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Tagged tracer simulations of black carbon in the Arctic: transport, source contributions, and budget

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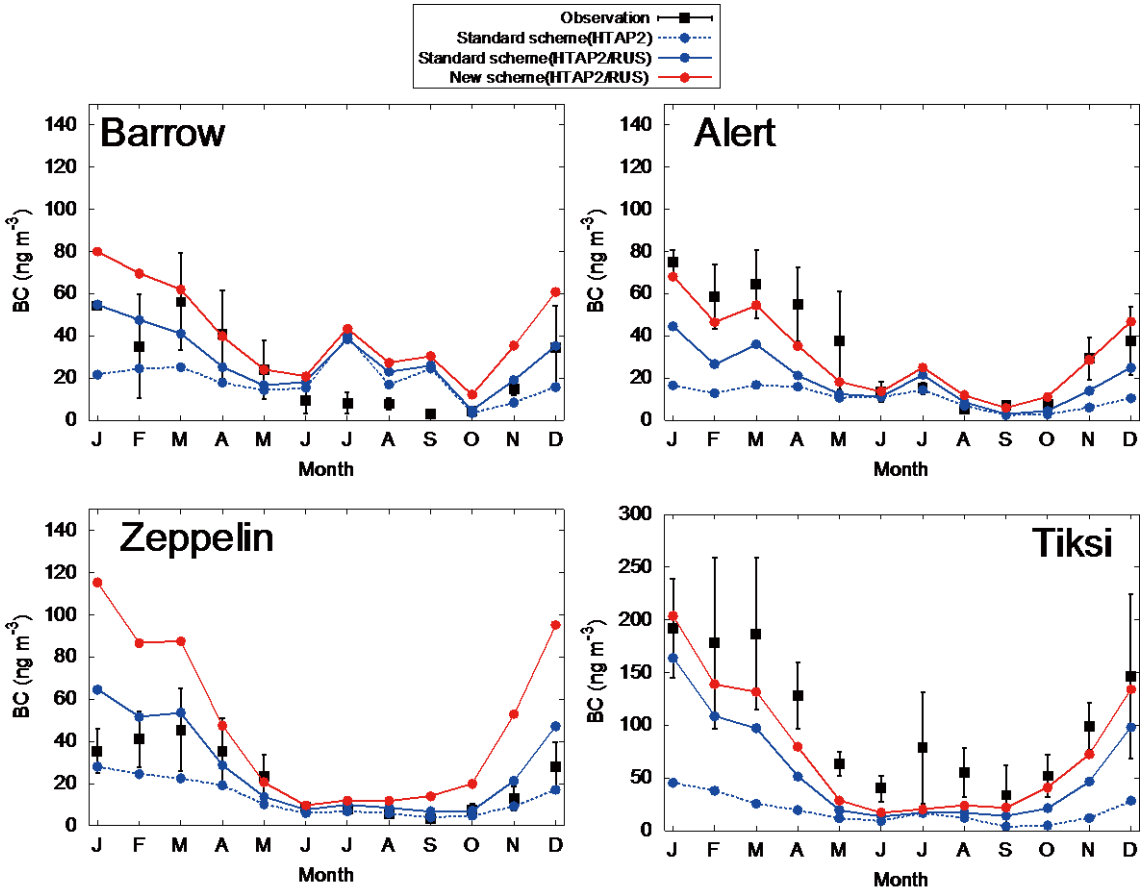

Figure S1: Observed (black squares) and modeled seasonal variations of BC mass concentrations at the Arctic sites. Solid blue and red lines indicate the results of the simulations by standard and new schemes with HTAPv2.2 and the inventory by Huang et al. (2015) for Russia, respectively. Dashed blue line shows the simulation with HTAPv2.2 by the standard scheme. The plots are monthly means and the error bars are standard deviations of interannual variations. Measurements are averaged for 2007–2011 at Barrow, Alert and Zeppelin, and for 2010–2014 at Tiksi.

Table S1. Detailed budgets of BC from individual sources for the period of 2007–2011.

Tracer[a]	Emission[b], Gg yr^{-1}	Poleward flux across 66°N (v>0), Gg yr^{-1}	Burden in the Arctic, Gg	Deposition to the Arctic, Gg yr^{-1}		Lifetime, days	
				Wet	Dry	Global	Arctic
EUR-AN	353.7 (2.6)	76.1	0.9	18.2	4.8	6.4	14.2
RUS-AN	196.8 (22.2)	103.0	1.5	26.7	15.2	9.1	12.9
JPN-AN	21.0 (0.0)	2.2	0.02	0.1	0.02	4.6	57.9
KOR-AN	38.9 (0.0)	3.1	0.04	0.2	0.04	4.6	47.7
NCH-AN	946.6 (0.0)	114.0	1.3	8.2	1.6	6.8	49.4
SCH-AN	838.5 (0.0)	56.1	0.6	1.8	0.3	6.0	96.3
SEA-AN	355.7 (0.0)	8.9	0.1	0.1	0.01	7.1	316.2
IND-AN	1196.7 (0.0)	58.2	0.6	0.9	0.1	7.4	217.6
MEC-AN	129.7 (0.0)	17.6	0.2	2.2	0.5	9.2	27.4
AFR-AN	1005.5 (0.0)	20.7	0.2	0.5	0.05	8.1	141.1
ALC-AN	20.6 (0.6)	5.2	0.07	1.1	0.3	6.2	17.5
NAM-AN	321.6 (0.0)	40.3	0.4	3.4	0.4	5.7	40.3
CAM-AN	78.8 (0.0)	2.5	0.03	0.06	0.006	6.3	131.2
SAM-AN	151.1 (0.0)	0.7	0.009	0.01	0.001	6.6	358.4
AUN-AN	13.7 (0.0)	0.02	0.0002	0.0001	0.00001	5.6	637.8
ROW-AN	15.7 (0.1)	1.7	0.02	0.2	0.06	4.7	30.5
EUR-BB	4.1 (0.0)	0.3	0.003	0.09	0.006	8.7	11.4
WRU-BB	8.6 (0.0)	2.0	0.02	0.9	0.007	7.6	7.1
S1-BB	0.7 (0.7)	0.5	0.007	0.3	0.1	8.0	6.5
S2-BB	5.8 (0.0)	2.1	0.02	0.7	0.07	7.8	10.8
S3-BB	5.9 (0.0)	1.9	0.02	0.5	0.05	8.2	13.6
S4-BB	24.3 (0.0)	8.0	0.09	1.5	0.1	9.1	21.2
S5-BB	46.6 (0.0)	16.3	0.2	5.2	0.4	8.0	12.0
S6-BB	22.1 (4.2)	11.8	0.1	6.5	1.4	6.5	6.7
JPK-BB	0.3 (0.0)	0.04	0.0004	0.004	0.0005	5.2	38.0
C1-BB	5.8 (0.0)	1.5	0.02	0.2	0.003	8.3	27.8
C2-BB	0.2 (0.0)	0.04	0.0004	0.003	0.0002	8.0	41.6
C3-BB	19.8 (0.0)	1.7	0.02	0.05	0.006	7.7	100.8
INC-BB	90.3 (0.0)	3.0	0.03	0.08	0.008	5.7	111.3
EQA-BB	39.5 (0.0)	0.7	0.01	0.004	0.001	8.2	876.6
IND-BB	42.8 (0.0)	2.4	0.02	0.07	0.006	8.0	106.6

MEC-BB	8.1 (0.0)	1.2	0.01	0.3	0.02	8.6	13.1
NAF-BB	402.5 (0.0)	7.3	0.07	0.2	0.03	7.6	117.5
SAF-BB	578.2 (0.0)	0.3	0.004	0.004	0.003	8.9	340.4
ALS-BB	10.1 (4.5)	6.2	0.1	3.6	1.0	6.9	7.7
WCA-BB	46.8 (1.1)	19.1	0.2	8.5	1.1	6.3	8.9
ECA-BB	7.1 (0.0)	1.6	0.02	0.5	0.04	5.6	12.4
NAM-BB	16.3 (0.0)	2.0	0.02	0.2	0.01	7.1	28.1
CAM-BB	18.5 (0.0)	0.5	0.005	0.02	0.002	6.1	80.9
NSA-BB	345.6 (0.0)	0.7	0.009	0.01	0.001	8.2	434.4
SSA-BB	36.7 (0.0)	0.1	0.001	0.0004	0.00005	8.4	657.2
AUN-BB	108.9 (0.0)	0.2	0.002	0.001	0.0002	6.5	681.7
ROW-BB	0.4 (0.0)	0.004	0.00005	0.0004	0.0001	4.8	37.1
Total	7580.9 (35.9)	601.8	7.1	93.1	27.9	7.3	21.3

[a]AN and BB indicate anthropogenic and biomass burning sources, respectively.

[b]Values in brackets denote emissions from north of 66°N.

Table S2. Detailed of the relative contributions from individual sources to the annual mean BC concentrations at the surface and 5 km altitude levels, annual deposition and burden in the Arctic (%).

Tracer[a]	Surface	5 km	Burden	Deposition
EUR-AN	13.4	12.2	12.6	19.0
RUS-AN	61.8	9.8	21.0	34.7
JPN-AN	0.1	0.5	0.3	0.1
KOR-AN	0.2	0.8	0.5	0.2
NCH-AN	6.6	29.4	18.7	8.0
SCH-AN	1.1	9.8	7.9	1.7
SEA-AN	< 0.1	0.5	1.5	0.1
SAS-AN	0.4	4.5	8.7	0.8
MEC-AN	2.0	3.2	2.8	2.2
AFR-AN	0.2	2.0	3.2	0.5
ALC-AN	1.4	0.9	1.0	1.2
NAM-AN	1.7	9.5	6.0	3.1
CAM-AN	<0.1	0.3	0.4	0.1
SAM-AN	<0.1	<0.1	0.1	<0.1
AUN-AN	<0.1	<0.1	<0.1	<0.1
ROW-AN	0.2	0.4	0.3	0.2
EUR-BB	<0.1	0.1	<0.1	0.1
WRU-BB	0.1	0.3	0.3	0.8
S1-BB	0.2	0.1	0.1	0.3
S2-BB	0.2	0.4	0.3	0.6
S3-BB	0.1	0.4	0.3	0.4
S4-BB	0.3	2.4	1.3	1.3
S5-BB	1.2	3.6	2.6	4.7
S6-BB	3.0	1.2	2.1	6.5
JPK-BB	<0.1	<0.1	<0.1	<0.1
C1-BB	0.1	0.5	0.3	0.2
C2-BB	<0.1	<0.1	<0.1	<0.1
C3-BB	<0.1	0.3	0.2	<0.1
INC-BB	<0.1	0.4	0.4	0.1
EQA-BB	<0.1	<0.1	0.2	<0.1
SAS-BB	<0.1	0.3	0.3	<0.1
MEC-BB	<0.1	0.2	0.2	0.3

NAF-BB	<0.1	1.0	1.0	0.2
SAF-BB	<0.1	<0.1	<0.1	<0.1
ALS-BB	2.4	1.0	1.4	3.8
WCA-BB	2.7	3.0	3.3	7.9
ECA-BB	0.1	0.4	0.2	0.4
NAM-BB	<0.1	0.4	0.3	0.2
CAM-BB	<0.1	0.1	<0.1	<0.1
NSA-BB	<0.1	<0.1	0.1	<0.1
SSA-BB	<0.1	<0.1	<0.1	<0.1
AUZ-BB	<0.1	<0.1	<0.1	<0.1
ROW-BB	<0.1	<0.1	<0.1	<0.1

[a]AN and BB indicate anthropogenic and biomass burning sources, respectively.

Table S3. Interannual variations (Minima–Maxima) among five years (2007–2011) of relative contributions from individual sources to the annual mean BC concentrations at the surface and 5 km altitude levels, annual deposition and burden in the Arctic (66°–90°N) (%).[a]

Tracer[b]	Surface	5 km	Burden	Deposition
EUR-AN	11.4–15.4 (13.4)	11.9–12.6 (12.2)	11.5–13.3 (12.6)	15.3–22.6 (19.0)
RUS-AN	55.6–67.2 (61.8)	8.8–11.7 (9.8)	19.0–23.9 (21.0)	29.0–40.0 (34.7)
EAS-AN[c]	6.5–9.5 (8.0)	36.9–43.2 (40.6)	25.8–28.6 (27.4)	8.9–11.1 (10.1)
NAM-AN[c]	2.8–3.5 (3.1)	8.8–12.7 (10.4)	6.4–7.7 (6.9)	3.7–4.8 (4.3)
OTH-AN[c]	2.6–3.2 (2.9)	9.6–12.2 (10.9)	15.1–19.1 (17.0)	3.6–4.4 (3.9)
SIB-BB[c]	2.3–11.2 (5.2)	4.9–16.9 (8.5)	4.2–11.8 (7.0)	8.2–24.0 (14.7)
ALC-BB[c]	3.0–8.2 (5.2)	2.7–6.8 (4.3)	3.6–7.1 (4.9)	10.0–14.7 (12.1)
OTH-BB[c]	0.3–0.5 (0.4)	2.6–4.1 (3.3)	2.6–3.8 (3.2)	0.9–1.8 (1.2)

[a]Values in brackets denote the 5-year averaged contributions.

[b]AN and BB indicate anthropogenic and biomass burning sources, respectively.

[c]EAS-AN (East Asia) is the sum of JPN-AN, KOR-AN, NCH-AN and SCH-AN; NAM-AN (North America) is the sum of NAM-AN and ALC-AN; OTH-AN is the sum of anthropogenic sources other than EUR-AN, RUS-AN, EAS-AN and NAM-AN; SIB-BB is the sum of WRU-BB, S1-BB, S2-BB, S3-BB, S4-BB, S5-BB and S6-BB; ALC-BB is the sum of ALC-BB, WCA-BB and EAC-BB; and OTH-BB is the sum of biomass burning sources other than SIB-BB and ALC-BB.