Supplement of

Distinctive aerosol-cloud-precipitation interactions in marine boundary layer clouds from the ACE-ENA and SOCRATES aircraft field campaigns

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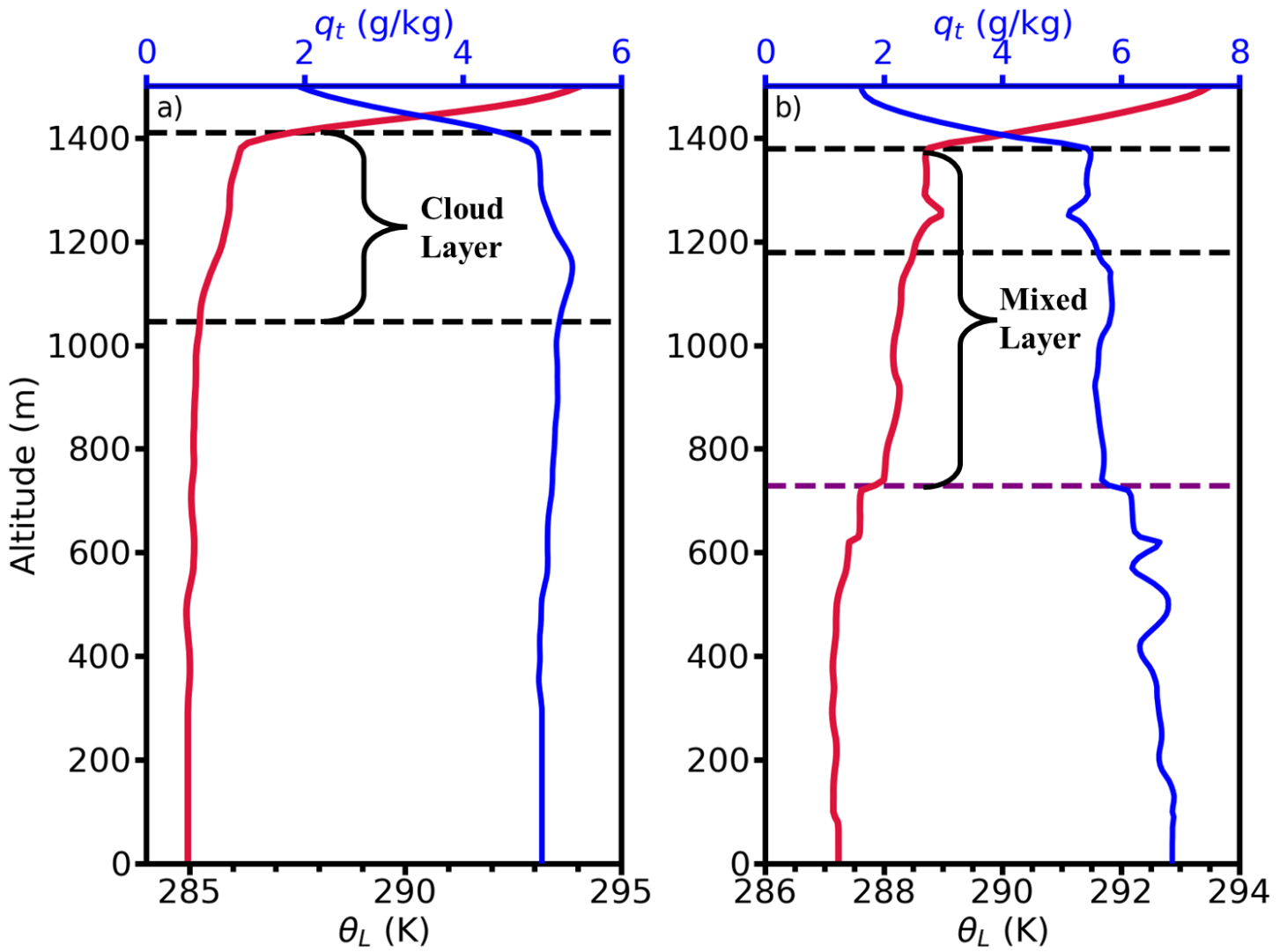
Figure S1. Illustration of mixed layer determination of a) coupled MBL case, and b) decoupled MBL case. Solid lines denote vertical variations of liquid water potential temperature (θ_L, red) and total water mixing ratio (q_t, blue). Black dashed line denotes cloud boundaries and purple dashed line denotes mixed layer base altitude.
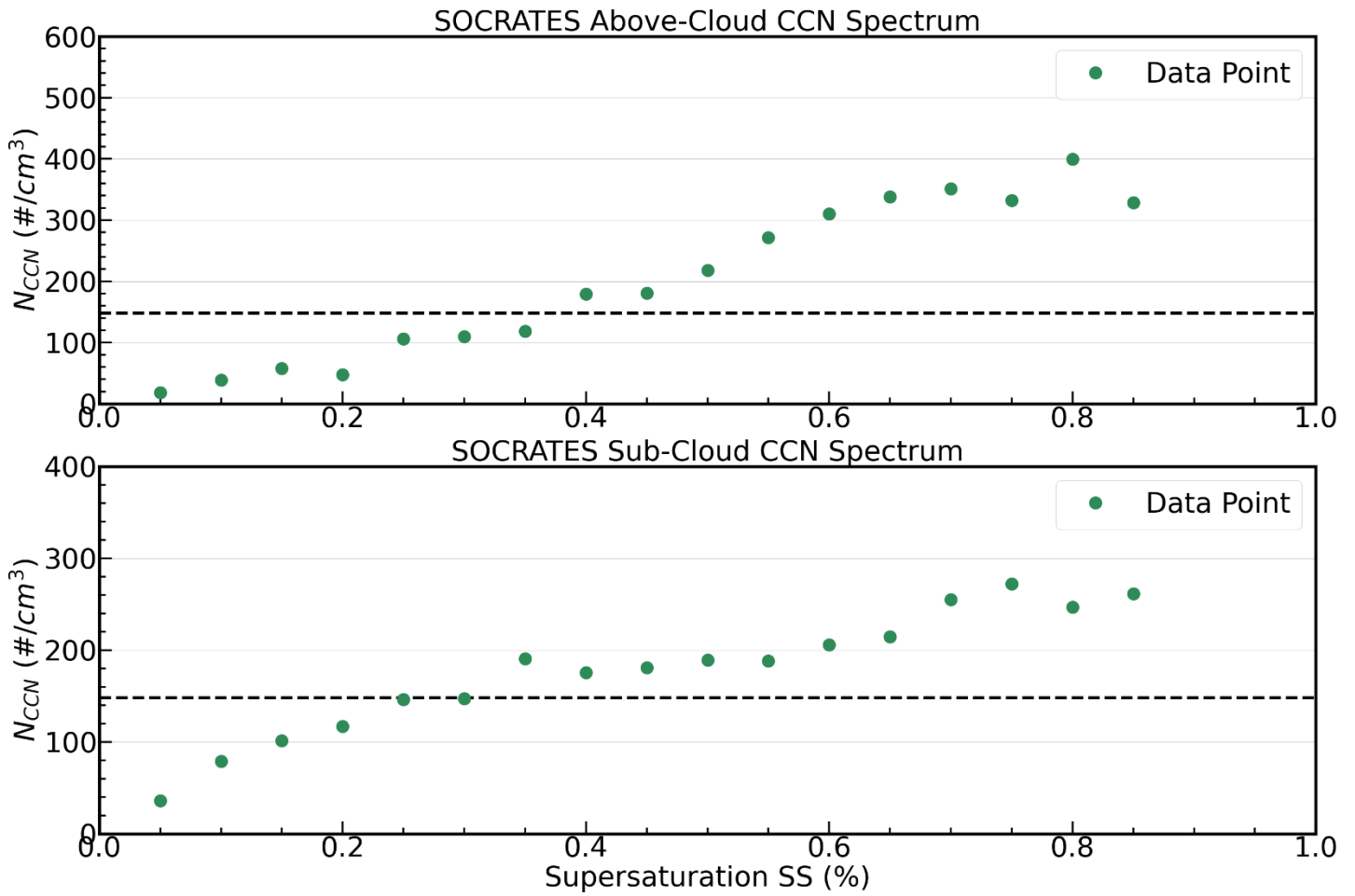
Figure S2. CCN spectra versus supersaturation during SOCRATES for a) above-cloud and b) sub-cloud regimes. Black dashed line denotes the averaged layer-mean N_c.

Figure S3. Coarse mode aerosol size distributions from PCASP (D_p = 1-3.2 µm) for a) above-cloud and b) sub-cloud regimes, during ACE-ENA summer (red) and winter (blue).
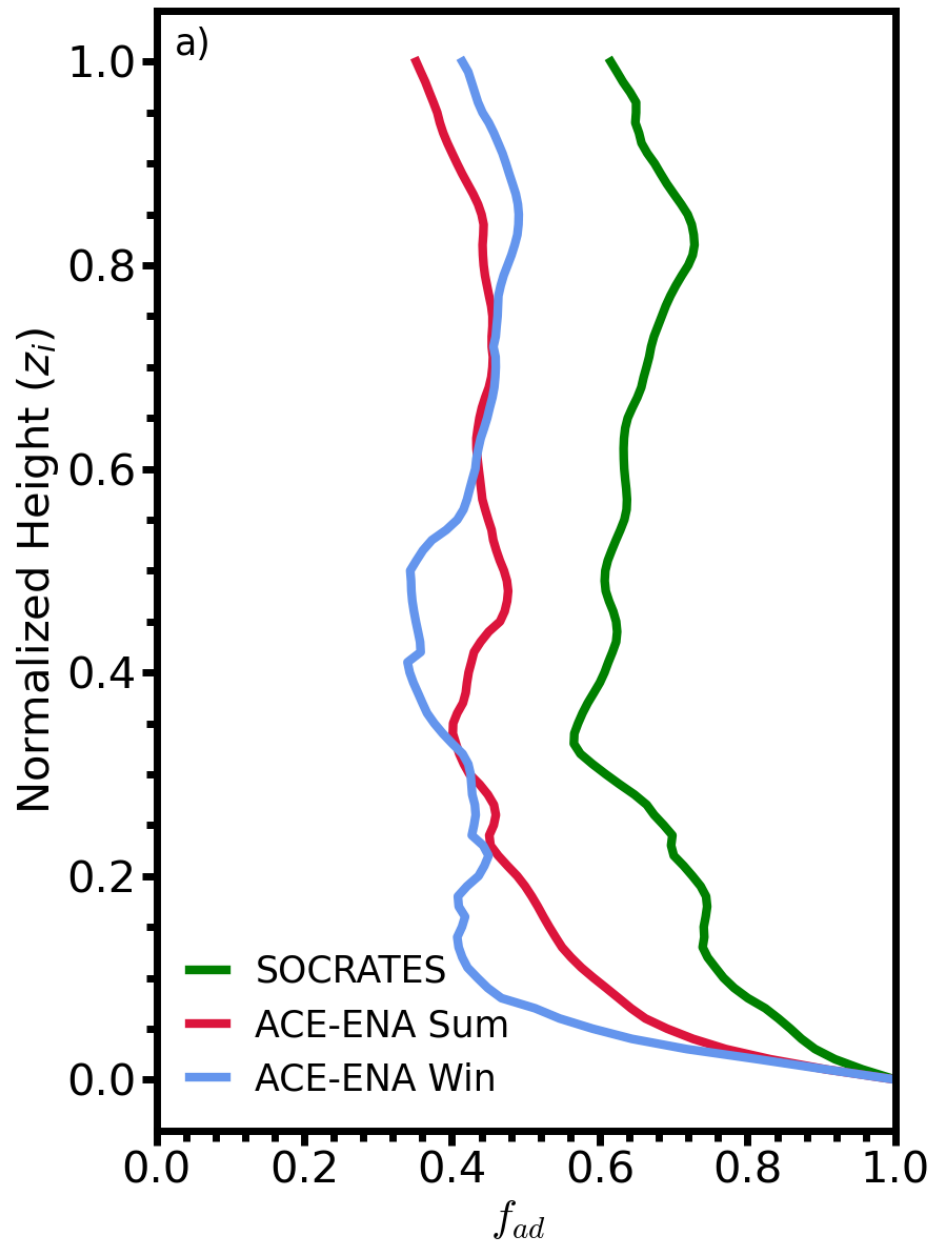
Figure S4. Vertical distributions of in-cloud sub-adiabaticity f_{ad}. ACE-ENA summer, winter and SOCRATES are color-coded with red, blue and green, respectively.
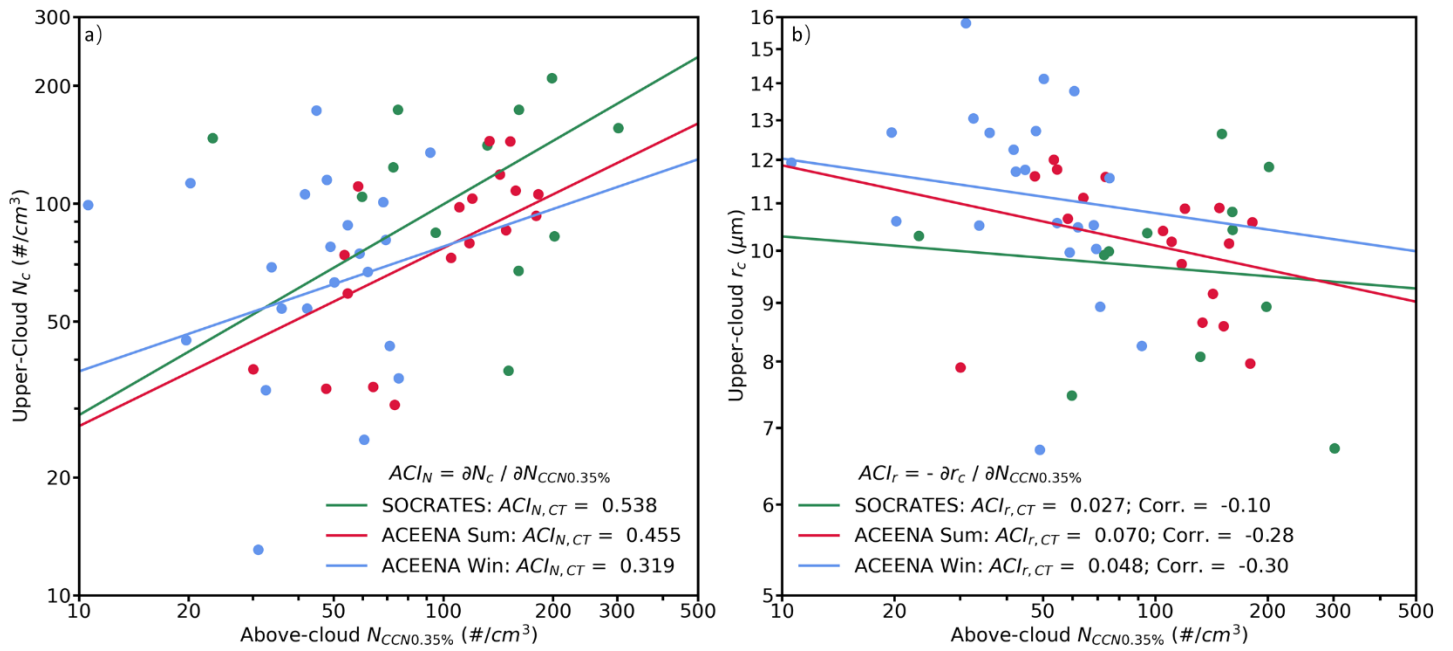
Figure S5. Scatterplots of a) upper-cloud N_c and b) r_c against the above-cloud $N_{CCN0.35\%}$. ACE-ENA summer, winter and SOCRATES are color-coded with red, blue and green, respectively.
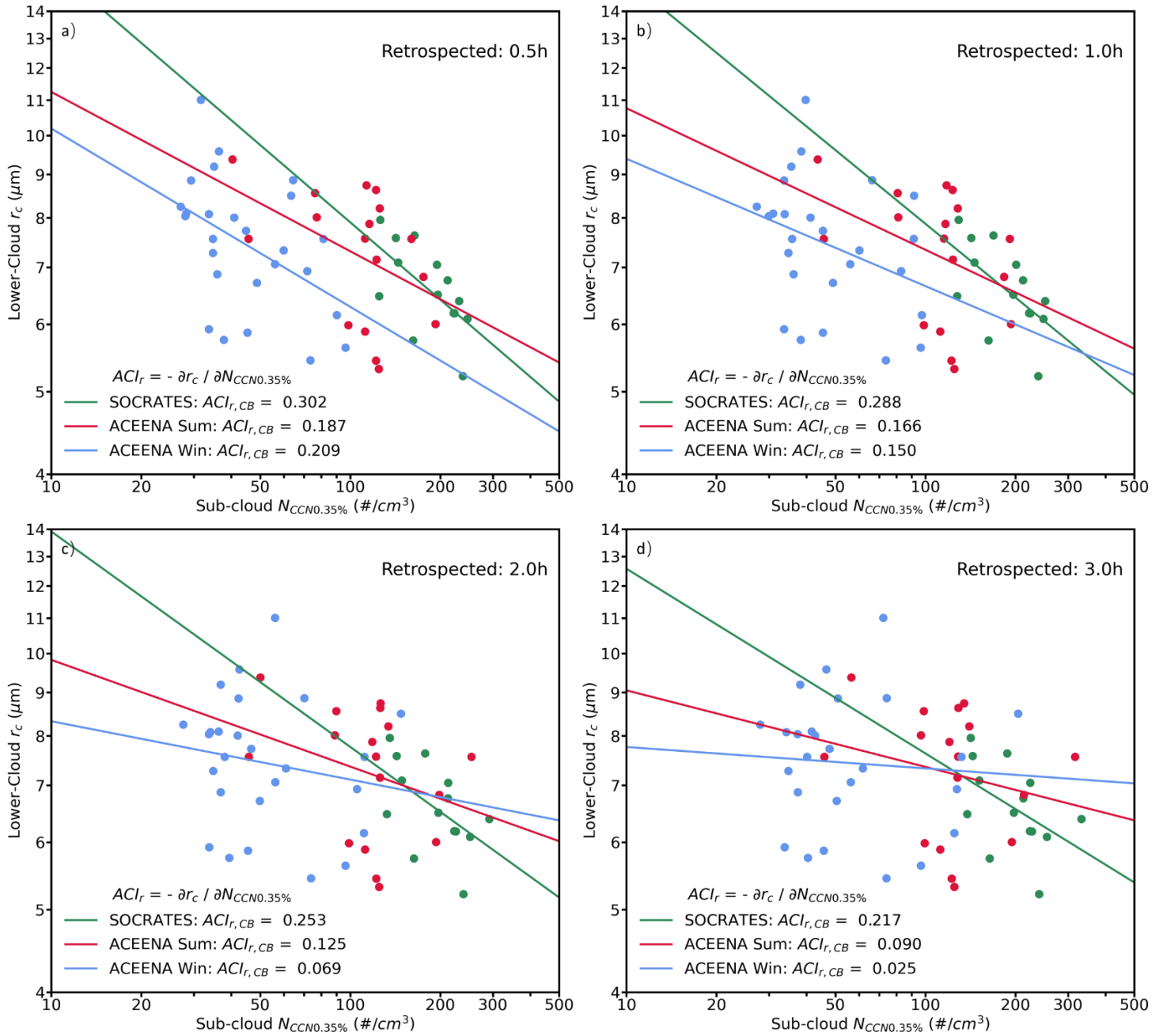
Figure S6. Scatterplots of lower-cloud r_c against the sub-cloud $N_{CCN0.35\%}$, at different $N_{CCN0.35\%}$ retrospective time of a) 0.5 hours, b) 1 hours, c) 2 hours and d) 3 hours.

Table S1. List of selected cloud profiles and associated macrophysics

		ACE-ENA summer					
Date	**Start UTC**	**End UTC**	**Precip.***	z_b	z_t	H_c	H_{mix}
20170628	9.65	10.8	0	659	797	138	797
20170630	9.9	11.3	1	909	1178	269	508
20170706	8.95	10.05	1	1151	1607	456	657
20170706	10.05	10.3	1	1344	1534	190	424
20170706	10.4	11.4	1	1320	1600	280	590
20170712	9.5	10.8	1	912	1273	361	593
20170712	10.8	11	1	373	597	224	307
20170712	11.1	12.3	1	750	1174	424	534
20170713	9	10.3	0	1140	1278	138	778
20170713	10.3	11.8	0	1169	1345	176	615
20170713	11.8	12.55	0	1139	1311	172	591
20170715	10.9	12.2	0	918	1080	162	610
20170715	12.45	13.6	1	1002	1423	421	613
20170718	8.9	9.1	1	627	964	337	964
20170718	9.1	10.9	1	588	1080	492	1080
20170718	10.9	11.9	1	646	970	324	970
20170720	9	10.8	1	233	1124	891	1124
20170720	10.8	11.1	1	546	1145	599	855
		ACE-ENA winter					
Date	**Start UTC**	**End UTC**	**Precip.***	z_b	z_t	H_c	H_{mix}
20180119	12.8	14.1	1	405	1009	604	1009
20180119	14.3	15.5	1	441	984	543	984
20180119	15.5	15.7	1	666	967	301	497
20180121	10.3	11.4	1	1113	1399	286	799
20180121	11.45	11.7	0	1152	1225	73	805
20180125	11.5	12.7	1	1191	1613	422	483
20180125	12.7	13	1	1235	1663	428	1663
20180125	13	14.1	1	1102	1655	553	755
20180126	11.1	11.2	0	1046	1410	364	1410
20180126	11.3	11.55	0	1104	1410	306	1410
20180126	11.55	13	0	1102	1494	392	1494
20180129	10.1	11.3	1	1180	1379	199	649
20180129	11.6	13	1	1077	1429	352	679
20180130	10.1	11.8	0	941	1396	455	1396
20180130	11.8	12.2	0	1034	1212	178	242
20180130	12.2	13.4	0	1056	1376	320	346
20180130	13.4	13.6	0	1214	1331	117	1201
20180207	17.9	18.8	0	1158	1512	354	1512
20180208	13.5	14.6	1	1680	2049	369	589
20180208	14.6	14.9	0	1925	2061	136	211
20180209	13.2	14.6	1	453	802	349	582
20180210	15	16.3	0	1371	1546	175	726

Date	Start UTC	End UTC	Precip.*	z_b	z_t	H_c	H_{mix}
20180211	11.95	13.55	1	548	1728	1180	1728
20180211	13.55	13.8	1	712	1888	1176	1888
20180212	11.7	13	0	1043	1287	244	1287
20180212	13.25	14.4	0	906	1233	327	1233
SOCRATES							
Date	**Start UTC**	**End UTC**	**Precip.***	z_b	z_t	H_c	H_{mix}
20180115	26.0833	26.25	0	2021	2259	238	909
20180128	26	26.17	1	741	1336	595	1336
20180131	4.667	4.783	1	1112	1599	487	999
20180203	27	27.25	1	702	1444	742	1444
20180203	27.333	27.5	0	1260	1741	481	1091
20180203	27.51	27.625	0	1065	1830	765	1110
20180204	26.933	27.367	1	1047	2221	1174	2221
20180204	27.417	27.667	1	1295	2256	961	1446
20180204	27.683	27.867	1	1759	2355	596	1295
20180207	24.833	25.033	0	2167	2397	230	677
20180217	27.417	27.7	1	903	1087	184	1087
20180217	27.733	27.983	1	907	1303	396	1053
20180217	28	28.075	1	820	1298	478	1008
20180217	28.075	28.167	1	956	1312	356	912
20180217	28.333	28.833	1	1028	1349	321	1349
20180217	29.117	29.2	1	752	1324	572	944
20180217	29.2	29.267	1	706	1324	618	1324
20180219	26.833	26.917	1	577	844	267	844
20180219	26.917	26.992	1	476	913	437	913
20180219	26.992	27.083	1	468	911	443	911
20180219	27.3	27.583	1	696	1045	349	1045
20180219	27.75	27.883	1	684	1228	544	918
20180219	27.883	27.958	1	646	1259	613	1259
20180219	27.958	28.083	1	805	1166	361	936
20180219	28.6	28.725	1	821	1119	298	589
20180219	28.725	28.817	1	622	1155	533	1155
20180219	28.817	28.917	1	855	1101	246	771
20180219	29.083	29.333	1	783	1145	362	1145

*Precipitation status of 1 means noticeable drizzle droplets ($N_d > 0.001$ cm^{-3}) exists below the cloud base, while 0 means the opposite.

Table S2. List of selected cloud profiles and associated microphysics

							ACE-ENA summer					
Date	**Start UTC**	**End UTC**	N_c	r_c	LWC_c	N_d	D_{mmd}	LWC_d	$N_{CCN,sc}$	$N_{CCN,ac}$	R_{CB}	L_{CCN}
20170628	9.65	10.8	66.2	6.3	0.065	0.0058	53.6	0.0006	112.0	104.9	0.0021	-0.05
20170630	9.9	11.3	115.7	6.7	0.130	0.0253	54.4	0.0037	192.3	157.7	0.0055	-0.75
20170706	8.95	10.05	104.9	9.1	0.347	0.4139	51.2	0.0179	108.7	120.0	0.0406	-6.65
20170706	10.05	10.3	71.6	8.1	0.181	0.0362	63.3	0.0030	98.3	117.7	0.0055	-0.39
20170706	10.4	11.4	89.3	9.0	0.264	0.3279	50.9	0.0143	122.4	110.6	0.0616	-5.87
20170712	9.5	10.8	125.6	8.0	0.245	0.0122	65.8	0.0030	73.4	152.6	0.0448	-7.71
20170712	10.8	11	81.8	9.9	0.304	0.1075	71.9	0.0281	120.4	148.4	0.0208	-2.80
20170712	11.1	12.3	86.2	8.7	0.200	0.0528	60.8	0.0093	109.1	142.8	0.0556	-8.56
20170713	9	10.3	143.5	8.1	0.322	0.0075	79.5	0.0036	121.4	133.8	0.0384	-2.20
20170713	10.3	11.8	123.3	5.8	0.093	0.0006	55.3	0.0001	124.7	179.8	0.0012	-0.09
20170713	11.8	12.55	105.2	6.0	0.086	0.0010	56.1	0.0002	121.9	182.0	0.0025	-0.18
20170715	10.9	12.2	34.2	8.5	0.087	0.0313	57.7	0.0037	45.6	30.1	0.0046	-0.09
20170715	12.45	13.6	33.2	12.1	0.205	0.5284	76.1	0.1485	37.2	73.5	0.1255	-6.44
20170718	8.9	9.1	99.0	9.3	0.354	0.0514	79.6	0.0175	114.9	58.3	0.0234	-1.82
20170718	9.1	10.9	81.3	11.4	0.509	0.2273	90.7	0.0991	71.7	53.4	0.1086	-9.05
20170718	10.9	11.9	62.7	11.1	0.369	0.2358	89.2	0.0881	73.2	54.6	0.1698	-8.00
20170720	9	10.8	45.9	10.8	0.180	0.5023	84.4	0.0975	168.0	64.2	0.1854	-15.19
20170720	10.8	11.1	55.5	9.9	0.187	0.3672	101.1	0.1280	128.9	47.6	0.7165	-62.67
							ACE-ENA winter					
Date	**Start UTC**	**End UTC**	N_c	r_c	LWC_c	N_d	D_{mmd}	LWC_d	$N_{CCN,sc}$	$N_{CCN,ac}$	R_{CB}	L_{CCN}
20180119	12.8	14.1	20.1	12.0	0.126	0.3981	108.6	0.1495	23.5	31.0	0.6008	-16.24
20180119	14.3	15.5	43.8	11.7	0.263	0.2391	78.8	0.0645	25.0	19.7	0.1591	-8.65
20180119	15.5	15.7	29.8	11.6	0.185	0.4405	69.9	0.0839	34.4	32.6	0.0304	-1.24
20180121	10.3	11.4	49.2	9.3	0.151	0.1644	61.5	0.0206	26.2	33.7	0.0938	-3.72
20180121	11.45	11.7	44.8	8.2	0.095	0.0057	59.0	0.0005	34.7	71.1	0.0031	-0.03
20180125	11.5	12.7	63.8	10.7	0.342	0.1775	76.5	0.0573	35.2	50.2	0.4493	-56.37
20180125	12.7	13	140.9	10.6	0.739	0.0770	98.1	0.0482	62.4	44.8	0.0481	-3.93
20180125	13	14.1	75.9	10.7	0.412	0.1450	93.7	0.0626	60.6	41.7	0.1781	-22.29
20180126	11.1	11.2	110.5	10.5	0.626	0.0698	94.4	0.0312	40.6	47.9	0.0110	-0.71
20180126	11.3	11.55	160.1	9.1	0.579	0.0135	80.9	0.0062	59.4	0.7	0.0097	-0.76
20180126	11.55	13	111.5	9.2	0.408	0.0206	68.8	0.0069	48.4	10.6	0.0102	-0.67
20180129	10.1	11.3	54.8	10.2	0.247	0.0739	60.3	0.0113	34.4	36.0	0.1082	-4.09
20180129	11.6	13	56.1	9.0	0.179	0.0200	61.7	0.0047	33.5	42.3	0.0038	-0.25
20180130	10.1	11.8	82.9	9.2	0.276	0.0993	72.7	0.0184	45.2	58.9	0.0025	-0.15
20180130	11.8	12.2	102.5	9.6	0.396	0.0057	93.0	0.0039	35.6	68.4	0.0037	-0.62
20180130	12.2	13.4	71.9	7.7	0.146	0.0261	61.3	0.0042	33.6	69.5	0.0146	-2.19
20180130	13.4	13.6	58.2	8.8	0.141	0.0097	65.6	0.0031	33.6	75.3	0.0038	-0.05
20180207	17.9	18.8	120.2	8.6	0.359	0.0084	72.7	0.0033	37.2	20.2	0.0173	-1.10
20180208	13.5	14.6	32.3	10.3	0.128	0.2630	74.1	0.0695	25.6	60.6	0.1173	-5.34
20180208	14.6	14.9	59.3	9.8	0.231	0.0086	68.1	0.0023	26.9	62.0	0.0043	-0.37
20180209	13.2	14.6	51.6	11.2	0.337	0.1209	92.7	0.0509	44.2	7.6	0.0169	-1.17

Date	Start UTC	End UTC	N_c	r_c	LWC_c	N_d	D_{mmd}	LWC_d	$N_{CCN,sc}$	$N_{CCN,ac}$	R_{CB}	L_{CCN}
20180210	15	16.3	69.3	7.7	0.159	0.0124	55.4	0.0024	55.9	54.6	0.0030	-0.11
20180211	11.95	13.55	54.0	10.3	0.170	0.3182	100.9	0.1142	71.1	6.3	0.2443	-20.28
20180211	13.55	13.8	50.5	9.2	0.100	0.2453	93.2	0.0313	83.2	1.8	0.1964	-13.91
20180212	11.7	13	126.6	7.9	0.282	0.0058	64.6	0.0012	73.4	92.0	0.0043	-0.23
20180212	13.25	14.4	75.9	6.8	0.108	0.0035	56.3	0.0007	96.3	49.0	0.0018	-0.08

SOCRATES

Date	Start UTC	End UTC	N_c	r_c	LWC_c	N_d	D_{mmd}	LWC_d	$N_{CCN,sc}$	$N_{CCN,ac}$	R_{CB}	L_{CCN}
20180115	26.0833	26.25	63.4	9.2	0.195	0.4686	51.5	0.0324	nan	160.9	0.0157	-0.59
20180128	26	26.17	107.4	9.1	0.269	0.3262	57.2	0.0284	122.9	nan	0.0581	-6.25
20180131	4.667	4.783	51.2	10.5	0.217	0.9472	55.1	0.0641	nan	nan	0.0422	-2.37
20180203	27	27.25	89.0	9.5	0.257	0.4372	51.8	0.0294	nan	95.1	0.0147	-1.51
20180203	27.333	27.5	189.1	6.8	0.222	0.0009	47.5	0.0001	nan	nan	0.0072	-1.35
20180203	27.51	27.625	267.8	6.6	0.258	0.0011	50.0	0.0001	nan	nan	0.0022	-0.92
20180204	26.933	27.367	101.9	7.3	0.157	0.0685	55.3	0.0048	237.7	59.8	0.0064	-0.78
20180204	27.417	27.667	169.0	7.8	0.261	0.0719	59.9	0.0061	189.4	nan	0.0458	-11.57
20180204	27.683	27.867	106.6	7.0	0.146	0.0752	55.7	0.0052	244.9	nan	0.0294	-3.25
20180207	24.833	25.033	79.0	6.9	0.107	0.0007	43.9	0.0000	nan	nan	0.0266	-1.61
20180217	27.417	27.7	157.9	7.6	0.245	0.1240	58.2	0.0125	nan	nan	0.0031	-0.19
20180217	27.733	27.983	136.5	7.9	0.251	0.1334	54.4	0.0109	143.2	nan	0.0234	-2.71
20180217	28	28.075	109.9	8.5	0.263	0.1419	71.4	0.0252	122.4	nan	0.0439	-5.15
20180217	28.075	28.167	201.1	8.3	0.418	0.1643	59.4	0.0165	nan	198.5	0.0999	-17.65
20180217	28.333	28.833	161.8	7.5	0.237	0.0592	56.0	0.0052	195.8	302.1	0.0072	-0.62
20180217	29.117	29.2	144.9	6.8	0.161	0.0415	59.0	0.0041	211.5	nan	0.0020	-0.39
20180217	29.2	29.267	129.2	7.3	0.174	0.0725	69.8	0.0114	211.2	nan	0.2970	-40.30
20180219	26.833	26.917	124.5	8.1	0.253	0.2345	53.2	0.0174	nan	72.9	0.0041	-0.36
20180219	26.917	26.992	159.3	9.1	0.463	0.2569	58.4	0.0261	159.1	nan	0.0557	-9.55
20180219	26.992	27.083	169.5	8.7	0.425	0.1897	58.8	0.0182	nan	161.0	0.0551	-10.21
20180219	27.3	27.583	163.9	9.7	0.502	0.4954	52.2	0.0372	222.3	nan	0.0136	-1.68
20180219	27.75	27.883	140.7	8.1	0.339	0.1568	54.9	0.0121	161.9	75.0	0.0038	-0.72
20180219	27.883	27.958	126.5	8.3	0.330	0.2488	65.9	0.0207	nan	23.2	0.0507	-7.02
20180219	27.958	28.083	76.2	9.8	0.315	0.3318	56.7	0.0203	141.7	201.7	0.0104	-0.69
20180219	28.6	28.725	43.1	11.9	0.238	0.7380	54.0	0.0568	nan	150.8	0.1010	-4.95
20180219	28.725	28.817	87.5	8.3	0.233	0.4196	68.9	0.0320	nan	nan	0.0444	-4.03
20180219	28.817	28.917	132.0	7.1	0.172	0.1080	58.0	0.0099	nan	132.0	0.0127	-1.20
20180219	29.083	29.333	208.9	7.1	0.256	0.1073	54.6	0.0092	221.2	nan	0.0055	-0.81