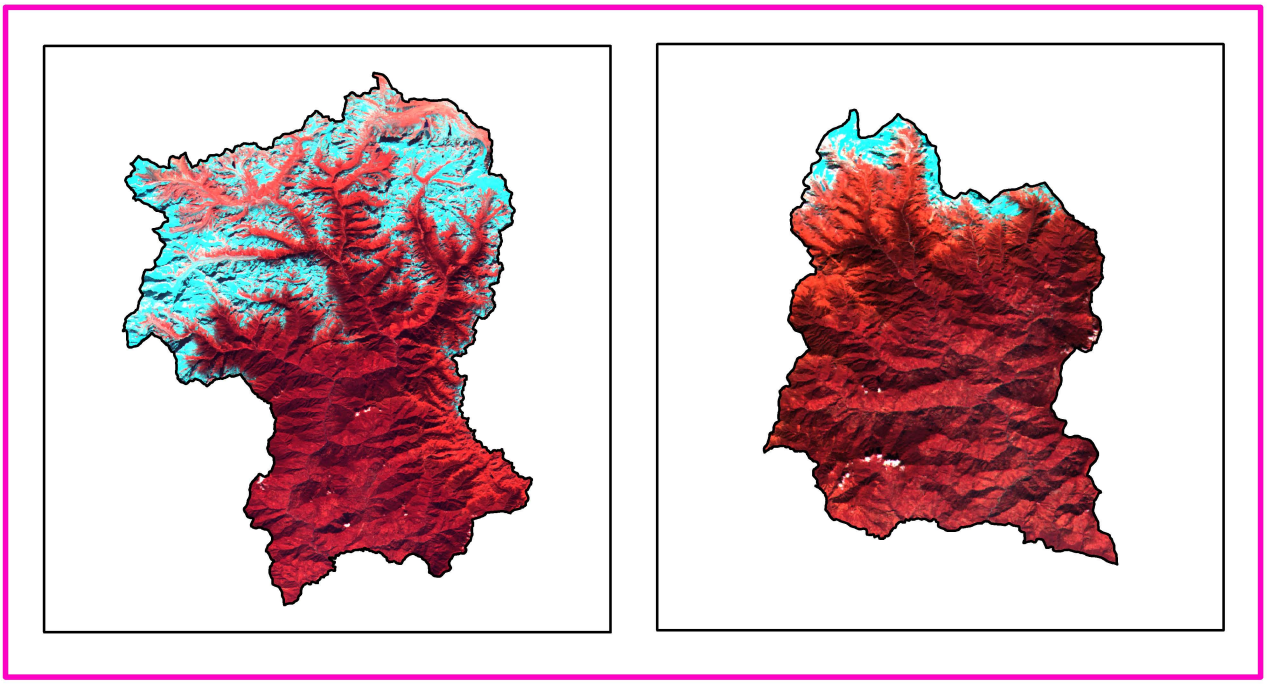
SNOW COVER ATLAS OF TISTA BASIN

Sub basins: Tista and Rangit

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

Year : 2009-10



Space Applications Centre (ISRO)
Ahmedabad - 380015

December 2012

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DOCUMENT CONTROL AND DATA SHEET

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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 2008 to June 2009. 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

CONTENTS

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 2008 to June 2009 were used in this study.

4. Normalised Difference Snow Index (NDSI):

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

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

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

To estimate NDSI, DN numbers were converted into reflectance. This involves conversion of digital numbers into the radiance values, known as sensor calibration, and then estimation of reflectance

from these radiance values. Various parameters needed for estimating spectral reflectance are maximum and minimum radiances and mean solar exo-atmospheric spectral irradiances in the satellite sensor bands, satellite data acquisition time, solar declination, solar zenith and solar azimuth angles, mean Earth-Sun distance etc. (Markham and Barker, 1987; Srinivasulu and Kulkarni, 2004).

5. Snow cover monitoring algorithm

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

6. Results and discussions

In this atlas, state and basin-wise snow cover statistics, maps, and seasonal depletion curves have been provided from October 2008 to June 2009. Snow accumulation and ablation pattern was estimated for Tista and Rangit basins in the Sikkim Himalaya. In Tista, maximum areal extent of 46% was observed in the end of October 2008 and reduced to 18% in the month of December. The highest

snow areal extent 15% was observed in Rangit basins for the month of December. It was reduced to 3% in the month of January. Continuous accumulation & ablation was observed in both the basin.

Acknowledgements

This investigation 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.

References

Agarwal, K. G., Kumar, V. and T. Das, 1983, Melt runoff for a subcatchment of Beas basin. In Proceedings of the First National Symposium on Seasonal Snow Cover, New Delhi, India, April 28-30, 43 p.

Foster, J. L. and Chang, A. T. C., 1993, Snow cover, in Atlas of satellite observations related to global change. R. J. Gurney, C.L. Parkinson and J. L. Foster (eds.), Cambridge University Press, Cambridge, pp. 361-370.

Hall, D. K., Riggs, G. A. and Salomonson, V. V., 1995, Development of methods for mapping global snow cover using moderate resolution Image Spectroradiometer data. Remote Sensing of Environment, 54, pp. 127-140.

Kulkarni, A. V., Mathur, P., Rathore, B. P., Alex, S., Thakur N. and Kumar, M. 2002, Effect of global warming on snow ablation pattern in the Himalayas. Current Science, 83(2), pp 120-123.

Kulkarni A. V., Singh, S. K., Mathur, P. and Mishra, V. D., 2006, Algorithm to monitor snow cover using AWiFS data of RESOURCESAT for the Himalayan region. International Journal of Remote Sensing, 27(12), pp 2449-2457.

Kulkarni, A. V., Randhawa, S. S. and Sood, R. K., 1997, A stream flow simulation model in snow covered areas to estimate hydro-power potential: a case study of Malana nala, H.P. Proc. of the First international Conference on Renewable Energy- Small Hydro, Hyderabad, pp 761-770.

Markham, B. L. and Barker, J. L., 1987, Thematic Mapper bandpass solar exoatmospheric irradiances. International Journal of Remote Sensing, 8(3), pp 517-523.

Singer, F. S. and Popham, R. W., 1963. Non-meteorological observations from satellite.
Astronautics and Aerospace Engineering 1(3), 89-92.

Srinivasulu, J. and Kulkarni, A. V., 2004, A satellite based spectral reflectance model for snow and glacier studies in the Himalayan terrain. Proceedings of the Indian Academy of Science (Earth and Planetary Science), 113 (1), pp. 117-128.

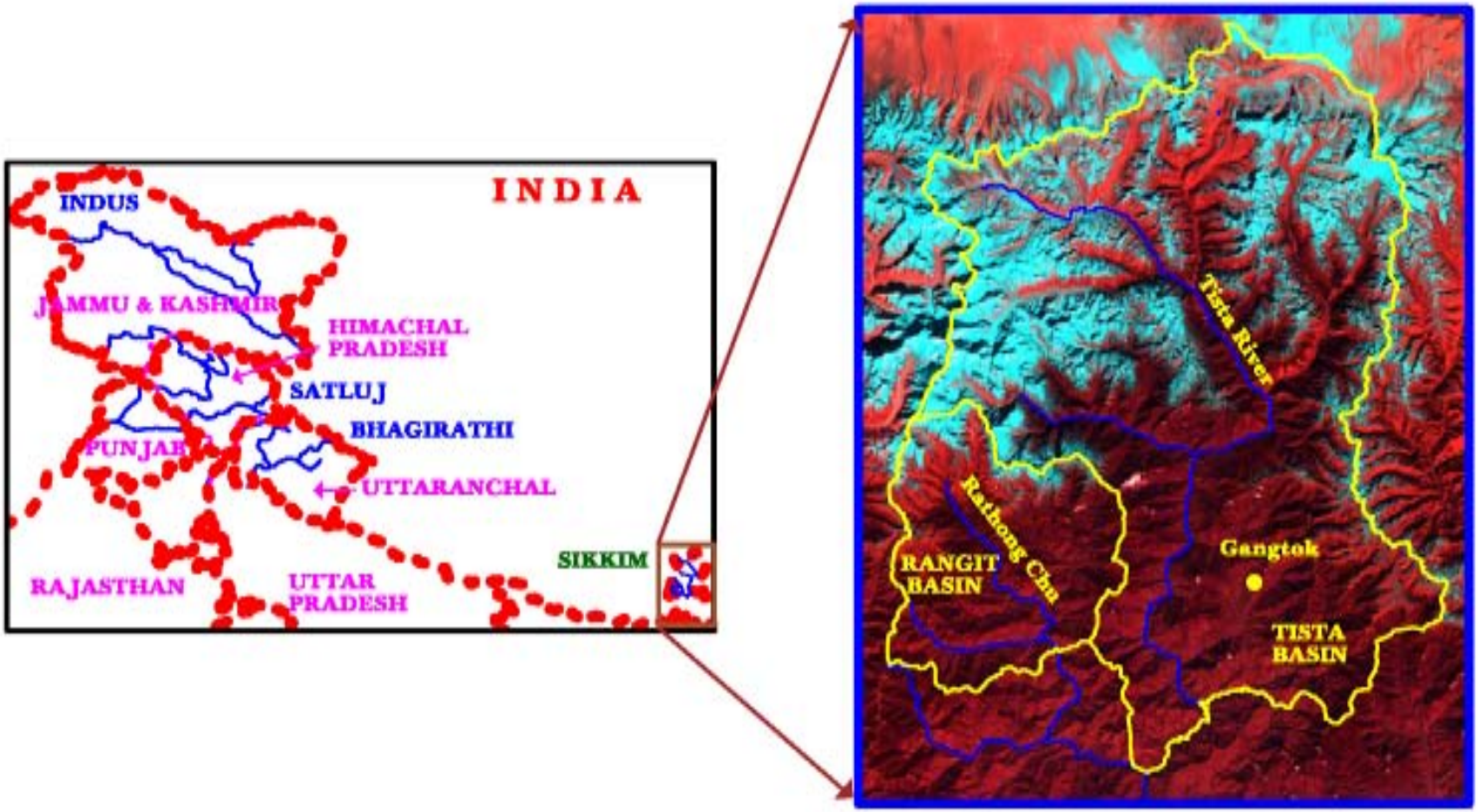


Figure 1: Location map of Tista and Rangit sub-basins (Part of Tista basin)

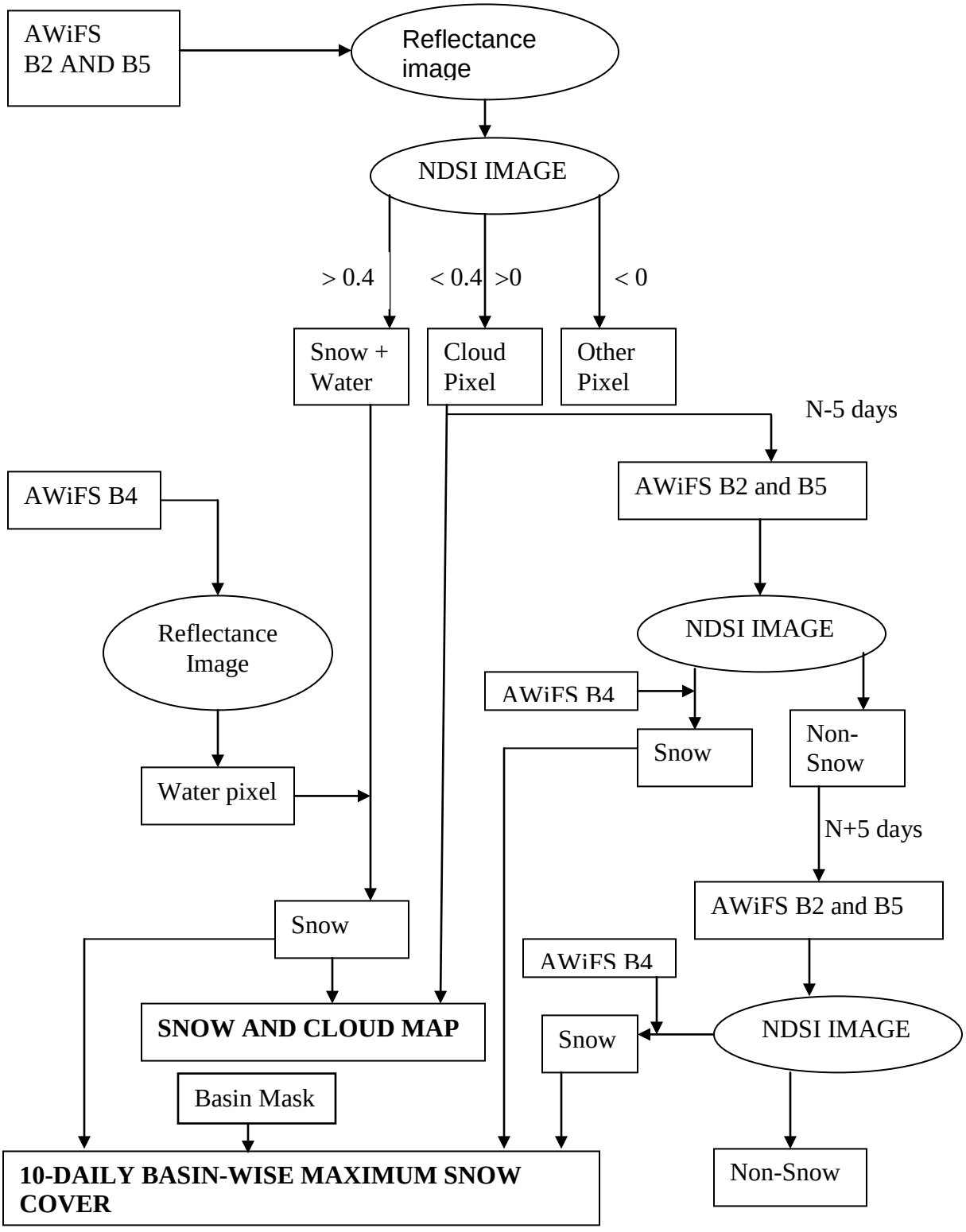


Figure 2: Algorithm for snow cover mapping using AWiFS data

TISTA BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: TISTA **BASIN AREA: 5310 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008							
1	10-Oct-08	832.9	16	5	21-Oct-08	533.3	10
2	11-Oct-08	799.8	15	6	25-Oct-08	802.9	15
3	15-Oct-08	635.0	12	7	30-Oct-08	2428.8	46
4	16-Oct-08	791.5	15				
November 2008							
8	8-Nov-08	2052.1	39	12	18-Nov-08	1498.6	28
9	9-Nov-08	1865.4	35	13	23-Nov-08	1832.5	35
10	13-Nov-08	1692.8	32	14	28-Nov-08	1396.1	26
11	14-Nov-08	1512.2	28				
December 2008							
15	2-Dec-08	1249.0	24	19	22-Dec-08	610.6	11
16	3-Dec-08	1133.0	21	20	26-Dec-08	818.1	15
17	8-Dec-08	995.3	19	21	27-Dec-08	2245.4	42
18	17-Dec-08	940.4	18				
January 2009							
22	10-Jan-09	2039.8	38	26	20-Jan-09	1025.4	19
23	14-Jan-09	1521.2	29	27	24-Jan-09	563.5	11
24	15-Jan-09	1471.5	28	28	29-Jan-09	851.7	16
25	19-Jan-09	1275.1	24	29	29-Jan-09	853.7	16
February 2009							
30	3-Feb-09	1215.8	23	35	17-Feb-09	1188.0	22
31	8-Feb-09	874.9	16	36	18-Feb-09	754.7	14
32	8-Feb-09	871.2	16	37	22-Feb-09	1703.6	32
33	12-Feb-09	2576.2	49	38	27-Feb-09	791.2	15
34	13-Feb-09	1937.3	36				
March 2009							
39	3-Mar-09	2021.0	38	42	9-Mar-09	1237.0	23
40	4-Mar-09	1990.5	37	43	14-Mar-09	1493.1	28
41	8-Mar-09	1720.9	32	44	23-Mar-09	1396.7	26
April 2009							
45	1-Apr-09	2937.5	55	48	25-Apr-09	973.8	18
46	6-Apr-09	908.6	17	49	25-Apr-09	973.4	18
47	16-Apr-09	415.6	8	50	26-Apr-09	590.6	11

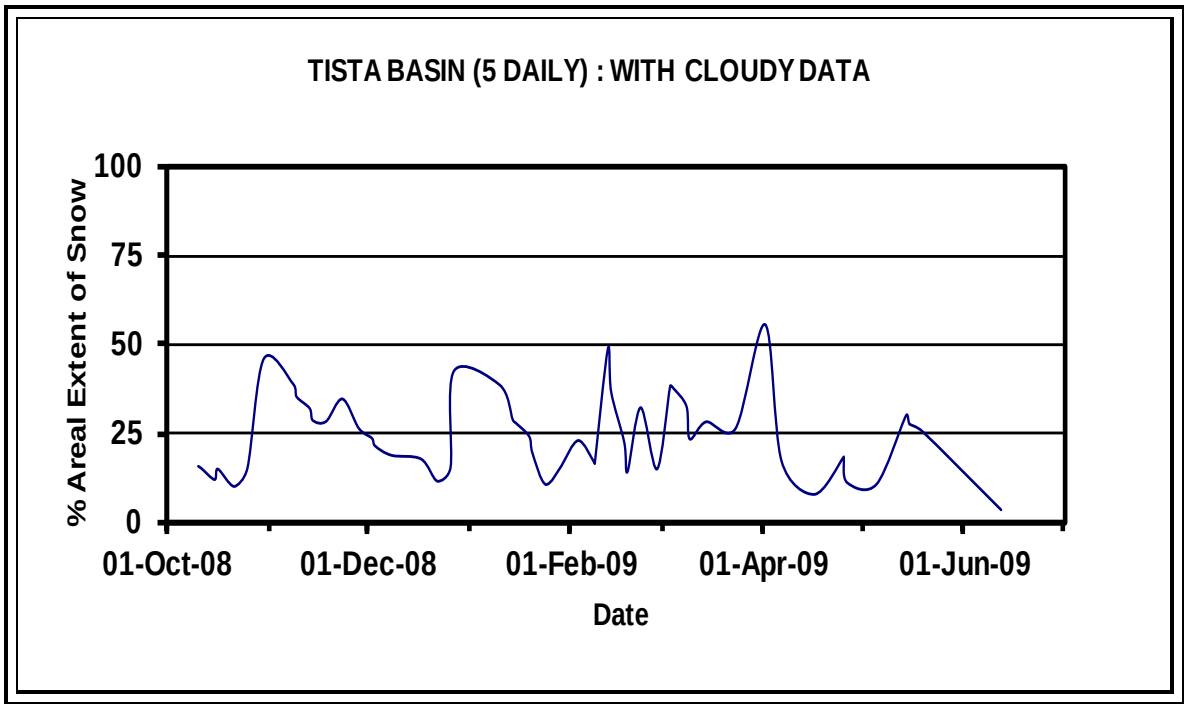
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
51	5-May-09	567.0	11	53	15-May-09	1460.2	27
52	14-May-09	1586.9	30	54	19-May-09	1349.4	25
June 2009							
55	12-Jun-09	185.7	3				

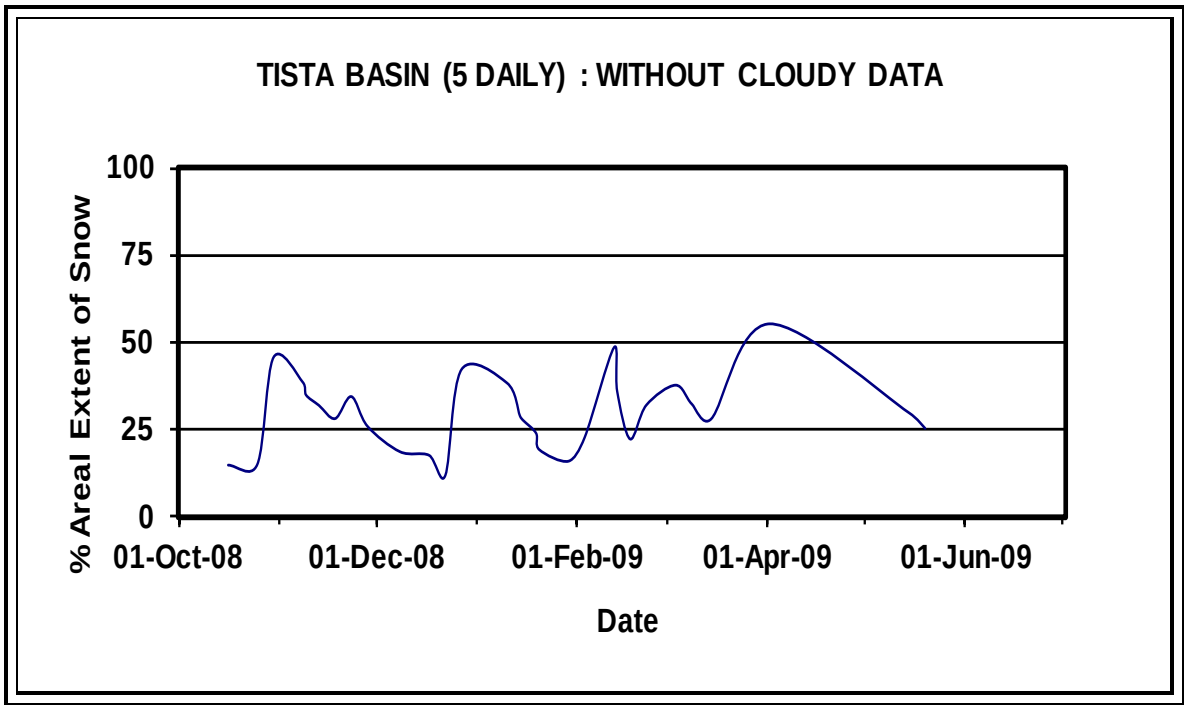
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: TISTA **BASIN AREA: 5310 Sq km**

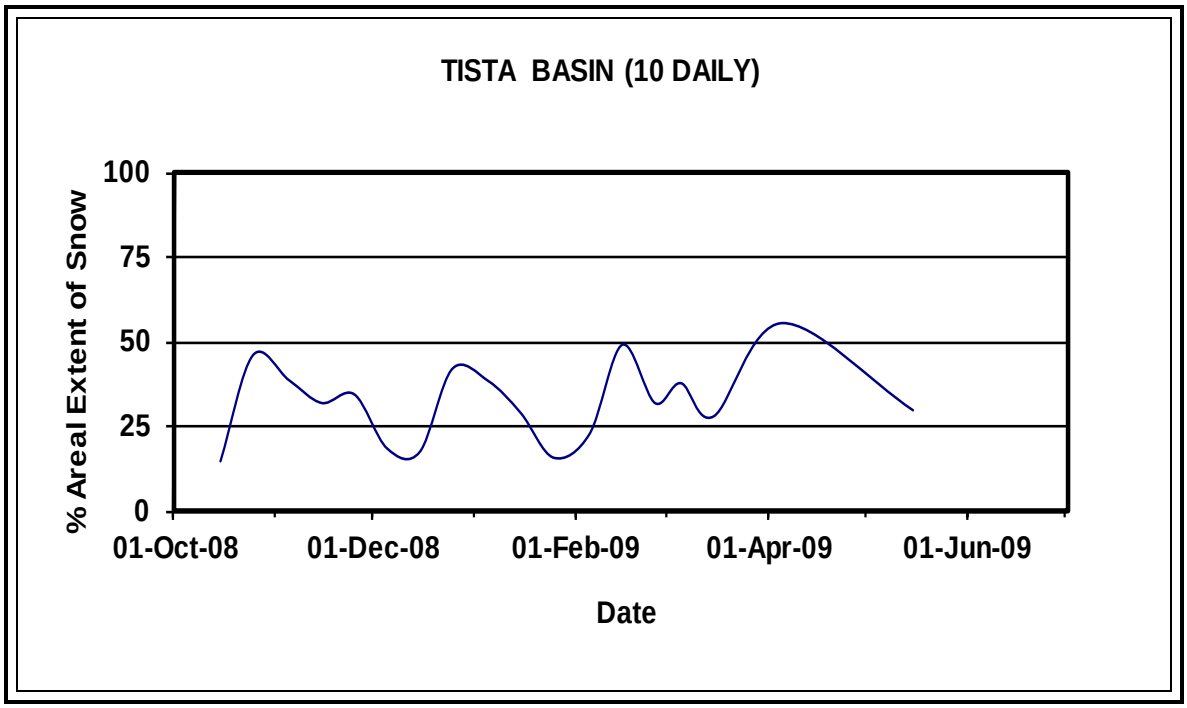
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
1	15-oct-08	796.5	15	3	5-Nov-08	2052.1	39
2	25-oct-08	2443	46	4	15-Nov-08	1564.5	32
				5	25-Nov-08	1832.5	35
December 2008				**January 2009**			
6	8-Dec-08	995.3	19	9	5-Jan-09	2039.8	38
7	17-Dec-08	940.4	18	10	15-Jan-09	1540	29
8	22-Dec-08	2073.0	42	11	25-Jan-09	851.7	16
February 2009				**March 2009**			
12	5-Feb-09	1221	23	15	5-Mar-09	2006.0	38
13	15-Feb-09	2602	49	16	15-Mar-09	1493.1	28
14	25-Feb-09	1669.2	32				
April 2009				**May 2009**			
18	5-Apr-09	2937.5	55	19	15-May-09	1586.9	30
June 2009							

Snow cover depletion curve



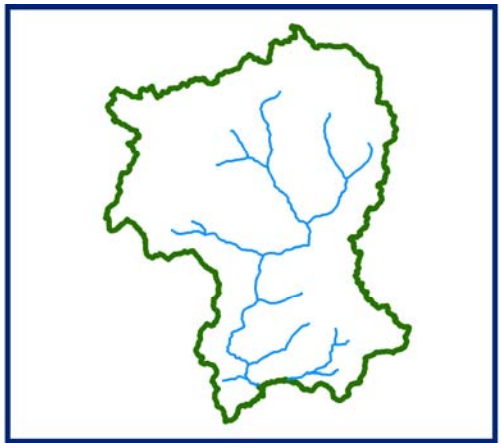


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : TISTA BASIN



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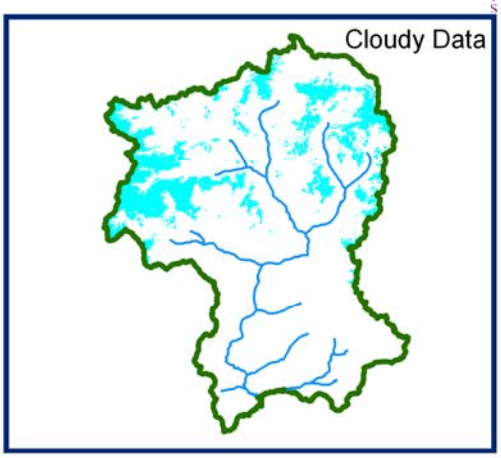

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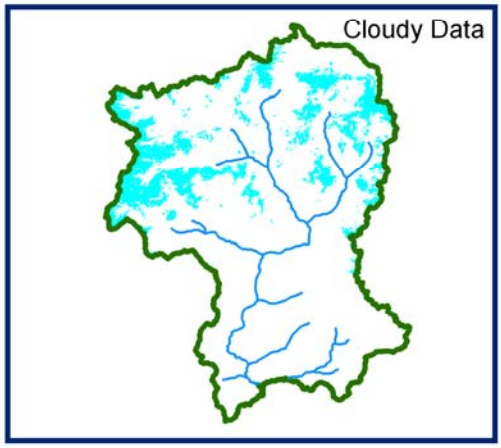

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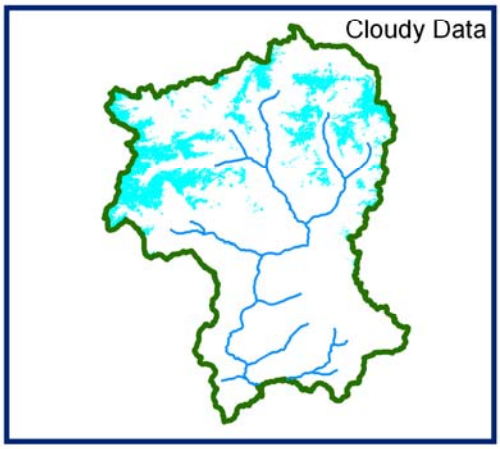

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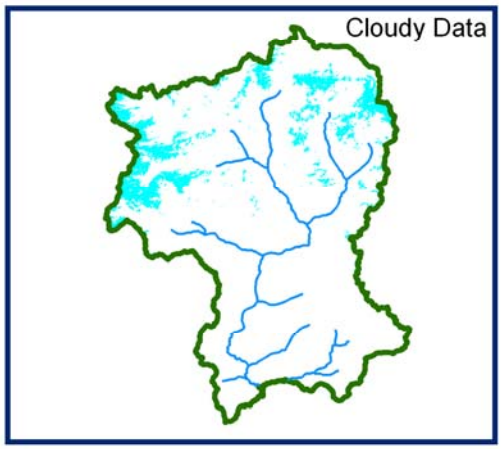

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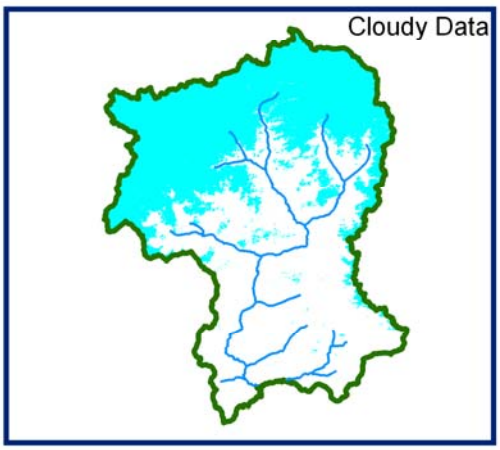


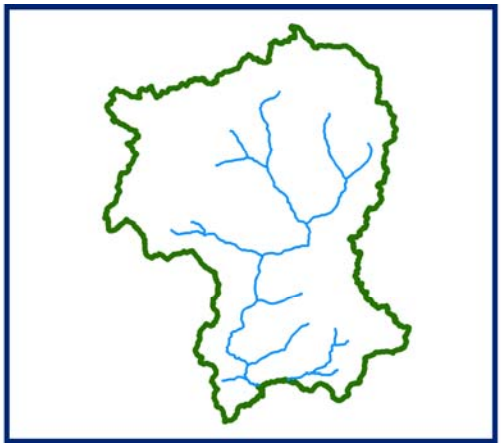
30 OCTOBER 2008

SNOW

37.5 0 37.5 75 112.50

Kilometers

10 DAILY SNOW COVER MAP: TISTA BASIN



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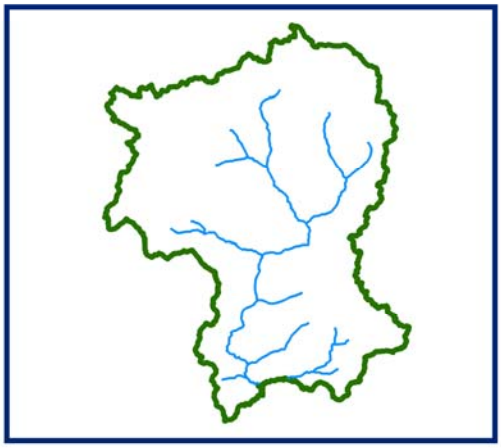

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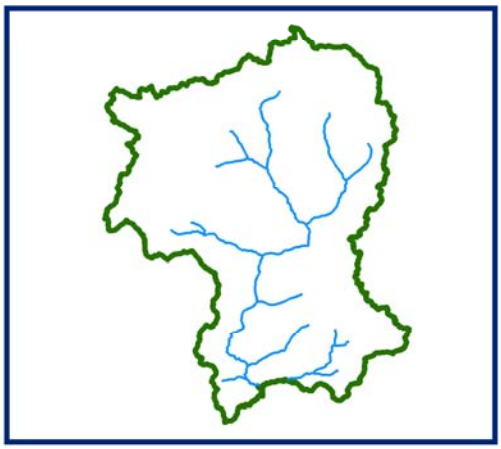

DATA USED

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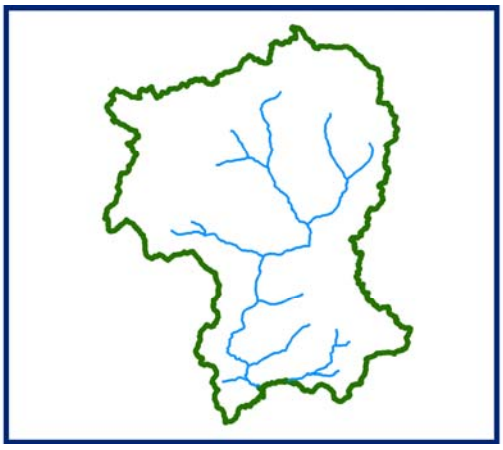
SNOW

0 5 10 20 30 40

Kilometers

SNOW COVER MAP : TISTA BASIN



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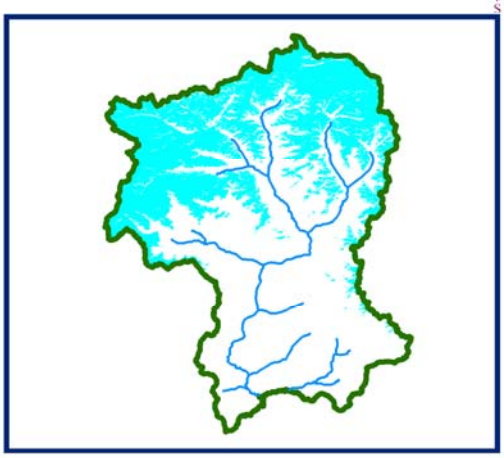

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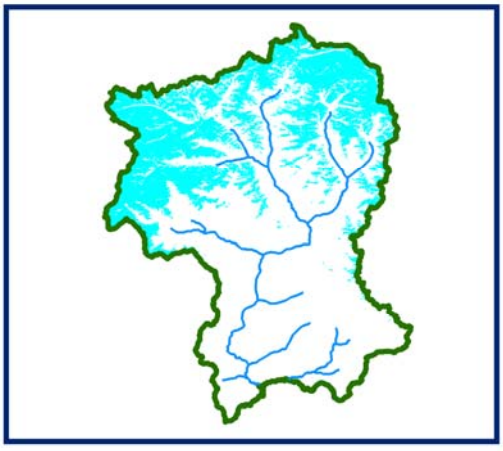

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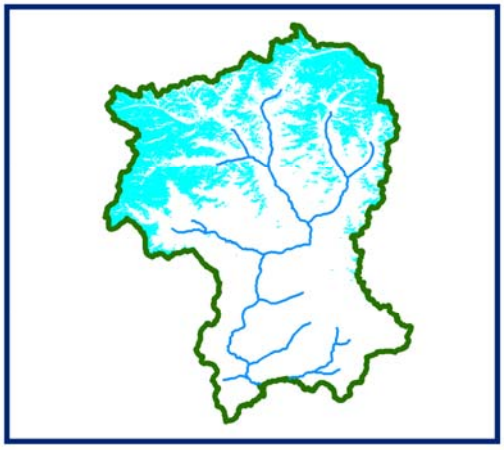

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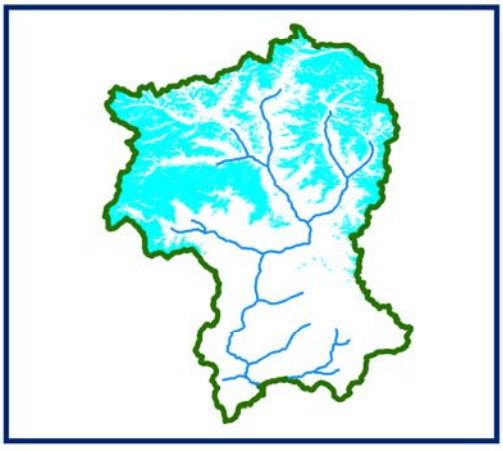

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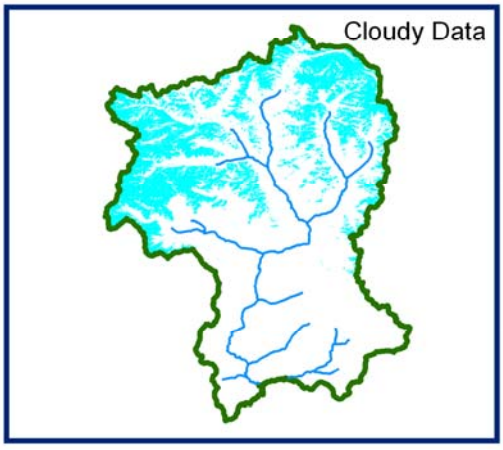


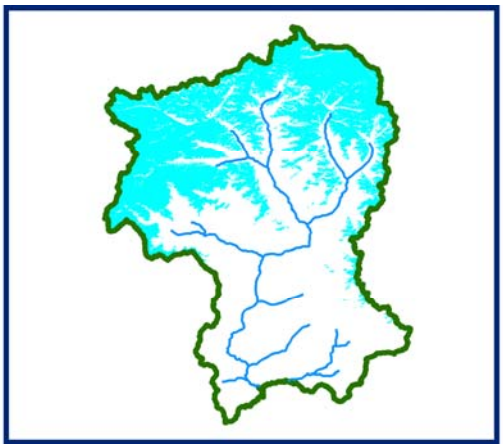
28 NOVEMBER 2008

SNOW

37.5 0 37.5 75 112.50

Kilometers

10 DAILY SNOW COVER MAP: TISTA BASIN



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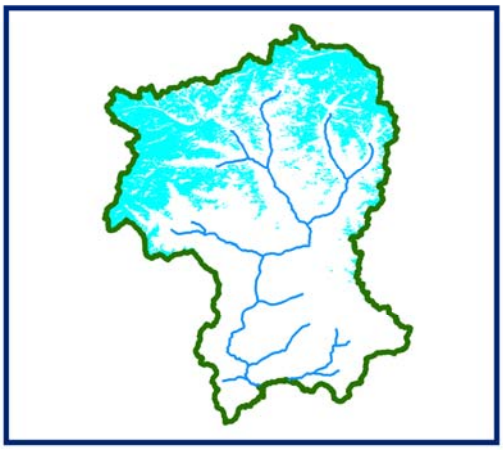

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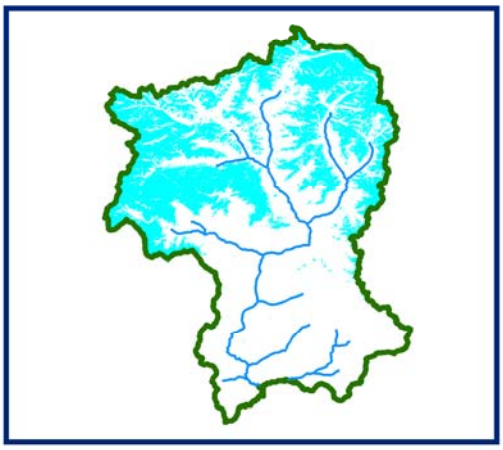

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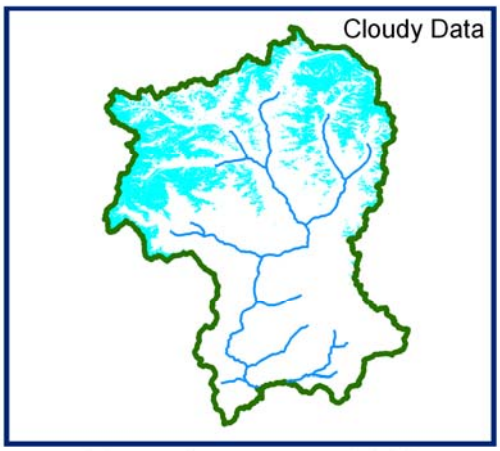
SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : TISTA BASIN



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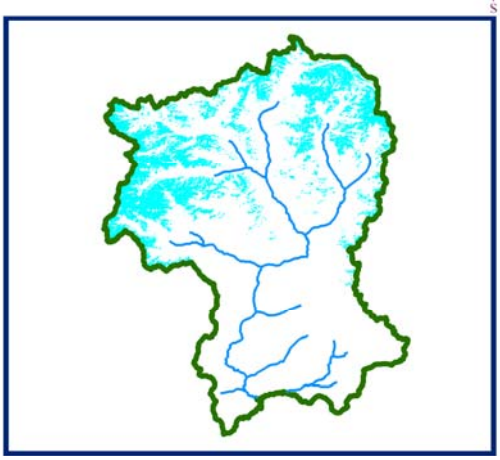

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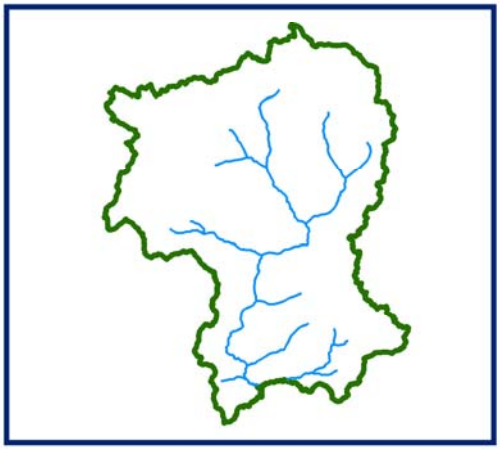

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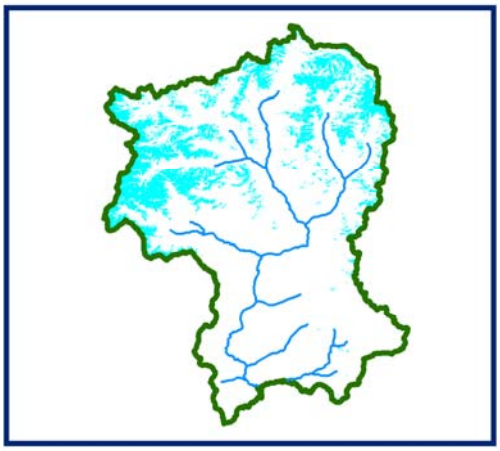
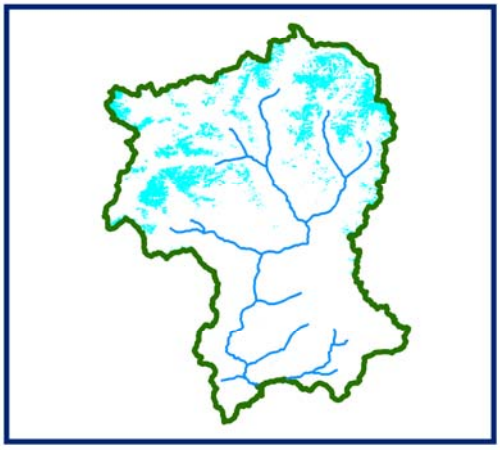
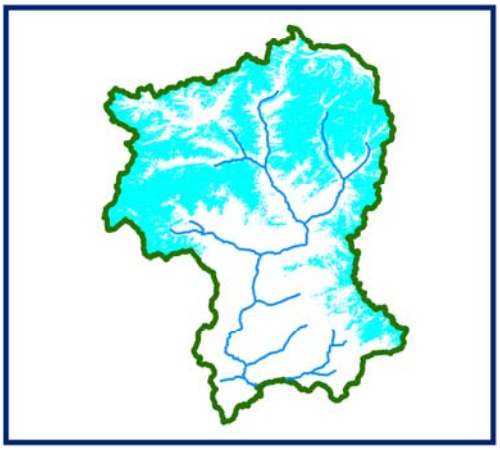


17 DECEMBER 2008



22 DECEMBER 2008



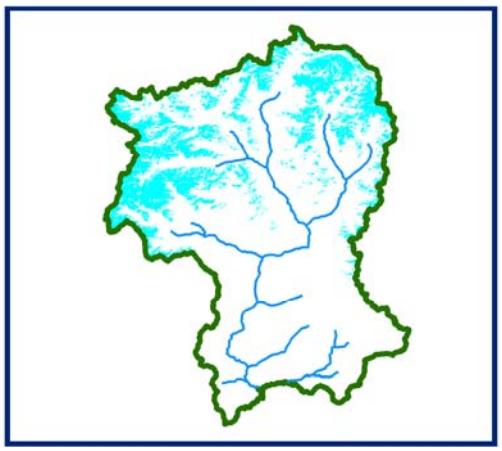
27 DECEMBER 2008

SNOW

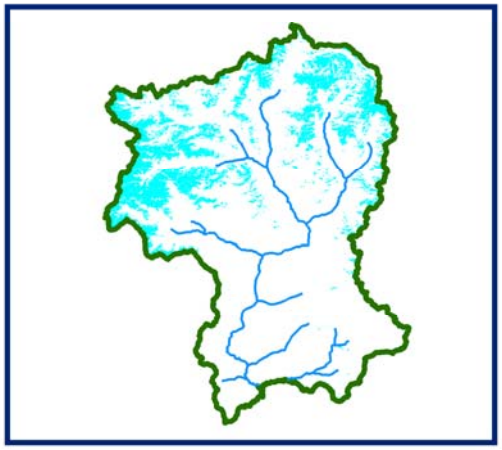
0 37.5 75 112.50

Kilometers

10 DAILY SNOW COVER MAP: TISTA BASIN



DATA USED
08 DECEMBER 2008



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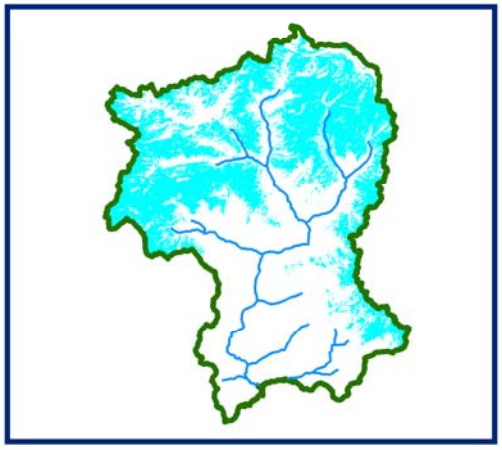
17 DECEMBER 2008

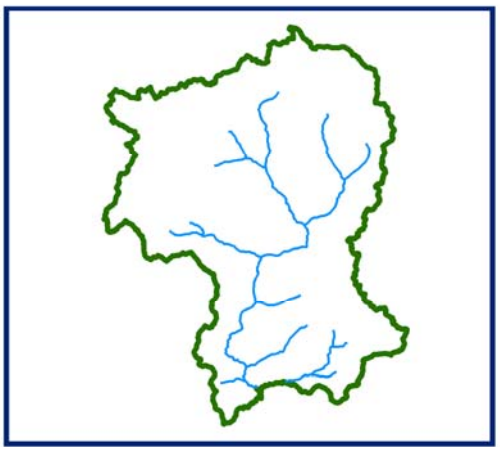


DATA USED
22 DECEMBER 2008
27 DECEMBER 2008

SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : TISTA BASIN



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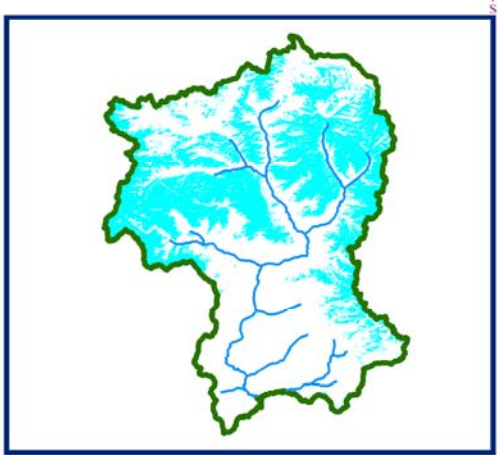
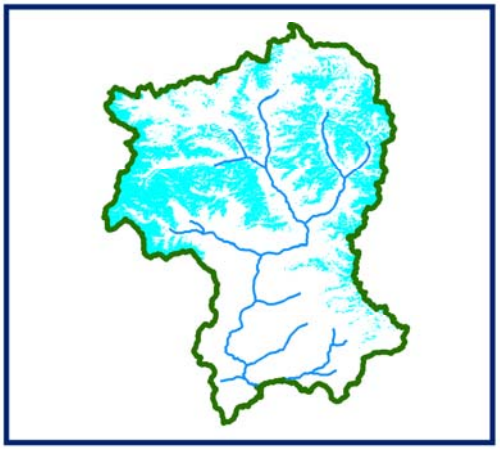
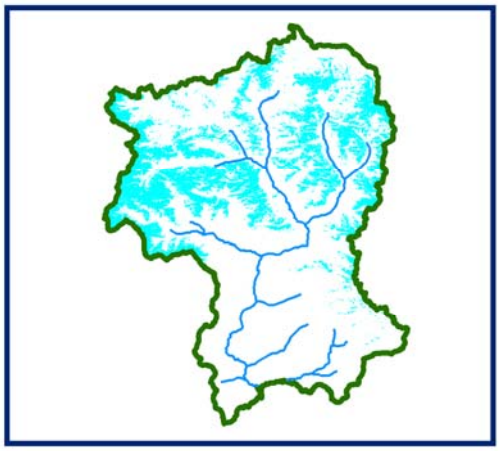


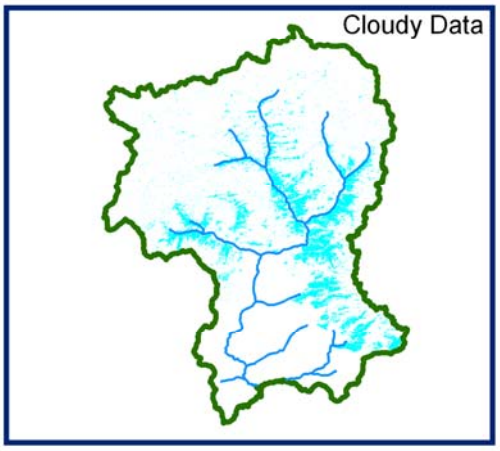
10 JANUARY 2009



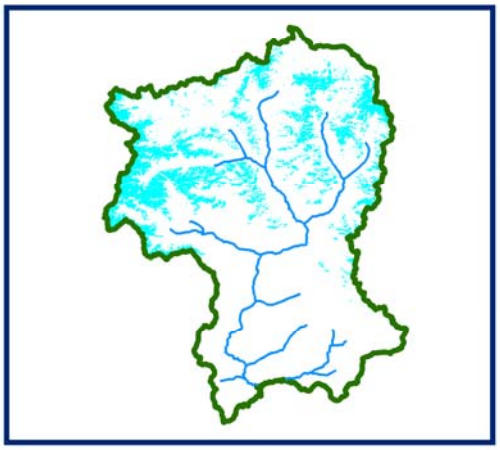
14 JANUARY 2009



19 JANUARY 2009



24 JANUARY 2009



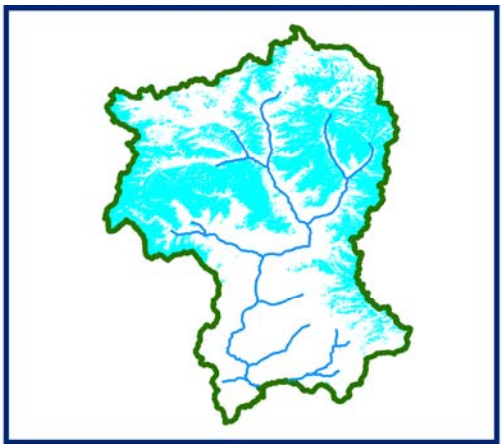
29 JANUARY 2009

SNOW

0 37.5 75 112.50

Kilometers

10 DAILY SNOW COVER MAP: TISTA BASIN



DATA USED
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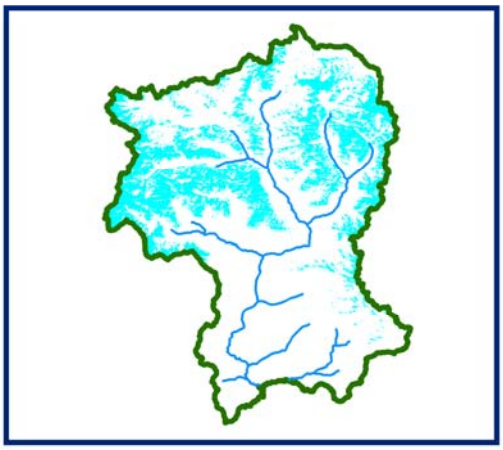
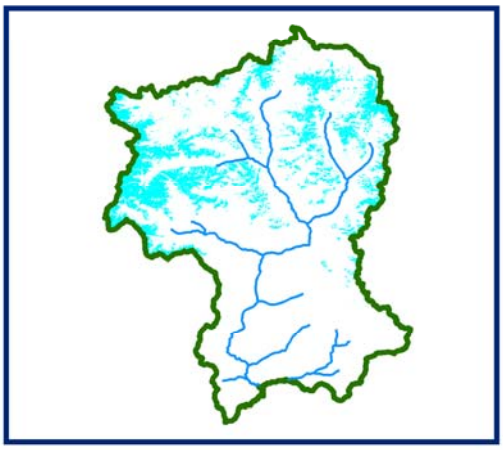


DATA USED
14 JANUARY 2009
19 JANUARY 2009

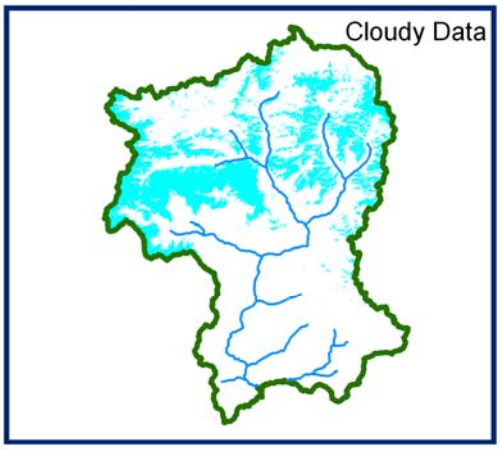


DATA USED
29 JANUARY 2009

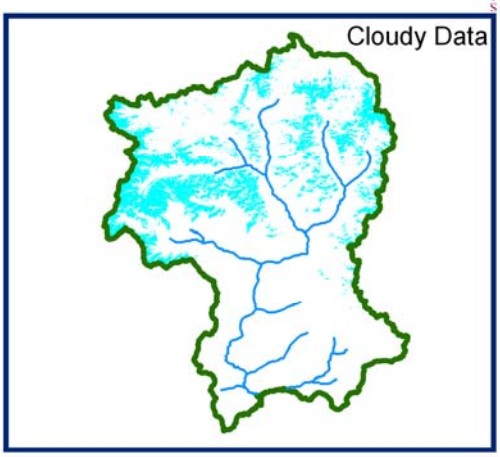
SNOW

0 5 10 20 30 40
Kilometers

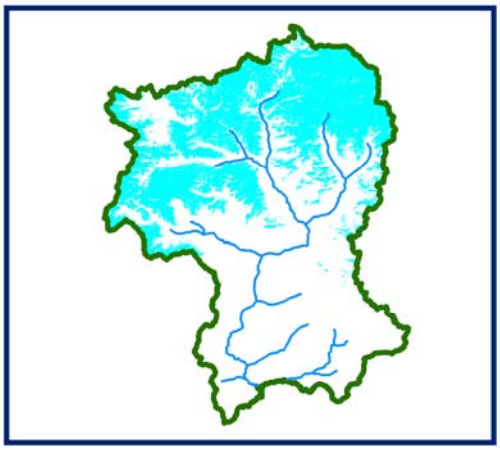
SNOW COVER MAP : TISTA BASIN



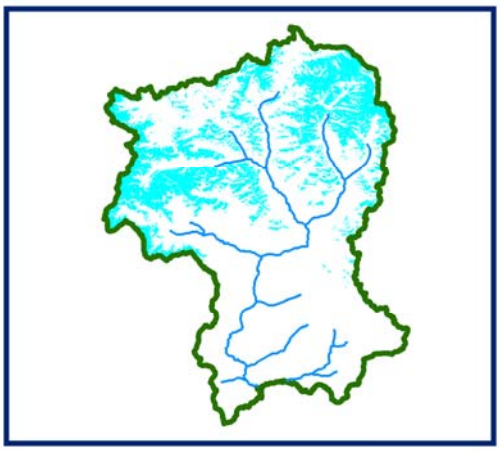
03 FEBRUARY 2009



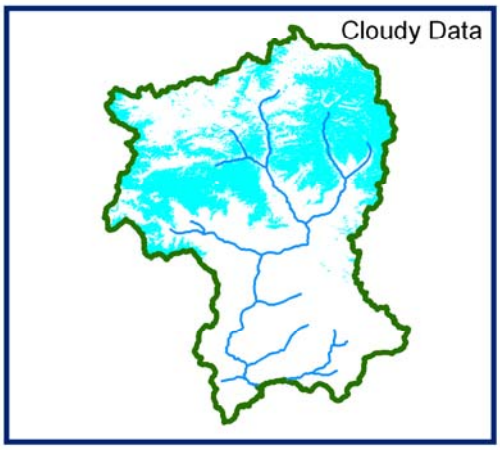
08 FEBRUARY 2009



13 FEBRUARY 2009



17 FEBRUARY 2009



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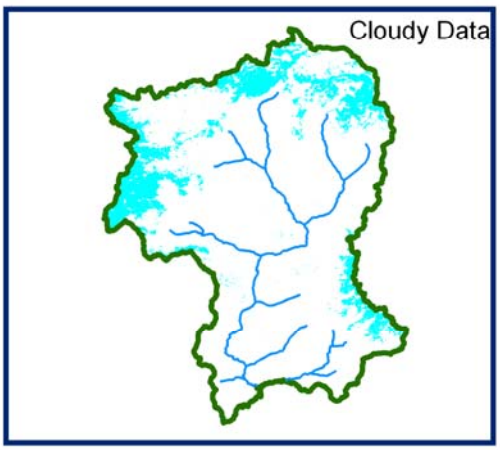


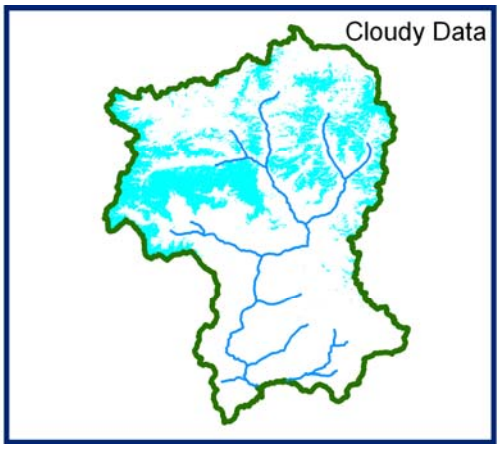
27 FEBRUARY 2009

SNOW

37.5 0 37.5 75 112.5 150

Kilometers

SNOW COVER MAP : TISTA BASIN



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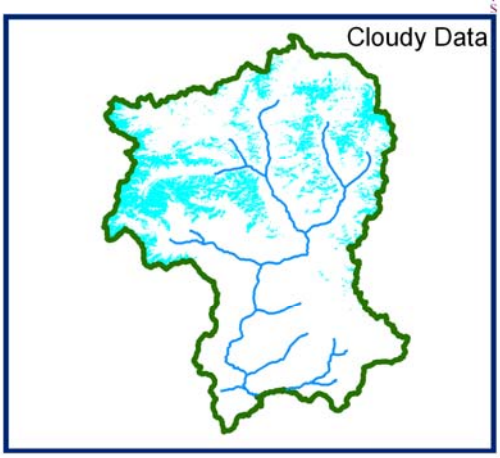

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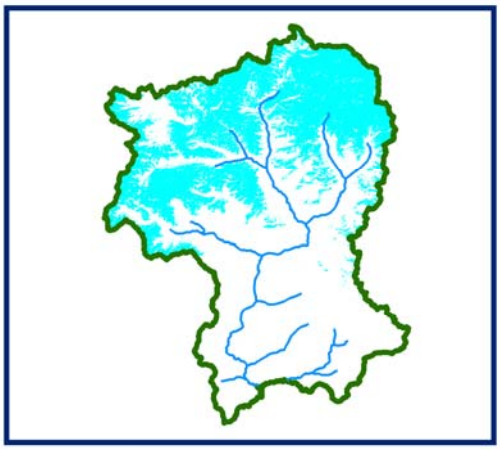

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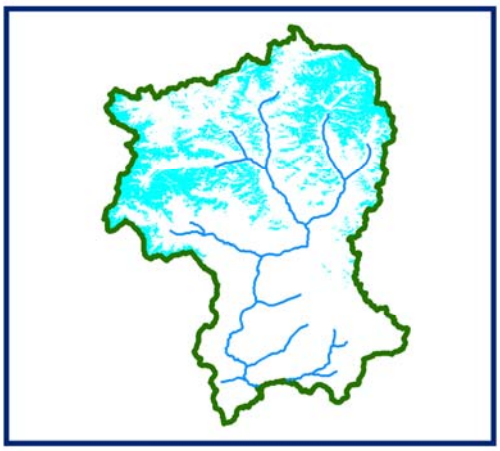

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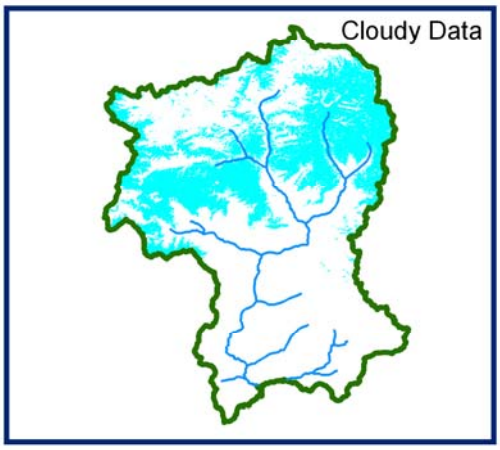
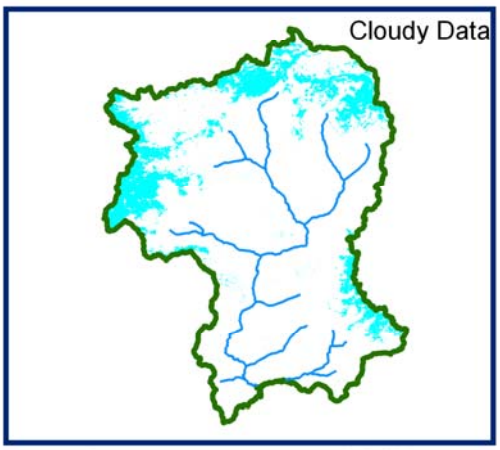


22 FEBRUARY 2009



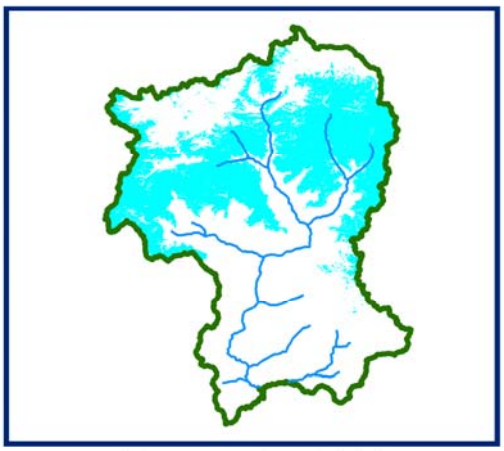
27 FEBRUARY 2009

SNOW

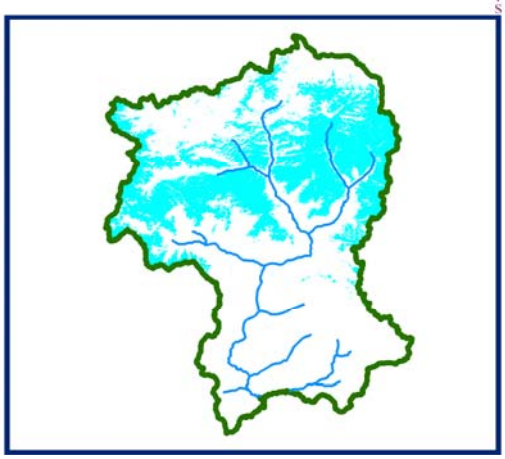
37.5 0 37.5 75 112.50

Kilometers

SNOW COVER MAP : TISTA BASIN



03 MARCH 2009



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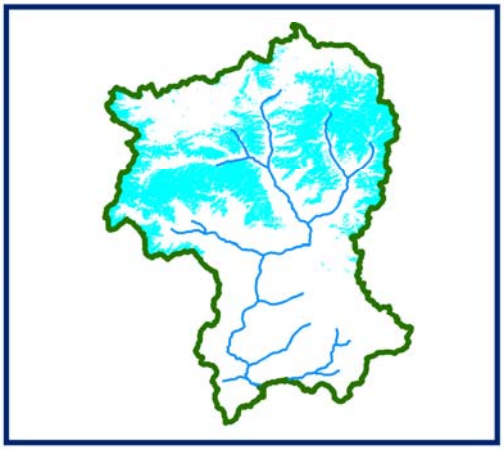

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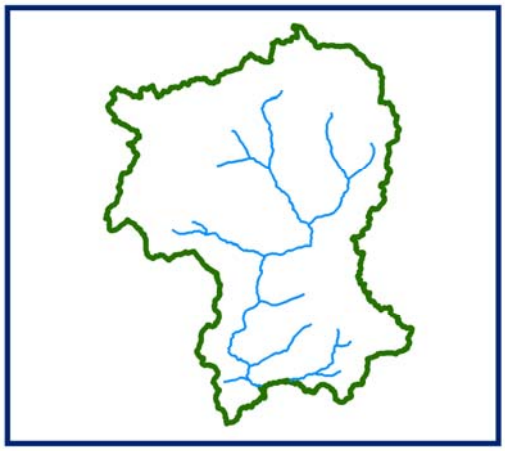

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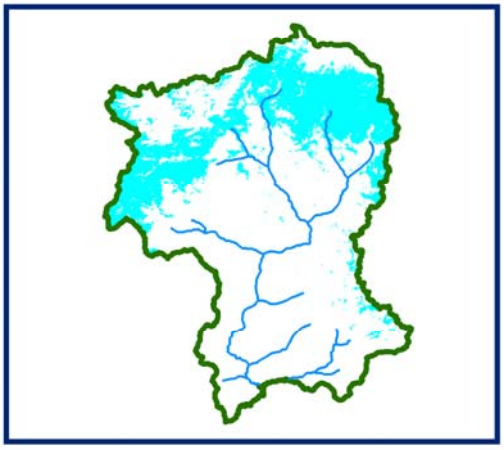
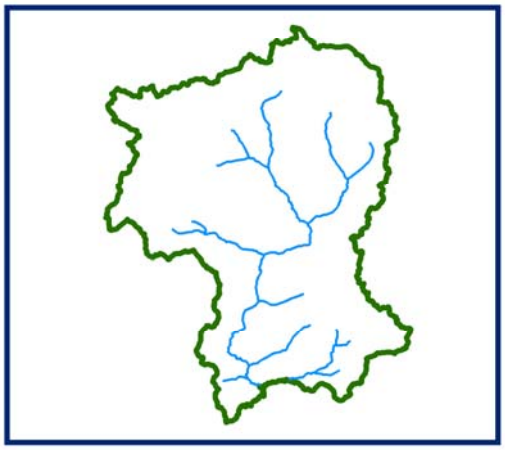


23 MARCH 2009



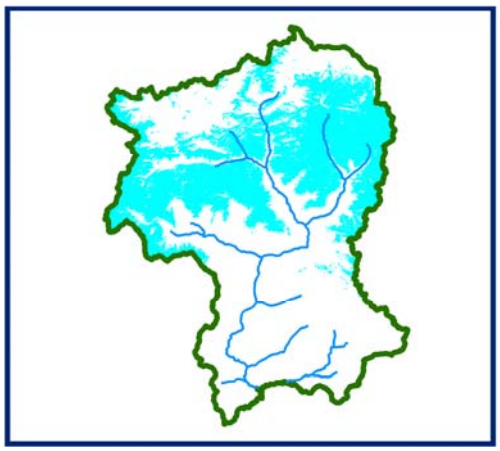
DATA NOT AVAILABLE

SNOW

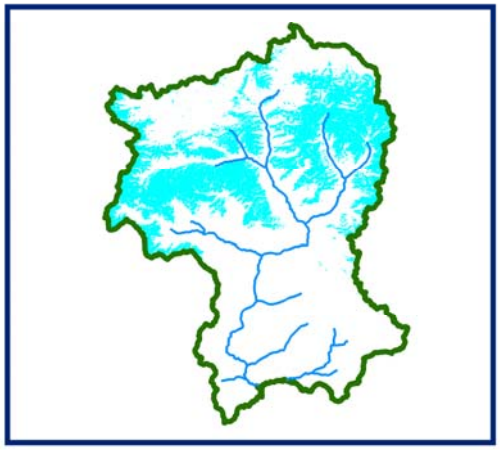
37.5 0 37.5 75 112.50

Kilometers

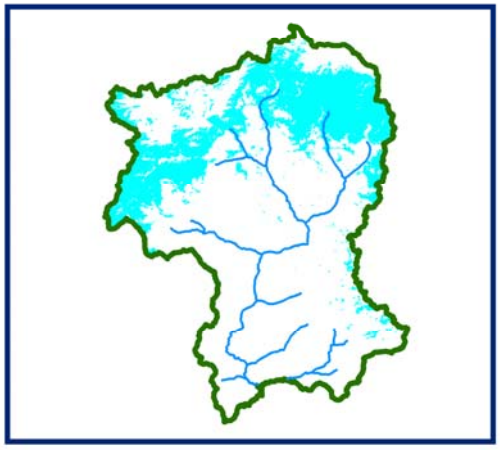
10 DAILY SNOW COVER MAP: TISTA BASIN



DATA USED
03 MARCH 2009
08 MARCH 2009



DATA USED
14 MARCH 2009

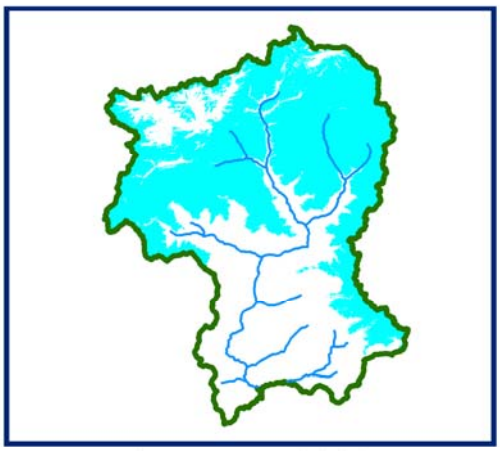


DATA USED
23 MARCH 2009

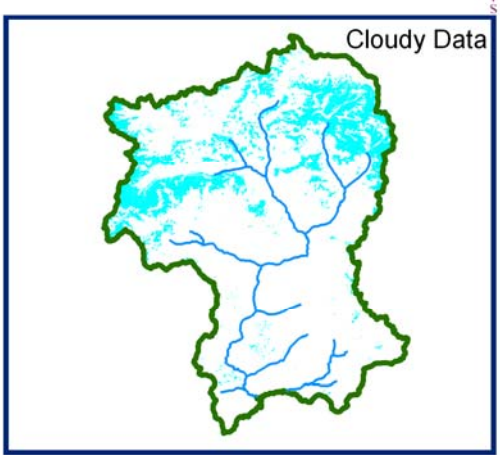
SNOW

0 5 10 20 30 40
Kilometers

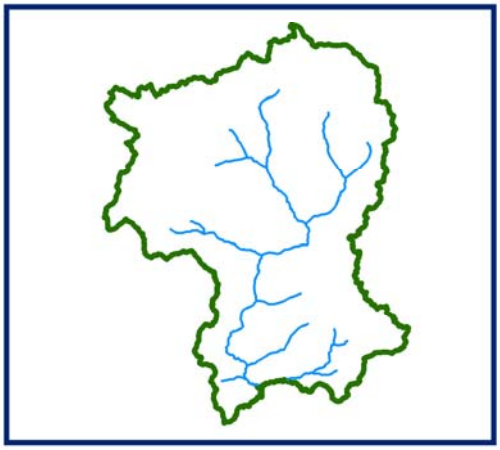
SNOW COVER MAP : TISTA BASIN



01 APRIL 2009



06 APRIL 2009



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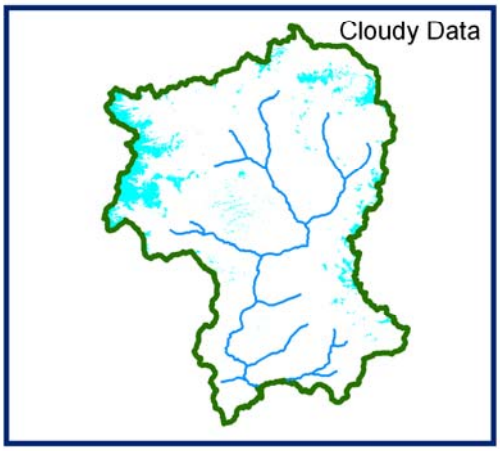
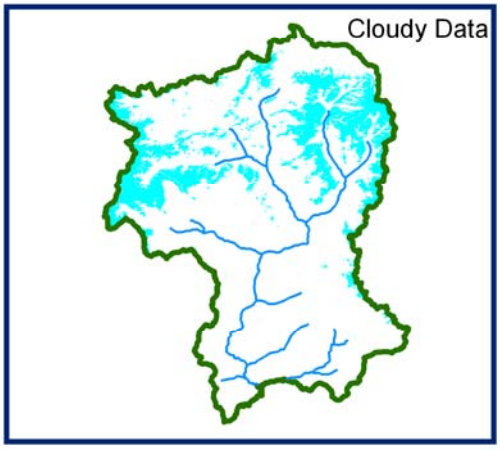
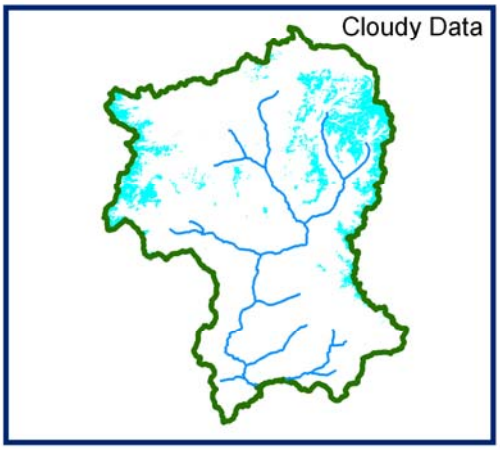


16 APRIL 2009



25 APRIL 2009



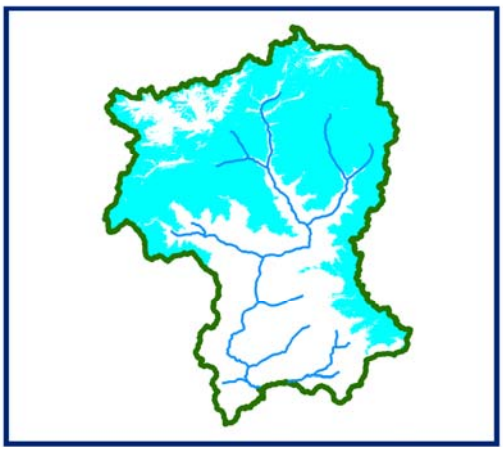
26 APRIL 2009

SNOW

37.5 0 37.5 75 112.5 150

Kilometers

10 DAILY SNOW COVER MAP: TISTA BASIN



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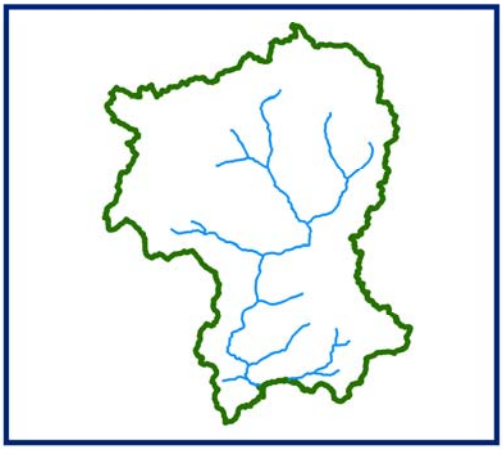
01 APRIL 2009



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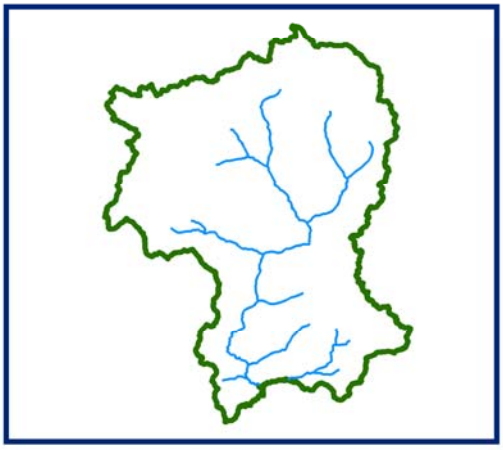
DATA NOT AVAILABLE

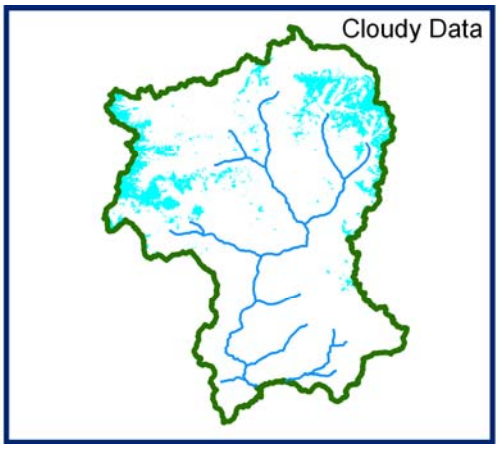


DATA USED
DATA NOT AVAILABLE

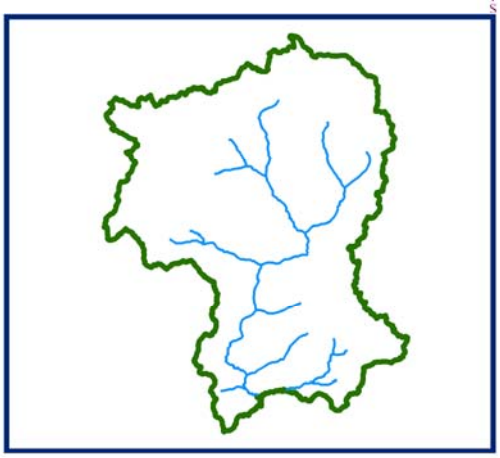
SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : TISTA BASIN



05 MAY 2009



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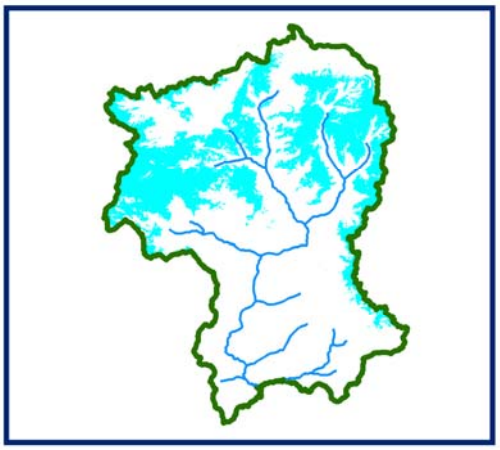
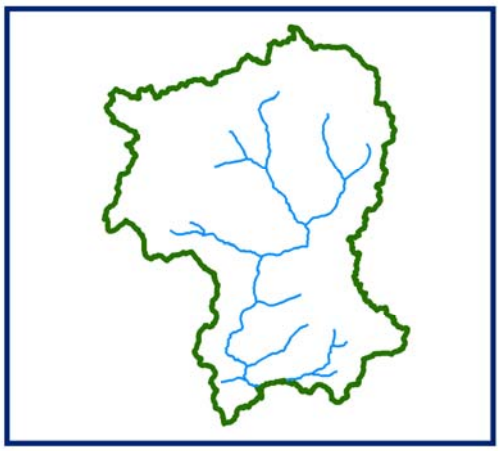


14 MAY 2009



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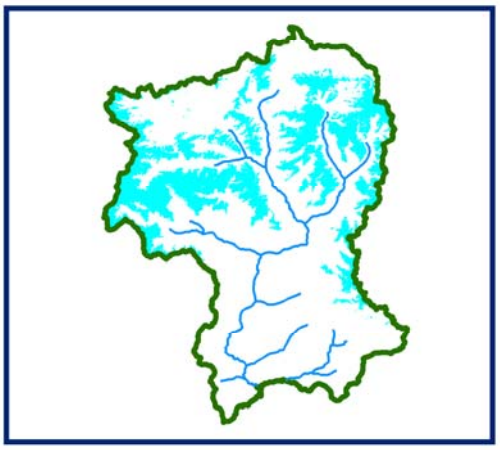
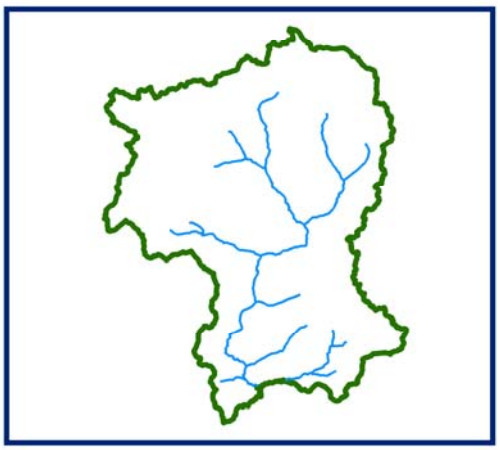


19 MAY 2009



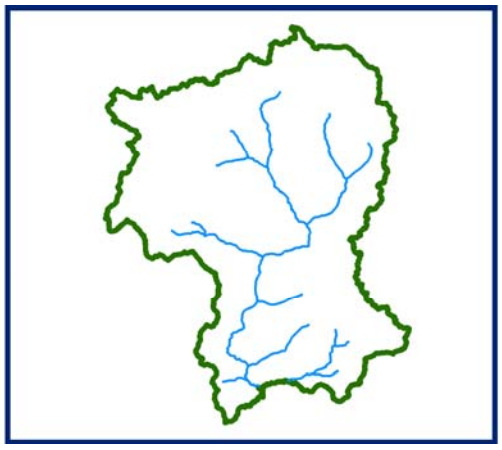
DATA NOT AVAILABLE

SNOW

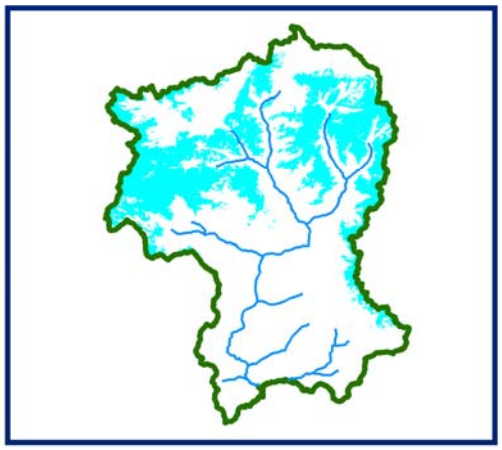
37.5 82.50

Kilometers

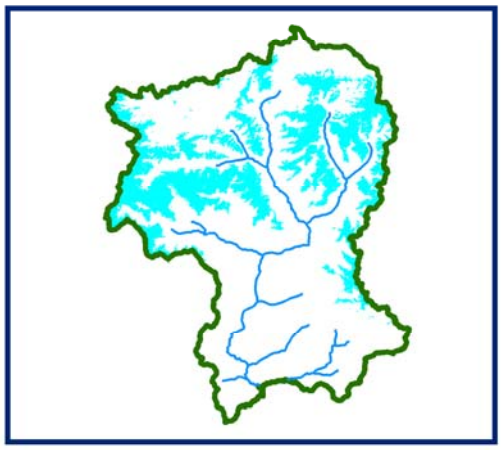
10 DAILY SNOW COVER MAP: TISTA BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
14 MAY 2009

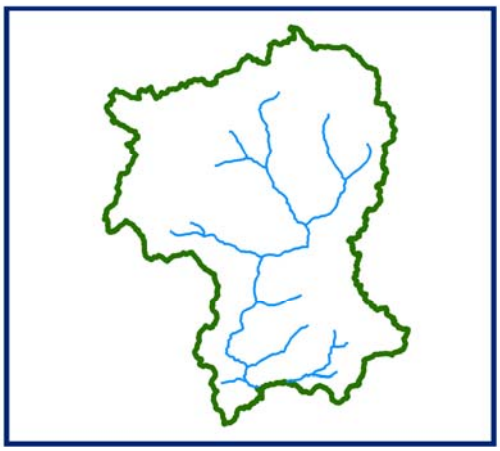


DATA USED
19 MAY 2009

SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : TISTA BASIN



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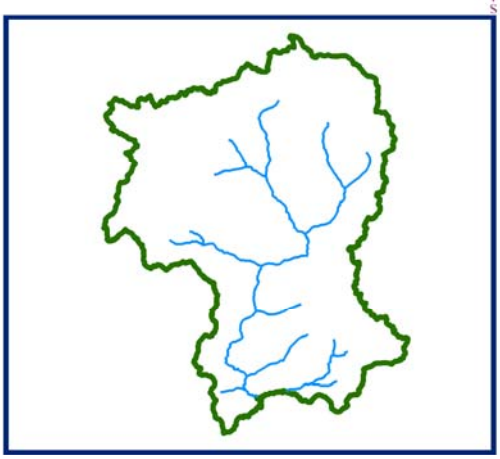

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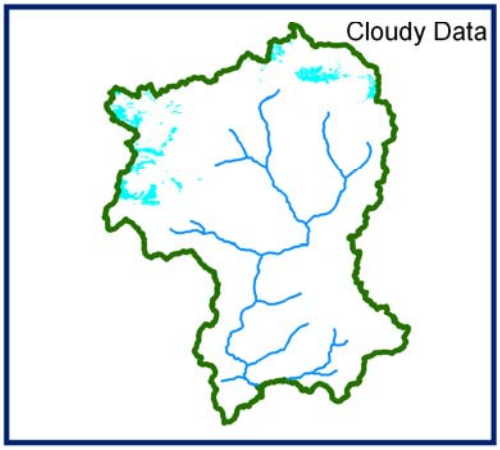
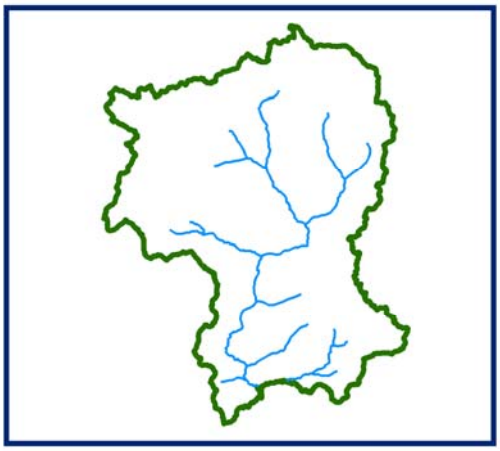


12 JUNE 2009



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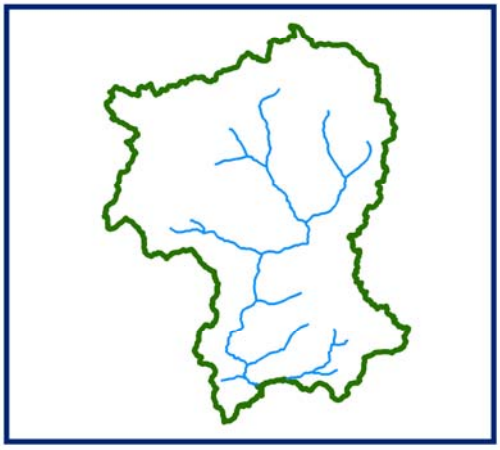

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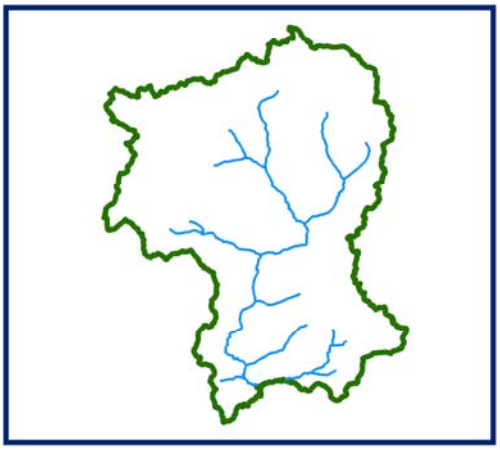
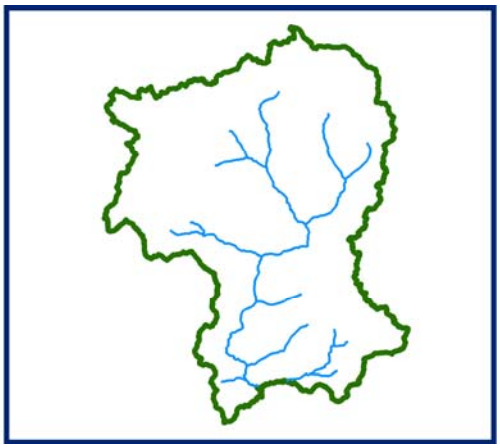


DATA NOT AVAILABLE

SNOW

0 37.5 75 150 225 300
Kilometers

10 DAILY SNOW COVER MAP: TISTA BASIN



DATA USED
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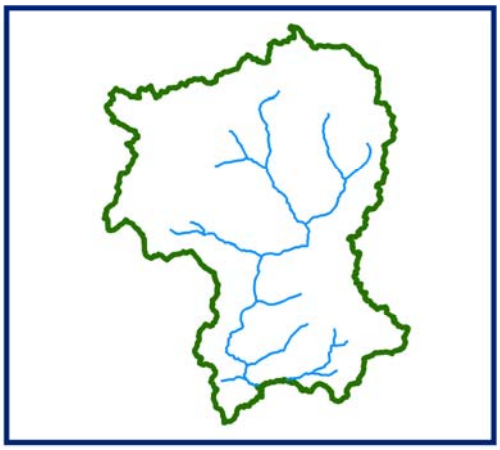

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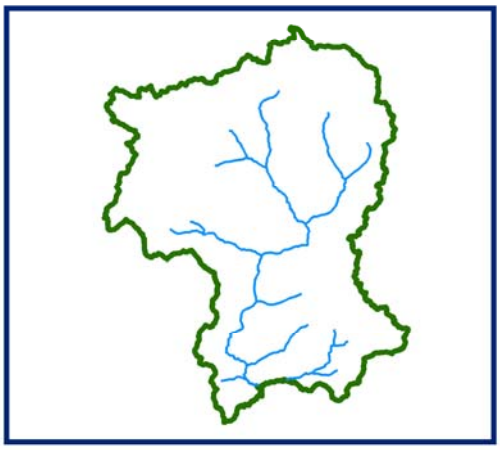


DATA USED
DATA NOT AVAILABLE

SNOW

0 5 10 20 30 40
Kilometers

RANGIT BASIN

AREAL EXTENT OF SNOW (5 DAILY)

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

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008							
1	10-Oct-08	69.7	4	5	21-Oct-08	49.1	3
2	11-Oct-08	44.1	3	6	25-Oct-08	59.1	4
3	15-Oct-08	36.0	2	7	30-Oct-08	186.2	11
4	16-Oct-08	61.3	4				
November 2008							
8	8-Nov-08	141.1	9	12	18-Nov-08	78.6	5
9	9-Nov-08	119.4	7	13	23-Nov-08	80.5	5
10	13-Nov-08	8.5	1	14	28-Nov-08	64.3	4
11	14-Nov-08	85.3	5				
December 2008							
15	3-Dec-08	57.9	4	18	22-Dec-08	6.1	1
16	8-Dec-08	57.0	3	19	26-Dec-08	141.5	9
17	17-Dec-08	53.3	3	20	27-Dec-08	237.3	15
January 2009							
21	10-Jan-09	122.4	8	25	20-Jan-09	60.3	4
22	14-Jan-09	84.5	5	26	24-Jan-09	45.3	3
23	15-Jan-09	81.7	5	27	29-Jan-09	51.5	3
24	19-Jan-09	64.0	4	28	29-Jan-09	53.0	3
February 2009							
29	3-Feb-09	68.9	4	34	17-Feb-09	48.8	3
30	8-Feb-09	51.3	3	35	18-Feb-09	36.2	2
31	8-Feb-09	51.2	3	36	22-Feb-09	56.7	3
32	12-Feb-09	58.6	4	37	27-Feb-09	91.9	6
33	13-Feb-09	65.4	4				
March 2009							
38	3-Mar-09	83.6	5	41	9-Mar-09	36.7	2
39	4-Mar-09	76.9	5	42	14-Mar-09	60.4	4
40	8-Mar-09	56.9	3	43	23-Mar-09	62.4	4
April 2009							
44	1-Apr-09	317.4	19	47	25-Apr-09	62.1	4
45	6-Apr-09	21.9	1	48	25-Apr-09	62.4	4
46	16-Apr-09	80.9	5	49	26-Apr-09	38.9	2

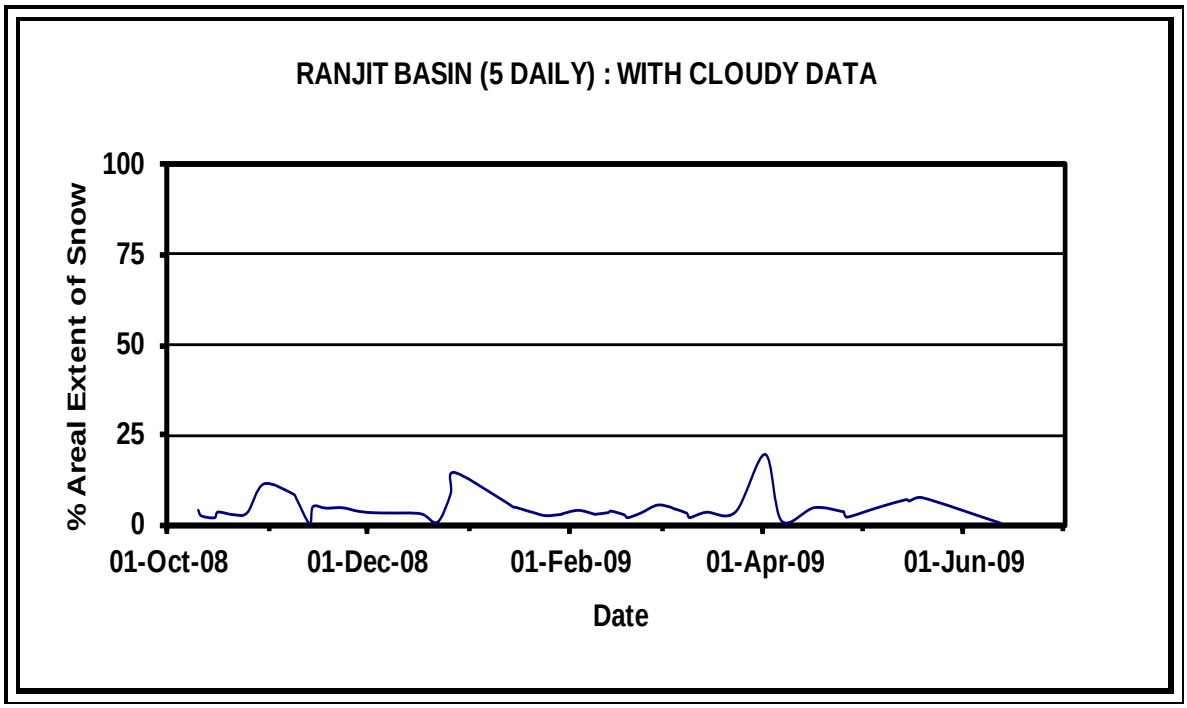
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
50	5-May-09	79.5	5	52	15-May-09	110.1	7
51	14-May-09	116.6	7	53	19-May-09	125.0	8
June 2009							
54	12-Jun-09	11.1	1				

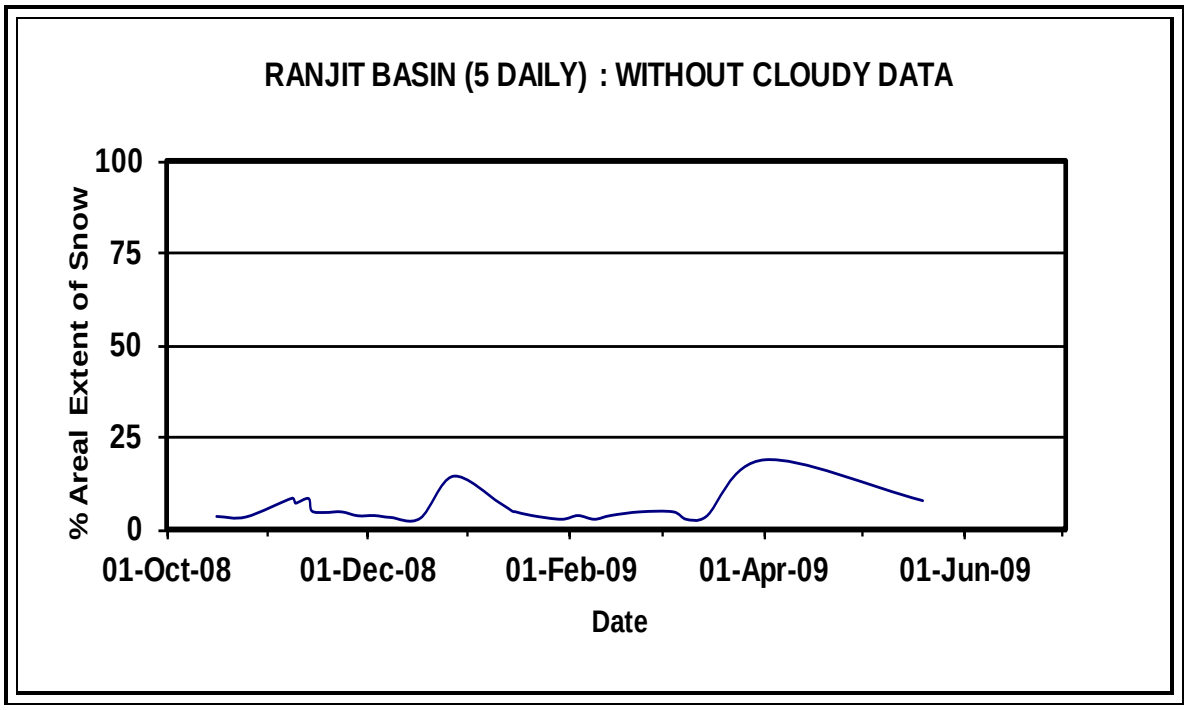
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: RANJIT **BASIN AREA: 1133 Sq km**

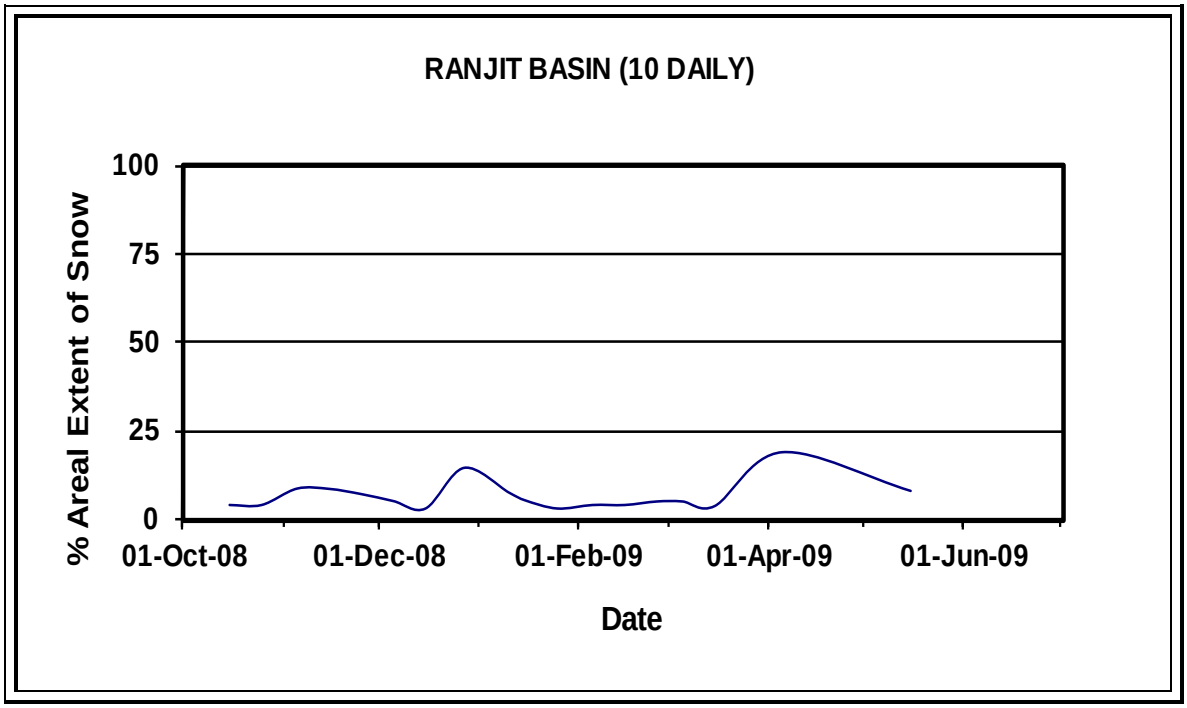
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
1	15-oct-08	45.36	4	3	5-Nov-08	97	9
2	25-oct-08	45.40	4	3	15-Nov-08	97.2	9
				4	25-Nov-08	80.5	7
December 2008				**January 2009**			
3	5-Dec-08	57.9	5	4	5-Jan-09	91	8
3	15-Dec-08	34	3	4	15-Jan-09	60.3	5
3	25-Dec-08	170	15	5	25-Jan-09	34	3
February 2009				**March 2009**			
6	5-Feb-09	63.9	4	7	5-Mar-09	74.7	5
	15-feb-09	45.35	4	7	15-Mar-09	45	4
	25-feb-08	33.99	5				
April 2009				**May 2009**			
8	5-Apr-09	317.4	19	9	15-May-09	125.0	8
June 2009							

Snow cover depletion curve



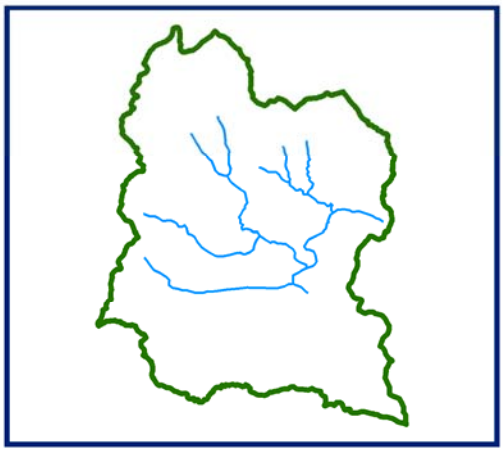


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : RANJIT BASIN



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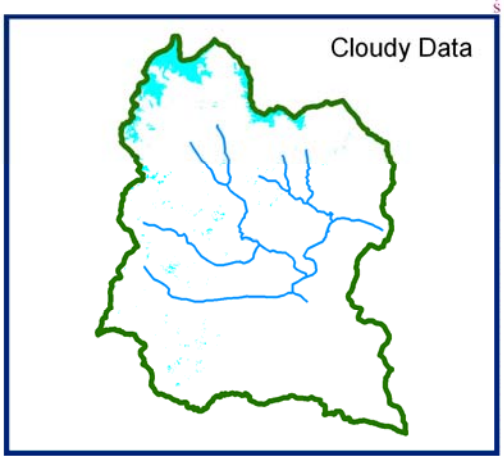
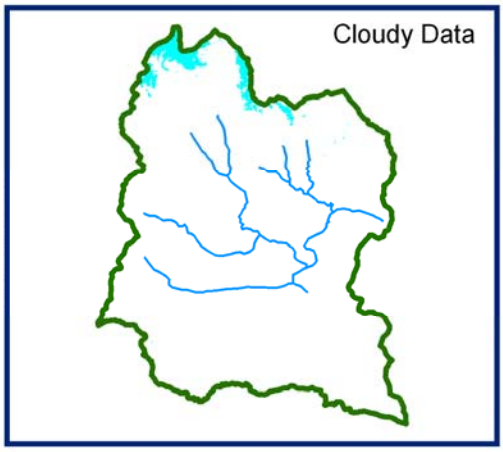


10 OCTOBER 2008



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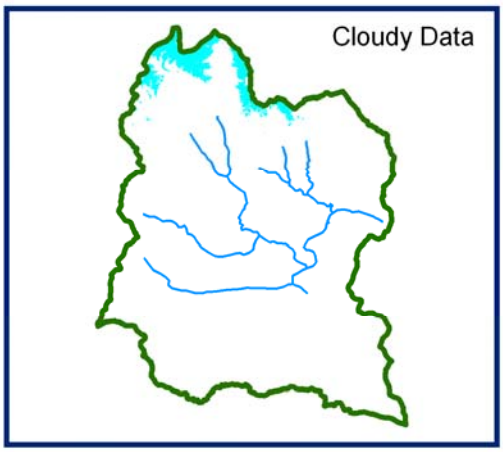

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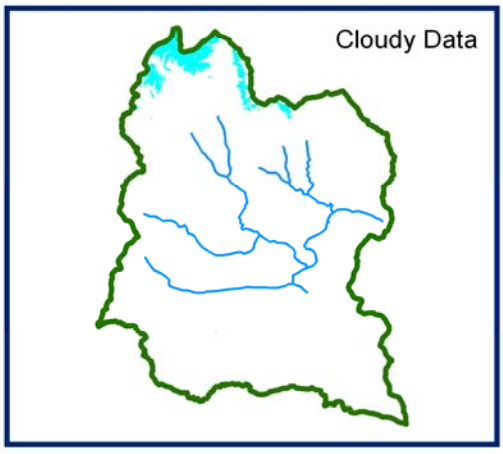
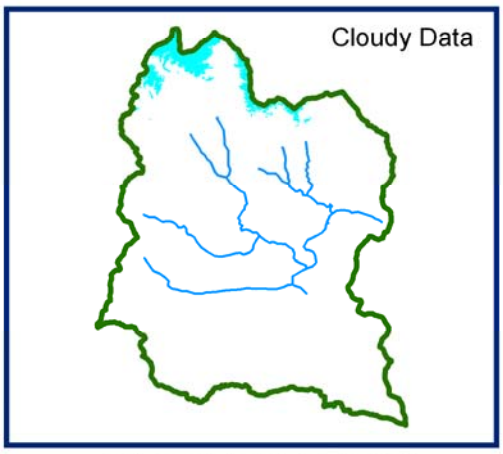


21 OCTOBER 2008

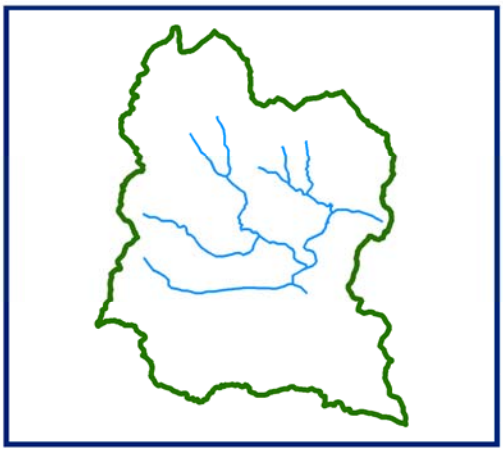


25 OCTOBER 2008

SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



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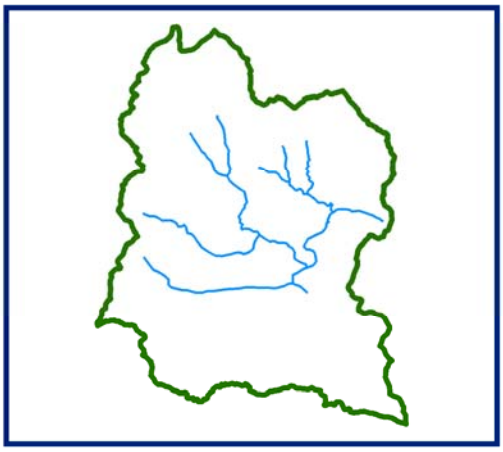

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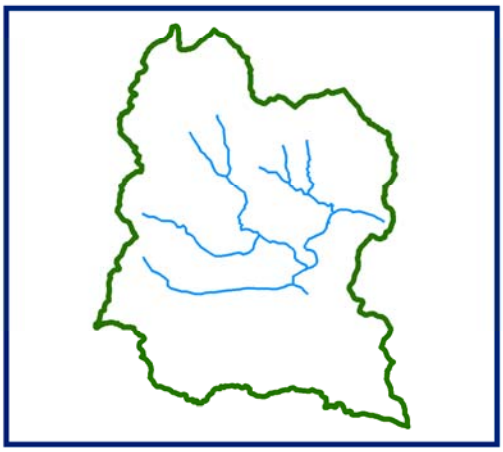

DATA USED
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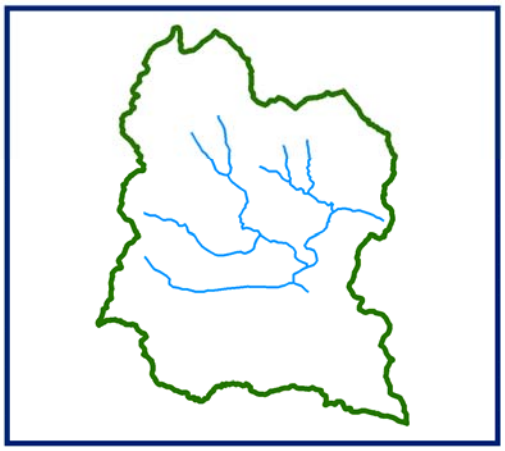
SNOW

0 2.5 5 10 15 20
Kilometers

SNOW COVER MAP : RANJIT BASIN



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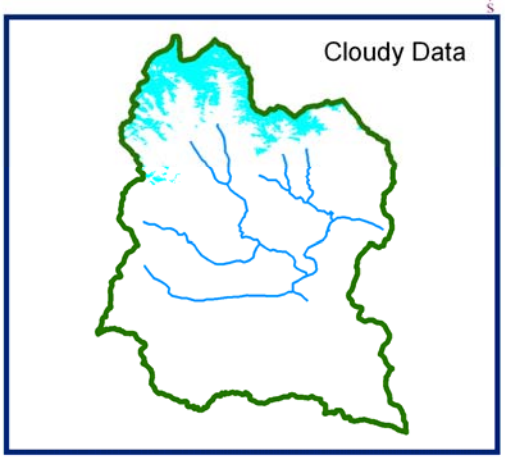
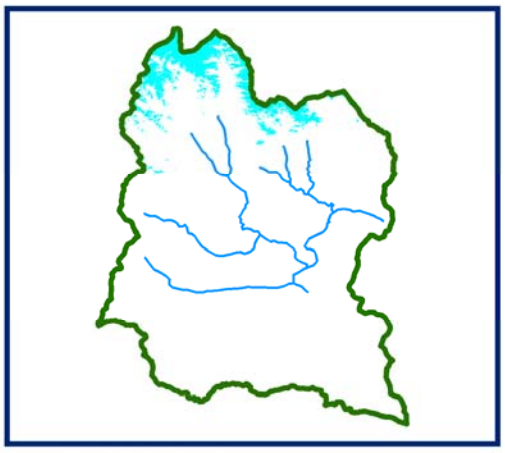
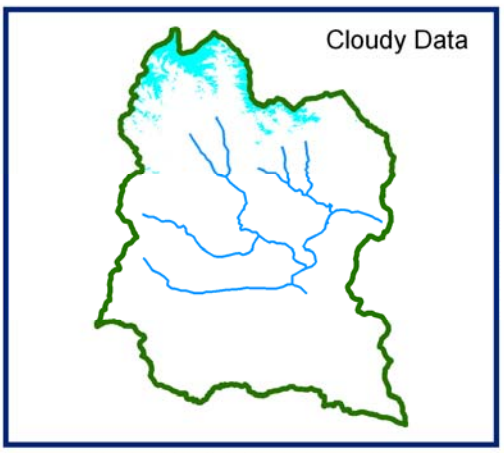


09 NOVEMBER 2008

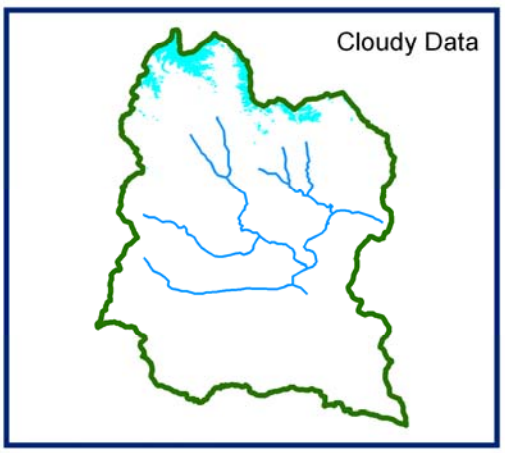


13 NOVEMBER 2008



18 NOVEMBER 2008

23 NOVEMBER 2008



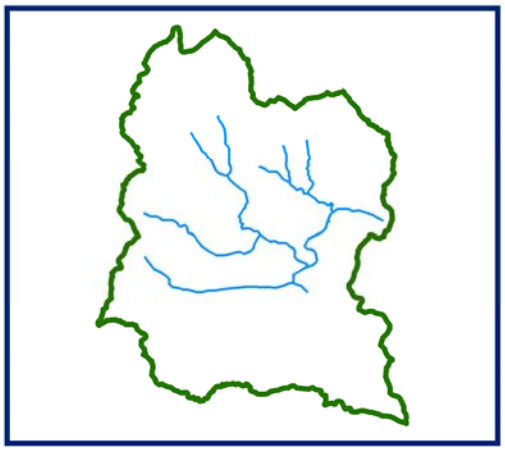
28 NOVEMBER 2008

SNOW

024 8 1216

Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



DATA USED
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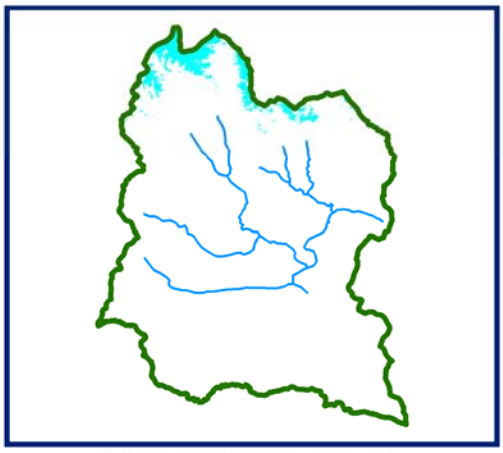
DATA USED
13 NOVEMBER 2008

DATA USED
23 NOVEMBER 2008

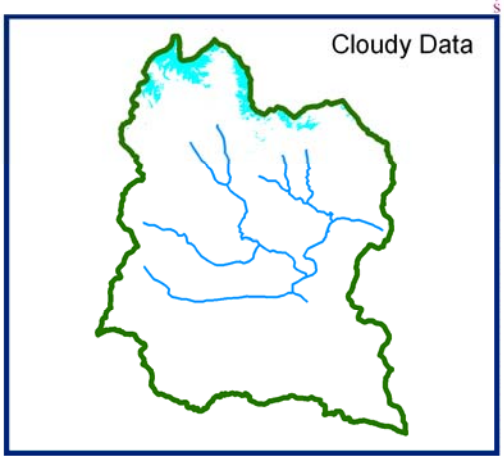
SNOW

0 2.5 5 10 15 20
Kilometers

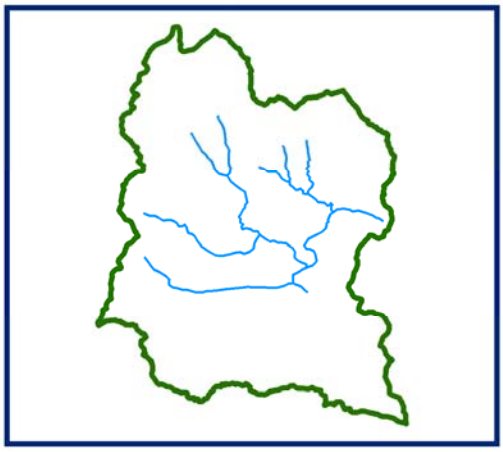
SNOW COVER MAP : RANJIT BASIN



03 DECEMBER 08



08 DECEMBER 08



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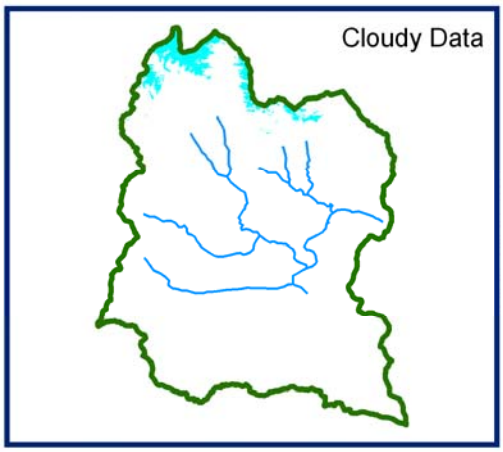
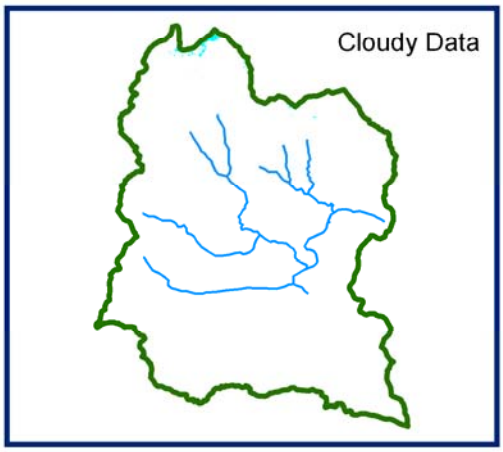
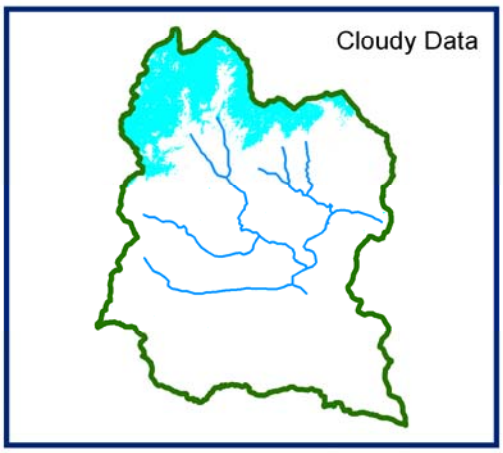


17 DECEMBER 08



22 DECEMBER 08

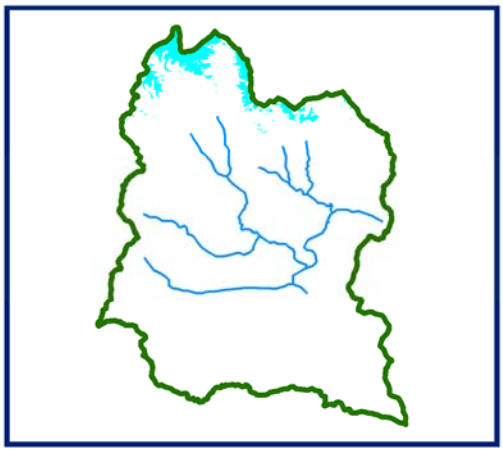


27 DECEMBER 08

SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



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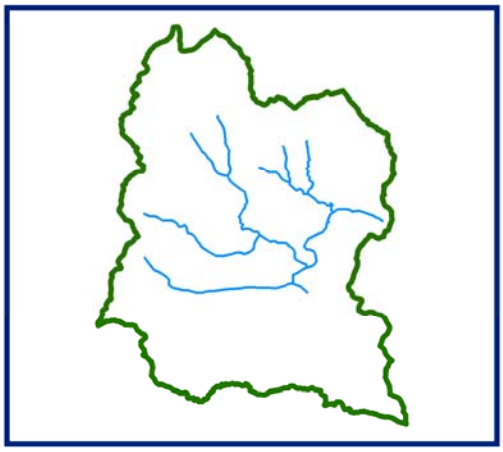

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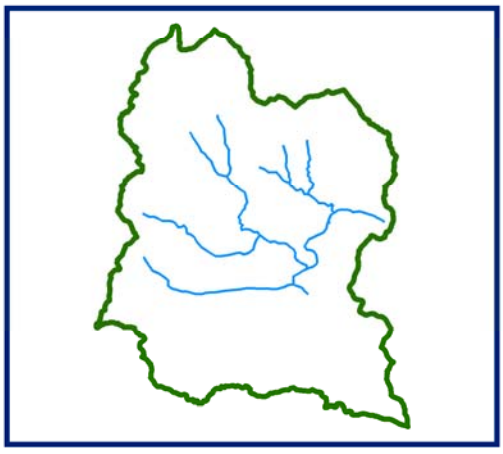
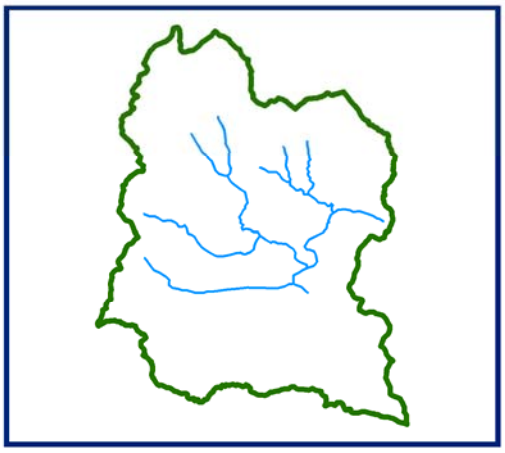


DATA USED
DATA NOT AVAILABLE

SNOW

0 2.5 5 10 15 20
Kilometers

SNOW COVER MAP : RANJIT BASIN



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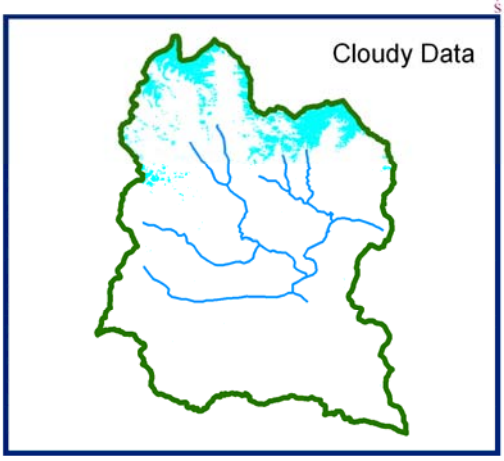
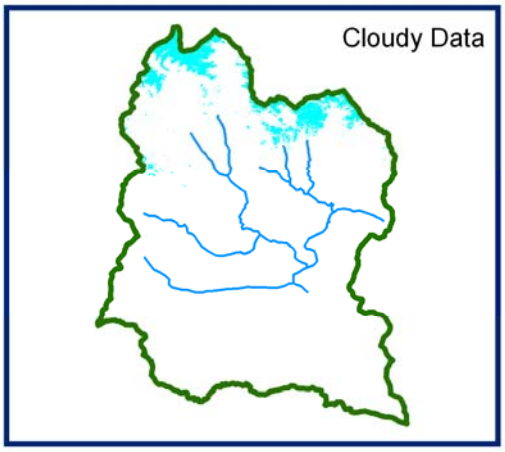
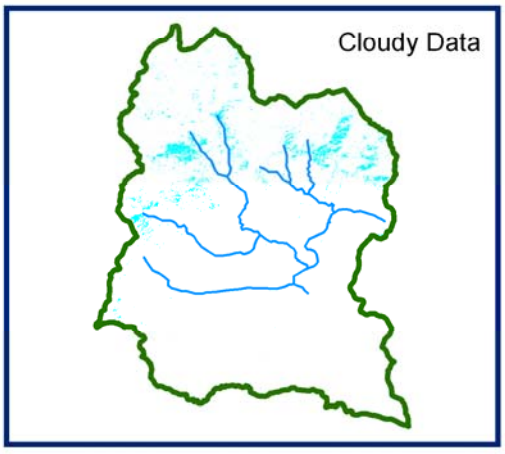


10 JANUARY 2009

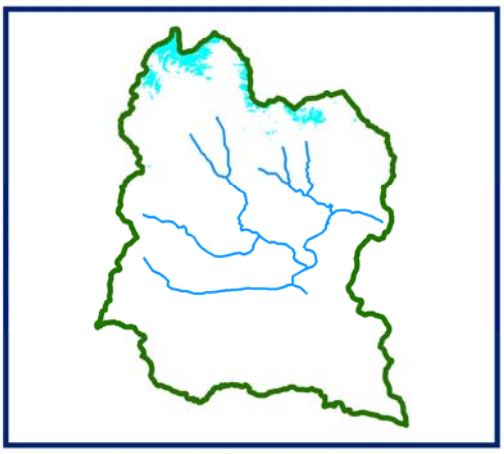


14 JANUARY 2009

20 JANUARY 2009



24 JANUARY 2009

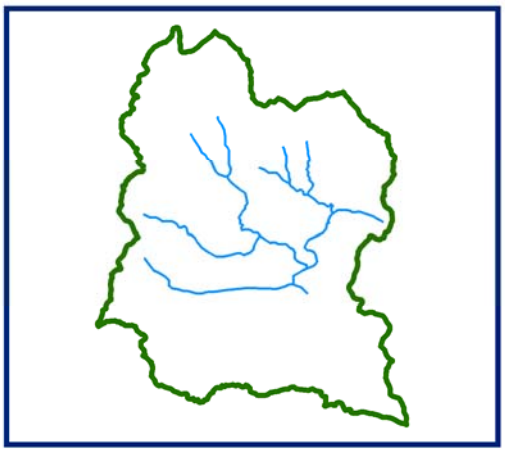


29 JANUARY 2009

SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



DATA USED
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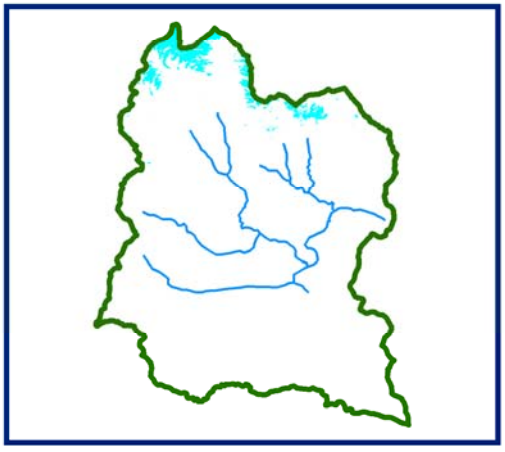
DATA USED
22 JANUARY 2009

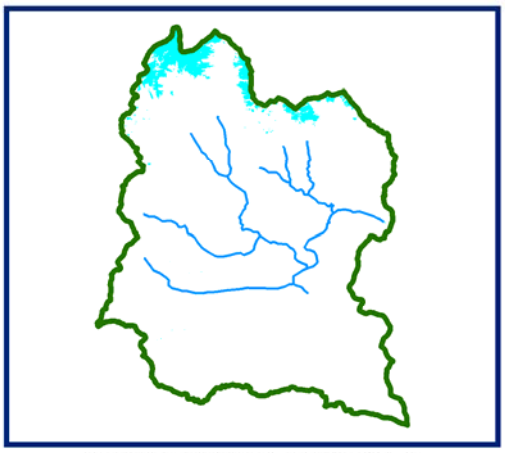


DATA USED
29 JANUARY 2009

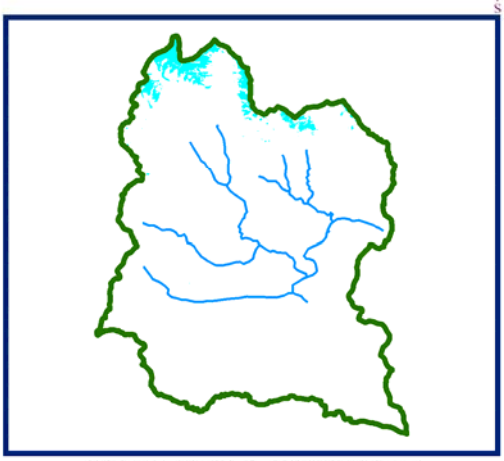
SNOW

0 2.5 5 10 15 20
Kilometers

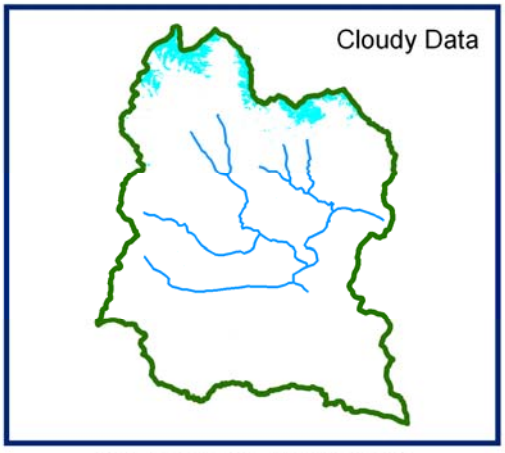
SNOW COVER MAP : RANJIT BASIN



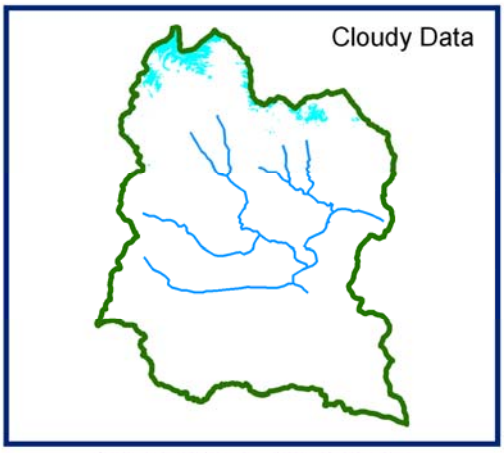
03 FEBRUARY 2009



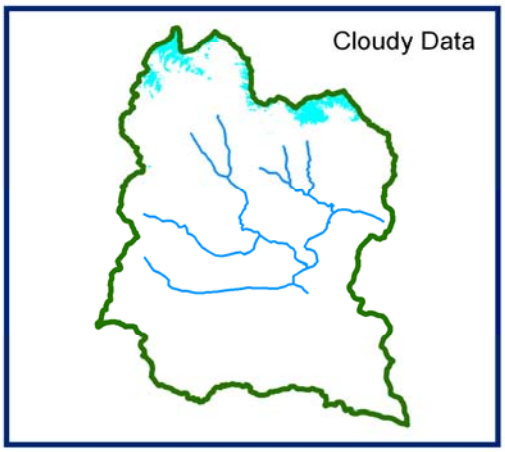
08 FEBRUARY 2009



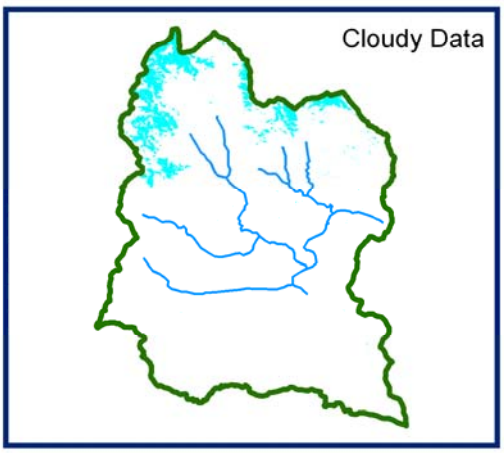
12 FEBRUARY 2009



17 FEBRUARY 2009



22 FEBRUARY 2009

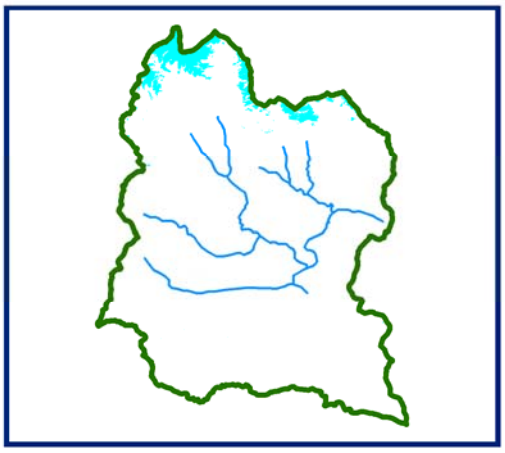


27 FEBRUARY 2009

SNOW

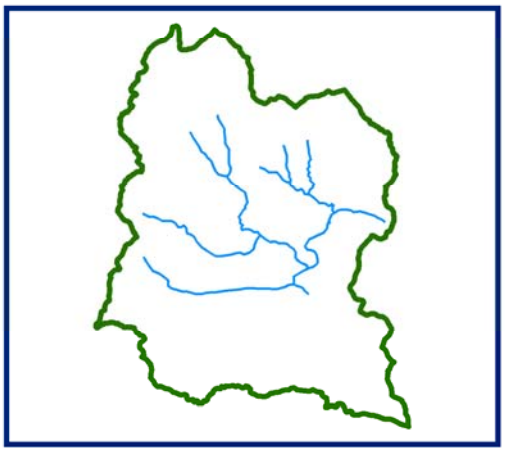
024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



DATA USED
03 FEBRUARY 2009
08 FEBRUARY 2009

DATA USED
DATA NOT AVAILABLE

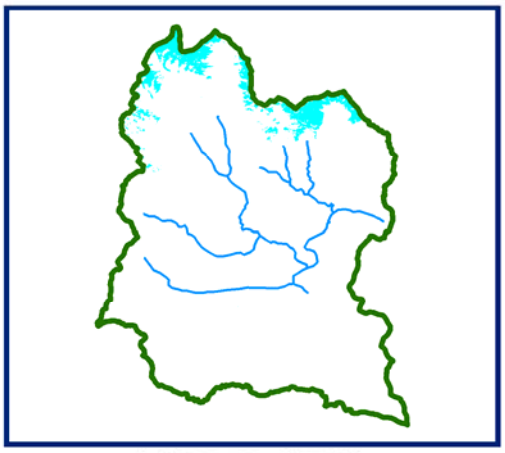


DATA USED
DATA NOT AVAILABLE

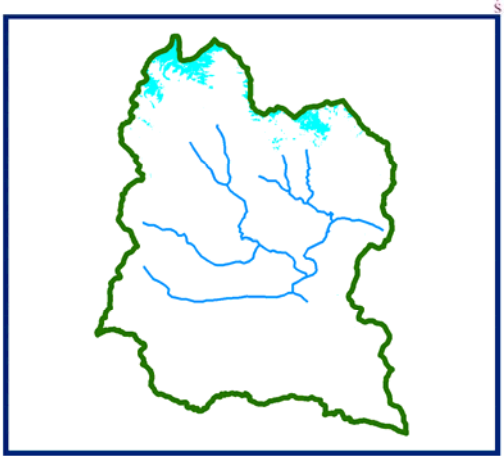
SNOW

0 2.5 5 10 15 20
Kilometers

SNOW COVER MAP : RANJIT BASIN



04 MARCH 09



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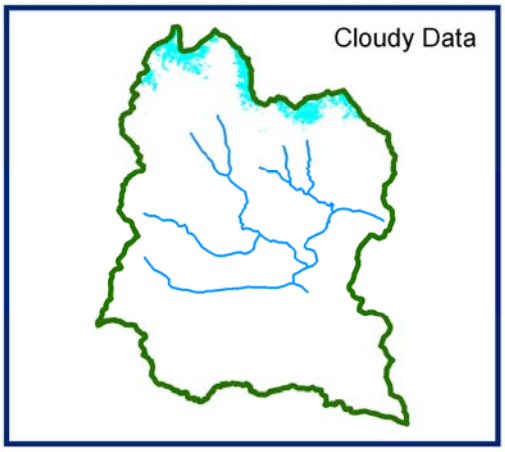

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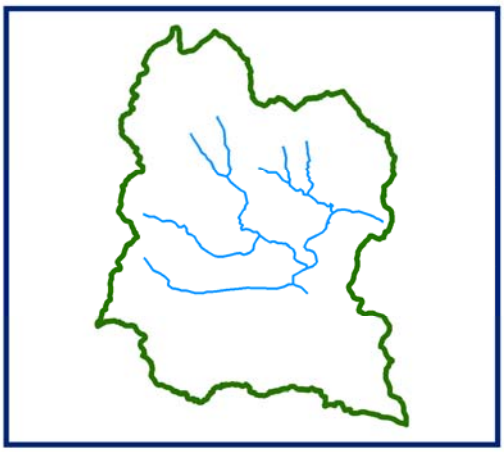

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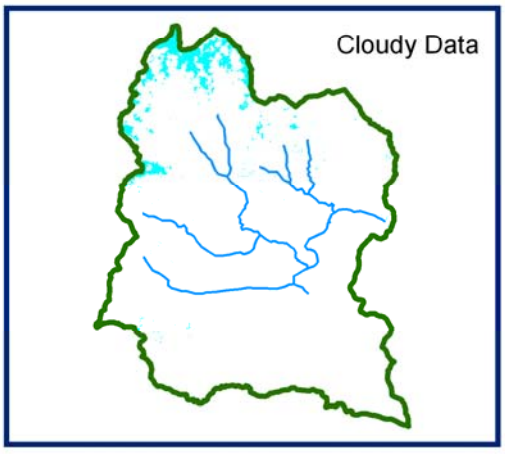

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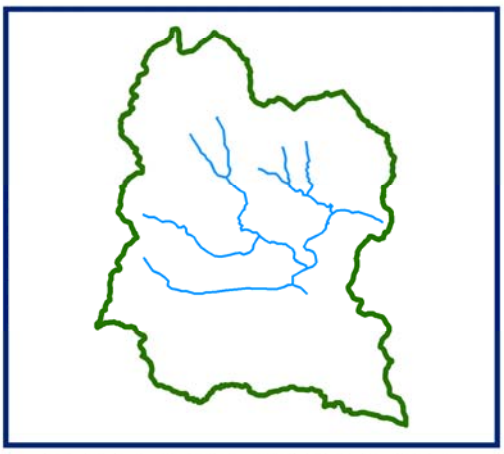
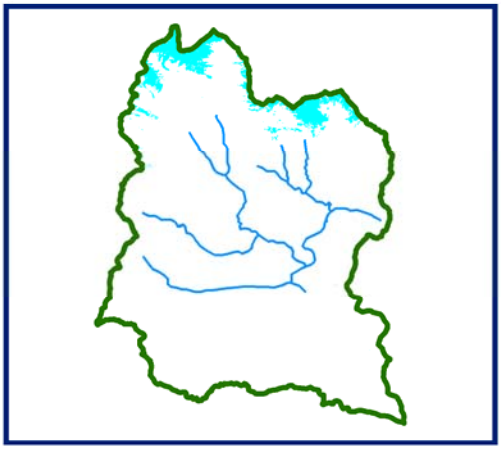


DATA NOT AVAILABLE

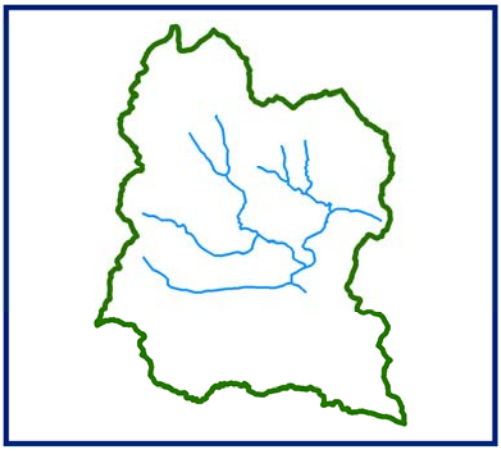
SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



DATA USED
04 MARCH 2009
08 MARCH 2009



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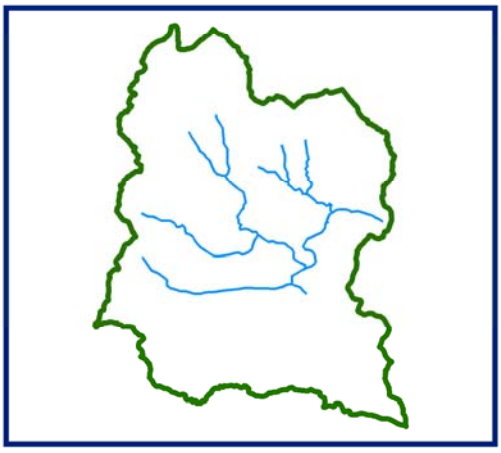

DATA USED
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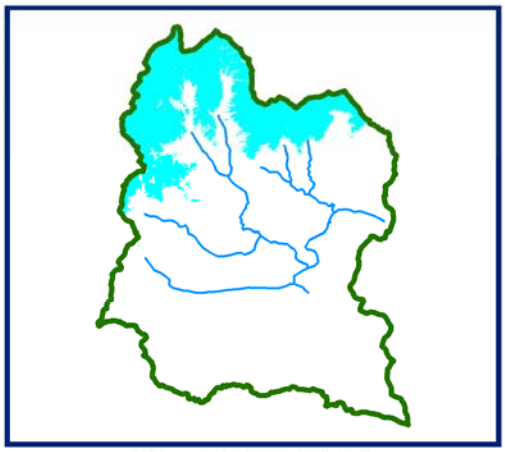
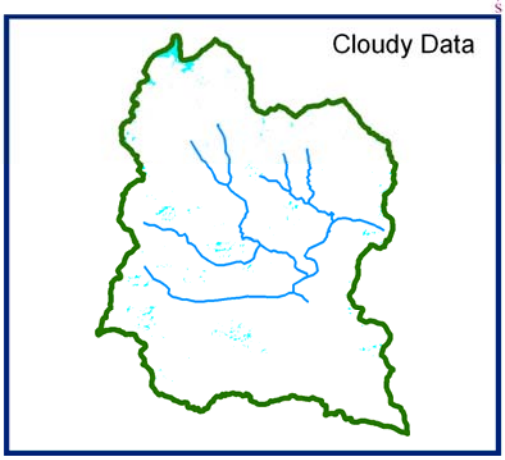
SNOW

0 2.5 5 10 15 20
Kilometers

SNOW COVER MAP : RANJIT BASIN



01 APRIL 2009



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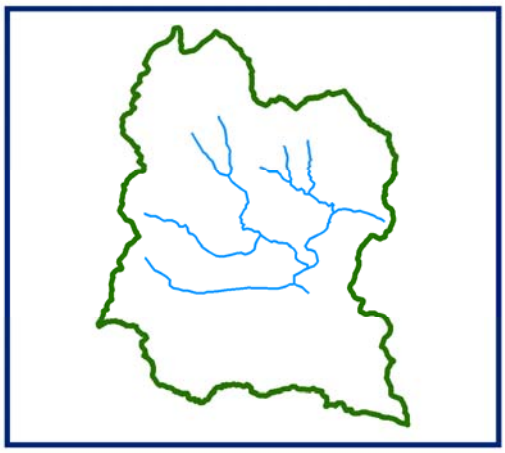

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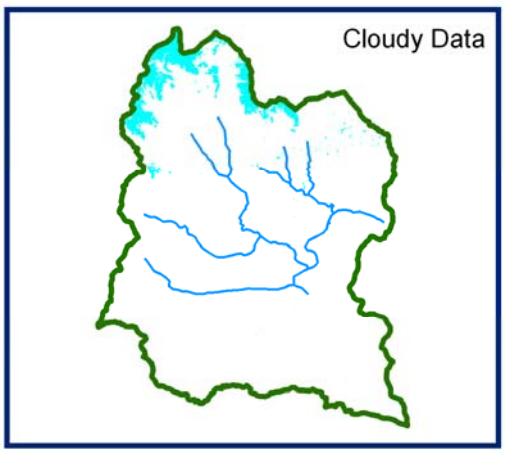
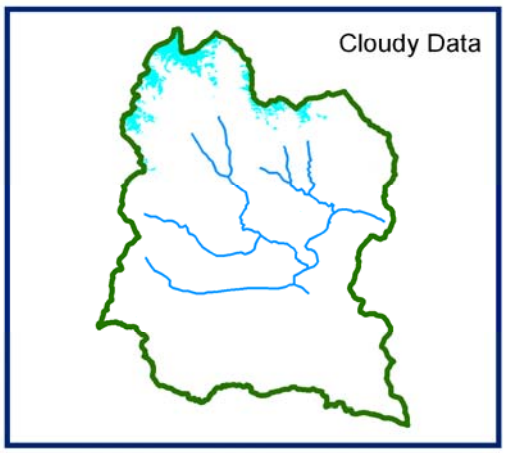
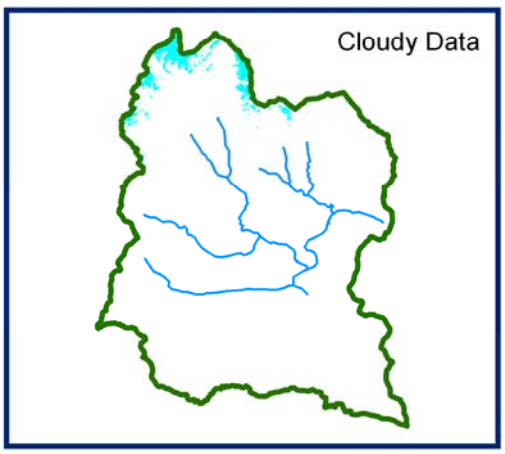


16 APRIL 2009



25 APRIL 2009

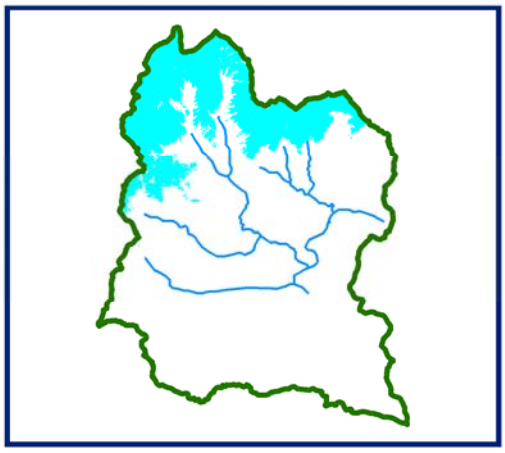


26 APRIL 2009

SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



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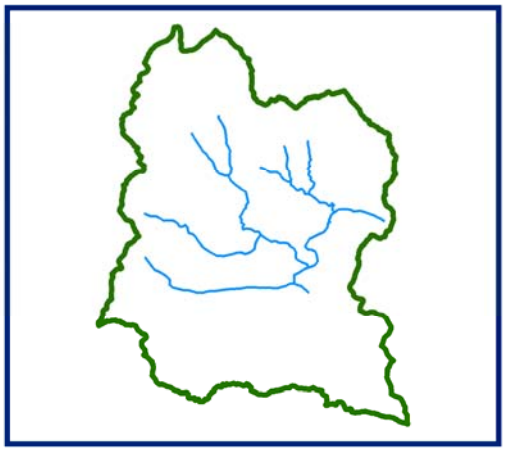

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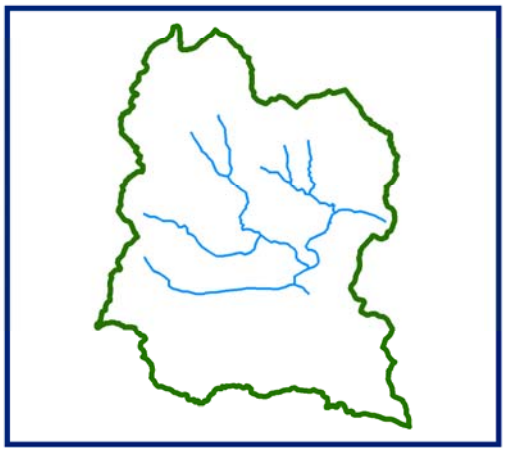

DATA USED
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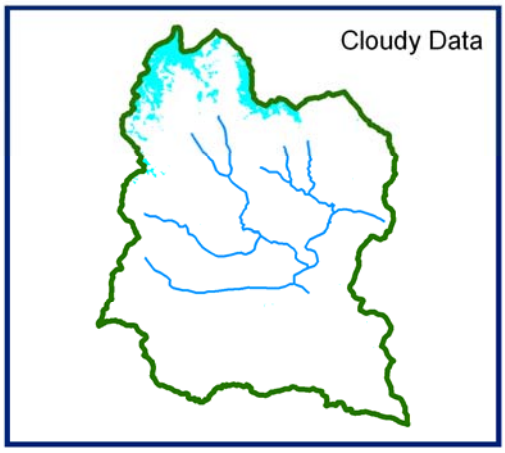
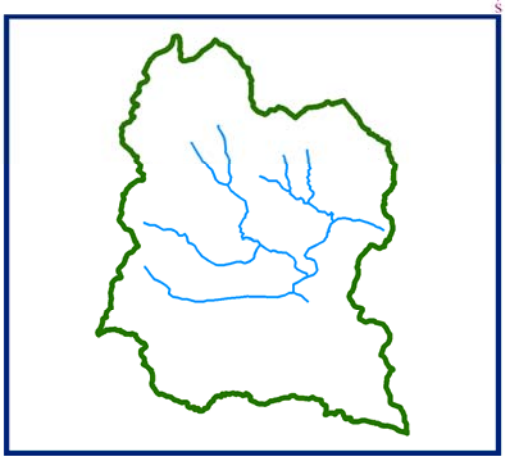
SNOW

0 2.5 5 10 15 20
Kilometers

SNOW COVER MAP : RANJIT BASIN



05 MAY 2009



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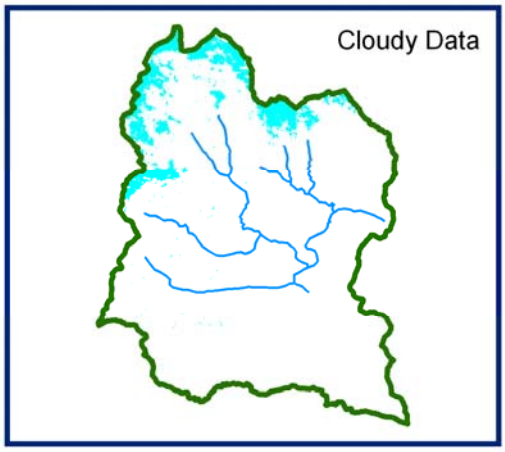

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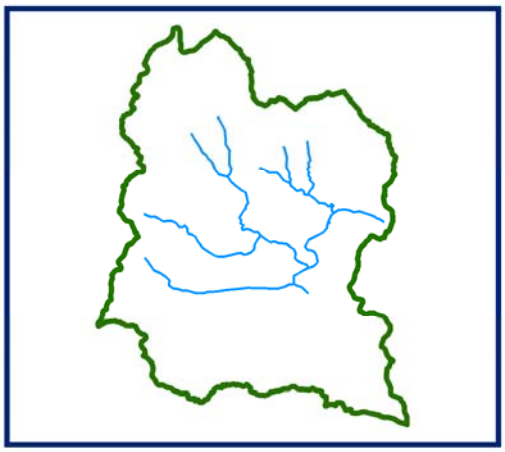

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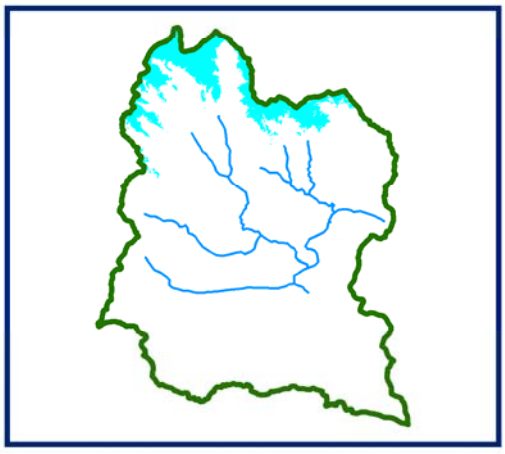
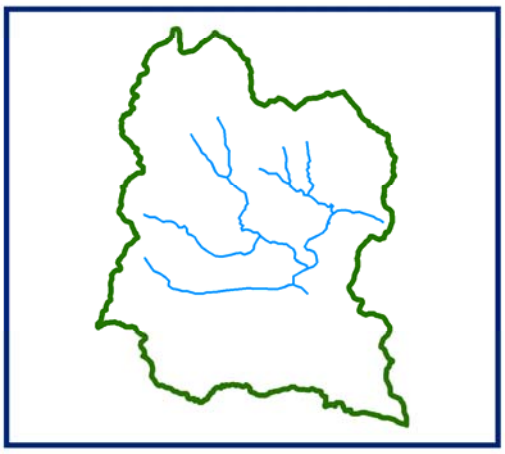


19 MAY 2009

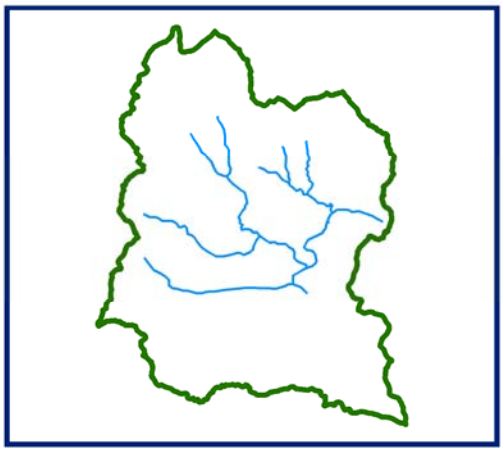


DATA NOT AVAILABLE

SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



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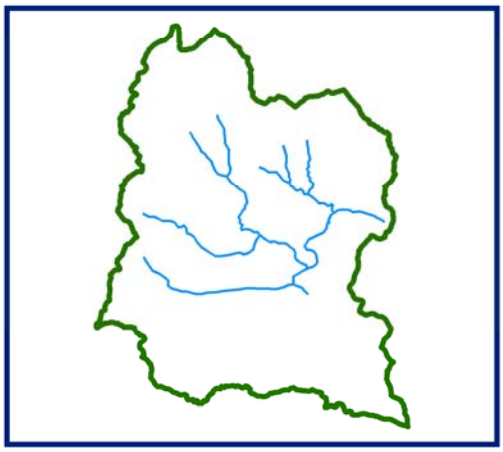
DATA USED
19 MAY 2009



DATA USED
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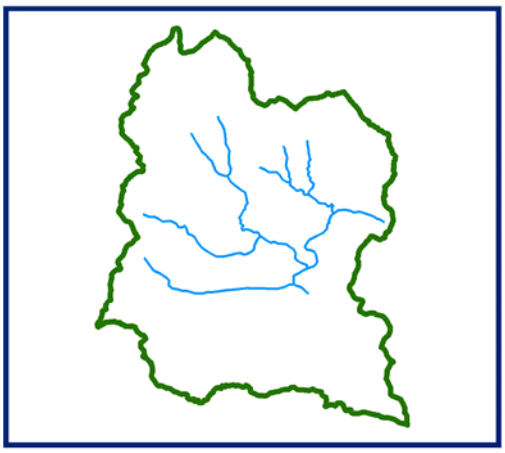
SNOW

0 2.5 5 10 15 20
Kilometers

SNOW COVER MAP : RANJIT BASIN



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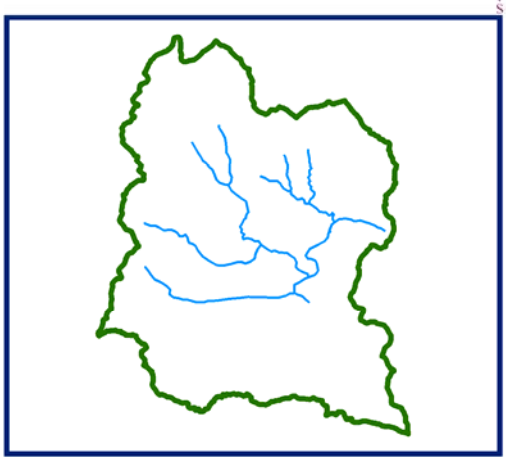

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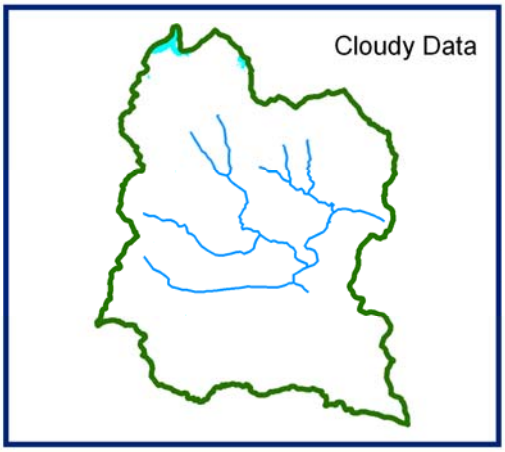
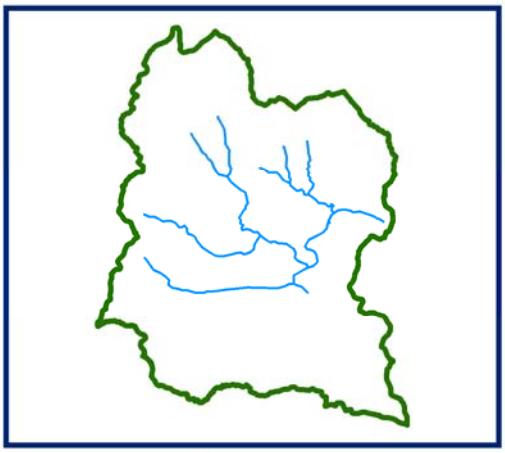


12 June 2009



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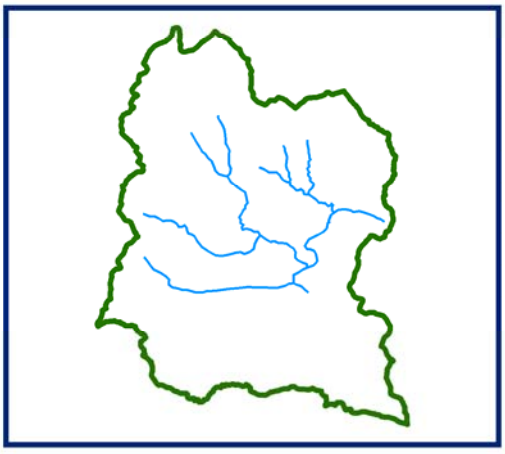

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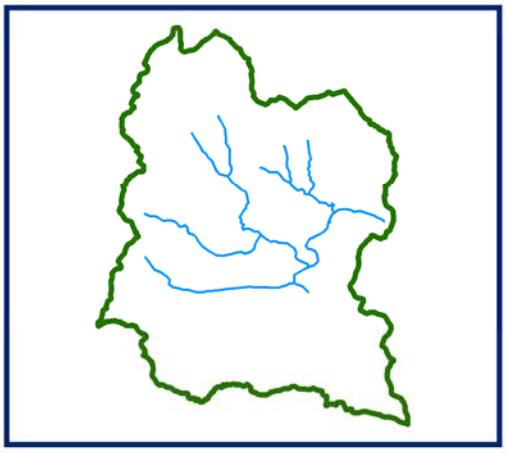

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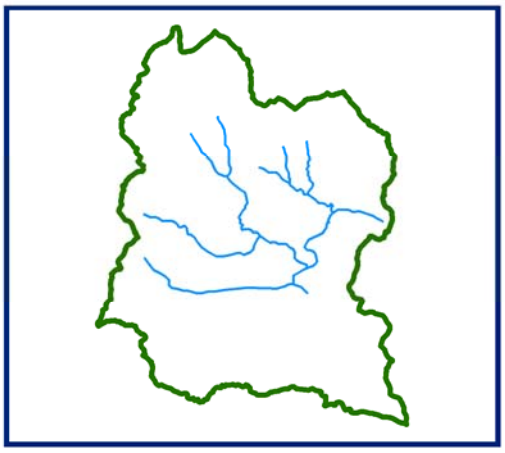
SNOW

024 8 1216
Kilometers

10 DAILY SNOW COVER MAP: RANJIT BASIN



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DATA USED
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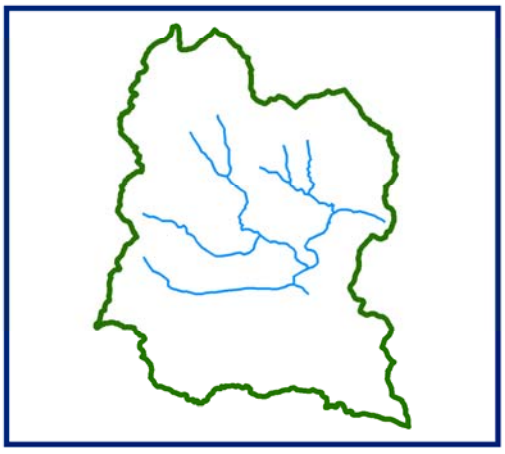

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SNOW

0 2.5 5 10 15 20
Kilometers