Article

Fine particle emissions from sauna stoves: Effects of combustion appliance and fuel, and implications for the Finnish emission inventory

Supplementary material

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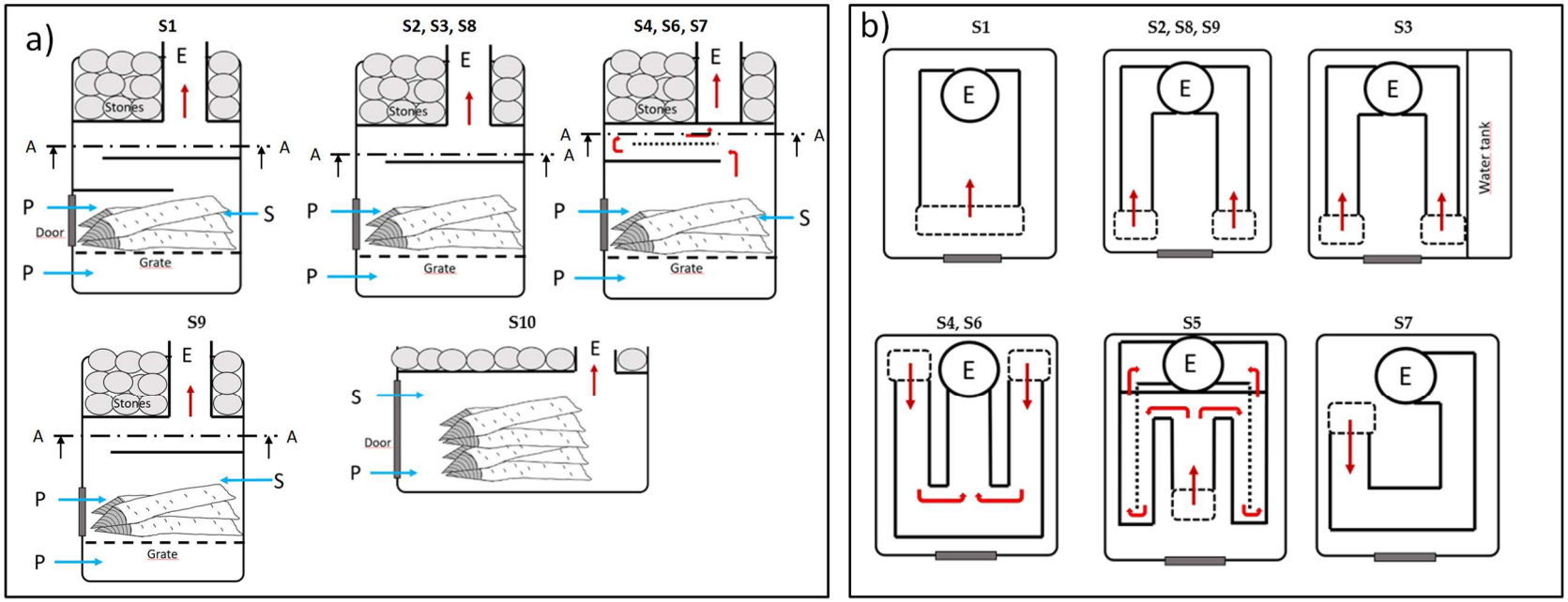


Figure S1. Schematic pictures of sauna stove structures from a) the right side of stove. b) the top view of cross-section A-A. P = primary air. S = secondary air. E = exhaust to stack. Panel b) describes the top most level of flue gas channels, additional lower levels are shown with dotted line. Red arrows describes the flue gas flows.

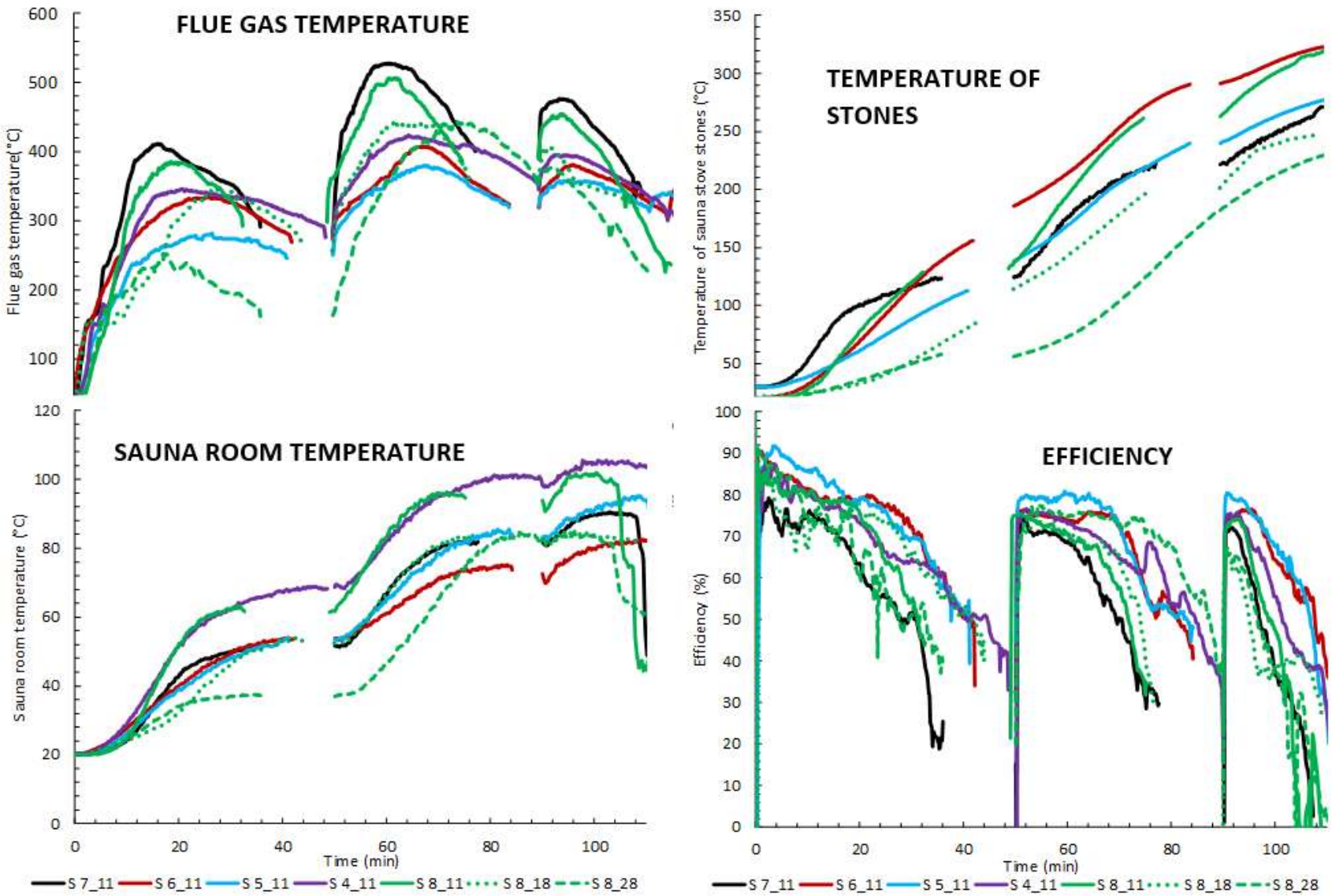


Figure S2. Real time temperature curves of flue gas, sauna room and stones of stove, and efficiency curves from selected sauna stove experiments. The second and third batch starting times are matched for each stove for better comparison of the curves.

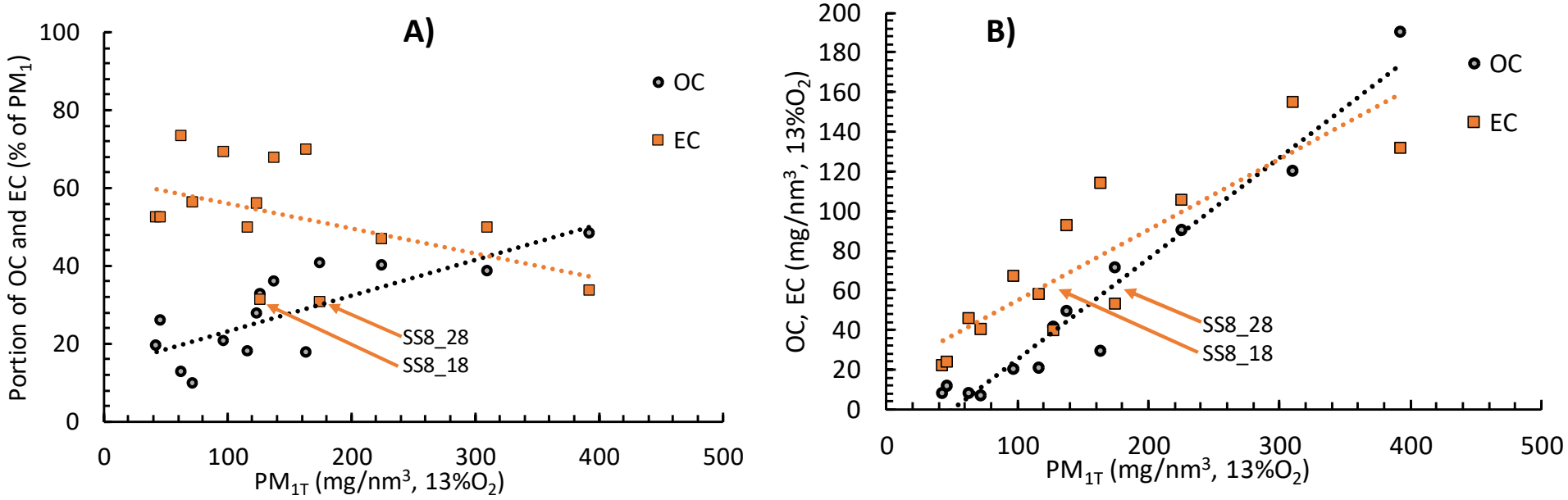


Figure S3. Portion of OC and EC of PM_1 (A) and OC and EC concentrations as a function of PM_1 (B).

Table S1. Concentrations of single PAH compounds (µg/nm^3 normalized to 20 °C, 1 atm and 13% O_2).

Test code (Stove _moisture%)	Acy [µg/nm^3]	Ace [µg/nm^3]	Fle [µg/nm^3]	Phe [µg/nm^3]	Ant [µg/nm^3]	1MPhe [µg/nm^3]	Fla [µg/nm^3]	Pyr [µg/nm^3]	BcP [µg/nm^3]	BaA [µg/nm^3]	CcdP [µg/nm^3]	Tri [µg/nm^3]	Chr [µg/nm^3]	5MChr [µg/nm^3]
S1_11	-	-	-	5,0 ± 4,3	1,3 ± 1,3	0,9 ± 0,5	69 ± 20	93 ± 26	10 ± 5	27 ± 18	7,6 ± 4,8	5,5 ± 4,2	28 ± 17	0,2 ± 0,2
S1_18	-	-	0,4 ± 0,1	1,3 ± 0,6	0,7 ± 0,5	0,2 ± 0,1	3,2 ± 3,3	4,1 ± 3,7	1,0 ± 0,2	2,7 ± 1,2	1,7 ± 1,1	0,8 ± 0,3	3,9 ± 0,3	-
S2_17	1,7 ± 0,9	0,3 ± 0,1	3,6 ± 2,0	664 ± 439	225 ± 183	126 ± 77	978 ± 412	478 ± 424	202 ± 91	632 ± 303	551 ± 369	74 ± 38	511 ± 185	5,5 ± 2,0
S3_17	0,7 ± 0,1	0,6 ± 0,2	1,0 ± 0,7	20 ± 28	5,9 ± 4,7	5,8 ± 7,4	250 ± 271	474 ± 207	288 ± 394	170 ± 50	199 ± 178	53 ± 42	120 ± 75	173 ± 169
S4_11	1,0 ± 0,0	0,4 -	1,1 ± 0,0	7,6 ± 2,2	2,0 ± 1,4	1,0 ± 0,4	91 ± 65	113 ± 83	39 ± 28	154 ± 104	143 ± 180	26 ± 20	130 ± 75	-
S5_11	0,6 ± 0,5	-	0,7 ± 0,4	3,4 ± 3,2	1,3 ± 0,9	1,3 ± 1,7	170 ± 238	202 ± 284	71 ± 89	264 ± 350	158 ± 242	32 ± 35	213 ± 260	3,0 ± 2,2
S6_11	2,5 ± 0,4	-	2,3 ±	183 ± 170	62 ± 57	88 ± 54	1850 ± 491	1299 ± 1484	373 ± 40	1257 ± 84	943 ± 34	203 ± 59	848 ± 14	9,1 ± 0,2
S7_11	-	-	-	6,5 ± 1,7	3,9 ± 1,8	2,1	127 ± 161	167 ± 210	39 ± 35	122 ± 143	57 ± 67	37 ± 44	117 ± 90	1,3
S8_11	2,6 ± 2,2	-	1,0	51 ± 49	17 ± 13	51 ± 18	1499 ± 209	1593 ± 213	257 ± 13	894 ± 52	868 ± 140	178 ± 26	639 ± 54	6,5 ± 1,6
S8_18	-	-	-	5,6 ± 1,3	10 ± 3,6	-	97 ± 26	137 ± 31	62 ± 11	198 ± 22	90 ± 49	32 ± 11	207 ± 43	-
S8_28	2,9	-	-	19 ± 26	6,8 ± 5,7	4,7 ± 5,5	216 ± 293	258 ± 327	67 ± 37	198 ± 122	83 ± 86	48 ± 28	222 ± 84	-
S9_11	-	-	-	11 ± 13	4,2 ± 3,8	-	20 ± 12	23 ± 11	5,6 ± 0,6	13 ± 0,5	3,4 ± ###	3,6 ± 1,0	17 ± 1,8	-
S10_11	-	-	-	1,6	1,9	-	15 ± 0,6	21 ± 1,1	5,5 ± 2,3	17 ± 6,3	4,6 ± 2,3	3,5 ± 2,2	23 ± 11	-
Average	**1,7 ± 0,7**	**0,4 ± 0,2**	**1,4 ± 0,7**	**75 ± 61**	**26 ± 23**	**28 ± 18**	**414 ± 169**	**374 ± 254**	**109 ± 57**	**304 ± 97**	**239 ± 104**	**54 ± 24**	**237 ± 70**	**28 ± 29**

Test code (Stove _moisture%)	BbF [µg/nm^3]	BkF [µg/nm^3]	BjF [µg/nm^3]	BeP [µg/nm^3]	BaP [µg/nm^3]	Per [µg/nm^3]	I123cdP [µg/nm^3]	DahA [µg/nm^3]	BghiP [µg/nm^3]	Antha [µg/nm^3]	DalP [µg/nm^3]	DaeP [µg/nm^3]	Cor [µg/nm^3]	DaiP [µg/nm^3]	DahP [µg/nm^3]
S1_11	20 ± 18	9,5 ± 8,5	14 ± 12	15 ± 12	17 ± 17	2,6 ± 2,4	14 ± 14	3,8	16 ± 14	2,7 ± 2,7	1,7	2,7	3,7 ± 1,7	-	-
S1_18	3,2 ± 0,3	1,9 ± 1,5	2,2 ± 0,4	2,4 ± 0,4	1,9 ± 1,4	0,3 ± 0,2	1,7 ± 0,5	-	2,3 ± 0,8	0,6	2,8	-	1,0 ± 0,8	-	-
S2_17	477 ± 176	339 ± 268	391 ± 180	349 ± 153	691 ± 346	107 ± 60	401 ± 188	64 ± 35	478 ± 224	236 ± 161	3,4 ± 3,2	45 ± 21	167 ± 90	4,7 ± 2,9	20 ± 19
S3_17	120 ± 105	211 ± 103	198 ± 118	172 ± 85	205 ± 65	148 ± 208	109 ± 41	108 ± 153	118 ± 74	140 ± 190	8 ± 13	10 ± 7,0	45 ± 19	217	-
S4_11	143 ± 86	62 ± 14	117 ± 72	104 ± 63	198 ± 150	31 ± 23	116 ± 78	7,8 ± 2,8	99 ± 33	71 ± 69	-	7,7	47 ± 29	-	-
S5_11	219 ± 261	46 ± 56	178 ± 222	157 ± 190	268 ± 392	43 ± 61	170 ± 215	27 ± 35	188 ± 240	60 ± 99	14	20 ± 26	112 ± 139	9,5 ± 11,5	10
S6_11	865 ± 50	838 ± 457	773 ± 28	682 ± 12	1401 ± 28	214 ± 2,4	749 ± 30	127 ± 15	485 ± 489	370 ± 38	12 ± 2,9	79 ± 17	126 ± 32	32 ± 6,4	19
S7_11	136 ± 111	70 ± 63	101 ± 93	103 ± 87	135 ± 202	56	117 ± 127	36	150 ± 164	76	3,2	40	108 ± 100	8,6	-
S8_11	684 ± 59	698 ± 53	560 ± 47	516 ± 52	1040 ± 110	157 ± 18	614 ± 66	91 ± 7,3	751 ± 95	335 ± 50	6,9 ± 3,5	64 ± 6,4	212 ± 72	5,4	16
S8_18	216 ± 71	103 ± 31	153 ± 50	166 ± 54	158 ± 49	28	151 ± 64	-	201 ± 79		-	-	69 ± 35	-	-
S8_28	219 ± 68	107 ± 42	161 ± 60	158 ± 55	164 ± 174	26 ± 25	142 ± 66	19 ± 10	153 ± 102	64	14 ± 7,5	13	62 ± 31	-	-
S9_11	11 ± 0,0	5,2 ± 0,1	7,5 ± 1,1	9,0 ± 0,1	4,5 ± 1,0	0,9 ± 0,1	5,6 ± 0,0	0,6 ± 0,0	8 ± 0,1		-	-	3 ± 1	-	-
S10_11	22 ± 12	12 ± 6,2	17 ± 9,5	18 ± 9,4	17 ± 9,6	3,0	22 ± 11	3,4	27 ± 13	2,6	1,7	1,9	13	-	-
Average	**241 ± 78**	**192 ± 85**	**206 ± 69**	**188 ± 59**	**331 ± 119**	**63 ± 40**	**201 ± 69**	**44 ± 32**	**206 ± 118**	**124 ± 87**	**6,9 ± 5,9**	**28 ± 15**	**74 ± 46**	**46 ± 7**	**16 ± 19**

"-" = below detection limit. If only one value given, only one value (of three repetition) has been above the detection limit.

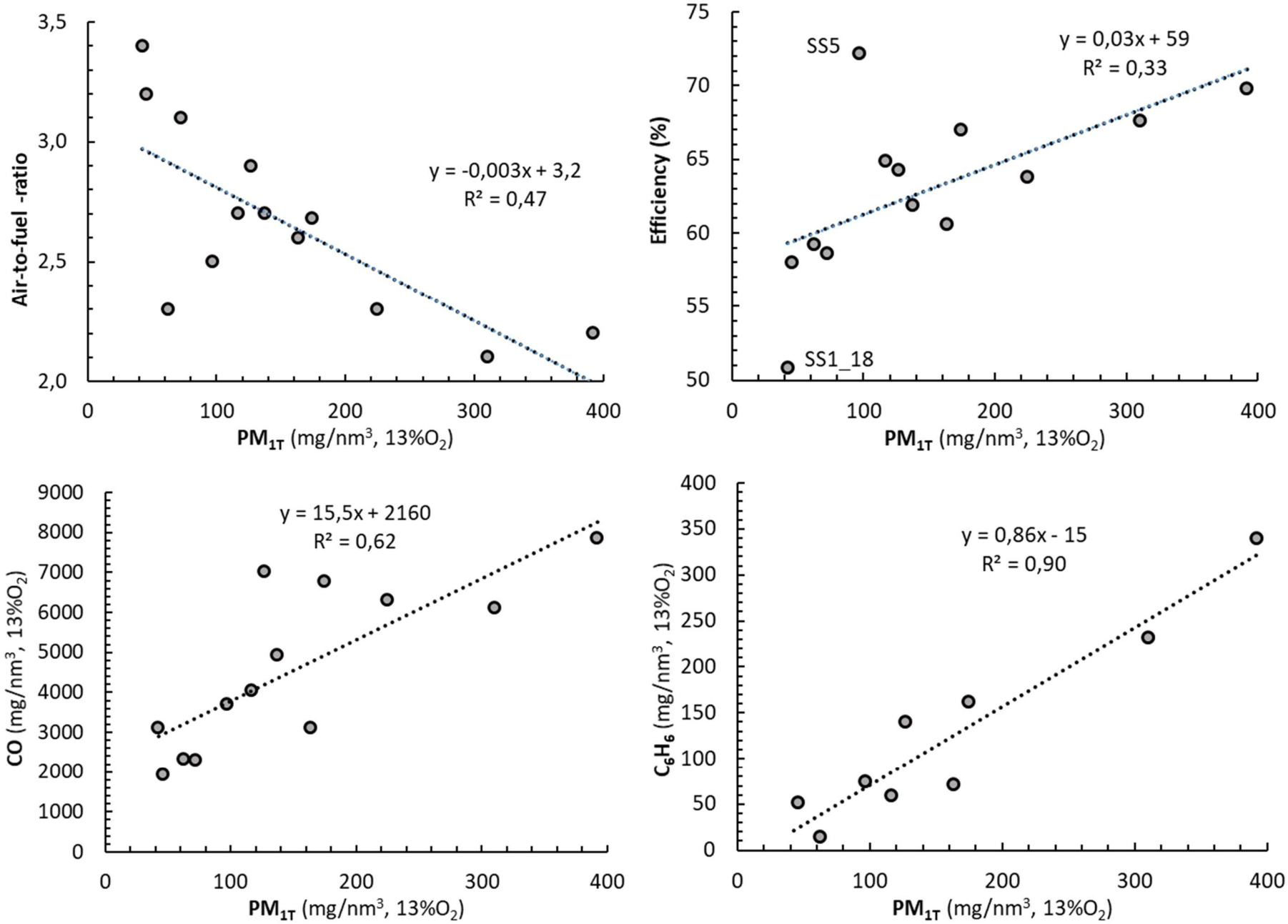
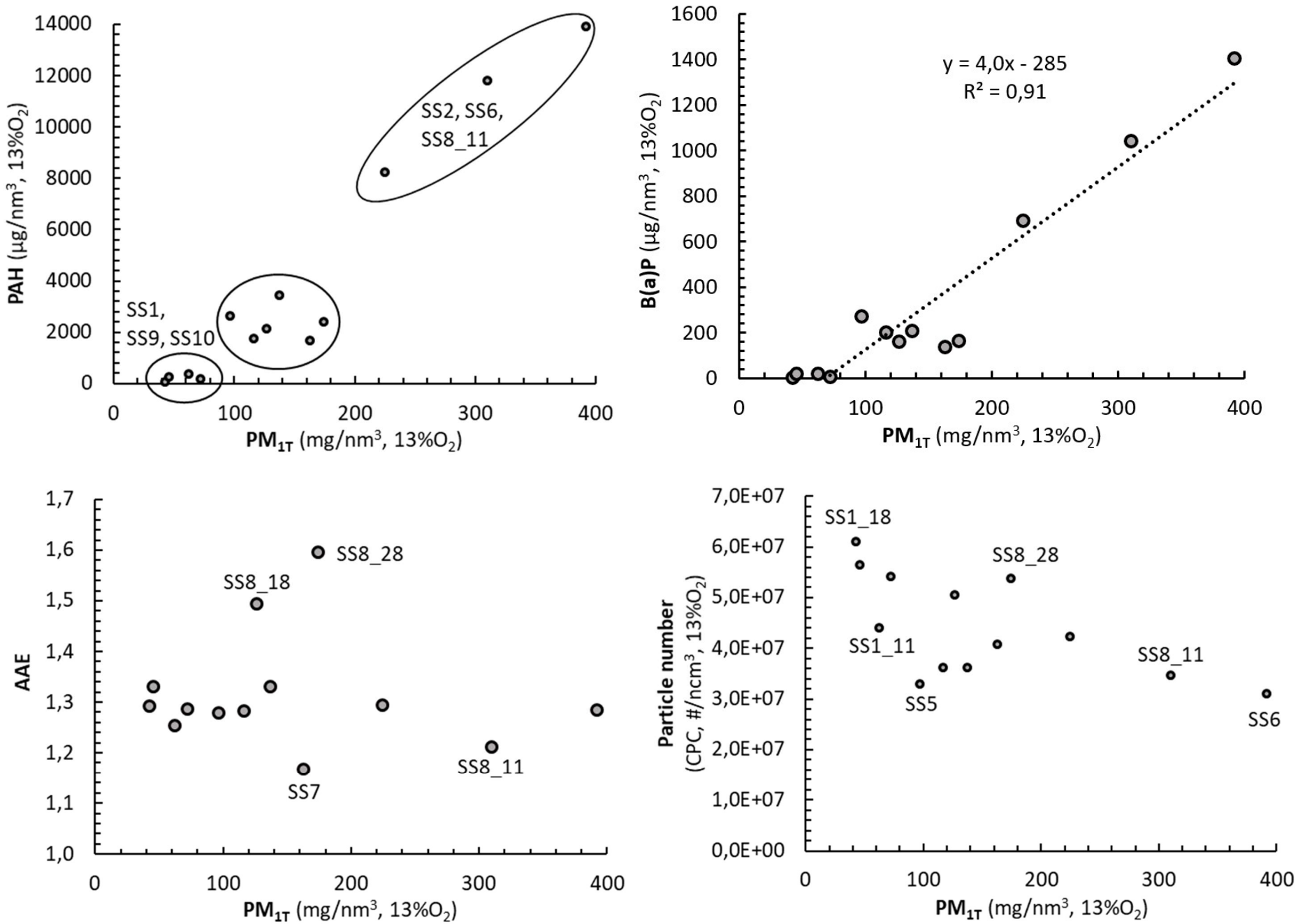


Figure S4 continues



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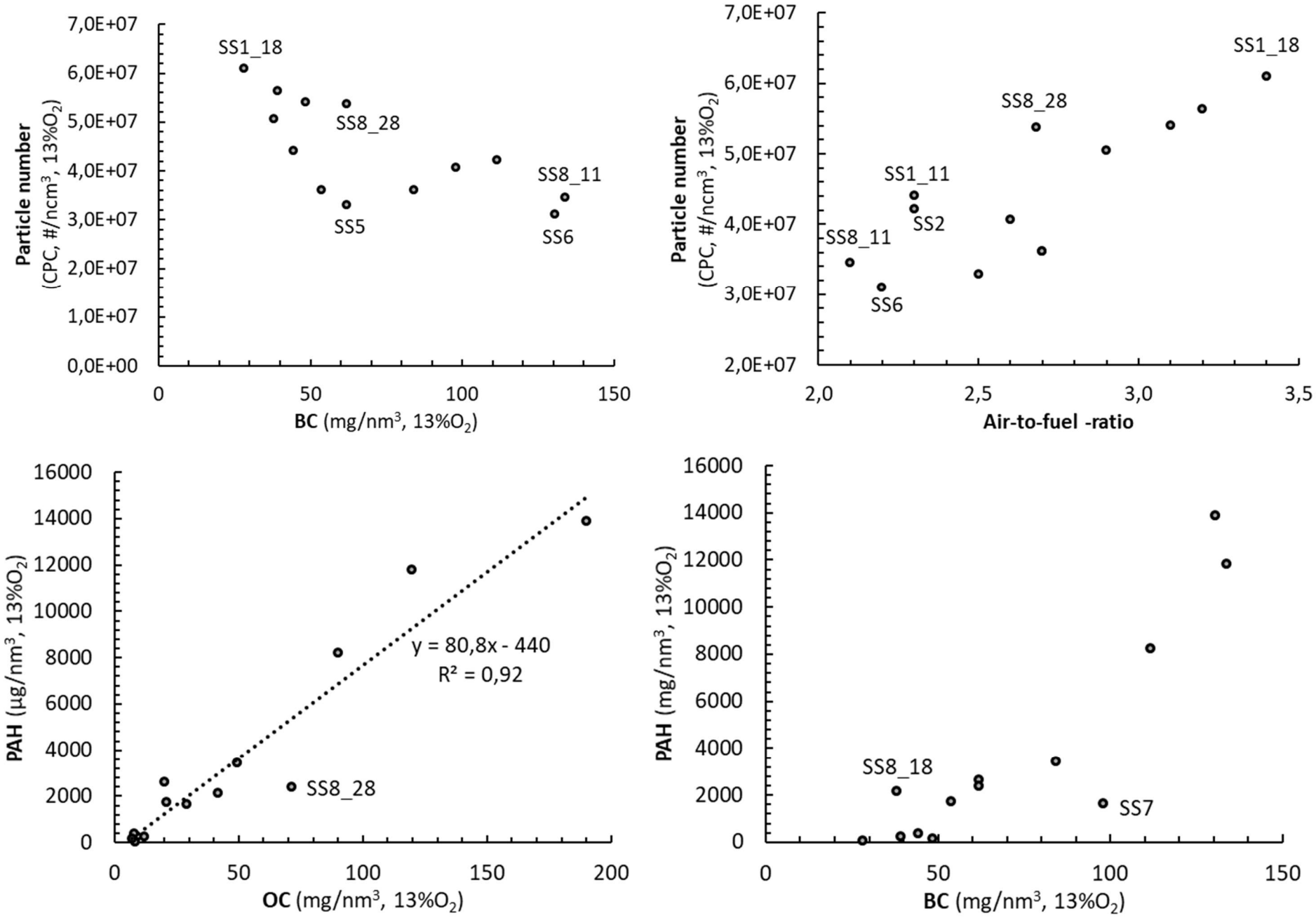

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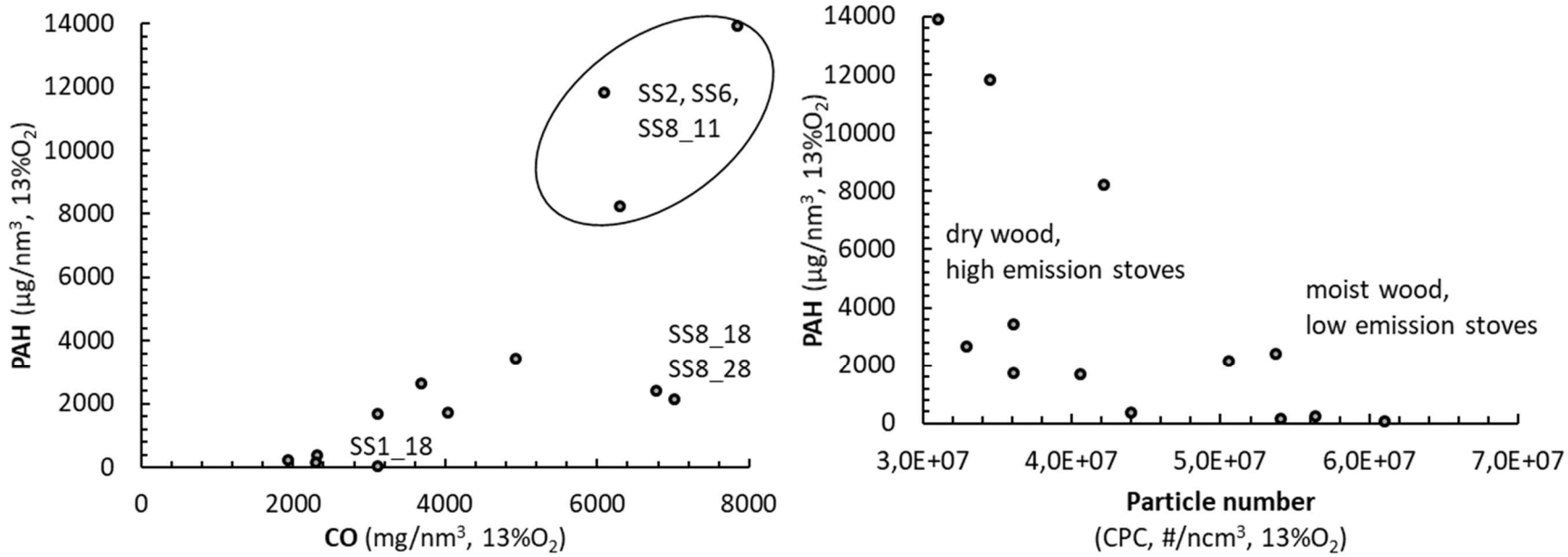


Figure S4. Correlations between different measured parameters (average values of each tests) in sauna stove experiments.

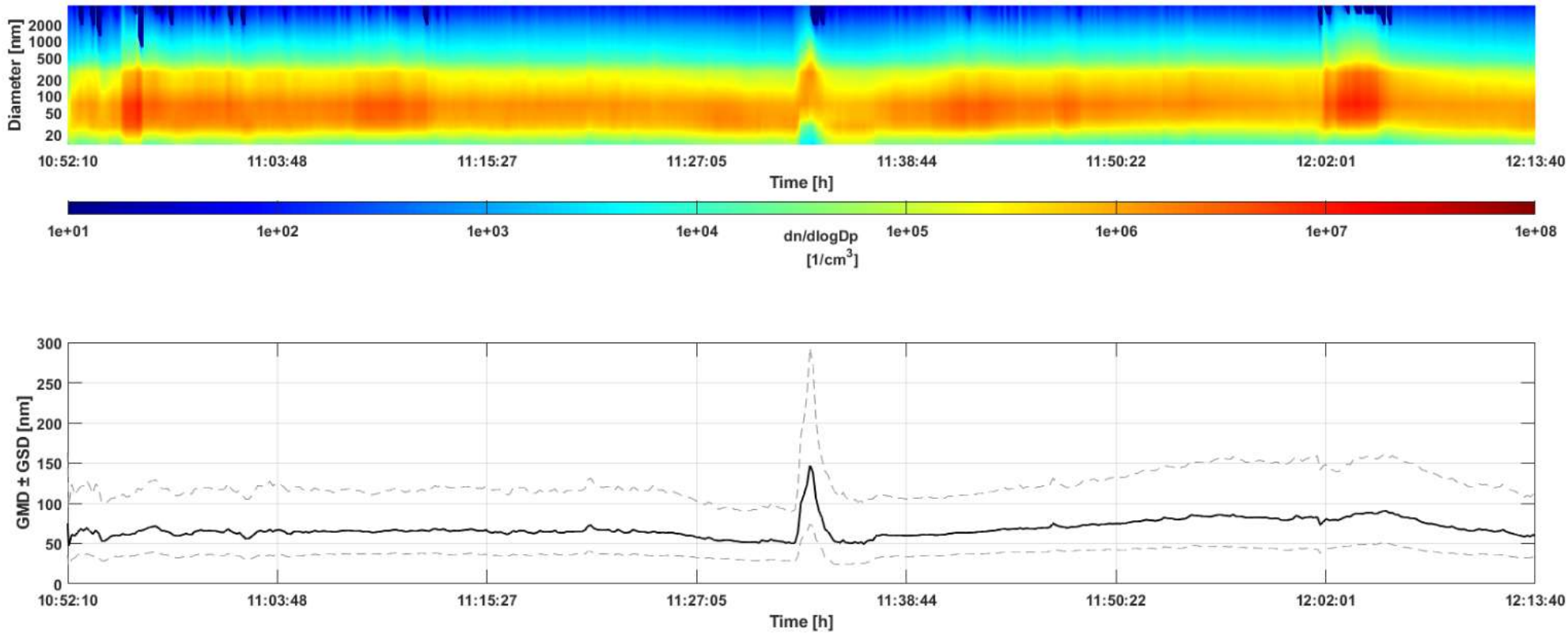
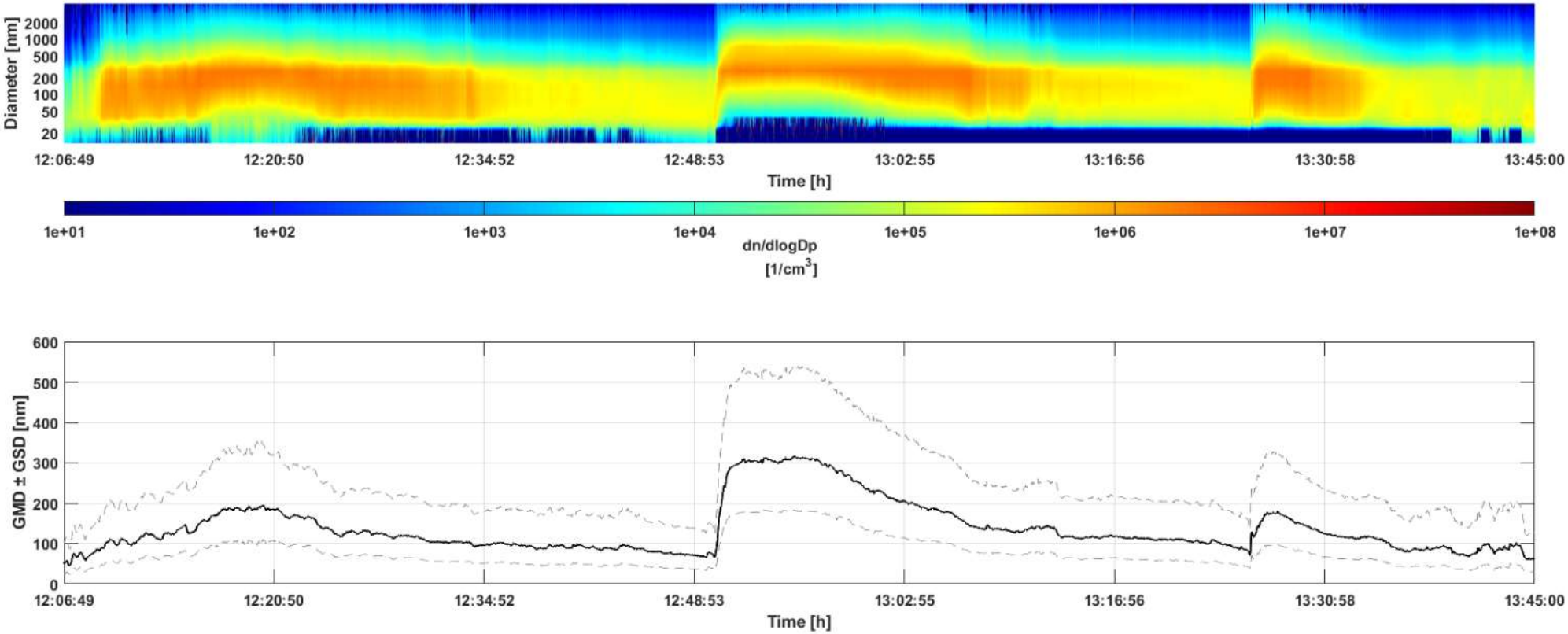


Figure S5 continues



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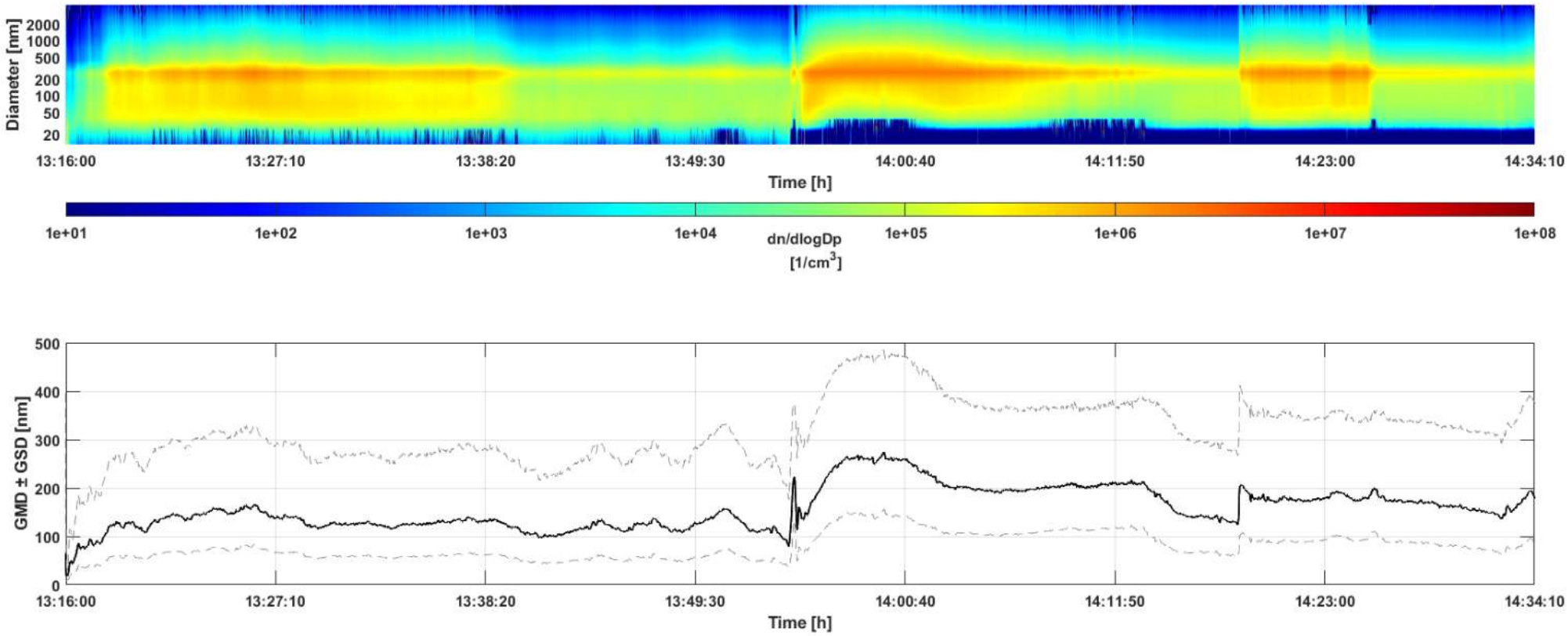

Figure S5. Number size distributions and particle geometric mean diameters (±geometric standard deviation) from the S1 (top), S6 (middle) and S7 (bottom figure).

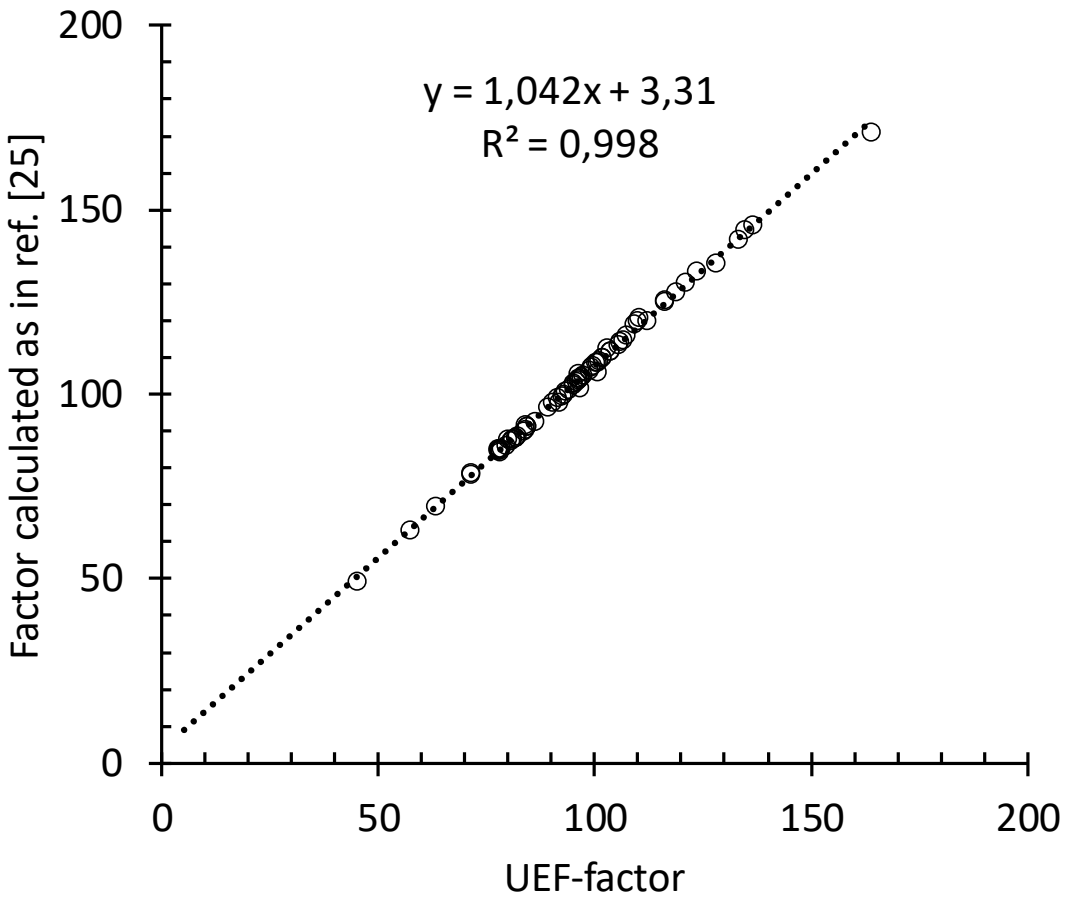

Figure S6. Correlations between UEF factor used in this study and calculation factor, which is used in previous studies (calculated as in Tissari [25]). Data points are average values of factors. In addition to this study, data include also other experiments performed at SIMO-facility.