Measurement of Light absorbing particles in surface snow of central and western Himalayan glaciers: spatial variability, radiative impacts, and potential source regions

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Figure S1. Surface condition of selected glaciers (a). Yala glacier in Nepal, (b). Thana glacier in Bhutan (c). Sachin glacier in Pakistan

Table S1. Parameters used for sensitivity analysis with SNICAR model for selected glaciers snow samples under the input parameters of direct incident radiation and mid-latitude winter, clear-sky conditions.

1 = solar zenith angle
2 = snow grain effective radius (µm)
3 = snowpack thickness (m)
4 = snowpack density (kg m^{-3})
5 = albedo of underlying ground (a. visible, 0.3-0.7µm, b. near-infrared, 0.7-5.0µm)
6 = MAC scaling factor (experimental) for BC
7= BC concentration (ppb, coated)
8 = dust concentration (ppm, 5.0–10.0 µm diameter)
Volcanic ash concentration (ppm) and Experimental particle 1 concentration (ppb) were set to 0

Site	1	2	3	4	5a	5b	6	7	8
Yala (May-2016)	78.29	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	65.27	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	52.08	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	38.92	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	26.15	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	15.19	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	12.61	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	21.68	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	34.06	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	47.13	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	60.33	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	73.42	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (May-2016)	86.19	500	0.11	220	0.22	0.42	1	140.82	4.5
Yala (Sept -2016)	85.50	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	72.56	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	59.96	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	48.23	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	38.29	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	31.92	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	31.42	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	37.02	550	0.10	240	0.25	0.45	1	68.97	4.3

Yala (Sept -2016)	46.57	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	58.10	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	70.62	550	0.10	240	0.25	0.45	1	68.97	4.3
Yala (Sept -2016)	83.55	550	0.10	240	0.25	0.45	1	68.97	4.3
Thana (Sept-2016)	86.84	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	73.76	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	60.73	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	48.18	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	36.79	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	28.12	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	25.23	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	29.87	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	39.45	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	51.23	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	63.94	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	77.04	550	0.10	240	0.25	0.45	1	39.39	34.63
Thana (Sept-2016)	89.90	550	0.10	240	0.25	0.45	1	39.39	34.63
Sachin (May-2016)	88.28	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	77.15	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	65.32	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	53.19	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	40.97	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	29.04	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	18.42	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	13.22	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	18.78	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	29.50	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	41.45	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	53.66	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	65.78	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	77.58	800	0.14	350	0.28	0.48	1	2381.38	100
Sachin (May-2016)	88.65	800	0.14	350	0.28	0.48	1	2530.00	100

Table S2: Surface concentration of individual samples collected from various glaciers and mountain valleys during pre-monsoon, monsoon and winter seasons.

Elevation	EC ngg^{-1}	OC ngg^{-1}	Dust gg^{-1}
Yala glacier summer (May 2016)			
4681	293.5586	761.6007	2.50
4881	54.28432	136.006	1.50
4882	85.91668	182.4214	9.50
5061	130.04	276.2132	4.50
5100	264.7962	572.4283	5.50
5165	78.28648	223.995	3.50
5200	2529.1	6708.673	196.50
5250	165.7292	354.2171	1.50
5325	108.8889	256.0858	1.50
5414	113.6366	232.1528	13.50
5498	113.0902	238.7028	1.50
Sachin glacier summer (May 2016)			
3405	2455.31	4272.24	66.45
3166	3274.945	4322.93	140.26
3340	2835.441	3665.21	102.63
3270	2874.646	4265.32	88.23
3200	2910.211	4452.62	253.52
3600	3436.154	4660.83	95.23
3480	3545.35	4832.36	78.46
3690	1384.651	3627.78	117.59
3548	2136.429	4144.67	109.71
3800	835.324	1422.20	58.12
3770	1232.753	3377.74	67.23
3610	1655.456	3708.22	35.24
Yala autumn (September 2016)			
5168	23.17	82.35	1.50
5176	64.30	162.80	12.00
5211	54.79	132.31	1.50
5288	39.65	103.16	2.50
5332	162.97	406.89	4.00
Thana glacier autumn (September 2016)			
5575	126.77	357.91	41.02
5535	25.45	100.87	26.31

5474	32.97	106.43	34.53
5426	22.66	70.65	19.42
5380	30.27	83.27	24.14
5324	23.98	78.54	66.60
5276	28.06	103.32	60.91
5276	43.39	84.82	37.26
5204	21.00	57.55	1.500

Table S3 BC and OC concentrations in glaciers from the Tibetan Plateau and its surroundings regions

Locations	Lat.	Lon.	Elevation	Sample type	BC	OC	Method used	References
Yala glacier (May)	28◦14′N	85◦37′E	5300	Surface snow	118.97	288.44	Thermal-Optical, DIR 2005	This study
Yala glacier(Sep)	28◦14′N	85◦37′E	5300	Surface snow	68.98	177.50	Thermal-Optical, DIR 2005	This study
Thana glacier	28◦01′N	90◦36′E	5400	Surface snow	39.39	115.93	Thermal-Optical, DIR 2005	This study
Sachin glacier (May)	35◦20′N	74◦45′E	3200	Surface snow	2381.39	3896.01	Thermal-Optical, DIR 2005	This study
Sachin glacier (Oct)	35◦20′N	74◦45′E	3200	Surface snow	3626.74	5449.70	Thermal-Optical, DIR 2005	This study
Tien Shan	43.1º N	86.82º E	4130	surface snow	400	1000	Thermal-Optical, DIR 2001	Xu et al., 2012
Tien Shan	43.1º N	86.82º E	4130	Bottom firn-pack	3000	6500	Thermal-Optical, DIR 2001	Xu et al., 2012
Tien Shan	43◦06′N	86.82º E	3947	fresh snow	16		Thermal-Optical, DIR 2001	Ming et al., 2016
Tien Shan	43º06′N	86.82º E	3947	aged snow	1507		Thermal-Optical, DIR 2001	Ming et al., 2016
Miaoergou, Tien Shan	43.05°N	94.32° E	4510	Snow pit	107		Coulometric titration-based analysis	Ming et al., 2009
Muji glacier	39.2ºN	73.73º E	5100	no melt snow	25	58	Thermal-Optical, DIR 2001	Yang et al., 2015
Muji glacier	39.2º N	73.73º E	5100	melt snow	730	326	Thermal-Optical, DIR 2001A	Yang et al., 2015
Laohugou glacier	39.17◦N	96.17º E	4870	fresh snow	849		Thermal-Optical, DIR 2001A	Li et al., 2016
Laohugou glacier	39.17◦N	96.17º E	4870	superimposed ice	24920		Thermal-Optical, DIR 2001A	Li et al., 2016
Zhadang glacier	30.48◦N	90.65º E	5651	fresh snow	51.9		Thermal-Optical, DIR 2001A	Qu et al., 2014
Zhadang glacier	30.48◦N	90.65º E	5593	superimposed ice	404		Thermal-Optical, DIR 2001A	Qu et al., 2014
East Rongbuk glacier,	28.04◦N	86.95º E	6300	snowpit	18		Coulometric titration-based analysis	Ming et al., 2009
East Rongbuk glacier,	28.03◦N	86.95º E	6518	ice core	1.5		SP2	Kaspari et al., 2011
Mera glacier	27.71◦N	86.88º E	5400	snow/ice	180		SP2	Kaspari et al., 2014
Mera glacier	27.72◦N	86.88º E	6400	snowpit	1		SP2	Kaspari et al., 2014
PLZ4	29.21◦N	96.92º E	5500	ice core	8		Thermal-Optical, DIR 2001A	Xu, Wang et al., 2009
Zuoqiupu glacier,	29.20◦N	96.92º E	5600	ice core	5	20	Thermal-Optical, DIR 2001	Xu, Cao et al., 2009
Northwest Greenland	77.92◦N	59.99º W	1992	surface snow	0.3	1.7	Thermal-optical	Aoki et al., 2014
Northwest Greenland	78.05◦N	67.63º W	1490	surface snow	2.3	8.1	Thermal-optical	Aoki et al., 2014
Holtedahlfonna,	79.14◦N	13.27º E	1150	ice core	45		Thermal-optical	Ruppel et al., 2014
Colle Gnifetti,	45.92◦N	7.87º E	4455	ice core	20		Elemental analysis	Thevernon et al., 2009