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Black carbon and mineral dust in snow cover on the Tibetan Plateau

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Supplementary Tables

Table S1. Sampling information for snow cover over the Tibetan Plateau.

Table S2. Parameters for sensitivity analysis with SNICAR model for snow cover in the Tibetan Plateau. 1-Incident radiation (a. Direct, b. Diffuse); 2- Solar zenith angle; 3- Surface spectral distribution (a. Mid-latitude winter, clear-sky, cloud amount<5. b. Mid-latitude winter, cloudy, cloud amount ≥5); 4- Snow grain effective radius (μm); 5- Snowpack thickness (m); 6- Snowpack density (kg m^{-3}); 7- Albedo of underlying ground (a. Visible, 0.3–0.7μm, b. Near-infrared, 0.7–5.0μm); 8-MAC scaling factor (experimental) for BC; 9-BC concentration (ppb, sulfate-coated); 10- Dust concentration (μg g^{-1}, 5.0–10.0 μm diameter); 11- Volcanic ash concentration (ppm); 12- Experimental particle 1 concentration (ng g^{-1}).

Table S3. Short-wave radiation input data at selected sites across the Tibetan Plateau close to the snow sampling sites.

Table S1. Sampling information for snow cover over the Tibetan Plateau regions.

Sites	Time	Lat. (°)	Long. (°)	Elevation (m)	Snow depth (cm)	Density (kg m^{-3})	Observed snow grain size (μm)	Snow type	Snow temperature (℃)
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 firn with hoar	–6.5
TP-S-1511-37	2015-11-30 18:10	35.37	99.29	4297	16	250	2000	Coarse firn 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 firn	–6.5
TP-S-1511-35	2015-11-30 13:25	34.11	97.65	4781	10	325	2000	Coarse firn 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 firn	–4
TP-S-1511-34	2015-11-30 11:41	33.61	97.24	4366	12	350	2000	Coarse firn 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	Firn	–5.0
TP-S-1511-2	2015-11-15 13:33	30.67	91.10	5036	6.8		1000	Firn	–3.7
TP-S-1511-3	2015-11-15 14:00	30.68	91.10	5124	9		1000	Fine firn	–0.14
TP-S-1511-4	2015-11-15 16:44	30.79	90.96	4687	5		1000	Fine firn	–2
TP-S-1511-5	2015-11-15 17:30	30.68	91.10	5096	17.1		500	Firn with wind crust	–4.8
TP-S-1511-6	2015-11-16 13:52	29.19	90.62	4762	6.8		1000	Firn	–3.7
TP-S-1511-16	2015-11-20 09:13	29.00	87.47	4798	9	300	1000	Fine firn	–17
TP-S-1511-27	2015-11-26 12:37	29.83	92.34	4971	17	150	3500	Coarse firn	–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 firn, 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 firn	–1.0
TP-S-1511-9	2015-11-18 12:13	28.82	87.93	4851	12.5	230	1500	Firn 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	Firn with wind crust and dirty layer	–17
TP-S-1511-18	2015-11-20 10:35	28.91	87.43	5042	8	250	3000	Firn 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 firn	–2.0
TP-S-1511-22	2015-11-21 14:09	28.52	86.17	5096	5	200	2000	Coarse firn	0
TP-S-1511-23	2015-11-22 13:12	28.65	86.08	4592	9	325	3000	Coarse firn with wind crust and hoar	
TP-S-1511-24	2015-11-22 14:11	28.76	85.66	4614	14	250	3000	Coarse firn	0.05
TP-S-1511-25	2015-11-22 15:07	28.90	85.40	4861	11.5	225	3000	Coarse firn	–2.5
TP-S-1511-26	2015-11-22 15:55	28.93	85.40	5166	12	275	1000	Fine firn with wind crust	0
TP-S-1511-8	2015-11-17 13:02	27.39	88.83	4150	5	275	1000	Fine firn	–0.4

Table S2. Parameters for sensitivity analysis with SNICAR model for snow cover in the 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

Table S3. Short-wave radiation input data at selected sites across the Tibetan Plateau close to the snow sampling sites.

		SW (W m^{-2})		SW (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

Supplementary Figures

Figure S1. Example of snow sampling sites over the Tibetan Plateau.

Figure S2. Snow grain size observation in the field (a) and measurement in the lab (b).

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

Figure S3. Automatic weather stations selected for the short-wave radiation input data across the Tibetan Plateau.

Figure S4. BC emissions arrived at the selected sites over the Tibetan Plateau region based on data drawn from http://inventory.pku.edu.cn/download/download.html (Wang et al., 2014). (A value 2 on the x axis means 2×10^6 g month^{-1}. The BC value is averaged over 48 h along the back trajectory path. And the value on the y axis is the number of trajectories in the respective BC bin. The bin width is 0.05, i.e. from 0 to 5 on the horizontal axis there are 100 bins.)

Figure S5. Distributions of changes of snow cover duration days caused by BC and mineral dust.

Fig S1.

Figure S1. Example of snow sampling sites over the Tibetan Plateau.

Fig S2.

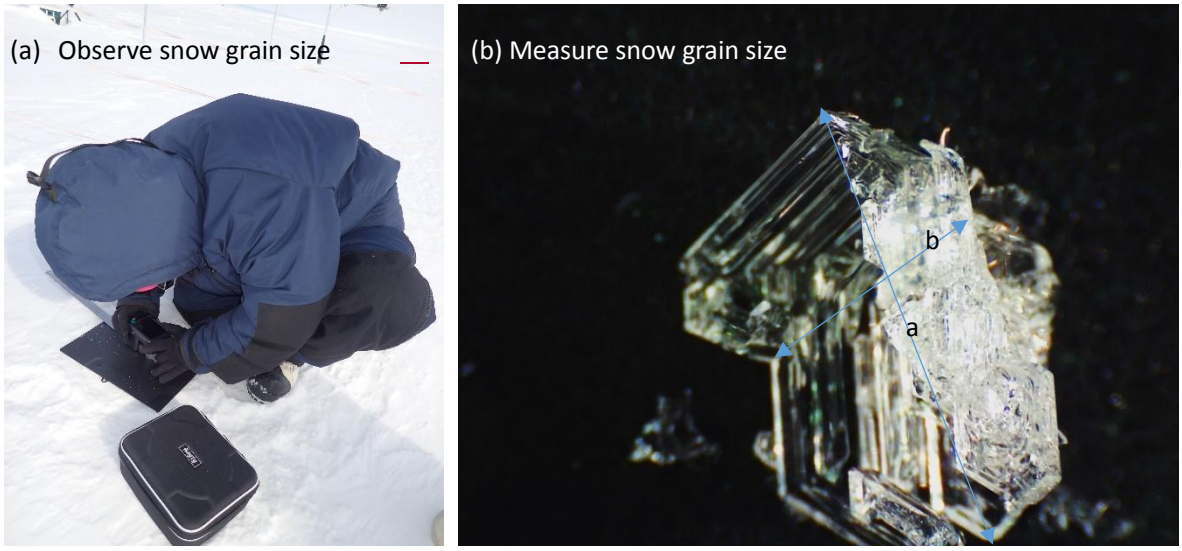
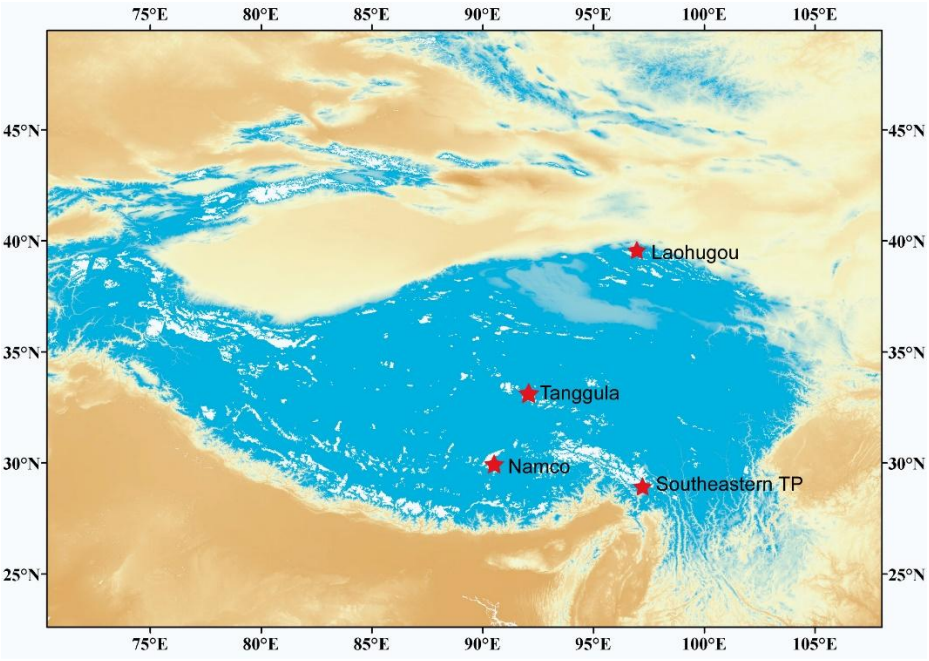


Figure S2. Snow grain size observation in the field (a) and measurement in the lab (b).

66 **Fig S3.**



67

68 Figure S3. Automatic weather stations selected in the Tibetan Plateau.

Fig S4.

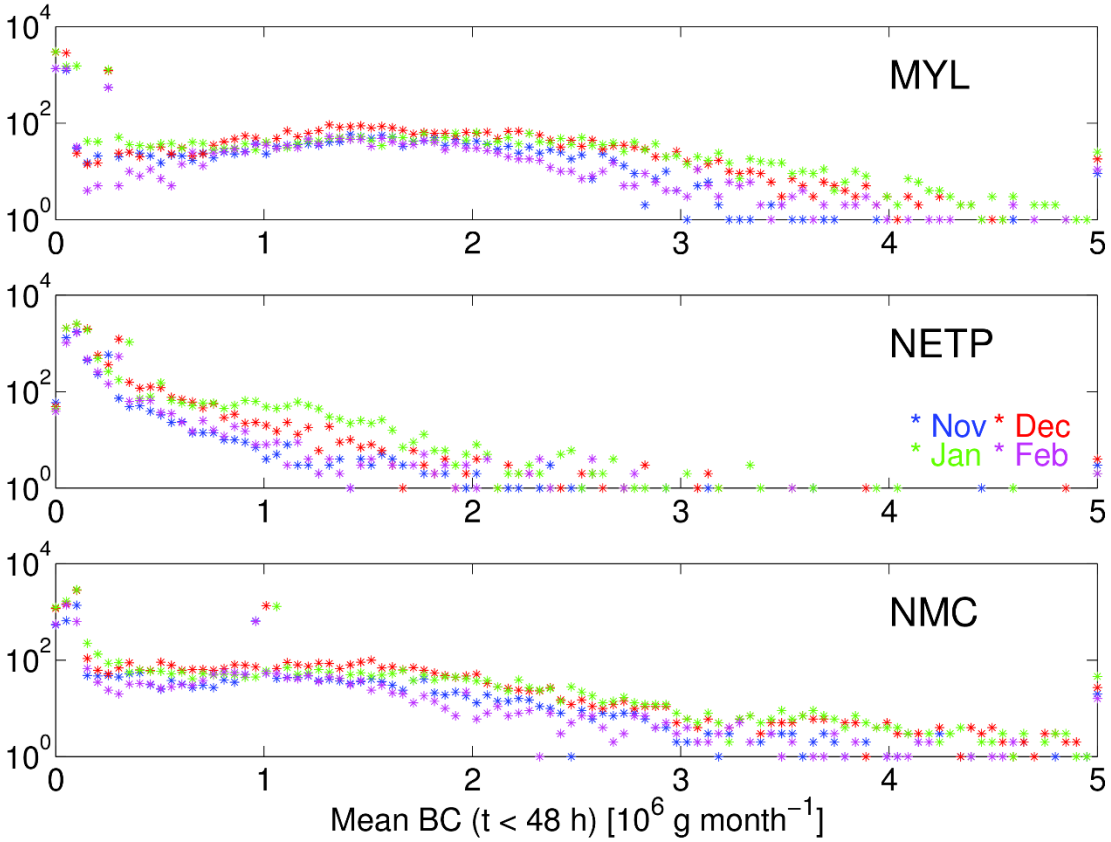


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Fig S5.

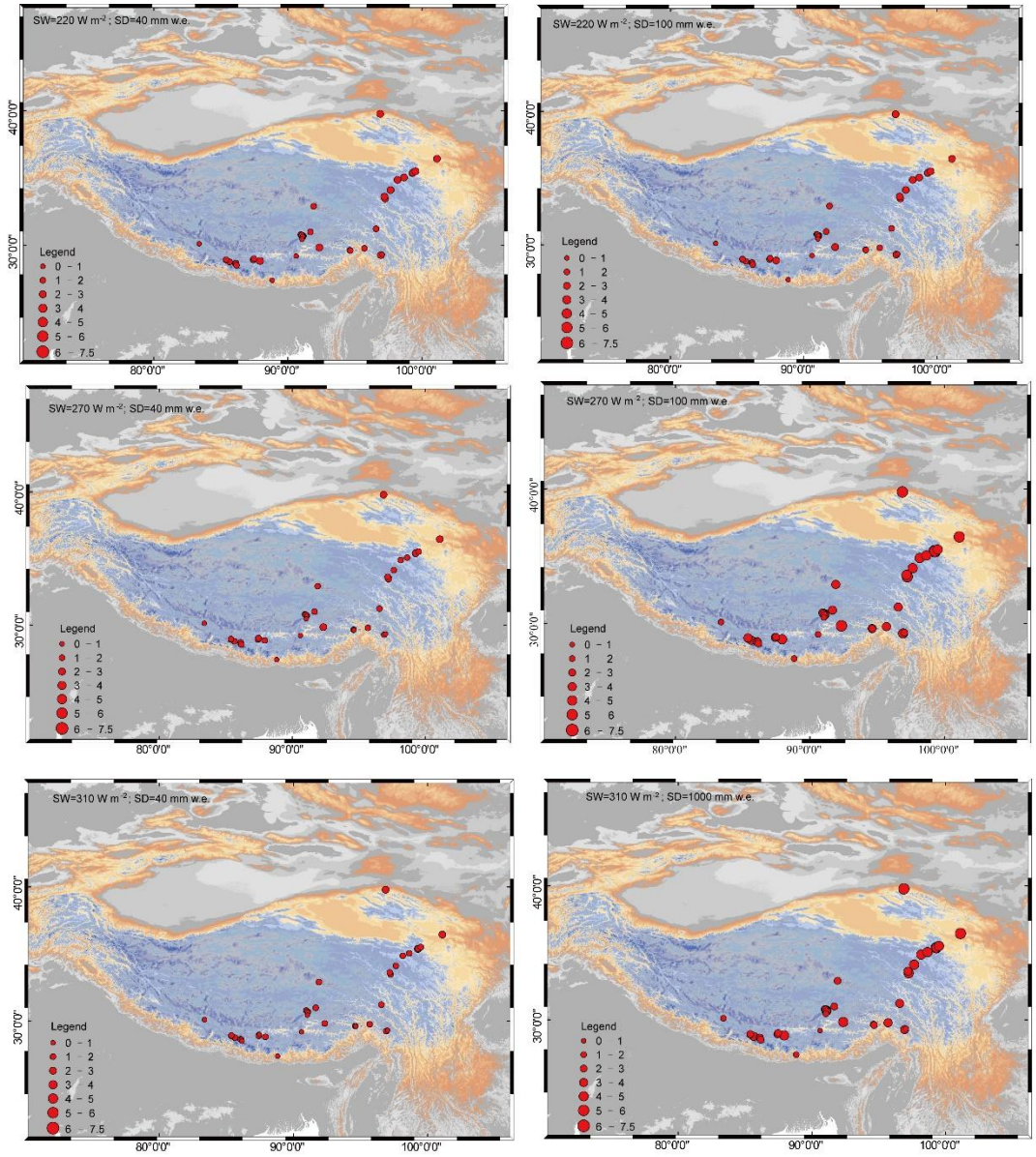

Figure S5. Distributions of changes of snow cover duration days caused by BC and mineral dust.

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

89 Data of BC and other light-absorbing impurities used in this study.

		Latitude	Longitude	Dust (μg g^{-1})	OC (ng g^{-1})	EC (ng g^{-1})
RegionI	MYL	30°06′44.48"	83°23′26.92"	24	1040	320
RegionI	TP-S-1511-1	30°26′48.11"	91°03′08.10"	126	3118	1283
RegionI	TP-S-1511-2	30°40′02.57"	91°05′50.31"	54	1444	469
RegionI	TP-S-1511-3	30°40′57.12"	91°05′47.75"	353	4912	5093
RegionI	TP-S-1511-4	30°47′18.66"	90°57′51.90"	213	3638	4193
RegionI	TP-S-1511-5	30°40′43.19"	91°05′51.93"	109	2416	1085
RegionI	TP-S-1511-6	29°11′35.68"	90°37′19.63"	43	682	251
RegionI	TP-S-1511-8	27°23′41.50"	88°50′00.97"	22	1904	575
RegionI	TP-S-1511-9	28°49′29.35"	87°55′50.39"	345	7182	3417
RegionI	TP-S-1511-16	29°00′06.58"	87°28′29.78"	87	2157	887
RegionI	TP-S-1511-17	28°57′36.21"	87°26′09.50"	92	1887	822
RegionI	TP-S-1511-18	28°54′20.55"	87°25′37.26"	102	3348	1278
RegionI	TP-S-1511-21	28°40′07.34"	86°07′59.56"	101	1387	1079
RegionI	TP-S-1511-22	28°31′09.09"	86°10′06.25"	226	2582	2201
RegionI	TP-S-1511-23	28°38′46.70"	86°04′53.89"	105	968	1072
RegionI	TP-S-1511-24	28°45′20.85"	85°39′30.23"	109	816	1042
RegionI	TP-S-1511-25	28°54′12.32"	85°23′56.49"	35	601	932
RegionI	TP-S-1511-26	28°55′43.29"	85°23′56.49"	65	521	759
RegionI	TP-S-1511-27	29°49′40.69"	92°20′41.66"	323	5659	3587
RegionI	TP-S-1511-28	29°37′52.95"	94°37′31.37"	55	2050	952
RegionI	TP-S-1511-29	29°36′34.35"	94°39′07.00"	27	747	256
RegionI	TP-S-1511-30	29°46′05.05"	95°41′53.40"	128	1046	1343
RegionI	TP-S-1511-31	29°15′46.05"	96°56′12.09"	238	2001	2117
RegionI	TP-S-1511-32	29°18′57.18"	97°01′51.04"	22	491	202
RegionI	LWQ1	31°13′15.18"	96°34′25.25"	71	3538	1735
RegionI	24K	30°59′26.26"	91°40′42.11"	114	876	877
RegionI	NMC	30°45′03.47"	91°01′23.56"	46	900	601
regionII	MD1	34°51′46.79"	98°09′54.84"	231	5002	3123
regionII	TGL	32°53′52.63"	91°55′15.56"	90	2722	1014
regionII	RYS 日月山	36°26′24.94"	101°06′41.38"	418	12676	8923
regionII	TP-S-1511-33	33°28′22.74"	97°14′32.89"	846	13880	17468
regionII	TP-S-1511-34	33°36′47.25"	97°11′22.76"	211	6428	4009
regionII	TP-S-1511-35	34°06′37.46"	97°39′04.35"	296	5466	4217
regionII	TP-S-1511-36	35°02′51.84"	98°39′00.67"	172	3279	3098
regionII	TP-S-1511-37	35°22′27.94"	99°17′21.59"	293	5238	7373
regionII	TP-S-1511-38	35°23′39.24"	99°18′28.07"	234	2840	4122
regionII	TP-S-1511-39	35°30′28.45"	99°30′29.71"	158	3657	2895
regionIII	LHG	39°29′49.46"	96°31′20.72"	255	1746	6250
regionIII	LHG	39°30′16.5"	96°30′23.07"	224	1688	3745
regionIII	LHG	39°31′43.41"	96°30′17.5"	120	1201	1282
regionIII	LHG	39°32′42.38"	96°29′54.76"	7	159	130
regionIII	LHG	39°34′13.09"	96°28′10.04"	99	1078	881

regionIII	LHG	39°35′11.44"	96°31′20.72"	45	672	569
regionIII	LHG	39°37′04.85"	96°26′53.43"	6	140	106
regionIII	LHG	39°37′45.46"	96°24′18.27"	39	463	293
regionIII	LHG	39°39′47.01"	96°21′12.15"	61	837	593
regionIII	LHG	39°42′39.12"	96°15′42.35"	76	1753	988