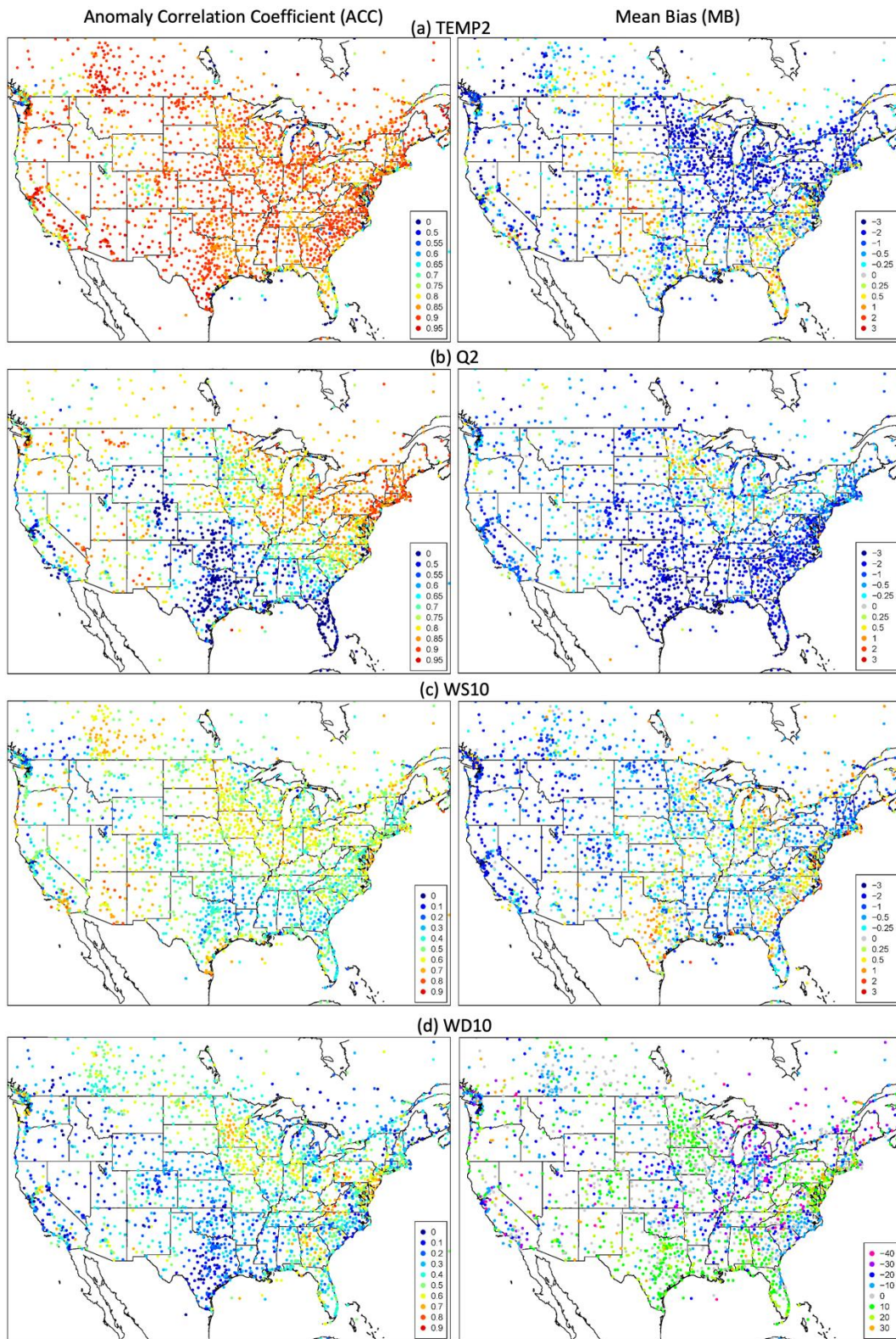*Supplement of*

Updates and evaluation of NOAA's online-coupled air quality model version 7 (AQMv7) within the Unified Forecast System

Wei Li et al.

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Figure S1: Anomaly correlation coefficient (ACC; left column) and mean bias (MB) between GFSv16.3 simulated and observed TEMP2 (a; °C), Q2(b; g/kg), WS10 (c; m/s), and WD10 (d; degree) at the surface in June 2023.
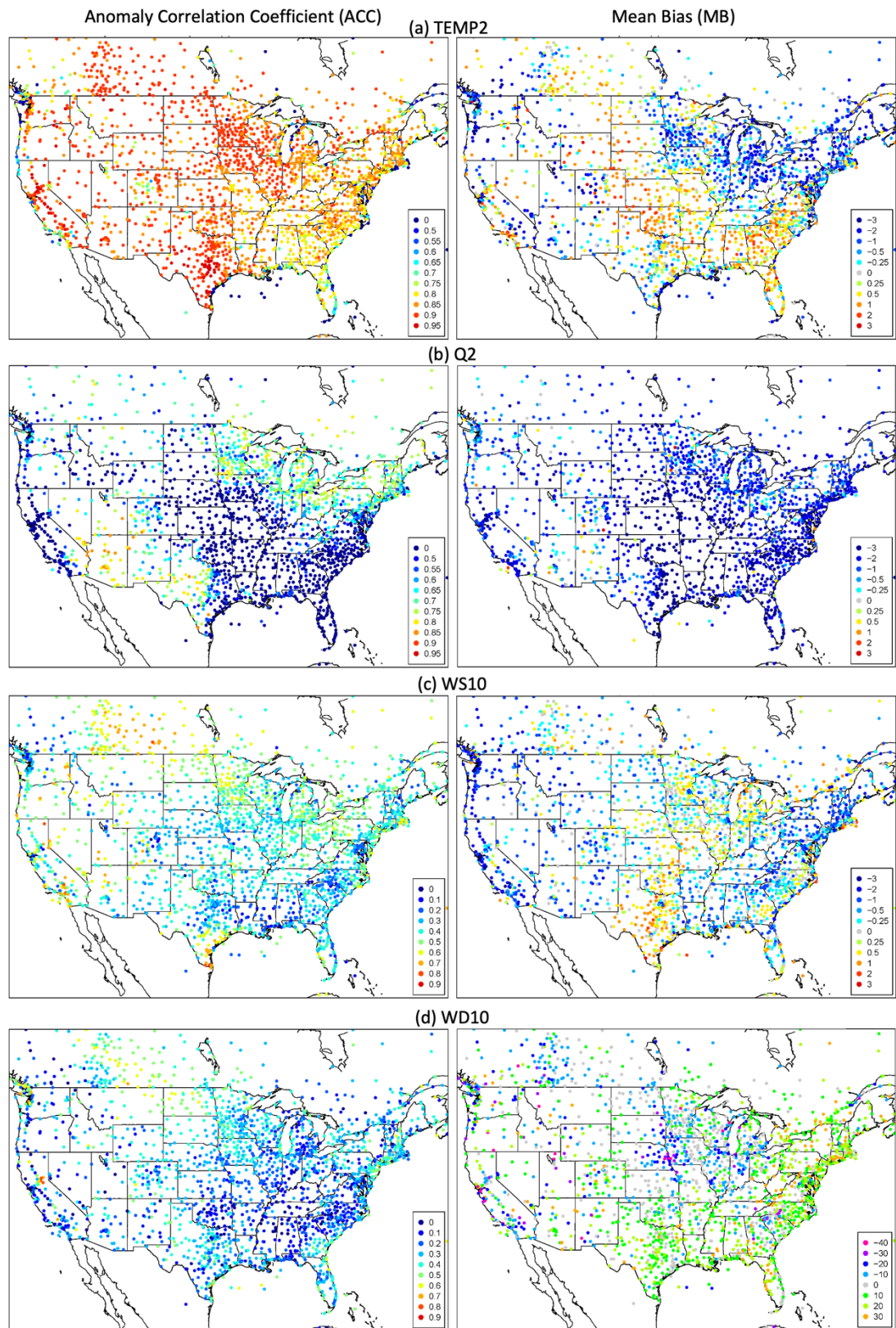
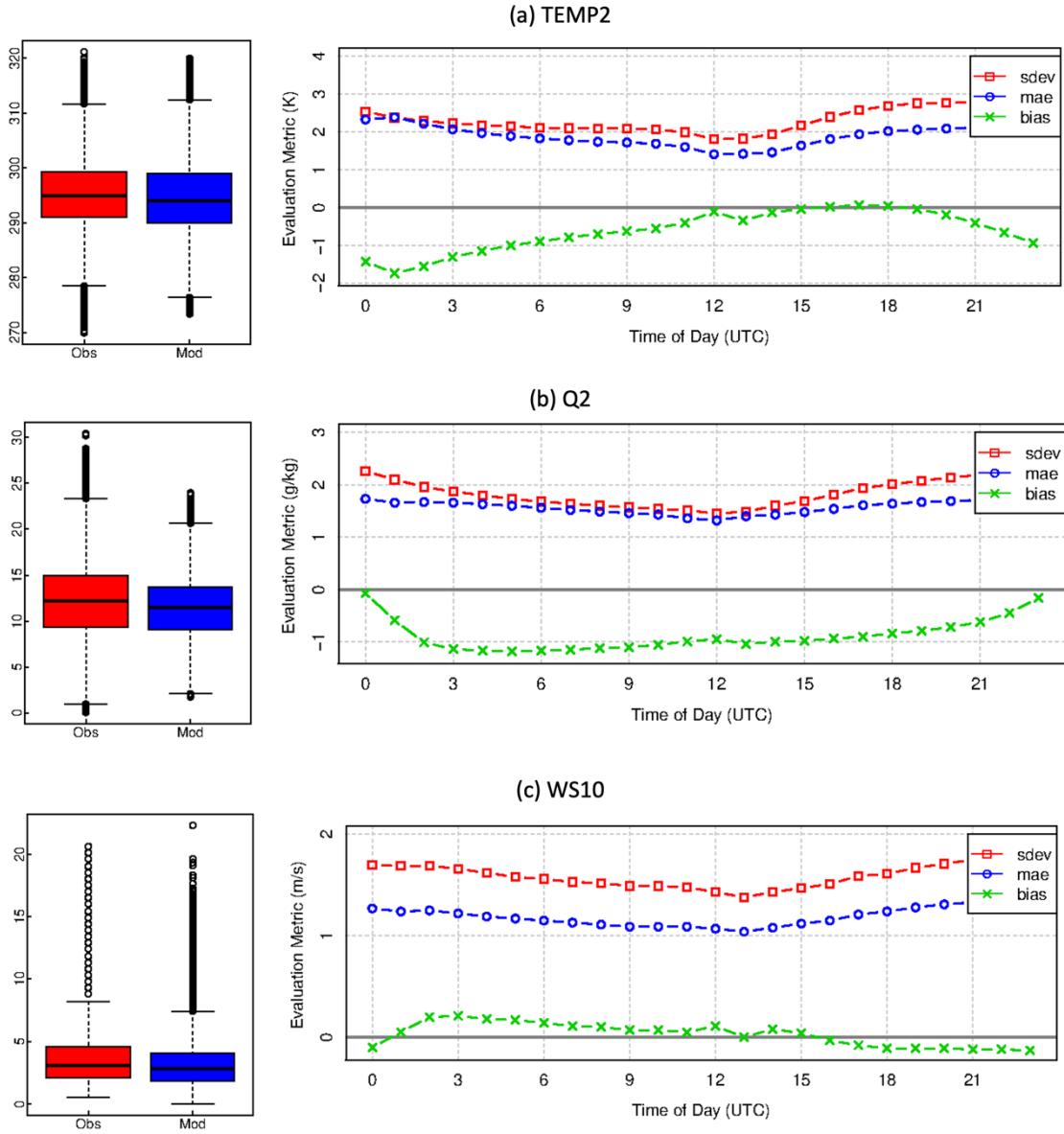**Figure S2: Same as Figure S1 but for July 2023.**

Figure S3: Boxplot (left column) and diurnal changes in three evaluation statistics (right column), including standard deviation (sdev; red), mean absolute error (mae; blue), and mean bias (gree), between GFSv16.3 simulated and observed TEMP2 (a; K), Q2(b; g/kg), and WS10 (c; m/s) at the surface across the eastern US (100°W east) of June 2023.

Figure S4: Same as Figure S3 but for the western US (100°W west) of June 2023.

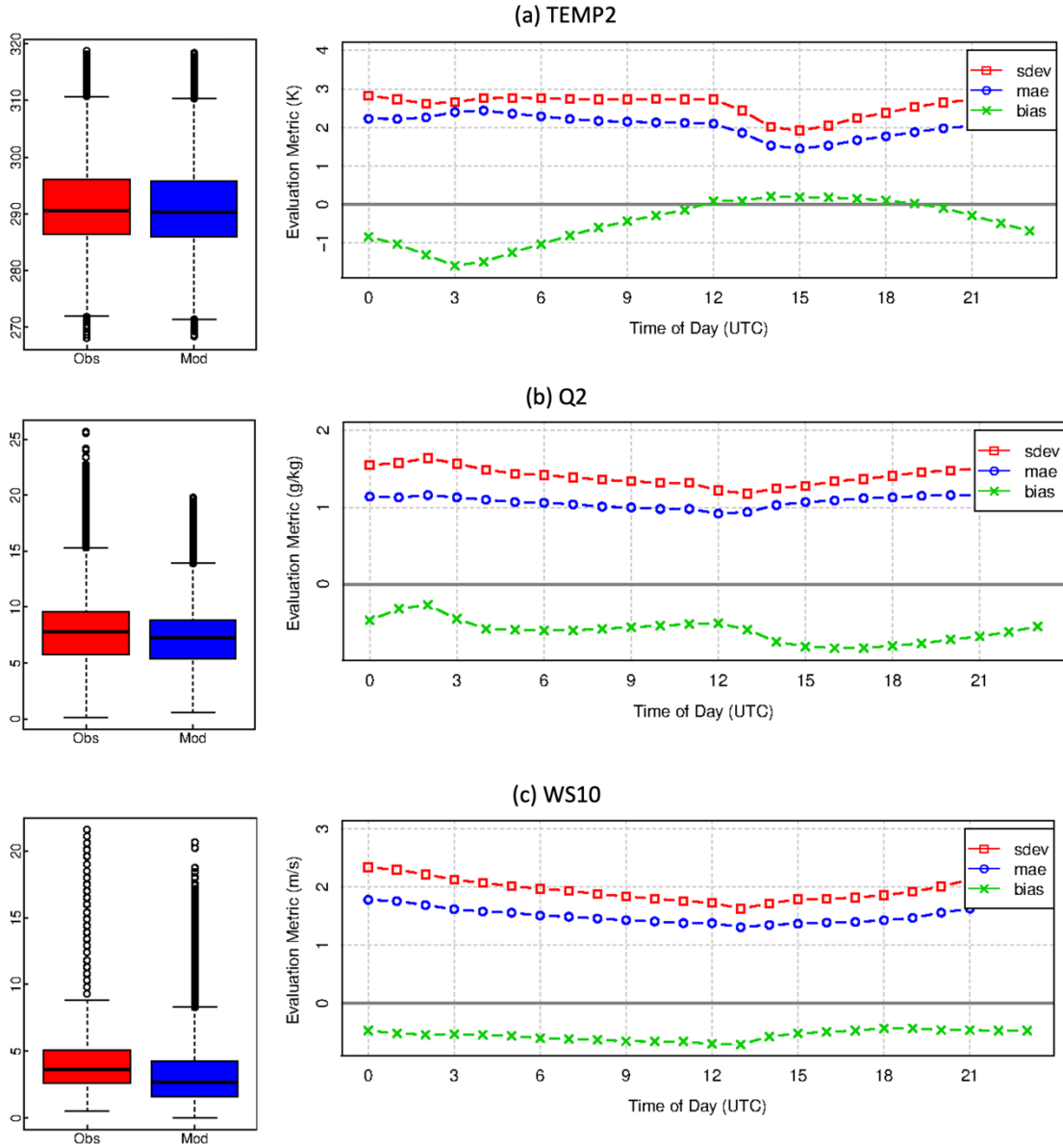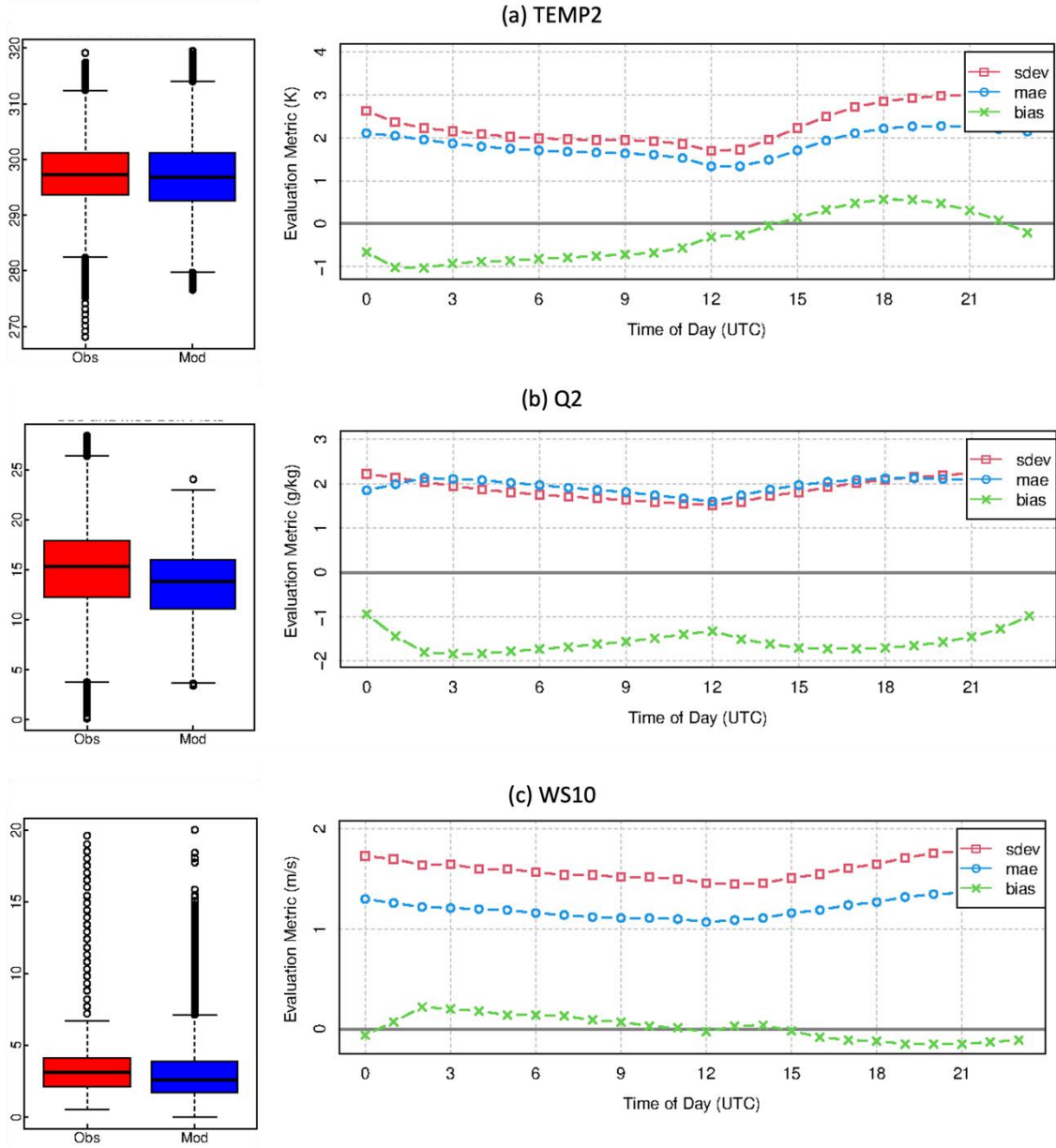**Figure S5: Same as Figure S3 but for the eastern US (100°W east) of July 2023.**
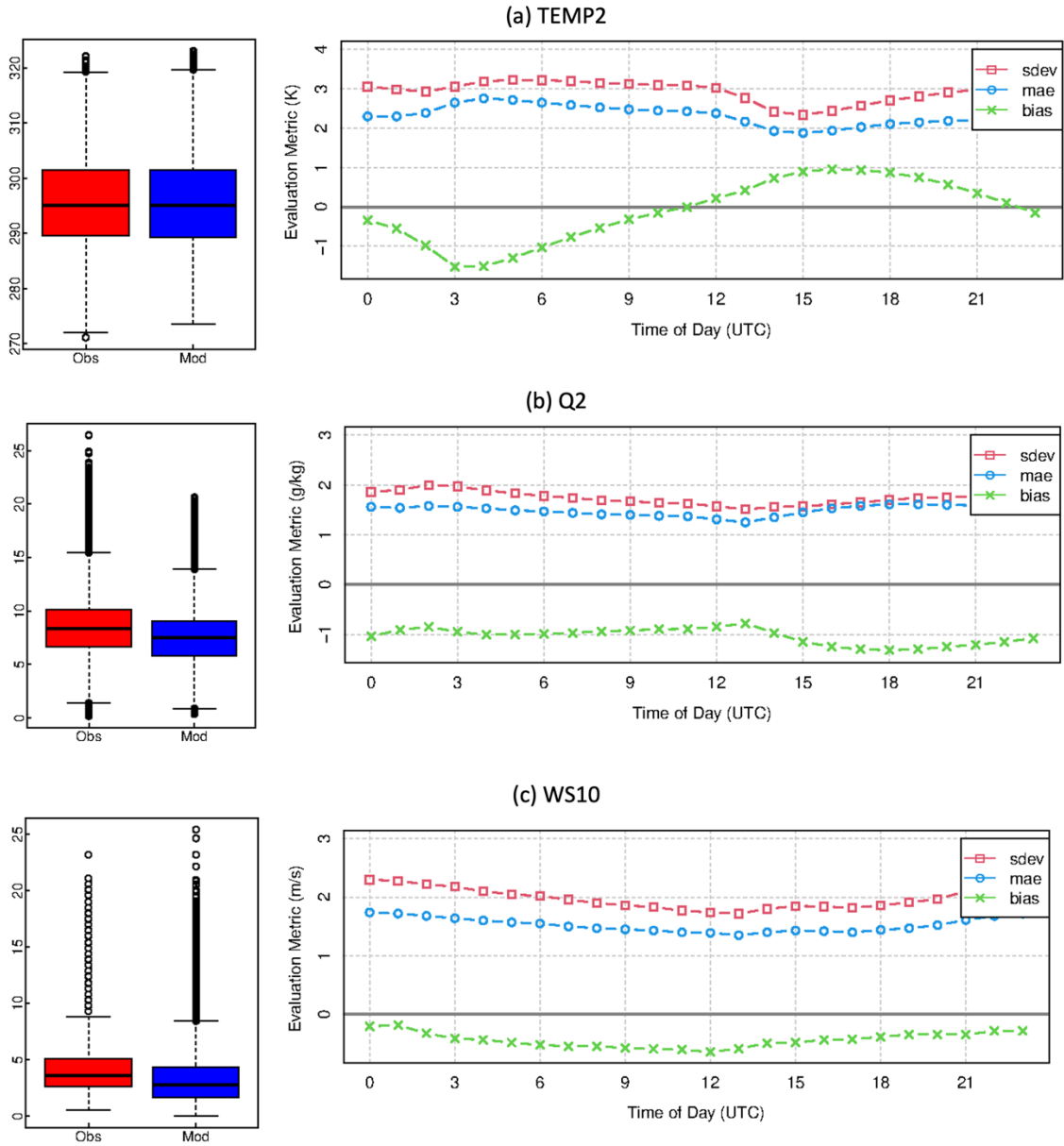
Figure S6: Same as Figure S3 but for the western US (100°W west) of July 2023.
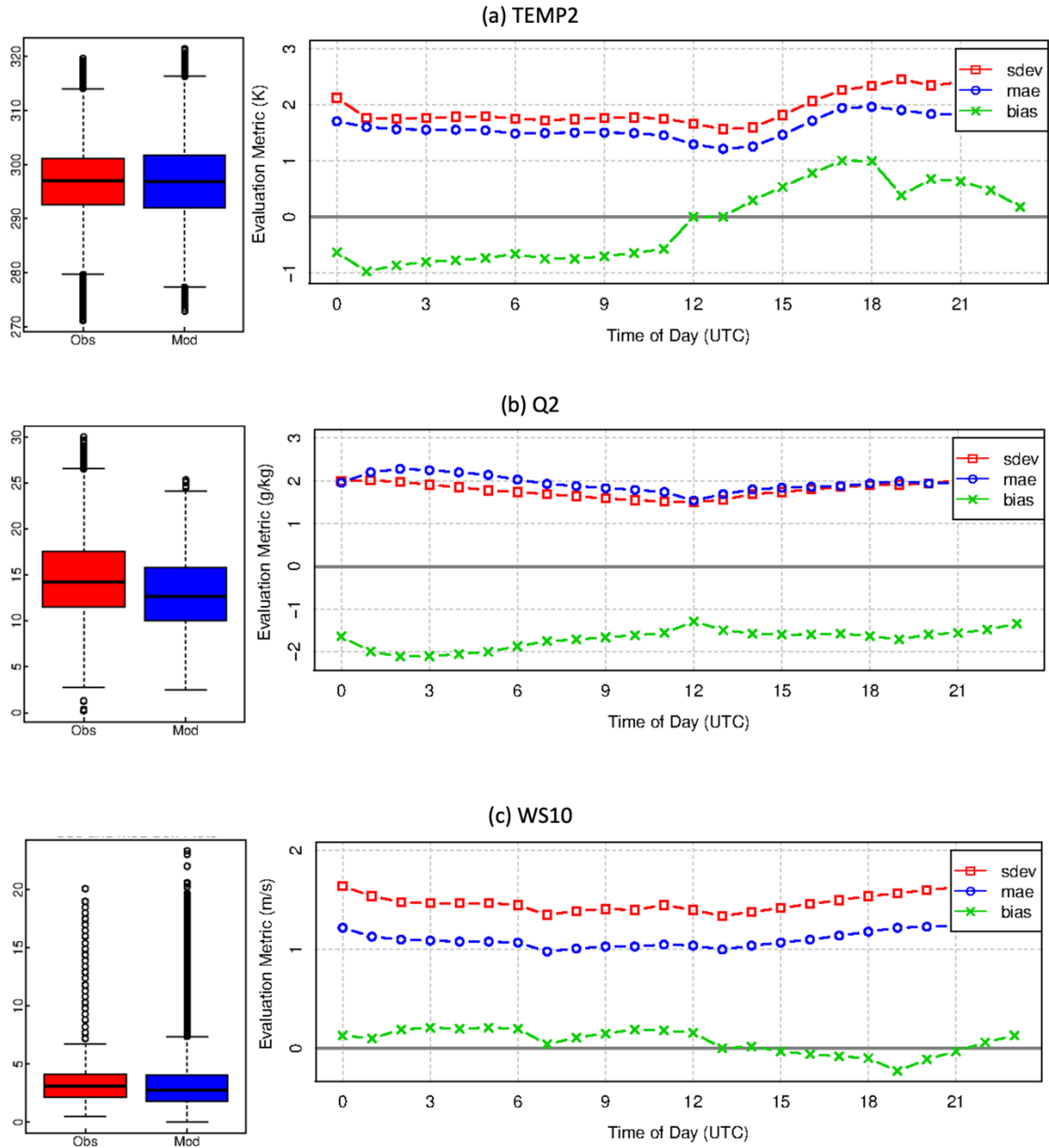
Figure S7: Same as Figure S3 but for the eastern US (100°W east) of August 2023.

(a) TEMP2

(b) Q2

(c) WS10
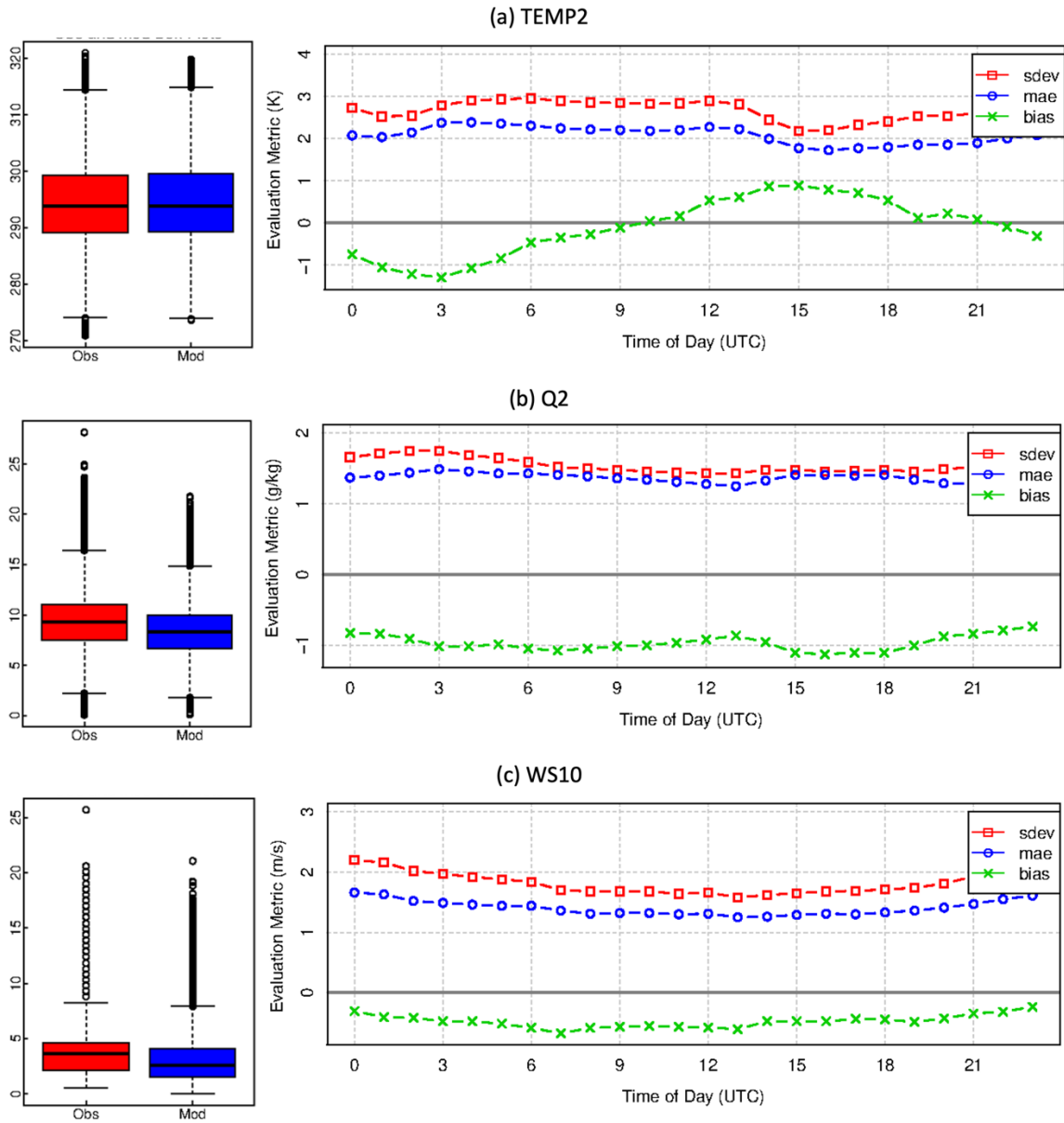
Figure S8: Same as Figure S3 but for the western US (100°W west) of August 2023.
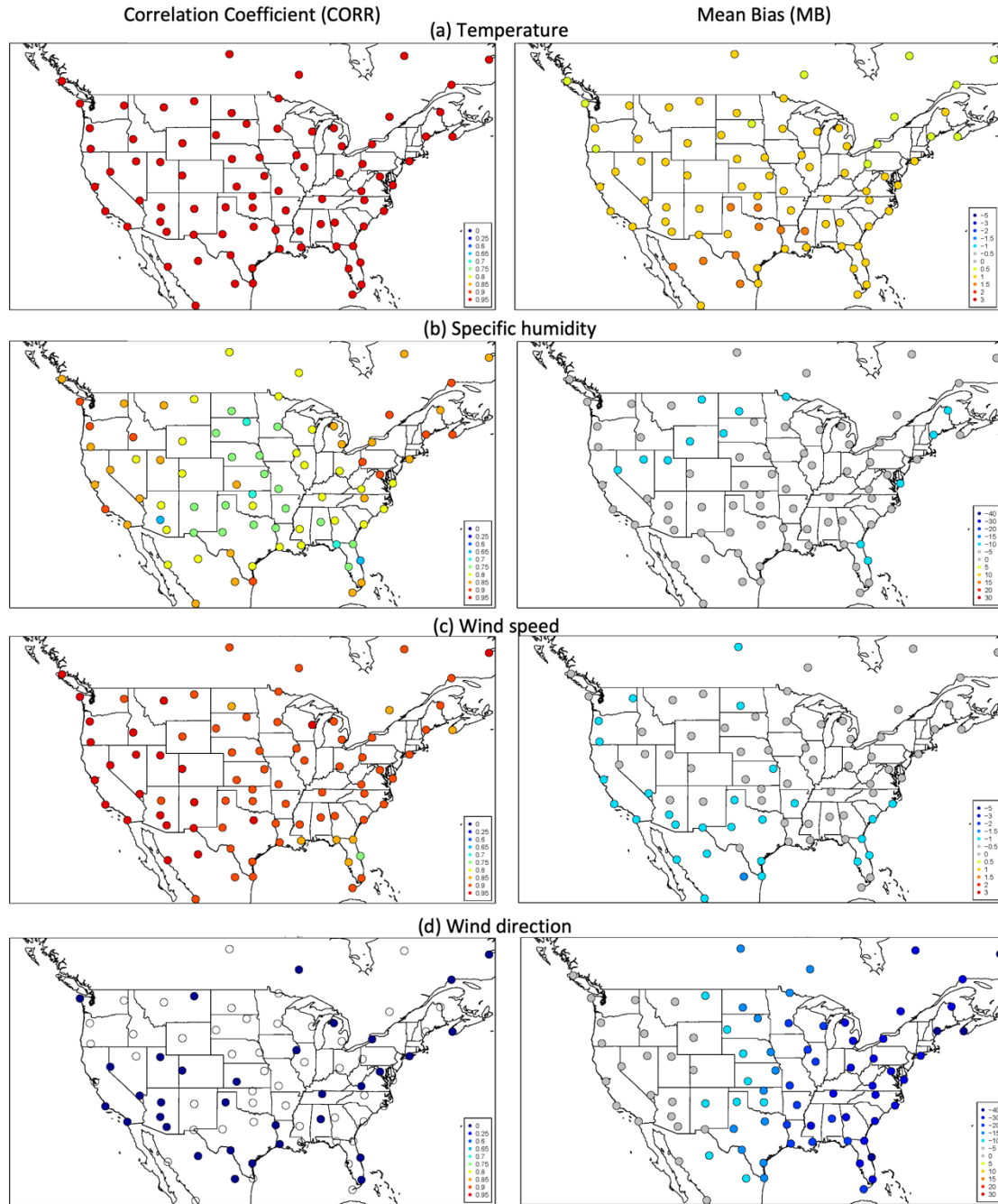
Figure S9: Correlation coefficient (CORR; left column) and mean bias (MB) between GFSv16.3 simulated and observed vertical distributions of temperature (a; °C), specific humidity (b; g/kg), wind speed (c; m/s), and wind direction (d; degree) in June 2023.

Figure S10: Same as Figure S9 but for July 2023.

Correlation Coefficient (CORR)

Mean Bias (MB)

(a) Temperature

(b) Specific humidity

(c) Wind speed

(d) Wind direction
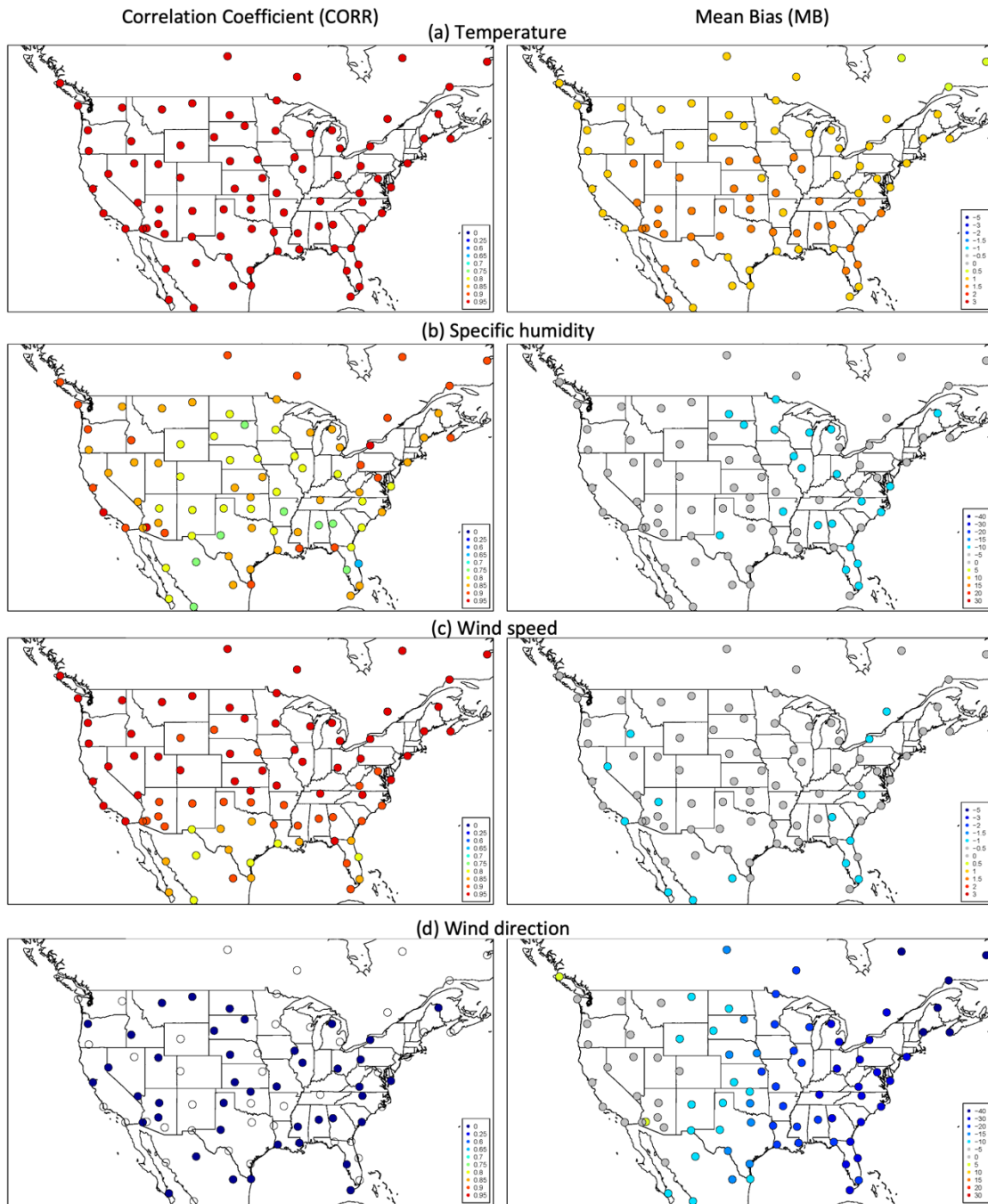
Figure S11: Same as Figure S9 but for August 2023.

Index of Agreement (IOA) Performance Metric Definition

$$\text{Index of Agreement} = 1 - \left[\frac{\sum_{1}^{n}(O - M)^2}{\sum_{1}^{n}\left(|M - \overline{O}| + |O - \overline{O}|\right)^2} \right]$$

M = predicted concentration
O = observed concentration

Table S1: MDA8 O$_3$ evaluation statistics of the AQMv7 and AQMv7_new simulations against the AirNow network in the CONUS and different regions in June 2023. The bold numbers in AQMv7_new indicates an improvement relative to those in AQMv7.

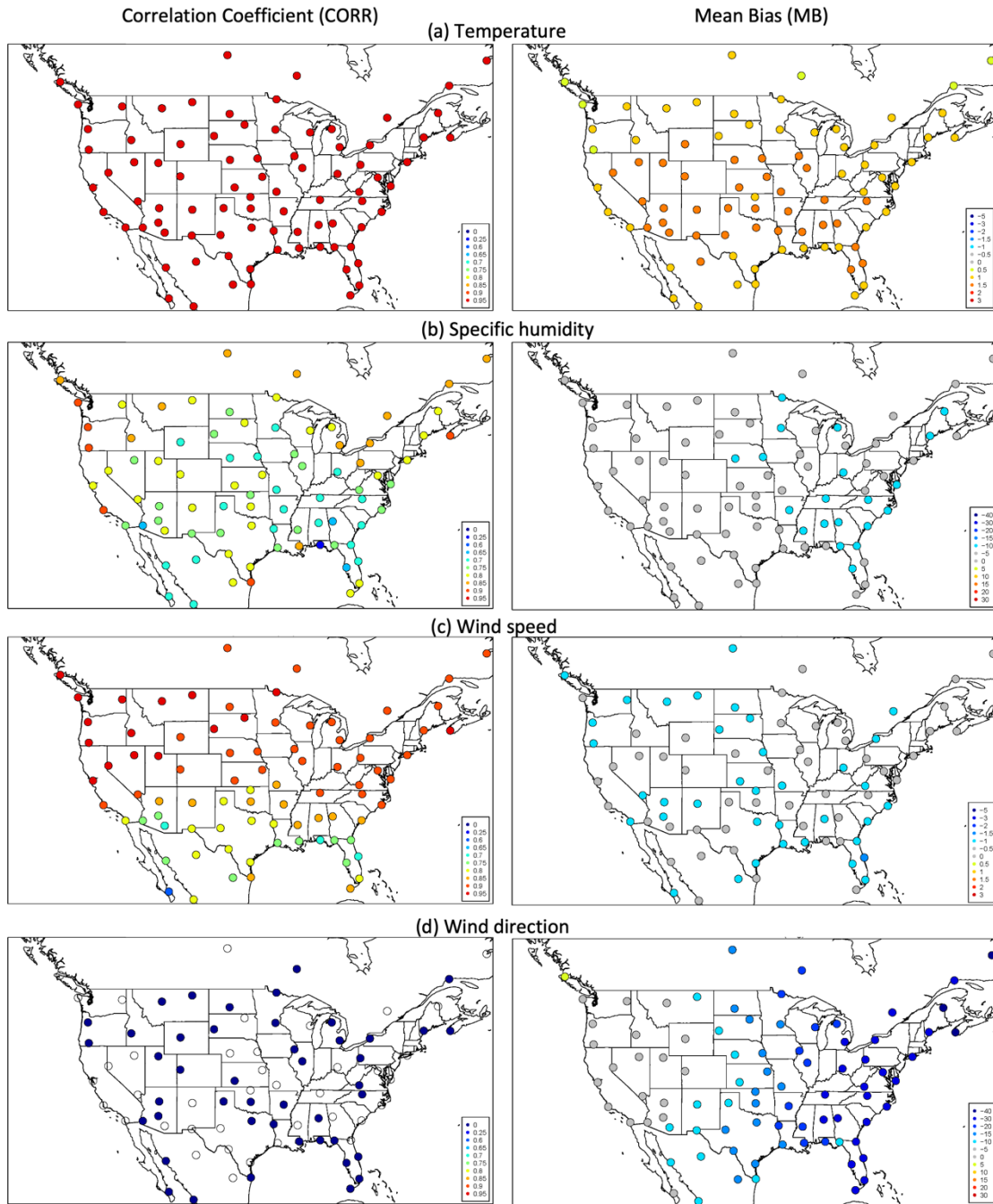| Region	Model	MB (ppb)	NMB (%)	MdnB (ppb)	NMdnB (%)	R^2	RMSE (ppb)	IOA
CONUS	AQMv7	-1.87	-3.82	-2.00	-4.07	0.40	11.12	0.76
	AQMv7_new	-2.10	-4.28	-2.32	-4.71	**0.41**	11.16	**0.78**
Region 1 (northeast)	AQMv7	6.09	15.38	5.71	15.07	0.52	10.98	0.80
	AQMv7_new	**5.75**	**14.50**	**4.99**	**13.18**	0.52	11.12	**0.81**
Region 2 (NY-NJ)	AQMv7	3.55	7.96	3.21	7.43	0.46	10.46	0.80
	AQMv7_new	4.17	9.35	3.28	7.58	**0.47**	11.09	0.80
Region 3 (mid-Atlantic)	AQMv7	-0.99	-1.96	-1.93	-3.22	0.36	9.97	0.76
	AQMv7_new	**-0.72**	**-1.42**	**-1.40**	**-2.76**	0.38	**9.92**	**0.78**
Region 4 (southeast)	AQMv7	1.06	2.19	1.22	2.52	0.43	9.65	0.76
	AQMv7_new	1.21	2.49	**1.08**	**2.22**	0.48	**9.31**	**0.80**
Region 5 (upper Midwest)	AQMv7	-9.50	-17.06	-10.02	-17.90	0.37	14.85	0.67
	AQMv7_new	**-9.46**	**-17.00**	**-9.95**	**-17.77**	0.39	**14.71**	**0.68**
Region 6 (south)	AQMv7	1.10	2.30	0.84	1.72	0.51	9.94	0.77
	AQMv7_new	**0.81**	**1.69**	**0.58**	**1.18**	0.52	**9.70**	**0.81**
Region 7 (central Great Plain)	AQMv7	-13.32	-21.46	-13.57	-22.23	0.21	16.42	0.53
	AQMv7_new	-13.36	-21.52	-13.80	-22.62	**0.24**	**16.39**	**0.55**
Region 8 (northern Great Plain)	AQMv7	-7.11	-13.15	-6.60	-12.14	0.11	11.31	0.54
	AQMv7_new	-7.84	-14.50	-7.47	-13.74	**0.13**	11.77	**0.56**
Region 9 (southwest)	AQMv7	-1.72	-3.45	-1.48	-2.92	0.59	8.43	0.84
	AQMv7_new	-2.51	-5.04	-2.28	-4.51	0.58	8.69	**0.85**
Region 10 (northwest)	AQMv7	-0.69	-1.76	-1.48	-3.83	0.49	7.68	0.82
	AQMv7_new	**-0.65**	**-1.67**	-1.67	-4.34	0.45	8.40	0.81

Table S2: Same as Table S1 but for July.

Region	Model	MB (ppb)	NMB (%)	MdnB (ppb)	NMdnB (%)	R^2	RMSE (ppb)	IOA
CONUS	AQMv7	1.94	4.21	1.60	3.44	0.51	9.48	0.83
	AQMv7_new	**1.79**	**3.89**	**1.42**	**3.07**	0.49	9.91	0.82
Region 1 (northeast)	AQMv7	6.55	14.89	6.13	14.09	0.57	10.80	0.81
	AQMv7_new	7.09	16.13	6.49	14.92	0.55	11.81	0.80
Region 2 (NY-NJ)	AQMv7	4.23	8.82	3.65	7.65	0.51	9.52	0.81
	AQMv7_new	5.37	11.19	4.62	9.67	**0.52**	10.66	0.80
Region 3 (mid-Atlantic)	AQMv7	3.48	7.27	3.40	7.12	0.39	8.92	0.76
	AQMv7_new	4.18	8.71	4.12	8.63	0.38	9.62	0.75
Region 4 (southeast)	AQMv7	7.35	18.04	7.27	17.77	0.55	10.28	0.74
	AQMv7_new	7.56	18.55	7.54	18.41	**0.56**	10.45	**0.76**
Region 5 (upper Midwest)	AQMv7	-3.39	-6.91	-3.25	-6.64	0.43	8.56	0.78
	AQMv7_new	**-3.31**	**-6.73**	-3.44	-7.01	0.43	8.77	**0.79**
Region 6 (south)	AQMv7	4.27	9.99	4.07	9.31	0.63	9.77	0.80
	AQMv7_new	**3.29**	**7.70**	**3.25**	**7.44**	0.57	**9.64**	**0.81**
Region 7 (central Great Plain)	AQMv7	-1.84	-3.75	-2.20	-4.45	0.15	8.40	0.63
	AQMv7_new	-2.69	-5.49	-3.22	-6.50	0.15	8.81	0.62
Region 8 (northern Great Plain)	AQMv7	-3.08	-5.99	-3.47	-6.70	0.37	7.84	0.74
	AQMv7_new	-4.32	-8.42	-4.76	-9.20	**0.40**	8.37	0.74
Region 9 (southwest)	AQMv7	0.44	0.81	-0.06	-0.11	0.61	10.18	0.87
	AQMv7_new	**0.09**	**0.17**	-0.57	-1.04	0.59	10.79	0.87
Region 10 (northwest)	AQMv7	0.59	1.48	0.56	1.45	0.60	7.13	0.87
	AQMv7_new	**0.52**	**1.32**	**0.05**	**0.13**	0.55	7.84	0.86

Table S3: Same as Table S1 but for August.

| Region	Model	MB (ppb)	NMB (%)	MdnB (ppb)	NMdnB (%)	R^2	RMSE (ppb)	IOA
CONUS	AQMv7	5.18	11.89	4.93	11.47	0.50	10.41	0.80
	AQMv7_new	**4.68**	**10.75**	**4.30**	**10.00**	0.48	**10.63**	0.80
Region 1 (northeast)	AQMv7	6.86	18.37	6.12	16.72	0.46	10.15	0.73
	AQMv7_new	6.86	18.39	6.25	17.06	**0.48**	10.36	**0.74**
Region 2 (NY-NJ)	AQMv7	7.64	19.04	6.61	19.68	0.48	11.04	0.73
	AQMv7_new	8.29	20.66	7.12	17.96	0.47	12.07	0.71
Region 3 (mid-Atlantic)	AQMv7	7.24	16.53	7.28	16.68	0.40	10.31	0.68
	AQMv7_new	7.58	17.29	7.56	17.34	0.38	10.92	0.67
Region 4 (southeast)	AQMv7	9.32	22.73	9.16	22.35	0.58	11.54	0.71
	AQMv7_new	**9.10**	**22.19**	**8.95**	**21.82**	0.58	**11.50**	**0.73**
Region 5 (upper Midwest)	AQMv7	5.52	12.78	4.83	11.33	0.44	9.99	0.76
	AQMv7_new	**5.24**	**12.15**	**4.48**	**10.50**	**0.48**	**9.88**	**0.77**
Region 6 (south)	AQMv7	1.19	2.40	1.05	2.08	0.66	8.57	0.86
	AQMv7_new	**-0.09**	**-0.19**	**-0.14**	**-0.27**	0.62	8.72	0.86
Region 7 (central Great Plain)	AQMv7	6.50	13.45	5.16	11.65	0.30	10.20	0.67
	AQMv7_new	**4.89**	**10.88**	**3.67**	**8.30**	0.27	**9.89**	0.67
Region 8 (northern Great Plain)	AQMv7	0.77	1.54	0.23	0.46	0.25	8.67	0.68
	AQMv7_new	-0.99	-2.00	-1.76	-3.52	**0.31**	**8.34**	**0.72**
Region 9 (southwest)	AQMv7	3.04	6.12	2.64	5.26	0.57	9.81	0.84
	AQMv7_new	**2.35**	**4.72**	**1.93**	**3.86**	0.57	10.02	**0.86**
Region 10 (northwest)	AQMv7	4.71	11.17	3.67	8.76	0.54	10.32	0.82
	AQMv7_new	4.94	11.72	**3.17**	**7.57**	0.47	11.76	0.79
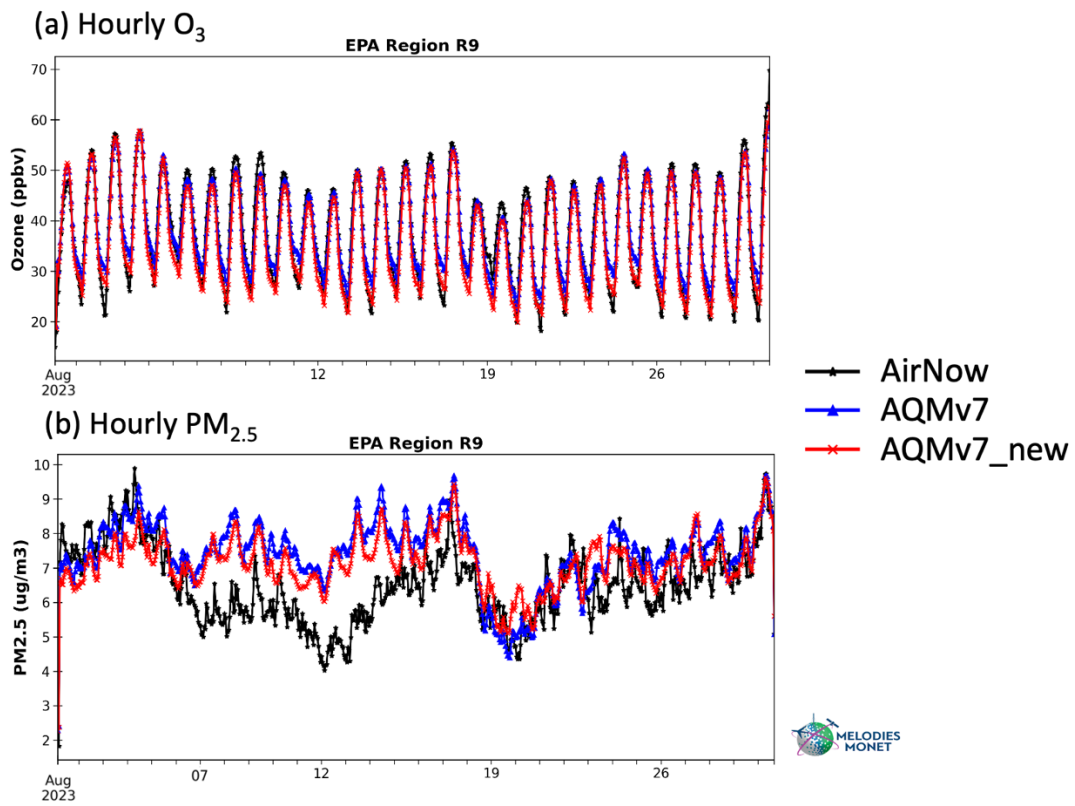
Figure S12: Hourly time series of O₃ and PM₂.₅ average over Region 9 in June 2023.

Table S4: Daily PM₂.₅ evaluation statistics of the AQMv7 and AQMv7_new simulations against the AirNow network in the CONUS and different regions in June 2023. The bold numbers in AQMv7_new indicates an improvement relative to those in AQMv7.

Region	Model	MB (ppb)	NMB (%)	MdnB (ppb)	NMdnB (%)	R^2	RMSE (ppb)	IOA
CONUS	AQMv7	-3.37	-24.74	-0.32	-4.02	0.47	16.02	0.66
	AQMv7_new	-5.03	-36.98	-1.23	-15.28	0.41	17.48	0.56
Region 1 (northeast)	AQMv7	0.73	6.45	2.38	34.37	0.38	11.22	0.71
	AQMv7_new	-2.86	-25.36	**-0.09**	**-1.35**	**0.45**	11.54	0.63
Region 2 (NY-NJ)	AQMv7	-4.99	-22.86	0.94	8.67	0.62	21.18	0.73
	AQMv7_new	-9.03	-41.35	-1.76	-16.24	**0.65**	23.90	0.63
Region 3 (mid-Atlantic)	AQMv7	-10.30	-40.19	-2.99	-18.96	0.64	26.08	0.64
	AQMv7_new	-14.00	-54.66	-6.01	-38.16	**0.66**	28.99	0.55
Region 4 (southeast)	AQMv7	-3.99	-29.66	-2.45	-22.43	0.47	7.82	0.62
	AQMv7_new	-5.34	-39.68	-3.48	-31.68	0.45	8.78	0.57
Region 5 (upper Midwest)	AQMv7	-11.80	-44.53	-5.69	-30.35	0.59	23.46	0.64
	AQMv7_new	-15.32	-57.83	-8.61	-45.89	0.48	27.33	0.51
Region 6 (south)	AQMv7	-2.91	-25.81	-2.05	-20.51	0.22	5.75	0.60
	AQMv7_new	-3.82	-33.92	-2.93	-29.32	0.18	6.39	0.55
Region 7 (central Great Plain)	AQMv7	-3.68	-23.53	-1.42	-11.44	0.44	13.18	0.58
	AQMv7_new	-6.01	-38.39	-3.44	-27.64	0.34	14.88	0.45
Region 8 (northern Great Plain)	AQMv7	-0.42	-6.08	-0.15	-2.57	0.06	6.19	0.46
	AQMv7_new	-0.61	-8.81	-0.29	-5.08	0.02	7.66	0.32
Region 9 (southwest)	AQMv7	0.96	14.84	0.93	15.75	0.22	3.44	0.67
	AQMv7_new	**0.68**	**10.49**	**0.82**	**13.79**	0.21	**3.25**	0.67
Region 10 (northwest)	AQMv7	2.34	54.65	1.94	50.09	0.12	4.06	0.51
	AQMv7_new	**1.74**	**40.59**	**1.44**	**37.20**	0.12	**3.53**	**0.54**

Table S5: Same as Table S3 but for July.

Region	Model	MB (ppb)	NMB (%)	MdnB (ppb)	NMdnB (%)	R^2	RMSE (ppb)	IOA
CONUS	AQMv7	-2.02	-18.96	-0.48	-5.92	0.31	10.65	0.58
	AQMv7_new	-2.78	-26.07	-1.08	-13.33	0.29	10.98	0.55
Region 1 (northeast)	AQMv7	-0.93	9.29	-0.09	-1.00	0.19	5.55	0.56
	AQMv7_new	-2.39	-23.82	-1.39	-15.77	0.13	6.15	0.51
Region 2 (NY-NJ)	AQMv7	-1.33	-11.10	0.31	3.11	0.23	7.06	0.52
	AQMv7_new	-2.55	-21.33	-1.00	-10.16	0.20	7.48	0.50
Region 3 (mid-Atlantic)	AQMv7	-1.43	-12.89	-0.18	-1.90	0.37	5.74	0.58
	AQMv7_new	-2.59	-23.35	-1.18	-12.63	0.29	6.34	0.53
Region 4 (southeast)	AQMv7	-1.97	-17.45	-0.92	-9.86	0.20	6.45	0.52
	AQMv7_new	-2.80	-24.89	-1.55	-16.63	**0.23**	6.65	**0.53**
Region 5 (upper Midwest)	AQMv7	-2.67	-21.23	-0.40	-4.22	0.26	8.83	0.51
	AQMv7_new	-4.29	-34.18	-1.78	-18.97	0.21	9.67	0.46
Region 6 (south)	AQMv7	-1.47	-12.37	-1.22	-11.35	0.61	3.96	0.86
	AQMv7_new	-2.65	-22.31	-2.30	-21.37	0.50	4.87	0.77
Region 7 (central Great Plain)	AQMv7	-2.25	-21.30	-0.87	-10.09	0.20	7.25	0.48
	AQMv7_new	-3.59	-33.99	-2.24	-25.88	0.17	7.90	0.44
Region 8 (northern Great Plain)	AQMv7	-3.16	-35.12	-1.82	-26.62	0.09	9.35	0.41
	AQMv7_new	**-3.10**	**-34.44**	**-1.69**	**-24.79**	0.06	9.47	0.37
Region 9 (southwest)	AQMv7	-0.28	-3.25	-0.14	-1.88	0.18	6.30	0.60
	AQMv7_new	-0.30	-3.58	**-0.06**	**-0.86**	0.17	6.30	0.59
Region 10 (northwest)	AQMv7	0.44	7.58	0.97	22.72	0.08	6.61	0.41
	AQMv7_new	**0.30**	**5.19**	**0.76**	**17.91**	**0.09**	**6.53**	**0.42**

Table S6: Same as Table S3 but for August.

Region	Model	MB (ppb)	NMB (%)	MdnB (ppb)	NMdnB (%)	R^2	RMSE (ppb)	IOA
CONUS	AQMv7	-0.62	-5.52	0.19	2.38	0.17	22.73	0.55
	AQMv7_new	-1.88	-16.60	-0.78	-9.70	0.16	**22.33**	0.55
Region 1 (northeast)	AQMv7	0.89	13.14	1.16	20.42	0.35	3.14	0.74
	AQMv7_new	**-0.85**	**-12.60**	**-0.44**	**-7.73**	0.20	3.48	0.61
Region 2 (NY-NJ)	AQMv7	1.71	20.26	1.71	22.81	0.30	4.00	0.70
	AQMv7_new	**0.01**	**0.17**	**0.05**	**0.62**	0.19	**3.94**	0.65
Region 3 (mid-Atlantic)	AQMv7	1.12	12.00	1.20	14.51	0.39	3.61	0.76
	AQMv7_new	**-0.70**	**-7.47**	**-0.47**	**-5.70**	0.32	3.67	0.72
Region 4 (southeast)	AQMv7	0.19	1.96	0.42	4.74	0.47	3.17	0.81
	AQMv7_new	-0.89	-9.07	-0.56	-6.41	0.42	3.39	0.77
Region 5 (upper Midwest)	AQMv7	0.50	4.26	0.81	7.45	0.28	6.37	0.71
	AQMv7_new	-2.54	-21.61	-1.96	-17.97	0.27	**5.99**	0.68
Region 6 (south)	AQMv7	-1.38	-13.62	-1.19	-12.23	0.42	3.80	0.77
	AQMv7_new	-2.20	-21.69	-2.18	-22.33	0.39	4.23	0.72
Region 7 (central Great Plain)	AQMv7	0.89	8.83	1.04	11.31	0.21	5.24	0.65
	AQMv7_new	-1.35	-13.39	**-1.00**	**-10.92**	0.18	**5.03**	0.63
Region 8 (northern Great Plain)	AQMv7	-1.72	-19.91	-0.84	-13.36	0.12	9.26	0.54
	AQMv7_new	-1.96	-22.70	-0.94	-14.96	0.08	9.80	0.48
Region 9 (southwest)	AQMv7	-0.14	-1.81	0.30	4.66	0.23	7.17	0.59
	AQMv7_new	-0.19	-2.48	**0.24**	**3.79**	0.22	7.20	0.58
Region 10 (northwest)	AQMv7	-3.28	-19.08	0.02	0.24	0.21	38.19	0.62
	AQMv7_new	-4.03	-23.41	-0.11	-1.44	0.21	**36.39**	**0.63**
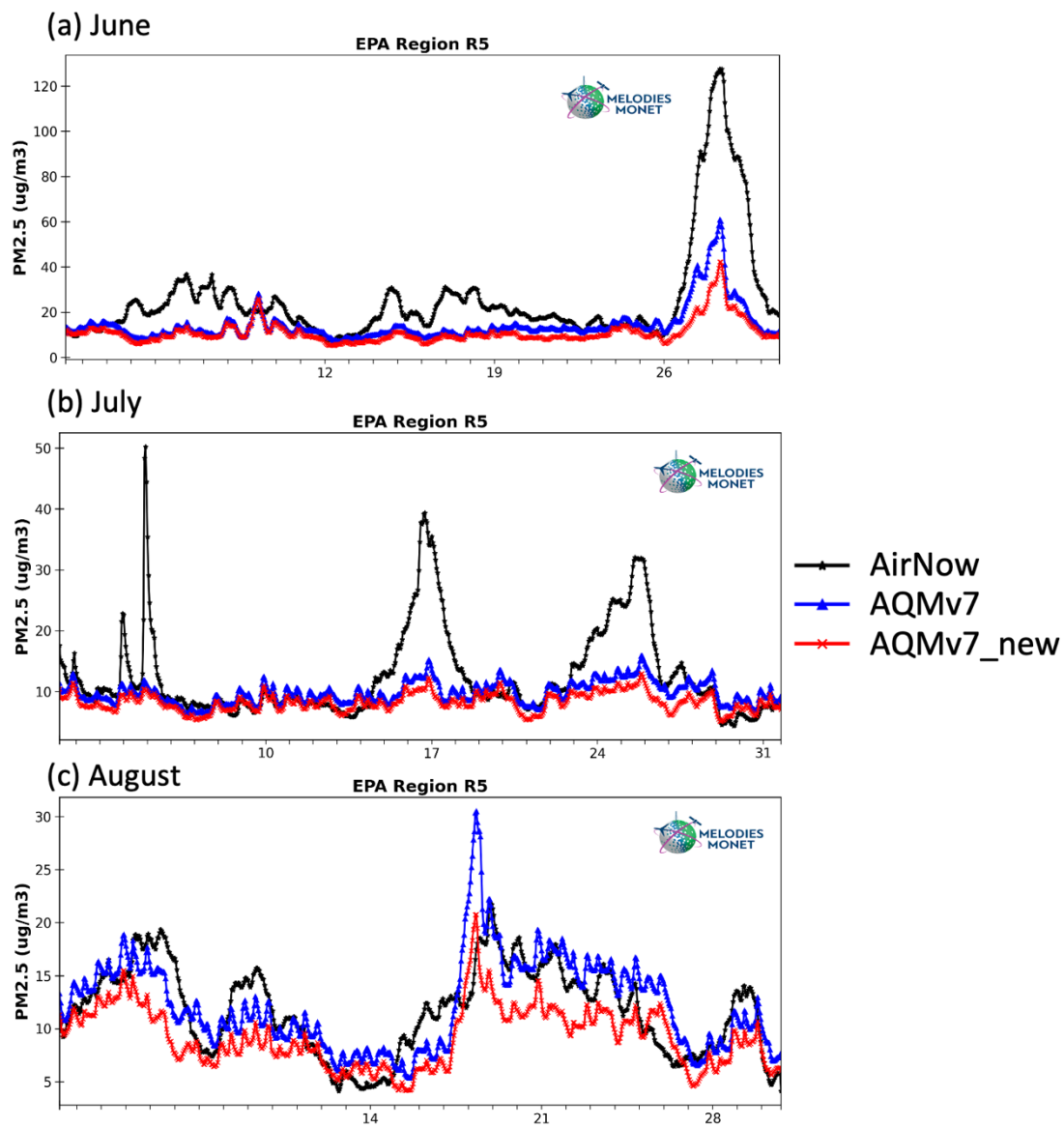
Figure S13: Hourly time series of and PM$_{2.5}$ average over Region 5 in June (a), July (b) and August (c) of 2023.