

1 **Supplementary materials for:**

2 **Black carbon and mineral dust in snow cover on the Third Pole**

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18 **Including:**

19 **Supplementary Tables S1-S3**

20 **Supplementary Figure S1-S4**

21 **Supplementary Tables**

22 **Table S1.** Sampling information for snow cover over the Tibetan Plateau (the Third Pole) regions.

23 **Table S2.** Parameters for sensitivity analysis with SNICAR model for glaciers in the southeastern Tibetan Plateau.

24 1-Incident radiation (a. Direct, b. Diffuse); 2- Solar zenith angle; 3- Surface spectral distribution (a. Mid-  
25 latitude winter, clear-sky, cloud amount <5. b. Mid-latitude winter, cloudy, cloud amount  $\geq 5$ ); 4- Snow grain  
26 effective radius ( $\mu\text{m}$ ); 5- Snowpack thickness (m); 6- Snowpack density ( $\text{kg m}^{-3}$ ); 7- Albedo of underlying  
27 ground (a. Visible, 0.3–0.7  $\mu\text{m}$ , b. Near-infrared, 0.7–5.0  $\mu\text{m}$ ); 8-MAC scaling factor (experimental) for BC;  
28 9-BC concentration (ppb, sulfate-coated); 10- Dust concentration ( $\mu\text{g g}^{-1}$ , 5.0–10.0  $\mu\text{m}$  diameter); 11-  
29 Volcanic ash concentration (ppm); 12- Experimental particle 1 concentration ( $\text{ng g}^{-1}$ ).

30 **Table S3.** Short-wave radiation at select sites across the Tibetan Plateau (the Third Pole) region.

31 **Table S1.** Sampling information for snow cover over the Tibetan Plateau (the Third Pole) regions.

Sites	Time	Lat. (°)	Long. (°)	Elevation (m)	Snow depth (cm)	Density (kg m <sup>-3</sup> )	Grain size (µm)	Snow type	Snow temperature (°C)
LHG	2015-12-29 12:00	39.50	96.52	4250	20				
RYS	2014-12-03 12:25	36.50	101.52	3396					
TP-S-1511-36	2015-11-30 16:48	35.44	98.65	4363	11	300	2000	Coarse firm with hoar	-6.5
TP-S-1511-37	2015-11-30 18:10	35.37	99.29	4297	16	250	2000	Coarse firm with wind crust and dirty layer	-7.0
TP-S-1511-38	2015-12-01 10:09	35.39	99.31	4298	18	225	2000		-15.0
TP-S-1511-39	2015-12-01 11:23	35.51	99.51	4405	14	225	2000	Coarse firm	-6.5
TP-S-1511-35	2015-11-30 13:25	34.11	97.65	4781	10	325	2000	Coarse firm with dirty layer	-5.0
MD	2014-12-03 12:10	34.86	98.17	4220					
TP-S-1511-33	2015-11-30 11:12	33.47	97.24	4259	7	225	1000	Coarse firm	-4
TP-S-1511-34	2015-11-30 11:41	33.61	97.24	4366	12	350	2000	Coarse firm with wind crust	-6.0
TGL	2014-12-10 12:40	32.90	91.92	5163					
LWQ	2014-12-04 12:20	31.22	96.57	4370					
24K	2014-12-06 12:47	30.99	91.68	5100					
NMC	2014-12-09 12:30	30.75	91.68	4729					
MYL	2014-12-10 12:30	30.11	83.39	4610					
TP-S-1511-1	2015-11-15 11:30	30.45	91.05	4216	3		200	Firm	-5.0
TP-S-1511-2	2015-11-15 13:33	30.67	91.10	5036	6.8		1000	Firm	-3.7
TP-S-1511-3	2015-11-15 14:00	30.68	91.10	5124	9		1000	Fine firm	-0.14
TP-S-1511-4	2015-11-15 16:44	30.79	90.96	4687	5		1000	Fine firm	-2
TP-S-1511-5	2015-11-15 17:30	30.68	91.10	5096	17.1		500	Firm with wind crust	-4.8
TP-S-1511-6	2015-11-16 13:52	29.19	90.62	4762	6.8		1000	Firm	-3.7
TP-S-1511-16	2015-11-20 09:13	29.00	87.47	4798	9	300	1000	Fine firm	-17
TP-S-1511-27	2015-11-26 12:37	29.83	92.34	4971	17	150	3000	Coarse firm	-5
TP-S-1511-28	2015-11-27 10:55	29.63	94.63	4304	12	200	2000		-1.5
TP-S-1511-29	2015-11-27 11:25	29.61	94.67	4523	24	200	3000	Hoar at the bottom	-4.5
TP-S-1511-30	2015-11-27 17:48	29.77	95.70	3728	11	400	2000		-1.5
TP-S-1511-31	2015-11-28 12:10	29.26	96.94	4582	12	250	2000	Coarse firm, ice at bottom	-0.05
TP-S-1511-32	2015-11-28 1:45	29.32	97.03	4745	20	175	2000	Fresh snow and firm	-1.0
TP-S-1511-9	2015-11-18 12:13	28.82	87.93	4851	12.5	230	1500	Firm with wind crust and dirty layer	-12.6
TP-S-1511-17	2015-11-20 10:02	28.96	87.44	5163	15	270	2000	Firm with wind crust and dirty layer	-17
TP-S-1511-18	2015-11-20 10:35	28.91	87.43	5042	8	250	3000	Firm with wind crust and dirty layer	-15
TP-S-1511-21	2015-11-21 13:13	28.67	86.13	4565	9	200	2000	Coarse firm	-2.0
TP-S-1511-22	2015-11-21 14:09	28.52	86.17	5096	5	200	2000	Coarse firm	0
TP-S-1511-23	2015-11-22 13:12	28.65	86.08	4592	9	325	3000	Coarse firm with wind crust and hoar	
TP-S-1511-24	2015-11-22 14:11	28.76	85.66	4614	14	250	3000	Coarse firm	0.05
TP-S-1511-25	2015-11-22 15:07	28.90	85.40	4861	11.5	225	3000	Coarse firm	-2.5
TP-S-1511-26	2015-11-22 15:55	28.93	85.40	5166	12	275	1000	Fine firm with wind crust	0
TP-S-1511-8	2015-11-17 13:02	27.39	88.83	4150	5	275	1000	Fine firm	-0.4

33 **Table S2.** Parameters for sensitivity analysis with SNICAR model for glaciers in the southeastern  
 34 Tibetan Plateau.

Site	1	2	3	4	5	6	7a	7b	8	9-BC	10-Dust	11	12
LHG*	direct	62.75	a		20		0.15	0.3	1	3745.46	224.49	0	0
RYS	direct	58.58	a		11		0.15	0.3	1	8922.53	417.65	0	0
TP-S-1511-36	direct	57.02	a		11		0.15	0.3	1	3097.59	172.04	0	0
TP-S-1511-37	direct	56.95	a		16		0.15	0.3	1	7373.45	292.97	0	0
TP-S-1511-38	direct	57.13	a		18		0.15	0.3	1	4122.43	233.86	0	0
TP-S-1511-39	direct	57.25	a		14		0.15	0.3	1	2894.96	157.78	0	0
TP-S-1511-35	direct	55.69	a		10		0.15	0.3	1	4217.19	295.80	0	0
MD	direct	56.94	a		11		0.15	0.3	1	3122.68	231.03	0	0
TP-S-1511-33	direct	55.05	a		7		0.15	0.3	1	17468.24	846.39	0	0
TP-S-1511-34	direct	55.19	a		12		0.15	0.3	1	4009.22	211.41	0	0
TGL	direct	55.8	a		11		0.15	0.3	1	1014.18	89.61	0	0
LWQ	direct	53.44	a		11		0.15	0.3	1	1734.68	71.11	0	0
24K	direct	53.46	a		11		0.15	0.3	1	876.75	113.52	0	0
NMC	direct	53.55	a		11		0.15	0.3	1	600.68	45.91	0	0
MYL	direct	53.01	a		11		0.15	0.3	1	319.89	23.92	0	0
TP-S-1511-1	direct	48.83	a		3		0.15	0.3	1	1283.33	125.53	0	0
TP-S-1511-2	direct	49.05	a		6.8		0.15	0.3	1	468.71	54.14	0	0
TP-S-1511-3	direct	49.06	a		9		0.15	0.3	1	5093.10	352.58	0	0
TP-S-1511-4	direct	49.17	a		5		0.15	0.3	1	4192.93	213.11	0	0
TP-S-1511-5	direct	49.06	a		17.1		0.15	0.3	1	1084.93	109.12	0	0
TP-S-1511-6	direct	47.83	a		6.8		0.15	0.3	1	250.69	42.80	0	0
TP-S-1511-16	direct	48.6	a		9		0.15	0.3	1	886.69	86.78	0	0
TP-S-1511-27	direct	50.69	a		17		0.15	0.3	1	3586.99	323.06	0	0
TP-S-1511-28	direct	50.68	a		12		0.15	0.3	1	952.23	55.50	0	0
TP-S-1511-29	direct	50.66	a		24		0.15	0.3	1	255.93	26.86	0	0
TP-S-1511-30	direct	50.82	a		11		0.15	0.3	1	1343.22	127.57	0	0
TP-S-1511-31	direct	50.49	a		12		0.15	0.3	1	2117.49	238.03	0	0
TP-S-1511-32	direct	50.55	a		20		0.15	0.3	1	201.70	21.58	0	0
TP-S-1511-9	direct	47.95	a		12.5		0.15	0.3	1	3417.06	344.93	0	0
TP-S-1511-17	direct	48.56	a		15		0.15	0.3	1	822.01	92.20	0	0
TP-S-1511-18	direct	48.51	a		8		0.15	0.3	1	1277.70	101.71	0	0
TP-S-1511-21	direct	48.5	a		9		0.15	0.3	1	1079.43	101.39	0	0
TP-S-1511-22	direct	48.35	a		5		0.15	0.3	1	2201.12	226.49	0	0
TP-S-1511-23	direct	48.7	a		9		0.15	0.3	1	1072.04	104.53	0	0
TP-S-1511-24	direct	48.81	a		14		0.15	0.3	1	1042.25	109.11	0	0
TP-S-1511-25	direct	48.95	a		11.5		0.15	0.3	1	931.68	35.29	0	0
TP-S-1511-26	direct	48.98	a		12		0.15	0.3	1	759.41	65.26	0	0
TP-S-1511-8	direct	46.28	a		5		0.15	0.3	1	574.95	22.39	0	0

36 **Table S3.** Shortwave radiation at select sites across the Tibetan Plateau (the Third Pole) region from  
 37 meteorological stations.

	SW ( $\text{W m}^{-2}$ )		SW ( $\text{W m}^{-2}$ )	
SETP				
	March, 2014	248	March, 2015	237
	April, 2014	288	April, 2015	259
	May, 2014	305	May, 2015	280
	June, 2014	265	June, 2015	250
NMC				
			March, 2015	264
			April, 2015	276
			May, 2015	306
			June, 2015	314
TGL				
	March, 2014	210		
	April, 2014	226		
	May, 2014	245		
	June, 2014	271		
LHG				
	March, 2014	229	March, 2015	238
	April, 2014	269	April, 2015	294
	May, 2014	311	May, 2015	305
	June, 2014	258	June, 2015	269

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39 **Supplementary Figures**

40 **Figure S1.** Example of snow sampling sites over the Third Pole region.

41 **Figure S2.** Spatial distributions of light-absorbing impurities in the Laohugou region. (a) BC, (b)  
42 OC, (c) Dust, and (d) ratio of OC to BC (OC/BC).

43 **Figure S3.** BC emissions arrived at the selected sites over the Third Pole region based on data drawn  
44 from <http://inventory.pku.edu.cn/download/download.html> (Wang et al., 2014). (A  
45 value 2 on the x axis means  $2 \times 10^6$  g month<sup>-1</sup>. The BC value is averaged over 48 h along  
46 the back trajectory path. And the value on the y axis is the number of trajectories in the  
47 respective BC bin. The bin width is 0.05, i.e. from 0 to 5 on the horizontal axis there are  
48 100 bins.)

49 **Figure S4.** Distributions of changes in snow cover duration caused by BC and dust.

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51 **Fig. S1**

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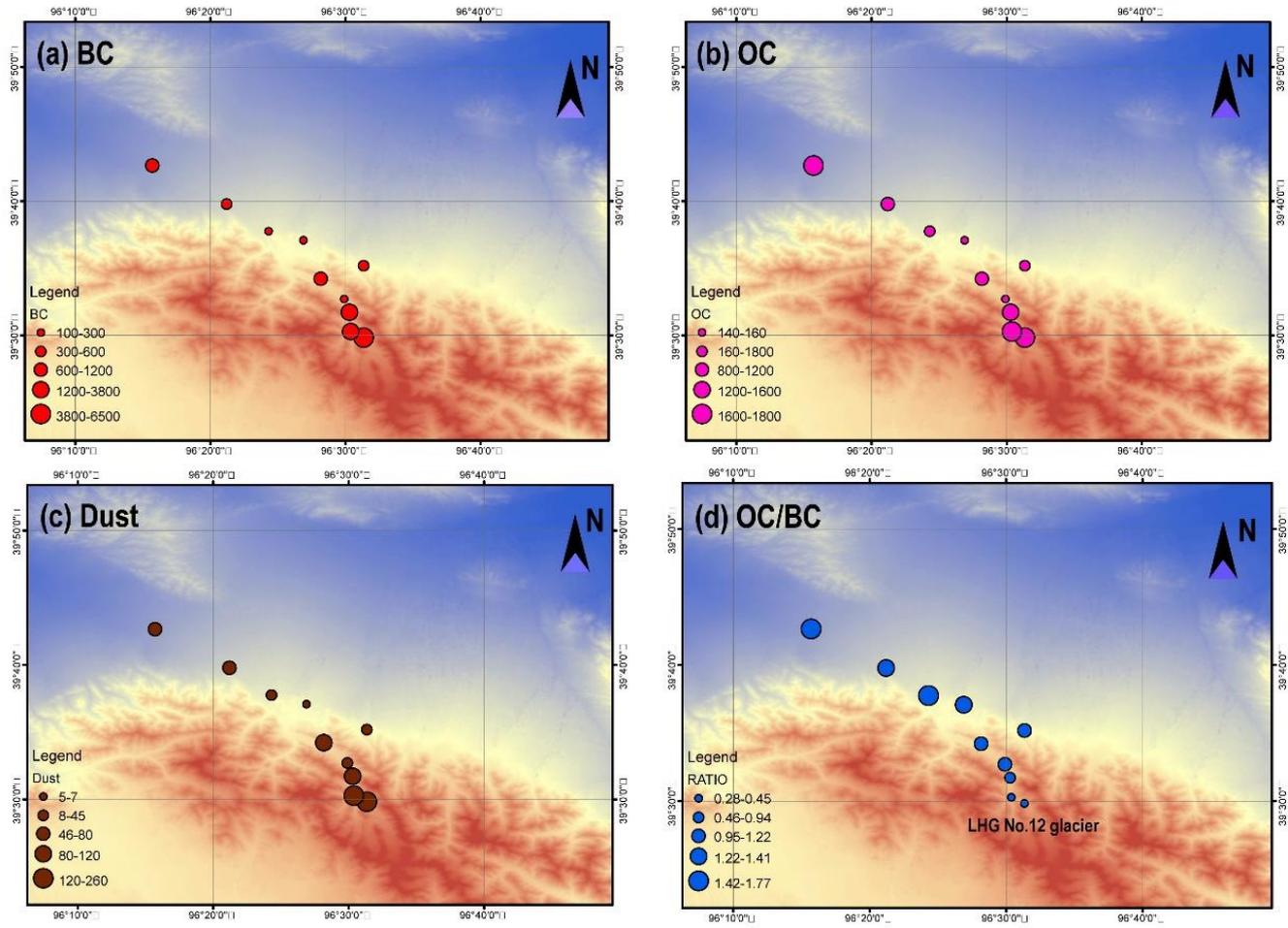


53



54 **Figure S1.** Example of snow sampling sites over the Third Pole region.

55 **Fig. S2**

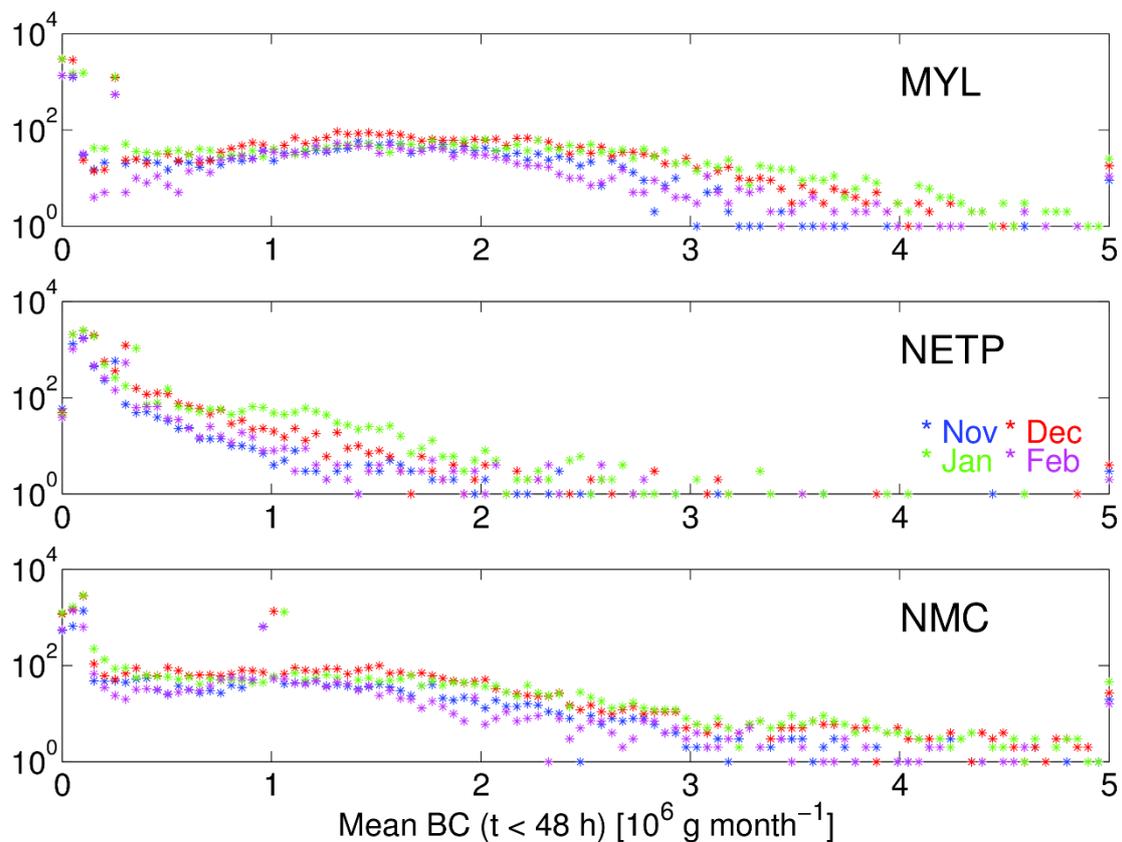


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57 **Figure S2.** Spatial distributions of light-absorbing impurities in the Laohugou region. (a) BC, (b) OC, (c) Dust, and  
58 (d) ratio of OC to BC (OC/BC).

59

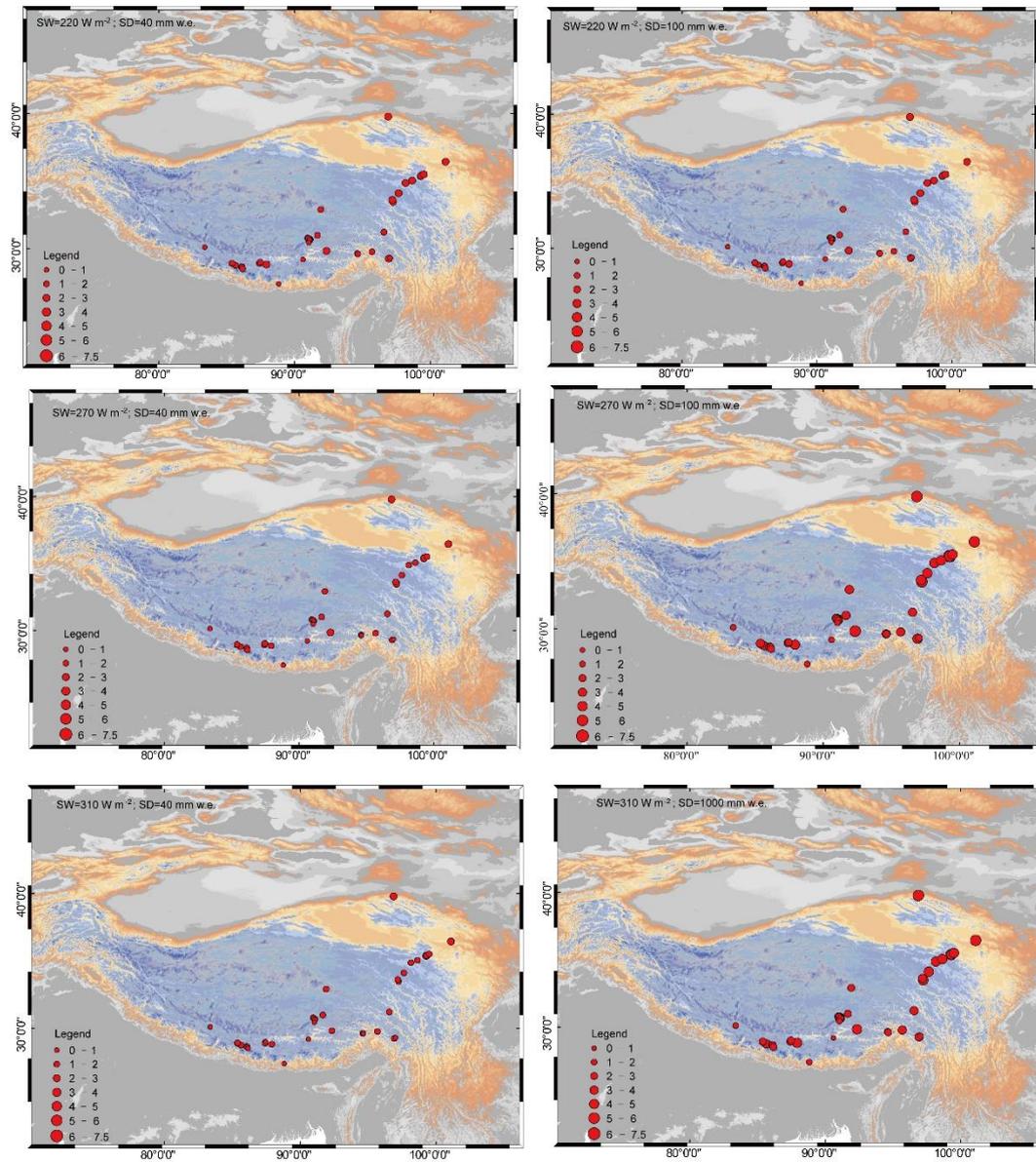
60 **Fig. S3**



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62 **Figure S3.** BC emissions arrived at the selected sites over the Third Pole region based on data drawn  
63 from <http://inventory.pku.edu.cn/download/download.html> (Wang et al., 2014). (A value 2 on the x  
64 axis means  $2 \times 10^6 \text{ g month}^{-1}$ . The BC value is averaged over 48 h along the back trajectory path.  
65 And the value on the y axis is the number of trajectories in the respective BC bin. The bin width is  
66 0.05, i.e. from 0 to 5 on the horizontal axis there are 100 bins.)

67 **Fig. S4**



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69 **Figure S4.** Distributions of changes in snow cover duration caused by BC and dust.

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73 References:

74 Wang, R., Tao, S., Shen, H., Huang, Y., Chen, H., Baljanski, Y., Boucher, O., Ciais, P., Shen, G., Li,  
75 W., Zhang, Y., Chen, Y., Lin, N., Su, S., Li, B., Liu, J., Liu, W.: Trend in black carbon  
76 emissions from 1960 to 2007, *Environ. Sci. Technol.*, doi:10.1021/es5021422, 2014.

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