SNOW COVER ATLAS OF SIKKIM

Sub basins: Sikkim, Tista and Rangit

(A Joint Project of Indian Space Research Organization and Ministry of Environment and Forests, Govt. of India)

Year: 2012-13







Space Applications Centre (ISRO) Ahmedabad-380015

& Sikkim State Council of Science & Technology Govt. of Sikkim, Gangtok - 737101 February 2014

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SPACE APPLICATIONS CENTRE (ISRO), AHMEDABAD - 380015

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Abstract	This atlas gives sub-basin-wise distribution of snow cover in the Tista basin from October 2012 to June 2013. The sub-basins included in this report are Tista, and Rangit. The areal extent of snow cover was estimated in fully automatic mode using Normalized Difference Snow Index (NDSI) based algorithm. For this purpose AWiFS sensor of Resourcesat satellite was used. This atlas gives snow cover products, statistics and seasonal snow depletion curve. It is expected that this data will be useful for hydrological and climatological applications.		
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1. Introduction

Snow covers almost 40 per cent of the Earth's land surface during Northern Hemisphere winter. This makes albedo and areal extent of snow as important component of the Earth's radiation balance (Foster and Chang, 1993). In addition, large areas in the Himalayas are also covered by snow during winter. Area of snow can change significantly during winter and spring. This can affect stream flow for rivers originating in the higher Himalayas. All the rivers originating from higher Himalayas receive almost 30-50 % of annual flow from snow and glacier melt run off (Agarwal et al., 1983). In addition, snow pack ablation is highly sensitive to climatic variation. Increase in atmospheric temperature can influence snowmelt and stream runoff pattern (Kulkarni et al., 2002). Therefore, mapping of the areal extent and reflectance of snow are important parameter for various climatological and hydrological applications. In addition, extent of snow cover can also be used as input for numerous other applications.

Mapping and monitoring of seasonal snow cover using field methods are normally very difficult in a mountainous terrain, like the Himalayas. Therefore, remote sensing techniques have been extensively used for snow cover monitoring. Snow cover monitoring using satellite images were started by using the TIROS-1 satellite from April 1960 (Singer and Popham 1963). Since then, the potential for operational satellite-based mapping has been enhanced by the development of higher temporal frequency and satellite sensors with higher spatial resolution. In addition, satellites with better radiometric resolutions, such as NOAA have been used successfully for snow mapping (Hall et al., 1995). This is possibly due to the distinct spectral reflectance characteristics of snow in visible and near infrared regions. India has launched series of Indian Remote Sensing satellite (IRS) to study the different earth resources. Previously launched satellites have flown with many sensors having different spatial, temporal and spectral resolutions. Recently launched RESOURCESAT-1 satellite has three different sensors namely LISS III, LISS IV & AWiFS with different spatial, temporal and spectral resolutions as desired for different applications. AWiFS (Advanced Wide Field Sensor) is an advanced version of earlier Indian satellite sensor WiFS (Wide Field Sensor) with improved spectral and spatial resolutions maintaining the same repetivity. There are a series of other polar orbiting satellites, like Landsat, NOAA and MODIS etc., which have provided information on different aspects of snow. Geo-stationary satellites also proved their utility in mapping/monitoring the snow-covered regions. Information generated from satellite observations has been extensively used for snowmelt runoff modeling (Kulkarni et al., 1997).

2. Study Area:

This Atlas gives distribution of snow cover in Sikkim state and two sub basins of the Tista basin. These are Tista and Rangit sub basins. Locations of these basins are shown in Figure 1.

3. Data used:

AWiFS, Resourcesat data from October 2012 to June 2013 were used in this study.

4. Normalised Difference Snow Index (NDSI):

In general, the reflectance of snow is high at the red end of the visible spectrum. It tends to decline in the near-infrared region until 1090 nm, where slight gain in reflectance occurs and gives a minor peak at approximately 1090 to 1100 nm. One of the important difficulties in snow cover monitoring is the presence of cloud cover. Cloud has strong reflectivity in visible, NIR and SWIR regions while snow absorbs in SWIR, and this difference can be utilized for snow/cloud discrimination. Normalized Difference Snow Index (NDSI) utilize the normalized ratio of green and SWIR and is used as an automated approach for snow mapping addressing the shadow and cloud problems in snow bound areas.

Normalized Difference Snow Index was calculated using the ratio of green wavelength (band 2) and SWIR (band 5) of AWiFS sensor:

Normalized Difference Snow Index (NDSI)=(band2-band5)(band2+band5)..1

To estimate NDSI, DN numbers were converted into reflectance. This involves conversion of digital numbers into the radiance values, known as sensor calibration, and then estimation of reflectance from these radiance values. Various parameters needed for estimating spectral reflectance are maximum and minimum radiances and mean solar exo-atmospheric spectral irradiances in the satellite sensor bands, satellite data acquisition time, solar declination, solar zenith and solar azimuth angles, mean Earth-Sun distance etc. (Markham and Barker, 1987; Srinivasulu and Kulkarni, 2004).

5. Snow cover monitoring algorithm

An algorithm is developed to provide changes in the areal extent of snow (Kulkarni et. al., 2006). Snow extent is estimated at an interval of 5-days and 10-days, depending upon availabilities of AWiFS data. In 5-daily product, snow extent is generated scene-wise. In this product, snow and cloud extents are given. Estimate of cloud is important because, at times, snow is covered by cloud and this may be classified as non-snow area, leading to erroneous conclusions. In 10-daily product, three scenes are analyzed, if available. For example, 10 March product data of 5, 10 and 15 March was used. If any pixel is identified as snow on any one date then this pixel will be classified as snow on final product. This provides snow cover at an interval of 10 days, an important requirement in hydrological applications. Therefore, this product is generated basin-wise. Since this product is using three scenes, probability becomes high that at least in one scene, pixel may be cloud-free and this helps in overcoming problem associated with snow under cloud cover. Since three consecutive cloud free scenes are not available, two corresponding data scenes have been merged to analyze maximum snow cover. This gives a composite snow cover extent for the mean date. For instance, 12 October scene is the product of 7 and 17 October. Differentiation between water and snow is difficult using NDSI image. In addition, separation of snow and water pixels is also difficult based on reflectance due to mountain shadow. Therefore, in the present algorithm, water bodies are marked in pre-winter season and are masked in the final products during winter. Flow diagram of the algorithm is given in Figure 2.

6. Results and discussions

In this atlas, state and basin-wise snow cover statistics, maps, and seasonal depletion curves have been provided from October 2012 to June 2013. Snow ablation pattern was estimated for Sikkim state, Tista and Rangit basins in the Sikkim Himalaya. In Sikkim, maximum areal extent of 60% snow cover was observed in 18thFebruary 2013. The highest areal snow extent of 69% in Tista basin and 27% in Rangit basins observed in the same day of the month. In Sikkim, snow extent of 48% was observed in the month of February which was reduced to 40% in March and 26% in the month of April 2013. The lowest snow recorded in the month of October-December in 2012 and June 2013 in Sikkim. In Tista basin lowest snow cover was observed 14% in June 2013. In Rangit basin, the highest month wise snow of 18% was recorded in February 2013 and the lowest 2% was recorded in the month of June 2013 and 3% each during October- December 2012. The highest snow cover of 27% was recorded in 18th February 2013 and followed by 26% in 23rd March 2013.

Acknowledgements

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Figure 1: Location map of Tista and Rangit sub-basins (Part of Tista basin)



Figure 2: Algorithm for snow cover mapping using AWiFS data

SIKKIM

AREAL EXTENT OF SNOW (5 DAILY)

STATE NAME: SIKKIM

AREA: 7096 sq km

		Snow				Snow	Snow	
	Date of	Cover	Snow		Date of	Cover	cover	
S No	Imagery	(sq km)	cover (%)	S No	Imagery	(sq km)	(%)	
OCTOBER 2012								
1	06-Oct-1(C)	845	12	2	07-Oct-12(PC)	743	10	
3	16-Oct-12(C)	1703	24	4	18-Oct-12(C)	744	10	
5	19-Oct-12(PC)	1288	18	6	23-Oct-12(PC)	1097	15	
7	26-Oct-12(C)	1597	22	8	28-Oct-12	1343	19	
9	30-Oct-12	1531	22					
			NOVEMBE	R 2012				
10	04-Nov-12(PC)	1338	19	11	05-Nov-12(PC)	1282	18	
12	09-Nov-12(PC)	1296	18	13	11-Nov-12(PC)	692	10	
14	12-Nov-12(PC)	758	11	15	14-Nov-12(C)	1354	19	
16	16-Nov-12	1018	14	17	17-Nov-12	827	12	
18	21-Nov-12	868	12	19	23-Nov-12(PC)	1102	16	
20	26-Nov-12	1281	18	21	28-Nov-12(PC)	1372	19	
			DECEMBE	R 2012			-	
22	01-Dec-12(PC)	987	14	23	03-Dec-12	1225	17	
24	05-Dec-12	938	13	25	06-Dec-12	745	10	
26	08-Dec-12	1024	14	27	10-Dec-12(PC)	731	10	
28	15-Dec-12	2259	32	29	17-Dec-12	1985	28	
30	18-Dec-12	1639	23	31	20-Dec-12(PC)	1176	17	
32	22-Dec-12(PC)	1383	19	33	23-Dec-12	1273	18	
34	27-Dec-12	1212	17	35	29-Dec-12	1015	14	
36	30-Dec-12	809	11					
			JANUARY	Z 2013				
37	01-Jan-13	1095	15	38	03-Jan-13(C)	634	9	
39	06-Jan-13	1195	17	40	08-Jan-13(C)	936	13	
41	13-Jan-13(C)	936	13	42	15-Jan-13(PC)	1059	15	
43	20-Jan-13(PC)	3664	52	44	22-Jan-13(PC)	2474	35	
45	23-Jan-13	2467	35	46	27-Jan-13	2100	30	
47	28-Jan-13	1884	27	48	30-Jan-13	2260	32	
			FEBRUAR	Y 2013				
49	04-Feb-13	2811	40	50	08-Feb-13	3033	43	
51	13-Feb-13	2003	28	52	18-Feb-13(PC)	4233	60	
53	21-Feb-13	3761	53	54	23-Feb-13(PC)	3798	54	
55	25-Feb-13	3679	52	56	26-Feb-13	3751	53	
MARCH 2013								
57	04-Mar-13	3061	43	58	07-Mar-13(PC)	2238	32	
59	09-Mar-13(PC)	2551	36	60	11-Mar-13(PC)	2404	34	
61	14-Mar-13(PC)	2899	41	62	16-Mar-13(C)	1964	28	
63	23-Mar-13(C)	3702	52	64	24-Mar-13	2798	39	
65	26-Mar-13(C)	3664	52					
	APRIL 2013							

66	04-Apr-13(C)	942	13	67	07-Apr-13(PC)	2338	33
68	13-Apr-13(PC)	2709	38	69	14-Apr-13(PC)	1267	18
70	26-Apr-13(PC)	2360	33	71	28-Apr-13(C)	1283	18
MAY 2013							
72	01-May-13(C)	1866	26	73	03-May-13(C)	2633	37
JUNE 2013							
74	11-June-13(PC)	817	12				

COMPOSITE SNOW COVER EXTENT OF SIKKIM

STATE NAME: SIKKIM

AREA: 7096 sq km

S No	Data used	Mean Date	Snow cover (sa km)	Snow cover
I		October 2012	(54 811)	/0
1	07-Oct-12	05.0 + 12	1055	15
1	16-Nov-12	05-Oct-12	1055	15
2	19-Oct-12	15-Oct-12	1288	18
	23-Oct-12	25-Oct-12	1461	21
3	28-Oct-12			
	29-Oct-12			
		November 2012		
	04-Nov-12	05-Nov-12		
4	05-Nov-12		1396	20
	09-Nov-12			
5	16-Nov-12	15-Nov-12	1018	14
6	21-Nov-12	25-Nov-12	868	12
		December 2012		
7	03-Dec-12	05-Dec-12	1240	17
	05-Dec-12			
0	15-Dec-12		207 (22
8	1/-Dec-12	15-Dec-12	2376	33
	18-Dec-12			
0	27-Dec-12 20 Dec 12	25 D - 12	1308	10
9	29-Dec-12 30 Dec 12	23-Dec-12		10
	50-DCC-12	January 2013		
10	01-Jan-13	oundary 2010		10
10	06-Jan-13	05-Jan-13	1327	19
11	20-Jan-13	25-Jan-13	3654	51
	23-Jan-13			
12	27-Jan-13	25-Jan-13	2560	36
	30-Jan-13			
		February 2013		
12	04-Feb-13	05 Ech 12	2170	40
15	08-Feb-13	05-Feb-13	5472	49
14	18-Feb-13	15-Feb-13	4233	60
15	25-Feb-13	25-Feb-13	3679	52
		March 2013		
16	04-Mar-13	05-Mar-13	3061	43
17	14-Mar-13	15-Mar-13	2221	16
17	24-Mar-13		3231	46
18	24-Mar-13	25-Mar-13	2798	39
		April 2013		
19	07-Apr-13	05-Apr-13	2338	33
20	13-Apr-13	15-Apr-13	2709	38
I	*	May 2013		•

21	3-May-13 26-April-13	5-May-2013	2633	37		
June 2013						
22	11-June-13 6-December-12	15-June-13	817	12		

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE



SNOW COVER MAPS





DATA USED 07 OCTOBER 2012



DATA USED 19 OCTOBER 2012







DATA USED 4 NOVEMBER 2012 5 NOVEMBER 2012 9 NOVEMBER 2012



DATA USED 16 NOVEMBER 2012







DATA USED 3 DECEMBER 2012 5 DECEMBER 2012



DATA USED

15 DECEMBER 2012 17 DECEMBER 2012 18 DECEMBER 2012







DATA USED 1 JANUARY 2013 6 JANUARY 2013



DATA USED 20 JANUARY 2013







DATA USED

4 FEBRUARY 2013 8 FEBRUARY 2013



DATA USED 18 FEBRUARY 2013





COMPOSITE SNOW COVER MAP (10 DAILY): TISTA BASIN



DATA USED 4 MARCH 2013



DATA USED 14 MARCH 2013







DATA USED 7 APRIL 2013



DATA USED 13 APRIL 2013







DATA USED 3 MAY 2013 26 APRIL 2013



DATA NOT AVAILABLE




COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA NOT AVAILABLE



DATA NOT AVAILABLE 11 JUNE 2013 6 NOVEMBER 2013



TISTA BASIN

AREAL EXTENT OF SNOW (5 DAILY)

AREA: 5466 sq km

BASIN NAME: TISTA

04-Apr-13(C)

67

878

		Snow	Snow			Snow	Snow
		Cover	cover			Cover	cover
S No	Date	(sq km)	(%)	S No	Date	(sq km)	(%)
		1	OCTOB	ER 2012			1
1	06-Oct-12(PC)	796	15	2	07-Oct-12(PC)	700	13
3	16-Oct-12(C)	1642	30	4	18-Oct-12(C)	706	13
5	19-Oct-12(PC)	1245	23	6	23-Oct-12(PC)	1054	19
7	26-Oct-12(C)	1532	28	8	28-Oct-12	1308	24
9	30-Oct-12	1477	27				
	l		NOVEMI	BER 2012			1
10	04-Nov-12(PC)	1283	23	11	05-Nov-12(PC)	1210	22
12	09-Nov-12(PC)	1240	23	13	11-Nov-12(PC)	656	12
14	12-Nov-12(PC)	724	13	15	14-Nov-12(C)	1309	24
16	16-Nov-12	973	18	17	17-Nov-12	/84	14
18	21-Nov-12	826	15	19	23-Nov-12(PC)	1050	19
20	26-Nov-12	1236	23	21	28-Nov-12(PC)	1312	24
		0.15	DECEME	SER 2012	02 D 12	1170	21
22	01-Dec-12(PC)	945	17	23	03-Dec-12	1173	21
24	05-Dec-12	898	16	25	06-Dec-12	708	13
26	08-Dec-12	977	18	27	10-Dec-12(PC)	692	13
28	15-Dec-12	2187	40	29	17-Dec-12	1918	35
30	18-Dec-12	1579	29	31	20-Dec-12(PC)	1221	22
32	22-Dec-12(PC)	1330	24	33	23-Dec-12	1139	21
34	27-Dec-12	1161	21	35	29-Dec-12	970	18
36	30-Dec-12	772	14				
		-	JANUAI	RY 2013			
37	01-Jan-13	1046	19	38	03-Jan-13(C)	597	11
39	06-Jan-13	1144	21	40	08-Jan-13(C)	901	16
41	13-Jan-13(C)	902	17	42	15-Jan-13(PC)	1011	18
43	20-Jan-13(PC)	3373	62	44	22-Jan-13(PC)	2398	44
45	23-Jan-13	2367	43	46	27-Jan-13	2034	37
47	28-Jan-13	1813	33	48	30-Jan-13	2185	40
			FEBRUA	RY 2013			
49	04-Feb-13	2470	45	50	08-Feb-13	2813	51
51	13-Feb-13	1887	35	52	18-Feb-13(PC)	3785	69
53	21-Feb-13	3469	63	54	23-Feb-13(PC)	3487	64
55	25-Feb-13	3368	62	56	25 Feb 13	3/66	63
55	25-100-15	5500	MARC	H 2013	20-100-13	5400	05
57	04-Mar-13	2881	53	58	$07_{Mar} 13(PC)$	2079	38
50	0 - Mar 13	2001		60	11_{Mar} 13(PC)	2019	40
61	1/ Mar 12(DC)	2715	 50	62	16 Mar 12(C)	1820	32
62	$\frac{14-101a1-15(FC)}{23 M_{or}}$	2713	50	64	$24 M_{or} 12$	2604	10
65	25 - 101a1 - 15(C)	3204 1529	200	66	24-ivial-15	2004	40
03	20-1/101 - 10(C)	1338	20 A DD II	2013	04-Apr-13(C)	0/0	10

16

68

07-Apr-13(PC)

2196

40

69	13-Apr-13(PC)	2492	46	70	14-Apr-13(PC)	1207	22
71	26-Apr-13(PC)	2148	39	72	28-Apr-13(C)	1150	21
			MAY	2013			
73	1-May-13(C)	1153	21	74	3-May-13(C)	2343	43
			JUNE	2013			
75	11-June-13(PC)	778	14				

COMPOSITE SNOW COVER EXTENT OF SIKKIM

BASIN NA	ME: TISTA		ARE	A: 5466 sq km
~			Snow cover	Snow cover
S No	Data used	Mean Date	(sq km)	%
		October 2012	2	T
1	07-Oct-12	05-Oct-12	1004	18
1	16-Nov-12	05-001-12	1004	10
2	19-Oct-12	15-Oct-12	1245	23
	23-Oct-12			
3	28-Oct-12	25-Oct-12	1410	26
	29-Oct-12			
		November 201	12	
	04-Nov-12			
4	05-Nov-12	05-Nov-12	1323	24
	09-Nov-12			
5	16-Nov-12	15-Nov-12	826	15
6	21-Nov-12	25-Nov-12	973	18
		December 201	2	
7	03-Dec-12	05 Day 12	1100	22
/	05-Dec-12	05-Dec-12	1190	22
	15-Dec-12			
8	17-Dec-12	15-Dec-12	2292	42
	18-Dec-12			
	27-Dec-12			
9	29-Dec-12	25-Dec-12	1252	23
	30-Dec-12			
		January 2013	3	I
10	01-Jan-13		1050	22
10	06-Jan-13	05-Jan-13	1270	23
11	20-Jan-13	25-Jan-13	3373	62
	23-Jan-13			
12	27-Jan-13	25-Jan-13	2457	45
	30-Jan-13			
		February 201	3	
13	04-Feb-13	05-Feb-13	3121	57
15	08-Feb-13	03-1-60-13	5121	57
14	18-Feb-13	15-Feb-13	3785	69
15	25-Feb-13	25-Feb-13	3368	62
		March 2013		
16	04-Mar-13	05-Mar-13	2881	53
17	14-Mar-13	15-Mar-13	2973	5/
1/	24-Mar-13	15-14141-15	2715	
18	24-Mar-13	25-Mar-13	2604	48
·		April 2013		
19	07-Apr-13	05-Apr-13	2196	40
20	13-Apr-13	15-Apr-13	2492	46
		May 2013		

21	3-May-2013 26-April-2013	5-May-2013	2343	43	
June 2013					
22	11-June-13 6-December-12	15-Nov-13	778	14	







SNOW COVER MAPS





DATA USED 07 OCTOBER 2012



DATA USED 19 OCTOBER 2012







DATA USED 4 NOVEMBER 2012 5 NOVEMBER 2012 9 NOVEMBER 2012











DATA USED

3 DECEMBER 2012 5 DECEMBER 2012



DATA USED

15 DECEMBER 2012 17 DECEMBER 2012 18 DECEMBER 2012









DATA USED 1 JANUARY 2013 6 JANUARY 2013

DATA USED 20 JANUARY 2013







DATA USED 4 FEBRUARY 2013 8 FEBRUARY 2013



DATA USED 18 FEBRUARY 2013















DATA USED 3 MAY 2013 26 APRIL 2013



DATA NOT AVAILABLE







DATA NOT AVAILABLE



DATA USED

11 JUNE 2013 6 NOVEMBER 2013



RANGIT BASIN

AREAL EXTENT	OF SNOW	(5 DAILY)
--------------	---------	-----------

BASIN NAME: RANGIT AREA: 1630sq km							
		Snow				Snow	Snow
		Cover	Snow			Cover	cover
S No	Date	(sq km)	cover (%)	S No	Date	(sq km)	(%)
	·		OCTOBI	ER 2012			
1	06-Oct-12(C)	47	3	2	07-Oct-12(PC)	42	3
3	16-Oct-12(C)	58	4	4	18-Oct-12(C)	37	2
5	19-Oct-12(C)	43	3	6	23-Oct-12(PC)	41	3
7	26-Oct-12(PC)	63	4	8	28-Oct-12	34	2
9	30-Oct-12	53	3				
			NOVEMB	ER 201	2		
10	04-Nov-12(PC)	53	3	11	05-Nov-12(PC)	71	4
12	09-Nov-12(PC)	55	3	13	11-Nov-12(PC)	35	2
14	12-Nov-12(PC)	35	2	15	14-Nov-12(C)	44	3
16	16-Nov-12	46	3	17	17-Nov-12	41	3
18	21-Nov-12	41	2	19	23-Nov-12	51	3
20	26-Nov-12(PC)	45	3	21	28-Nov-12(PC)	58	4
			DECEMB	ER 201	2		-
22	01-Dec-12	42	3	23	03-Dec-12	51	3
24	05-Dec-12	41	2	25	06-Dec-12	37	2
26	08-Dec-12(PC)	47	3	27	10-Dec-12(PC)	38	2
28	15-Dec-12	72	4	29	17-Dec-12	65	4
30	18-Dec-12	61	4	31	20-Dec-12	44	3
32	22-Dec-12	52	3	33	23-Dec-12	52	3
34	27-Dec-12	49	3	35	29-Dec-12	45	3
36	30-Dec-12	38	2				
			JANUAF	RY 2013			-
37	01-Jan-13	48	3	38	03-Jan-13(PC)	35	2
39	06-Jan-13	51	3	40	08-Jan-13(PC)	34	2
41	13-Jan-13(PC)	34	2	42	15-Jan-13(PC)	47	3
43	20-Jan-13	287	18	44	22-Jan-13(PC)	71	4
45	23-Jan-13	98	6	46	27-Jan-13(PC)	64	4
47	28-Jan-13	71	4	48	30-Jan-13	76	5
			FEBRUA	RY 201	3		1
49	04-Feb-13	338	21	50	08-Feb-13	217	13
51	13-Feb-13(PC)	115	7	52	18-Feb-13	446	27
53	21-Feb-13	289	18	54	23-Feb-13(PC)	308	19
55	21-Feb-13	309	10	56	25-Feb-13(PC)	281	17
- 55	25-100-15	509	19 MADCI	H 2012	20-100-13(FC)	201	1/
57	0.4-Mar $13(PC)$	177	11	58	$07_{\rm Mar}$ 13(PC)	158	10
50	$\frac{0.9}{100} \text{ Mar} 12(\text{DC})$	82	5	60	$\frac{0.7 - 101 - 10(\Gamma C)}{11 \text{ Mar} 12(C)}$	100	10
59	14 Mor 12(PC)	0J 101	J 11	62	11 - 101a1 - 15(C)	170	12 0
62	14 - 1V1ar - 15(PC) 22 Mar 12	181	26	64	10-1v1ar-13(C)	102	ð 12
05	25 - 101 M = 12(0)	41/	20	04	24-1v1ar-13	192	12
65	20-1/101 - 13(C)	91		2012			
		~~~	APRIL	2013		100	0
66	04-Apr-13(C)	60	4	6/	$\downarrow$ 0/-Apr-13(PC)	139	9

68	13-Apr-13(PC)	212	13	69	14-Apr-13(PC)	57	3
70	26-Apr-13(C)	209	13	71	28-Apr-13(PC)	132	8
			MAY	2013			
72	1-May-13(C)	233	14	73	3-May-13	291	18
			JUNE	2013			
74	11-June-2013	38	2				

## COMPOSITE SNOW COVER EXTENT OF SIKKIM

S No         Data used         Mean Date (sq km)         Snow cover (sq km)         Snow cover %           1         07-Oct-12 16-Nov-12         05-Oct-12         52         3           2         19-Oct-12         15-Oct-12         43         3           2         19-Oct-12         15-Oct-12         43         3           2         23-Oct-12         25-Oct-12         50         3           29-Oct-12         25-Oct-12         50         3           29-Oct-12         05-Nov-12         66         4           09-Nov-12         05-Nov-12         41         2           5         16-Nov-12         05-Nov-12         41         2           7         03-Dec-12         05-Dec-12         52         3           8         17-Dec-12         05-Dec-12         84         5           18-Dec-12         15-Dec-12         84         5           9         27-Dec-12         25-Dec-12         54         3           10         01-Jan-13         05-Jan-13         287         18           11         20-Jan-13         25-Jan-13         100         6           30-Jan-13         05-Feb-13         349         21 <th>BASIN N</th> <th>AME: RANGIT</th> <th></th> <th>ARI</th> <th>EA: 1630sq km</th>	BASIN N	AME: RANGIT		ARI	EA: 1630sq km
S No         Data used         Mean Date         (sq km)         %           October 2012           1 $07-\text{Oct-12}$ $05-\text{Oct-12}$ $52$ $3$ 2 $19-\text{Oct-12}$ $15-\text{Oct-12}$ $43$ $3$ 3 $23-\text{Oct-12}$ $25-\text{Oct-12}$ $50$ $3$ 3 $23-\text{Oct-12}$ $25-\text{Oct-12}$ $50$ $3$ 29-Oct-12 $25-\text{Oct-12}$ $50$ $3$ 6 $21-\text{Nov-12}$ $05-\text{Nov-12}$ $46$ $3$ 6 $21-\text{Nov-12}$ $25-\text{Nov-12}$ $41$ $2$ 7 $03-\text{Dec-12}$ $05-\text{Dec-12}$ $52$ $3$ 8 $15-\text{Dec-12}$ $15-\text{Dec-12}$ $84$ $5$ 18-Dec-12 $15-\text{Dec-12}$ $84$ $5$ 9 $29-\text{Dec-12}$ $25-\text{Jan-13}$ $287$ $18$ 10 $01-\text{Jan-13}$ $05-\text{Jan-13}$ $287$ $18$ 12 $23-\text{Jan-13}$ $25-\text{Jan-13}$ $100$ $6$				Snow cover	Snow cover
October 2012           1         07-Oct-12 16-Nov-12         05-Oct-12         52         3           2         19-Oct-12         15-Oct-12         43         3           3         23-Oct-12         25-Oct-12         50         3           29-Oct-12         25-Oct-12         50         3           29-Oct-12         November 2012         4         04-Nov-12         05-Nov-12         66         4           09-Nov-12         05-Nov-12         46         3         6         21-Nov-12         41         2           5         16-Nov-12         05-Nov-12         41         2         2           7         03-Dec-12         05-Dec-12         52         3           8         17-Dec-12         05-Dec-12         54         5           9         27-Dec-12         25-Dec-12         54         3           9         27-Dec-12         25-Jan-13         287         18           10         01-Jan-13         05-Jan-13         287         18           12         27-Jan-13         25-Jan-13         100         6           30-0-Jan-13         05-Feb-13         349         21           13	S No	Data used	Mean Date	(sq km)	%
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1       16-Nov-12       05-Oct-12       32       3         2       19-Oct-12       15-Oct-12       43       3         3       23-Oct-12       25-Oct-12       50       3         3       28-Oct-12       25-Oct-12       50       3         29-Oct-12       05-Nov-12       66       4 $04$ -Nov-12       05-Nov-12       66       4 $09$ -Nov-12       15-Nov-12       46       3         5       16-Nov-12       25-Nov-12       41       2         December 2012         7       03-Dec-12       05-Dec-12       52       3         8       17-Dec-12       15-Dec-12       84       5         9       27-Dec-12       15-Dec-12       84       5         9       29-Dec-12       25-Dec-12       54       3         10       01-Jan-13       05-Jan-13       287       18         12       27-Jan-13       25-Jan-13       100       6         30-Jan-13       05-Feb-13       349       21         14       18-Feb-13       05-Feb-13       349       21         14       18-Feb-13       05-Mar-13       177<	1	07-Oct-12	05-Oct-12	52	3
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12       27-541-13       25-541-13       100       0         30-Jan-13       February 2013         13       04-Feb-13       05-Feb-13       349       21         14       18-Feb-13       15-Feb-13       446       27         15       25-Feb-13       25-Feb-13       309       19         March 2013         16       04-Mar-13       05-Mar-13       177       11         16       04-Mar-13       05-Mar-13       177       11         17       14-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13	12	23-Jall-13 27_Jan_13	25-Ian-13	100	6
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13       04-Feb-13 08-Feb-13       05-Feb-13       349       21         14       18-Feb-13       15-Feb-13       446       27         15       25-Feb-13       25-Feb-13       309       19         March 2013         16       04-Mar-13       05-Mar-13       177       11         16       04-Mar-13       05-Mar-13       177       11         17       14-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13	I	50 Juli 15	February 201	3	
13       08-Feb-13       05-Feb-13       349       21         14       18-Feb-13       15-Feb-13       446       27         15       25-Feb-13       25-Feb-13       309       19         March 2013         16       04-Mar-13       05-Mar-13       177       11         17       14-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13		04-Feb-13	1 051 dui y 201	•	
14       18-Feb-13       15-Feb-13       446       27         15       25-Feb-13       25-Feb-13       309       19         March 2013         16       04-Mar-13       05-Mar-13       177       11         17       14-Mar-13 24-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13	13	08-Feb-13	05-Feb-13	349	21
15         25-Feb-13         25-Feb-13         309         19           March 2013         March 2013         11         11           16         04-Mar-13         05-Mar-13         177         11           17         14-Mar-13         05-Mar-13         257         16           18         24-Mar-13         25-Mar-13         192         12           April 2013           19         07-Apr-13         05-Apr-13         139         9           20         13-Apr-13         15-Apr-13         212         13	14	18-Feb-13	15-Feb-13	446	27
March 2013           16         04-Mar-13         05-Mar-13         177         11           17         14-Mar-13         15-Mar-13         257         16           18         24-Mar-13         25-Mar-13         192         12           April 2013           19         07-Apr-13         05-Apr-13         139         9           20         13-Apr-13         15-Apr-13         212         13	15	25-Feb-13	25-Feb-13	309	19
16       04-Mar-13       05-Mar-13       177       11         17       14-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         May 2013	10	2010010	March 2013		
10       04 Mar 15       05 Mar 15       177       11         17       14-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13	16	04-Mar-13	05-Mar-13	177	11
17       14-Mar-13 24-Mar-13       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13	10	04 10101 15	05 10101 15	1//	11
17       14 Mar 15       15-Mar-13       257       16         18       24-Mar-13       25-Mar-13       192       12         April 2013         19       07-Apr-13       05-Apr-13       139       9         20       13-Apr-13       15-Apr-13       212       13		14-Mar-13			
18         24-Mar-13         25-Mar-13         192         12           April 2013           19         07-Apr-13         05-Apr-13         139         9           20         13-Apr-13         15-Apr-13         212         13	17	24-Mar-13	15-Mar-13	257	16
April 2013         19         07-Apr-13         05-Apr-13         139         9           20         13-Apr-13         15-Apr-13         212         13	18	24-Mar-13	25-Mar-13	192	12
19         07-Apr-13         05-Apr-13         139         9           20         13-Apr-13         15-Apr-13         212         13	10	2	Anril 2013		12
20         13-Apr-13         15-Apr-13         212         13           May 2013         May 2013         May 2013         May 2013         May 2013	19	07-Apr-13	05-Apr-13	139	9
<u> </u>	20	13-Anr-13	15-Anr-13	212	13
	20	15 1101-15	<u> </u>	<i>L</i> 1 <i>L</i>	15

21	3-May-2013 26-April-2013	05-May-2013	291	18	
June 2013					
22	11-June-13 6-Dec-12	15-June-13	38	2	







# **SNOW COVER MAPS**




DATA USED 07 OCTOBER 2012 16 NOVEMBER 2012



DATA USED 19 OCTOBER 2012







DATA USED 4 NOVEMBER 2012 5 NOVEMBER 2012 9 NOVEMBER 2012



DATA USED 16 NOVEMBER 2012







DATA USED 3 DECEMBER 2012 5 DECEMBER 2012











DATA USED 1 JANUARY 2013 6 JANUARY 2013



DATA USED 20 JANUARY 2013







DATA USED 4 FEBRUARY 2013 8 FEBRUARY 2013



DATA USED 18 FEBRUARY 2013







DATA USED 4 MARCH 2013



#### DATA USED 14 MARCH 2013 24 MARCH 2013











DATA USED 3 MAY 2013 26 APRIL 2013



DATA NOT AVAILABLE







DATA NOT AVAILABLE



### DATA USED 11 JUNE 2013

6 NOVEMBER 2013

