S1 Background

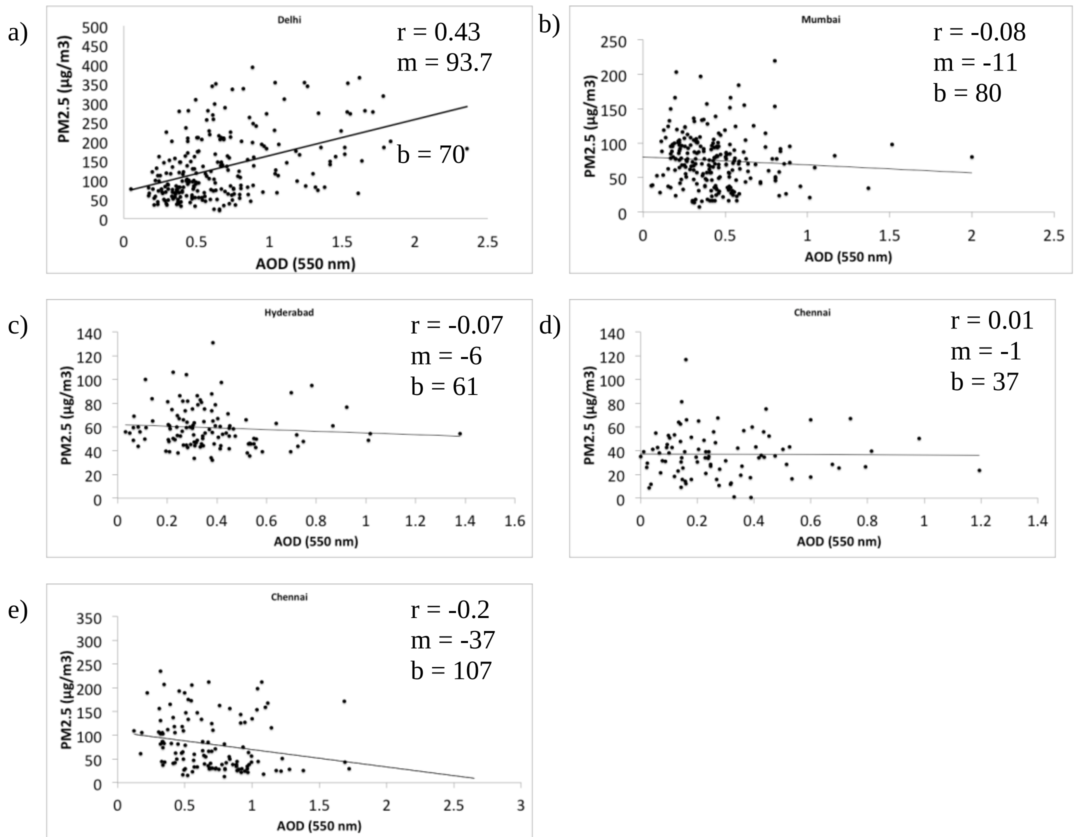


Figure S1: Comparison of ground-based regulatory-grade monitor data for $PM_{2.5}$ collected at US embassy and consulate locations in India at Delhi (a), Mumbai (b), Hyderabad and Chennai (d and e) to AOD at 550nm as measured by MODIS satellites, using daily-averaged measurements for both quantities. Data reflect the period of 2013 to 2016. Figures also present the correlation coefficient r, together with slope m and intercept b of the best-fit linear relationship. While there is notable correlation of AOD to surface $PM_{2.5}$ is Delhi, the other sites exhibit very low correlation or even anticorrelation. This analysis was conducted by former Columbia University undergraduate student Karen Xia, supported by a Columbia Earth Institute Research Internship.

S2 Ground-based Monitoring Sites

Table S1: Seasonal definitions. Temperature and humidity columns indicate the averages for the season, along with the interquartile range in parenthesis. Data were obtained from internal temperature and humidity sensors within the RAMP monitors deployed to each area. Statistics were computed for the spatial averages of temperature and humidity across all RAMP locations within each area which were active during the time period in question.

Season	Area	Start	End	Temperature [°C]	Humidity [%]
Winter	Pittsburgh	Jan. 01, 2018	Feb. 28, 2018	1 (-5 to 7)	74 (66 to 83)
Spring	Pittsburgh	Mar. 01, 2018	May 31, 2018	12 (3 to 20)	64 (52 to 77)
Summer	Pittsburgh	June 01, 2018	Aug. 31, 2018	25 (21 to 29)	69 (59 to 80)
Fall	Pittsburgh	Sep. 01, 2018	Dec. 31, 2018	11 (3 to 20)	77 (70 to 86)
Wet Season 1	Rwanda	Apr. 01, 2017	June 14, 2017	23 (19 to 26)	67 (57 to 78)
Dry Season 1	Rwanda	June 15, 2017	Sep. 14, 2017	22 (19 to 26)	52 (43 to 61)
Wet Season 2	Rwanda	Sep. 15, 2017	Dec. 14, 2017	22 (18 to 26)	65 (55 to 77)
Dry Season 2	Rwanda	Dec. 15, 2017	Feb. 13, 2018	23 (19 to 26)	67 (55 to 78)
Wet Season 3	Rwanda	Feb. 14, 2018	May 31, 2018	21 (17 to 23)	75 (65 to 85)

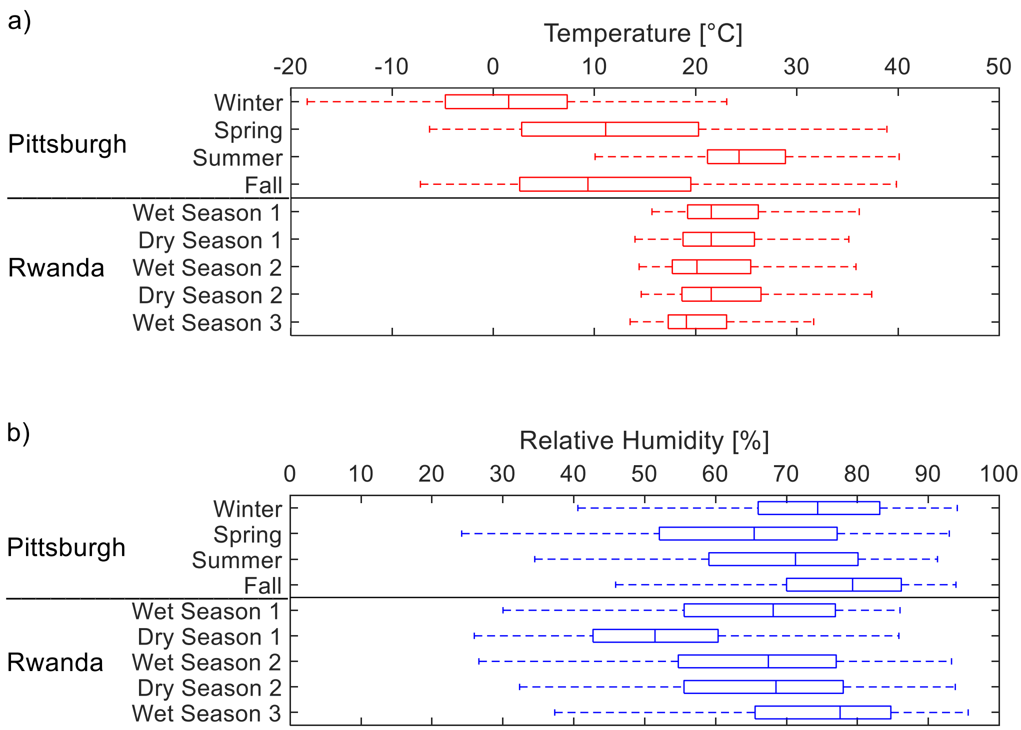


Figure S2: Box plots of seasonal temperature (a) and relative humidity (b) data for Pittsburgh and Rwanda. Data are obtained from internal temperature and humidity sensors within the RAMP monitors deployed in each area. Data represent hourly temperature and humidity values averaged spatially across all RAMP locations within each area which were active during the time period in question.

Table S2: Statistics for AOD at 470nm in the areas of interest for the entire period of overlap with ground monitoring.

Area	**Average**	**Percentiles**				
		5th	25th	50th	75th	95th
Pittsburgh	0.28	0.05	0.14	0.26	0.39	0.55
Rwanda	0.36	0.13	0.24	0.33	0.48	0.29
Kinshasa	0.46	0.02	0.22	0.42	0.55	1.10
Malawi	0.25	0.06	0.13	0.21	0.32	0.58
Addis Ababa	0.28	0.09	0.17	0.26	0.36	0.54
Kampala	0.34	0.15	0.23	0.30	0.44	0.63

Table S3: Statistics for AOD at 550nm in the areas of interest for the entire period of overlap with ground monitoring.

Area	**Average**	**Percentiles**				
		5th	25th	50th	75th	95th
Pittsburgh	0.20	0.03	0.10	0.18	0.27	0.39
Rwanda	0.26	0.09	0.17	0.24	0.34	0.43
Kinshasa	0.34	0.01	0.15	0.31	0.40	0.81
Malawi	0.18	0.04	0.09	0.15	0.23	0.42
Addis Ababa	0.20	0.07	0.12	0.19	0.26	0.39
Kampala	0.24	0.11	0.16	0.21	0.32	0.46

Table S4: Statistics for surface $PM_{2.5}$ concentration in the areas of interest for the entire period. Values in micrograms per meter cubed.

Area	**Average**	**Percentiles**				
		5th	25th	50th	75th	95th
Pittsburgh	9.70	3.53	5.84	8.44	12.3	20.2
Rwanda	39.4	12.0	22.1	34.1	50.8	85.9
Kinshasa	49.9	11.1	27.7	41.5	64.0	114
Malawi	37.6	3.54	10.1	21.1	43.5	118
Addis Ababa	20.3	6	11	16	25	50
Kampala	60.5	25	37	51	75	126

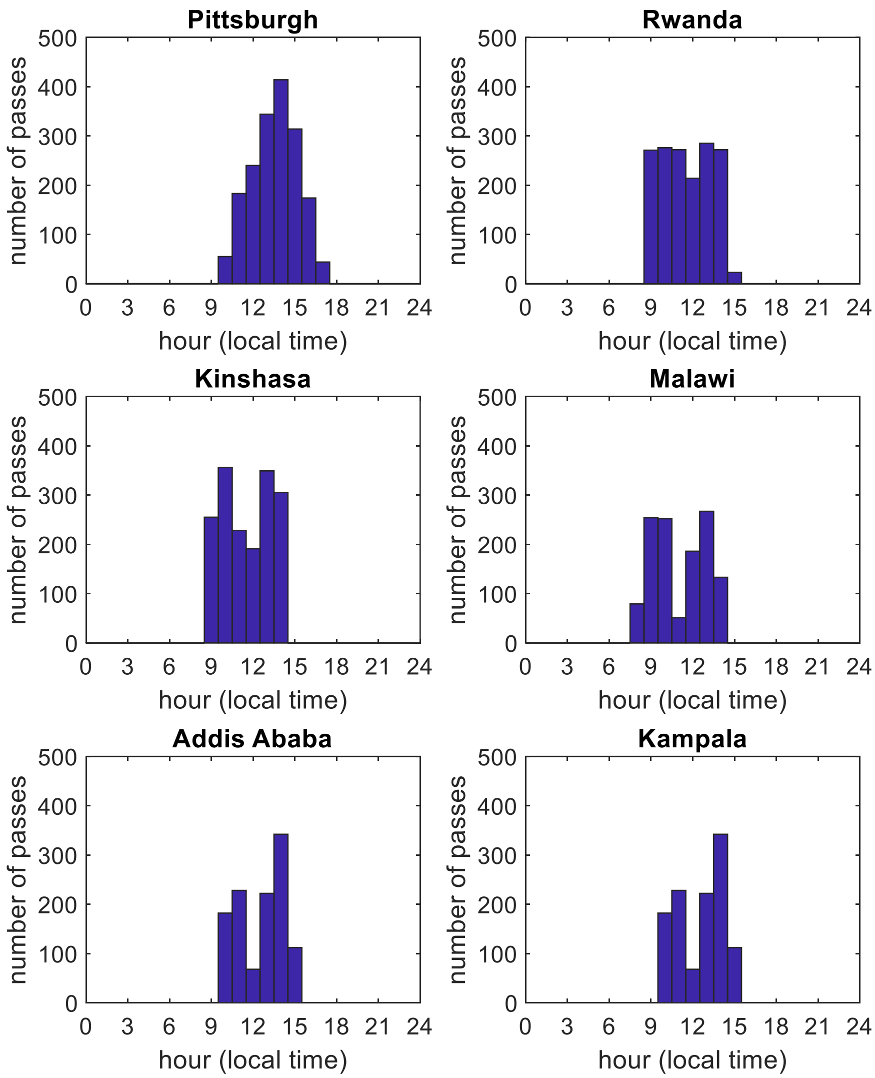


Figure S3: Histograms of satellite overpass times for each area of interest.

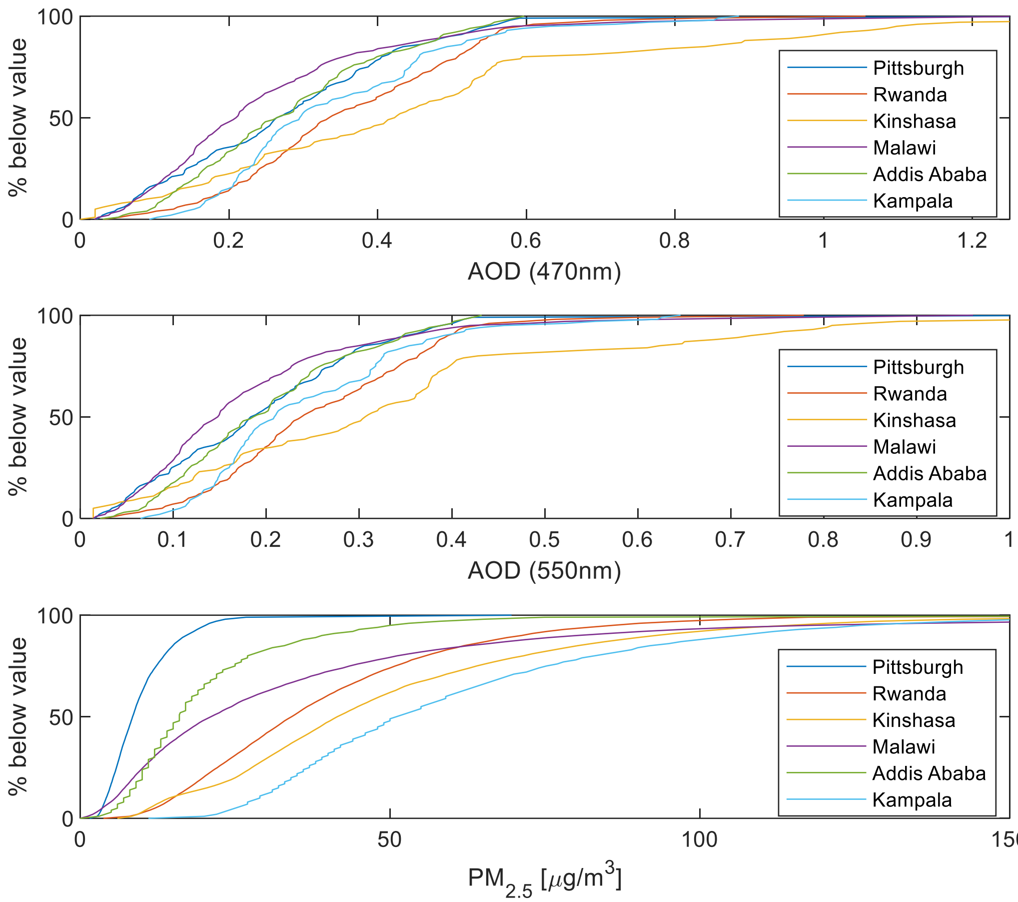
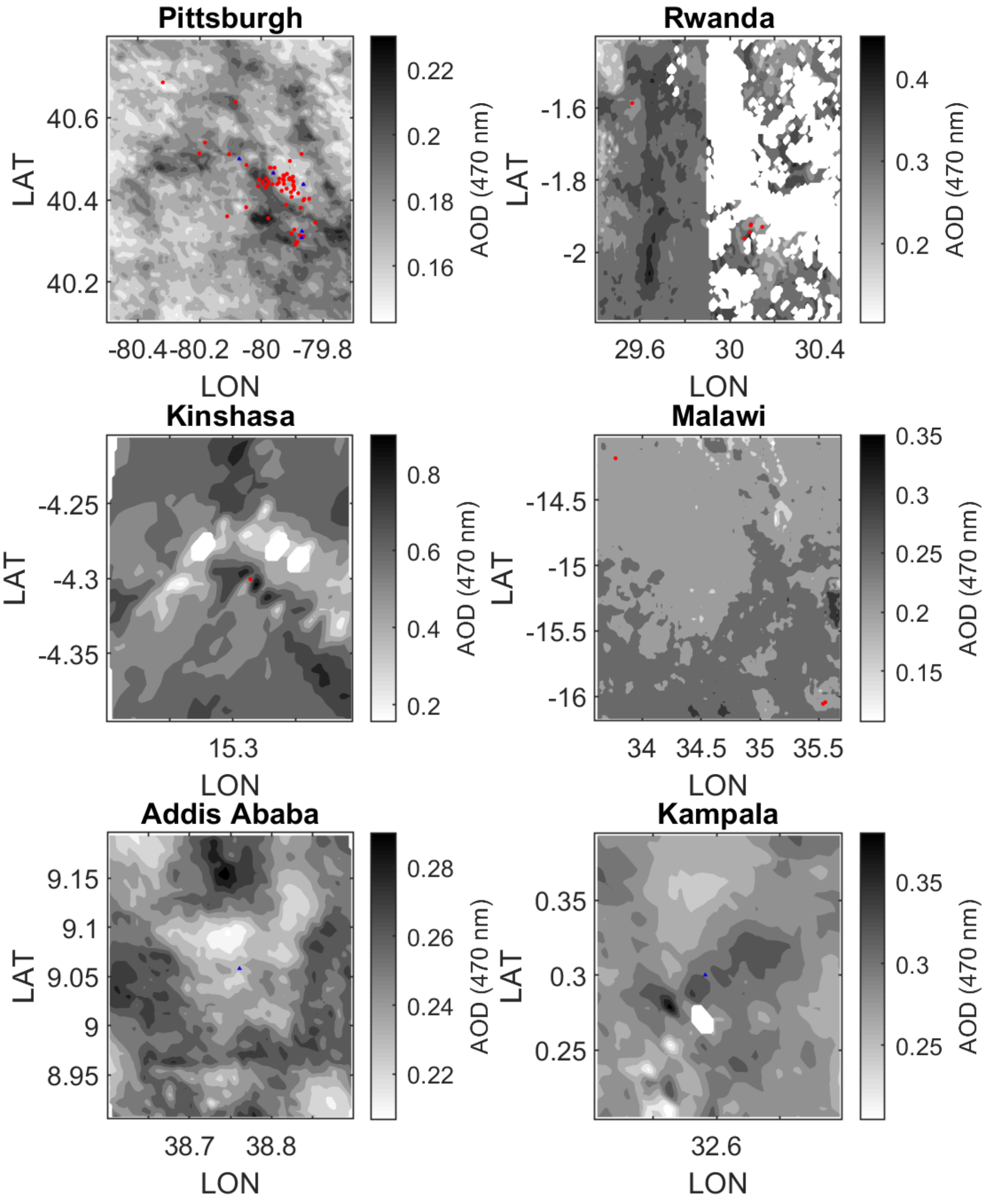


Figure S4: Cumulative Distribution Function plots of AOD and PM2.5 surface concentrations for each of the areas of interest. Values reflect averages across all the ground monitoring site locations within each area.



35 **Figure S5: Maps depicting the average AOD for each area over the time period considered in the paper. Blue dots represent sites of regulatory-grade monitors used in the analysis, while red dots represent sites of low-cost sensor deployments.**

S3 Assessment metrics

Let $\epsilon_{i,t}$ denote the difference (or error) between the estimate of ground-level $PM_{2.5}$ derived from the satellite data for site i at time t, $\hat{y}_{i,t}$ (which is either $\hat{y}_{i,t,\text{prior}}$ or $\hat{y}_{i,t,\text{post}}$ depending on which approach is being used), and the measurement of surface $PM_{2.5}$ at the same time from the ground-based monitor, $y_{i,t}$:

$$\epsilon_{i,t} = \hat{y}_{i,t} - y_{i,t}, \tag{S-1}$$

Various statistics are used in this paper to summarize these differences. Among these is the Pearson correlation coefficient, r, which provides a measure of the linearity of the relationship between these quantities. For a site i, this is defined as:

$$\mathrm{r}_i = \frac{\sum_{t\in T_{\text{ap}}}(\hat{y}_{i,t}-\bar{\bar{y}}_i)(y_{i,t}-\bar{y}_i)}{\sqrt{\sum_{t\in T_{\text{ap}}}(\hat{y}_{i,t}-\bar{\bar{y}}_i)^2}\sqrt{\sum_{t\in T_{\text{ap}}}(y_{i,t}-\bar{y}_i)^2}}, \tag{S-2}$$

where:

$$\bar{\bar{y}}_i = \frac{1}{n_{\text{ap},i}}\sum_{t\in T_{\text{ap}}}\hat{y}_{i,t} \quad \bar{y}_i = \frac{1}{n_{\text{ap},i}}\sum_{t\in T_{\text{ap}}}y_{i,t}, \tag{S-3}$$

and where $n_{\text{ap},i}$ denotes the number of measures taken at site i during the application period T_{ap}.

Another metric used is the mean absolute error (MAE). This measures the average absolute value of the differences during the application period:

$$\text{MAE}_i = \frac{1}{n_{\text{ap},i}}\sum_{t\in T_{\text{ap}}}|\epsilon_{i,t}|, \tag{S-4}$$

To allow for comparison between sites with different average concentrations, a normalized version of the MAE, the Coefficient of Variation of the MAE (CvMAE) is used:

$$\text{CvMAE}_i = \frac{\text{MAE}_i}{\bar{y}_i}, \tag{S-5}$$

Finally, to assess systematic differences, the bias is used:

$$\text{bias}_i = \frac{1}{n_{\text{ap},i}}\sum_{t\in T_{\text{ap}}}\epsilon_{i,t}, \tag{S-6}$$

The bias is normalized and presented as the mean-normalized bias (MNB):

$$\text{MNB}_i = \frac{\text{bias}_i}{\bar{y}_i}, \tag{S-7}$$

S4 Methods

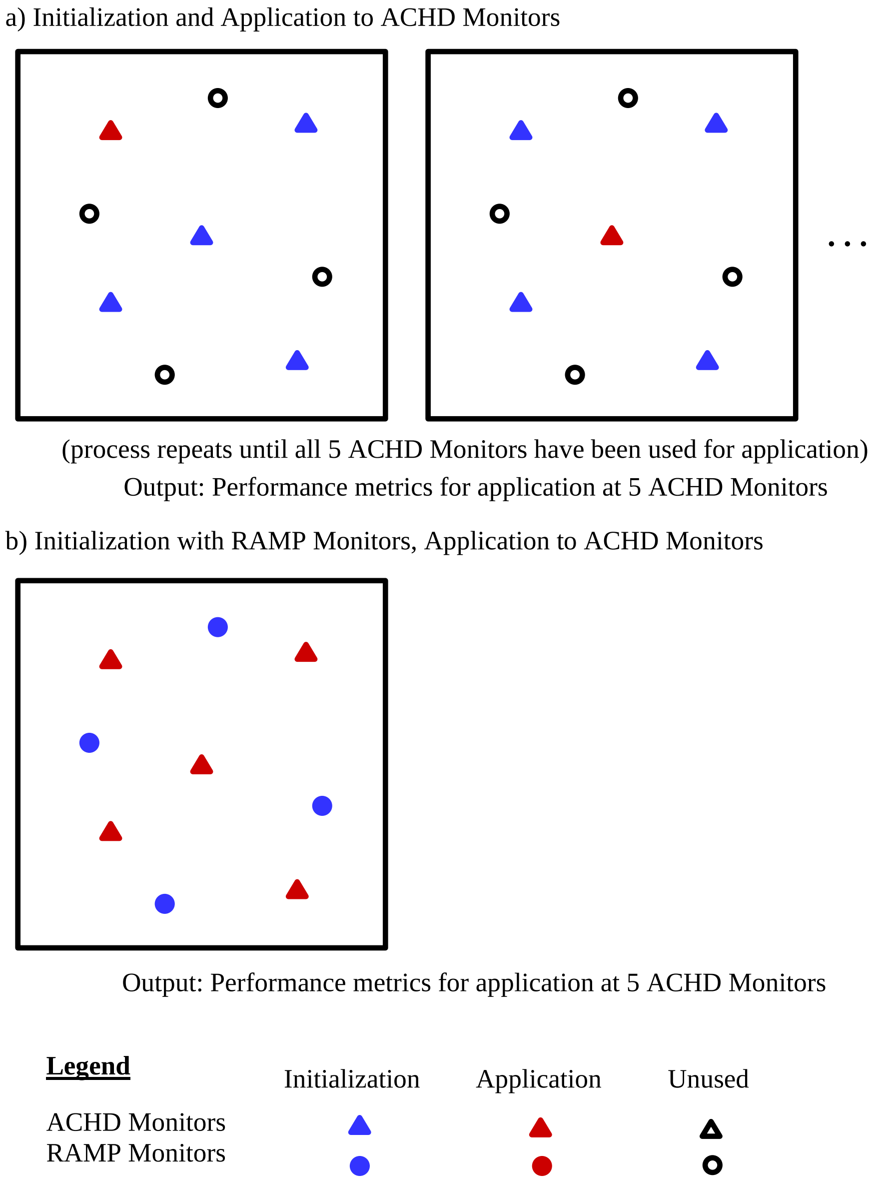


Figure S6: Diagram of method used for assessing performance of methods used ACHD regulatory (a) or RAMP low-cost (b) monitors as ground sites in Sect. 3.1.

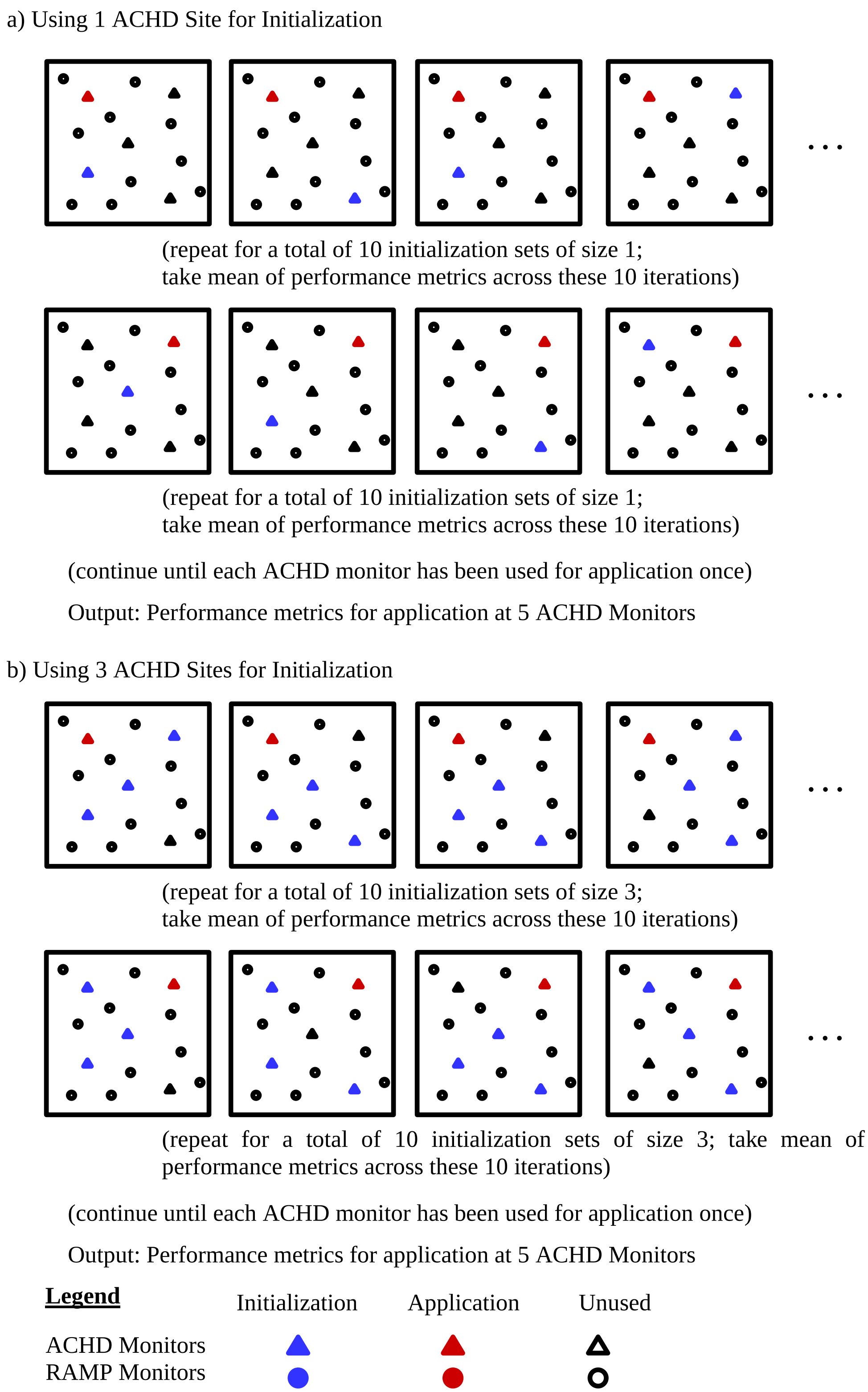


Figure S7: Examples of methods used for assessing performance versus number of ground monitors for one (a) or three (b) ACHD regulatory monitors in Sect. 3.2.

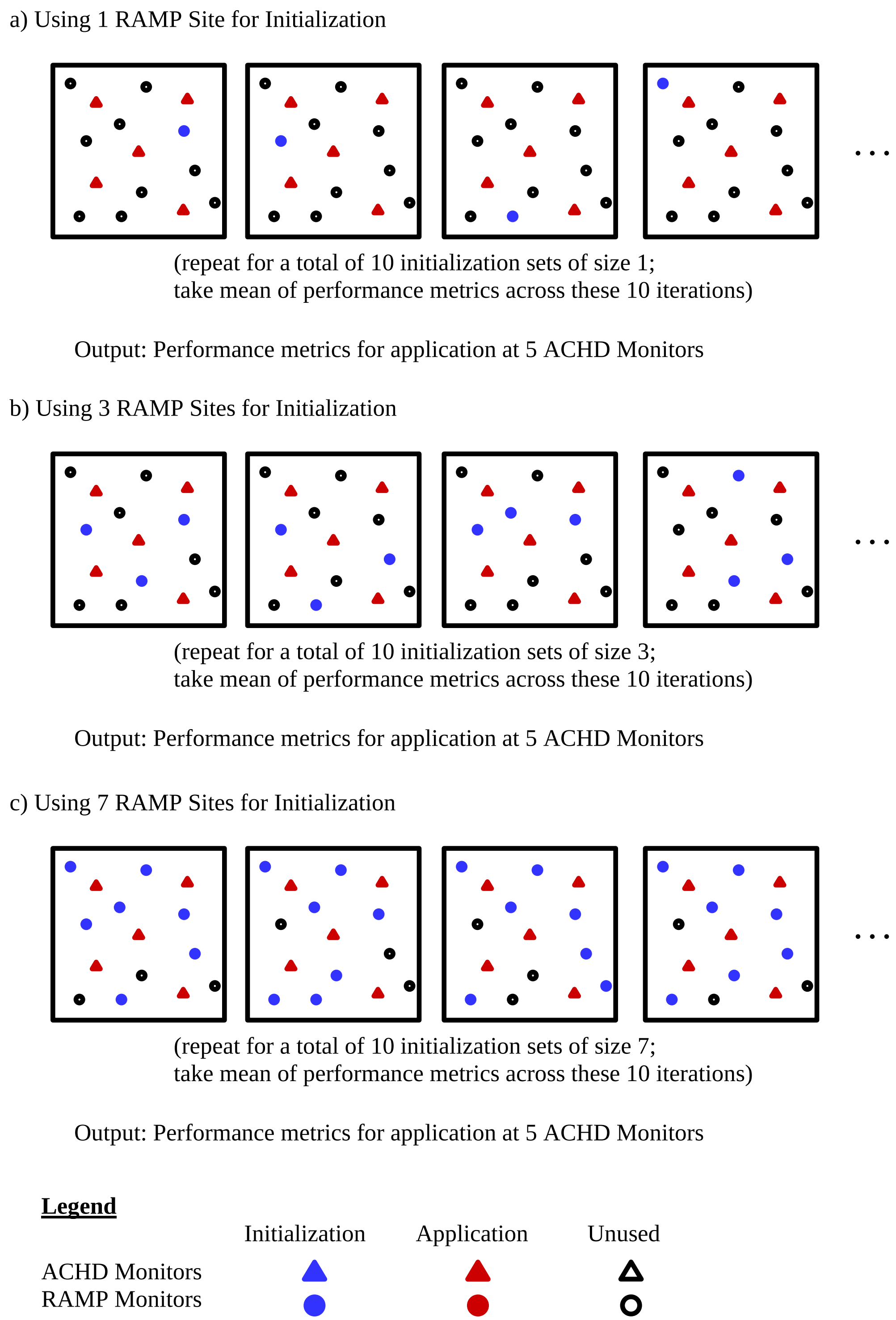


Figure S8: Examples of methods used for assessing performance versus number of ground monitors for one (a), three (b), or seven (c) RAMP low-cost monitors in Sect. 3.2.

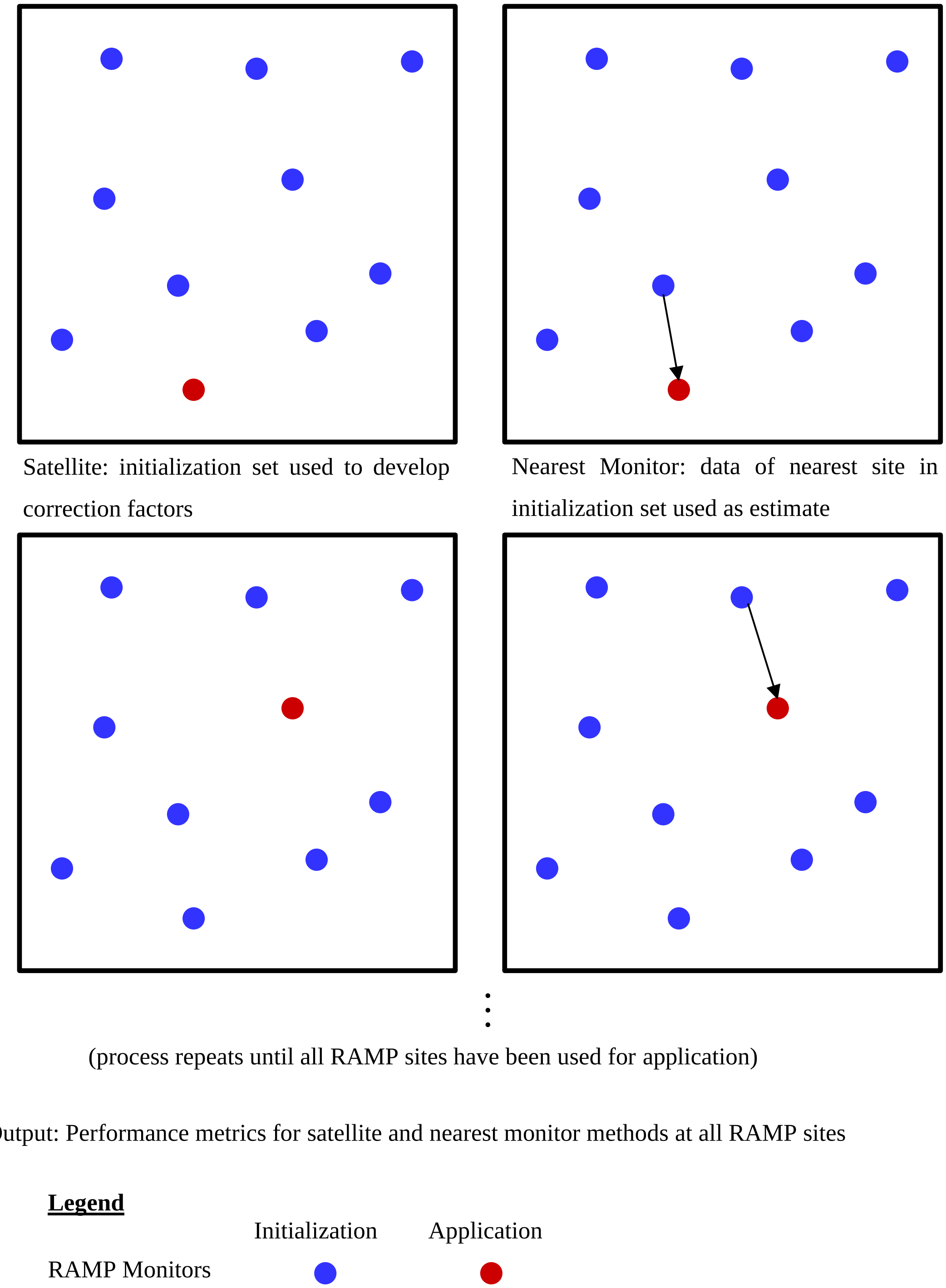


Figure S9: Comparison of satellite and nearest monitor methods of Sect. 3.3.