Supplementary Information (SI) for Environmental Science: Processes & Impacts.
This journal is © The Royal Society of Chemistry 2024

Supplementary Information

Conversion of OPC Measurement to APS-Equivalent Values

The APS measures particle concentrations in 52 bins for particle aerodynamic diameters of ~0.5 to 20 µm, and the OPC measures particle concentrations in 24 bins for particle optical diameters of 0.35 to 40 µm. Salt particle concentrations generated by the nebulizer were negligible above 3 µm optical diameter. Therefore, evaluation of the CR box performance was limited to particles with optical diameters of 0.35 to 3 µm, which covers the primary range of interest for air cleaners due to the known health impacts of particles in this size range.

The APS particle size bins were converted from aerodynamic diameter to mobility diameter using Equation 1:

$$D_m = \left(\frac{\rho_o}{\rho_p}\right)^{0.5} D_a \quad (1)$$

Where D_m is the mobility diameter for a theoretical spherical particle, ρ_o is the density of water (1 g/cm^3), ρ_p is the density of the particle (2 g/cm^3 for NaCl), and D_a is the aerodynamic diameter as measured by the APS. After the APS particle diameter bins were converted to mobility diameter using Equation 1, they were aligned with the corresponding OPC optical diameter bins (which assumes that the particles are spherical). The particle concentrations for the matched bins were then correlated using the available data from the first round of testing with both instruments. A cubic equation was fit to correlate each OPC to the APS data for each particle size bin "j", with the following empirical form:

$$APS_{(j)} = a1_{(j)} OPC_{(j)} + a2_{(j)} {OPC_{(j)}}^2 + a3_{(j)} {OPC_{(j)}}^3 \quad (2)$$

Where OPC and APS are the respective measured particle concentrations in particles per cubic centimetre. The coefficients for Equation 2 for each bin are listed in Table S1. The data used to determine each correlation for Table S1 is shown in Figure S1 and S2.

Table S1: APS and OPC particle diameter bins and coefficients for cubic OPC and APS correlation

Bin (j)	APS Mobility Diameter (µm)	OPC Optical Diameter (µm)	Coefficients for OPC-1, Eq 2			Coefficients for OPC-2, Eq 2		
			a1 (-)	a2 (cm^3/p)	a2 (cm^6/p^3)	a1 (-)	a2 (cm^3/p)	a2 (cm^6/p^3)
0	≤ 0.46	0.35 – 0.46	2.97E+00	-1.08E-01	4.33E-03	2.76E+00	-8.77E-02	3.79E-03
1	0.46 – 0.66	0.46 – 0.66	2.23E+00	1.72E-03	4.10E-04	2.27E+00	3.74E-03	4.14E-04
2	0.66 – 1.03	0.66 – 1.0	3.31E+00	5.74E-03	3.55E-04	3.22E+00	1.49E-02	1.98E-04
3	1.03 – 1.28	1.0 –1.3	2.52E+00	3.49E-02	-9.06E-04	2.61E+00	2.86E-02	-8.04E-04
4	1.28 – 1.72	1.3 – 1.7	1.49E+00	-1.24E-03	-1.50E-04	1.50E+00	-1.99E-03	-1.19E-04
5	1.72 – 2.30	1.7 – 2.3	1.64E+00	-5.08E-03	-1.84E-03	1.60E+00	-1.18E-02	-1.13E-03
6	2.30 – 3.07	2.3 – 3.0	1.46E+00	3.19E-02	-3.73E-02	1.43E+00	2.96E-02	-3.46E-02

For each CR Box test, the particle loss rate was measured with OPC-1. For consistency, the test data were analysed starting at the time the particle concentration for bin 0 dropped below 26 p/cm^3 (per the OPC-1 measurement) for a period of 20 minutes. In 6 of 60 tests, there was not 20 minutes of data available after the concentration dropped below 26 p/cm^3, and the available data (14-19 minutes) was used in these cases. The OPC-1 values were converted to corresponding APS values with Equation 2.

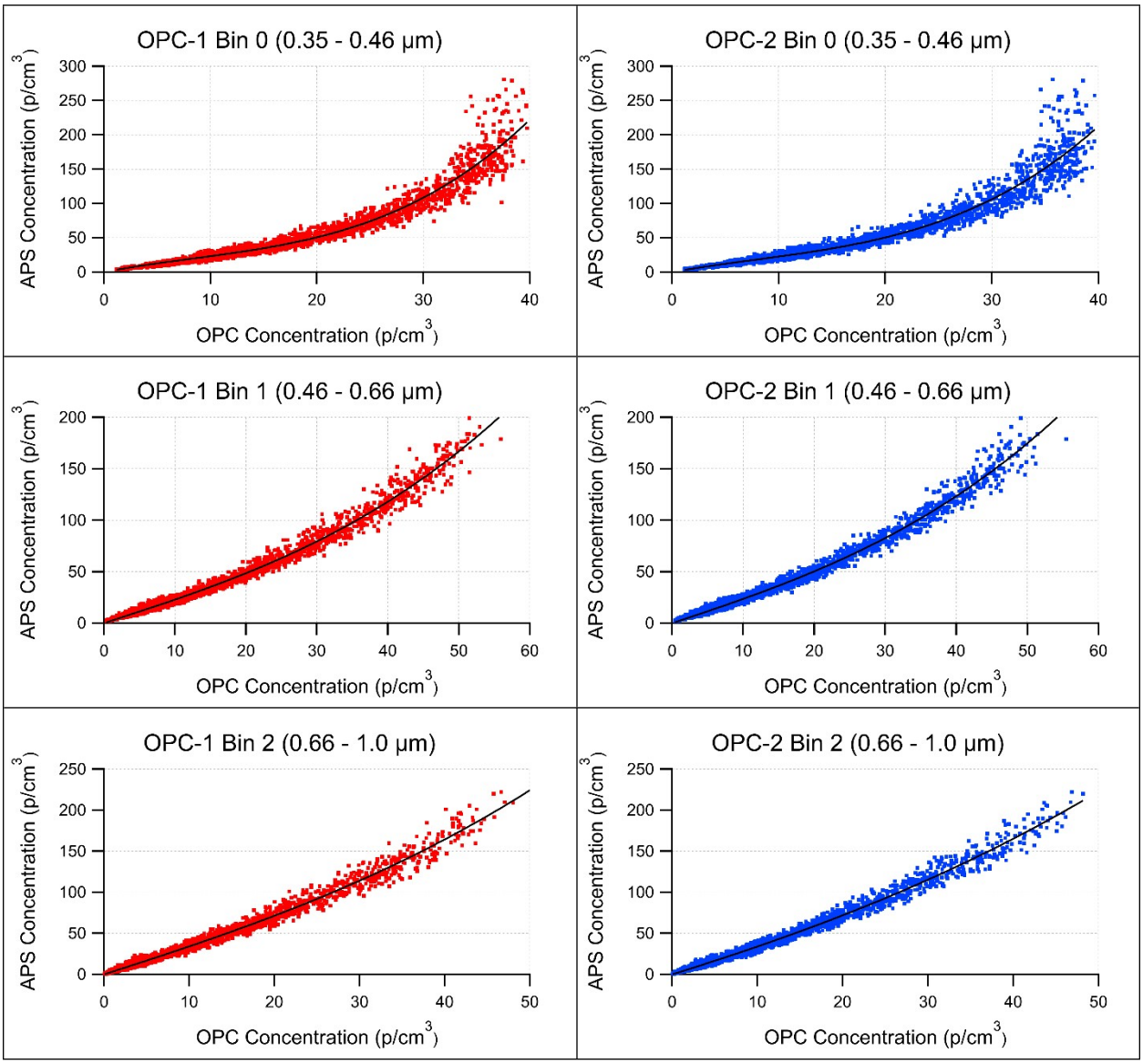

Figure S1: Empirical cubic correlations between low-cost OPC and laboratory grade APS data for bins 0 to 2 of the OPC. Coefficients for least-squares regression are contained in Table 2.

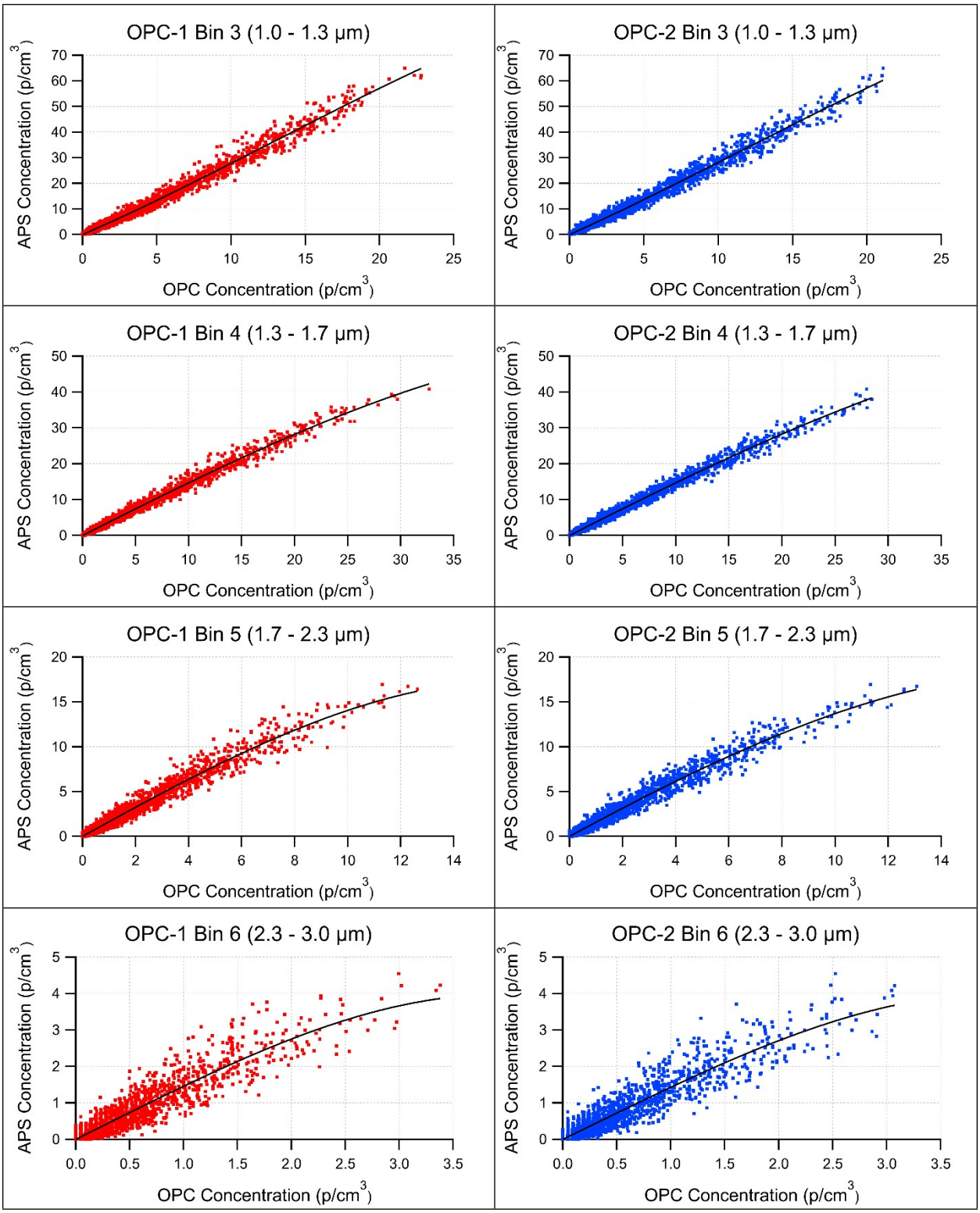

Figure S2: Empirical cubic correlations between low-cost OPC and laboratory grade APS data for bins 3 to 6 of the OPC. Coefficients for least-squares regression are contained in Table 2.

CADR Versus Cumulative Mass correlations

The fit coefficients for each box for CADR versus cumulative mass are shown in Table S2 and S3.

Table S2: Linear fit coefficients for Box 2, 3, and 4 from Figure 2 (y=K0+K1x)

	High Speed		Medium Speed		Low Speed	
Size Range (um)	K0	K1	K0	K1	K0	K1
0.35-1.0	8.034E+02	-6.291E+01	6.834E+02	-5.458E+01	5.301E+02	-4.061E+01
1.0-3.0	1.101E+03	-6.949E+01	8.865E+02	-5.658E+01	6.891E+02	-4.422E+01

Table S3: Quadratic fit coefficients for Box 1 from Figure 2 ($y=K0+K1x+K2x^2$)

	High Speed			Medium Speed			Low Speed		
Size Range (um)	K0	K1	K2	K0	K1	K2	K0	K1	K2
0.35-1.0	1.187E+03	-7.794E+00	-2.411E+00	8.643E+02	2.658E+01	-5.100E+00	6.834E+02	5.407E-01	-2.767E+00
1.0-3.0	1.397E+03	2.102E+01	-4.787E+00	9.694E+02	6.339E+01	-8.314E+00	7.700E+02	1.521E+01	-4.110E+00

CADR Results Tables

CADR values for each bin with specified particle optical diameter range, as well as average CADR values presented in Figure 2, are shown for high speed (Table S4), medium speed (Table S5), and low speed (Table S6).

Table S4: CADR results for all CR boxes for high speed. CADR units are m^3/hr.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 1.0 µm	Average 1.0 – 3.0 µm	Average 0.35 – 3.0 µm
1	0	1109	1196	1244	1371	1366	1393	1415	1183	1386	1299
1	70	933	1152	1284	1414	1381	1454	1563	1123	1453	1312
1	140	858	1062	1120	1198	1259	1303	1293	1013	1263	1156
1	210	710	968	1028	1099	1155	1174	1318	902	1187	1065
1	280	753	943	1033	1103	1196	1199	1245	910	1186	1067
2	0	734	870	970	1057	1096	1115	1159	858	1106	1000
2	70	528	695	783	890	921	1002	1026	669	960	835
2	140	472	574	673	742	816	858	1004	573	855	734
2	210	516	612	678	761	785	851	902	602	825	729
2	280	377	484	557	651	702	776	882	473	753	633
3	0	785	917	1002	1118	1177	1361	1412	902	1267	1110
3	70	617	836	892	989	1057	1058	1154	782	1064	943
3	140	605	731	802	899	943	999	1077	712	979	865
3	210	574	664	737	819	889	979	1067	659	938	818
3	280	506	625	720	817	883	970	1060	617	933	798
4	0	668	809	923	1011	1028	1150	1257	800	1112	978
4	70	697	844	929	1008	1026	1047	1067	823	1037	945
4	140	627	736	822	912	965	1013	1133	728	1006	887
4	210	471	669	771	853	900	975	979	637	927	803
4	280	513	634	722	841	890	1006	1220	623	989	832

Table S5: CADR results for all CR boxes for medium speed. CADR units are m^3/hr.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 1.0 µm	Average 1.0 – 3.0 µm	Average 0.35 – 3.0 µm
1	0	807	859	913	958	1002	1002	869	860	958	916
1	70	788	925	996	1094	1128	1133	1216	903	1143	1040
1	140	661	825	913	943	983	960	1003	800	972	898
1	210	530	696	758	803	812	854	810	661	820	752
1	280	577	703	753	818	861	845	934	678	865	784
2	0	563	632	709	816	823	867	898	635	851	758
2	70	469	561	637	703	736	804	836	555	770	678
2	140	377	440	510	574	624	693	770	442	665	570
2	210	398	486	549	601	620	686	705	478	653	578
2	280	367	421	491	560	590	611	618	426	595	523
3	0	649	786	818	919	948	992	973	751	958	869
3	70	522	663	741	831	841	913	883	642	867	771
3	140	457	560	633	692	727	787	751	550	739	658
3	210	488	526	591	658	689	765	837	535	737	651
3	280	502	570	654	743	783	895	867	575	822	716
4	0	727	777	821	885	940	964	970	775	940	869
4	70	649	705	758	828	858	873	837	704	849	787
4	140	522	637	654	745	759	794	826	604	781	705
4	210	567	656	710	765	804	837	912	644	830	750
4	280	474	560	623	733	769	875	858	552	808	699

Table S6: CADR results for all CR boxes for low speed. CADR units are m^3/hr.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 1.0 µm	Average 1.0 – 3.0 µm	Average 0.35 – 3.0 µm
1	0	632	683	719	768	797	761	704	678	758	724
1	70	606	654	697	779	792	832	851	652	814	744
1	140	453	575	646	684	686	603	621	558	649	610
1	210	335	421	462	481	496	511	472	406	490	454
1	280	494	497	534	566	581	613	601	508	590	555
2	0	484	507	550	655	659	703	660	514	669	603
2	70	426	477	514	601	616	639	779	472	659	579
2	140	308	339	385	444	479	510	575	344	502	434
2	210	401	416	459	500	523	522	530	425	519	479
2	280	253	320	358	407	442	472	484	310	451	391
3	0	632	683	719	768	797	761	704	678	758	724
3	70	284	507	595	687	708	672	654	462	680	587
3	140	374	420	471	522	554	620	605	421	575	509
3	210	274	398	455	514	568	625	547	376	563	483
3	280	277	399	480	517	573	674	667	385	608	512
4	0	533	566	619	674	690	714	753	573	708	650
4	70	502	566	606	678	681	726	709	558	698	638
4	140	430	462	499	540	572	615	612	463	584	533
4	210	487	514	560	615	612	628	564	520	605	568
4	280	340	434	490	569	599	679	707	422	639	546

SPFE Results Tables

SPFE values for each bin with specified particle optical diameter range, as well as average SPFE values presented in Figure 4, are shown for high speed (Table S7), medium speed (Table S8), and low speed (Table S9).

Table S7: SPFE results for all CR boxes for high speed. SPFE is a unitless ratio.

CR Box	Days Elapsed	0.35 – 0.46 μm	0.46 – 0.66 μm	0.66 – 1.0 μm	1.0 – 1.3 μm	1.3 – 1.7 μm	1.7 – 2.3 μm	2.3 – 3.0 μm	Average 0.35 – 1.0 μm	Average 1.0 – 3.0 μm	Average 0.35 – 3.0 μm
1	0	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99
1	210	0.72	0.87	0.91	0.92	0.93	0.94	0.96	0.83	0.94	0.89
1	280	0.67	0.83	0.88	0.89	0.91	0.94	0.95	0.79	0.92	0.87
2	0	0.69	0.72	0.78	0.84	0.86	0.86	0.90	0.73	0.87	0.81
2	210	0.41	0.47	0.50	0.52	0.58	0.57	0.59	0.46	0.57	0.52
2	280	0.20	0.29	0.40	0.39	0.40	0.45	0.41	0.30	0.41	0.36
3	0	0.72	0.73	0.78	0.82	0.82	0.83	0.88	0.74	0.84	0.80
3	210	0.44	0.56	0.61	0.64	0.65	0.64	0.70	0.53	0.66	0.61
3	280	0.36	0.45	0.55	0.60	0.60	0.70	0.68	0.45	0.65	0.56
4	0	0.64	0.67	0.72	0.75	0.78	0.80	0.87	0.68	0.80	0.75
4	210	0.39	0.56	0.61	0.61	0.68	0.66	0.72	0.52	0.67	0.60
4	280	0.29	0.41	0.49	0.49	0.52	0.65	0.56	0.40	0.56	0.49

Table S8: SPFE results for all CR boxes for medium speed. SPFE is a unitless ratio.

CR Box	Days Elapsed	0.35 – 0.46 μm	0.46 – 0.66 μm	0.66 – 1.0 μm	1.0 – 1.3 μm	1.3 – 1.7 μm	1.7 – 2.3 μm	2.3 – 3.0 μm	Average 0.35 – 1.0 μm	Average 1.0 – 3.0 μm	Average 0.35 – 3.0 μm
1	0	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99
1	210	0.72	0.87	0.91	0.92	0.93	0.94	0.96	0.83	0.94	0.89
1	280	0.67	0.83	0.88	0.89	0.91	0.94	0.95	0.79	0.92	0.87
2	0	0.69	0.72	0.78	0.84	0.86	0.86	0.90	0.73	0.87	0.81
2	210	0.41	0.47	0.50	0.52	0.58	0.57	0.59	0.46	0.57	0.52
2	280	0.20	0.29	0.40	0.39	0.40	0.45	0.41	0.30	0.41	0.36
3	0	0.72	0.73	0.78	0.82	0.82	0.83	0.88	0.74	0.84	0.80
3	210	0.44	0.56	0.61	0.64	0.65	0.64	0.70	0.53	0.66	0.61
3	280	0.36	0.45	0.55	0.60	0.60	0.70	0.68	0.45	0.65	0.56
4	0	0.64	0.67	0.72	0.75	0.78	0.80	0.87	0.68	0.80	0.75
4	210	0.39	0.56	0.61	0.61	0.68	0.66	0.72	0.52	0.67	0.60
4	280	0.29	0.41	0.49	0.49	0.52	0.65	0.56	0.40	0.56	0.49

Table S9: SPFE results for all CR boxes for low speed. SPFE is a unitless ratio.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 1.0 µm	Average 1.0 – 3.0 µm	Average 0.35 – 3.0 µm
1	0	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00
1	210	0.77	0.91	0.94	0.95	0.96	0.98	0.95	0.87	0.96	0.92
1	280	0.73	0.87	0.91	0.93	0.94	0.94	0.95	0.84	0.94	0.90
2	0	0.64	0.70	0.75	0.82	0.81	0.83	0.82	0.70	0.82	0.77
2	210	0.39	0.49	0.52	0.56	0.62	0.63	0.61	0.47	0.61	0.55
2	280	0.24	0.30	0.38	0.43	0.39	0.50	0.55	0.31	0.46	0.40
3	0	0.69	0.75	0.79	0.81	0.82	0.84	0.87	0.75	0.83	0.80
3	210	0.42	0.59	0.65	0.68	0.67	0.69	0.70	0.55	0.69	0.63
3	280	0.36	0.49	0.55	0.57	0.63	0.63	0.69	0.47	0.63	0.56
4	0	0.62	0.71	0.76	0.80	0.80	0.82	0.85	0.70	0.82	0.77
4	210	0.39	0.59	0.64	0.66	0.68	0.73	0.77	0.54	0.71	0.64
4	280	0.28	0.42	0.48	0.57	0.52	0.59	0.73	0.39	0.60	0.51

Total Flow Rate Results Tables

Total flow rate for each bin with specified particle optical diameter range, as well as average flow rate and standard deviation values presented in Figure 5, are shown for high speed (Table S10), medium speed (Table S11), and low speed (Table S12).

Table S10: Total flow rate results for all CR boxes for high speed. Flow rate units are m^3/hr.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 3.0 µm	Standard Deviation 0.35– 3.0 µm
1	0	1083	1132	1165	1278	1261	1276	1275	1210	58
1	210	917	1027	1044	1088	1123	1128	1228	1079	66
1	280	1049	1057	1079	1129	1200	1147	1166	1118	47
2	0	999	1109	1132	1141	1153	1154	1125	1116	23
2	210	1132	1142	1187	1276	1163	1279	1283	1209	56
2	280	1628	1438	1178	1429	1491	1452	1795	1487	168
3	0	1021	1165	1174	1248	1307	1489	1442	1264	121
3	210	1206	1063	1074	1123	1199	1338	1325	1190	103
3	280	1276	1242	1168	1199	1287	1217	1361	1250	59
4	0	966	1100	1158	1218	1176	1282	1286	1169	69
4	210	1093	1066	1135	1234	1175	1293	1170	1167	67
4	280	1602	1378	1310	1510	1503	1370	1930	1515	191

Table S11: Total flow rate results for all CR boxes for medium speed. Flow rate units are m^3/hr.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 3.0 µm	Standard Deviation 0.35– 3.0 µm
1	0	791	812	853	886	920	908	742	845	58
1	210	673	723	744	770	767	805	704	741	32
1	280	783	768	778	830	835	794	827	802	24
2	0	728	732	762	853	826	860	831	799	45
2	210	999	929	939	949	942	952	934	949	11
2	280	1481	1206	1083	1177	1185	1125	1117	1196	59
3	0	883	998	962	1035	1048	1076	972	996	42
3	210	1024	837	852	896	887	943	1015	922	58
3	280	1415	1112	1069	1154	1206	1220	1218	1199	63
4	0	1083	1045	1012	1032	1086	1060	1002	1046	27
4	210	1458	1066	1009	1095	1097	1056	1104	1126	59
4	280	1676	1229	1141	1248	1307	1288	1209	1300	77

Table S12: Total flow rate results for all CR boxes for low speed. Flow rate units are m^3/hr.

CR Box	Days Elapsed	0.35 – 0.46 µm	0.46 – 0.66 µm	0.66 – 1.0 µm	1.0 – 1.3 µm	1.3 – 1.7 µm	1.7 – 2.3 µm	2.3 – 3.0 µm	Average 0.35 – 3.0 µm	Standard Deviation 0.35– 3.0 µm
1	0	601	624	650	689	709	666	600	649	35
1	210	391	395	417	421	424	426	386	408	14
1	280	628	497	511	522	525	549	523	536	20
2	0	701	632	640	700	705	734	674	684	34
2	210	939	718	740	747	696	676	703	745	38
2	280	901	864	751	766	912	756	695	806	70
3	0	684	34	861	826	820	846	865	815	53
3	210	745	38	568	567	594	635	714	640	64
3	280	806	70	677	686	740	768	770	769	70
4	0	796	711	724	743	752	750	763	749	18
4	210	1150	770	759	813	768	732	598	799	83
4	280	1082	890	870	858	983	986	822	927	62

Raw Power Data

The complete set of power monitoring data is shown in Figure S3. As explained in the main text, the power meter for Box 2 did not log data for the last deployment period. Periodic observations of the box recorded that it was running at low speed as expected during this period.

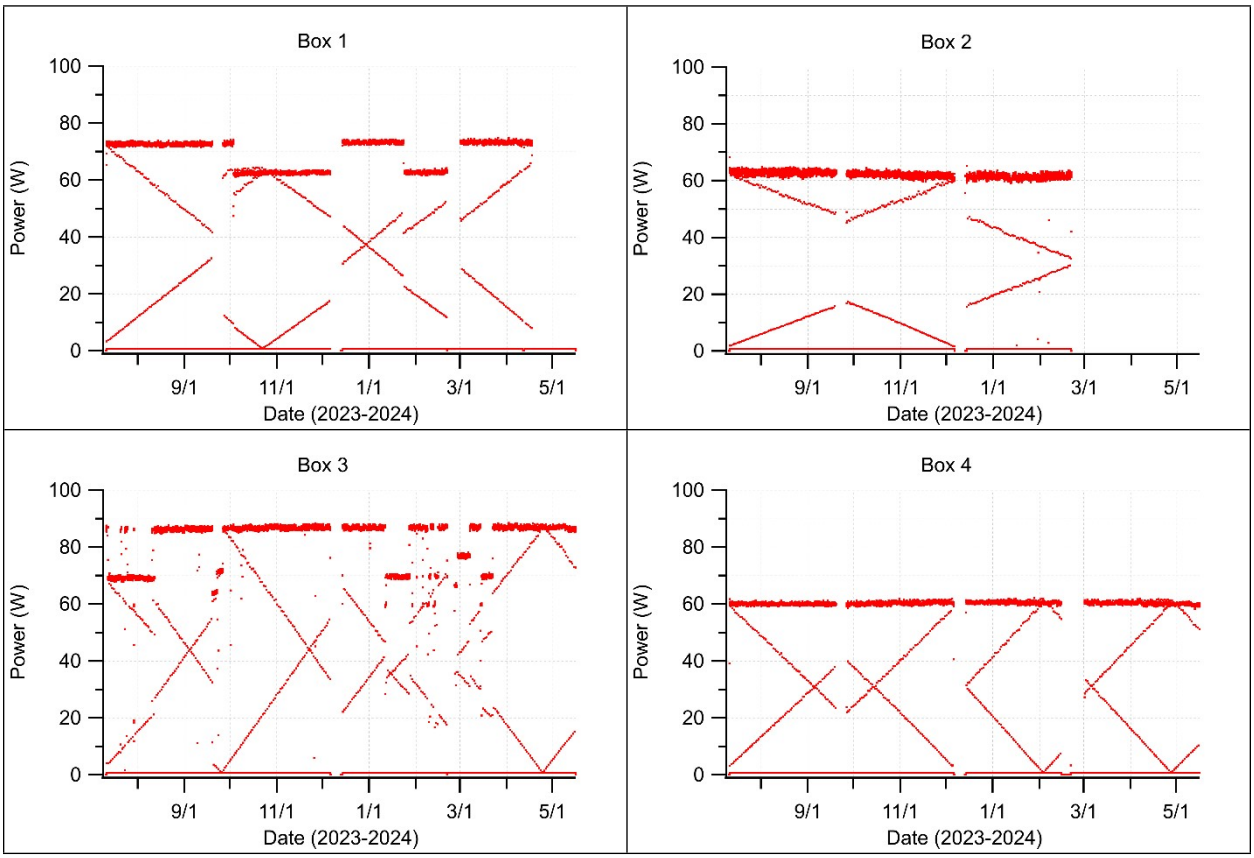

Figure S3: All power motoring data for CR Boxes 1 to 4. Each steady state power level indicates distinct fan speed (only Box 1 and Box 3 were used at multiple speeds by the occupants).

Pressure Drop Data

The differential pressure measurements for each CR box at each speed are shown in Table S13.

Table S13: Pressure differential across CR Box filters by box, speed, and days elapsed

	High Speed				Medium Speed				Low Speed			
Days Elapsed	Box 1 (Pa)	Box 2 (Pa)	Box 3 (Pa)	Box 4 (Pa)	Box 1 (Pa)	Box 2 (Pa)	Box 3 (Pa)	Box 4 (Pa)	Box 1 (Pa)	Box 2 (Pa)	Box 3 (Pa)	Box 4 (Pa)
0	7.2	7.2	7.1	7.2	5.4	5.6	5.7	5.7	4.0	4.1	4.2	4.2
210	10.3	8.2	8.6	8.7	6.7	5.5	6.2	6.0	5.7	4.4	4.9	4.8
280	10.9	8.2	8.9	9	8.1	6.2	7	7.2	5.7	4.6	5.1	5.2

CADR Measurement Uncertainty

To estimate the uncertainty of the CADR measurement method, at the end of the experiment the CADR of Box 3 on speed high was measured 10 times (Table S14). Box 3 had been used intermittently over two months since testing concluded, so the results are slightly lower than the 40-week measurement. The uncertainty (two standard deviations) was 6% of the average measurement for 0.35 to 1 μm optical diameter particles and 5% for 1 to 3 optical diameter particles.

Table S14: Repeat CADR measurement for Box 3 for medium speed. CADR units are m^3/hr.

Test	0.35 – 0.46 μm	0.46 – 0.66 μm	0.66 – 1.0 μm	1.0 – 1.3 μm	1.3 – 1.7 μm	1.7 – 2.3 μm	2.3 – 3.0 μm	Average 0.35 – 1.0 μm	Average 1.0 – 3.0 μm
1	389	613	707	807	874	926	1014	570	905
2	459	604	674	770	791	883	940	579	846
3	464	604	686	767	815	880	1022	585	871
4	449	612	694	767	834	902	1028	585	883
5	477	614	690	780	824	931	937	594	868
6	393	582	661	736	814	917	948	545	854
7	447	585	668	746	818	903	1008	567	869
8	458	596	678	769	797	923	976	577	866
9	394	607	683	775	818	842	898	562	833
10	489	626	697	821	845	879	971	604	879
							Average	577	867
							2*STD	34	40
							Percent	6%	5%