Evaluating wildfire emissions projection methods in comparisons of simulated and observed air quality

Uma Shankar[1], Donald McKenzie[2], Jeffrey P. Prestemon[3], Bok Haeng Baek[4], Mohammed Omary[4], Dongmei Yang[4], Aijun Xiu[4], Kevin Talgo[5], William Vizuete[1]

[1]Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, NC, 27599-7431, USA
[2] School of Environmental and Forest Sciences, University of Washington, Seattle, WA, 98195, USA
[3]USDA Forest Service, Southern Research Station, Research Triangle Park, North Carolina, 27709, USA
[4]University of North Carolina at Chapel Hill—Institute for the Environment, Chapel Hill, NC, 27517, USA
[5]CSRA Incorporated, Research Triangle Park, North Carolina, 27709, USA

Correspondence to: William Vizuete (airquality@unc.edu)

Supplemental Tables and Figures

Table S1. Model performance statistics for monthly-averaged ozone vs. AQS✦ observations

Month	Ozone (ppb)				NME⅄ (%)			NMB✖ (%)		
	AQS	Stat. d-s†	Dyn. d-s‡	NEI Bmrk*	Stat. d-s	Dyn. d-s	NEI Bmrk	Stat. d-s	Dyn. d-s	NEI Bmrk
Jan	24.4	25.3	25.3	25.3	38.4	38.4	38.4	3.6	3.6	3.6
Feb	28.2	28.9	28.9	28.9	33.3	33.3	33.3	2.4	2.4	2.4
Mar	34.0	37.1	37.1	37.1	31.5	31.5	31.5	9.0	9.0	9.1
Apr	38.4	41.9	41.8	41.8	28.4	28.4	28.4	9.2	9.0	8.8
May	32.9	40.3	40.3	40.2	39.1	39.1	39.0	22.7	22.6	22.4
Jun	30.6	37.5	37.4	37.4	38.6	38.5	38.4	22.7	22.5	22.3
Jul	29.0	36.5	36.3	36.2	41.9	41.7	41.5	25.5	25.0	24.5
Aug	30.7	39.1	39.0	38.7	45.5	45.3	45.0	27.3	26.8	26.2
Sep	30.0	34.8	34.6	34.4	40.0	39.9	39.6	16.0	15.5	14.8
Oct	30.2	32.6	32.3	32.2	37.7	37.8	37.8	8.0	6.8	6.7
Nov	25.0	29.3	29.2	29.2	43.3	43.2	43.2	17.2	16.8	16.7
Dec	24.0	24.4	24.4	24.4	35.3	35.3	35.3	1.8	1.8	1.8

Symbols key: ✦AQS: Air Quality System; ⅄Normalized Mean Error; ✖Normalized Mean Bias; †Statistical d-s; ‡Dynamical d-s; *NEI Benchmark.

Table S2. Model performance statistics for monthly-averaged total $PM_{2.5}$ vs. IMPROVE✦ observations

	Total $PM_{2.5}$ (μg m^{-3})				NME⅄ (%)			NMB✕ (%)		
Month	**IMPROVE**	**Stat. d-s†**	**Dyn. d-s‡**	**NEI Bmrk***	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk***	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**
Jan	7.0	11.5	11.5	11.5	75.9	75.9	75.9	65.1	65.1	65.1
Feb	8.4	13.7	13.7	13.7	71.7	71.7	71.7	63.1	63.1	63.1
Mar	7.2	10.8	10.8	10.8	64.7	64.8	64.7	50.0	49.9	49.9
Apr	8.5	9.3	9.1	9.0	43.4	42.2	41.7	9.2	6.6	5.3
May	7.6	7.4	7.2	7.1	47.5	47.1	46.0	-3.0	-4.9	-7.3
Jun	8.8	7.1	7.0	6.8	36.9	36.5	37.9	-19.8	-20.8	-23.4
Jul	9.8	8.2	7.5	7.6	41.2	40.0	40.2	-16.3	-23.7	-22.6
Aug	9.5	9.0	8.5	8.2	41.0	39.7	38.6	-5.2	-10.1	-13.3
Sep	7.6	9.9	9.5	8.7	61.6	57.2	48.8	30.6	24.8	15.2
Oct	6.9	10.8	10.2	10.1	69.0	63.0	61.1	56.2	47.9	45.7
Nov	6.5	10.9	10.5	10.5	79.4	78.3	74.9	67.3	64.4	61.6
Dec	8.0	10.9	11.3	10.9	46.6	45.7	46.6	36.4	35.5	36.4

Symbols key: ✦Interagency Monitoring of Protected Visual Environments network; ⅄Normalized Mean Error; ✕Normalized Mean Bias; †Statistical d-s; ‡Dynamical d-s; *NEI Benchmark.

Table S3. Model performance statistics for monthly-averaged sulfate (SO_4) vs. IMPROVE✦ observations

	SO_4 (μg m^{-3})				NME⅄ (%)			NMB⅄ (%)		
Month	**IMPROVE**	**Stat. d-s†**	**Dyn. d-s‡**	**NEI Bmrk⋆**	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**
Jan	1.7	2.4	2.4	2.4	53.6	53.6	53.6	37.6	37.6	37.6
Feb	2.4	2.9	2.9	2.9	45.7	45.7	45.7	22.8	22.8	22.8
Mar	2.0	3.5	3.5	3.6	83.7	83.7	83.9	77.2	77.2	77.3
Apr	2.2	4.1	4.1	4.1	89.4	89.3	89.2	81.8	81.5	81.4
May	2.4	3.9	3.9	3.9	77.1	76.9	76.6	63.3	63.1	62.6
Jun	2.6	3.9	3.9	3.9	56.6	58.3	56.3	47.9	49.2	47.4
Jul	2.9	4.5	4.4	4.5	66.0	61.9	65.8	56.4	51.4	56.1
Aug	3.0	4.9	4.8	4.9	72.6	72.4	70.6	61.0	60.6	58.9
Sep	2.1	4.4	4.4	4.4	113.0	113.0	113.0	107.0	107.0	107.0
Oct	1.7	3.8	3.8	3.8	126.0	126.0	125.0	123.0	122.0	122.0
Nov	1.5	3.1	3.1	3.1	116.0	116.0	115.0	107.0	107.0	106.0
Dec	1.9	1.9	2.0	1.9	38.7	38.3	38.7	-1.4	0.6	-1.4

Symbols key: ✦Interagency Monitoring of Protected Visual Environments network; ⅄Normalized Mean Error; ⋆Normalized Mean Bias; †Statistical d-s; ‡Dynamical d-s; **⋆**NEI Benchmark.

Table S4. Model performance statistics for monthly-averaged ammonium (NH_4) vs. IMPROVE✦ observations

	NH_4 (μg m^{-3})				NME⅄ (%)			NMB✖ (%)		
Month	**IMPROVE**	**Stat. d-s†**	**Dyn. d-s‡**	**NEI Bmrk***	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**
Jan	1.2	1.3	1.3	1.3	40.4	40.4	40.4	8.6	8.6	8.6
Feb	1.6	2.0	2.0	2.0	44.8	44.8	44.8	25.6	25.6	25.6
Mar	1.1	1.7	1.7	1.7	68.0	68.0	68.1	53.7	53.7	53.7
Apr	1.0	1.5	1.4	1.4	67.7	67.0	66.3	42.2	41.1	40.4
May	1.0	1.1	1.1	1.1	57.0	56.6	56.2	7.4	6.6	5.5
Jun	1.1	1.1	1.1	1.1	47.1	48.0	47.2	7.4	8.0	6.4
Jul	1.2	1.3	1.3	1.3	49.7	45.7	48.9	15.0	7.8	11.7
Aug	1.2	1.3	1.3	1.3	54.7	54.6	53.5	9.3	8.0	7.3
Sep	0.9	1.3	1.3	1.2	75.0	73.3	69.1	48.7	46.8	42.2
Oct	0.7	1.3	1.3	1.3	93.8	92.2	91.8	80.0	78.2	77.6
Nov	0.8	1.4	1.4	1.4	97.4	97.2	95.8	81.2	79.4	79.4
Dec	1.3	1.1	1.1	1.1	31.7	31.5	31.7	-16.2	-16.8	-16.2

Symbols key: ✦Interagency Monitoring of Protected Visual Environments network; ⅄Normalized Mean Error; ✖Normalized Mean Bias; †Statistical d-s; ‡Dynamical d-s; *NEI Benchmark.

Table S5. Model performance statistics for monthly-averaged nitrate (NO_3) vs. IMPROVE✦ observations

	NO_3 (μg m^{-3})				NME⅄ (%)			NMB✖ (%)		
Month	**IMPROVE**	**Stat. d-s†**	**Dyn. d-s‡**	**NEI Bmrk✶**	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**	**Stat. d-s**	**Dyn. d-s**	**NEI Bmrk**
Jan	1.8	2.4	2.4	2.4	77.4	77.4	77.4	36.2	36.2	36.2
Feb	2.3	3.9	3.9	3.9	87.8	87.8	87.8	68.2	68.2	68.2
Mar	1.2	2.4	2.4	2.4	132.0	132.0	132.0	109.0	109.0	109.0
Apr	0.6	1.0	1.0	1.0	134.0	132.0	130.0	66.1	63.0	61.1
May	0.4	0.5	0.5	0.5	123.0	121.0	118.0	35.0	32.2	28.7
Jun	0.2	0.3	0.3	0.3	140.0	141.0	139.0	44.9	41.3	41.6
Jul	0.2	0.4	0.3	0.4	168.0	146.0	164.0	59.5	31.7	52.2
Aug	0.2	0.4	0.4	0.4	207.0	200.0	198.0	110.0	102.0	95.3
Sep	0.2	0.5	0.5	0.5	238.0	232.0	216.0	154.0	146.0	128.0
Oct	0.3	1.1	1.1	1.1	278.0	270.0	267.0	234.0	223.0	220.0
Nov	0.8	2.0	2.0	2.0	189.0	182.0	185.0	165.0	157.0	160.0
Dec	1.8	2.2	2.2	2.2	55.5	52.6	55.5	18.4	14.2	18.4

Symbols key: ✦Interagency Monitoring of Protected Visual Environments network; ⅄Normalized Mean Error; ✖Normalized Mean Bias; †Statistical d-s; ‡Dynamical d-s; ✶NEI Benchmark.

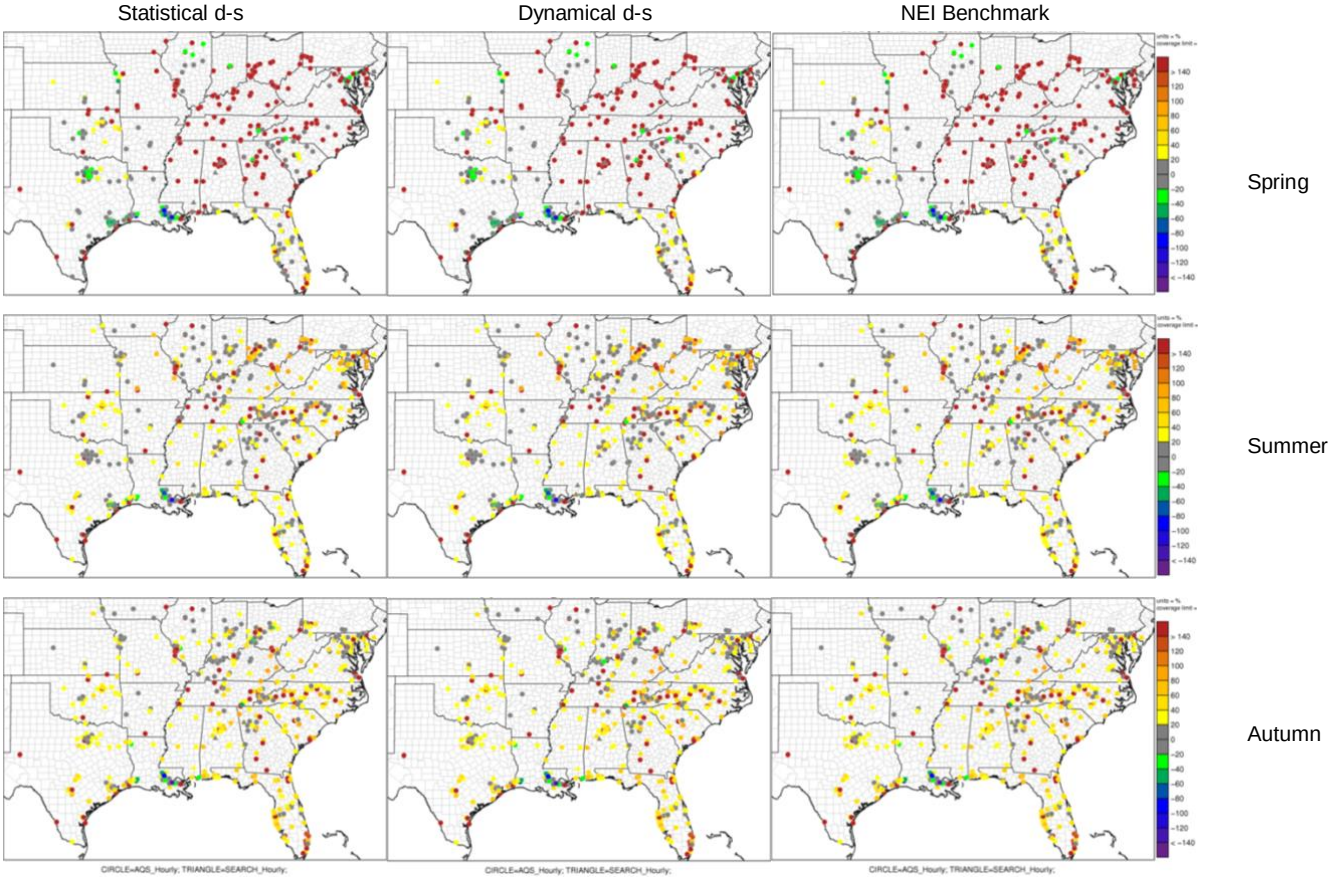

Figure S1. Spatial distribution of hourly ozone Mean Fractional Bias with respect to AQS and SEARCH measurements in each season for each modeled case.

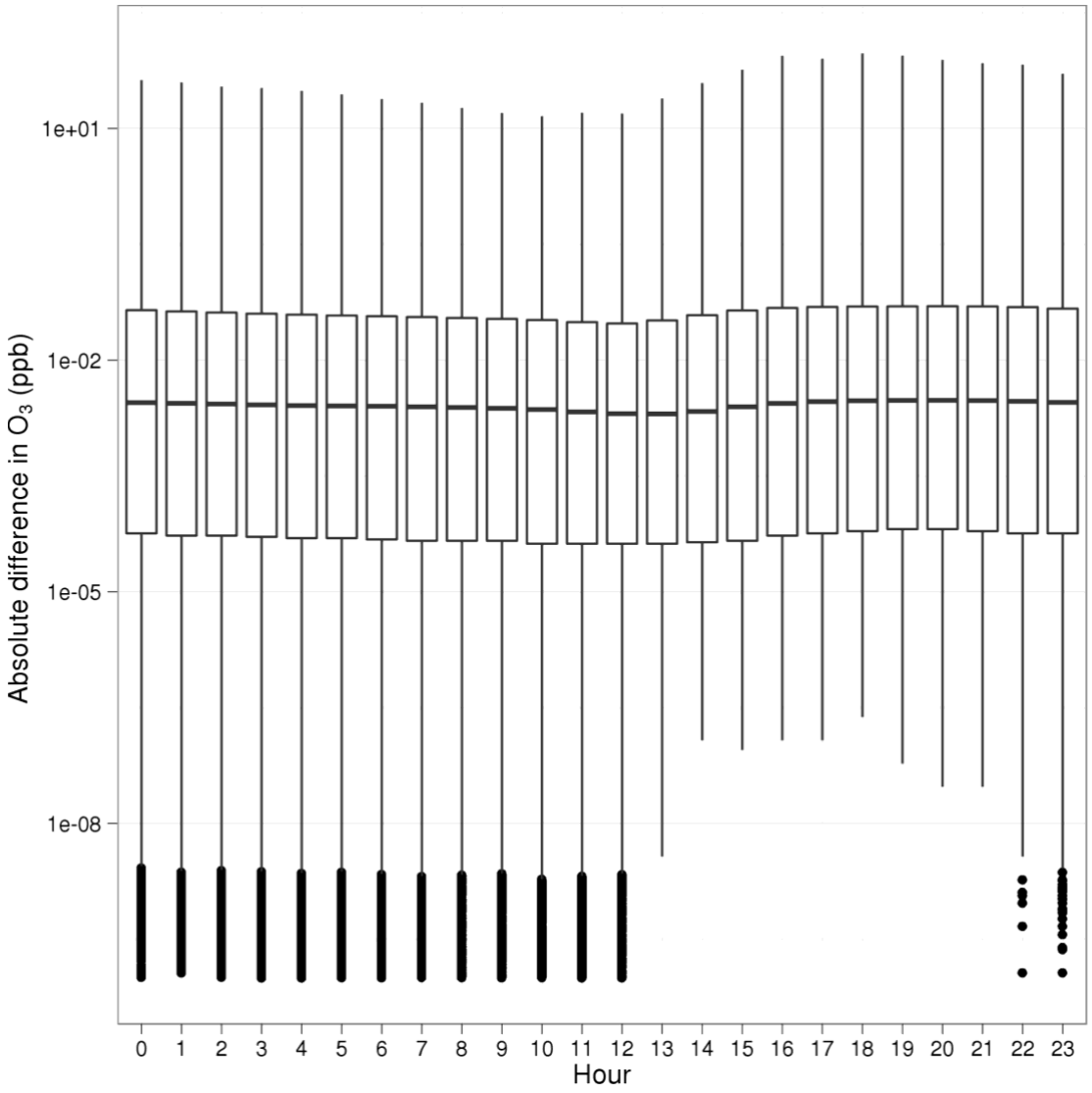

Figure S2. Absolute difference between the statistical d-s and dynamical d-s cases in 1-h O_3 mixing ratios (ppb) from Hour 0 - 23 (local standard time) for the 2010 fire season (March 1 – November 30) over the whole domain (level 1).

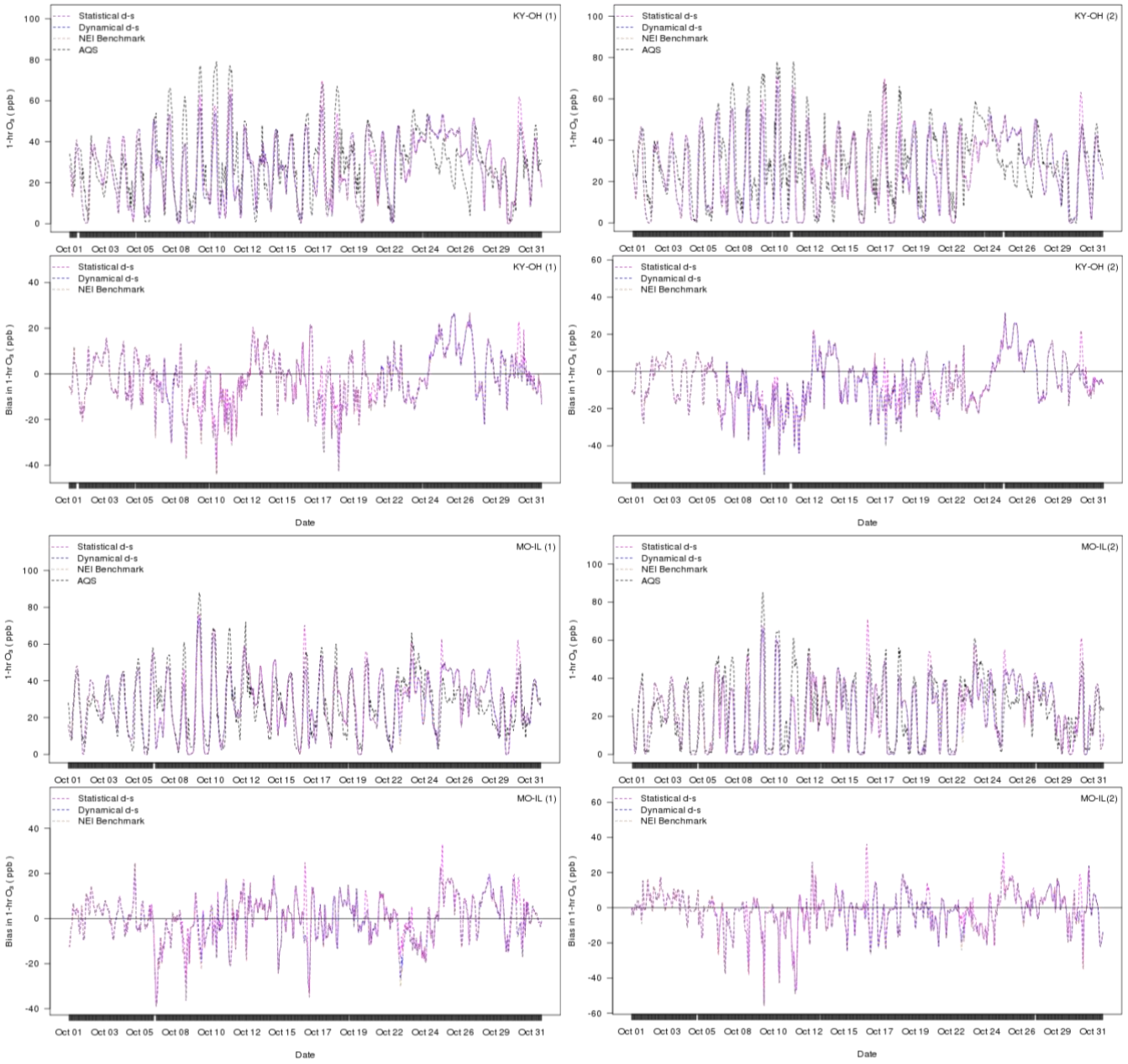

Figure S3. 1-h ozone mixing ratios (ppb) and bias (ppb) relative to AQS observations at four sites in October 2010. UL – KY-OH (1): site 210590005, located on the KY-OH border; UR – KY-OH (2): site 210910012, located on the KY-OH border; LL – MO-IL (1): site 291831002 located on the MO-IL border; LR – MO-IL (2): site 295100085 located on the MO-IL border.

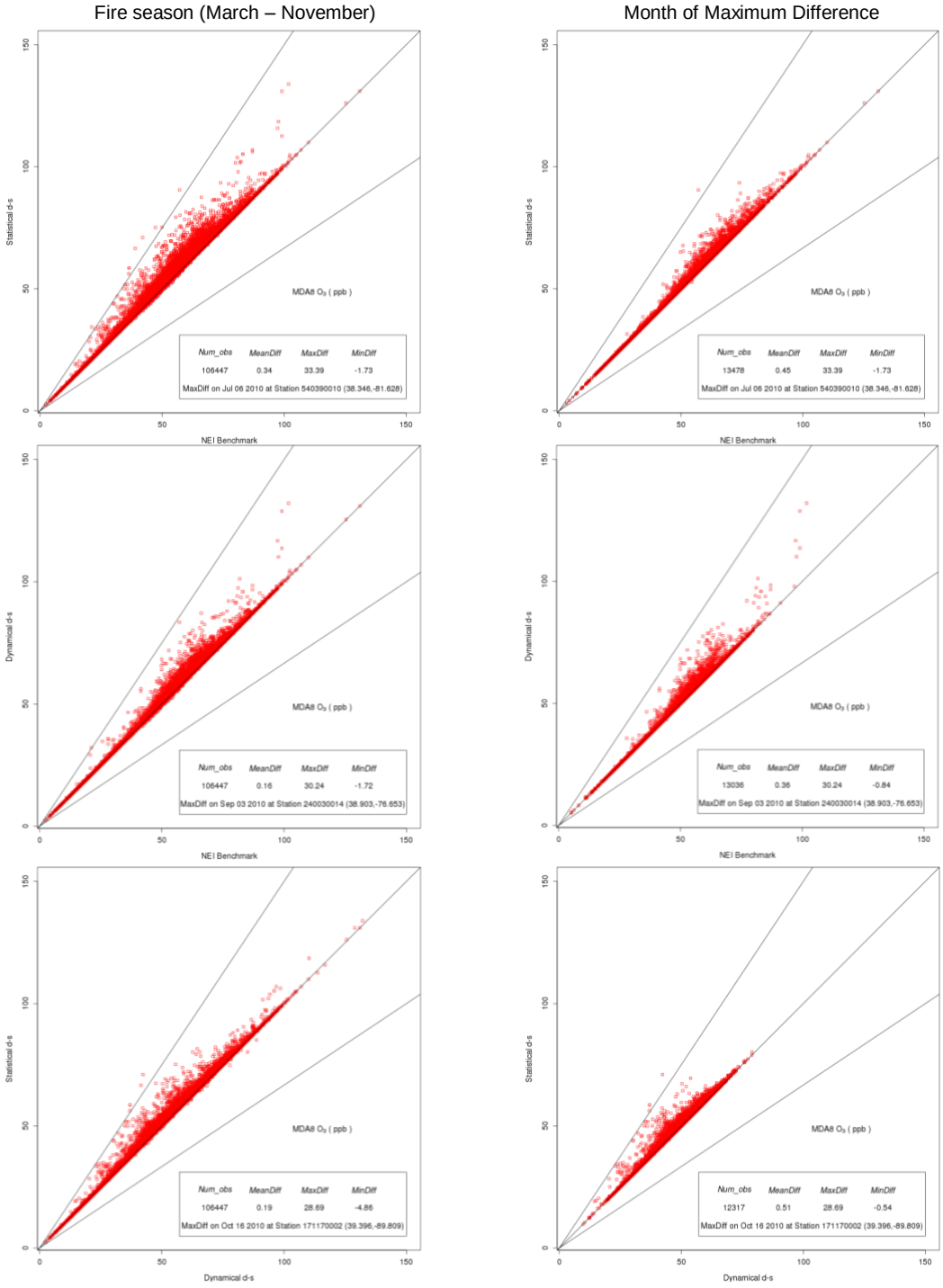

Figure S4. Comparisons of wildfire emissions methods for daily maximum 8-h average (MDA8) O_3 (ppb) predicted at grid cells containing Air Quality System (AQS) monitors and wildfires in 2010. Right: top – July; middle – September; bottom – October.

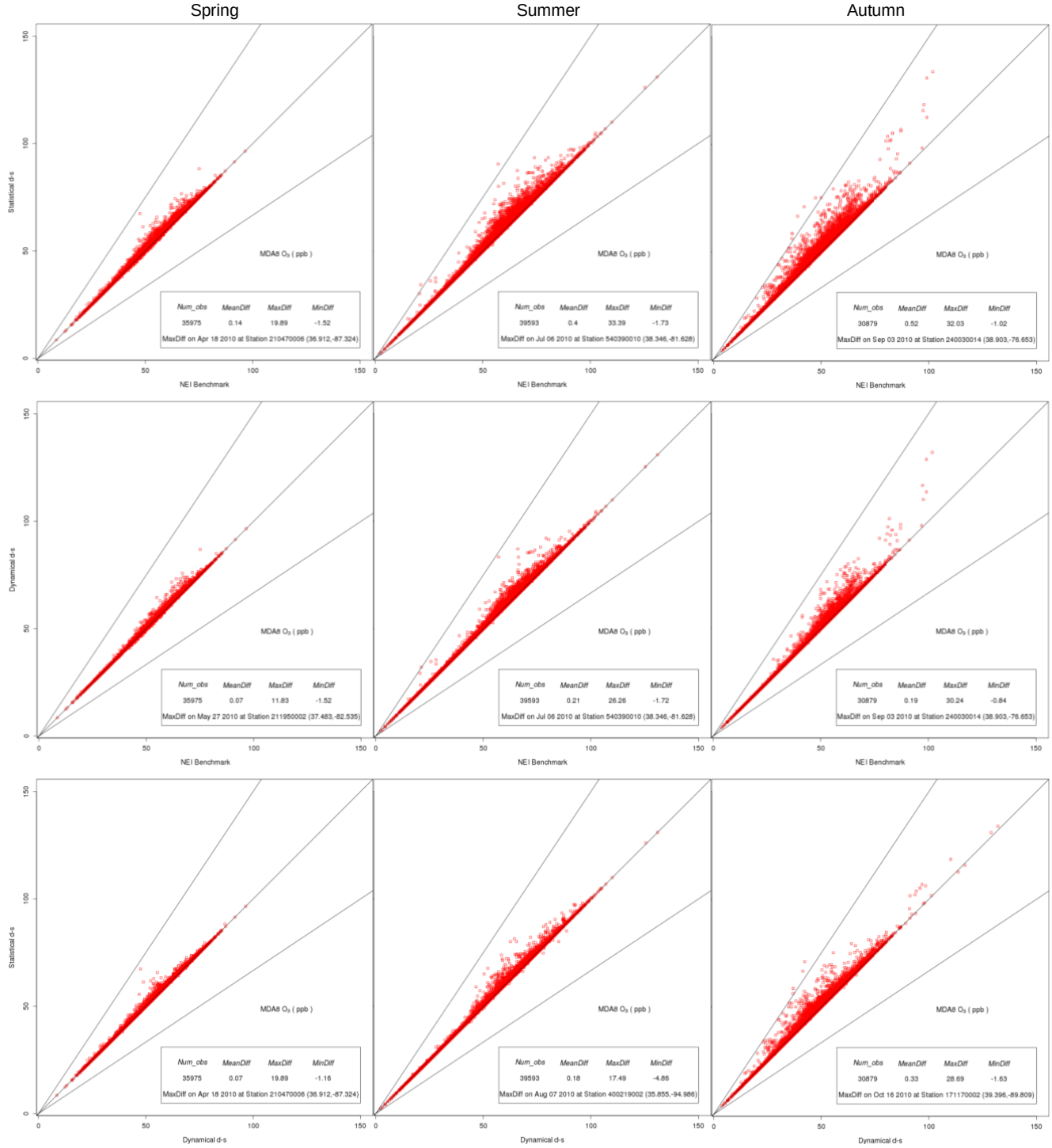

Figure S5. Seasonal comparisons of wildfire emissions for daily maximum 8-h average (MDA8) O_3 (ppb) at grid cells containing both Air Quality System (AQS) monitors and wildfires in 2010.

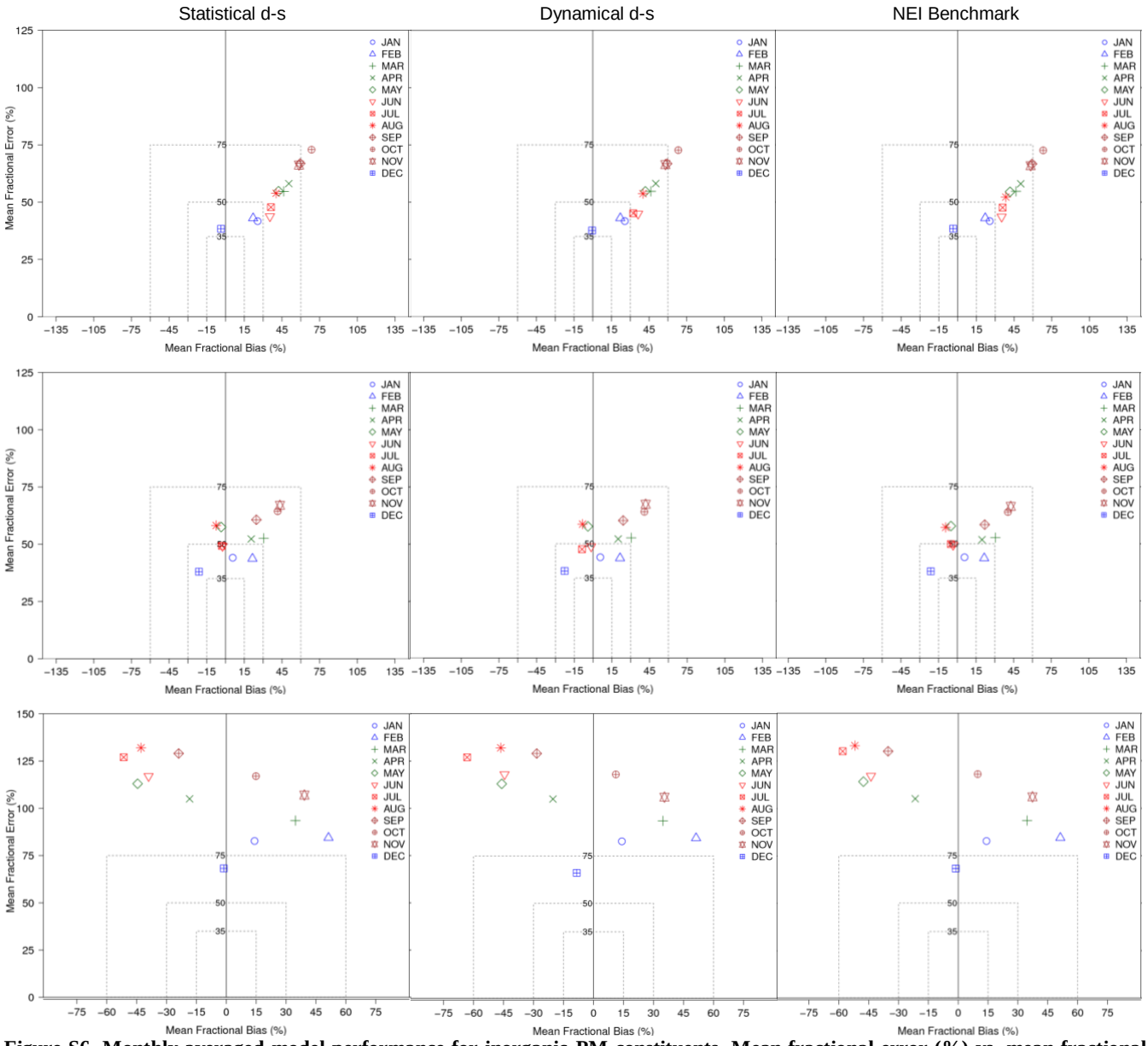

Figure S6. Monthly-averaged model performance for inorganic PM constituents. Mean fractional error (%) vs. mean fractional bias (%) relative to observations from the IMPROVE monitoring network for: Top row: sulfate (SO_4); middle row: ammonium (NH_4); bottom row: nitrate (NO_3).

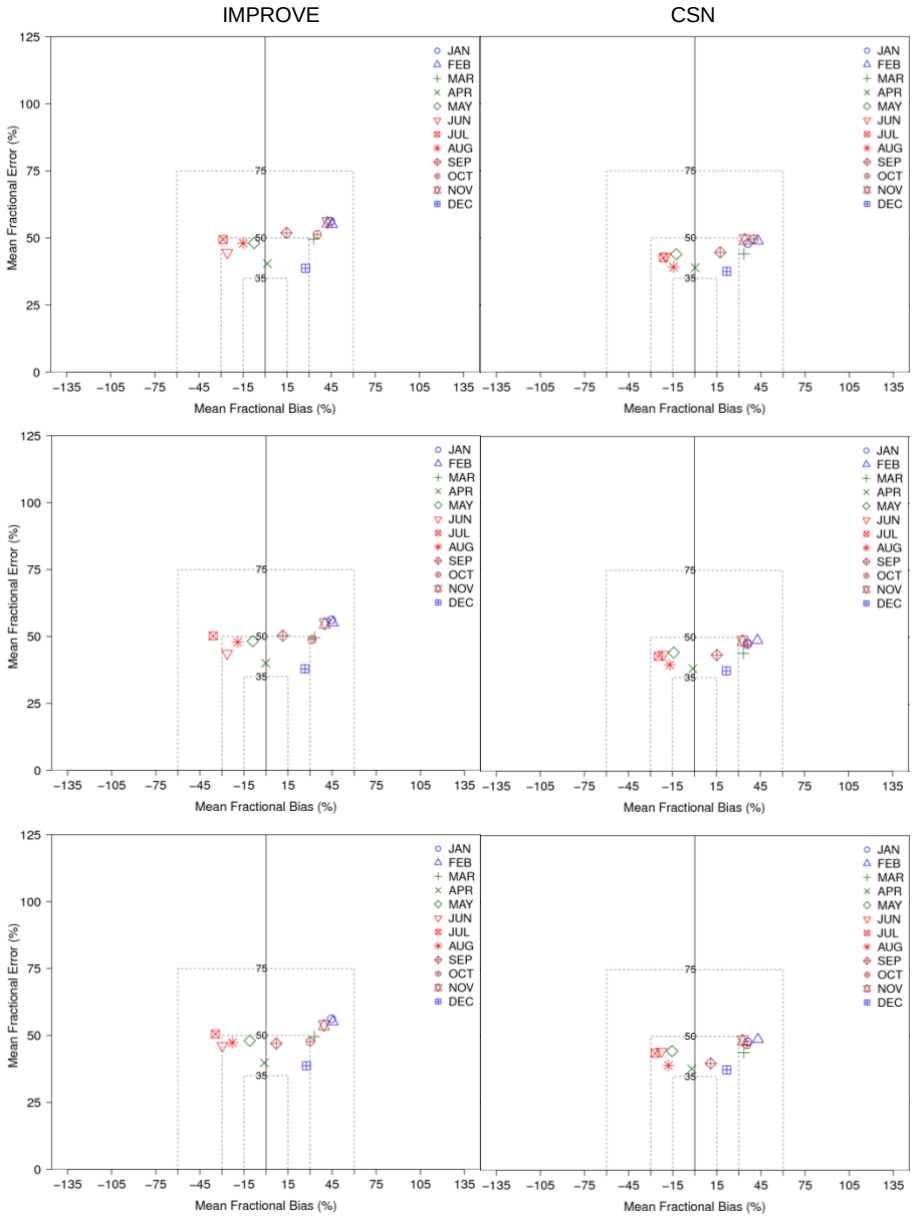

Figure S7. Monthly-averaged model performance comparisons for total $PM_{2.5}$ between the IMPROVE and CSN monitoring networks.

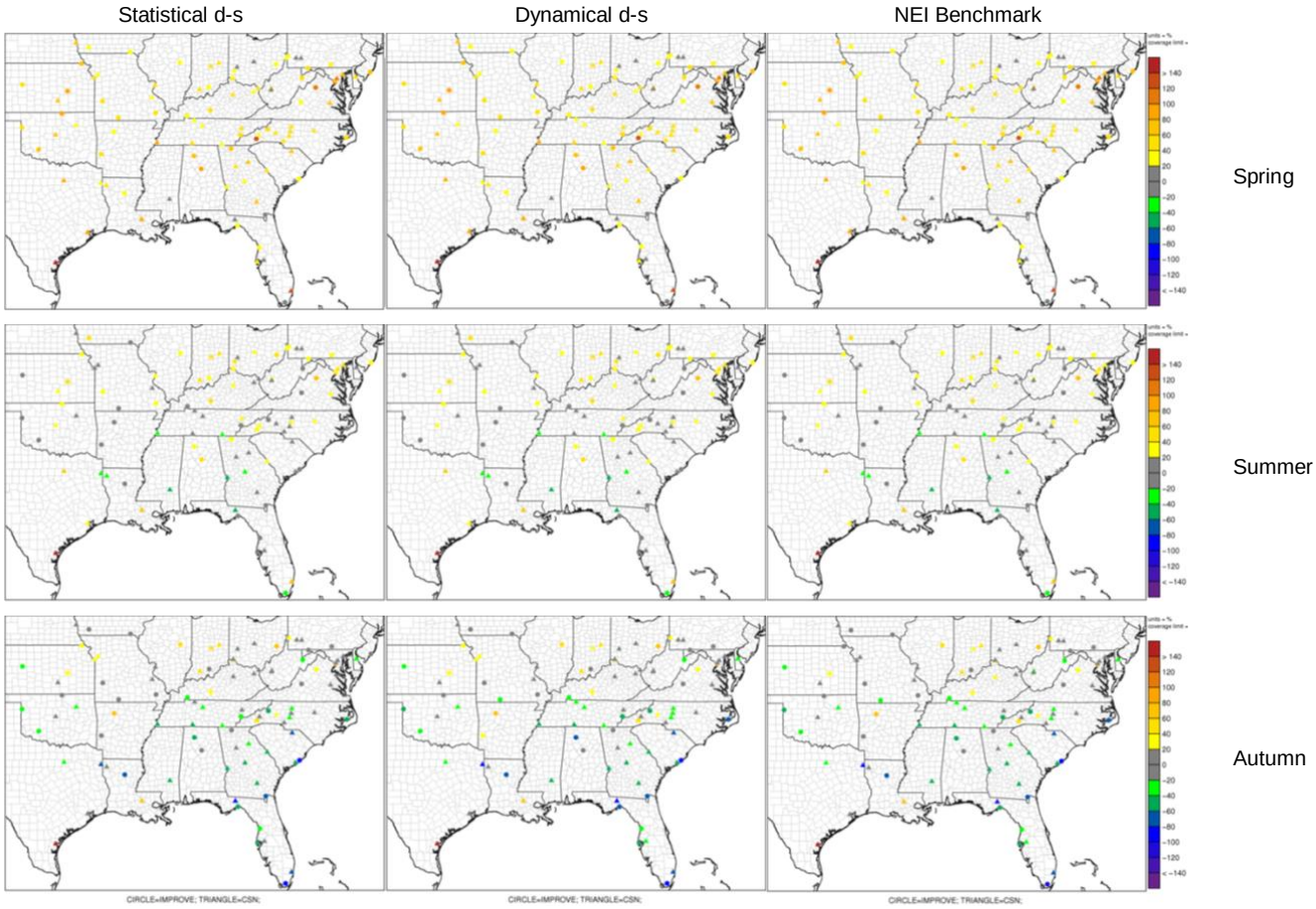

Figure S8. Spatial distribution of total $PM_{2.5}$ Mean Fractional Bias with respect to IMPROVE and CSN measurements in each season for each modeled case.

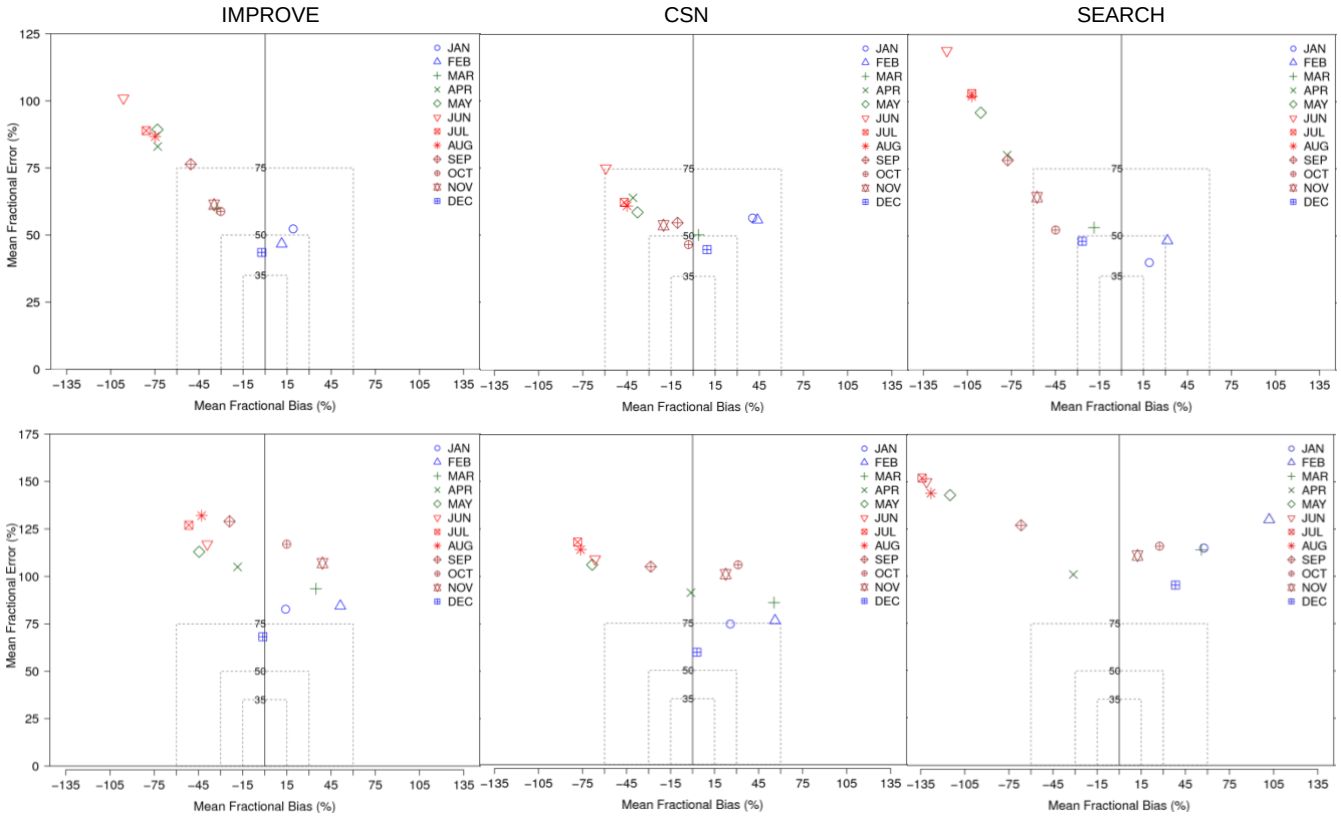

Figure S9. Monthly-averaged model performance comparisons for PM constituents from statistical d-s against multiple monitoring networks. Mean fractional error (%) vs. mean fractional bias (%) relative to observations. Top row: organic carbon (OC); bottom row: nitrate (NO_3).

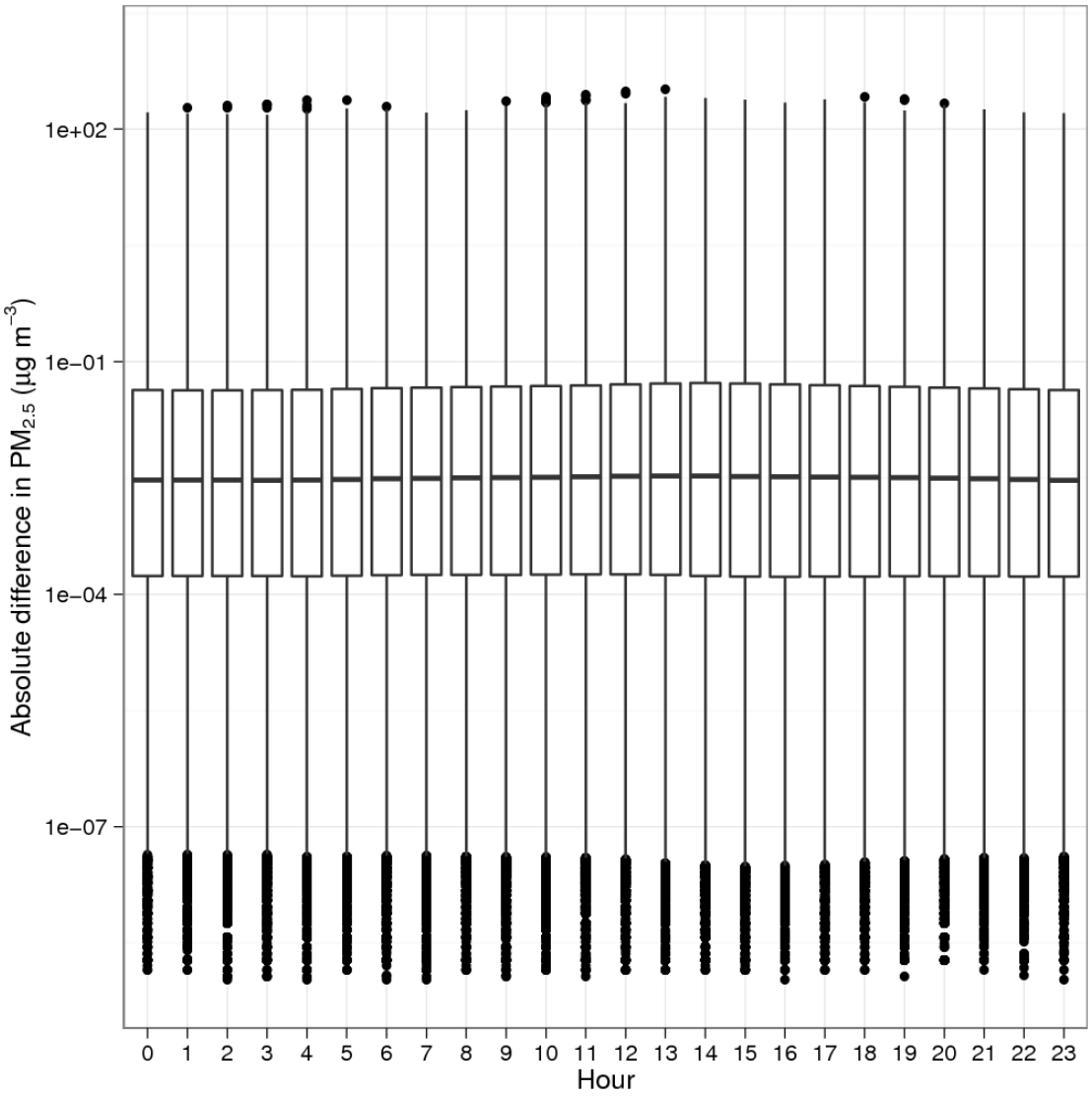

Figure S10. Absolute difference between the statistical d-s and dynamical d-s cases in in $PM_{2.5}$ concentrations (µg m^{-3}) from Hour 0 - 23 (local standard time) for the 2010 fire season (March 1 – November 30) over the whole domain (level 1).

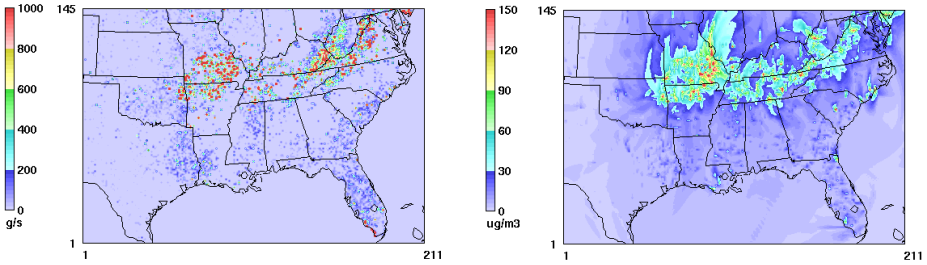

Figure S11. Maximum absolute difference between statistical d-s and dynamical d-s in each grid cell over the fire season in: L – hourly $PM_{2.5}$ column emissions (g/s), and R – hourly $PM_{2.5}$ concentrations (µg m^{-3}) in model layer 1. Here the fire season is defined as April 23 – November 30; almost all grid cell maxima in absolute hourly $PM_{2.5}$ concentration differences occurred in this time period.