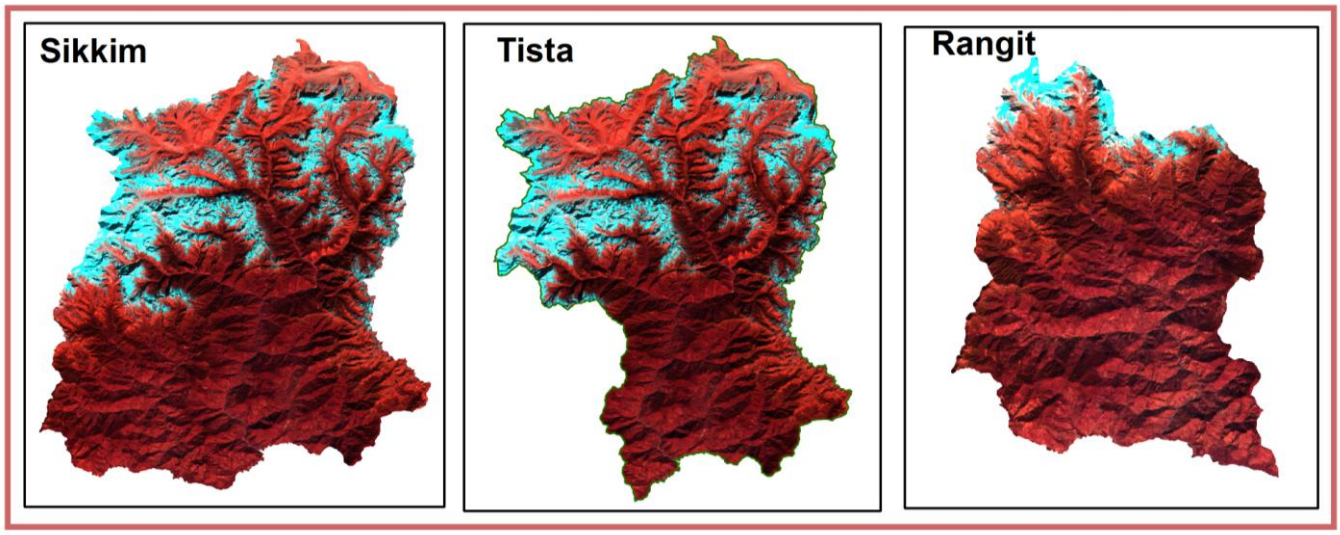
SNOW COVER ATLAS OF SIKKIM

Sub basins: Sikkim, Tista and Rangit

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

Year: 2013-2014



Space Applications Centre (ISRO)
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&
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Abstract	This atlas gives subbasin-wise distribution of snow cover in the Tista basin from October 2013 to June 2014. The subbasins 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.
Key words	Snow cover, NDSI, AWiFS, depletion curve, Tista, and Rangit basins.
Security Classification	Unrestricted
Distribution	Among concerned

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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 data from October 2013 to June 2014 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:

$$Normalized\,Difference\,Snow\,Index(NDSI) = (band2 - band5)/(band2 + band5) \quad ..(1)$$

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 2013 to June 2014. Snow ablation pattern was estimated for Sikkim state, Tista and Rangit basins in the Sikkim Himalaya. In Sikkim, maximum areal extent of 52% snow was observed in the month of May 2014 in cloud cover data of 29 May 2014, and 50%

snow was observed in cloud free data in the month of February 2014. The highest snow extent of 59 % observed in Tista basin in the months of February, and March with cloud free data and in the month of June in cloudy data. In Rangit basins, maximum areal extent of snow of 28% and 23% observed in the month of May 2014 and October 2013 with cloudy data and 21% snow with cloud free data in February 2014 respectively. In Sikkim, the lowest snow recorded in the month of October with 9% snow followed by 25% snow in December in cloud free data. Similarly, the lowest areal extent of snow of 10% in Tista basin and 3% in Rangit basin recorded in the same month of October 2013.

Acknowledgements

This investigation was jointly carried out by Space Applications Centre, Ahmedabad and Sikkim State council of Science and Technology, Gangtok. The project was jointly financed by Ministry of Environment, Forest and Climate Change (MoEF&CC) and Department of Space (DOS). The authors are grateful to Shri Tapan Mishra, Director, Space Applications Centre, Ahmedabad for continuous guidance and encouragement during the investigation. Authors would like to thank Dr. P. K. Pal, Deputy Director, EPSA, and Dr Manab Chakraborty GD, GSAG/EPSA SAC for their suggestions and comments on the atlas.

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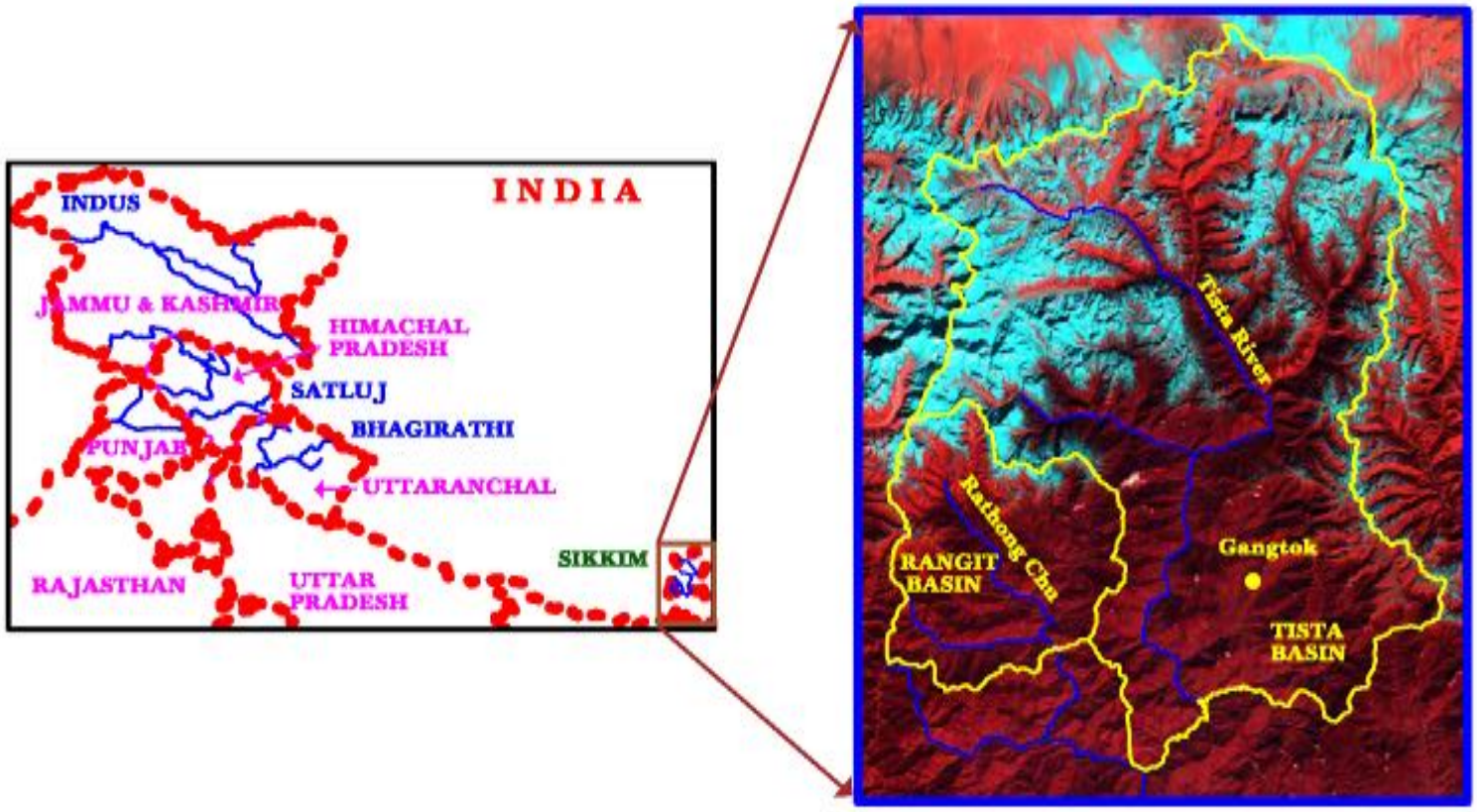
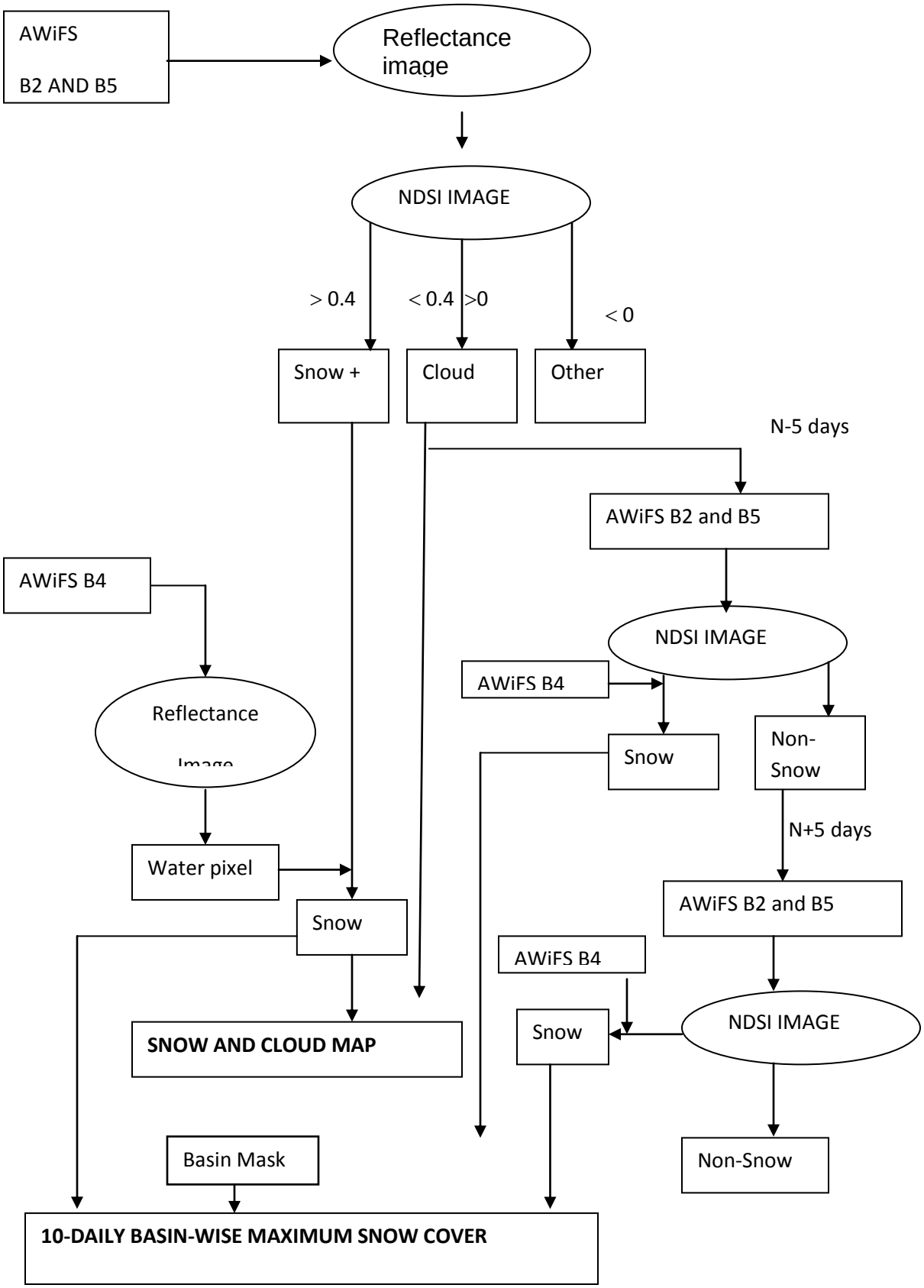


Figure 1: Location map of Tista and Rangit sub-basins (Part of Tista basin)

Figure 2: Algorithm for snow cover mapping using AWiFS data



SIKKIM

AREAL EXTENT OF SNOW (5 DAILY)

STATE: SIKKIM AREA: 7096 Km^2

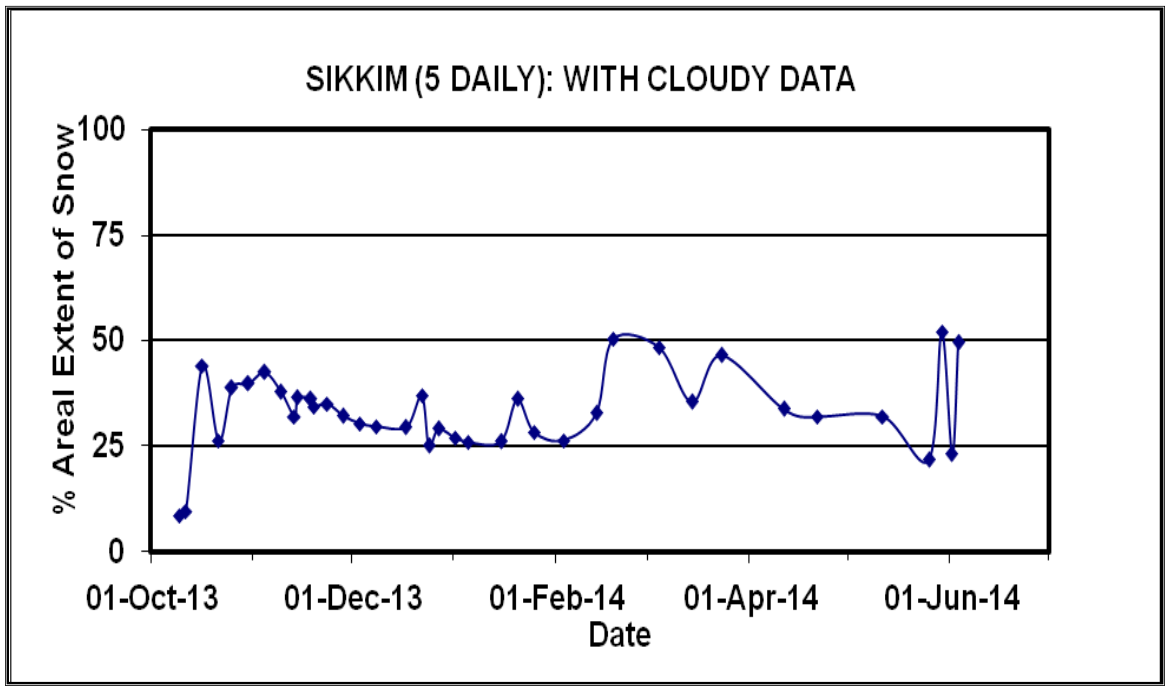
S No	Date	Snow Cover Km^2	Snow Cover %	S No	Date	Snow Cover Km^2	Snow Cover %
October 2013							
1	09-Oct-13	608	9	**2**	11-Oct-13	675	10
3	16-Oct-13	3124	44	**4**	21-Oct-13(PC)	1858	26
5	25-Oct-13(PC)	2756	39	**6**	30-Oct-13(C)	2822	40
November 2013							
7	04-Nov-13	3017	43	**8**	09-Nov-13(PC)	2680	38
9	13-Nov-13(C)	2269	32	**10**	14-Nov-13	2587	36
11	18-Nov-13	2565	362	**12**	19-Nov-13	2434	34
13	23-Nov-13	2481	35	**14**	24-Nov-13	608	9
15	28-Nov-13	2284	32				
December 2013							
16	03-Dec-13	2151	30	**17**	08-Dec-13	2104	30
18	17-Dec-13	2090	29	**19**	22-Dec-13	2619	37
20	24-Dec-13	1783	25	**21**	27-Dec-13	2062	29
January 2014							
22	01-Jan-14	1908	27	**23**	05-Jan-14(PC)	1845	26
24	15-Jan-14(PC)	1854	26	**25**	20-Jan-14	2564	36
26	25-Jan-14	2005	28				
February 2014							
27	03-Feb-14	1869	26	**28**	13-Feb-14(PC)	2323	33
29	18-Feb-14	3571	50				
March 2014							
30	04-Mar-14(PC)	3431	48	**31**	14-Mar-14	2513	35
32	23-Mar-14(PC)	3306	47				
April 2014							
33	11-Apr-14(PC)	2399	34	**34**	21-Apr-14	2264	32
May 2014							
35	11-May-14(PC)	2269	32	**36**	25-May-14(C)	1539	22
37	29-May-14(PC)	3696	52				
June 2014							
38	01-Jun-14(PC)	1641	23	**39**	03-Jun-14(C)	3517.45	50

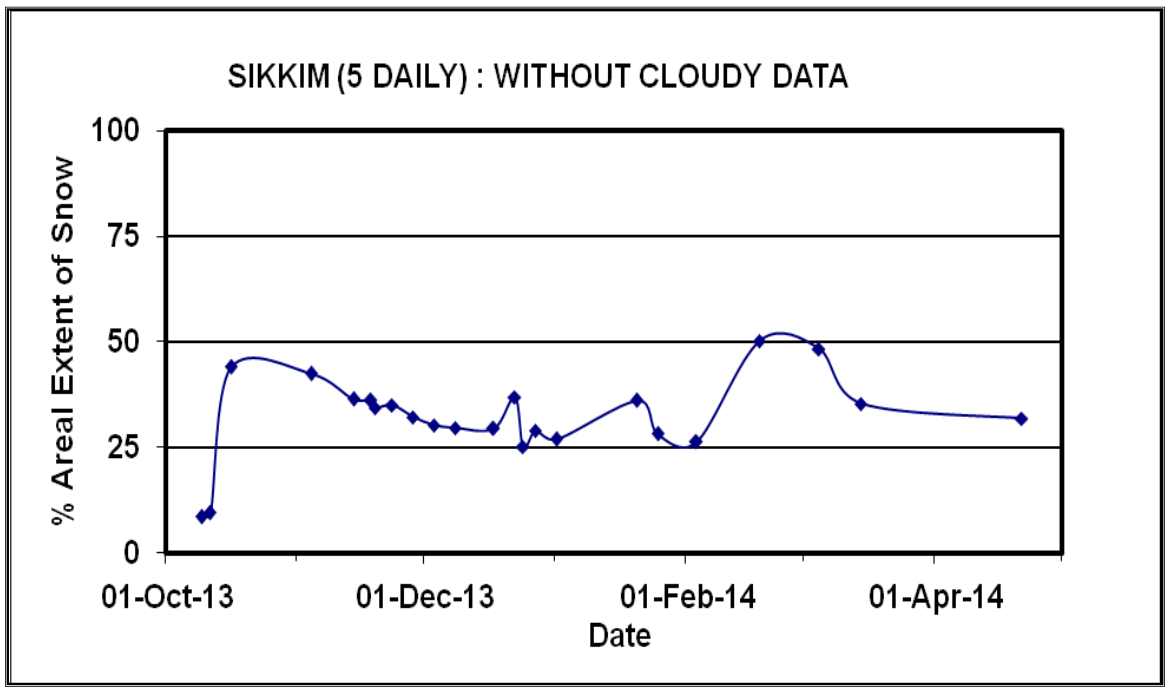
COMPOSITE SNOW COVER EXTENT OF SIKKIM

STATE: SIKKIM AREA: 7096 Km^2

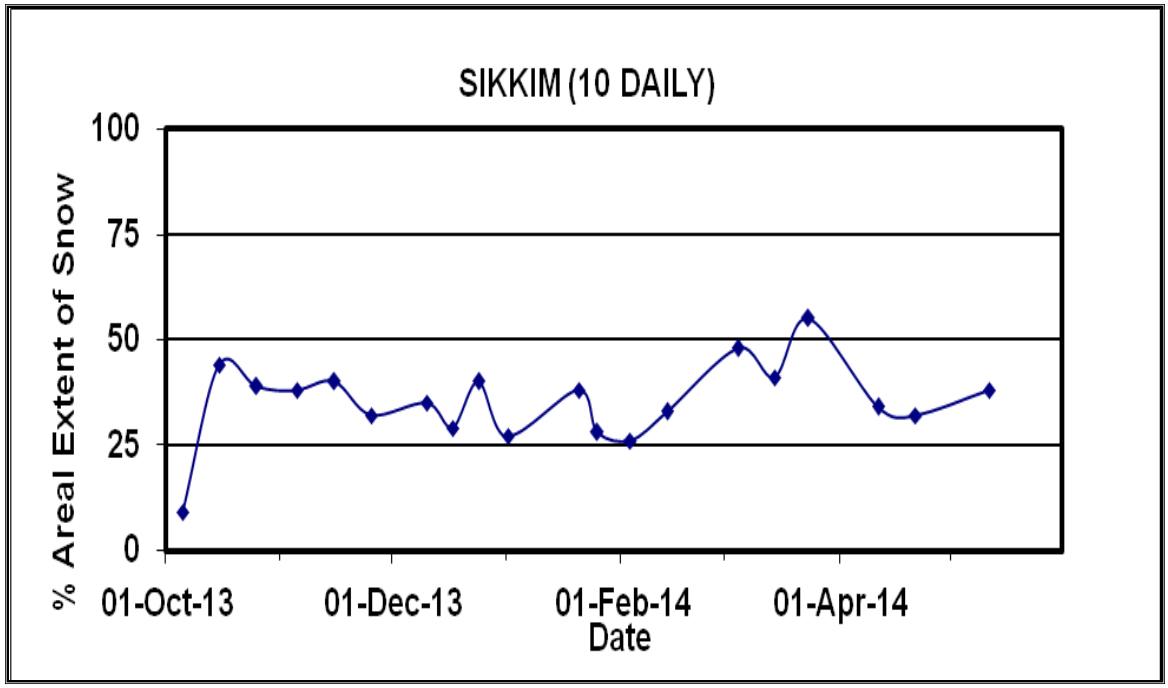
S No	Data used	Mean Date	Snow cover (Km^2)	Snow cover %
October 2013				
1	09-Oct-13	09-Oct-13	608	9
	11-Oct-13 16-Oct-13	16-Oct-13	3125	44
3	25-Oct-13	25-Oct-13	2756	39
November 2013				
4	09-Nov-13	09-Nov-13	2680	38
5	14-Nov-13 18-Nov-13 19-Nov-13	18-Nov-13	1018	14
6	23-Nov-13	23-Nov-13	2284	32
December 2013				
7	03-Dec-14 08-Dec-14	08-Dec-13	2474	35
8	17-Dec-14	17-Dec-13	2090	29
9	22-Dec-14 24-Dec-14 27-Dec-14	24-Dec-13	2811	40
January 2014				
10	01-Jan-14	01-Jan-14	1908	27
11	15-Jan-14 20-Jan-14	20-Jan-14	2728	38
12	25-Jan-14	25-Jan-14	2005	28
February 2014				
13	03-Feb-14	03-Feb-14	1869	26
14	13-Feb-14	13-Feb-14	2323	33
March 2014				
15	04-Mar-14	04-Mar-14	3431	48
16	14-Mar-14 18-Mar-14	14-Mar-14	2942	41
17	23-Mar-14 18-Feb-14	23-Mar-14	3888	55
April 2014				
18	11-Apr-14	11-Apr-14	2399	34
19	21-Apr-14	21-Apr-14	2264	32
May 2014				
20	11-May-14	11-May-14	2684	38

SNOW COVER DEPLETION CURVE



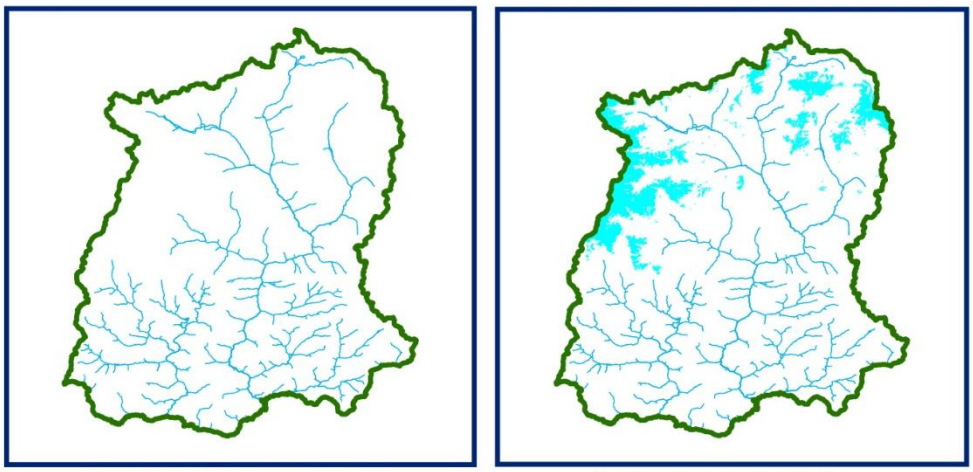


SNOW COVER DEPLETION CURVE



SNOW COVER MAP

5 DAILY SNOW COVER MAP: SIKKIM



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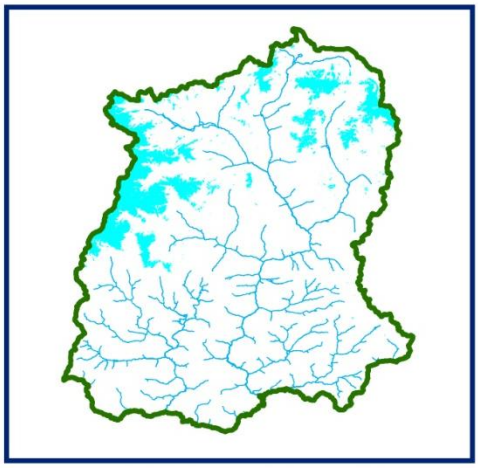

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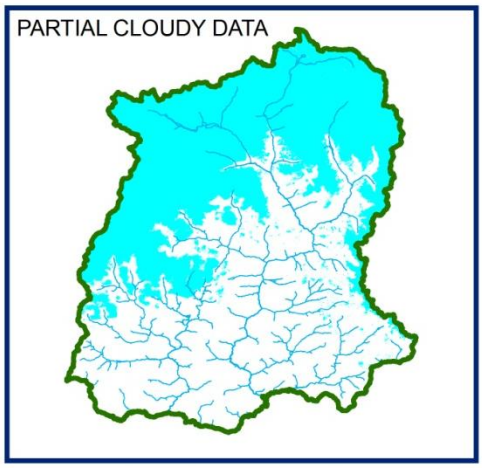

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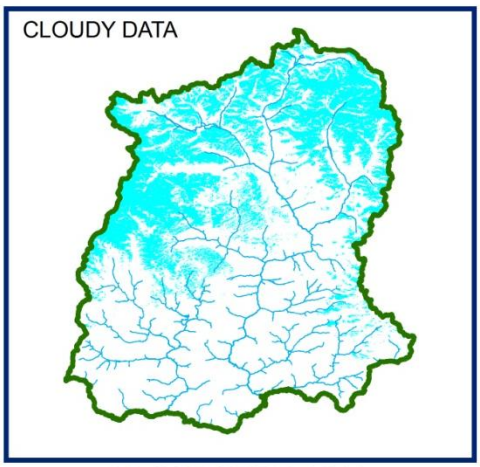

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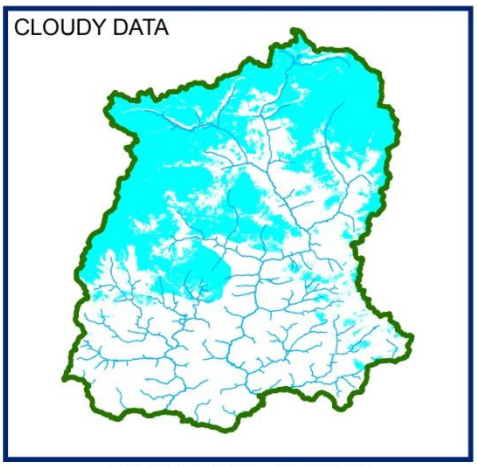


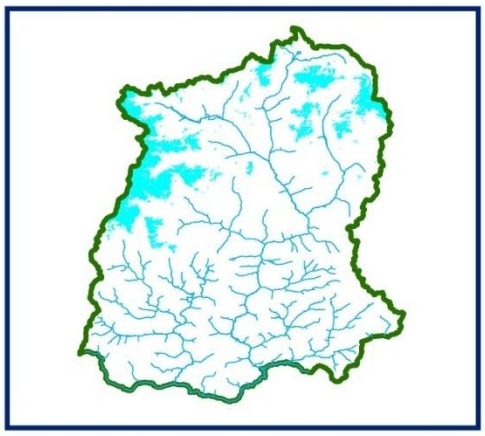
30 OCTOBER 2013

0 15 30 60 90 120

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



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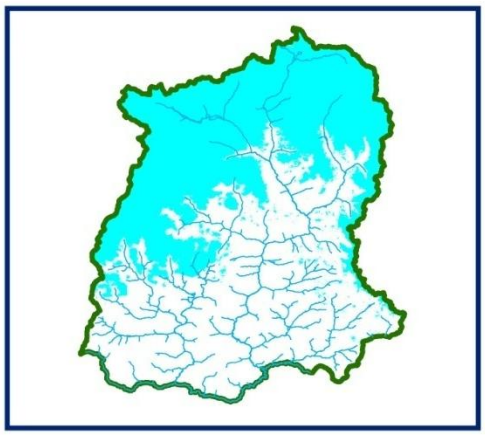

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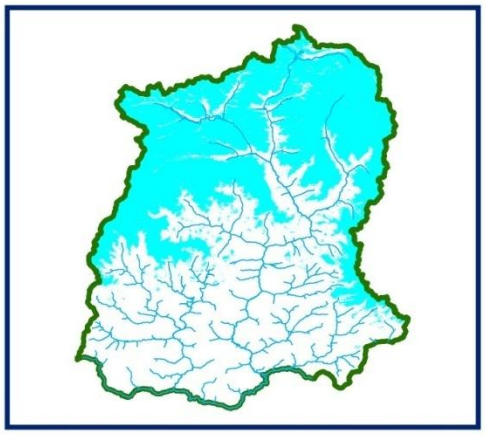

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SNOW

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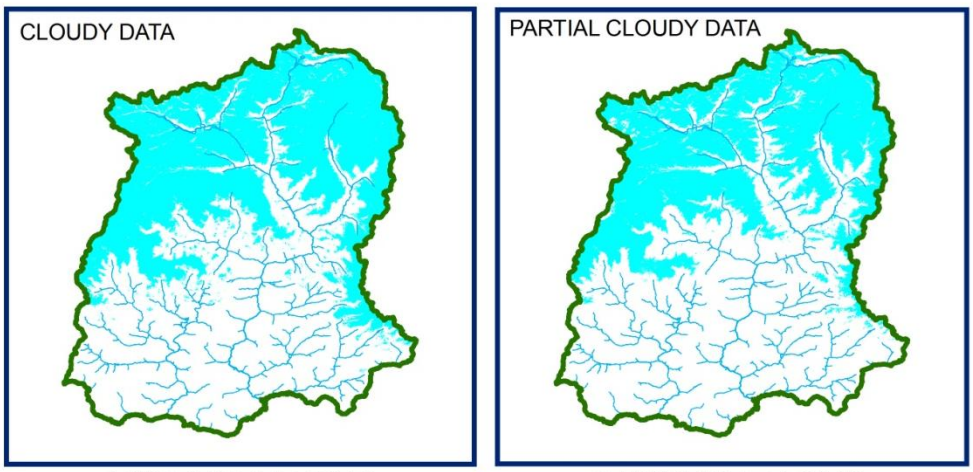
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



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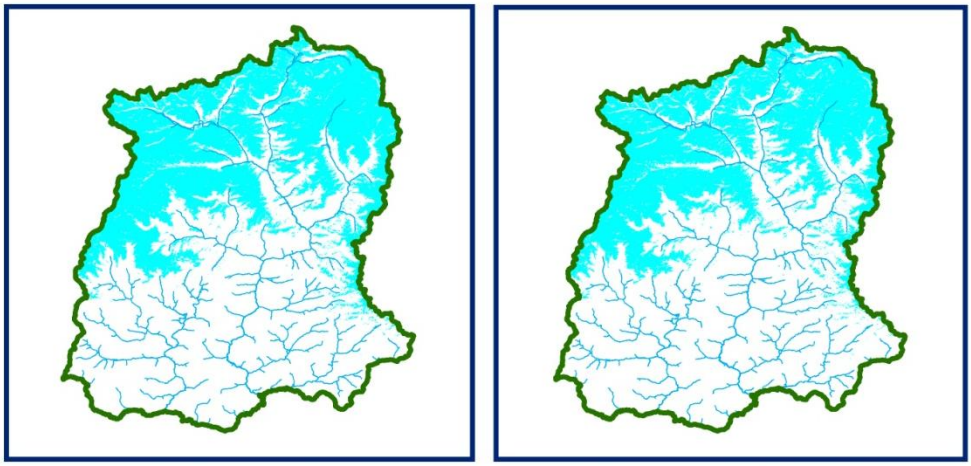

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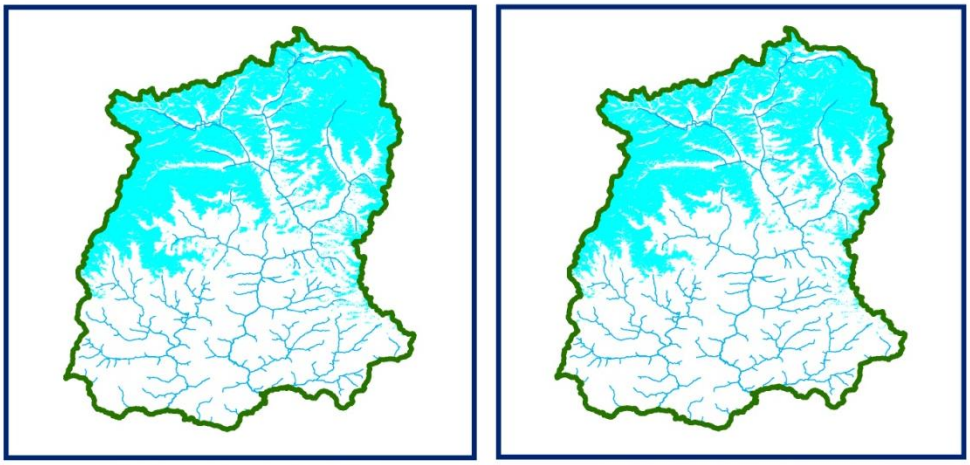

23 NOVEMBER 2013 **28 NOVEMBER 2013**

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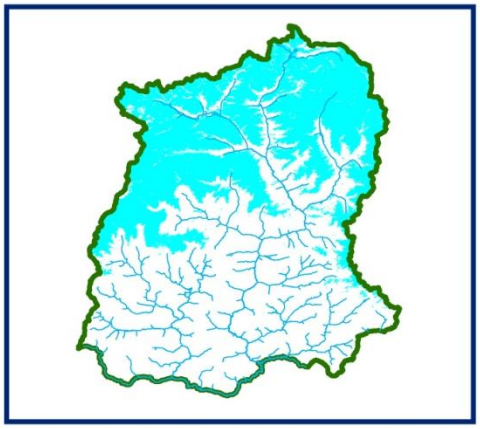
Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



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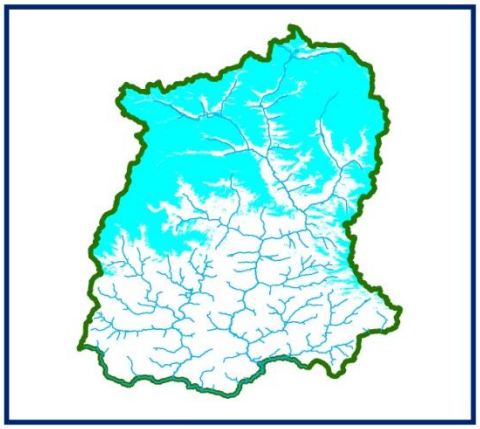

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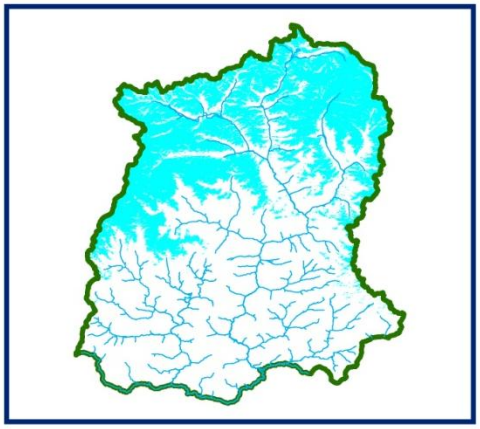
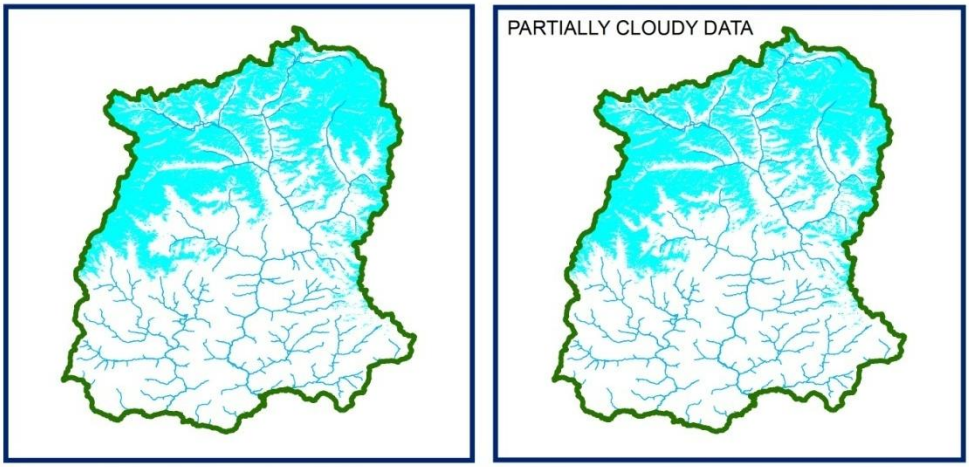


DATA USED
23 NOVEMBER 2013
28 NOVEMBER 2013

SNOW

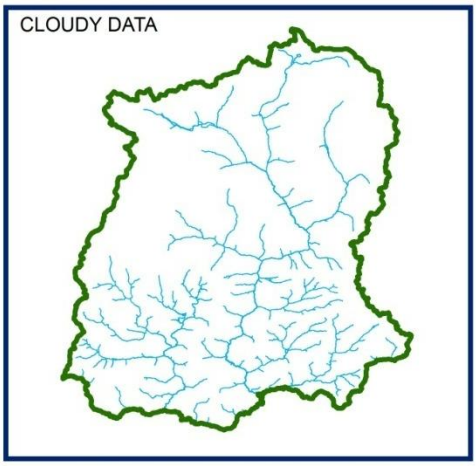
0 15 30 60 90 120
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



3 DECEMBER 2013

8 DECEMBER 2013



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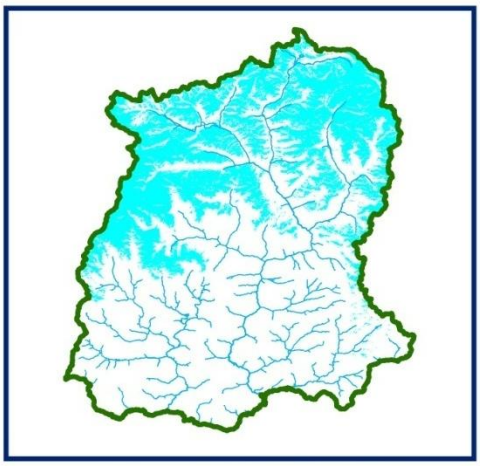

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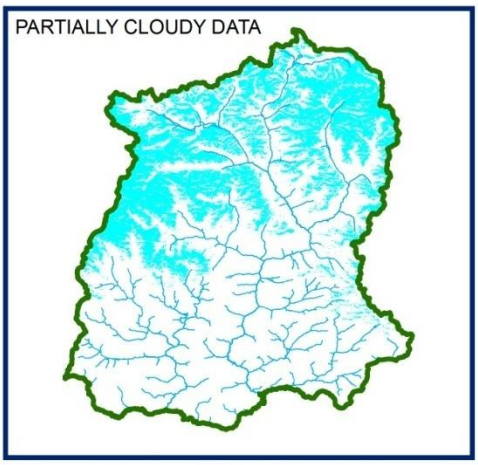

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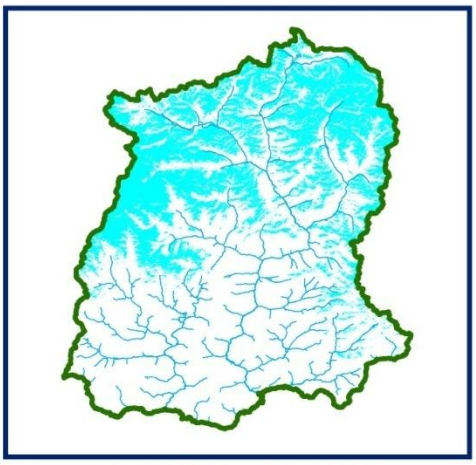

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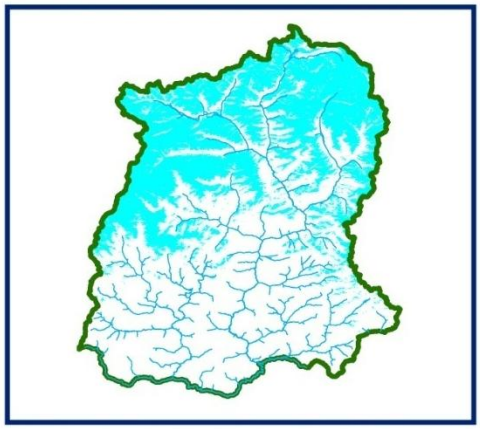
Kilometers

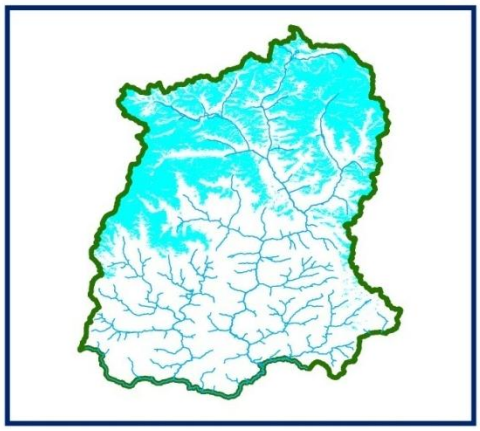
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



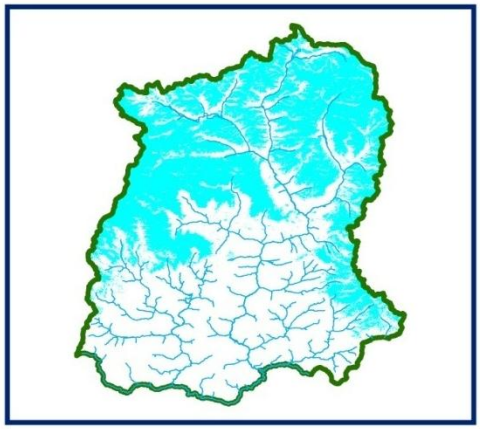
DATA USED

3 DECEMBER 2013
8 DECEMBER 2013



DATA USED

17 DECEMBER 2013



DATA USED

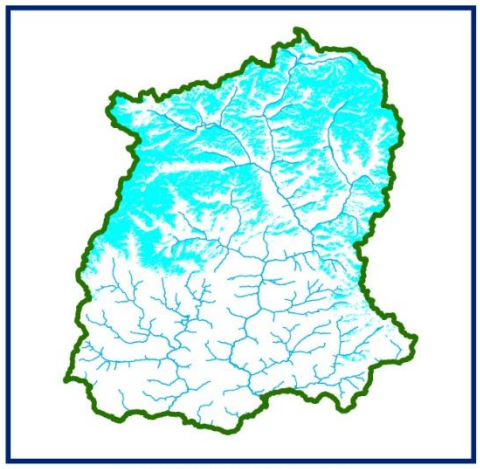
22 DECEMBER 2013
24 DECEMBER 2013
27 DECEMBER 2013

SNOW

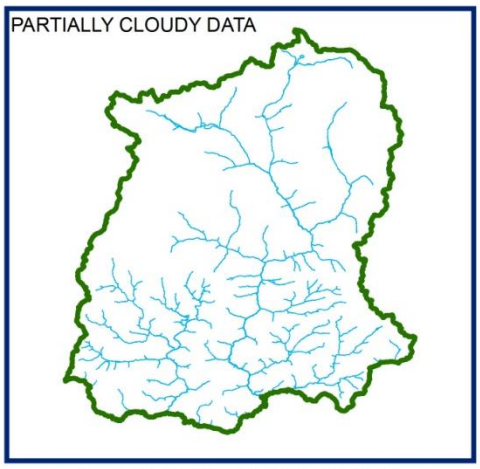
0 20 40 80 120 160

Kilometers

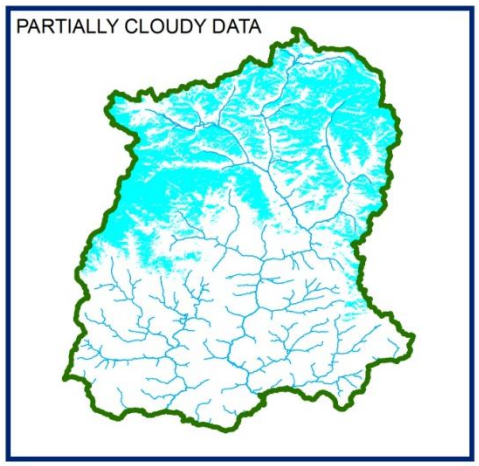
5 DAILY SNOW COVER MAP: SIKKIM



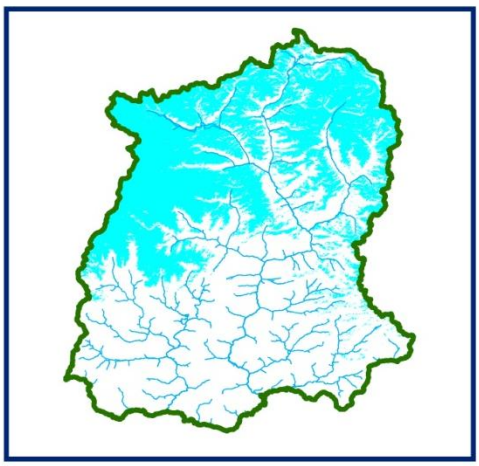
1 JANUARY 2014



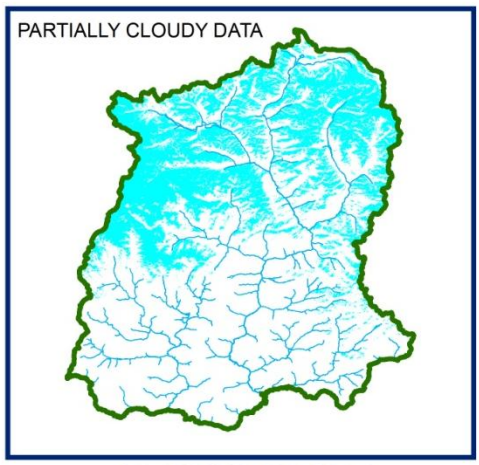
DATA NOT AVAILABLE



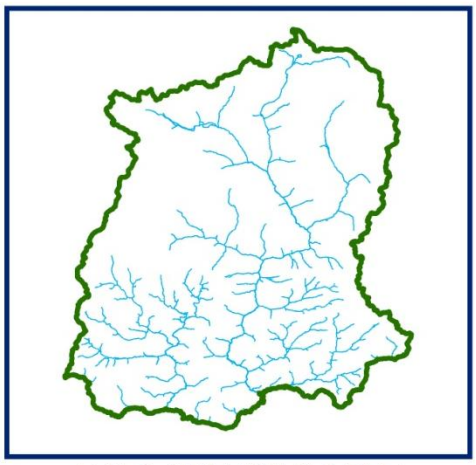
15 JANUARY 2014



20 JANUARY 2014



25 JANUARY 2014



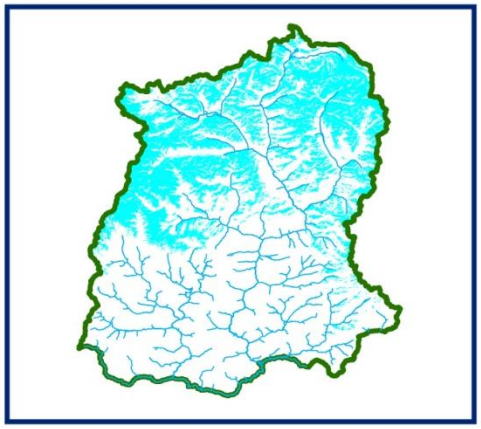
DATA NOT AVAILABLE

0 15 30 60 90 120

Kilometers

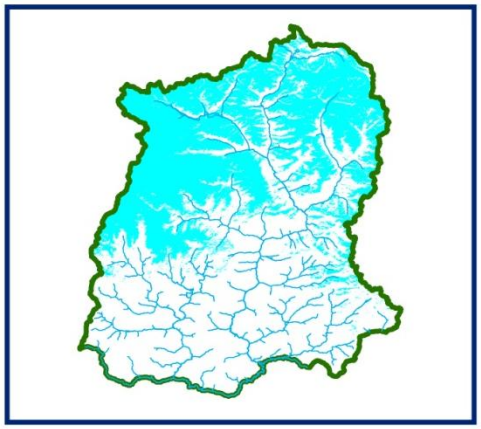
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



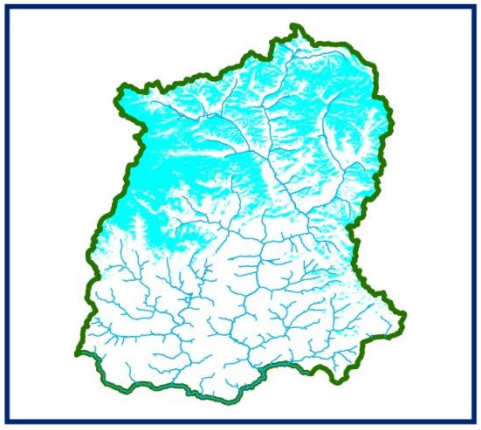
DATA USED

1 JANUARY 2014



DATA USED

15 JANUARY 2014
20 JANUARY 2014



DATA USED

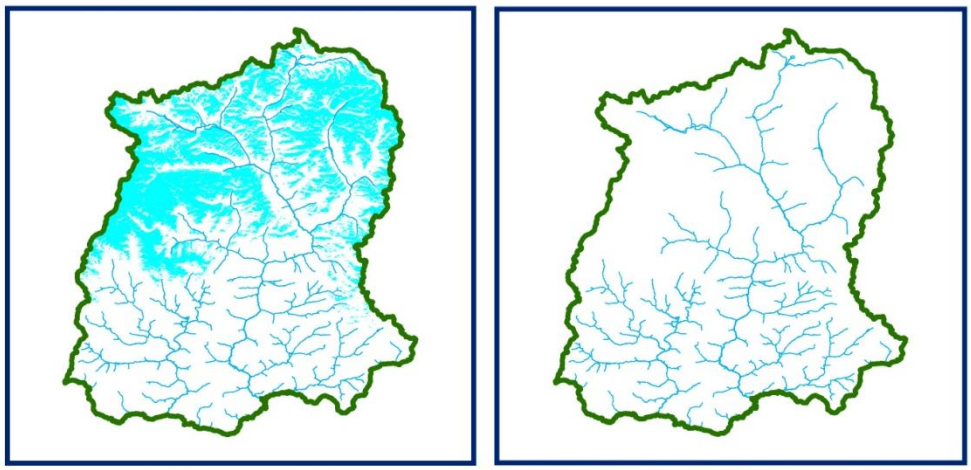
25 JANUARY 2014

SNOW

0 20 40 80 120 160

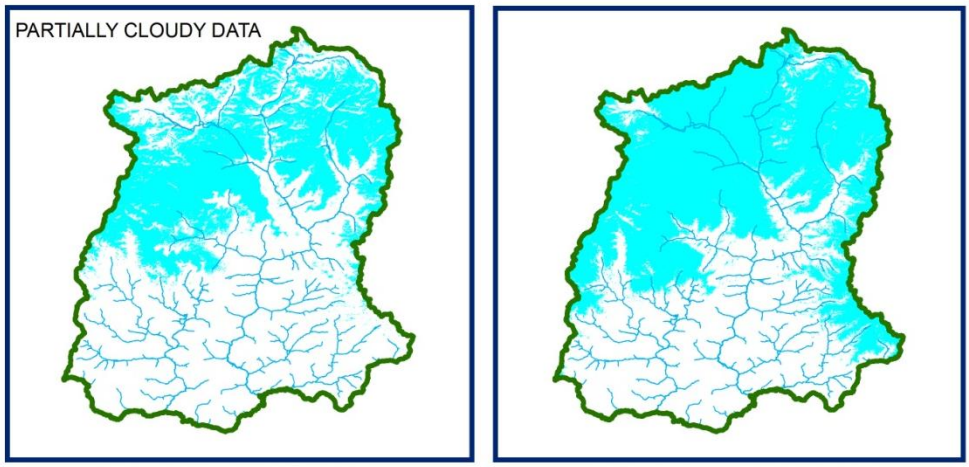
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



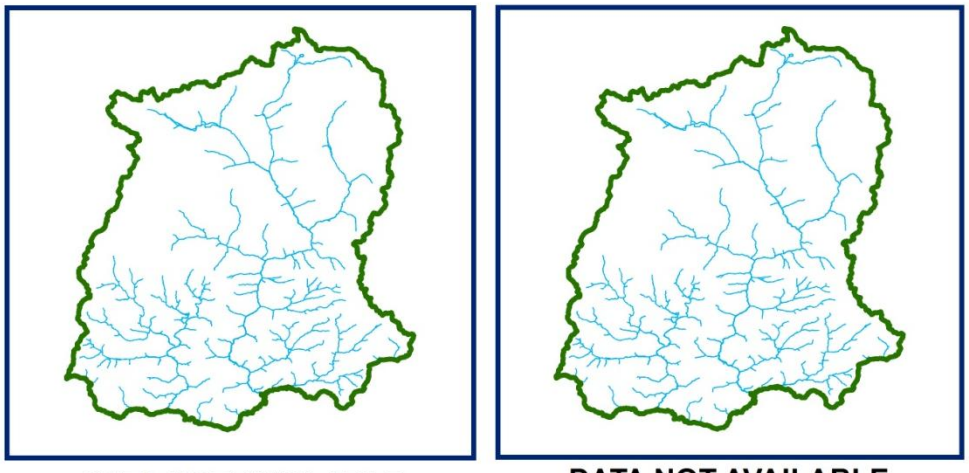
3 FEBRUARY 2014

DATA NOT AVAILABLE



13 FEBRUARY 2014

18 FEBRUARY 2014



DATA NOT AVAILABLE

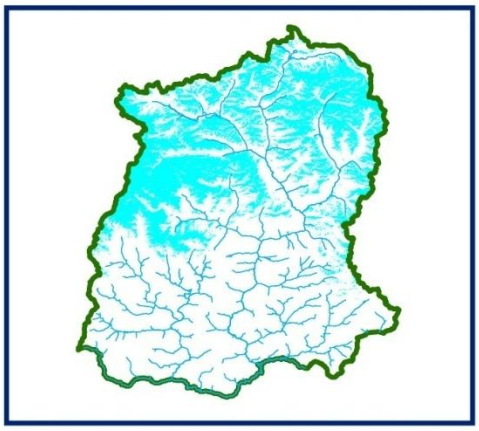
DATA NOT AVAILABLE

0 15 30 60 90 120

Kilometers

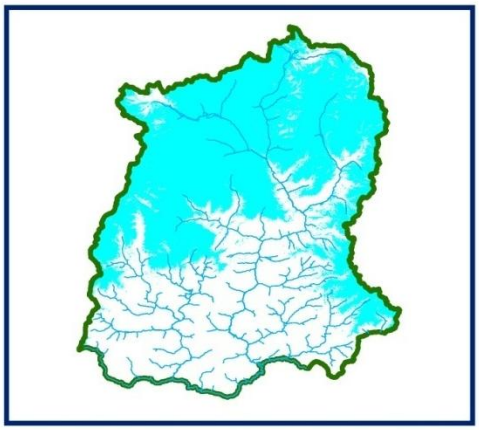
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



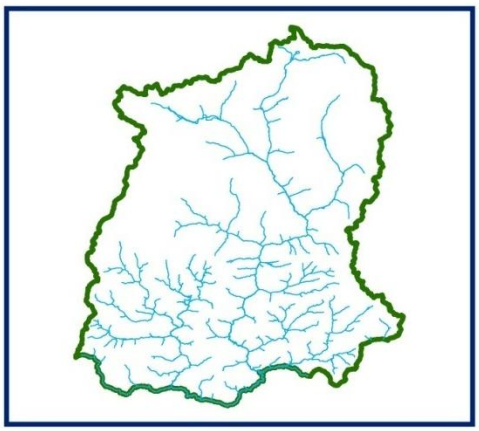
DATA USED

3 FEBRUARY 2014



DATA USED

18 FEBRUARY 2014



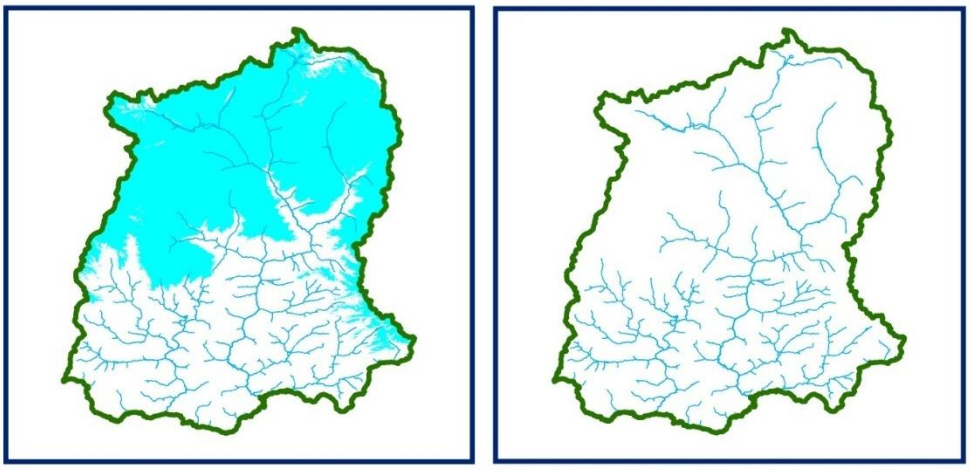
NO DATA AVAILABLE

SNOW

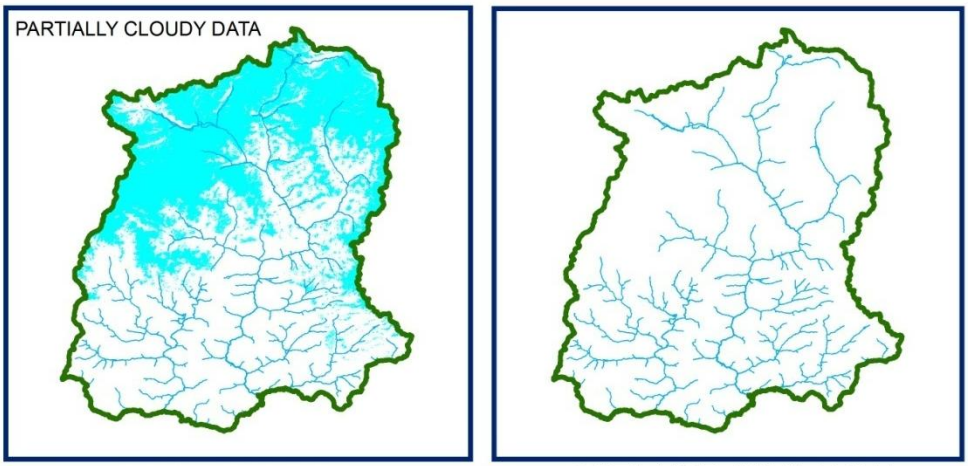
0 20 40 80 120 160

Kilometers

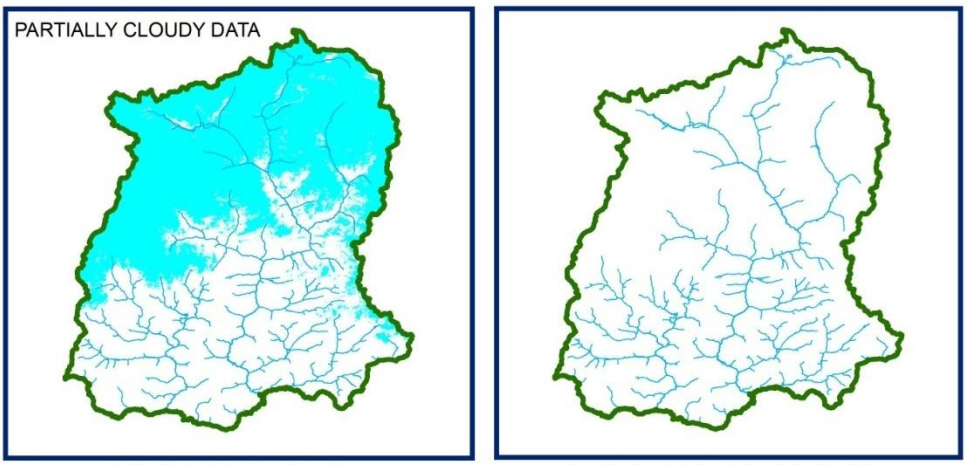
5 DAILY SNOW COVER MAP: SIKKIM



4 MARCH 2014 | DATA NOT AVAILABLE



14 MARCH 2014 | DATA NOT AVAILABLE



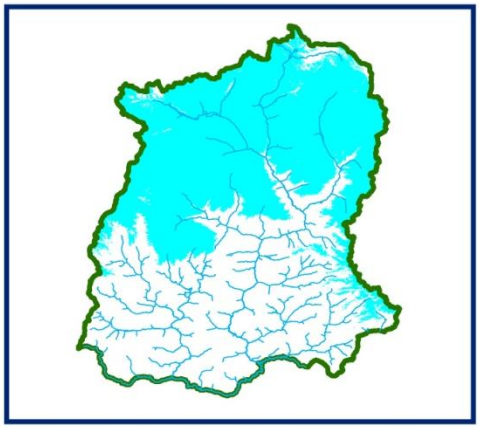
23 MARCH 2014 | DATA NOT AVAILABLE

0 15 30 60 90 120

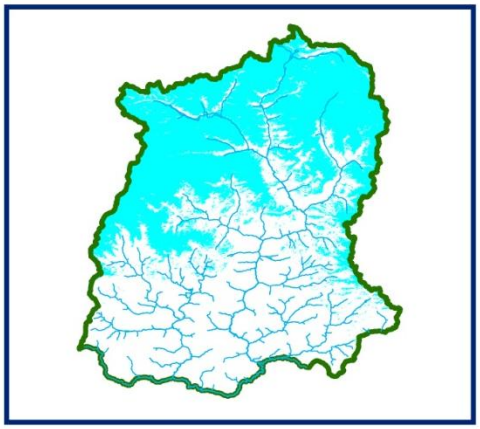
Kilometers

SNOW

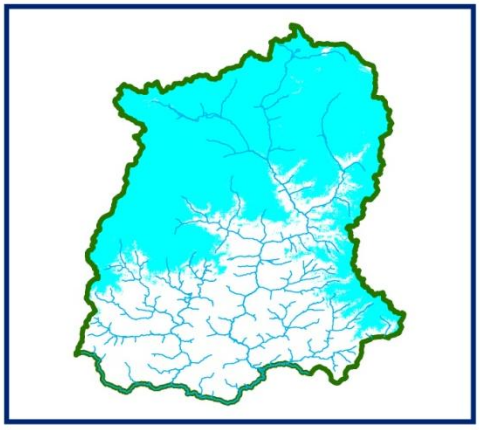
COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA USED
4 MARCH 2014



DATA USED
14 MARCH 2014
18 NOVEMBER 2013

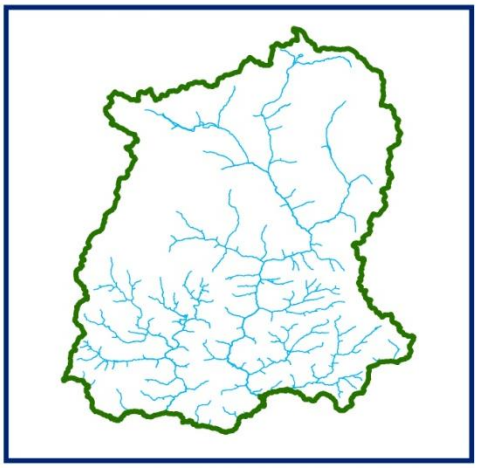


DATA USED
23 MARCH 2014
18 FEBRUARY 2014

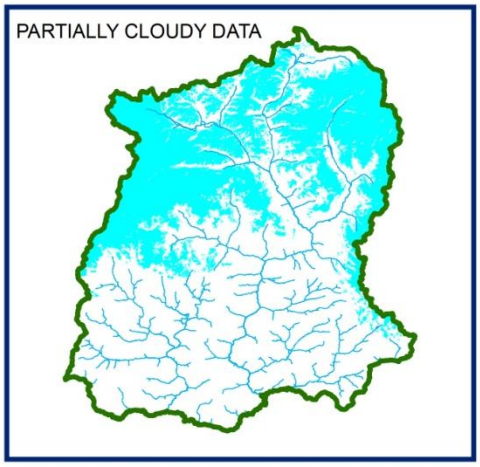
SNOW

0 20 40 80 120 160
Kilometers

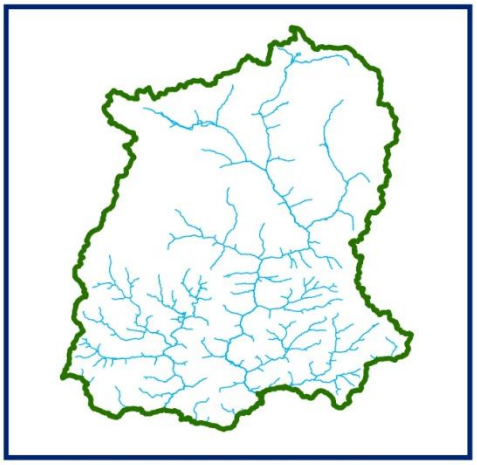
5 DAILY SNOW COVER MAP: SIKKIM



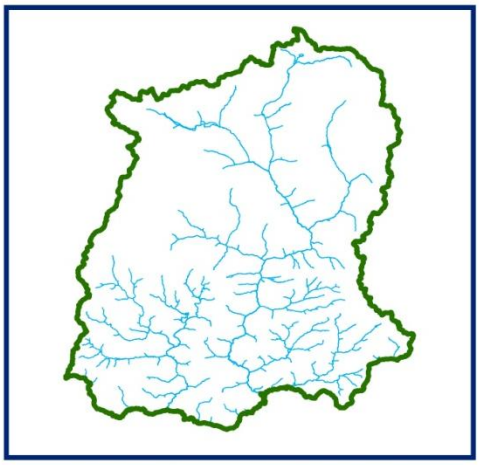
DATA NOT AVAILABLE



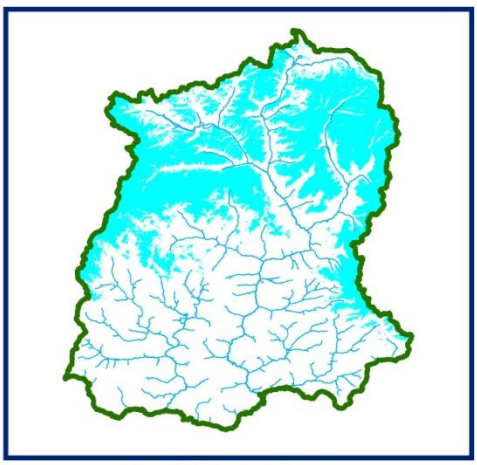
11 APRIL 2014



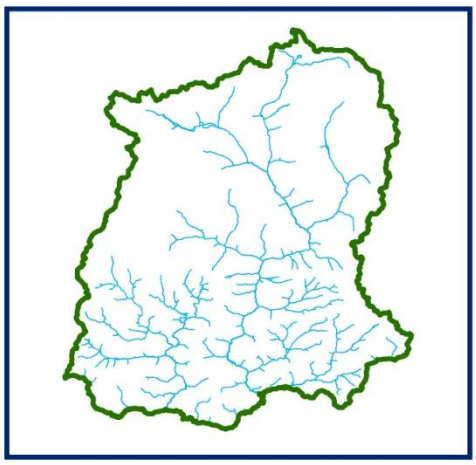
DATA NOT AVAILABLE



DATA NOT AVAILABLE



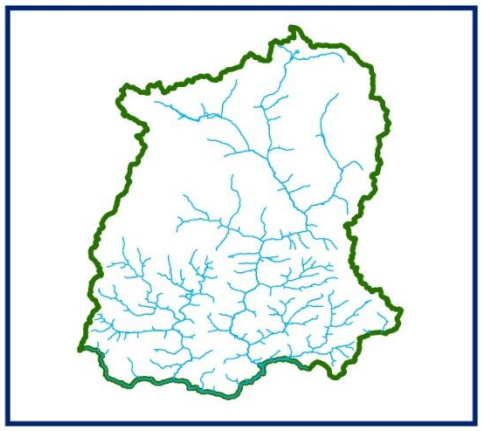
21 APRIL 2014



DATA NOT AVAILABLE

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



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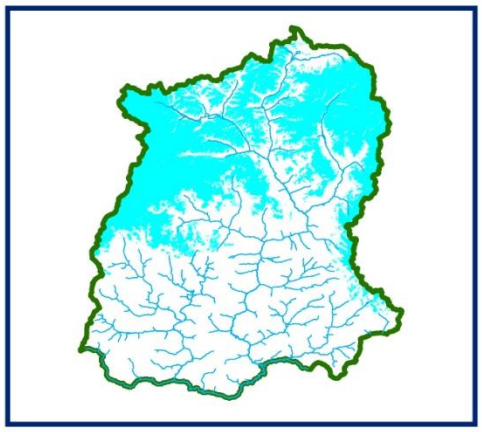
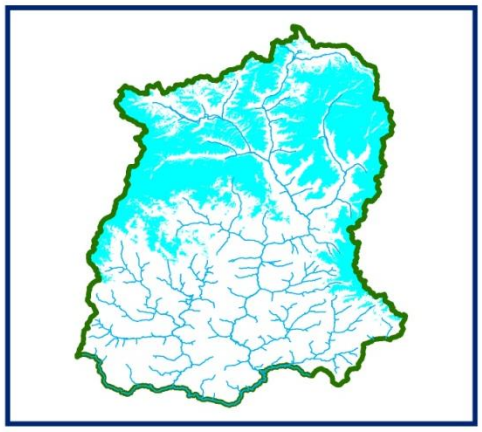


DATA USED

11 APRIL 2014



DATA USED

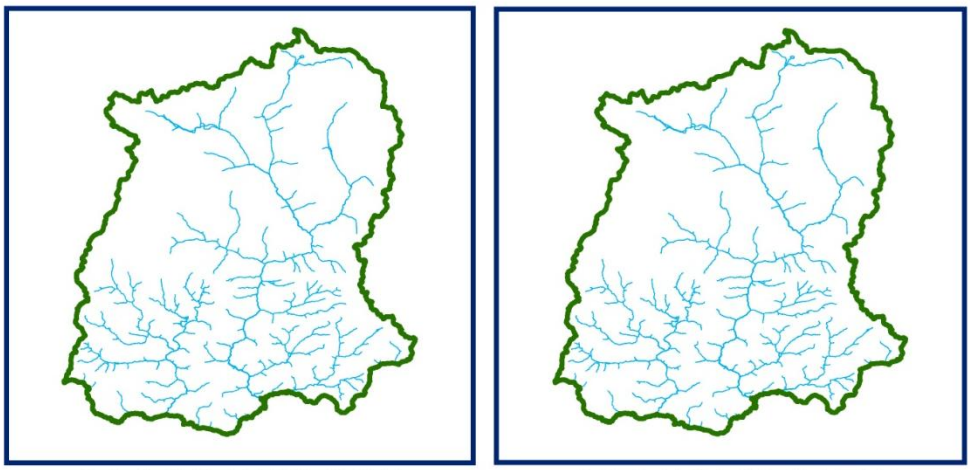
21 APRIL 2014

SNOW

0 20 40 80 120 160

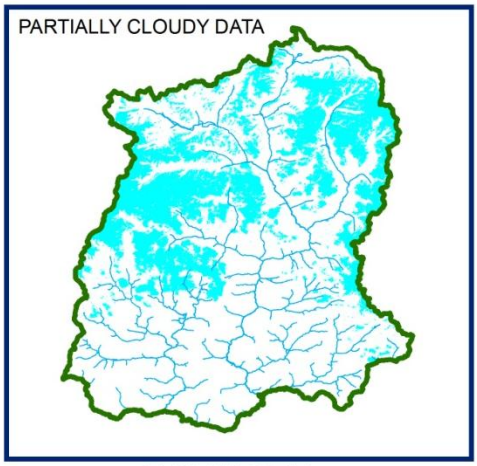
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM

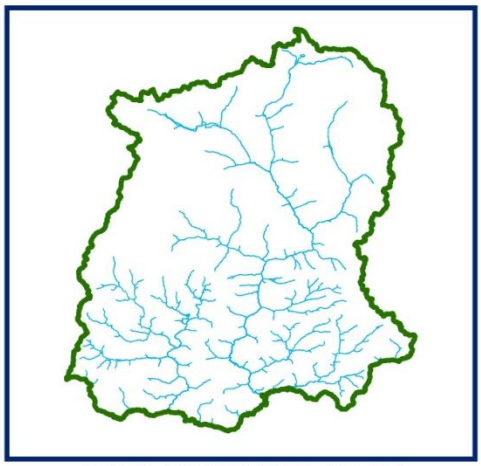


DATA NOT AVAILABLE

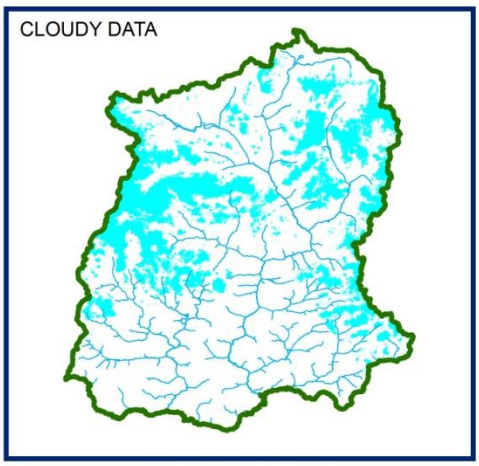
DATA NOT AVAILABLE



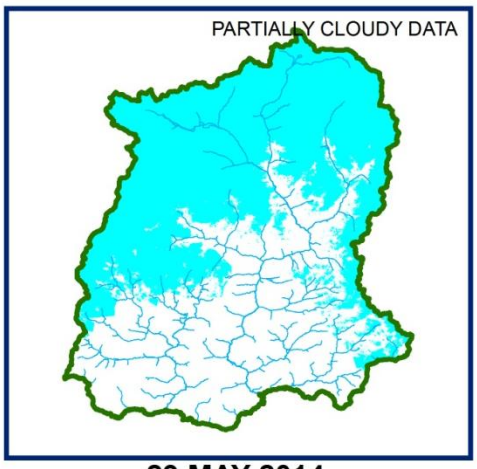
11 MAY 2014



DATA NOT AVAILABLE



25 MAY 2014



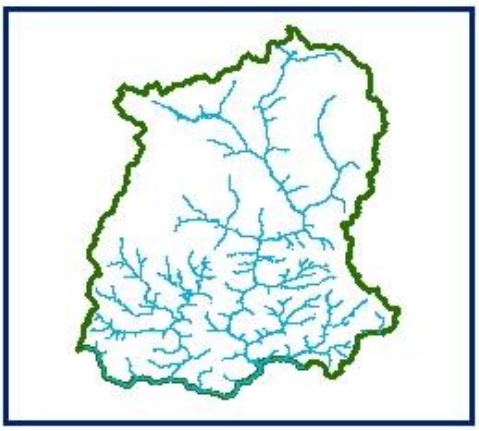
29 MAY 2014

0 15 30 60 90 120

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA NOT AVAILABLE

DATA USED

11 MAY 2014
21 APRIL 2014

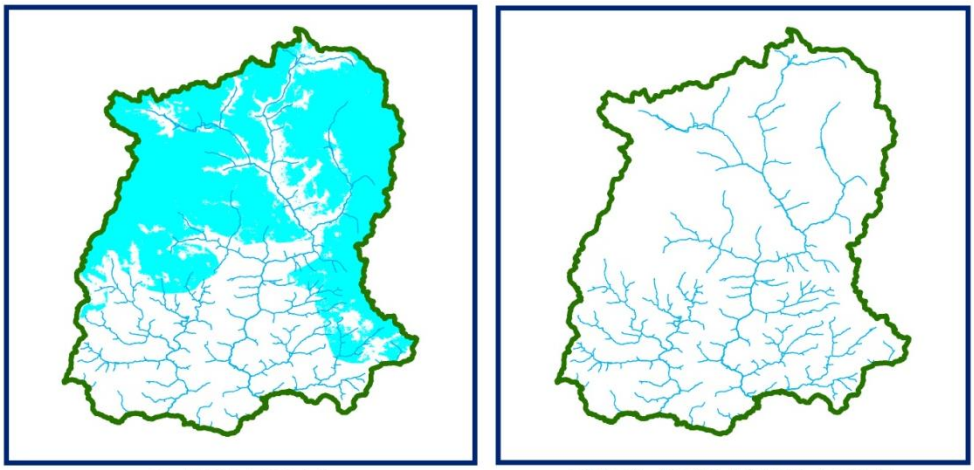
DATA NOT AVAILABLE

SNOW

0 20 40 80 120 160

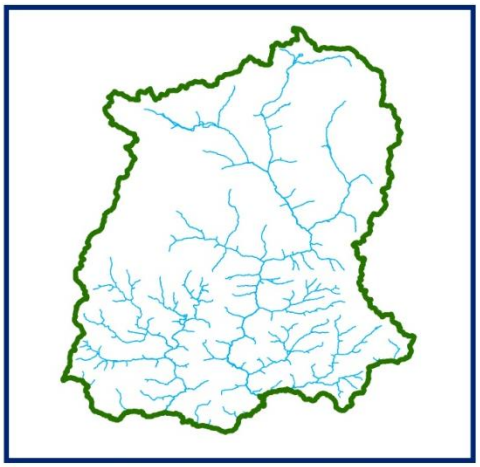
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



3 JUNE 2014

DATA NOT AVAILABLE



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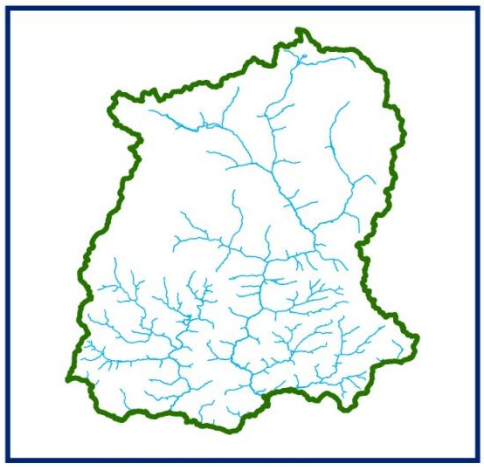

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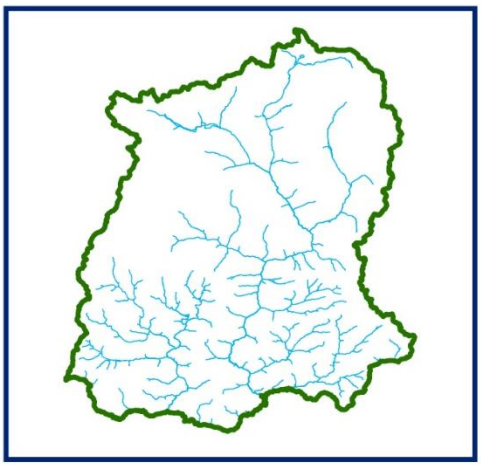

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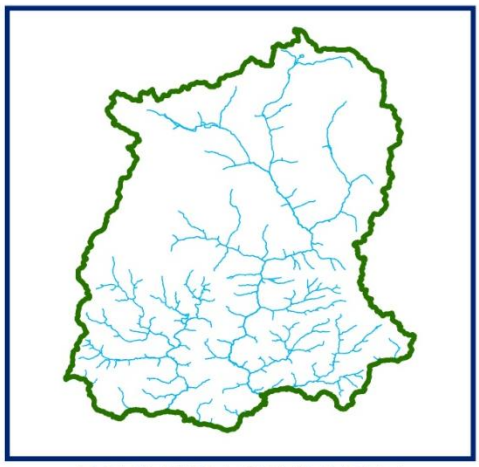


DATA NOT AVAILABLE

0 15 30 60 90 120

Kilometers

SNOW

TISTA BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: TISTA AREA: 5466 Km^2

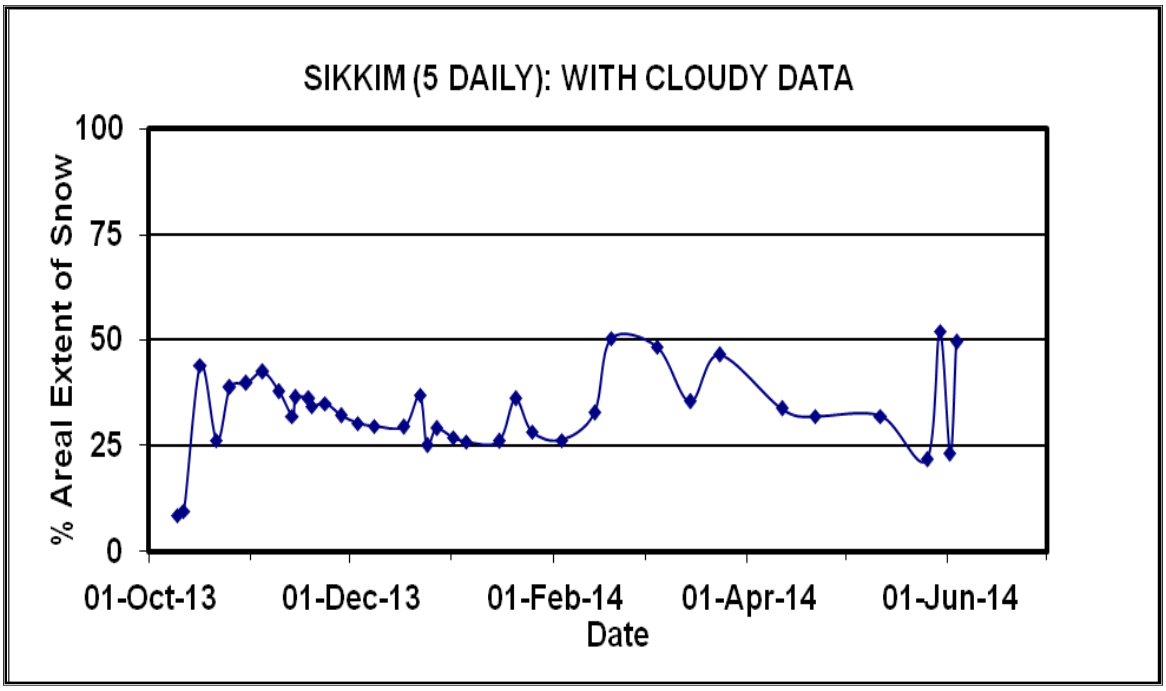
S No	Date	Snow Cover (Km^2)	Snow Cover %	S No	Date	Snow Cover (Km^2)	Snow Cover %
October 2013							
1	09-Oct-13	564	10	**2**	11-Oct-13	613	11
3	16-Oct-13	2740	50	**4**	21-Oct-13(PC)	1727	32
5	25-Oct-13(PC)	2461	45	**6**	30-Oct-13(C)	2523	46
November 2013							
7	04-Nov-13	2792	51	**8**	09-Nov-13(PC)	2500	46
9	13-Nov-13	2078	38	**10**	14-Nov-13	2413	44
11	18-Nov-13	2375	43	**12**	19-Nov-13	2276	42
13	23-Nov-13(C)	2317	42	**14**	24-Nov-13	564	10
15	28-Nov-13	2135	39				
December 2013							
16	03-Dec-13	2027	37	**17**	08-Dec-13	1989	36
18	17-Dec-13	1955	36	**19**	22-Dec-13	2400	44
20	24-Dec-13	1670	31	**21**	27-Dec-13	1936	35
January 2014							
22	01-Jan-14	1809	33	**23**	05-Jan-14(PC)	1722	31
24	15-Jan-14(PC)	1765	32	**25**	20-Jan-14	2369	43
26	25-Jan-14	1904	35				
February 2014							
27	03-Feb-14	1765	32	**28**	13-Feb-14(PC)	2221	41
29	18-Feb-14	3232	59				
March 2014							
30	04-Mar-14(PC)	3240	59	**31**	14-Mar-14	2401	44
32	23-Mar-14(PC)	3012	55				
April 2014							
33	11-Apr-14(PC)	2259	41	**34**	21-Apr-14	2139	39
May 2014							
35	11-May-14(PC)	2139	39	**36**	25-May-14(C)	1322	24
37	29-May-14(PC)	3218	59				
June 2014							
38	01-Jun-14(PC)	1570	29	**39**	03-Jun-14(C)	3257	60

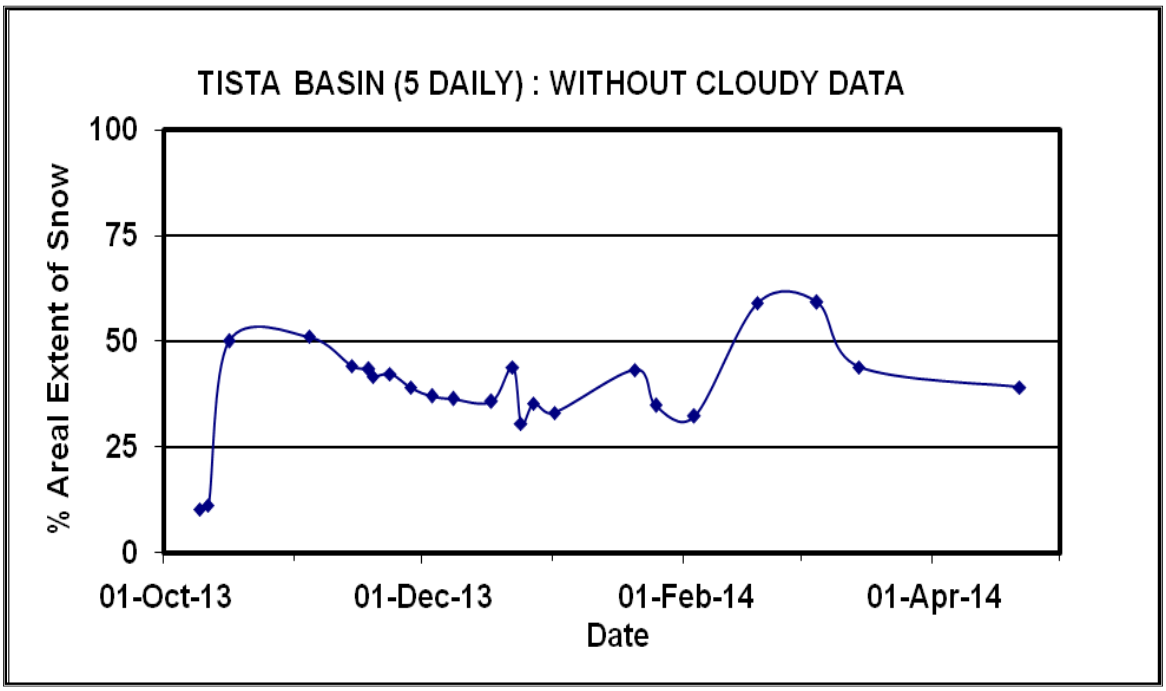
COMPOSITE SNOW COVER EXTENT OF SIKKIM

BASIN NAME: TISTA AREA: 5466 Km^2

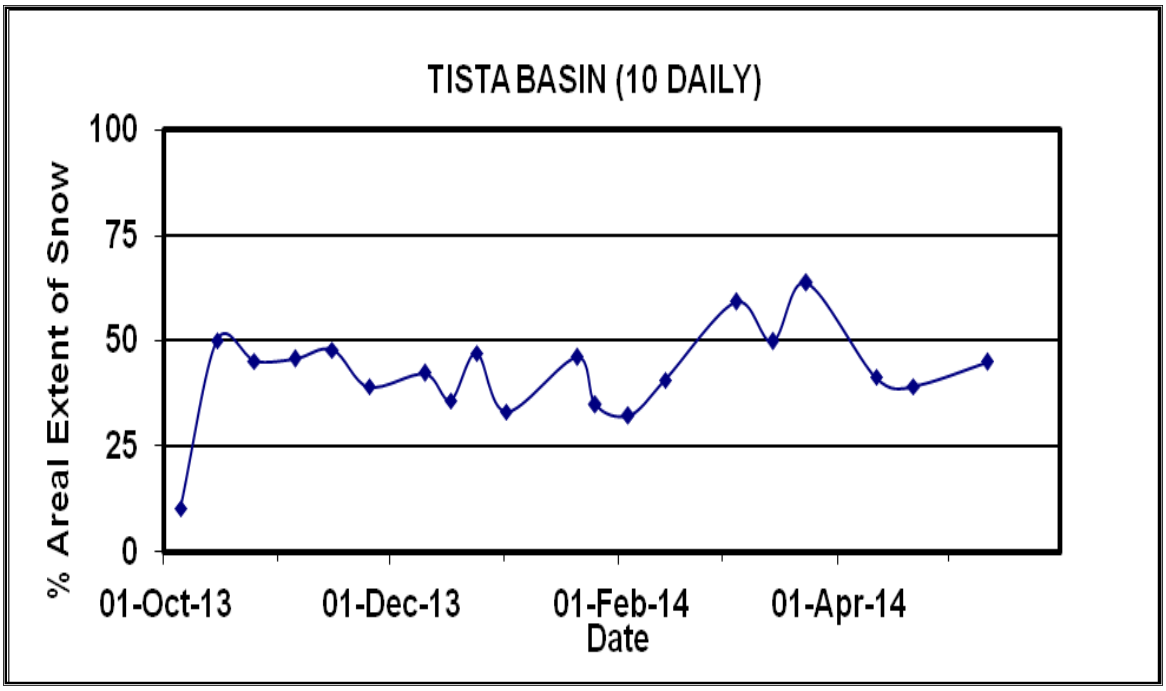
S No	Data used	Mean Date	Snow cover (km^2)	Snow cover %
October 2013				
1	09-Oct-13	09-Oct-13	564	10
2	11-Oct-13 16-Oct-13	16-Oct-13	2740	50
3	25-Oct-13	25-Oct-13	2465	45
November 2013				
4	09-Nov-13	09-Nov-13	2500	46
5	14-Nov-13 18-Nov-13 19-Nov-13	18-Nov-13	2616	48
6	23-Nov-13	23-Nov-13	2135	39
December 2013				
7	03-Dec-14 08-Dec-14	08-Dec-13	2311	42
8	17-Dec-14	17-Dec-13	1955	36
9	22-Dec-14 24-Dec-14 27-Dec-14	24-Dec-13	2568	47
January 2014				
10	01-Jan-14	01-Jan-14	1809	33
11	15-Jan-14 20-Jan-14	20-Jan-14	2518	46
12	25-Jan-14	25-Jan-14	1904	35
February 2014				
13	03-Feb-14	03-Feb-14	1765	32
14	13-Feb-14	13-Feb-14	2221	41
March 2014				
15	04-Mar-14	04-Mar-14	3240	59
16	14-Mar-14 18-Mar-14	14-Mar-14	2722	50
17	23-Mar-14 18-Feb-14	23-Mar-14	3487	64
April 2014				
18	11-Apr-14	11-Apr-14	2259	41
19	21-Apr-14	21-Apr-14	2139	39
May 2014				
20	11-May-14	11-May-14	2440	45

SNOW COVER DEPLETION CURVE



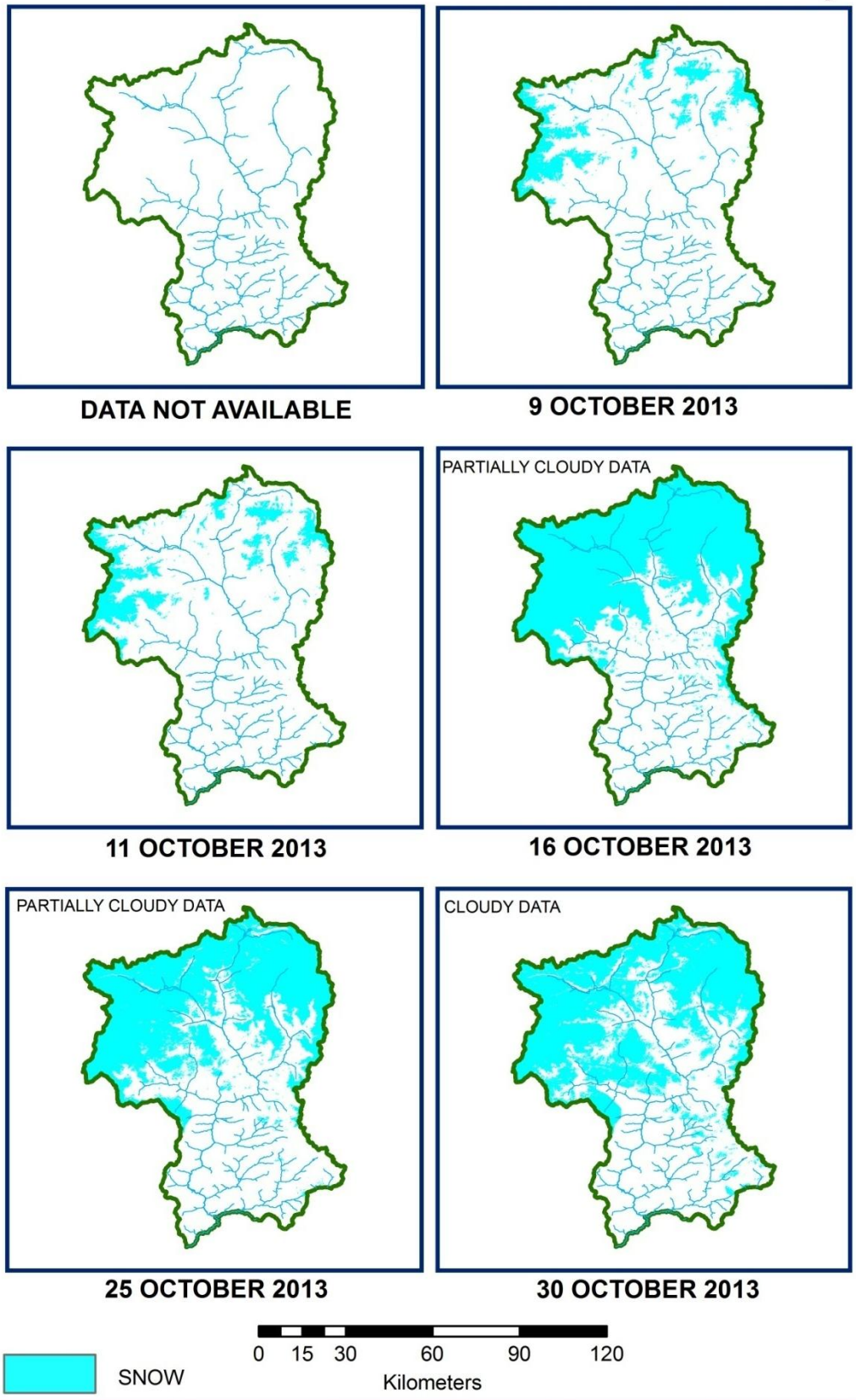


SNOW COVER DEPLETION CURVE

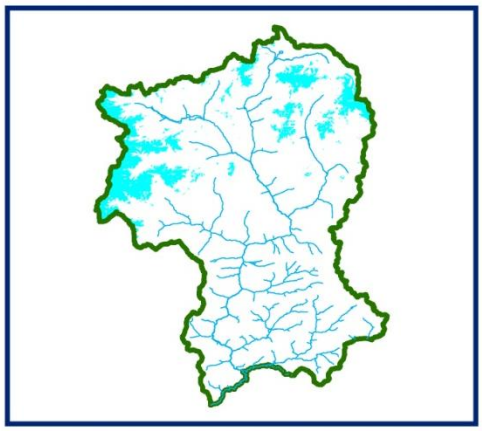


SNOW COVER MAP

5 DAILY SNOW COVER MAP: TISTA

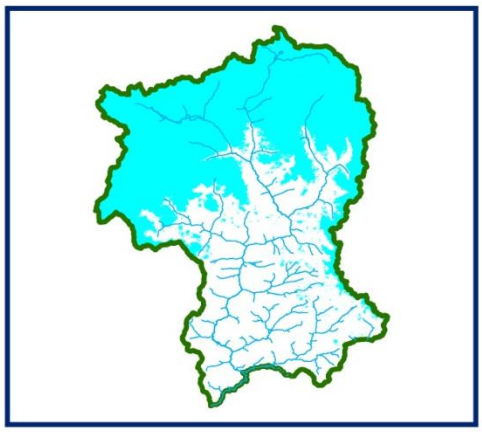


COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED

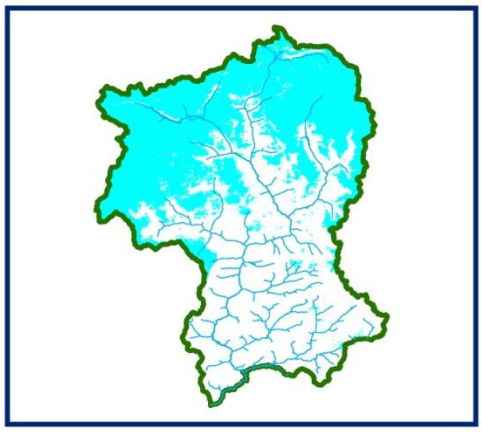
9 OCTOBER 2013



DATA USED

11 OCTOBER 2013

16 OCTOBER 2013



DATA USED

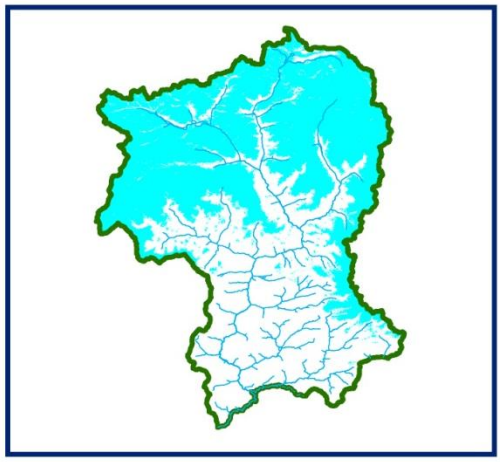
25 OCTOBER 2013

SNOW

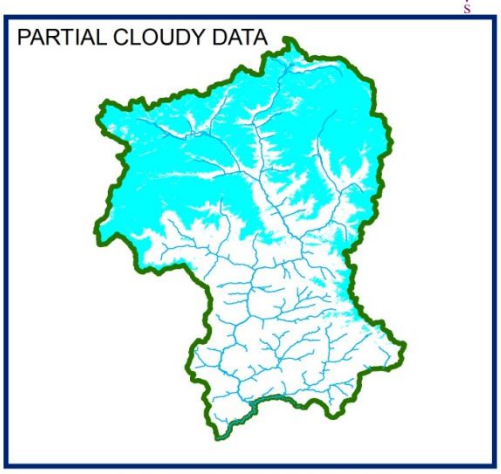
0 15 30 60 90 120

Kilometers

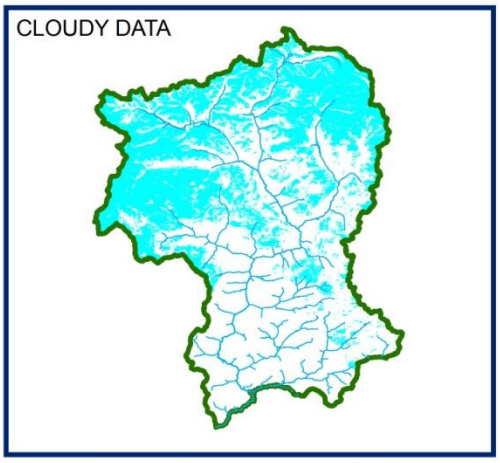
5 DAILY SNOW COVER MAP: TISTA



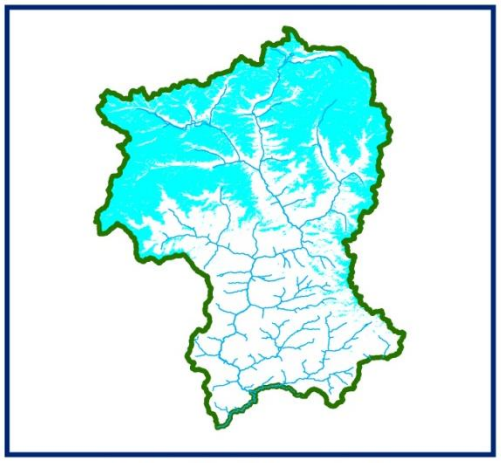
4 NOVEMBER 2013



9 NOVEMBER 2013

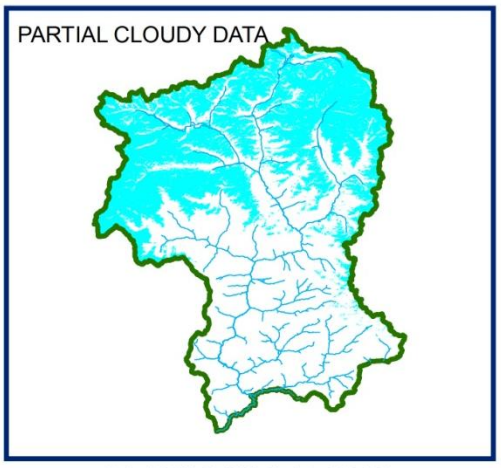


13 NOVEMBER 2013



19 NOVEMBER 2013

23 NOVEMBER 2013



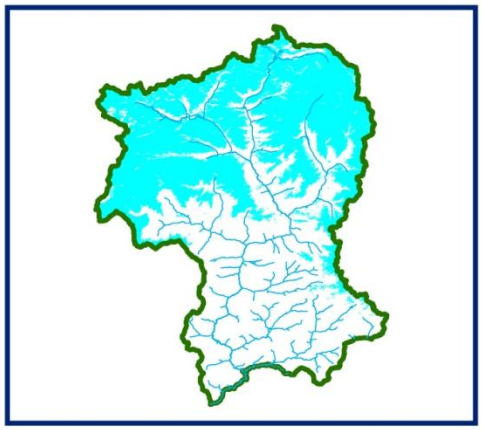
28 NOVEMBER 2013

0 15 30 60 90 120

Kilometers

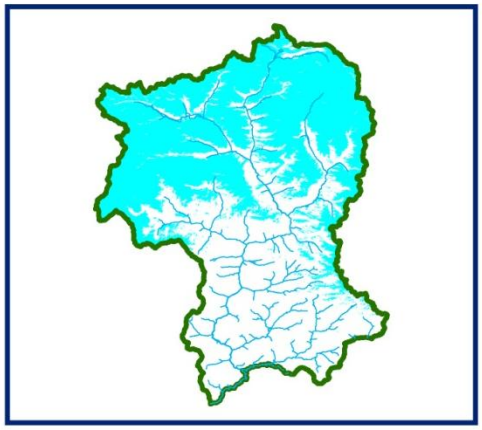
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



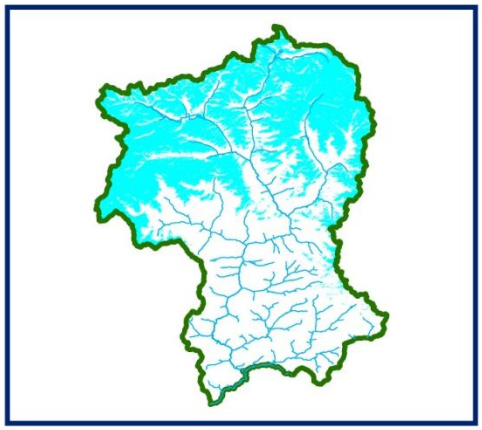
DATA USED

9 NOVEMBER 2013



DATA USED

14 NOVEMBER 2013
18 NOVEMBER 2013
19 NOVEMBER 2013



DATA USED

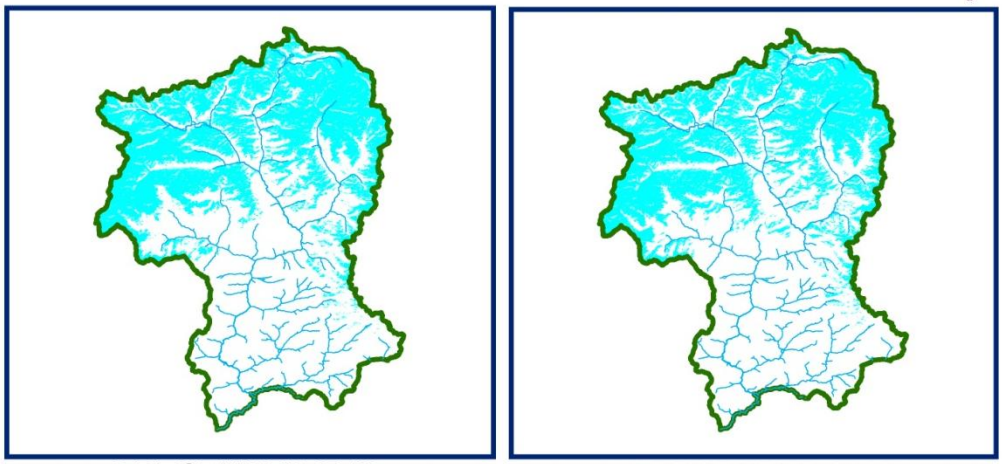
23 NOVEMBER 2013
28 NOVEMBER 2013

SNOW

0 20 40 80 120 160

Kilometers

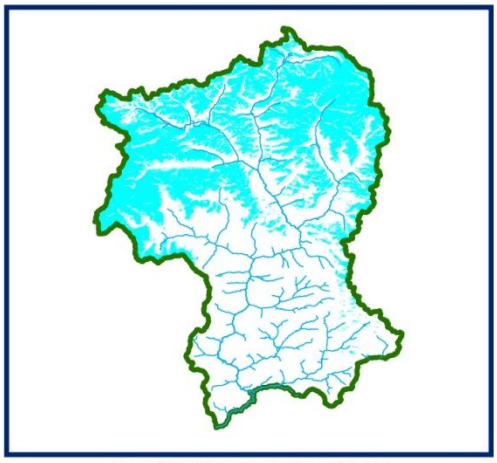
5 DAILY SNOW COVER MAP: TISTA



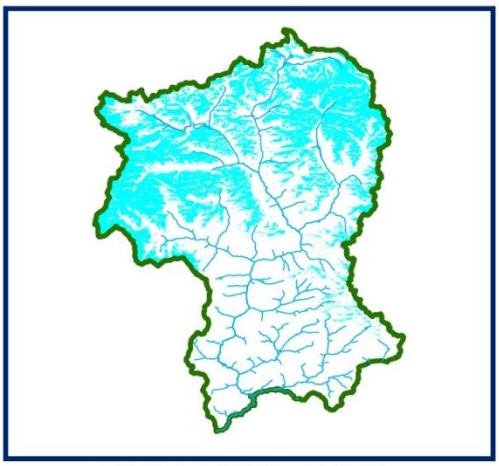
3 DECEMBER 2013

8 DECEMBER 2013

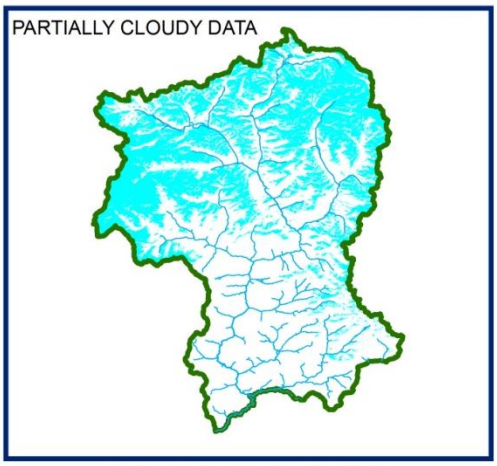
DATA NOT AVAILABLE



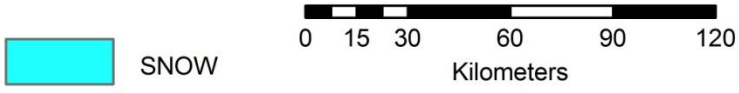
17 DECEMBER 2013



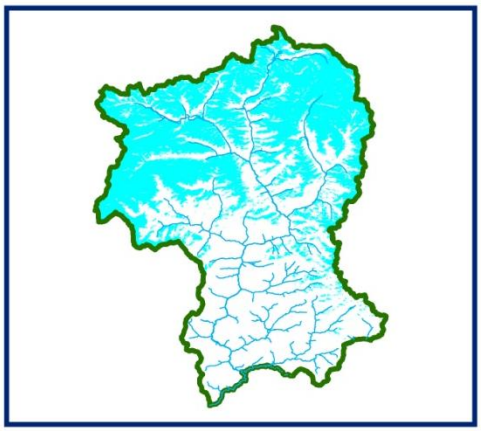
24 DECEMBER 2013



27 DECEMBER 2013

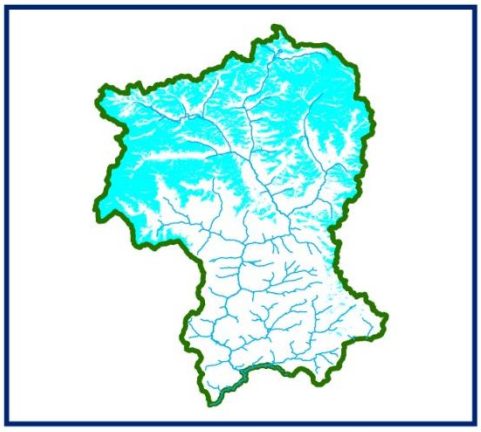


COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



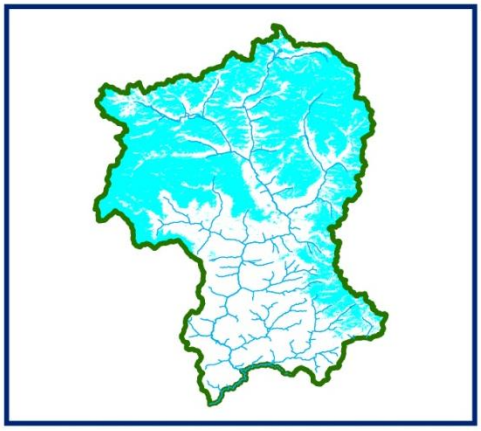
DATA USED

3 DECEMBER 2013
8 DECEMBER 2013



DATA USED

17 DECEMBER 2013



DATA USED

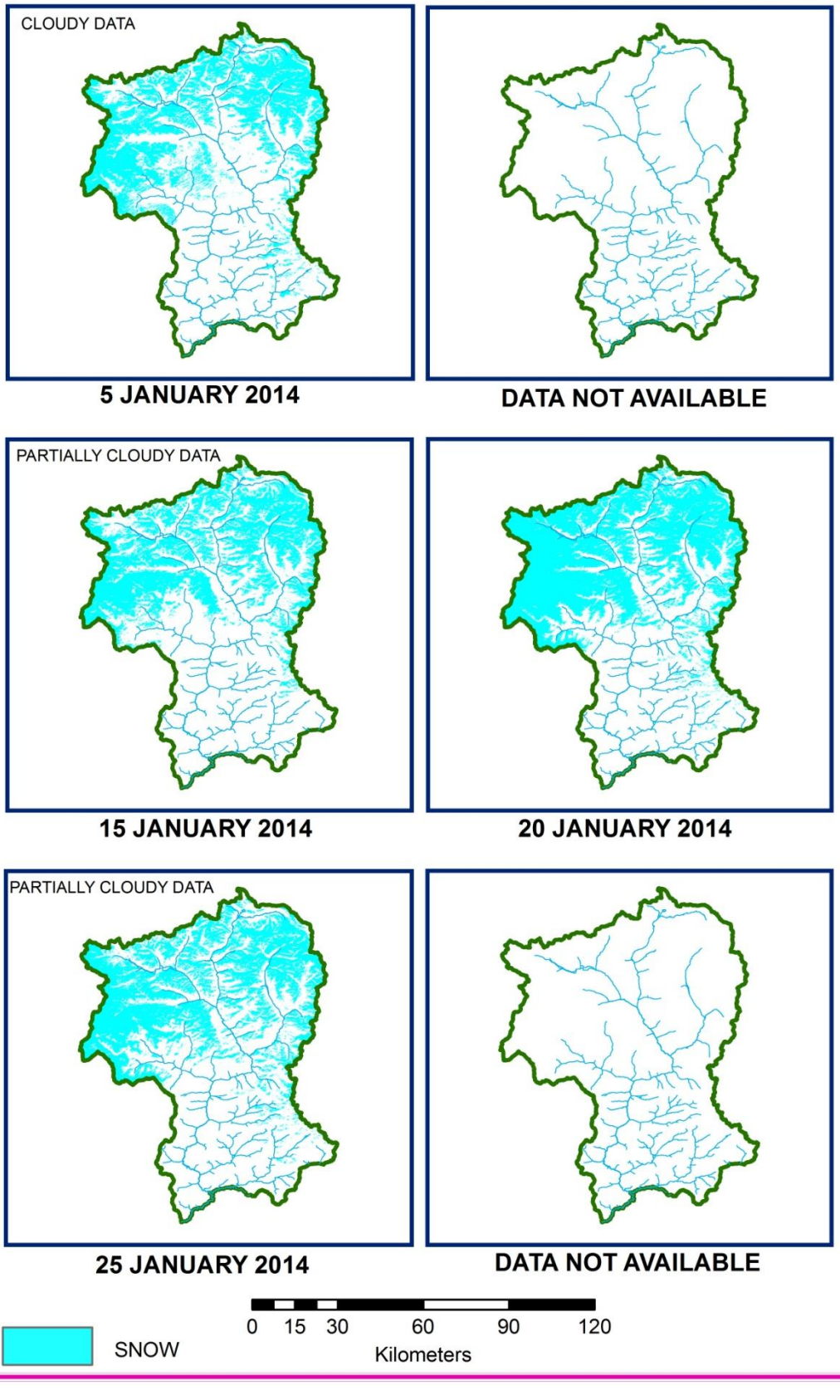
22 DECEMBER 2013
24 DECEMBER 2013
27 DECEMBER 2013

SNOW

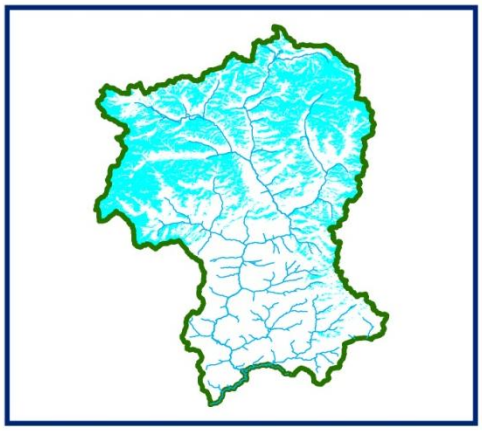
0 20 40 80 120 160

Kilometers

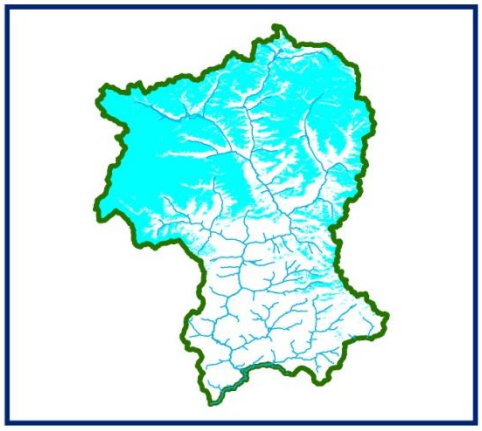
5 DAILY SNOW COVER MAP: TISTA



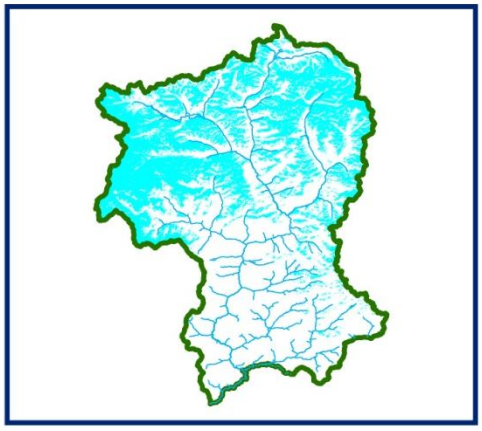
COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED
1 JANUARY 2014



DATA USED
15 JANUARY 2014
20 JANUARY 2014

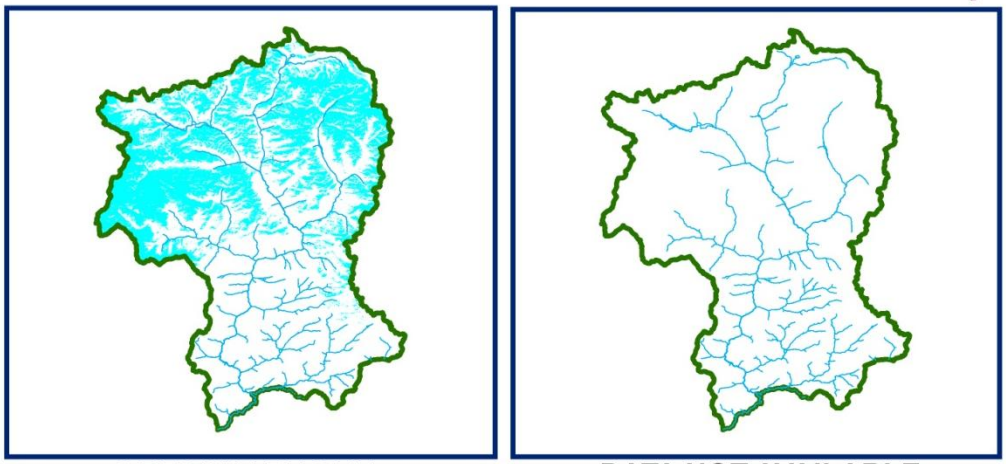


DATA USED
25 JANUARY 2014

SNOW

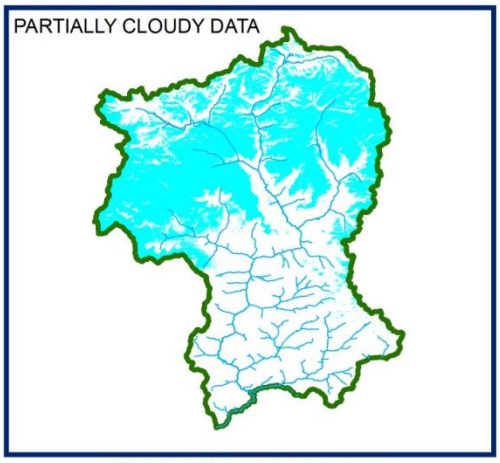
0 20 40 80 120 160
Kilometers

5 DAILY SNOW COVER MAP: TISTA

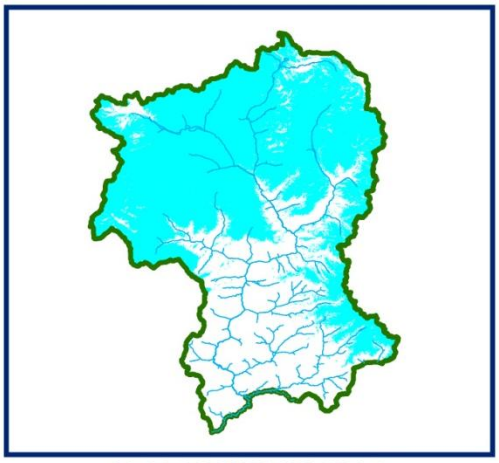


3 FEBRUARY 2014

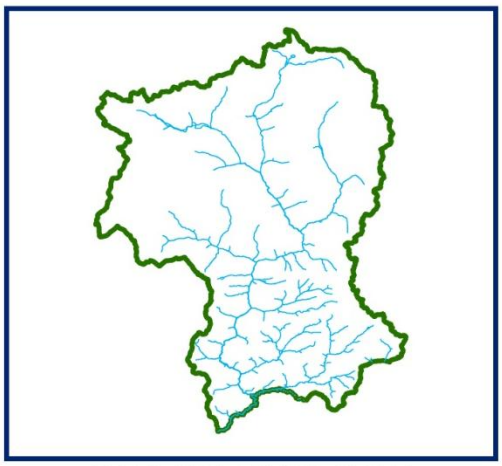
DATA NOT AVAILABLE



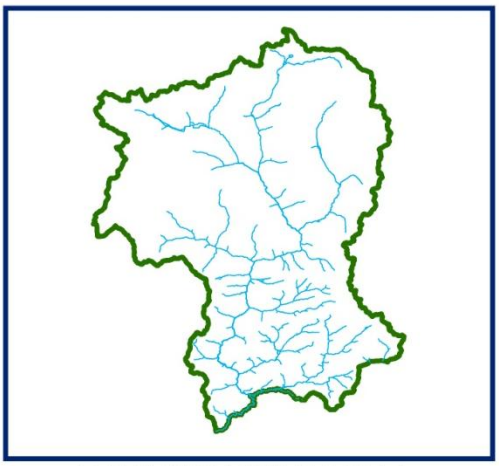
13 FEBRUARY 2014



18 FEBRUARY 2014



DATA NOT AVAILABLE



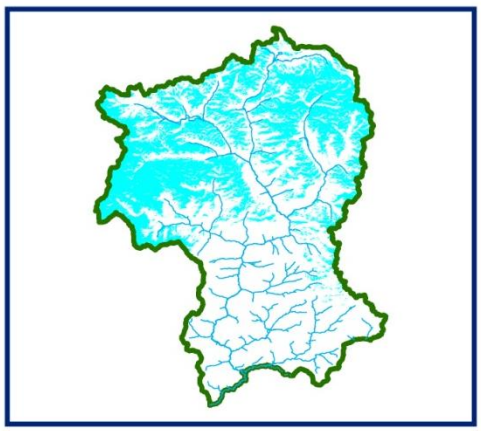
DATA NOT AVAILABLE

0 15 30 60 90 120

Kilometers

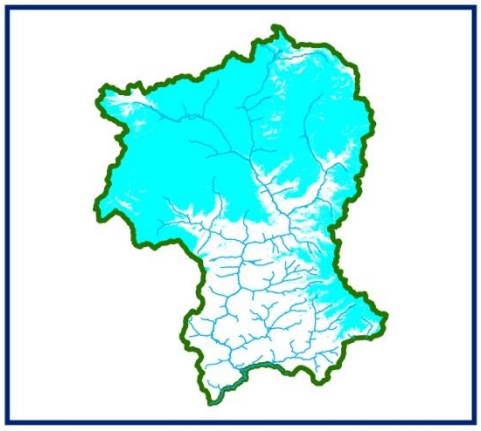
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



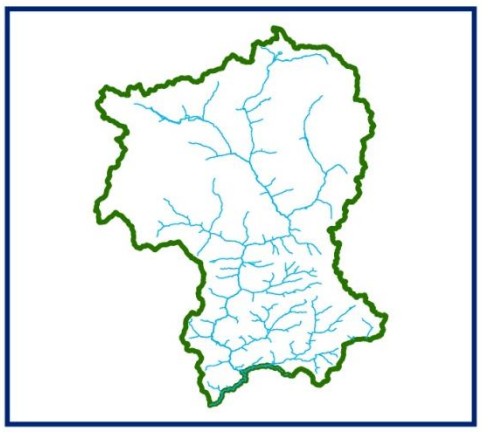
DATA USED

3 FEBRUARY 2014



DATA USED

18 FEBRUARY 2014



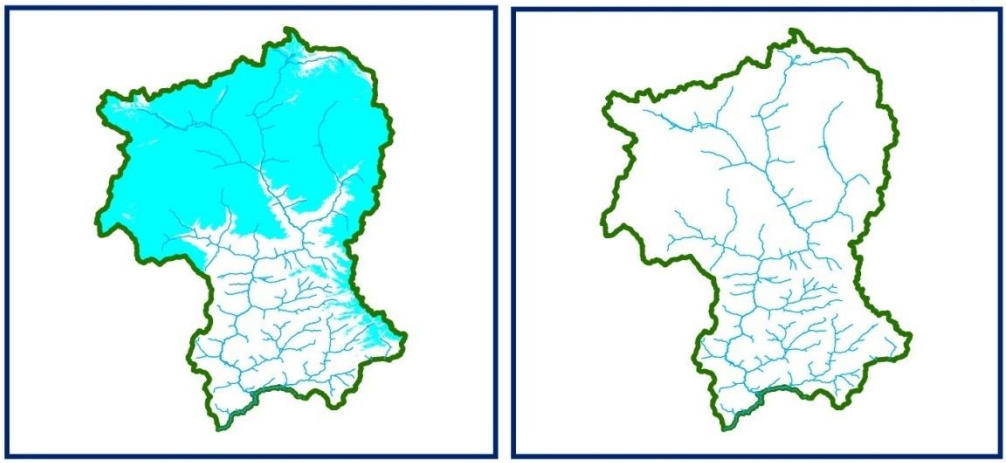
NO DATA AVAILABLE

SNOW

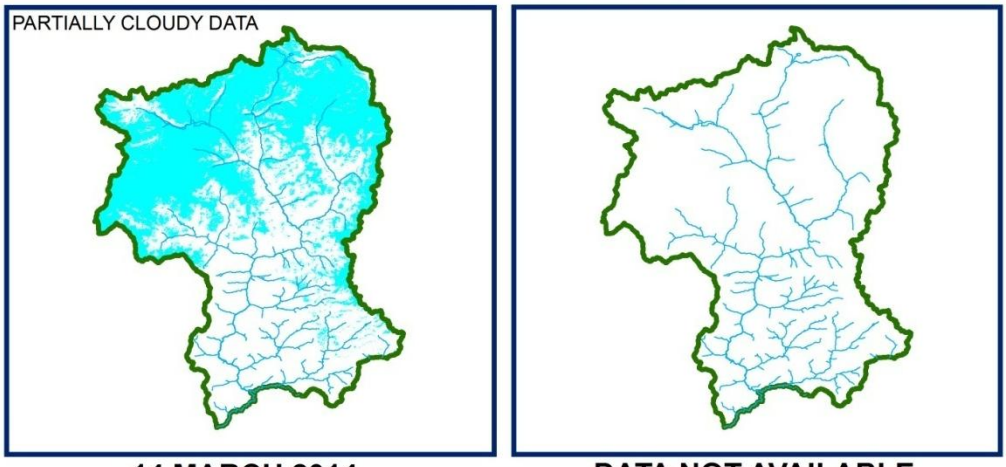
0 20 40 80 120 160

Kilometers

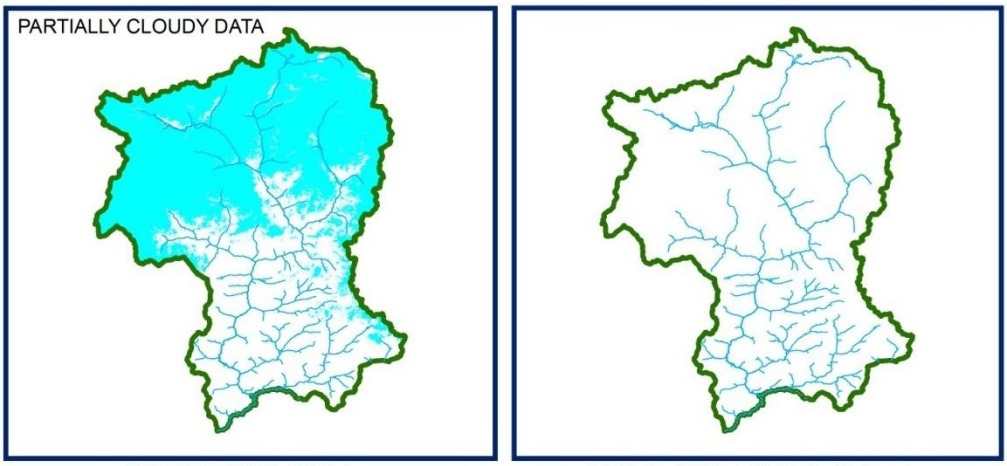
5 DAILY SNOW COVER MAP: TISTA



4 MARCH 2014 | DATA NOT AVAILABLE



14 MARCH 2014 | DATA NOT AVAILABLE



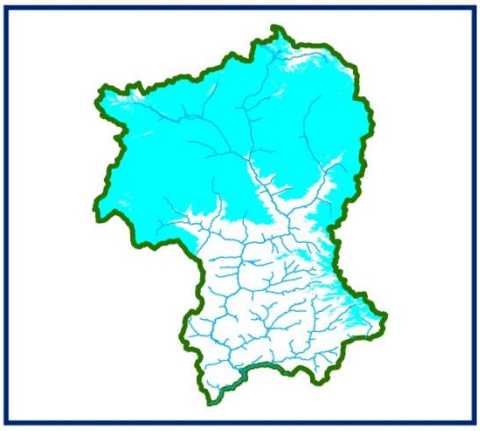
23 MARCH 2014 | DATA NOT AVAILABLE

0 15 30 60 90 120

Kilometers

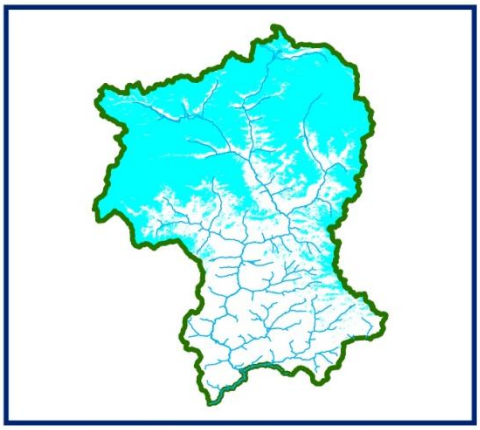
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



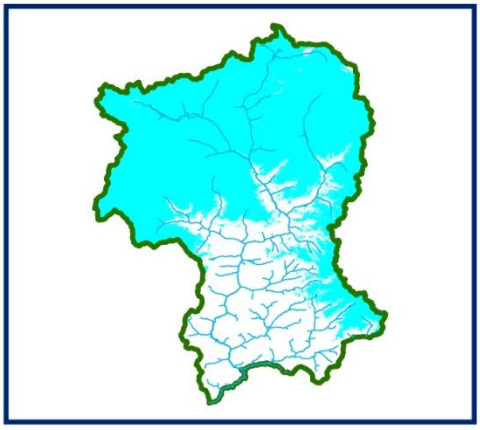
DATA USED

4 MARCH 2014



DATA USED

14 MARCH 2014
18 NOVEMBER 2014



DATA USED

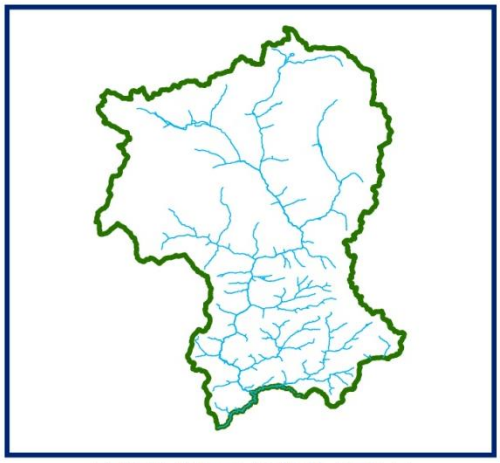
23 MARCH 2014
18 FEBRUARY 2014

SNOW

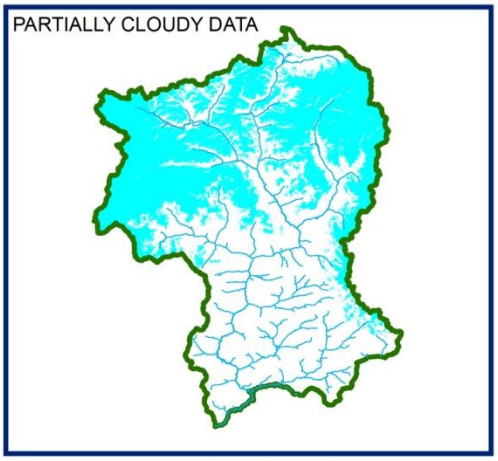
0 20 40 80 120 160

Kilometers

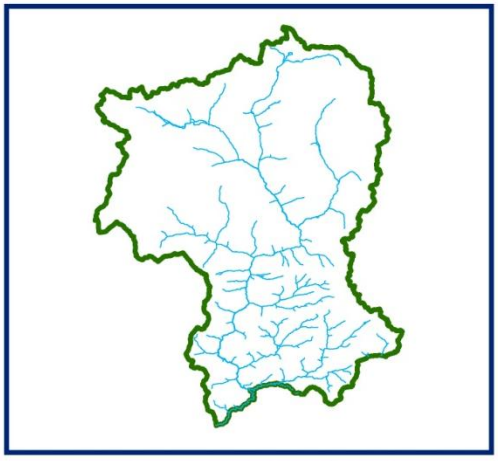
5 DAILY SNOW COVER MAP: TISTA



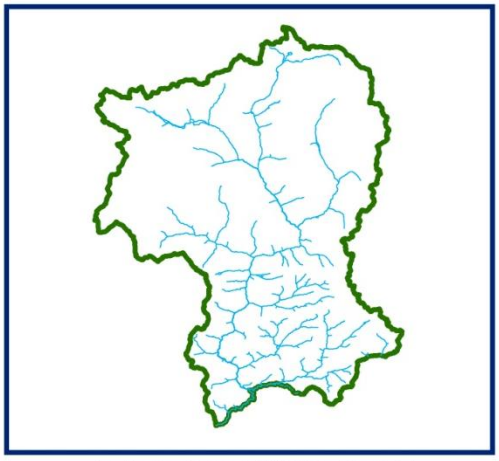
DATA NOT AVAILABLE



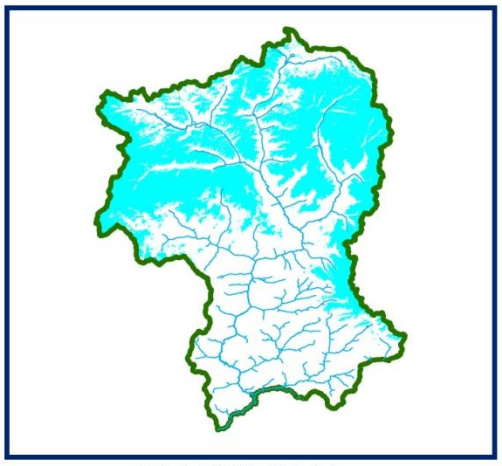
11 APRIL 2014



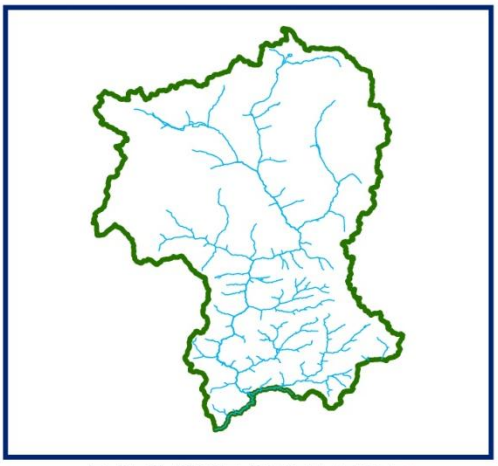
DATA NOT AVAILABLE



DATA NOT AVAILABLE



21 APRIL 2014



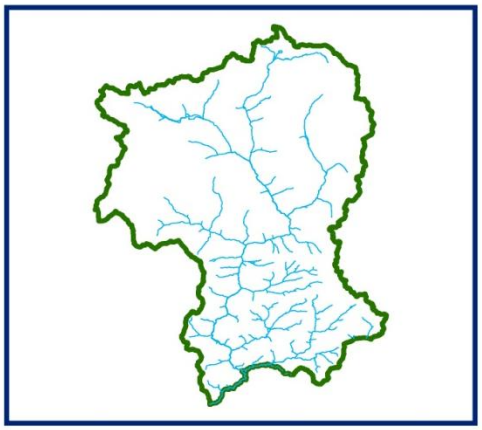
DATA NOT AVAILABLE

0 15 30 60 90 120

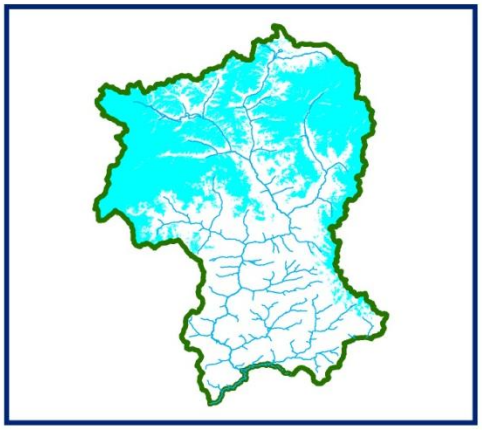
Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

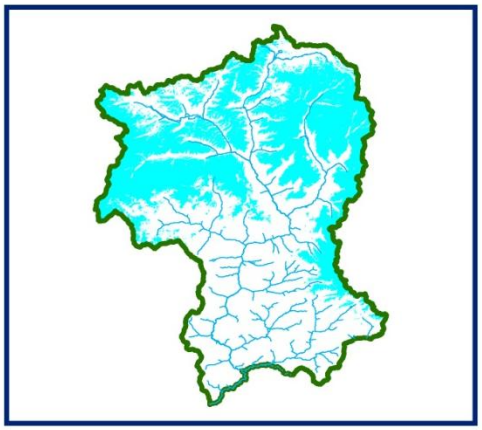


DATA NOT AVAILABLE



DATA USED

11 APRIL 2014



DATA USED

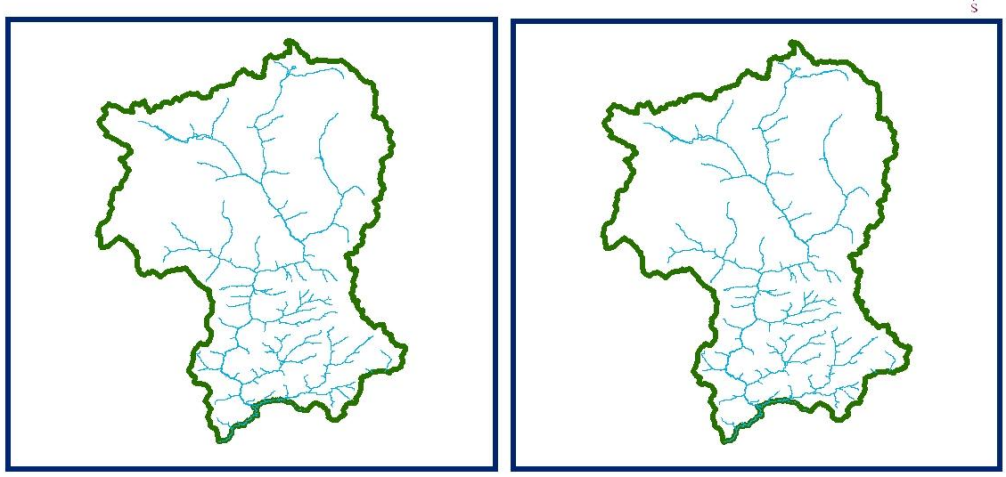
21 APRIL 2014

SNOW

0 20 40 80 120 160

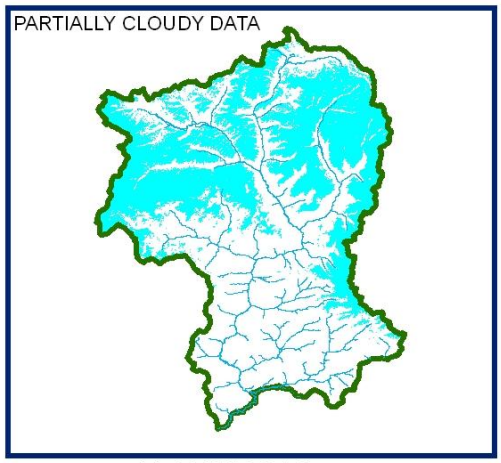
Kilometers

5 DAILY SNOW COVER MAP: TISTA

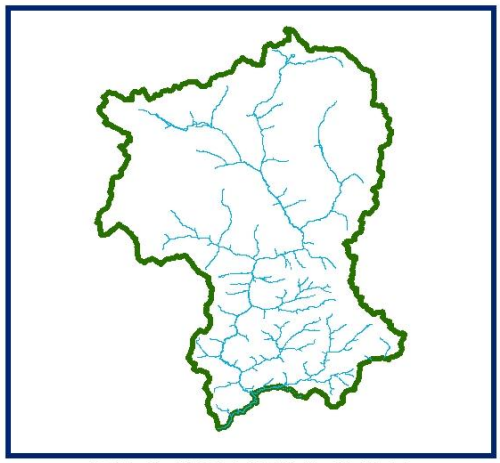


DATA NOT AVAILABLE

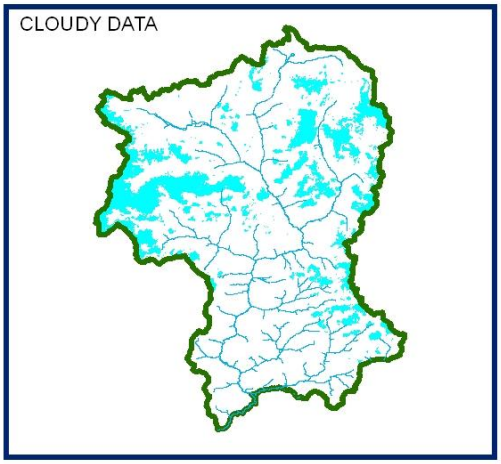
DATA NOT AVAILABLE



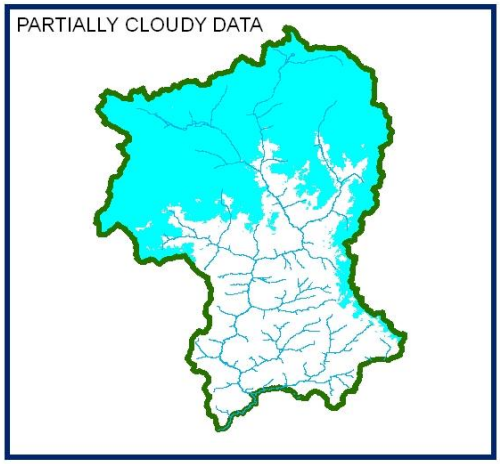
11 MAY 2014



DATA NOT AVAILABLE



25 MAY 2014



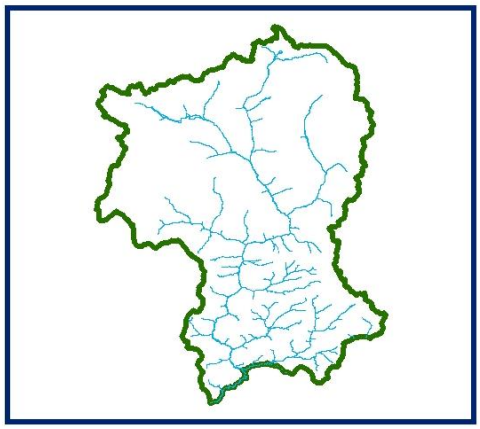
29 MAY 2014

SNOW

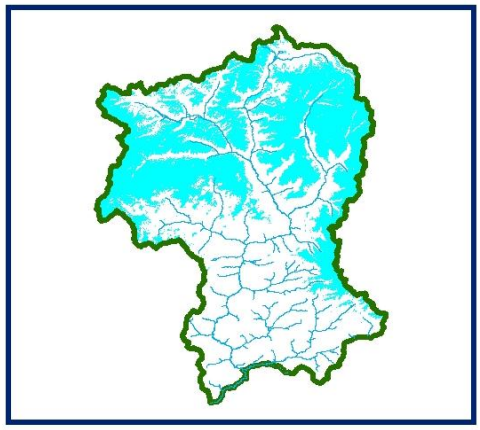
0 15 30 60 90 120

Kilometers

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



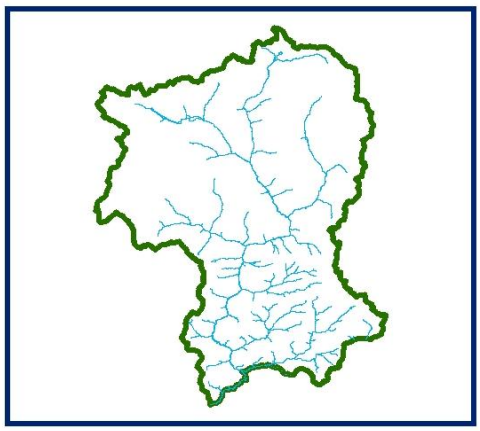
DATA NOT AVAILABLE



DATA USED

11 MAY 2014

21 APRIL 2014



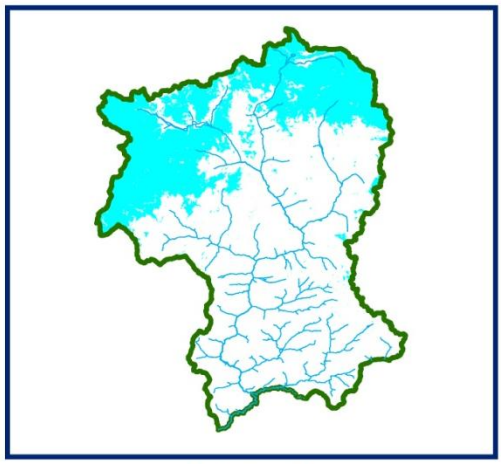
DATA NOT AVAILABLE

SNOW

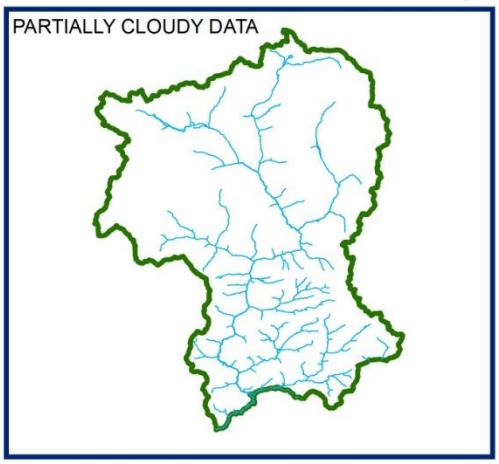
0 20 40 80 120 160

Kilometers

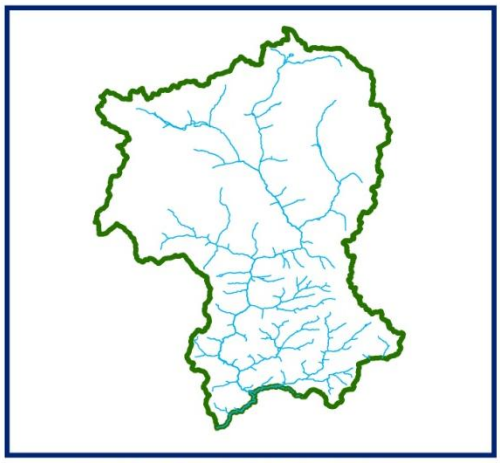
5 DAILY SNOW COVER MAP: TISTA



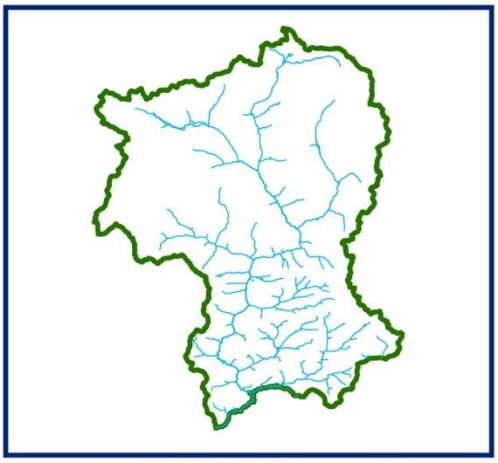
1 JUNE 2014



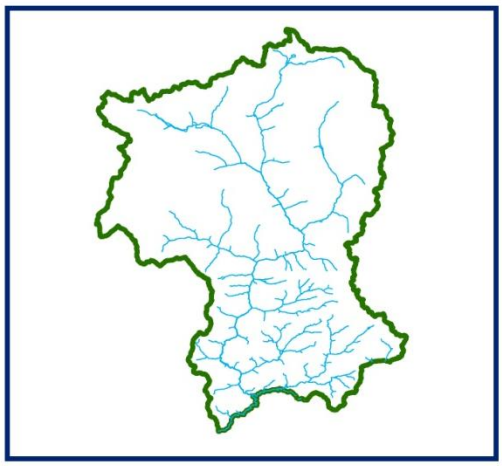
DATA NOT AVAILABLE



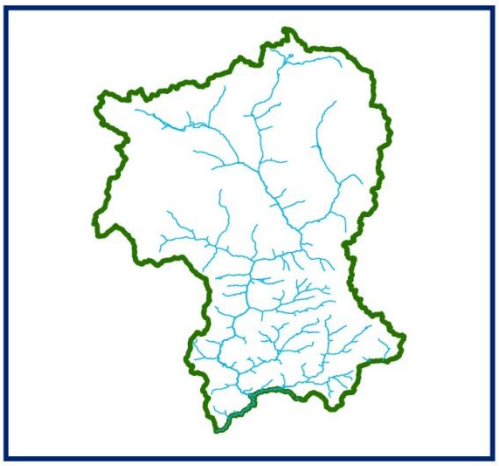
DATA NOT AVAILABLE



DATA NOT AVAILABLE



DATA NOT AVAILABLE



DATA NOT AVAILABLE

0 15 30 60 90 120

Kilometers

SNOW

RANGIT BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: RANGIT AREA: 1630 Km^2

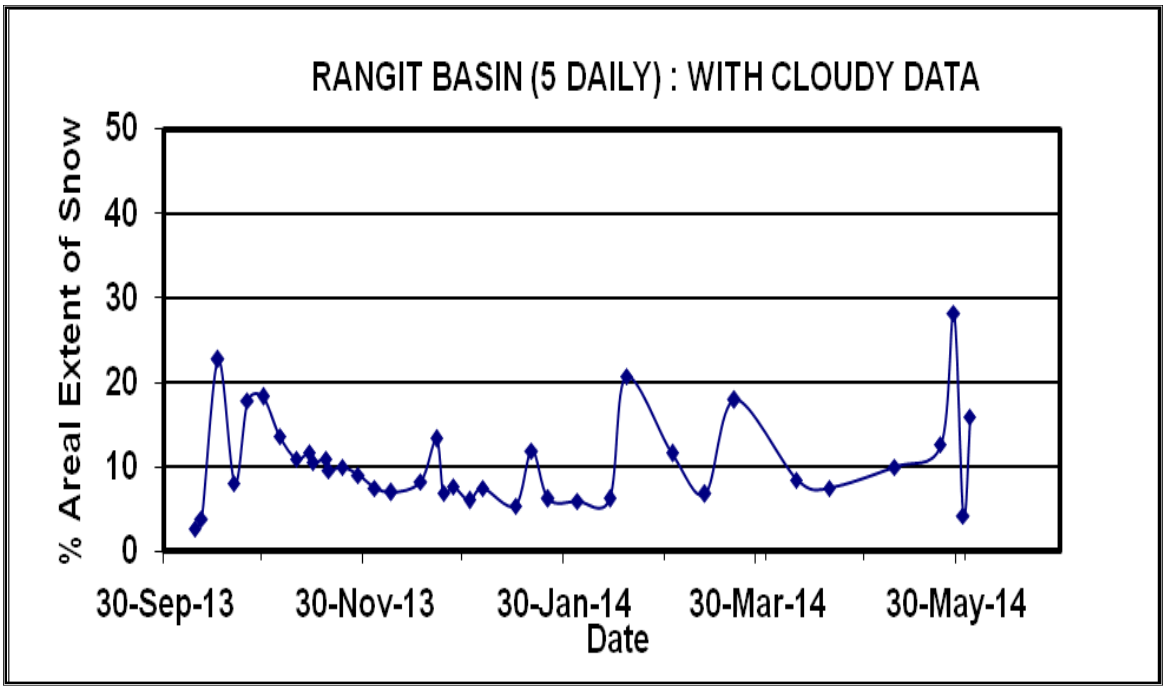
S No	Date	Snow Cover Km^2	Snow Cover %	S No	Date	Snow Cover Km^2	Snow Cover %
October 2013							
1	09-Oct-13	44	3	**2**	11-Oct-13	62	4
3	16-Oct-13	370	23	**4**	21-Oct-13(PC)	131	8
5	25-Oct-13(PC)	194	12	**6**	30-Oct-13(C)	298	18
November 2013							
7	04-Nov-13	223	14	**8**	09-Nov-13(PC)	178	11
9	13-Nov-13	191	12	**10**	14-Nov-13	172	11
11	18-Nov-13	177	11	**12**	19-Nov-13	157	10
13	23-Nov-13(C)	163	10	**14**	24-Nov-13	44	3
15	28-Nov-13	147	9				
December 2013							
16	03-Dec-13	123	7	**17**	08-Dec-13	115	7
18	17-Dec-13	134	8	**19**	22-Dec-13	217	13
20	24-Dec-13	112	7	**21**	27-Dec-13	125	8
January 2014							
22	01-Jan-14	99	6	**23**	05-Jan-14(PC)	122	7
24	15-Jan-14(PC)	88	5	**25**	20-Jan-14	194	12
26	25-Jan-14	101	6				
February 2014							
27	03-Feb-14	97	6	**28**	13-Feb-14(PC)	101	6
29	18-Feb-14	337	21				
March 2014							
30	04-Mar-14(PC)	189	12	**31**	14-Mar-14	110	7
32	23-Mar-14(PC)	292	18				
April 2014							
33	11-Apr-14(PC)	138	8	**34**	21-Apr-14	121.34	8
May 2014							
35	11-May-14(PC)	163	10	**36**	25-May-14(C)	205.59	13
37	29-May-14(PC)	460	28				
June 2014							
38	01-Jun-14(C)	69	4	**39**	03-Jun-14(PC)	259	16

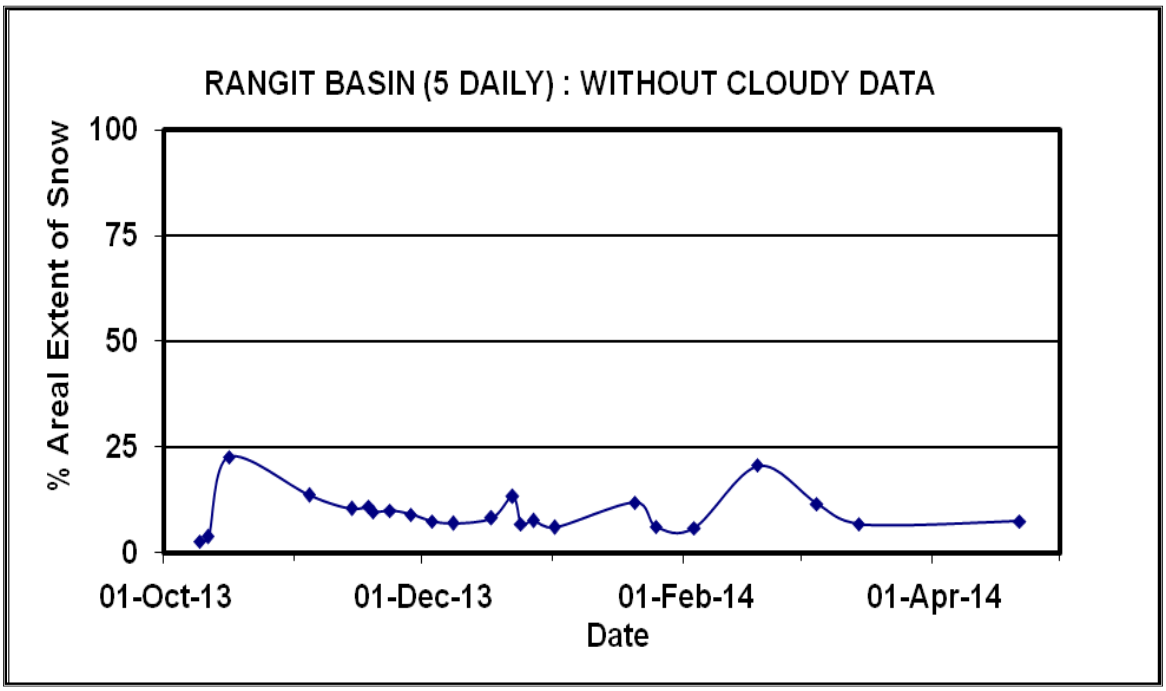
COMPOSITE SNOW COVER EXTENT OF SIKKIM

BASIN NAME: RANGIT AREA: 1630 Km^2

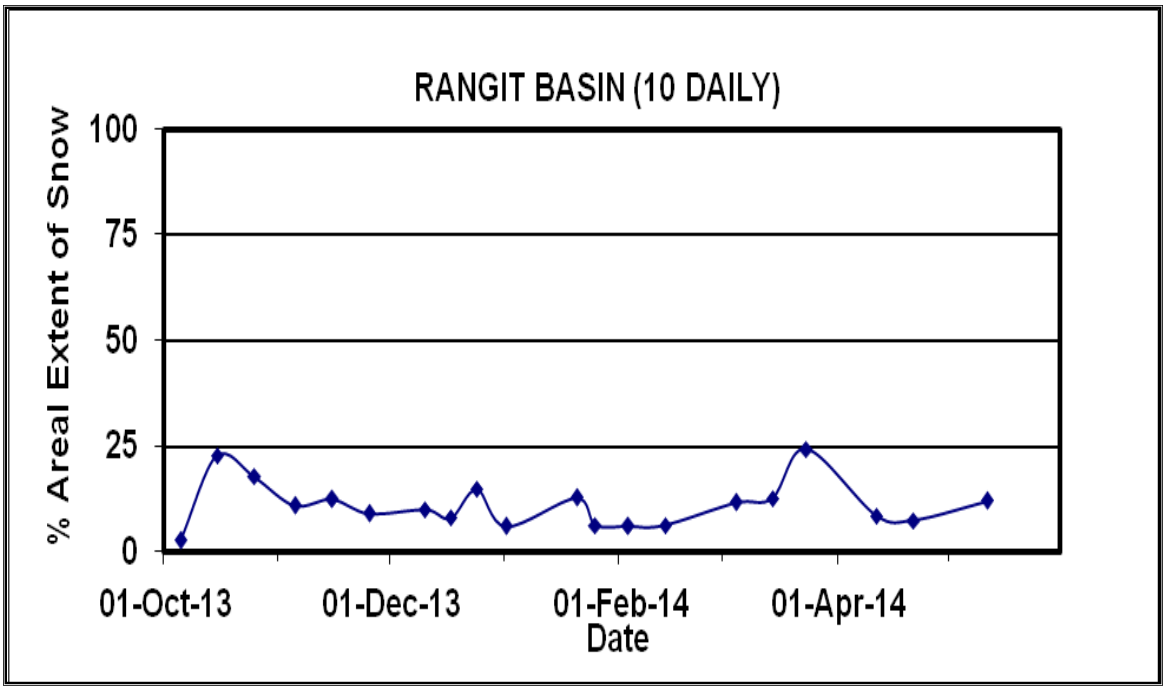
S No	Data used	Mean Date	Snow cover (km^2)	Snow cover %
October 2013				
1	09-Oct-13	09-Oct-13	44	3
2	11-Oct-13 16-Oct-13	16-Oct-13	242	15
3	25-Oct-13	25-Oct-13	194	12
November 2013				
4	09-Nov-13	09-Nov-13	178	11
5	14-Nov-13 18-Nov-13 19-Nov-13	18-Nov-13	204	12
6	23-Nov-13	23-Nov-13	147	9
December 2013				
7	03-Dec-14 08-Dec-14	08-Dec-13	162	10
8	17-Dec-14	17-Dec-13	134	8
9	22-Dec-14 24-Dec-14 27-Dec-14	24-Dec-13	241	15
January 2014				
10	01-Jan-14	01-Jan-14	99	6
11	15-Jan-14 20-Jan-14	20-Jan-14	209	13
12	25-Jan-14	25-Jan-14	101	6
February 2014				
13	03-Feb-14	03-Feb-14	97	6
14	18-Feb-14	18-Feb-14	337	21
March 2014				
15	04-Mar-14	04-Mar-14	189	12
16	14-Mar-14 18-Mar-14	14-Mar-14	207	13
17	23-Mar-14 18-Feb-14	23-Mar-14	397	24
April 2014				
18	11-Apr-14	11-Apr-14	138	8
19	21-Apr-14	21-Apr-14	121	7
May 2014				
20	11-May-14	11-May-14	201	12

SNOW COVER DEPLETION CURVE



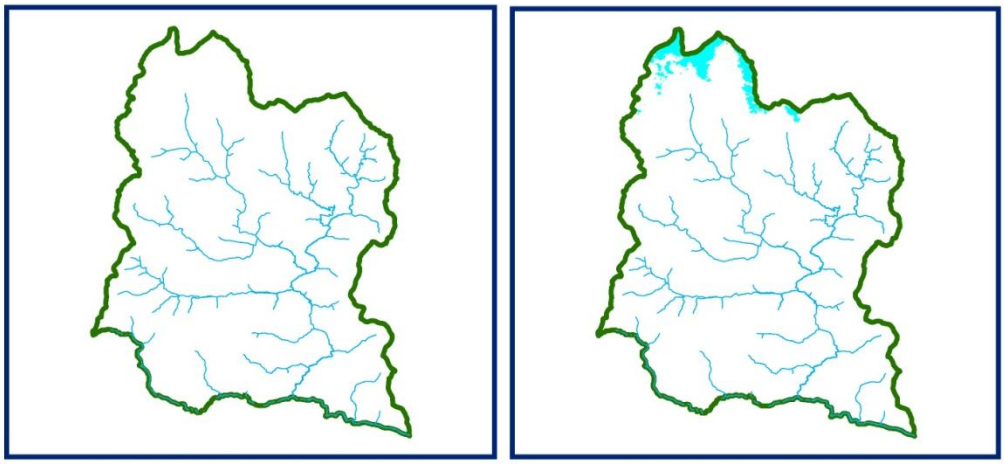


SNOW COVER DEPLETION CURVE



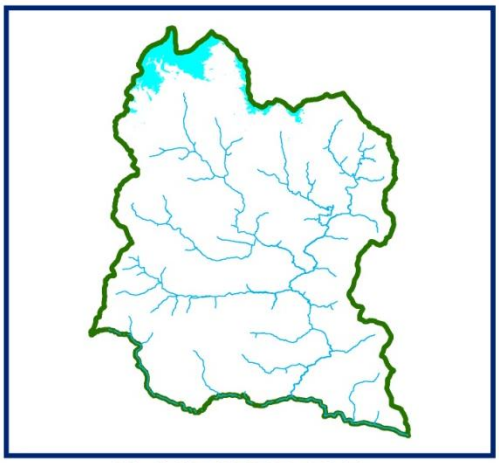
SNOW COVER MAP

5 DAILY SNOW COVER MAP: RANGIT BASIN

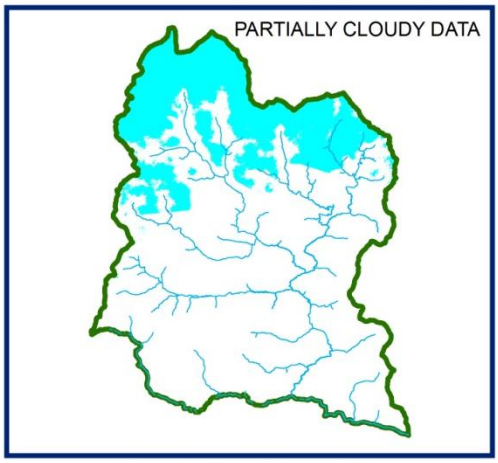


DATA NOT AVAILABLE

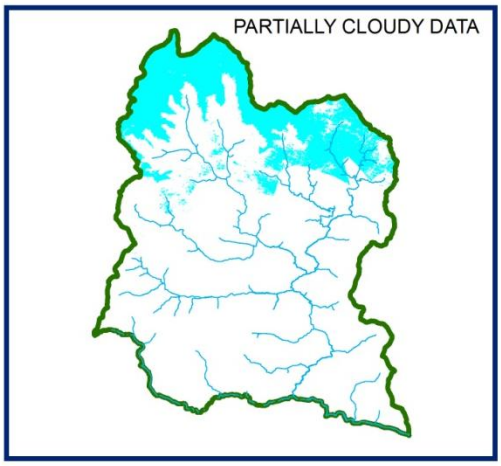
9 OCTOBER 2013



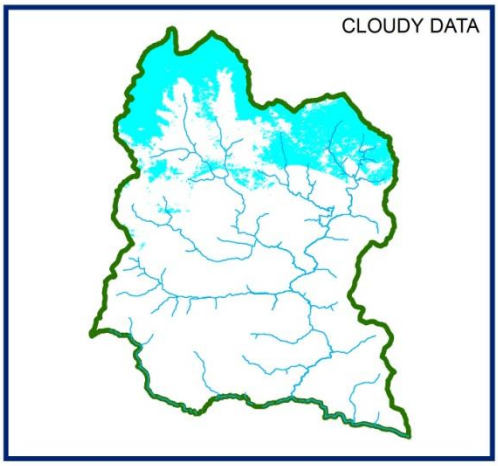
11 OCTOBER 2013



16 OCTOBER 2013

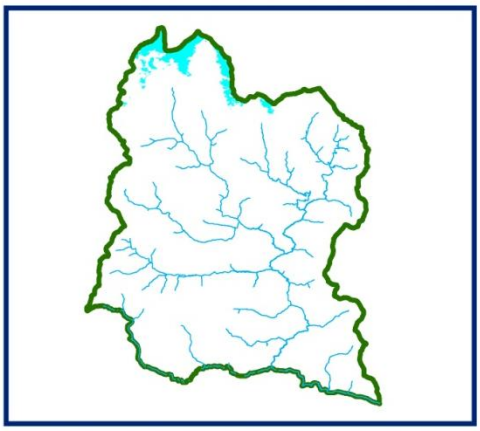


25 OCTOBER 2013

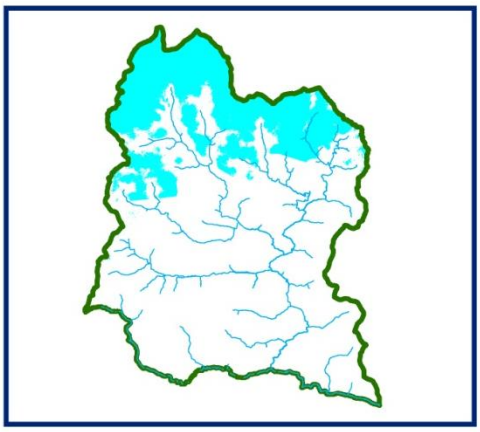


30 OCTOBER 2013

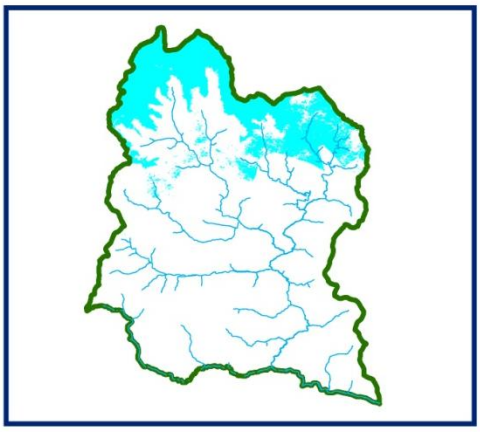
COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED
9 OCTOBER 2013



DATA USED
11 OCTOBER 2013
16 OCTOBER 2013

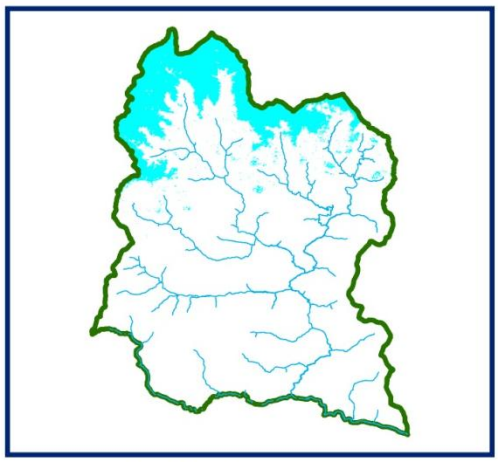


DATA USED
25 OCTOBER 2013

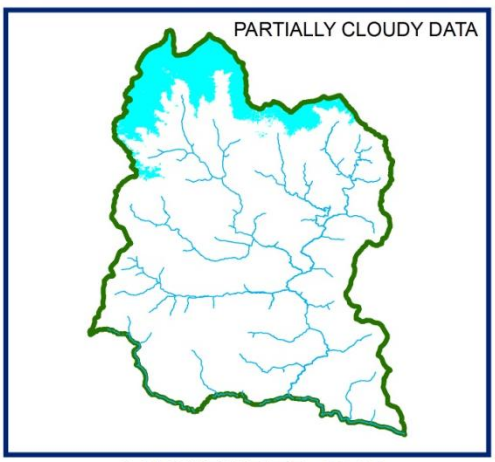
SNOW

0 10 20 40 60 80
Kilometers

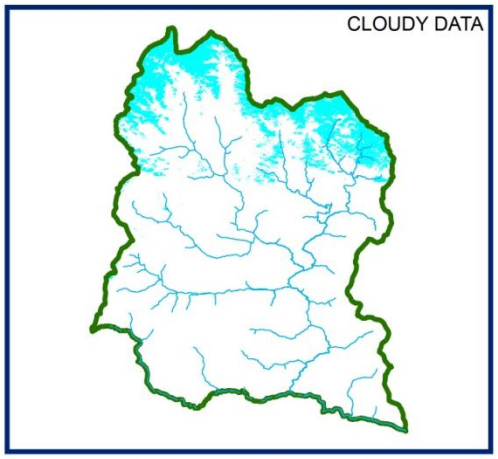
5 DAILY SNOW COVER MAP: TISTA BASIN



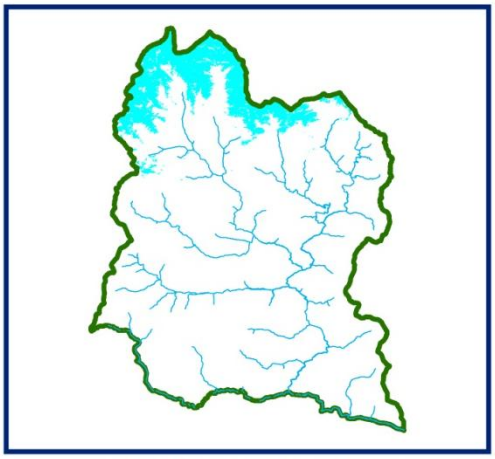
4 NOVEMBER 2013



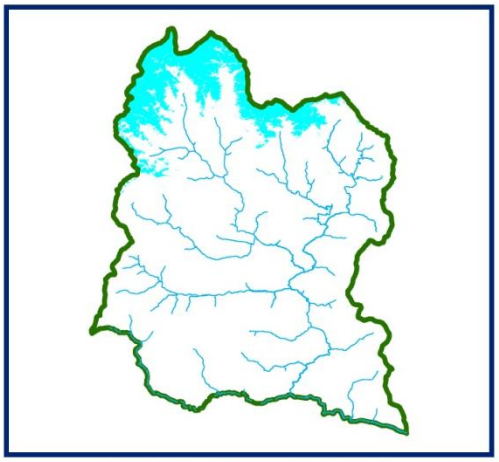
9 NOVEMBER 2013



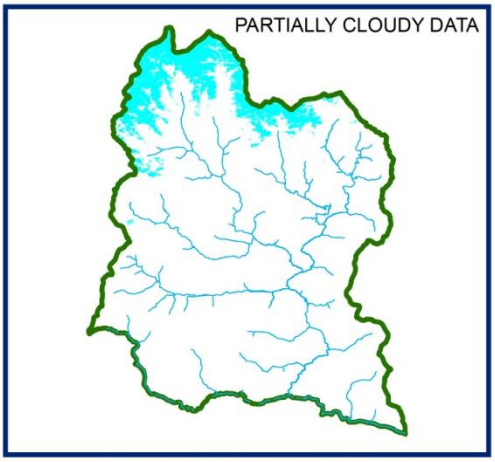
13 NOVEMBER 2013



19 NOVEMBER 2013



23 NOVEMBER 2013



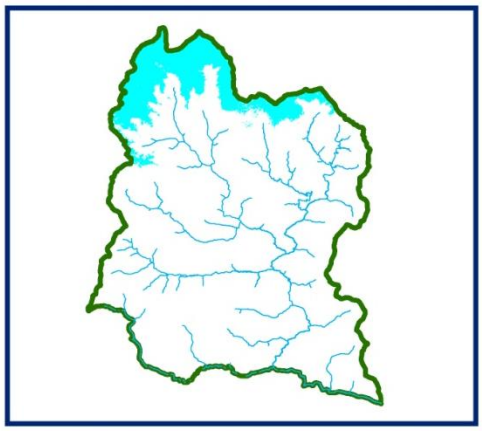
28 NOVEMBER 2013

0 5 10 20 30 40

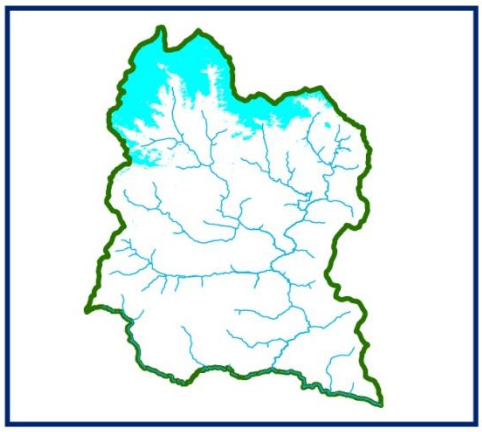
Kilometers

SNOW

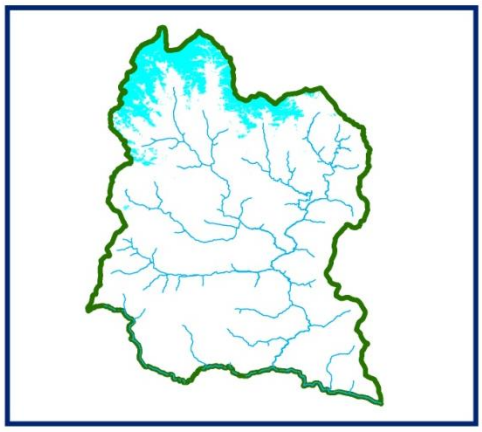
COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED
9 NOVEMBER 2014



DATA USED
14 NOVEMBER 2013
18 NOVEMBER 2013
19 NOVEMBER 2013

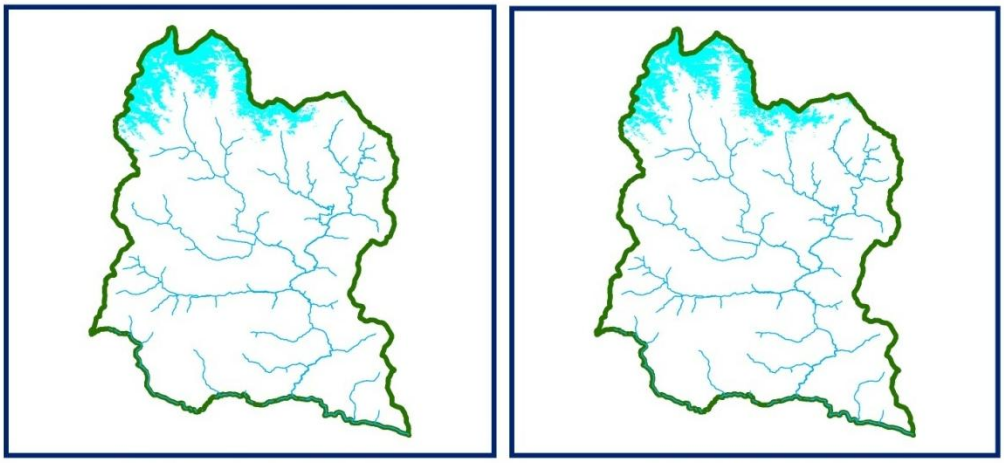


DATA USED
23 NOVEMBER 2013
28 NOVEMBER 2013

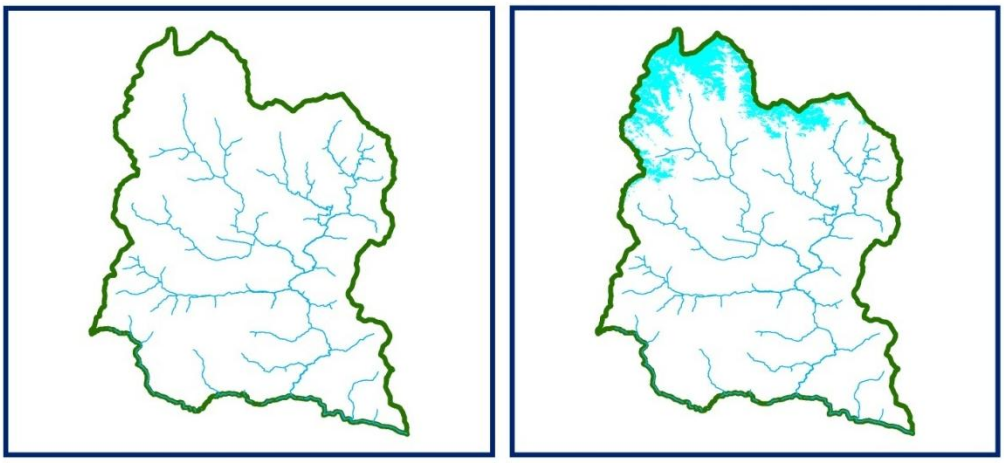
SNOW

0 10 20 40 60 80
Kilometers

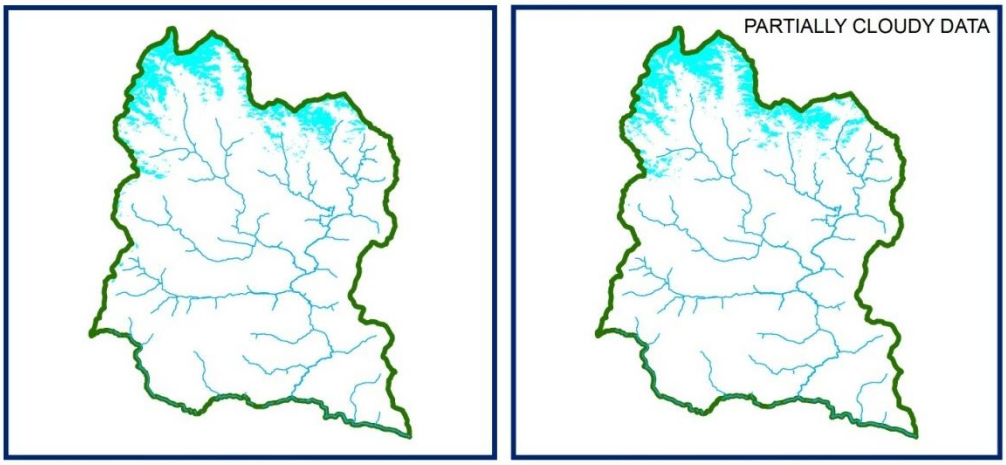
5 DAILY SNOW COVER MAP: TISTA BASIN



3 DECEMBER 2013 | 8 DECEMBER 2013



DATA NOT AVAILABLE | 17 DECEMBER 2013



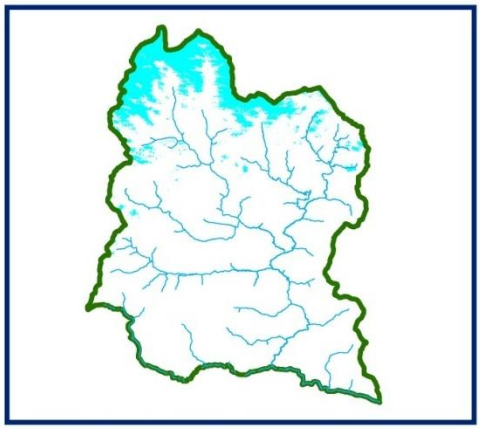
24 DECEMBER 2013 | 27 DECEMBER 2013

0 5 10 20 30 40

Kilometers

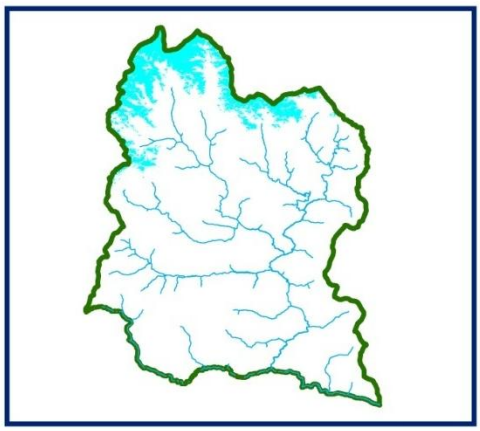
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



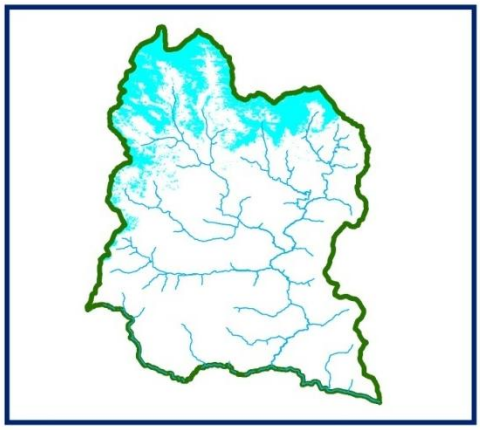
DATA USED

3 DECEMBER 2013
8 DECEMBER 2013



DATA USED

17 DECEMBER 2013



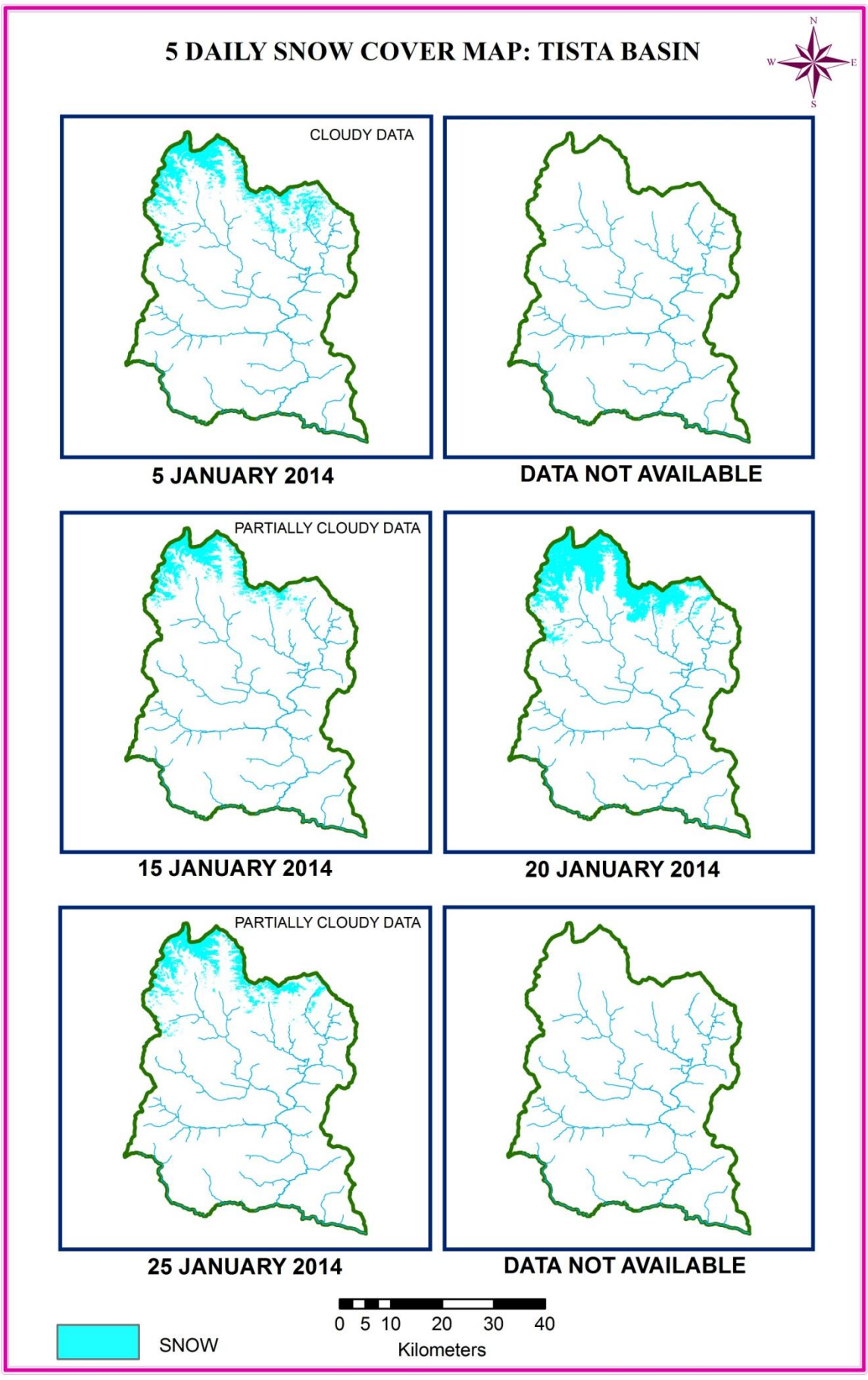
DATA USED

22 DECEMBER 2013
24 DECEMBER 2013
27 DECEMBER 2013

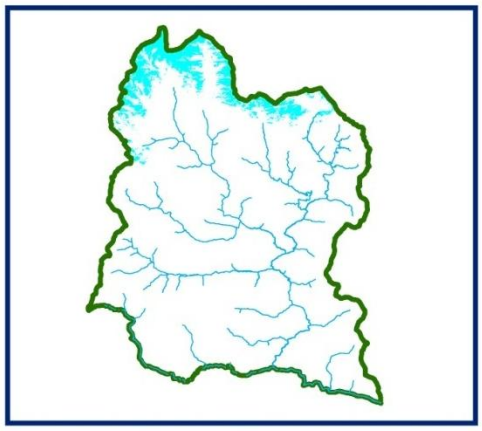
SNOW

0 10 20 40 60 80

Kilometers

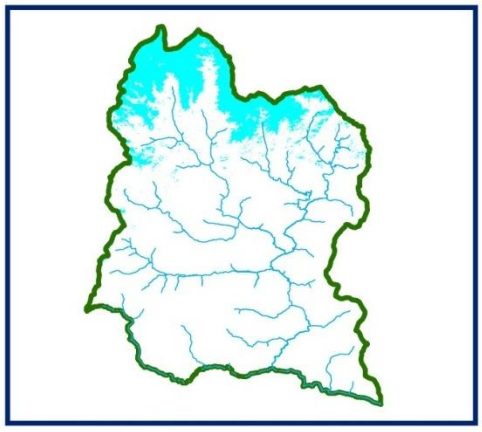

5 DAILY SNOW COVER MAP: TISTA BASIN
N
W
E
S
CLOUDY DATA
5 JANUARY 2014
DATA NOT AVAILABLE
PARTIALLY CLOUDY DATA
15 JANUARY 2014
20 JANUARY 2014
PARTIALLY CLOUDY DATA
25 JANUARY 2014
DATA NOT AVAILABLE
0 5 10 20 30 40
Kilometers
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED

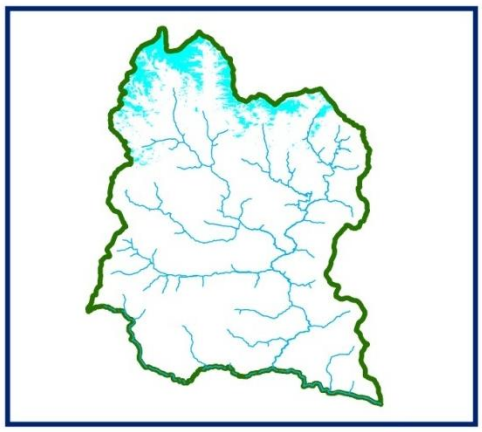
1 JANUARY 2014



DATA USED

15 JANUARY 2014

20 JANUARY 2014



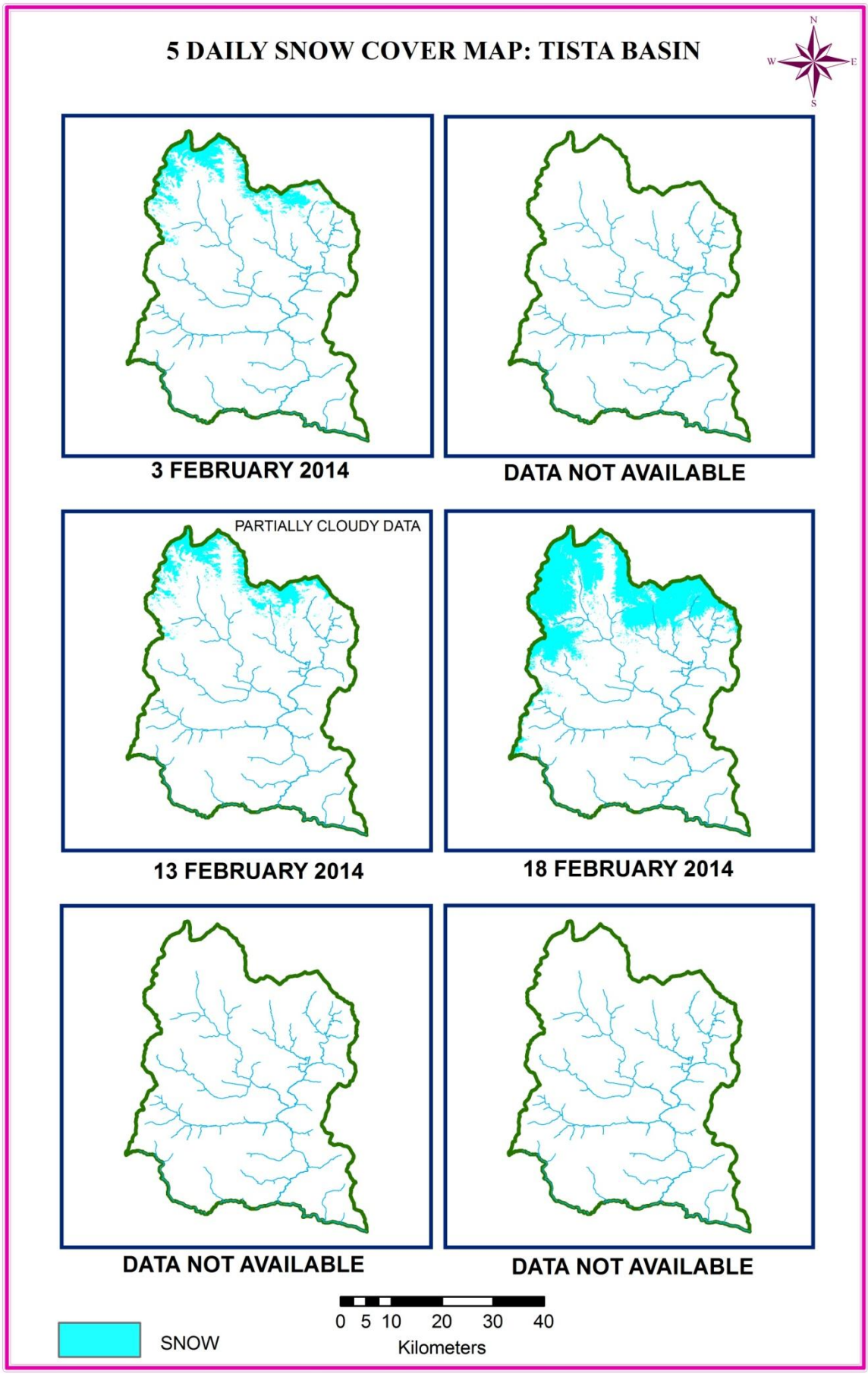
DATA USED

25 JANUARY 2014

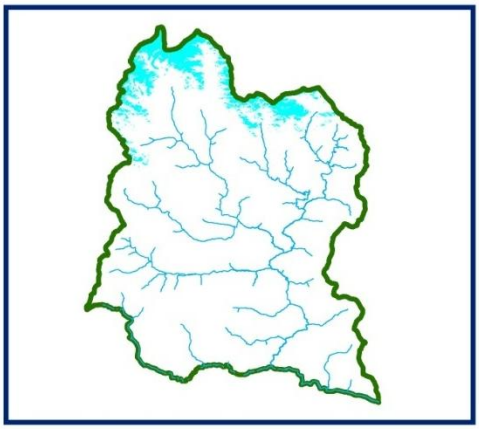
SNOW

0 10 20 40 60 80

Kilometers

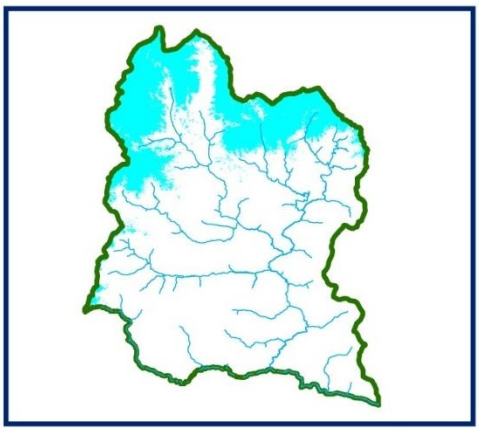

5 DAILY SNOW COVER MAP: TISTA BASIN
N
W
E
S
3 FEBRUARY 2014
DATA NOT AVAILABLE
PARTIALLY CLOUDY DATA
13 FEBRUARY 2014
18 FEBRUARY 2014
DATA NOT AVAILABLE
DATA NOT AVAILABLE
0 5 10 20 30 40
Kilometers
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



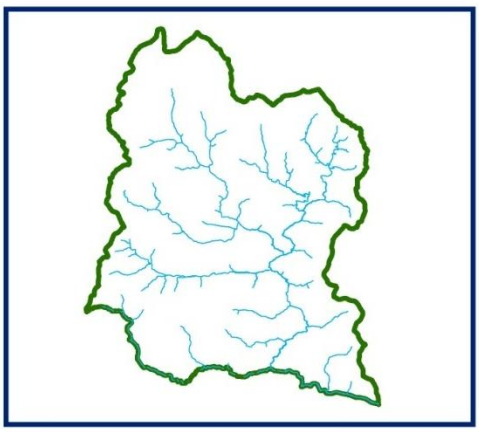
DATA USED

3 FEBRUARY 2014



DATA USED

18 FEBRUARY 2014



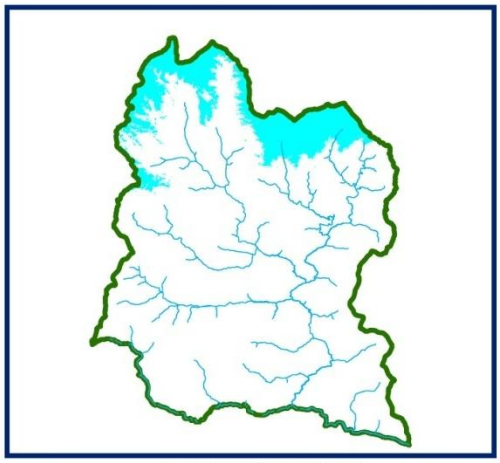
NO DATA AVAILABLE

SNOW

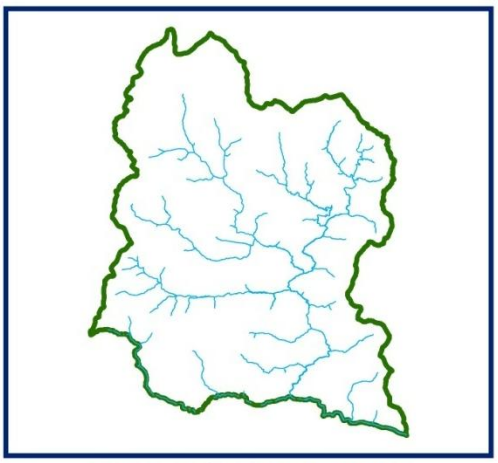
0 10 20 40 60 80

Kilometers

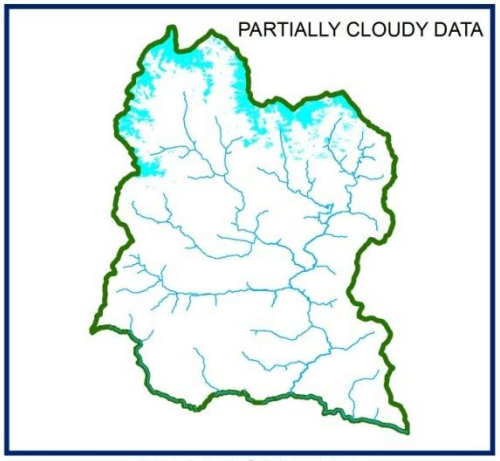
5 DAILY SNOW COVER MAP: TISTA BASIN



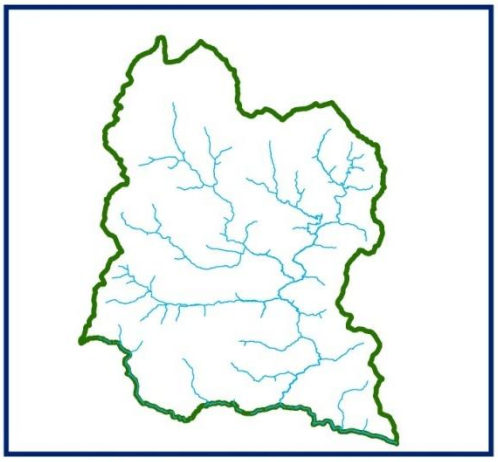
4 MARCH 2014



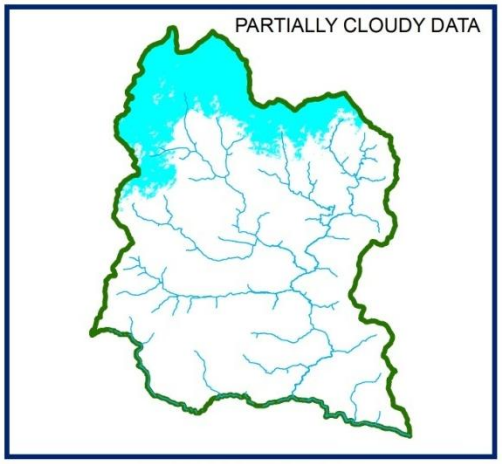
DATA NOT AVAILABLE



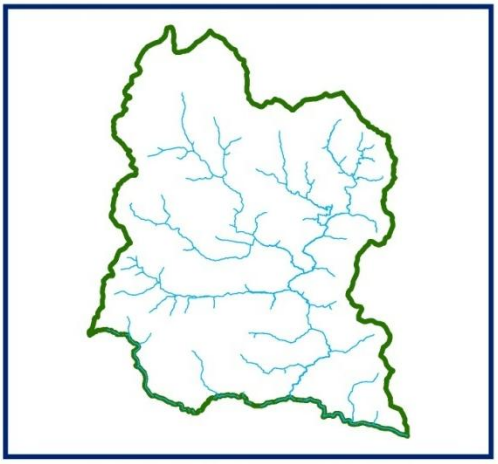
14 MARCH 2014



DATA NOT AVAILABLE



23 MARCH 2014



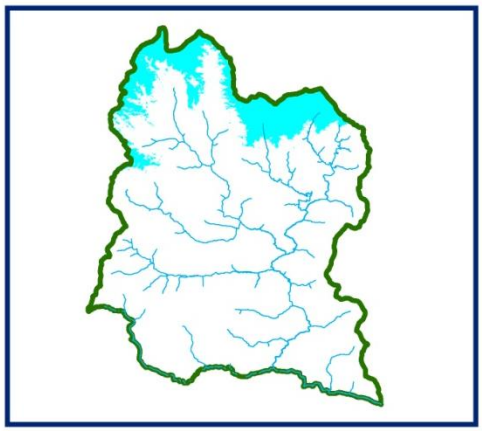
DATA NOT AVAILABLE

SNOW

0 5 10 20 30 40

Kilometers

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED
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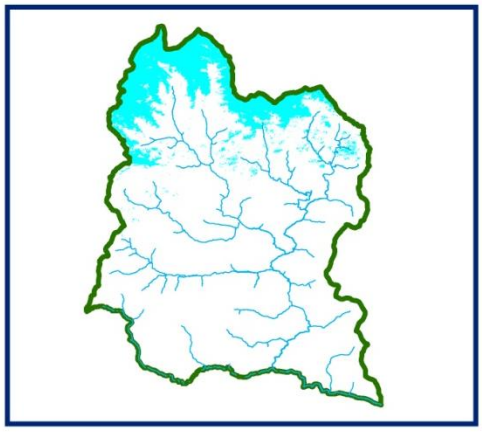

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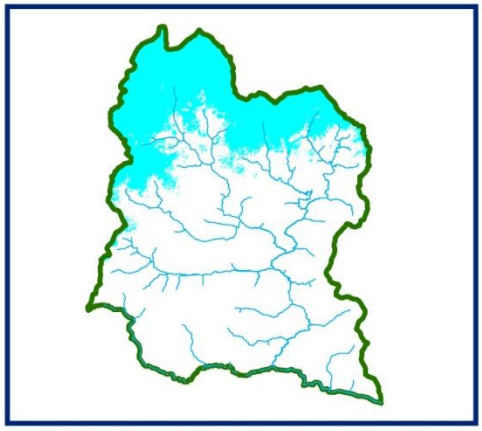
18 NOVEMBER 2014

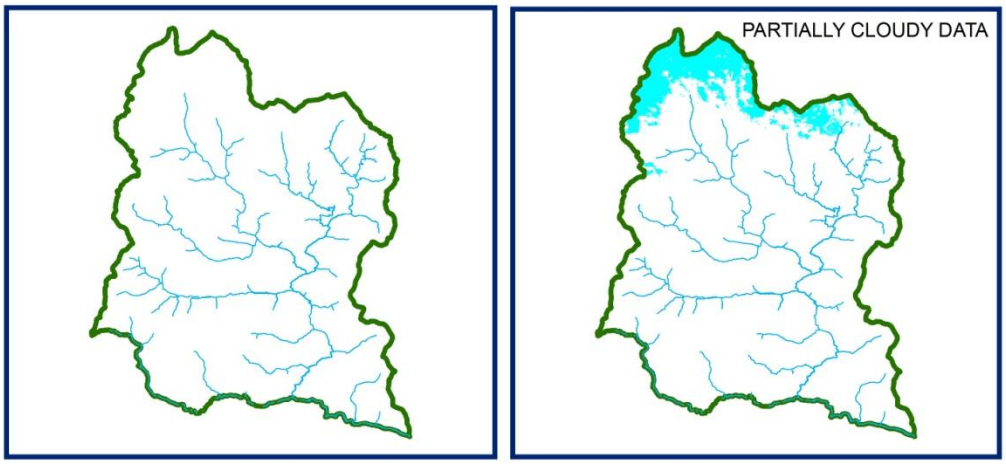


DATA USED
23 MARCH 2014
18 FEBRUARY 2014

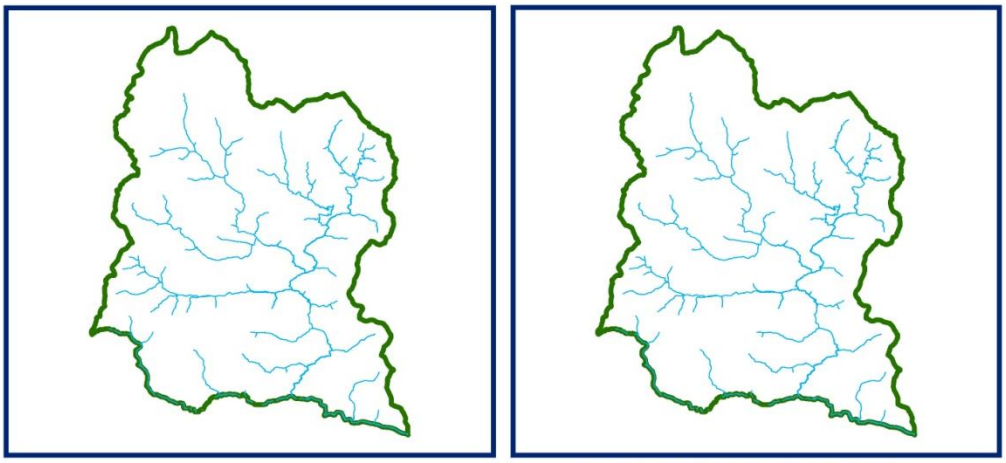
SNOW

0 10 20 40 60 80
Kilometers

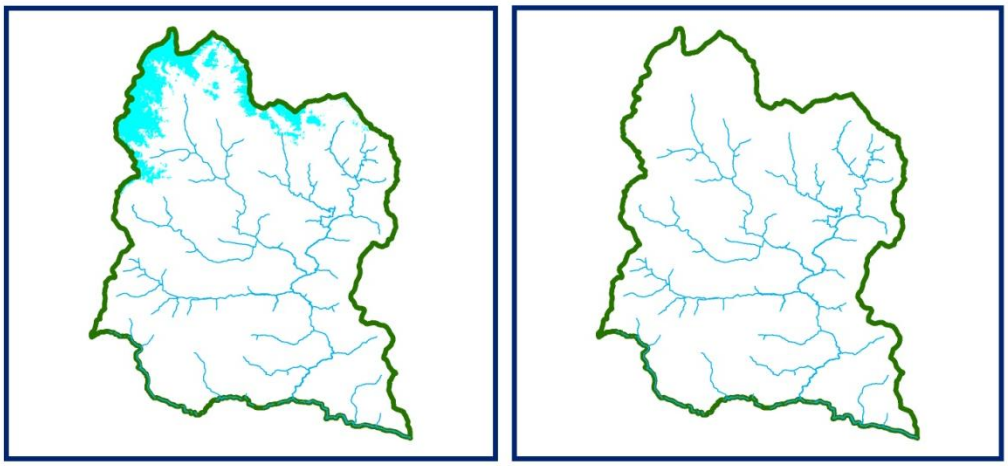
5 DAILY SNOW COVER MAP: TISTA BASIN



DATA NOT AVAILABLE | 11 APRIL 2014



DATA NOT AVAILABLE | DATA NOT AVAILABLE

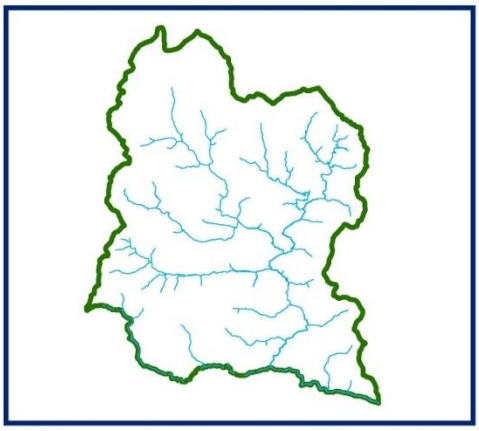


21 APRIL 2014 | DATA NOT AVAILABLE

SNOW

0 5 10 20 30 40
Kilometers

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



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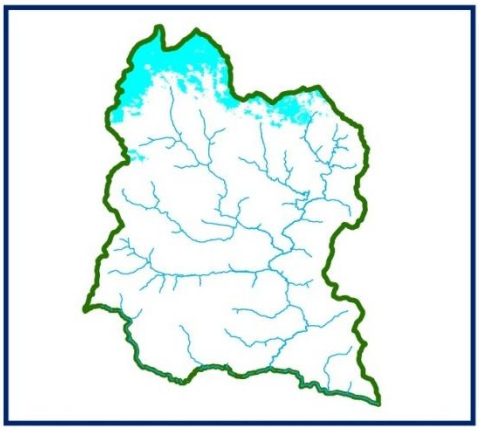
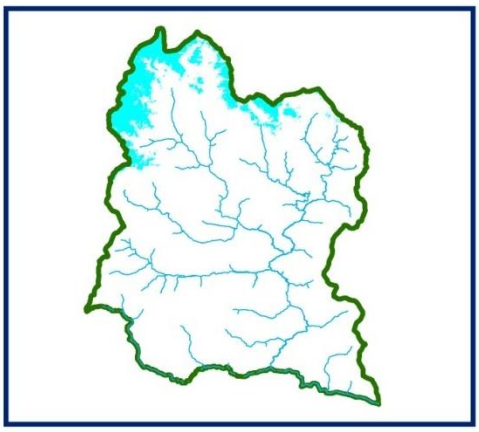


DATA USED

11 APRIL 2014



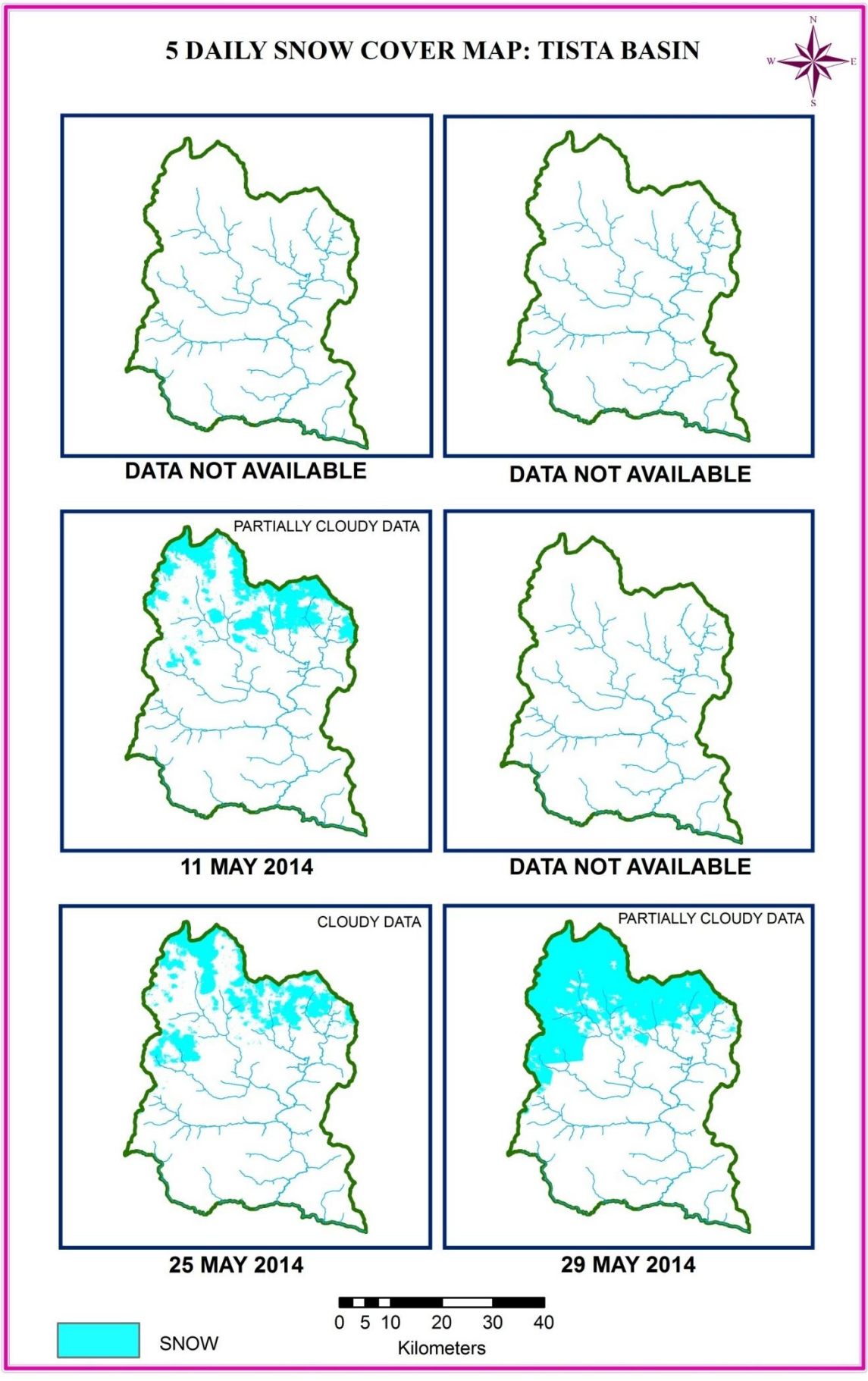
DATA USED

21 APRIL 2014

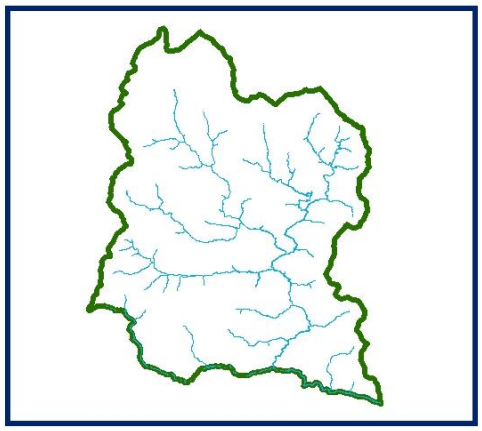
SNOW

0 10 20 40 60 80

Kilometers


5 DAILY SNOW COVER MAP: TISTA BASIN
N
W
E
S
DATA NOT AVAILABLE
DATA NOT AVAILABLE
PARTIALLY CLOUDY DATA
11 MAY 2014
DATA NOT AVAILABLE
CLOUDY DATA
25 MAY 2014
PARTIALLY CLOUDY DATA
29 MAY 2014
0 5 10 20 30 40
Kilometers
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



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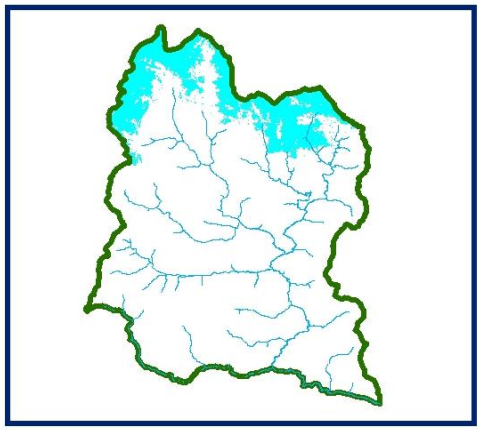
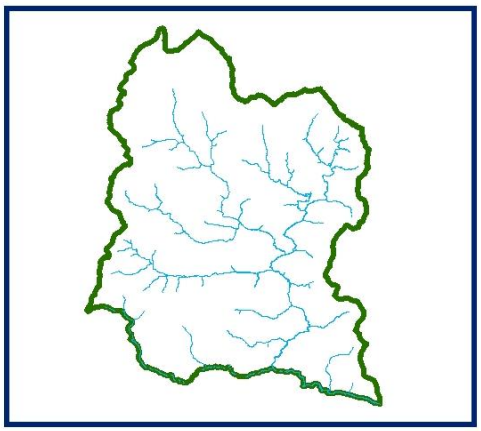


DATA USED

11 MAY 2014

21 APRIL 2014



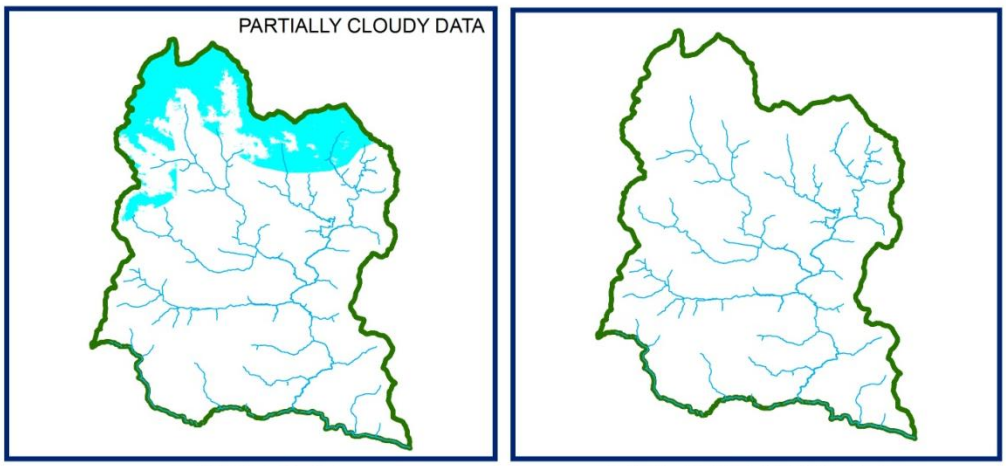
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80

Kilometers

5 DAILY SNOW COVER MAP: TISTA BASIN



3 JUNE 2014

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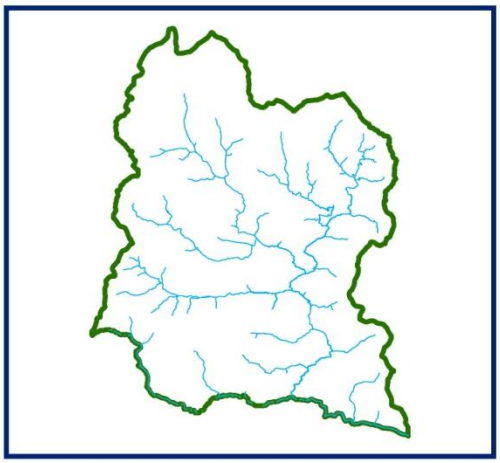

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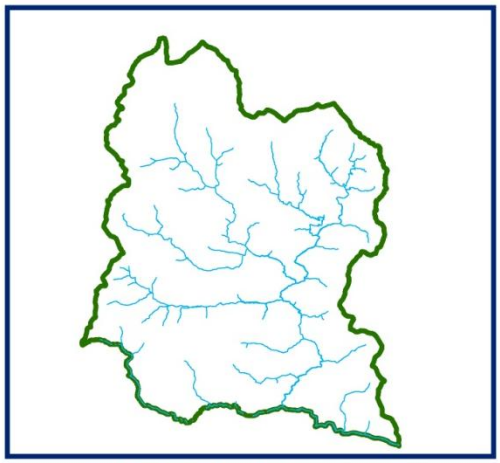

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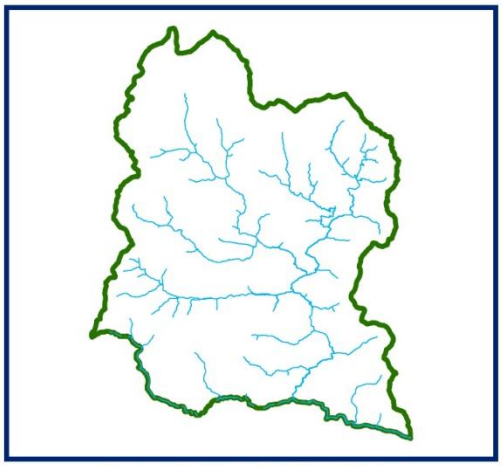

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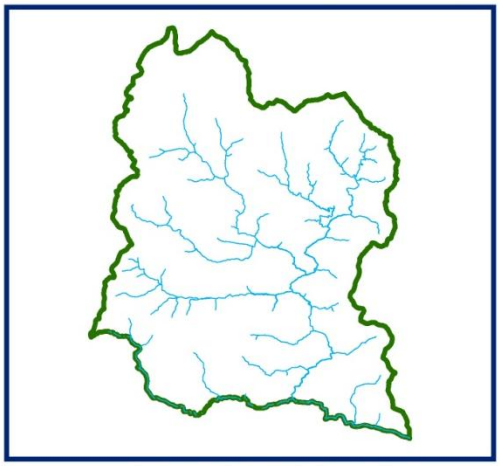

DATA NOT AVAILABLE

0 5 10 20 30 40

Kilometers

SNOW