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Towards a hygroscopic growth calibration for low-cost $PM_{2.5}$ sensors

Milan Y. Patel et al.

Correspondence to: Ronald C. Cohen (rccohen@berkeley.edu)

Table S1. Summary statistics for the datasets from the Laney and LA sites for Plantower $PM_{2.5}$ measurements (PM $PM_{2.5}$, in µg/m^3), BME relative humidity measurements (RH, %), and EPA AQS $PM_{2.5}$ measurements (AQS $PM_{2.5}$, in µg/m^3). Cumulative frequency distributions are shown in Figure S8

Statistic	Laney			LA		
	PT $PM_{2.5}$	**RH**	**AQS $PM_{2.5}$**	**PT $PM_{2.5}$**	**RH**	**AQS $PM_{2.5}$**
count	17024	17024	17024	12701	12701	12701
mean	9.74	51.83	9.11	12.14	46.89	13.41
std	10.58	18.79	6.34	9.86	22.88	8.39
min	0.00	2.48	-5.0	0	1.22	-3.0
25%	2.71	34.94	5.0	5.14	27.29	8.2
50%	6.13	55.41	8.0	9.67	46.23	12.0
75%	11.97	67.68	12.0	16.15	67.84	17.0
max	73.52	100	60.0	144.51	100	265.3

Table S2. Sinusoidal fitting parameters for κ, m, and the Sulfate and EC fractions at the Laney Site as shown in Figure 1. The sine wave takes the form $y = a * \sin\left(\frac{2\pi}{365} * (x - \delta)\right) + b$ where x is the day of the year and the phase shift δ has units of days. The goodness of fit is given by r, the Pearson Correlation between the true values and the sine wave fit.

y	a	b	δ	r
κ (2021)	0.286	0.498	53.3	0.73
κ (2022)	0.242	0.366	72.8	0.86
m (2021)	0.998	1.668	53.2	0.85
m (2022)	0.745	1.429	73.6	0.89
Sulfate Fraction	0.046	0.091	94.0	0.63
EC Fraction	0.046	0.071	265.8	0.74

Table S3. Monthly performance statistics for the sensor at Laney, relative to the co-located EPA AQS site, before and after the calibration was applied (r: Pearson Correlation Coefficient, MFB: Mean Fractional Bias, NRMSE: Normalized Root-Mean-Square Error).

Month	Before Calibration			After Calibration		
	r	**MFB**	**NRMSE**	**r**	**MFB**	**NRMSE**
Jan 2021	0.818	0.455	0.918	0.842	-0.021	0.43
Feb 2021	0.740	-0.023	0.666	0.808	-0.101	0.529
Mar 2021	0.711	-0.305	0.558	0.789	-0.152	0.461
Apr 2021	0.666	-0.335	0.486	0.768	-0.087	0.343

May 2021	0.611	-0.406	0.553	0.755	-0.145	0.365
Jun 2021	0.728	-0.433	0.702	0.84	-0.205	0.479
Jul 2021	0.564	-0.154	0.54	0.714	0.035	0.452
Aug 2021	0.825	0.134	0.47	0.863	0.203	0.519
Sep 2021	0.782	0.107	0.606	0.836	-0.021	0.543
Oct 2021	0.727	-0.358	0.581	0.815	-0.575	0.684
Nov 2021	0.862	0.809	1.051	0.914	-0.1	0.263
Dec 2021	0.902	0.971	1.563	0.914	-0.004	0.425
Jan 2022	0.886	0.925	1.157	0.924	0.202	0.363
Feb 2022	0.862	0.446	0.896	0.896	0.187	0.555
Mar 2022	0.622	-0.2	0.57	0.726	-0.272	0.491
Apr 2022	0.647	-0.325	0.549	0.731	-0.201	0.459
May 2022	0.721	-0.406	0.577	0.808	-0.208	0.427
Jun 2022	0.674	-0.345	0.537	0.77	-0.127	0.431
Jul 2022	0.716	-0.263	0.57	0.783	-0.112	0.5
Aug 2022	0.741	-0.109	0.533	0.794	-0.015	0.517
Sep 2022	0.570	-0.201	0.515	0.705	-0.211	0.453
Oct 2022	0.728	0.123	0.556	0.764	-0.164	0.417
Nov 2022	0.870	0.181	0.627	0.901	-0.27	0.412
Dec 2022	0.916	0.391	0.918	0.934	-0.253	0.384

Table S4. Sinusoidal fitting parameters for κ, m, and the Sulfate and EC fractions at the LA Site as shown in Figure 6. The sine wave takes the form $y = a * \sin\left(\frac{2\pi}{365} * (x - \delta)\right) + b$ where x is the day of the year and the phase shift δ has units of days. The goodness of fit is given by r, the Pearson Correlation between the true values and the sine wave fit.

y	**a**	**b**	**δ**	**r**
κ	0.057	0.248	34.9	0.36
m	0.211	1.307	70.0	0.65
Sulfate Fraction	0.072	0.115	100.5	0.77
EC Fraction	0.042	0.086	267.9	0.64

Table S5. Performance statistics for the sensor in LA relative to its nearest EPA AQS site with different calibration schemes applied (R^2: Coefficient of Determination, RMSE: Root-Mean-Square Error)

Calibration Scheme	**R^2**	**RMSE** (μg/m^3)

No Calibration	0.312	6.96
National EPA Calibration	0.116	7.89
Seasonal RH Calibration	0.472	6.09

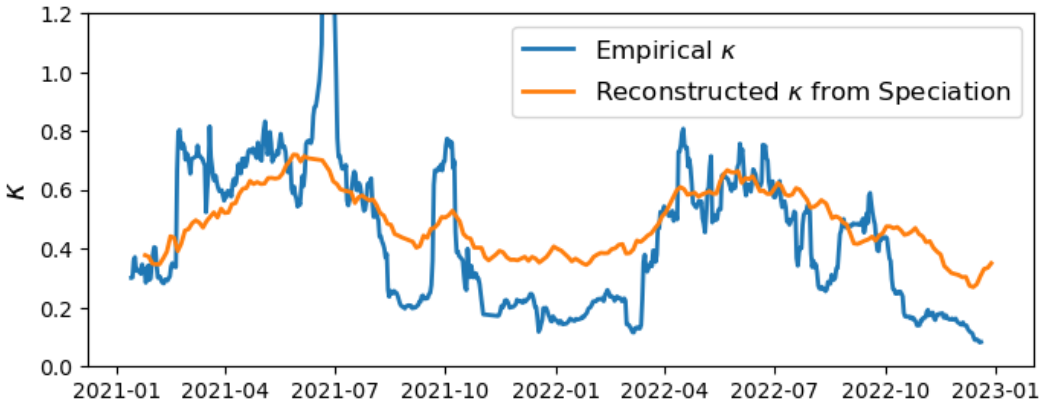

Figure S1. Empirically calculated κ for the Laney site (Table 1), as shown in Figure 1a, alongside κ reconstructed from particle speciation data, displayed as a 4-week rolling average. Note the speciation data is not collocated with the $PM_{2.5}$ measurements. An organic matter/organic carbon ratio of 1.6 was used to assign the organic matter fraction of the particle.

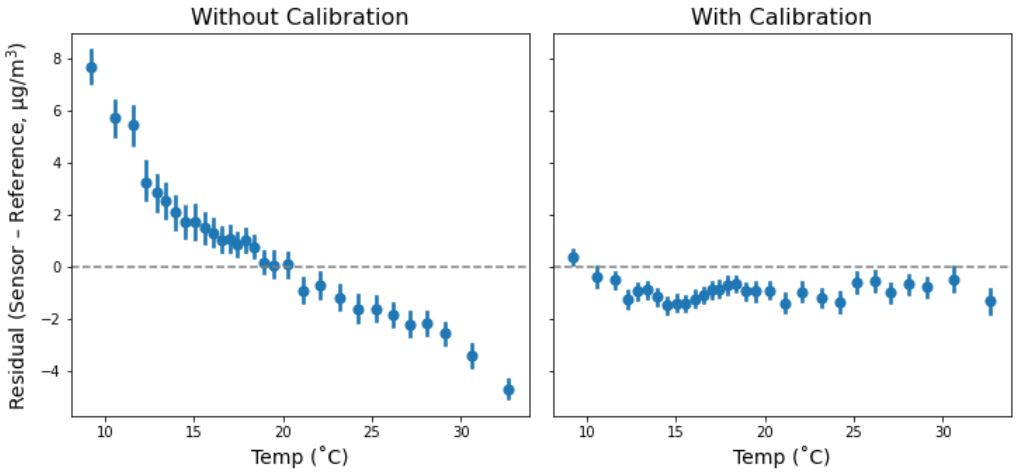

Figure S2. Measurement residuals (Sensor output – EPA AQS values) for Laney data without and with the seasonal RH dependence calibration, binned into 30 temperature bins.

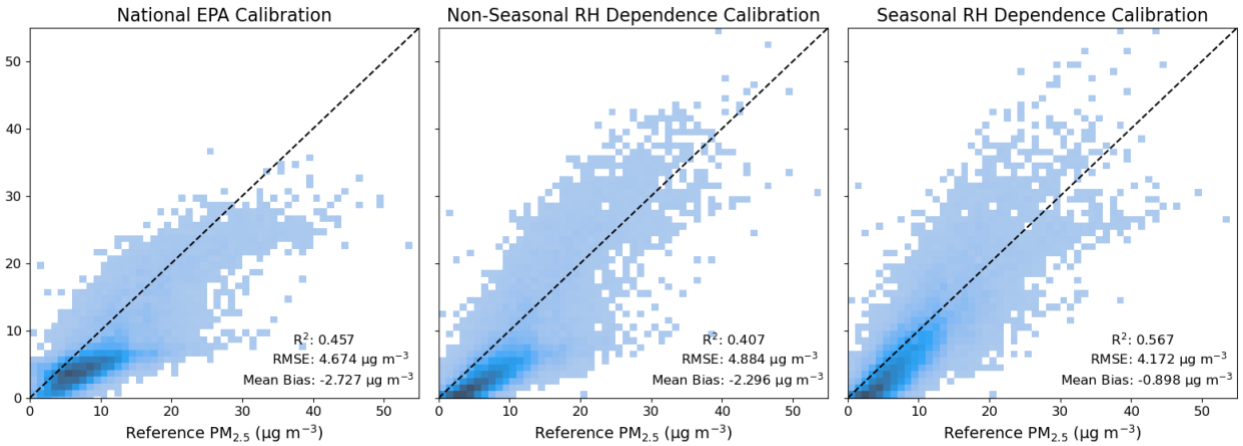

Figure S3. Sensor predicted $PM_{2.5}$ values versus EPA reference values for Laney site from 2021–2022 with different correction algorithms. The non-seasonal RH dependence calibration uses a constant optimized κ and m value (κ = 0.311, m = 1.02) rather than values changing sinusoidally in time (Figure 1). Performance metrics are the Coefficient of Determination (R^2), root-mean-square error (RMSE), and mean bias.

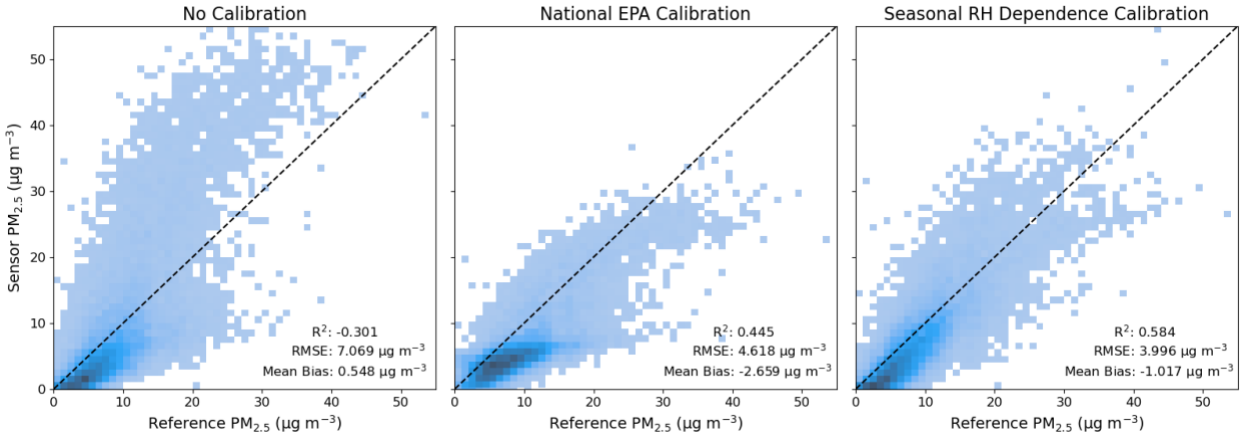

Figure S4. Reproduction of Figure 4 with bad air quality days (Aug 20 – Sep 16, 2021) removed. Sensor predicted $PM_{2.5}$ values versus EPA reference values for Laney site from 2021–2022 with different correction algorithms. Performance metrics are the Coefficient of Determination (R^2), root-mean-square error (RMSE), and mean bias.

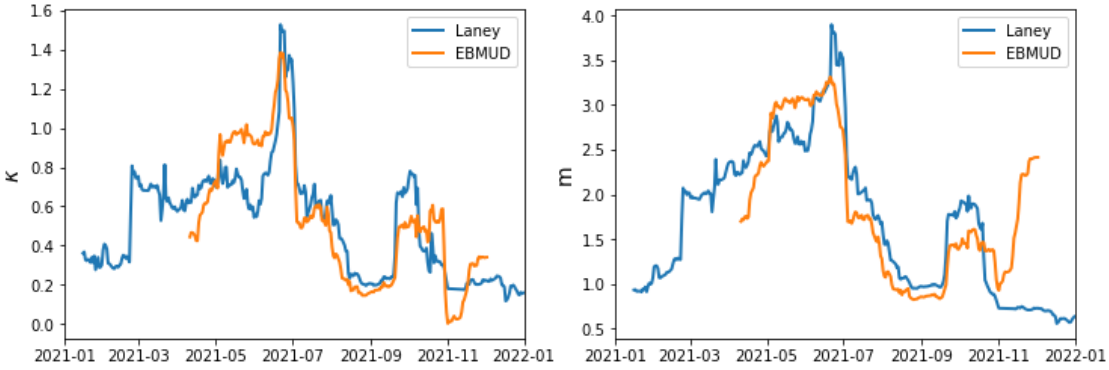

Figure S5. Calculated calibration parameters for two co-location sites in the Bay Area, CA: Laney and EBMUD (Table 1).

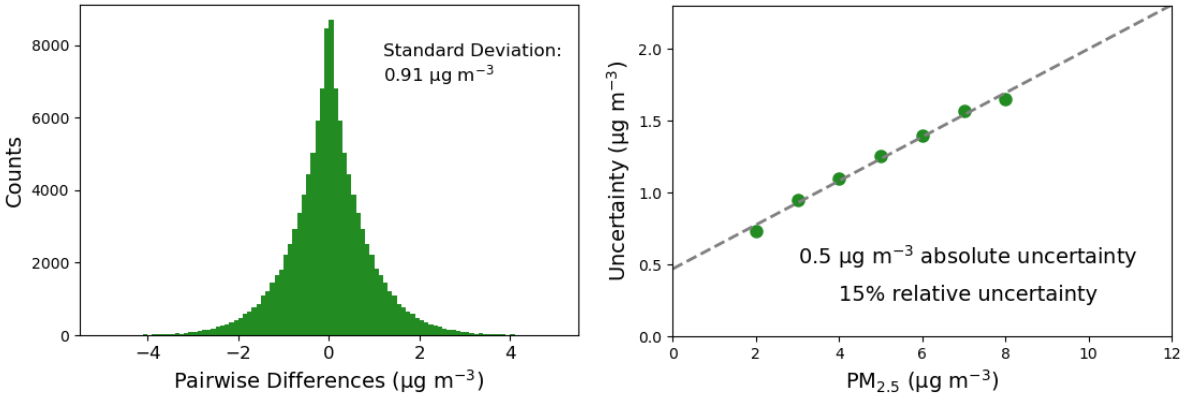

Figure S6. Pairwise differences of 17 Plantowers from two different manufacturer batches from 2 months of co-location in lab show that instrument noise is about 1 µg m^{-3}, similar to the manufacturer's reported uncertainty. Analysis by size bin shows that the uncertainty is an absolute uncertainty of about 0.5 µg m^{-3} with an added relative uncertainty of about 15%.

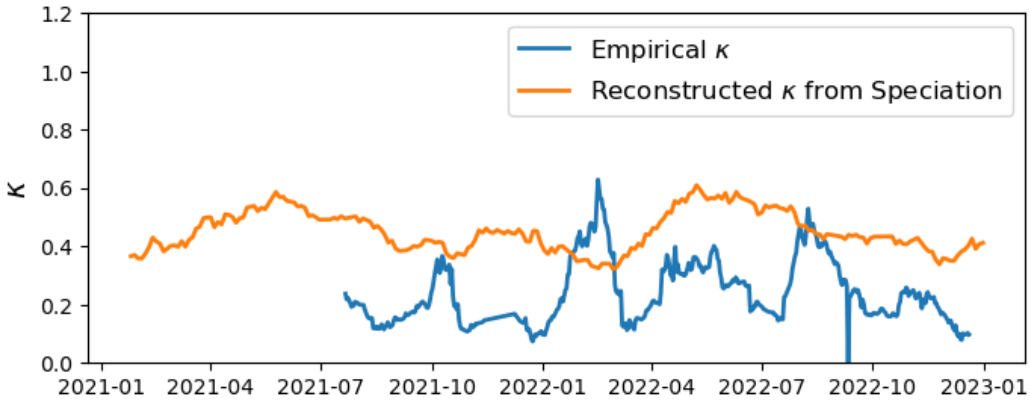

Figure S7. Empirically calculated κ for the Los Angeles site (Table 1), as shown in Figure 6a, alongside κ reconstructed from particle speciation data, displayed as a 4-week rolling average. An organic matter/organic carbon ratio of 1.6 was used to assign the organic matter fraction of the particle.

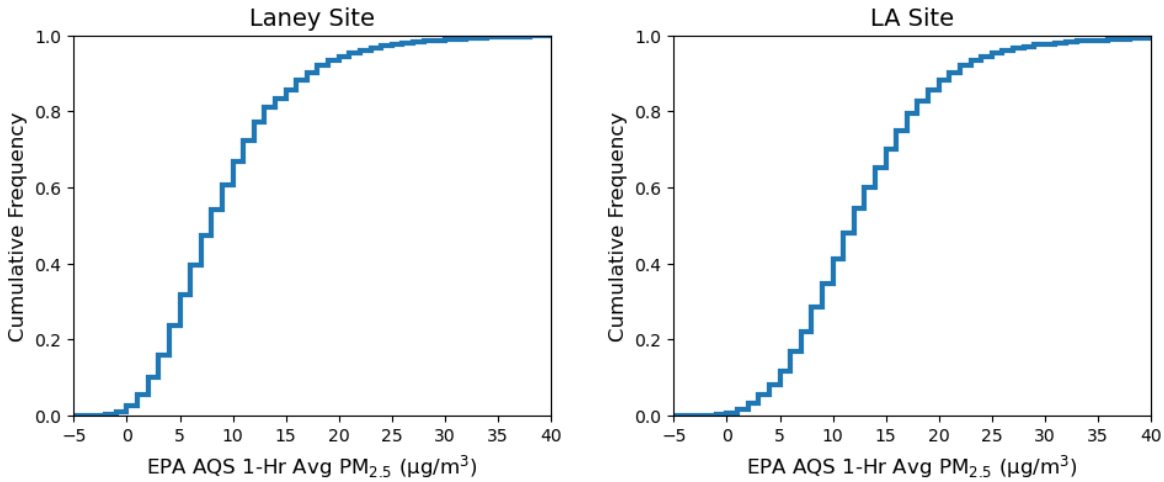

Figure S8. Cumulative frequency distributions for EPA AQS measurements at the Laney and LA EPA reference sites (Table 1).