Supplementary Material: ENSO Modulation of $PM_{2.5}$ air pollution in Central Kalimantan, Indonesia revealed by a dense network of Purple Air sensors

1. Sensor Network

1.1 Sensor Network 2023

Table S1. Purple Air monitors used to provide long-term $PM_{2.5}$ monitoring across Central Kalimantan, Indonesia between August 2023 and January 2025, used in this analysis. Anonymous sensor names are provided, their location, and the sensor ID for the outdoor sensor at each location. In addition, information is included on the location type and building type. Sites are coloured by location type (green: rural, grey: urban, blue: remote).

Sensor Name	Location	Outdoor Sensor ID	Location Type	Building Type
PLK_01	Palangkaraya	Kali_01	Urban	Household
KR_05	Kereng	Kali_08	Urban	Hospital
TT_03	Tanjung Taruna	Kali_05	Rural	Household
SBG_01	Sebangau	Kali_07 *(replaced with Kali_34 on 08/10/2024)*	Remote	-

Sensor Network Map 2023

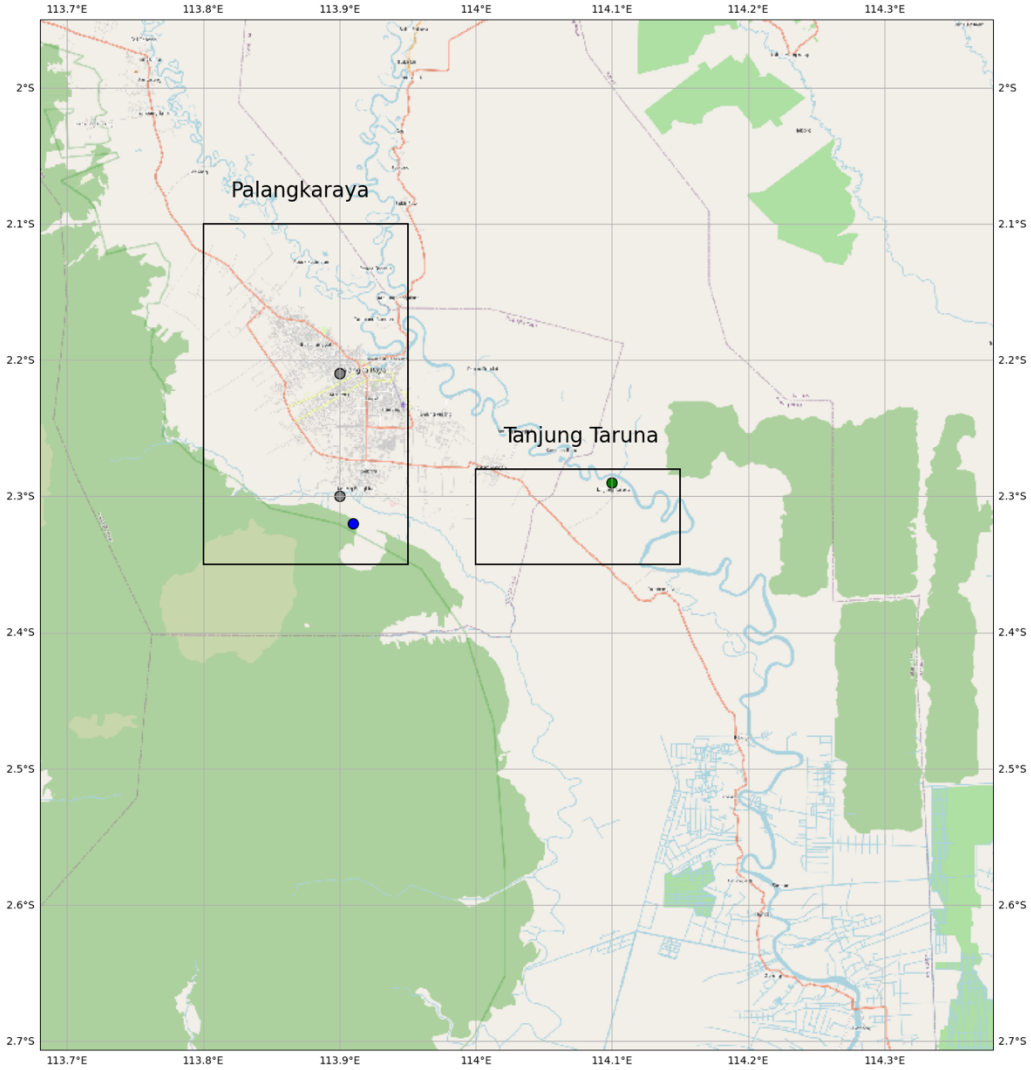


Figure S1. Map of long-term Purple Air sensor locations (a) across Pulang Pisau, Central Kalimantan between 2023 and 2024. Locations for Purple Air sensor in Palangkaraya and Tanjung Taruna are highlighted. Sites are coloured by site type (urban: grey, rural: green and remote: blue). Latitude and longitude of locations have been limited to two decimal places to maintain volunteer anonymity.

1.2 Sensor Network 2024

Table S2. Outdoor Purple Air monitors deployed across Central Kalimantan, Indonesia between June 2024 and January 2025, used in this analysis. Anonymous sensor names are provided, their location, and the sensor ID for the outdoor sensor at each location. In addition, information is included on the location type, and building type. Sites are coloured by location type (green: rural, grey: urban, blue: remote).

1. Sensor Name	Location	Sensor ID outdoor	Location Type	Building Type	notes
2. PLK_01	Palangkaraya	Kali_01	Urban	Household	
3. PLK_02	Palangkaraya	Kali_90	Urban	Household	
4. PLK_04	Palangkaraya	Kali_82	Urban	Household	
5. PLK_05	Palangkaraya	Kali_46	Urban	Hotel	
6. PLK_06	Palangkaraya	Kali_106	Urban	School	
7. PLK_07	Palangkaraya	Kali_20	Urban	Household	
8. PLK_08	Palangkaraya	Kali_18	Urban	Household	
9. PLK_09	Palangkaraya	Kali_114	Urban	Office	
10. PLK_10	Palangkaraya	Kali_23, Kali_111, Kali_112	Urban	Reference Monitor Site (for collocation)	Not used in analysis*
11. PLK_12	Palangkaraya	Kali_76	Urban	Household	
12. PLK_14	Palangkaraya	Kali_102	Urban	University Dormitory	
13. PLK_15	Palangkaraya	Kali_105	Urban	Hotel	
14. PLK_16	Palangkaraya	Kali_110	Urban	Household	
15. PLK_17	Palangkaraya	Kali_36	Urban	Office	
16. PLK_19	Palangkaraya	Kali_98	Urban	Office	
17. PLK_21	Palangkaraya	Kali_41	Urban	Household	
18. PLK_23	Palangkaraya	Kali_39	Urban	Office	
19. PLK_26	Palangkaraya	Kali_11	Urban	Household	
20. PLK_27	Palangkaraya	Kali_13	Urban	Office	
21. PLK_29	Palangkaraya	Kali_48	Urban	University Teaching Building	
22. PLK_30	Palangkaraya	Kali_42	Urban	Hospital	
23. KR_05	Kereng	Kali_08	Urban	Hospital	
24. KR_07	Kereng	Kali_96	Urban	School	

25. KR_08	Kereng	Kali_94	Urban	Household	
26. KR_09	Kereng	Kali_92	Urban	Household	
27. KR_10	Kereng	Kali_88	Urban	Household	
28. KR_11	Kereng	Kali_31	Urban	Household	
29. TT_03	Tanjung Taruna	Kali_05	Rural	Household	
30. TT_08	Tanjung Taruna	Kali_78	Rural	Household	
31. TT_09	Tanjung Taruna	Kali_74	Rural	Office	
32. TT_11	Tanjung Taruna	Kali_29	Rural	School	
33. TT_12	Tanjung Taruna	Kali_86	Rural	Household	
34. TT_13	Tanjung Taruna	Kali_27	Rural	Household	
35. TT_14	Tanjung Taruna	Kali_25	Rural	Household	
36. TTH_02	Tumbang Tahai	Kali_54	Rural	Office	
37. TTH_03	Tumbang Tahai	Kali_56	Rural	School	
38. TTH_04	Tumbang Tahai	Kali_52	Rural	School	
39. TTH_05	Tumbang Tahai	Kali_63	Rural	Household	
40. TTH_07	Tumbang Tahai	Kali_67	Rural	Household	
41. TTH_08	Tumbang Tahai	Kali_65	Rural	Household	
42. TTH_09	Tumbang Tahai	Kali_16	Rural	Household	
43. GH_02	Gohong	Kali_108	Rural	Office	
44. GH_03	Gohong	Kali_22	Rural	School	
45. BR_01	Bukit Raya	Kali_72	Urban	Household	
46. SBG_01	Sebangau	Kali_07 (replaced with 34)	Remote	Sebangau	Kali_07 replaced with Kali_34 on 08.10.2024

Sensor Network Map 2024

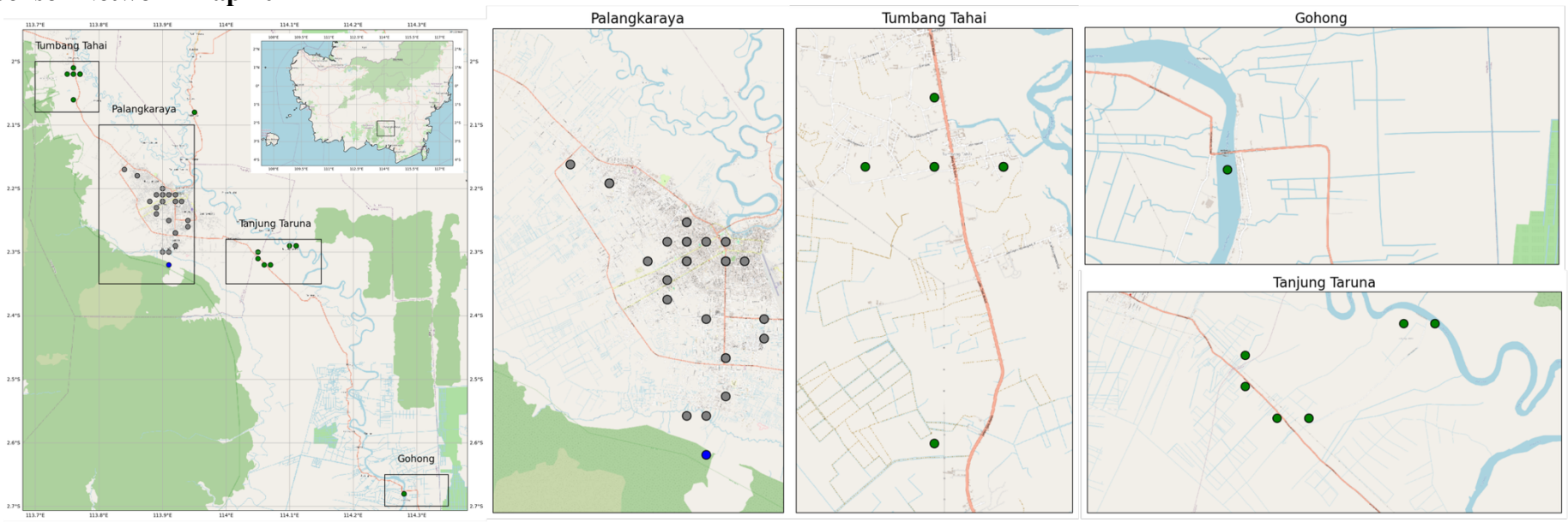


Figure S2. Map of Purple Air sensor locations (a) across Pulang Pisau, Central Kalimantan, with individual locations included in this study marked on, and named, for reference. Map inset indicates location of study region in Borneo. Locations and volunteer codes for Purple Air sensor in (b) Palangkaraya (c) Tumbang Tahai (d) Tanjung Taruna and (e) Gohong, as marked locations on (a). In (a) – (e) sites are coloured by site type (urban: grey, rural: green and remote: blue). Latitude and longitude of locations have been limited to two decimal places to maintain volunteer anonymity.

1.3 Sensor Network 2025

Table S3. Purple Air monitors deployed across Central Kalimantan, Indonesia between Februrary 2025 and October 2025. Anonymous sensor names are provided, their location, and the sensor ID for the outdoor sensor at each location. In addition, information is included on the location type and building type. Sites are coloured by location type (grey: urban, blue: remote).

Sensor Name	Location	Outdoor Sensor ID	Location Type	Building Type
PLK_04	Palangkaraya	Kali_82	Urban	Household
PLK_07	Palangkaraya	Kali_20	Urban	Household
PLK_17	Palangkaraya	Kali_36	Urban	Office (DLH)
PLK_19	Palangkaraya	Kali_97	Urban	Office (Fire Station)
SBG_01	Sebangau	Kali_07 *(replaced with Kali_34 on 08/10/2024)*	Remote	-
MB_01	Mungku Baru	Kali_70	Remote	Household

Sensor Network Map 2025

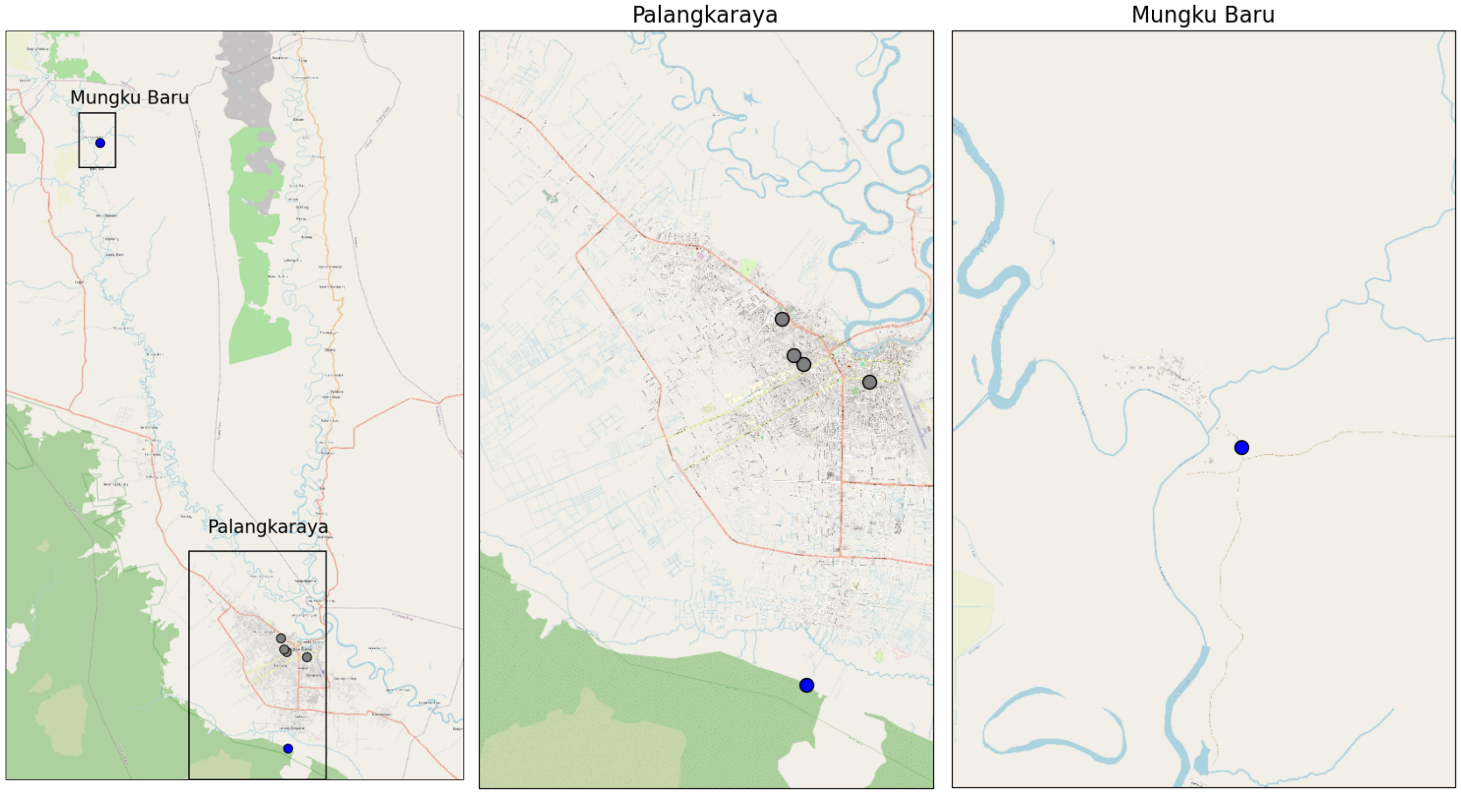


Figure S3. Map of Purple Air sensor locations across Pulang Pisau, Central Kalimantan in 2025. Locations for Purple Air sensor in Palangkaraya and Mungku Baru are highlighted. Sites are coloured by site type (urban: grey, rural: green and remote: blue). Latitude and longitude of locations have been limited to two decimal places to maintain volunteer anonymity.

2. Relative Humidity Adjustment of Sensors

We collocated 3 Purple Air sensors with a reference grade air quality monitor at the Indonesian Ministry of Environment and Forestry (KLHK) in Palangkaraya for the period July 1st 2024 to January 8th 2025. The reference grade sensor used is the Horiba Air Pollution Dust Analyzer (APDA) as the FRM (HORIBA) for $PM_{2.5}$ monitoring (Kurniawati et al., 2024). Beta-ray attenuation is used to measure $PM_{2.5}$ concentrations. While hourly measurements are taken, data is only provided at daily-mean time resolution. There is no documentation available on data quality procedures.

We compare daily-mean concentrations from the 3 Purple Air sensors (sensor_names: kali_111, kali_112, kali_23) with daily mean concentrations from the reference grade sensor for the period July 1st 2024 to January 8th 2025. Without adjustment, the Purple Air sensors capture variability well (r=0.84) but overestimate concentrations (NMBF=0.75, NMAE=0.77, RMSE=37.2), most likely due to high ambient RH in the region. We utilise the most studied method for correction of low-cost sensors and use multiple linear regression (MLR) (McFarlane et al., 2021, Mattheiu-Campbell et al., 2024, Barkjohn et al., 2021). We choose this method due to its simple, transparent nature. We choose to only consider RH (Equation S1), as several studies have found this to improve Purple Air performance (McFarlane et al., 2021, Mattheiu-Campbell et al., 2024, Barkjohn et al., 2021). While some single-site studies have found temperature improves $PM_{2.5}$ prediction, there is no known mechanism for temperature influencing light scattering so we do not consider this in our adjustment.

$$\text{corrected } PM_{2.5\ (cf\_1)} = a_1 \times PM_{2.5\ (cf\_1)} + a_2 \times RH + i \quad \textit{corrected PM2.5 (cf\_1)} = a1 \times \textit{PM2.5 (cf\_1)} + a2 \times RH + i \tag{S1}$$

$a_1 = 0.49441527 \qquad a_2 = -0.06550617 \qquad i = 3.1348177901293326$

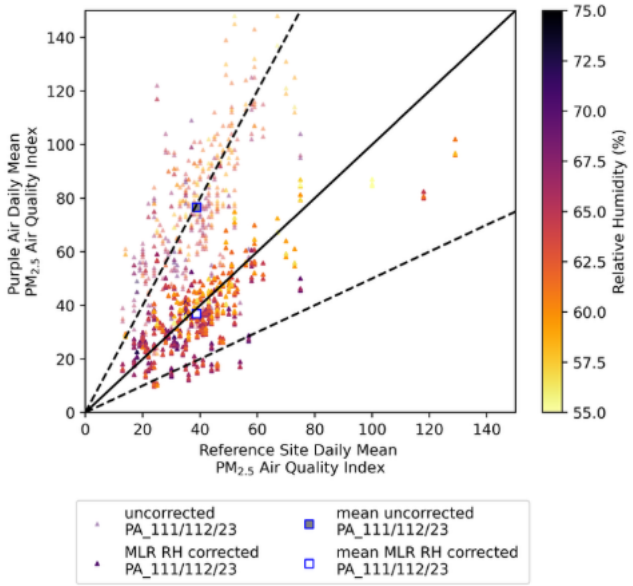


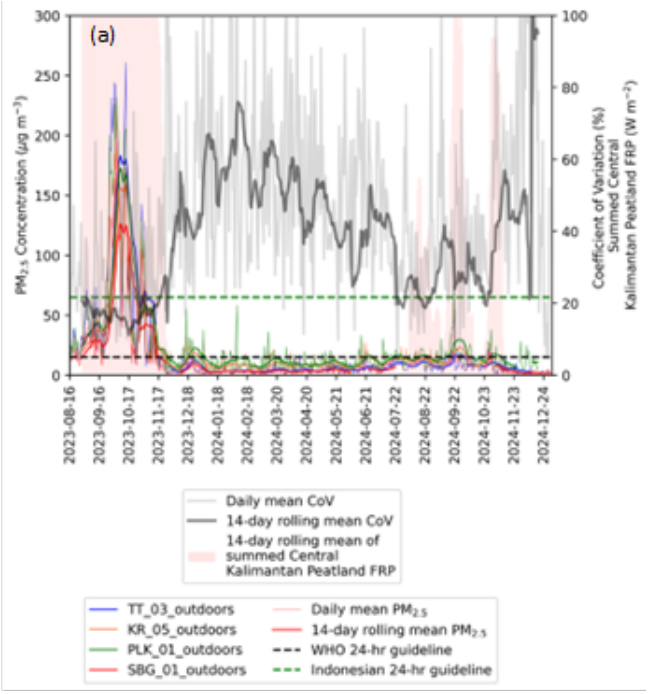
Figure S4. (a) Comparison of daily mean $PM_{2.5}$ Air Quality Index data from reference site and Purple Air sensors (sensor names: kali_111, kali_112, kali_23). Data are shown before (uncorrected: transparent) and after applying a linear correction including relative humidity

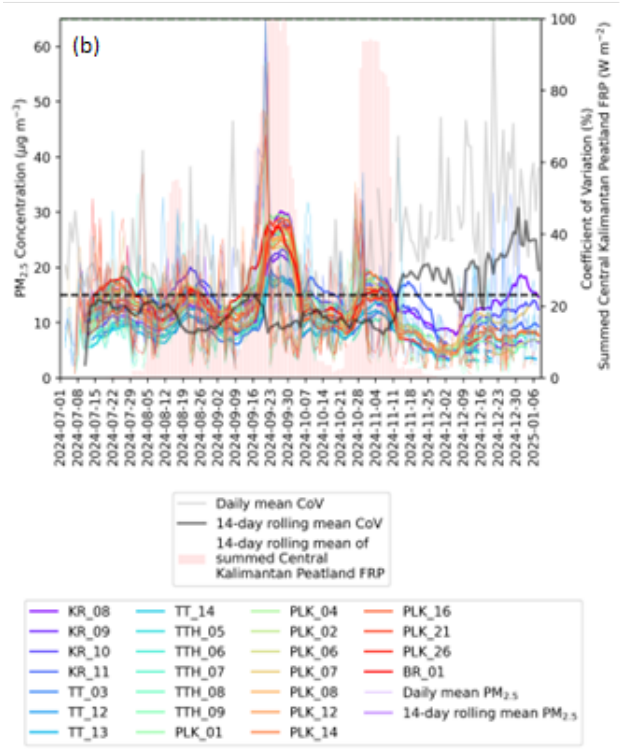
(RH) (corrected: solid colours), as a function of RH. The mean concentration across all days is indicated by the coloured squares with blue border (grey: uncorrected, white: corrected).

The MLR model we use is in Equation 1. a_1 and a_2 are the fitted model coefficients, $PM_{2.5(cf\_1)}$ is the daily mean $PM_{2.5(cf\_1)}$, RH is the relative humidity (in %, measured by the PurpleAir sensors), and i is the fitted model intercept.

We randomly select 70% of available data for training of the MLR model but weight selection by the bias to observations. The model regressor score is 0.69. We find that including an additive RH term (Equation S1) improves Purple Air performance substantially (r= 0.89, NMBF=0.02, NMAE=0.17, RMSE=10.5) (Figure S2). Therefore, we use Equation 1 to correct hourly and daily data from all 110 Purple Air sensors in this work.

3. $PM_{2.5}$ Concentrations





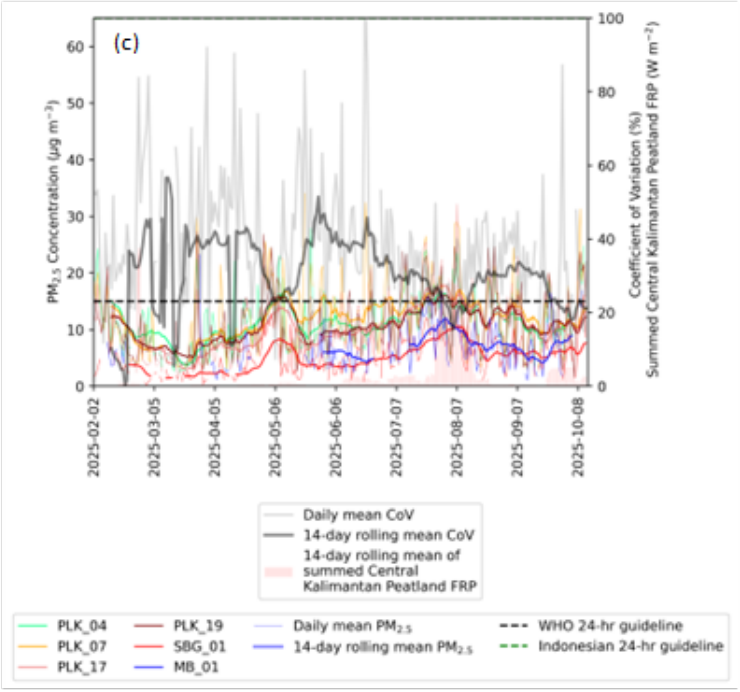


Figure S5. Timeseries of outdoor $PM_{2.5}$ concentrations in (a) Tanjung Taruna (TT_03), Kereng (KR_05), Palangkaraya (PLK_01) and Sebangau (SBG_01) sites between August 16th 2023 and January 1st 2025, (b) Kereng (KR_##), Tanjung Taruna (TT_##), Tumbang Tahai (TTH_##), Palangkaraya (PLK_##) and Bukit Rawi (BR_01) sites between July 1st 2024 and January 8th 2025 and (c) Palangkaraya (PLK_##), Sebangau (SBG_##) and Munkgu Baru (MB_##) sites between February 2nd 2025 and October 12th 2025. Daily mean (thin line) and rolling 14-day mean (thick line) $PM_{2.5}$ concentrations are shown for each site. The World Health Organisation (WHO) (dashed black line) and the Indonesian (dashed green line) 24-hour guideline $PM_{2.5}$ concentrations (15 μg m^{-3} and 65 μg m^{-3}, respectively) are included for reference. The daily mean (thin line) and 14-day rolling mean (thick line) coefficient of variation (CoV) and 14-day rolling mean of summed Central Kalimantan Peatland fire radiative power (FRP) from VIIRS (red bars) are also shown.