nature climate change

SUPPLEMENTARY INFORMATION

DOI: 10.1038/NCLIMATE2880

Response of Arctic temperature to changes in emissions of short-lived climate forcers

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Model set-up

The configuration and output of the five models used in this study are shown in table S1. The defined regions are shown in figure S1. The emissions for each component, sector and region are given in Table S2.

Table S1: Configuration, resolution and references for the models used in this study. All models use identical 2010 ECLIPSE emissions (IIASA) and 2006-2010 inter-annually-varying prescribed SST's.

Model	Configuration and output	Resolution	References
CAM5.2	Meteorology generated by the model. MAM7 aerosols. Aerosol direct+ snow/ice RF	1.9°×2.5°. 30 vertical levels	Liu et al. (2012) Wang et al (2013) Neale et al (2010)
CanAM4.2	Meteorology generated by the model, with nudging of winds and temperature towards a free control run. PLA Aerosol model. Aerosol direct+indirect+snow/ice RF (global emissions only).	T63. 49 vertical levels	von Salzen, et al. (2013) von Salzen (2006) Peng et al. (2012) Ma et al. (2008)
NorESM	Meteorology generated by the model. Cam-Oslo aerosol module. Aerosol direct+indirect RF	1.9°×2.5°, 26 vertical levels.	Kirkevåg et al.(2013) Iversen et al. (2013) Bentsen et al. (2013)
Oslo-CTM2	ECMWF reanalysis from the Integrated Forecast System (IFS) model. Bulk aerosols. O_3 direct RF	T42, 60 vertical levels.	Skeie et al. (2011) Myhre et al. (2009)
SMHI-MATCH	ECMWF ERA-Interim reanalysis meteorology. Bulk aerosols. Aerosol direct+O_3 direct RF	0.75°×0.75°, 20N-90N, 38 vertical levels.	Andersson et al. (2007) Robertson et al. (1999)

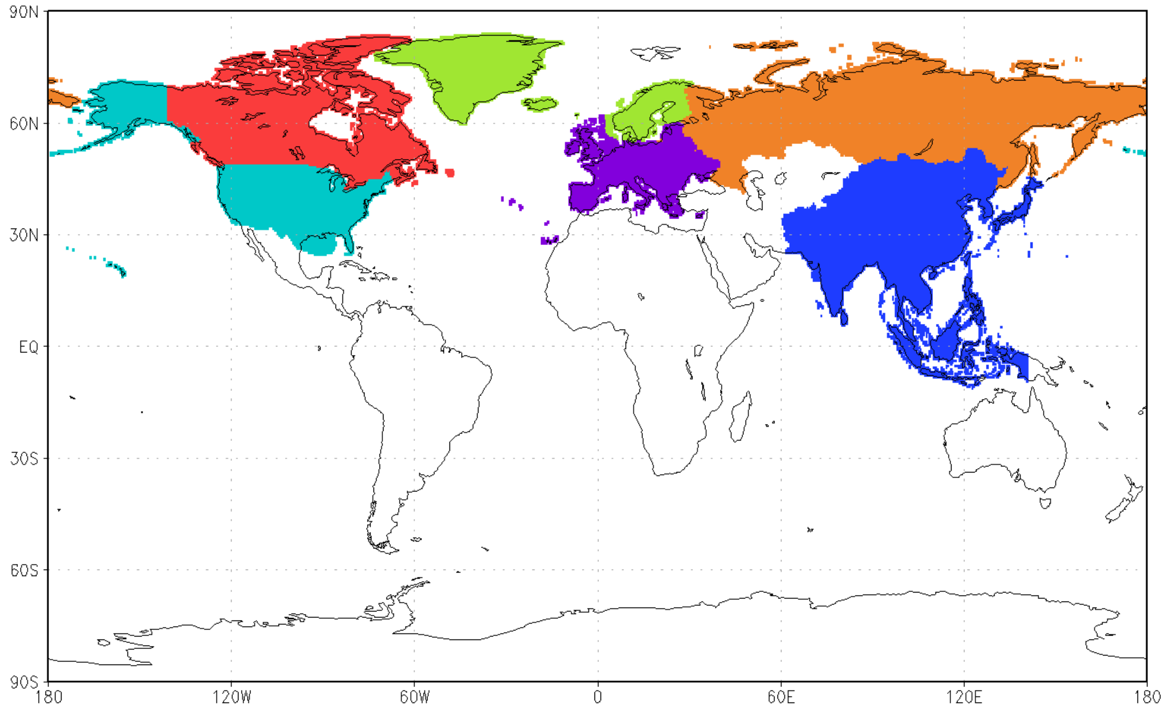

Figure S1: Definition of the 7 regions used in this study; USA, Canada, Nordic countries, Rest-of-Europe, Russia, East+South Asia, and Rest-of-World.

Table S2a. Global anthropogenic 2010 emissions of BC (Gg C), OC (Gg C), and SO_2 (Gg S).

Global anthropogenic BC, OC (C) and SO_2 (S) 2010 emissions (Gg)

	United States			Canada			Russia			Nordic Countries			Rest of Europe			East and South Asia			Rest of the world		
	BC	**OC**	**SO_2**	**BC**	**OC**	**SO_2**	**BC**	**OC**	**SO_2**	**BC**	**OC**	**SO_2**	**BC**	**OC**	**SO_2**	**BC**	**OC**	**SO_2**	**BC**	**OC**	**SO_2**
Domestic	49	120	102	25	51	22	22	45	82	9.3	26	4.3	146	253	311	1780	5642	1970	1020	3570	620
Energy/industrial /waste	13	39	3613	3.7	3.6	924	19	33	2182	1.8	1.6	51	27	37	2974	750	1377	20583	148	469	10229
Transport	131	109	49	18	15	17	52	57	44	10	6.4	2.2	170	90	66	608	488	457	350	268	216
Agricultural Fires	16	55	5.9	1.8	6.5	0.7	24	77	3.4	0.9	2.7	0.2	27	90	7.3	175	641	33	97	441	38
Gas Flaring	4	1	0	2.9	0.6	0.0	65	13	0.2	1.1	0.2	0.0	3.7	0.7	0.0	15	3.0	0.0	137	27	0.4

Table S2b. Global anthropogenic 2010 emissions of NOx, CO and VOC (Gg).

Global anthropogenic NOx, CO and VOC 2010 emissions (Gg)																					
	United States			Canada			Russia			Nordic Countries			Rest of Europe			East and South Asia			Rest of the world		
	NO_x	**CO**	**VOC**	**NO_x**	**CO**	**VOC**	**NO_x**	**CO**	**VOC**	**NO_x**	**CO**	**VOC**	**NO_x**	**CO**	**VOC**	**NO_x**	**CO**	**VOC**	**NO_x**	**CO**	**VOC**
Domestic	792	1800	1071	98	898	246	130	1085	402	25	348	106	750	6264	1407	2005	124900	12439	1349	75386	1242
Energy/industrial/waste	6402	7551	2941	568	2446	349	2578	4558	1951	257	1204	159	3634	6275	1745	19858	98438	2018	8277	16486	6324
Transport	6553	28775	2598	770	2424	287	2852	6475	843	421	915	107	6088	11603	1861	16415	58903	5134	12223	51623	3170
Agricultural Fires	27	1140	125	3,3	138	15	6,5	1708	189	1,4	60	6,8	28	1967	212	61	15158	1414	178	7936	277
Gas Flaring	2,8	12	0,00	2,2	9,6	0,00	65	388	0,00	0,96	3,9	0,00	4,5	12	0,00	15	90	0,00	137	820	0,00

Equilibrium Arctic surface temperature

The RCSs for the Arctic response region are given in Table S3. Figure S2 shows the sensitivity to Arctic BC forcing at different altitudes and are based on Flanner (2013).

Table S3. Arctic climate sensitivity factors in units of K/(W/m^2)

	Forcing Agent			
Forcing Location	**Atmospheric BC**	**Ozone**	**Scattering Aerosol**	**BC in snow and ice**
90°S - 28°S	0.06	0.06	0.06	0.18
28°S - 28°N	0.31	0.13	0.16	0.93
28°N - 60°N	0.15	0.05	0.17	0.45
60°N - 90°N	VR[a]	0.07	0.31	1.06

[a] VR indicates use of vertically-resolved forcing.

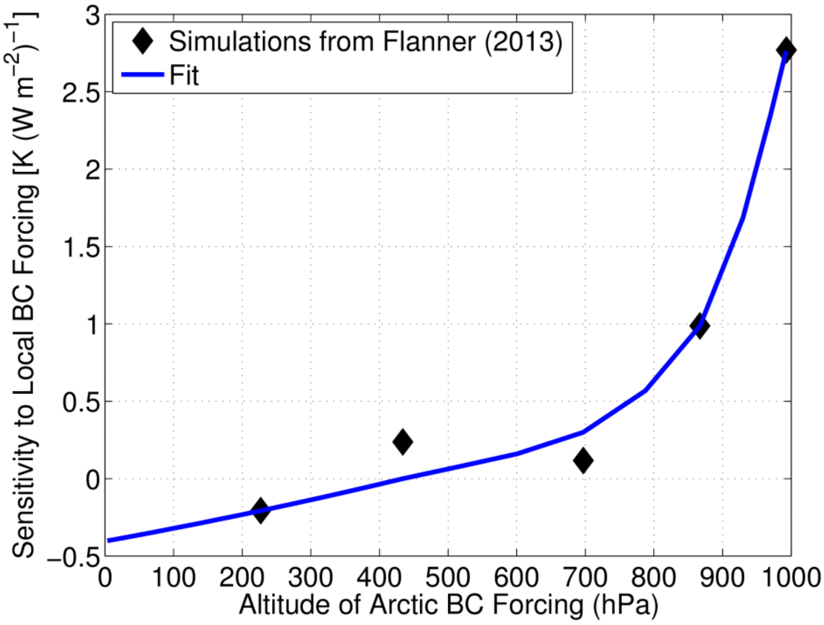

Figure S2: Arctic surface temperature response to BC radiative forcings exerted at different altitudes, derived from simulations described by Flanner (2013).

Forcing calculations

Table S4 gives an overview of the estimated Arctic forcings for all combinations of sectors, components and regions of emissions. To illustrate that also RF exerted outside the Arctic is taken into account in eq. (1). Table S5 is included to show the direct RF by BC within the three other latitude bands for emissions in all sectors and emission regions. Note that in the final calculation of temperature response, all forcings (for all components) in all latitude bands are included (cf. eq. (1) in Methods). Table S6 shows the regional RF in each of the four latitude bands for global emissions of SLCFs. The forcing calculations for each model are available at http://folk.uio.no/mariasan/data/.

Table S4. Arctic model mean BC, OC and SO_4 RF (in mWm^{-2}). Numbers in bracelets are the model range. For indirect forcings and snow/ice by sectors/regions only results from one model were available

Arctic mean	**Black carbon direct radiative forcing (mWm^{-2})**						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	3.8 (1.8, 5.1)	2.1 (1.8, 2.5)	4.3 (4.2, 4.4)	1.3 (1.1, 1.5)	15 (14, 16)	258 (173, 401)	132 (18, 331)
Energy/industrial /waste	1.3 (0.5, 1.6)	0.5 (0.3, 0.6)	5.2 (3.7, 7.3)	0.4 (0.3, 0.4)	3.5 (2.4, 4.6)	91 (37, 132)	19 (4.0, 42)
Transport	11 (4.3, 15)	1.5 (0.9, 2.0)	15 (9.1, 22.3)	1.9 (1.5, 2.2)	18 (9.9, 24)	64 (22, 96)	41 (6.8, 93)
Agricultural Fires	1.4 (0.4, 1.9)	0.3 (0.2, 0.4)	4.9 (3.1, 6.6)	0.1 (0.07, 0.2)	3.7 (2.0, 4.8)	25 (8.1, 40)	13 (2.0, 31)
Grass+Forest Fires	5.7 (2.7, 8.6)	36 (9.7, 57)	94 (48, 167)	0.05 (0.01, 0.05)	0.5 (0.1, 0.7)	46 (24, 75)	241 (18, 685)
Gas Flaring	0.2 (0.04, 0.4)	0.3 (0.2, 0.5)	21 (21, 22)	0.2 (0.1, 0.2)	0.3 (0.1, 0.5)	1.5 (0.1, 3.3)	16 (3.1, 33)

Arctic mean	**Black carbon snow/ice radiative forcing (mWm^{-2})**						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	1.0	1.8	7.2	1.8	9.6	25	4.6
Energy/industrial /waste	0.2	0.3	4.8	0.2	1.1	5.8	1.5
Transport	2.1	0.8	12	1.5	4.1	4.1	2.8
Agricultural Fires	0.3	0.2	2.7	0.05	0.9	1.3	1.0
Grass+Forest Fires	1.2	3.4	8.3	0.01	0.03	2.2	0.7
Gas Flaring	0.05	0.2	45.5	0.1	0.1	0.03	1.6

Arctic mean	**Organic carbon direct radiative forcing (mWm^{-2})**						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	-0.08 (-0.4, 0.3)	0.1 (-0.04, 0.4)	0.2 (-0.3, 0.9)	-0.02 (-0.13, 0.17)	0.8 (-0.6, 3.4)	-0.5 (-54 ,54)	-18 (-57, 2.0)
Energy/industrial /waste	-0.06 (-0.2, 0.04)	0.00 (-0.01, 0.02)	-0.01 (-0.3, 0.4)	0,00 (-0,01, 0,01)	-0.03 (-0.1, 0.1)	-2.4 (-9.9, 3.3)	-2.1 (-6.4, 0.2)
Transport	-0.1 (-0.2, 0.01)	0.01 (-0.02, 0.07)	0.2 (-0.6, 1.3)	0.00 (-0.05, 0.09)	-0.02 (-0.2, 0.4)	-0.8 (-4.4, 2.2)	-1.1 (-3.5, 0.3)
Agricultural Fires	-0.09 (-0.2, 0.01)	0.00 (-0.02, 0.01)	-0.1 (-0.4, 0.2)	-0.01 (-0.01, 0.00)	-0.2 (-0.3, -0.04)	-2.4 (-8.2, 1.2)	-2.8 (-8.2, 0.1)
Grass+Forest Fires	-1.4 (-3.3, 0.5)	-4.6 (-11, 3.6)	13.0 (-15, 64)	-0.01 (-0.01, -0.01)	-0.1 (-0.2, -0.06)	-3.1 (-26, 18)	-76 (-230, 3.0)
Gas Flaring	0.00 (-0.01, 0.00)	0.01 (0.00, 0.02)	0.5 (-0.2, 1.7)	0.00 (0.00, 0.01)	0.00 (0,00,-0,00)	-0.01(-0.04, 0.00)	-0.08 (-0.3, 0.04)

Arctic mean	**Organic carbon indirect cloud radiative forcing (mWm^{-2})**						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	-0.8	-0.8	-2.9	-2.9	-3.8	-15.2	-2.4
Energy/industrial /waste	-0.3	-0.1	-2.4	-0.2	-0.8	-5.5	-0.9
Transport	-0.9	-0.2	-4.5	-0.7	-1.6	-1.7	-0.8
Agricultural Fires	-0.4	-0.2	-2.7	-0.1	-1.7	-2.7	-1.1
Grass+Forest Fires	-40	-76	-114	-0.1	-0.3	-6.8	-3.0
Gas Flaring	0.0	0.0	-3.0	0.0	0.0	0.0	-0.1

Arctic mean	**Sulphate direct radiative forcing (mWm^{-2})**						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	-0.4 (-0.8, 0.1)	-0.07 (-0.09, -0.03)	-0.9 (-1.5, -0.4)	-0.04 (-0.06, -0.02)	-1.5 (-1.9, -0.7)	-8.7 (-20, -1.2)	-4.5 (-12 , -0.5)
Energy/industrial/waste	-22 (-39, 7.7)	-9.8 (-14, -7.5)	-34 (-47, -21)	-0.97 (-1.2, -0.64)	-34 (-46, -24)	-115 (-259, -24)	-93 (-239, -12)
Transport	-0.14, (-0.24 -0.07)	-0.07 (-0.10, -0.05)	-0.83 (-1.2, -0.61)	-0.05 (-0.07, -0.04)	-0.39 (-0.53, -0.22)	-2.1 (-4.3, -0.48)	-1.5 (-3.9, -0.18)
Agricultural Fires	-0.02 (-0.03, -0.01)	-0.01 (-0.01, 0.00)	-0.01 (-0.05, 0.05)	0.00 (0.00, 0.00)	-0.02 (-0.06, 0.03)	-0.06 (-0.12, -0.02)	-0.33 (-0.89, -0.03)
Grass+Forest Fires	-0.34 (-0.71, -0.10)	-1.3 (-2.0, -0.98)	-2.5 (-3.2, -1.1)	0.00 (0.00, 0.00)	-0.01 (0.02, -0.01)	-0.96 (-2.5, -0.14)	-9.1 (-27, -0.16)
Gas Flaring	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	-0.01 (-0.01, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)

Arctic mean	**Sulphate indirect cloud radiative forcing (mWm^{-2})**						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	-0.5	-0.2	-1.7	-0.2	-2.3	-5.9	-1.4
Energy/industrial /waste	-29	-34	-87	-4.1	-64	-86	-36
Transport	-0.4	-0.2	-2.0	-0.2	-0.6	-2.0	-0.6
Agricultural Fires	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.1
Grass+Forest Fires	-3.9	-6.2	-11	0.0	0.0	-0.4	-0.2
Gas Flaring	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Arctic mean	Ozone direct radiative forcing (mWm^{-2})						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	1.2 (1.0, 1.3)	0.3 (0.2, 0.3)	0.3 (0.3, 0.4)	0.1 (0.1, 0.1)	1.3 (1.0, 1.5)	8.7 (7.0, 10)	1.8 (0.6, 3.1)
Energy/industrial/waste	8.5 (7.6, 9.4)	1.3 (1.2, 1.4)	5.0 (4.0, 6.1)	0.6 (0.4, 0.8)	4.0 (2.7, 5.3)	19 (15, 22)	5.6 (3.7, 7.5)
Transport	11 (11, 12)	2.0 (1.8, 2.1)	6.1 (5.0, 7.2)	1.0 (0.7, 1.2)	6.6 (4.7, 8.5)	14 (9.8, 18)	7.9 (5.2, 11)
Agricultural Fires	0.2 (0.1, 0.2)	0.02 (0.0, 0.02)	0.2 (0.2, 0.2)	0.01 (0.01, 0.01)	0.3 (0.2, 0.3)	1.0 (0.9, 1.2)	0.3 (0.2, 0.4)
Grass+Forest Fires	0.5 (0.5, 0.5)	3.5 (3.5, 3.5)	8.5 (8.5, 8.5)	0.005 (0.00, 0.00)	0.01 (0.0, 0.01)	0.9 (0.9, 0.9)	0.2 (0.2, 0.2)
Gas Flaring	0.01 (0.00, 0.01)	0.01 (0.01, 0.01)	0.3 (0.2, 0.3)	0.003 (0.00, 0.00)	0.01 (0.0, 0.01)	0.0 (0.0, 0.01)	0.1 (0.1, 0.1)

Table S5: Model mean BC RF (in mWm^{-2}) in latitude bands outside the Arctic (28°N-60°N, 28°S-28°N, and 90°S-28°S average). Numbers in bracelets are the model range. Similar forcing calculations has been done for all components (BC snow/ice, SO_4 direct and indirect, OC direct and indirect and ozone).

28°N-60°N mean	Black carbon direct radiative forcing (mWm-2)						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	6.8 (6.1, 8.0)	2.2 (1.7, 2.7)	2.6 (1.9, 3.6)	0.5 (0.3, 0.7)	17 (12, 23)	349 (278, 434)	146 (44, 337)
Energy/industrial/waste	2.2 (1.9, 2.5)	0.4 (0.4, 0.5)	3.3 (2.2, 4.7)	0.2 (0.1, 0.2)	4.0 (3.1, 5.5)	128 (101, 149)	25 (14, 45)
Transport	20 (17, 23)	1.6 (1.4, 1.8)	9.2 (5.4, 13)	0.7 (0.5, 1.0)	22 (18, 27)	84 (53, 105)	57 (34, 102)
Agricultural Fires	2.4 (1.9, 2.7)	0.2 (0.2, 0.3)	3.8 (2.9, 5.1)	0.1 (0.04, 0.1)	4.3 (3.4, 5.8)	32 (21, 41)	16 (7.9, 31)
Grass+Forest Fires	4.2 (3.4, 5.2)	14 (3.6, 24)	33 (22, 51)	0.002 (0.00, .004)	0.8 (0.6, 1.0)	46 (26, 73)	247 (27, 685)
Gas Flaring	0.5 (0.4, 0.6)	0.2 (0.1, 0.2)	5.1 (4.4, 6.6)	0.1 (0.1, 0.1)	0.2 (0.2, 0.3)	1.8 (0.4, 3.5)	24 (17, 37.6)

28°S-28°N mean	Black carbon direct radiative forcing (mWm-2)						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	0.9 (0.7, 1.0)	0.1 (0.1, 0.1)	0.1 (0.1, 0.1)	0.0 (0.0, 0.0)	2.8 (2.2, 3.5)	139 (130 148)	119 (104, 133)
Energy/industrial/waste	0.3 (0.2, 0.3)	0.0 (0.0, 0.0)	0.2 (0.2, 0.3)	0.0 (0.0, 0.0)	0.7 (0.6, 0.9)	38 (33 43)	14 (13, 14)
Transport	2.8 (2.1, 3.5)	0.1 (0.0, 0.1)	0.7 (0.7, 0.7)	0.1 (0.1, 0.1)	4.5 (3.7, 5.2)	30 (21 38)	29 (27, 31)
Agricultural Fires	0.3 (0.2, 0.4)	0.0 (0.0, 0.0)	0.3 (0.3, 0.3)	0.0 (0.0, 0.0)	0.9 (0.7, 1.1)	13 (10 16)	8.5 (8.1, 8.9)
Grass+Forest Fires	0.5 (0.5, 0.5)	0.8 (0.5, 1.0)	1.1 (0.6, 1.5)	0.0 (0.0, 0.0)	0.3 (0.3, 0.4)	29 (20, 38)	250 (175, 324)
Gas Flaring	0.1 (0.1, 0.2)	0.0 (0.0, 0.0)	0.3 (0.3, 0.4)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	1.1 (0.7, 1.5)	13 (12, 13)

90°S-28°S mean	Black carbon direct radiative forcing (mWm-2)						
	United States	Canada	Russia	Nordic Countries	Rest of Europe	East and South Asia	Rest of the world
Domestic	0.10 (0.00, 0.19)	0.02 (0.00, 0.03)	0.02 (0.00, 0.03)	0.00 (0.00, 0.01)	0.18 (0.02, 0.34)	36.80 (26, 47)	43 (30, 56)
Energy/industrial/ waste	0.03 (0.00, 0.07)	0.00 (0.00, 0.01)	0.03 (0.00, 0.06)	0.00 (0.00, 0.00)	0.05 (0.01, 0.10)	9.79 (4.4, 15)	5.3 (3.6, 7.0)
Transport	0.34 (0.01, 0.67)	0.01 (0.00, 0.03)	0.10 (0.01, 0.19)	0.01 (0.00, 0.02)	0.30 (0.04, 0.56)	8.57 (1.8, 15)	12 (7.8, 17
Agricultural Fires	0.04 (0.00, 0.08)	0.00 (0.00, 0.00)	0.04 (0.01, 0.07)	0.00 (0.00, 0.00)	0.06 (0.01, 0.11)	3.15 (0.4, 5.9)	5.2 (3.7, 6.7)
Grass+Forest Fires	0.01 (0.00, 0.02)	0.01 (0.01, 0.01)	0.05 (0.05, 0.06)	0.00 (0.00, 0.00)	0.01 (0.01, 0.01)	6.74 (4.0, 9.4)	92 (88, 96)
Gas Flaring	0.01 (0.00, 0.03)	0.00 (0.00, 0.00)	0.05 (0.01, 0.10)	0.00 (0.00, 0.00)	0.00 (0.00, 0.01)	0.33 (0.01, 0.7)	1.6 (0.4, 2.8)

Table S6. Annual model mean RF in each latitude band (from global emissions) (in mWm^{-2}). Numbers in bracelets are the model range.

	Radiative forcing (mWm^{-2})					
Latitude band	BC atm direct	BC snow/ice	OC direct	OC indirect	SO_4 direct	SO_4 indirect
60°N - 90°N	547 (288, 808)	123 (86, 160)	34 (-35, 159)	-245 (-303, -187)	-252 (-491, -51)	-566 (-735, -397)
28°N - 60°N	661 (315, 1075)	81 (44, 118)	-68 (-154, 21)	-377 (-389, -366)	-645 (-947, -225)	-1814 (-2823, -804)
28°S - 28°N	582 (258, 883)	0.08 (0.003, 0.1)	-141 (-186, -85)	-127 (-434, 179)	-236 (-357, -100)	-815 (-1228, -402)
90°S - 28°S	177 (37, 277)	1 (1, 2)	-22 (-65, 7)	-15 (-126, 96)	-46 (-73, -19)	-161 (-180, -141)

Table S7 shows all the equilibrium responses for all sectors, regions and components as shown in in Figure 1.

Table S7. Arctic equilibrium surface temperature response (in K) as shown in Fig 1.

	Arctic equilibrium surface temperature response (K)						
	BC direct	**BC snow**	**OC direct**	**OC indirect**	**SO_4 direct**	**SO_4 indirect**	**O_3 direct**
United States							
Domestic	1.67E-03	2.17E-03	-2.59E-04	-1.62E-03	-3.80E-04	-6.54E-04	2.60E-04
Energy+Industrial+Waste	5.16E-04	4.82E-04	-1.08E-04	-4.60E-04	-1.95E-02	-3.54E-02	1.89E-03
Transport	4.81E-03	3.65E-03	-2.74E-04	-1.31E-03	-2.34E-04	-3.92E-04	2.36E-03
Agricultural Fires	5.65E-04	5.20E-04	-1.50E-04	-5.85E-04	-2.08E-05	-4.04E-05	3.61E-05
Grass+Forest Fires	1.61E-03	1.25E-03	-1.19E-03	-1.44E-02	-1.64E-04	-1.35E-03	3.01E-05
Gas Flaring	1.13E-04	5.75E-05	-1.81E-06	-7.82E-06	-2.13E-07	-1.21E-07	1.45E-06
Canada							
Domestic	8.17E-04	3.02E-03	-2.42E-05	-9.81E-04	-6.25E-05	-1.37E-04	4.59E-05
Energy+Industrial+Waste	1.41E-04	4.72E-04	-3.18E-06	-5.25E-05	-6.91E-03	-1.97E-02	1.88E-04
Transport	5.21E-04	1.38E-03	-1.51E-05	-2.12E-04	-6.44E-05	-1.40E-04	2.56E-04
Agricultural Fires	1.05E-04	4.01E-04	-1.36E-05	-1.65E-04	-3.90E-06	-8.73E-06	4.15E-06
Grass+Forest Fires	7.34E-03	3.57E-03	-3.70E-03	-2.72E-02	-6.00E-04	-2.16E-03	1.49E-04
Gas Flaring	1.16E-04	2.43E-04	2.14E-06	-1.15E-05	-2.33E-07	-2.02E-07	1.02E-06
Russia							
Domestic	1.91E-03	9.08E-03	8.11E-06	-1.43E-03	-4.81E-04	-7.40E-04	5.65E-05
Energy+Industrial+Waste	1.76E-03	6.12E-03	-7.19E-05	-1.12E-03	-1.69E-02	-3.56E-02	6.63E-04
Transport	4.80E-03	1.52E-02	-4.83E-05	-2.08E-03	-4.20E-04	-8.19E-04	7.30E-04
Agricultural Fires	1.61E-03	3.99E-03	-1.92E-04	-1.59E-03	-9.82E-06	-3.16E-05	4.25E-05
Grass+Forest Fires	2.17E-02	9.15E-03	4.50E-04	-4.43E-02	-1.13E-03	-3.83E-03	3.95E-04
Gas Flaring	1.15E-02	4.93E-02	1.38E-04	-9.85E-04	-3.53E-06	-8.41E-06	2.68E-05
Nordic Countries							
Domestic	1.02E-03	2.00E-03	-2.58E-05	-1.14E-03	-1.75E-05	-6.23E-05	1.37E-05
Energy+Industrial+Waste	2.22E-04	2.79E-04	-3.01E-06	-6.23E-05	-3.88E-04	-1.46E-03	6.92E-05
Transport	1.28E-03	1.63E-03	-5.46E-06	-2.66E-04	-2.27E-05	-7.72E-05	9.84E-05
Agricultural Fires	5.96E-05	5.60E-05	-5.50E-06	-4.60E-05	-8.00E-07	-1.91E-06	1.52E-06
Grass+Forest Fires	8.64E-06	6.94E-06	-3.47E-06	-3.18E-05	-7.04E-07	-2.28E-06	1.91E-07
Gas Flaring	2.71E-04	1.17E-04	1.79E-07	-1.10E-05	-3.32E-07	-7.00E-08	3.90E-07
Rest of Europe							
Domestic	6.71E-03	1.20E-02	-2.39E-05	-3.94E-03	-1.03E-03	-1.50E-03	2.48E-04
Energy+Industrial+Waste	1.59E-03	1.52E-03	-9.13E-05	-5.58E-04	-2.20E-02	-3.44E-02	6.82E-04
Transport	8.35E-03	5.47E-03	-1.74E-04	-1.27E-03	-4.01E-04	-4.33E-04	1.15E-03
Agricultural Fires	1.54E-03	1.24E-03	-2.71E-04	-1.32E-03	-2.43E-05	-5.78E-05	4.96E-05
Grass+Forest Fires	2.33E-04	4.76E-05	-1.22E-04	-2.73E-04	-9.82E-06	-1.76E-05	3.32E-07
Gas Flaring	3.26E-04	1.27E-04	-6.91E-07	-1.37E-05	-3.08E-07	-1.14E-07	7.82E-07
South and East Asia							
Domestic	9.63E-02	4.26E-02	-1.95E-03	-3.67E-02	-5.72E-03	-7.93E-03	4.35E-03
Energy+Industrial+Waste	3.15E-02	1.05E-02	-2.10E-03	-7.90E-03	-7.20E-02	-1.02E-01	7.65E-03
Transport	2.24E-02	8.71E-03	-5.36E-04	-3.20E-03	-1.06E-03	-2.41E-03	7.95E-03
Agricultural Fires	9.03E-03	3.80E-03	-1.47E-03	-4.65E-03	-4.94E-05	-1.94E-04	4.94E-04
Grass+Forest Fires	1.57E-02	2.90E-03	-1.62E-03	-1.02E-02	-3.91E-04	-6.05E-04	5.43E-05
Gas Flaring	6.04E-04	9.09E-05	-5.31E-06	-2.45E-05	-2.53E-07	-4.30E-07	1.28E-05
Rest of World							
Domestic	5.84E-02	7.93E-03	-5.86E-03	-1.73E-02	-2.12E-03	-2.96E-03	3.52E-03
Energy+Industrial+Waste	8.12E-03	2.60E-03	-9.50E-04	-2.73E-03	-4.23E-02	-6.03E-02	5.38E-03
Transport	1.77E-02	5.13E-03	-5.14E-04	-1.79E-03	-8.18E-04	-1.16E-03	8.93E-03
Agricultural Fires	5.12E-03	1.61E-03	-1.01E-03	-2.91E-03	-1.19E-04	-2.04E-04	3.03E-04
Grass+Forest Fires	1.12E-01	1.55E-03	-2.34E-02	-3.78E-02	-2.68E-03	-2.93E-03	1.38E-05
Gas Flaring	7.78E-03	3.15E-03	-4.29E-05	-1.81E-04	-5.01E-06	-2.32E-06	9.09E-05

Transient Arctic surface temperature response to mitigation of SLCFs

Figure S3 shows the transient response in annual mean Arctic surface temperature by component. The MFTR scenario also include significant reductions in methane which shows a slower response than the more short-lived SLCFs, but accounts for more than 50% of the net response from 2055 and onwards.

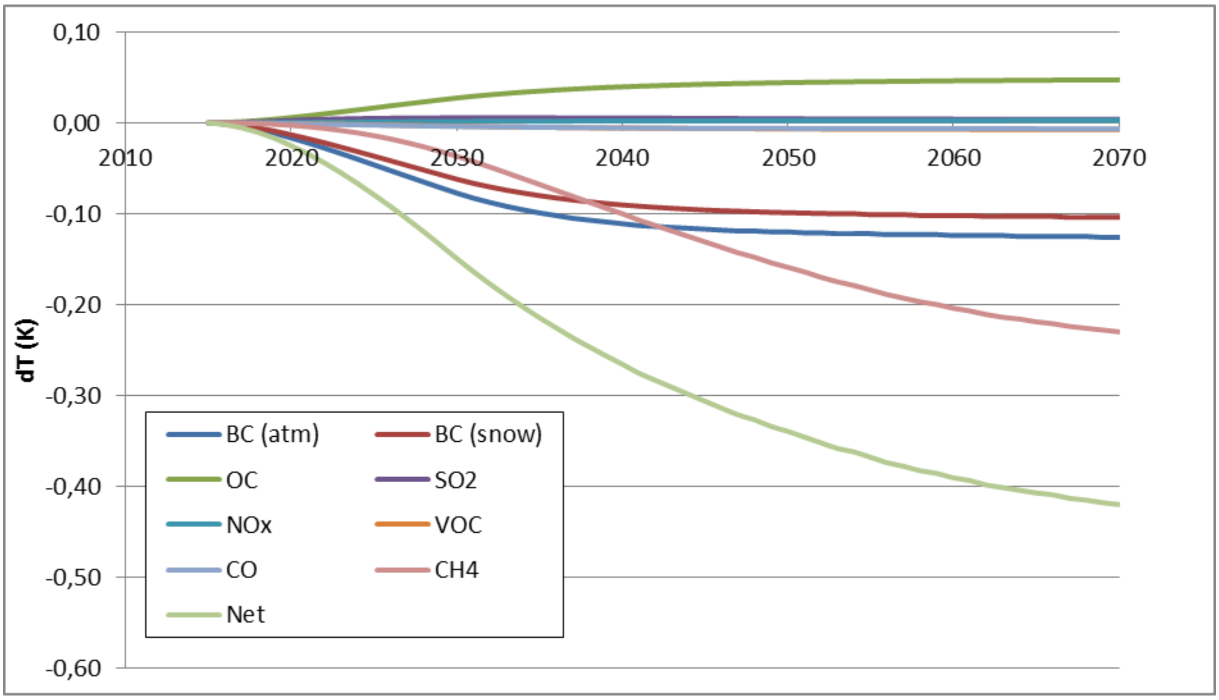

Figure S3: Estimated transient response in annual mean Arctic surface temperature by component using equation (3) above. For BC the response to atmospheric forcing and snow-albedo forcing is separated.

Uncertainty estimate

The estimated total net impact of the reducing emissions of SLCFs (not including methane or HFCs) according to the MIT scenario is a reduction in the Arctic warming of 0.2K in 2050.The uncertainty in this estimate is quite difficult to quantify. There is uncertainty in the calculations of both the emission-to-forcing and the forcing-to-response parts. The latter can further be divided into a more general global climate sensitivity uncertainty (i.e. corresponding to but not equal to the transient climate response (TCR) from a linear growth in CO_2 since the forcing agents are different, mainly BC in the MIT scenario) and the uncertainty in the geographical patterns introduced through the RCS.

To give a rough estimate of the uncertainty in the Arctic response to the mitigation in the MIT scenario, we have split the uncertainty in three factors, assumed to be independent and uncorrelated. For the emission to forcing uncertainty we use the model range of the mid-latitude and Arctic forcing of all (global) BC emissions to estimate this uncertainty. This give an uncertainty of ±53%.

For the global TCR as given by IPCC (Stocker et al., 2013) give a likely range of 1.0 to 2.5°C, corresponding to a ± 43% uncertainty.

For the uncertainty in the regional patterns of forcing-response we have very limited basis for estimating the uncertainty. Only a few very specific model results relating to the BC response have been published (Sand et al. 2013, Flanner 2013). Shindell (2012) evaluate the RCS-based approach by comparing it to four coupled atmosphere ocean climate models driven by historical changes in aerosols (Shindell et al., 2010), however using RCSs only for sulphate. Shindell concludes (after scaling with the global climate sensitivity of each model) that: ”These ARTP results are in good accord with the actual responses in those models. Nearly all ARTP estimates fall within ±20% of the actual responses”. However, Shindell notes that the difference in the Arctic is larger. Based on this very limited information, we have assumed an uncertainty of ±50% for the RCS coefficients.

The total uncertainty (roughly consistent with the 90% confidence interval) is thus taken to be ±84%, so that the estimate for the total Arctic response in 2050 to the mitigation scenario (MIT) is 0.2±0.17K

For the equilibrium runs the indirect effects and the BC on snow to regional emissions were calculated with only one model (NorESM and CAM5, respectively). We have assumed that BC in snow has the same uncertainties as BC in the atmosphere and that the indirect effects have the same uncertainties as the direct effects.

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