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Supporting Information for

Seasonality of Global and Arctic Black Carbon Processes in the AMAP Models

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Text S1. Impact of atmospheric processes on BC concentrations and burdens in CanAM and CESM

Similar to CNTRL, the largest transport to the Arctic region occurs in summer in most of the sensitivity experiments. STF_WD produces the largest transport in spring (Fig. S4). The annual mean BC transport to the Arctic region is 0.353, 0.256, 0.201, 0.187, 0.140 kilotons per day in STF_WD, AGE, CONV_WD, CONV_TR and DRYD respectively (Table S3). These results indicate that transport to the Arctic increases with decreasing efficiency of wet deposition of BC.

All of the sensitivity experiments produce higher BC burdens than CNTRL. In CanAM STF_WD and AGE produce seasonal cycles with concentration maxima in summer instead of winter or spring (Fig. S3 and S4). CONV_WD, DRYD and CONV_TR essentially reproduce the seasonality in CNTRL, with higher burdens overall. STF_WD and AGE produce substantial increases in dry deposition (Fig. S5) whereas CONV_WD produces smaller changes. CESM also produces relatively high burdens in each sensitivity experiment with largest burdens in AGE. It also yields the highest atmospheric residence times since BC scavenging is controlled by dry deposition while wet deposition is very small (Fig. S6; Table S4).

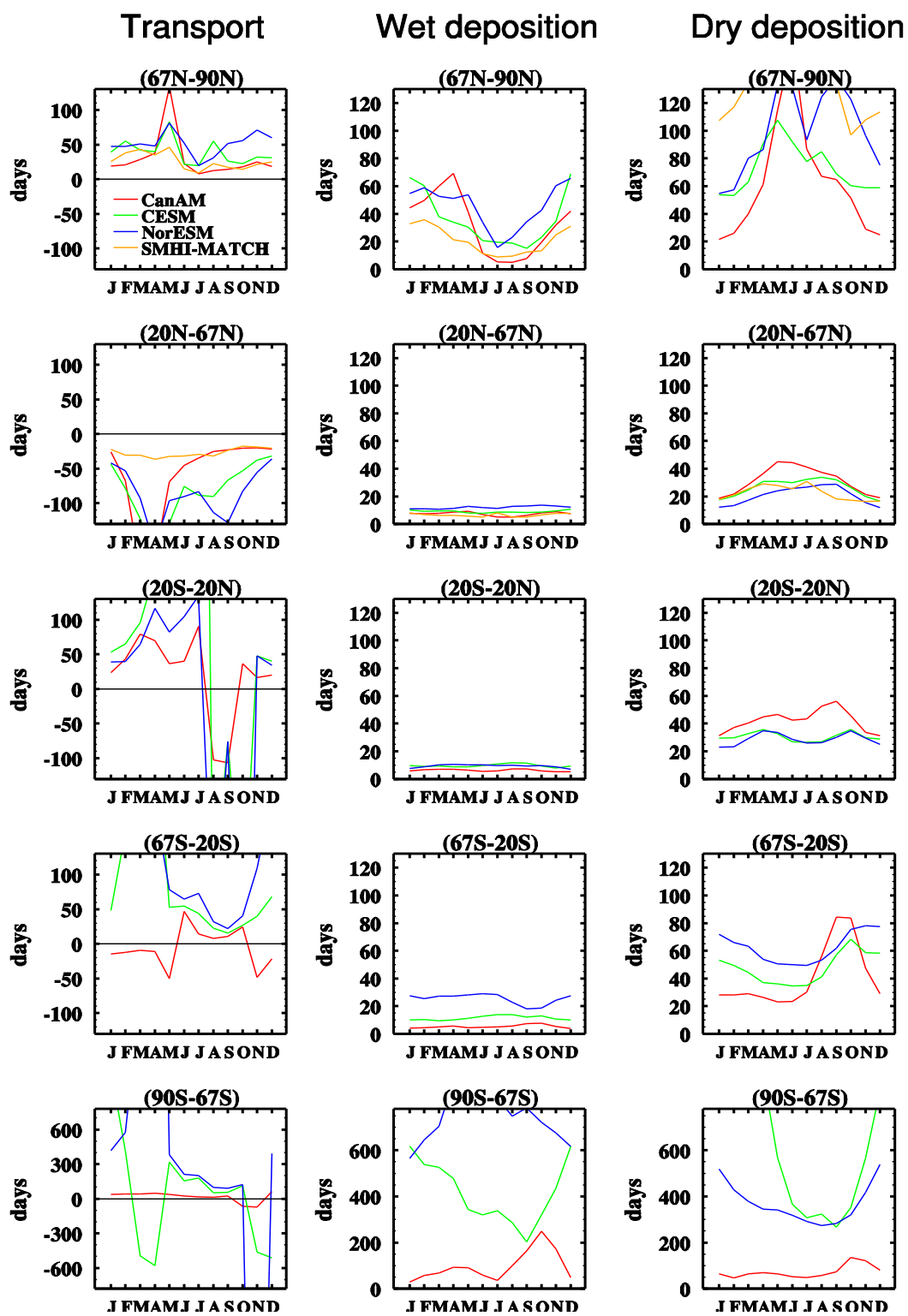


Fig. S1. Process timescales for transport, wet and dry deposition. For each region, these are calculated as the ratio of the BC burden over BC fluxes and are expressed in units of time. Note different y-axis scaling for the Antarctic region (bottom panels).

BC Transport ($\times 10^{-12}$ kg/m²/s)

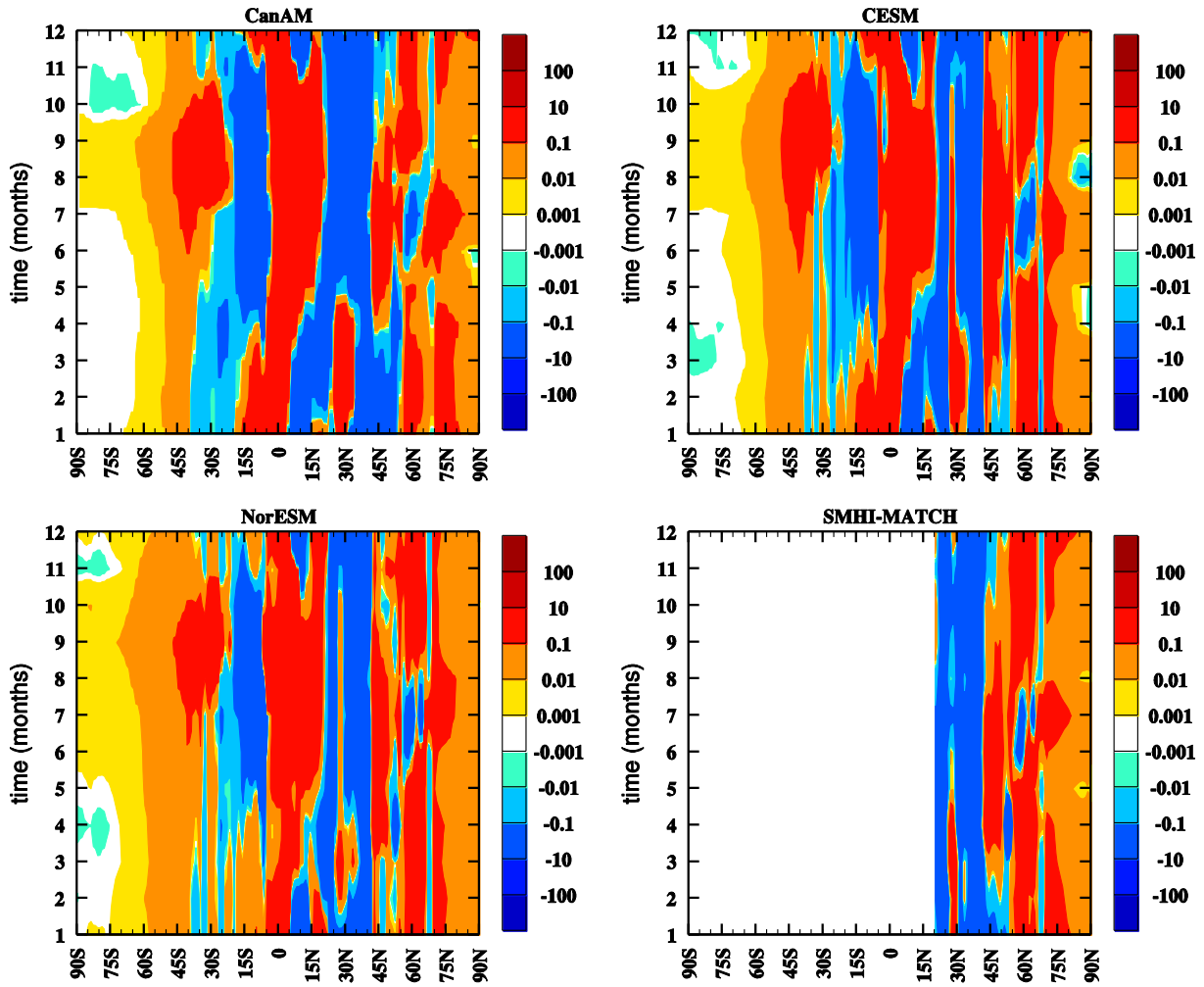


Fig. S2. Time-latitude plot of the zonal mean BC transport in different models.

Relative Contribution of Wet and Dry Deposition

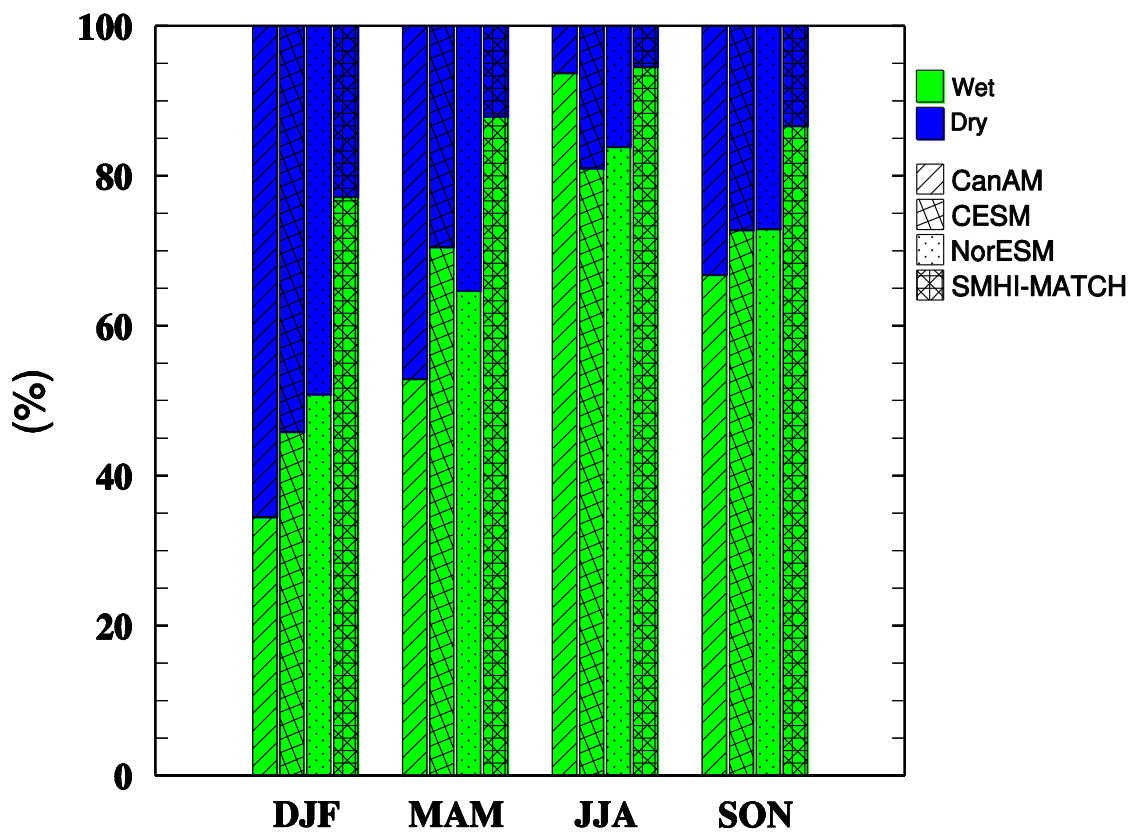


Fig. S3. Seasonal mean contribution of wet and dry deposition (%) in total deposition rates.

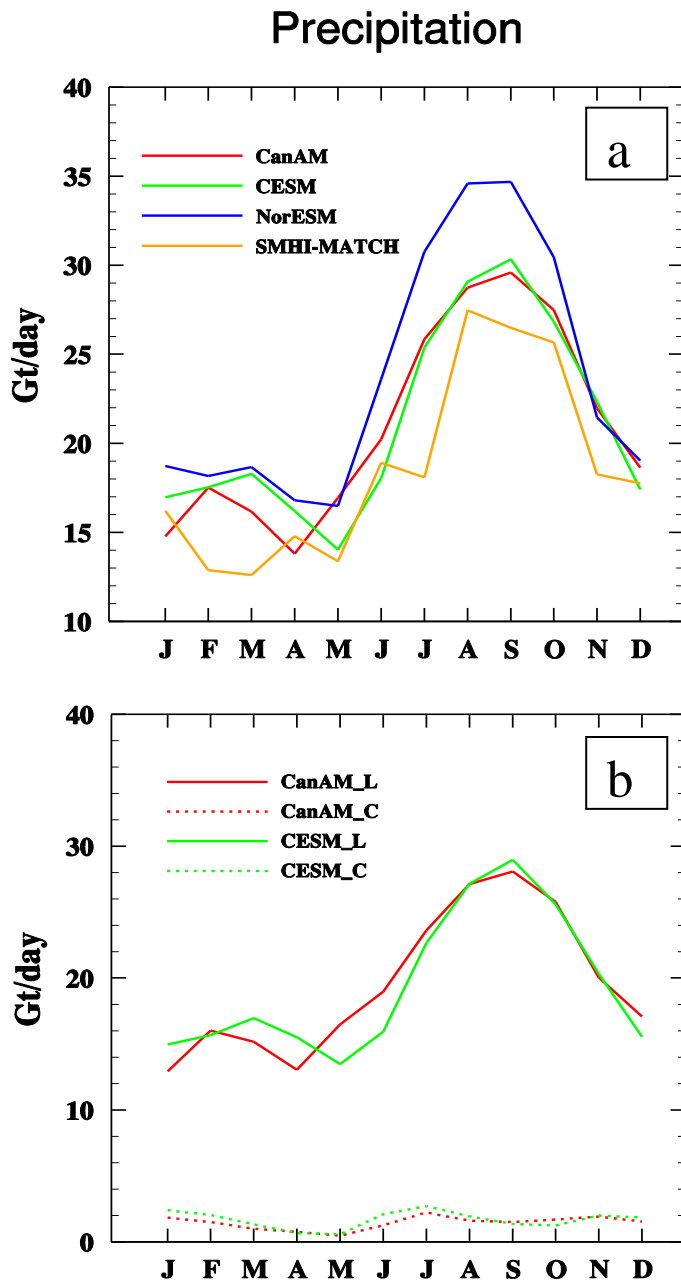


Fig. S4. (a) Total precipitation amounts in the Arctic. (b) Large scale (full lines) and convective (dashed lines) precipitation in CanAM and CESM (Note for (b) data was not available for SMHI-MATCH and NorESM).

CanAM

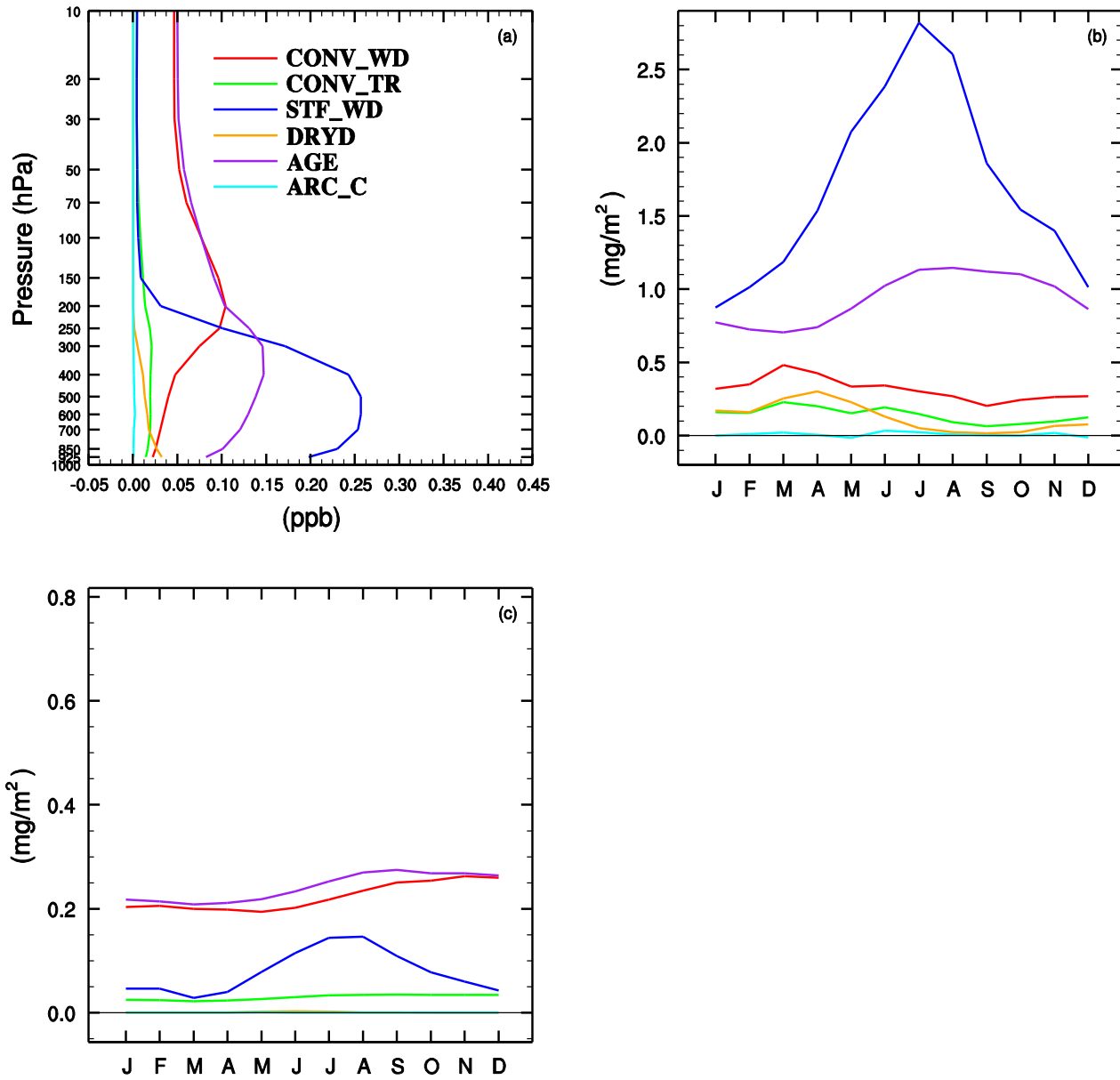


Fig. S5. Same as Fig. 5 (a-c) but for an addition of a sensitivity experiment (ARC_C). In ARC_C convective wet deposition in the Arctic (north of 60°N) was disabled to understand the role of local convective wet deposition processes on BC vertical concentration profiles.

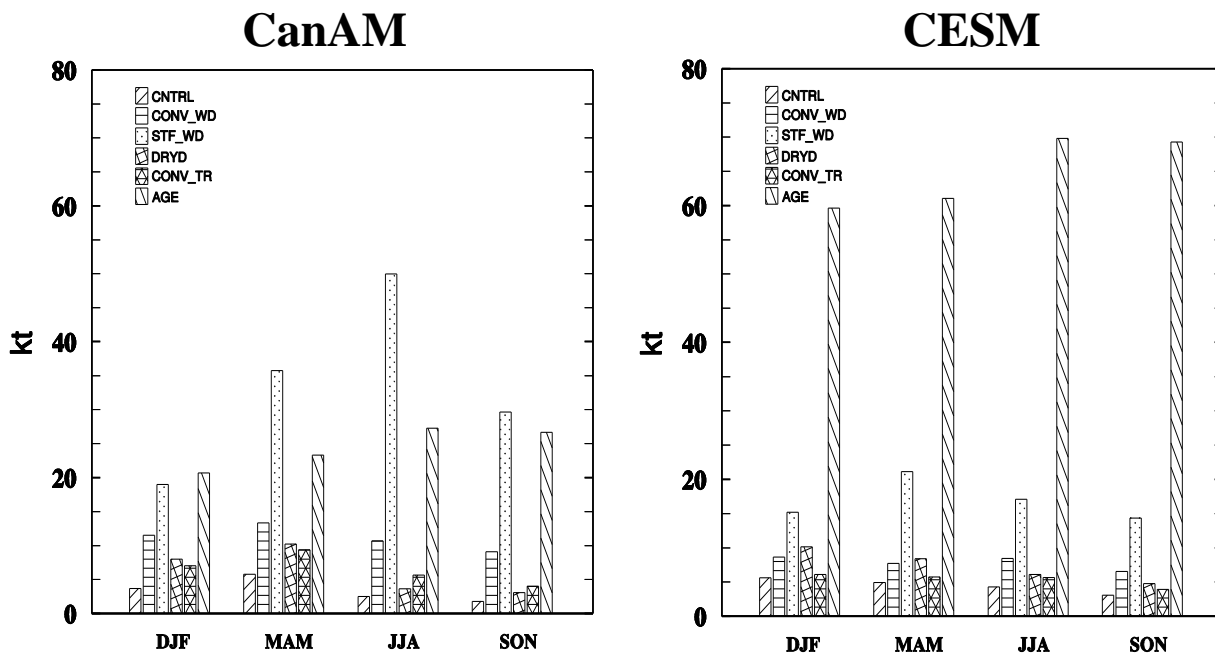


Fig. S6. BC burden (kilotonnes) comparison between control and sensitivity experiments in the Arctic.

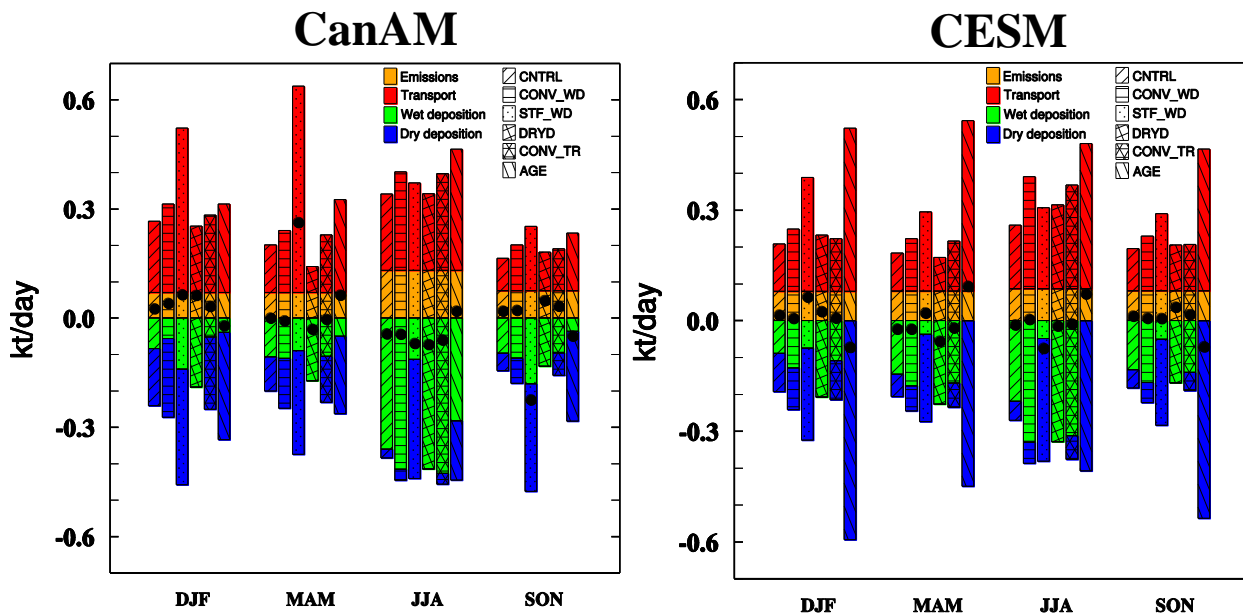


Fig. S7. Comparison of BC processes (kilotonnes/day) between CNTRL and the sensitivity experiments in the Arctic. Black filled circles represent net source (transport+emissions minus deposition). Note that black dots are NOT multiplied by 5 here.

Tables S1-S4:

Table S1. Annual mean BC emission (kilotnnes/day), transport (kilotnnes/day), wet and dry deposition (kilotnnes/day) and burden (kilotnnes) in the models. Multi-Model Mean (MMM) for each region are given at the bottom. Multi-model mean values (MMM) are provided at the bottom.

		(67°N- 90°N)	(20°N- 67°N)	(20°S- 20°N)	(67°S- 20°S)	(90°S- 67°S)	(90°S- 90°N)
CanAM	Emission	0.087	11.631	8.726	1.095	0.000	21.540
	Transport	0.155	-1.595	1.043	0.395	0.002	-
	Wet dep.	-0.161	-7.956	-8.517	-1.328	-0.001	-17.962
	Dry dep.	-0.08	-2.083	-1.263	-0.164	-0.001	-3.590
	Burden	3.442	58.577	52.505	7.905	0.071	122.500
CESM	Emission	0.082	11.091	8.318	0.962	0.000	20.453
	Transport	0.133	-1.013	0.375	0.434	0.002	-
	Wet dep.	-0.146	-7.357	-6.562	-1.126	-0.001	-15.192
	Dry dep.	-0.066	-2.727	-2.152	-0.272	-0.001	-5.216
	Burden	4.477	66.517	64.194	13.249	0.504	148.942
NorESM	Emission	0.094	11.288	8.498	1.009	0.000	20.889
	Transport	0.138	-1.032	0.591	0.450	0.006	-
	Wet dep.	-0.164	-6.273	-6.837	-1.062	-0.002	-14.338
	Dry dep.	-0.063	-3.982	-2.256	-0.399	-0.004	-6.709
	Burden	6.188	75.109	62.975	24.722	1.474	170.468
SMHI- MATCH	Emission	0.050	11.364	-	-	-	-
	Transport	0.142	-1.843	-	-	-	-
	Wet dep.	-0.166	-7.297	-	-	-	-
	Dry dep.	-0.025	-2.221	-	-	-	-
	Burden	3.304	47.398	-	-	-	-
MMM	Emission	0.078	11.344	8.514	1.022	0	20.961
	Transport	0.142	-1.371	0.67	0.426	0.003	-
	Wet dep.	-0.159	-7.221	-7.305	-1.172	-0.001	-15.831
	Dry dep.	-0.059	-2.753	-1.89	-0.278	-0.002	-5.172
	Burden	4.353	61.9	59.891	15.292	0.683	147.303

Table S2. Annual mean BC process time scales (days). For each region, these are calculated as the ratio of the BC burden over BC fluxes. Multi-model mean values (MMM) are provided at the bottom.

		(67°N- 90°N)	(20°N- 67°N)	(20°S- 20°N)	(67°S- 20°S)	(90°S- 67°S)	(90°S- 90°N)
CanAM	Transport	22.2	36.7	50.3	20	35.5	-
	Wet dep.	21.4	7.4	6.2	6	71	7
	Dry dep.	43.0	28.1	41.6	48.2	71	34.1
	Residence time	14.3	5.8	5.4	5.3	35.5	5.7
CESM	Transport	33.7	65.7	171.2	30.5	252	-
	Wet dep.	30.7	9	10	12	504	10
	Dry dep.	67.8	24.4	30	48.7	504	28.6
	Residence time	21.1	6.6	7.4	9.5	252	7.3
NorESM	Transport	44.8	72.9	106.6	54.9	245.7	-
	Wet dep.	37.7	12	9.2	23.3	737	11.9
	Dry dep.	98.5	18.9	27.9	62	368.5	25.4
	Residence time	27.3	7.3	6.9	16.9	245.7	8.1
SMHI- MATCH	Transport	23.3	25.7	-	-	-	-
	Wet dep.	19.9	6.5	-	-	-	-
	Dry dep.	132.2	21.3	-	-	-	-
	Residence time	17.3	5	-	-	-	-
MMM	Transport	30.7	-45.1	89.4	35.9	227.7	
	Wet dep.	27.4	8.6	8.2	13.0	683.0	9.3
	Dry dep.	73.8	22.5	31.7	55.0	341.5	28.5
	Residence time	20.0	6.2	6.5	10.5	227.7	7.0

Table S3. Annual mean BC transport (kilotnnes/day), wet and dry deposition (kilotonnes/day), burden (kilotonnes) and atmospheric residence time (days) in CanAM for the CNTRL and the sensitivity runs. The definition of residence time is same as in table S2. Emissions for each sensitivity simulation are same as in CNTRL.

		(67°N-90°N)	(90°S-90°N)
CNTRL	Emission	0.087	21.54
	Transport	0.155	-
	Wet dep.	-0.161	-17.962
	Dry dep.	-0.08	-3.59
	Burden	3.442	122.5
	Residence time	14.3	5.7
CONV_WD	Transport	0.201	-
	Wet dep.	-0.173	-17.169
	Dry dep.	-0.113	-4.393
	Burden	11.147	331.713
	Residence time	39	15.4
CONV_TR	Transport	0.187	-
	Wet dep.	-0.169	-17.323
	Dry dep.	-0.104	-4.231
	Burden	6.513	194.285
	Residence time	23.9	9
STF_WD	Transport	0.353	-
	Wet dep.	-0.129	-13.997
	Dry dep.	-0.306	-7.515
	Burden	33.595	515.257
	Residence time	77.2	24
DRYD	Transport	0.14	-
	Wet dep.	-0.225	-21.549
	Dry dep.	0.000	0.000
	Burden	6.226	152.009
	Residence time	27.7	7.1
AGE	Transport	0.256	-
	Wet dep.	-0.101	-13.604
	Dry dep.	-0.229	-7.913
	Burden	24.48	516.26
	Residence time	74.2	24

Table S4. Same as Table S3 but for CESM.

		(67°N-90°N)	(90°S-90°N)
CNTRL	Emission	0.082	20.453
	Transport	0.133	-
	Wet dep.	-0.146	-15.192
	Dry dep.	-0.066	-5.216
	Burden	4.477	148.942
	Residence time	21.1	7.3
CONV_WD	Transport	0.191	-
	Wet dep.	-0.199	-14.051
	Dry dep.	-0.073	-6.413
	Burden	7.846	329.612
	Residence time	28.8	16.1
CONV_TR	Transport	0.171	-
	Wet dep.	-0.182	-13.841
	Dry dep.	-0.071	-6.654
	Burden	5.344	246.375
	Residence time	21.1	12
STF_WD	Transport	0.236	-
	Wet dep.	-0.053	-12.291
	Dry dep.	-0.236	-8.071
	Burden	16.939	295.74
	Residence time	58.6	14.5
DRYD	Transport	0.150	-
	Wet dep.	-0.232	-20.401
	Dry dep.	0.000	0.000
	Burden	7.350	203.723
	Residence time	31.7	10
AGE	Transport	0.41922	-
	Wet dep.	0.000	-0.018
	Dry dep.	-0.498	-20.384
	Burden	64.950	1489.302
	Residence time	130.4	73