Electronic Supplementary Material (ESI) for Environmental Science: Atmospheres.

The Supplementary Material

Quantifying the dominant sources influencing the 2016 particulate matter pollution episode over northern India

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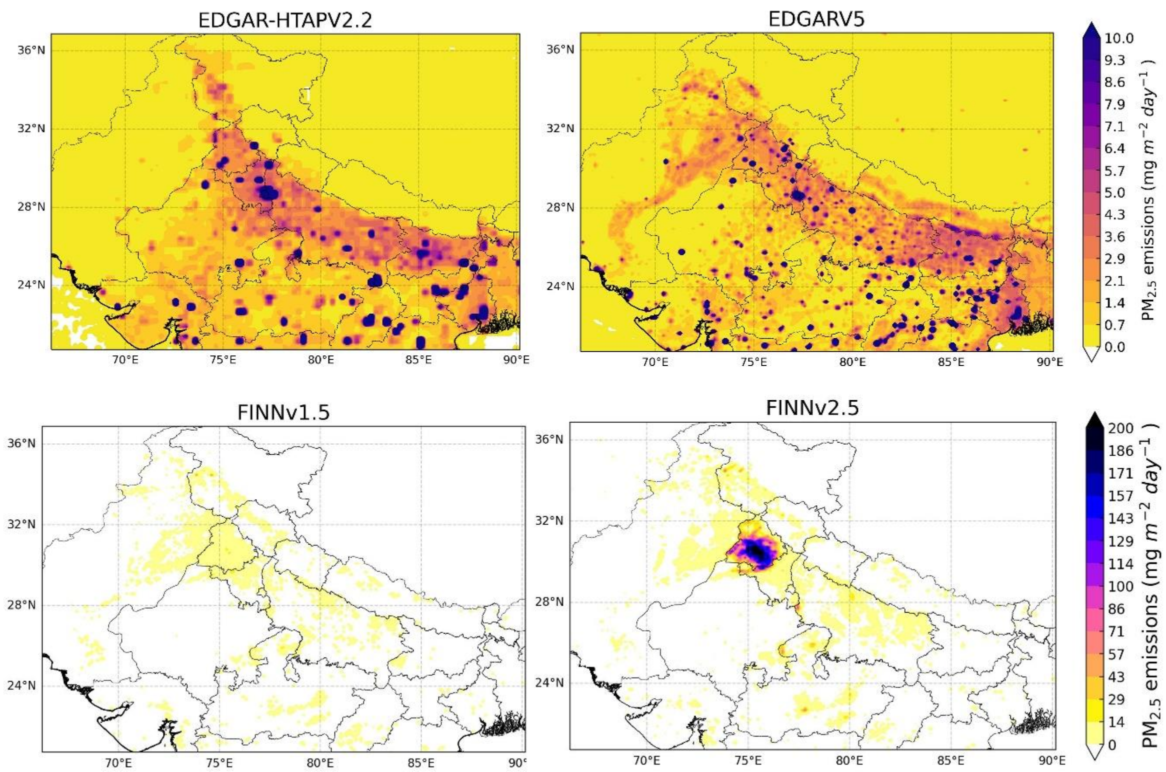

Figure S1. Upper panels: comparison of daily mean $PM_{2.5}$ anthropogenic emissions from the EDGAR-HTAPv2.2 (2010) and EDGAR-v5.0 (2015) inventories averaged over Oct-Nov. Lower panels: comparison of daily mean fire $PM_{2.5}$ emissions from FINNv1.5 and FINNv2.5 averaged over 15 October - 30 November 2016. The emissions of trace gases (CO, NO_X, and NMVOCs) show similar differences between FINNv1.5 and FINNv2.5 datasets.

Table S1. Locations of the measurement sites used for meteorology and chemistry evaluation. The areas corresponding to the three IGP (Indo-Gangetic plain) regions are shown in Figure 1.

	Meteorology (ASOS, Radiosonde)	**$PM_{2.5}$**	**BC**
Upper IGP	Amritsar Chandigarh Ludhiaha	Panchkula Mohali	Chandigarh
Middle IGP	Delhi Agra	Delhi Gurgaon Rohtak Agra	Delhi
Lower IGP	Kolkata Varanasi Lucknow Gorakhpur Ranchi Jamshedpur Patina	Kanpur Kolkata Lucknow Patna Varanasi Muzaffarpur	Varanasi Kolkata

S. 1. Meteorology evaluation

Figure S2 shows the temporal variation of observed and simulated hourly 2-m temperature (T2), relative humidity (RH), wind speed (WS), and wind rose plots averaged over the available observation sites in each IGP sub-region 29 Oct – 11 Nov. Statistical bias and error metrics are provided in Table S2. These show that the overall statistical performance of the model, especially for the middle and lower IGP, fulfils the benchmarks suggested by Emery and Tai [1] with MAE for T2 ≈ 2 °C and RMSE for WS ≤ 2 m s^{-1}. In general, the model underestimates T2 and RH (by ≈ 2 - 3 °C and 15 – 30 % on average, respectively) and overestimates WS (by 1 - 1.5 m s^{-1}). The model represents well the daily and diurnal temporal variability in meteorology across all the IGP regions with $r > 0.9$ for T2 and RH and $r > 0.6$ for WS, with the best performance across the middle IGP (Figure S3). The modelled diurnal variation of planetary boundary layer height (PBLH, Figure S3) averaged over the meteorological observation sites shows typical diurnal evolution (deeper during the peak afternoon hours (1- 2 km) and shallower at night (< 500 m)) with the highest daytime height (up to 2 km) over the middle IGP. Overall, the meteorological variables show a characteristic diurnal variation, reflecting a strong influence of meteorology on the mixing of near-surface pollutants over the study region, as noted previously [2–4].

Table S2. Summary of statistical comparison modelled and observed meteorology variables averaged across the surface measurement sites in the upper, middle, and lower IGP regions during 29 Oct – 10 Nov. The statistical metrics are mean bias (MB), normalized mean bias (NMB), mean absolute error (MAE), root mean square error (RMSE) and Pearson's correlation coefficient (*r*).

	MB / unit	**NMB**	**MAE / unit**	**RMSE / unit**	***r***
Temperature (^oC)					
Upper	3	0.15	3.04	3.52	0.94
Middle	2.1	0.09	2.16	2.46	0.97
Lower	-0.65	-0.03	0.77	0.94	0.99
RH (%)					
Upper	-28.4	-0.36	28.7	33.0	0.79
Middle	-14.7	-0.23	14.7	16.5	0.92
Lower	2.64	0.04	3.96	4.97	0.97
Wind Speed (m s^{-1})					
Upper	1.46	3.46	1.51	1.67	0.63
Middle	0.61	0.63	0.80	0.93	0.81
Lower	0.99	0.89	1.03	1.23	0.59

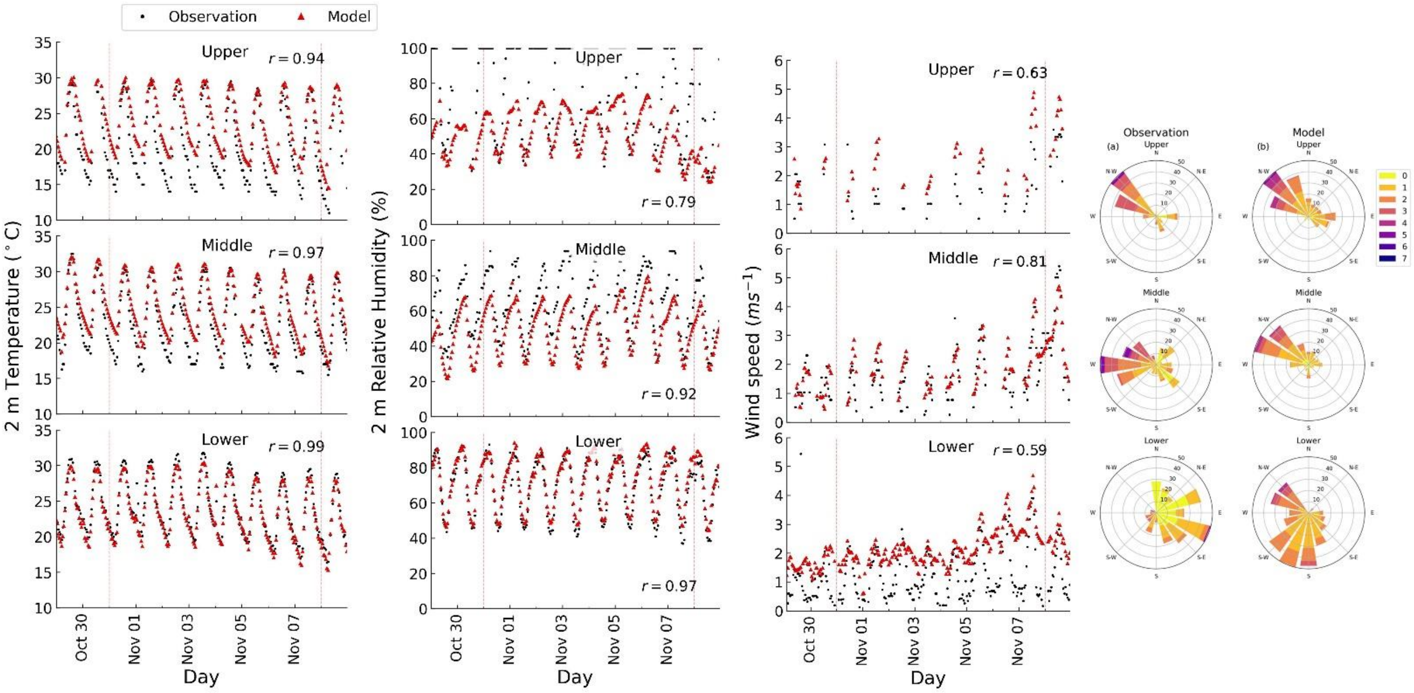

Figure S2 Comparison of hourly modelled (red markers) and observed (black markers) 2-m temperature, relative humidity, 10-m wind speed and wind roses averaged across the surface measurement sites in the upper, middle, and lower IGP regions. The vertical dashed lines in each time series panel delineate the pollution episode, and inset *r* values give the Pearson's correlation coefficient.

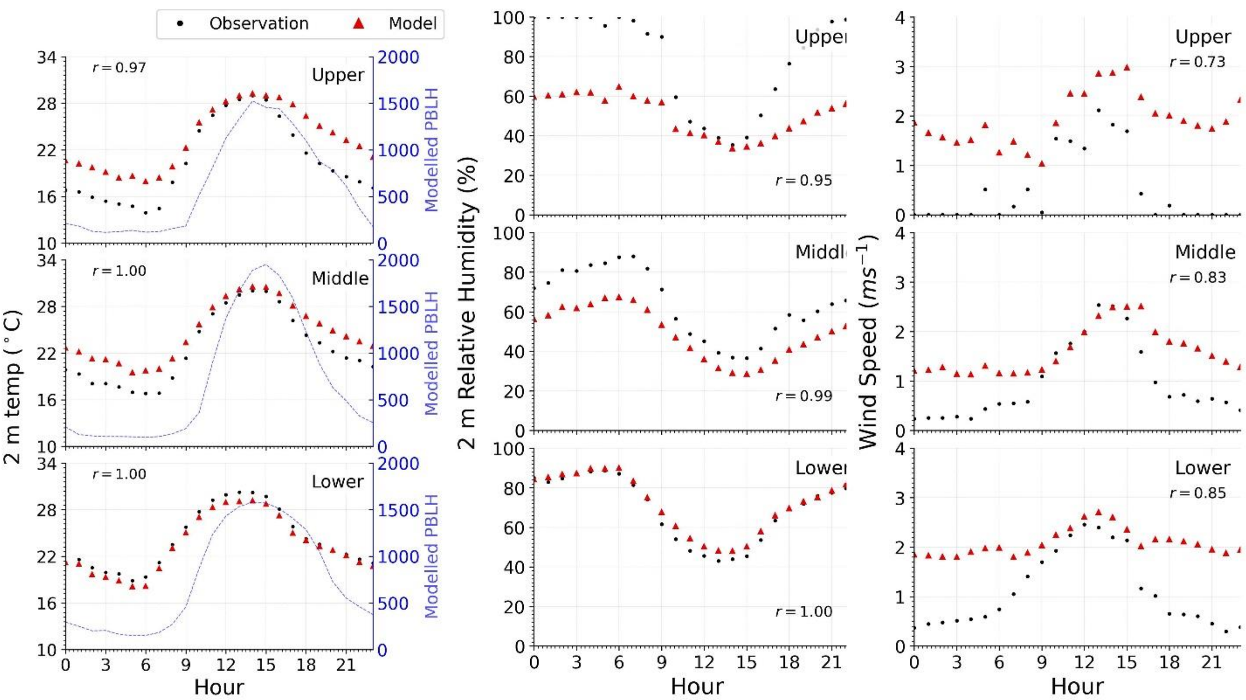

Figure S3 Comparison of diurnal modelled (red markers) and observed (black markers) 2-m temperature, relative humidity, 10-m wind speed averaged across the surface measurement sites in the upper, middle, and lower IGP regions. The secondary y-axis (blue colour) in temperature time series shows the modelled diurnal planetary boundary layer height (PBLH), and inset *r* values in all panels give the Pearson's correlation coefficient.

Table S3. Summary of statistical comparison modelled and observed meteorology variables averaged across the surface measurement sites in the upper, middle, and lower IGP regions during 29 Oct – 10 Nov. The statistical metrics used for comparison are mean bias (MB), normalized mean bias (NMB), mean absolute error (MAE), root mean square error (RMSE) and Pearson's correlation coefficient (*r*).

Variable	**MB / unit**	**NMB**	**MAE / unit**	**RMSE / unit**	***r***
$PM_{2.5}$ / μg m^{-3}					
Upper	-25.2	-0.2	39.7	62.7	0.53
Middle	-133	-0.3	190	259	0.34
Lower	-88.2	-0.4	92	136	0.46
BC / μg m^{-3}					
Upper	-12.4	-0.82	12.3	15.2	0.58
Middle	-17.7	-0.55	19.3	24.5	0.20
Lower	-13.2	-0.75	9.8	18.2	0.42
AOD (AERONET)					
Lahore	-1.07	-0.62	1.08	1.38	0.21
Kanpur	-0.35	-0.42	0.35	0.43	0.66
AOD (MODIS)	-0.04	-0.09	0.42	0.23	0.78

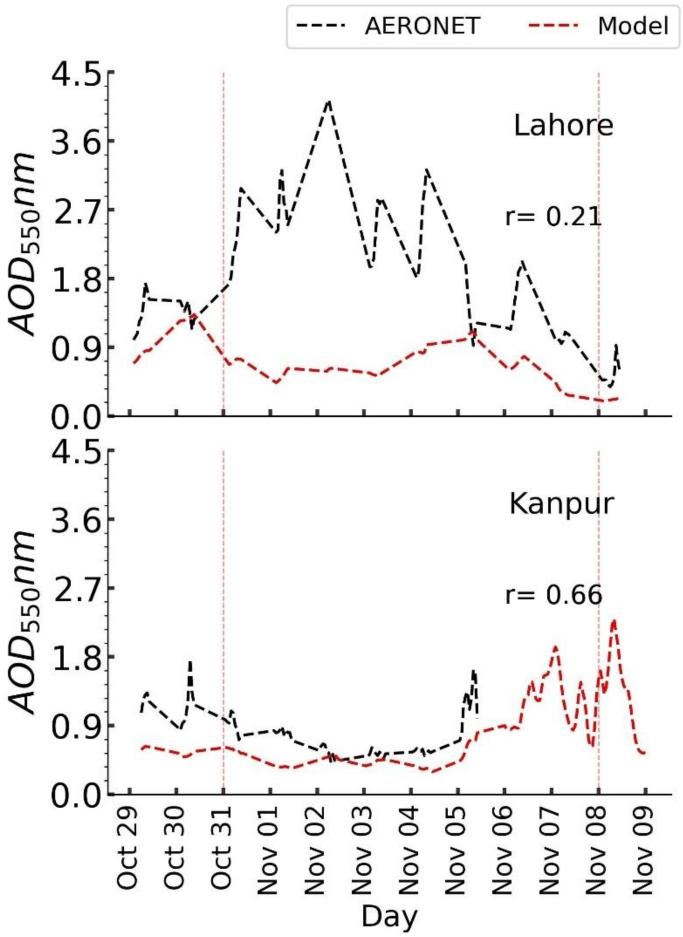

Figure S4. Comparison of modelled (red) and observed (black) hourly AOD (550nm) across AERONET locations in Lahore and Kanpur (upper and lower IGP regions, respectively). The vertical dashed lines in each panel delineate the pollution episode, and the *r* values are the Pearson's correlation coefficients.

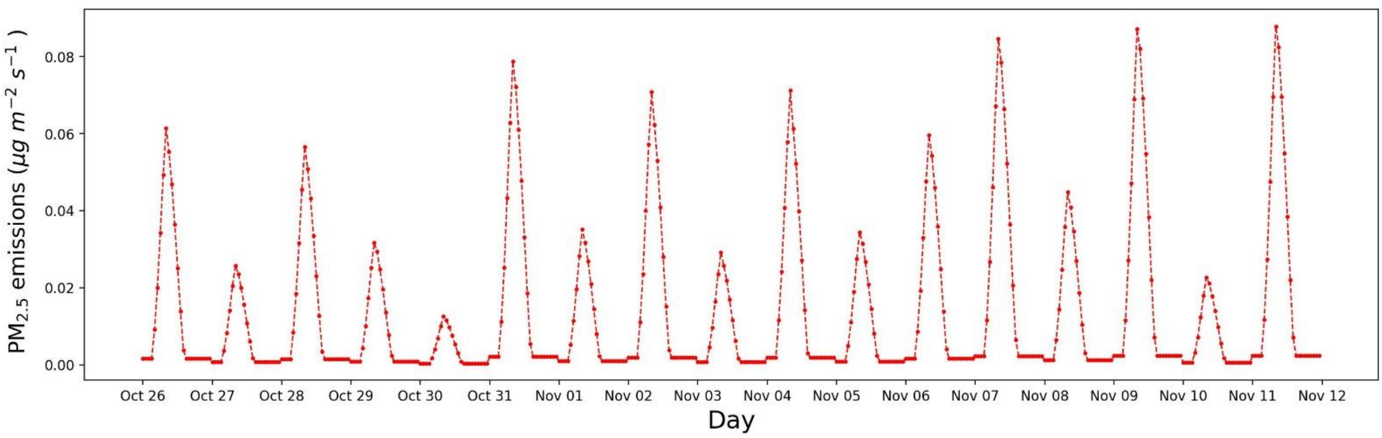

Figure S5. Hourly varying fire emissions of $PM_{2.5}$ across the NW states of Punjab and Haryana in the domain between 26 Oct – 11 Nov 2016 from the FINNv2.5.

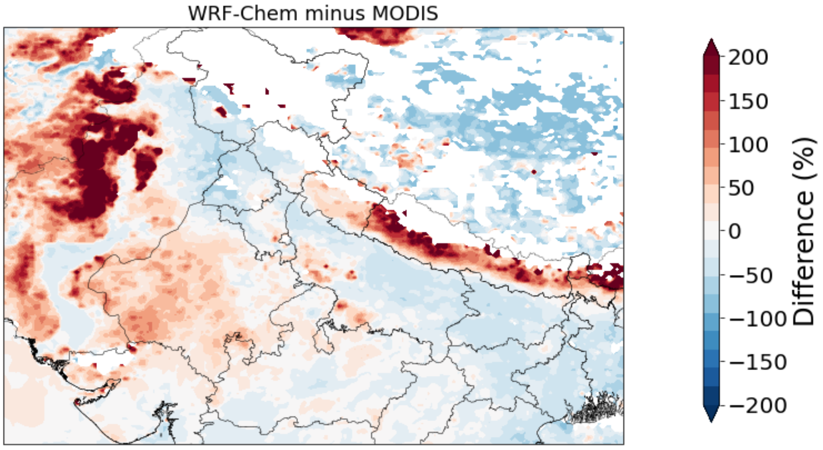

Figure S6. Percentage differences between the model and satellite AOD (550nm) values.

References

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