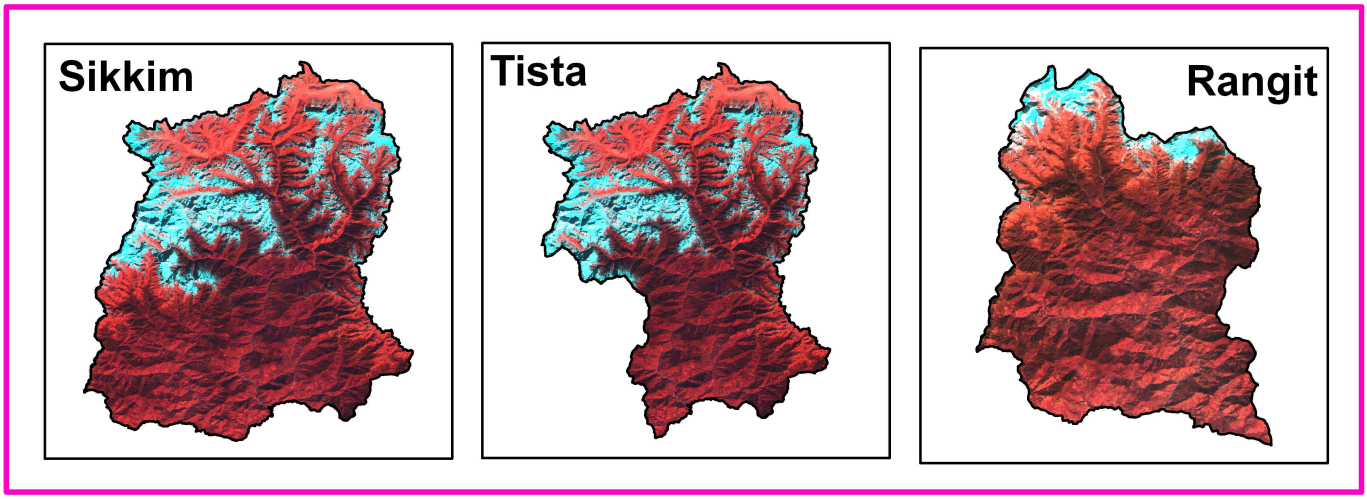
SNOW COVER ATLAS OF SIKKIM

Sub basins: Sikkim, Tista and Rangit

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

Year : 2010-11



Space Applications Centre (ISRO)
Ahmedabad - 380015

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

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Abstract	This atlas gives subbasin-wise distribution of snow cover in the Tista basin from October 2010 to June 2011. 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, Sikkim, Tista and Rangit.
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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 2010 to June 2011 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 2010 to June 2011. Snow ablation pattern was estimated for Sikkim state, Tista and Rangit basins in the Sikkim Himalaya. In Sikkim, maximum areal extent of 51% was observed in the month of February 2011. The highest snow areal extent 60.72% was observed in Tista

and 21.26% in Rangit basins, respectively in the same month. In Sikkim, maximum areal extent of snow (32%) was observed in the year. This was reduced to 26 % in March and reduced to 19% in the month of May 2011. The lowest snow recorded in the month of October and December 2010 in Sikkim and in Tista basin. The highest snow present of 11% in Rangit basin was recorded in February 2011.

Acknowledgements

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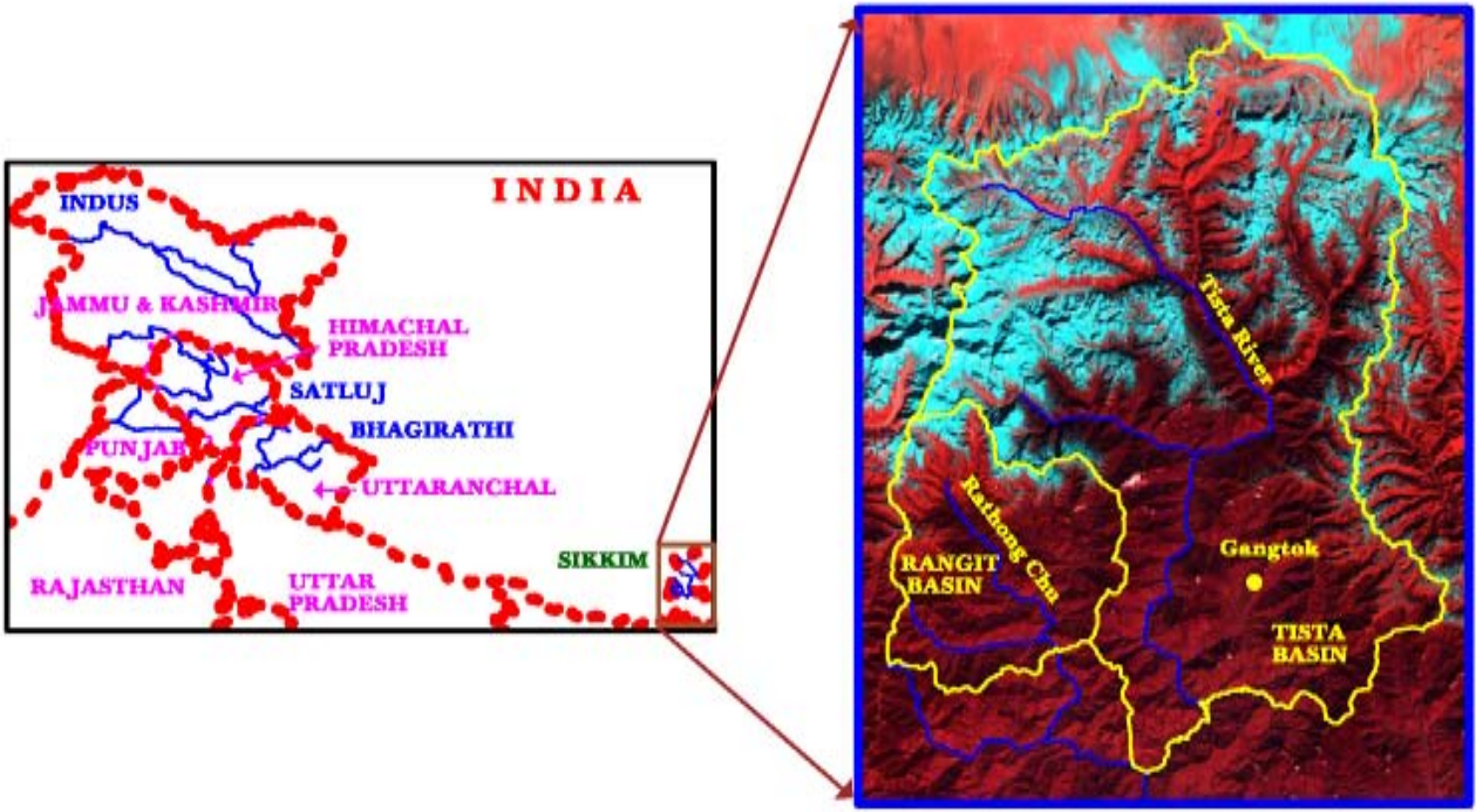


Figure 1: Location map of Tista and Rangit sub-basins (Part of Tista basin)

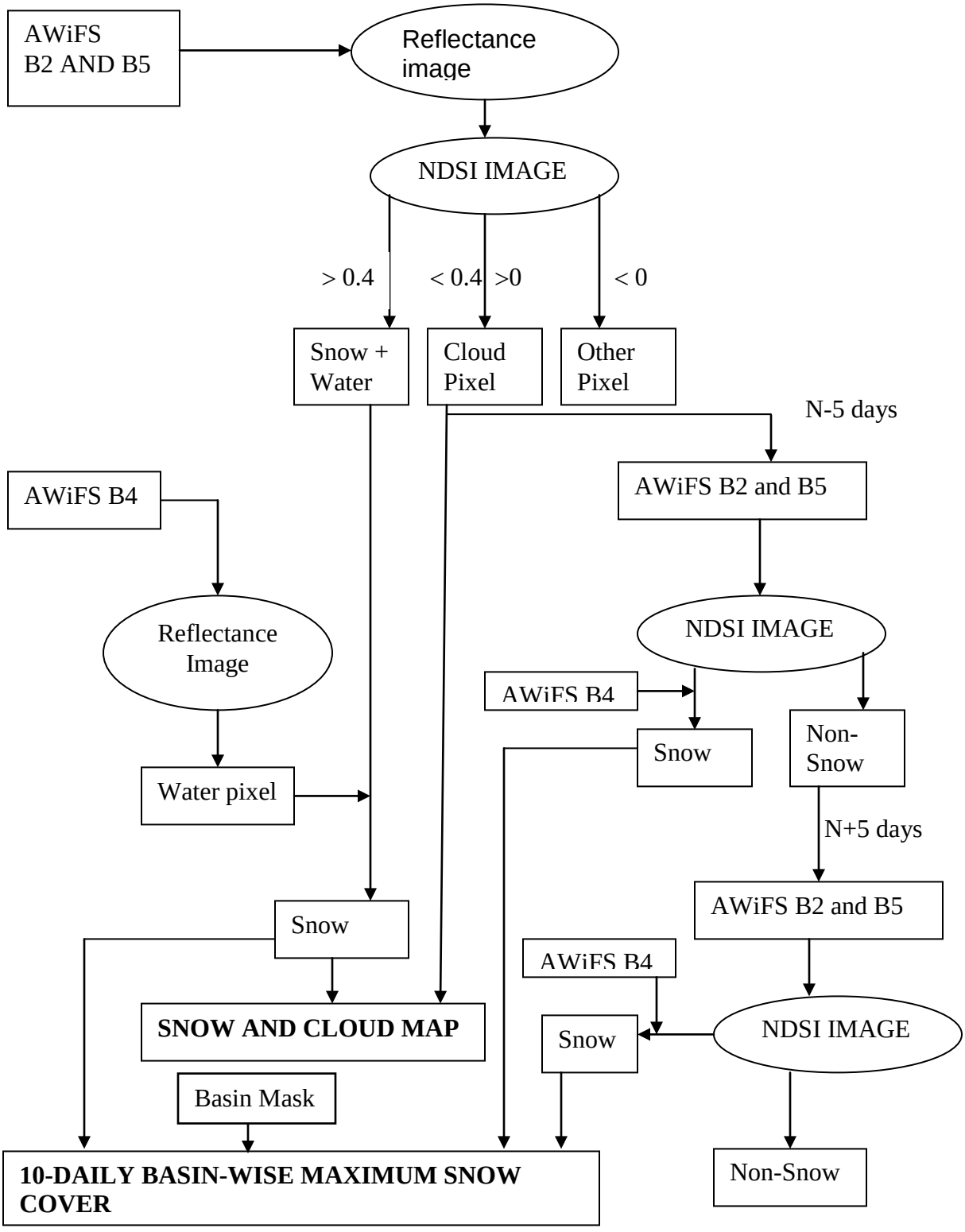


Figure 2: Algorithm for snow cover mapping using AWiFS data

SIKKIM STATE

AREAL EXTENT OF SNOW (5 DAILY)
2010-2011

STATE NAME: SIKKIM SIKKIM AREA: 7096 sq km

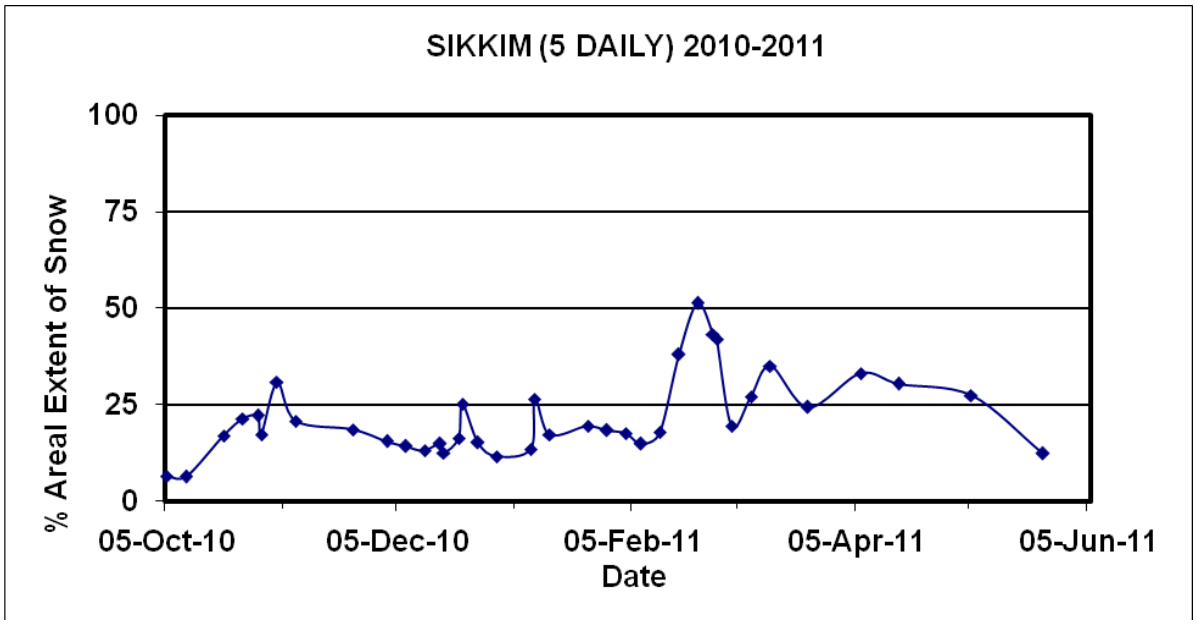
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2010							
1	5-Oct-10(C)	466.99	7	2	10-Oct-10(C)	451.60	6
3	20-Oct-10(C)	1207.02	17	4	25-Oct-10(PC)	1518.42	21
5	29-Oct-10(PC)	1576.52	22	6	30-Oct-10(PC)	1222.34	17
November 2010							
7	03-Nov-10(PC)	2187.16	31	8	08-Nov-10(PC)	1472.37	21
9	23-Nov-10(PC)	1316.34	19				
December 2010							
10	02-Dec-10(PC)	1098.61	15	11	7-Dec-10(PC)	1010.43	14
12	12-Dec-10(PC)	936.37	13	13	16-Dec-10	1056.18	15
14	17-Dec-10	888.02	13	15	21-Dec-10	1159.46	16
16	22-Dec-10(PC)	1790.08	25	17	26-Dec-10(PC)	1077.45	15
18	31-Dec-10(PC)	822.92	12				
January 2011							
19	9-Jan-11(PC)	952.28	13	20	10-Jan-11	1872.00	26
21	14-Jan-11(PC)	1221.37	17	22	24-Jan-11(PC)	1381.73	19
23	29-Jan-11(PC)	1305.09	18				
February 2011							
24	03-Feb-11	1248.99	18	25	07-Feb-11(PC)	1056.18	15
26	12-Feb-11(PC)	1265.50	18	27	17-Feb-11(C)	2702.36	38
28	22-Feb-11(PC)	3641.07	51	29	26-Feb-11(PC)	3068.64	43
30	27-Feb-11(PC)	2973.16	42				
March 2011							
31	03-Mar-11(C)	1382.44	19	32	08-Mar-11(PC)	1927.36	27
33	13-Mar-11(PC)	2487.89	35	34	23-Mar-11(PC)	1728.89	24
April 2011							
35	6-Apr-05(PC)	2354.51	33	36	16-Apr-05(PC)	2160.66	30
May 2011							
37	24-May-11(C)	879.96	12	38	5-May-05(PC)	1941.31	27
June 2011							
39							

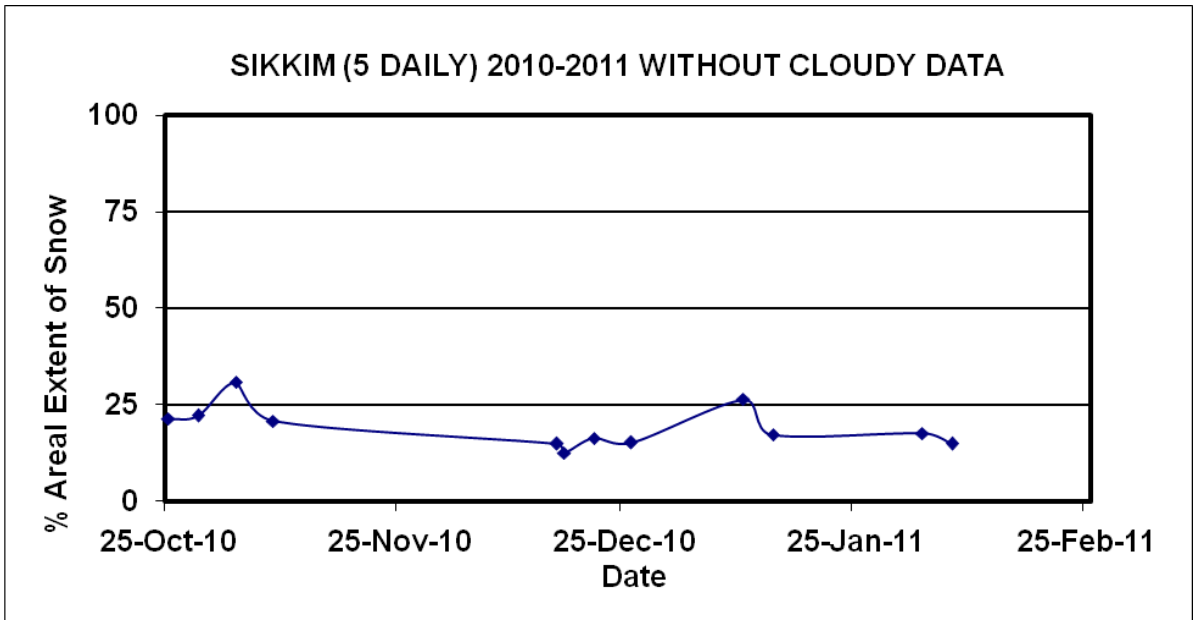
AREAL EXTENT OF SNOW (10 DAILY)
2010-2011

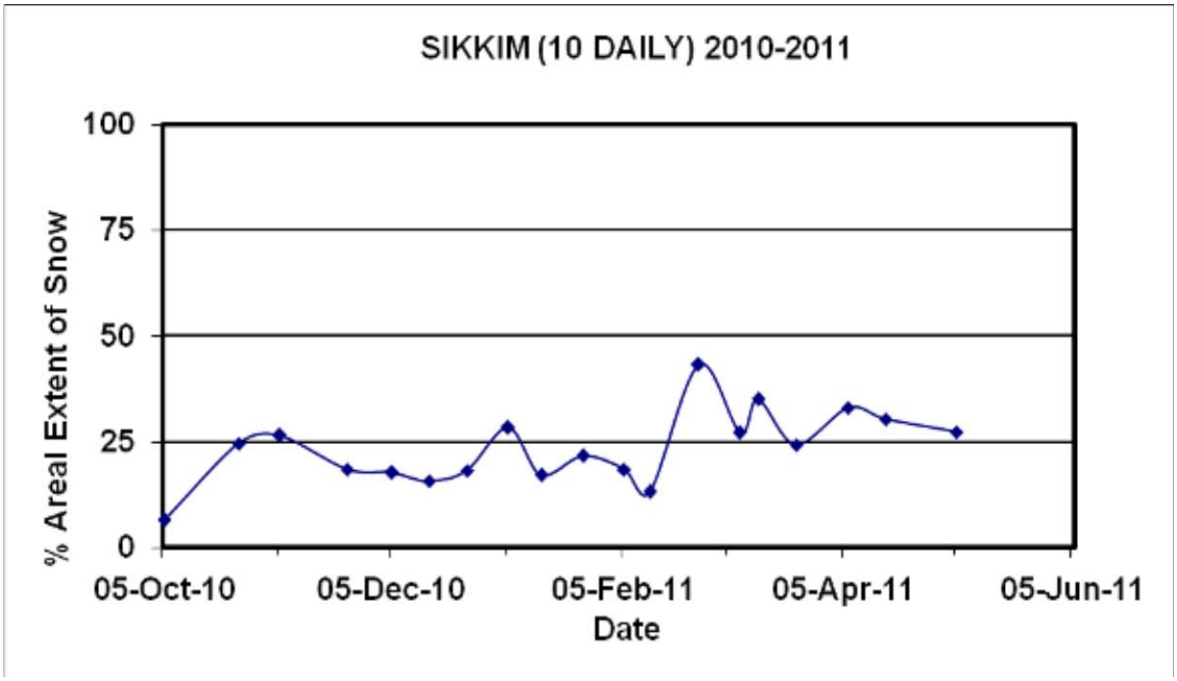
STATE NAME: SIKKIM **SIKKIM AREA: 7096 sq km**

S. No	Data Used	Mean Date	Snow cover (sq km)	Snow cover (%)
October 2010				
1	05-Oct-2010	05-Oct-2010	466.99	7
2	25-Oct-2010 29-Nov-2010 30-Nov-2010	25-Oct-2010	1746.33	25
November 2010				
3	03-Nov-2010 08-Nov-2010	05-Nov-2010	1885.93	27
4	23-Nov-2010	23-Nov-2010	1316.34	19
December 2011				
5	02-Dec-2010 07-Dec-2010	05-Dec-2010	1262.27	18
6	16-Dec-2010 17-Dec-2010	15-Dec-2010	1117.84	16
7	21-Dec-2010 26-Dec-2010	25-Dec-2010	1291.23	18
January 2011				
8	09-Jan-2011 10-Jan-2011	5-Jan-2011	2014.71	28
9	14-Jan-2011	14-Jan-2011	1221.37	17
10	24-Jan-2011 29-Jan-2011	25-Jan-2011	1542.95	22
February 2011				
11	03-Feb-2011 07-Feb-2011	05-Feb-0211	1313..69	19
12	12-Feb-2011	12-Feb-2011	936.37	13
13	22-Feb-2011 26-Feb-2011 27-Feb-2011	25-Feb-2011	3067.91	43
March 2011				
14	08-Mar-2011	08-Mar-2011	1927.36	27
15	13-Mar-2011	13-Mar-2011	24.87.04	35
16	23-Mar-2011	23-Mar-2011	1728.89	24
April 2011				
17	06-Apr-2011	06-Apr-2011	2354.51	33
18	16-Apr-2011	16-Apr-2011	2160.66	30
May 2011				
19	5-May-2011	5-May-2011	1941.31	27

SNOW COVER DEPLETION CURVE

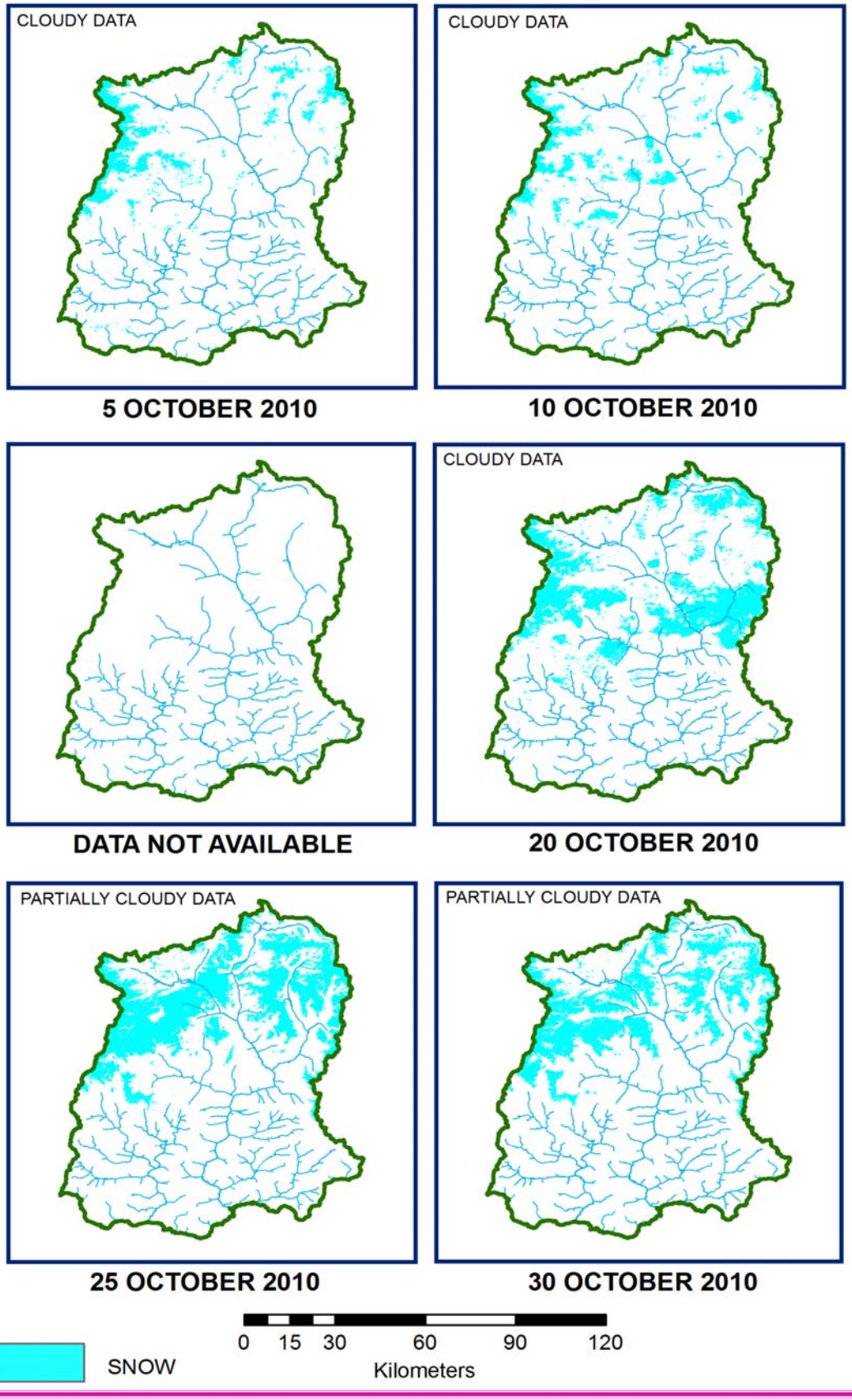





SIKKIM (10 DAILY) 2010-2011
% Areal Extent of Snow
100
75
50
25
0
05-Oct-10
05-Dec-10
05-Feb-11
05-Apr-11
05-Jun-11
Date

SNOW COVER MAPS

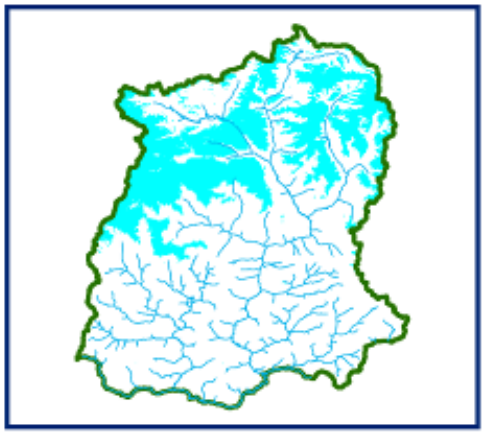
5 DAILY SNOW COVER MAP: SIKKIM



COMPOSITE SNOW COVER MAP : SIKKIM

DATA USED
05 OCTOBER 2010

DATA USED
OCTOBER 2010

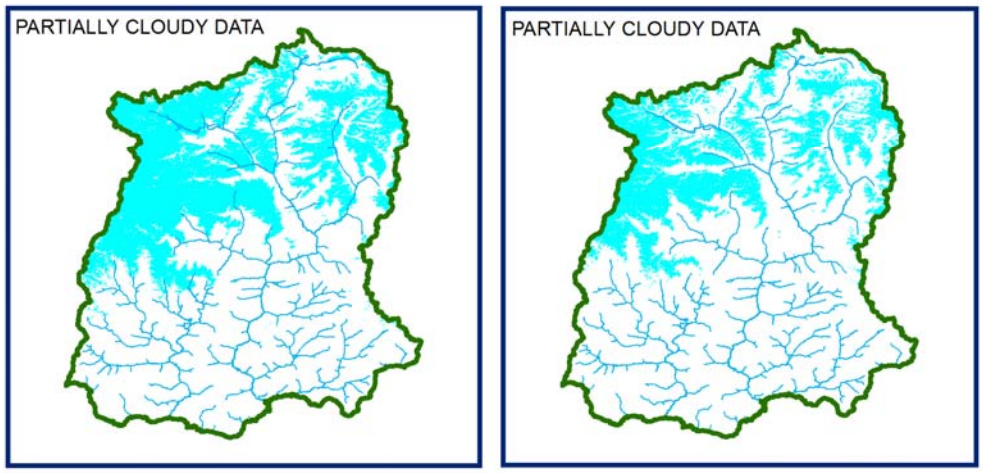


DATA USED
25 OCTOBER 2010
29 OCTOBER 2010
30 OCTOBER 2010

SNOW

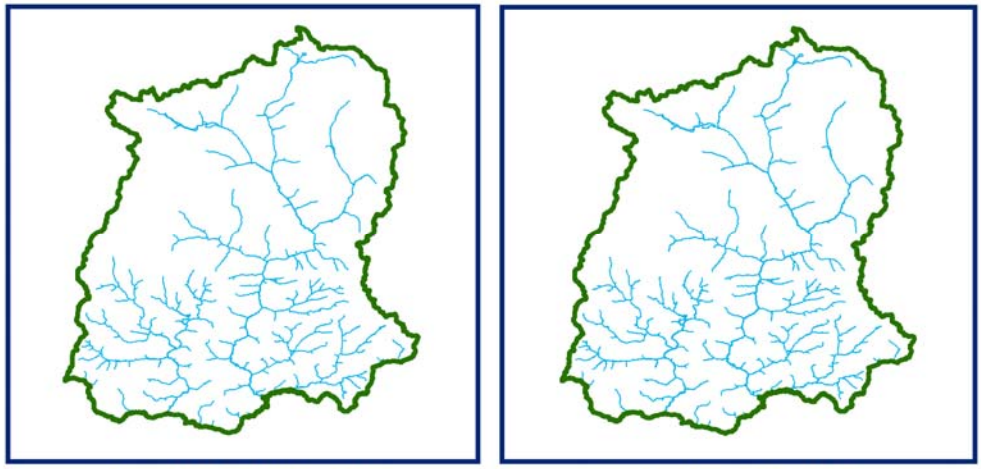
0 20 40 80 120 160
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



3 NOVEMBER 2010

8 NOVEMBER 2010



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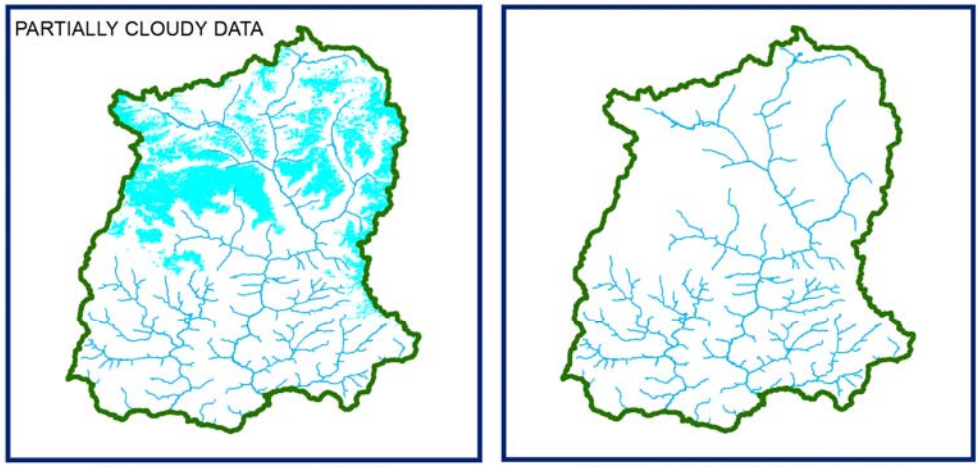


23 NOVEMBER 2010

DATA NOT AVAILABLE

0 15 30 60 90 120

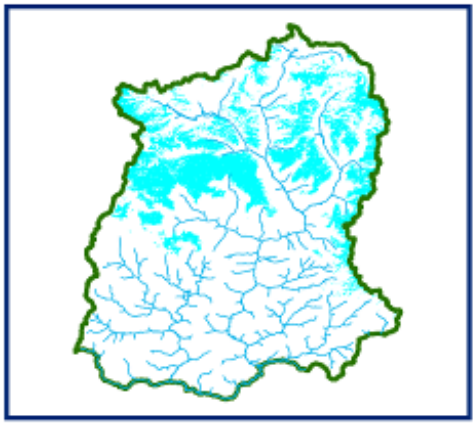
Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

DATA USED
03 NOVEMBER 2010
08 NOVEMBER 2010

DATA USED
NOVEMBER 2010

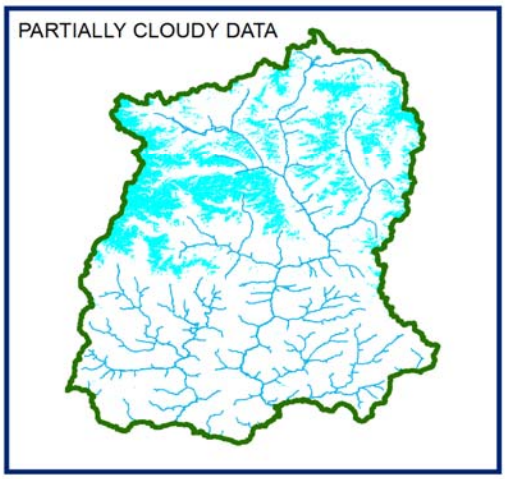


DATA USED
23 NOVEMBER 2010

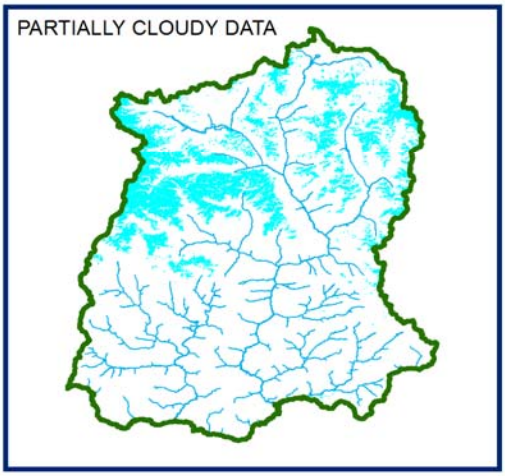
SNOW

0 20 40 80 120 160
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



2 DECEMBER 2010



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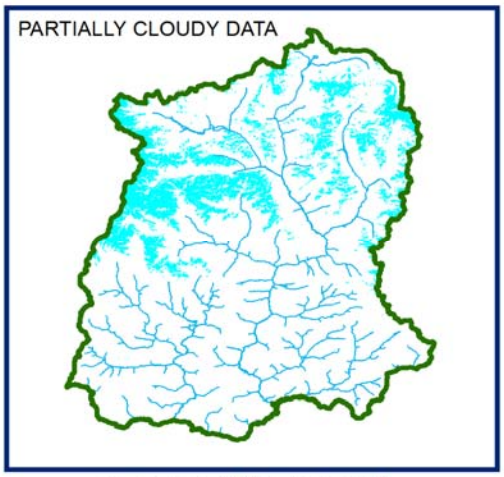

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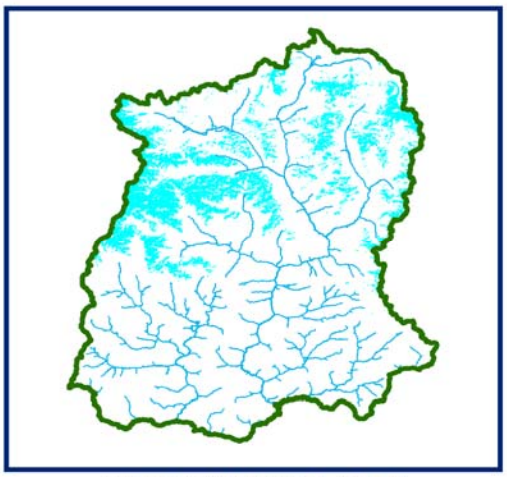

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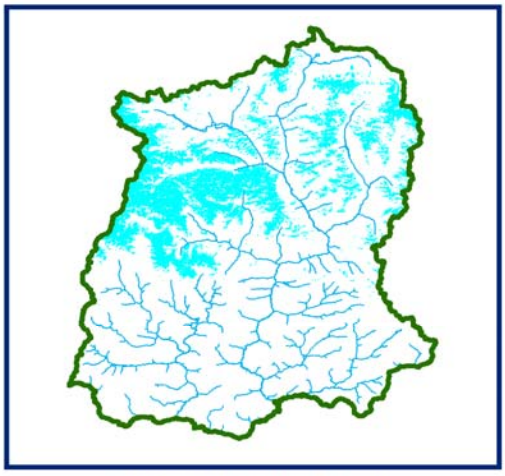


21 DECEMBER 2010

26 DECEMBER 2010

0 15 30 60 90 120

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

DATA USED

02 DECEMBER 2010
07 DECEMBER 2010

DATA USED

16 DECEMBER 2010
17 DECEMBER 2010

DATA USED

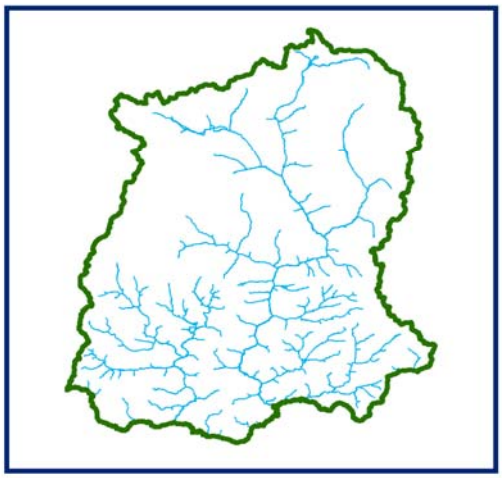
21 DECEMBER 2010
26 DECEMBER 2010

SNOW

0 20 40 80 120 160

Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



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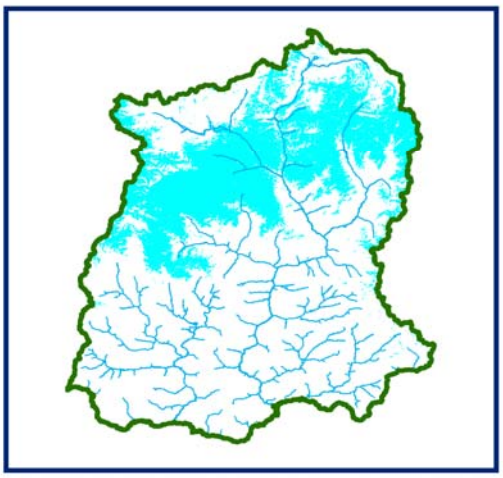
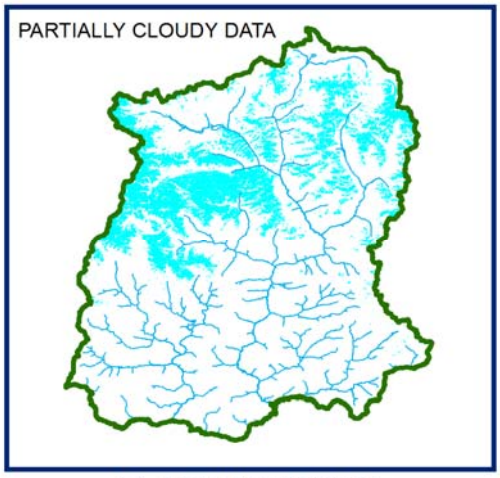
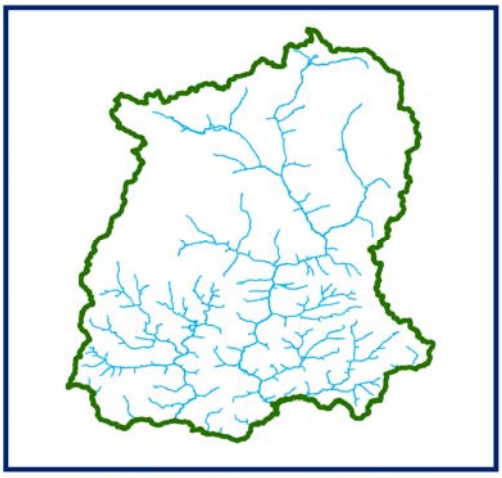


10 JANUARY 2010



14 JANUARY 2010



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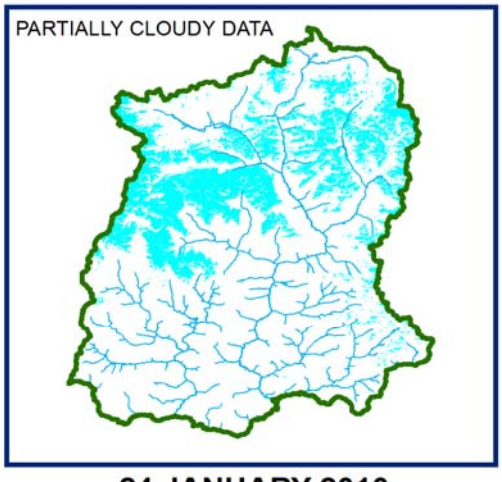
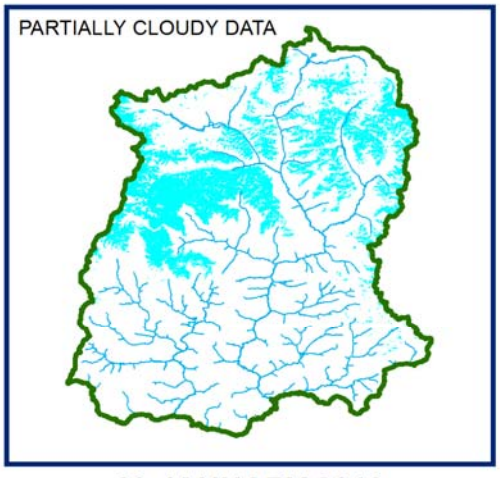


24 JANUARY 2010



29 JANUARY 2010

0 15 30 60 90 120

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

DATA USED

09 JANUARY 2011
10 JANUARY 2011

DATA USED

14 JANUARY 2011

DATA USED

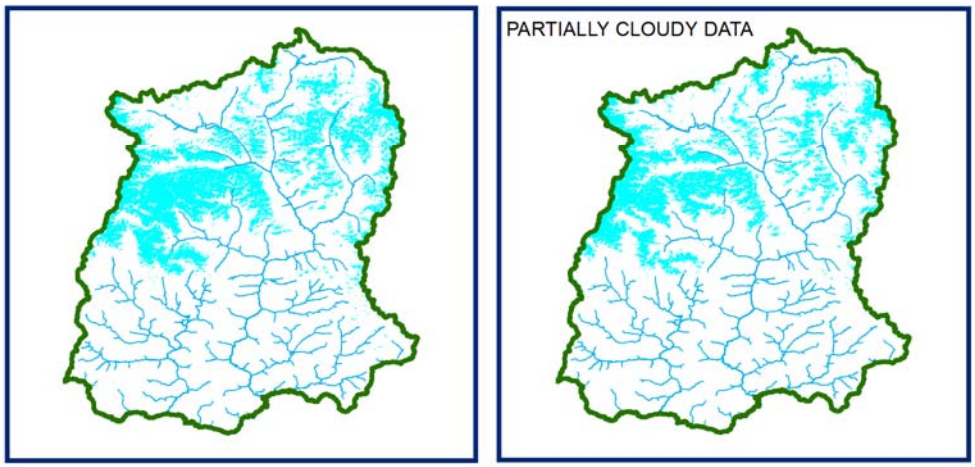
24 JANUARY 2011
29 JANUARY 2011

SNOW

0 20 40 80 120 160

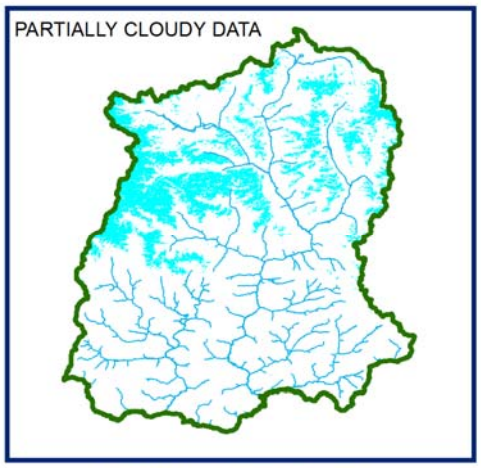
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM

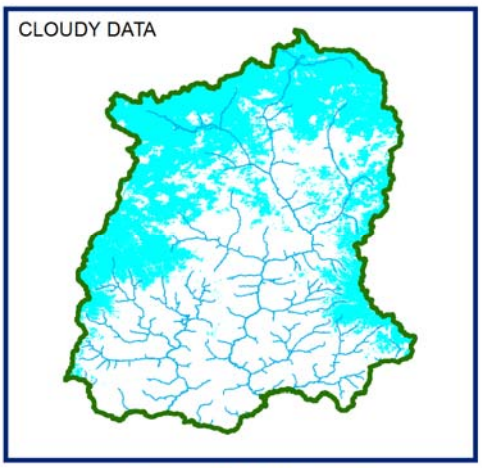


3 FEBRUARY 2011

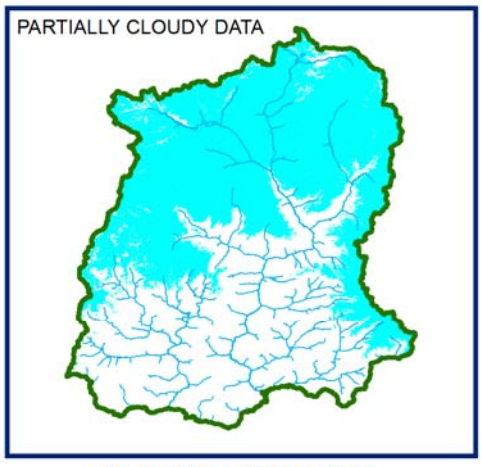
7 FEBRUARY 2011



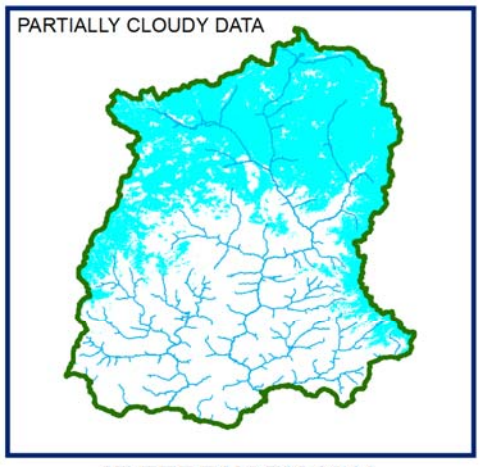
12 FEBRUARY 2011



17 FEBRUARY 2011



22 FEBRUARY 2011



27 FEBRUARY 2011

SNOW

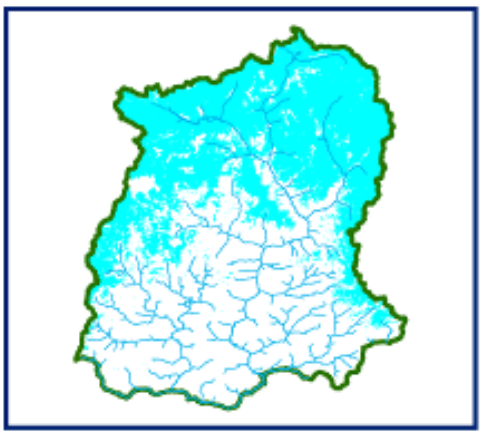
0 15 30 60 90 120

Kilometers

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

DATA USED
03 FEBRUARY 2011
07 FEBRUARY 2011

DATA USED
12 FEBRUARY 2011

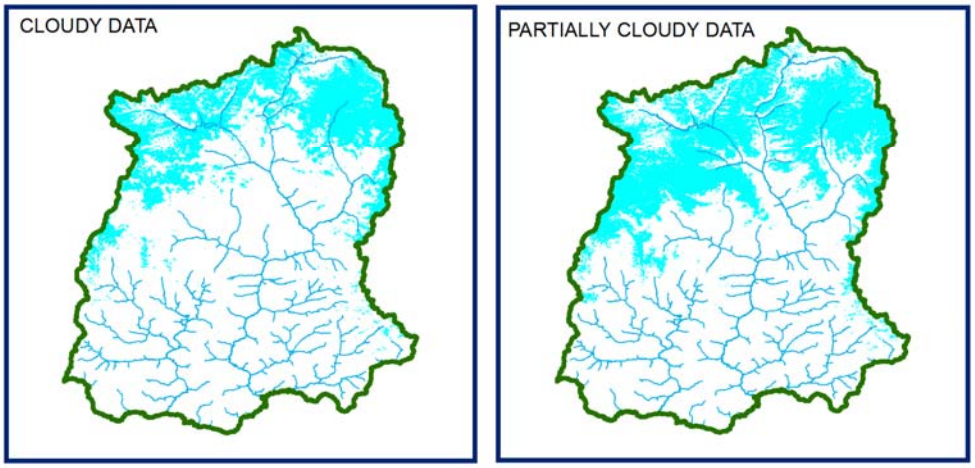


DATA USED
22 FEBRUARY 2011
26 FEBRUARY 2011
27 FEBRUARY 2011

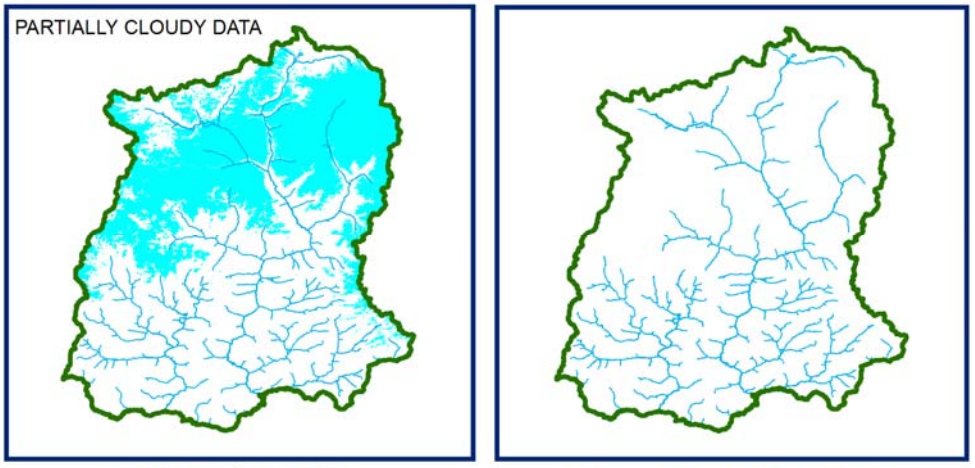
SNOW

0 20 40 80 120 160
Kilometers

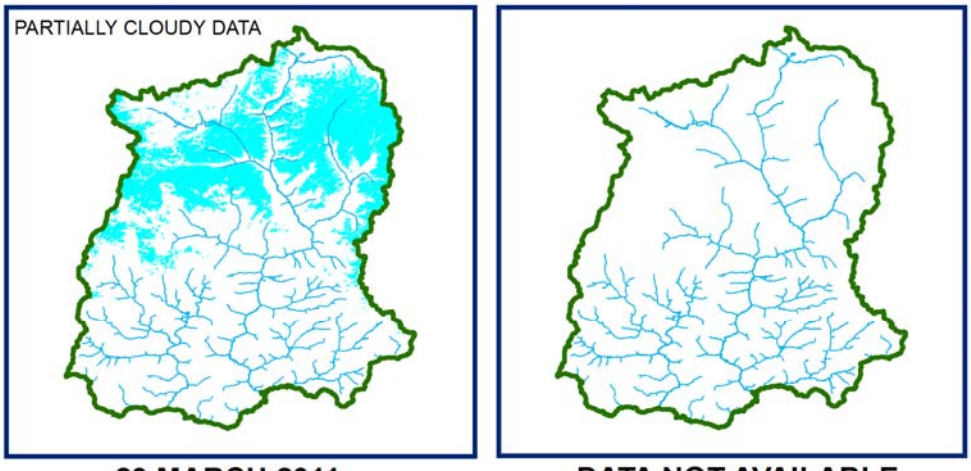
5 DAILY SNOW COVER MAP: SIKKIM



3 MARCH 2011 | 8 MARCH 2011



13 MARCH 2011 | DATA NOT AVAILABLE



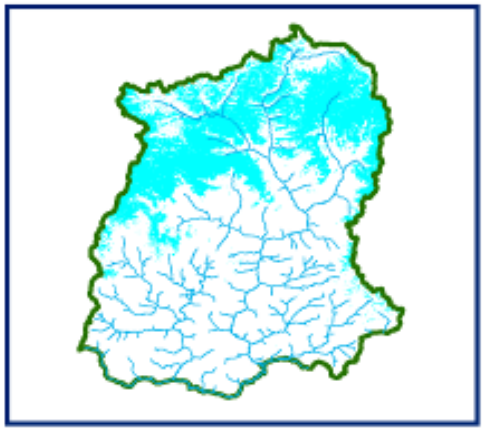
23 MARCH 2011 | DATA NOT AVAILABLE

SNOW

0 15 30 60 90 120

Kilometers

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

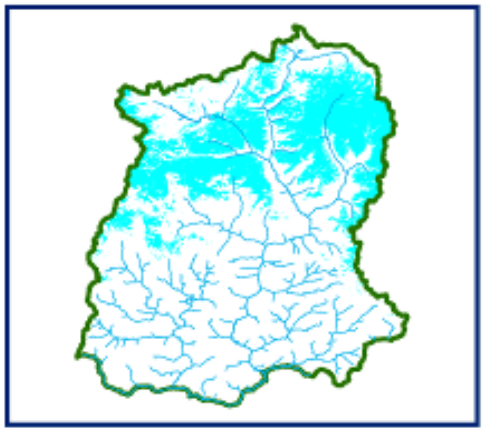


DATA USED

08 MARCH 2011

DATA USED

13 MARCH 2011



DATA USED

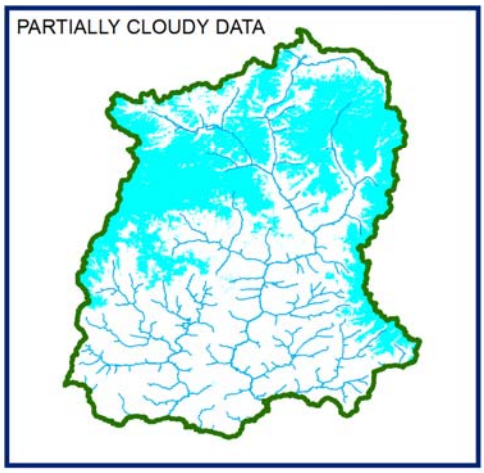
23 MARCH 2011

SNOW

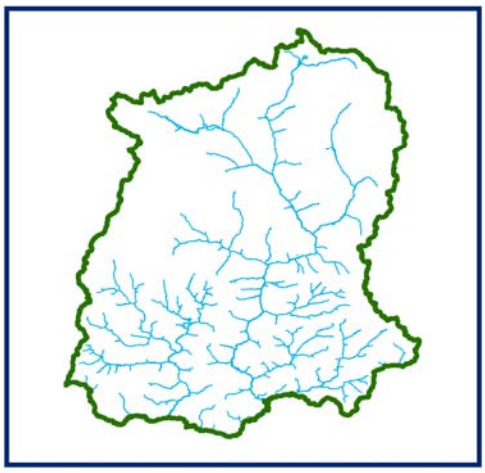
0 20 40 80 120 160

Kilometers

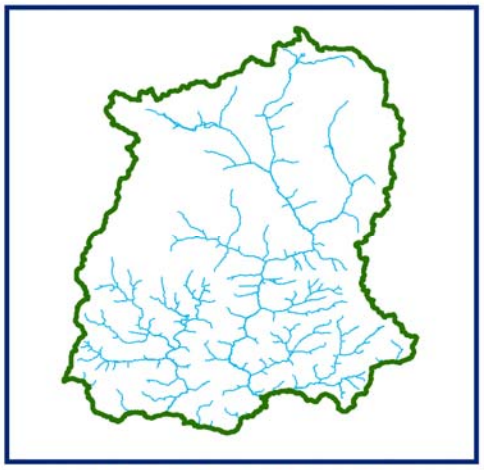
5 DAILY SNOW COVER MAP: SIKKIM



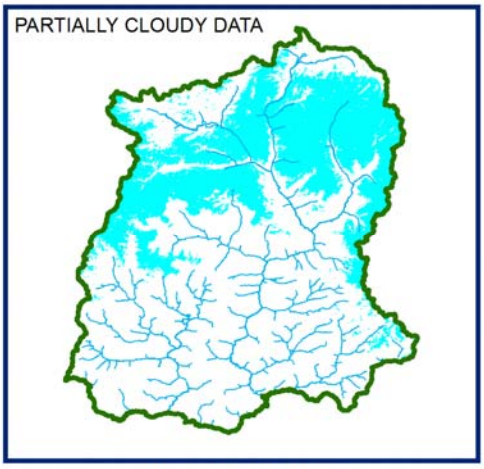
6 APRIL 2011



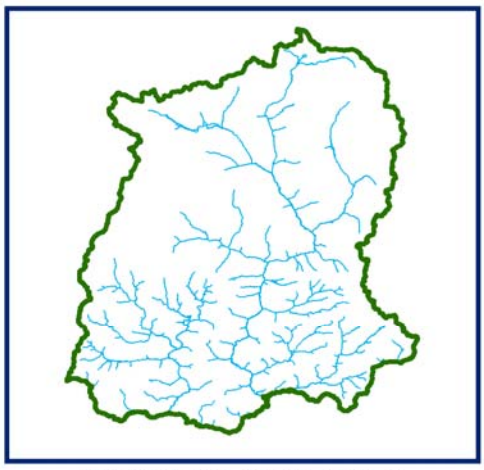
DATA NOT AVAILABLE



DATA NOT AVAILABLE



16 APRIL 2011



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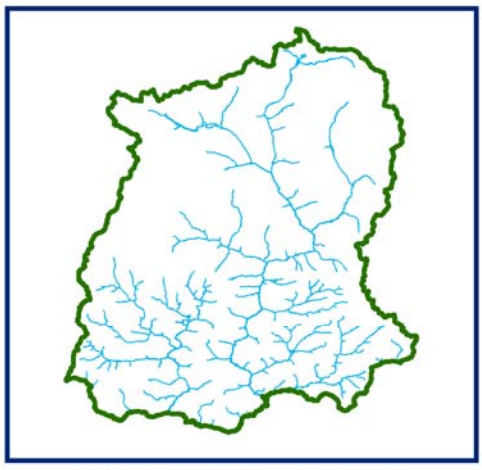
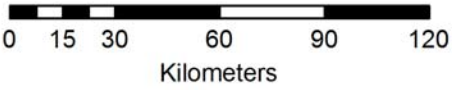


DATA NOT AVAILABLE



SNOW

COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

DATA USED
06 APRIL 2011

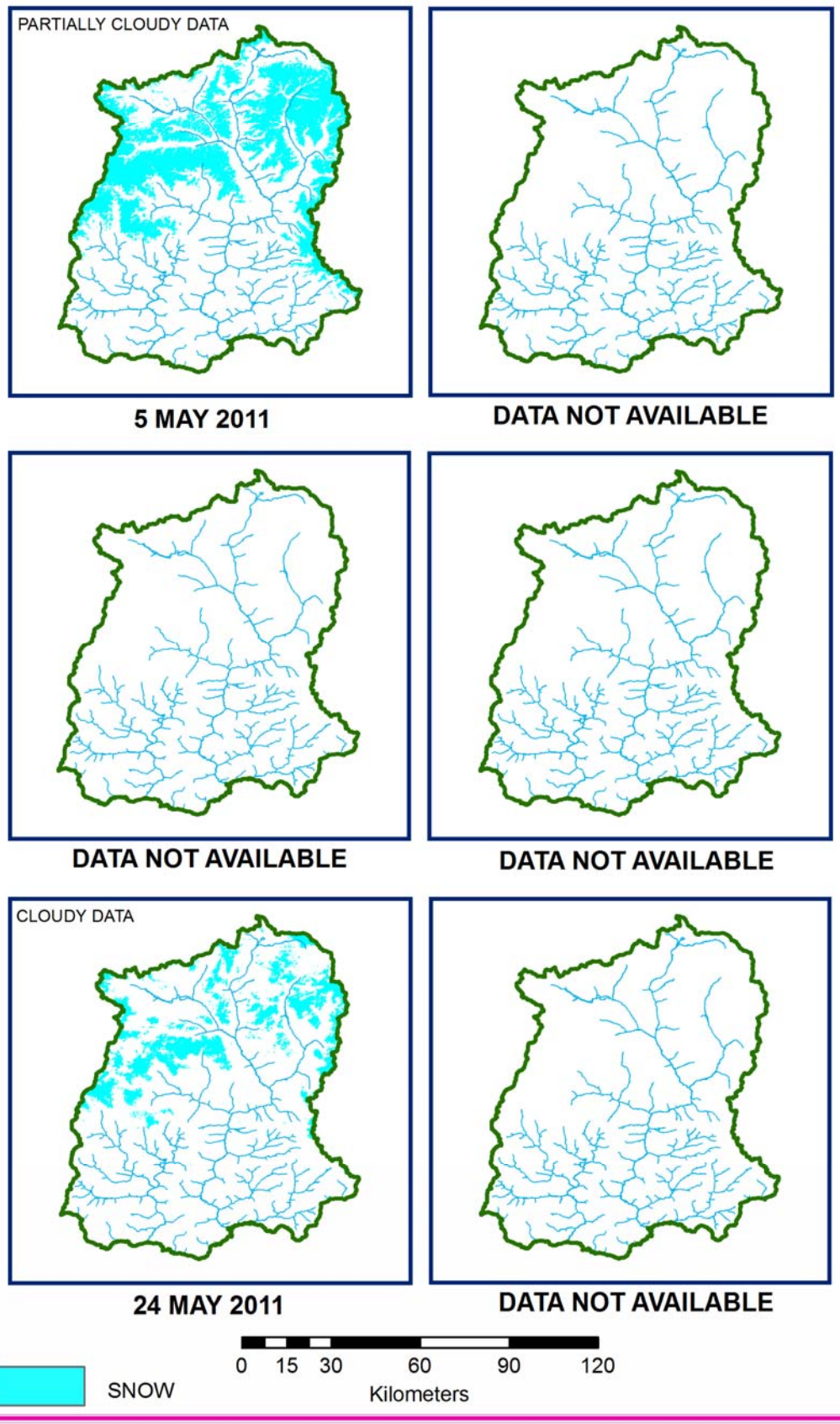
DATA USED
16 APRIL 2011

DATA USED
APRIL 2011

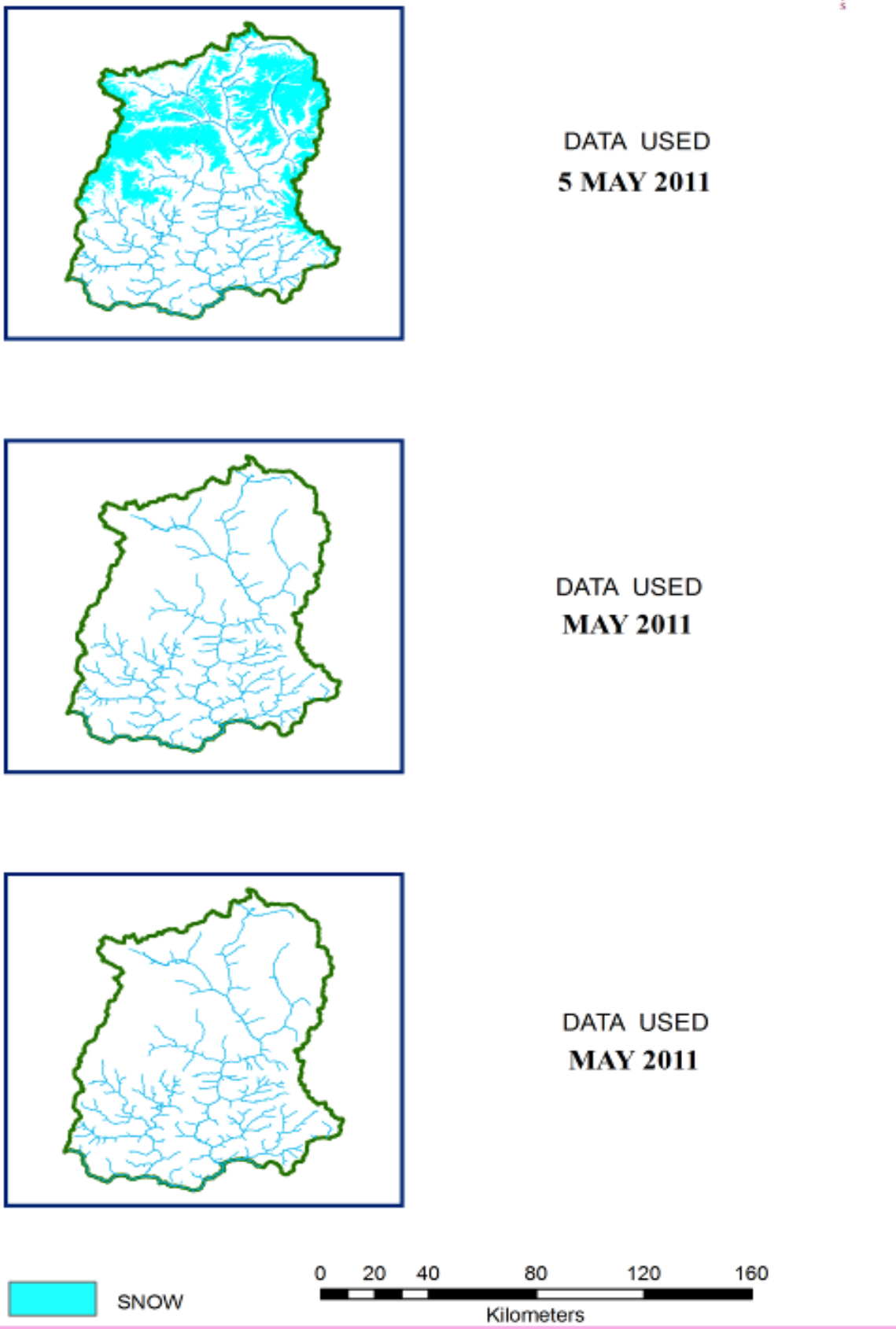
SNOW

0 20 40 80 120 160
Kilometers

5 DAILY SNOW COVER MAP: SIKKIM



COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



TISTA BASIN

AREAL EXTENT OF SNOW (5 DAILY)
2010-2011

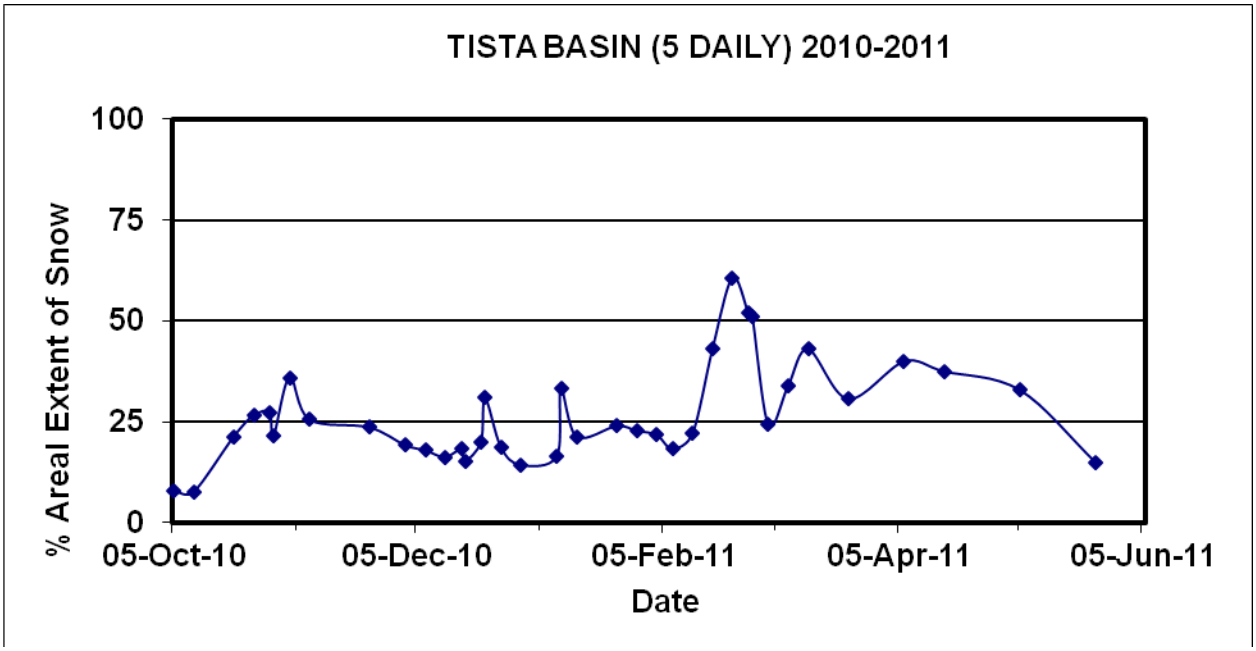
BASIN NAME: TISTA **BASIN AREA: 5466 sq km**

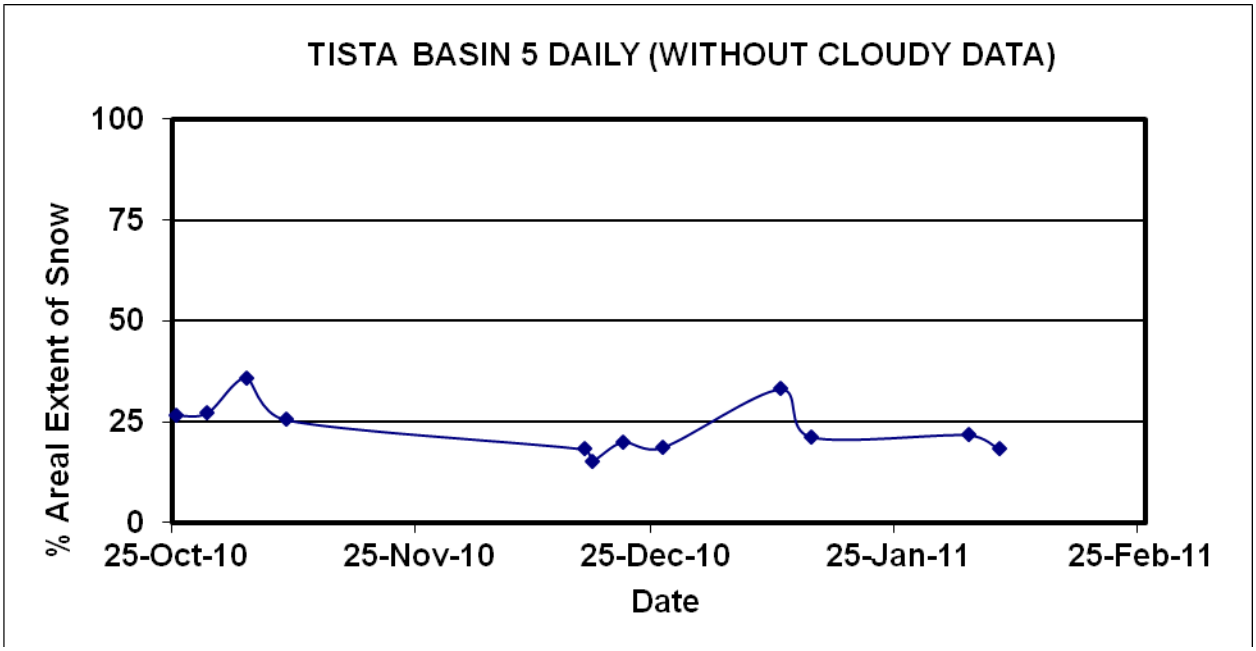
S. No	Date	Snow cover (sq km)	Snow cover (%)	S. No	Date	Snow cover (sq km)	Snow cover (%)
October 2010							
1	5-Oct-10(C)	430.26	8	2	10-Oct-10(C)	417.00	8
3	20-Oct-10(C)	1164.68	21	4	25-Oct-10(PC)	1453.46	27
5	29-Oct-10(PC)	1494.00	27	6	30-Oct-10(PC)	1169.88	21
November 2010							
7	03-Nov-10(PC)	1967.50	36	8	08-Nov-10(PC)	1397.11	26
9	23-Nov-10(PC)	1291.80	24				
December 2010							
10	02-Dec-10(PC)	1050.25	19	11	7-Dec-10(PC)	979.91	18
12	12-Dec-10(PC)	887.41	16	13	16-Dec-10	996.31	18
14	17-Dec-10	838.08	15	15	21-Dec-10	1098.15	20
16	22-Dec-10(PC)	1691.12	31	17	26-Dec-10(PC)	1020.48	19
18	31-Dec-10(PC)	780.94	14				
January 2011							
19	9-Jan-11(PC)	903.24	17	20	10-Jan-11	1812.02	33
21	14-Jan-11(PC)	1163.46	21	22	24-Jan-11(PC)	1310.06	24
23	29-Jan-11(PC)	1244.95	23				
February 2011							
24	03-Feb-11	1190.40	22	25	07-Feb-11(PC)	996.31	18
26	12-Feb-11(PC)	1205.79	22	27	17-Feb-11(C)	2354.54	43
28	22-Feb-11(PC)	3318.89	61	29	26-Feb-11(PC)	2838.09	52
30	27-Feb-11(PC)	2784.92	51				
March 2011							
31	03-Mar-11(C)	1326.27	24	32	08-Mar-11(PC)	1860.78	34
33	13-Mar-11(PC)	2350.20	43	34	23-Mar-11(PC)	1675.79	31
April 2011							
35	6-Apr-05(PC)	2182.76	40	36	16-Apr-05(PC)	2050.53	38
May 2011							
37	24-May-11(C)	816.35	15	38	5-May-05(PC)	1798.66	33
June 2011							

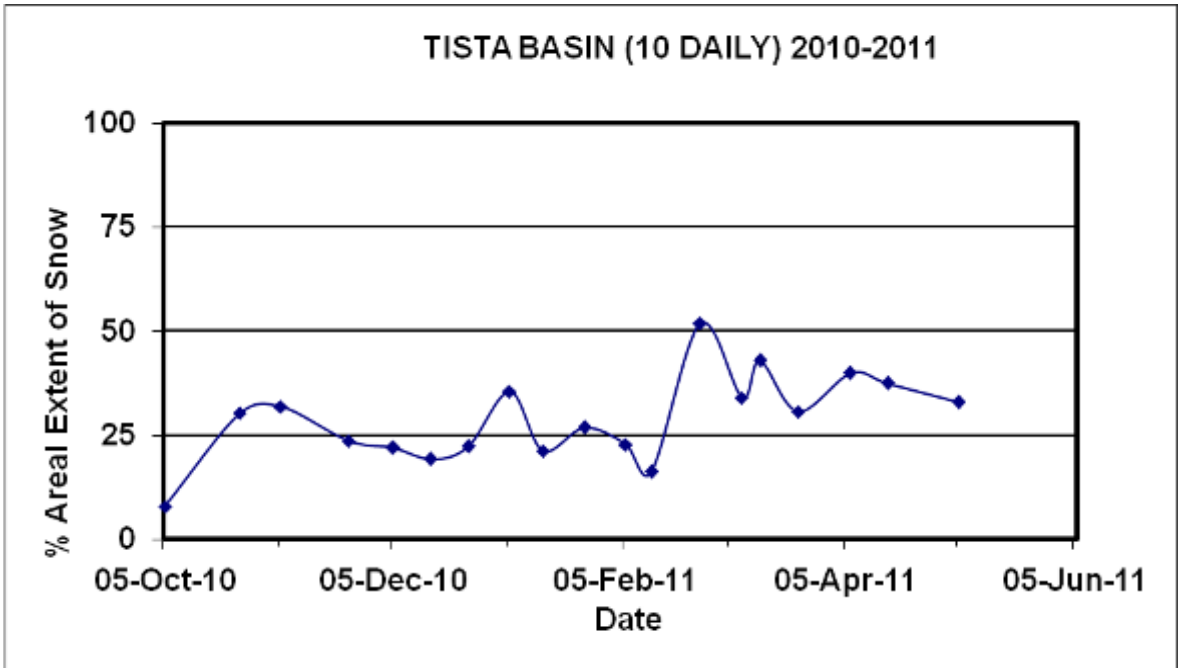
AREAL EXTENT OF SNOW (10 DAILY)
2010-2011

BASIN NAME: TISTA BASIN **BASIN AREA: 5466 sq km**

S. No	Data Used	Mean Date	Snow cover (sq km)	Snow cover (%)
October 2010				
1	05-Oct-2010	05-Oct-2010	430.26	8
2	25-Oct-2010 29-Nov-2010 30-Nov-2010	25-Oct-2010	1655.77	30
November 2010				
3	03-Nov-2010 08-Nov-2010	05-Nov-2010	1745.76	32
4	23-Nov-2010	23-Nov-2010	1291.80	24
December 2010				
5	02-Dec-2010 07-Dec-2010	05-Dec-2010	1204.13	22
6	16-Dec-2010 17-Dec-2010	15-Dec-2010	1054.12	19
7	21-Dec-2010 26-Dec-2010	25-Dec-2010	1222.76	22
January 2011				
8	09-Jan-2011 10-Jan-2011	5-Jan-2011	1943.02	36
9	14-Jan-2011	14-Jan-2011	1663.46	21
10	24-Jan-2011 29-Jan-2011	25-Jan-2011	1466.73	27
February 2011				
11	03-Feb-2011 07-Feb-2011	05-Feb-0211	1244.48	23
12	12-Feb-2011	12-Feb-2011	887.41	16
13	22-Feb-2011 26-Feb-2011 27-Feb-2011	25-Feb-2011	2836.14	52
March 2011				
14	08-Mar-2011	08-Mar-2011	1860.78	37
15	13-Mar-2011	13-Mar-2011	2350.20	43
16	23-Mar-2011	23-Mar-2011	1675.79	31
April 2011				
17	06-Apr-2011	06-Apr-2011	2182.76	40
18	16-Apr-2011	16-Apr-2011	2050.53	38
May 2011				
19	5-May-2011	5-May-2011	1798.66	33

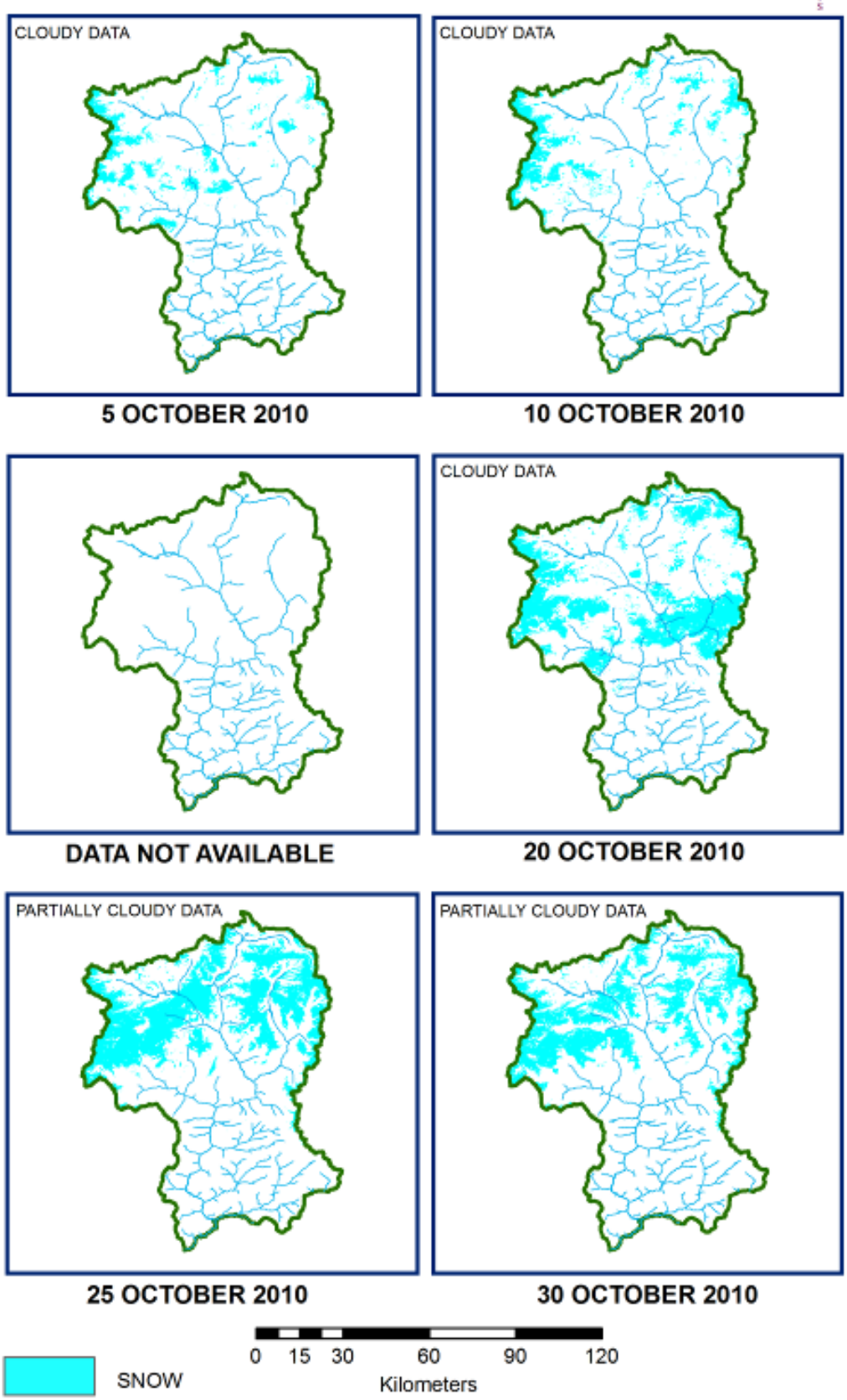

TISTA BASIN (5 DAILY) 2010-2011
% Areal Extent of Snow
100
75
50
25
0
05-Oct-10
05-Dec-10
05-Feb-11
05-Apr-11
05-Jun-11
Date


TISTA BASIN 5 DAILY (WITHOUT CLOUDY DATA)
% Areal Extent of Snow
100
75
50
25
0
25-Oct-10
25-Nov-10
25-Dec-10
25-Jan-11
25-Feb-11
Date


TISTA BASIN (10 DAILY) 2010-2011
% Areal Extent of Snow
100
75
50
25
0
05-Oct-10
05-Dec-10
05-Feb-11
05-Apr-11
05-Jun-11
Date

SNOW COVER MAPS

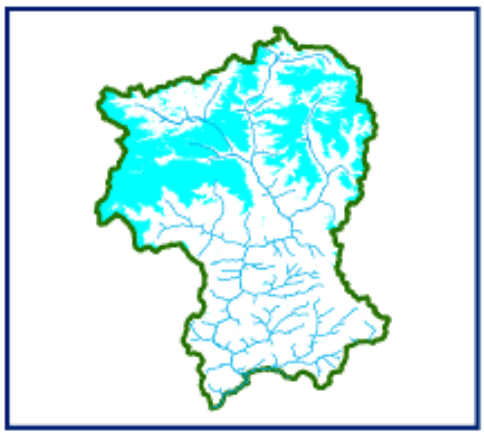
5 DAILY SNOW COVER MAP: TISTA



COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

DATA USED
05 OCTOBER 2010

DATA USED
OCTOBER 2010

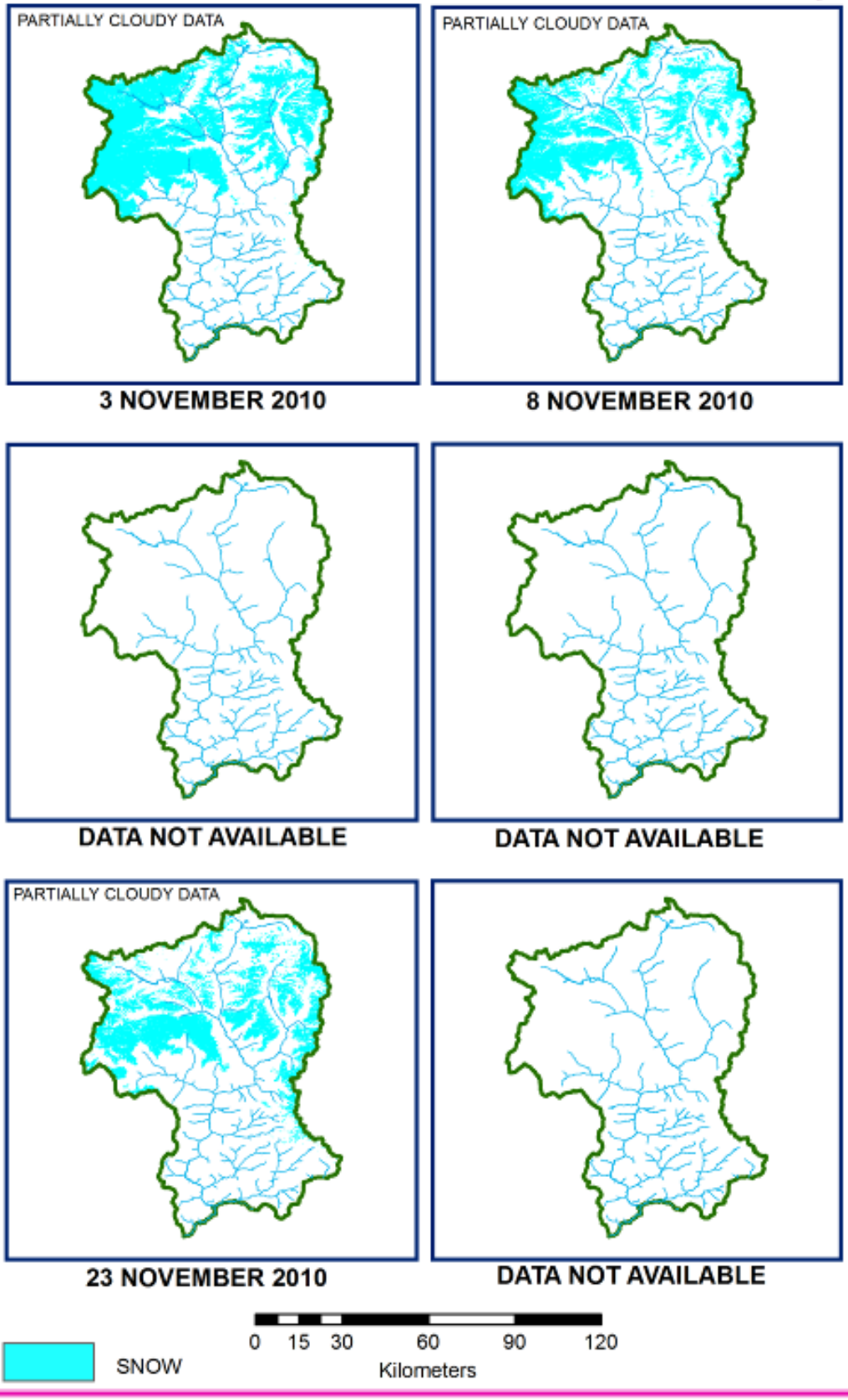


DATA USED
25 OCTOBER 2010
29 OCTOBER 2010
30 OCTOBER 2010

SNOW

0 20 40 80 120 160
Kilometers

5 DAILY SNOW COVER MAP: TISTA



COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

DATA USED
03 NOVEMBER 2010
08 NOVEMBER 2010

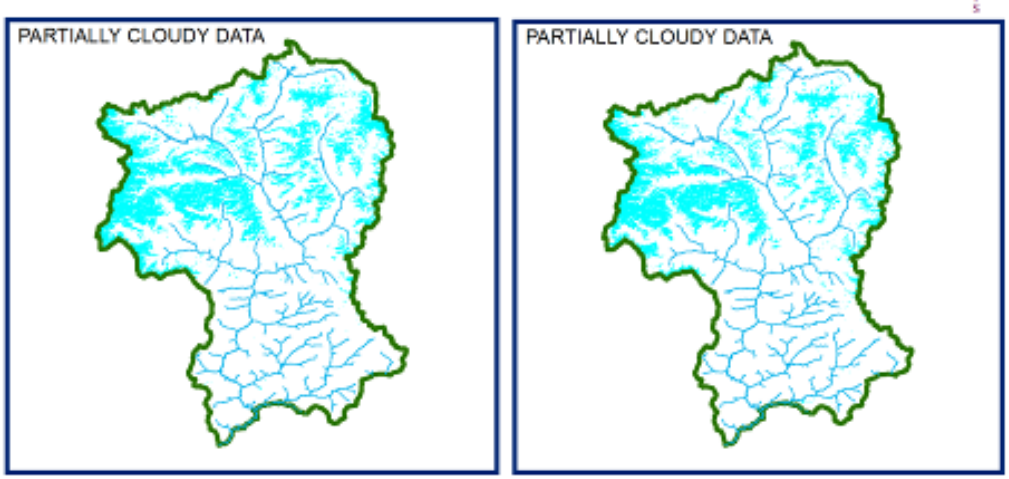
DATA USED
NOVEMBER 2010

DATA USED
23 NOVEMBER 2010

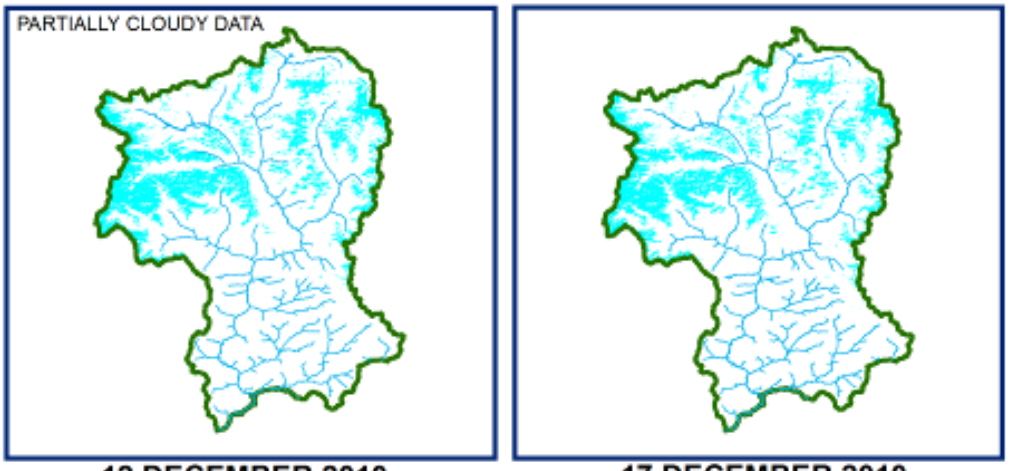
SNOW

0 20 40 80 120 160
Kilometers

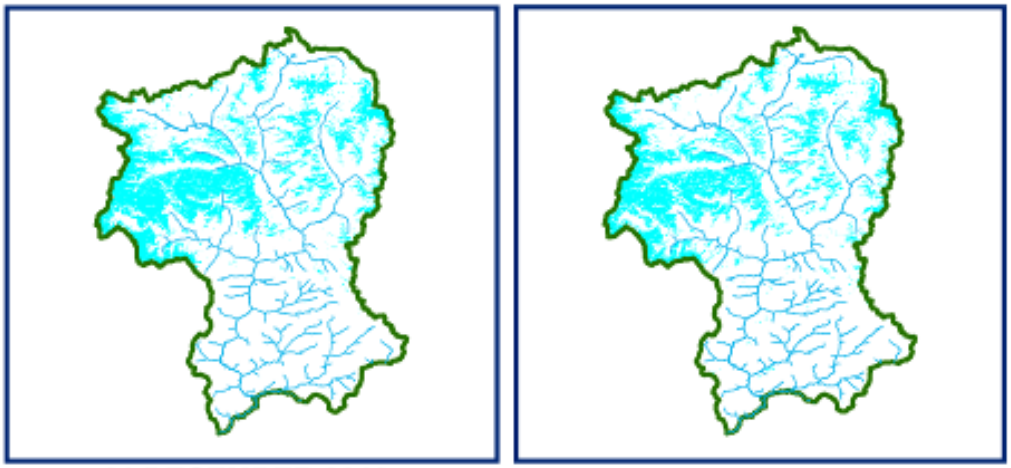
5 DAILY SNOW COVER MAP: TISTA



2 DECEMBER 2010 | 7 DECEMBER 2010



12 DECEMBER 2010 | 17 DECEMBER 2010



21 DECEMBER 2010 | 26 DECEMBER 2010

0 15 30 60 90 120

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

DATA USED

02 DECEMBER 2010
07 DECEMBER 2010

DATA USED

16 DECEMBER 2010
17 DECEMBER 2010

DATA USED

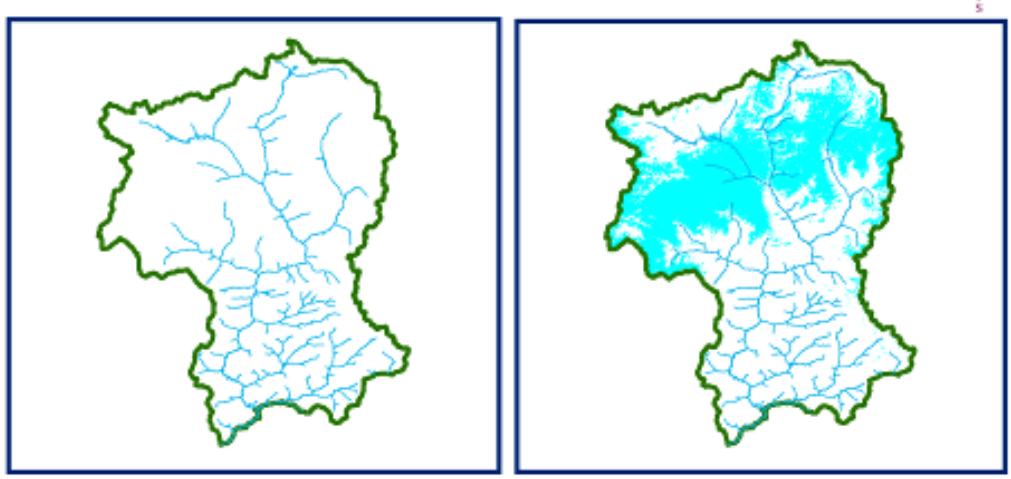
21 DECEMBER 2010
26 DECEMBER 2010

SNOW

0 20 40 80 120 160

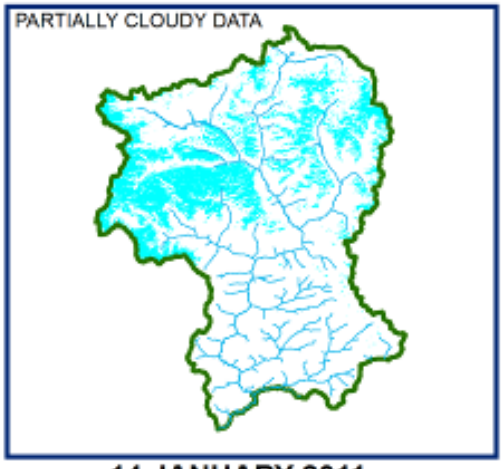
Kilometers

5 DAILY SNOW COVER MAP: TISTA



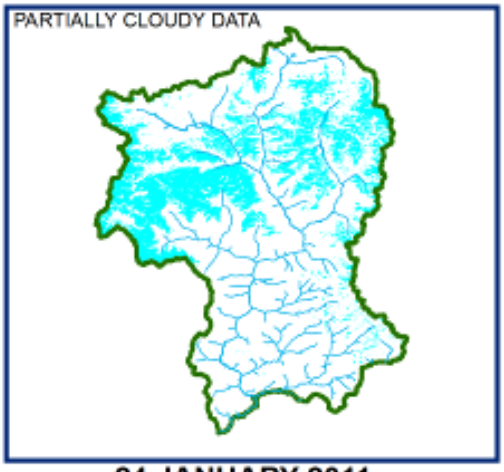
DATA NOT AVAILABLE

10 JANUARY 2011

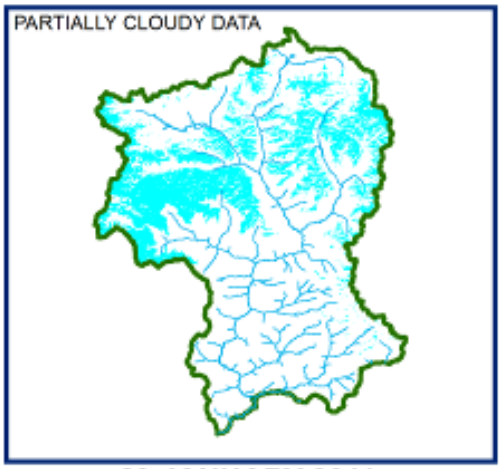


14 JANUARY 2011

DATA NOT AVAILABLE



24 JANUARY 2011



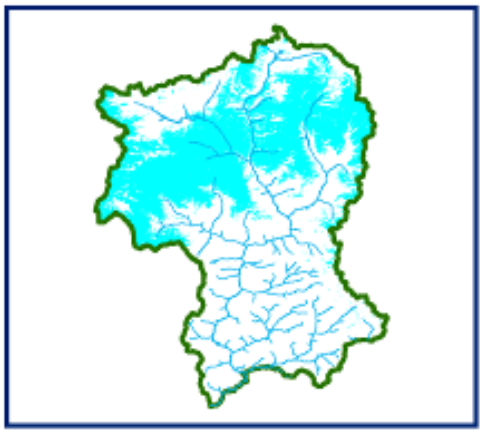
29 JANUARY 2011

0 15 30 60 90 120

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED

09 JANUARY 2011
10 JANUARY 2011

DATA USED

14 JANUARY 2011

DATA USED

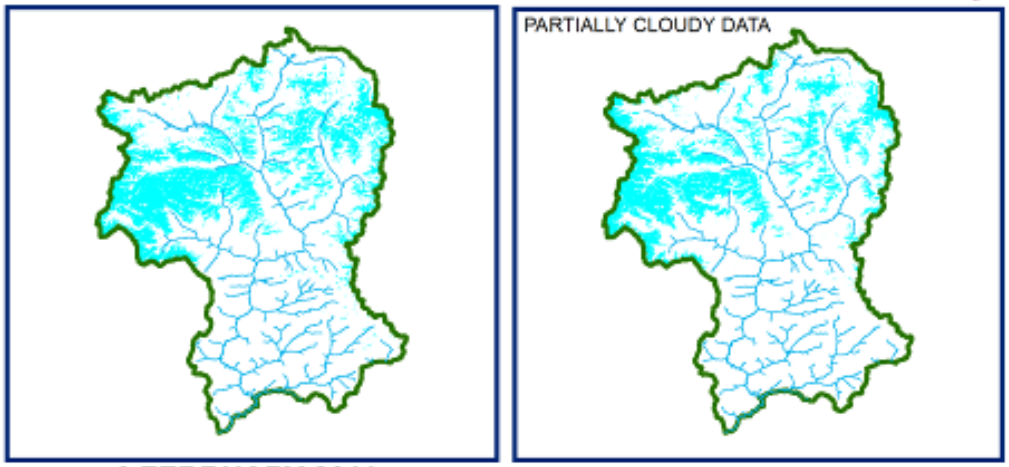
24 JANUARY 2011
29 JANUARY 2011

SNOW

0 20 40 80 120 160

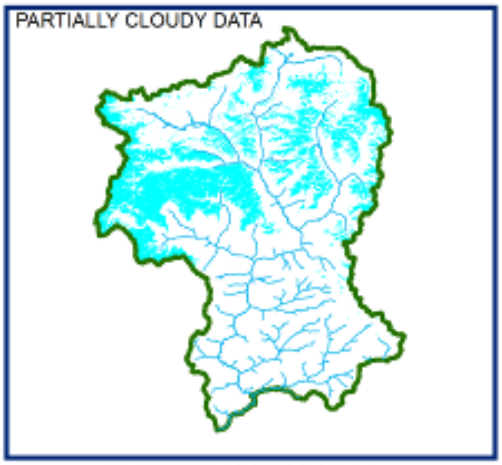
Kilometers

5 DAILY SNOW COVER MAP: TISTA

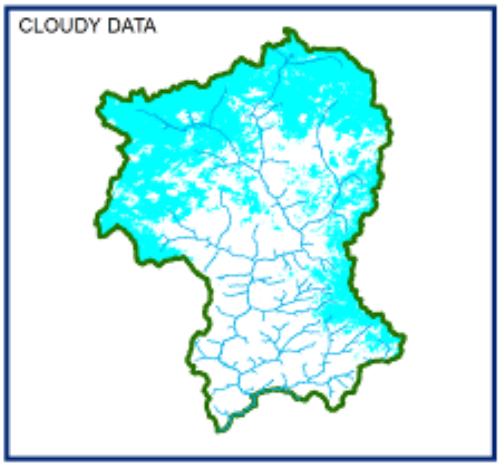


3 FEBRUARY 2011

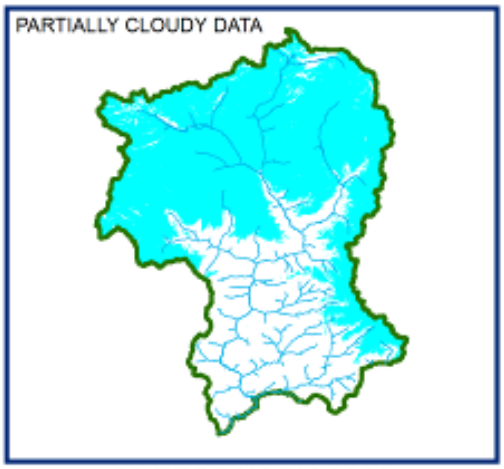
7 FEBRUARY 2011



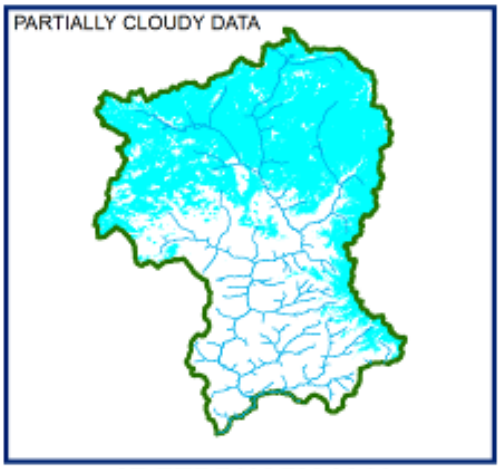
12 FEBRUARY 2011



17 FEBRUARY 2011



22 FEBRUARY 2011



27 FEBRUARY 2011

0 15 30 60 90 120

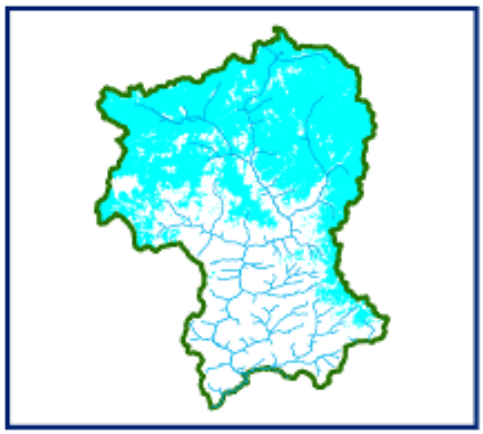
Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

DATA USED
03 FEBRUARY 2011
07 FEBRUARY 2011

DATA USED
12 FEBRUARY 2011

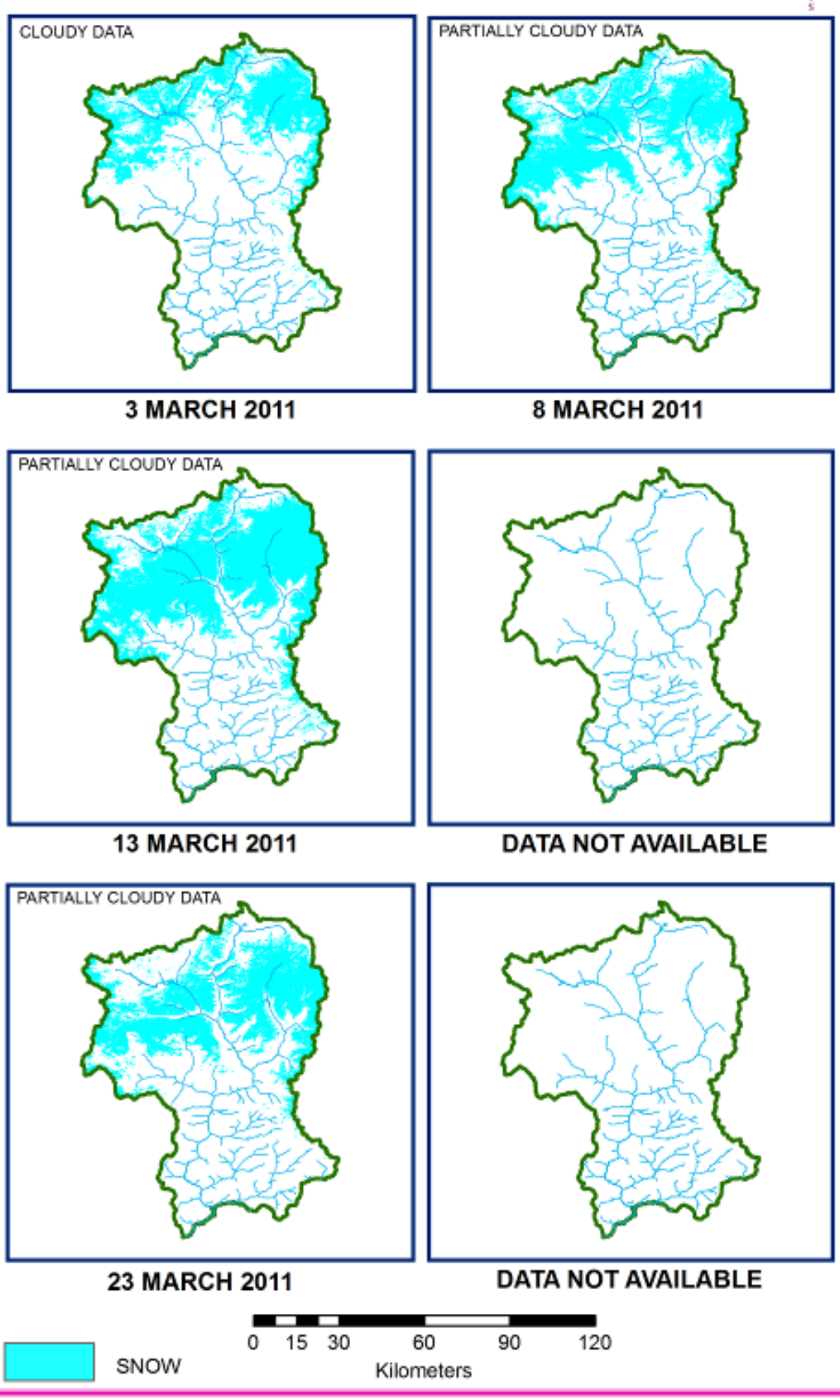


DATA USED
22 FEBRUARY 2011
26 FEBRUARY 2011
27 FEBRUARY 2011

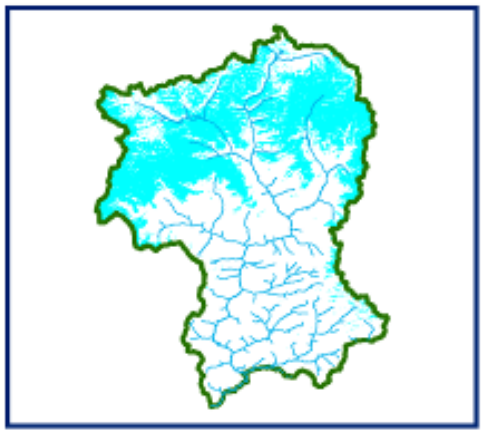
SNOW

0 20 40 80 120 160
Kilometers

5 DAILY SNOW COVER MAP: TISTA

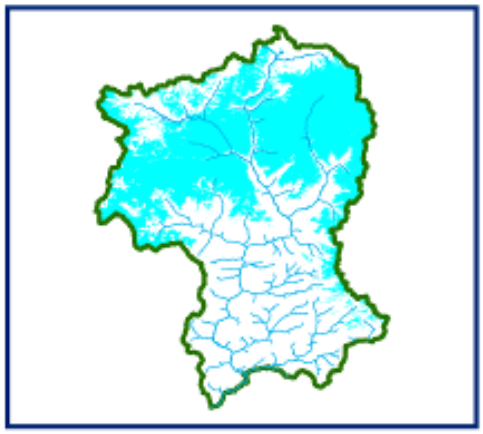


COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED

08 MARCH 2011



DATA USED

13 MARCH 2011

DATA USED

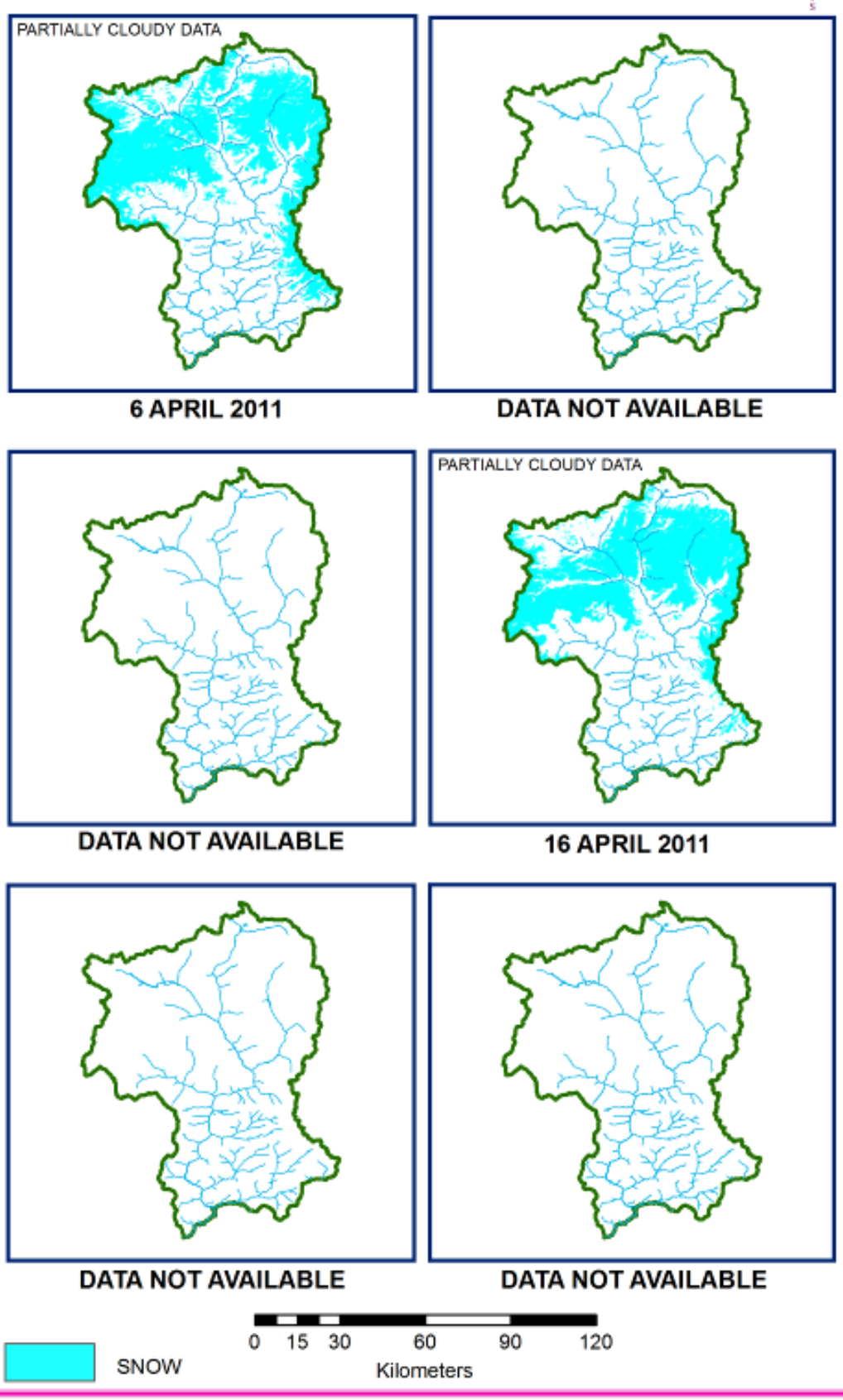
23 MARCH 2011

SNOW

0 20 40 80 120 160

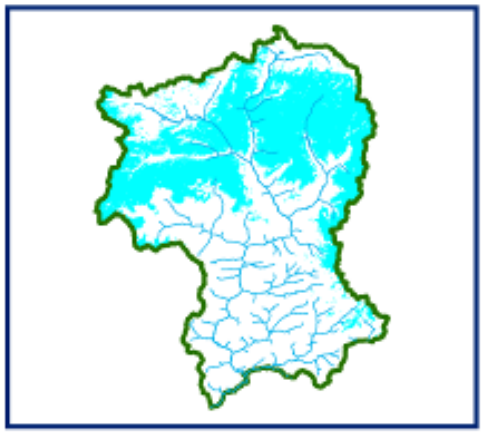
Kilometers

5 DAILY SNOW COVER MAP: TISTA



COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

DATA USED
06 APRIL 2011

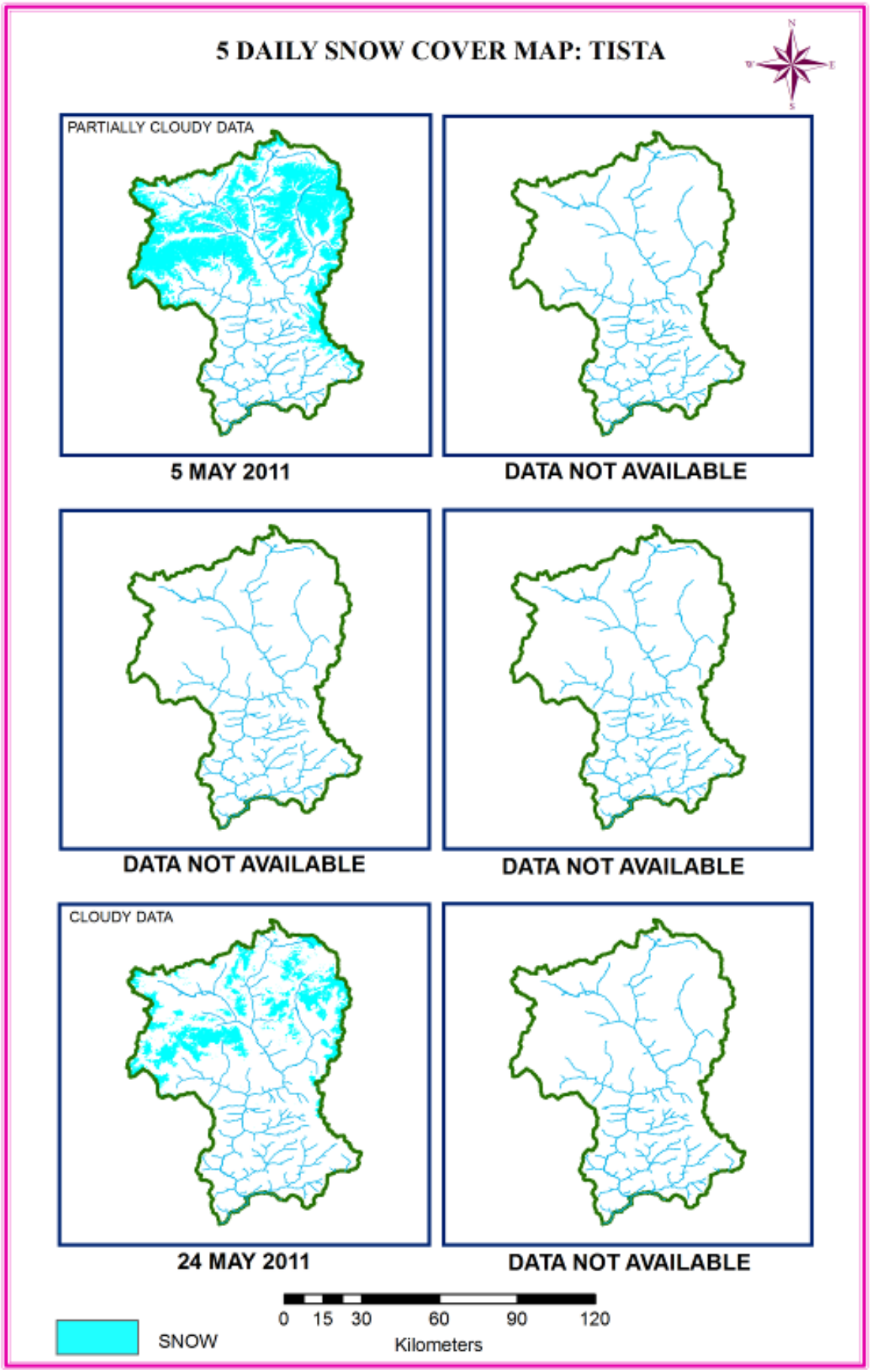


DATA USED
16 APRIL 2011

DATA USED
APRIL 2011

SNOW

0 20 40 80 120 160
Kilometers


5 DAILY SNOW COVER MAP: TISTA
PARTIALLY CLOUDY DATA
5 MAY 2011
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
24 MAY 2011
DATA NOT AVAILABLE
0 15 30 60 90 120
Kilometers
SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

DATA USED

5 MAY 2011

DATA USED

MAY 2011

DATA USED

MAY 2011

SNOW

0 20 40 80 120 160

Kilometers

RANGIT BASIN

AREAL EXTENT OF SNOW (5 DAILY)
2010-2011

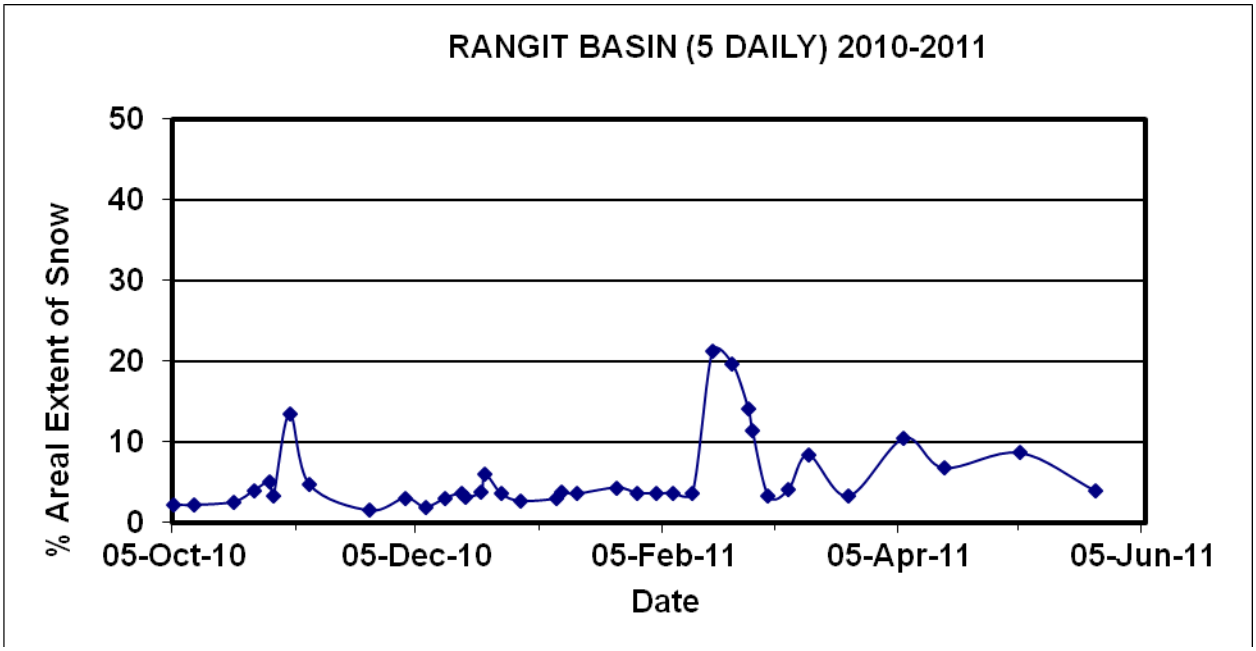
BASIN NAME: RANGIT BASIN AREA: 1630 sq km

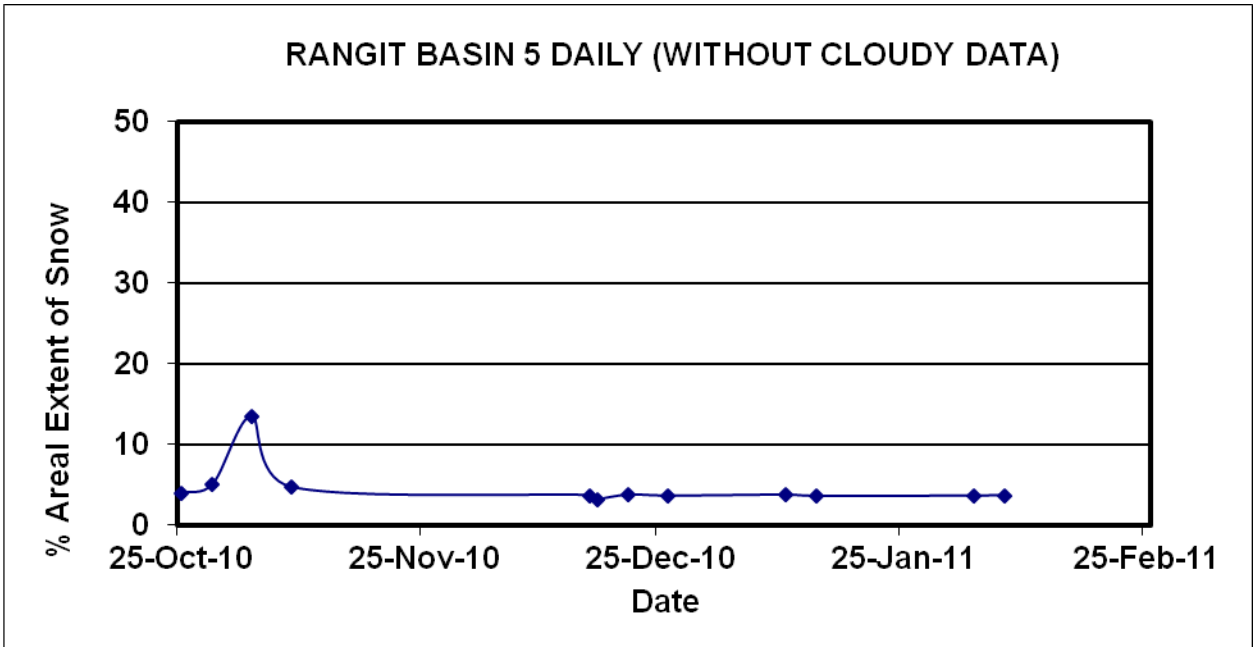
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2010							
1	5-Oct-10(C)	36.67	2	2	10-Oct-10(C)	35.49	2
3	20-Oct-10(C)	41.85	3	4	25-Oct-10(PC)	64.14	4
5	29-Oct-10(PC)	82.70	5	6	30-Oct-10(PC)	53.89	3
November 2010							
7	03-Nov-10(PC)	220.14	14	8	08-Nov-10(PC)	76.85	5
9	23-Nov-10(PC)	24.37	2				
December 2010							
10	02-Dec-10(PC)	49.41	3	11	7-Dec-10(PC)	31.23	2
12	12-Dec-10(PC)	49.35	3	13	16-Dec-10	60.00	4
14	17-Dec-10	52.00	3	15	21-Dec-10	61.11	4
16	22-Dec-10(PC)	98.79	6	17	26-Dec-10(PC)	58.96	4
18	31-Dec-10(PC)	43.43	3				
January 2011							
19	9-Jan-11(PC)	49.09	3	20	10-Jan-11	60.75	4
21	14-Jan-11(PC)	58.29	4	22	24-Jan-11(PC)	70.66	4
23	29-Jan-11(PC)	60.35	3				
February 2011							
24	03-Feb-11	58.90	4	25	07-Feb-11(PC)	60.00	4
26	12-Feb-11(PC)	60.36	4	27	17-Feb-11(C)	346.48	21
28	22-Feb-11(PC)	320.98	20	29	26-Feb-11(PC)	229.57	14
30	27-Feb-11(PC)	116.71	11				
March 2011							
31	03-Mar-11(C)	53.79	3	32	08-Mar-11(PC)	66.06	4
33	13-Mar-11(PC)	136.56	8	34	23-Mar-11(PC)	53.24	3
April 2011							
35	6-Apr-05(PC)	170.22	10	36	16-Apr-05(PC)	110.18	7
May 2011							
37	24-May-11(C)	63.50	4	38	5-May-05(PC)	140.77	9

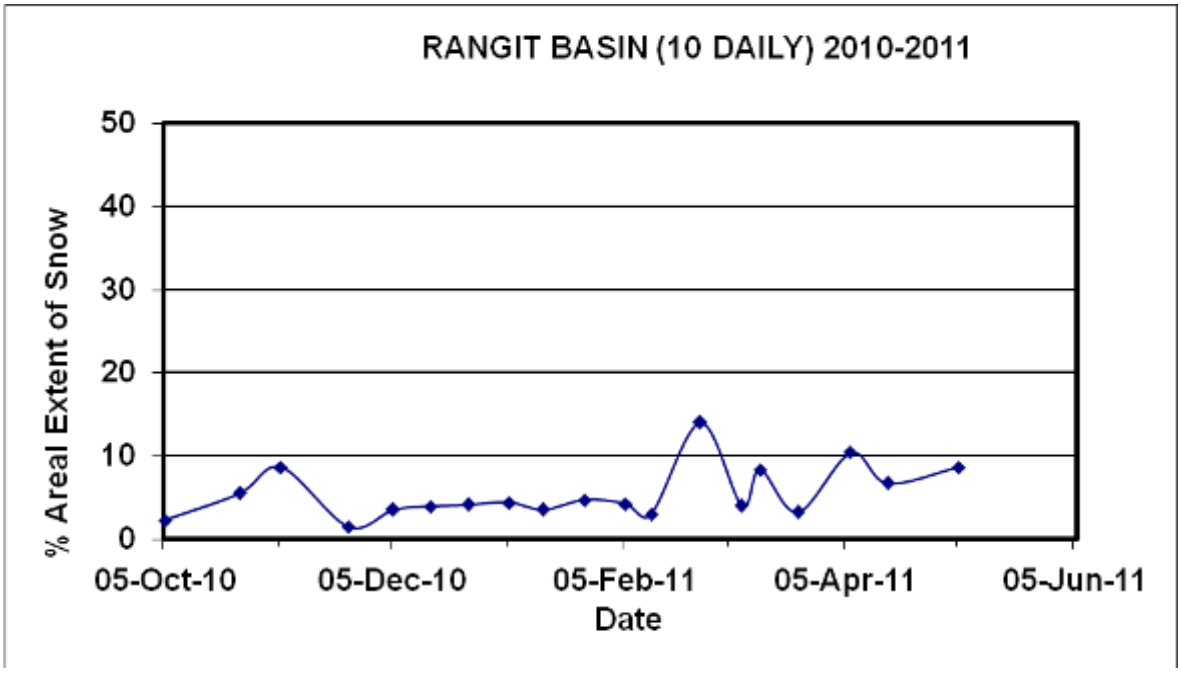
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: RANGIT **BASIN AREA: 1630 sq km**

S No	Data Used	Mean Date	Snow cover (sq km)	Snow cover (%)
October 2010				
1	05-Oct-2010	05-Oct-2010	36.67	2
2	25-Oct-2010 29-Nov-2010 30-Nov-2010	25-Oct-2010	90.45	6
November 2010				
3	03-Nov-2010 08-Nov-2010	05-Nov-2010	141.25	9
4	23-Nov-2010	23-Nov-2010	24.37	2
December 2010				
5	02-Dec-2010 07-Dec-2010	05-Dec-2010	57.82	4
6	16-Dec-2010 17-Dec-2010	15-Dec-2010	64.44	4
7	21-Dec-2010 26-Dec-2010	25-Dec-2010	68.60	4
January 2011				
8	09-Jan-2011 10-Jan-2011	5-Jan-2011	72.50	4
9	14-Jan-2011	14-Jan-2011	58.29	4
10	24-Jan-2011 29-Jan-2011	25-Jan-2011	77.37	5
February 2011				
11	03-Feb-2011 07-Feb-2011	05-Feb-0211	70.06	4
12	12-Feb-2011	12-Feb-2011	49.35	3
13	22-Feb-2011 26-Feb-2011 27-Feb-2011	25-Feb-2011	229.02	14
March 2011				
14	08-Mar-2011	08-Mar-2011	66.06	4
15	13-Mar-2011	13-Mar-2011	136.56	8
16	23-Mar-2011	23-Mar-2011	53.24	3
April 2011				
17	06-Apr-2011	06-Apr-2011		
18	16-Apr-2011	16-Apr-2011	110.18	7
May 2011				
19	5-May-2011	5-May-2011	140.77	9

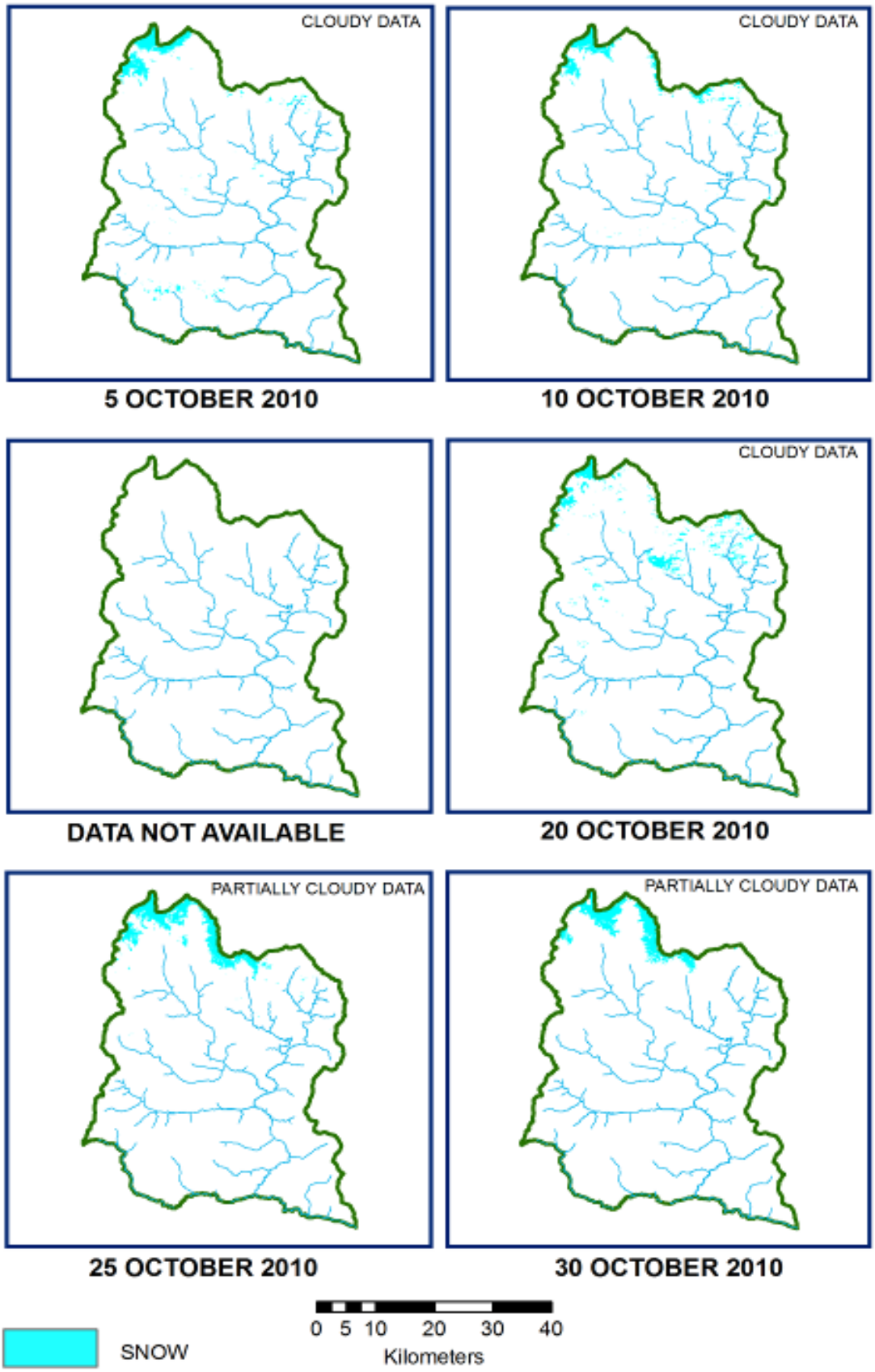

RANGIT BASIN (5 DAILY) 2010-2011
% Areal Extent of Snow
50
40
30
20
10
0
05-Oct-10
05-Dec-10
05-Feb-11
05-Apr-11
05-Jun-11
Date


RANGIT BASIN 5 DAILY (WITHOUT CLOUDY DATA)
% Areal Extent of Snow
50
40
30
20
10
0
25-Oct-10
25-Nov-10
25-Dec-10
25-Jan-11
25-Feb-11
Date


RANGIT BASIN (10 DAILY) 2010-2011
% Areal Extent of Snow
50
40
30
20
10
0
05-Oct-10
05-Dec-10
05-Feb-11
05-Apr-11
05-Jun-11
Date

SNOW COVER MAPS

5 DAILY SNOW COVER MAP: RANGIT BASIN



COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED
05 OCTOBER 2010

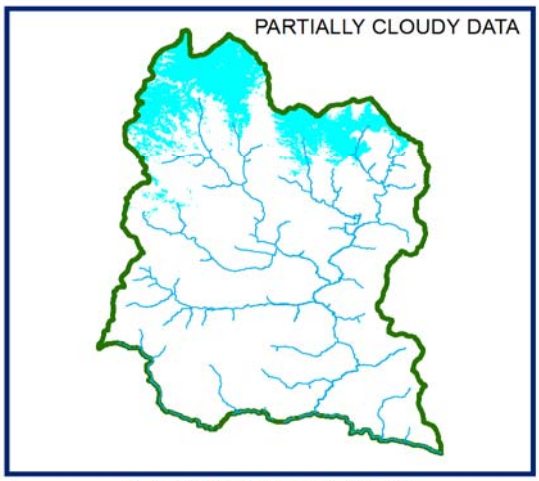
DATA USED
OCTOBER 2010

DATA USED
25 OCTOBER 2010
29 OCTOBER 2010
30 OCTOBER 2010

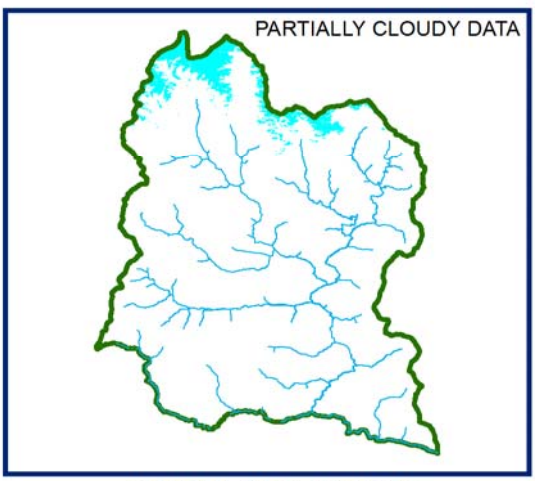
SNOW

0 10 20 40 60 80
Kilometers

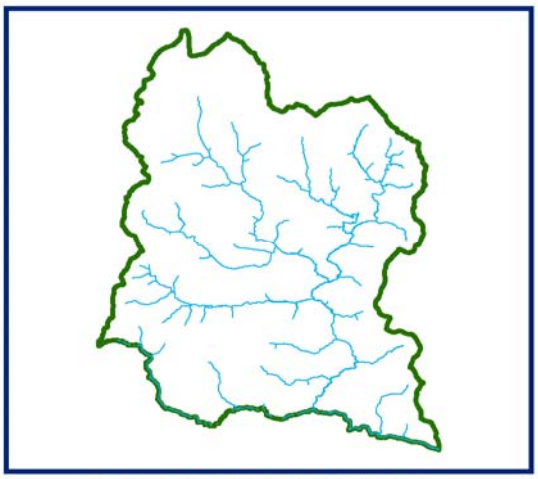
5 DAILY SNOW COVER MAP: RANGIT BASIN



3 NOVEMBER 2010



8 NOVEMBER 2010



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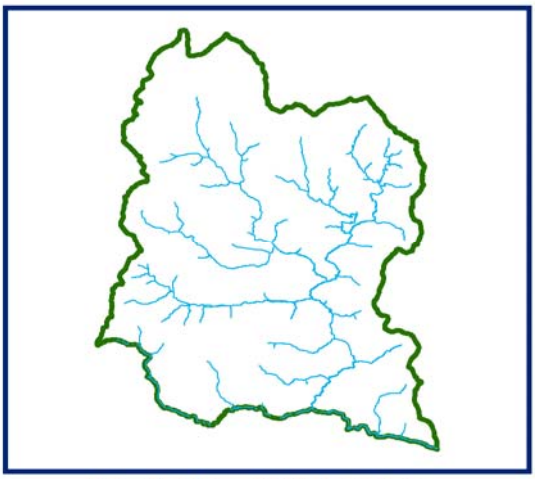

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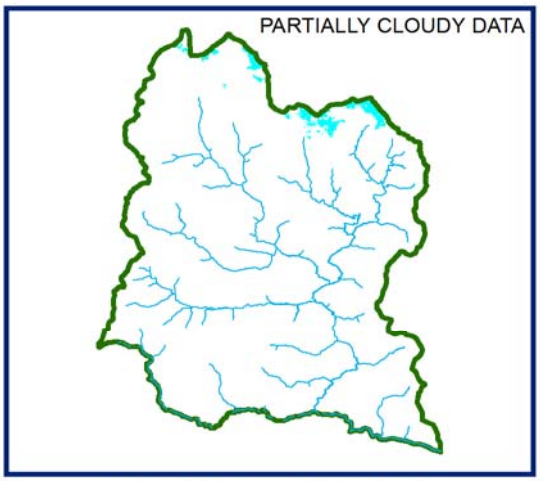
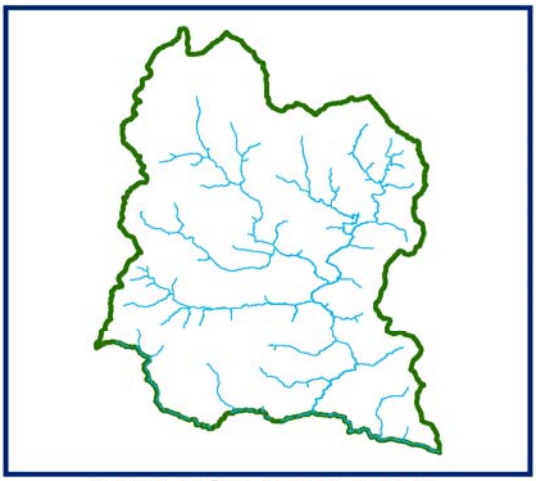


23 NOVEMBER 2010



DATA NOT AVAILABLE

SNOW

0 5 10 20 30 40

Kilometers

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED
03 NOVEMBER 2010
08 NOVEMBER 2010

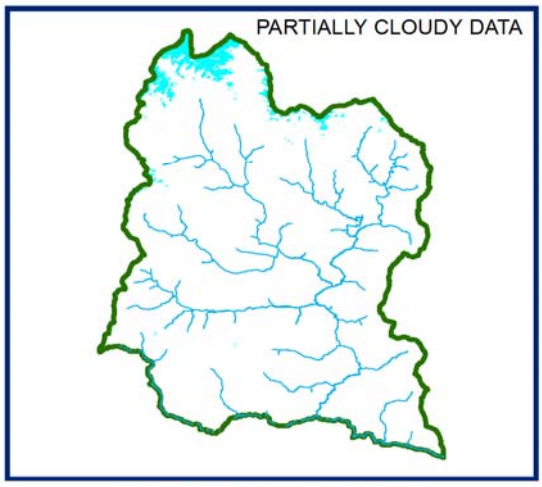
DATA USED
NOVEMBER 2010

DATA USED
23 NOVEMBER 2010

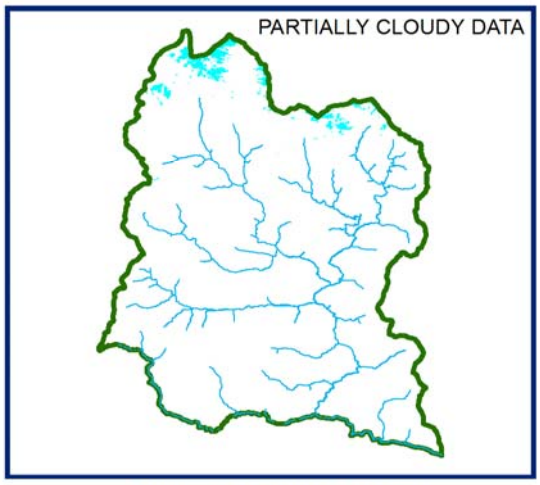
SNOW

0 10 20 40 60 80
Kilometers

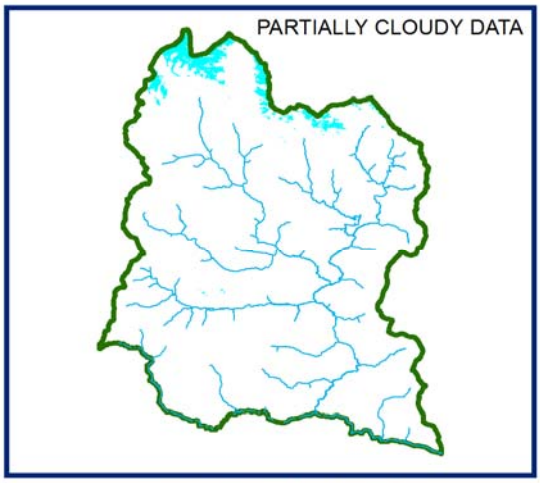
5 DAILY SNOW COVER MAP: RANGIT BASIN



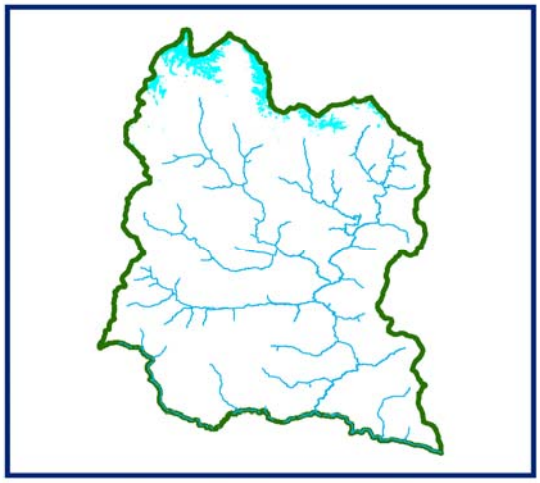
2 DECEMBER 2010



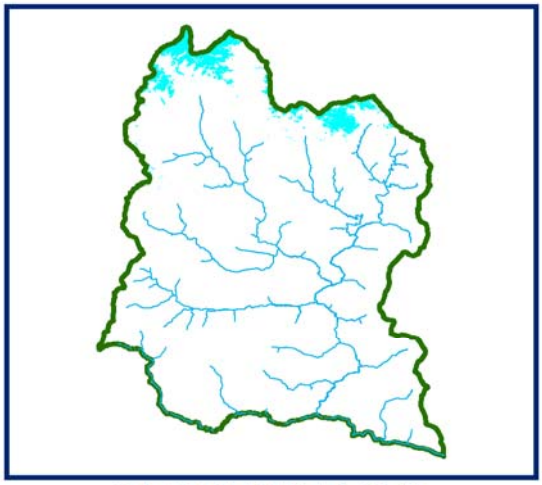
7 DECEMBER 2010



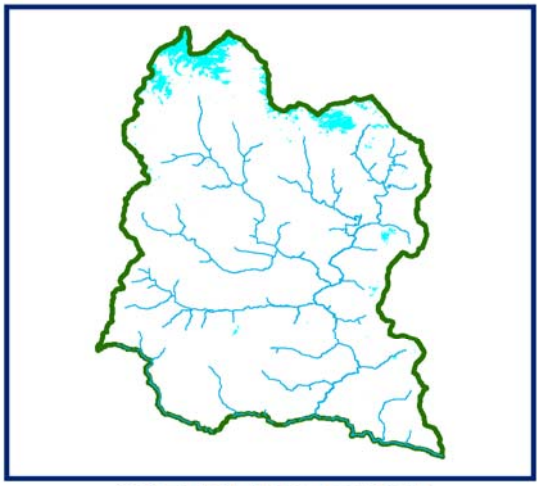
12 DECEMBER 2010



17 DECEMBER 2010



21 DECEMBER 2010



26 DECEMBER 2010

0 5 10 20 30 40

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED

02 DECEMBER 2010
07 DECEMBER 2010

DATA USED

16 DECEMBER 2010
17 DECEMBER 2010

DATA USED

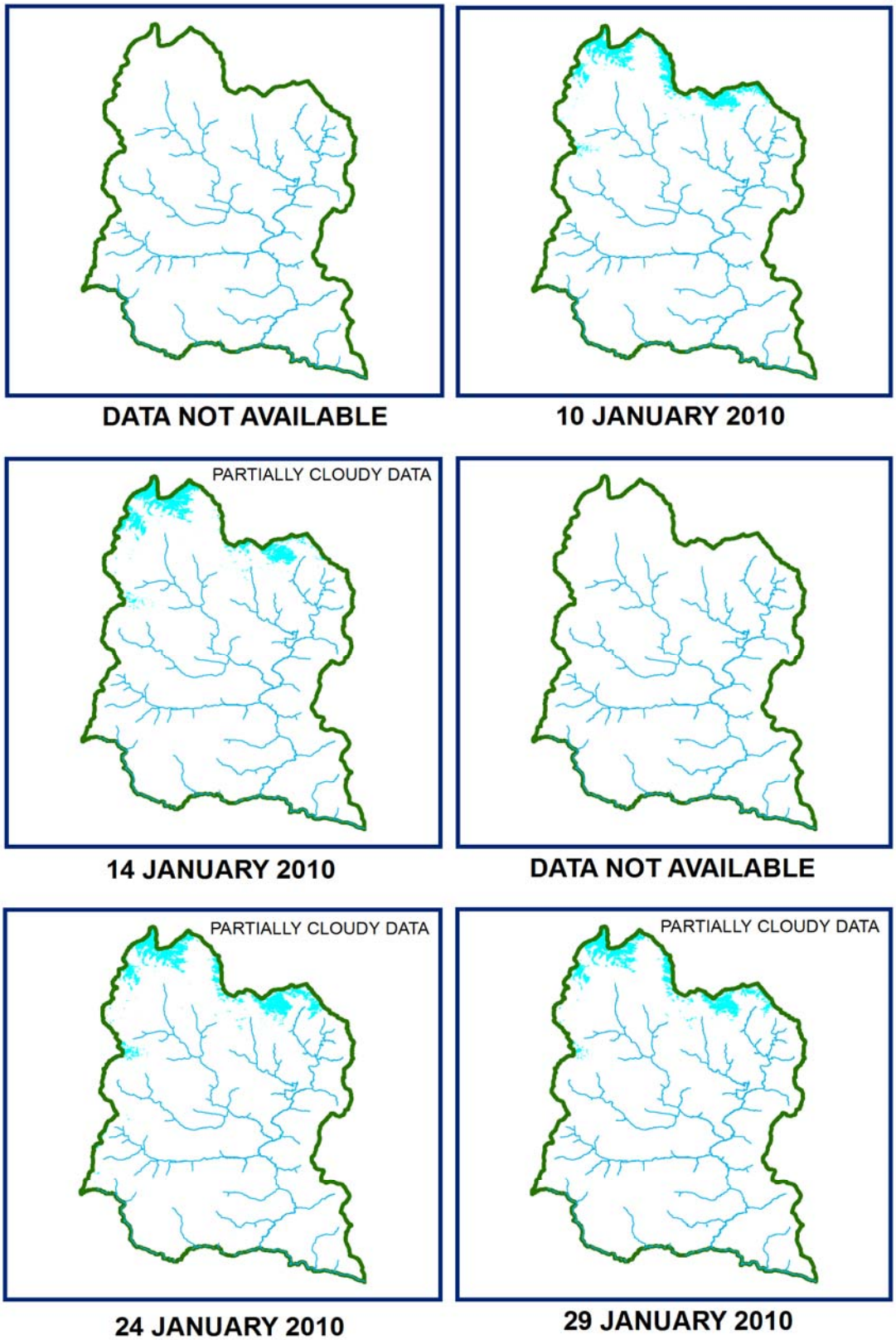
21 DECEMBER 2010
26 DECEMBER 2010

SNOW

0 10 20 40 60 80

Kilometers

5 DAILY SNOW COVER MAP: RANGIT BASIN



COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED

09 JANUARY 2011
10 JANUARY 2011

DATA USED

14 JANUARY 2011

DATA USED

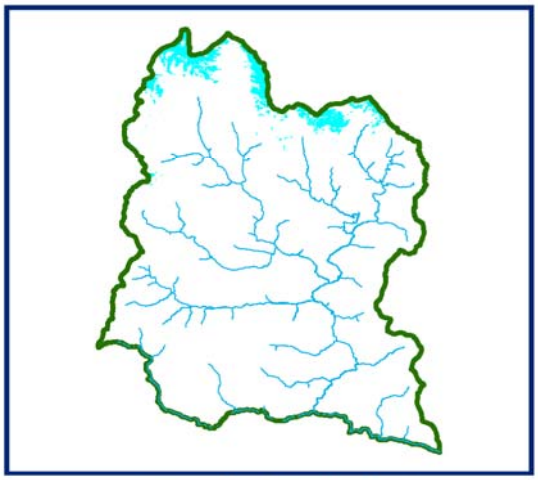
24 JANUARY 2011
29 JANUARY 2011

SNOW

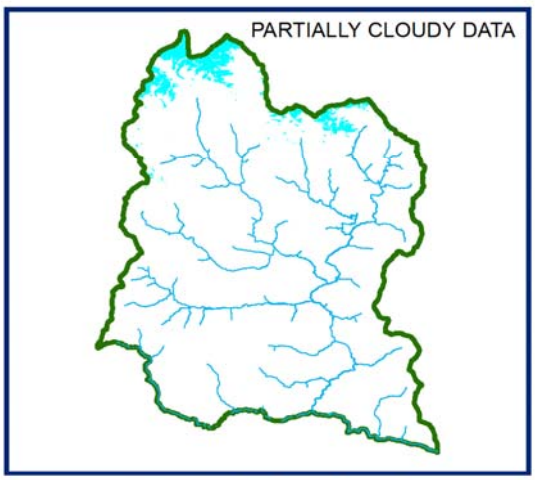
0 10 20 40 60 80

Kilometers

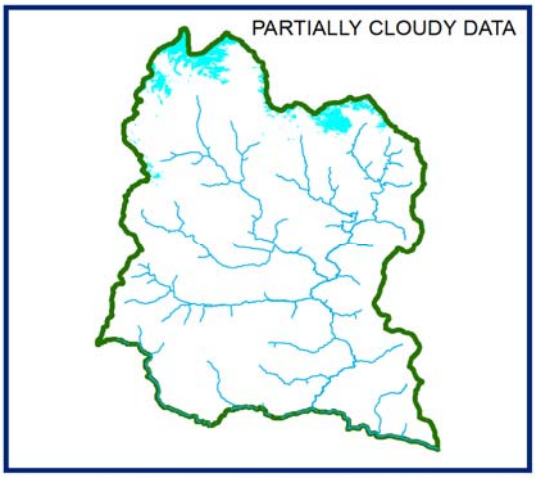
5 DAILY SNOW COVER MARANGIT BASIN



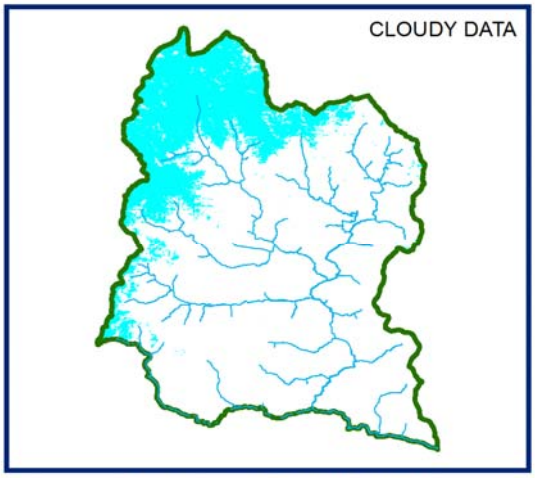
3 FEBRUARY 2011



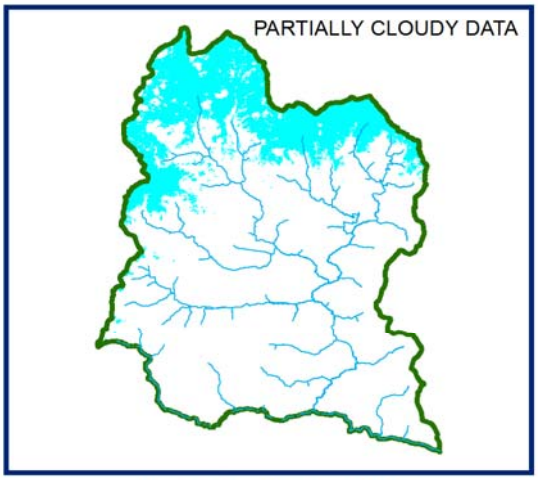
7 FEBRUARY 2011



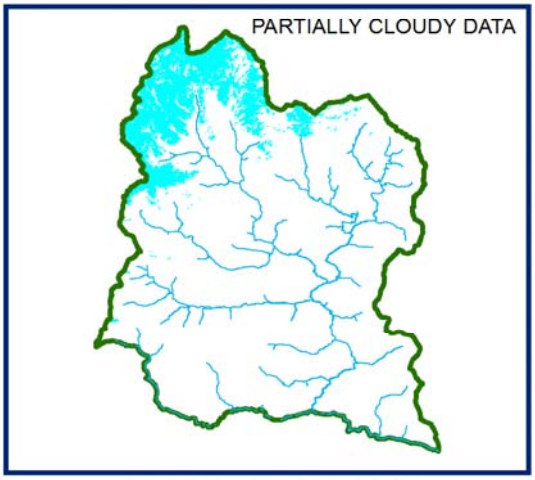
12 FEBRUARY 2011



17 FEBRUARY 2011



22 FEBRUARY 2011



27 FEBRUARY 2011

0 5 10 20 30 40

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED
03 FEBRUARY 2011
07 FEBRUARY 2011

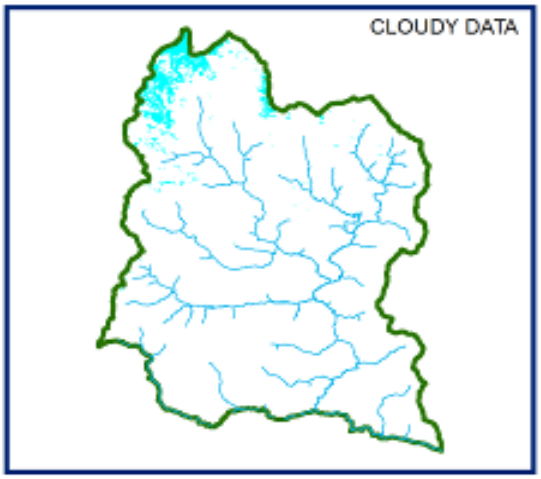
DATA USED
12 FEBRUARY 2011

DATA USED
22 FEBRUARY 2011
26 FEBRUARY 2011
27 FEBRUARY 2011

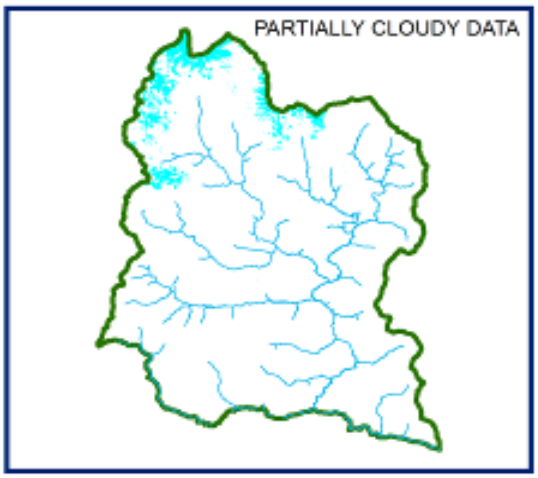
SNOW

0 10 20 40 60 80
Kilometers

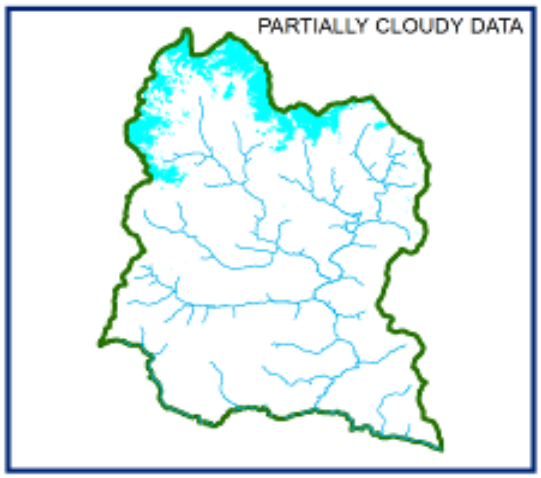
5 DAILY SNOW COVER MAP: RANGIT BASIN



3 MARCH 2011

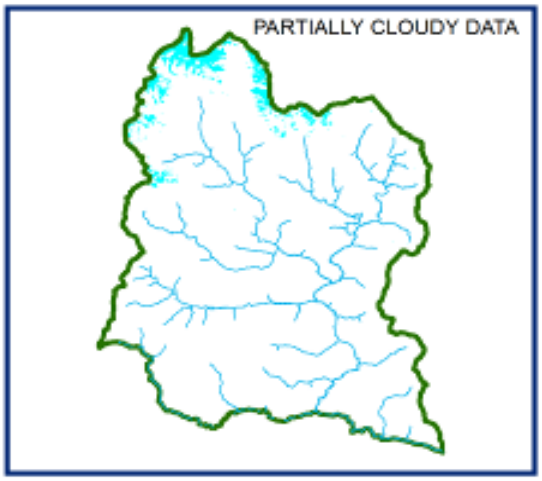


8 MARCH 2011



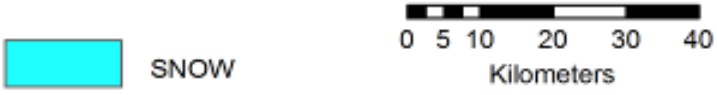
13 MARCH 2011

DATA NOT AVAILABLE



23 MARCH 2011

DATA NOT AVAILABLE



COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED
08 MARCH 2011

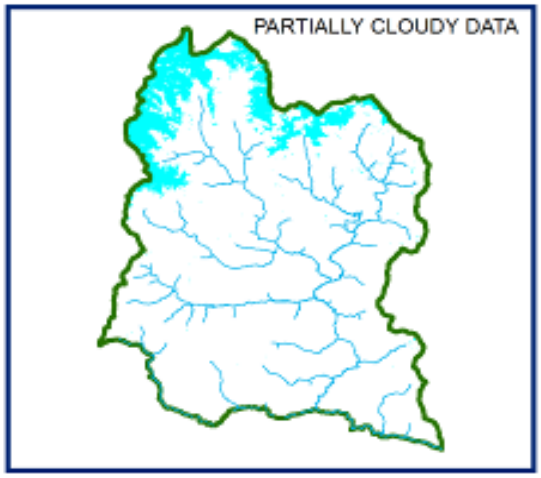
DATA USED
13 MARCH 2011

DATA USED
23 MARCH 2011

SNOW

0 10 20 40 60 80
Kilometers

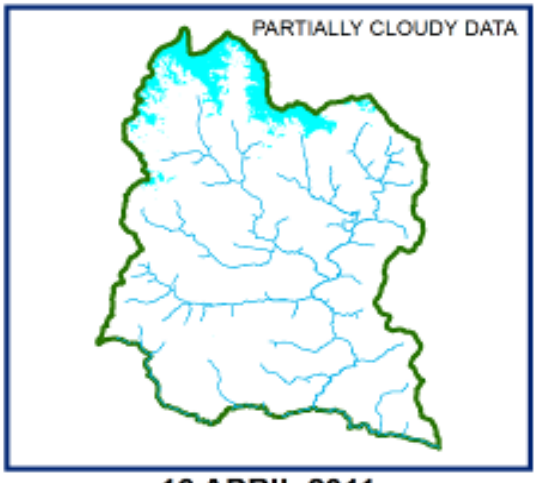
5 DAILY SNOW COVER MAP: RANGIT BASIN



6 APRIL 2011

DATA NOT AVAILABLE

DATA NOT AVAILABLE



16 APRIL 2011

DATA NOT AVAILABLE

DATA NOT AVAILABLE

0 5 10 20 30 40

Kilometers

SNOW

COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED
06 APRIL 2011

DATA USED
16 APRIL 2011

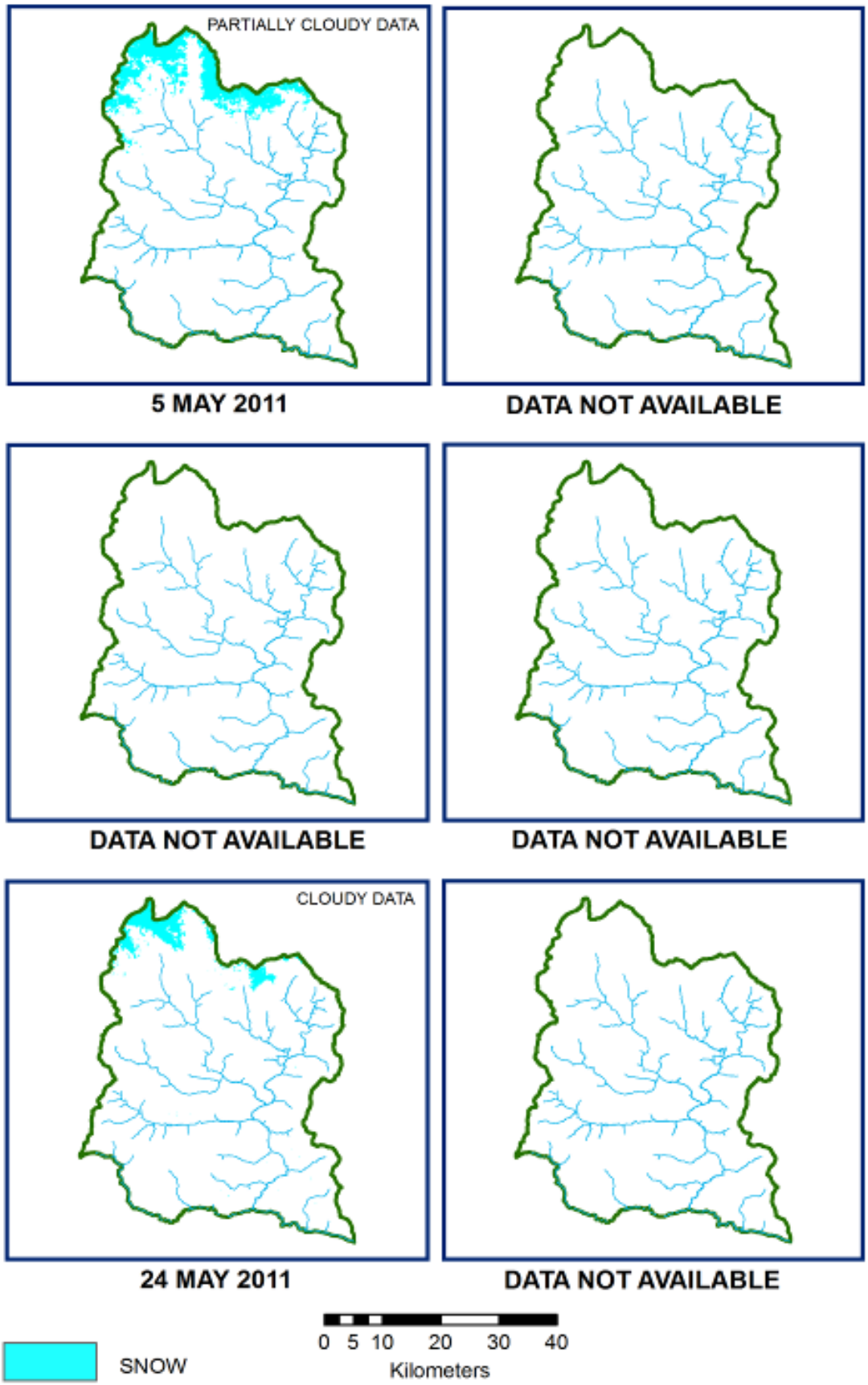
DATA USED
APRIL 2011

SNOW

0 10 20 40 60 80

Kilometers

5 DAILY SNOW COVER MAP: RANGIT BASIN



COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

DATA USED
5 MAY 2011

DATA USED
MAY 2011

DATA USED
MAY 2011

SNOW

0 10 20 40 60 80
Kilometers