GOPA	Gore Pass	0.118	0.222	0.042	0.086	0.703	-0.551
GRAN	Grant NE	0.392	1.143	0.239	0.639	0.946	-0.942
LYCR	Lyons Crest CO	0.887	1.576	0.561	1.2	0.597	-0.395
ROMO	Core Site	0.149	0.491	0.075	0.194	1.076	-1.076
SPRI	Springfield CO	2.259	4.205	1.21	2.127	0.648	-0.538
TICR	Timber Creek	0.136	0.367	0.055	0.246	0.84	-0.778

**Table 5.36.** Summer campaign N(-III) model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	AlpineVisitorCent.	0.184	0.763	0.067	0.284	1.164	-1.164
BEME	Beaver Meadows	0.255	0.829	0.081	0.377	0.987	-0.987
BRUS	Brush CO	1.038	8.719	0.32	3.82	1.527	-1.527
GOPA	Gore Pass CO	0.224	0.558	0.082	0.149	0.848	-0.848
LYCR	Lyons Crest CO	0.846	2.833	0.281	1.412	1.019	-0.949
ROMO	Core Site	0.253	0.711	0.104	0.373	0.91	-0.854
TICR	Timber Creek	0.246	0.416	0.113	0.12	0.591	-0.541



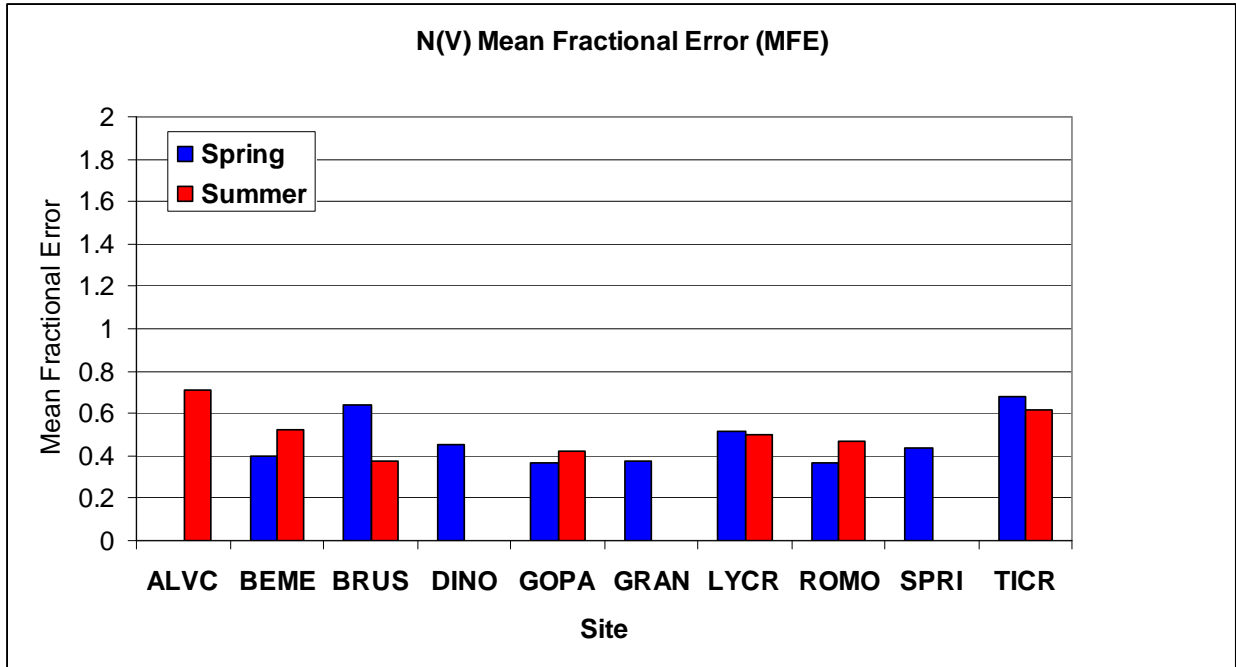


Figure 5.188. Spring and summer campaign N(V) mean fractional error (MFE) as a function of site location.

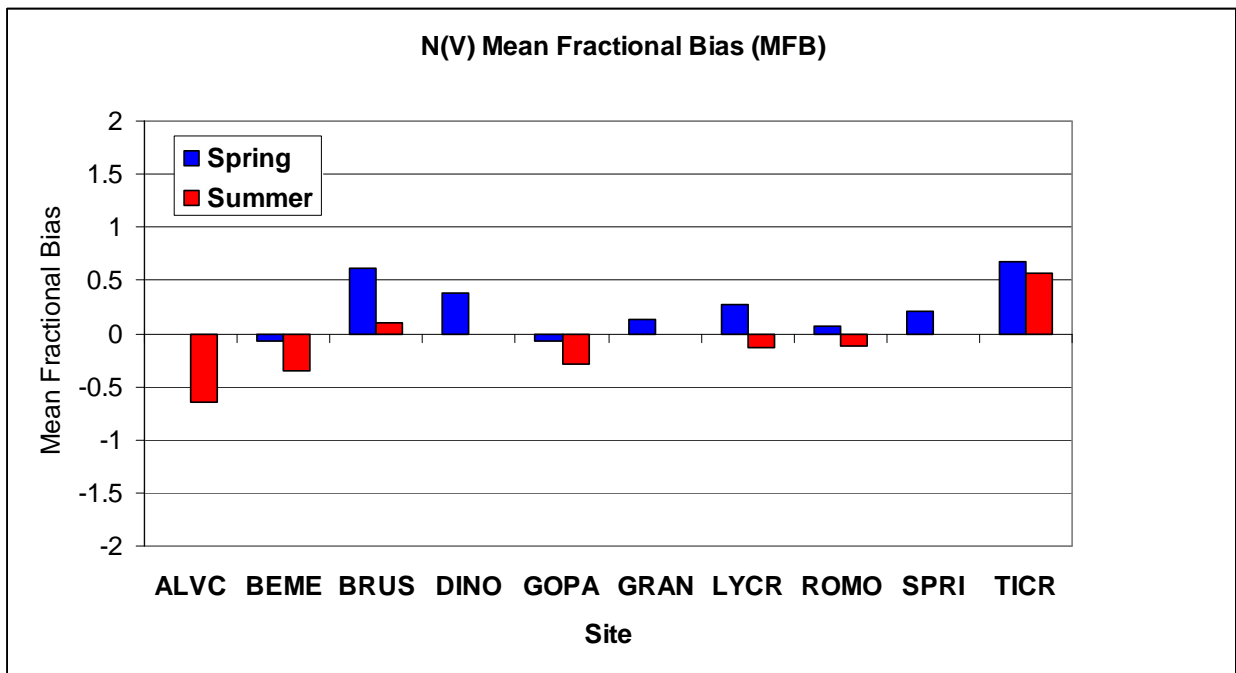


Figure 5.189. Spring and summer campaign N(V) mean fractional bias (MFB) as a function of site location.

**Table 5.37.** Spring campaign N(V) model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO,

respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
BEME	Beaver Meadows	0.54	0.646	0.283	0.366	0.397	-0.064
BRUS	Brush CO	1.911	0.825	1.593	0.42	0.638	0.609
DINO	Dinosaur NM UT	0.858	0.556	0.441	0.24	0.451	0.375
GOPA	Gore Pass	0.405	0.438	0.18	0.183	0.366	-0.07
GRAN	Grant NE	1.413	1.204	1.245	0.843	0.377	0.137
LYCR	Lyons Crest CO	1.867	1.221	1.619	0.744	0.516	0.28
ROMO	Core Site	0.533	0.563	0.265	0.261	0.369	0.076
SPRI	Springfield CO	0.652	0.653	0.367	0.98	0.436	0.213
TICR	Timber Creek	0.432	0.204	0.165	0.078	0.683	0.678

**Table 5.38.** Summer campaign N(V) model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME,  $\mu\text{g m}^{-3}$ ), study mean of the observed concentrations (MO,  $\mu\text{g m}^{-3}$ ), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	Alpine Visitor Cent.	0.4	0.751	0.192	0.193	0.711	-0.644
BEME	Beaver Meadows	0.531	0.74	0.282	0.308	0.526	-0.349
BRUS	Brush CO	1.273	1.157	0.432	0.419	0.372	0.096
GOPA	Gore Pass CO	0.462	0.568	0.298	0.208	0.423	-0.293
LYCR	Lyons Crest CO	1.483	1.887	0.664	1.155	0.498	-0.13
ROMO	Core Site	0.683	0.713	0.445	0.33	0.47	-0.11
TICR	Timber Creek	0.581	0.267	0.384	0.101	0.617	0.568

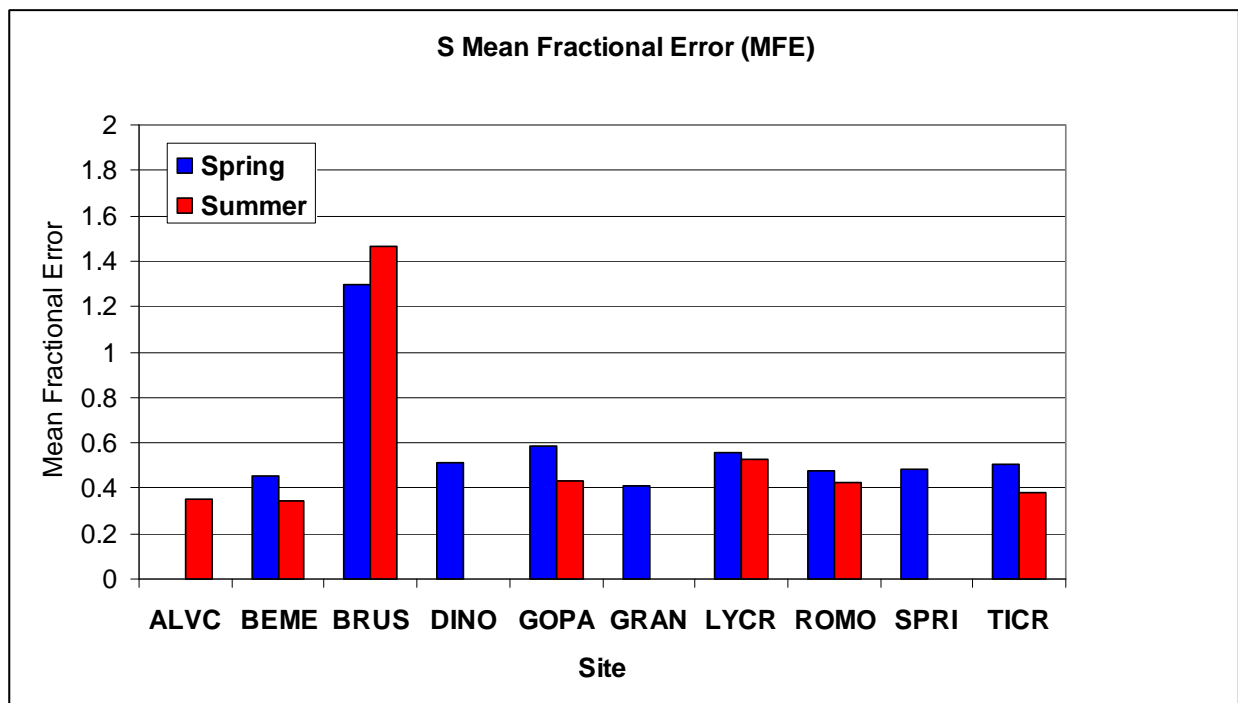


Figure 5.190. Spring and summer campaign S (=SO<sub>2</sub>+SO<sub>4</sub><sup>-2</sup>) mean fractional error (MFE) as a function of site location.

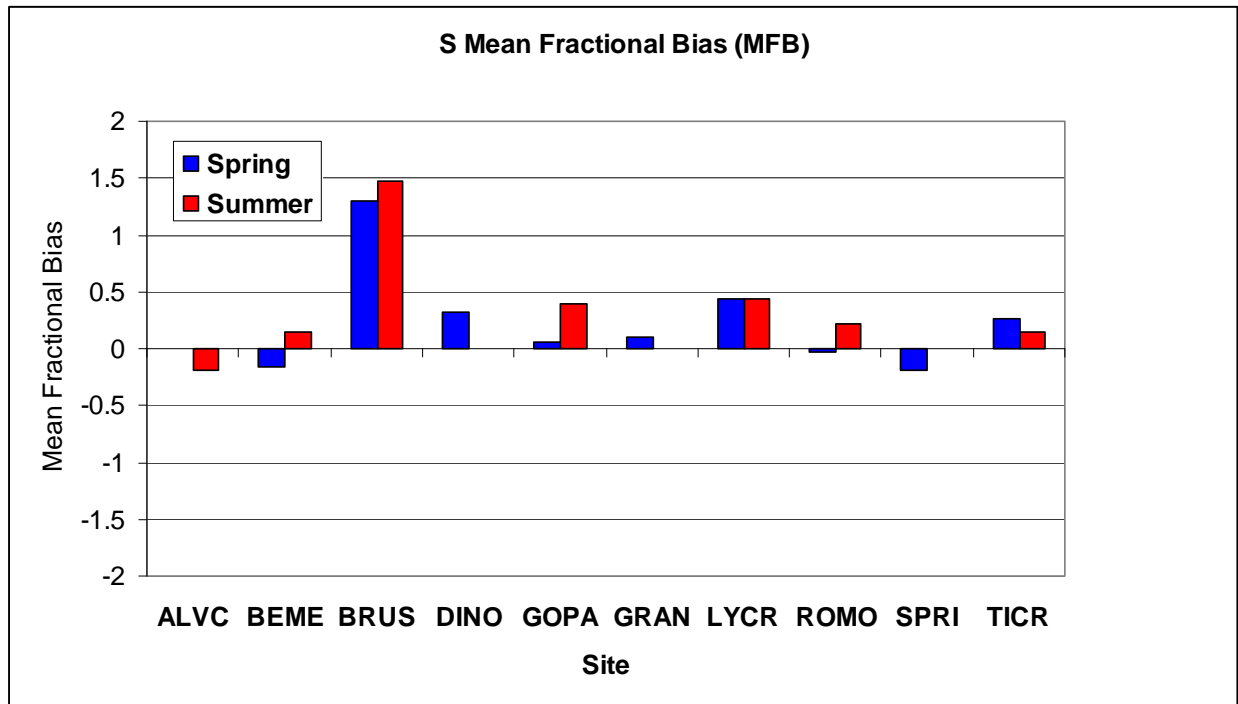


Figure 5.191. Spring and summer campaign S (=SO<sub>2</sub>+SO<sub>4</sub><sup>-2</sup>) mean fractional bias (MFB) as a function of site location.

**Table 5.39.** Spring campaign S model performance statistics. See text for a description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME, µg m<sup>-3</sup>), study mean of the observed concentrations (MO, µg m<sup>-3</sup>), standard deviation of the estimated and observed mean concentration (SDE and SDO, respectively, µg m<sup>-3</sup>), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME (µg m <sup>-3</sup> )	MO (µg m <sup>-3</sup> )	SDE (µg m <sup>-3</sup> )	SDO (µg m <sup>-3</sup> )	MFE	MFB
BEME	Beaver Meadows	0.643	0.774	0.297	0.389	0.457	-0.155
BRUS	Brush CO	7.924	1.446	4.379	0.786	1.296	1.296
DINO	Dinosaur NM UT	0.748	0.598	0.289	0.411	0.513	0.322
GOPA	Gore Pass	0.731	0.647	0.419	0.786	0.588	0.055
GRAN	Grant NE	1.528	1.321	1.006	0.579	0.413	0.099
LYCR	Lyons Crest CO	1.966	1.168	1.284	0.61	0.556	0.439
ROMO	Core Site	0.642	0.668	0.3	0.322	0.479	-0.027
SPRI	Springfield CO	0.805	0.999	0.443	0.55	0.481	-0.195
TICR	Timber Creek	0.581	0.436	0.255	0.196	0.502	0.264

**Table 5.40.** Summer campaign S model performance statistics. See text for description of column headings. The column headings refer to the site ID and site name, study mean of the estimated concentrations (ME, µg m<sup>-3</sup>), study mean of the observed concentrations (MO, µg m<sup>-3</sup>), standard deviation of the estimated and observed mean concentration (SDE and SDO,

respectively,  $\mu\text{g m}^{-3}$ ), and the mean fractional error (MFE) and the mean fractional bias (MFB). The rows of the table correspond to the site locations.

Site ID	Site Name	ME ( $\mu\text{g m}^{-3}$ )	MO ( $\mu\text{g m}^{-3}$ )	SDE ( $\mu\text{g m}^{-3}$ )	SDO ( $\mu\text{g m}^{-3}$ )	MFE	MFB
ALVC	Alpine Visitor Cent.	0.794	0.933	0.317	0.214	0.353	-0.197
BEME	Beaver Meadows	0.935	0.795	0.391	0.281	0.347	0.14
BRUS	Brush CO	9.908	1.423	3.589	0.744	1.468	1.468
GOPA	Gore Pass CO	1	0.629	0.475	0.204	0.433	0.387
LYCR	Lyons Crest CO	2.056	1.354	0.716	0.658	0.53	0.445
ROMO	Core Site	1.023	0.775	0.534	0.265	0.425	0.214
TICR	Timber Creek	0.924	0.765	0.443	0.278	0.384	0.145

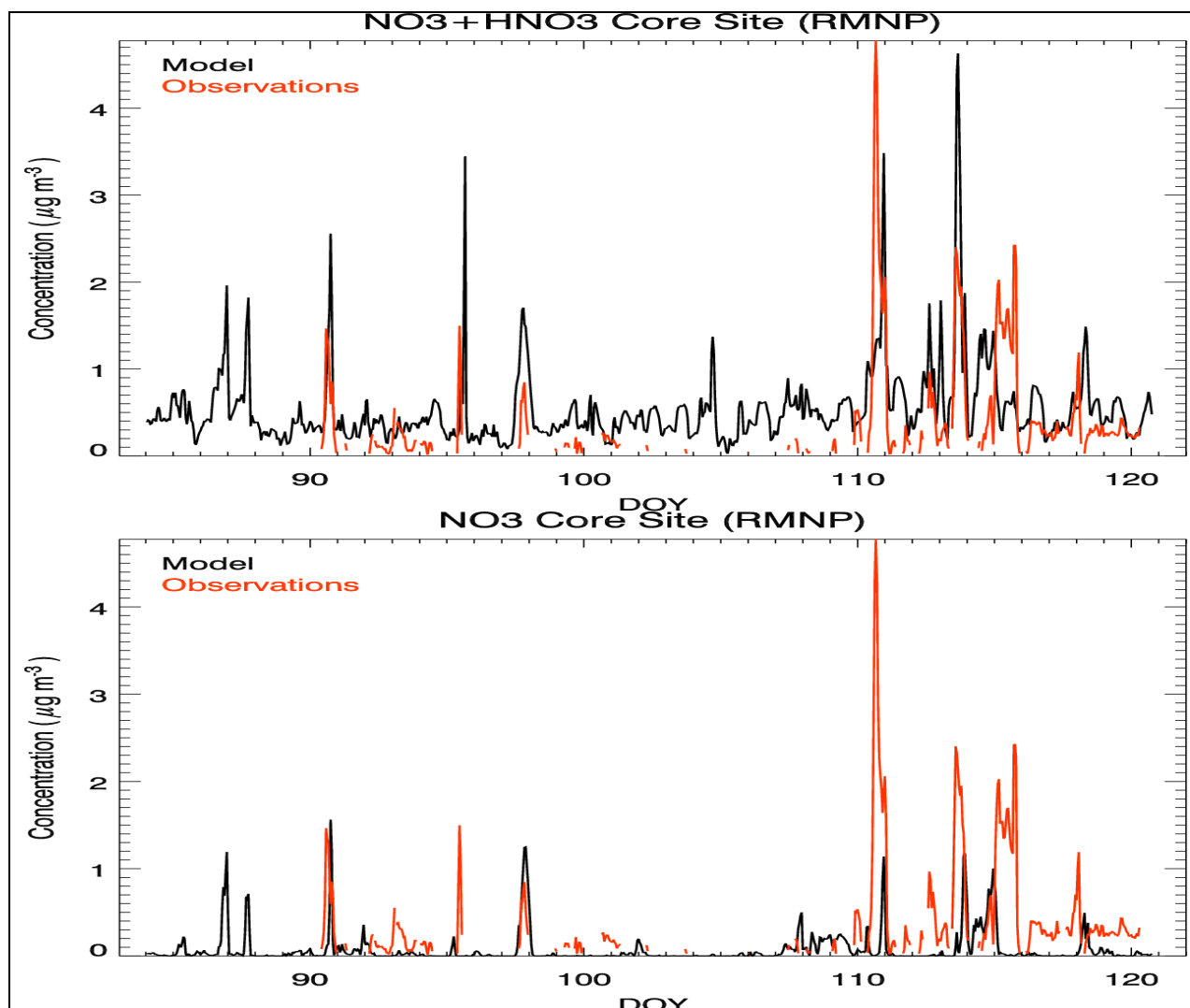


Figure 5.192. (a) Time series of model results of total oxidized nitrogen concentrations ( $\text{N(V)}=\text{NO}_3^-(\text{p}) + \text{HNO}_3(\text{g})$ ) (in black) and hourly ambient nitrate concentrations ( $\text{NO}_3^-$ ) at the core site (in red) during the spring campaign (DOY 85–121, March 26 to May 1, 2006). (b) Time series of model results of  $\text{NO}_3^-$  concentrations (in black) and observed hourly ambient  $\text{NO}_3^-$  concentrations (in red). Units are in  $\mu\text{g m}^{-3}$ .

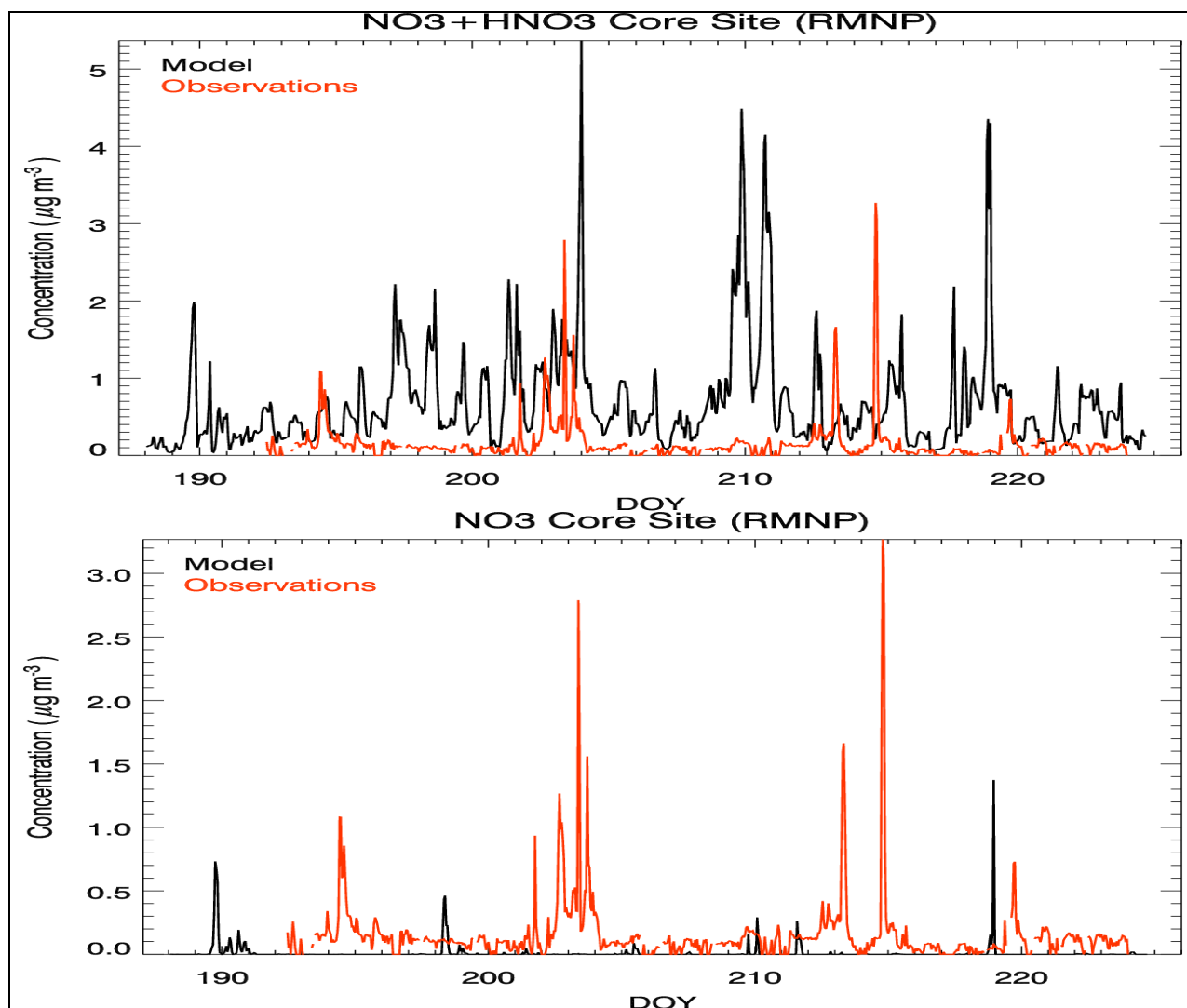


Figure 5.193. (a) Time series of model results of total oxidized nitrogen concentrations ( $N(V)=NO_3^-(p)+HNO_3(g)$ ) (in black) and hourly ambient  $NO_3^-$  concentrations at the core site (in red) during the summer campaign (DOY 188 to 224, 7 July-12 August 2006). (b) Time series of model results of  $NO_3^-$  concentrations (in black) and observed hourly ambient  $NO_3^-$  concentrations (in red). Units are in  $\mu g m^{-3}$ .

<b>Spring</b>	<b>Summer</b>
---------------	---------------

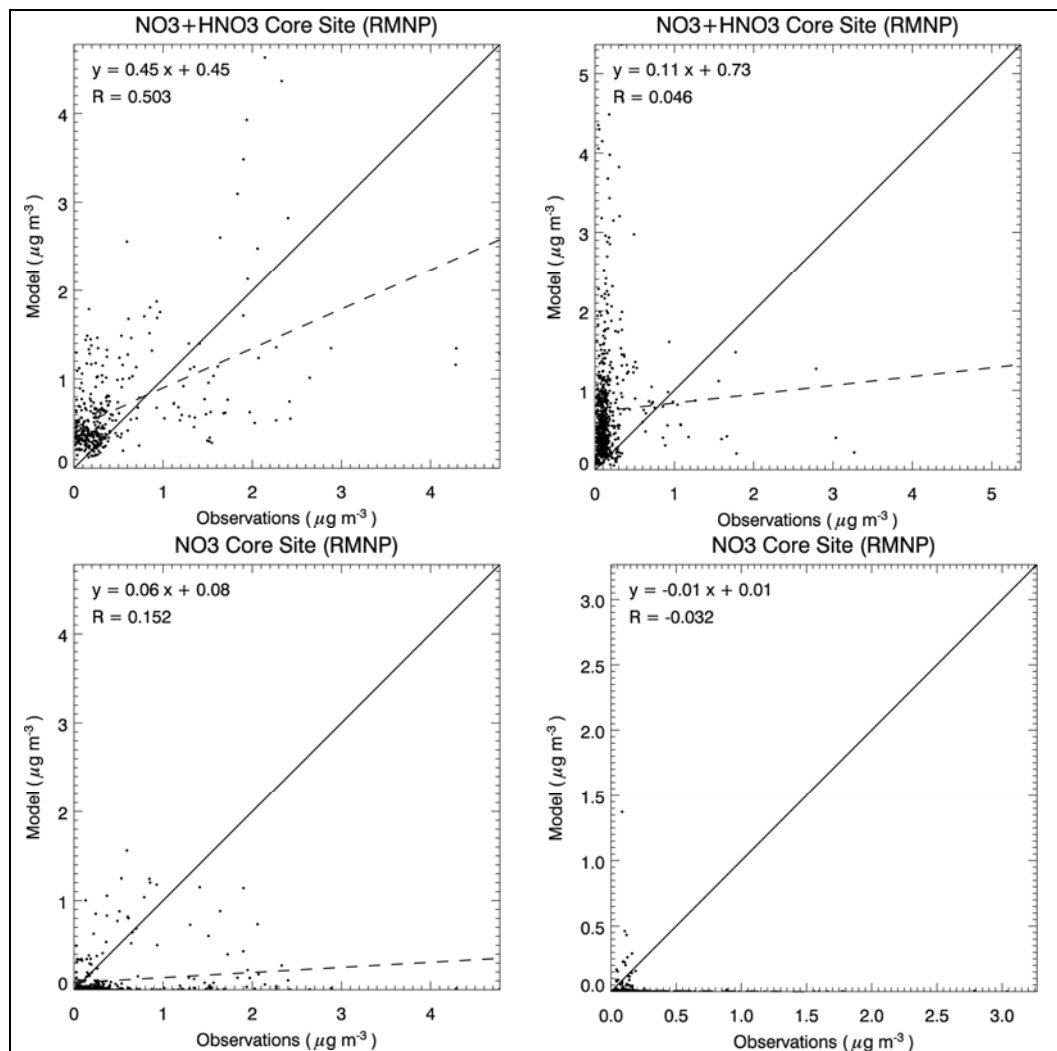


Figure 5.194. Comparisons of hourly predicted (y-axis) and observed (x-axis) N(V) concentrations (top panel) and NO<sub>3</sub><sup>-</sup> concentrations (bottom panel) at the core site. Units are in  $\mu\text{g m}^{-3}$ . Spring campaign results are shown on the left and summer campaign results on the right. A best-fit linear regression equation is printed on each plot along with the correlation coefficient (R). The one-to-one line is solid and the best-fit line is dashed.

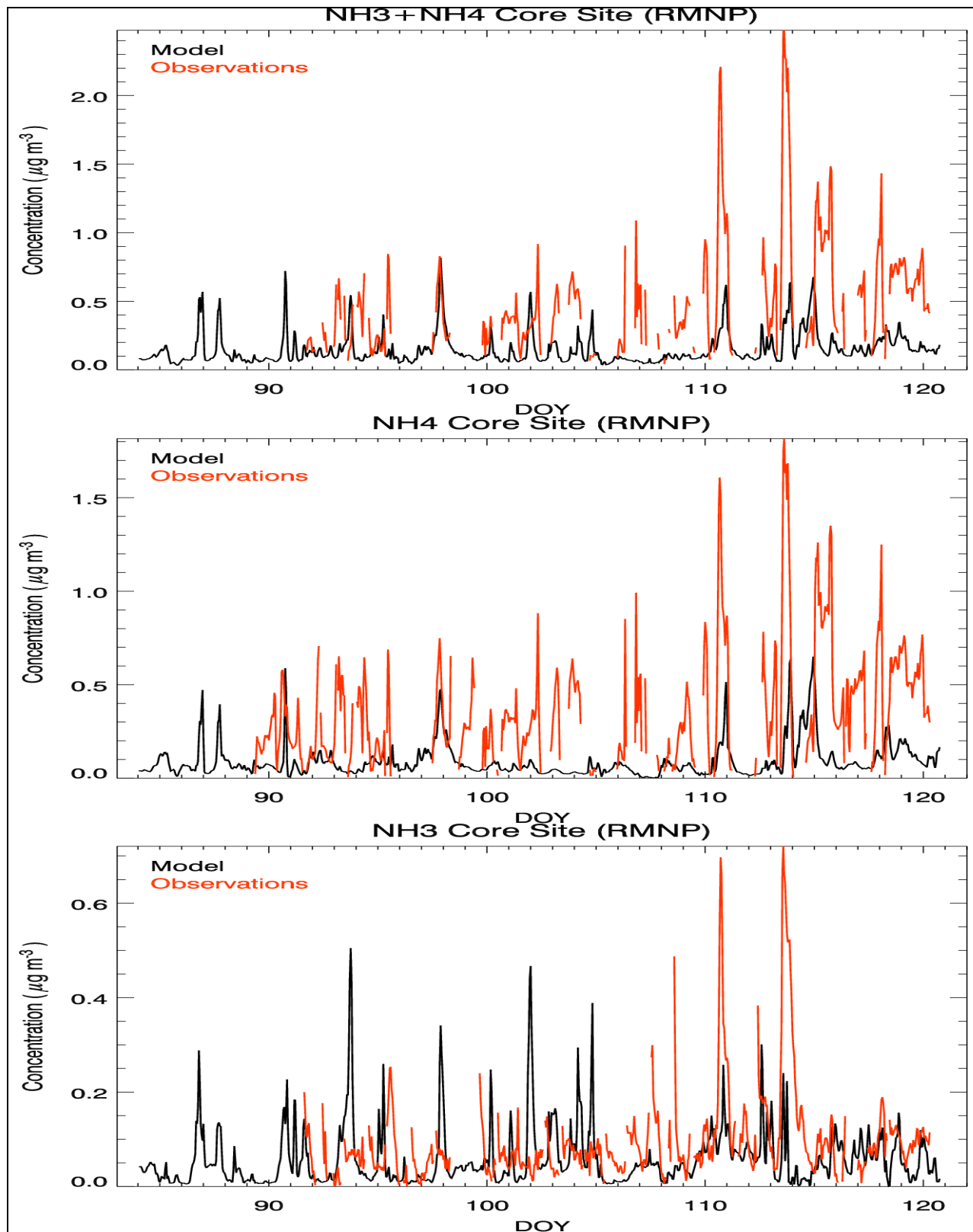
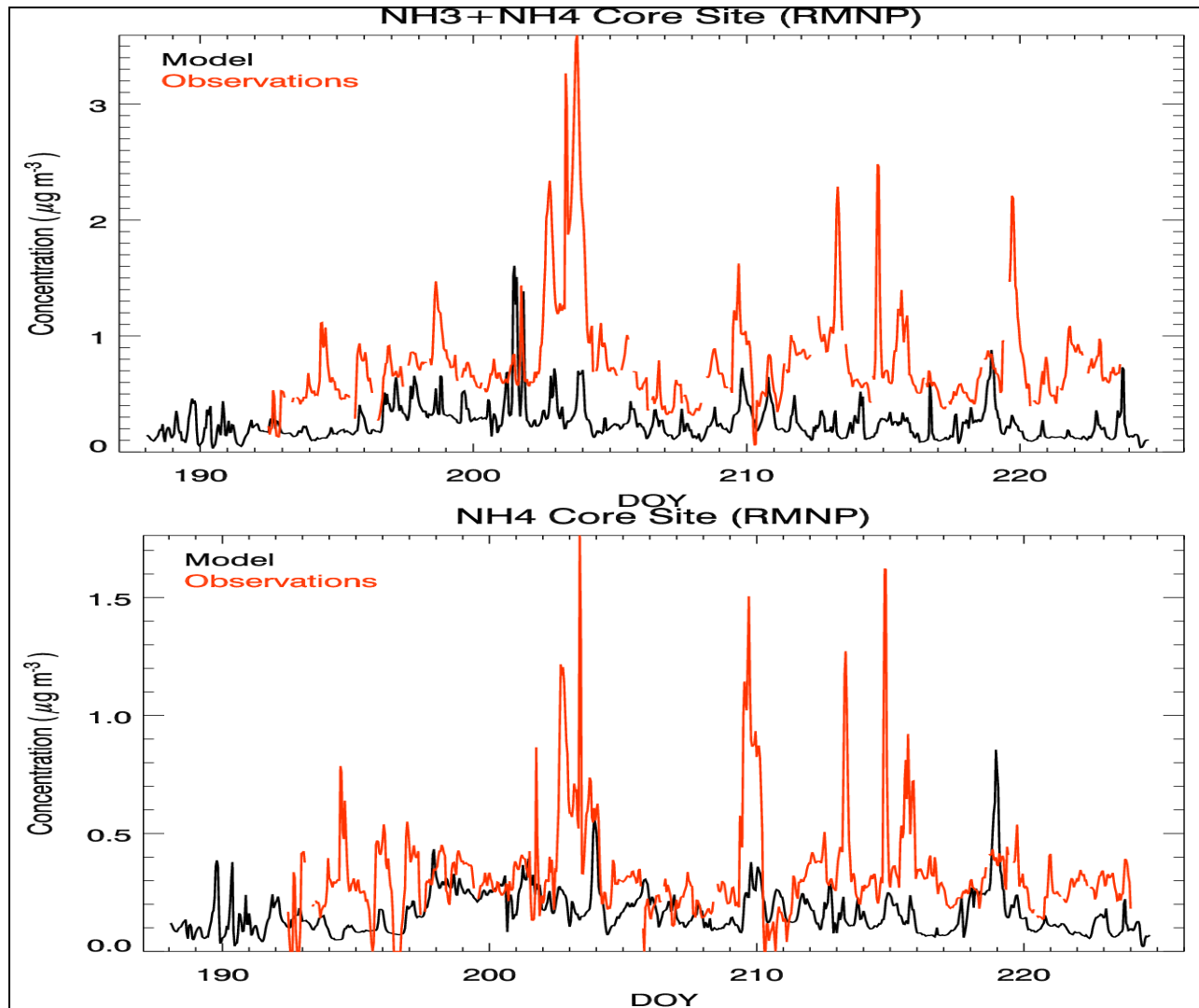


Figure 5.195. (a) Time series of model results of total reduced nitrogen concentrations (N(-III)=NH<sub>4</sub><sup>+</sup>(p) + NH<sub>3</sub>(g)) (in black) and hourly ambient observed N(-III) concentrations (in red) at the core site during the spring campaign (DOY 85–121, March 26 to May 1, 2006). (b) Time

series of model results of  $\text{NH}_4^+$  concentrations (in black) and hourly ambient observed  $\text{NH}_4^+$  concentrations (in red). (c) Time series of model results of  $\text{NH}_3$  concentrations (in black) and hourly ambient observed  $\text{NH}_3$  concentrations (in red). Units of  $\mu\text{g m}^{-3}$ .





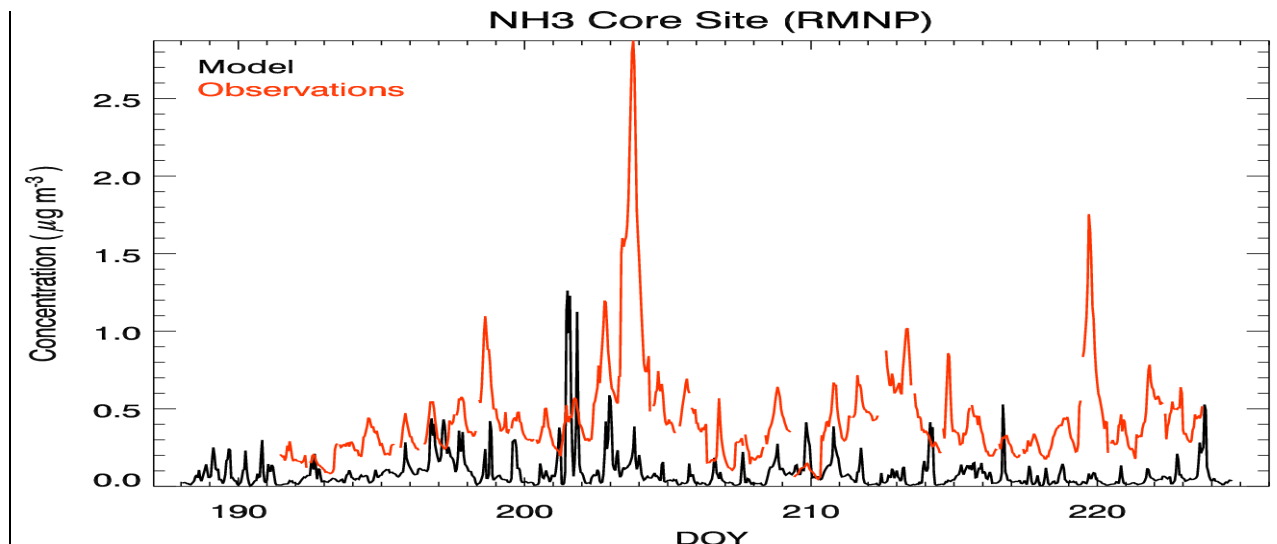
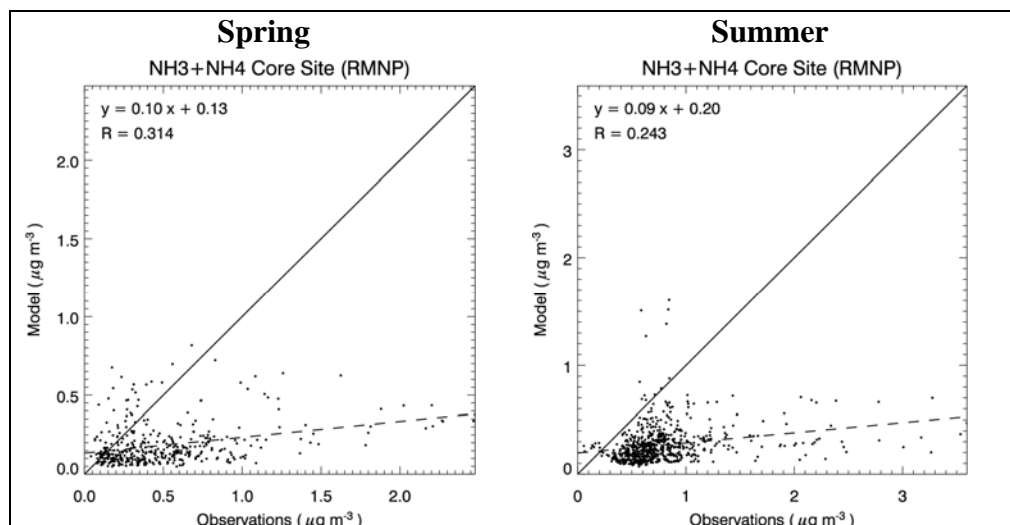


Figure 5.196. (a) Time series of model results of total reduced nitrogen concentrations (N(-III))= $\text{NH}_4^+(\text{p})+\text{NH}_3(\text{g})$  (in black) and hourly ambient observed N(-III) concentrations (in red) at the core site during the summer campaign (DOY 188–224, July 7 to August 12, 2006). (b) Time series of model results of  $\text{NH}_4^+$  (in black) and hourly ambient observed  $\text{NH}_4^+$  concentrations (in red). (c) Time series of model results of  $\text{NH}_3$  concentrations (in black) and hourly ambient observed  $\text{NH}_3$  concentrations (in red). Units of  $\mu\text{g m}^{-3}$ .



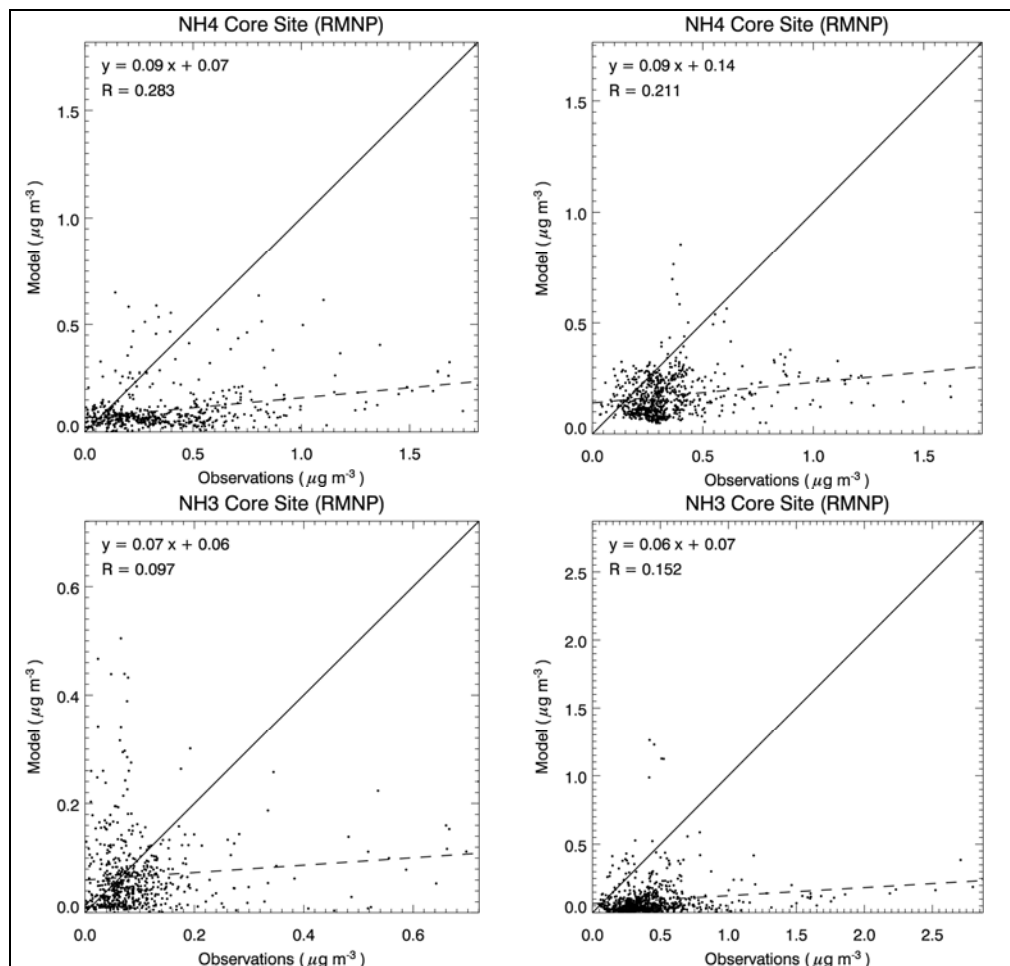


Figure 5.197. Comparisons of hourly predicted (y-axis) and observed (x-axis) total reduced nitrogen (N(-III)=NH<sub>3</sub>(g)+NH<sub>4</sub><sup>+</sup>(p)) concentrations (top panel), NH<sub>4</sub><sup>+</sup> concentrations (middle panel) and NH<sub>3</sub> concentrations (bottom panel) at the core site. Spring campaign results are shown on the left and summer campaign results on the right. A best-fit linear regression equation is printed on each plot along with the correlation coefficient (R). The one-to-one line is solid and the best-fit line is dashed. Units of  $\mu\text{g m}^{-3}$ .

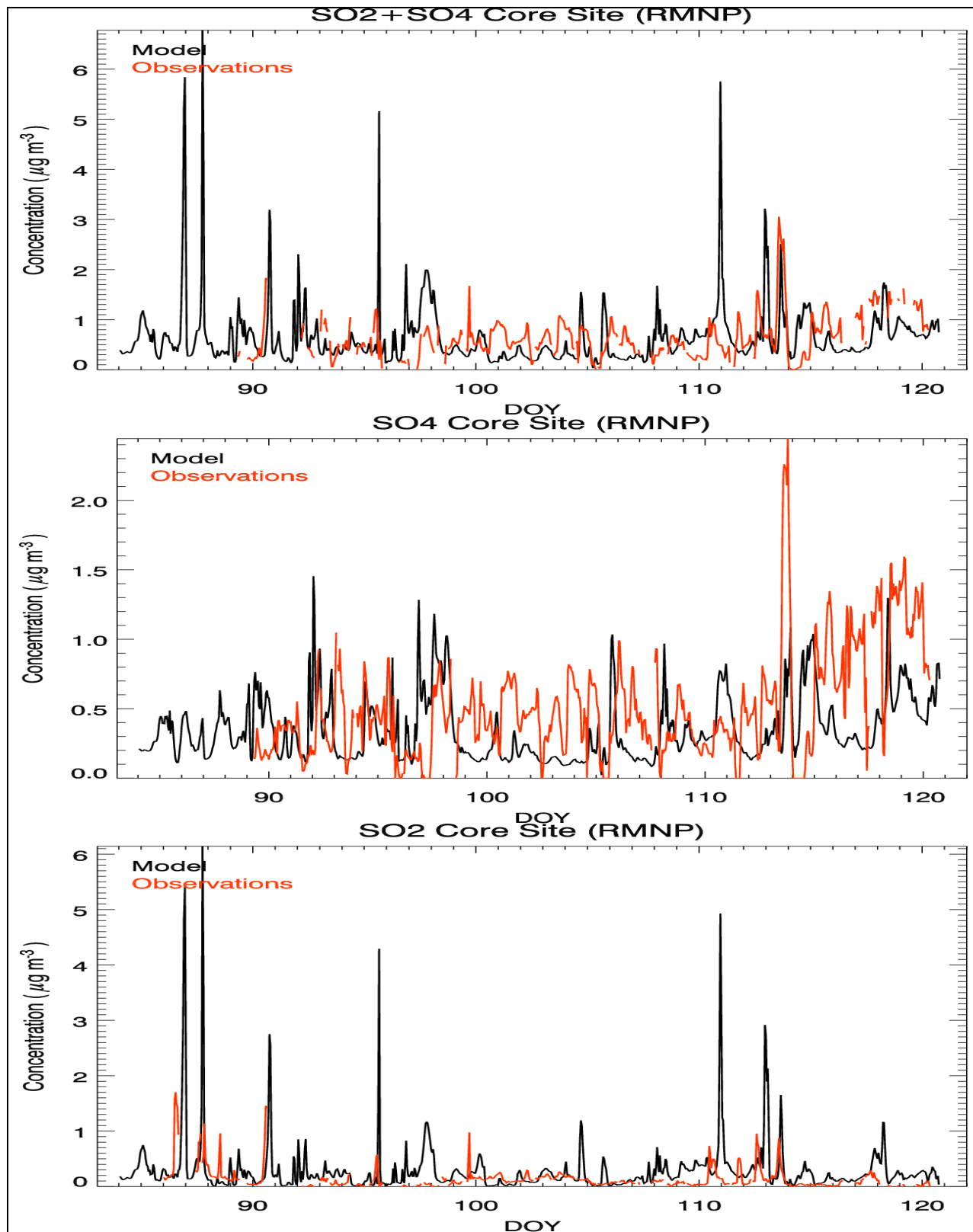


Figure 5.198. (a) Time series of model results of total sulfur concentrations ( $S = \text{SO}_2(\text{g}) + \text{SO}_4^{-2}(\text{p})$ ) (in black) and hourly ambient total S concentrations at the core site (in red) during the spring campaign (DOY 85–121, March 26 to May 1, 2006). (b) Time series of model results of  $\text{SO}_4^{-2}$

concentrations (in black) and observed hourly ambient  $\text{SO}_4^{-2}$  concentrations (in red). (c) Similar time series but for  $\text{SO}_2$  concentrations. Units are in  $\mu\text{g m}^{-3}$ .

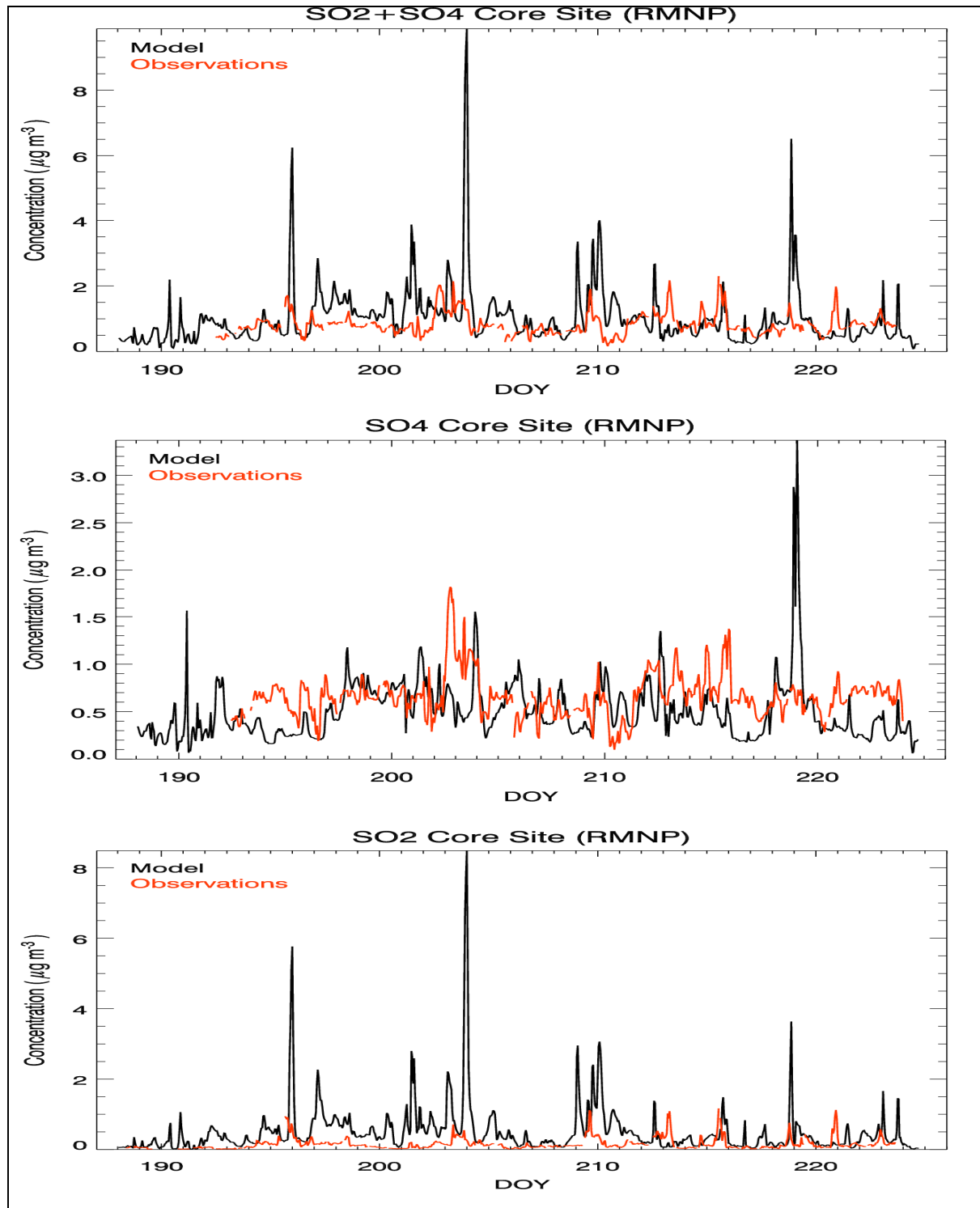
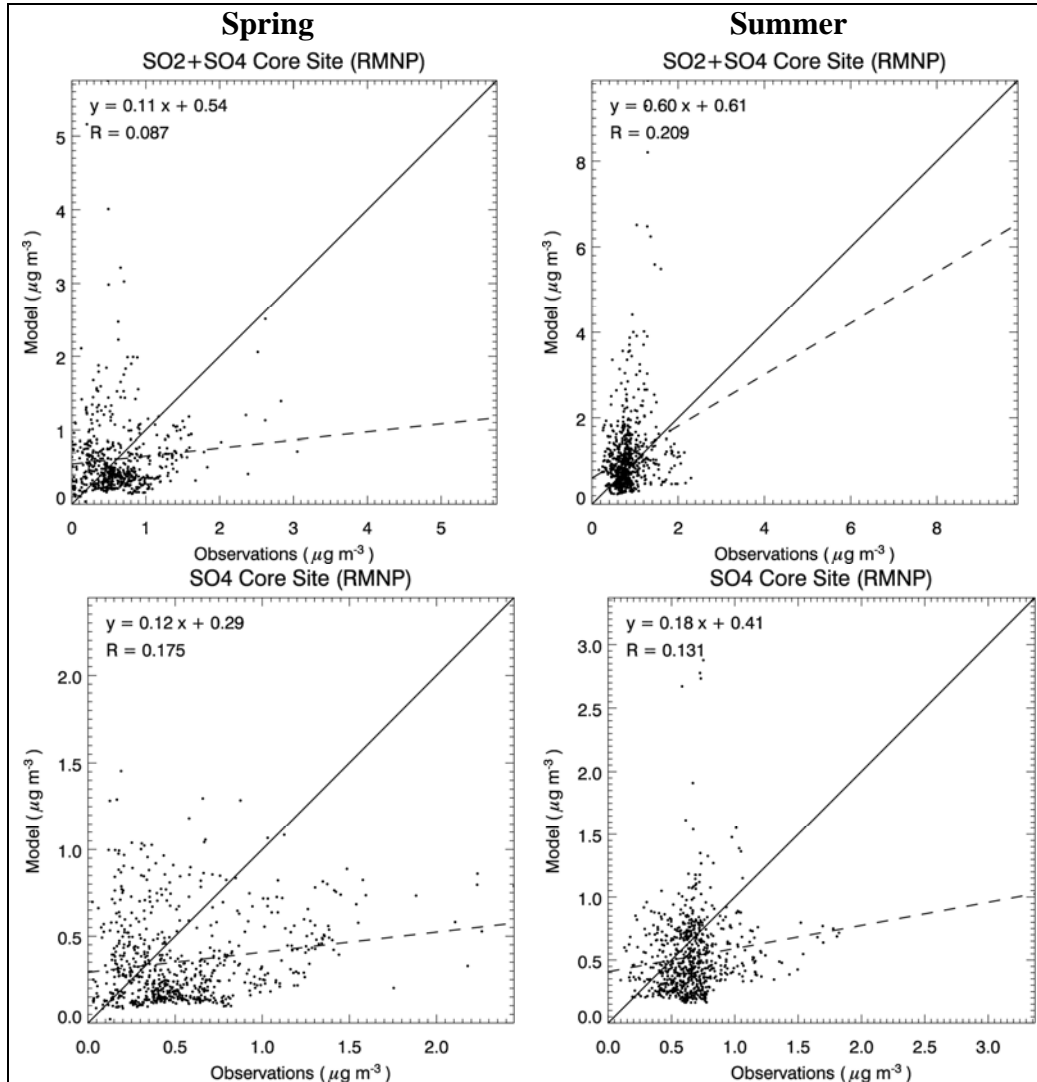


Figure 5.199. (a) Time series of model results of total sulfur concentrations ( $S = SO_2(g) + SO_4^{2-}(p)$ ) (in black) and hourly ambient total S concentrations at the core site (in red) during the summer campaign (DOY 188–224, July 7 to August 12, 2006). (b) Time series of model results of  $SO_4^{2-}$  concentrations (in black) and observed hourly ambient  $SO_4^{2-}$  concentrations (in red). (c) Similar time series but for  $SO_2$  concentrations. Units are in  $\mu g m^{-3}$ .



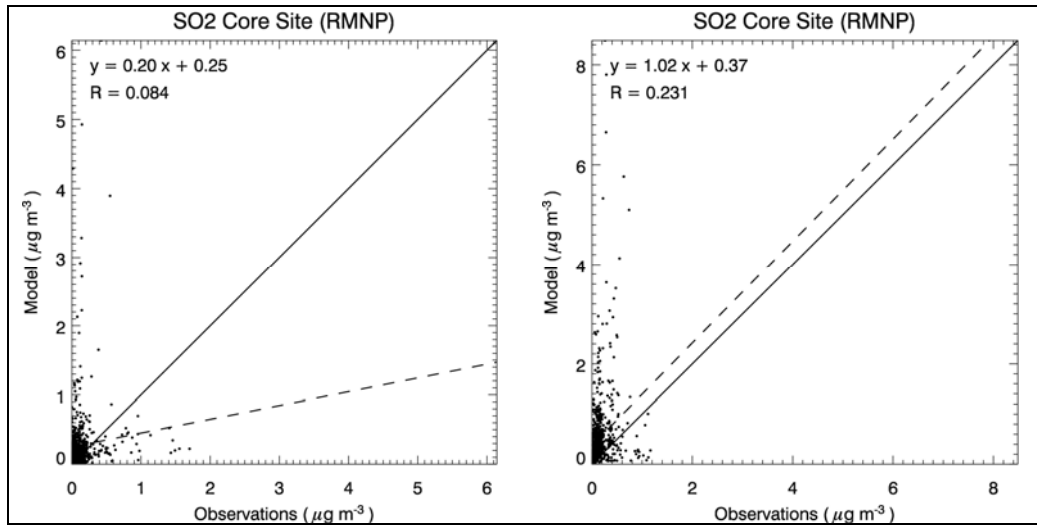
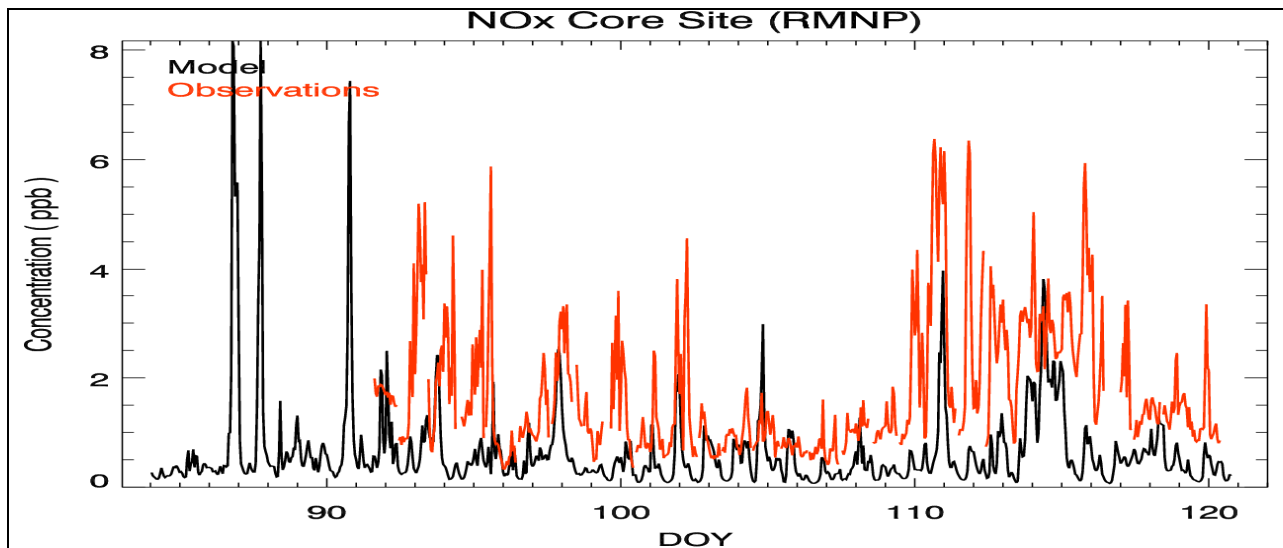


Figure 5.200. Comparisons of hourly predicted (y-axis) and observed (x-axis) total sulfur ( $S=SO_2(g)+SO_4^{-2}(p)$ ) concentrations (top panel),  $SO_4^{-2}$  concentrations (middle panel), and  $SO_2$  concentrations (bottom panel) at the core site. Spring campaign results are shown on the left and summer campaign results on the right. A best-fit linear regression equation is printed on each plot along with the correlation coefficient (R). The one-to-one line is solid and the best-fit line is dashed. Units are in  $\mu\text{g m}^{-3}$ .



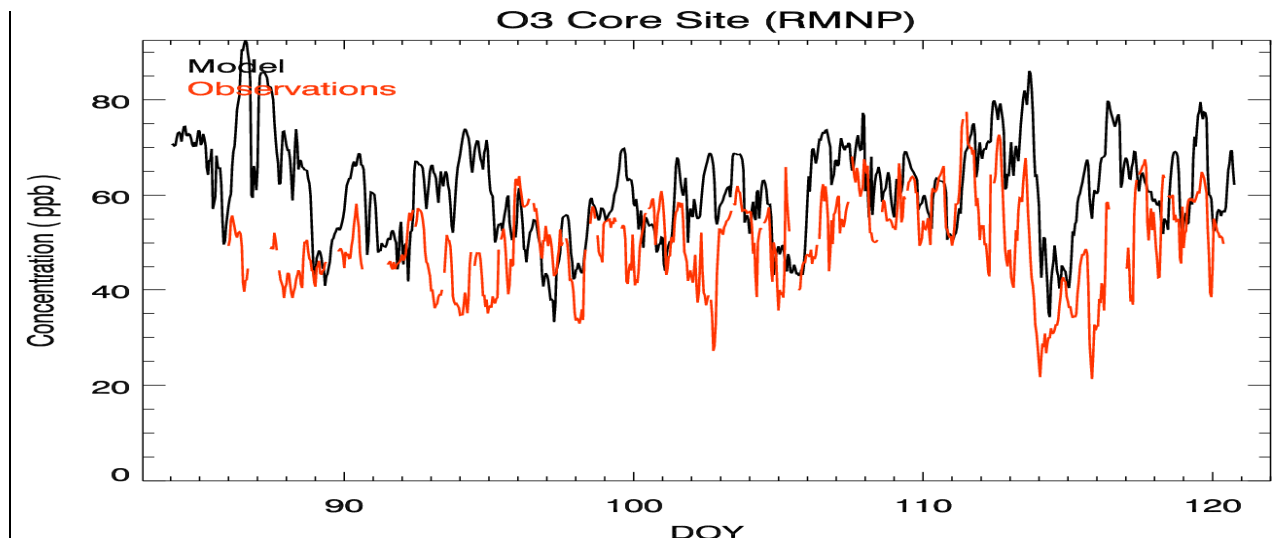
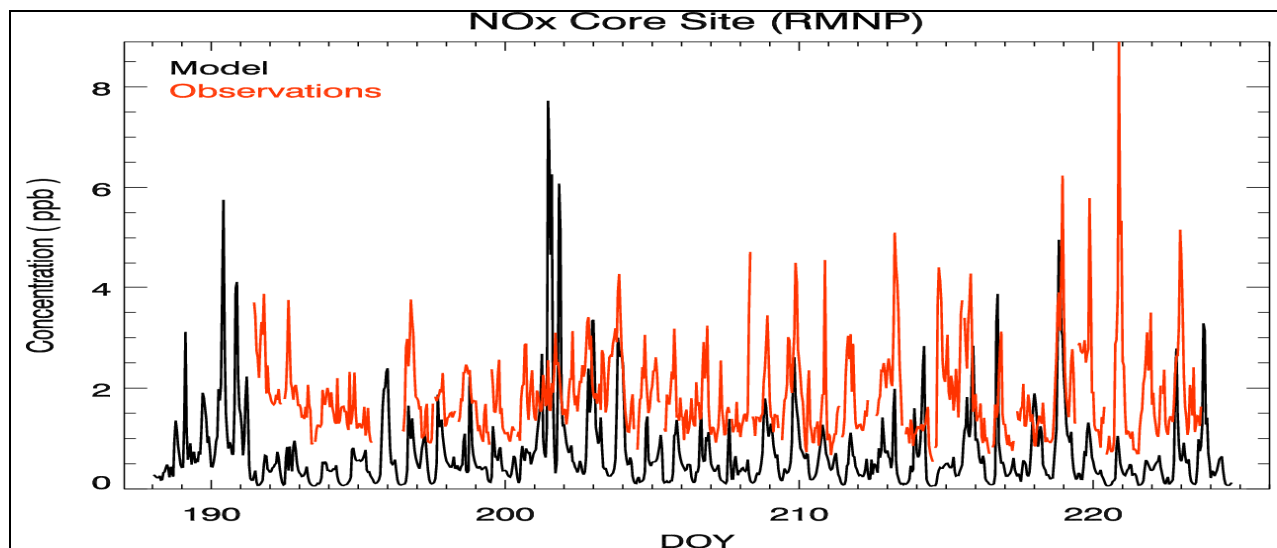


Figure 5.201. (a) Time series of model results of  $\text{NO}_x$  concentrations (in black) and hourly observed  $\text{NO}_x$  concentrations (in red) at the core site during the spring campaign (DOY 85–121, March 26 to May 1, 2006). (b) Time series of model results of ozone concentrations (in black) and observed hourly ozone concentrations (in red). Units are in ppb.



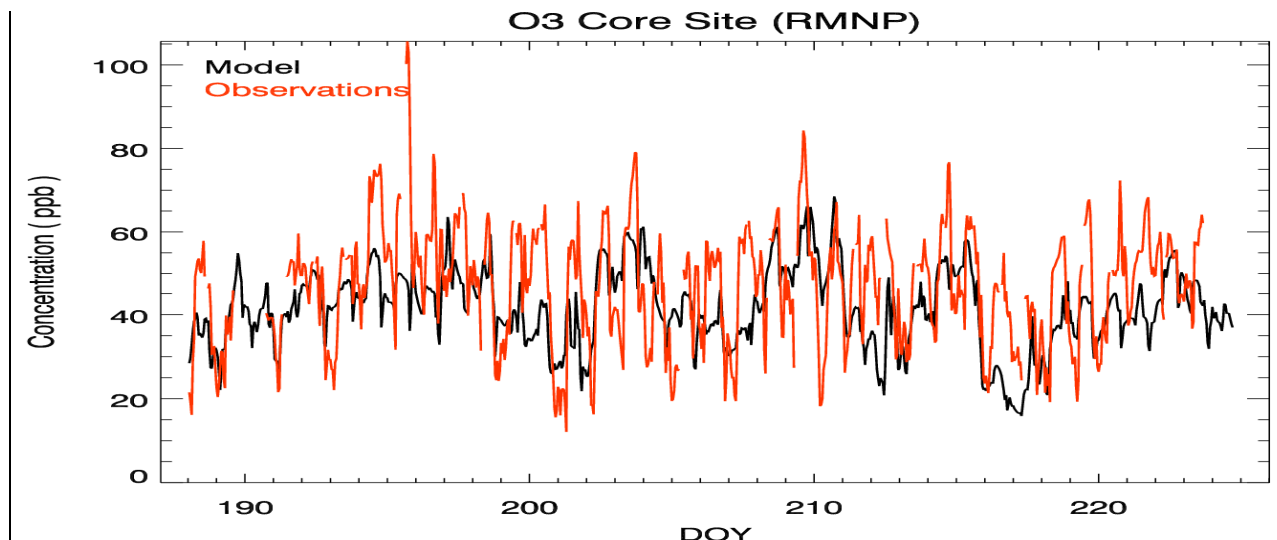
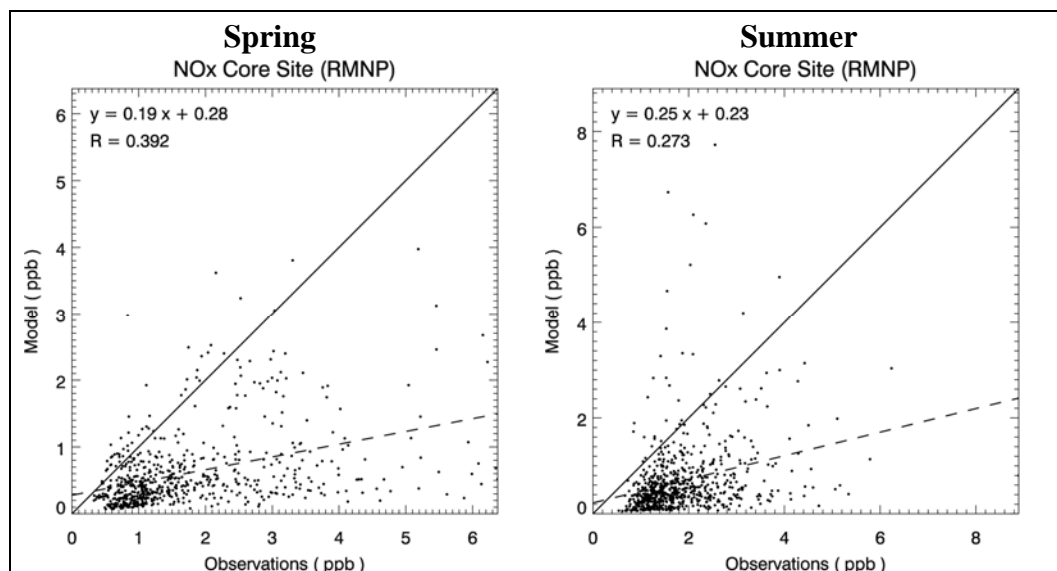


Figure 5.202. (a) Time series of model results of  $\text{NO}_x$  concentrations (in black) and hourly observed  $\text{NO}_x$  concentrations (in red) at the core site during the summer campaign (DOY 188–224, July 7 to August 12, 2006). (b) Time series of model results of ozone concentrations (in black) and observed hourly ozone concentrations (in red). Units are in ppb.





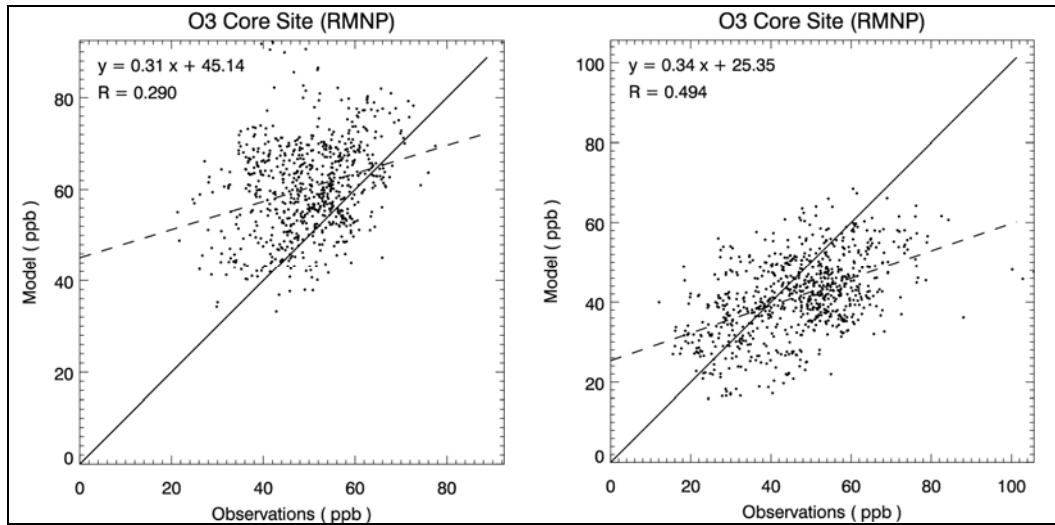
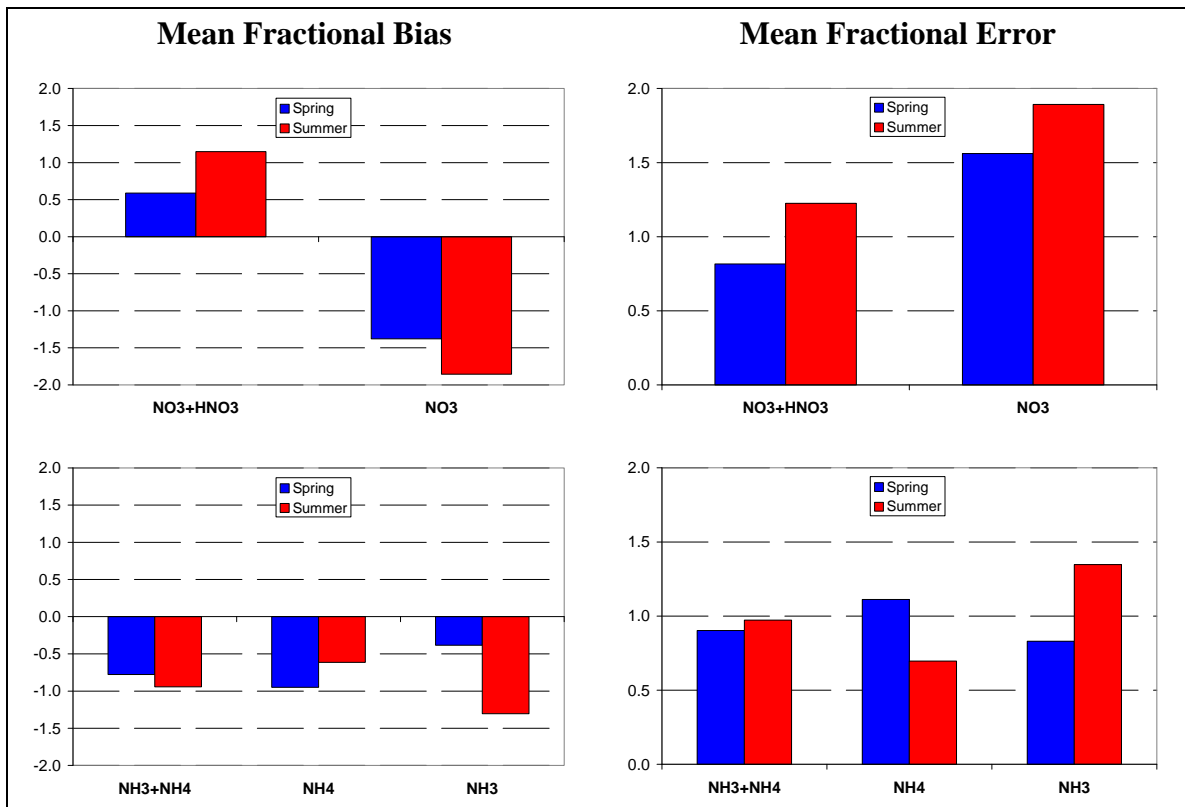


Figure 5.203. Comparisons of hourly predicted (y-axis) and observed (x-axis)  $\text{NO}_x$  concentrations (top panel) and  $\text{O}_3$  concentrations (bottom panel). Spring campaign results are shown on the left and summer campaign on the right. A best-fit linear regression equation is printed on each plot along with the correlation coefficient (R). The one-to-one line is solid and the best-fit line is dashed. Units are in ppb.



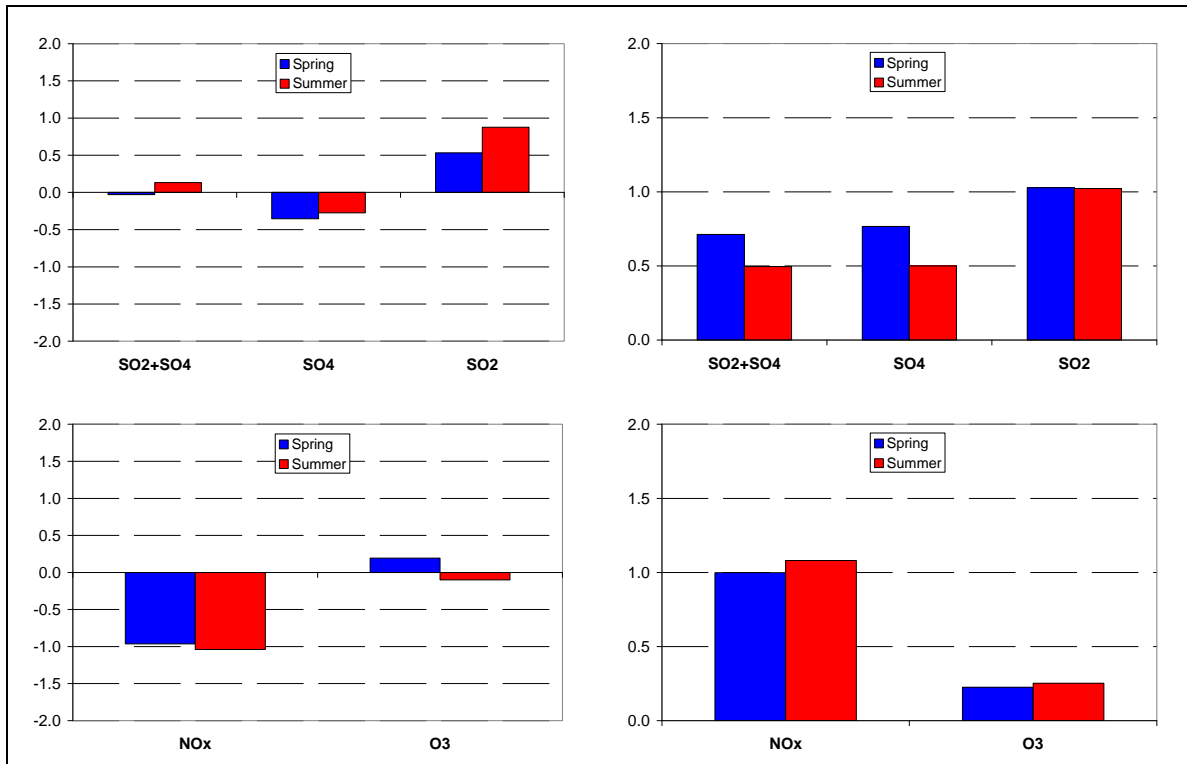


Figure 5.204. Mean fractional bias (left column) and mean fractional error (right column) for the spring (blue) and summer (red) campaigns at the core site. Total oxidized nitrogen (N(V)) and  $\text{NO}_3^-$  (top panel), total reduced nitrogen (N(-III)),  $\text{NH}_3$  and  $\text{NH}_4^+$  (second panel), sulfur species (total S),  $\text{SO}_2$  and  $\text{SO}_4^{2-}$  (third panel), and  $\text{NO}_x$  and  $\text{O}_3$  (bottom panel).

**Table 5.41.** Model performance statistics during both spring and summer RoMANS campaigns, using hourly ambient data from the core site.

	Spring							
	N(V) ( $\mu\text{g}/\text{m}^3$ )	$\text{NO}_3^-$ ( $\mu\text{g}/\text{m}^3$ )	N(-III) ( $\mu\text{g}/\text{m}^3$ )	$\text{NH}_3$ ( $\mu\text{g}/\text{m}^3$ )	$\text{NH}_4^+$ ( $\mu\text{g}/\text{m}^3$ )	Total S ( $\mu\text{g}/\text{m}^3$ )	$\text{SO}_4^{2-}$ ( $\mu\text{g}/\text{m}^3$ )	$\text{SO}_2$ ( $\mu\text{g}/\text{m}^3$ )
Mean Obs.	0.48	0.48	0.51	0.10	0.38	0.63	0.53	0.14
Mean Model	0.67	0.11	0.19	0.07	0.10	0.61	0.35	0.28
STD <sup>a</sup> Obs.	0.67	0.67	0.41	0.10	0.31	0.43	0.37	0.20
STD Model	0.59	0.25	0.13	0.07	0.10	0.54	0.25	0.48
MBE <sup>b</sup>	0.19	-0.37	-0.32	-0.03	-0.28	-0.02	-0.18	0.14
MNBE <sup>c</sup> (%)	271.1%	-50.1%	-43.3%	46.5%	-39.5%	976.6%	10.9%	10291.8%
MAGE <sup>d</sup>	0.44	0.43	0.36	0.07	0.30	0.45	0.35	0.24
MANGE <sup>e</sup> (%)	287.6%	105.0%	64.0%	124.7%	84.1%	1030.4%	86.9%	10324.6%
MFE <sup>f</sup> (%)	81.7%	156.1%	90.3%	83.0%	111.2%	71.3%	76.7%	102.8%
MFB <sup>g</sup> (%)	58.8%	-138.0%	-77.8%	-38.3%	-95.0%	-3.0%	-35.4%	53.3%
	Summer							
	N(V) ( $\mu\text{g}/\text{m}^3$ )	$\text{NO}_3^-$ ( $\mu\text{g}/\text{m}^3$ )	N(-III) ( $\mu\text{g}/\text{m}^3$ )	$\text{NH}_3$ ( $\mu\text{g}/\text{m}^3$ )	$\text{NH}_4^+$ ( $\mu\text{g}/\text{m}^3$ )	Total S ( $\mu\text{g}/\text{m}^3$ )	$\text{SO}_4^{2-}$ ( $\mu\text{g}/\text{m}^3$ )	$\text{SO}_2$ ( $\mu\text{g}/\text{m}^3$ )
Mean Obs.	0.18	0.18	0.78	0.43	0.34	0.83	0.66	0.16
Mean Model	0.75	0.01	0.27	0.09	0.17	1.11	0.53	0.53
STD <sup>a</sup> Obs.	0.29	0.29	0.45	0.32	0.21	0.33	0.23	0.17
STD Model	0.69	0.07	0.17	0.13	0.09	0.96	0.32	0.75
MBE <sup>b</sup>	0.57	-0.17	-0.51	-0.34	-0.17	0.28	-0.13	0.38

MNBE <sup>c</sup> (%)	723.8%	-89.7%	-59.7%	-72.8%	-38.8%	45.4%	-10.7%	458.6%
MAGE <sup>d</sup>	0.63	0.18	0.53	0.36	0.19	0.56	0.29	0.42
MANGE <sup>e</sup> (%)	729.1%	100.4%	64.5%	79.1%	51.0%	73.3%	46.3%	468.4%
MFE <sup>f</sup> (%)	122.5%	189.2%	97.3%	134.7%	69.6%	49.6%	50.0%	102.3%
MFB <sup>g</sup> (%)	114.9%	-185.6%	-94.4%	-130.5%	-61.4%	13.3%	-27.5%	87.7%

<sup>a</sup>Standard Deviation

<sup>b</sup>Mean Bias Error

<sup>c</sup>Mean Normalized Bias Error (%)

<sup>d</sup>Mean Absolute Gross Error

<sup>e</sup>Mean Absolute Normalized Gross Error (%)

<sup>f</sup>Mean Fractional Error (%)

<sup>g</sup>Mean Fractional Bias (%)