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Supplementary material

The impact of US wildland fires on ozone and particulate matter: a comparison of measurements and CMAQ model predictions from 2008 to 2012

Joseph L. Wilkins[A,B], George Pouliot[A], Kristen Foley[A], Wyat Appel[A] and Thomas Pierce[A]

[A]US Environmental Protection Agency, Computational Exposure Division, National Exposure Research Laboratory, Research Triangle Park, NC 27711, USA.

[B]Corresponding author. Email: wilkins.joseph@epa.gov

Fire seasons explained in detail

2008 and 2012 had dryer than normal conditions across the CONUS with sustained heat during the summer. These years also saw a quick dissipation of winter snow packs leaving vulnerable conditions in the West. Summer 2009 weather patterns featured low pressure systems and cool temperature over the Central US with high pressure and above-normal warmth in the West and southern states. The Northwest in particular experienced record highs with Seattle reaching 103 in July and Phoenix recoding its hottest August till that year. For fire season 2010 the Western U.S. had a persistent pattern of low pressure troughs producing a very cool spring and wetter than normal conditions. However, the South East U.S. in 2010 had a hotter than normal spring and summer months. Strong westerly flow dominated the spring pattern across the U.S. in 2011, effectively splitting the country between cold to the north and west and warm to the south and east. Temperatures were generally below normal across the most the US except the South Central (Texas, Louisiana, Arizona region).

Representativeness challenges are present whenever gridded predictions from a deterministic model are compared to observed data at a point in time and space, as deterministic models calculate the average outcome over a grid for a given set of conditions, while the stochastic component (e.g. sub-grid variations) embedded in the observations is not accounted for. These issues are somewhat mitigated for the comparisons made here, since observations from the IMPROVE network are daily averages, while the CASTNet observations are weekly averages and mostly measuring secondary products. The longer temporal averaging helps reduce the impact of stochastic processes, which can have a large impact on shorter (e.g. hourly) periods of observation.

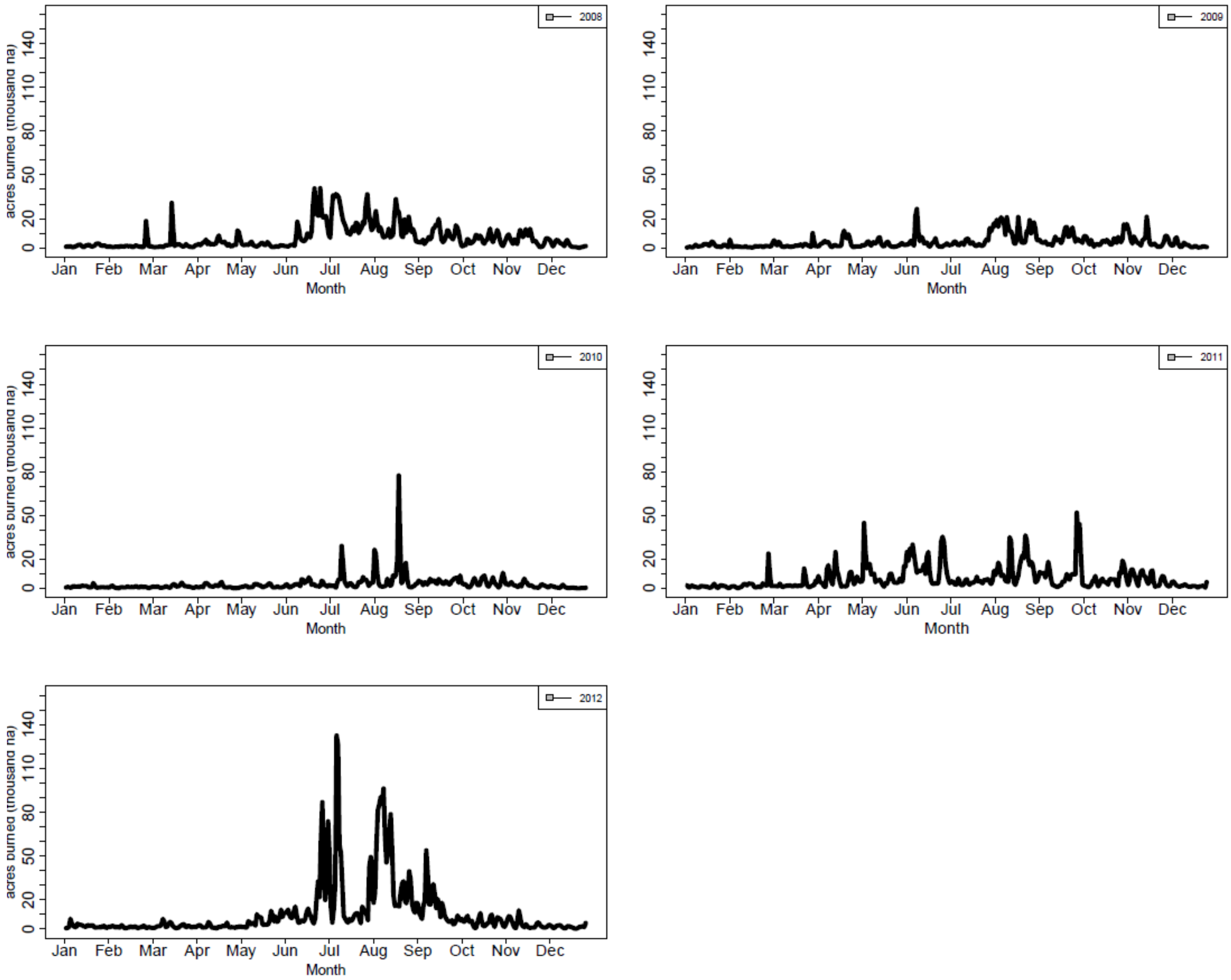

Fig. S1. Time series of daily wildland fire acres burned from SMARTFIRE2 for the fire influenced US region of the Intermountain West (IW) (2008–2012). Values are reported in thousands of hectares (1000 ha = 10 km^2, 1 ha = 2.47 acres).

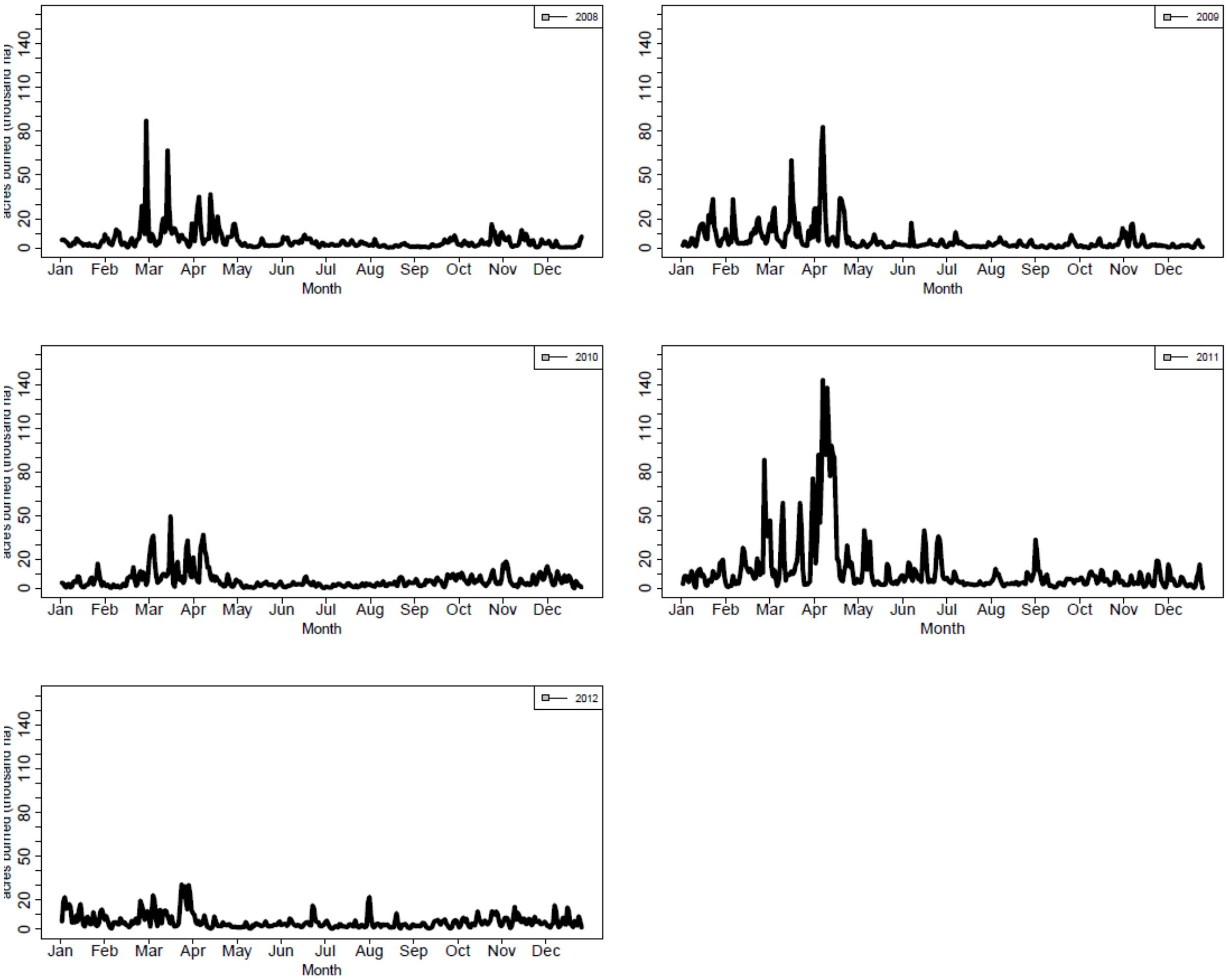

Fig. S2. Time series of daily wildland fire acres burned from SMARTFIRE2 for the fire influenced US region of the Southcentral (SC) (2008–2012). Values are reported in thousands of hectares (1000 ha = 10 km^2, 1 ha = 2.47 acres).

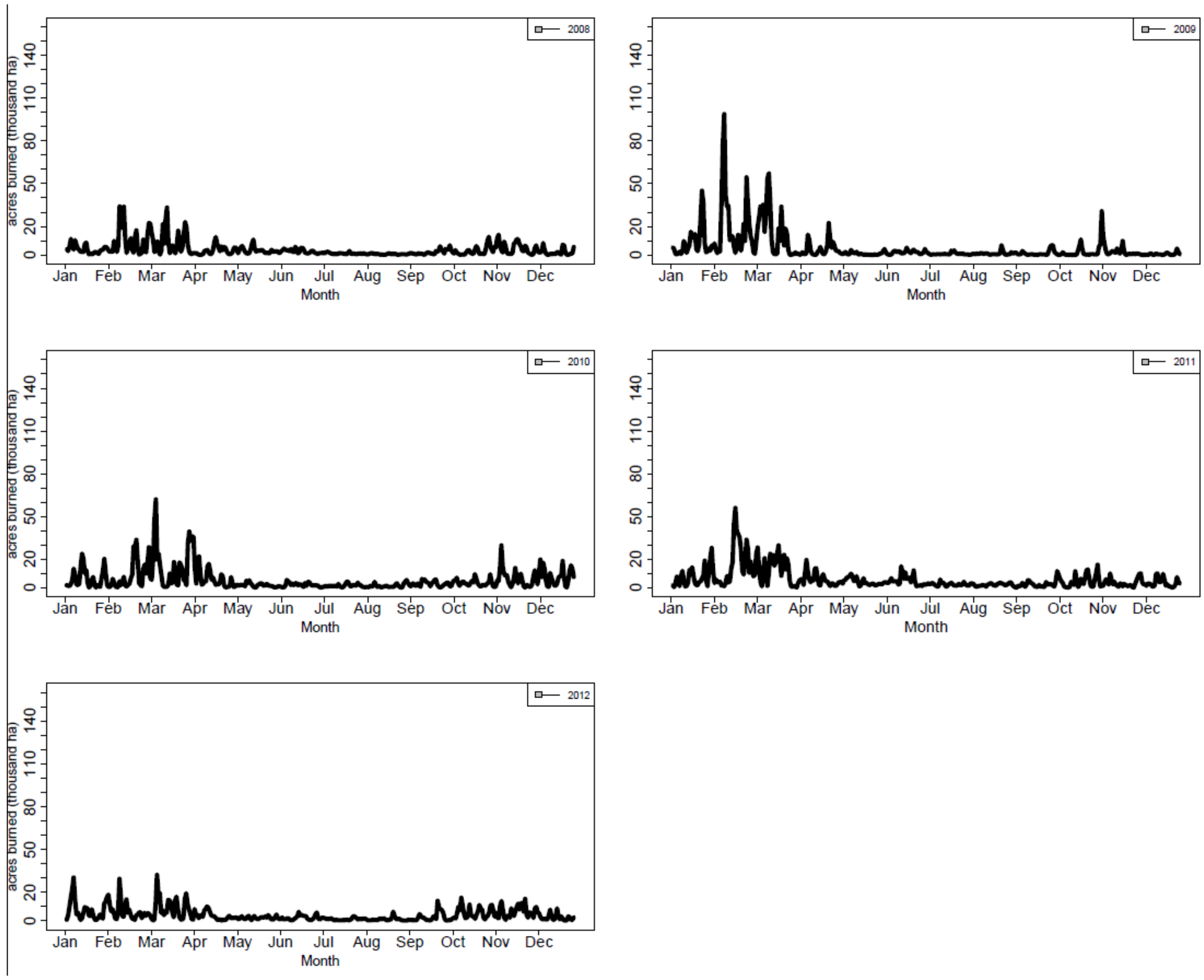

Fig. S3. Time series of daily wildland fire acres burned from SMARTFIRE2 for the fire influenced US region of the Southeast (SE) (2008–2012). Values are reported in thousands of hectares (1000 ha = 10 km^2, 1 ha = 2.47 acres).

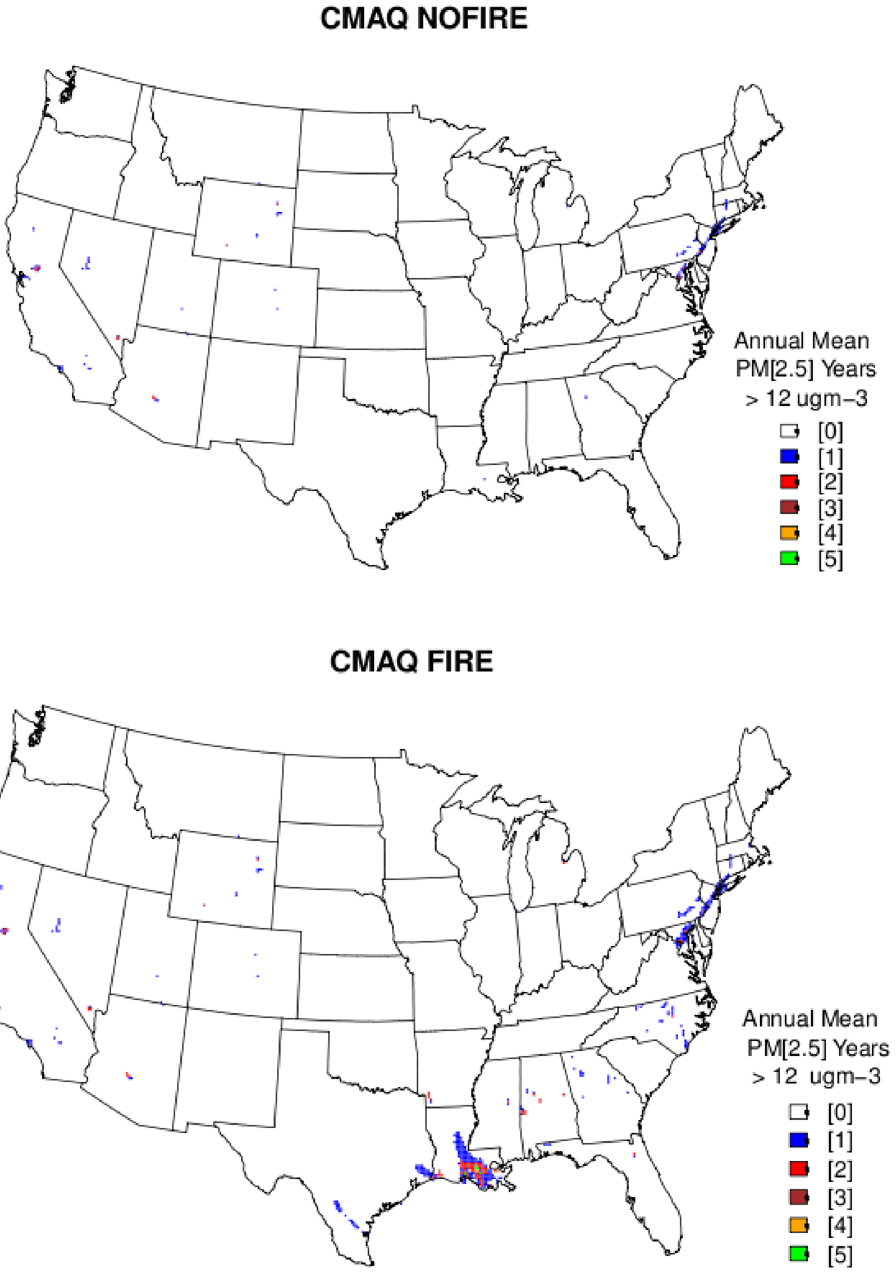

Fig. S4. Spatial maps depicting model $PM_{2.5}$ number of annually averaged grid cells above 12 μg m^{-3} for the Continental US 2008–2012 (*a*) without fires included, (*b*) with fires included.

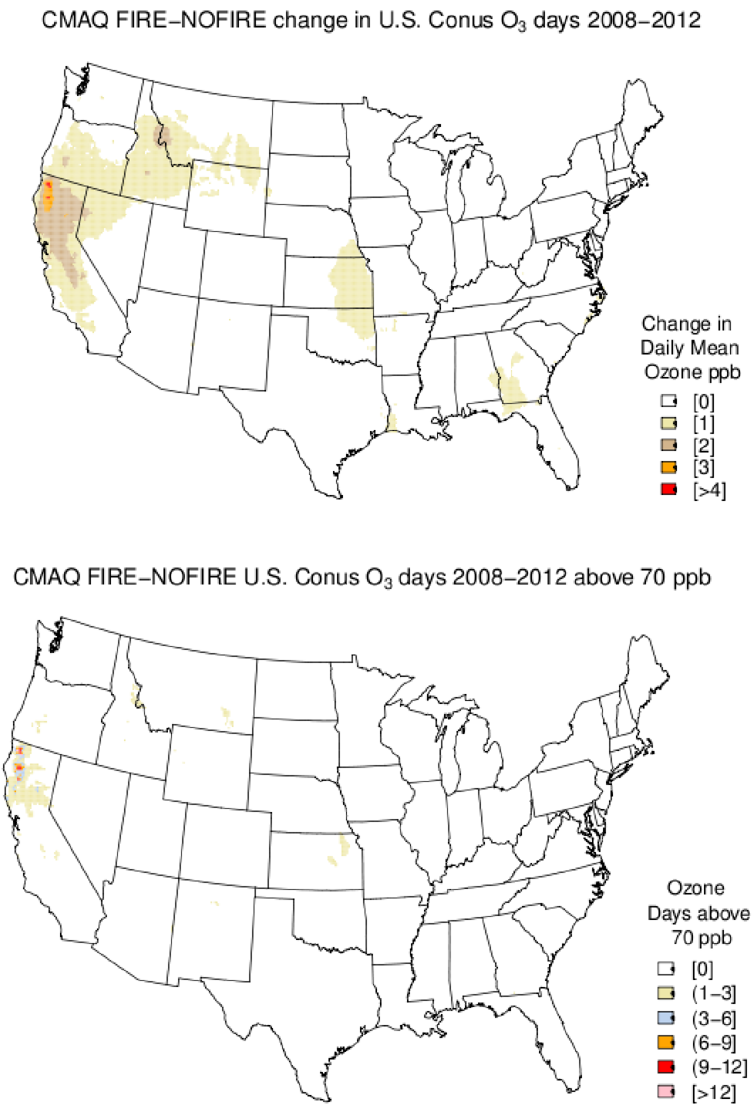

Fig. S5. Spatial maps depicting, with and without fire, model mean-ozone (O_3) 8-h maximum for the Continental United States (*a*) the difference between daily mean O_3 (*b*) Fire-O_3 days, referring to the number of days above 70 ppb that fires contributed to.

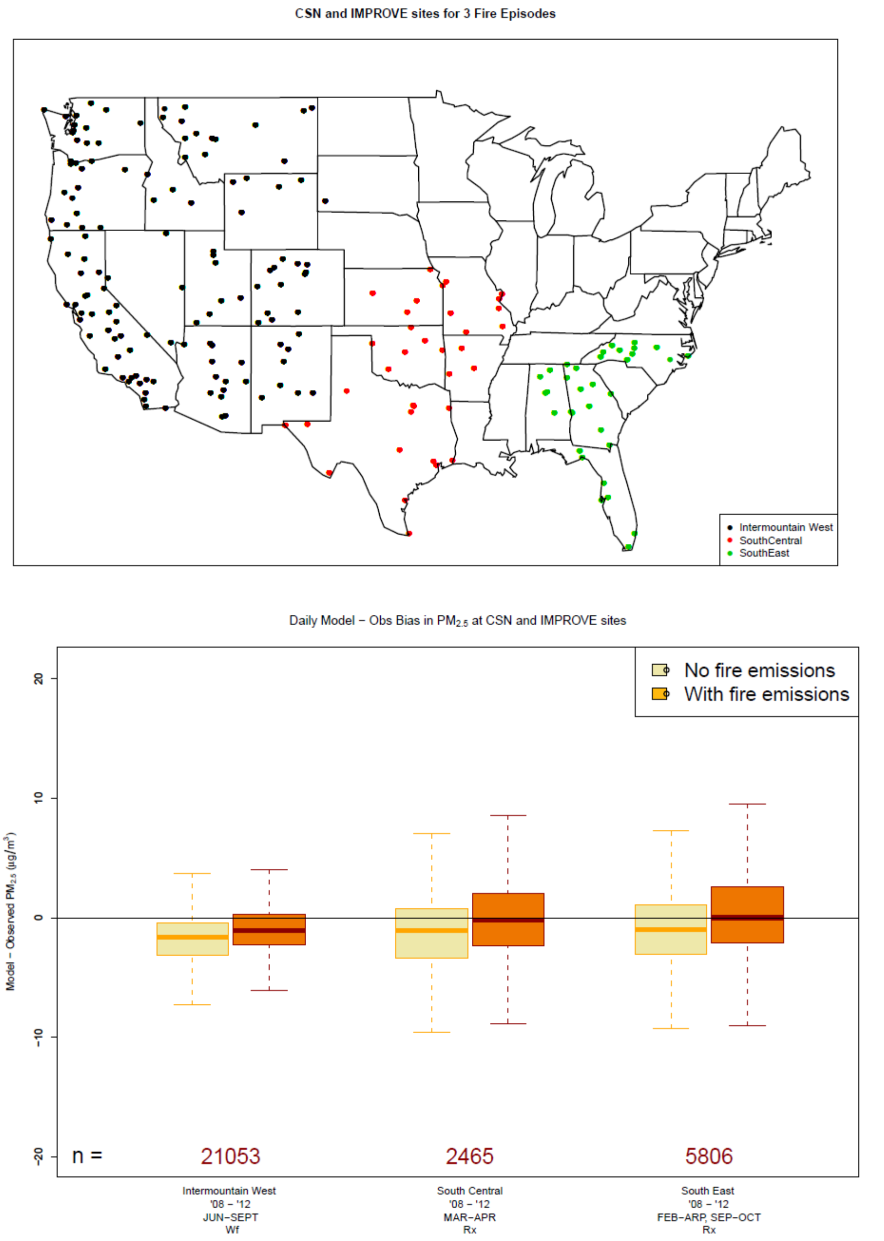

Fig. S6. Plots depicting daily model-observation bias in $PM_{2.5}$ for select fire regimes identified in the Continental United States, (top) site pairs locations for the Intermountain West (black dots), Southcentral (red dots), and Southeast (green dots) (bottom) model-observation bias with 'No fire emissions' (yellow) and 'with fire emissions' (orange). Reference statistic summary located in Table 4 of the manuscript.

Table S1. Community Multiscale Air Quality (CMAQ) and WRF Model Options for all simulations

		Options	References
Model Options			
	CMAQ Version	5.0.1 (except 5.0.2 for 2012)	Byun and Schere, 2006
	Chemistry	CB05	Yarwood G, 2005
	Grid projection	Lambert Conformal	
	H Res	12 km	
	V Res	35 layers	
	Boundary Conditions	GEOS-CHEM version 9-01-01	
	Model top	50 mb	
	Spinup period	10 days	
Meteorology Options	Off-line	Yes	
	WRF version		Skamarock et al, 2008
	Initialization	NCEP/NCAR Reanalysis	Skamarock et al, 2008
	FDDA	NCEP/NCAR Reanalysis	Skamarock et al, 2008
	Landuse	MODIS	
	Cumulus Parameterization	Kain–Fritsch 2 cumulus parameterization	Kain, 2004
	Radiation	RRTMg	Iacono et al., 2008
	PBL	Asymmetric Convective Model version 2	Pleim, 2007a and b
	Land Surface Model	Pleim-Xu	Xiu and Pleim, 2001; Pleim and Xiu, 1995

Table S2. Emission inventory information by year

Emission Sector Information by Year	2008	2009	2010	2011	2012
Electric Generation (CEMS data)	2008	2009	2010	2011	2012
Plume Rise	In-line	In-line	In-line	In-line	In-line
Mobile Source Emissions	2008 emission factors from MOVES 2010b, 2008 VMT data, 2008 Meterology for SMOKE/MOVES	2009 emission factors from MOVES 2010b, 2009 VMT data, 2009 Meterology for SMOKE/MOVES	2009 emission factors from MOVES 2010b, 2010 VMT data, 2010 Meterology for SMOKE/MOVES	2011 emission factors from MOVES 2010b, 2011 VMT data, 2011 Meterology for SMOKE/MOVES	2011 emission factors from MOVES 2010b, 2012 VMT data, 2012 Meterology for SMOKE/MOVES
Biogenic Emissions Inventory System (BEIS) version	version 3.14	version 3.14	version 3.14	version 3.14	version 3.14
Canada	2006 inventory	2006 inventory	2006 inventory	2010 inventory	2010 inventory
Mexico	2008 grown from 1999	2008 grown from 1999	2008 grown from 1999	Mexico 2008 not grown	Mexico 2008 not grown

Table S3. Extension of (Table 4) Statistics summary for Community Multiscale Air Quality (CMAQ) model-observed PM2.5 fire regimes 2008-2012

Comparison of observed and CMAQ modelled $PM_{2.5}$ concentrations for different regions of the US. The Intermountain West was dominated by wildfires (WF), and Southcentral and Southeast was dominated by prescribed burns (Rx). Only the CMAQ grid cells containing observations from either the AQS, IMPROVE or CASTNet networks are used in the comparison

Region	**Years**	**Cmaq sim**	**Month**	**Fire Type**	**Obs Mean**	**CMAQ Mean**	N	r	**RMSE**	**NMB**	**NME**	**MB**	**ME**
					$PM_{2.5}$/Cell	**$PM_{2.5}$/cell**	# obs		(μg m^{-3})	**%**	**%**	(μg m^{-3})	(μg m^{-3})
CONUS	’08 - ‘12	Nofire	1-12	WF/Rx	7.36	7.39	160934	0.63	5.88	0.45	46.3	0.03	3.41
	’08 - ‘12	Fire	1-12	WF/Rx	7.36	8.11	160934	0.65	6.22	10.2	47.57	0.75	3.50
			3-10	WF/Rx	7.45	6.56	108443	0.61	5.05	-11.9	42.3	-0.88	3.15
			3-10	WF/Rx	7.45	7.26	108443	0.65	5.22	-2.57	41.5	-0.19	3.09
Intermountain west	'09,'10,'11	Nofire	3-10	WF	4.81	4.51	26193	0.52	4.83	-6.08	55.2	-0.29	2.65
		Fire	3-10	WF	4.81	4.96	26193	0.56	5.00	3.08	53.6	0.15	2.58
	’08, ‘12	Nofire	3-10	WF	5.78	4.56	16630	0.39	6.35	-21.2	59.1	-1.22	3.42
		Fire	3-10	WF	5.78	6.10	16630	0.63	6.72	5.53	55.5	0.32	3.21
	’08 - ‘12	Nofire	6-9	WF	5.81	4.00	21053	0.37	6.03	-31.1	58.1	-1.81	3.38
		Fire	6-9	WF	5.81	5.48	21053	0.60	6.43	-5.77	53.5	-0.34	3.11
South Central	'09,'10,'12	Nofire	3-10	RX	8.58	6.73	5910	0.55	4.55	-21.5	38.2	-1.85	3.28
		Fire	3-10	RX	8.58	7.50	5910	0.52	5.02	-12.6	38.4	-1.08	3.30
	’08, ‘11	Nofire	3-10	RX	9.45	7.13	3843	0.57	5.38	-24.6	38.2	-2.33	3.62
		Fire	3-10	RX	9.45	8.10	3843	0.59	5.22	-14.3	36.0	-1.36	3.41
	’08 - ‘12	Nofire	3-4	RX	8.88	7.42	2465	0.49	5.51	-16.4	36.9	-1.46	3.28
		Fire	3-4	RX	8.88	8.97	2465	0.47	6.52	1.01	40.1	0.09	3.56
South East	'09,'10,'12	Nofire	3-10	RX	9.55	7.31	5875	0.64	4.48	-23.5	35.2	-2.25	3.36

		Fire	3-10	RX	9.55	8.21	5875	0.65	4.55	-14.0	34.4	-1.34	3.29
	’08, ‘11	Nofire	3-10	RX	11.1	8.61	3617	0.65	5.35	-22.4	35.3	-2.48	3.92
		Fire	3-10	RX	11.1	9.74	3617	0.65	5.32	-12.2	34.1	-1.35	3.78
	’08 - ‘12	Nofire	2-4, 9,10	RX	9.06	8.03	5806	0.62	4.46	-11.3	34.0	-1.03	3.08
		Fire	2-4, 9,10	RX	9.06	9.80	5806	0.67	5.48	8.32	38.2	0.75	3.46