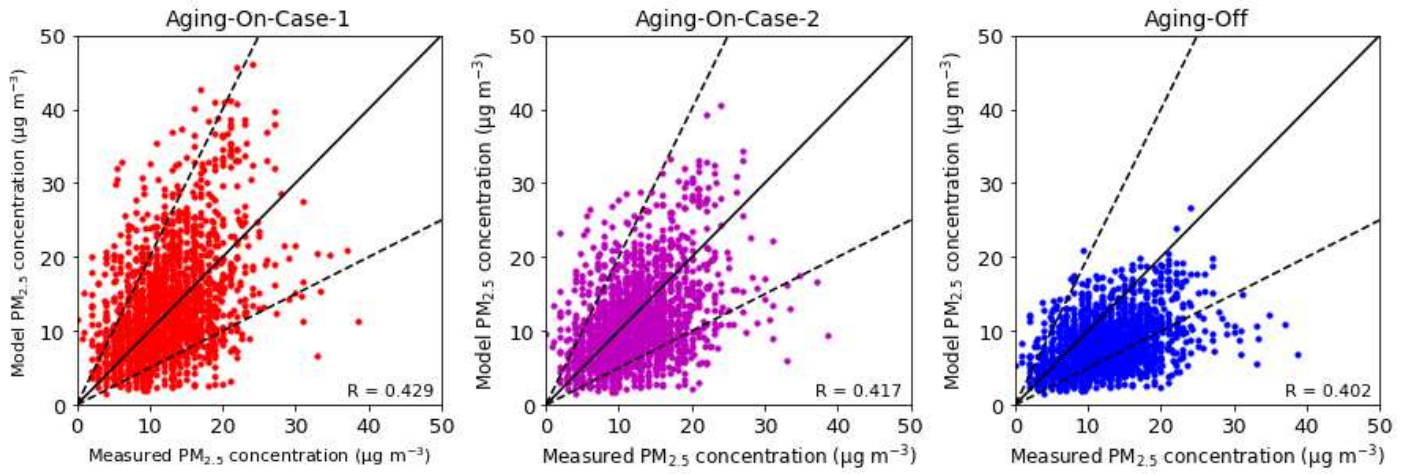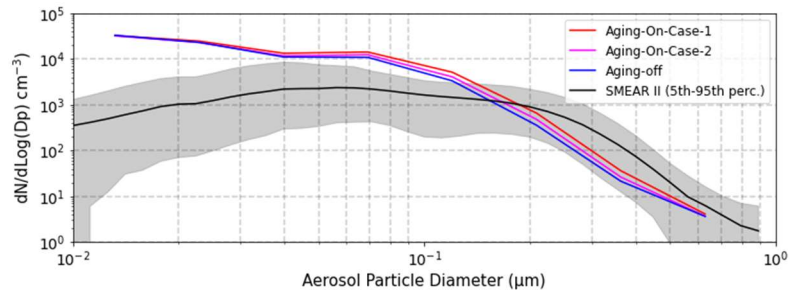**Supplement**

Figure S1: Daily average model (y-axis) and measured (x-axis) air concentrations of PM$_{2.5}$ for the Aging-On-Case-1 (left), the Aging-On-Case-2 (center) and the Aging-Off (right) BSOA schemes at the Air Quality e-Reporting (AQ e-Reporting) station (Table S1). Solid line indicates the 1:1 line. The dashed lines delimits 1:2 and 2:1 lines. Units are in μg m^{-3}.

Figure S2: Measured (black) and modelled (various colors) median size distribution comparison at the SMEAR-II site stations. The shaded areas indicated the 5th and 95th interquartile range.

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Table S1: Air Quality e-Reporting (AQ e-Reporting) stations used for the additional PM$_{2.5}$ comparison on the coarser resolution grid (30km).

Site	Latitude (deg)	Longitude (deg)	Elevation (m a.s.l.)	Country
ES0006R	39.87	4.31	78	Spain
ES0008R	43.43	-4.85	134	Spain
ES0010R	42.31	3.31	76	Spain
ES0901A	43.24	-8.31	160	Spain
ES1648A	36.23	-5.66	189	Spain
ES1688A	39.89	-0.06	37	Spain
ES1878A	37.01	-6.57	22	Spain
ES1961A	43.66	-7.37	173	Spain
IT0952A	41.88	12.26	66	Italy
IT1179A	44.83	11.96	-2	Italy
IT1451A	44.66	11.63	11	Italy
IT1464A	45.49	9.55	115	Italy
IT1553A	43.91	11.00	48	Italy
IT1596A	45.83	12.51	14	Italy
IT1665A	40.45	18.11	10	Italy
IT1740A	41.06	15.72	187	Italy
IT1796A	43.33	13.67	110	Italy
IT1865A	44.99	11.07	16	Italy
IT1914A	44.87	10.66	22	Italy
IT1915A	43.93	12.62	165	Italy
IT1919A	44.74	11.94	0	Italy
IT1921A	44.92	11.17	4	Italy
IT1924A	44.98	10.01	48	Italy
IT1927A	44.52	11.98	1	Italy
IT2131A	45.73	13.48	0	Italy
IT2142A	41.54	15.44	150	Italy
IT2249A	42.15	11.74	11	Italy

Table S2: Model evaluation for PM$_{2.5}$ as predicted by the three BSOA schemes at the Air Quality e-Reporting (AQ e-Reporting) stations (from 15 June until 30 August of 2019). Statistics is performed at 1-day time resolution.

Variable	Mean	MB	MGE	RMSE	MFB	MFE
Aging-On-Case-1 (μg m^{-3})	13.4	1.1	5.3	7.0	0.1	0.4
Aging-On-Case-2 (μg m^{-3})	11.3	-0.9	4.7	6.1	-0.1	0.4
Aging-Off (μg m^{-3})	8.1	-4.1	5.1	6.5	-0.4	0.5
Obs (μg m^{-3})	12.3	-	-	-	-	-