Supplement of Atmos. Chem. Phys., 15, 7585–7604, 2015
http://www.atmos-chem-phys.net/15/7585/2015/
doi:10.5194/acp-15-7585-2015-supplement

Atmospheric Chemistry and Physics Open Access

Supplement of

The relationship between cloud condensation nuclei (CCN) concentration and light extinction of dried particles: indications of underlying aerosol processes and implications for satellite-based CCN estimates

Y. Shinozuka et al.

Correspondence to: Y. Shinozuka (yohei.shinozuka@nasa.gov)

Table S1. The results of bivariate regression analysis for 0.1-0.3% supersaturation.

Ang. Exp.	N	log10(Ext.)	log10(CCN)	Slope	Intercept	RMSe
California, USA, 10s avg., \leq 1 km alt., 0.27% SS						
1.1-1.3	108	1.35±0.45	2.48±0.26	0.40±0.29	1.96±0.06	1.56
1.3-1.5	489	1.82±0.55	2.71±0.29	0.42±0.08	1.96±0.03	1.49
1.5-1.7	1017	1.90±0.40	2.84±0.28	0.59±0.07	1.73±0.03	1.45
1.7-1.9	1481	1.93±0.36	2.96±0.26	0.62±0.05	1.76±0.02	1.38
1.9-2.1	1859	1.87±0.29	3.02±0.19	0.55±0.05	1.99±0.02	1.28
2.1-2.3	1222	1.77±0.25	3.02±0.18	0.61±0.07	1.95±0.02	1.27
2.3-2.5	411	1.68±0.27	3.01±0.22	0.77±0.11	1.72±0.03	1.26
Southern Great Plains, USA, 240s avg.						
0.1-0.3	124	1.23±0.32	2.22±0.38	0.62±0.36	1.54±0.14	2.45
0.3-0.5	232	1.18±0.34	2.29±0.29	0.57±0.16	1.66±0.06	1.83
0.5-0.7	439	1.25±0.35	2.38±0.30	0.60±0.10	1.67±0.04	1.72
0.7-0.9	976	1.33±0.36	2.50±0.31	0.59±0.06	1.74±0.03	1.71
0.9-1.1	1927	1.42±0.36	2.59±0.31	0.59±0.04	1.78±0.02	1.68
1.1-1.3	3849	1.51±0.34	2.71±0.30	0.61±0.03	1.80±0.02	1.70
1.3-1.5	6472	1.55±0.31	2.78±0.31	0.67±0.03	1.76±0.02	1.76
1.5-1.7	5725	1.52±0.29	2.83±0.33	0.74±0.04	1.72±0.02	1.93
1.7-1.9	2814	1.48±0.30	2.87±0.32	0.74±0.05	1.79±0.02	1.81
1.9-2.1	887	1.41±0.34	2.88±0.36	0.89±0.08	1.63±0.04	1.77
2.1-2.3	200	1.24±0.31	2.81±0.34	1.04±0.17	1.52±0.07	1.61
Cape Cod, USA, 240s avg.						
0.3-0.5	242	1.51±0.20	2.13±0.28	1.13±0.24	0.46±0.10	1.63
0.5-0.7	408	1.53±0.23	2.28±0.36	0.93±0.14	0.90±0.06	2.09
0.7-0.9	257	1.35±0.22	2.23±0.29	0.95±0.21	0.98±0.08	1.74
0.9-1.1	282	1.22±0.22	2.21±0.29	0.94±0.19	1.11±0.06	1.70
1.1-1.3	304	1.15±0.22	2.25±0.30	1.03±0.20	1.09±0.06	1.71
1.3-1.5	329	1.14±0.22	2.33±0.29	0.84±0.21	1.41±0.07	1.85
1.5-1.7	382	1.14±0.23	2.42±0.28	0.75±0.19	1.59±0.06	1.85
1.7-1.9	543	1.25±0.30	2.52±0.37	0.78±0.11	1.59±0.04	2.05
1.9-2.1	381	1.33±0.34	2.57±0.48	0.75±0.11	1.66±0.04	2.7
Black Forest, Germany, 240s avg.						
0.9-1.1	349	1.58±0.50	1.75±0.61	0.34±0.10	1.53±0.07	3.96
1.1-1.3	1223	1.69±0.44	1.87±0.60	0.54±0.07	1.22±0.05	3.53
1.3-1.5	3763	1.64±0.35	1.98±0.56	0.74±0.05	0.98±0.03	3.28
1.5-1.7	5279	1.62±0.28	2.04±0.56	1.05±0.06	0.55±0.04	3.42
1.7-1.9	1422	1.55±0.30	1.98±0.59	0.99±0.11	0.68±0.07	3.73
Ganges Valley, India, 240s avg.						
0.1-0.3	245	2.26±0.21	2.41±0.49	2.45±0.58	-3.07±0.40	2.79
0.3-0.5	549	2.38±0.25	2.59±0.46	1.54±0.23	-1.02±0.17	2.37
0.5-0.7	2233	2.38±0.24	2.70±0.39	1.34±0.10	-0.47±0.08	2.09
0.7-0.9	4524	2.17±0.26	2.56±0.41	0.92±0.06	0.64±0.04	2.23
0.9-1.1	2396	1.90±0.28	2.31±0.45	0.73±0.07	1.04±0.04	2.59
1.1-1.3	858	1.50±0.24	1.89±0.53	1.14±0.15	0.35±0.07	2.91
Graciosa Island, Azores, 240s avg.						
-0.5--0.3	202	1.42±0.29	1.66±0.26	0.54±0.08	0.96±0.09	1.65
-0.3--0.1	2913	1.56±0.24	1.93±0.26	0.92±0.02	0.52±0.03	1.60
-0.1-0.1	4117	1.51±0.26	2.11±0.28	0.86±0.02	0.85±0.02	1.62
0.1-0.3	4438	1.43±0.26	2.19±0.28	0.78±0.02	1.10±0.02	1.65
0.3-0.5	2865	1.33±0.26	2.25±0.28	0.83±0.02	1.18±0.02	1.62
0.5-0.7	1819	1.27±0.27	2.29±0.29	0.78±0.02	1.33±0.02	1.61
0.7-0.9	1127	1.22±0.27	2.31±0.31	0.88±0.03	1.26±0.03	1.69
0.9-1.1	625	1.22±0.30	2.38±0.33	0.87±0.04	1.36±0.04	1.68
1.1-1.3	186	1.14±0.31	2.33±0.34	0.72±0.08	1.57±0.07	1.91
Svalbard, 300s avg.						
-0.3--0.1	142	0.45±0.34	1.50±0.36	0.51±0.39	1.38±0.04	2.21
-0.1-0.1	212	0.45±0.32	1.54±0.33	0.50±0.28	1.40±0.03	2.01
0.1-0.3	233	0.44±0.36	1.53±0.45	0.67±0.24	1.32±0.03	2.42
0.3-0.5	362	0.68±0.55	1.73±0.38	0.51±0.11	1.46±0.02	1.85
0.5-0.7	392	0.57±0.35	1.71±0.40	0.65±0.16	1.42±0.02	2.14
0.7-0.9	451	0.58±0.32	1.76±0.35	0.73±0.17	1.38±0.02	1.93
0.9-1.1	746	0.49±0.44	1.92±0.35	-0.21±0.11	2.17±0.01	2.45
1.1-1.3	807	0.67±0.32	1.89±0.34	0.86±0.12	1.33±0.02	1.74
1.3-1.5	872	0.72±0.32	1.96±0.34	0.90±0.12	1.33±0.02	1.78
1.5-1.7	829	0.76±0.31	2.00±0.34	0.87±0.11	1.36±0.02	1.67
1.7-1.9	596	0.70±0.34	1.96±0.35	0.79±0.13	1.44±0.02	1.71
1.9-2.1	360	0.61±0.35	1.88±0.36	0.68±0.20	1.53±0.03	2.13
2.1-2.3	185	0.42±0.33	1.80±0.40	0.89±0.37	1.46±0.04	2.00
2.3-2.5	118	0.37±0.26	1.78±0.31	1.28±0.91	1.28±0.07	1.77
Niamey, Niger, 240s avg.						
0.1-0.3	174	2.34±0.27	1.70±0.39	0.60±0.21	0.49±0.24	2.54
0.3-0.5	1271	2.21±0.27	1.62±0.52	0.56±0.07	0.72±0.08	4.08
0.5-0.7	1068	1.92±0.27	1.62±0.62	0.42±0.07	1.24±0.07	5.57
0.7-0.9	1169	1.77±0.22	1.82±0.55	0.38±0.08	1.42±0.07	4.22
0.9-1.1	952	1.75±0.22	1.95±0.46	0.47±0.09	1.32±0.08	3.16
1.1-1.3	620	1.75±0.26	1.94±0.49	0.47±0.10	1.32±0.09	3.30
1.3-1.5	252	1.82±0.31	2.05±0.47	0.39±0.15	1.55±0.13	3.23
1.5-1.7	138	1.85±0.33	2.14±0.49	0.75±0.21	0.90±0.20	2.86

Ang. Exp. is the Angstrom exponent of the extinction coefficient, N is the number of data points, Ext. is the 500 nm extinction coefficient (Mm^{-1}) for dried particles, CCN is the CCN concentration (cm^{-3}). RMSe given here is 10 raised to the root mean square of the fitting error; an RMSe of 2, for example, means that the deviation of individual data points is typically within a factor of 2 of the best estimate. The values after the ± symbol indicates the standard deviation or the square root of the variance.

Table S2. The results of bivariate regression analysis for 0.5-0.7% supersaturation.

Ang. Exp.	N	log10(Ext.)	log10(CCN)	Slope	Intercept	RMSe
Southern Great Plains, USA, 240s avg.						
0.5-0.7	209	1.34±0.37	2.81±0.35	0.65±0.16	1.98±0.07	2.00
0.7-0.9	471	1.43±0.39	2.90±0.37	0.56±0.11	2.14±0.05	2.10
0.9-1.1	1126	1.49±0.36	2.96±0.33	0.54±0.07	2.18±0.03	1.89
1.1-1.3	2597	1.53±0.33	3.01±0.32	0.53±0.05	2.23±0.02	1.89
1.3-1.5	4391	1.55±0.31	3.10±0.28	0.54±0.04	2.28±0.02	1.75
1.5-1.7	3457	1.52±0.29	3.16±0.30	0.72±0.05	2.07±0.02	1.76
1.7-1.9	1646	1.49±0.31	3.16±0.33	0.88±0.06	1.85±0.03	1.74
1.9-2.1	381	1.40±0.36	3.15±0.39	1.02±0.12	1.72±0.06	1.77
Cape Cod, USA, 240s avg.						
0.3-0.5	215	1.69±0.23	2.55±0.26	0.93±0.18	0.98±0.08	1.46
0.5-0.7	293	1.59±0.20	2.64±0.44	0.82±0.21	1.41±0.09	2.68
0.7-0.9	310	1.39±0.21	2.71±0.21	0.64±0.20	1.84±0.07	1.53
0.9-1.1	331	1.30±0.25	2.75±0.25	0.75±0.19	1.78±0.07	1.64
1.1-1.3	450	1.24±0.25	2.83±0.25	0.68±0.13	2.00±0.04	1.63
1.3-1.5	530	1.21±0.27	2.91±0.23	0.60±0.11	2.19±0.04	1.54
1.5-1.7	509	1.18±0.29	2.95±0.23	0.56±0.11	2.30±0.04	1.54
1.7-1.9	598	1.35±0.34	3.08±0.26	0.51±0.08	2.41±0.03	1.60
1.9-2.1	643	1.40±0.30	3.15±0.31	0.55±0.08	2.40±0.03	1.86
2.1-2.3	119	1.26±0.28	3.16±0.23	0.70±0.20	2.29±0.06	1.39
Black Forest, Germany, 240s avg.						
0.9-1.1	104	1.60±0.49	2.91±0.34	0.58±0.09	1.99±0.05	1.51
1.1-1.3	393	1.63±0.47	2.92±0.36	0.60±0.05	1.96±0.03	1.65
1.3-1.5	1319	1.61±0.37	3.03±0.30	0.63±0.04	2.03±0.02	1.56
1.5-1.7	1929	1.61±0.28	3.13±0.30	0.71±0.04	2.00±0.02	1.69
1.7-1.9	477	1.55±0.30	3.14±0.33	0.73±0.06	2.02±0.04	1.76
Ganges Valley, India, 240s avg.						
0.3-0.5	170	2.37±0.26	3.31±0.28	0.94±0.13	1.08±0.09	1.37
0.5-0.7	669	2.38±0.23	3.34±0.26	1.01±0.09	0.93±0.06	1.42
0.7-0.9	1423	2.16±0.25	3.24±0.26	0.92±0.04	1.25±0.03	1.34
0.9-1.1	791	1.90±0.29	3.11±0.32	0.99±0.06	1.25±0.03	1.40
1.1-1.3	280	1.53±0.25	2.81±0.37	1.26±0.16	0.90±0.08	1.63
1.3-1.5	134	1.22±0.18	2.45±0.35	1.62±0.36	0.50±0.13	1.73
Graciosa Island, Azores, 240s avg.						
-0.5--0.3	118	1.38±0.30	2.07±0.28	0.87±0.13	0.89±0.13	1.76
-0.3--0.1	1488	1.57±0.23	2.36±0.24	0.97±0.04	0.85±0.04	1.61
-0.1-0.1	2038	1.51±0.26	2.56±0.26	0.84±0.03	1.30±0.03	1.62
0.1-0.3	2267	1.43±0.26	2.61±0.26	0.83±0.03	1.43±0.03	1.65
0.3-0.5	1446	1.33±0.26	2.69±0.26	0.89±0.03	1.52±0.03	1.51
0.5-0.7	904	1.26±0.27	2.74±0.24	0.73±0.03	1.82±0.03	1.45
0.7-0.9	581	1.22±0.26	2.76±0.27	0.85±0.05	1.74±0.04	1.58
0.9-1.1	318	1.20±0.32	2.81±0.32	0.76±0.06	1.91±0.05	1.69
Svalbard, 300s avg.						
-0.1-0.1	129	0.52±0.37	1.75±0.32	0.71±0.70	1.40±0.08	2.09
0.1-0.3	166	0.42±0.32	1.77±0.40	1.21±0.78	1.23±0.08	2.81
0.3-0.5	245	0.67±0.52	1.92±0.43	0.66±0.18	1.53±0.03	1.97
0.5-0.7	293	0.57±0.33	1.89±0.33	0.97±0.43	1.32±0.06	2.26
0.7-0.9	435	0.62±0.33	1.87±0.31	0.79±0.25	1.39±0.04	1.86
0.9-1.1	522	0.63±0.34	1.91±0.33	0.93±0.24	1.32±0.04	1.99
1.1-1.3	614	0.71±0.31	1.99±0.31	0.96±0.21	1.30±0.03	1.81
1.3-1.5	711	0.72±0.30	2.03±0.30	0.93±0.21	1.35±0.03	1.81
1.5-1.7	615	0.72±0.30	2.05±0.28	0.89±0.21	1.40±0.03	1.72
1.7-1.9	450	0.67±0.35	2.03±0.31	0.74±0.22	1.55±0.03	1.77
1.9-2.1	280	0.57±0.32	2.01±0.36	0.91±0.44	1.49±0.06	2.14
2.1-2.3	172	0.40±0.32	1.92±0.38	1.37±0.83	1.27±0.09	2.56
Niamey, Niger, 240s avg.						
0.1-0.3	238	2.26±0.27	2.51±0.34	0.49±0.10	1.44±0.12	2.13
0.3-0.5	1479	2.19±0.30	2.65±0.44	0.45±0.04	1.73±0.04	2.64
0.5-0.7	924	2.02±0.30	2.78±0.45	0.74±0.05	1.35±0.05	2.51
0.7-0.9	784	1.85±0.26	2.84±0.33	0.98±0.05	1.05±0.05	1.80
0.9-1.1	544	1.82±0.28	2.95±0.33	0.98±0.05	1.17±0.04	1.60
1.1-1.3	300	1.84±0.30	3.05±0.32	0.99±0.06	1.24±0.05	1.43
1.3-1.5	134	1.92±0.37	3.21±0.34	0.87±0.07	1.55±0.07	1.41

Ang. Exp. is the Angstrom exponent of the extinction coefficient, N is the number of data points, Ext. is the 500 nm extinction coefficient (Mm^{-1}) for dried particles, CCN is the CCN concentration (cm^{-3}). RMSe given here is 10 raised to the root mean square of the fitting error; an RMSe of 2, for example, means that the deviation of individual data points is typically within a factor of 2 of the best estimate. The values after the ± symbol indicates the standard deviation or the square root of the variance.

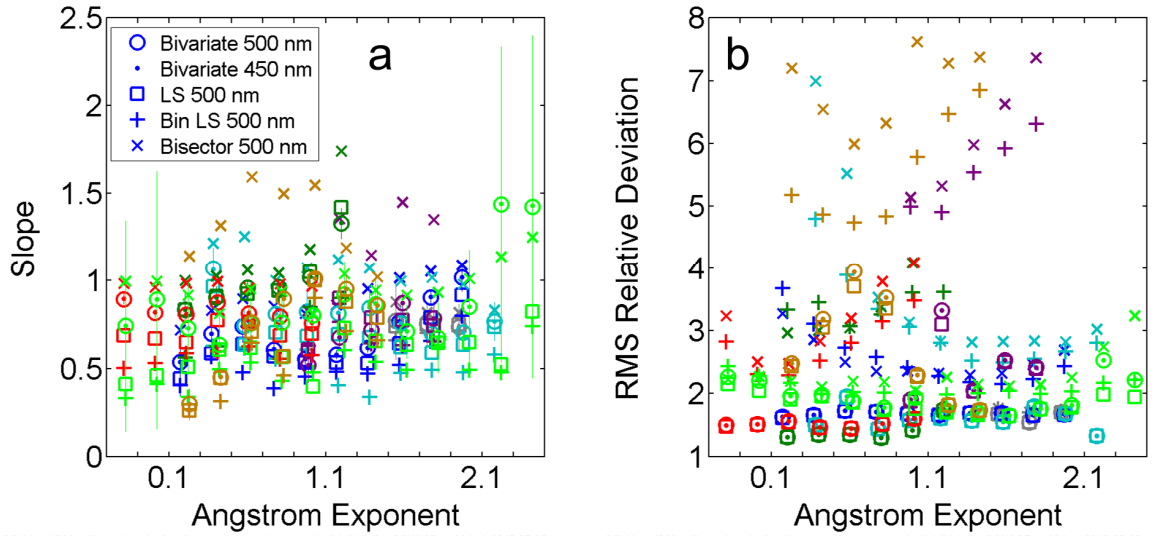

Figure S1. Results of additional regression analysis. The color corresponds to the locations indicated in Figure 3a. The dot is for the 450 nm extinction coefficient; all others are for 500 nm. The square is for the standard least-squares method, the plus for the same method applied after the individual data points are averaged over 0.5-wide $\log_{10}\sigma$ bins, and the cross for the bisector method. The two bivariate markers and the standard least-squares overlap between each other in several cases, especially for the RMS relative deviation.

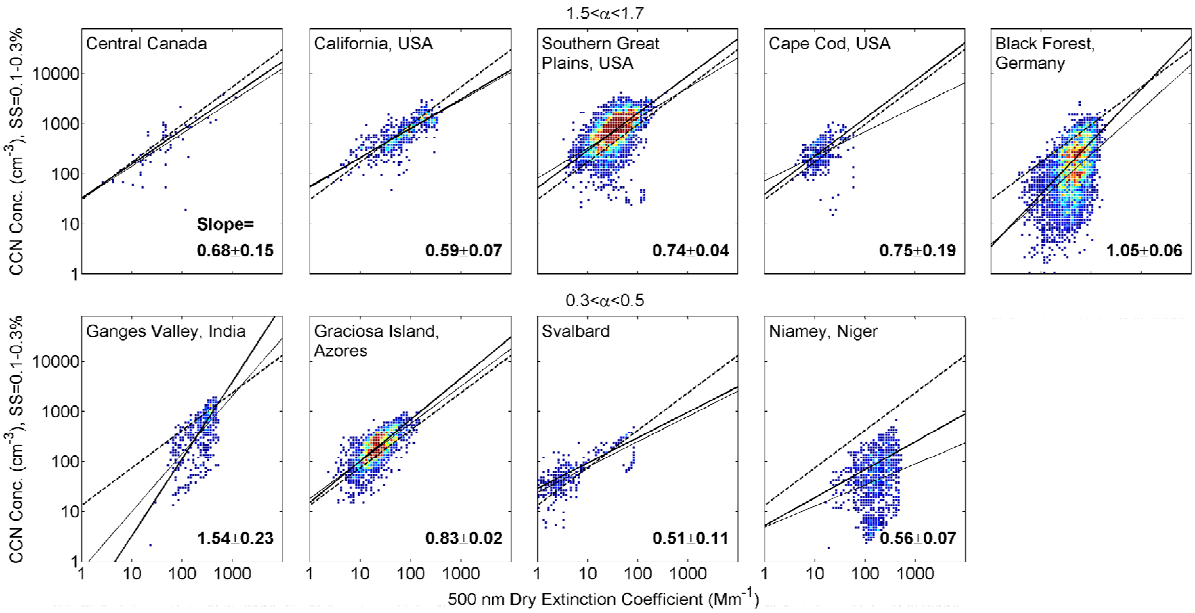

Figure S2. Same as Figure 2 but for supersaturation of 0.1-0.3% instead of 0.3-0.5%. This includes data from DISCOVER-AQ California for Angstrom exponent between 1.5 and 1.7.

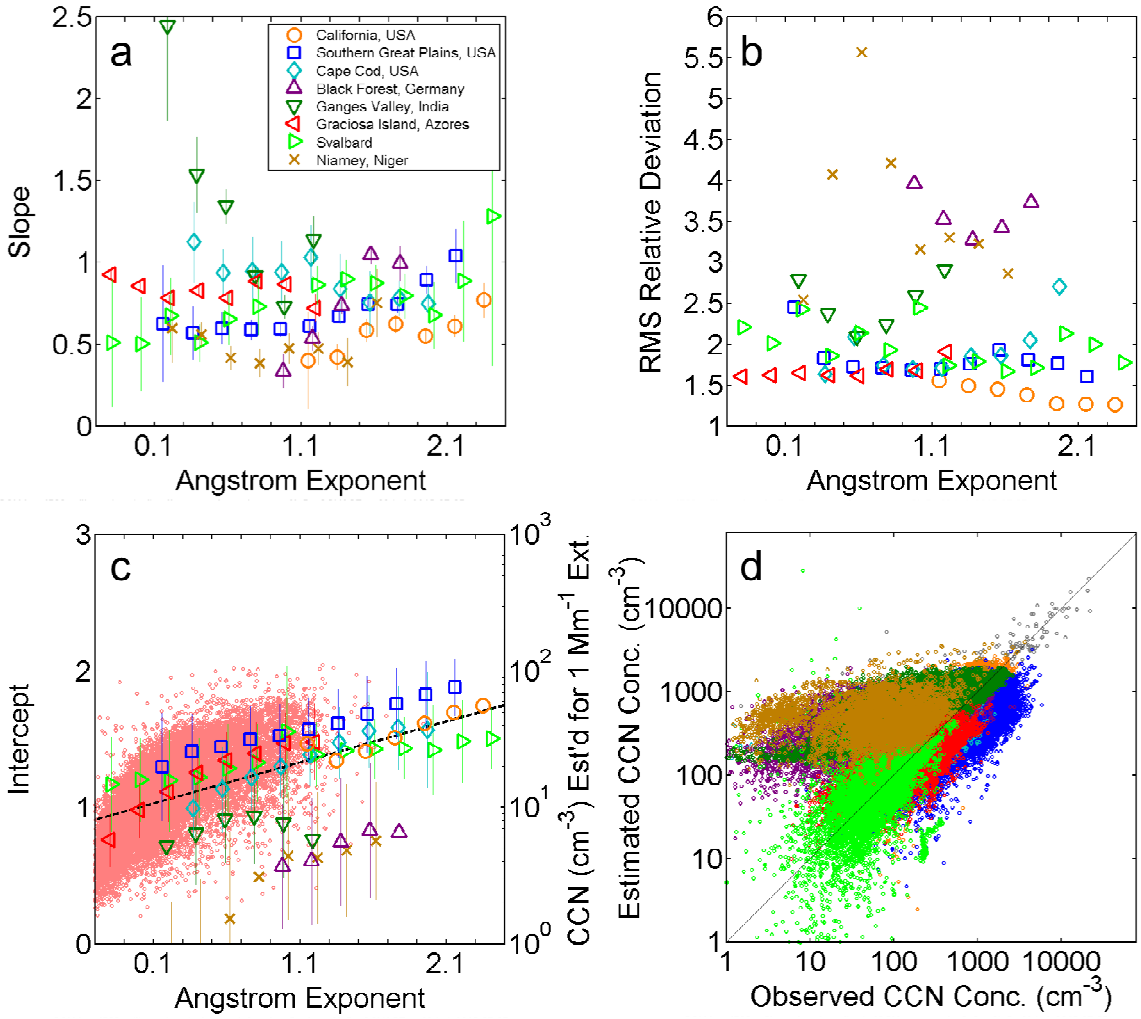

Figure S3. Same as Figure 3 but for supersaturation of 0.1-0.3% instead of 0.3-0.5%. The RMS difference calculated for all but Niamey data is a factor of 3.0.

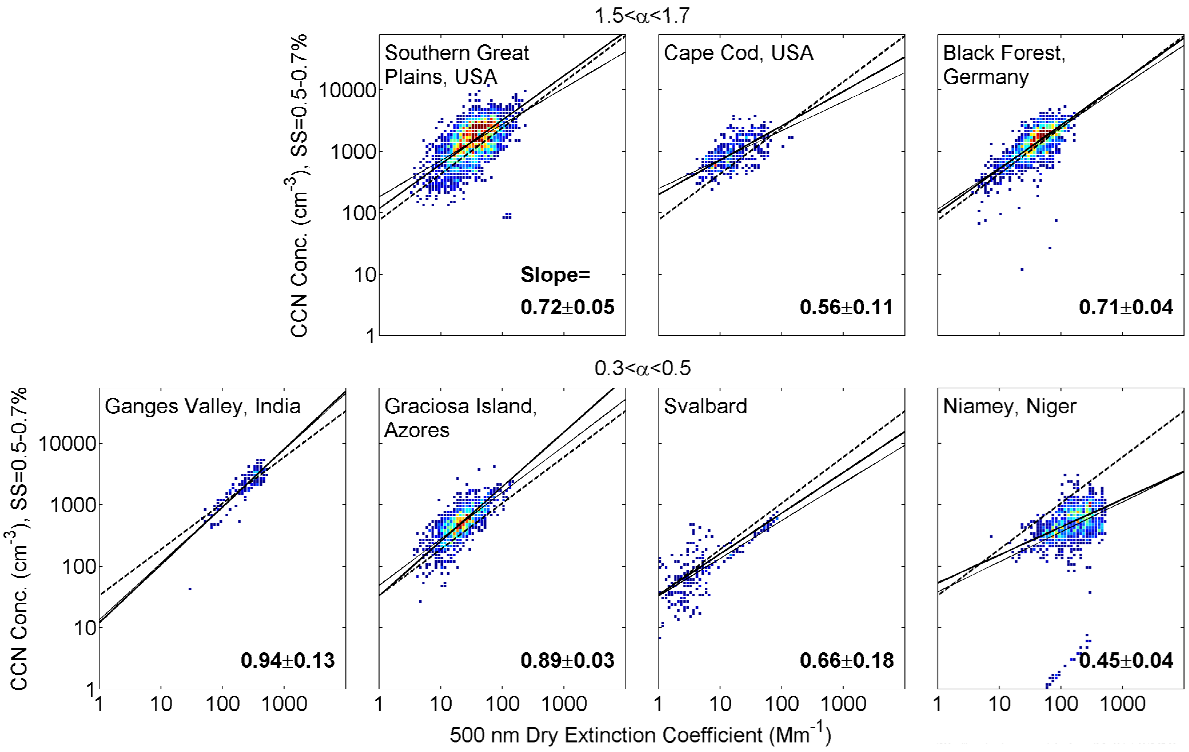

Figure S4. Same as Figure 2 but for supersaturation of 0.5-0.7% instead of 0.3-0.5%.

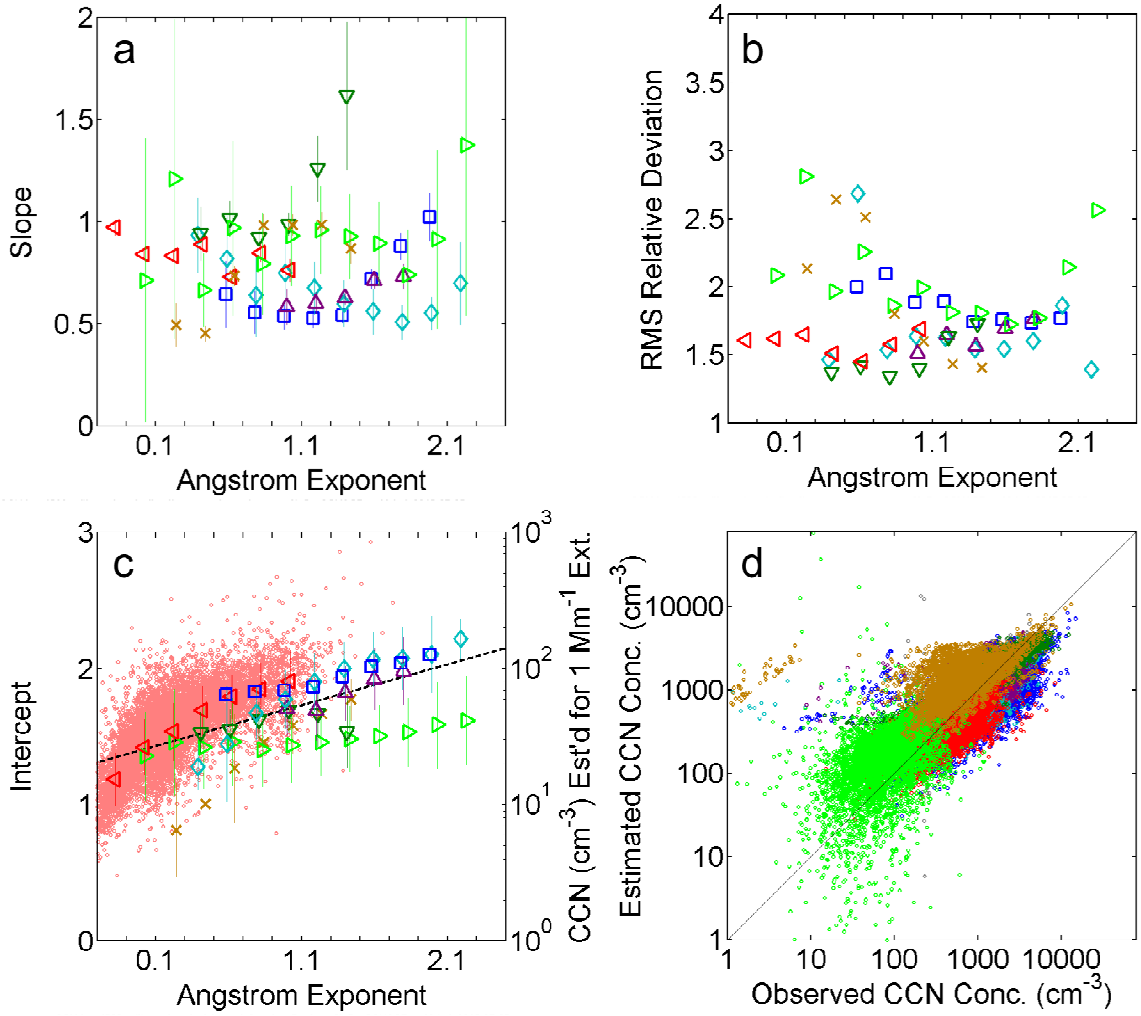

Figure S5. Same as Figure 3 but for supersaturation of 0.5-0.7% instead of 0.3-0.5%. The RMS difference calculated for all but Niamey data is a factor of 2.1.