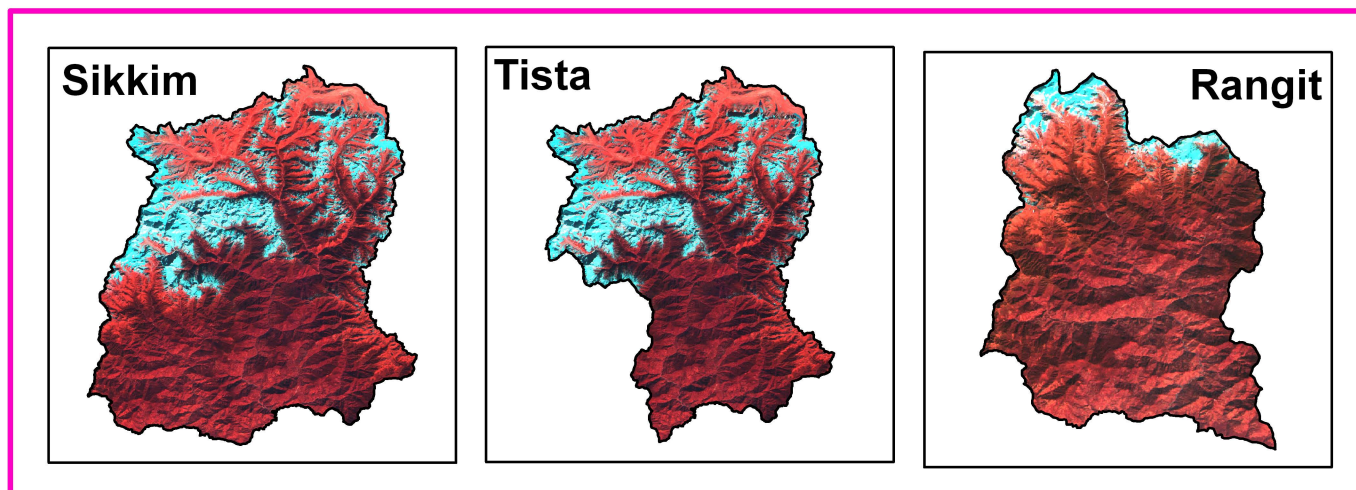


# SNOW COVER ATLAS OF SIKKIM

Sub basins: Sikkim, Tista and Rangit

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

Year : 2011-12



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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**SPACE APPLICATIONS CENTRE (ISRO), AHMEDABAD - 380015**

**DOCUMENT CONTROL AND DATA SHEET**

Report Number	SAC/EPsA/MPSG/SGP/SN/ 85 /2013
Month and year of publication	February 2013
Title	Snow cover Atlas of Sikkim
Type of Report	Scientific Report
No. of pages	67
No. of figures, Charts & Tables	50, 9 & 6
Authors	Team members
No. of References	9
Originating Unit	Geo Sciences Division, Marine, Geo and Planetary Sciences Group, Earth, Ocean, Atmosphere, Planetary Sciences and Applications area, Space Applications Centre (ISRO), Ahmedabad-15
Abstract	This atlas gives subbasin-wise distribution of snow cover in the Tista basin from October 2011 to June 2012. 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.
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 2011 to June 2012 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:

$$\text{Normalized Difference Snow Index (NDSI)} = (\text{band 2} - \text{band 5}) / (\text{band 2} + \text{band 5}) \quad \dots(1)$$

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 September 2011 to May 2012. Snow ablation pattern was estimated for Sikkim state, Tista and Rangit basins in the Sikkim Himalaya. In Sikkim, maximum areal extent of 50% was observed in the month of March 2012. The highest snow areal extent of 61% observed in Tista and

21% in Rangit basins, respectively in the same month. In Sikkim, in the month of January, snow extent of 40 % was observed, which is highest percent in the year. This was reduced to 36 % in March and reduced to 17% in the month of May 2012. The lowest snow recorded in the month of September, October and December in 2011 and April and May in 2012 in Sikkim and in Tista basin. In Rangit basin, the highest snow present of 11% was recorded in February 2012 and the lowest 4% was recorded in the month of October 2011.

### **Acknowledgements**

This investigation was jointly carried out by Space Applications Centre, Ahmedabad and Sikkim State council of Science and Technology, Gangtok. It was carried out under Snow and Glacier Studies Project, a joint initiative of Ministry of Environment and Forest (MoEF) and Department of Space (DOS). The authors are grateful to Shri A. S. Kiran Kumar, Director, Space Applications Centre, Ahmedabad for continuous guidance and encouragement during the investigation. Authors would like to thank Dr. J. S. Parihar, Deputy Director, EPSA, SAC for their suggestions and comments on the manuscript.

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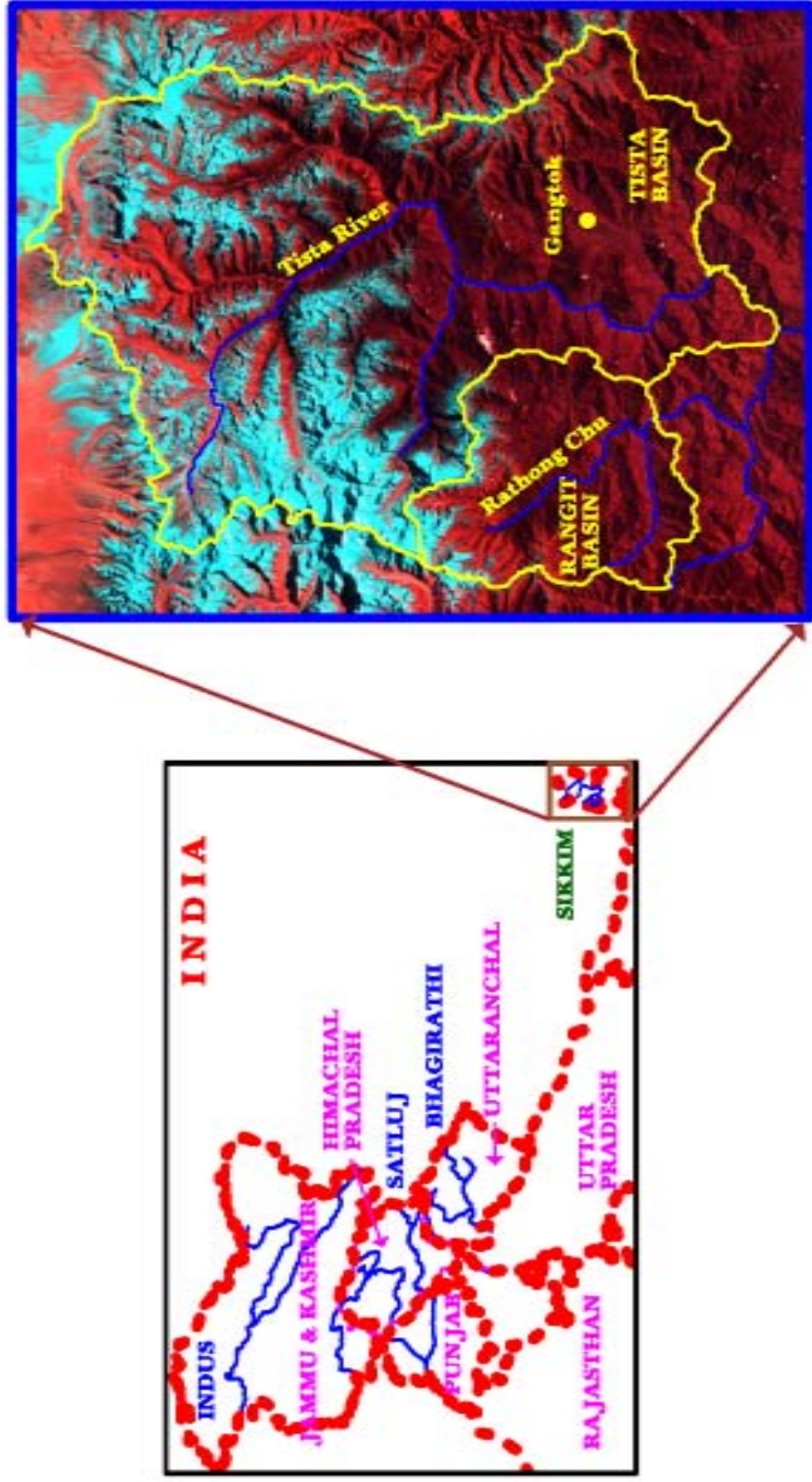
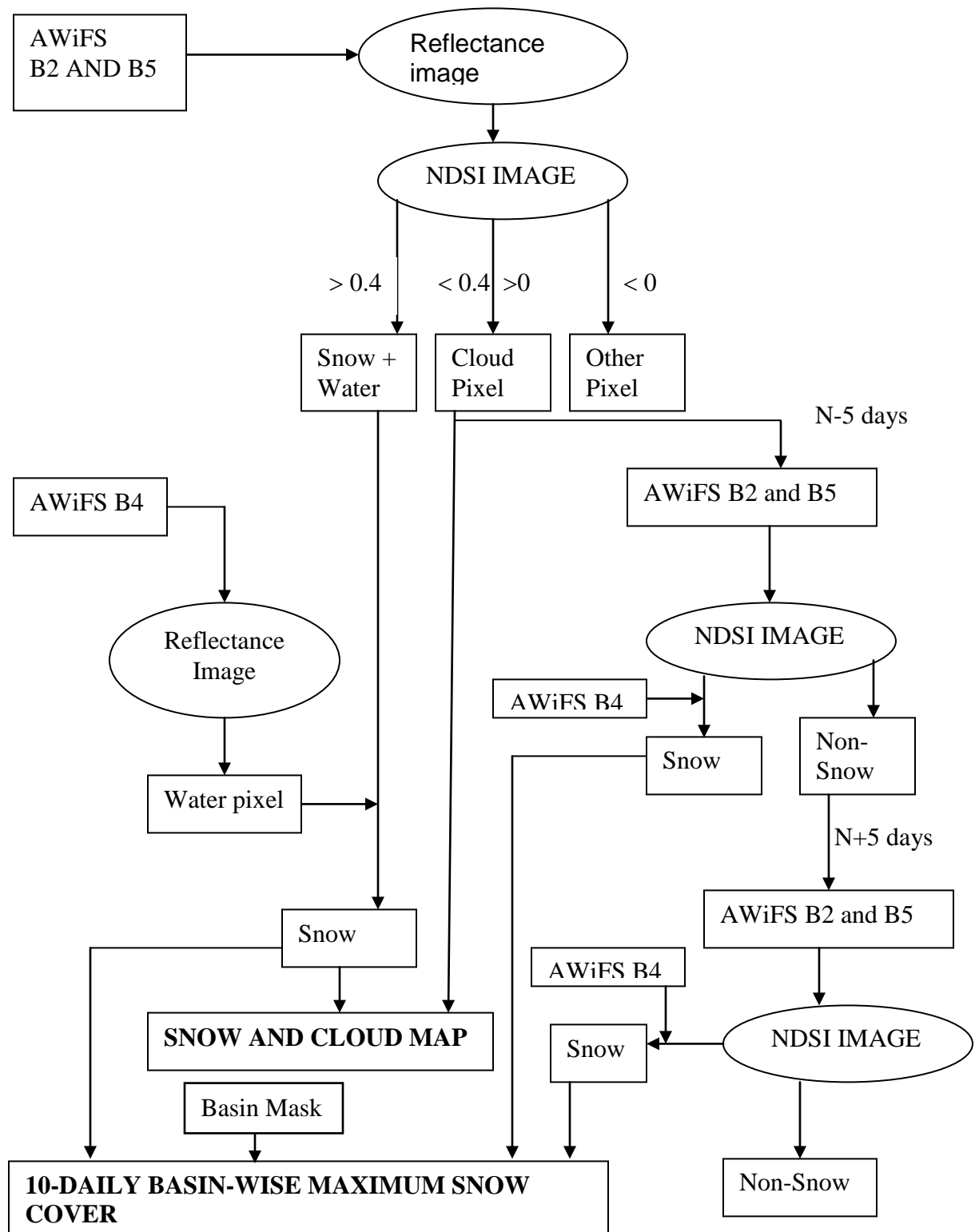


Figure 1: Location map of Tista and Rangit sub-basins (Part of Tista basin)



**Figure 2: Algorithm for snow cover mapping using AWiFS data**



*SIKKIM*

# AREAL EXTENT OF SNOW (5 DAILY)

STATE NAME: SIKKIM

SIKKIM AREA: 7096 sq km

S. No	Date	Snow cover (sq km)	Snow cover (%)	S. No	Date	Snow cover (sq km)	Snow cover (%)
<b>September 2011</b>							
1	30Sept2011(PC)	776	11				
<b>October 2011</b>							
2	6-Oct-11(PC)	741	10	3	10-Oct-11(C)	597	8
4	20-Oct-11(C)	596	8	5	24-Oct-11	2427	34
6	25-Oct-11(PC)	1739	25	7	29-Oct-11(PC)	1610	23
8	30-Oct-11(C)	1292	18				
<b>November 2011</b>							
9	10-Nov-11	2270	32	10	13-Nov-11(C)	904	13
11	17-Nov-11(PC)	2026	29	12	18-Nov11(PC)	2104	30
13	20-Nov-11	2281	32	14	22-Nov-11	1691	24
15	27-Nov-11	1420	20				
<b>December 2011</b>							
16	02-Dec-11	1194	17	17	07-Dec-11(PC)	964	14
18	09-Dec-11(PC)	1315	19	19	11-Dec-11(C)	992	14
20	12-Dec-11(C)	597	8	21	16-Dec-11(PC)	1021	14
22	17-Dec-11(PC)	1006	25	23	19-Dec-11	1320	19
24	21-Dec-11	1065	19	25	24-Dec-11(PC)	947	13
26	26-Dec-11	906	13	27	28-Dec-11	1056	15
28	31-Dec-11	822	12				
<b>January 2012</b>							
29	05-Jan-12(PC)	3340	47	30	10-Jan-12(PC)	2827	40
31	19-Jan-12(PC)	3367	47	32	24-Jan-12(PC)	2731	38
33	26-Jan-12(PC)	3013	42	34	28-Jan-12(C)	1667	23
35	31-Jan-12(PC)	2945	42				
<b>February 2012</b>							
36	02-Feb-12	2777	39	37	05-Feb-12	2667	38
38	07-Feb-12	2157	30	39	22-Feb-12	2734	39
40	24-Feb-12(PC)	3169	45				

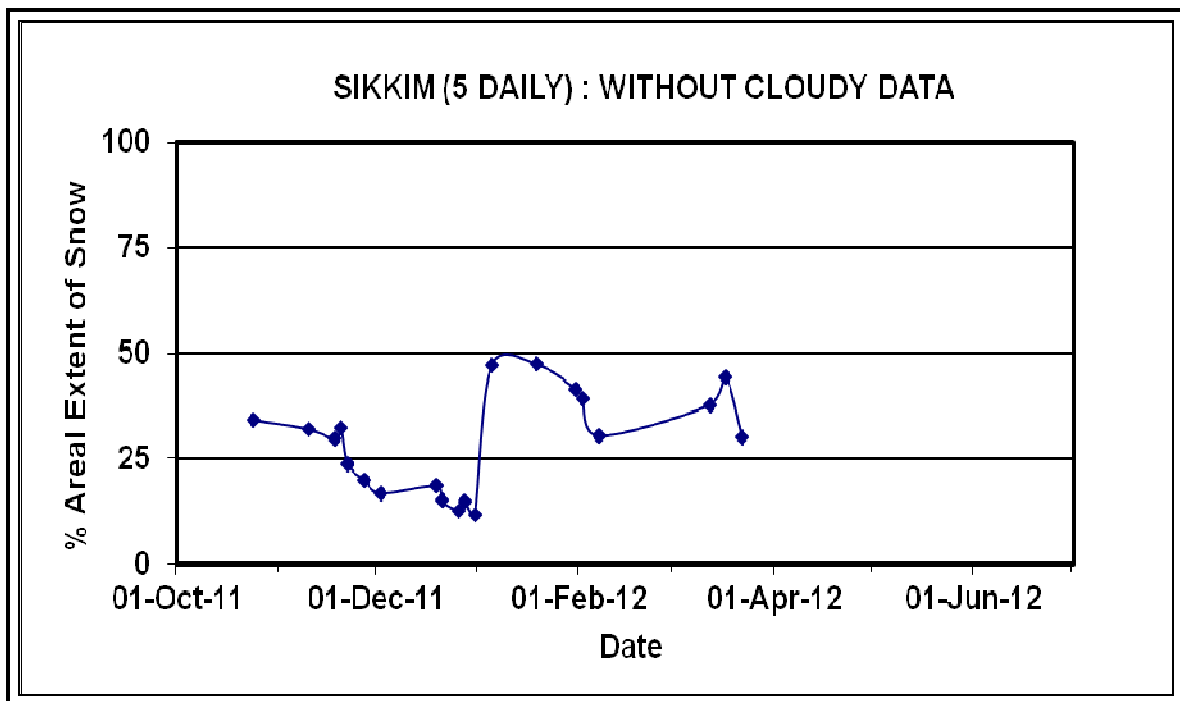
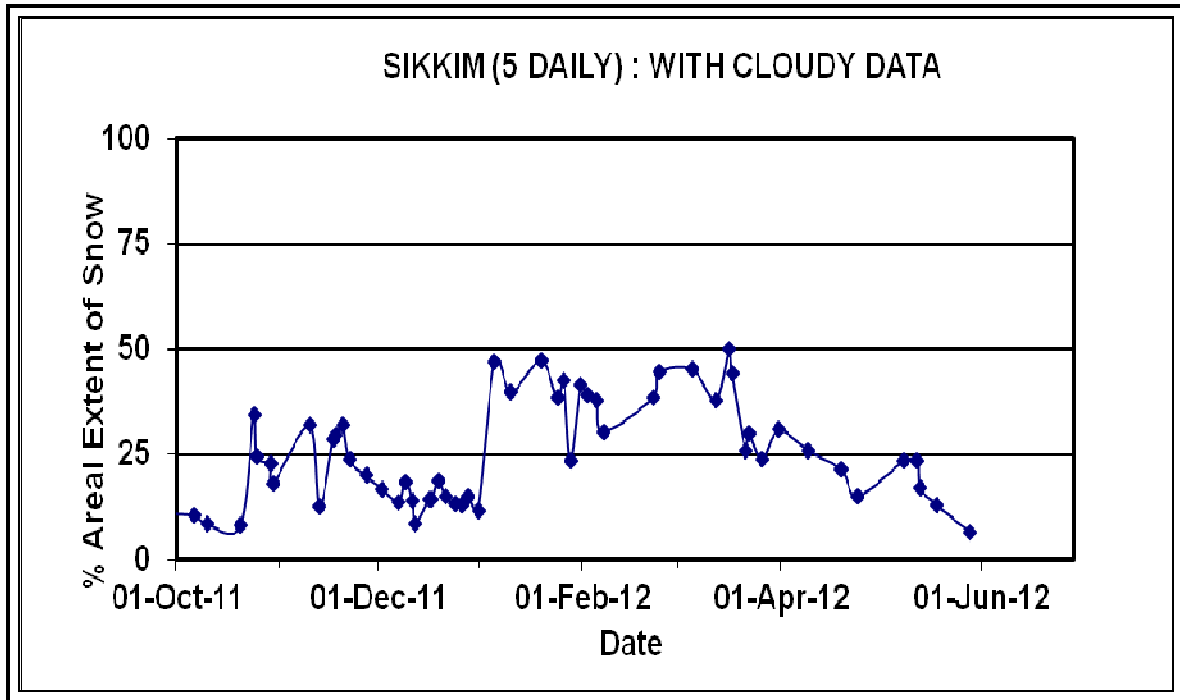
<b>March 2012</b>							
41	05-Mar-12(PC)	3213	45	42	12-Mar-12	2682	38
43	16-Mar-12(PC)	3542	50	44	17-Mar12(PC)	3150	44
45	21-Mar-12(PC)	1845	26	46	22-Mar12(PC)	2127	30
47	26-Mar-12(PC)	1684	24	48	31-Mar12(PC)	2191	31
<b>April 2012</b>							
49	09-Apr-12(C)	1841	26	50	19-Apr-12(PC)	1524	21
51	24-Apr-12(PC)	1070	15				
<b>May 2012</b>							
52	08-May-12(PC)	1666	23	53	12-May-12	1672	24
54	13-May-12(PC)	1209	17	55	18-May-12(C)	927	13
56	28-May-12(C)	463	7				

**AREAL EXTENT OF SNOW (10 DAILY)****STATE NAME: SIKKIM****SIKKIM AREA: 7096 sq km**

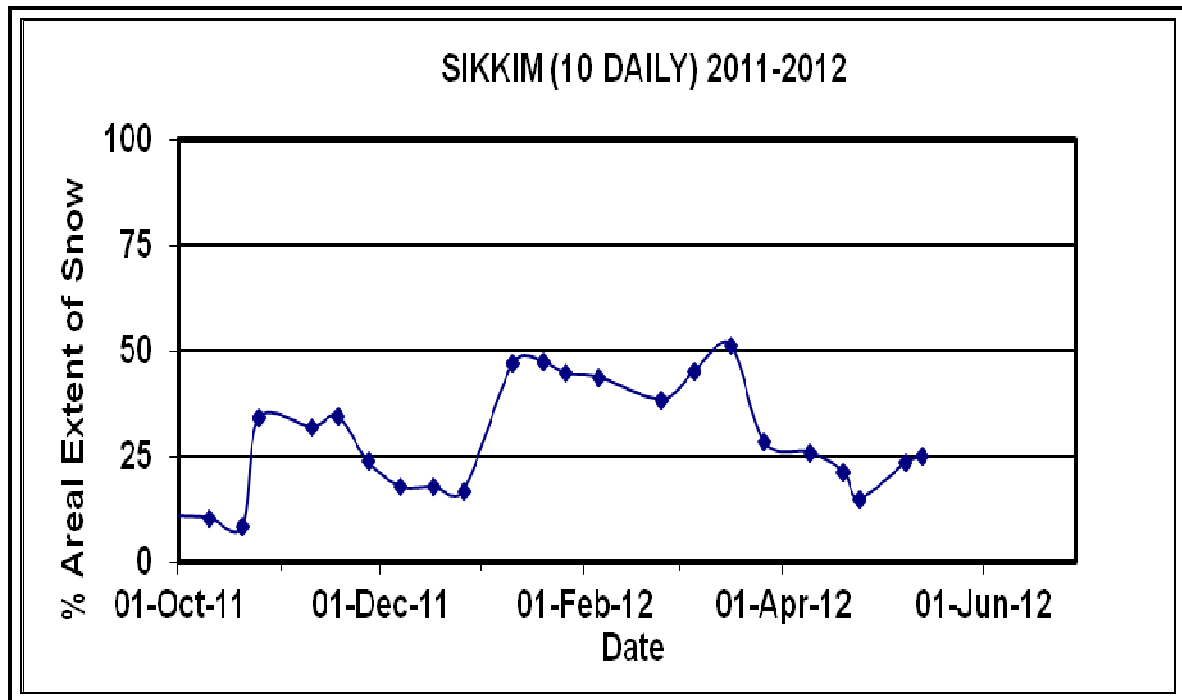
<b>S. No</b>	<b>Data Used</b>	<b>Mean Date</b>	<b>Snow cover (sq km)</b>	<b>Snow cover (%)</b>
<b>September 2011</b>				
<b>1</b>	30-Sept-2011	30-Sept-2011	776	11
<b>October 2011</b>				
2	10-Oct-2011	10-Oct-2011	741	10
3	20-Oct-2011	20-Oct-2011	596	8
4	25-Oct-2011	25-Oct-2011	2417	34
<b>November 2011</b>				
5	10-Nov-2011	10-Nov-2011	2270	32
6	18-Nov-2011	18-Nov-2011	2450	35
7	27-Nov-2011	27-Nov-2011	1691	24
<b>December 2011</b>				
8	07-Dec-2011	07-Dec-2011	1267	18
9	17-Dec-2011	17-Dec-2011	1265	18
10	26-Dec-2011	26-Dec-2011	1203	17
<b>January 2012</b>				
11	10-Jan-2012	10-Jan-2012	3340	47
12	19-Jan-2012	19-Jan-2012	3367	47
13	26-Jan-2012	26-Jan-2012	3169	45

<b>February 2012</b>				
14	05-Feb-2012	05-Feb-2012	3106	44
15	24-Feb-2012	24-Feb-2012	2734	39
<b>March 2012</b>				
16	05-Mar-2012	05-Mar-2012	3213	45
17	16-Mar-2012	16-Mar-2012	3641	51
18	26-Mar-2012	26-Mar-2012	2014	28
<b>April 2012</b>				
19	09-Apr-2012	09-Apr-2012	1841	26
20	19-Apr-2012	19-Apr-2012	1524	21
21	24-Apr-2012	24-Apr-2012	1070	15
<b>May 2012</b>				
22	08-May-2012	08-May-2012	1666	23
23	13-May-2012	13-May-2012	1777	25

## Snow cover depletion curve



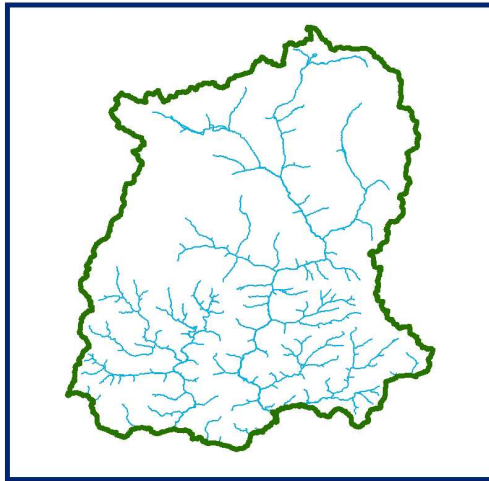
### Snow cover depletion curve



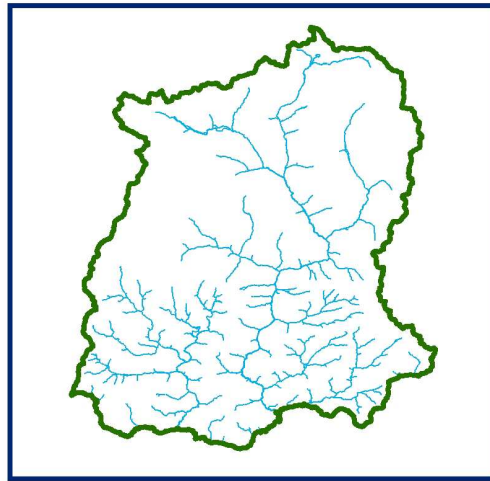
# *SNOW COVER MAPS*



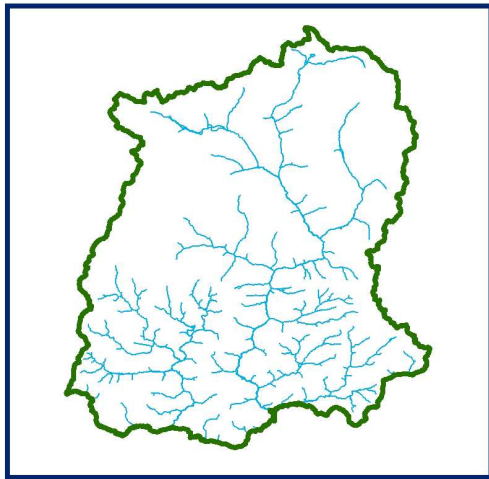
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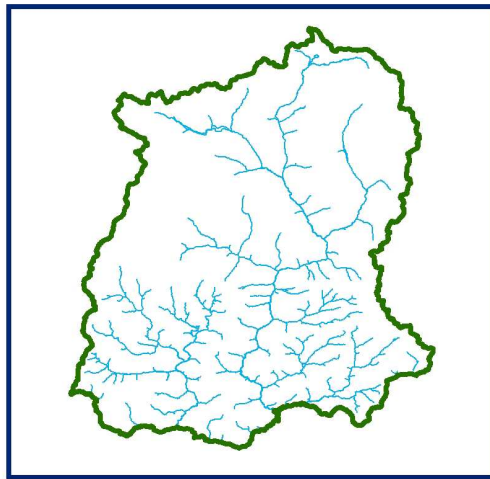
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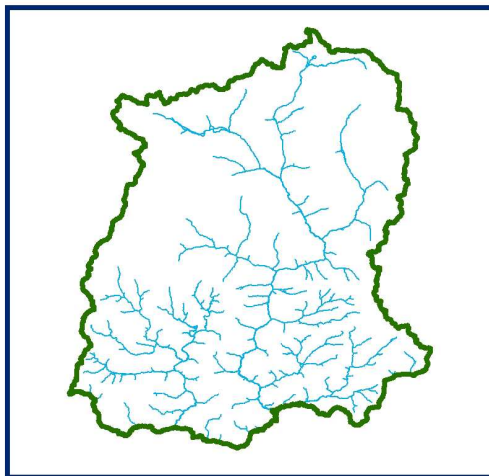
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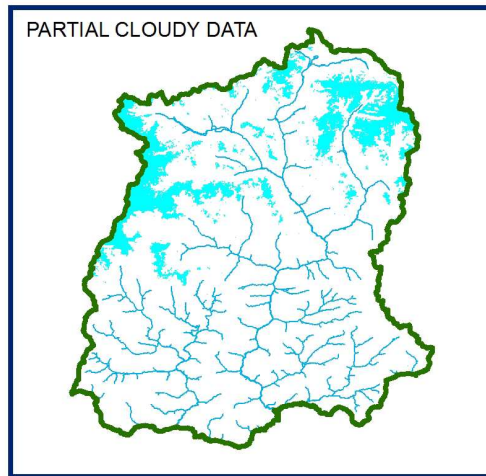
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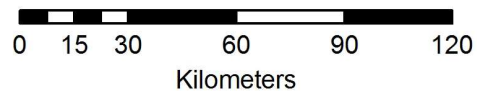
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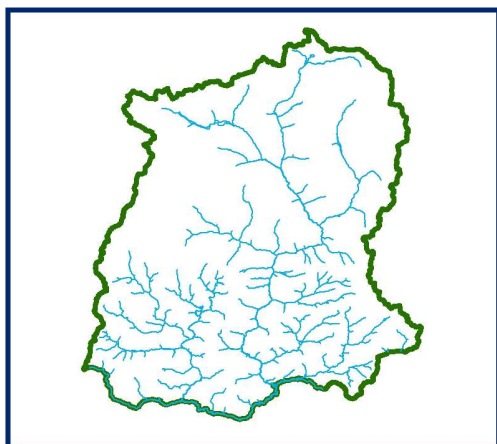
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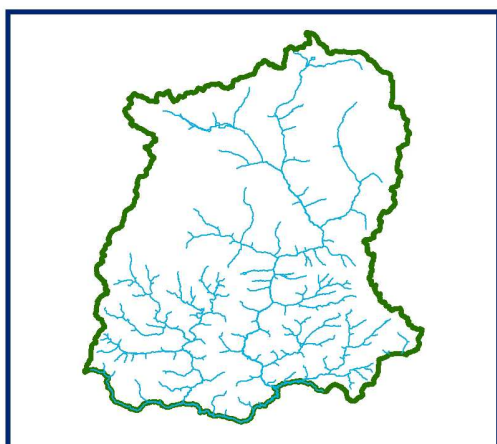
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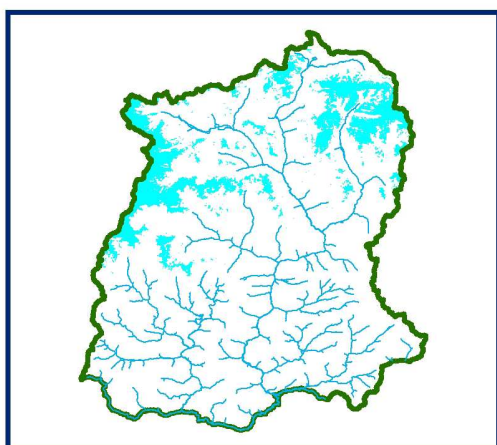
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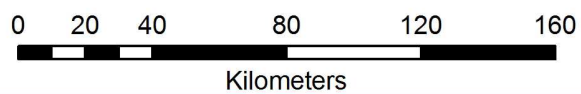
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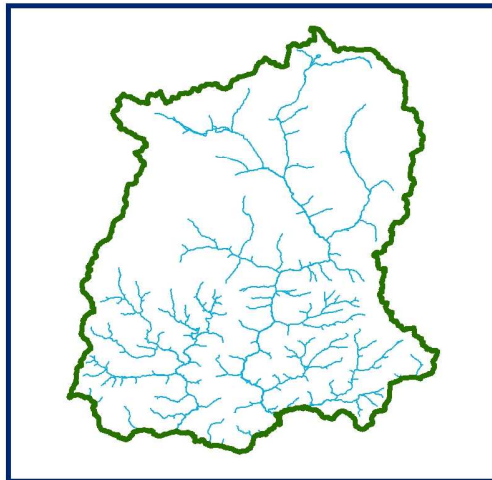
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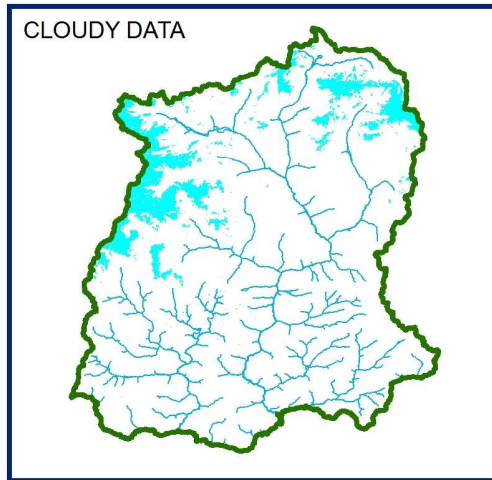
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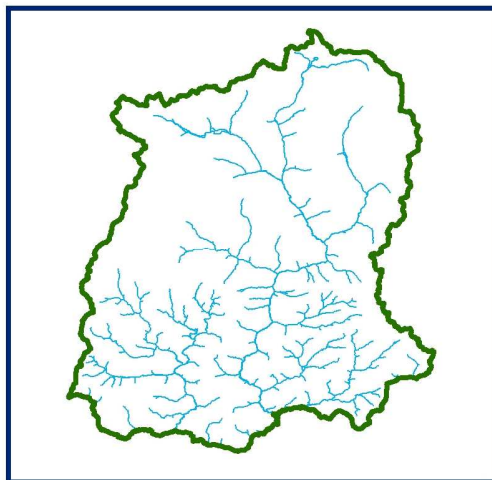
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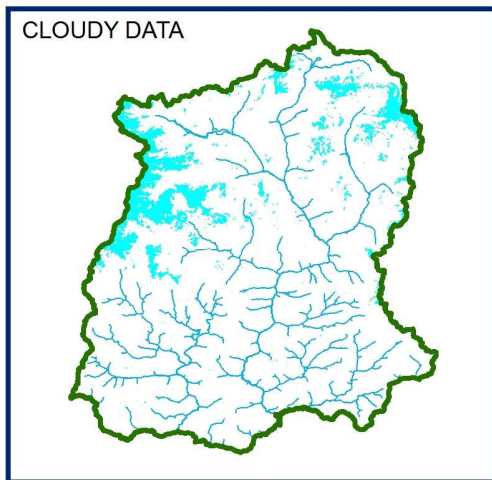
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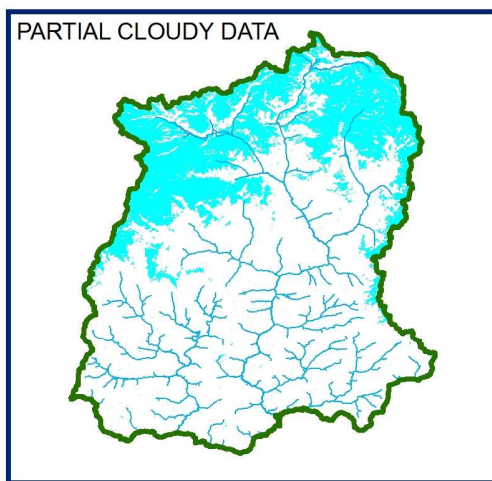
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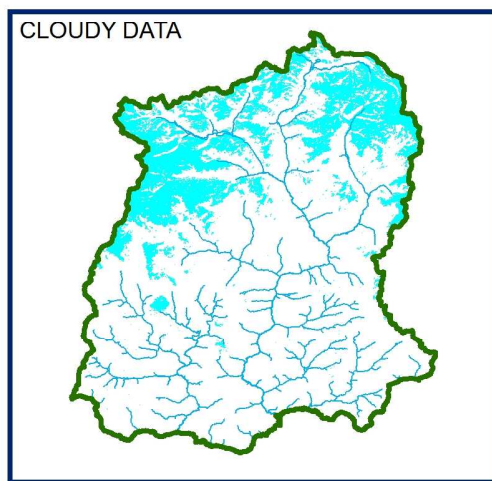
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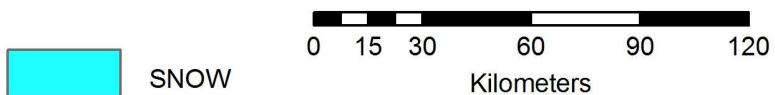
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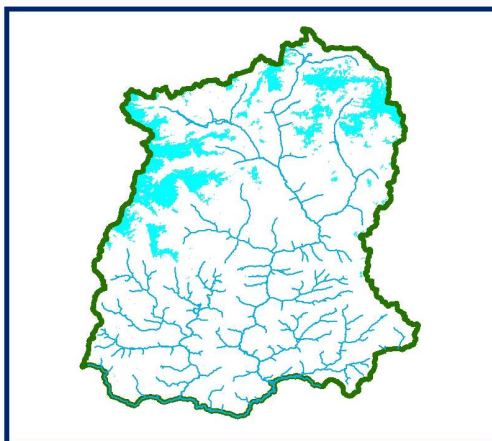
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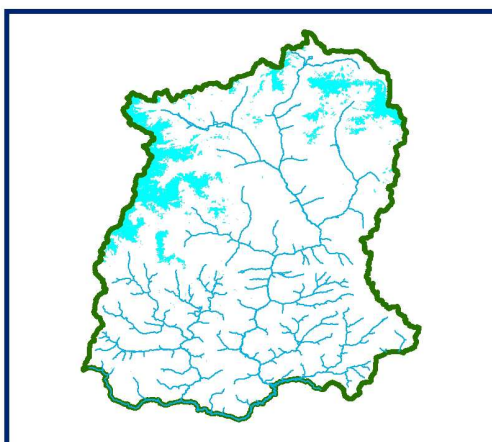
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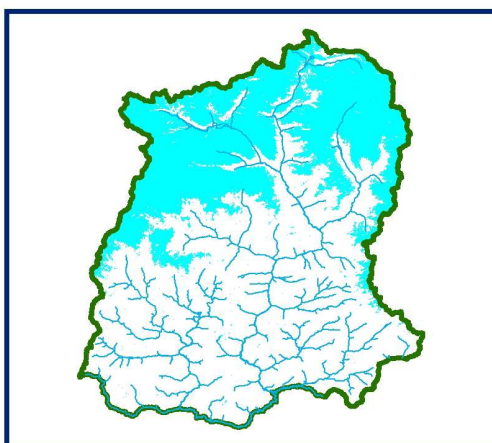
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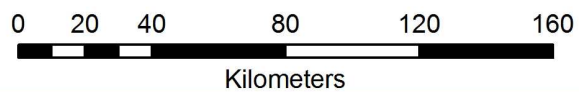
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DATA USED  
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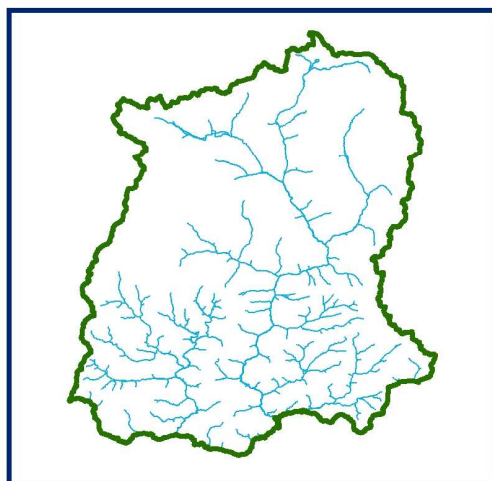


SNOW

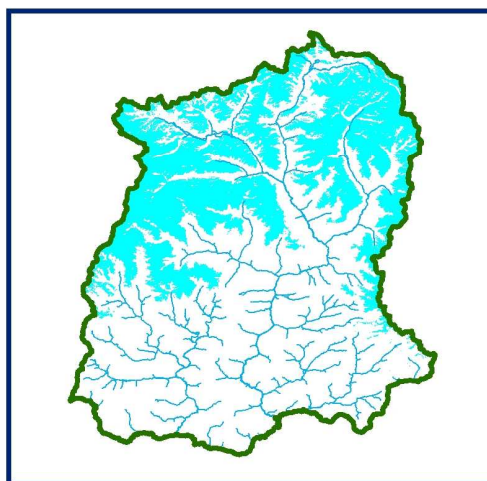




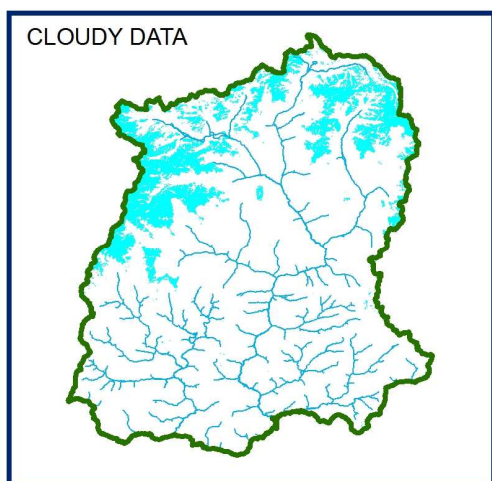
## 5 DAILY SNOW COVER MAP: SIKKIM



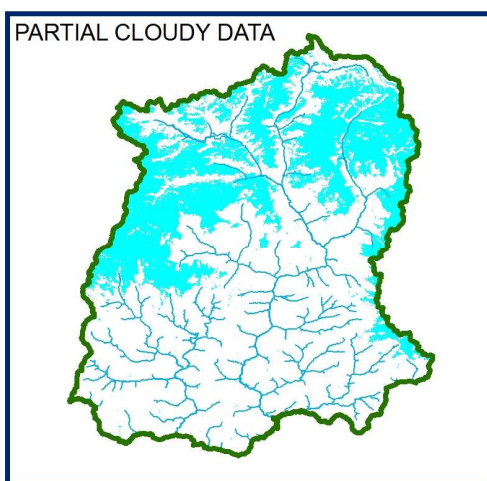
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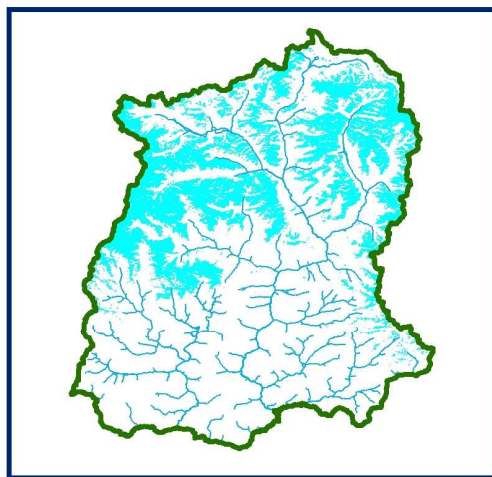
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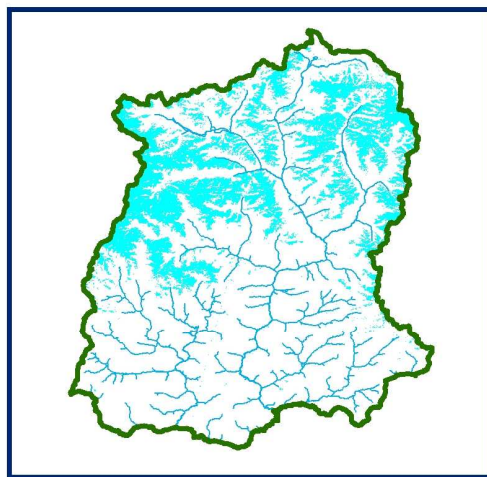
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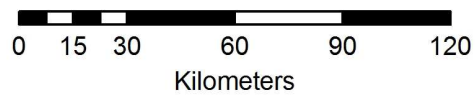
**22 NOVEMBER 2011**



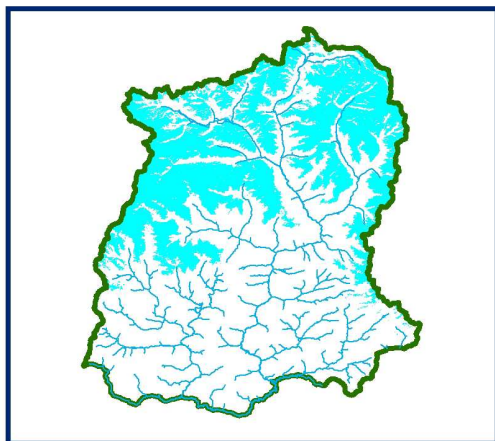
**27 NOVEMBER 2011**



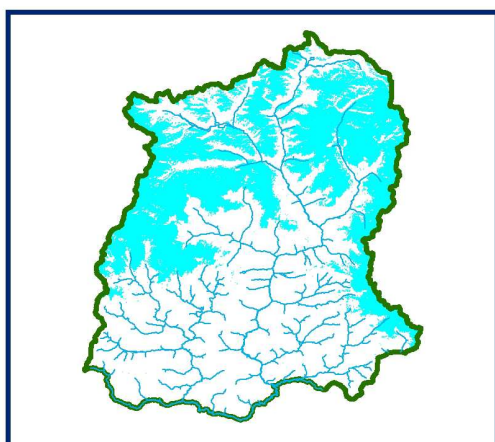
**SNOW**



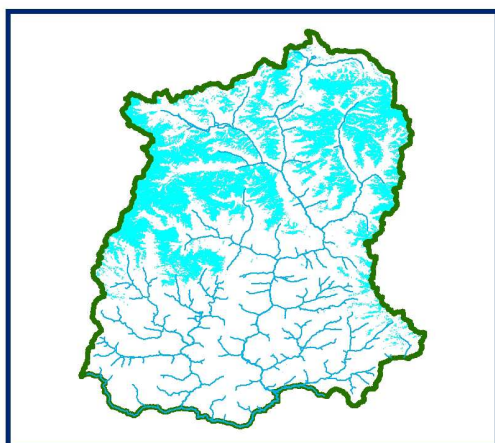
## COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA USED  
**10 NOVEMBER 2011**



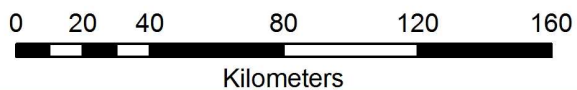
DATA USED  
**17 NOVEMBER 2011**  
**18 NOVEMBER 2011**  
**20 NOVEMBER 2011**



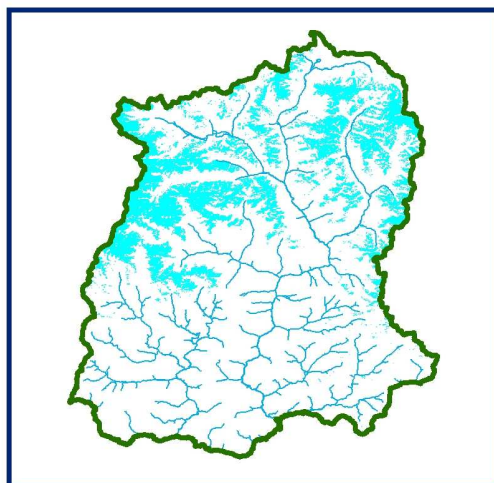
DATA USED  
**22 NOVEMBER 2011**  
**27 NOVEMBER 2011**



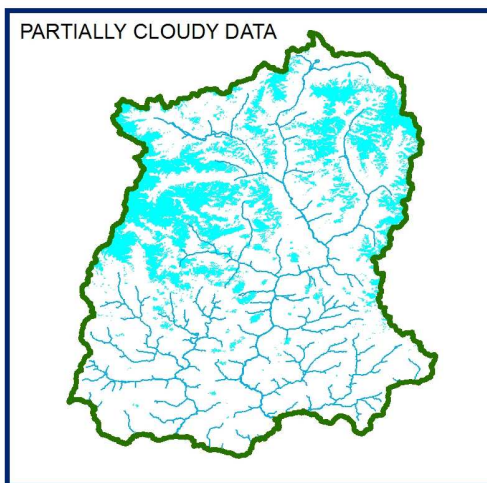
SNOW



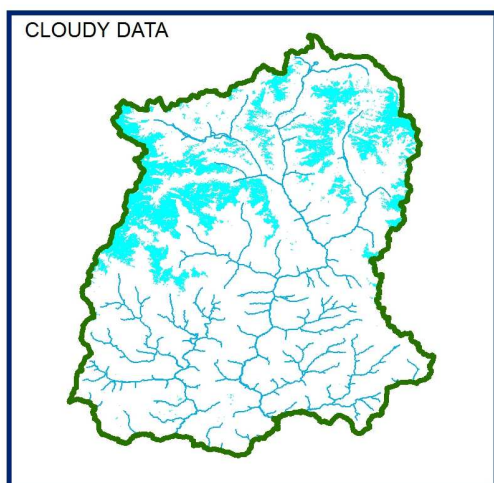
## 5 DAILY SNOW COVER MAP: SIKKIM



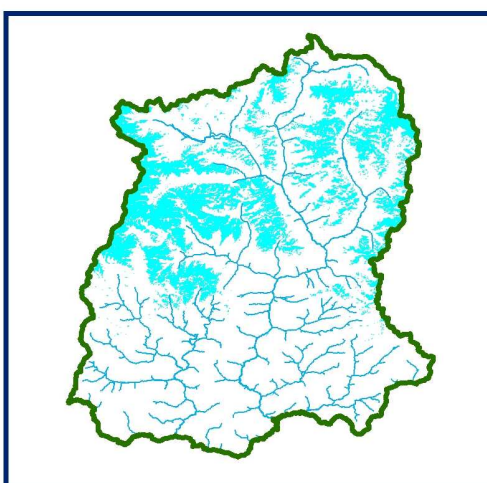
**2 DECEMBER 2011**



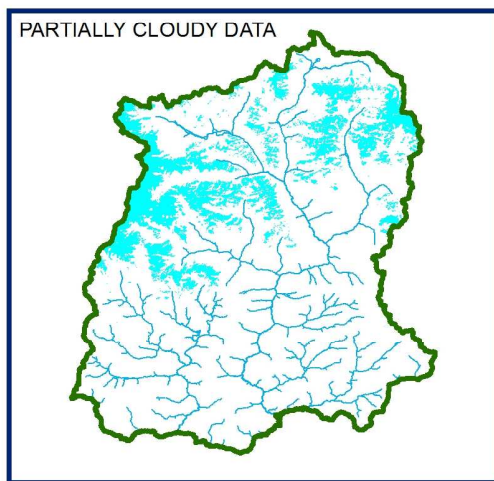
**9 DECEMBER 2011**



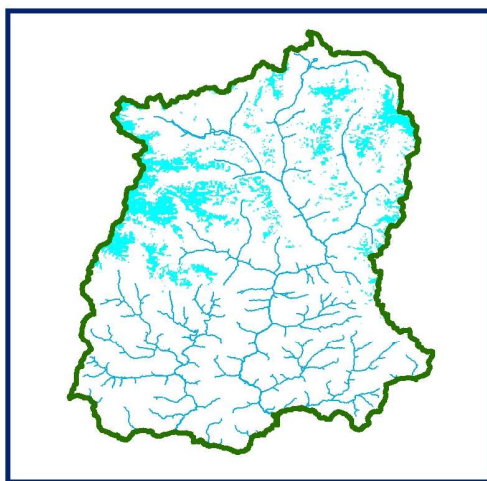
**11 DECEMBER 2011**



**19 DECEMBER 2011**



**24 DECEMBER 2011**



**28 DECEMBER 2011**

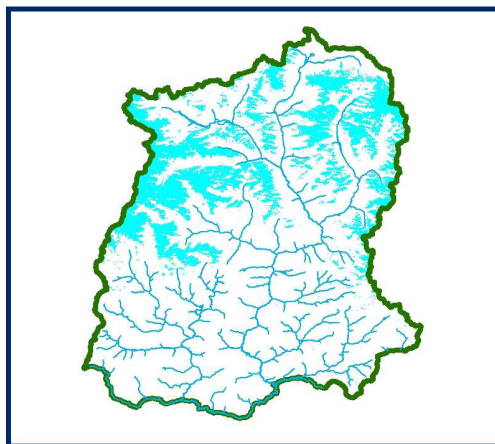


SNOW

0 15 30 60 90 120  
Kilometers



## COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

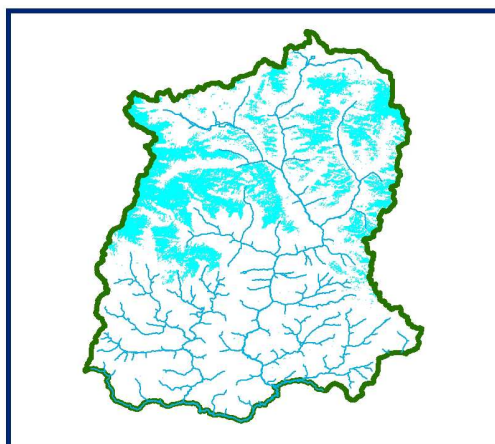


DATA USED

**2 DECEMBER 2011**

**7 DECEMBER 2011**

**9 DECEMBER 2011**

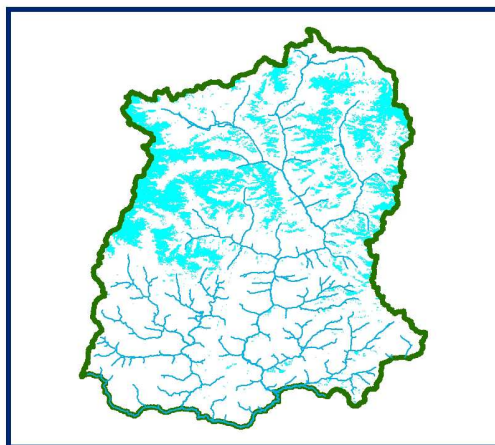


DATA USED

**16 DECEMBER 2011**

**17 DECEMBER 2011**

**19 DECEMBER 2011**



DATA USED

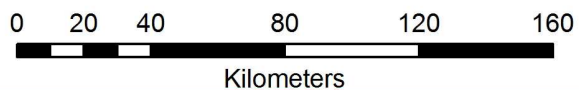
**21 DECEMBER 2011**

**26 DECEMBER 2011**

**28 DECEMBER 2011**

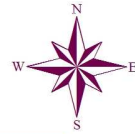


SNOW

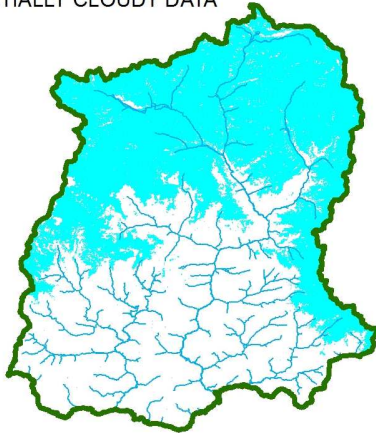




## 5 DAILY SNOW COVER MAP: SIKKIM

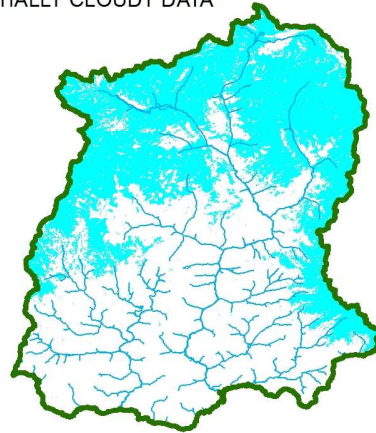


PARTIALLY CLOUDY DATA



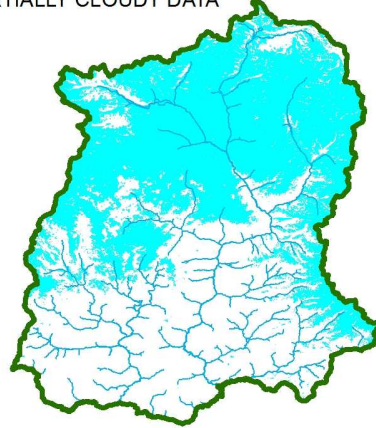
**5 JANUARY 2012**

PARTIALLY CLOUDY DATA

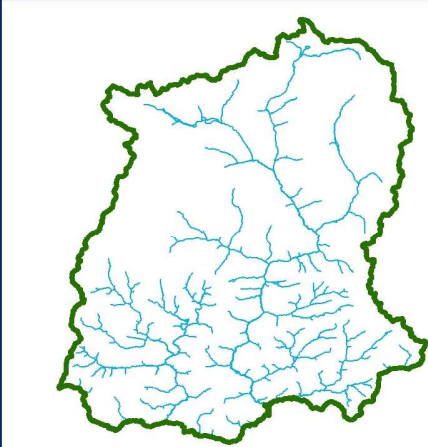


**10 JANUARY 2012**

PARTIALLY CLOUDY DATA

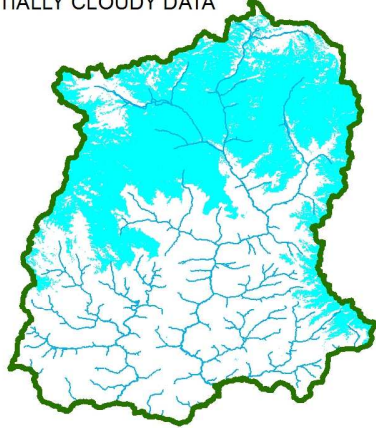


**19 JANUARY 2012**



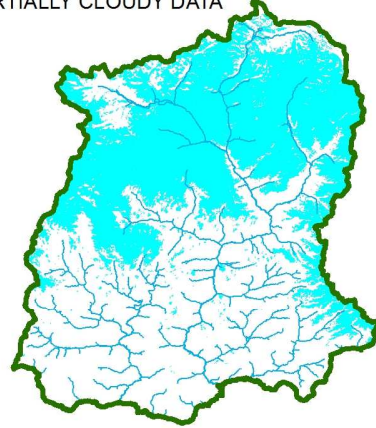
**DATA NOT AVAILABLE**

PARTIALLY CLOUDY DATA

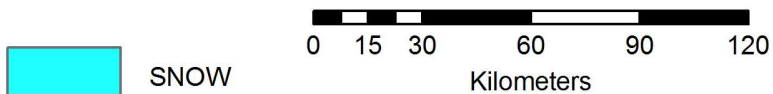


**24 JANUARY 2012**

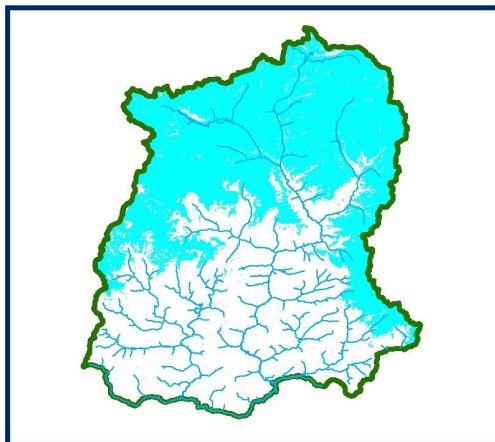
PARTIALLY CLOUDY DATA



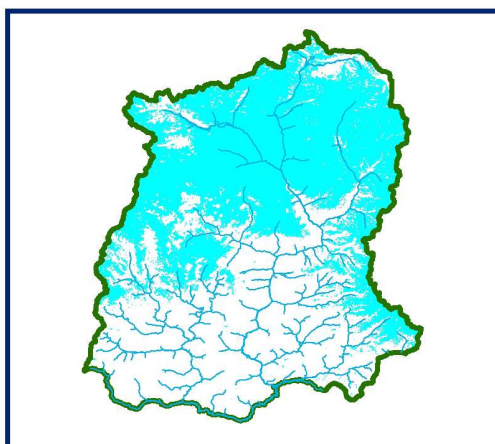
**31 JANUARY 2012**



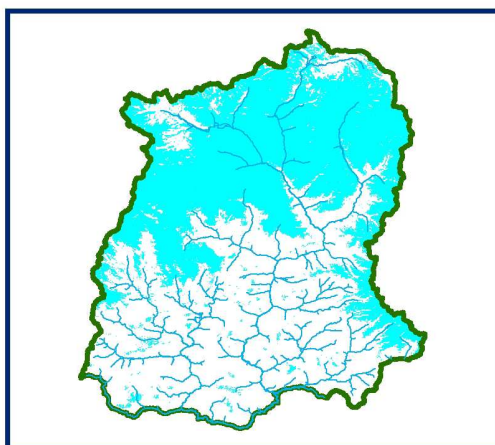
## COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA USED  
**5 JANUARY 2012**  
**10 JANUARY 2012**



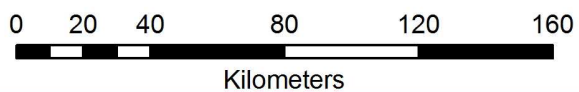
DATA USED  
**19 JANUARY 2012**



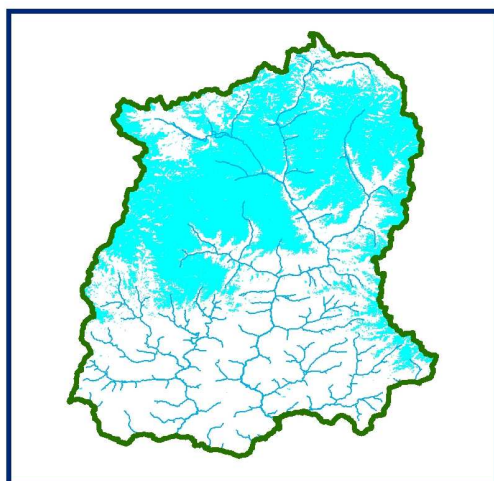
DATA USED  
**24 JANUARY 2012**  
**26 JANUARY 2012**  
**31 JANUARY 2012**



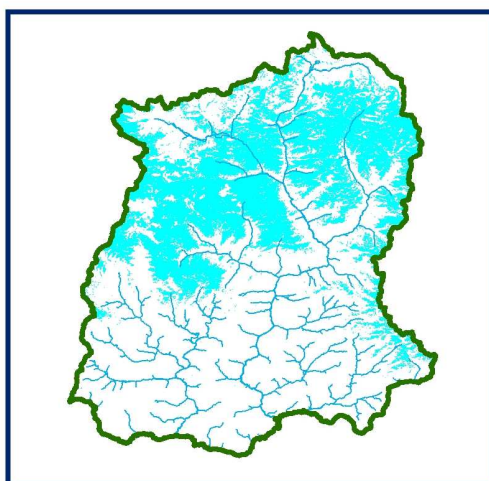
SNOW



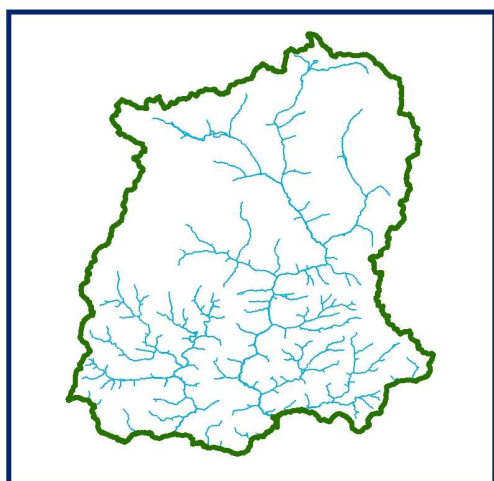
## 5 DAILY SNOW COVER MAP: SIKKIM



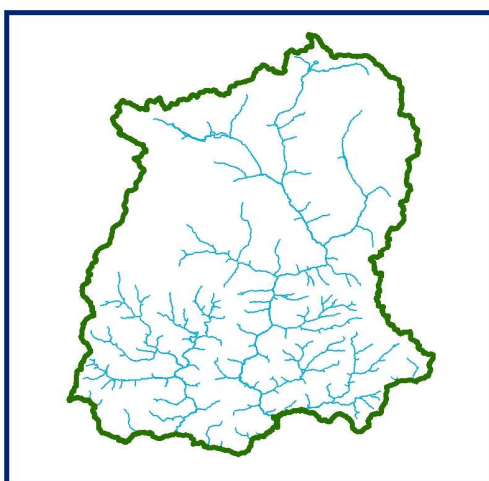
**2 FEBRUARY 2012**



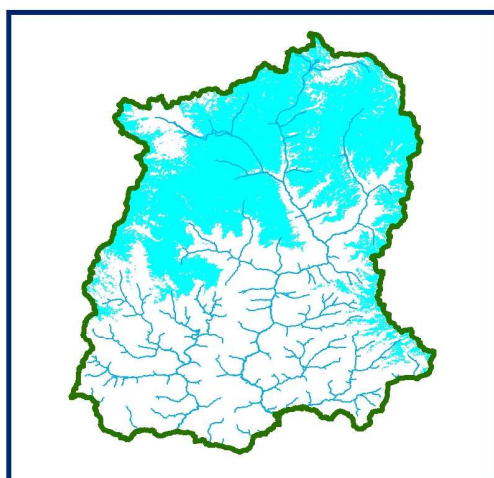
**7 FEBRUARY 2012**



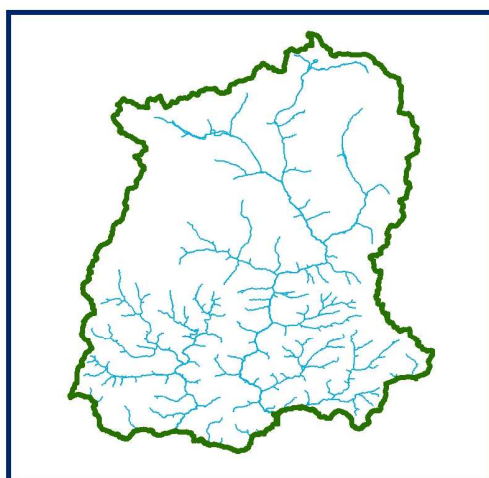
**DATA NOT AVAILABLE**



**DATA NOT AVAILABLE**



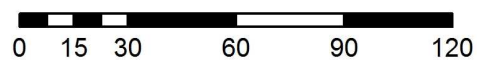
**22 FEBRUARY 2012**



**DATA NOT AVAILABLE**



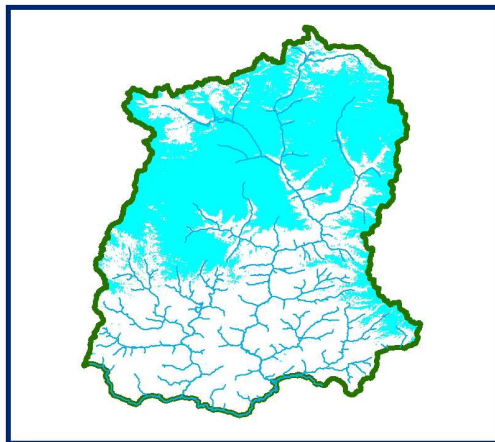
**SNOW**



Kilometers



## COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM

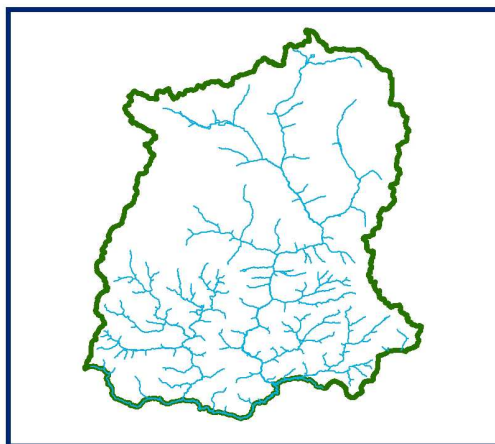


DATA USED

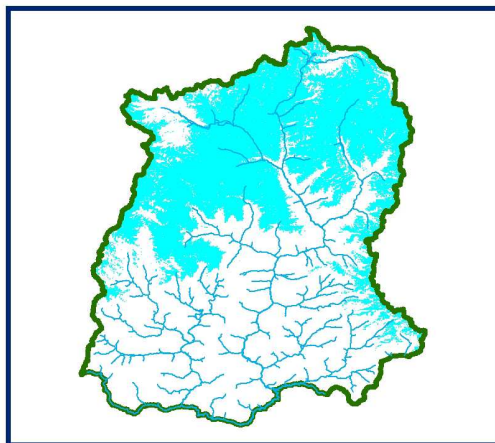
**2 FEBRUARY 2012**

**5 FEBRUARY 2012**

**7 FEBRUARY 2012**



NO DATA AVAILABLE



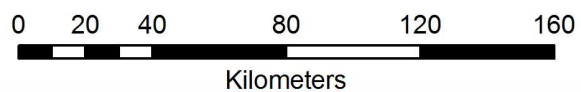
DATA USED

**22 FEBRUARY 2012**

**24 FEBRUARY 2012**



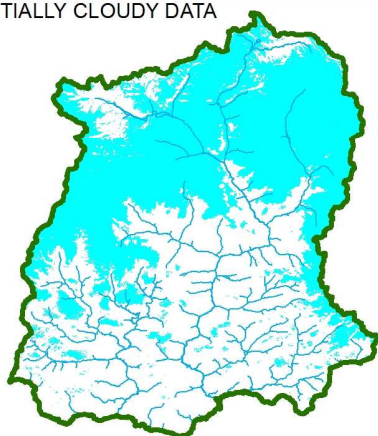
SNOW



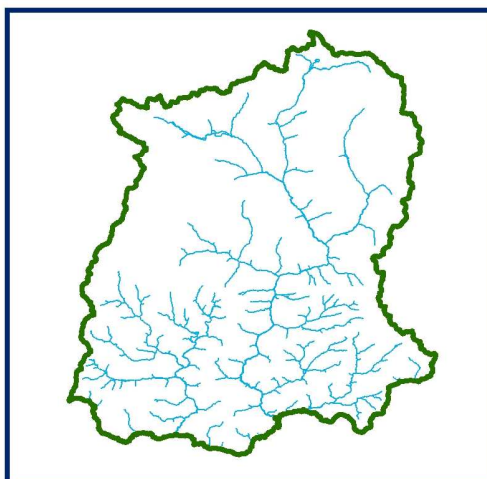
# 5 DAILY SNOW COVER MAP: SIKKIM



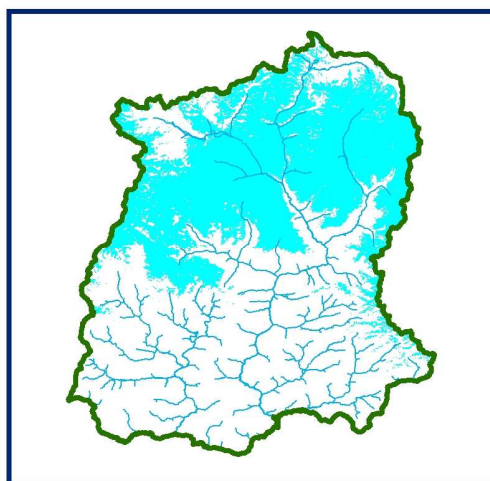
PARTIALLY CLOUDY DATA



**5 MARCH 2012**

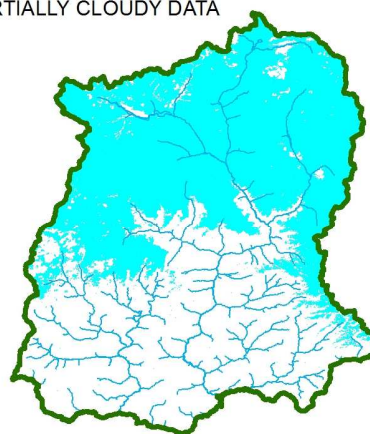


**DATA NOT AVAILABLE**



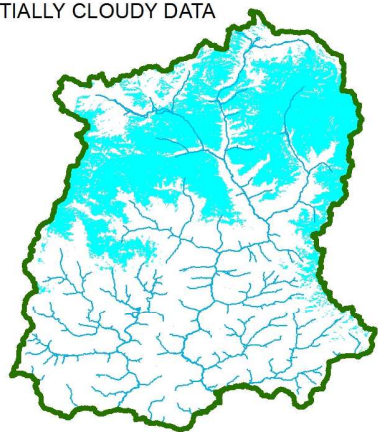
**12 MARCH 2012**

PARTIALLY CLOUDY DATA



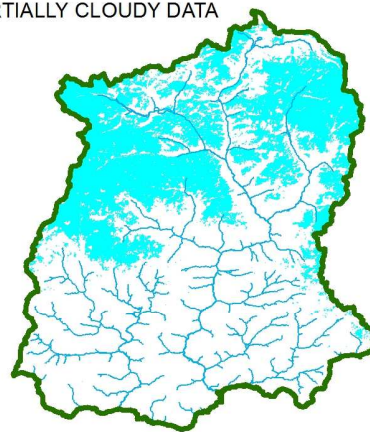
**16 MARCH 2012**

PARTIALLY CLOUDY DATA



**22 MARCH 2012**

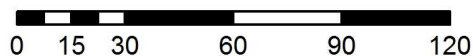
PARTIALLY CLOUDY DATA



**31 MARCH 2012**

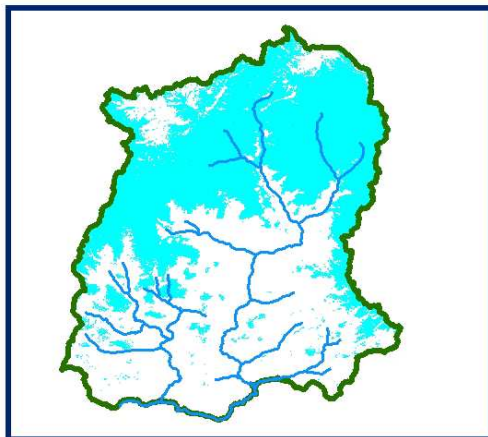


SNOW

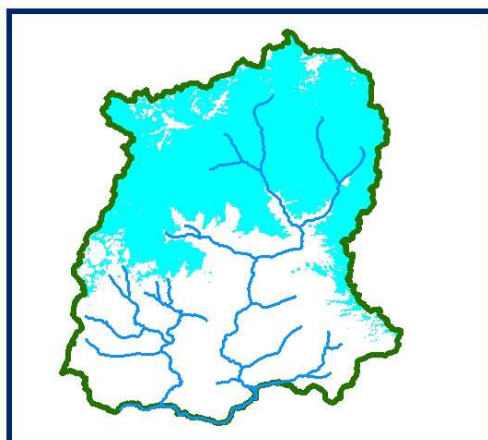


Kilometers

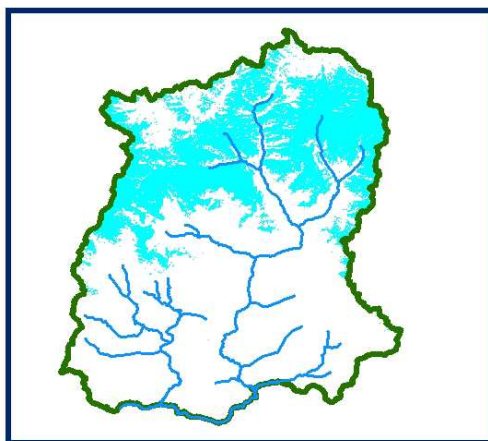
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**5 MARCH 2012**



DATA USED  
**12 MARCH 2012**  
**16 MARCH 2012**  
**17 MARCH 2012**



DATA USED  
**21 MARCH 2012**  
**26 MARCH 2012**  
**31 MARCH 2012**

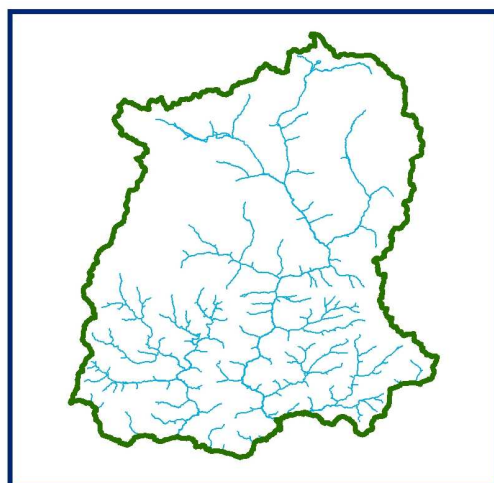


SNOW

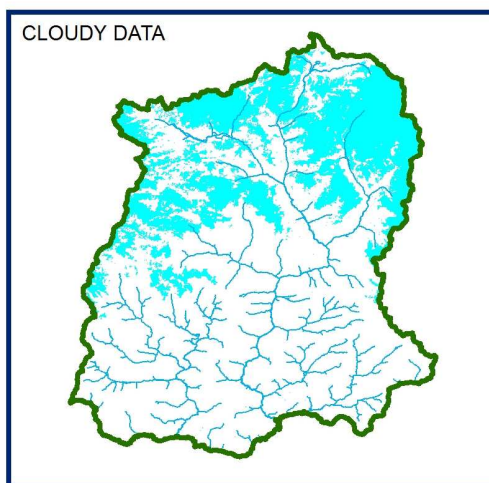
0 12.5 25 50 75 100  
Kilometers



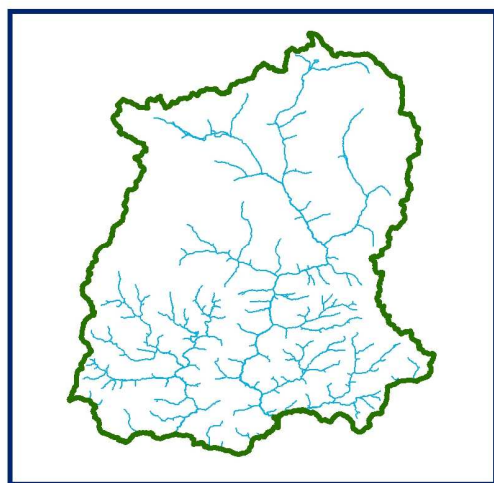
# 5 DAILY SNOW COVER MAP: SIKKIM



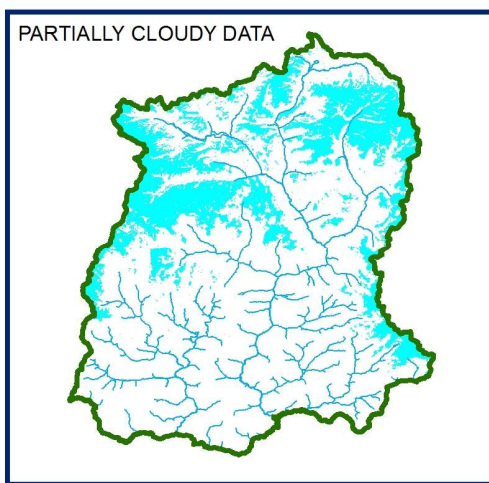
**DATA NOT AVAILABLE**



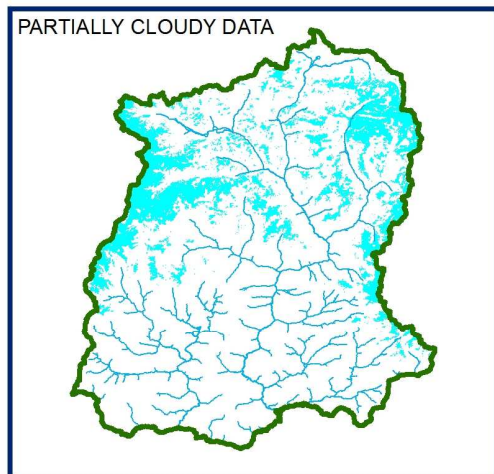
**9 APRIL 2012**



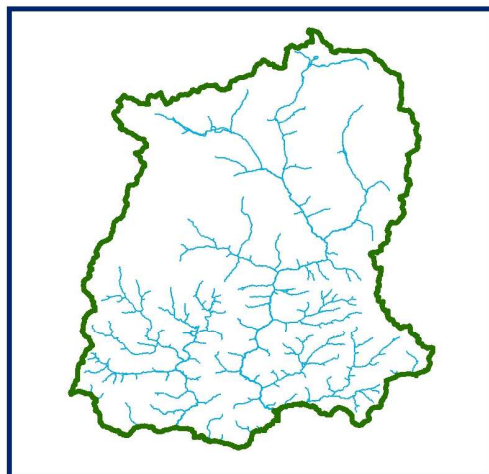
**DATA NOT AVAILABLE**



**19 APRIL 2012**



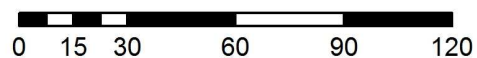
**24 APRIL 2012**



**DATA NOT AVAILABLE**

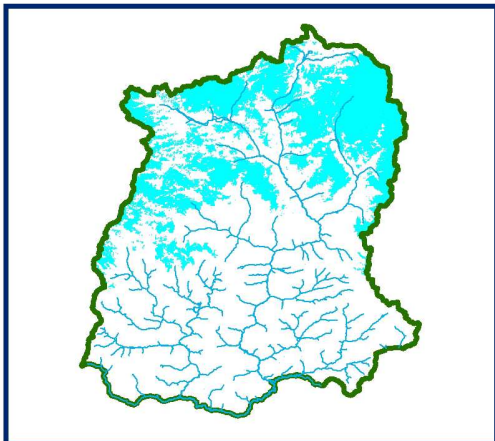


**SNOW**

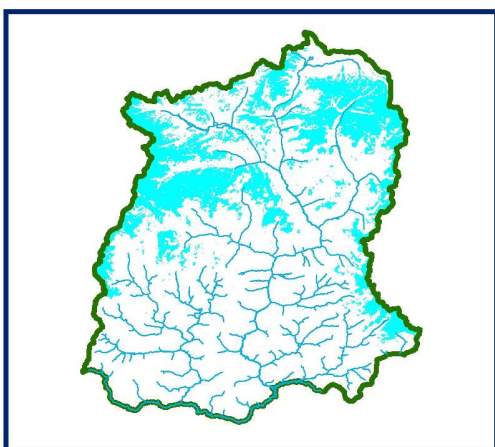


Kilometers

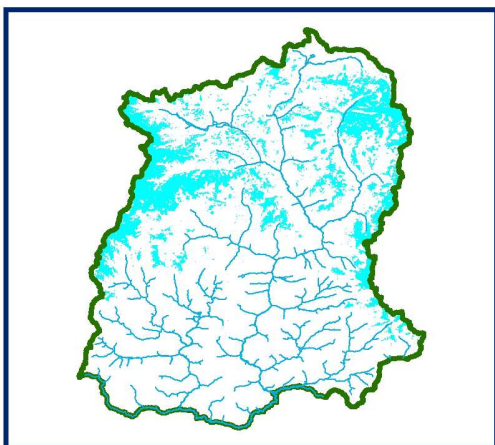
## COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA USED  
**9 APRIL 2012**



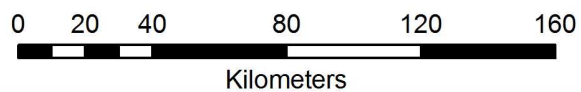
DATA USED  
**19 APRIL 2012**



DATA USED  
**24 APRIL 2012**

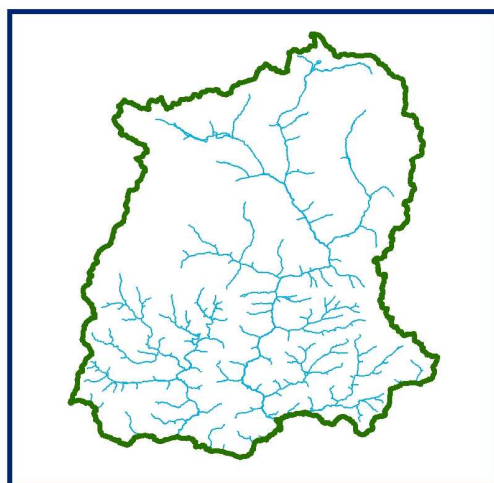


SNOW

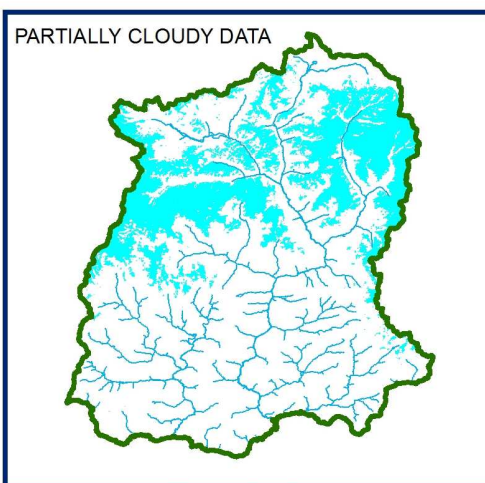




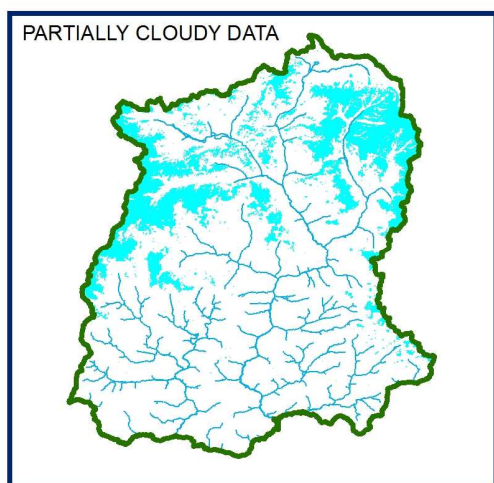
## 5 DAILY SNOW COVER MAP: SIKKIM



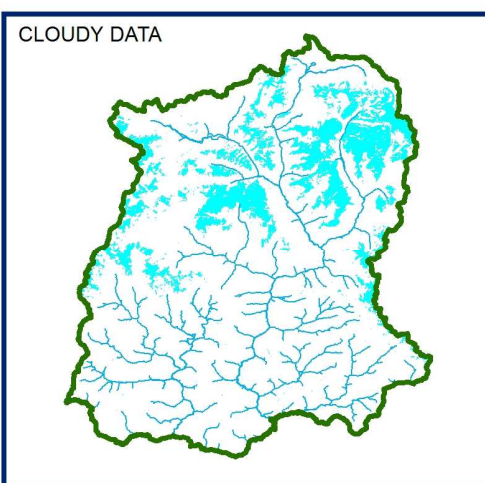
**DATA NOT AVAILABLE**



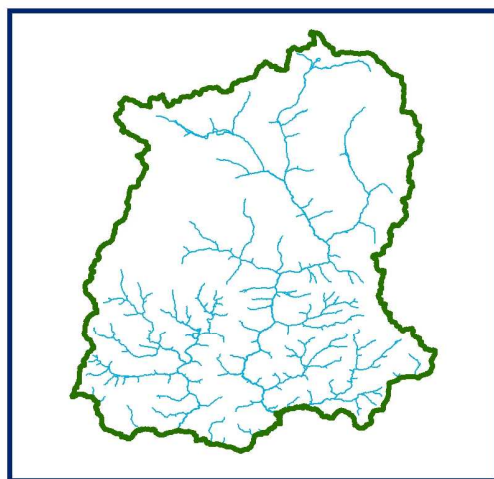
**8 MAY 2012**



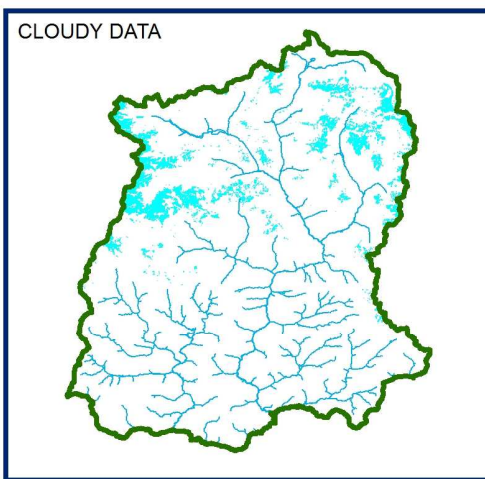
**13 MAY 2012**



**18 MAY 2012**



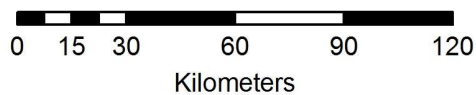
**DATA NOT AVAILABLE**



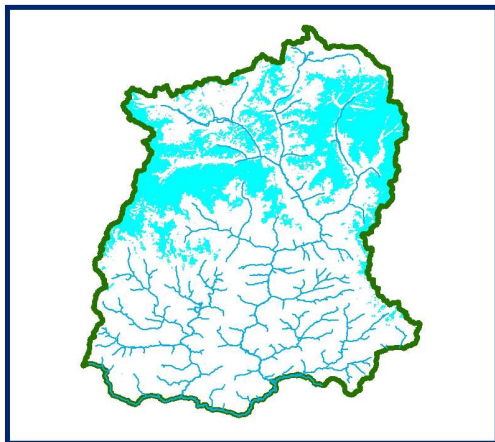
**28 MAY 2012**



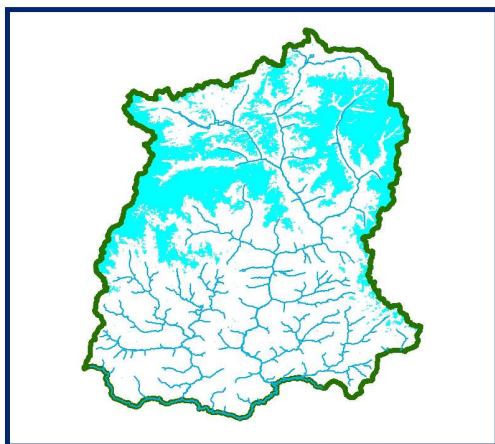
**SNOW**



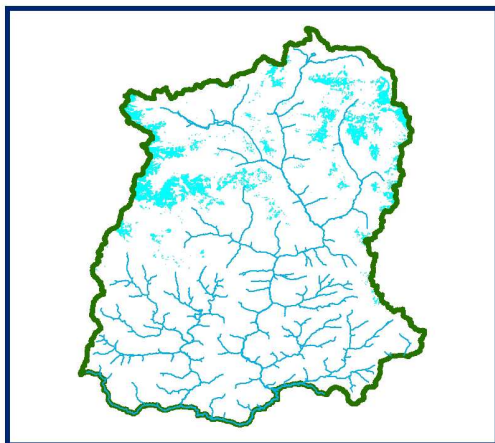
## COMPOSITE SNOW COVER MAP (10 DAILY) : SIKKIM



DATA USED  
**8 MAY 2012**



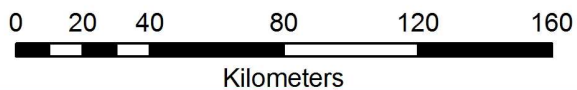
DATA USED  
**12 MAY 2012**  
**13 MAY 2012**  
**18 MAY 2012**



DATA USED  
**28 MAY 2012**



SNOW



*TISTA BASIN*

# AREAL EXTENT OF SNOW (5 DAILY)

**BASIN NAME: TISTA**

**TISTA AREA: 5466 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
<b>September 2011</b>							
1	30Sept2011(PC)	728	13				
<b>October 2011</b>							
2	6-Oct-11(PC)	741	14	3	10-Oct-11(C)	544	10
4	20-Oct-11(C)	524	10	5	24-Oct-11(C)	2321	52
6	25-Oct-11(PC)	1683	31	7	29-Oct-11(PC)	1554	28
8	30-Oct-11(C)	1240	23				
<b>November 2011</b>							
9	10-Nov-11	2097	38	10	13-Nov-11(C)	854	16
11	17-Nov-11(PC)	1847	34	12	18-Nov11(PC)	1886	35
13	20-Nov-11	2060	38	14	22-Nov11	1556	28
15	27-Nov-11	1325	24				
<b>December 2011</b>							
16	02-Dec-11	1194	22	17	07-Dec-11(PC)	964	18
18	09-Dec-11(PC)	1315	24	19	11-Dec-11(C)	939	17
20	12-Dec-11(C)	556	10	21	16-Dec-11(PC)	964	18
22	17-Dec-11(PC)	929	17	23	19-Dec-11	1223	22
24	21-Dec-11	1000	18	25	24-Dec-11(PC)	883	16
26	26-Dec-11	853	16	27	28-Dec-11	994	18
28	31-Dec-11	775	14				
<b>January 2012</b>							
29	05-Jan-12(PC)	3111	57	30	10-Jan-12(PC)	2629	48
31	19-Jan-12(PC)	3113	57	32	24-Jan-12(PC)	2597	48
33	26-Jan-12(PC)	2817	52	34	28-Jan-12(C)	1584	29
35	31-Jan-12(PC)	2787					
<b>February 2012</b>							
36	02-Feb-12	2584	47	37	05-Feb-12	2557	47
38	07-Feb-12	2054	38	39	22-Feb-12	2602	48

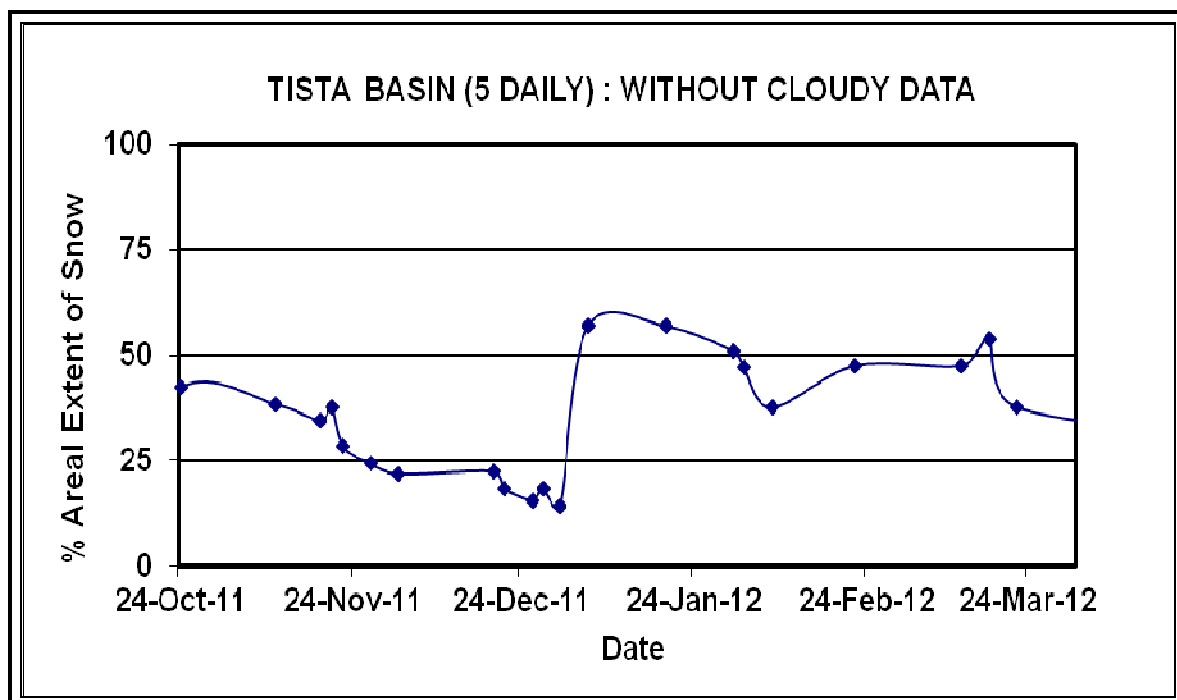
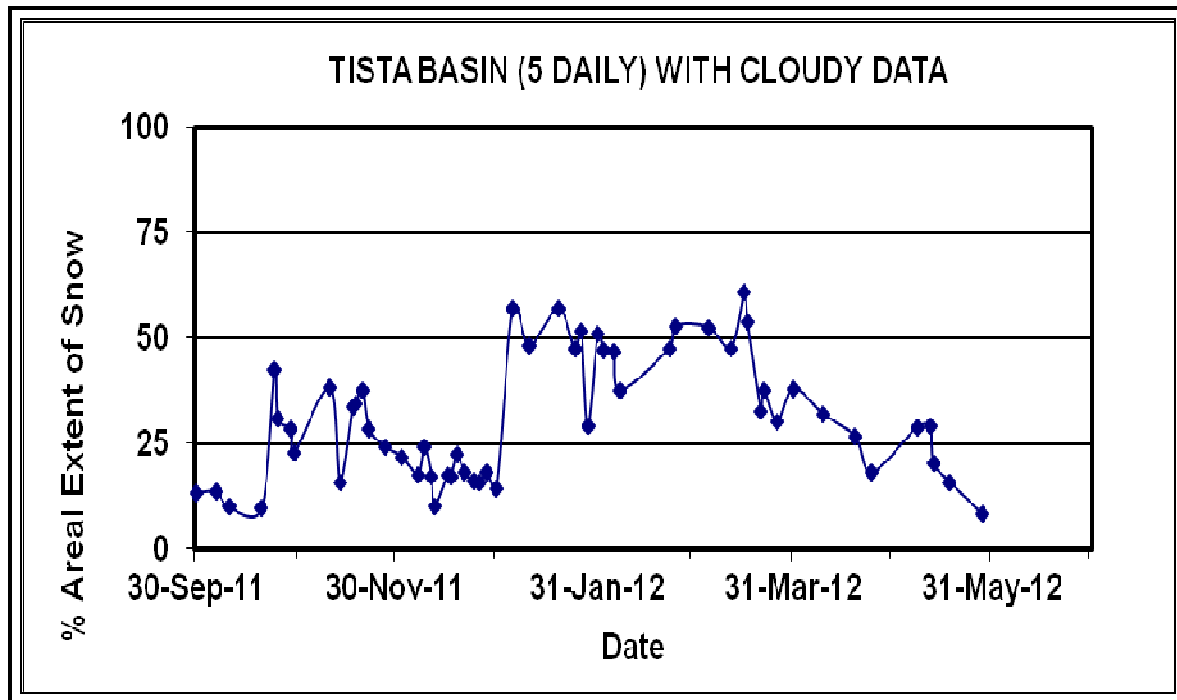
40	24-Feb-12(PC)	2891	53				
<b>March 2012</b>							
41	05-Mar-12(PC)	2872	53	42	12-Mar-12	2603	48
43	16-Mar-12(PC)	3321	61	44	17-Mar12(PC)	2947	54
45	21-Mar-12(PC)	1786	33	46	22-Mar12(PC)	2058	38
47	26-Mar-12(PC)	1642	30	48	31-Mar12(PC)	2082	38
<b>April 2012</b>							
49	09-Apr-12(C)	1752	32	50	19-Apr-12(PC)	1449	27
51	24-Apr-12(PC)	987	18				
<b>May 2012</b>							
52	08-May-12(PC)	1580	29	53	12-May12(PC)	1590	29
54	13-May-12(PC)	1114	20	55	18-May-12(C)	870	16
56	28-May-12(C)	448	8				

**AREAL EXTENT OF SNOW (10 DAILY)****NAME: TISTA BASIN****TISTA AREA: 5466 sq km**

<b>S. No</b>	<b>Data Used</b>	<b>Mean Date</b>	<b>Snow cover (sq km)</b>	<b>Snow cover (%)</b>
<b>September 2011</b>				
1	30-Sept-2011	30-Sept-2011	728	13
<b>October 2011</b>				
2	10-Oct-2011	10-Oct-2011	694	13
3	20-Oct-2011	20-Oct-2011	524	10
4	25-Oct-2011	25-Oct-2011	2310	42
<b>November 2011</b>				
5	10-Nov-2011	10-Nov-2011	2097	38
6	18-Nov-2011	18-Nov-2011	2202	40
7	27-Nov-2011	27-Nov-2011	1556	28
<b>December 2011</b>				
8	07-Dec-2011	07-Dec-2011	1185	22
9	17-Dec-2011	17-Dec-2011	1176	22
10	26-Dec-2011	26-Dec-2011	1130	21
<b>January 2012</b>				
11	10-Jan-2012	10-Jan-2012	3111	57
12	19-Jan-2012	19-Jan-2012	3113	57
13	26-Jan-2012	26-Jan-2012	2943	54
<b>February 2012</b>				

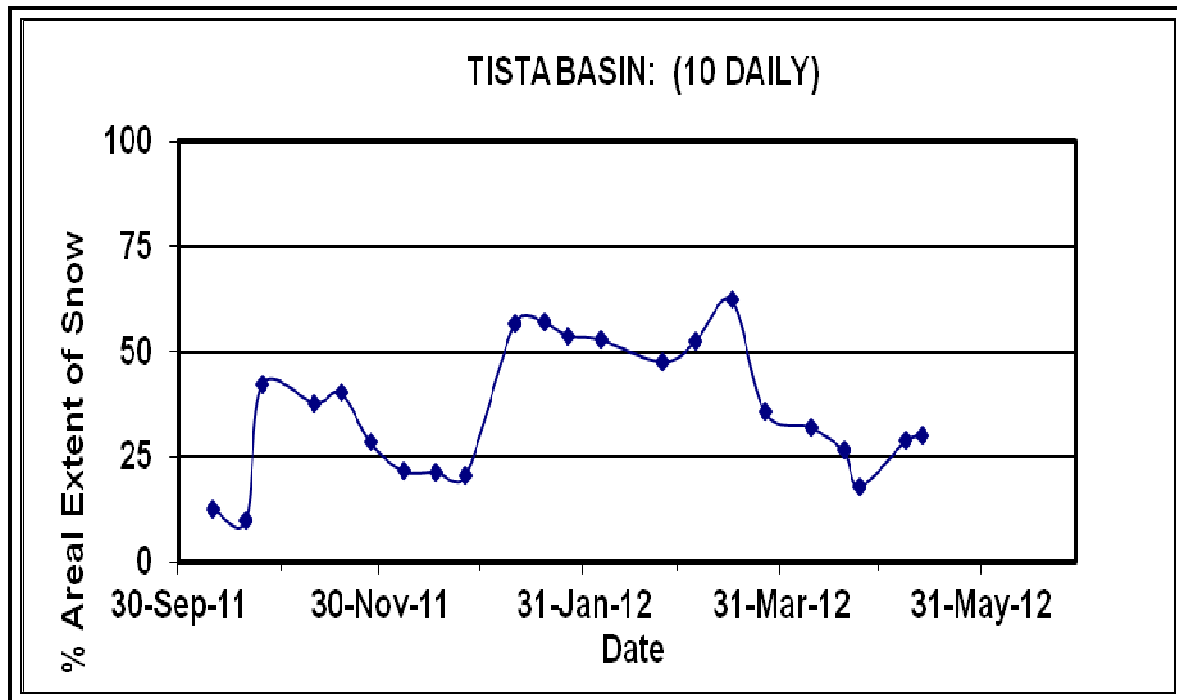
14	05-Feb-2012	05-Feb-2012	2890	53
15	24-Feb-2012	24-Feb-2012	2601	48
<b>March 2012</b>				
16	05-Mar-2012	05-Mar-2012	2872	53
17	16-Mar-2012	16-Mar-2012	3405	62
18	26-Mar-2012	26-Mar-2012	1951	36
<b>April 2012</b>				
19	09-Apr-2012	09-Apr-2012	1752	32
20	19-Apr-2012	19-Apr-2012	1449	27
21	24-Apr-2012	24-Apr-2012	987	18
<b>May 2012</b>				
22	08-May-2012	08-May-2012	1580	29
23	13-May-2012	13-May-2012	1656	30

## Snow cover depletion curve



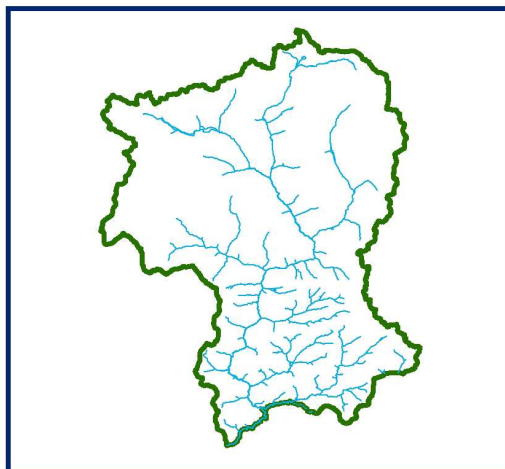
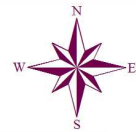


## Snow cover depletion curve



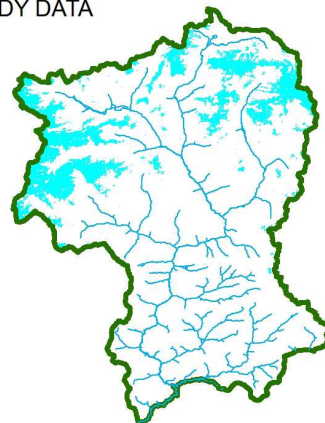
# *SNOW COVER MAP*

## 5 DAILY SNOW COVER MAP: TISTA

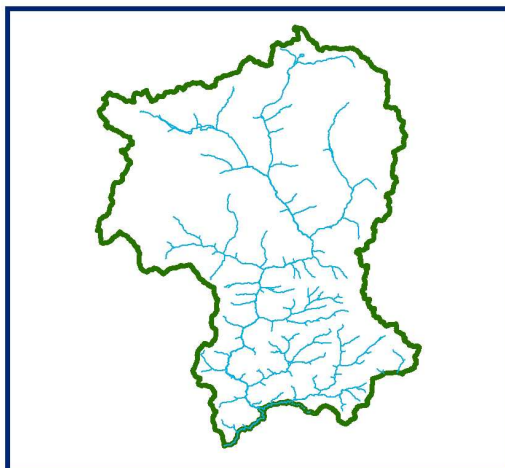


**DATA NOT AVAILABLE**

CLOUDY DATA

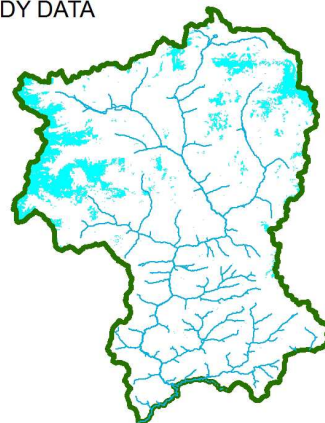


**6 OCTOBER 2011**



**10 OCTOBER 2011**

CLOUDY DATA



**20 OCTOBER 2011**

PARTIAL CLOUDY DATA



**25 OCTOBER 2011**

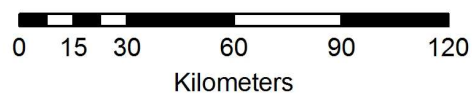
CLOUDY DATA



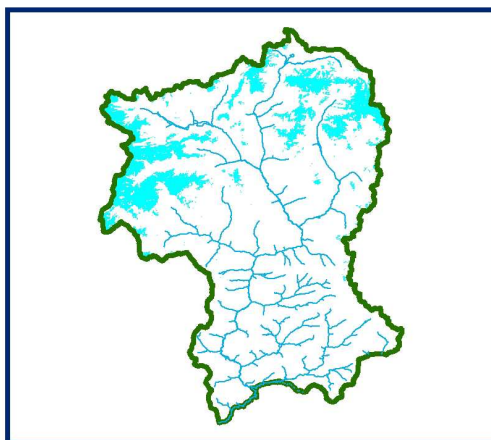
**30 OCTOBER 2011**



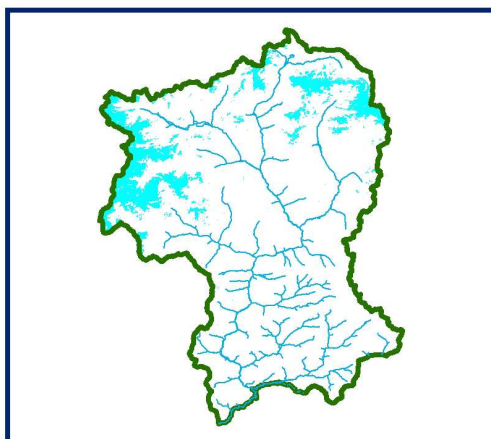
**SNOW**



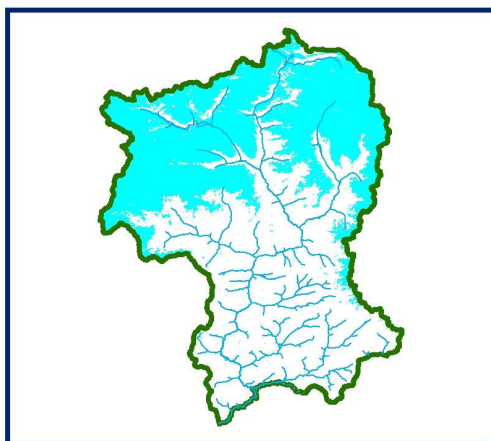
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**06 OCTOBER 2011**  
**10 OCTOBER 2011**



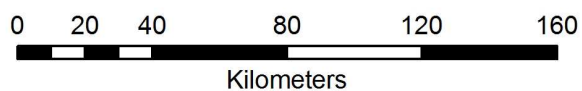
DATA USED  
**11 OCTOBER 2011**  
**20 OCTOBER 2011**



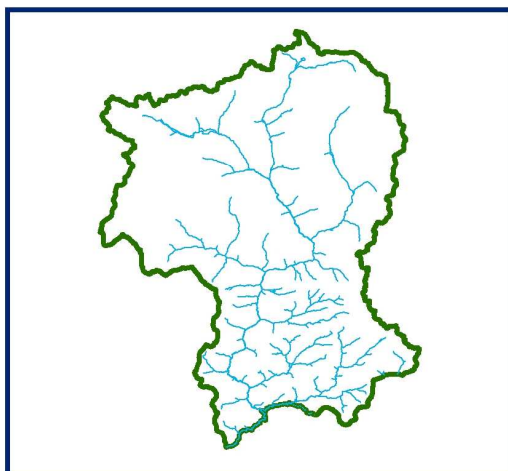
DATA USED  
**24 OCTOBER 2011**  
**25 OCTOBER 2011**  
**29 OCTOBER 2011**



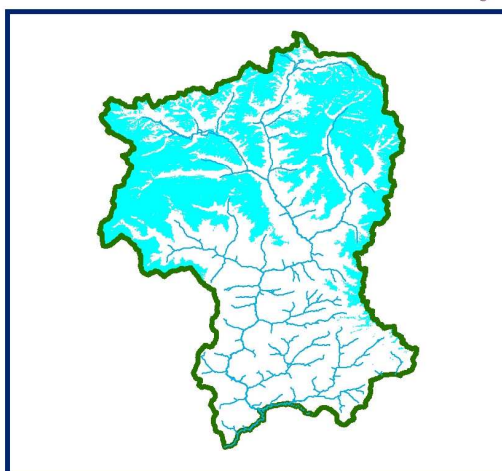
SNOW



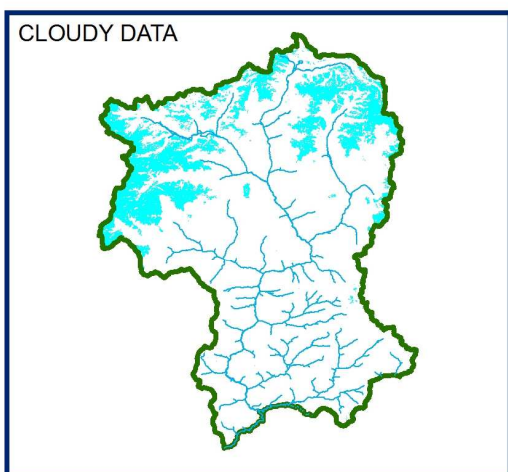
## 5 DAILY SNOW COVER MAP: TISTA



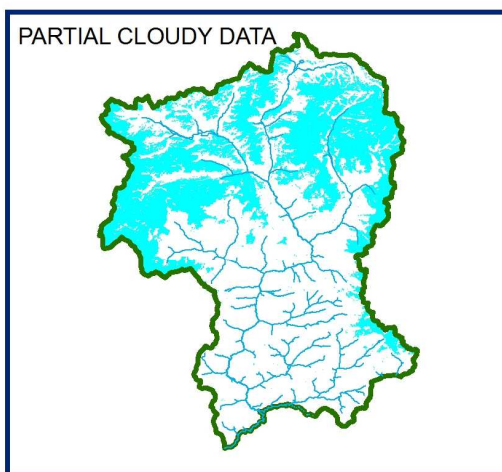
**DATA NOT AVAILABLE**



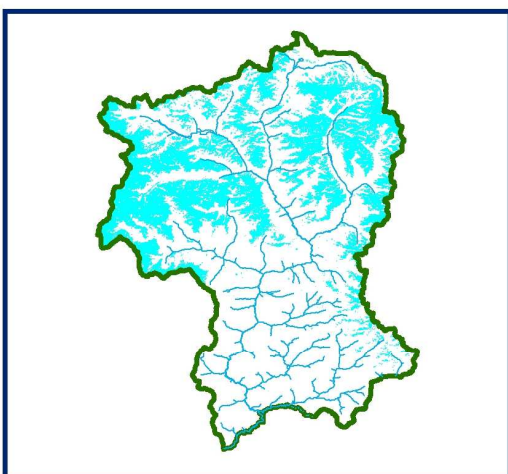
**10 NOVEMBER 2011**



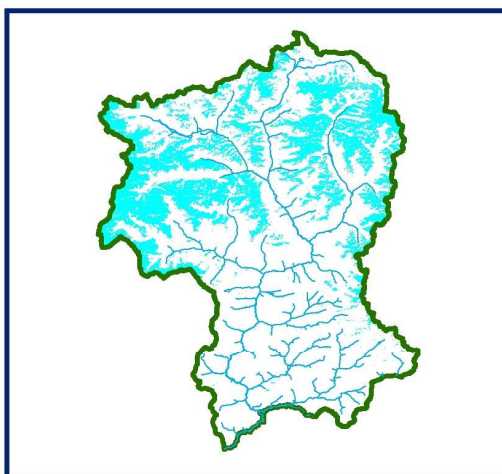
**13 NOVEMBER 2011**



**17 NOVEMBER 2011**



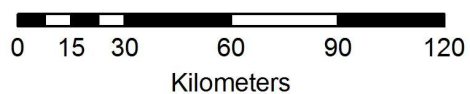
**22 NOVEMBER 2011**



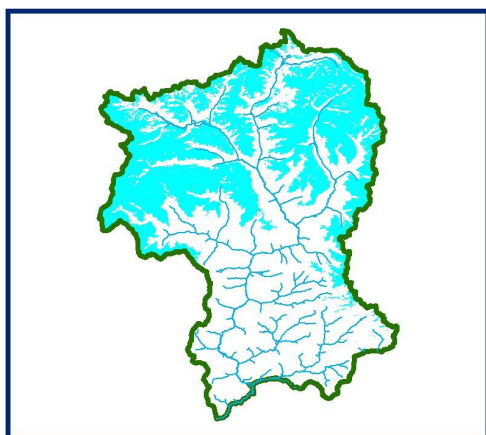
**27 NOVEMBER 2011**



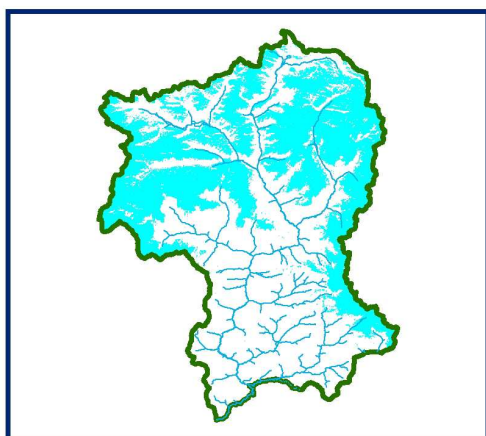
SNOW



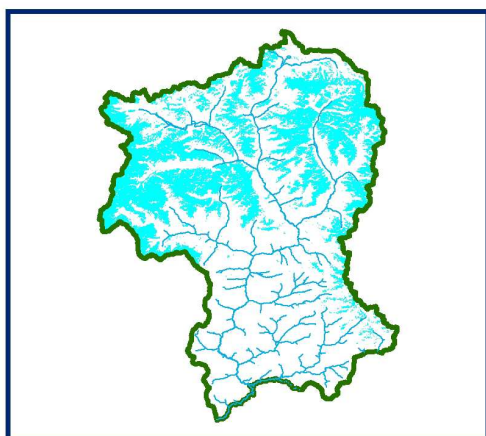
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**10 NOVEMBER 2011**



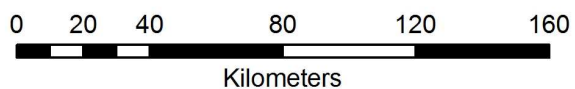
DATA USED  
**17 NOVEMBER 2011**  
**18 NOVEMBER 2011**  
**20 NOVEMBER 2011**



DATA USED  
**22 NOVEMBER 2011**  
**27 NOVEMBER 2011**

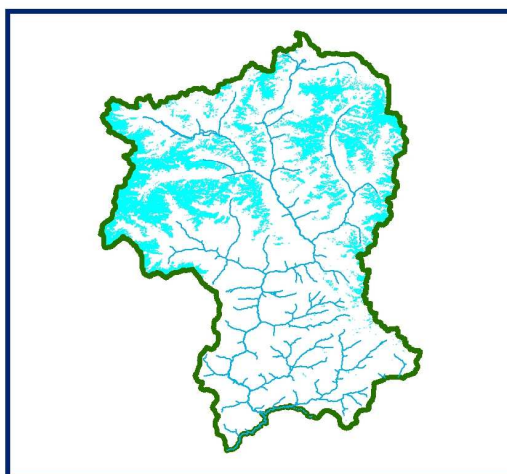


SNOW

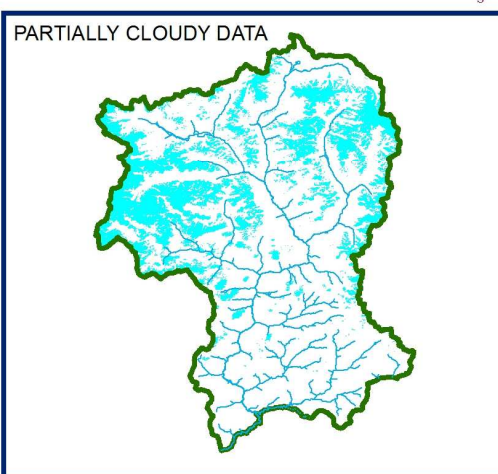




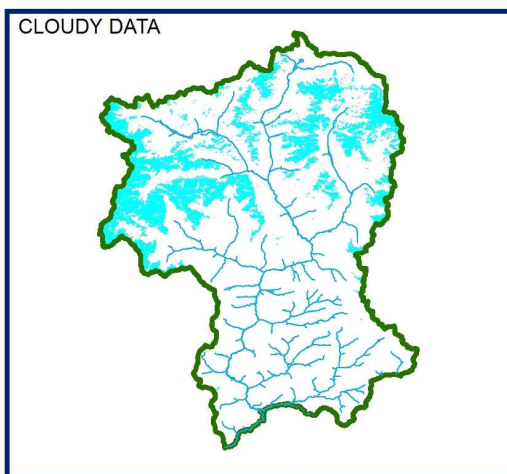
## 5 DAILY SNOW COVER MAP: TISTA



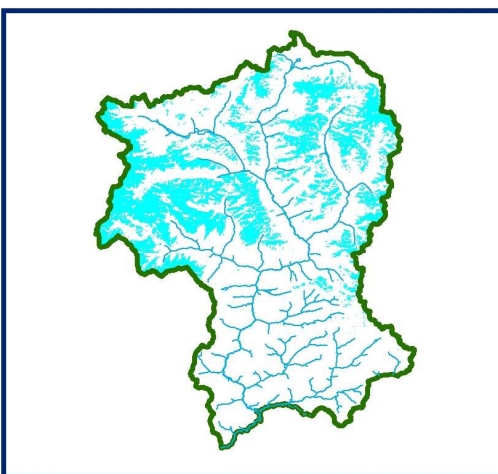
**2 DECEMBER 2011**



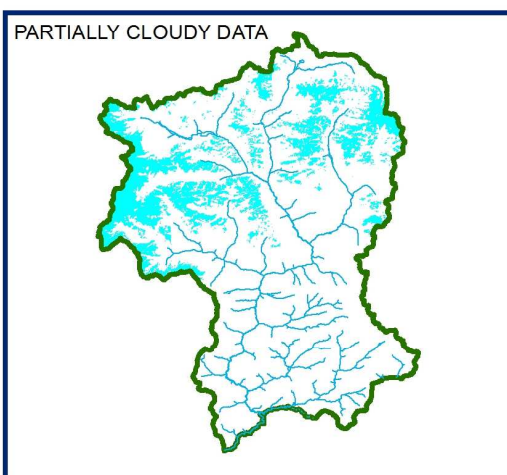
**9 DECEMBER 2011**



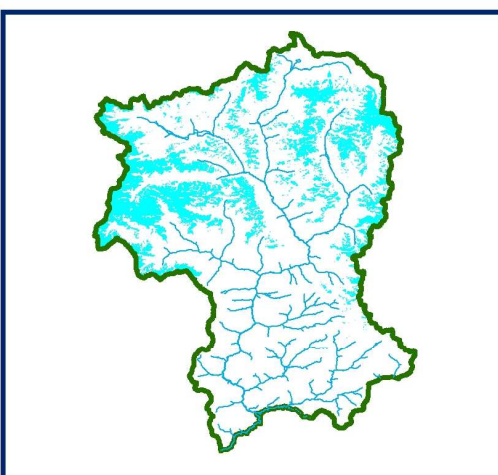
**11 DECEMBER 2011**



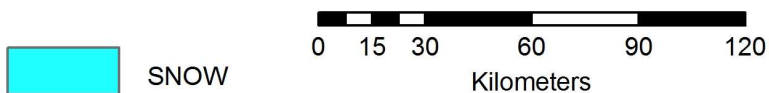
**19 DECEMBER 2011**



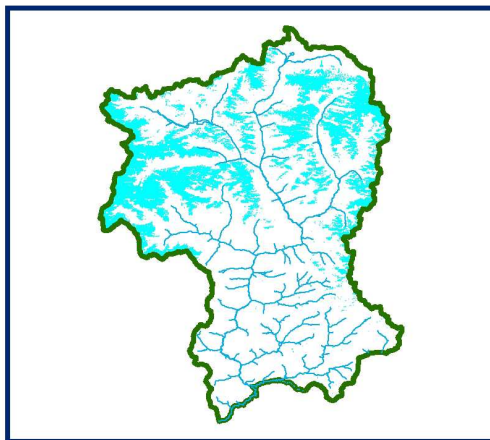
**21 DECEMBER 2011**



**28 DECEMBER 2011**



# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

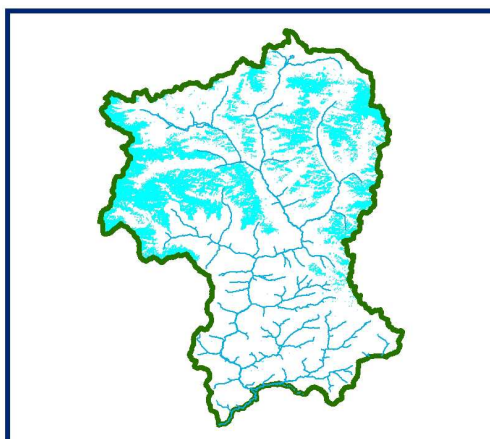


DATA USED

**2 DECEMBER 2011**

**7 DECEMBER 2011**

**9 DECEMBER 2011**

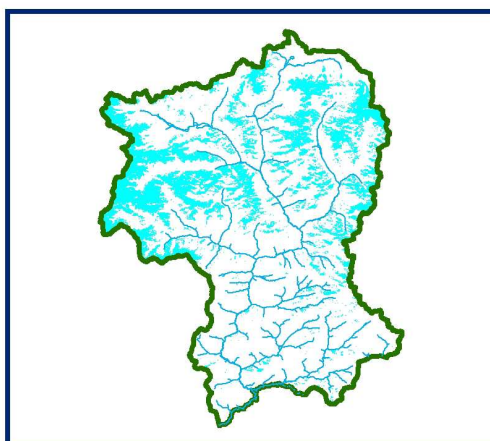


DATA USED

**16 DECEMBER 2011**

**17 DECEMBER 2011**

**19 DECEMBER 2011**



DATA USED

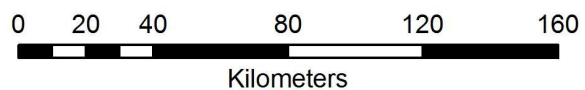
**21 DECEMBER 2011**

**26 DECEMBER 2011**

**28 DECEMBER 2011**



SNOW





## 5 DAILY SNOW COVER MAP: TISTA

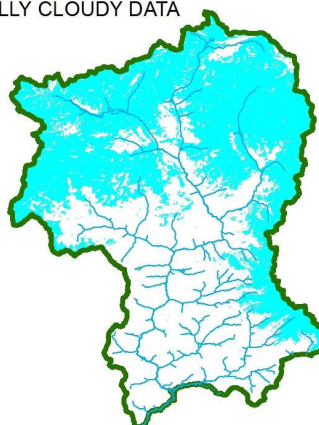


PARTIALLY CLOUDY DATA

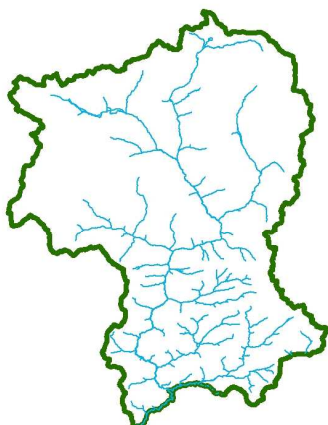


5 JANUARY 2012

PARTIALLY CLOUDY DATA



10 JANUARY 2012



DATA NOT AVAILABLE

PARTIALLY CLOUDY DATA



19 JANUARY 2012

PARTIALLY CLOUDY DATA



24 JANUARY 2012

PARTIALLY CLOUDY DATA



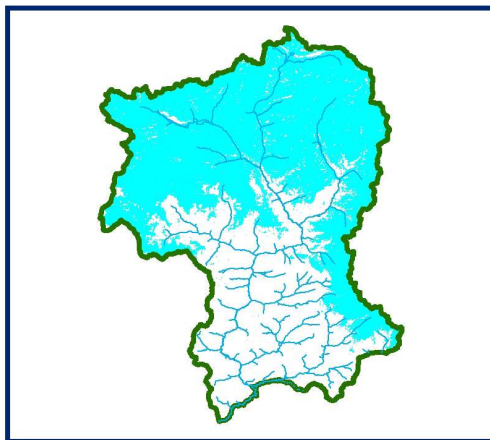
31 JANUARY 2012



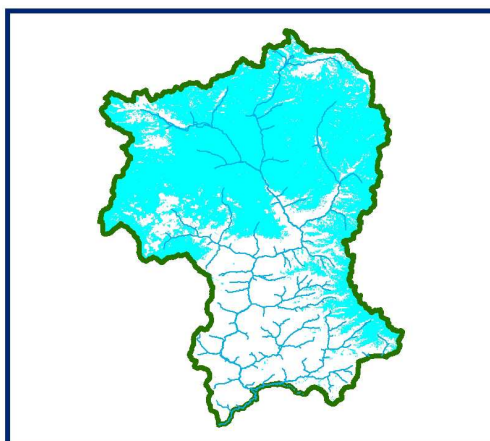
SNOW

0 15 30 60 90 120  
Kilometers

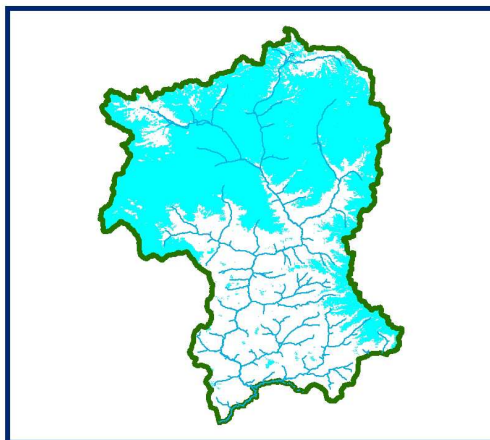
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**5 JANUARY 2012**  
**10 JANUARY 2012**



DATA USED  
**19 JANUARY 2012**



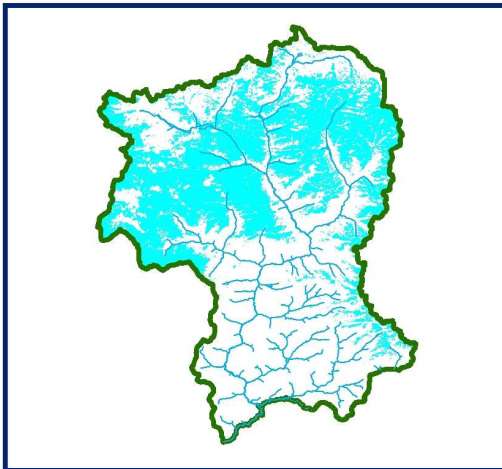
DATA USED  
**24 JANUARY 2012**  
**26 JANUARY 2012**  
**31 JANUARY 2012**



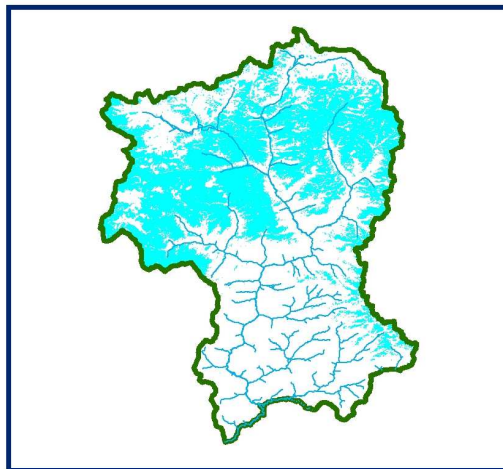
SNOW



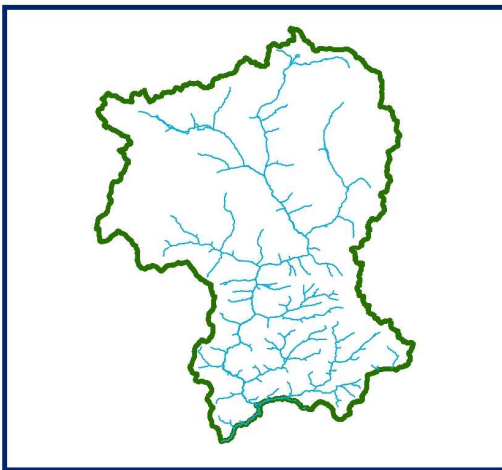
## 5 DAILY SNOW COVER MAP: TISTA



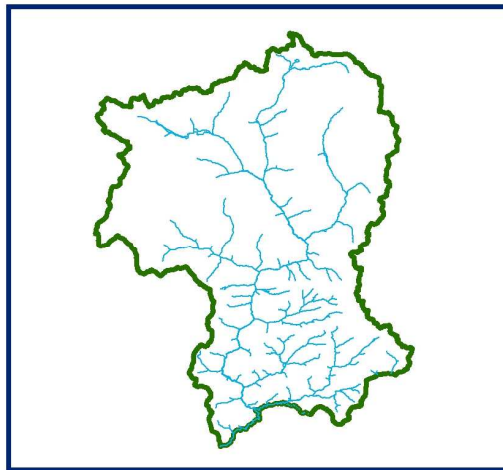
2 FEBRUARY 2012



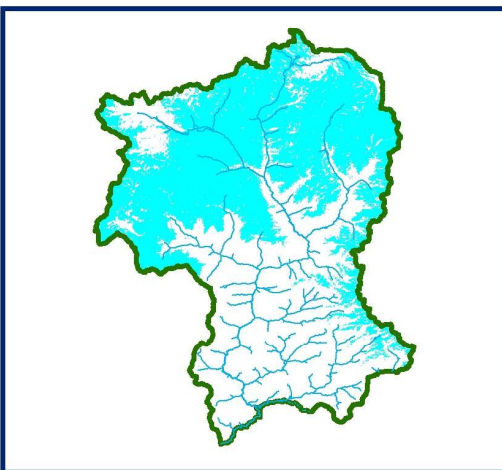
7 FEBRUARY 2012



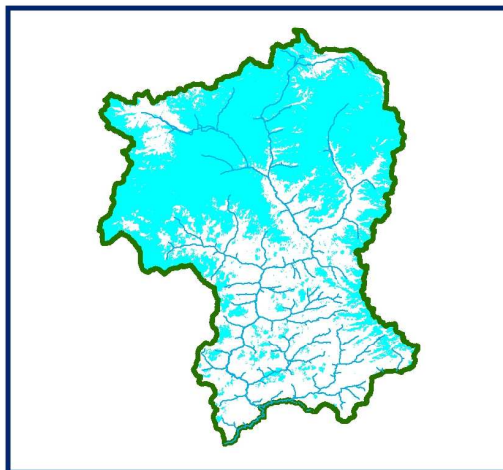
DATA NOT AVAILABLE



DATA NOT AVAILABLE



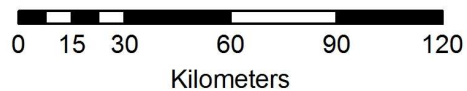
22 FEBRUARY 2012



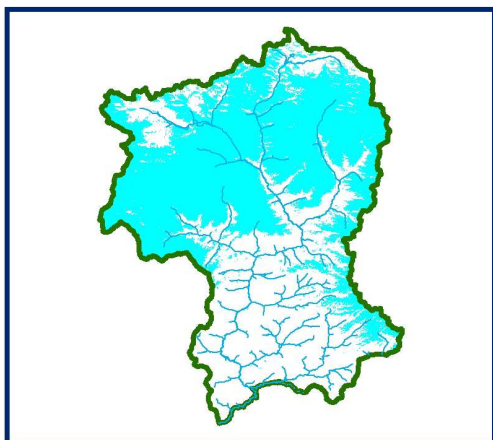
24 FEBRUARY 2012



SNOW



# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN

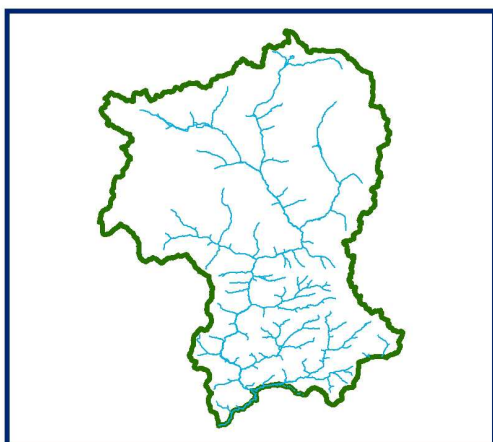


DATA USED

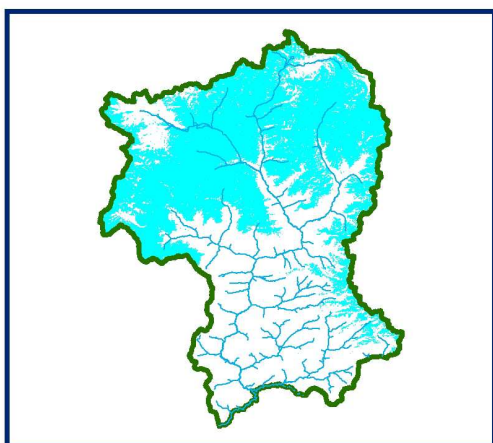
**2 FEBRUARY 2012**

**5 FEBRUARY 2012**

**7 FEBRUARY 2012**



NO DATA AVAILABLE



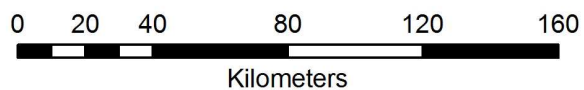
DATA USED

**22 FEBRUARY 2012**

**24 FEBRUARY 2012**



SNOW

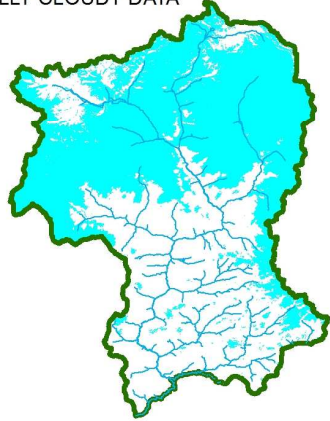




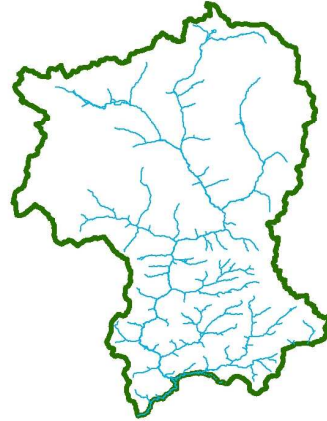
## 5 DAILY SNOW COVER MAP: TISTA



PARTIALLY CLOUDY DATA



**5 MARCH 2012**



**DATA NOT AVAILABLE**



**12 MARCH 2012**

PARTIALLY CLOUDY DATA



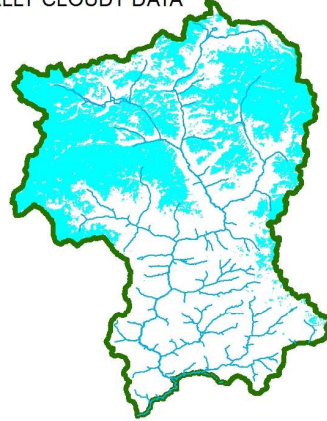
**16 MARCH 2012**

PARTIALLY CLOUDY DATA



**22 MARCH 2012**

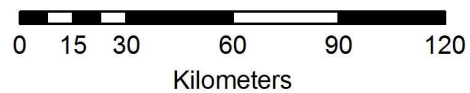
PARTIALLY CLOUDY DATA



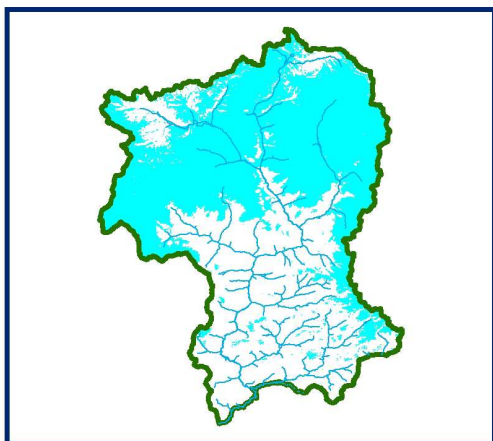
**31 MARCH 2012**



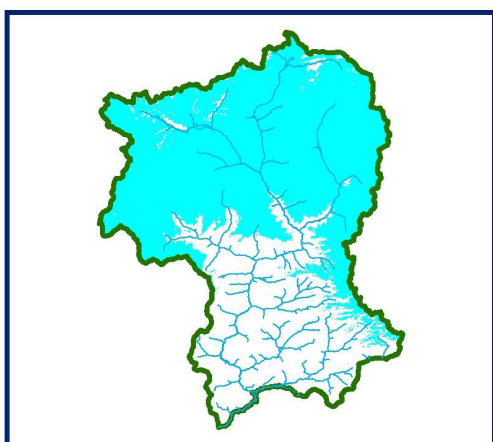
SNOW



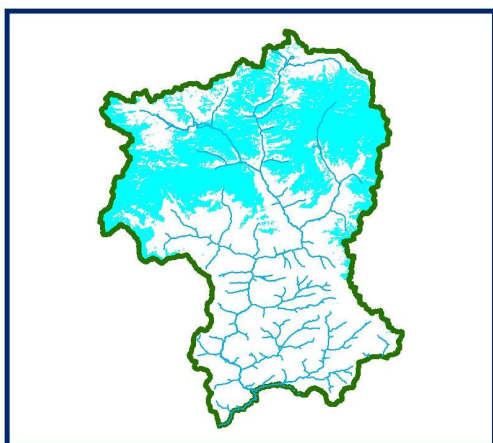
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**5 MARCH 2012**



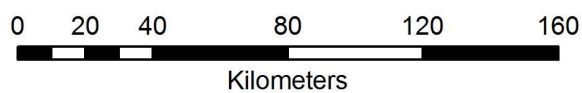
DATA USED  
**12 MARCH 2012**  
**16 MARCH 2012**  
**17 MARCH 2012**



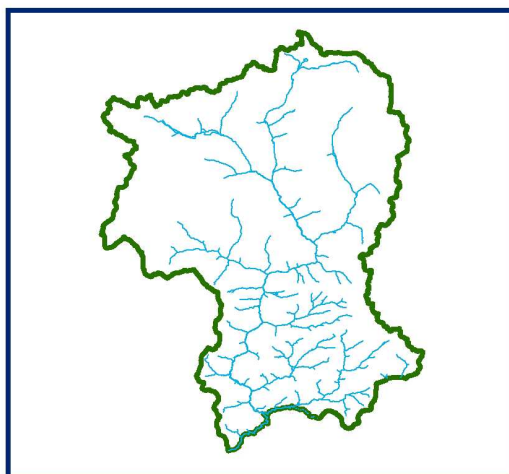
DATA USED  
**21 MARCH 2012**  
**26 MARCH 2012**  
**31 MARCH 2012**



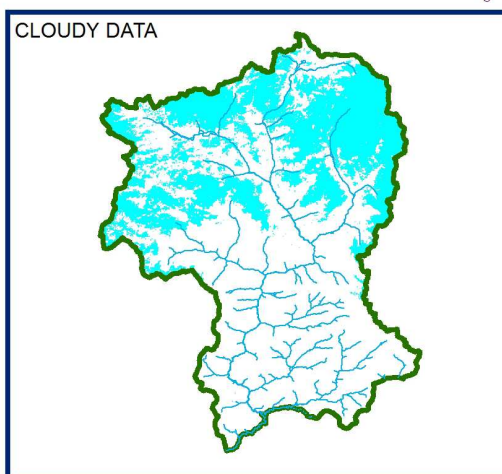
SNOW



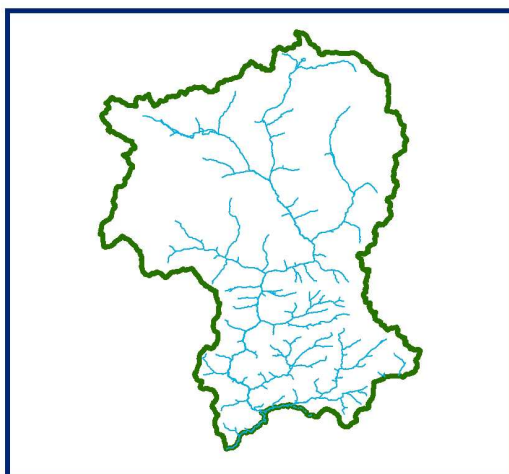
## 5 DAILY SNOW COVER MAP: TISTA



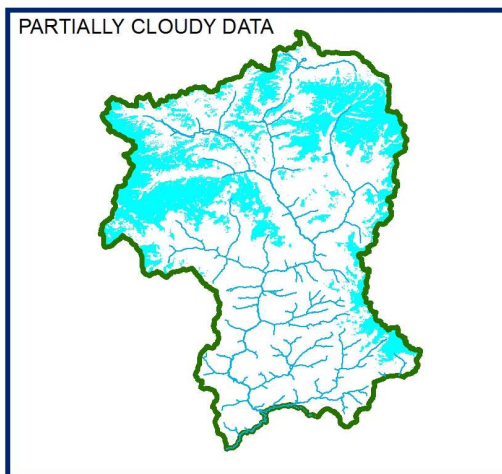
**DATA NOT AVAILABLE**



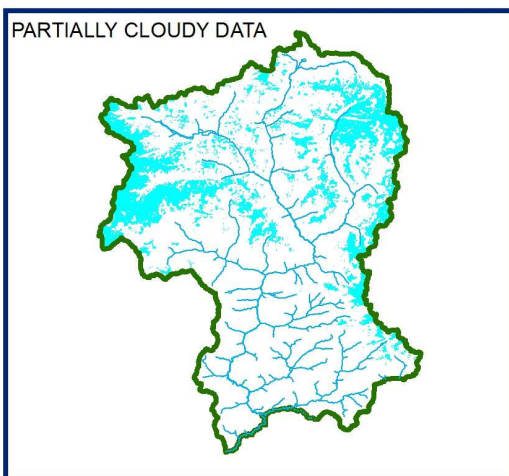
**9 APRIL 2012**



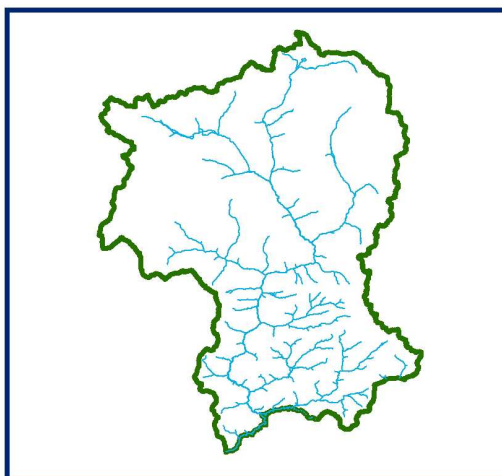
**DATA NOT AVAILABLE**



**19 APRIL 2012**



**24 APRIL 2012**



**DATA NOT AVAILABLE**

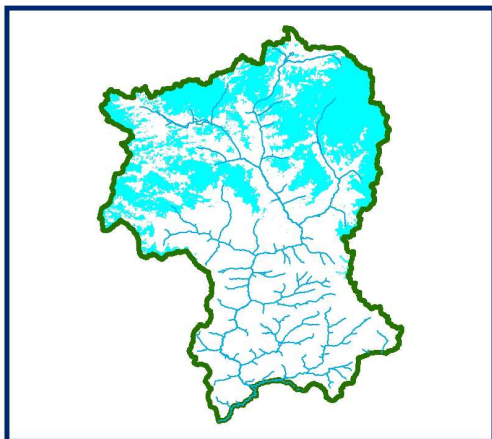


**SNOW**

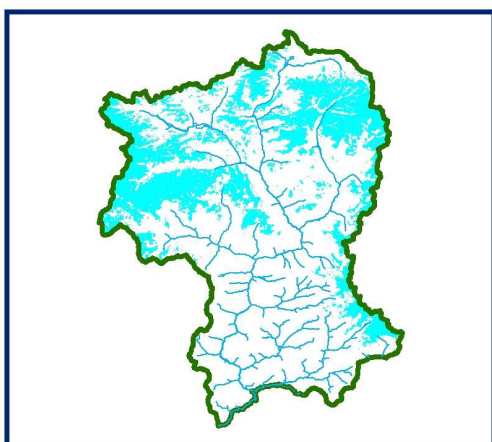
0 15 30 60 90 120

Kilometers

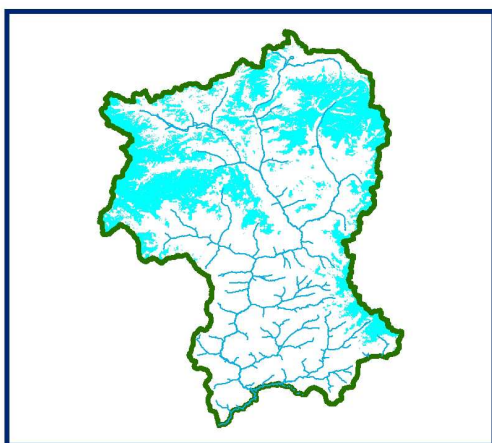
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**9 APRIL 2012**



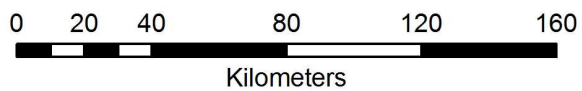
DATA USED  
**19 APRIL 2012**



DATA USED  
**24 APRIL 2012**

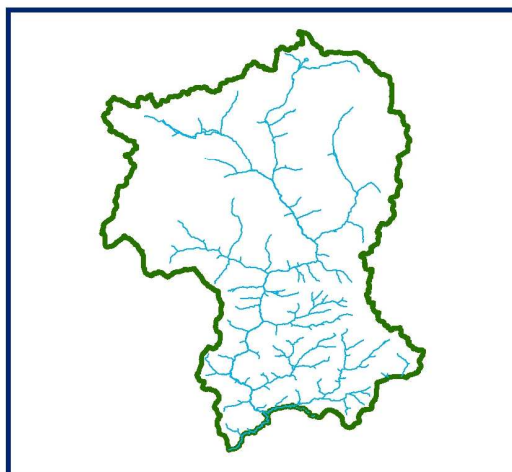


SNOW

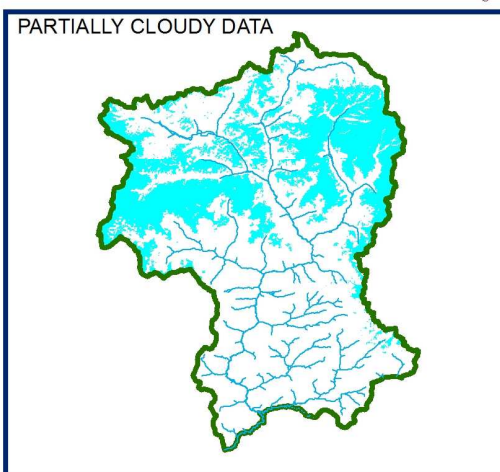




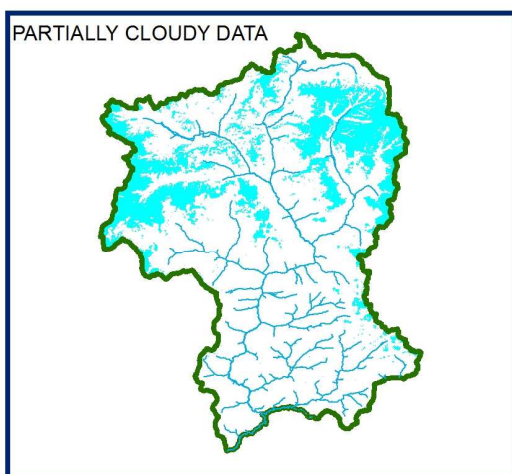
## 5 DAILY SNOW COVER MAP: TISTA



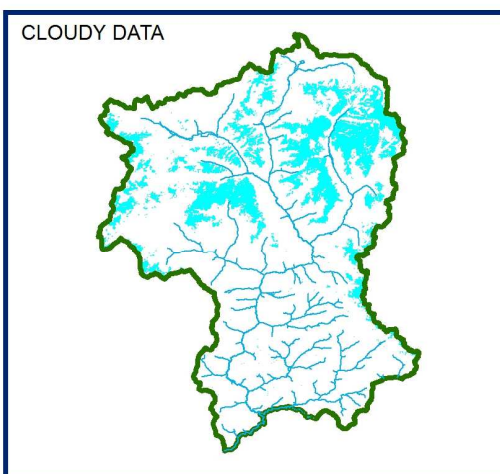
**DATA NOT AVAILABLE**



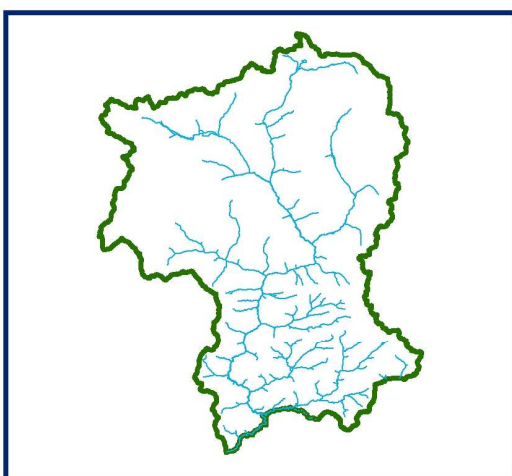
**8 MAY 2012**



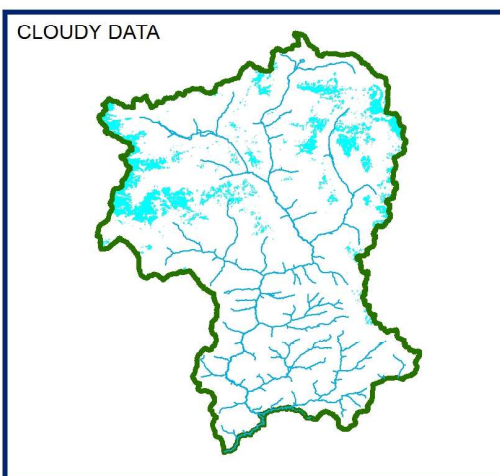
**13 MAY 2012**



**18 MAY 2012**



**DATA NOT AVAILABLE**



**28 MAY 2012**

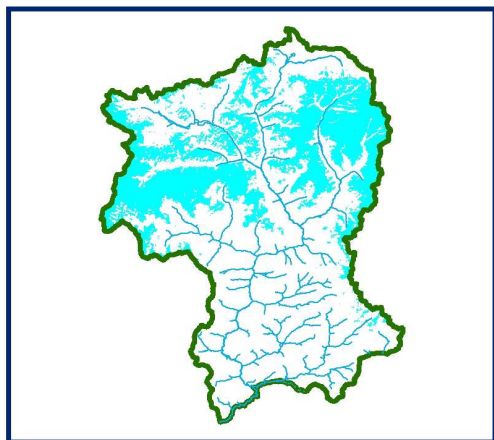


**SNOW**

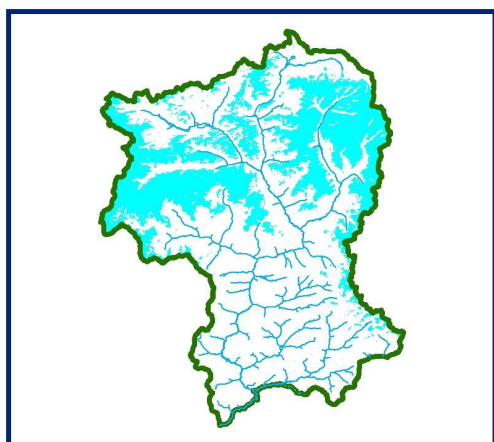
0 15 30 60 90 120

Kilometers

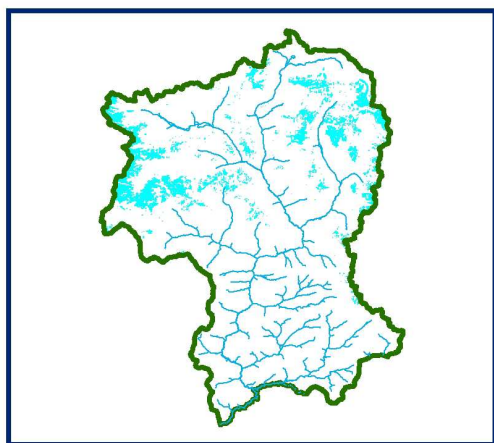
# COMPOSITE SNOW COVER MAP (10 DAILY):TISTA BASIN



DATA USED  
**8 MAY 2012**



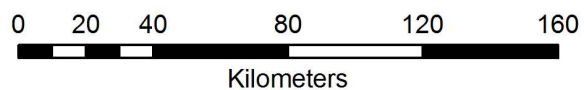
DATA USED  
**12 MAY 2012**  
**13 MAY 2012**  
**18 MAY 2012**



DATA USED  
**28 MAY 2012**



SNOW



*RANGIT BASIN*

# AREAL EXTENT OF SNOW (5 DAILY)

**BASIN NAME: RANGIT BASIN**

**RANGIT AREA: 1630 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
<b>September 2011</b>							
1	30Sept2011(PC)	47	3				
<b>October 2011</b>							
2	6-Oct-11(PC)	47	3	3	10-Oct-11(C)	53	3
4	20-Oct-11(C)	45	3	5	24-Oct-11(PC)	106	7
6	25-Oct-11(PC)	55	3	7	29-Oct-11(PC)	55	3
8	30-Oct-11(C)	52	3				
<b>November 2011</b>							
9	10-Nov-11(C)	172	11	10	13-Nov-11(C)	51	3
11	17-Nov-11(PC)	178	11	12	18-Nov11(PC)	218	13
13	20-Nov-11	220	13	14	22-Nov11	134	8
15	27-Nov-11	95	6				
<b>December 2011</b>							
16	02-Dec-11	75	5	17	07-Dec-11(PC)	59	4
18	09-Dec-11(PC)	82	5	19	11-Dec-11(C)	52	3
20	12-Dec-11(C)	41	2	21	16-Dec-11(PC)	57	4
22	17-Dec-11(PC)	78	5	23	19-Dec-11	97	6
24	21-Dec-11	66	4	25	24-Dec-11	66	4
26	26-Dec-11	52	3	27	28-Dec-11	63	4
28	31-Dec-11	48	3				
<b>January 2012</b>							
29	05-Jan-12(PC)	216	13	30	10-Jan-12(PC)	196	12
31	19-Jan-12(PC)	254	16	32	24-Jan-12(PC)	134	8
33	26-Jan-12(PC)	196	12	34	28-Jan-12(C)	81	5
35	31-Jan-12(PC)	147	9				
<b>February 2012</b>							
36	02-Feb-12	193	12	37	05-Feb-12	119	7
38	07-Feb-12	103	6	39	22-Feb-12	133	8
40	24-Feb-12(PC)	278	17				

<b>March 2012</b>							
41	05-Mar-12(PC)	340	21	42	12-Mar-12	79	5
43	16-Mar-12(PC)	221	14	44	17-Mar12(PC)	202	12
45	21-Mar-12(PC)	58	4	46	22-Mar12(PC)	69	4
47	26-Mar-12(PC)	42	3	48	31-Mar12(PC)	109	7
<b>April 2012</b>							
49	09-Apr-12(C)	89	5	50	19-Apr-12(PC)	78	5
51	24-Apr-12(PC)	82	5				
<b>May 2012</b>							
52	08-May-12(PC)	83	5	53	12-May12(PC)	82	5
54	13-May-12(PC)	94	6	55	18-May-12(C)	56	3
56	28-May-12(C)	48	3				

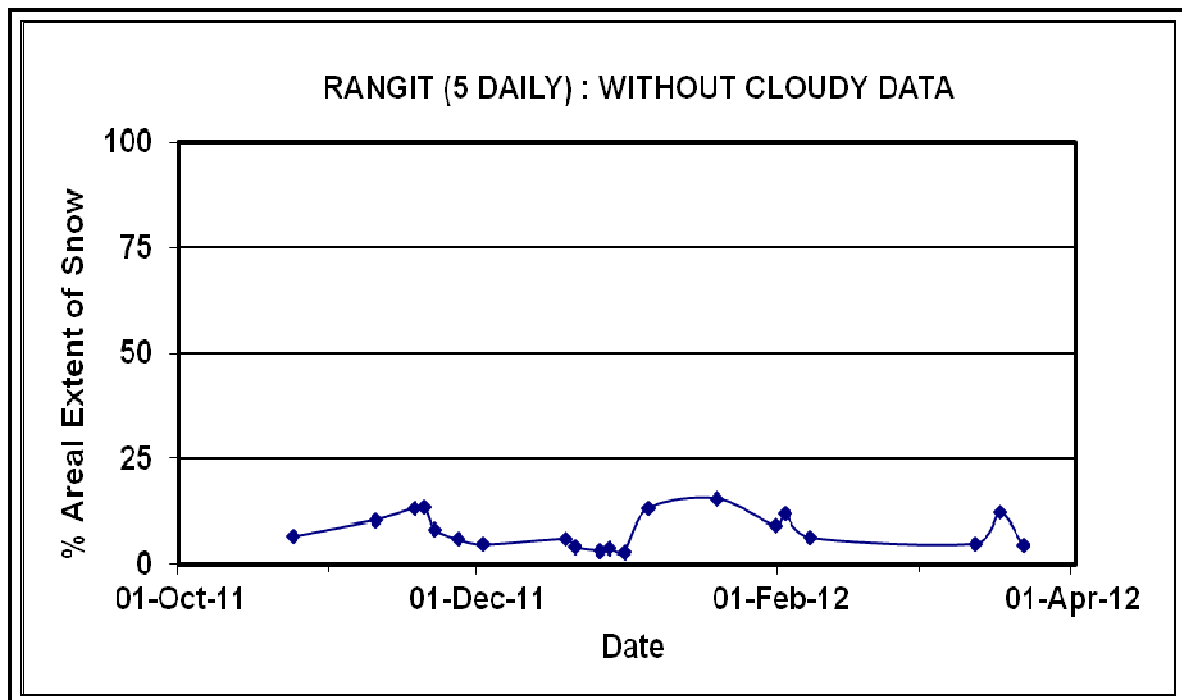
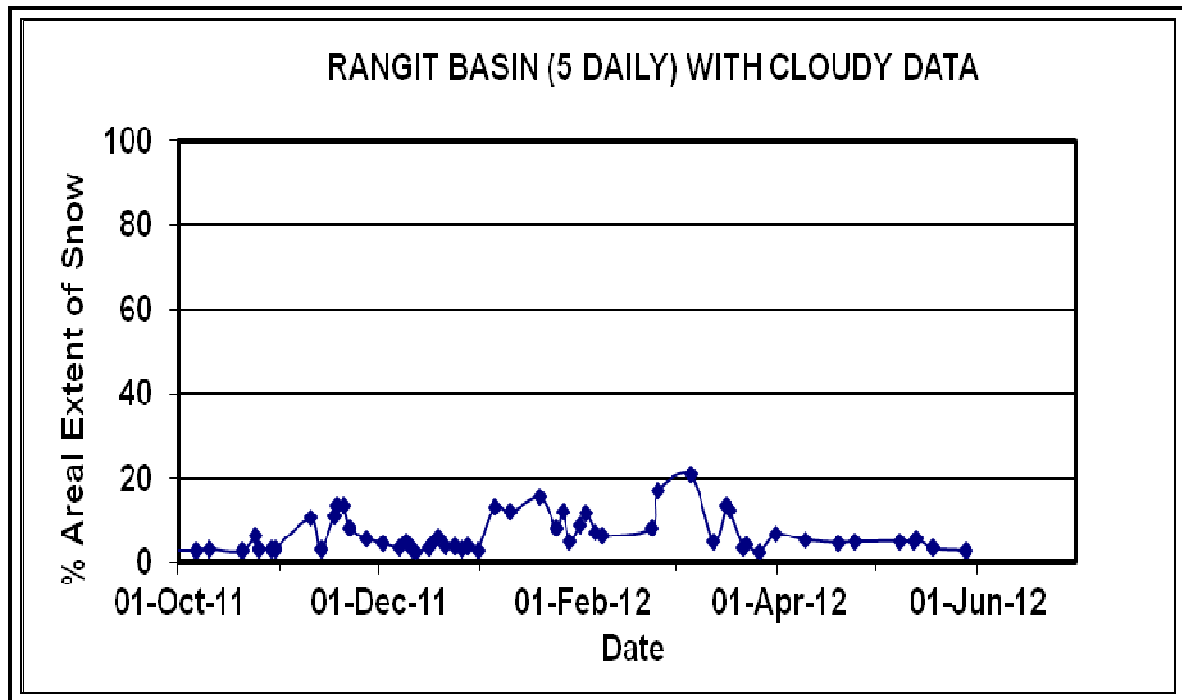
**AREAL EXTENT SNOW (10 DAILY)****NAME: RANGIT BASIN****RANGIT AREA: 1630 sq km**

<b>S. No</b>	<b>Data Used</b>	<b>Mean Date</b>	<b>Snow cover (sq km)</b>	<b>Snow cover (%)</b>
<b>September 2011</b>				
1	30-Sept-2011	30-Sept-2011	47	3
<b>October 2011</b>				
2	10-Oct-2011	10-Oct-2011	47	3
3	20-Oct-2011	20-Oct-2011	45	3
4	25-Oct-2011	25-Oct-2011	105	6
<b>November 2011</b>				
5	10-Nov-2011	10-Nov-2011	172	11
6	18-Nov-2011	18-Nov-2011	247	15
7	27-Nov-2011	27-Nov-2011	134	8
<b>December 2011</b>				
8	07-Dec-2011	07-Dec-2011	82	5
9	17-Dec-2011	17-Dec-2011	90	6
10	26-Dec-2011	26-Dec-2011	73	4
<b>January 2012</b>				
11	10-Jan-2012	10-Jan-2012	216	13
12	19-Jan-2012	19-Jan-2012	254	16
13	26-Jan-2012	26-Jan-2012	223	11

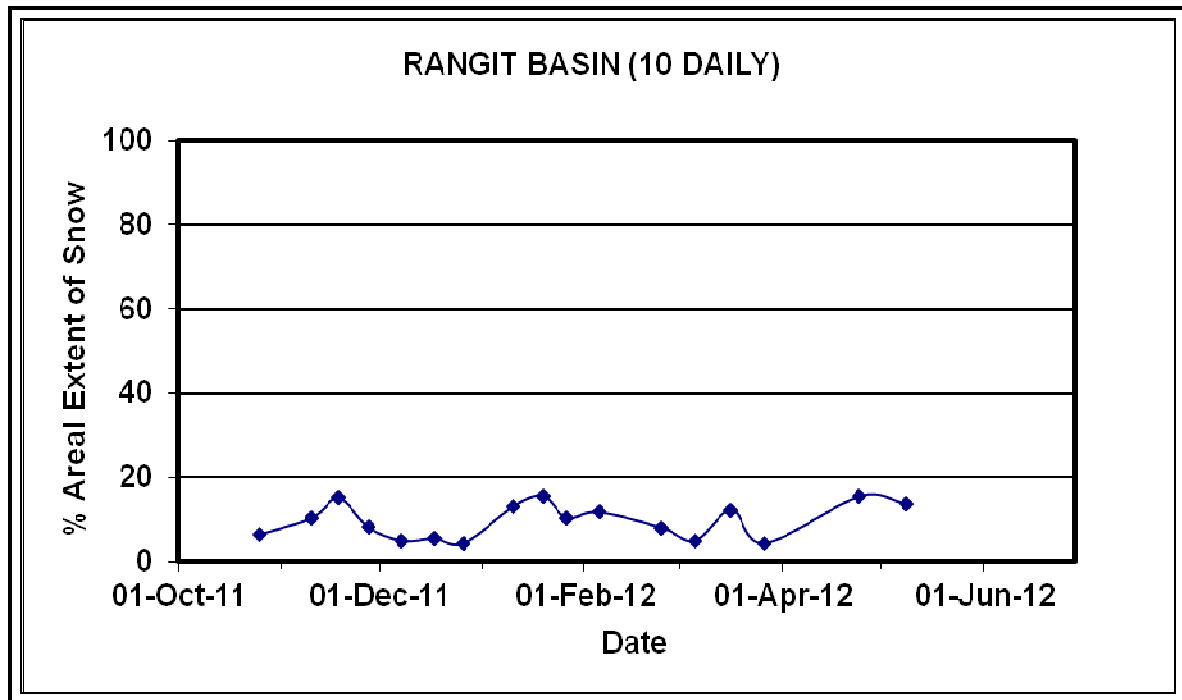
<b>February 2012</b>				
14	05-Feb-2012	05-Feb-2012	216	8
15	24-Feb-2012	24-Feb-2012	132	8
<b>March 2012</b>				
16	05-Mar-2012	05-Mar-2012	340	5
17	16-Mar-2012	16-Mar-2012	236	6
18	26-Mar-2012	26-Mar-2012	63	4
<b>April 2012</b>				
19	09-Apr-2012	09-Apr-2012	89	5
20	19-Apr-2012	19-Apr-2012	78	13
21	24-Apr-2012	24-Apr-2012	82	16
<b>May 2012</b>				
22	08-May-2012	08-May-2012	83	14
23	13-May-2012	13-May-2012	94	6



## Snow cover depletion curve

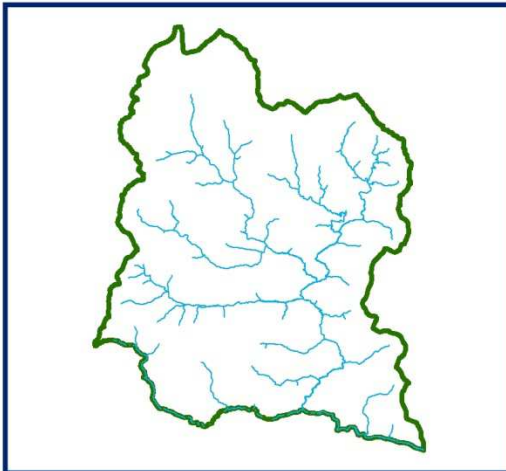


## Snow cover depletion curve

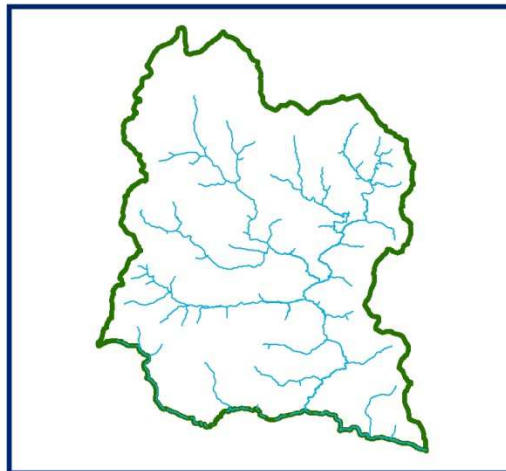


# *SNOW COVER MAP*

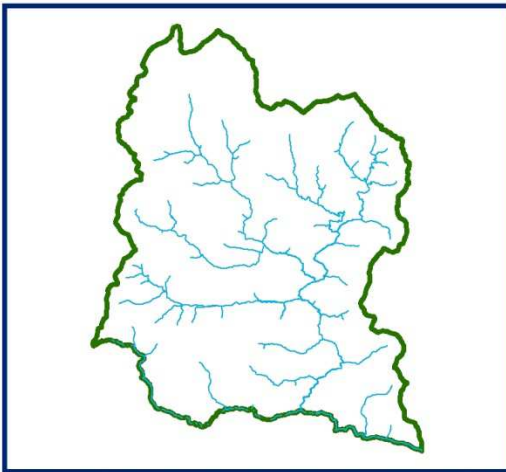
## 5 DAILY SNOW COVER MAP: RANGIT BASIN



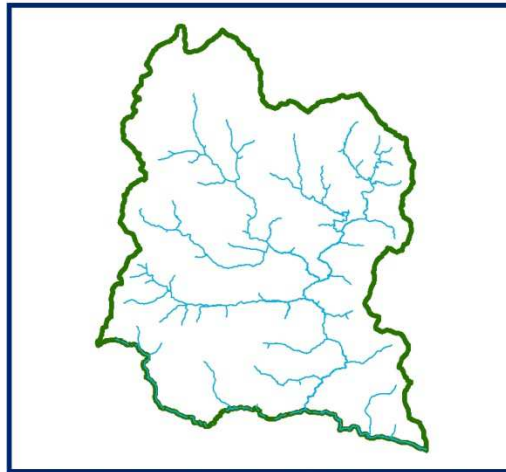
DATA NOT AVAILABLE



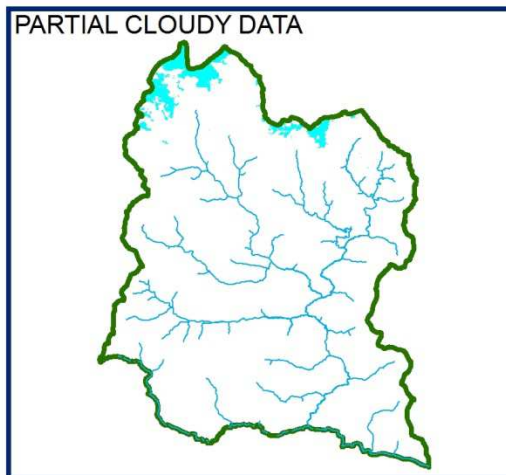
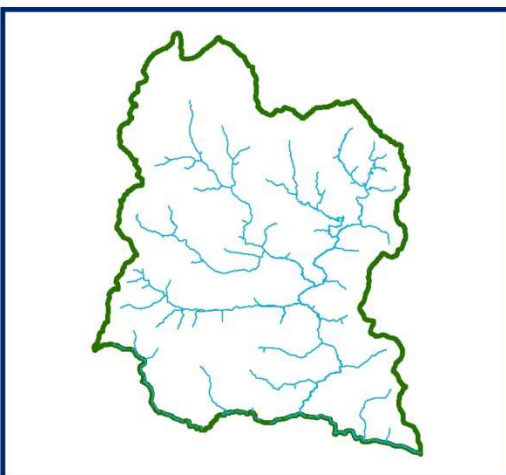
DATA NOT AVAILABLE



DATA NOT AVAILABLE



DATA NOT AVAILABLE



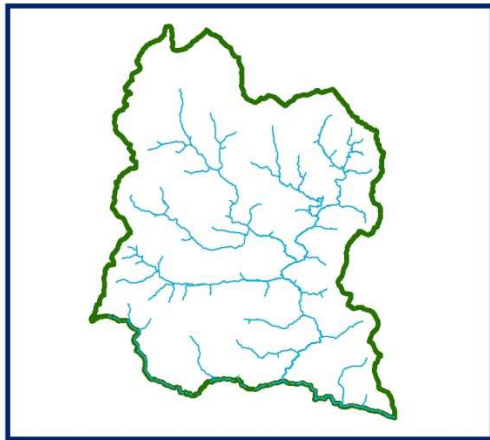
30 SEPTEMBER 2011



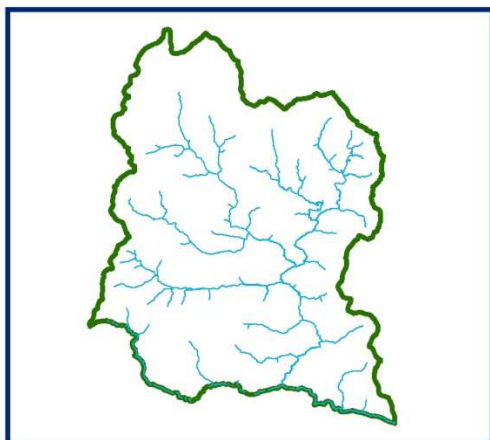
SNOW

0 5 10 20 30 40  
Kilometers

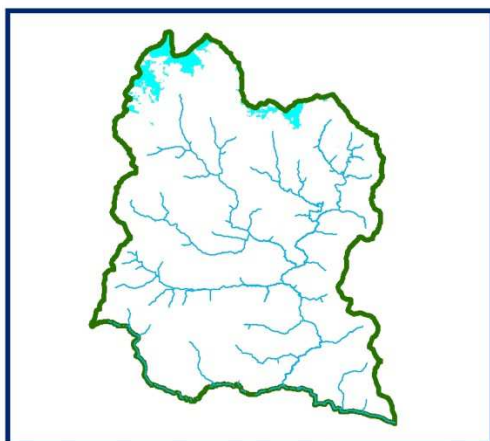
# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA NOT AVAILABLE

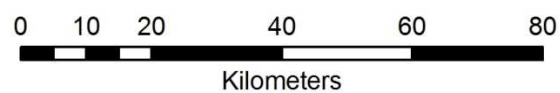


DATA NOT AVAILABLE

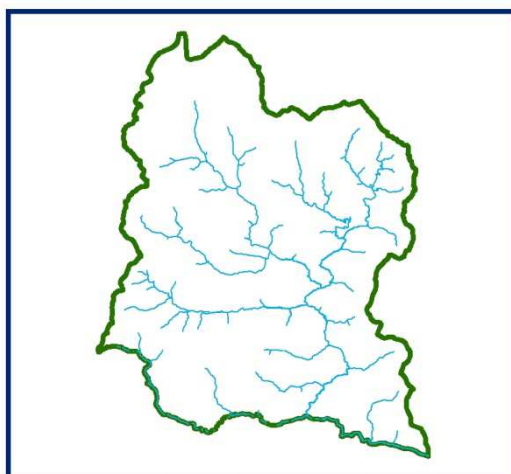


DATA USED  
30 SEPTEMBER 2011

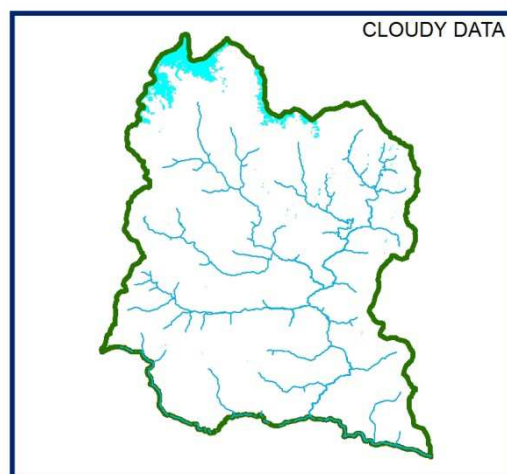
 SNOW



# 5 DAILY SNOW COVER MAP: RANGIT BASIN

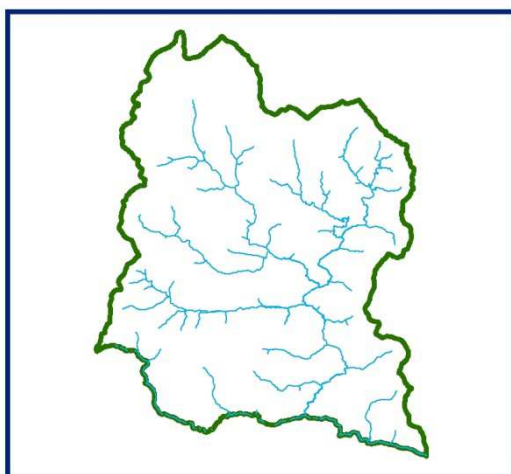


DATA NOT AVAILABLE

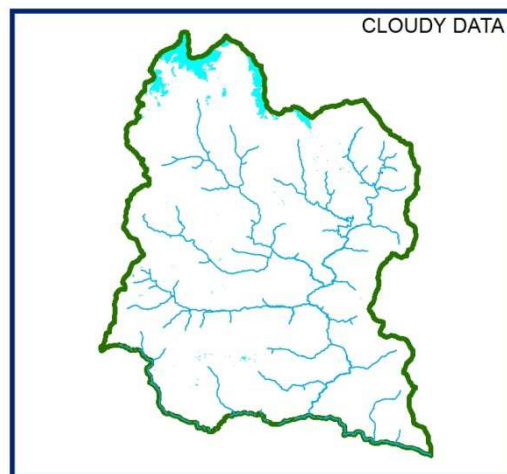


CLOUDY DATA

10 OCTOBER 2012

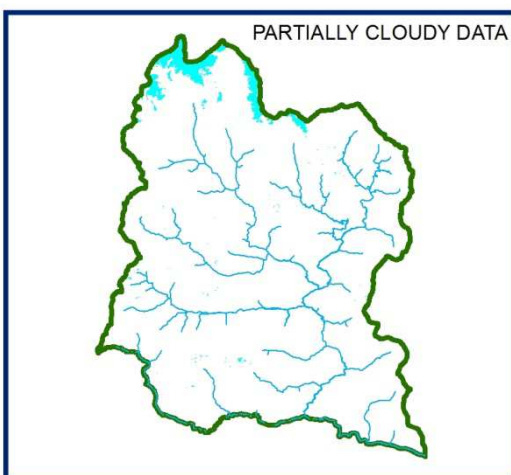


DATA NOT AVAILABLE



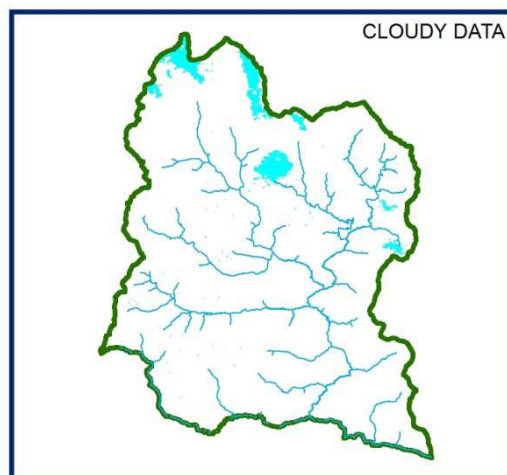
CLOUDY DATA

20 OCTOBER 2011



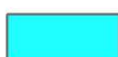
PARTIALLY CLOUDY DATA

25 OCTOBER 2011

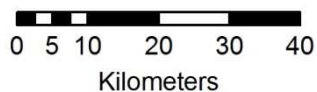


CLOUDY DATA

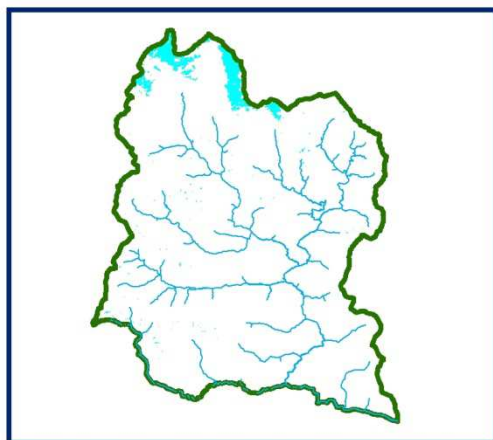
30 OCTOBER 2011



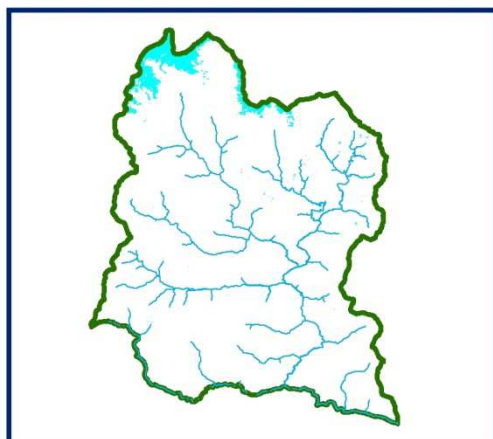
SNOW



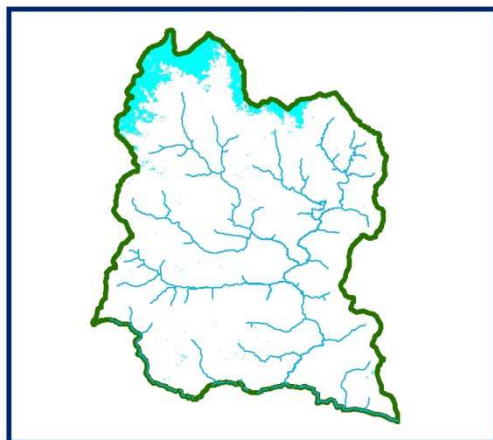
# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED  
**06 OCTOBER 2011**  
**10 OCTOBER 2011**



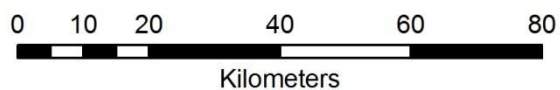
DATA USED  
**11 OCTOBER 2011**  
**20 OCTOBER 2011**



DATA USED  
**24 OCTOBER 2011**  
**25 OCTOBER 2011**  
**29 OCTOBER 2011**

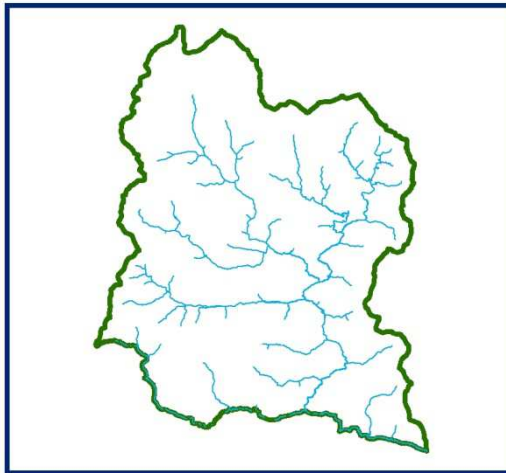
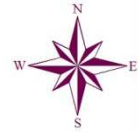


SNOW

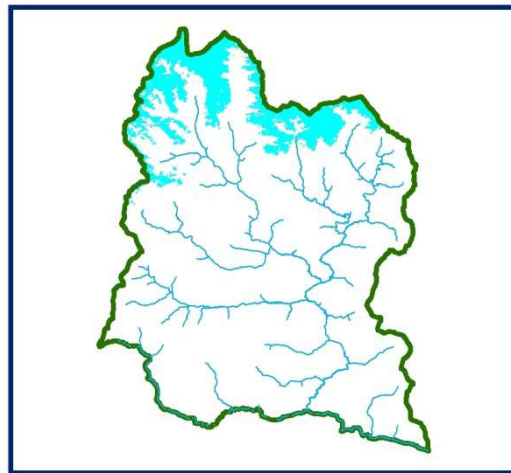




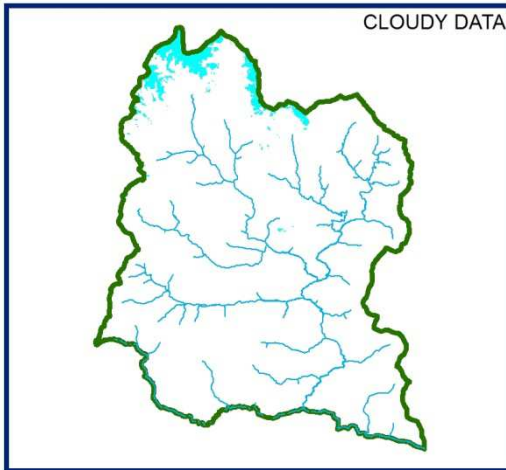
## 5 DAILY SNOW COVER MAP: RANGIT BASIN



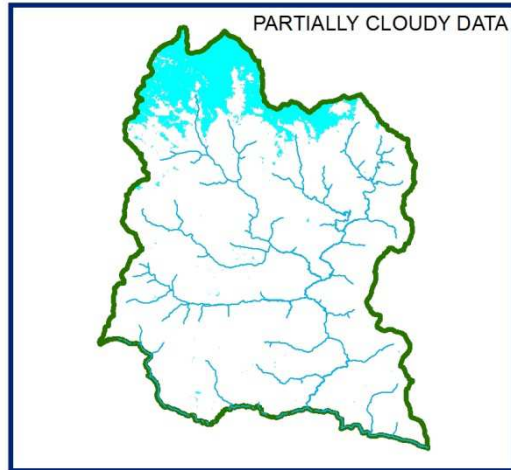
DATA NOT AVAILABLE



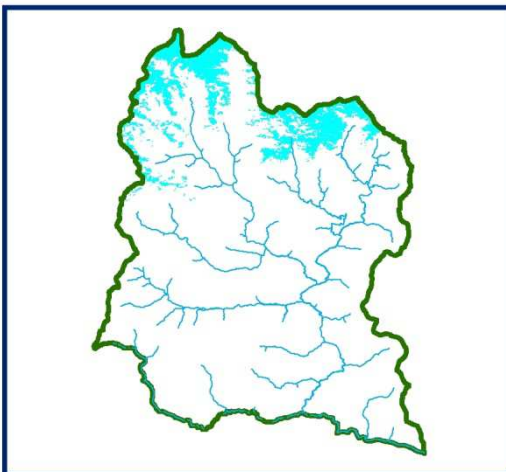
10 NOVEMBER 2011



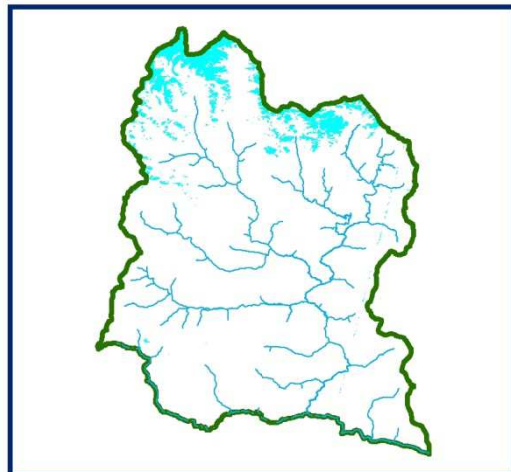
13 NOVEMBER 2011



17 NOVEMBER 2011



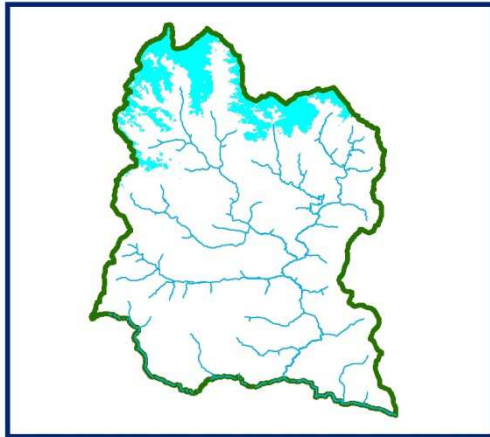
22 NOVEMBER 2011



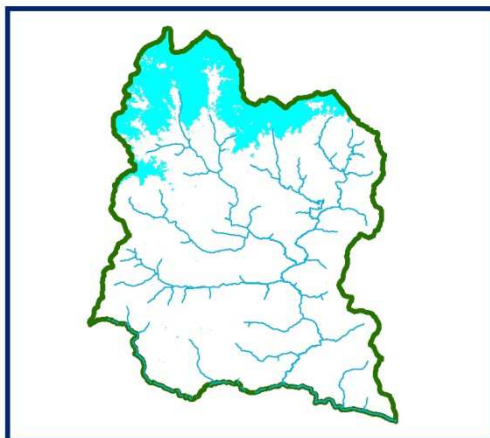
27 NOVEMBER 2011



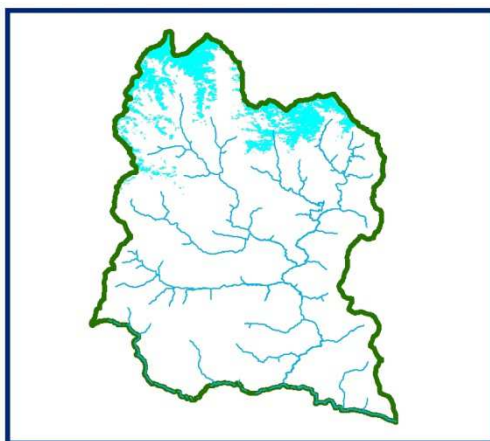
# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED  
**10 NOVEMBER 2011**



DATA USED  
**17 NOVEMBER 2011**  
**18 NOVEMBER 2011**  
**20 NOVEMBER 2011**

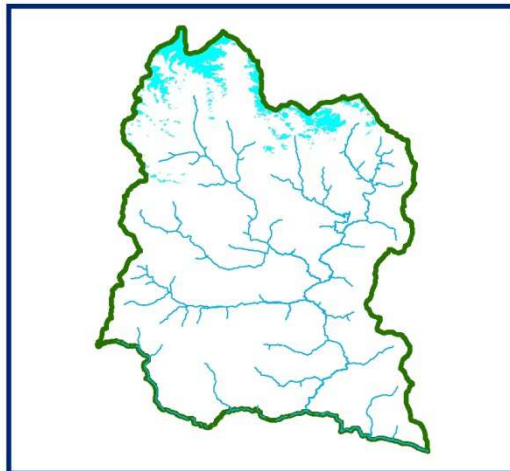


DATA USED  
**22 NOVEMBER 2011**  
**27 NOVEMBER 2011**

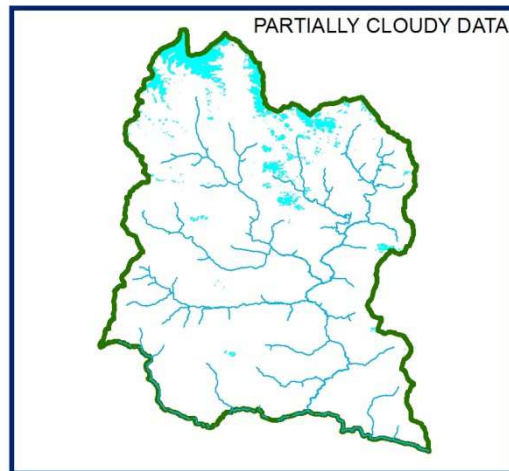
 SNOW

0 10 20 40 60 80  
Kilometers

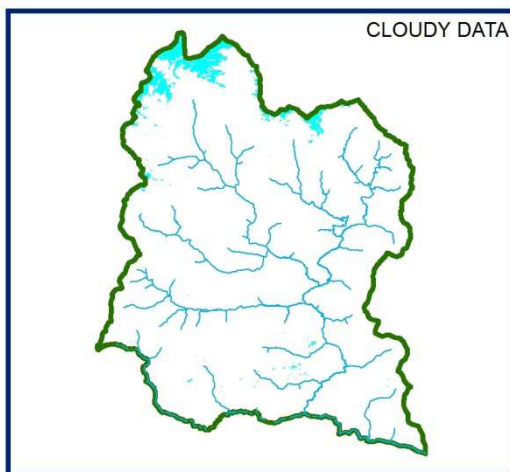
## 5 DAILY SNOW COVER MAP: RANGIT BASIN



**2 DECEMBER 2011**



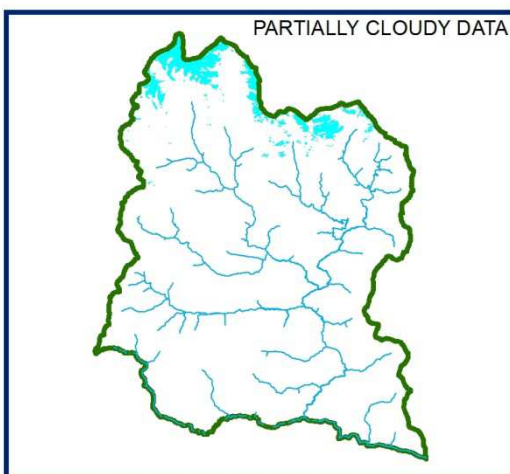
**9 DECEMBER 2011**



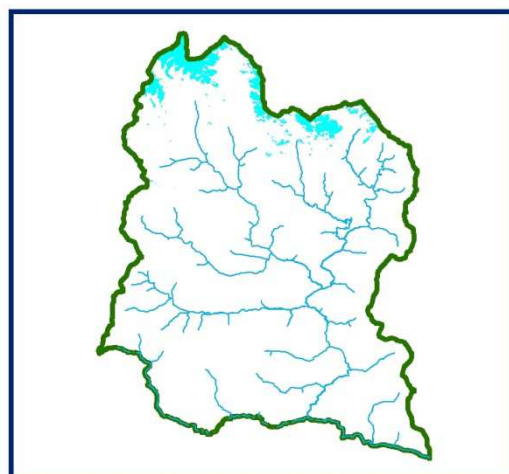
**11 DECEMBER 2011**



**19 DECEMBER 2011**



**24 DECEMBER 2011**



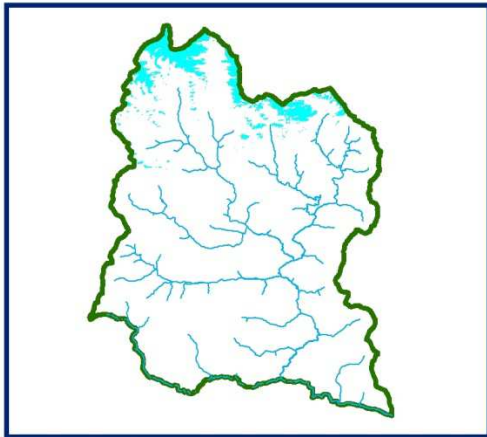
**28 DECEMBER 2011**



SNOW

0 5 10 20 30 40  
Kilometers

# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

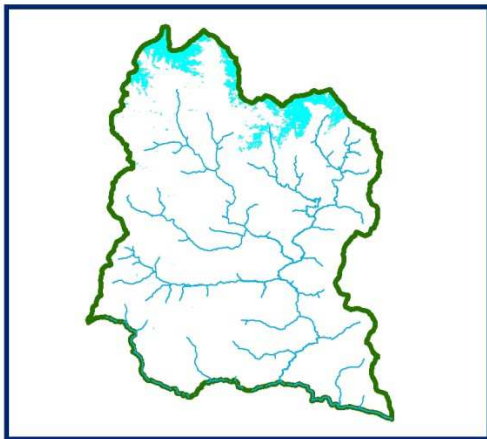


DATA USED

**2 DECEMBER 2011**

**7 DECEMBER 2011**

**9 DECEMBER 2011**

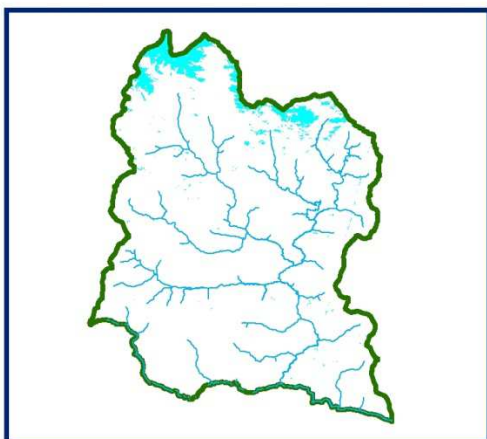


DATA USED

**16 DECEMBER 2011**

**17 DECEMBER 2011**

**19 DECEMBER 2011**



DATA USED

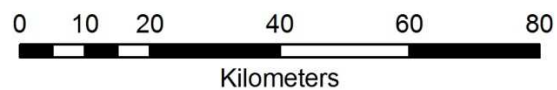
**21 DECEMBER 2011**

**26 DECEMBER 2011**

**28 DECEMBER 2011**

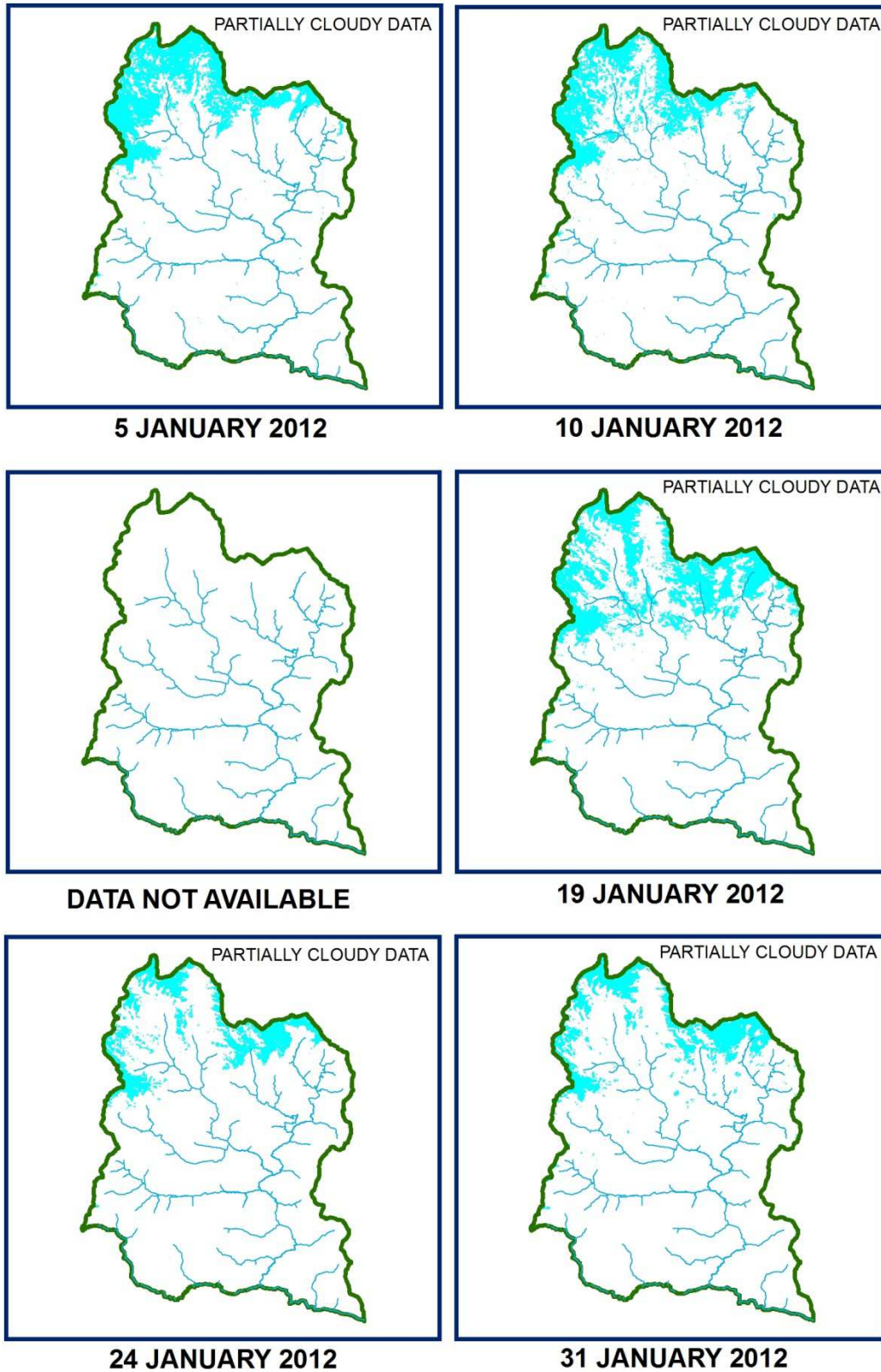


SNOW



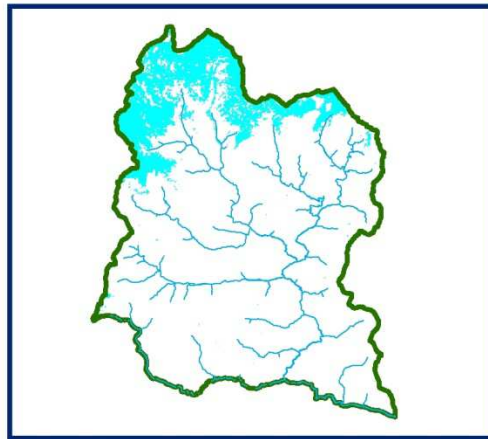


## 5 DAILY SNOW COVER MAP: RANGIT BASIN

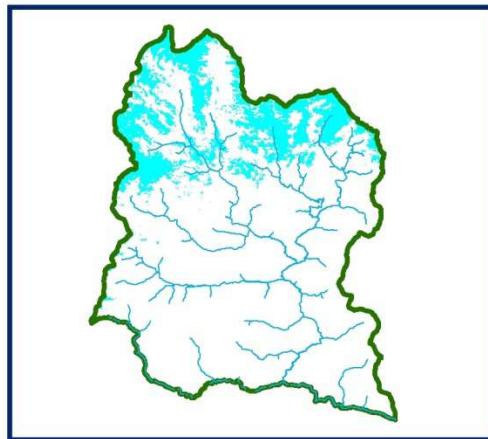


5

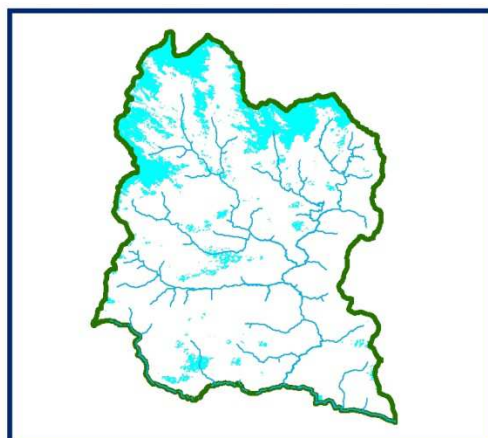
## COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED  
**5 JANUARY 2012**  
**10 JANUARY 2012**



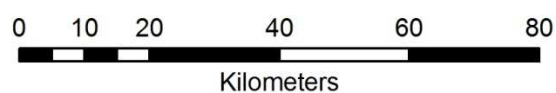
DATA USED  
**19 JANUARY 2012**



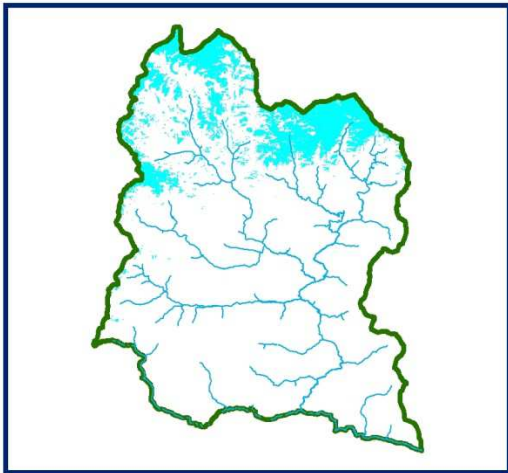
DATA USED  
**24 JANUARY 2012**  
**26 JANUARY 2012**  
**31 JANUARY 2012**



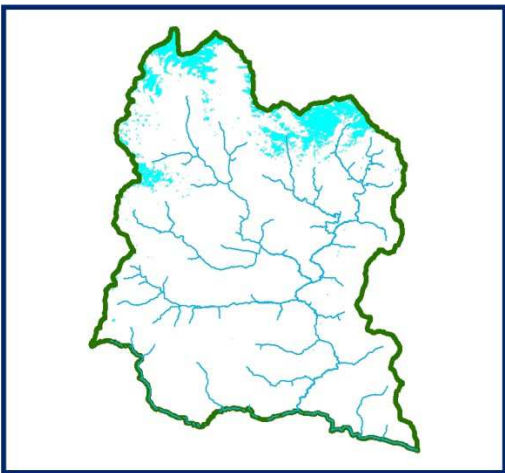
SNOW



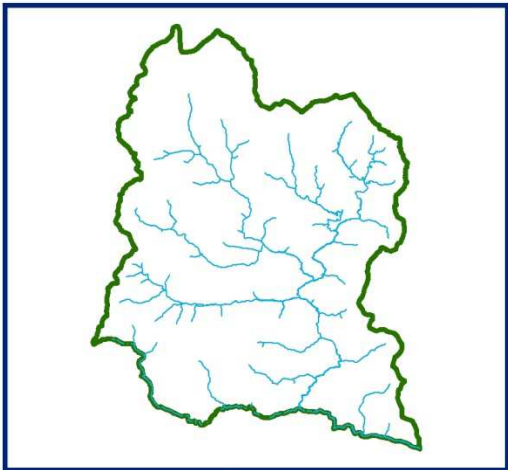
5 DAILY SNOW COVER MAP: RANGIT BASIN



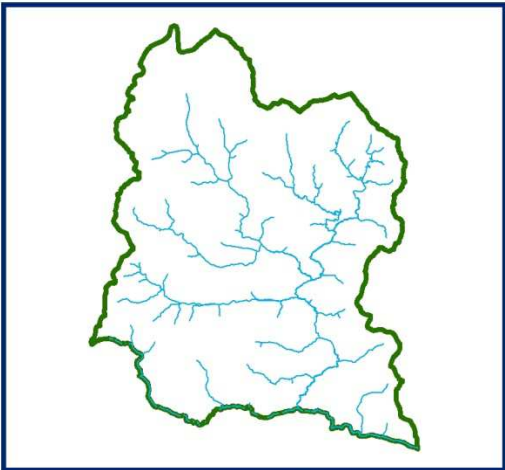
3 FEBRUARY 2012



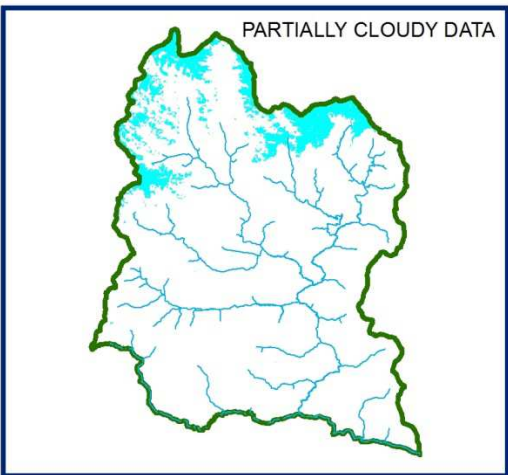
7 FEBRUARY 2012



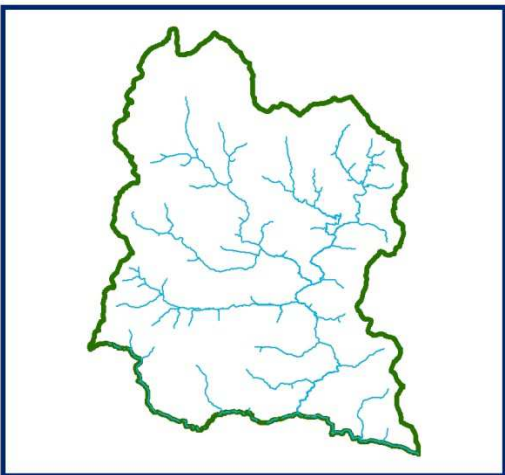
DATA NOT AVAILABLE



DATA NOT AVAILABLE



22 FEBRUARY 2012

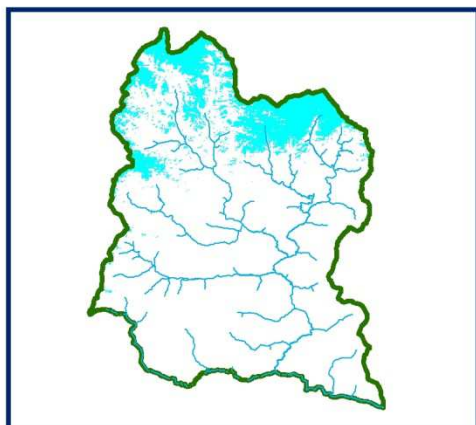


DATA NOT AVAILABLE





# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN

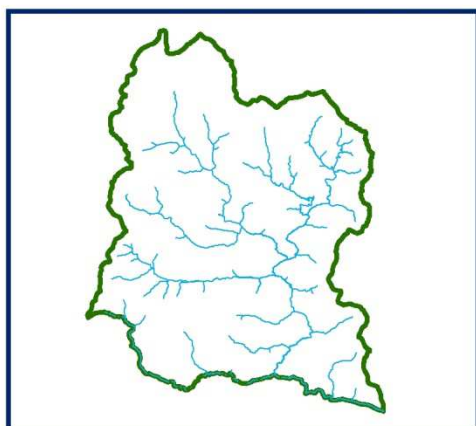


DATA USED

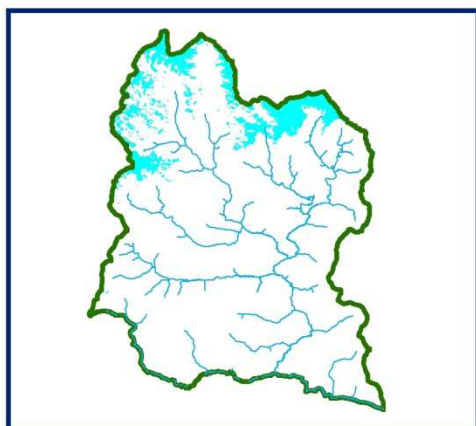
**2 FEBRUARY 2012**

**5 FEBRUARY 2012**

**7 FEBRUARY 2012**



NO DATA AVAILABLE



DATA USED

**22 FEBRUARY 2012**

**24 FEBRUARY 2012**



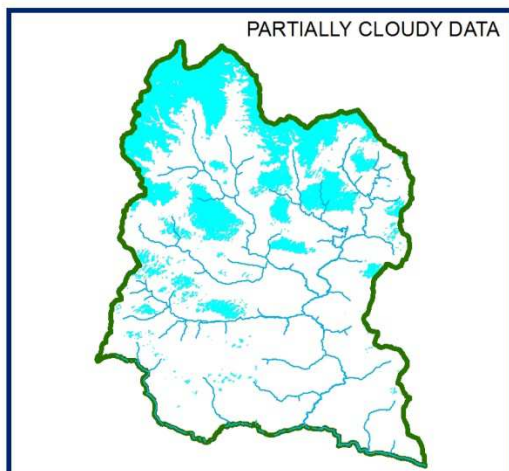
SNOW

0 10 20 40 60 80

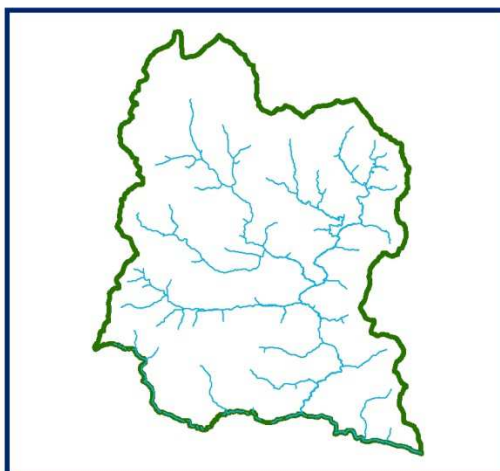


Kilometers

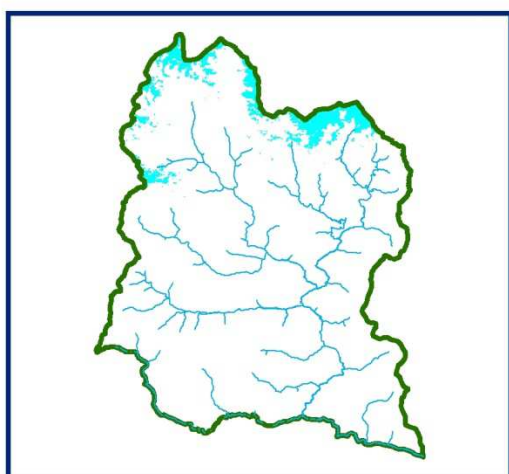
## 5 DAILY SNOW COVER MAP: RANGIT BASIN



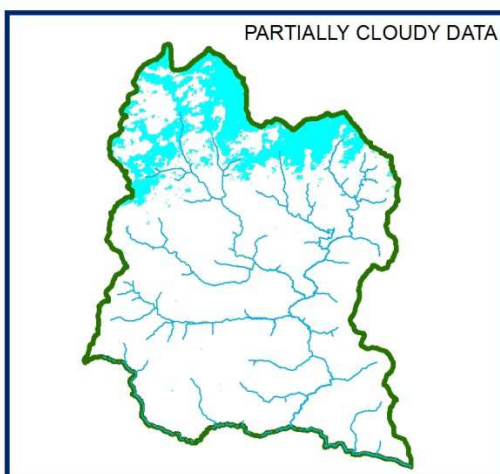
**5 MARCH 2012**



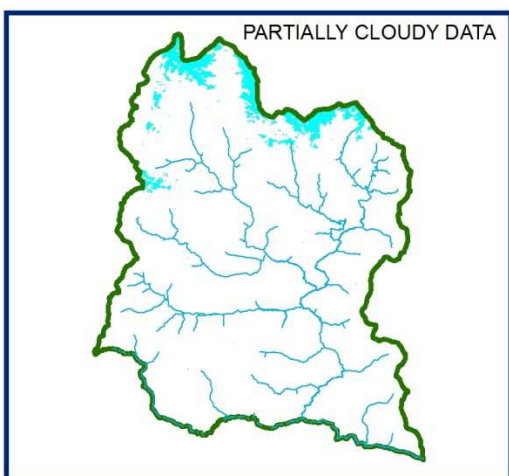
**DATA NOT AVAILABLE**



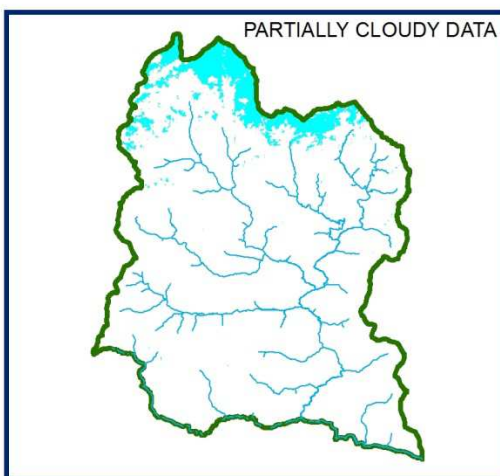
**12 MARCH 2012**



**16 MARCH 2012**



**22 MARCH 2012**



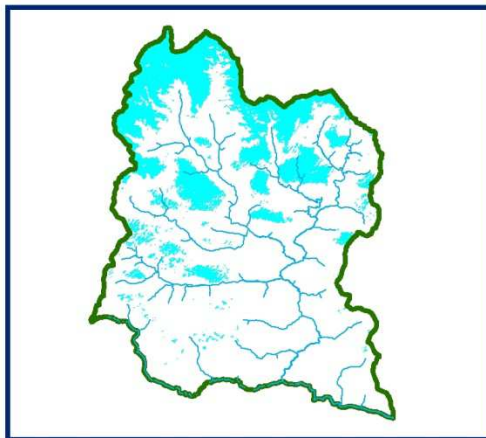
**31 MARCH 2012**



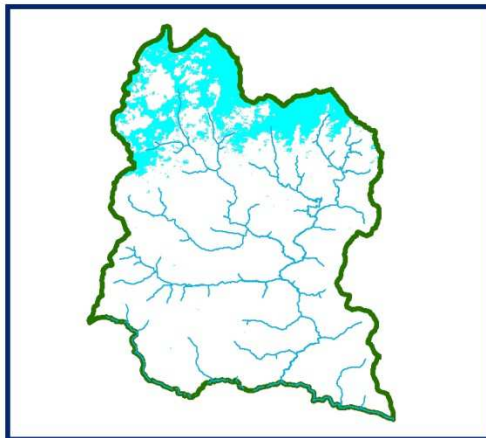
SNOW

0 5 10 20 30 40  
Kilometers

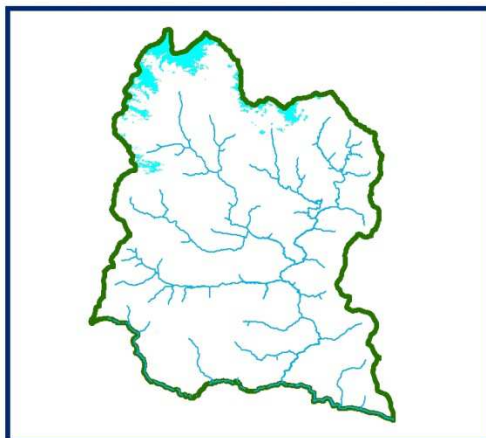
# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED  
**5 MARCH 2012**



DATA USED  
**12 MARCH 2012**  
**16 MARCH 2012**  
**17 MARCH 2012**



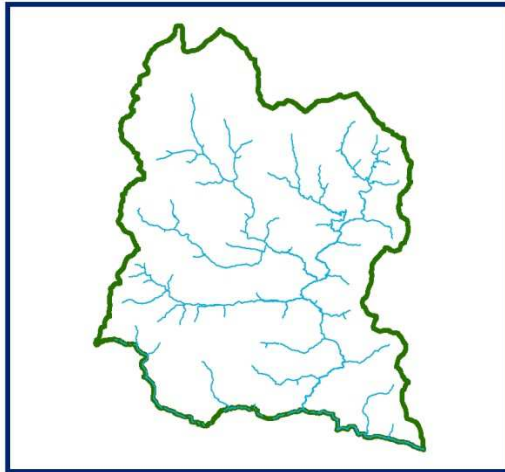
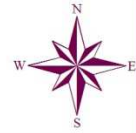
DATA USED  
**21 MARCH 2012**  
**26 MARCH 2012**  
**31 MARCH 2012**



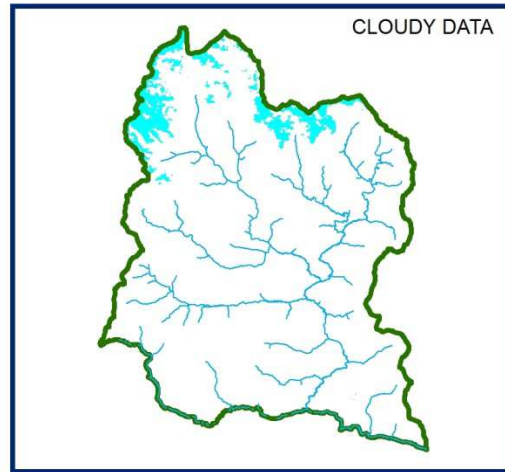
SNOW



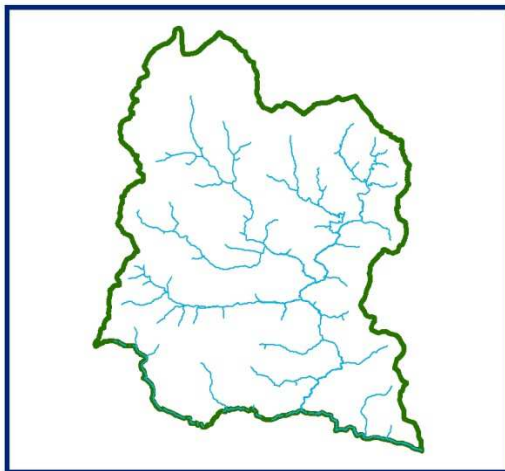
## 5 DAILY SNOW COVER MAP: RANGIT BASIN



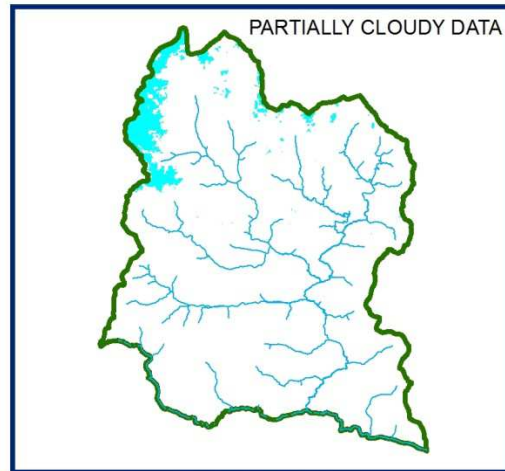
DATA NOT AVAILABLE



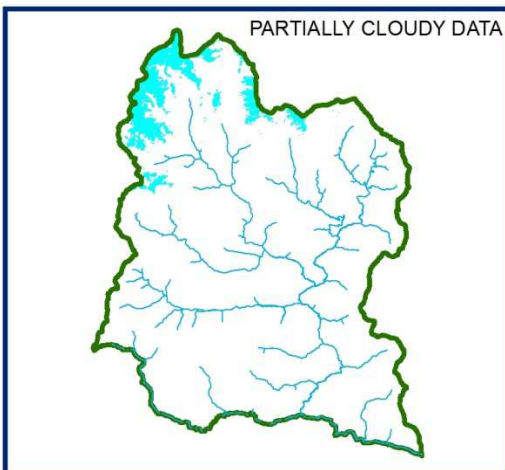
9 APRIL 2012



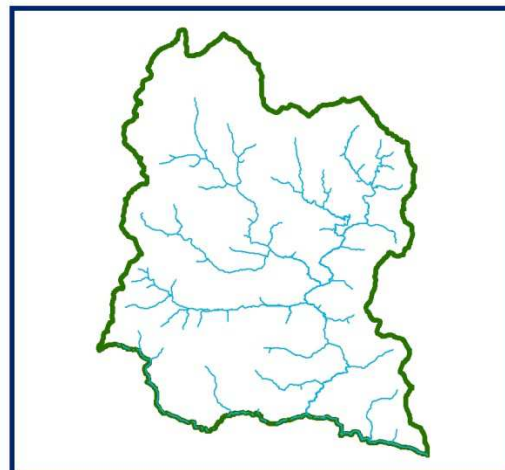
DATA NOT AVAILABLE



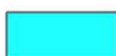
19 APRIL 2012



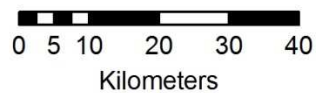
24 APRIL 2012



DATA NOT AVAILABLE

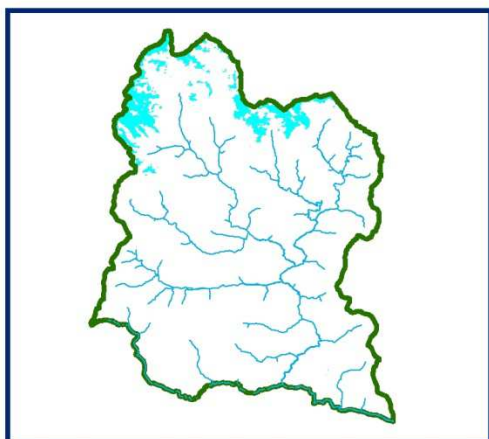


SNOW

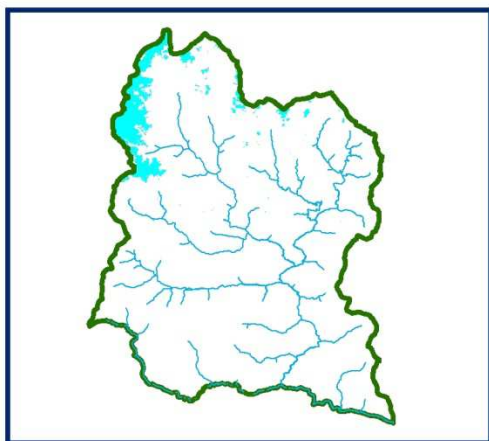




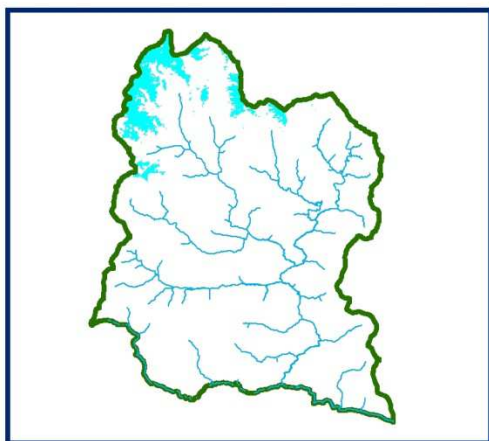
# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



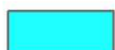
DATA USED  
**9 APRIL 2012**



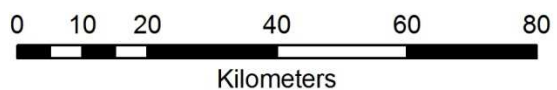
DATA USED  
**19 APRIL 2012**



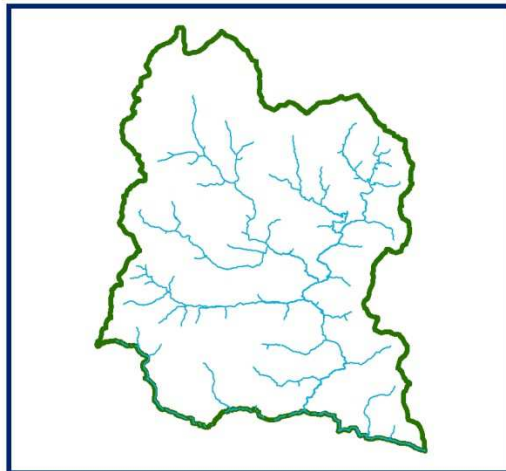
DATA USED  
**24 APRIL 2012**



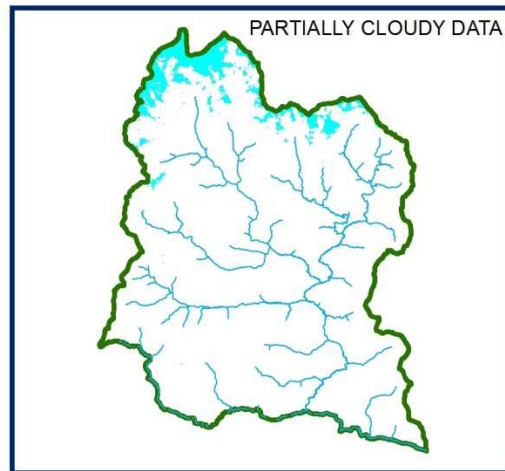
SNOW



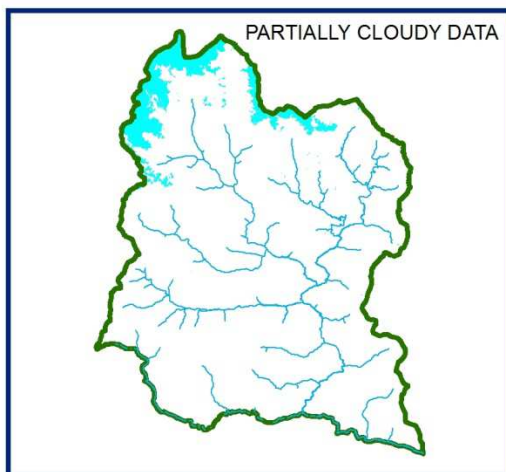
## 5 DAILY SNOW COVER MAP: RANGIT BASIN



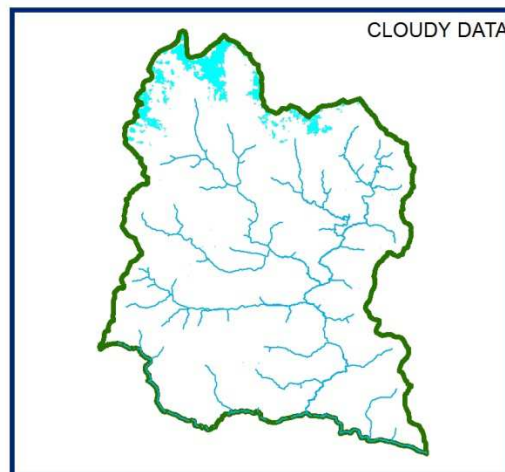
**DATA NOT AVAILABLE**



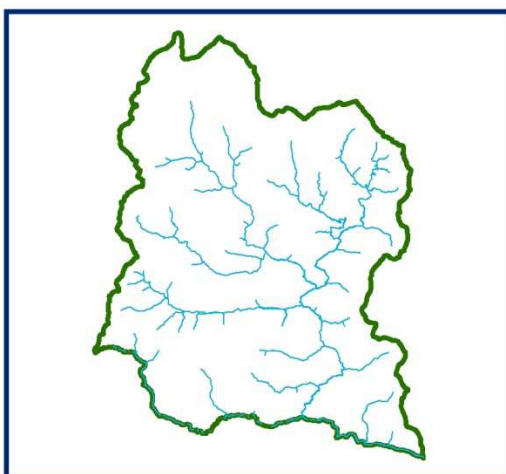
**8 MAY 2012**



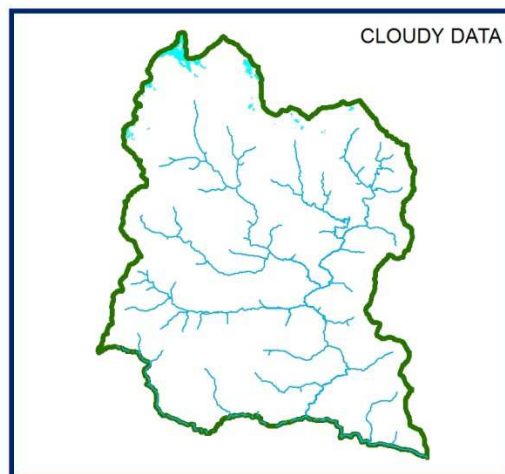
**13 MAY 2012**



**18 MAY 2012**



**DATA NOT AVAILABLE**



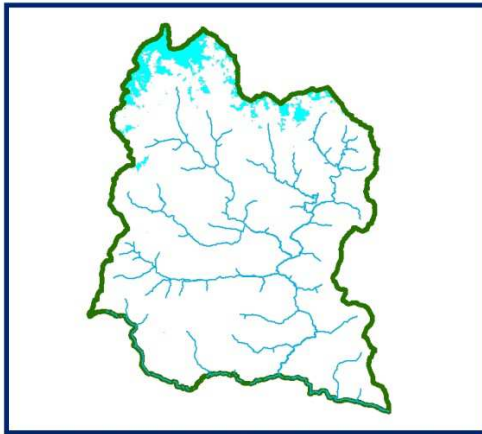
**28 MAY 2012**



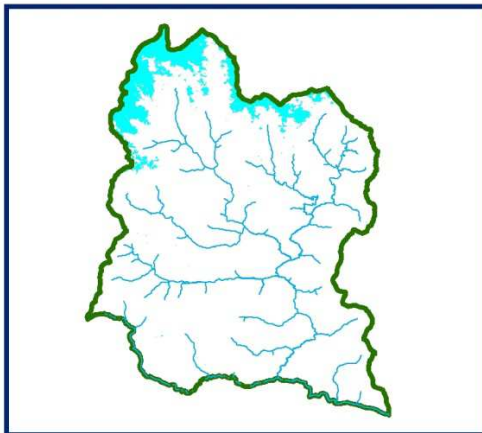
**SNOW**

0 5 10 20 30 40  
Kilometers

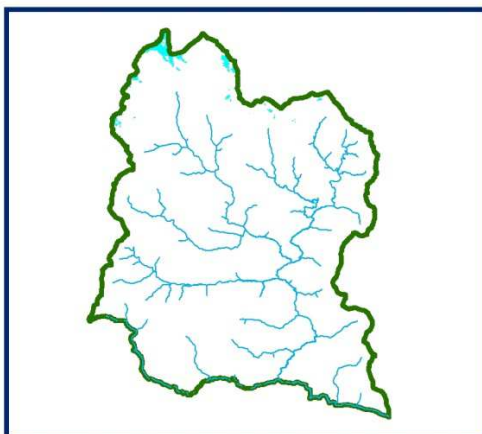
# COMPOSITE SNOW COVER MAP (10 DAILY):RANGIT BASIN



DATA USED  
**8 MAY 2012**



DATA USED  
**13 MAY 2012**



DATA USED  
**28 MAY 2012**



SNOW

