Seasonal impact of regional outdoor biomass burning on air pollution in three Indian cities: Delhi, Bengaluru, and Pune

Supplemental Information

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Table S1. Details of HYSPLIT back trajectories (Stein et al, 2015; Rolph 2016) for each of the three cities used in this analysis. Selection of heights for each city and season is described in Section 2.2.

City	Coordinates	Burning Season	Peak Burning Months	Heights Used (km)	Range of Data	Missing Days
Delhi	28.6139° N, 72.2090° E	Post-monsoon	Oct-Nov	0.5	2007-2013	*2008*: Oct 24-27; *2009*: Oct 7-10; *2011*: Nov 2-5
		Pre-monsoon	Apr-May	0.5, 1, 1.5	2008-2009, 2011-2013	*2008*: Mar 20-23, Apr 9-12, 27-30; *2009*: Mar 17-31, Apr 1, May 4-7; *2012*: Mar 1-4, 10-13
Bengaluru	12.9667° N, 77.5667° E	Pre-monsoon	Feb-Mar	0.5		
Pune	18.5203° N, 73.8567° E	Pre-monsoon	Mar-Apr			

Table S2. List of stations in the Central Pollution Control Board (CPCB) dataset of PM_{10} (in μg m^{-3}) for Delhi, Bengaluru, and Pune. Data are available at http://cpcb.nic.in/.

City	Area	Station Name	Data Availability	
			Start	End
Delhi	Industrial	Mayapuri Industrial Area	Jan 2005	Feb 2010
		Shadara	Dec 2004	Dec 2014
		Shahzada Bagh	Dec 2004	Dec 2014
	Residential	Ashok Vihar	Dec 2004	Feb 2006
		BSZ Marg	Jul 2005	Sep 2005
		DCE	Jun 2005	Jul 2005
		Janakpuri	Dec 2004	Dec 2014
		N.Y. School	Jun 2005	Feb 2010
		Nizamuddin	Dec 2004	Dec 2014
		Pritampura	Dec 2004	Dec 2014
		Siri Fort	Dec 2004	Dec 2014
		Town Hall	Jan 2005	Feb 2010
Bengaluru	Industrial	AMCO Batteries	Apr 2004	Feb 2006
		KHB Industrial Area	Aug 2004	Feb 2010
		Graphite India	Apr 2004	Jan 2012
		Peenya Industrial Area	Sep 2004	Mar 2010
	Residential	AMCO Batteries	Mar 2006	Feb 2010
		Anand Rao Circle	Apr 2008	Apr 2008
		R. V. College	Dec 2009	Feb 2010
		Yeshwanthpura	Feb 2006	May 2011
		Victoria Hospital	Sep 2004	Nov 2014
Pune	Industrial	Bhosari	Mar 2005	Jan 2010
	Residential	Nalstop	Mar 2005	Jan 2010
		Swargate	Mar 2005	Jan 2010

Table S3. Details and data availability for Delhi and Bengaluru visibility stations

City	Station	Data Availability	
		Start	End
Delhi	421810	Apr 1996	Jul 2015
	421820	Jul 1942	
Bengaluru	427056	Jul 2008	
	432950	Jan 1973	
	432960	Sep 1942	
	433025	May 2005	

Table S4. AERONET Pune station details and data availability

City	Station Coordinates	Wavelength (nm) Used	Data Availability	
			Start	End
Pune	18.537° N, 73.805° E	440	Jan 2008	May 2014

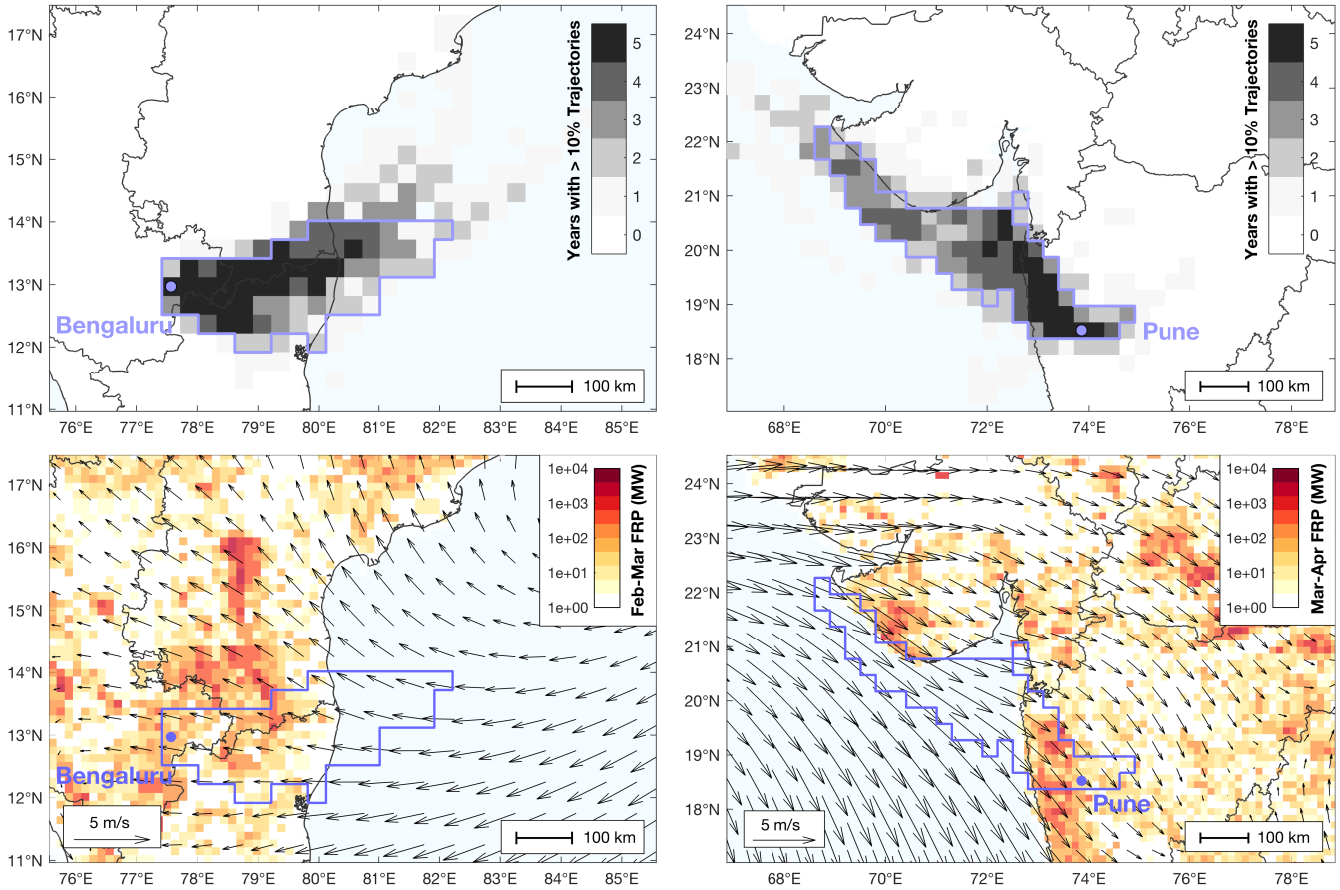


Figure S1. Bengaluru and Pune composite pre-monsoon airsheds, total season FRP, and average winds. The composite pre-monsoon airsheds are approximated from the intersection of more than 10 % of total HYSPLIT back trajectories with 0.3° x 0.3° pixels. The top panels show the interannual variability of seasonal airsheds in depicted in shades of gray; darker colors represent a high number of years with back trajectories passing through that location. The bottom panels show the average seasonal FRP (MW, in logarithmic scale) aggregated to 15 km x 15 km spatial resolution. Average seasonal surface winds at 10 m above surface are averaged to 0.5° x 0.5° spatial resolution.

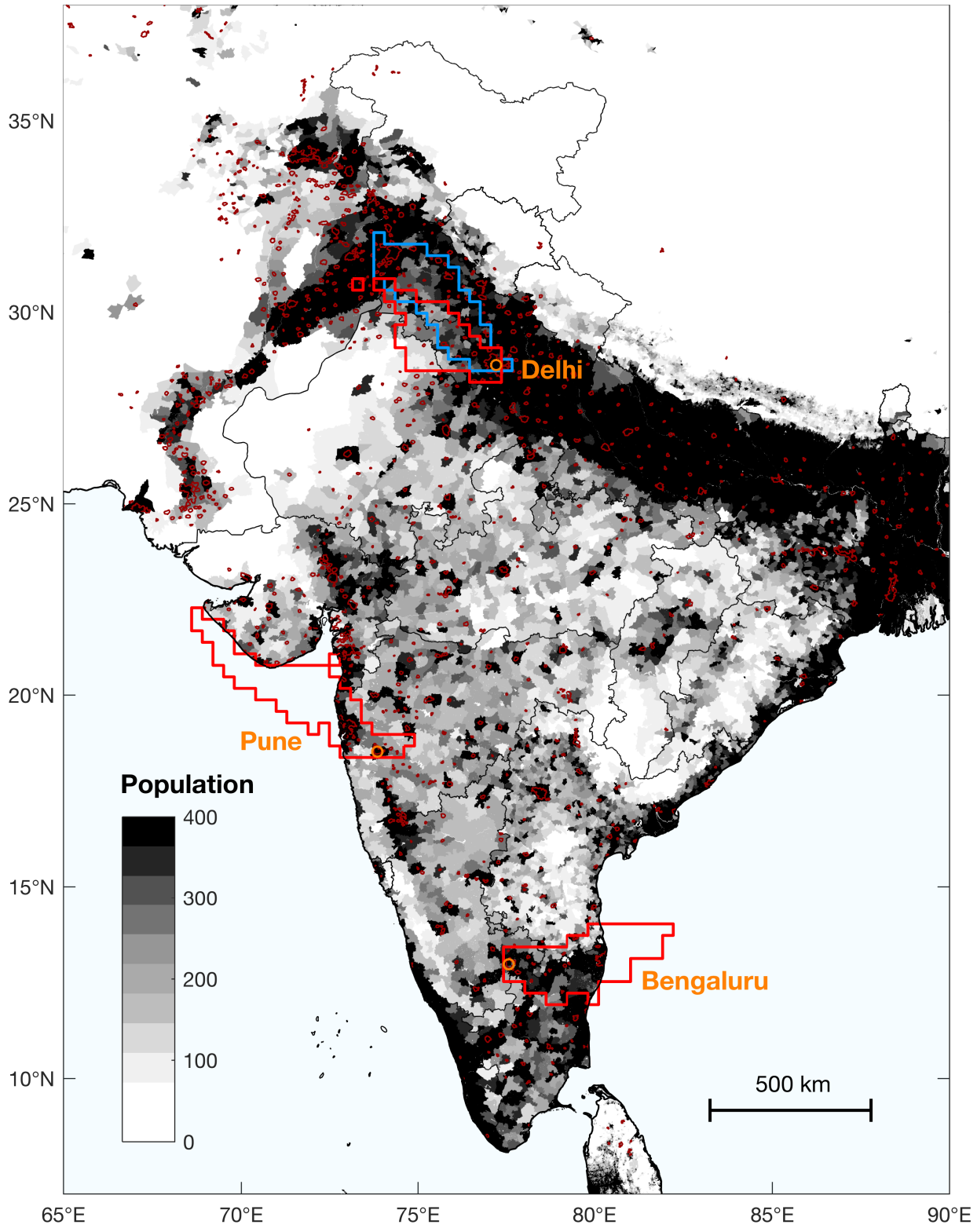


Figure S2. Estimated population count in Delhi composite pre-monsoon and post-monsoon airsheds and Bengaluru and Pune composite pre-monsoon airsheds. 2010 UN-adjusted GPWv4 human population count is overlain with average 2007-2013 post-monsoon Delhi airshed (in blue) and average 2008-2009, 2011-2013 pre-monsoon Delhi, Bengaluru, and Pune airsheds (in red). The starting HYSPLIT trajectory locations for the three cities are marked in open red circles. Dark red polygons denote urban areas.

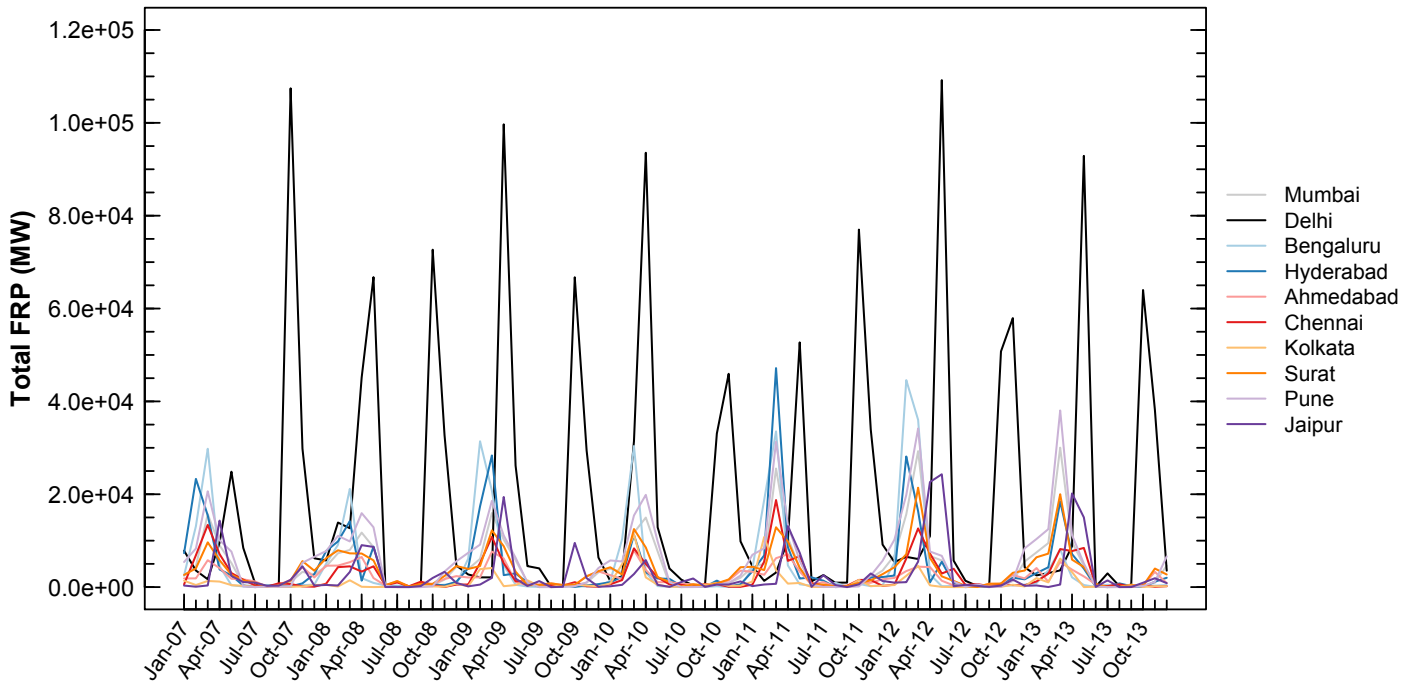
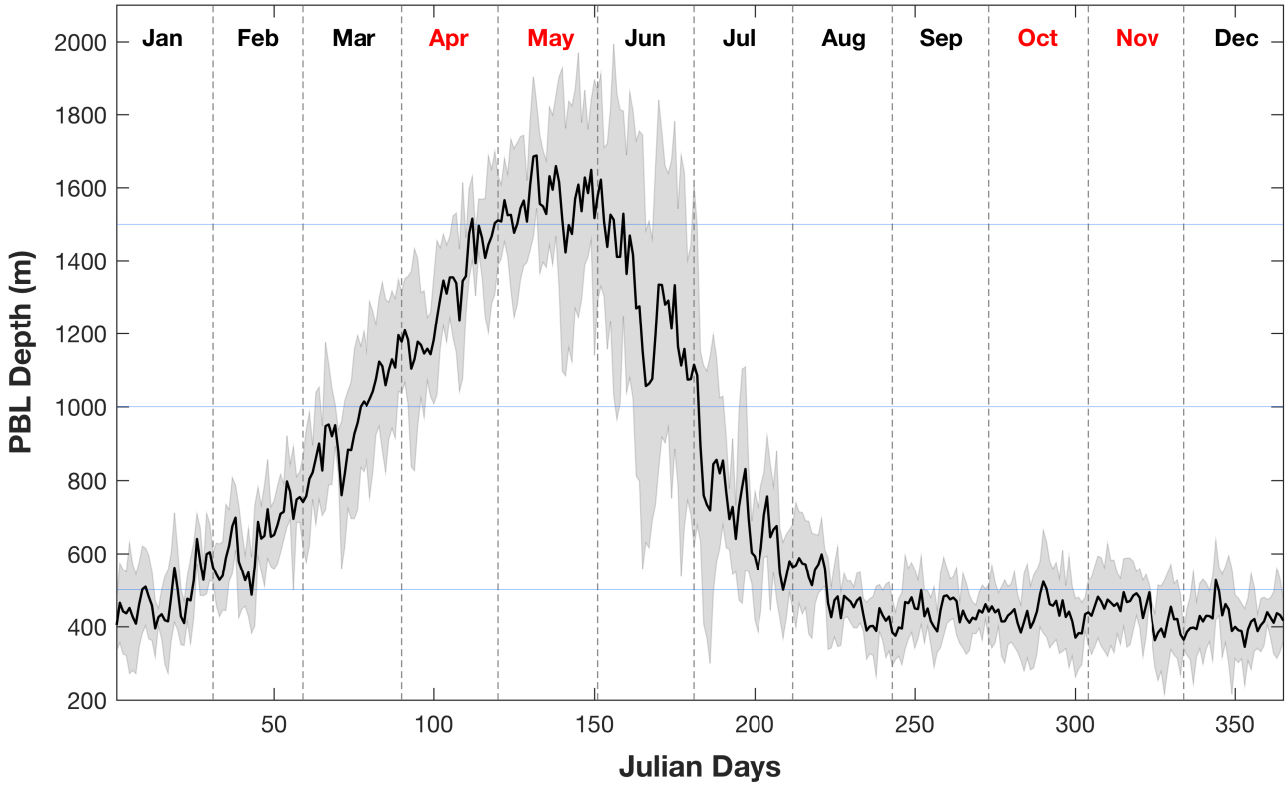
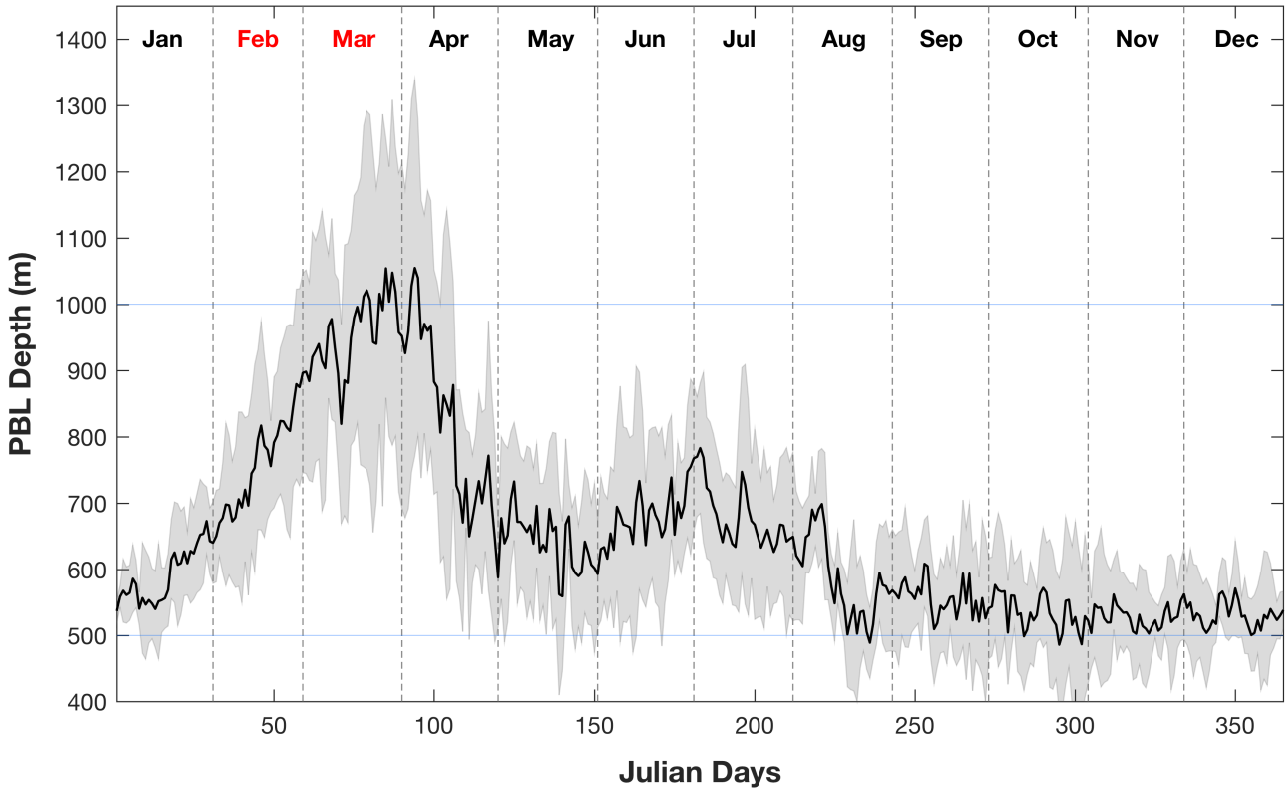


Figure S3. Monthly fire radiative power (FRP) (from MODIS Aqua+Terra; in MW) extracted from a 200km radius around the 10 most populous cities in India from January 2007 to December 2013. The three cities with the highest average annual FRP are Delhi (black), Bengaluru (light blue), and Pune (light purple).

(a)


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
PBL Depth (m)
2000
1800
1600
1400
1200
1000
800
600
400
200
50
100
150
200
250
300
350
Julian Days

(b)


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
PBL Depth (m)
1400
1300
1200
1100
1000
900
800
700
600
500
400
50
100
150
200
250
300
350
Julian Days

(c)

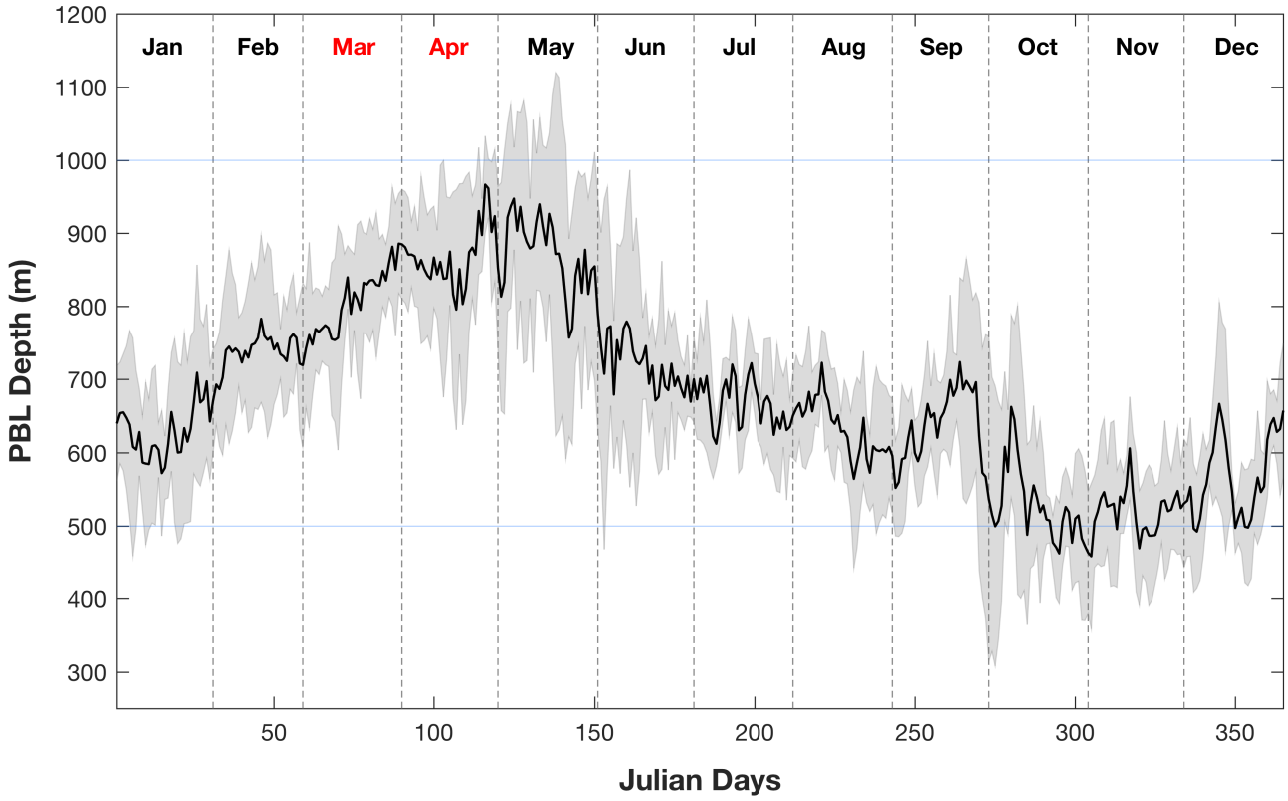
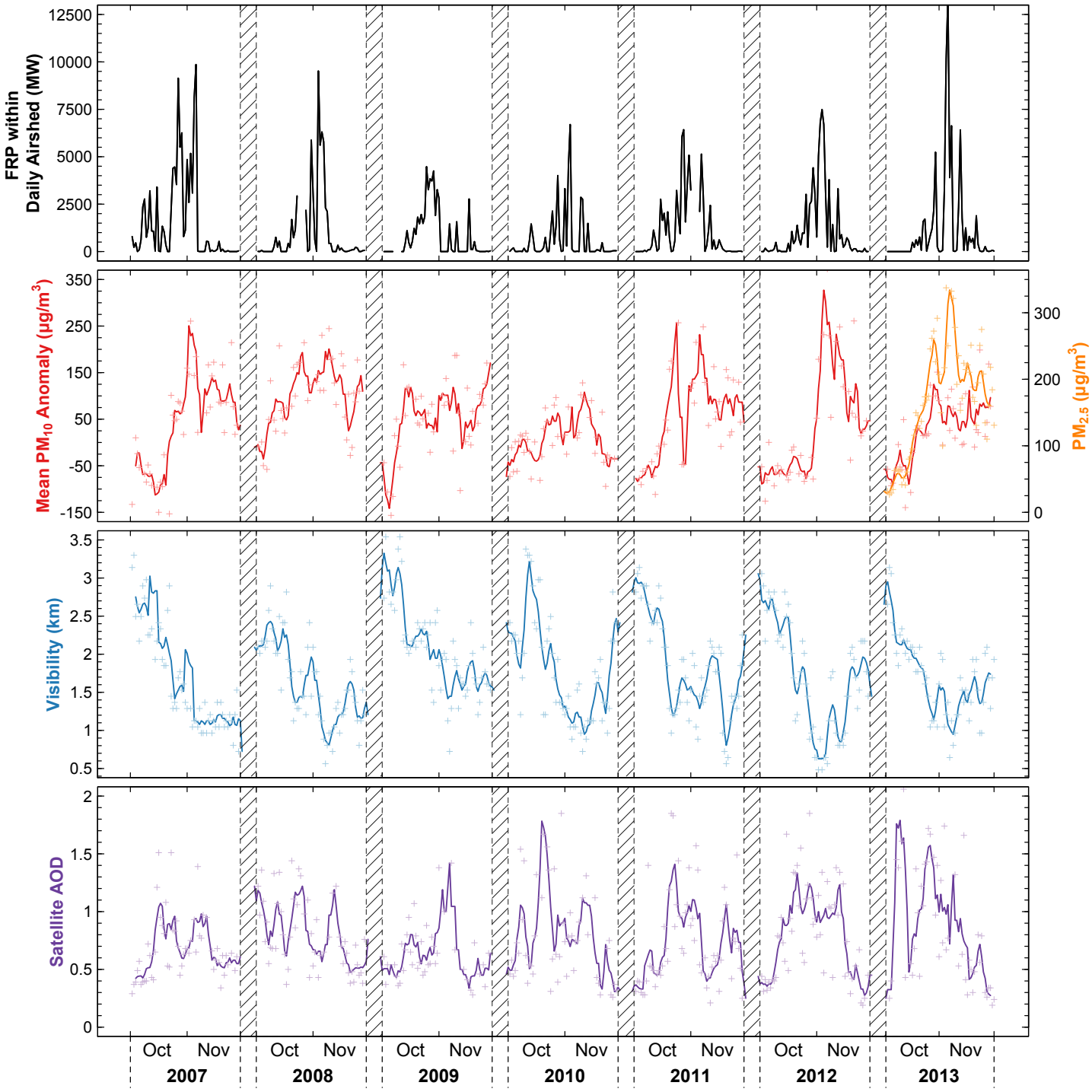
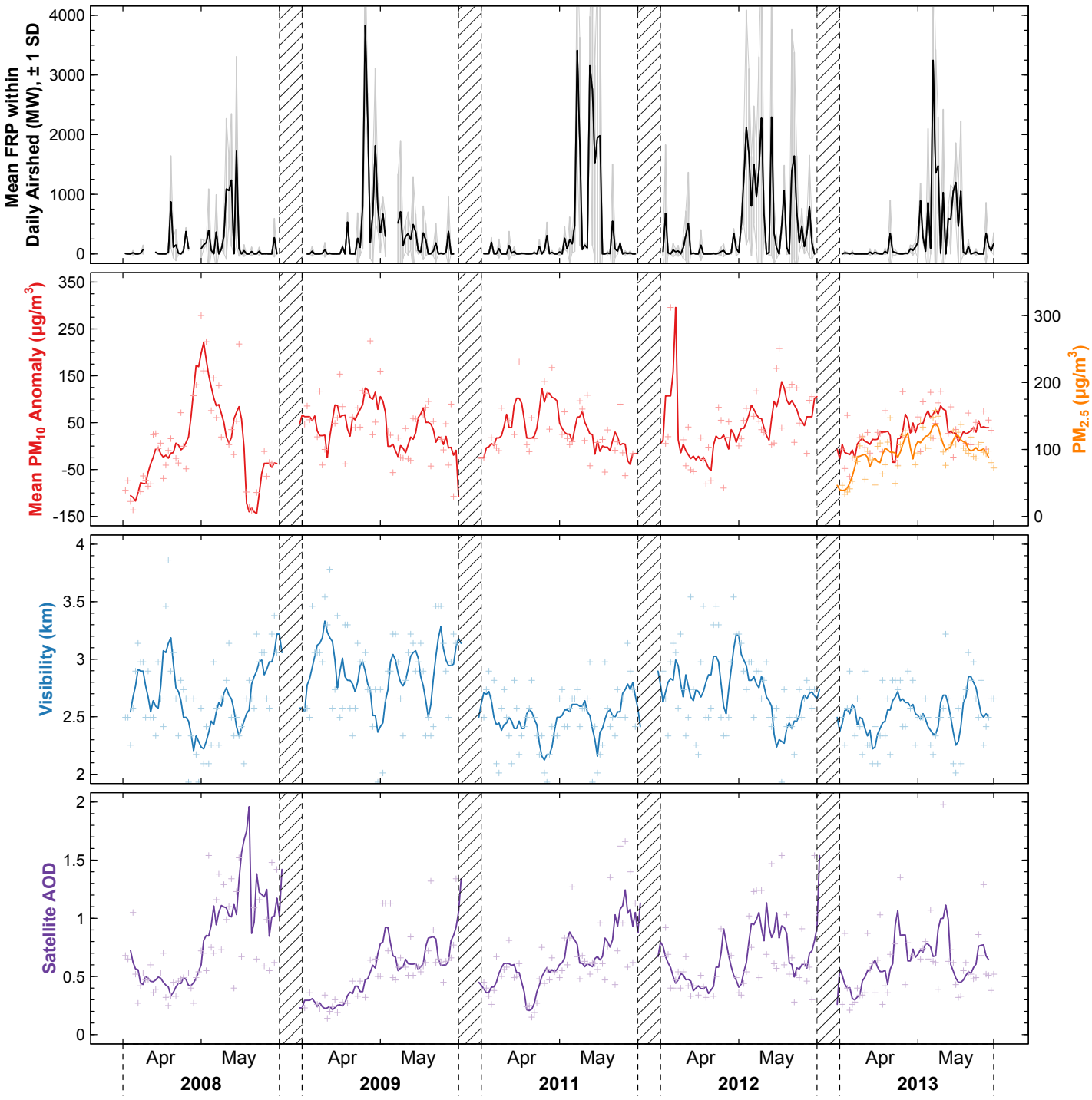


Figure S4. Average daily boundary layer height (m) in 2007-2012 in a) Delhi, b) Bengaluru, and c) Pune, as estimated from MERRA meteorological fields. Blue lines indicate the three heights (500 m, 1 km, 1.5 km) from which HYSPLIT back trajectories are run. Months in the defined pre-monsoon and post-monsoon burning seasons for each city are noted in red font. For the pre-monsoon burning season in Delhi's airshed, we select heights of 500 m, 1 km, and 1.5 km for tracking the influence of smoke; for the post-monsoon burning season, we select the 500 m height. For the pre-monsoon burning seasons in Bengaluru and Pune's airsheds, we also select the 500 m height.

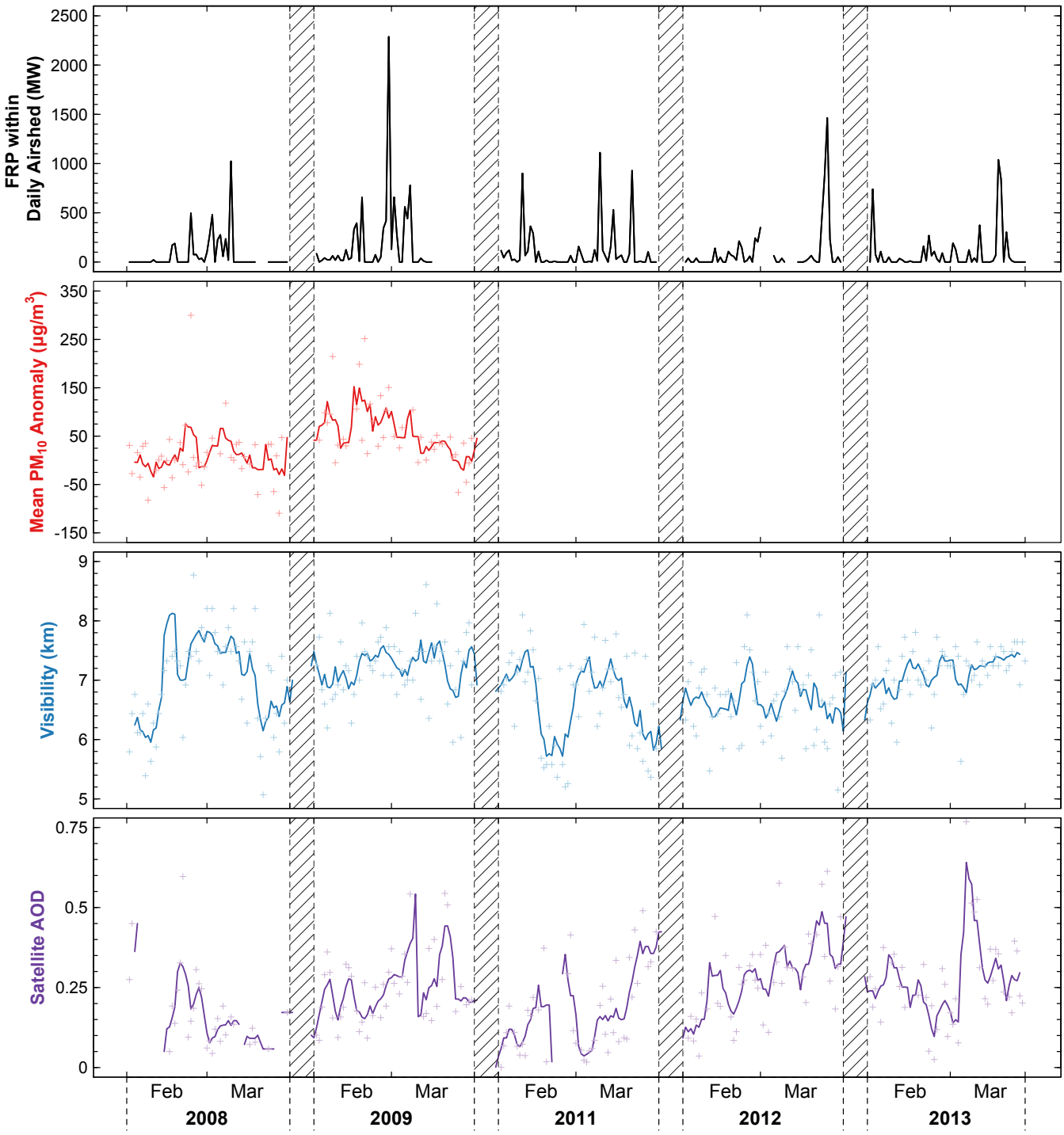
(a)


FRP within Daily Airshed (MW)
12500
10000
7500
5000
2500
0
Mean PM10 Anomaly (µg/m3)
350
250
150
50
-50
-150
PM2.5 (µg/m3)
300
200
100
0
Visibility (km)
3.5
3
2.5
2
1.5
1
0.5
Satellite AOD
2
1.5
1
0.5
0
Oct
Nov
2007
2008
2009
2010
2011
2012
2013

(b)


Mean FRP within Daily Airshed (MW), ± 1 SD
4000
3000
2000
1000
0
Mean PM10 Anomaly (µg/m3)
350
250
150
50
-50
-150
PM2.5 (µg/m3)
300
200
100
0
Visibility (km)
4
3.5
3
2.5
2
Satellite AOD
2
1.5
1
0.5
0
Apr
May
2008
2009
2011
2012
2013

(c)


FRP within Daily Airshed (MW)
2500
2000
1500
1000
500
0
Mean PM10 Anomaly (µg/m3)
350
250
150
50
-50
-150
Visibility (km)
9
8
7
6
5
Satellite AOD
0.75
0.5
0.25
0
Feb
Mar
2008
2009
2011
2012
2013

(d)

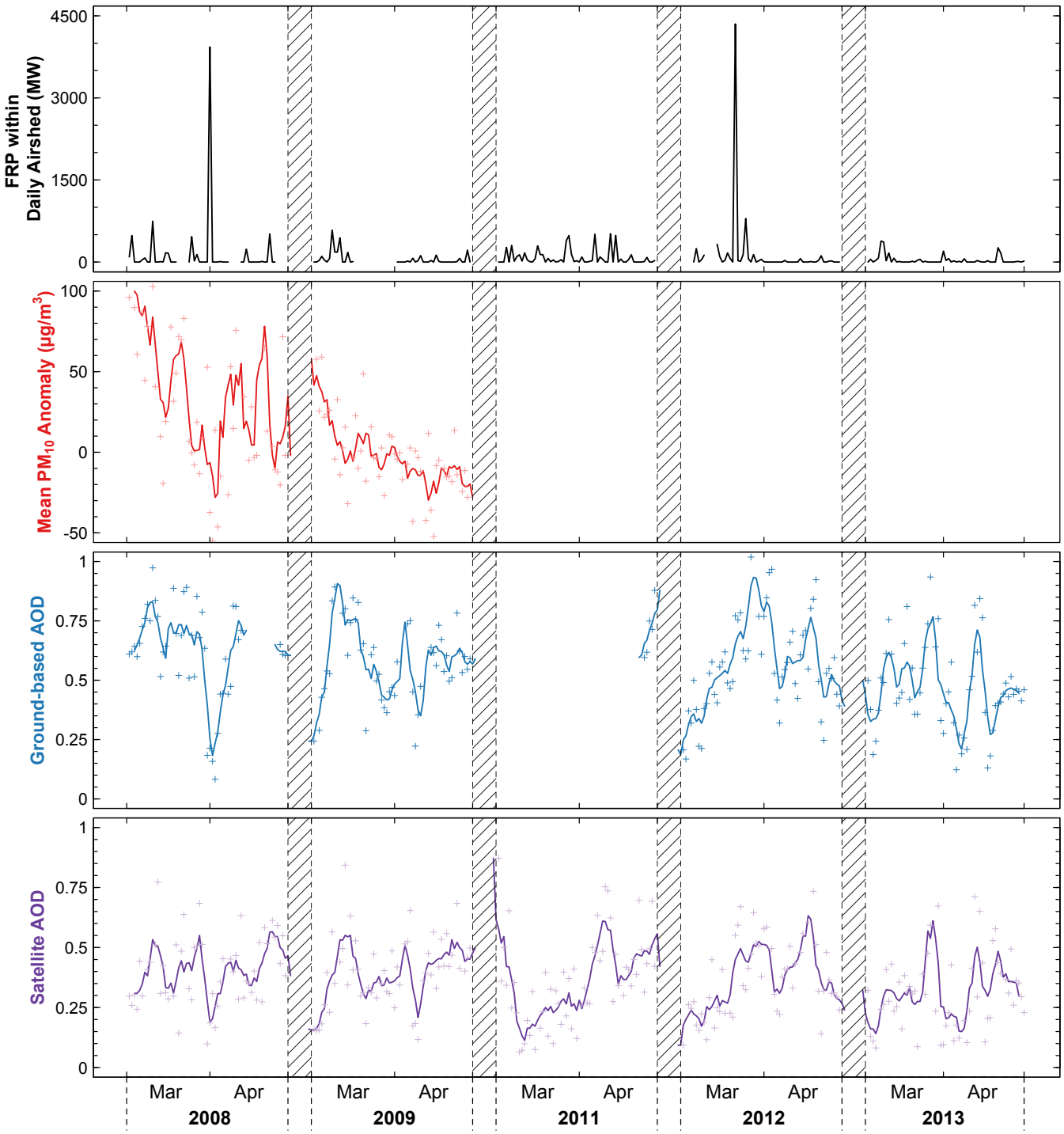


Figure S5. Time series of average FRP within the daily airshed (MW, ± 1 SD) and air quality metrics, including PM_{10} anomaly (µg m^{-3}), $PM_{2.5}$ (µg m^{-3}), visibility (km), ground-based AOD, and satellite AOD for a) Delhi post-monsoon, b) Delhi pre-monsoon, c) Bengaluru pre-monsoon, and d) Pune pre-monsoon. Daily air quality observations are depicted as points and with a 5-day moving average line. For the pre-monsoon burning season, we omit 2010 due to missing HYSPLIT data.

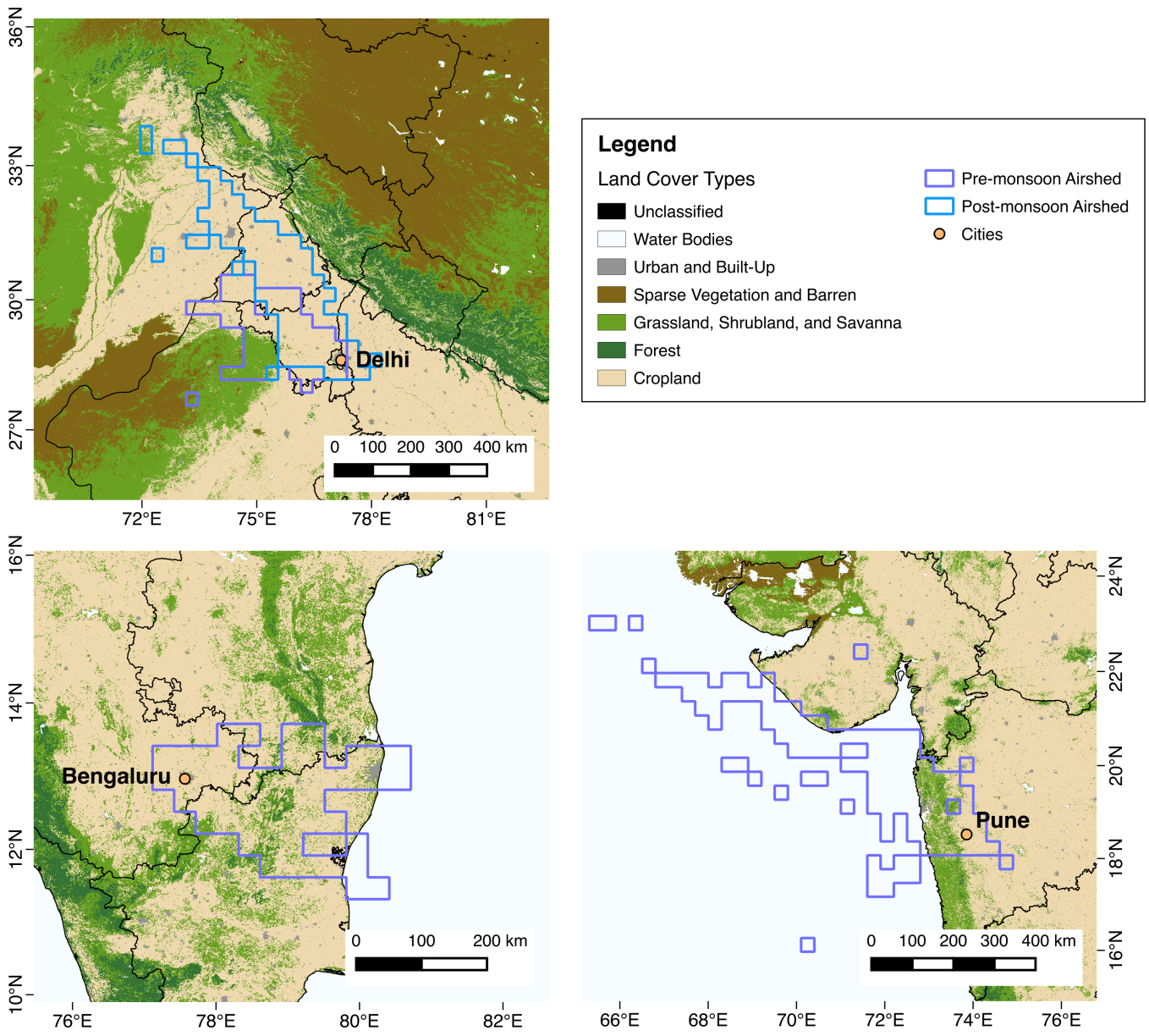


Figure S6. Delhi pre-monsoon and post-monsoon airsheds and Bengaluru and Pune pre-monsoon airsheds with simplified MCD12Q1 land cover types, using 2008 as an example.

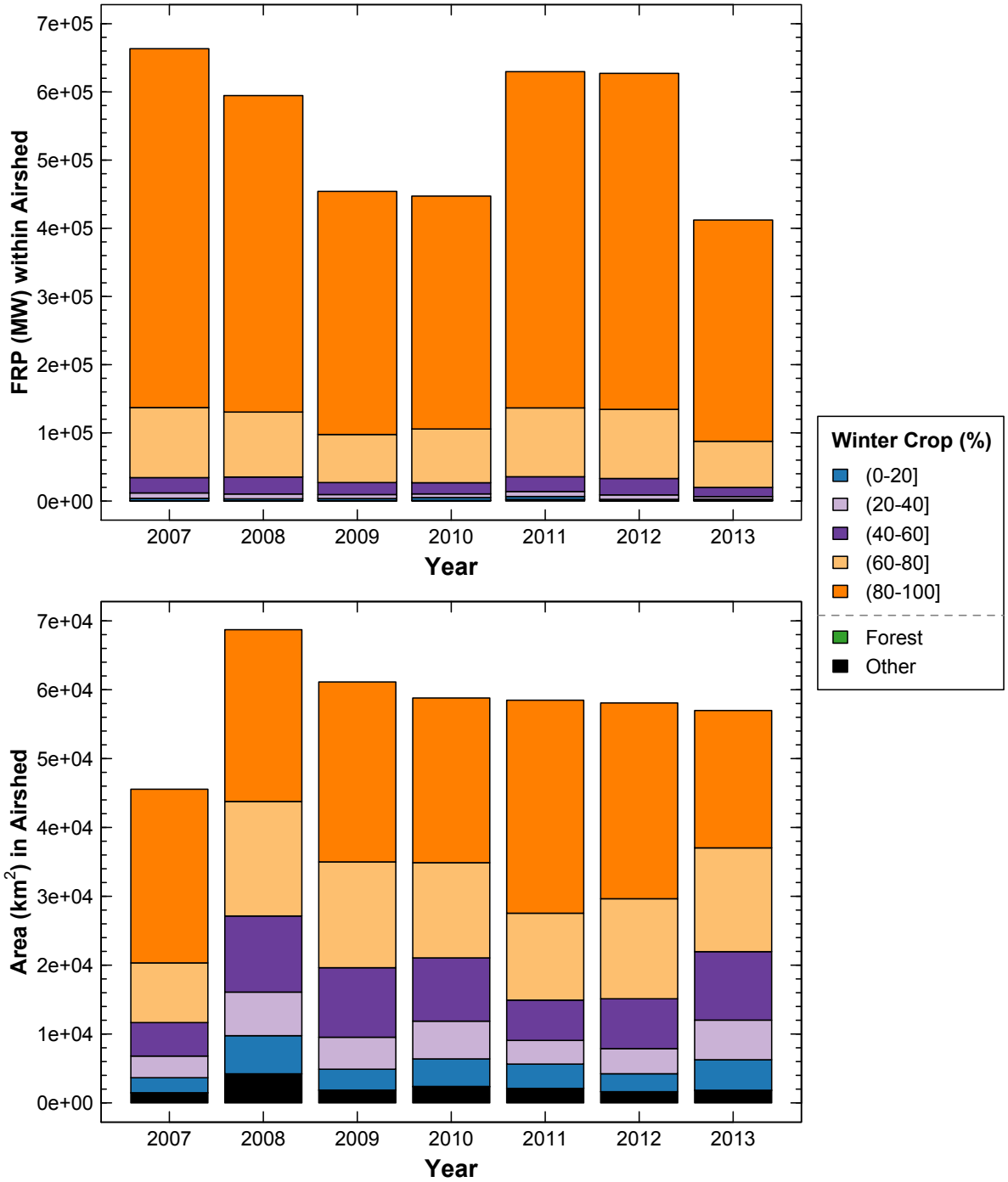


Figure S7. Annual FRP and area by Jain et al. (2013; 2017) winter crop quintiles in Bengaluru and Pune pre-monsoon airsheds. Winter crop percentiles refer to the % winter crop that covers each pixel.

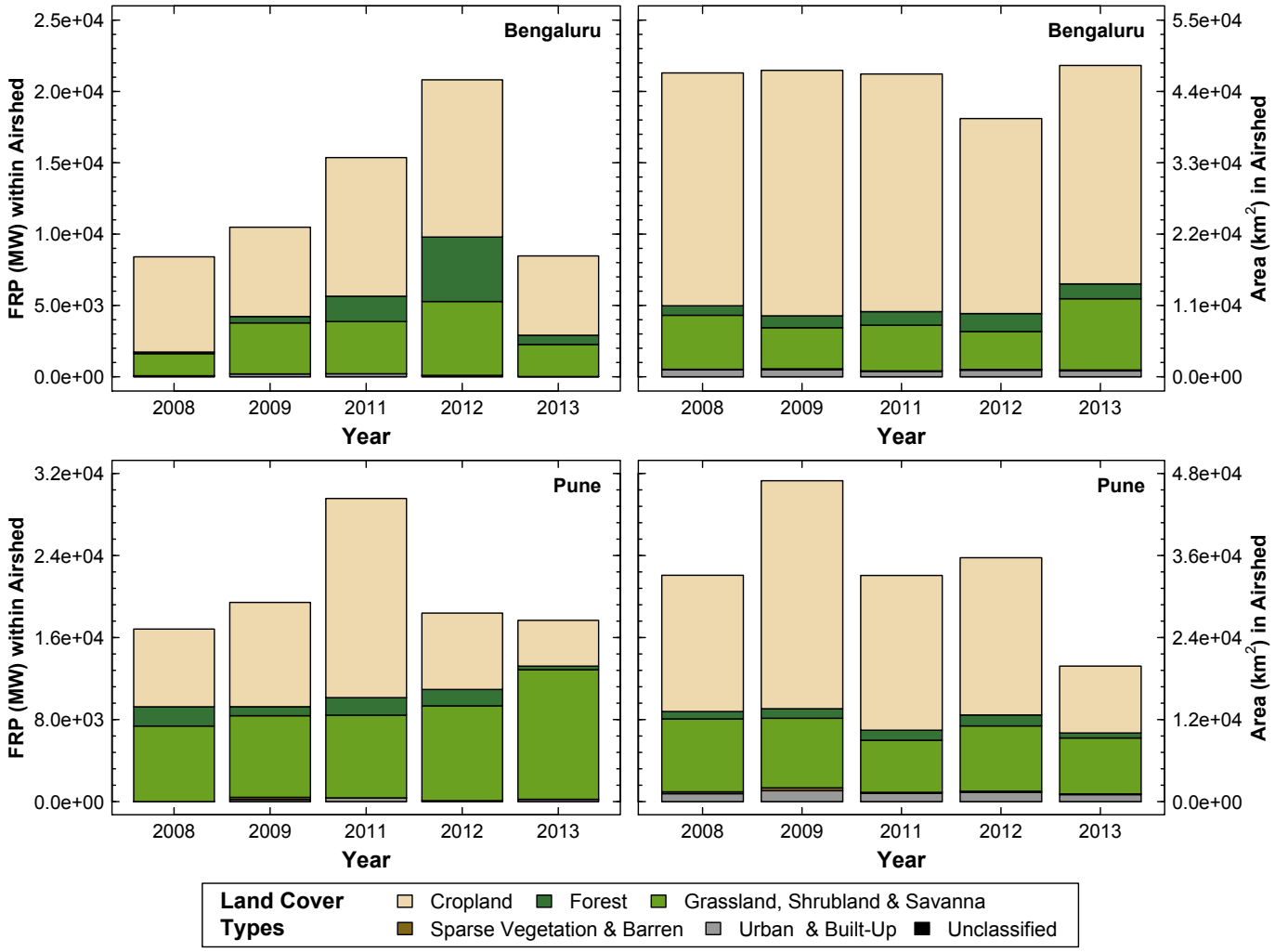


Figure S8. Annual FRP and area by simplified MCD12Q1 land cover types in Bengaluru and Pune pre-monsoon airsheds. The top panels show the FRP contribution and total area for each land cover class within the 2008-2009 and 2011-2013 Bengaluru pre-monsoon airsheds; the bottom panels show those within the Pune pre-monsoon airsheds.

Table S5. FRP and local meteorology regression models of a) Bengaluru and b) Pune pre-monsoon air quality for the 5-day averaging window. FRP refers to the total FRP within the daily Bengaluru and Pune airsheds; meteorological variables were from local observations were observations at HAL Bengaluru Airport, Kempegowda International Airport (BLR), and Pune International Airport (PNQ). 2008 meteorological data for Bengaluru were from HAL, and 2011-2013 from BLR; 2009 data were not recorded at either airport. For wind direction in degrees, 0 = North, 90 = East, 180 = South, and 270 = West. Wind direction data were not available for Pune. Detrended variables for the final multiple linear regression models are selected from best subset regression and BIC. Meteorological variables uninformative to the regression models are not shown. The statistical significance (based on p-values) of the regression coefficients is denoted as follows: 0-0.001 '***', 0.001-0.01 '**', 0.01-0.05 '*', 0.05-0.1 ''. Standard errors of the regression coefficients are shown in parentheses.

(a)

Predictors	PM_{10} Anomaly	Visibility	Satellite AOD
		Pre-monsoon	
Ordinary R^2	0.45	0.57	0.34
Adjusted R^2	0.39	0.53	0.3
FRP (1000 MW)	—	—	—
Max Temp (°C)	—	—	0.038*** (0.009)
Min Dew Point (°C)	—	-0.063*** (0.014)	0.006* (0.003)
Max Humidity (%)	-3.24* (1.14)	—	—
Mean Wind Speed (km h^{-1})	—	0.157*** (0.042)	—
Max Wind Speed (km h^{-1})	—	-0.061* (0.023)	—
Wind Direction (degrees)	—	-0.005* (0.002)	—

(b)

Predictors	PM_{10} Anomaly	Ground-based AOD	Satellite AOD
		Pre-monsoon	
Ordinary R^2	0.31	0.21	0.49
Adjusted R^2	0.24	0.18	0.48
FRP (1000 MW)	—	—	—
Min Temp (°C)	-6.74* (2.39)	—	—
Max Temp (°C)	—	—	0.02** (0.006)
Min Dew Point (°C)	—	0.021* (0.008)	0.022*** (0.003)
Max Humidity (%)	-1.13 (0.6)	—	—
Mean Wind Speed (km h^{-1})	—	-0.061** (0.021)	—

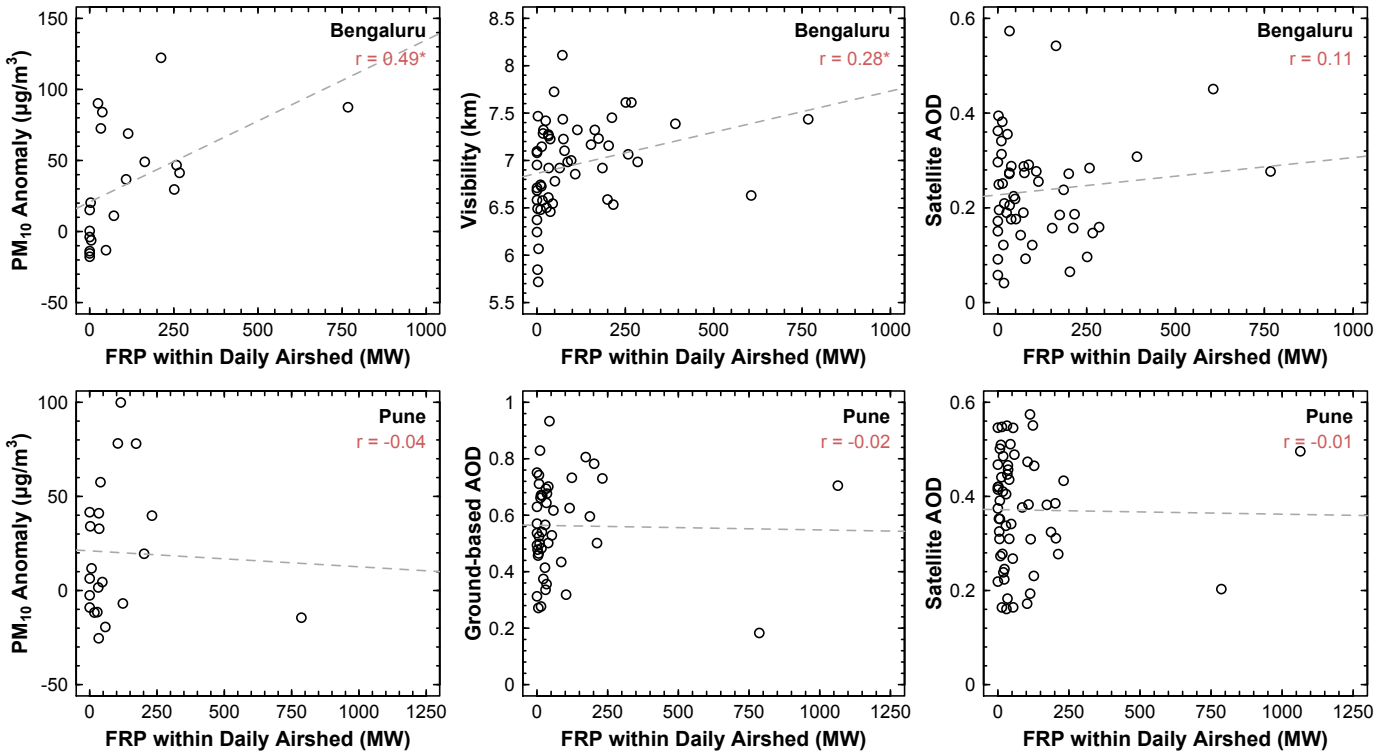


Figure S9. Correlations between FRP within the daily Bengaluru and Pune airsheds (MW) and local Bengaluru and Pune air quality observations (PM_{10} anomaly, visibility, ground-based and satellite AOD). The top panels depict the scatterplots for the 5-day averaging window for Bengaluru, and the bottom panels depict those for Pune during the respective pre-monsoon burning seasons. Starred correlations are statistically significant (p-value < 0.05).

Table S6. Summary statistics for correlations between total FRP within the daily airshed and air quality variables for a) Delhi post-monsoon, b) Delhi pre-monsoon, c) Bengaluru pre-monsoon, and d) Pune pre-monsoon. Statistics for the 3-day, 5-day, 7-day averaging windows are shown. Bolded correlations denote statistical significance (p-value < 0.05).

(a)

Delhi post-monsoon	FRP in Daily Airshed (MW)	PM_{10} Anomaly (μg m^{-3})				Visibility (km)				Satellite AOD			
	95 % CI	95 % CI	r	p-value	df	95 % CI	r	p-value	df	95 % CI	r	p-value	df
3-day	(802,1330)	**(30,61)**	**0.33**	**0**	**129**	**(1.68,1.88)**	**-0.3**	**0**	**135**	(0.73,0.84)	0.1	0.26	132
5-day	(775,1376)	**(30,67)**	**0.3**	**0.01**	**82**	**(1.65,1.91)**	**-0.32**	**0**	**82**	(0.71,0.84)	0.2	0.07	82
7-day	(821,1489)	**(25,68)**	**0.41**	**0**	**54**	**(1.64,1.95)**	**-0.38**	**0**	**54**	(0.73,0.87)	0.23	0.09	54

(b)

Delhi pre-monsoon	FRP in Daily Airshed (MW)	PM_{10} Anomaly (μg m^{-3})				Visibility (km)				Satellite AOD			
	95 % CI	95 % CI	r	p-value	df	95 % CI	r	p-value	df	95 % CI	r	p-value	df
3-day	(204,411)	(17,47)	0.15	0.14	91	(2.6,2.71)	-0.13	0.19	95	(0.58,0.7)	0.07	0.48	93
5-day	(196,410)	**(16,44)**	**0.26**	**0.05**	**58**	(2.59,2.72)	-0.08	0.56	58	(0.57,0.72)	0.13	0.32	58
7-day	(187,448)	(14,49)	0.26	0.1	38	(2.57,2.72)	-0.09	0.57	38	(0.55,0.71)	0.27	0.1	38

(c)

Bengaluru pre-monsoon	FRP in Daily Airshed (MW)	PM_{10} Anomaly (μg m^{-3})				Visibility (km)				Satellite AOD			
	95 % CI	95 % CI	r	p-value	df	95 % CI	r	p-value	df	95 % CI	r	p-value	df
3-day	(67,142)	**(15,46)**	**0.46**	**0.01**	**30**	(6.84,7.06)	0.25	0.12	88	(0.21,0.27)	0.11	0.32	79
5-day	(62,142)	**(15,50)**	**0.49**	**0.02**	**19**	**(6.83,7.08)**	**0.28**	**0.04**	**53**	(0.21,0.27)	0.11	0.46	49
7-day	(67,141)	**(12,56)**	**0.55**	**0.03**	**13**	**(6.83,7.11)**	**0.32**	**0.05**	**37**	(0.2,0.27)	0.11	0.51	36

(d)

Pune pre-monsoon	FRP in Daily Airshed (MW)	PM_{10} Anomaly (μg m^{-3})				Ground-based AOD				Satellite AOD			
	95% CI	95 % CI	r	p-value	df	95 % CI	r	p-value	df	95 % CI	r	p-value	df
3-day	(44,141)	(6,28)	-0.1	0.59	32	(0.52,0.61)	-0.1	0.42	66	(0.34,0.4)	-0.11	0.29	90
5-day	(41,133)	(4,33)	-0.04	0.86	20	(0.51,0.61)	-0.02	0.9	43	(0.34,0.4)	-0.01	0.92	56
7-day	(46,135)	(2,35)	-0.15	0.6	13	(0.51,0.62)	-0.09	0.65	28	(0.33,0.4)	-0.16	0.32	37

Table S7. Correlation coefficients of air quality variables for a) Delhi post-monsoon, b) Delhi pre-monsoon, c) Bengaluru pre-monsoon, and d) Pune pre-monsoon. Minimum and maximum correlation coefficients refer to those for the lowest and highest correlations for the 3-day, 5-day, and 7-day averaging windows.

(a)

Delhi post-monsoon	PM_{10} Anomaly	Visibility	Satellite AOD
PM_{10} Anomaly	1	—	—
Visibility	Min: -0.64 Max: -0.67	1	—
Satellite AOD	Min: 0.1 Max: 0.2	Min: -0.31 Max: -0.35	1

(b)

Delhi pre-monsoon	PM_{10} Anomaly	Visibility	Satellite AOD
PM_{10} Anomaly	1	—	—
Visibility	Min: -0.21 Max: -0.38	1	—
Satellite AOD	Min: 0.05 Max: 0.16	Min: -0.12 Max: -0.19	1

(c)

Bengaluru pre-monsoon	PM_{10} Anomaly	Visibility	Satellite AOD
PM_{10} Anomaly	1	—	—
Visibility	Min: 0.38 Max: 0.41	1	—
Satellite AOD	Min: 0.02 Max: 0.12	Min: -0.09 Max: -0.38	1

(d)

Pune pre-monsoon	PM_{10} Anomaly	Ground-based AOD	Satellite AOD
PM_{10} Anomaly	1	—	—
Ground-based AOD	Min: 0.28 Max: 0.37	1	—
Satellite AOD	Min: -0.04 Max: -0.17	Min: 0.75 Max: 0.8	1

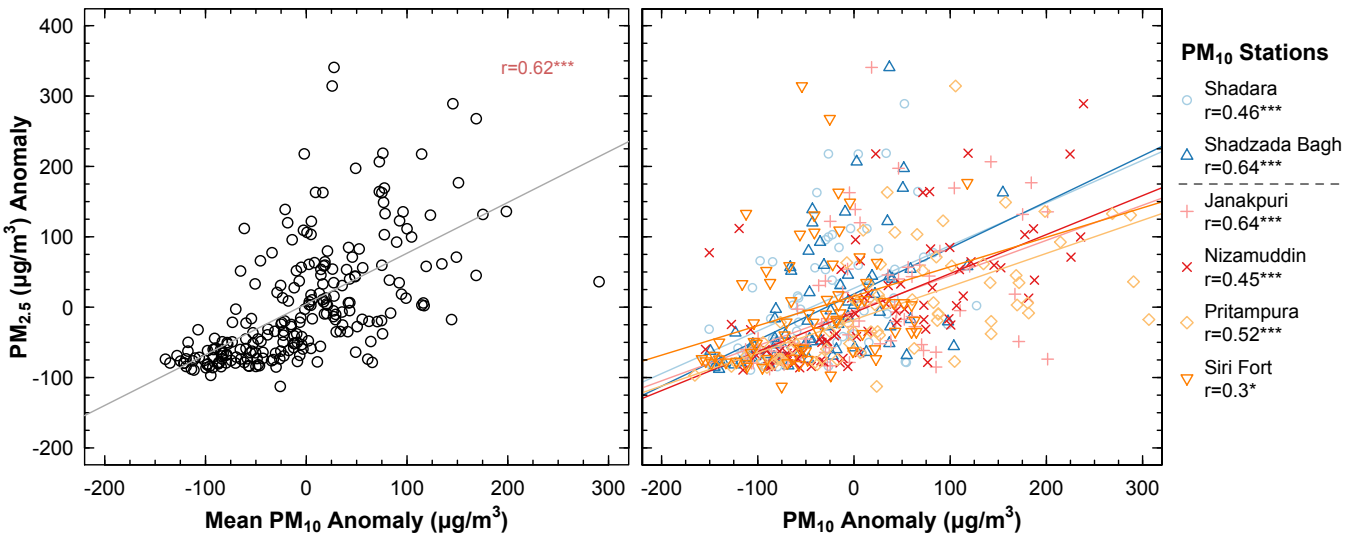


Figure S10. Correlations between daily station PM_{10} anomalies (µg m^{-3}) and $PM_{2.5}$ anomalies (µg m^{-3}) in Delhi in 2013. The left panel shows the correlation between daily station mean PM_{10} anomalies and $PM_{2.5}$ anomalies. The right panel shows the correlations between PM_{10} anomalies (µg m^{-3}) at individual stations and $PM_{2.5}$ anomalies. The statistical significance (based on p-values) is denoted as follows: 0-0.001 '***', 0.001-0.01 '**', 0.01-0.05 '*', 0.05-0.1 ''.

Table S8. One and two sample t-tests with 95 % confidence intervals of FRP within the daily airshed on normal and extreme air pollution days as defined by a) average station PM_{10} anomalies (μg m^{-3}), b) visibility (km), c) satellite AOD, d) ground-based AOD, and e) station $PM_{2.5}$ (μg m^{-3}) in Delhi, Bengaluru, and Pune during the respective post-monsoon and pre-monsoon burning seasons for the 3-day, 5-day, and 7-day averaging windows. Bolded rows denote statistical significance (p-value < 0.05) and a positive 95 % confidence interval in the difference of FRP within the daily airshed between normal and extreme days ($FRP_{extreme}$ - FRP_{normal}).

(a)

City, season	Avg. Window	Normal PM_{10} Days (≤Mean+1 SD)			High PM_{10} Days (>Mean+1 SD)			Welch Two Sample t-test		
		PM_{10} Anomaly (μg m^{-3})	FRP (MW)	df	PM_{10} Anomaly (μg m^{-3})	FRP (MW)	df	$FRP_{Extreme-Normal}$ (MW)	p-value	df
Delhi post-monsoon	**3-day**	**(11,36)**	**(652,1182)**	**115**	**(171,231)**	**(929,3352)**	**14**	**(-9,2457)**	**0.05**	**16**
	5-day	**(9,41)**	**(600,1208)**	**70**	**(148,204)**	**(1055,2972)**	**12**	**(117,2102)**	**0.03**	**15**
	7-day	**(7,44)**	**(644,1333)**	**47**	**(141,204)**	**(1148,3163)**	**7**	**(136,2199)**	**0.03**	**9**
Delhi pre-monsoon	3-day	(4,26)	(196,422)	81	(128,206)	(-14,775)	10	(-333,476)	0.71	12
	5-day	(1,27)	(184,425)	49	(88,132)	(29,563)	9	(-292,276)	0.95	14
	7-day	(4,35)	(162,440)	34	(75,158)	(-138,1011)	4	(-428,699)	0.56	5
Bengaluru pre-monsoon	3-day	(6,31)	(13,93)	25	(92,122)	(-89,703)	5	(-141,650)	0.16	5
	5-day	(4,34)	(27,129)	16	(68,124)	(-294,815)	3	(-366,731)	0.37	3
	7-day	(3,33)	(21,146)	11	(68,144)	(-293,752)	2	(-342,634)	0.35	2
Pune pre-monsoon	3-day	(-5,11)	(-2,199)	26	(61,93)	(-17,170)	6	(-149,106)	0.73	26
	5-day	(-4,18)	(-2,184)	17	(51,106)	(22,194)	3	(-91,126)	0.74	18
	7-day	(-5,22)	(-9,196)	11	(15,115)	(36,146)	2	(-107,102)	0.96	12

(b)

City, season	Avg. Window	Normal Visibility Days (≥Mean+1 SD)			Low Visibility Days (<Mean+1 SD)			Welch Two Sample t-test		
		Visibility (km)	FRP (MW)	df	Visibility (km)	FRP (MW)	df	$FRP_{Extreme-Normal}$ (MW)	p-value	df
Delhi post-monsoon	**3-day**	**(1.87,2.07)**	**(627,1083)**	**109**	**(0.94,1.06)**	**(976,2873)**	**26**	**(97,2042)**	**0.03**	**29**
	5-day	(1.83,2.08)	(660,1295)	67	(0.96,1.12)	(614,2369)	15	(-408,1435)	0.26	20
	7-day	(1.85,2.14)	(715,1431)	43	(0.97,1.13)	(506,2405)	11	(-613,1377)	0.43	15
Delhi pre-monsoon	3-day	(2.67,2.78)	(165,375)	82	(2.2,2.32)	(153,908)	13	(-128,649)	0.17	15
	5-day	(2.67,2.78)	(188,426)	49	(2.25,2.36)	(-12,577)	9	(-333,284)	0.87	13
	7-day	(2.65,2.79)	(145,405)	32	(2.25,2.4)	(9,1035)	6	(-269,763)	0.3	7
Bengaluru pre-monsoon	3-day	(7.07,7.25)	(70,149)	72	(5.99,6.22)	(-37,199)	16	(-151,94)	0.63	20
	5-day	(6.96,7.17)	(71,161)	47	(5.89,6.45)	(-4,21)	6	(-153,-62)	0	51
	7-day	(7.01,7.25)	(73,160)	31	(6.06,6.4)	(-17,108)	6	(-142,-1)	0.05	16

(c)

City, season	Avg. Window	Normal Satellite AOD Days (≤Mean+1 SD)			High Satellite AOD Days (>Mean+1 SD)			Welch Two Sample t-test		
		Satellite AOD	FRP (MW)	df	Satellite AOD	FRP (MW)	df	$FRP_{Extreme-Normal}$ (MW)	p-value	df
Delhi post-monsoon	3-day	(0.62,0.72)	(825,1447)	112	(1.25,1.43)	(435,1248)	20	(-797,208)	0.25	51
	5-day	(0.64,0.75)	(698,1354)	72	(1.2,1.46)	(573,2235)	10	(-495,1251)	0.37	14
	7-day	(0.67,0.79)	(785,1524)	47	(1.09,1.39)	(183,2132)	7	(-1002,1009)	0.99	10
Delhi pre-monsoon	3-day	(0.51,0.59)	(178,411)	80	(1.02,1.38)	(159,690)	13	(-154,414)	0.35	19
	5-day	(0.5,0.6)	(174,401)	49	(0.95,1.28)	(32,728)	9	(-266,452)	0.58	12
	7-day	(0.49,0.6)	(131,414)	32	(0.91,1.2)	(151,914)	6	(-129,650)	0.16	9
Bengaluru pre-monsoon	3-day	(0.18,0.22)	(70,147)	69	(0.38,0.53)	(-45,370)	10	(-156,264)	0.58	11
	5-day	(0.18,0.23)	(65,151)	43	(0.36,0.52)	(-84,325)	6	(-193,218)	0.89	7
	7-day	(0.18,0.23)	(65,140)	32	(0.32,0.5)	(-86,354)	4	(-186,249)	0.71	4
Pune pre-monsoon	3-day	(0.3,0.35)	(39,144)	74	(0.55,0.59)	(29,108)	16	(-87,42)	0.48	78
	5-day	(0.31,0.37)	(39,111)	47	(0.51,0.55)	(-87,379)	9	(-163,306)	0.51	10
	7-day	(0.29,0.36)	(37,149)	29	(0.49,0.52)	(20,145)	8	(-90,69)	0.79	25

(d)

City, season	Avg. Window	Normal Ground-based AOD Days (≤Mean+1 SD)			High Ground-based AOD Days (>Mean+1 SD)			Welch Two Sample t-test		
		Ground-based AOD	FRP (MW)	df	Ground-based AOD	FRP (MW)	df	$FRP_{Extreme-Normal}$ (MW)	p-value	df
Pune pre-monsoon	3-day	(0.49,0.57)	(27,160)	58	(0.79,0.92)	(-7,139)	8	(-122,66)	0.55	30
	5-day	(0.47,0.57)	(19,157)	37	(0.73,0.86)	(2,158)	6	(-105,89)	0.86	23
	7-day	(0.48,0.58)	(20,152)	25	(0.74,0.88)	(-17,271)	3	(-93,174)	0.49	7

(e)

City, season	Avg. Window	Normal $PM_{2.5}$ Days (≤Mean+1 SD)			High $PM_{2.5}$ Days (>Mean+1 SD)			Welch Two Sample t-test		
		$PM_{2.5}$ ($\mu g\ m^{-3}$)	FRP (MW)	df	$PM_{2.5}$ ($\mu g\ m^{-3}$)	FRP (MW)	df	$FRP_{Extreme-Normal}$ (MW)	p-value	df
Delhi post-monsoon	**3-day**	**(111,182)**	**(361,1625)**	**16**	**(204,403)**	**(1522,8122)**	**2**	**(998,6659)**	**0.02**	**4**
Delhi pre-monsoon	3-day	(80,103)	(-13,328)	14	(99,172)	(-35,542)	2	(-139,311)	0.38	4

Table S9. R and Matlab packages used for statistical and geospatial analyses and data visualization

	Purpose	Package	Reference(s)
R	Geospatial	raster	Hijmans, 2015
		rgeos	Bivand and Rundel, 2015
		maptools	Bivand and Lewin-Koh, 2016
		mapproj	McIlroy, 2015
		maps	Becker and Wilks, 2016
		rgdal	Bivand et al, 2015
		spdep	Bivand and Piras, 2015; Bivand et al, 2013
		sp	Pebesma and Bivand 2005; Bivand et al, 2013
		fields	Nychka et al, 2016
	Statistical	leaps	Lumley, 2009
		pracma	Borchers, 2015
		usdm	Naimi, 2015
	Data Format and Visualization, Miscellaneous	R.matlab	Bengtsson, 2016
		zoo	Zeileis and Grothendieck, 2005
		plyr	Wickham, 2011
Matlab		cbrewer	Robert, 2011
		freezeColors/unfreeze Colors	Iverson, 2015
		m_map	Pawlowicz, 2014
		lat_lon_proportions	Sullivan, 2011

We used the R Project for Statistical Computing (R), Matlab, and QGIS for all statistical and geospatial analyses (R Core Team 2015, Matlab 2016; Table S8). R Code to approximate of HYSPLIT-derived airsheds and estimate FRP within airshed is available at https://github.com/tianjialiu/HyAirshed-RPackage.

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