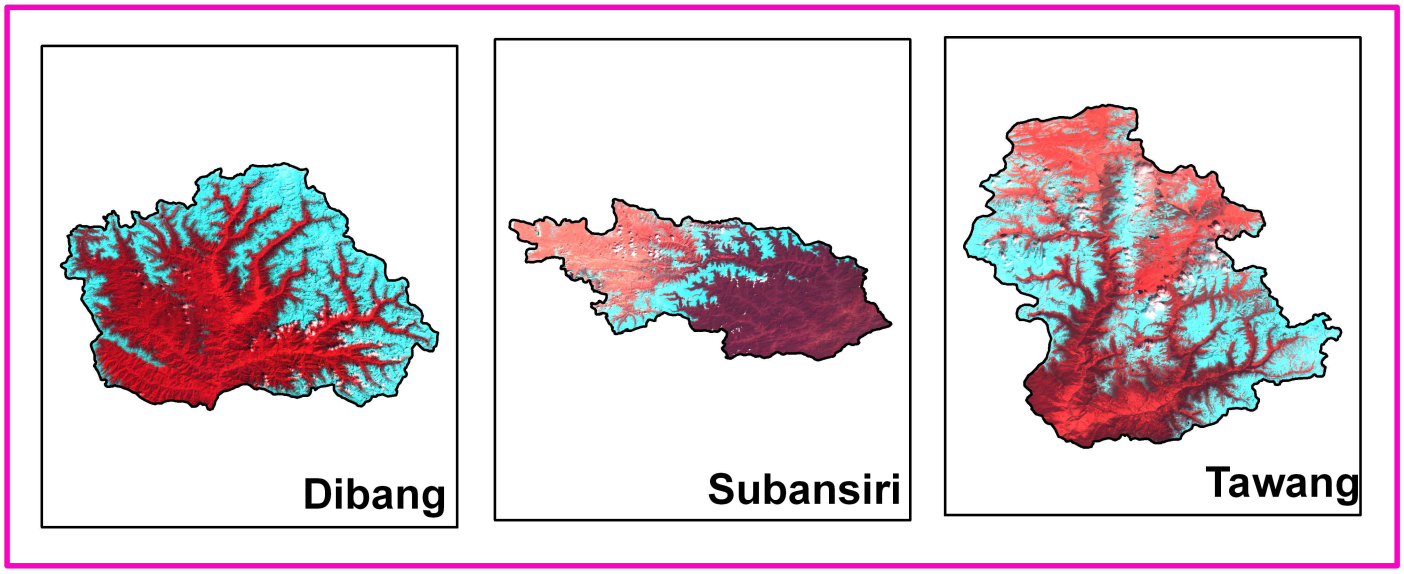
SNOW COVER ATLAS OF BRAHMAPUTRA BASIN

Sub basins: Dibang, Subansiri and Tawang

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

Year : 2008-09



Space Applications Centre (ISRO)
Ahmedabad - 380015

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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 sub basin-wise distribution of snow cover in the Brahmaputra basin from October 2008 to June 2009. The sub basins included in this report are Dibhang, Subansiri and Tawang. 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, Dibhang, Subansiri and Tawang basins.
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 three subbasins of the Brahmaputra basin. These are Dibang, Subansiri and Tawang 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. If three consecutive scenes are not available, then all available scenes in 10 days window was used in the analysis. 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, basin-wise snow cover statistics, maps, and seasonal depletion curves have been provided from October 2008 to June 2009. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. In the Tawang river basin, in the end of November, 2008, 77 percent area was covered by seasonal snow. This was reduced to 38 percent at the end of January, 2009. Continuous accumulation & ablation was observed till mid of May, 2009. Dibang sub-basin also shows accumulation and ablation of snow throughout the winter season and maximum snow was observed 40%. Subansiri sub-basin also shows accumulation and ablation of snow throughout the winter season but percentage areal extent snow is very less compare to Tawangs.

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.

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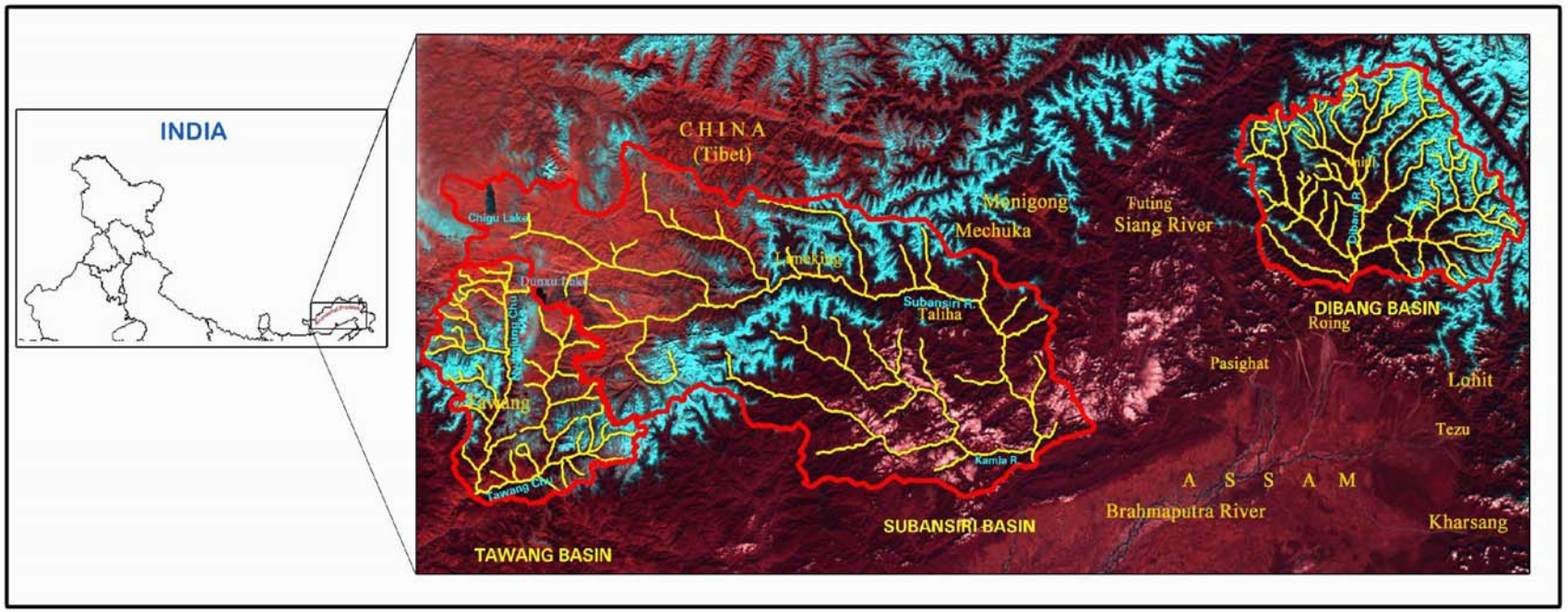


Figure 1: Location map of Dibang, Subansiri and Tawang sub-basins (Part of Brahmputra basin)

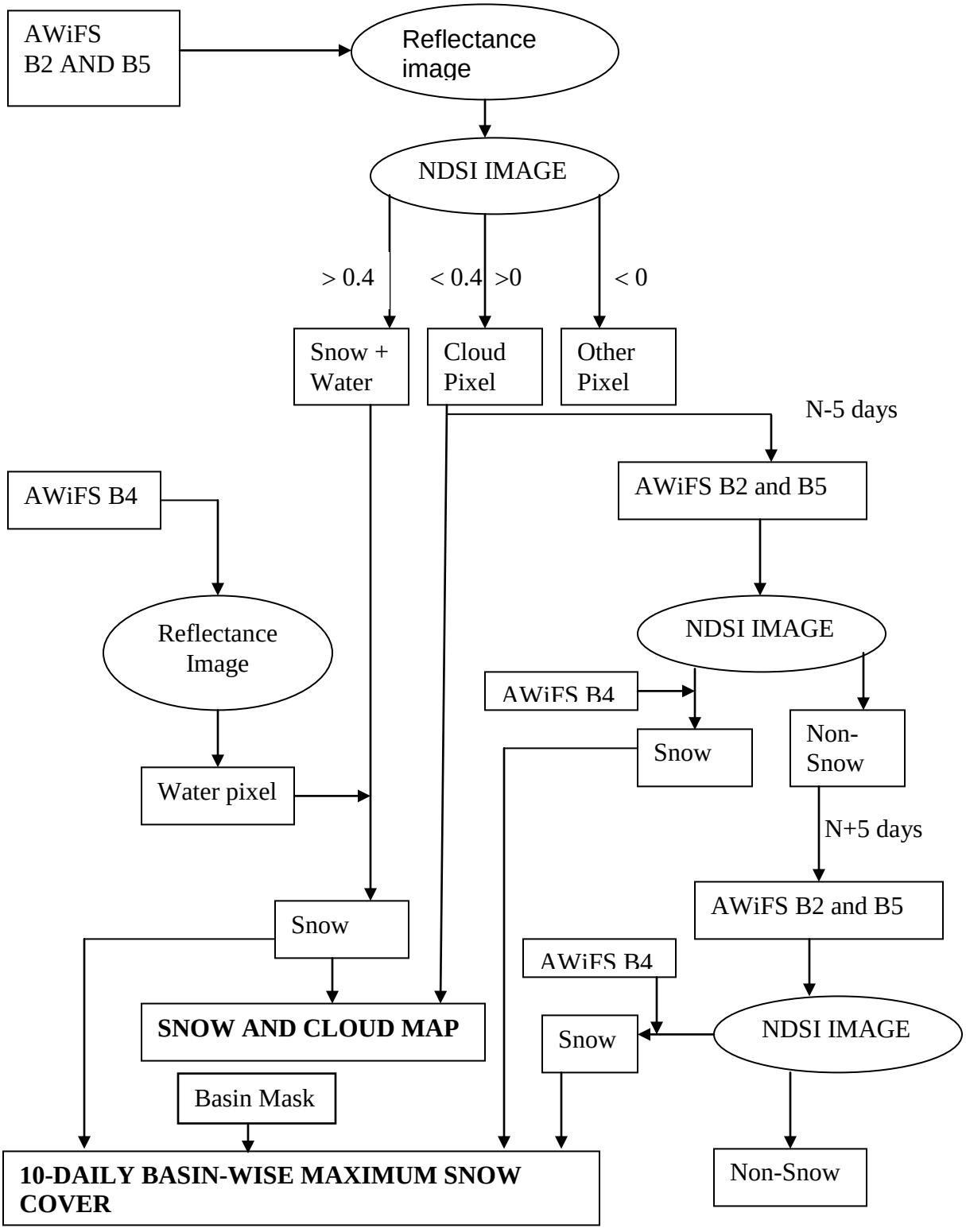


Figure 2: Algorithm for snow cover mapping using AWiFS data

DIBHANG BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: DIBANG **BASIN AREA: 9171 sq km**

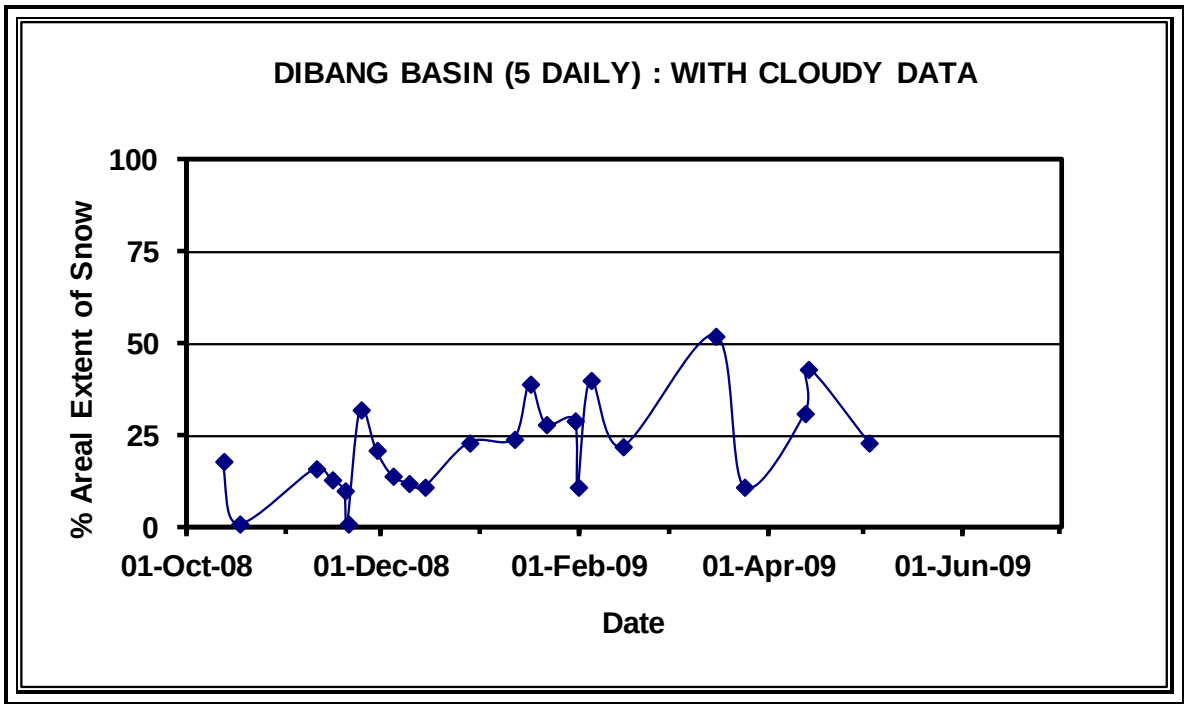
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008							
1	12-Oct-08	1657	18				
2	17-Oct-08	102	1				
November 2008							
3	10-Nov-08	1508	16	6	20-Nov-08	75	1
4	15-Nov-08	1191	13	7	24-Nov-08	2927	32
5	19-Nov-08	884	10	8	29-Nov-08	1920	21
December 2008							
9	4-Dec-08	1269	14	11	14-Dec-08	982	11
10	9-Dec-08	1082	12	12	28-Dec-08	2149	23
January 2009							
13	11-Jan-09	2221	24	16	30-Jan-09	2638	29
14	16-Jan-09	3599	39	17	31-Jan-09	1054	11
15	21-Jan-09	2553	28				
February 2009							
18	4-Feb-09	3668	40				
19	14-Feb-09	2042	22				
March 2009							
20	15-Mar-09	4740	52				
21	24-Mar-09	987	11				
April 2009							
22	12-Apr-09	2831	31				
23	13-Apr-09	3966	43				
May 2009							
24	2-May-09	2138	23				

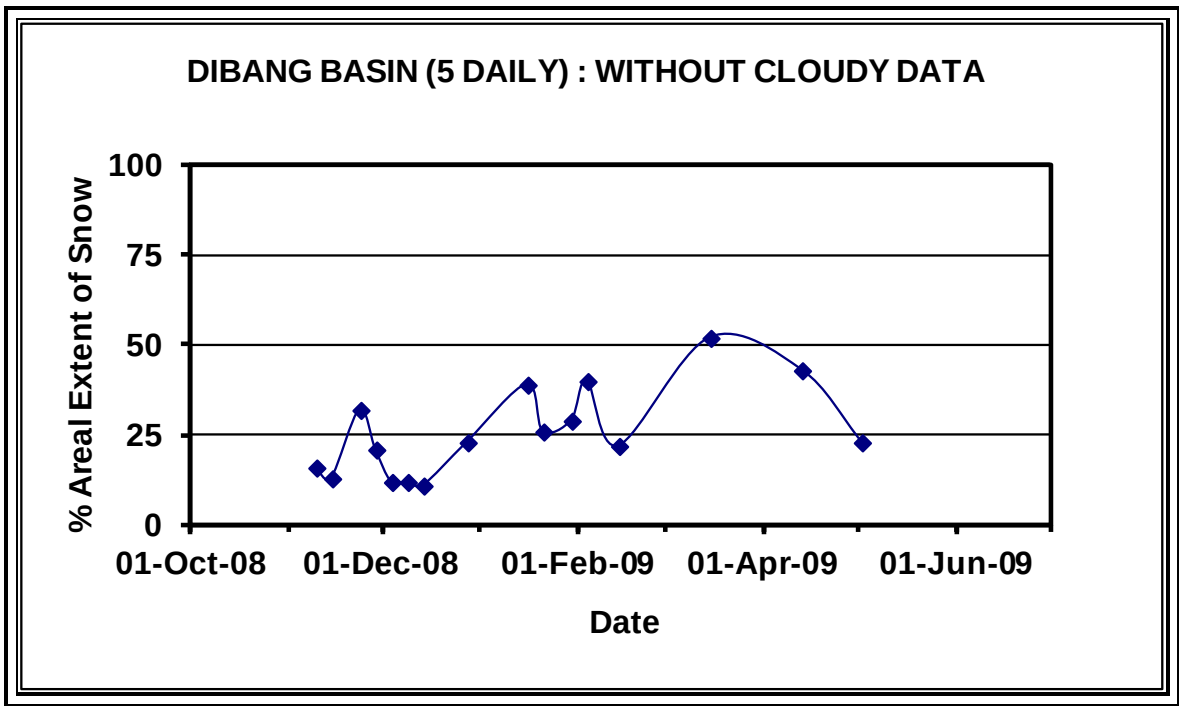
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: DIBANG **BASIN AREA: 9171 Sq km**

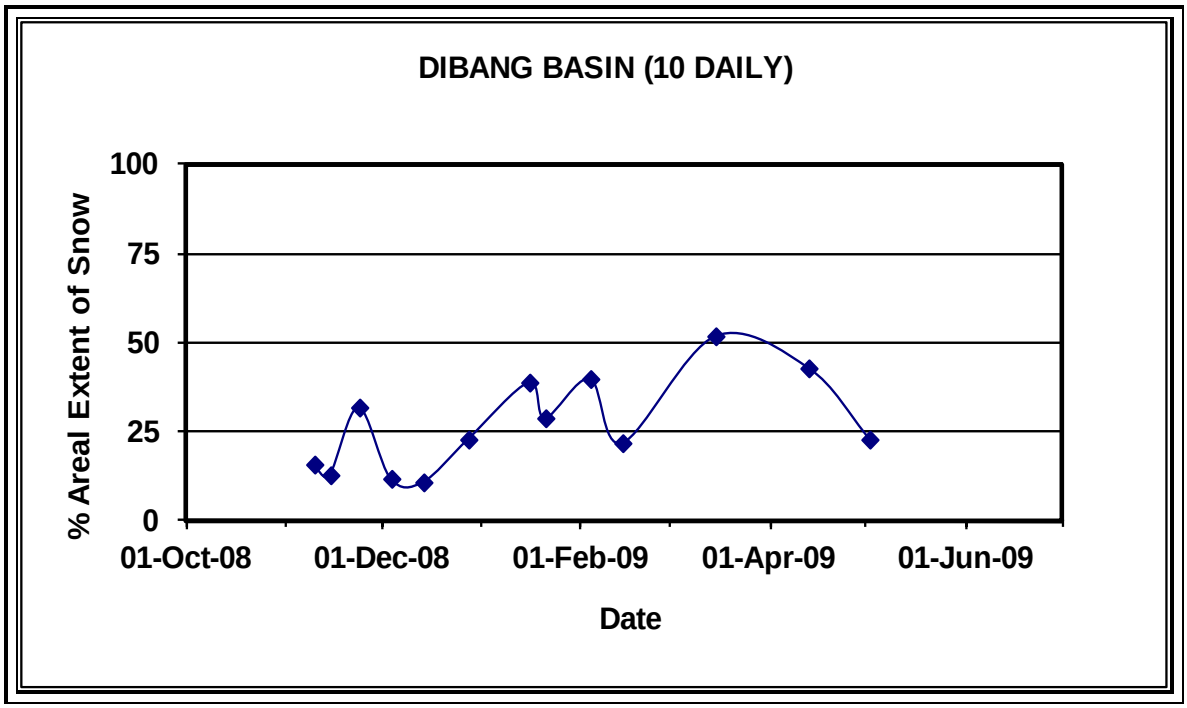
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
November 2008				**December 2008**			
1	10-Nov-08	1508	16	4	4-Dec-08	1057	12
2	15-Nov-08	1191	13	5	15-Dec-08	1009	11
3	24-Nov-08	2935	32	6	28-Dec-08	2149	23
January 2009				**February 2009**			
7	16-Jan-09	3599	39	9	4-Feb-09	3668	40
8	21-Jan-09	2423	26	10	14-Feb-09	2042	22
March				**April 2009**			
11	15-March-09	4769	52	12	13-Apr-09	3966	43
May 2009				**June**			
13	2-May-09	2138	23				

Snow cover depletion curve



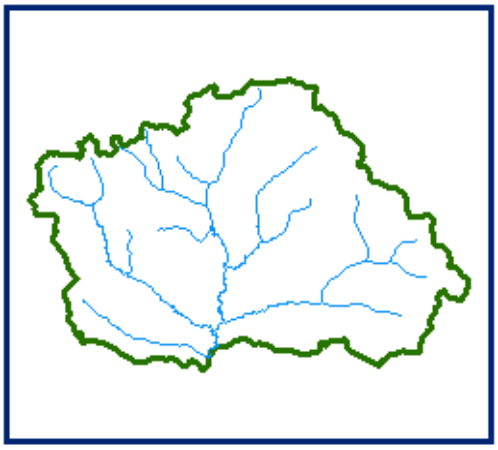


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : DIBANG BASIN



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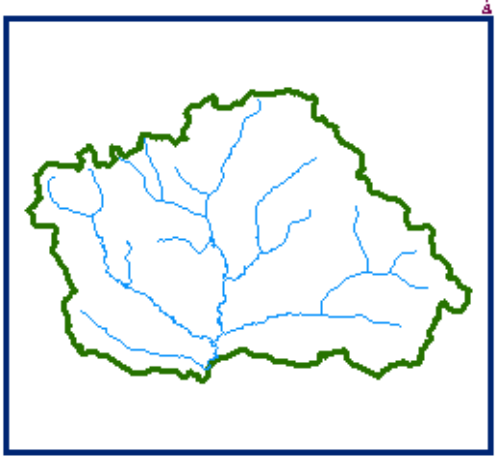

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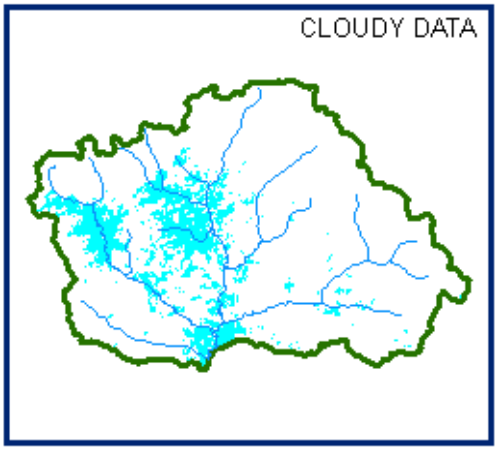

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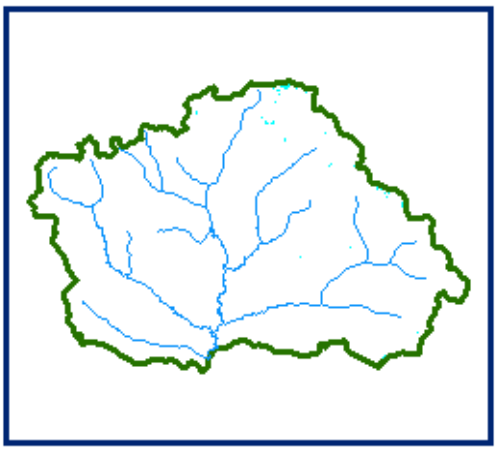

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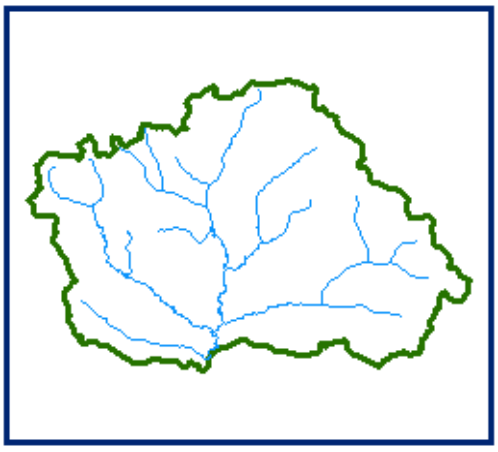

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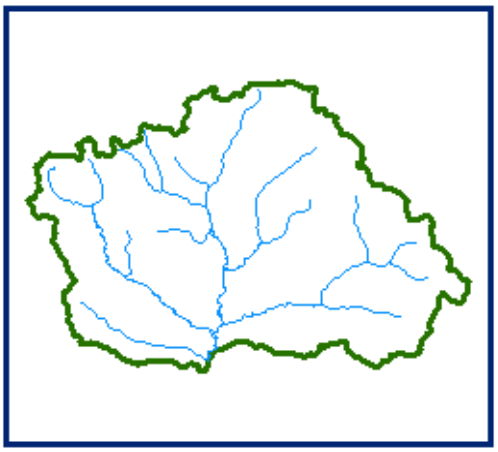

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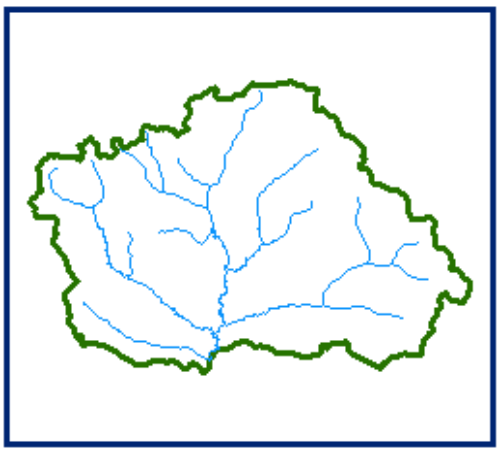
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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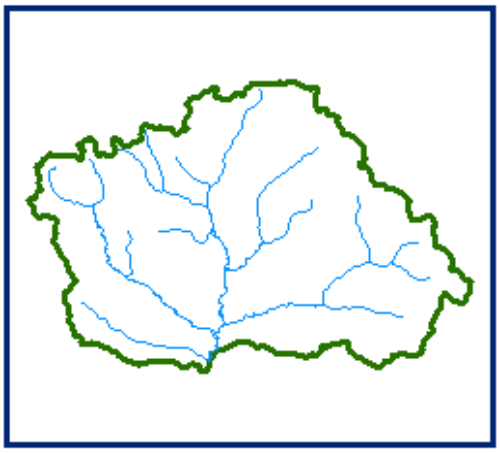

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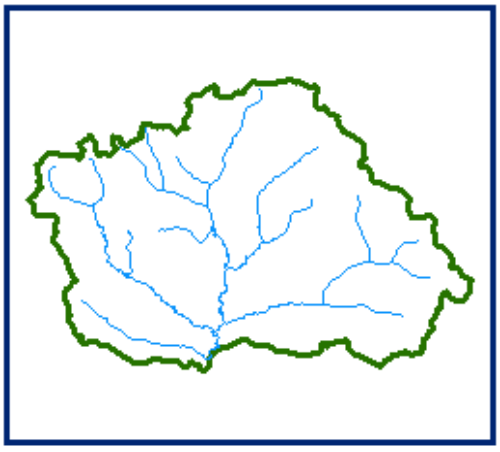

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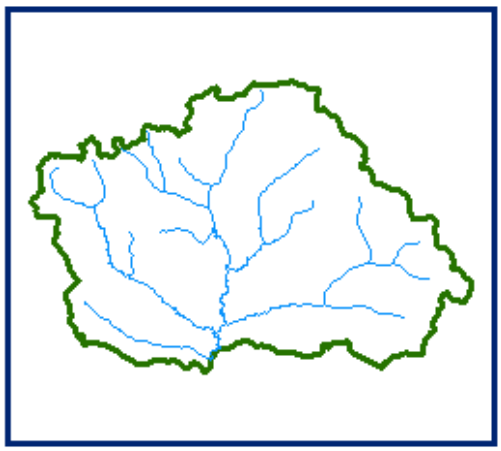
SNOW

0 20 40 80 120 160
Kilometers

SNOW COVER MAP : DIBANG BASIN



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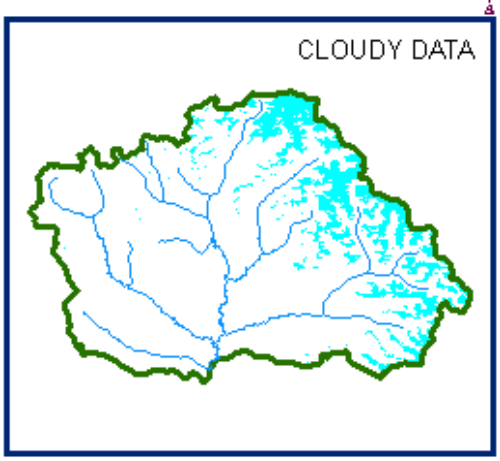

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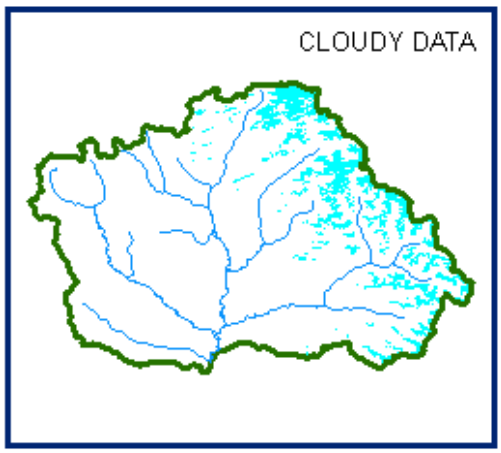

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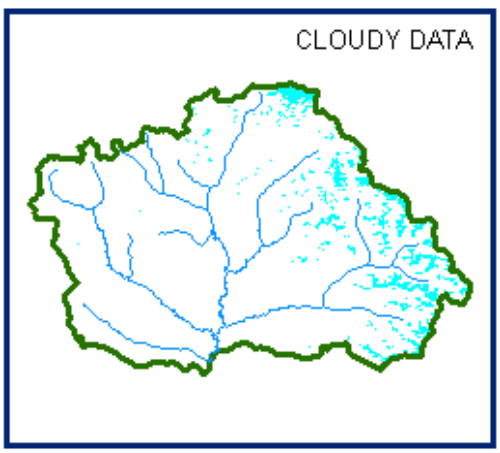

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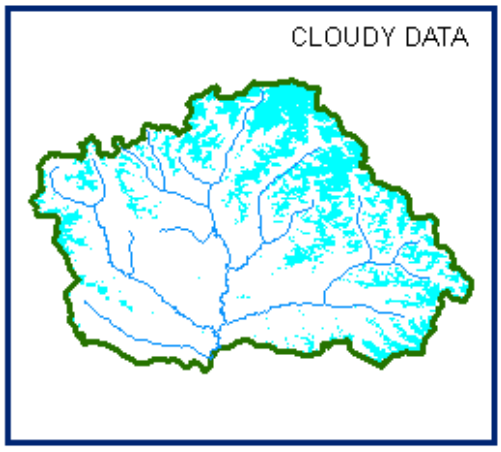

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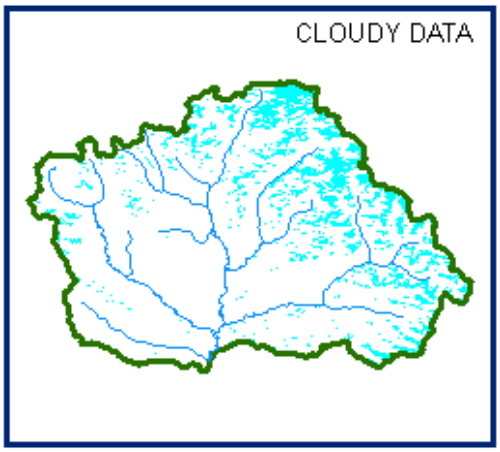

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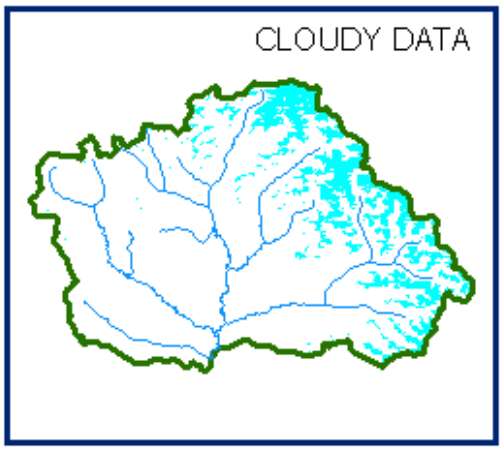
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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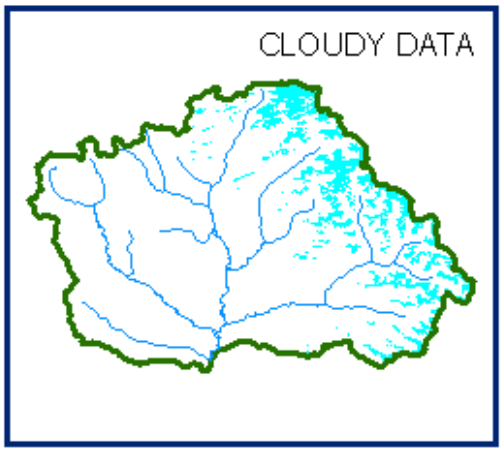

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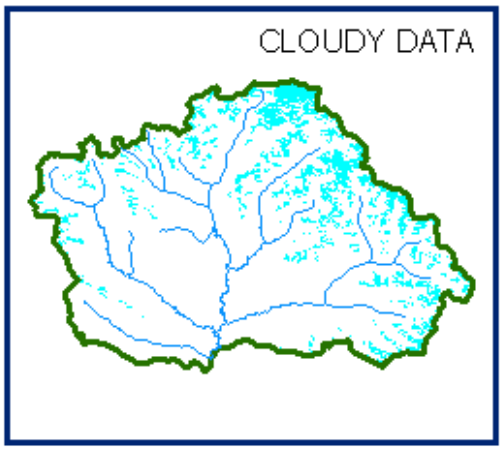

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SNOW

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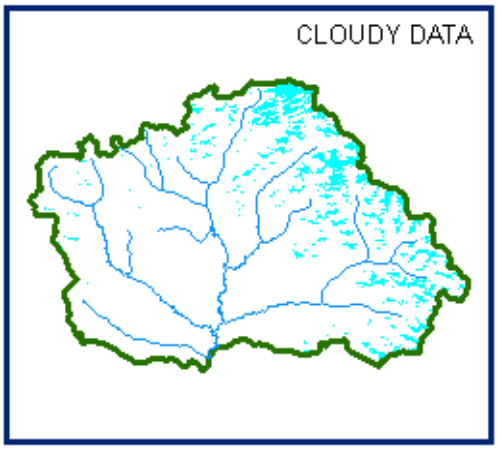
Kilometers

SNOW COVER MAP : DIBANG BASIN



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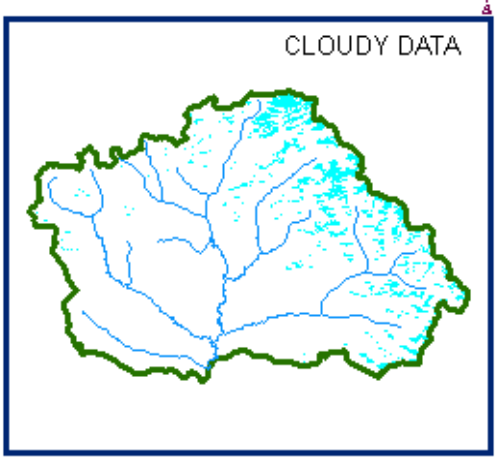

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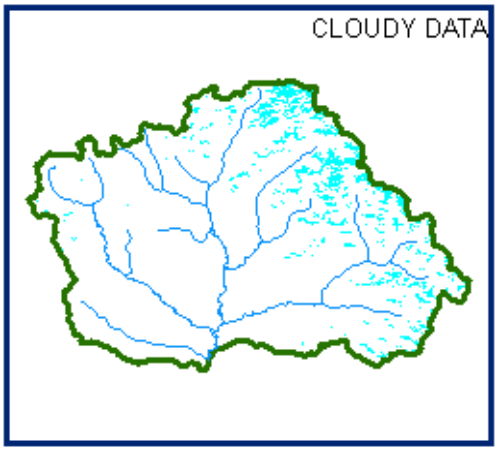

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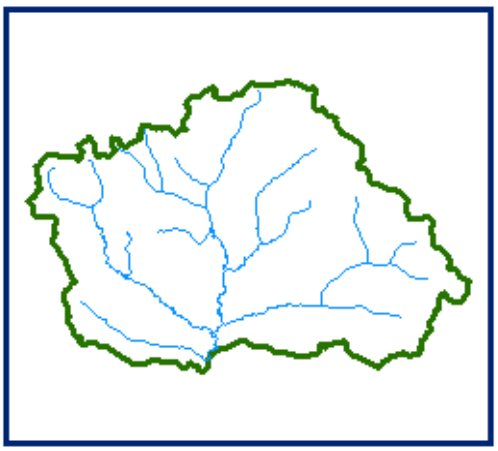

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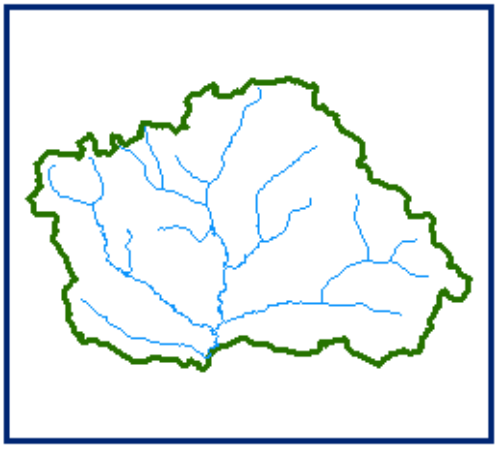

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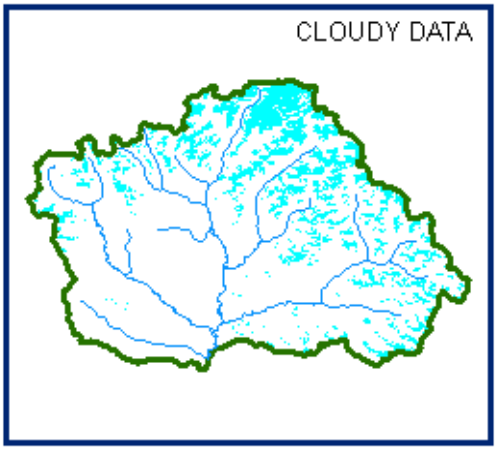

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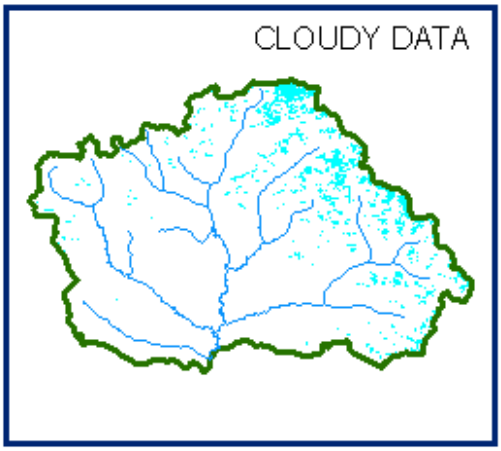
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: **DIBANG BASIN**



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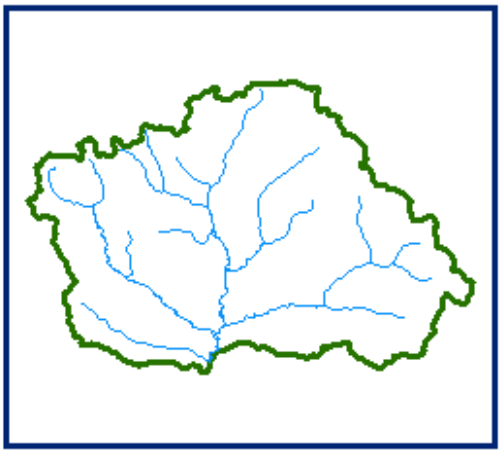

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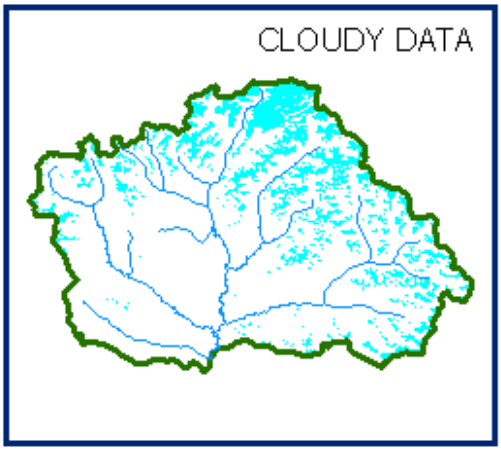

DATA USED
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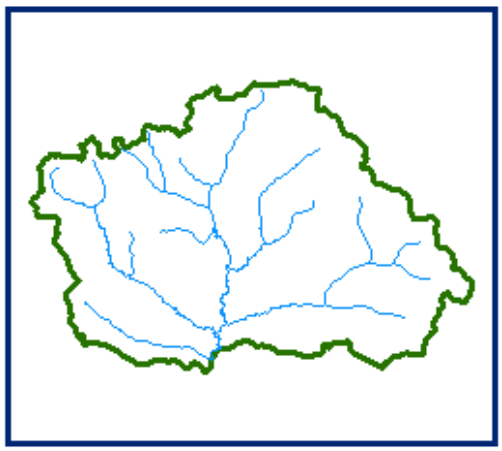
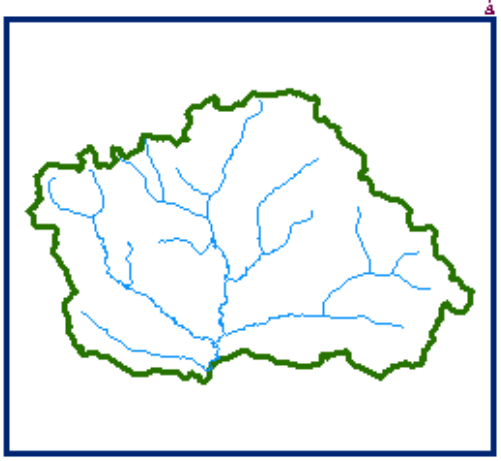
SNOW

0 20 40 80 120 160
Kilometers

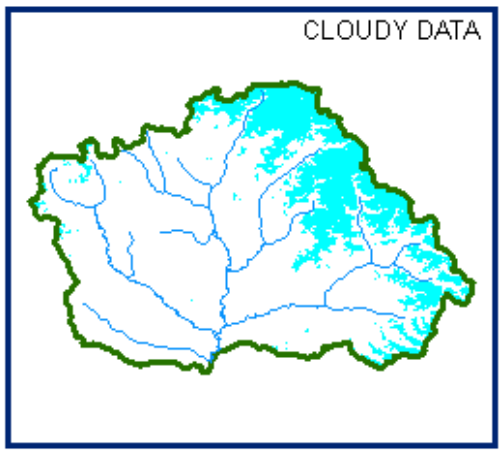
SNOW COVER MAP : DIBANG BASIN



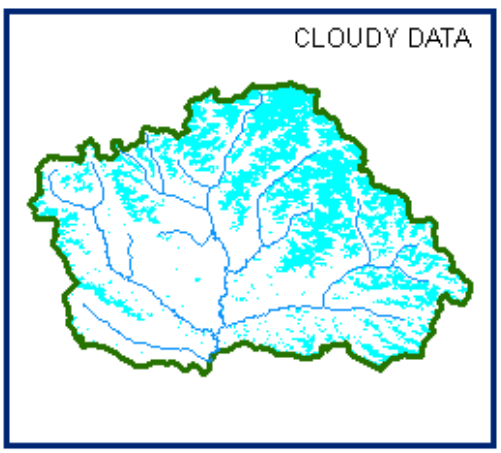
DATA NOT AVAILABLE



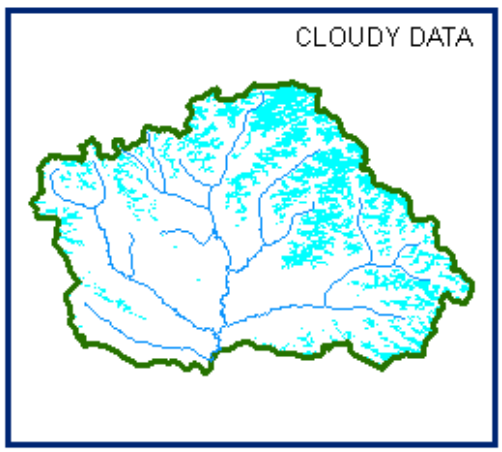
DATA NOT AVAILABLE



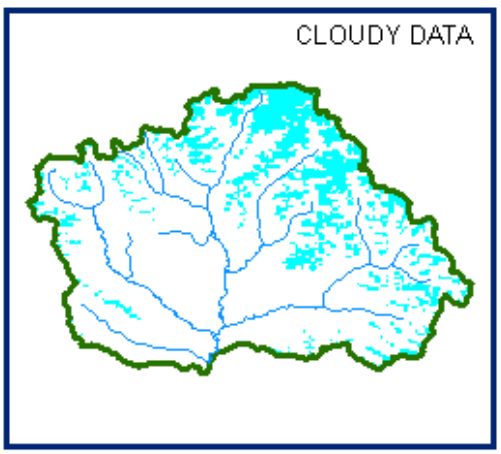
11-JAN-09



16-JAN-09



21-JAN-09



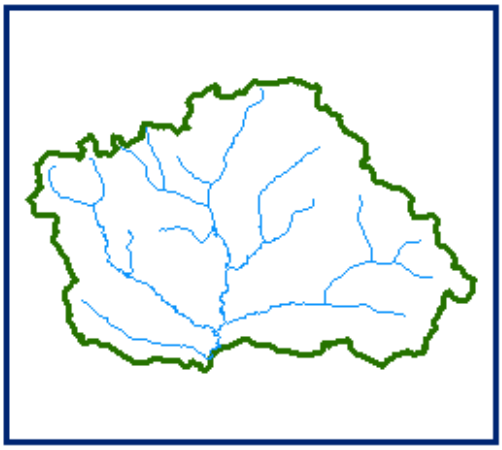
30-JAN-09

SNOW

0 15 30 60 90 120

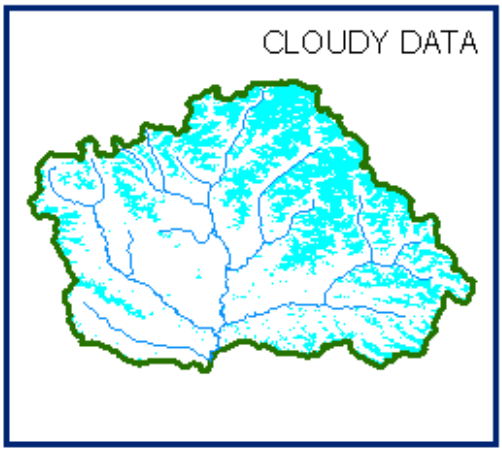
Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



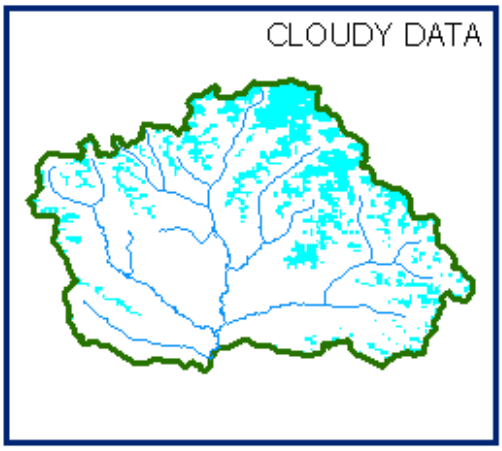
DATA USED

DATA NOT AVAILABLE



DATA USED

16-JAN-09



DATA USED

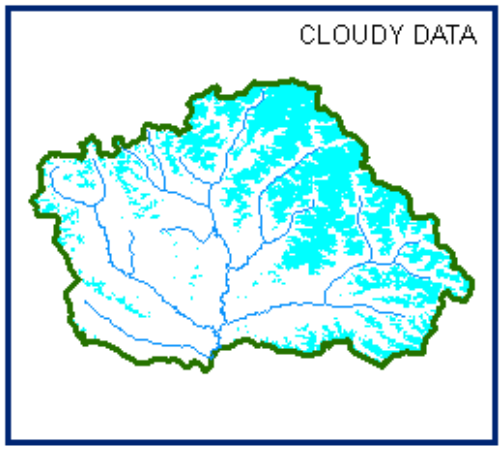
21-JAN-09

SNOW

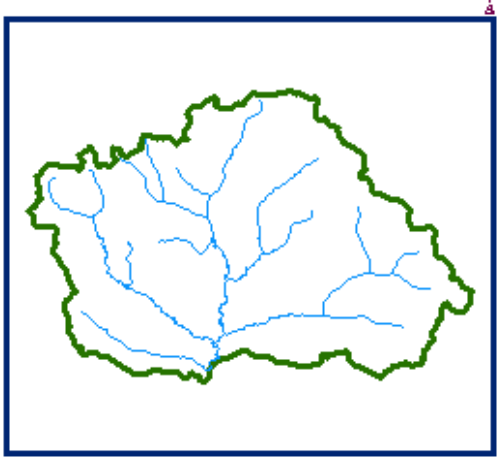
0 20 40 80 120 160

Kilometers

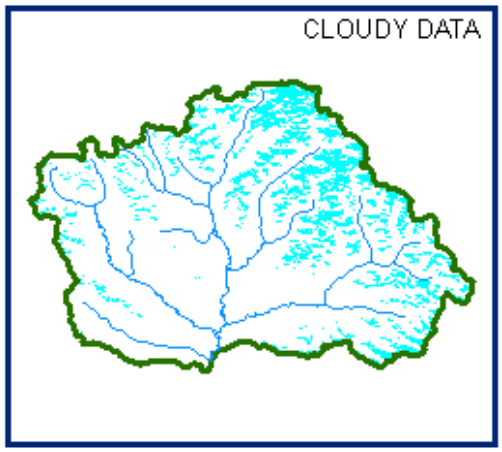
SNOW COVER MAP : DIBANG BASIN



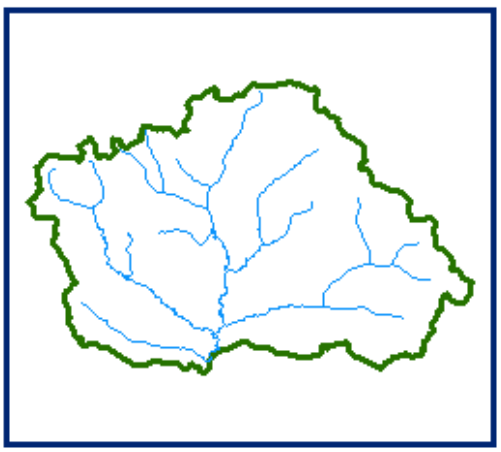
04-FEB-09



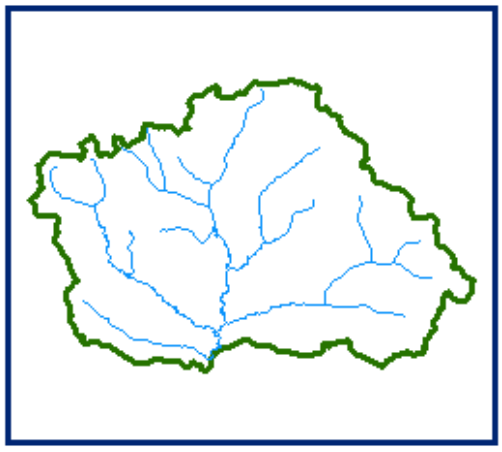
DATA NOT AVAILABLE



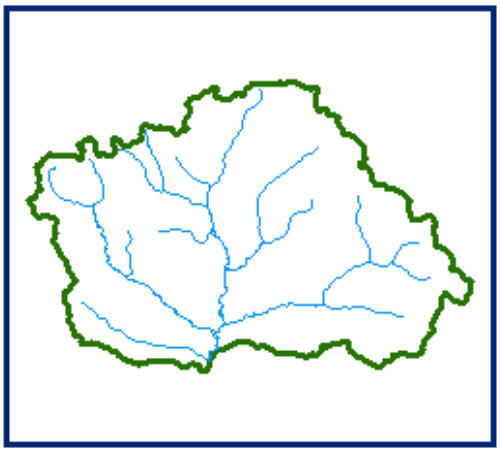
14-FEB-09



DATA NOT AVAILABLE



DATA NOT AVAILABLE



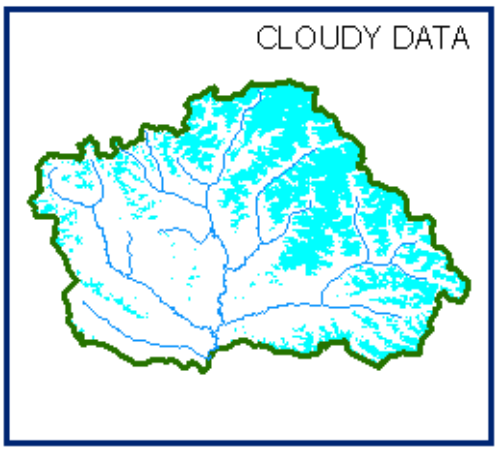
DATA NOT AVAILABLE

SNOW

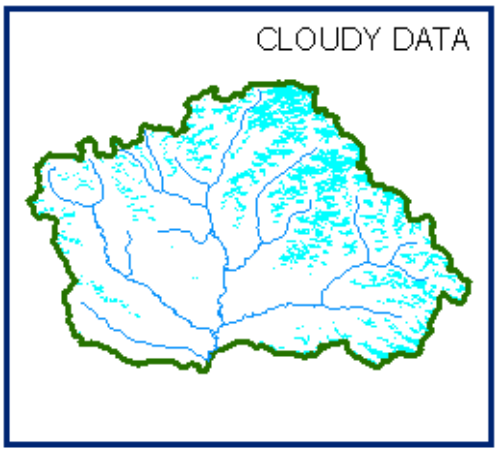
0 15 30 60 90 120

Kilometers

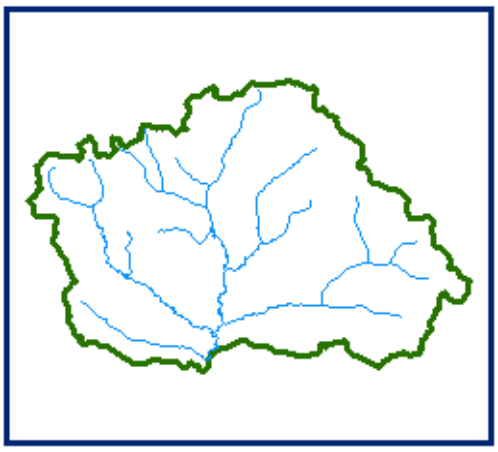
10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
04-FEB-09



DATA USED
14-FEB-09

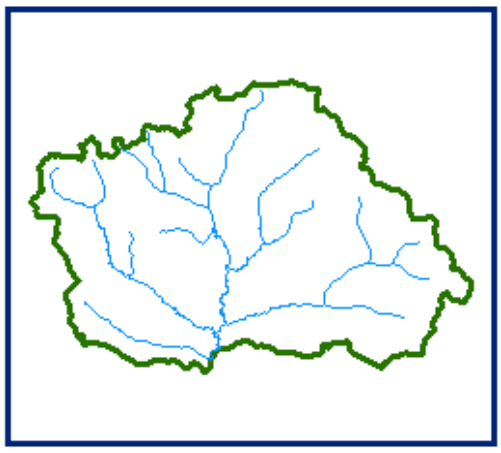


DATA USED
DATA NOT AVAILABLE

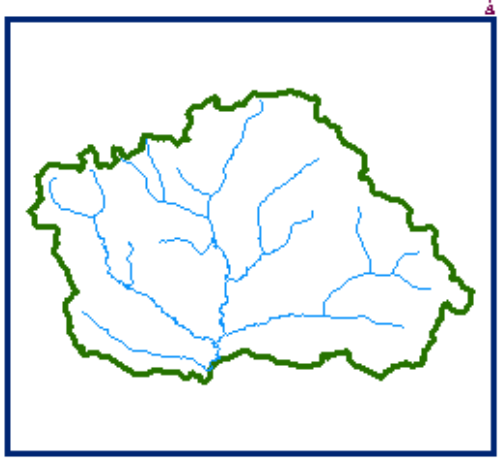
SNOW

0 20 40 80 120 160
Kilometers

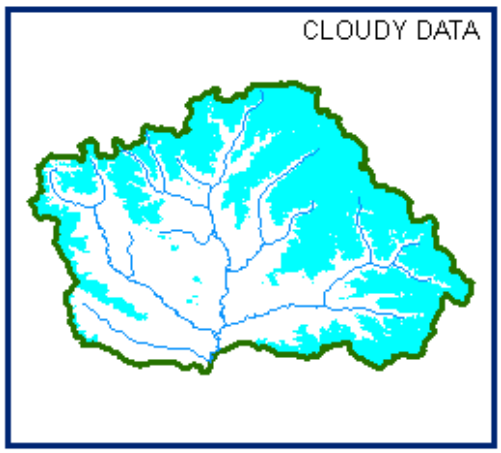
SNOW COVER MAP : DIBANG BASIN



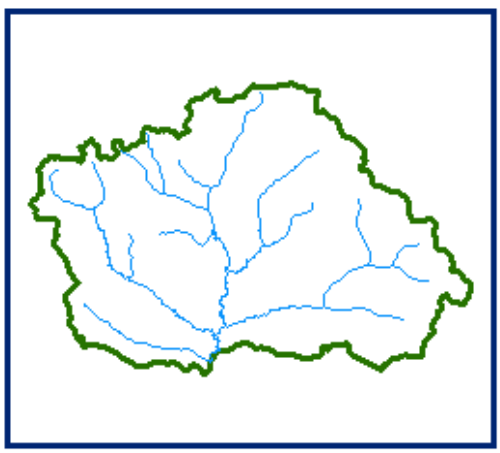
DATA NOT AVAILABLE



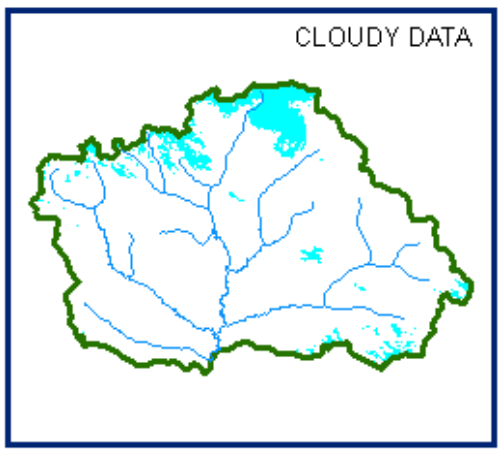
DATA NOT AVAILABLE



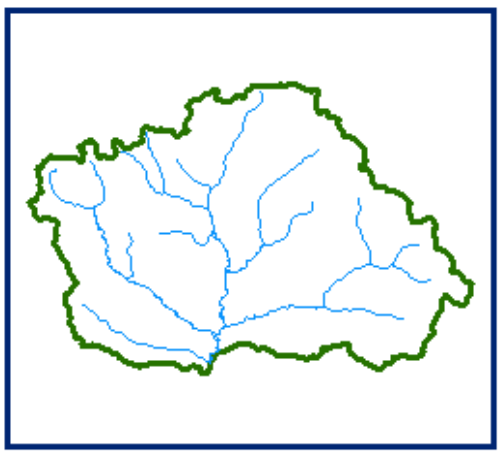
15-MAR-09



DATA NOT AVAILABLE



24-MAR-09



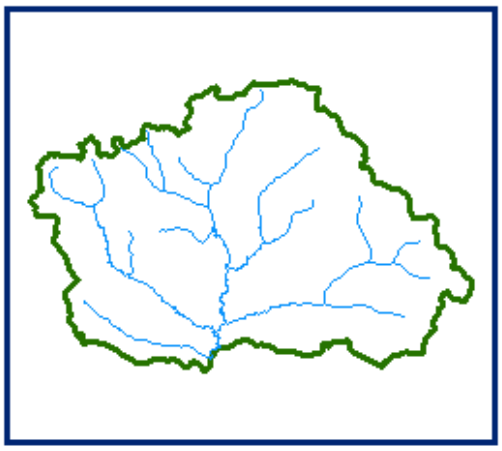
DATA NOT AVAILABLE

SNOW

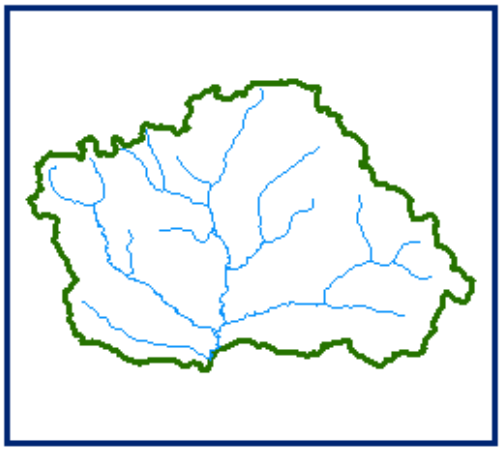
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
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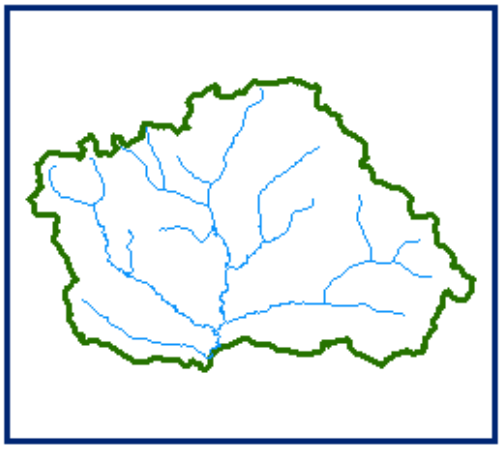
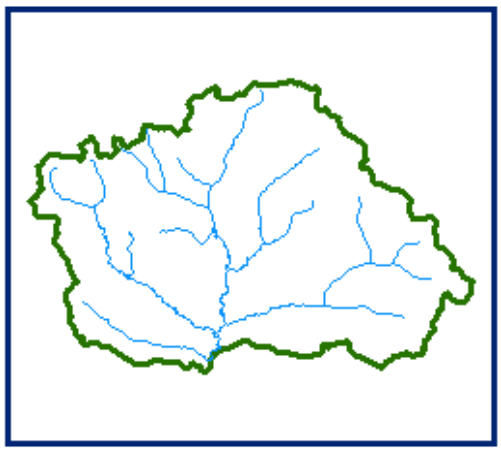


DATA USED
DATA NOT AVAILABLE

SNOW

0 20 40 80 120 160
Kilometers

SNOW COVER MAP : DIBANG BASIN



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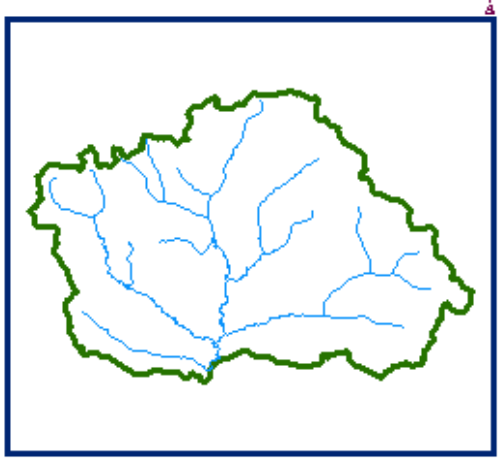

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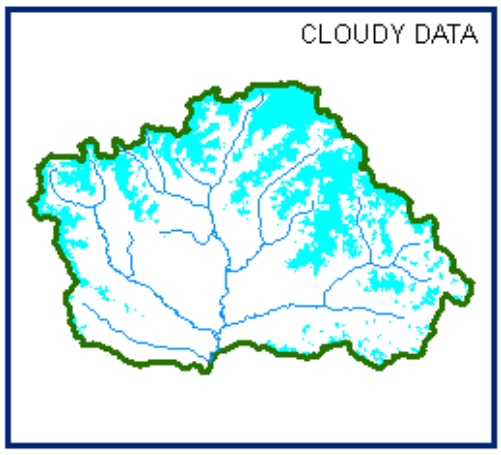
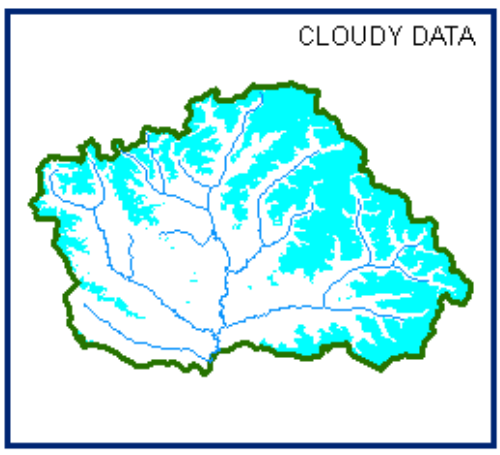
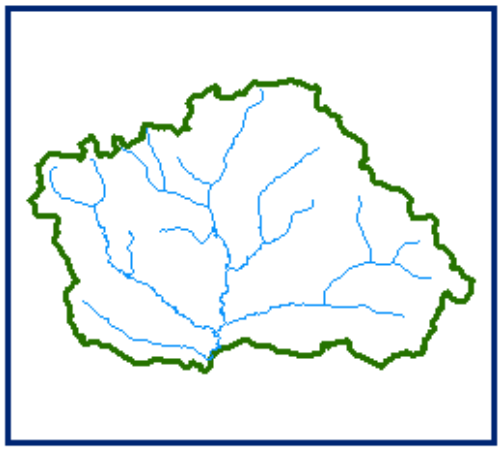


12-APR-09



13-APR-09



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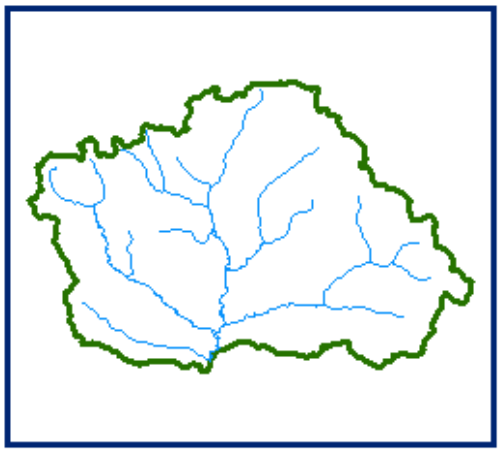


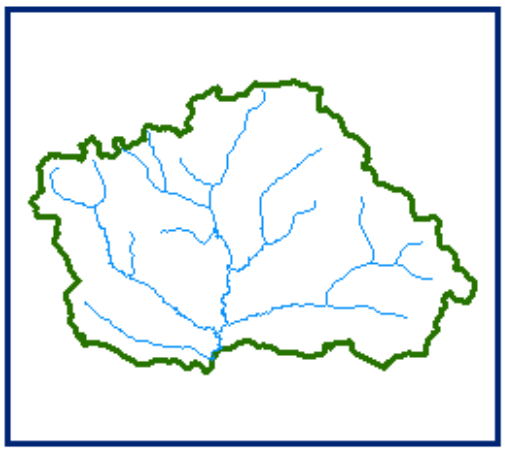
DATA NOT AVAILABLE

SNOW

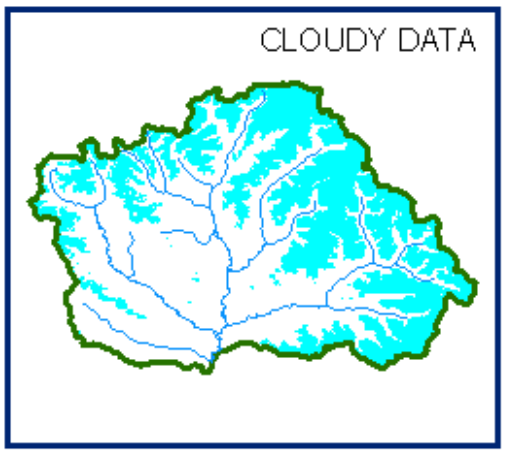
0 15 30 60 90 120

Kilometers

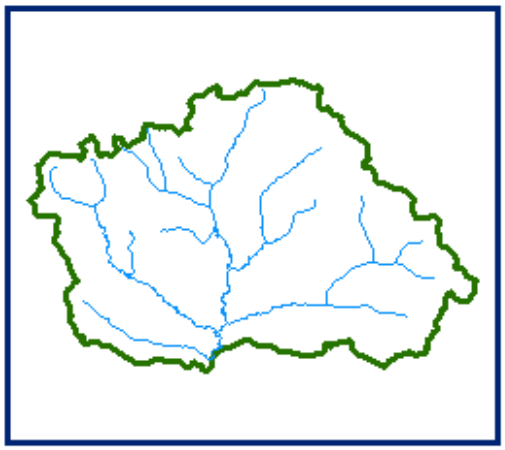
10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
13-APR-09

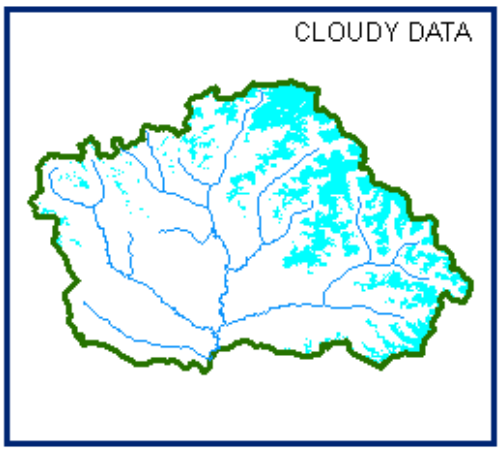


DATA USED
DATA NOT AVAILABLE

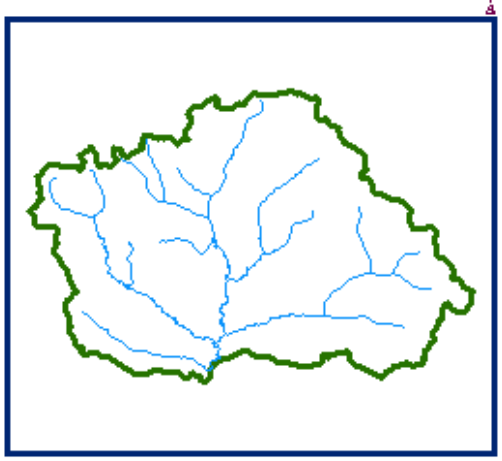
SNOW

0 20 40 80 120 160
Kilometers

SNOW COVER MAP : DIBANG BASIN



02-MAY-09



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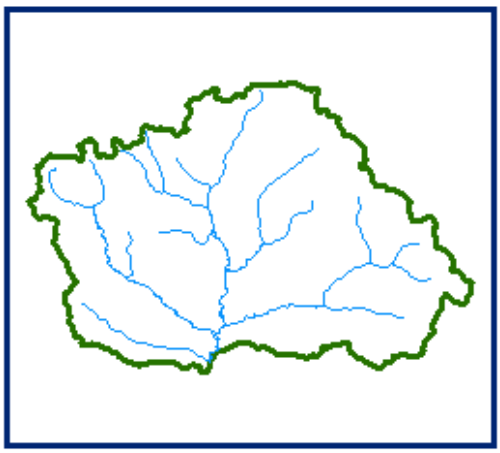
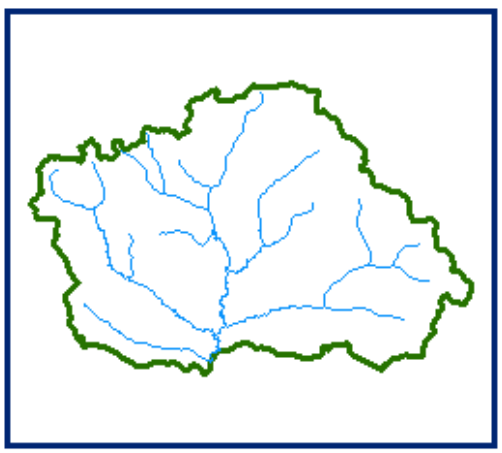


DATA NOT AVAILABLE



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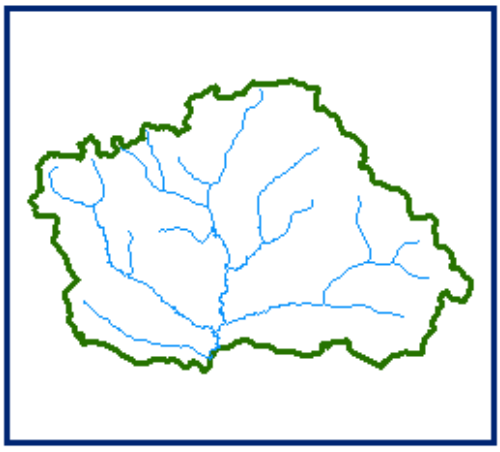

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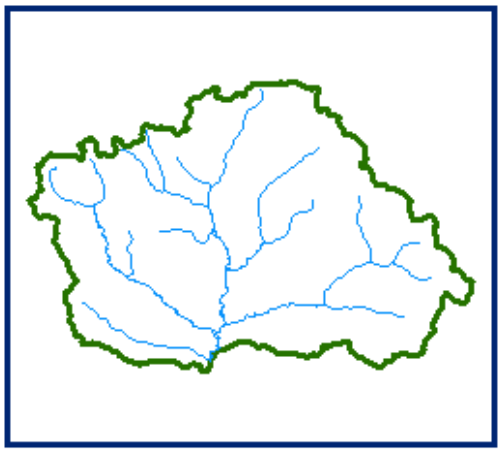


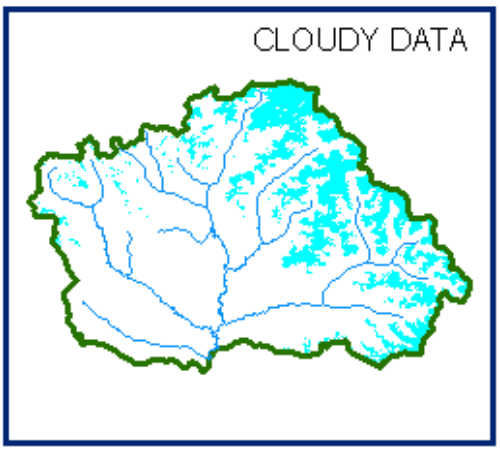
DATA NOT AVAILABLE

SNOW

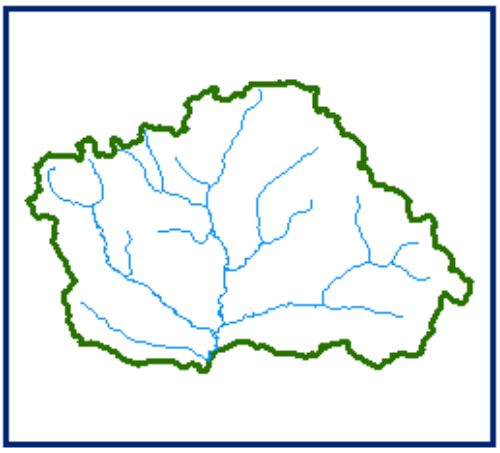
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
02-MAY-09



DATA USED
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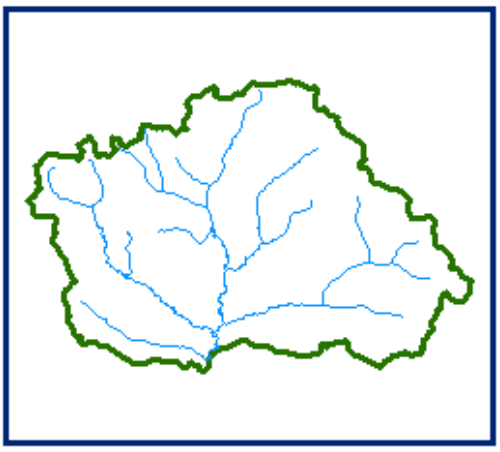
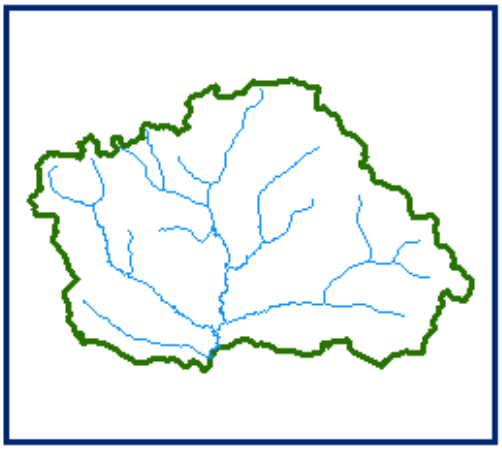


DATA USED
DATA NOT AVAILABLE

SNOW

0 20 40 80 120 160
Kilometers

SNOW COVER MAP : DIBANG BASIN



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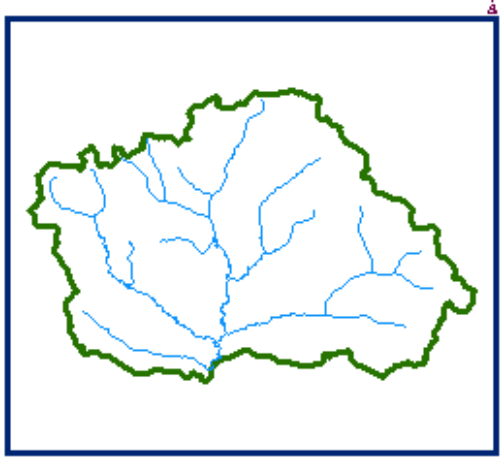

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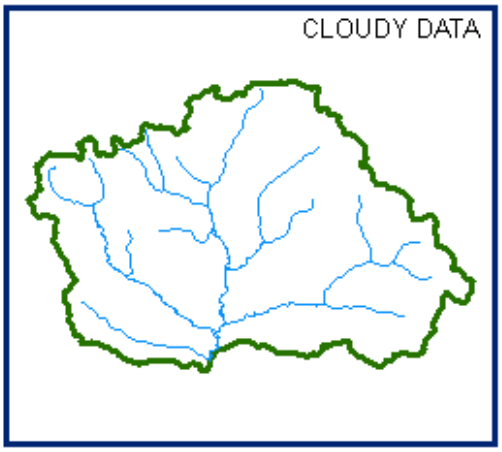

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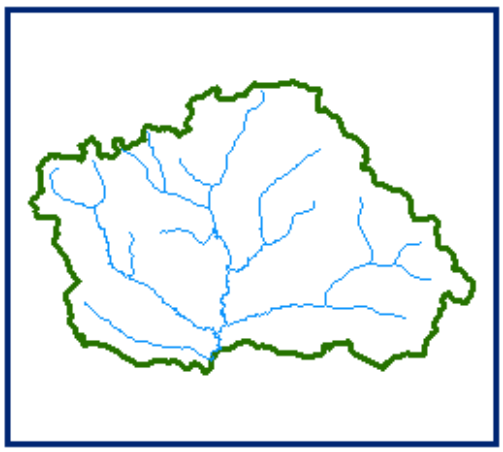

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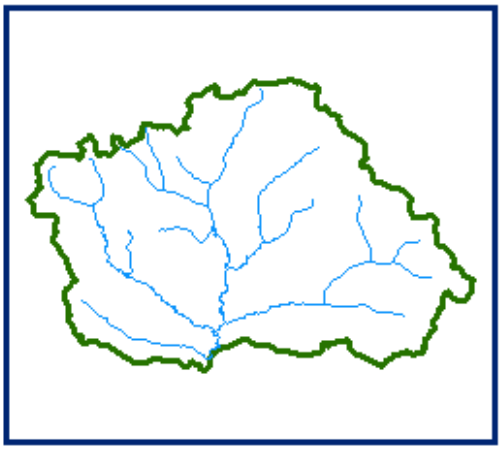

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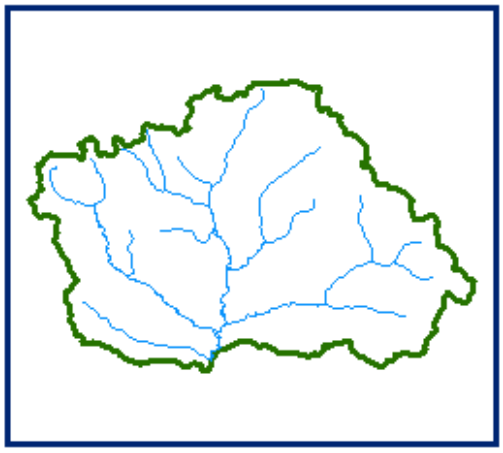


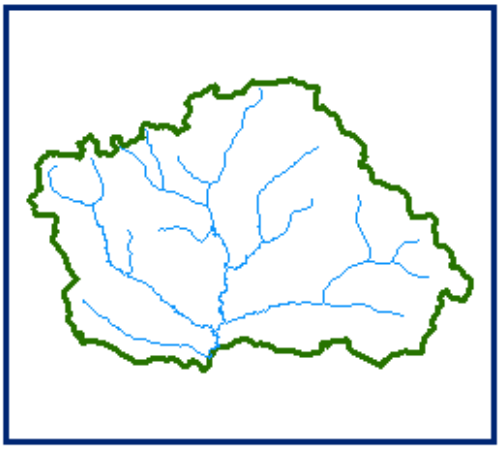
DATA NOT AVAILABLE

SNOW

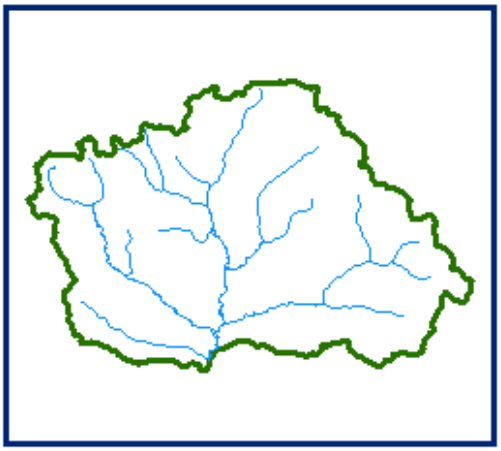
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
DATA NOT AVAILABLE



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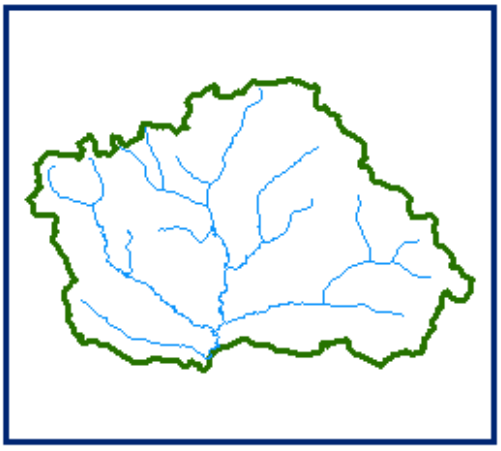


DATA USED
DATA NOT AVAILABLE

SNOW

0 20 40 80 120 160
Kilometers

SUBANSIRI BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: SABANSIRI **BASIN AREA: 25329 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008							
1	12-Oct-08	10334	41	2	16-Oct-08	792	3
3	17-Oct-08	862	3	4	21-Oct-08	977	4
November 2008							
5	9-Nov-08	9245	36	6	10-Nov-08	9246	37
7	14-Nov-08	7532	30	8	19-Nov-08	7381	29
9	24-Nov-08	6734	27	10	28-Nov-08	6840	27
11	29-Nov-08	6284	25				
December 2008							
12	3-Dec-08	6134	24	13	8-Dec-08	5841	23
14	27-Dec-08	5127	20				
January 2009							
15	1-Jan-09	4034.	16	16	6-Jan-09	4433	18
17	11-Jan-09	4396	17	18	16-Jan-09	4318	17
19	20-Jan-09	3168	13	20	21-Jan-09	3045	12
21	30-Jan-09	3077	12				
February 2009							
22	4-Feb-09	2753	11	23	8-Feb-09	2896	11
24	9-Feb-09	2374	9	25	13-Feb-09	2874	11
26	14-Feb-09	2496	10	27	18-Feb-09	1232	5
March 2009							
28	9-Mar-09	1720	7	29	14-Mar-09	3335	13
30	24-Mar-09	3043	12				
April 2009							
31	12-Apr-09	3520	14	32	26-Apr-09	820	3

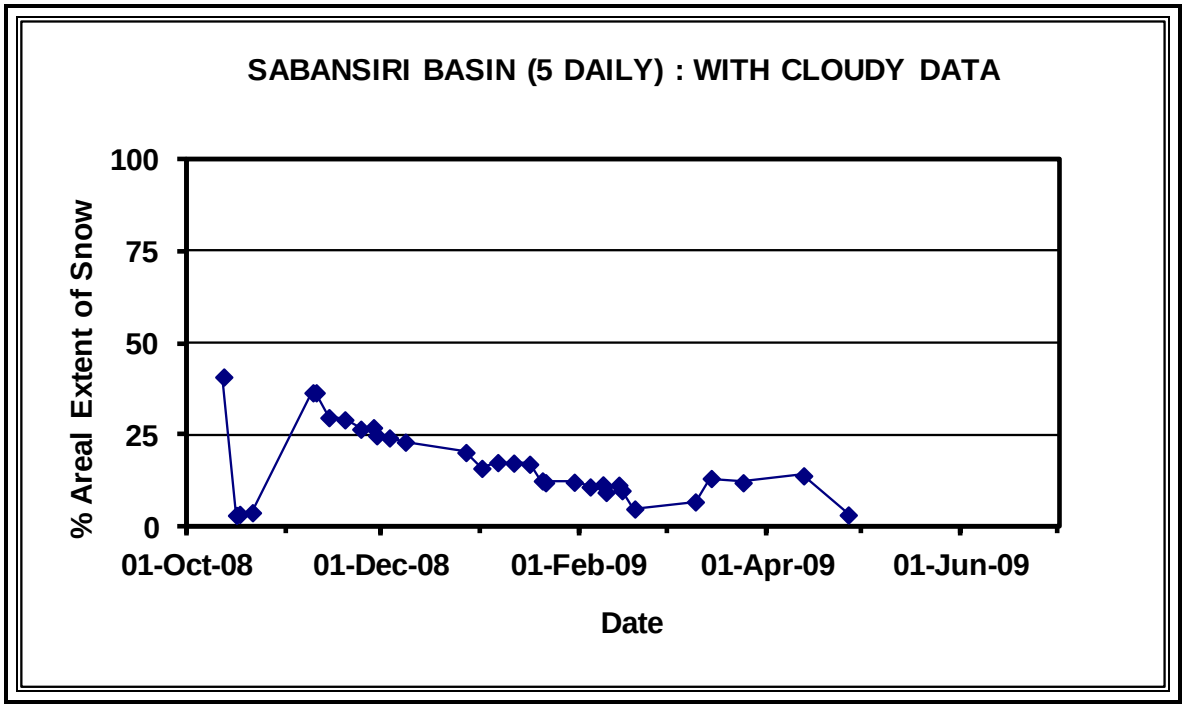
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
June 2009							
July 2009							

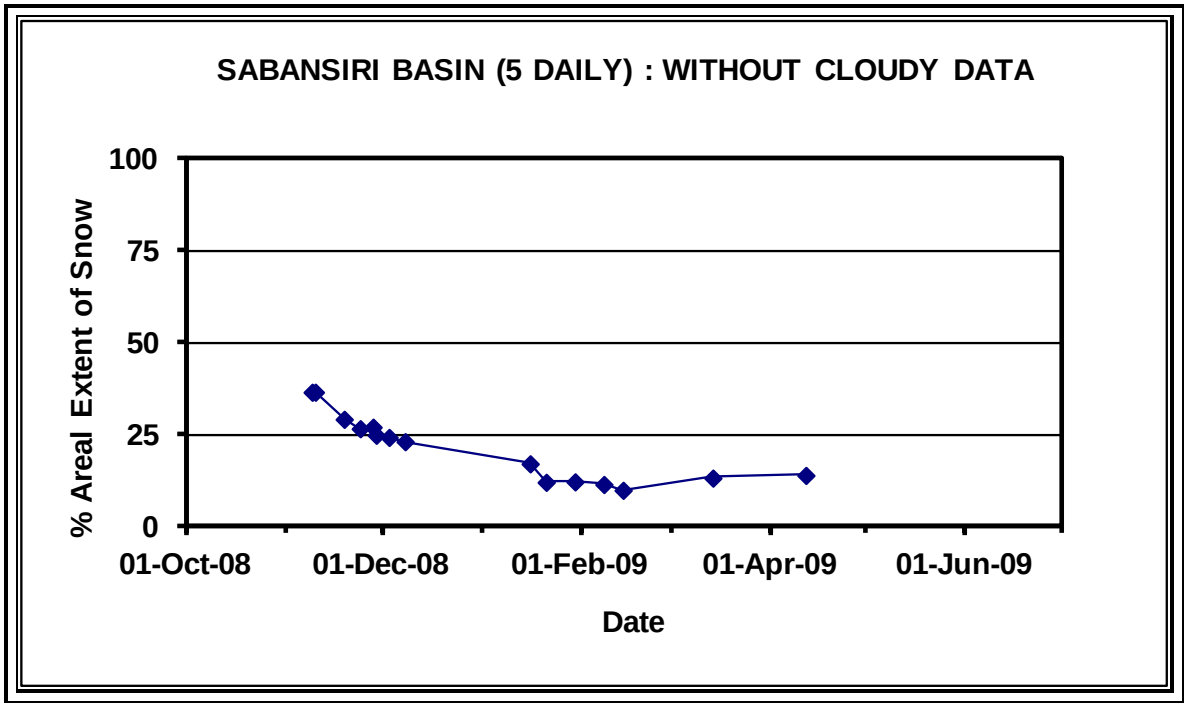
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: SABANSIRI **BASIN AREA: 25329 sq km**

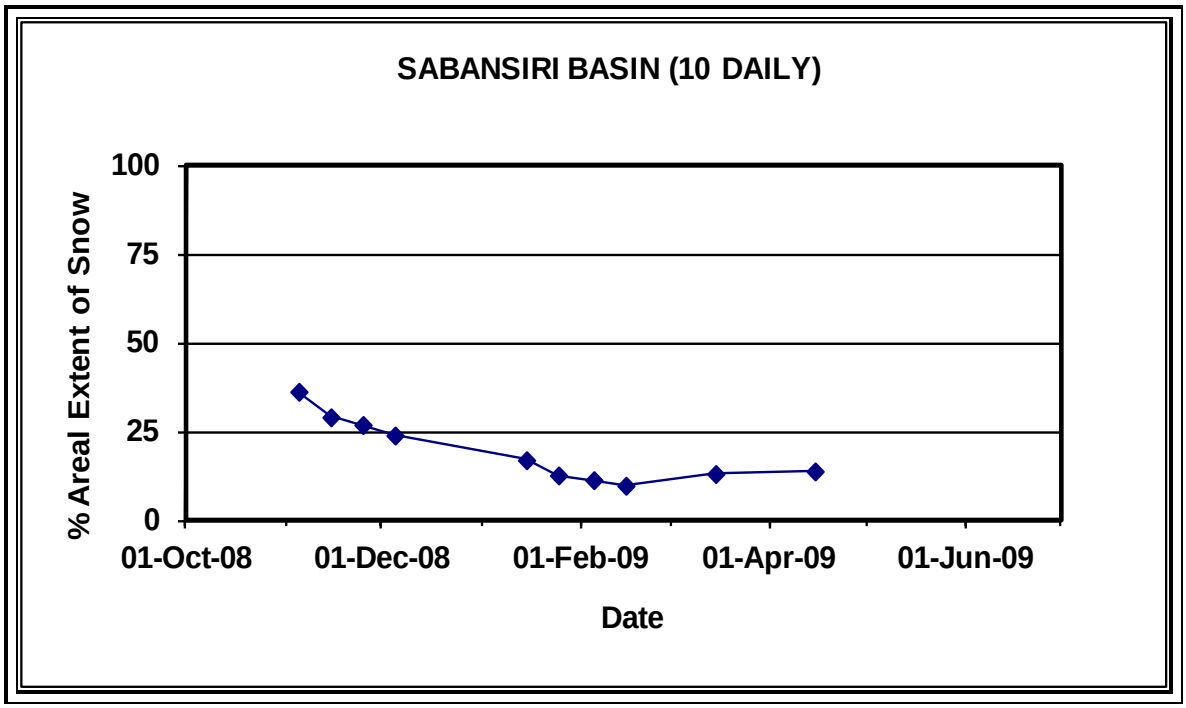
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
				1	9-Nov-08	9201	36
				2	19-Nov-08	7381	29
				3	28-Nov-08	6833	27
December 2008				**January 2009**			
4	8-Dec-08	6079	24	5	16-Jan-09	4318	17
				6	21-Jan-09	3233	13
February 2009				**March 2009**			
7	5-Feb-09	2786	11	8	14-Mar-09	3335	13
7	15-Feb-09	2533	10				
April 2009				**May 2009**			
	15-Apr-09	3546	14				
June 2009				**July 2009**			

Snow cover depletion curve



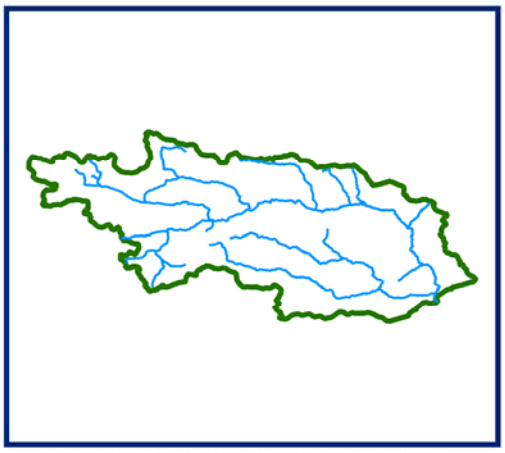


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : SABANSIRI BASIN



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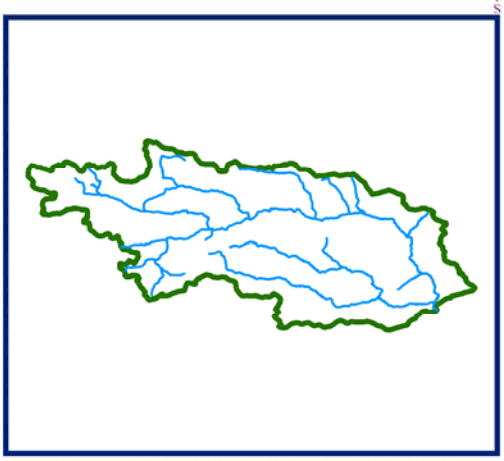

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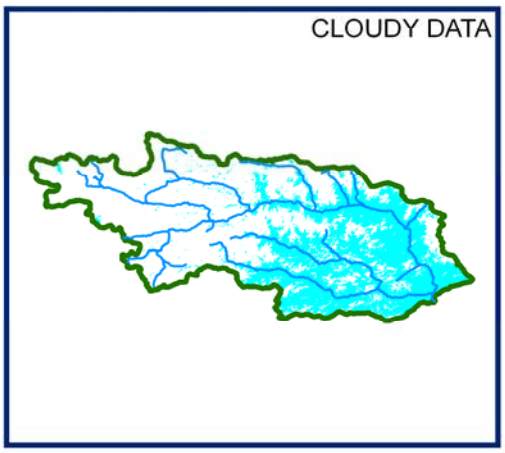
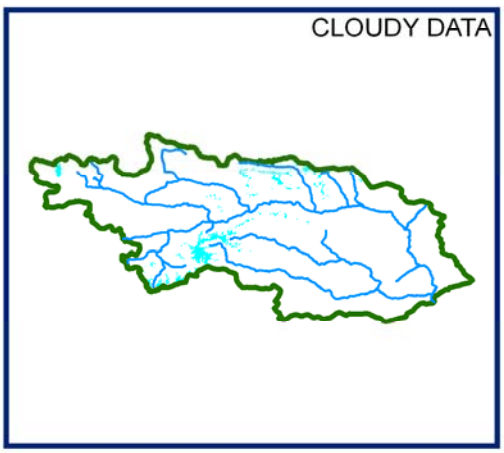
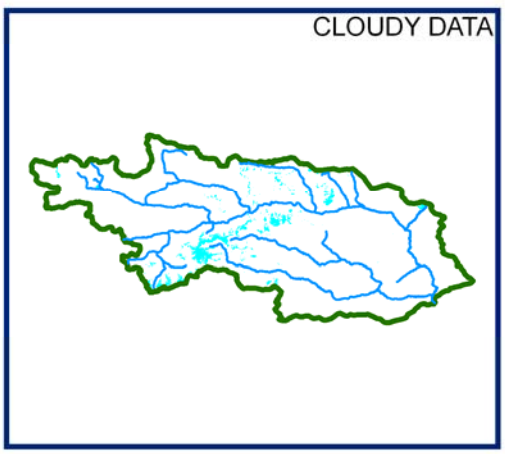


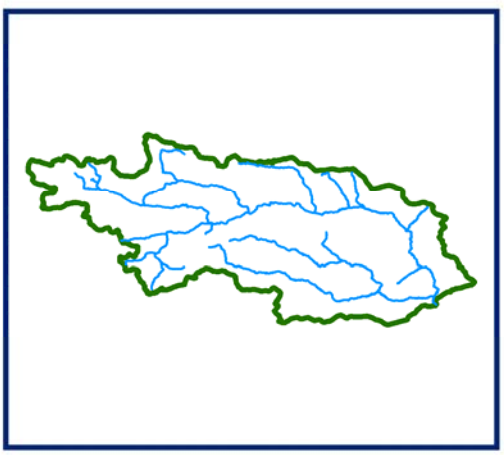
12 OCTOBER 2008



17 OCTOBER 2008



21 OCTOBER 2008



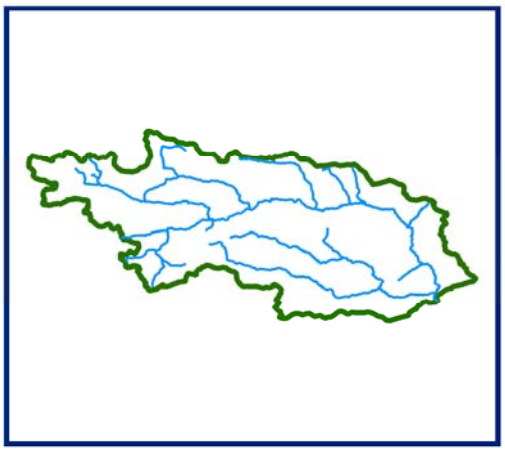
DATA NOT AVAILABLE

SNOW

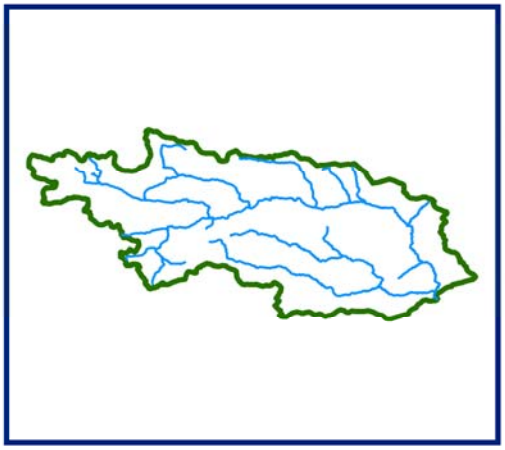
0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



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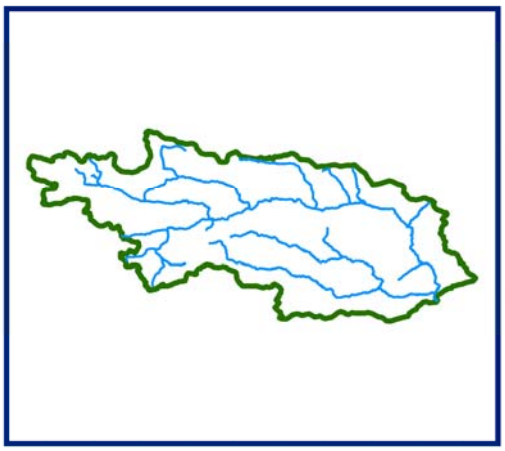
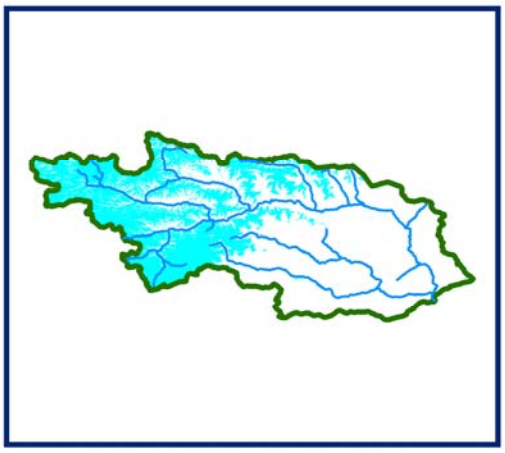


DATA USED
DATA NOT AVAILABLE

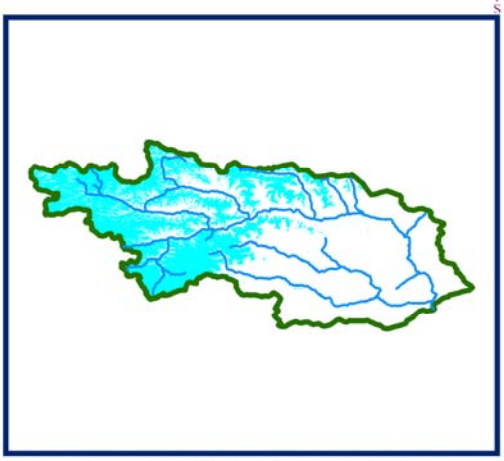
SNOW

0 35 70 140 210 280
Kilometers

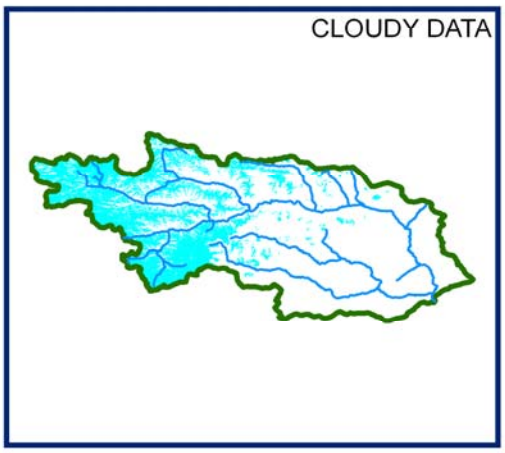
SNOW COVER MAP : SABANSIRI BASIN



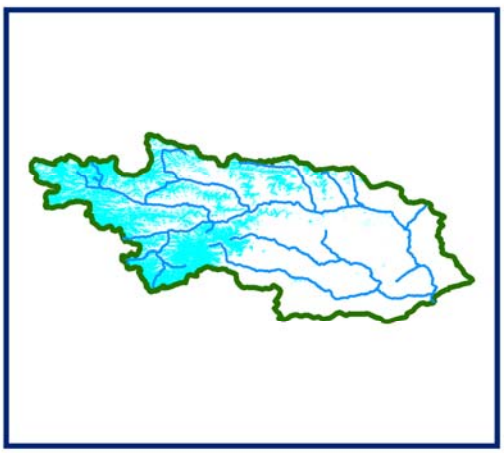
9 NOVEMBER 2008



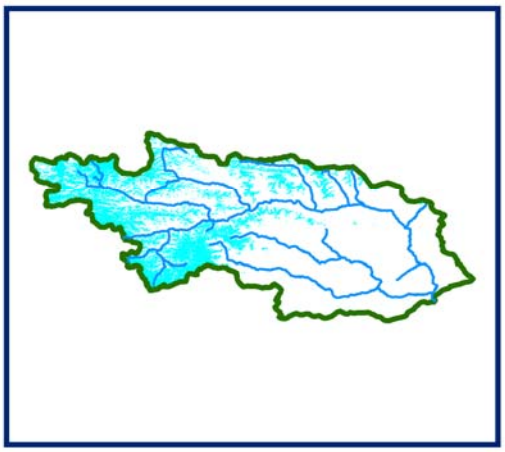
10 NOVEMBER 2008



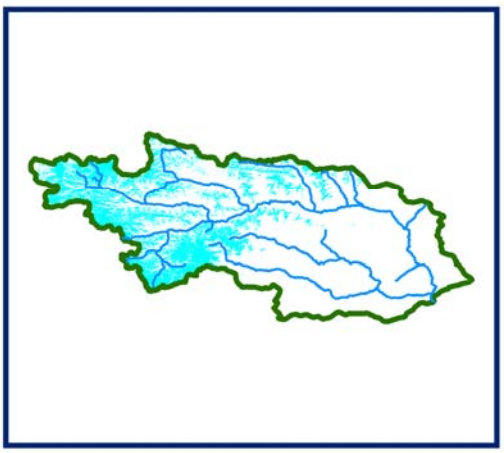
14 NOVEMBER 2008



19 NOVEMBER 2008



24 NOVEMBER 2008



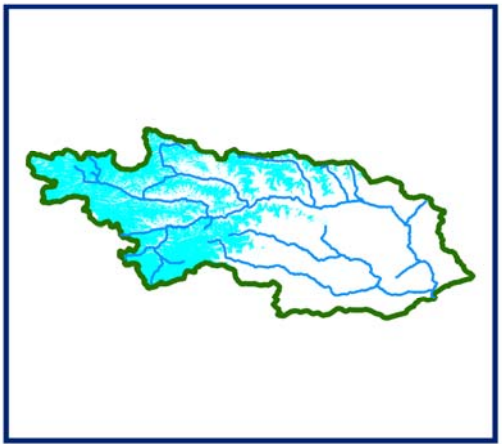
29 NOVEMBER 2008

SNOW

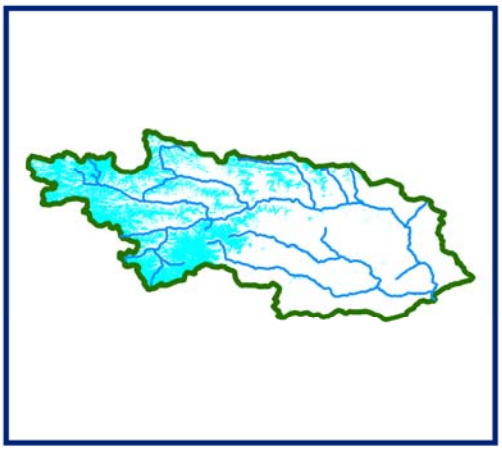
0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED
09 NOVEMBER 2008
10 NOVEMBER 2008



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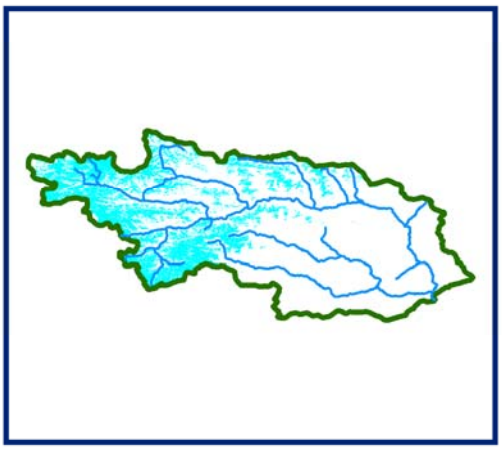
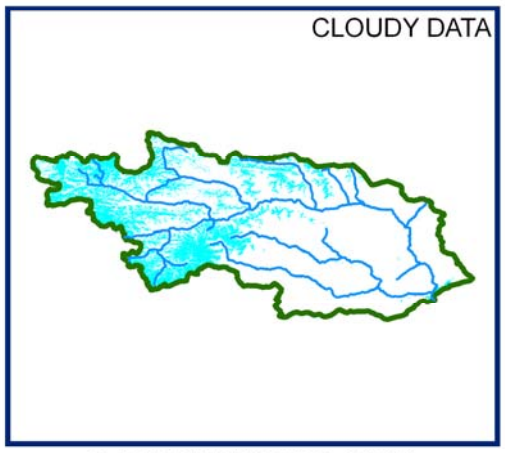


DATA USED
24 NOVEMBER 2008
28 NOVEMBER 2008
29 NOVEMBER 2008

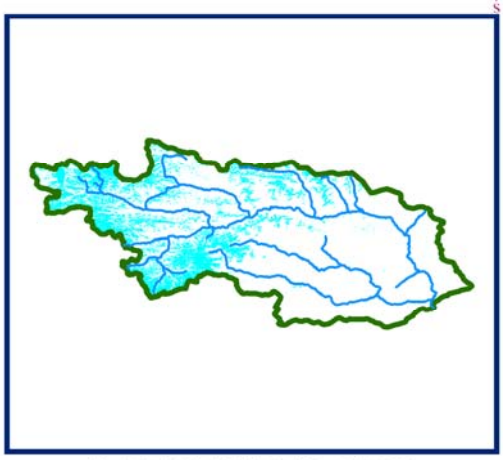
SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SABANSIRI BASIN



3 DECEMBER 2008



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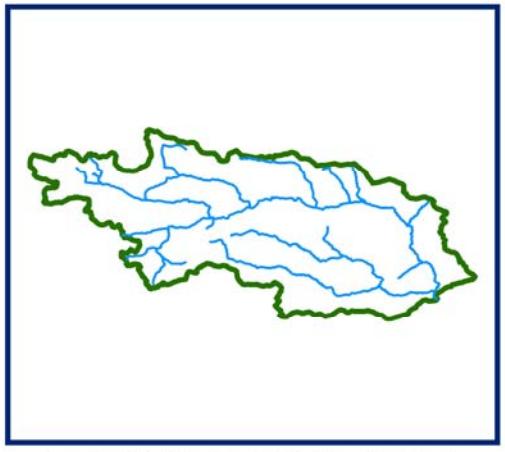

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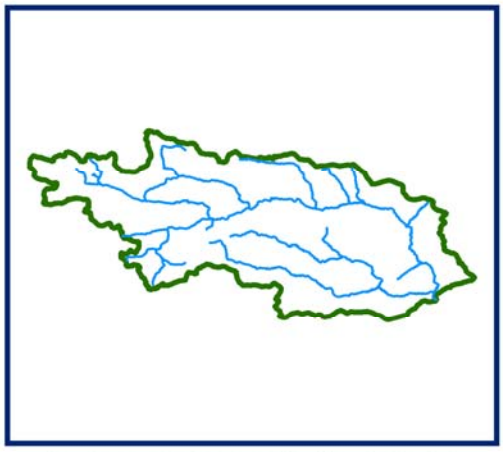

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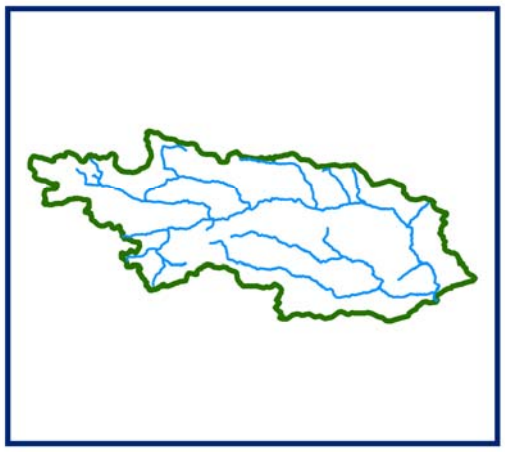

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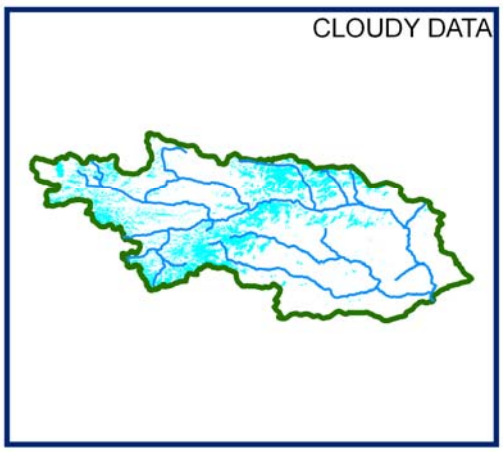


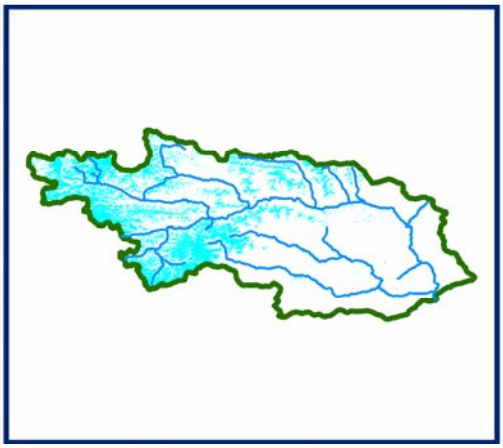
27 DECEMBER 2008

SNOW

0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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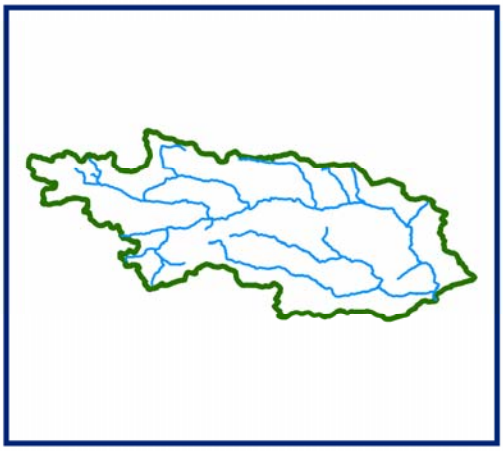

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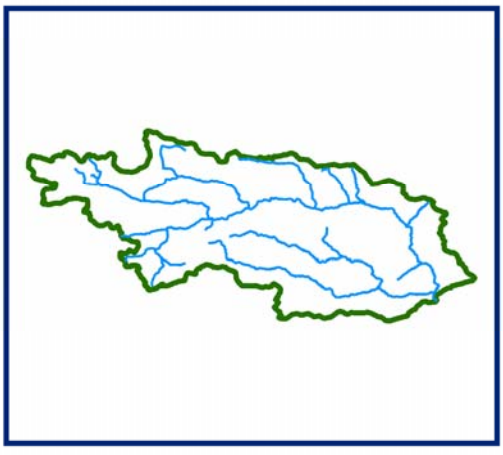
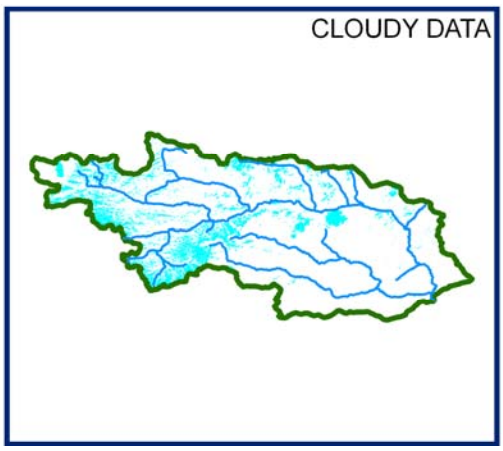


DATA USED
DATA NOT AVAILABLE

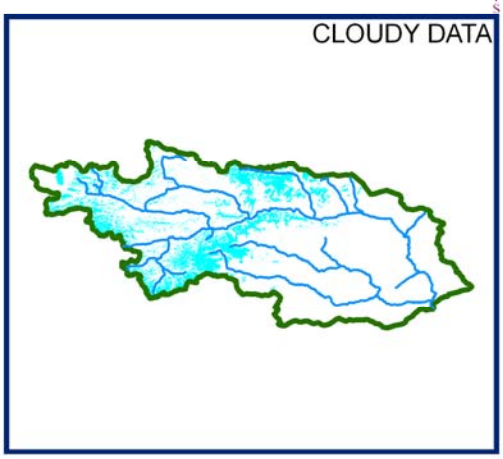
SNOW

0 35 70 140 210 280
Kilometers

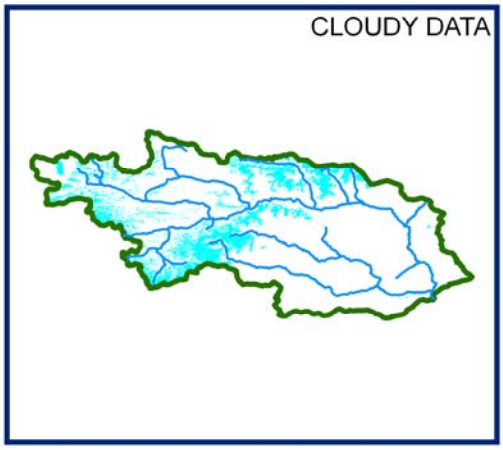
SNOW COVER MAP : SABANSIRI BASIN



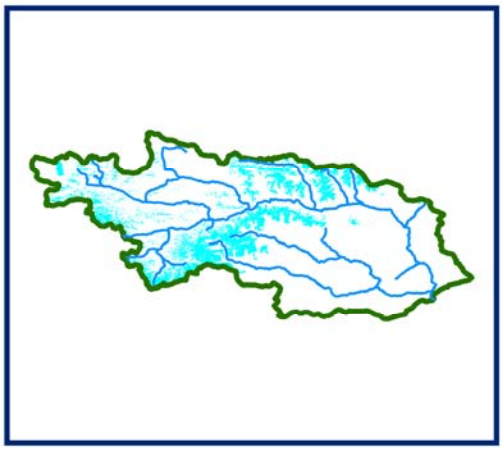
1 JANUARY 2009



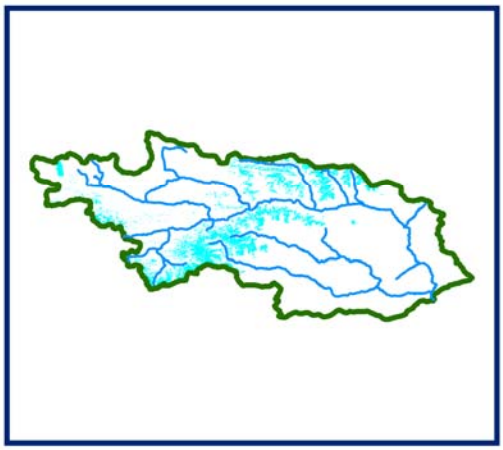
6 JANUARY 2009



11 JANUARY 2009



16 JANUARY 2009



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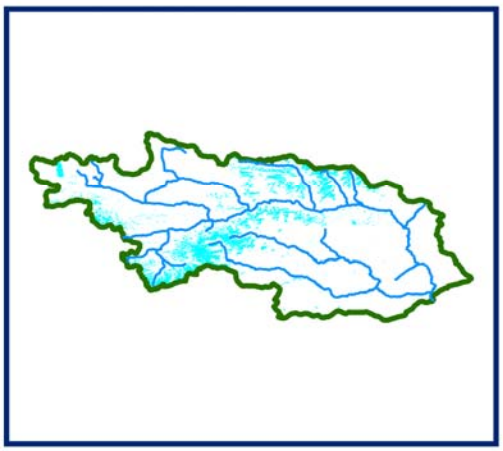


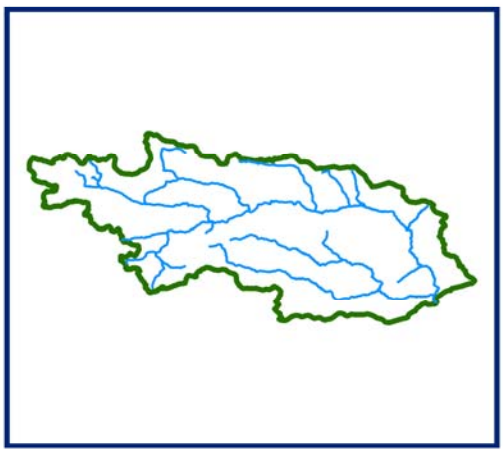
30 JANUARY 2009

SNOW

0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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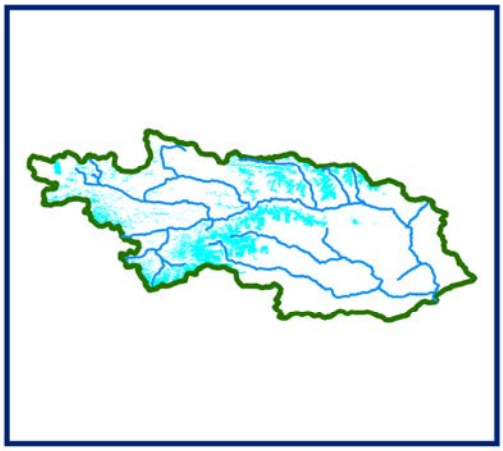

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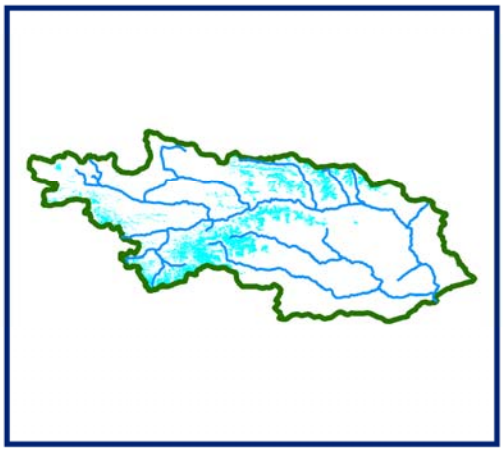
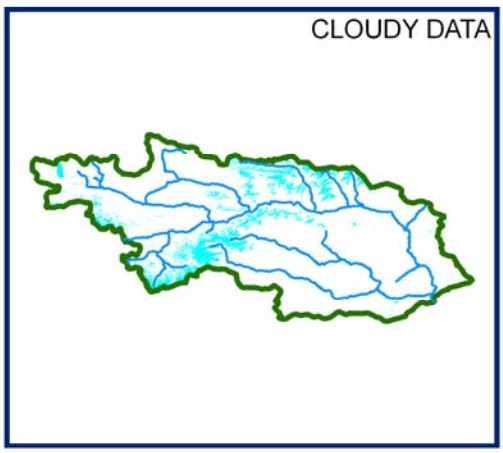


DATA USED
21 JANUARY 2009
30 JANUARY 2009

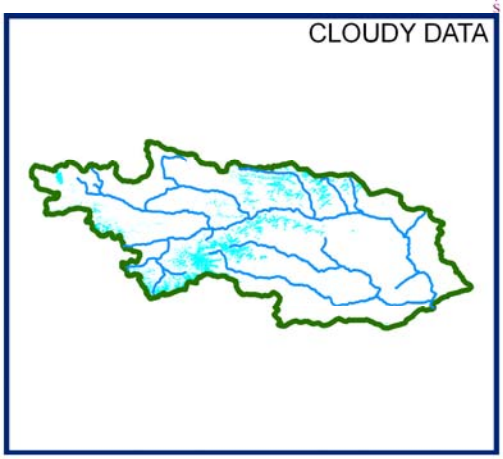
SNOW

0 35 70 140 210 280
Kilometers

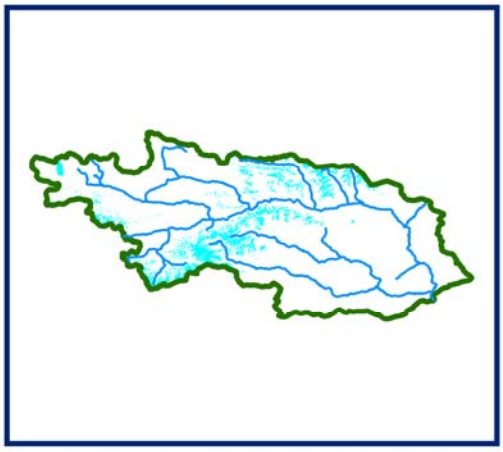
SNOW COVER MAP : SABANSIRI BASIN



4 FEBRUARY 2009



9 FEBRUARY 2009



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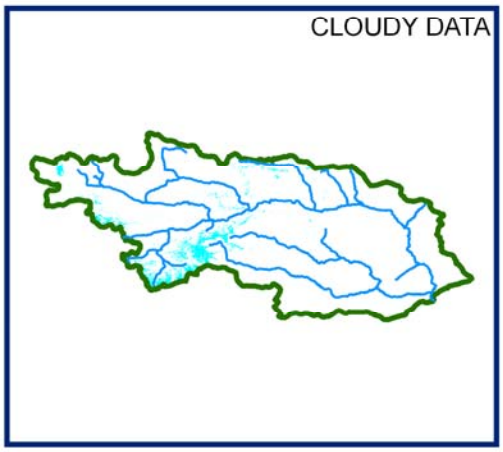
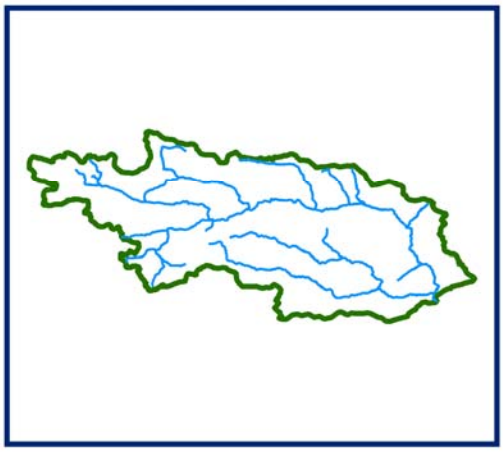


18 FEBRUARY 2009



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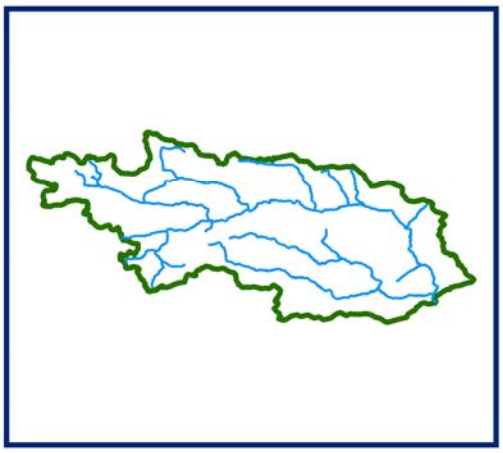


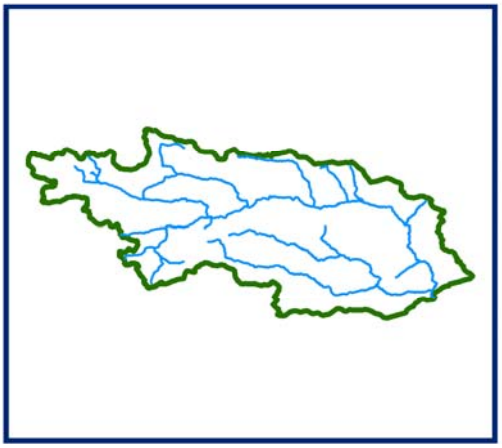
DATA NOT AVAILABLE

SNOW

0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED
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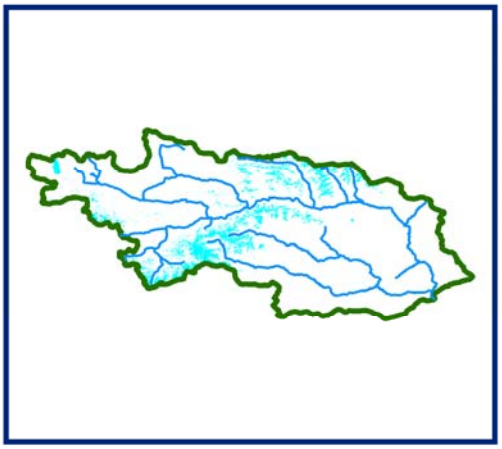

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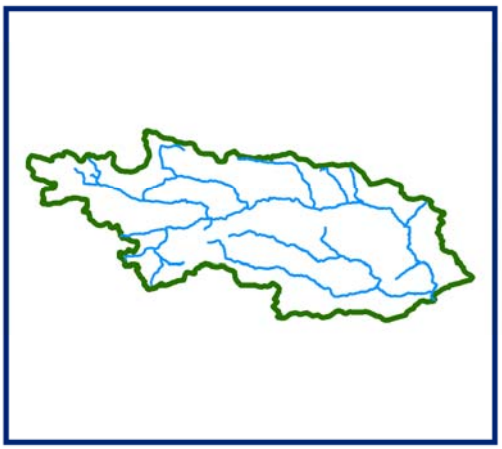
14 FEBRUARY 2009

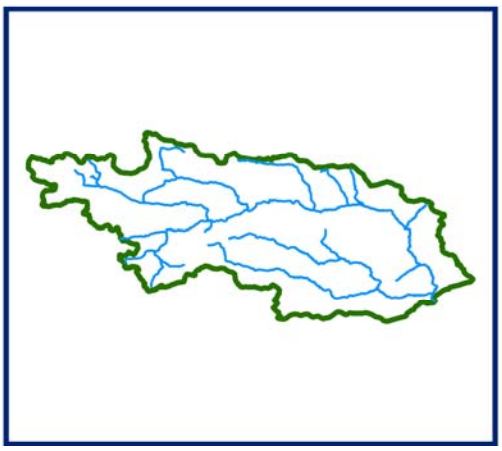


DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SABANSIRI BASIN



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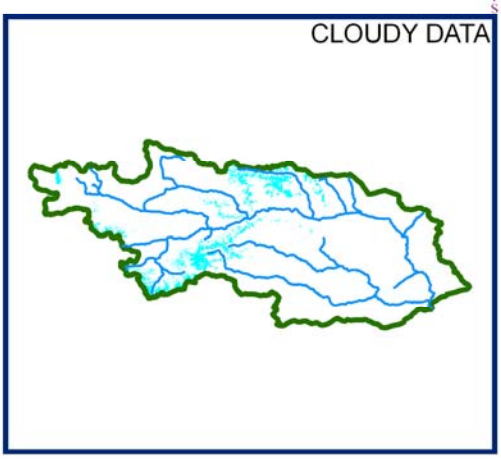
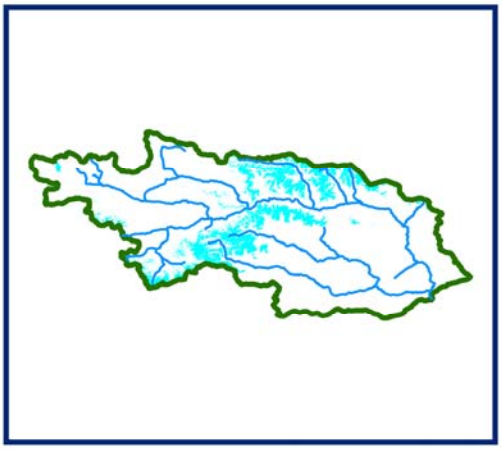
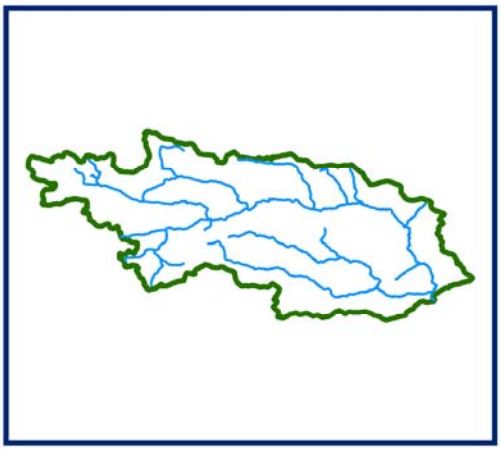


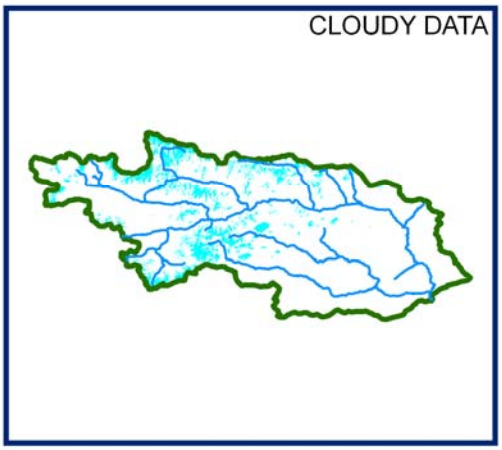
9 MARCH 2009



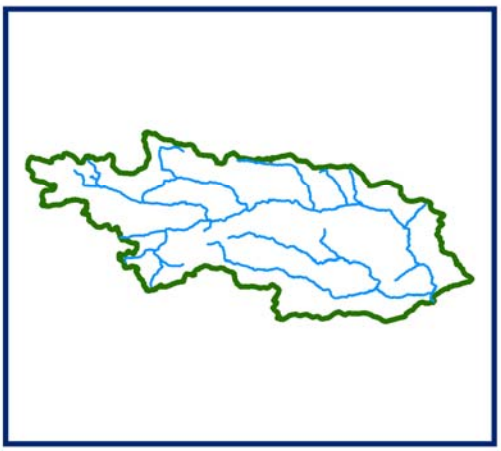
14 MARCH 2009



DATA NOT AVAILABLE



24 MARCH 2009



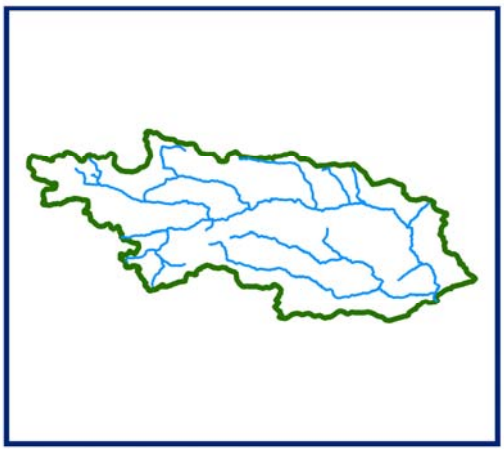
DATA NOT AVAILABLE

SNOW

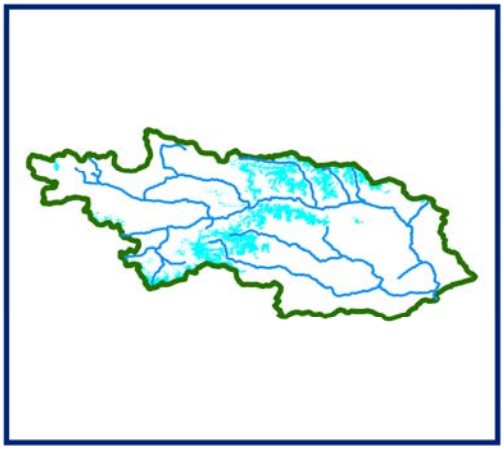
0 40 80 160 240 320

Kilometers

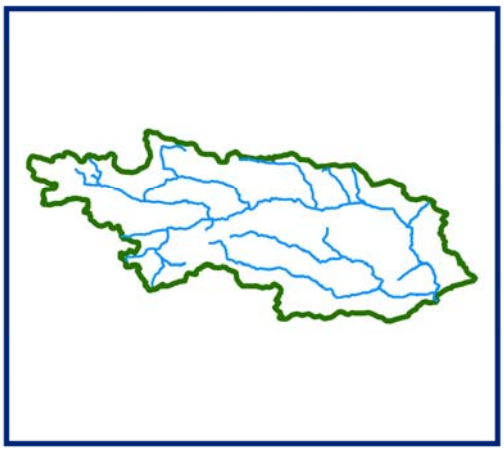
10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
14 MARCH 2009

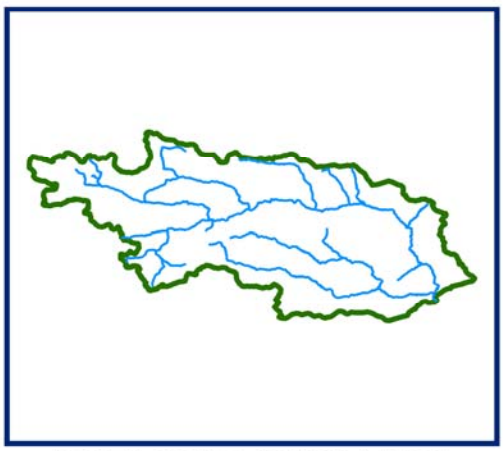


DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SABANSIRI BASIN



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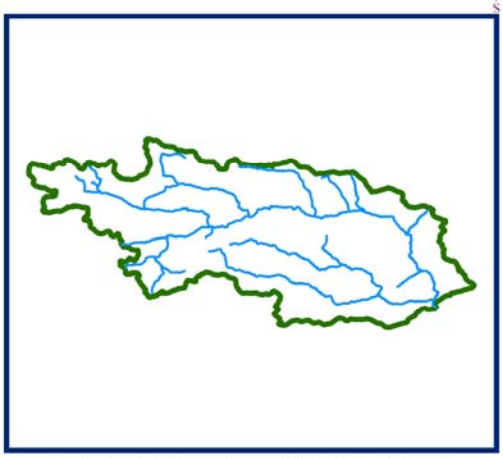

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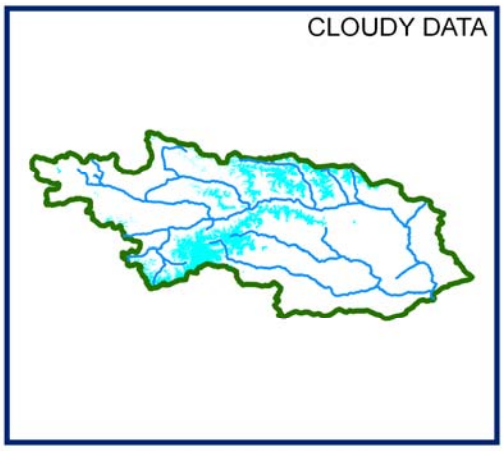
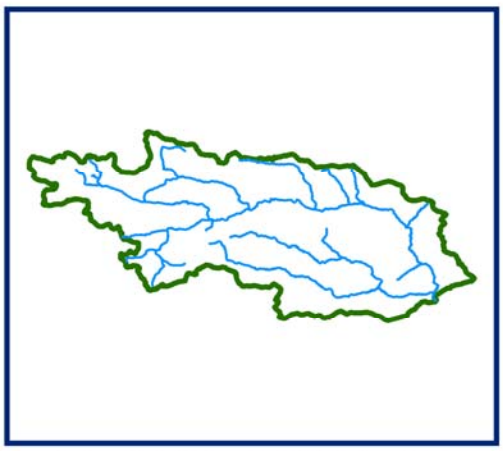


12 APRIL 2009



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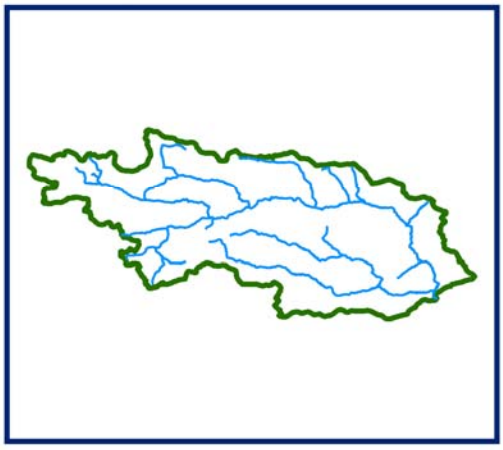

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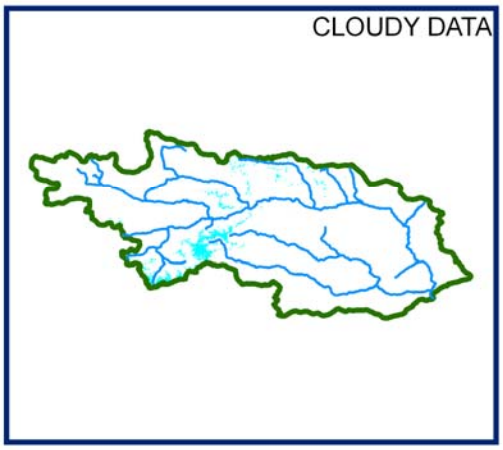


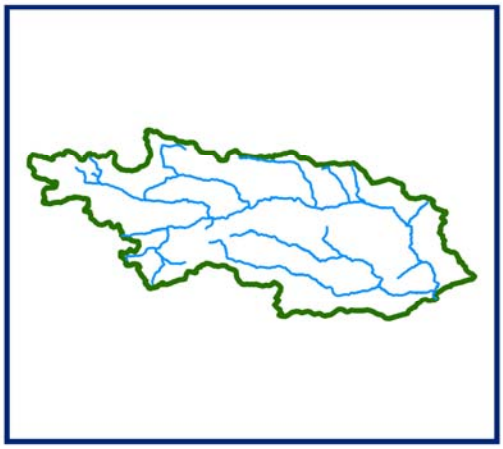
26 APRIL 2009

SNOW

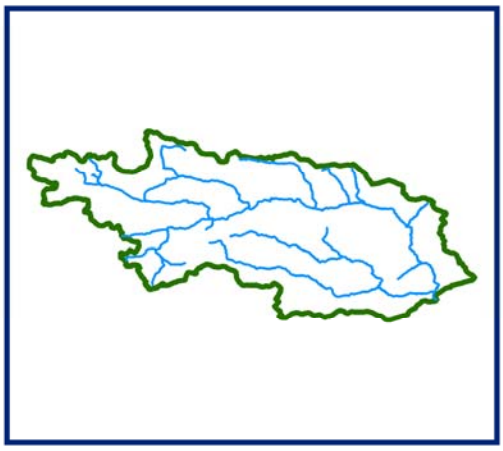
0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



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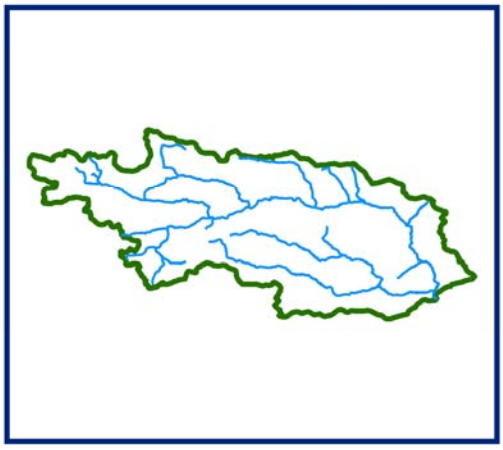
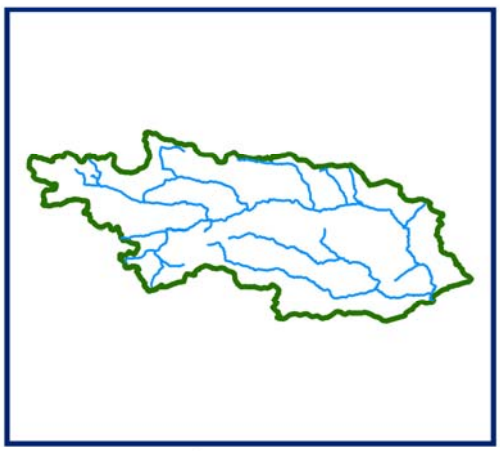


DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SABANSIRI BASIN



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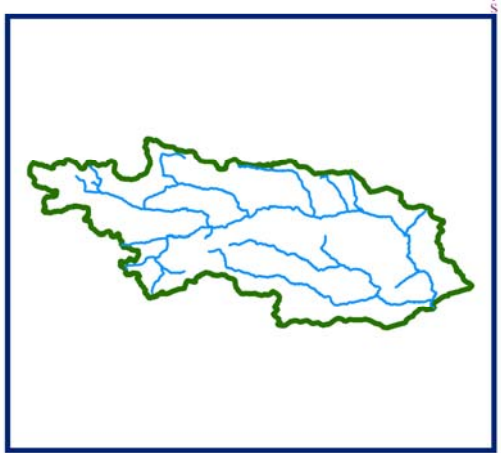

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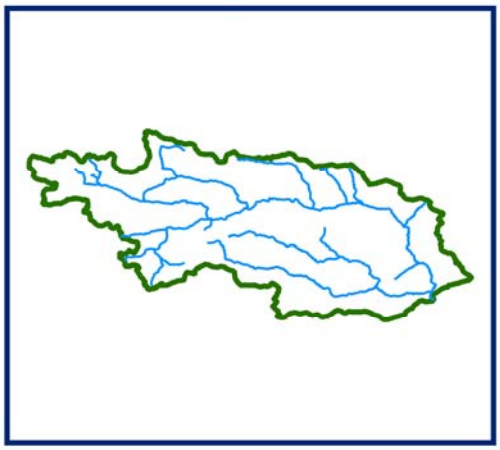

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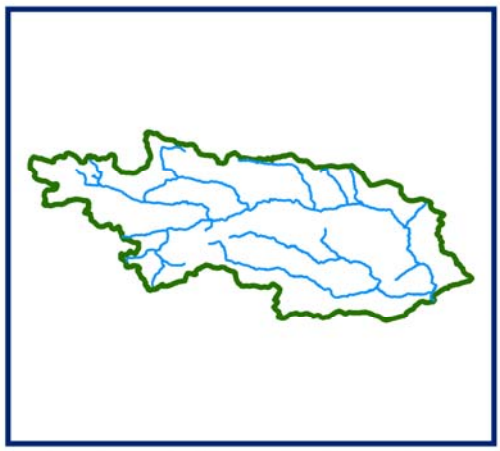

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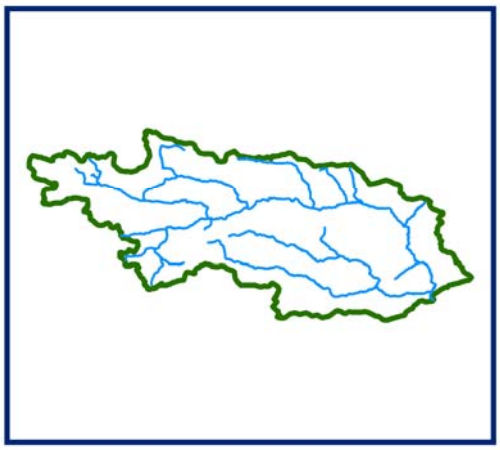

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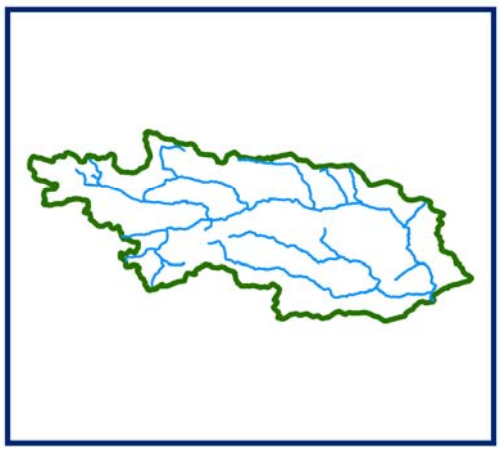


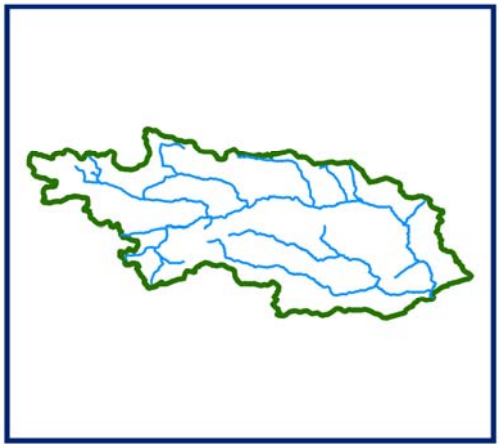
DATA NOT AVAILABLE

SNOW

0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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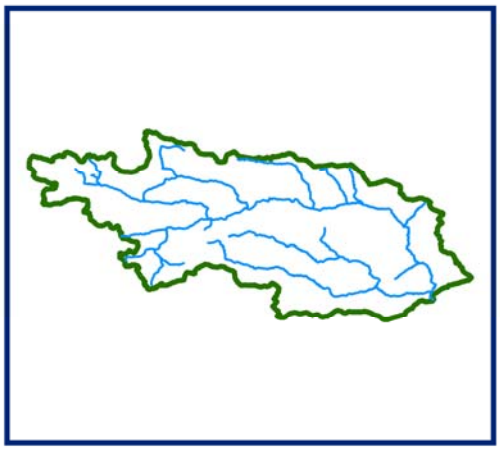

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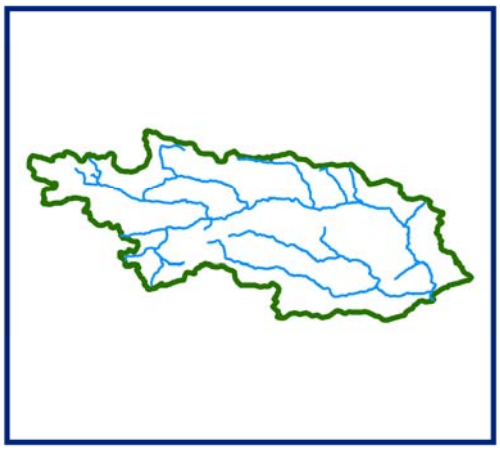
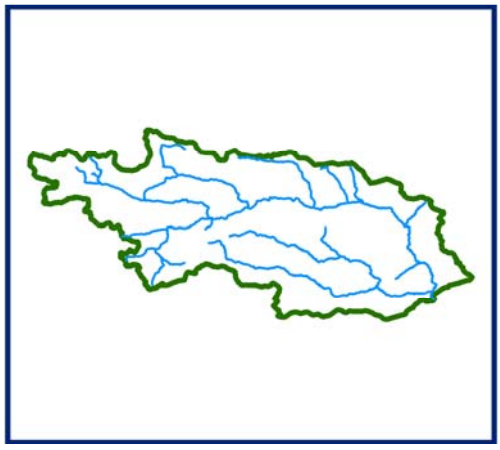


DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SABANSIRI BASIN



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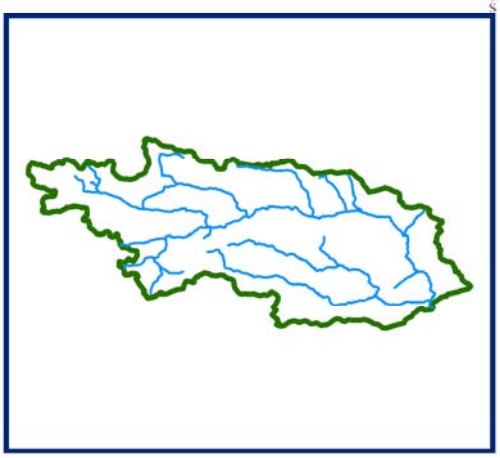

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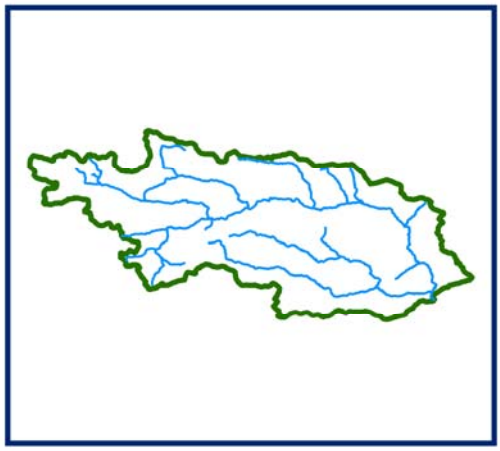

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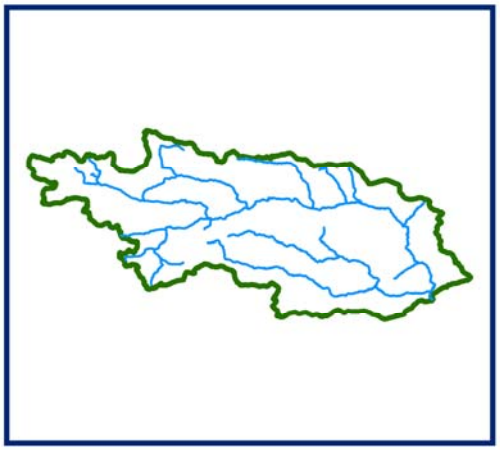

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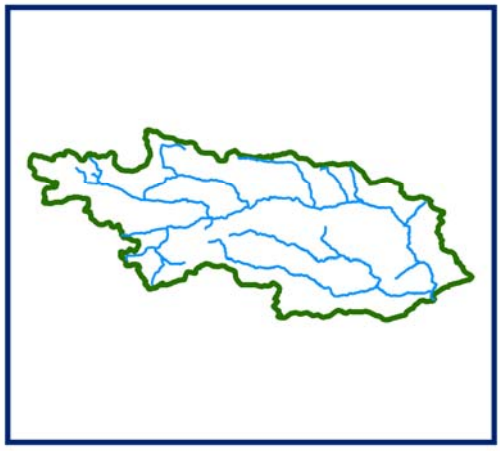

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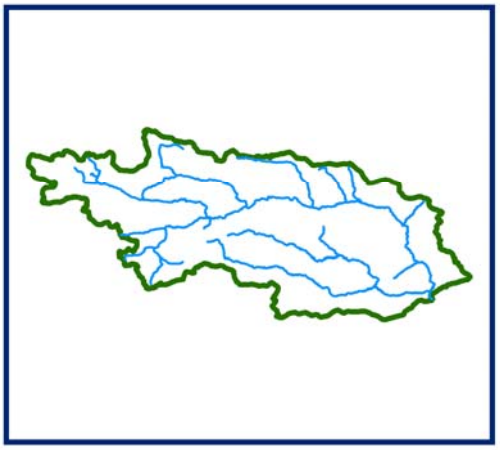


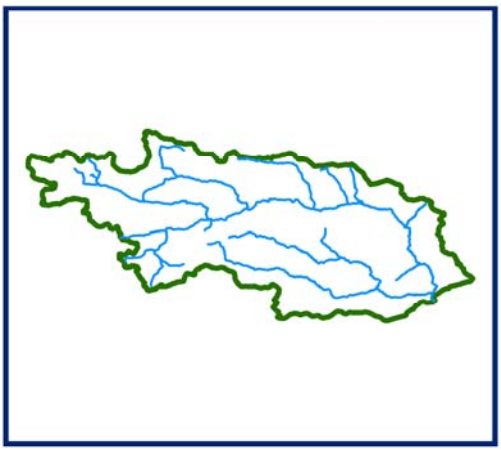
DATA NOT AVAILABLE

SNOW

0 40 80 160 240 320

Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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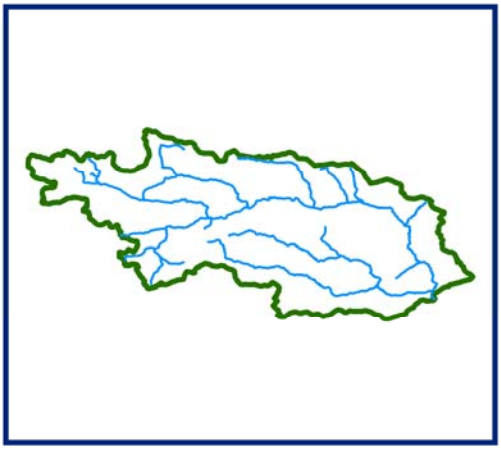

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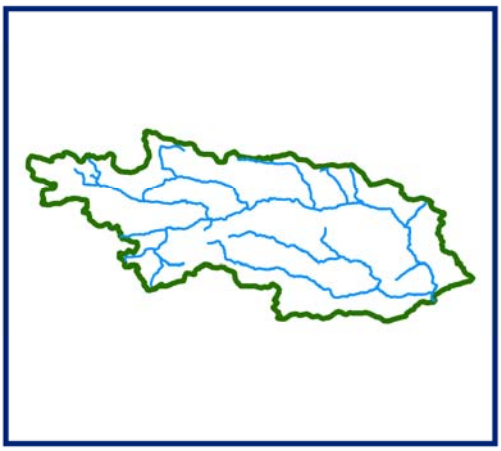


DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers

TAWANG BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: TAWANG **BASIN AREA: 6725 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008							
1	11-Oct-08	515	8	2	12-Oct-08	1516	23
3	16-Oct-08	505	8	4	21-Oct-08	405	6
5	30-Oct-08	5172	77				
November 2008							
6	9-Nov-08	4930	73	7	14-Nov-08	4642	69
8	19-Nov-08	4384	65	9	23-Nov-08	4251	63
10	24-Nov-08	4020	60	11	28-Nov-08	4092	61
12	29-Nov-08	3932	58				
December 2008							
13	3-Dec-08	3857	57	14	8-Dec-08	3738	56
15	17-Dec-08	3444	51	16	22-Dec-08	3141	47
17	27-Dec-08	3125	46				
January 2009							
18	1-Jan-09	3802	57	19	6-Jan-09	3773	56
20	10-Jan-09	3859	57	21	11-Jan-09	3143	47
22	15-Jan-09	3445	51	23	16-Jan-09	3096	46
24	20-Jan-09	2989	44	25	30-Jan-09	2537	38
February 2009							
26	3-Feb-09	3215	48	27	4-Feb-09	2465	37
28	8-Feb-09	2420	36	29	9-Feb-09	2241	33
30	13-Feb-09	2273	34	31	18-Feb-09	2133	32
32	27-Feb-09	1803	27				
March 2009							
33	4-Mar-09	3270	49	34	9-Mar-09	3351	50
35	14-Mar-09	2880	43	36	23-Mar-09	2488	37
37	24-Mar-09	2367	35				
April 2009							
38	12-Apr-09	3352	50	39	16-Apr-09	2144	32
40	26-Apr-09	1618	24				

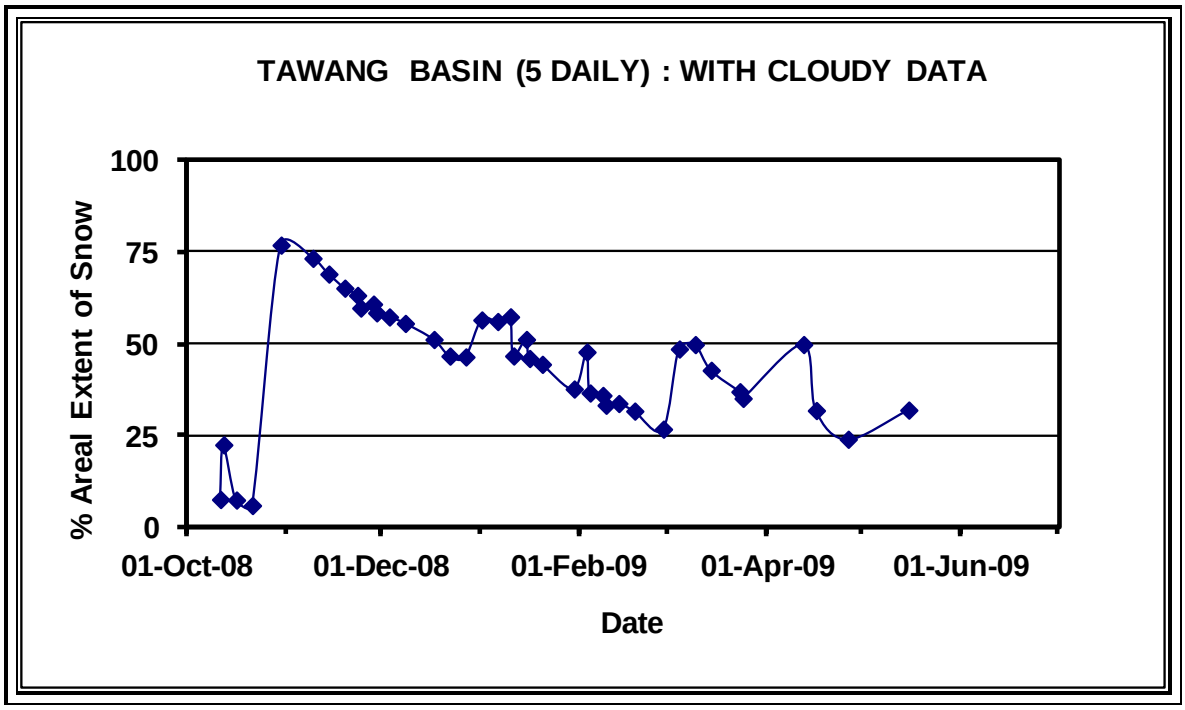
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
41	15-May-09	2106	31				
June 2009							
July 2009							

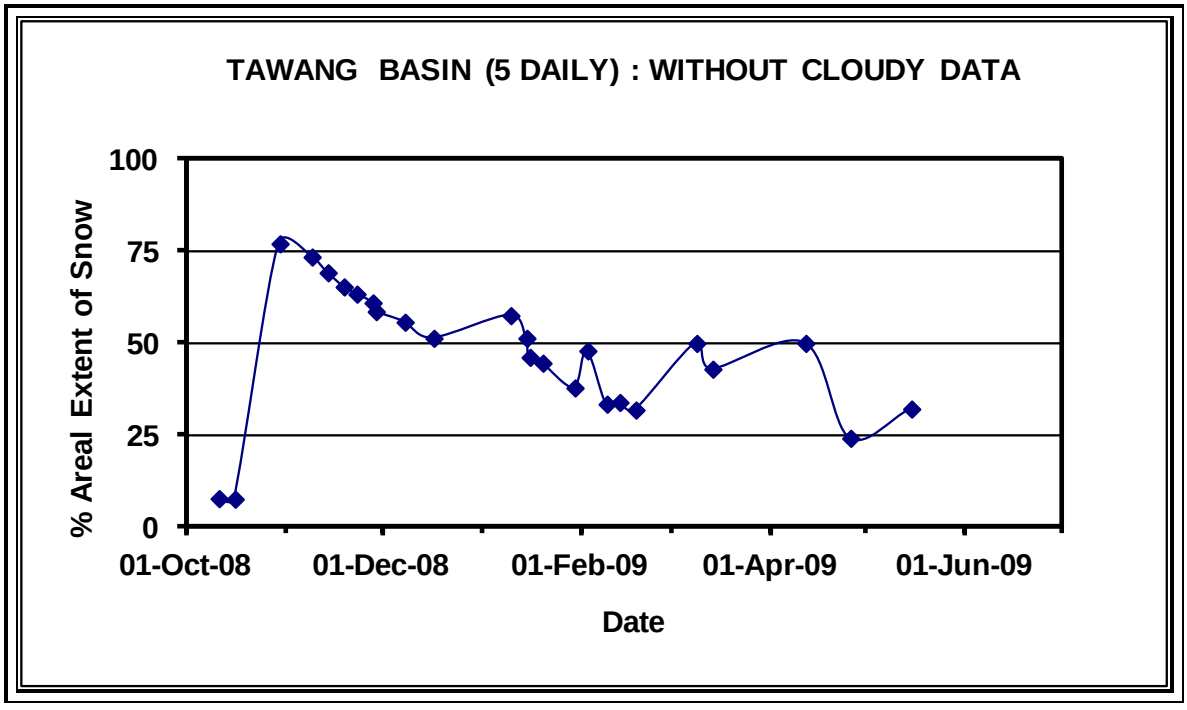
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: TAWANG **BASIN AREA: 6725 sq km**

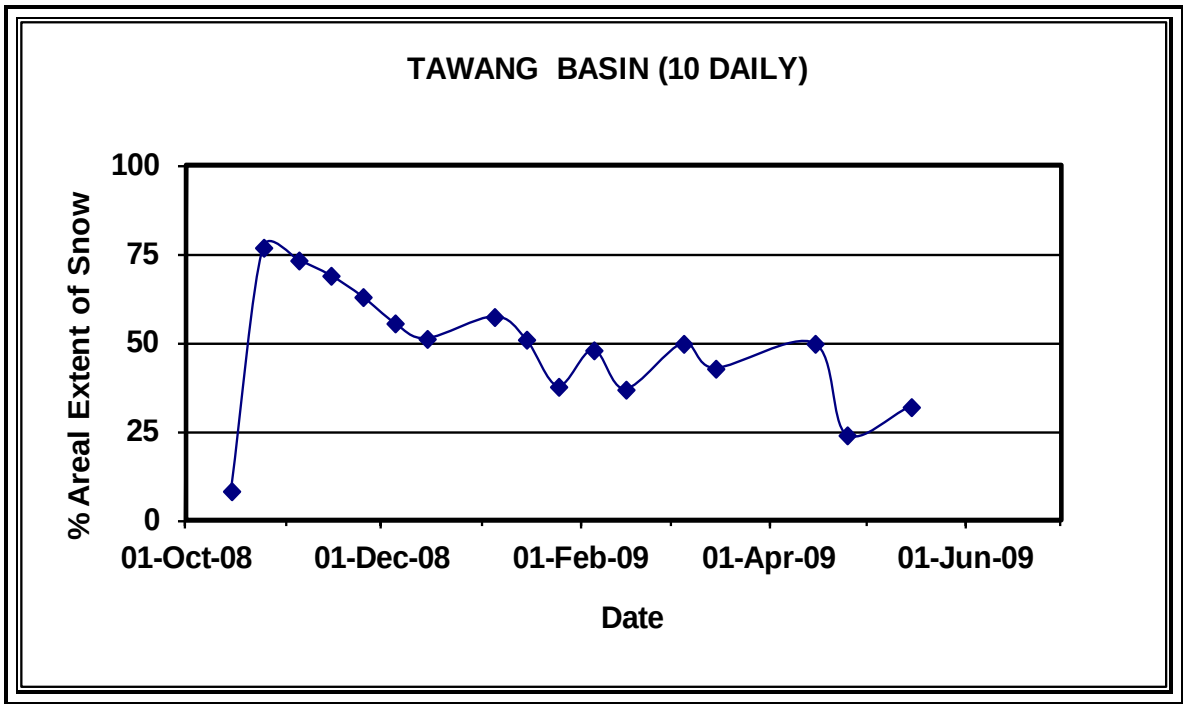
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
1	11-Oct-08	559	8	3	9-Nov-08	4930	73
2	30-Oct-08	5172	77	4	14-Nov-08	4640	69
				5	28-Nov-08	4237	63
December 2008				**January 2009**			
6	8-Dec-08	3738	56	8	10-Jan-09	3859	57
7	17-Dec-08	3444	51	9	16-Jan-09	3430	51
				10	30-Jan-09	2537	38
February 2009				**March 2009**			
11	3-Feb-09	3228	48	13	9-Mar-09	3351	50
12	13-Feb-09	2483	37	14	14-Mar-09	2880	43
April 2009				**May 2009**			
15	12-Apr-09	3352	50	17	15-May-09	2152	32
16	25-Apr-09	1614	24				
June 2009				**July 2009**			

Snow cover depletion curve



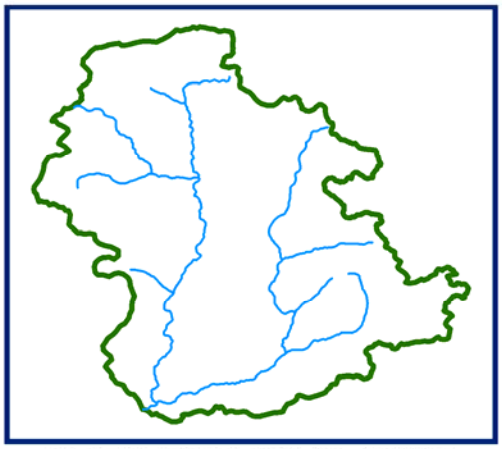


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : TAWANG BASIN



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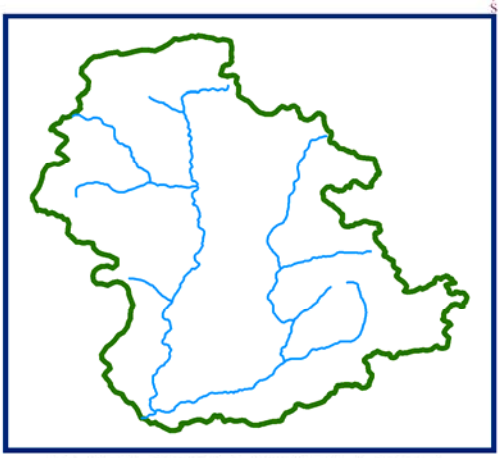
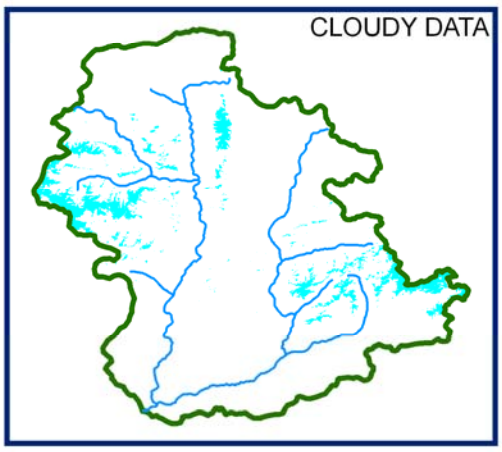


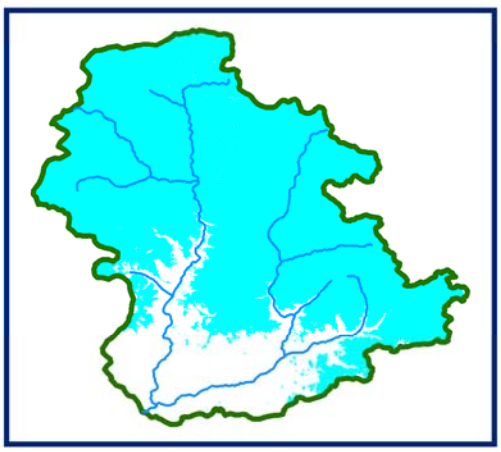
DATA NOT AVAILABLE

11 OCTOBER 2008

16 OCTOBER 2008



21 OCTOBER 2008



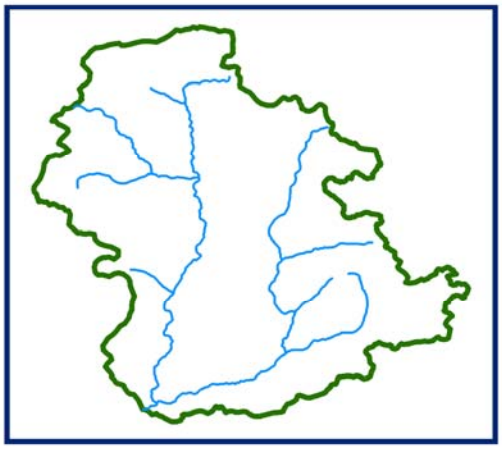
30 OCTOBER 2008

SNOW

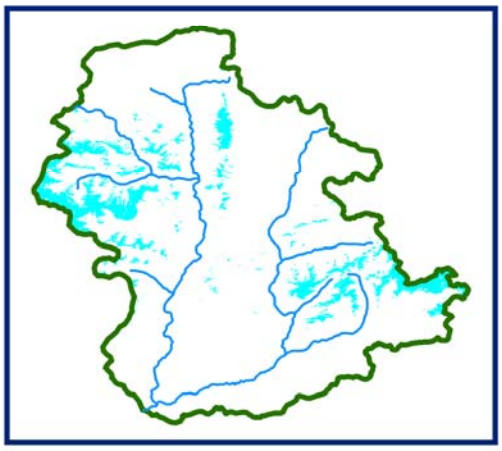
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
DATA NOT AVAILABLE



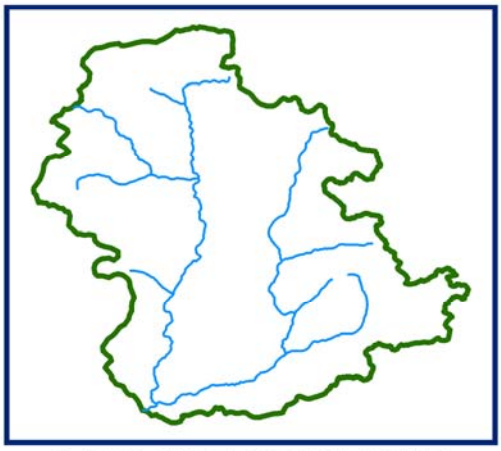
DATA USED
11 OCTOBER 2008
16 OCTOBER 2008

DATA USED
30 OCTOBER 2008

SNOW

0 10 20 40 60 80
Kilometers

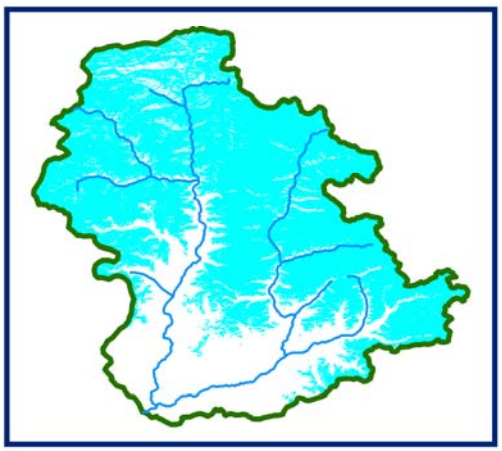
SNOW COVER MAP : TAWANG BASIN



DATA NOT AVAILABLE

9 NOVEMBER 2008

14 NOVEMBER 2008



19 NOVEMBER 2008

23 NOVEMBER 2008

29 NOVEMBER 2008

SNOW

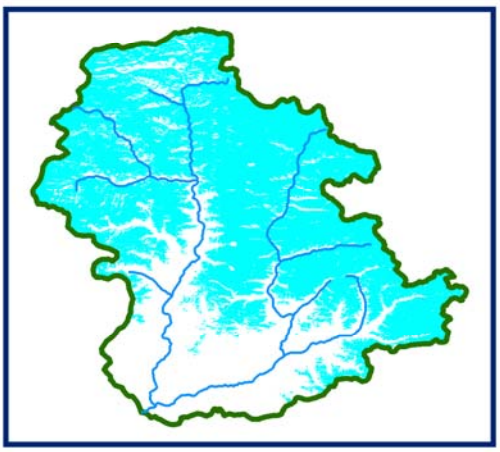
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN

DATA USED
09 NOVEMBER 2008

DATA USED
14 NOVEMBER 2008
19 NOVEMBER 2008

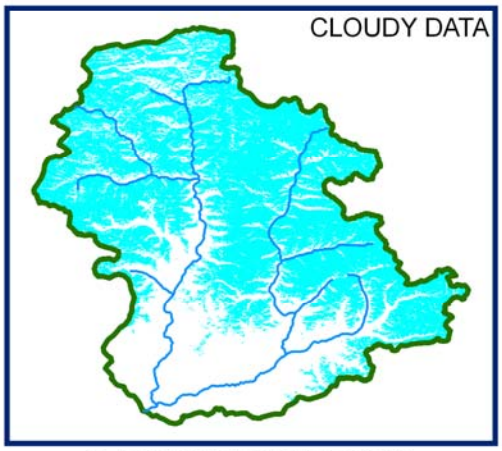


DATA USED
23 NOVEMBER 2008
28 NOVEMBER 2008
29 NOVEMBER 2008

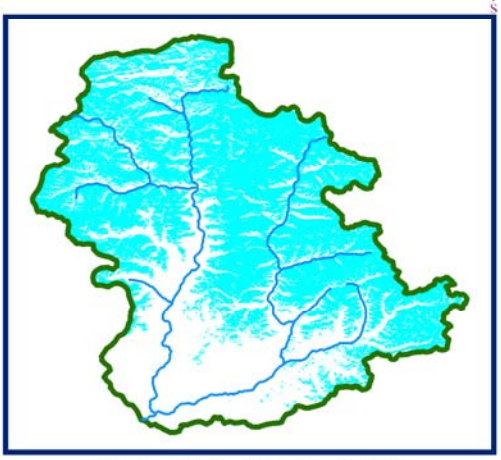
SNOW

0 10 20 40 60 80
Kilometers

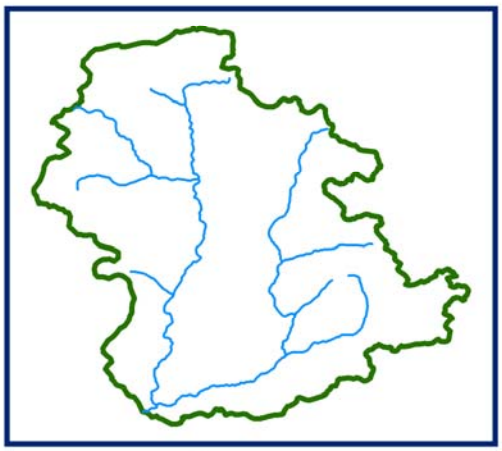
SNOW COVER MAP : TAWANG BASIN



3 DECEMBER 2008



8 DECEMBER 2008



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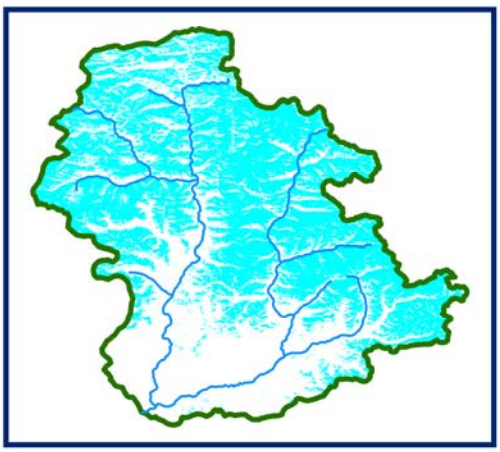
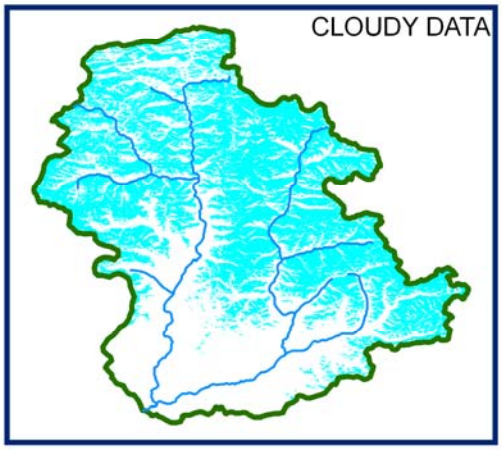
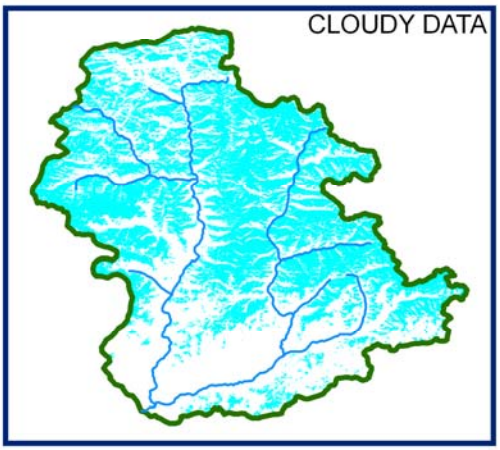


17 DECEMBER 2008



22 DECEMBER 2008



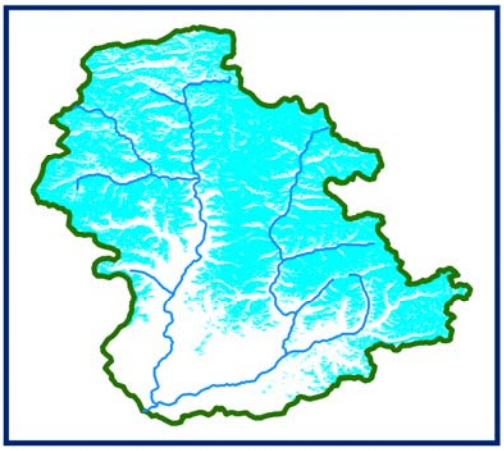
27 DECEMBER 2008

SNOW

0 15 30 60 90 120

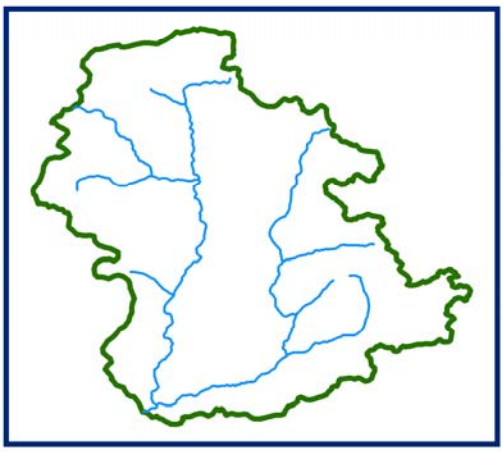
Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
08 DECEMBER 2008

DATA USED
17 DECEMBER 2008

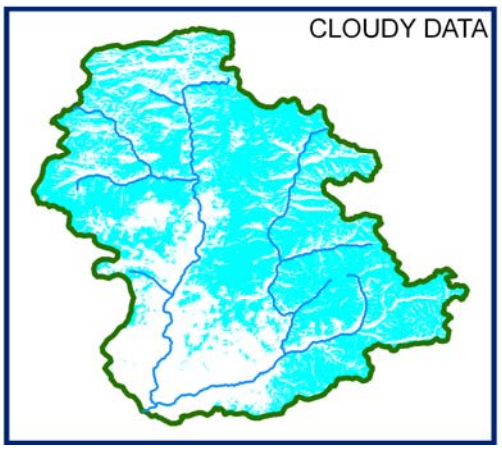


DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN

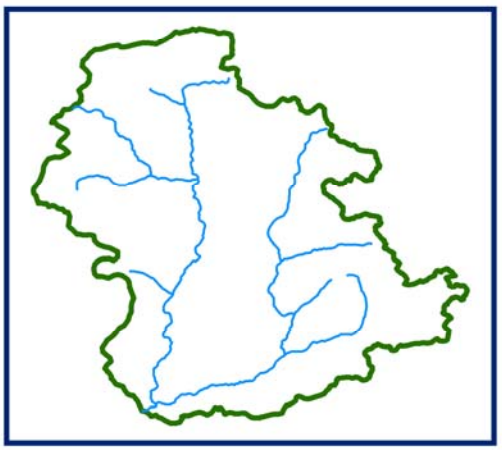


1 JANUARY 2009

10 JANUARY 2009

15 JANUARY 2009

20 JANUARY 2009



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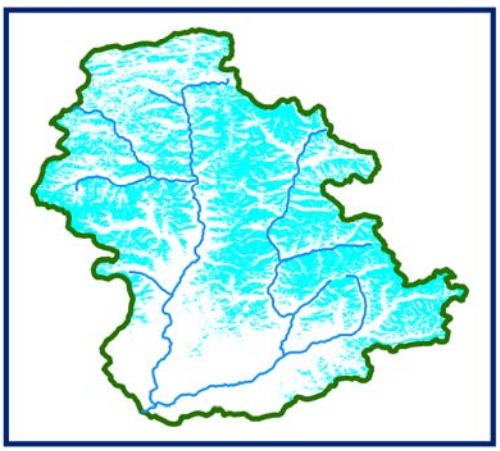


30 JANUARY 2009

SNOW

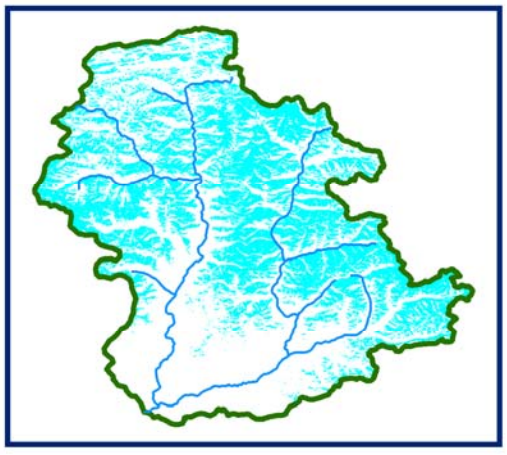
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN

DATA USED
10 JANUARY 2009

DATA USED
15 JANUARY 2009
16 JANUARY 2009
20 JANUARY 2009

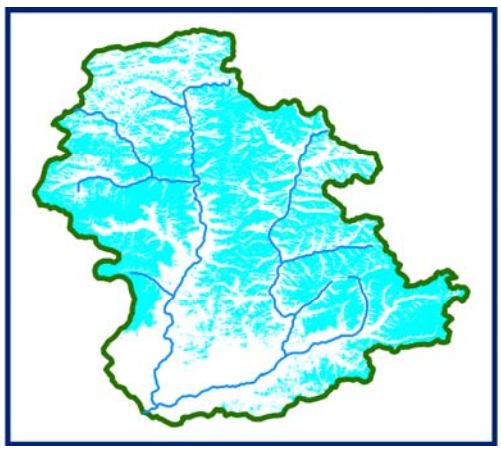


DATA USED
30 JANUARY 2009

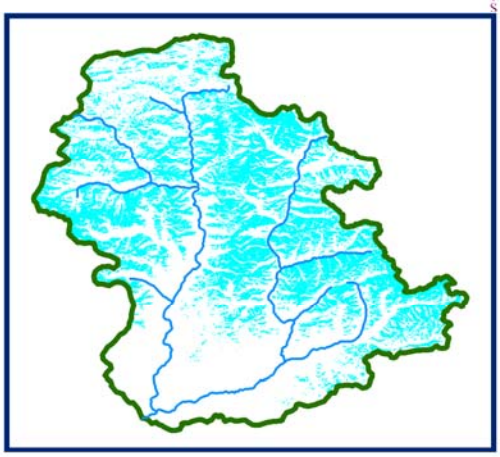
SNOW

0 10 20 40 60 80
Kilometers

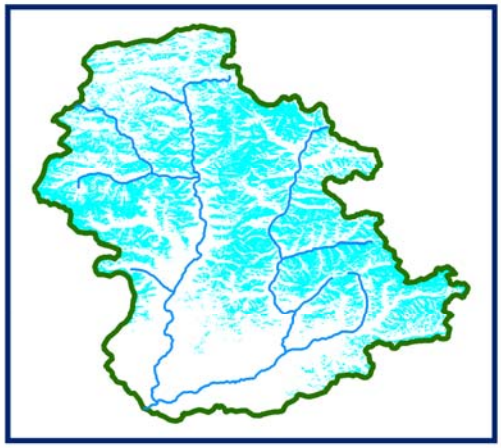
SNOW COVER MAP : TAWANG BASIN



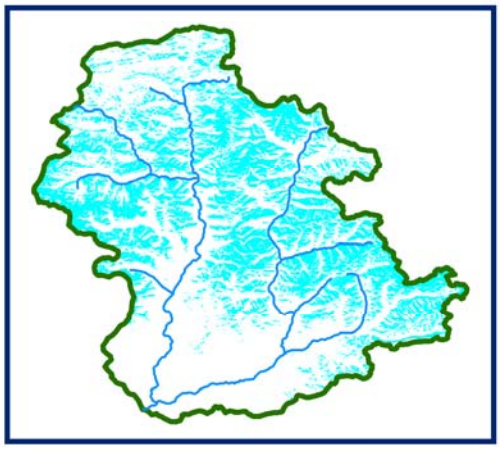
3 FEBRUARY 2009



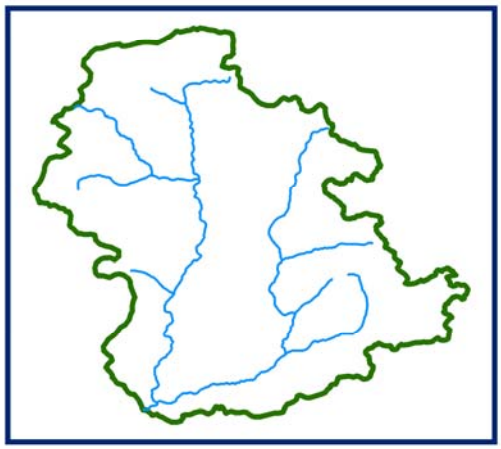
9 FEBRUARY 2009



13 FEBRUARY 2009



18 FEBRUARY 2009



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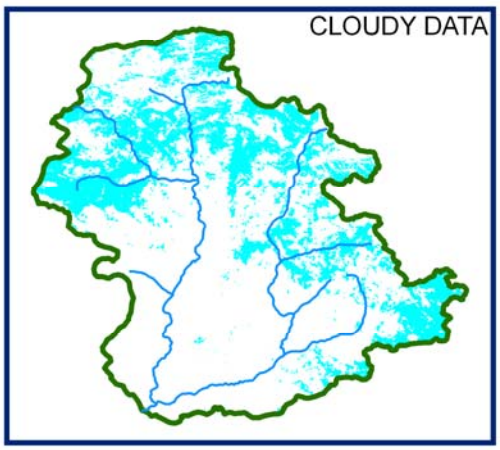


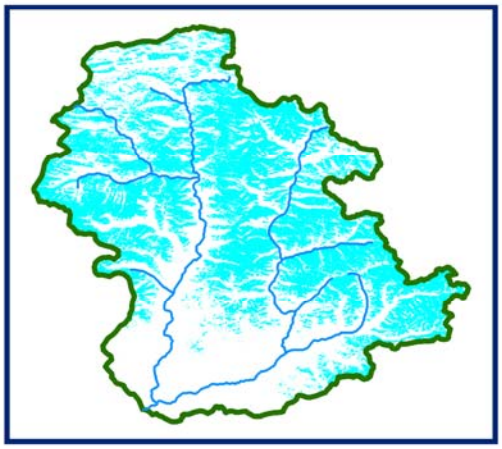
27 FEBRUARY 2009

SNOW

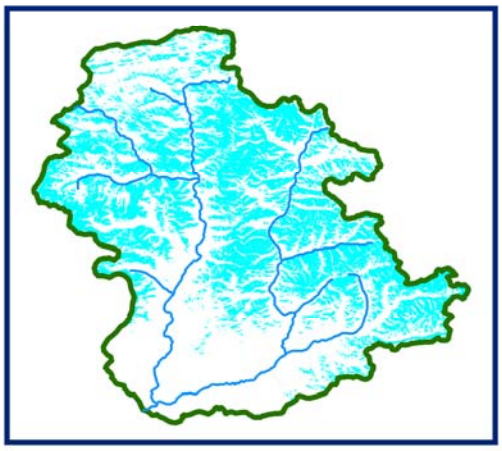
0 15 30 60 90 120

Kilometers

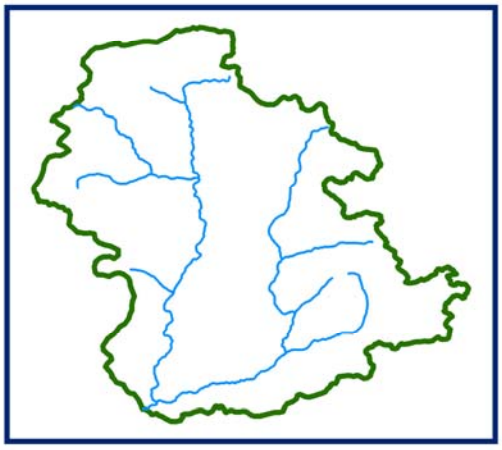
10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
03 FEBRUARY 2009
09 FEBRUARY 2009



DATA USED
13 FEBRUARY 2009
18 FEBRUARY 2009

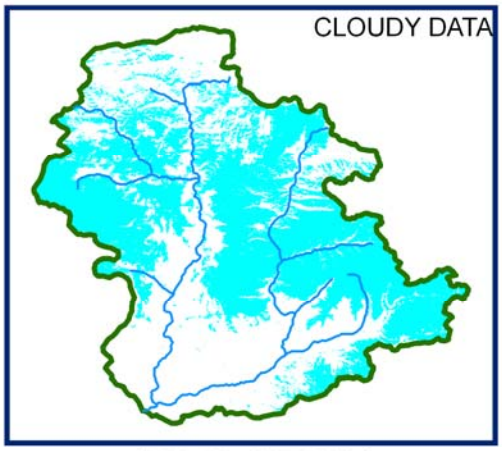


DATA USED
DATA NOT AVAILABLE

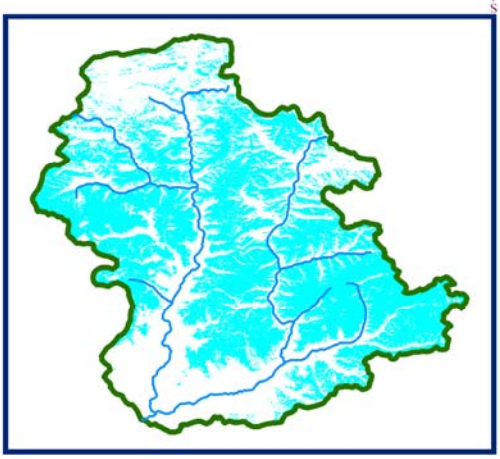
SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN

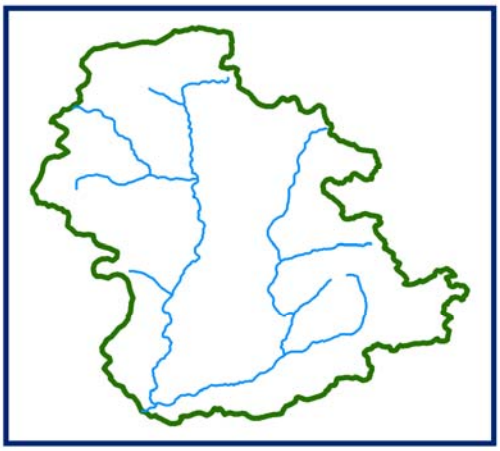


4 MARCH 2009

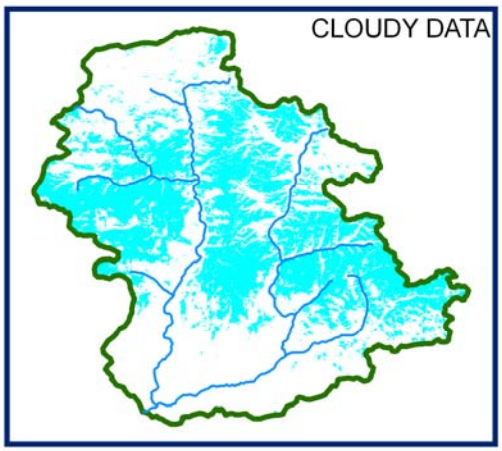


9 MARCH 2009

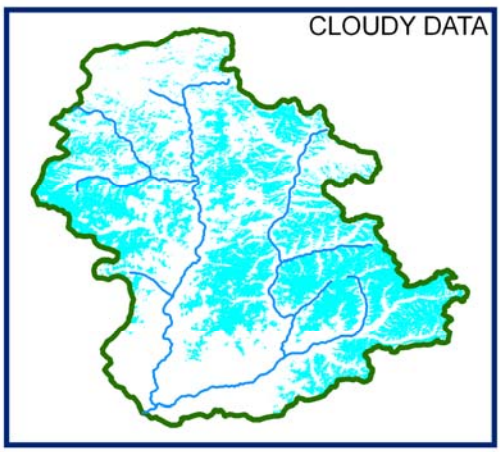
14 MARCH 2009



DATA NOT AVAILABLE



23 MARCH 2009



24 MARCH 2009

SNOW

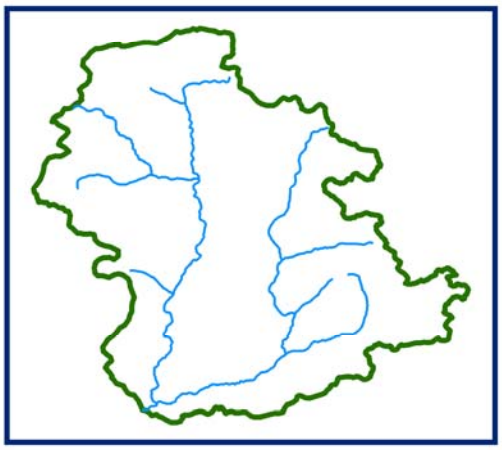
0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN

DATA USED
09 MARCH 2009

DATA USED
14 MARCH 2009

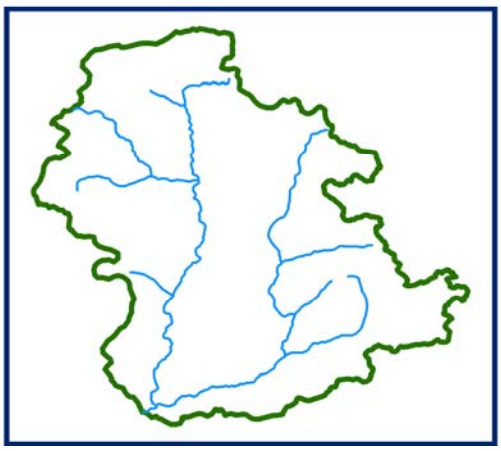


DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



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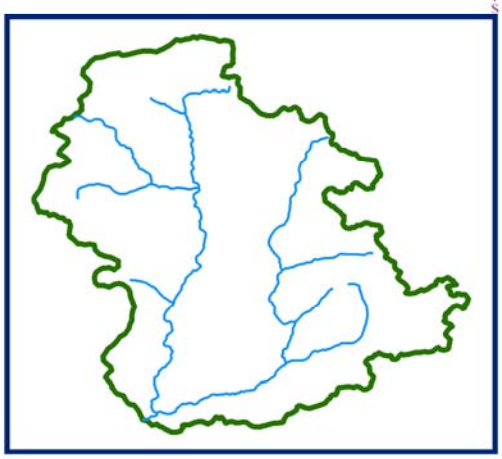
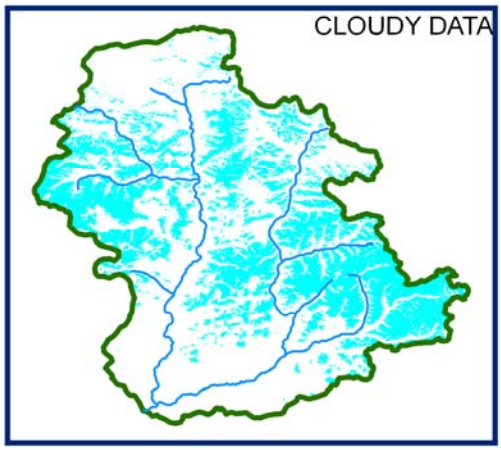
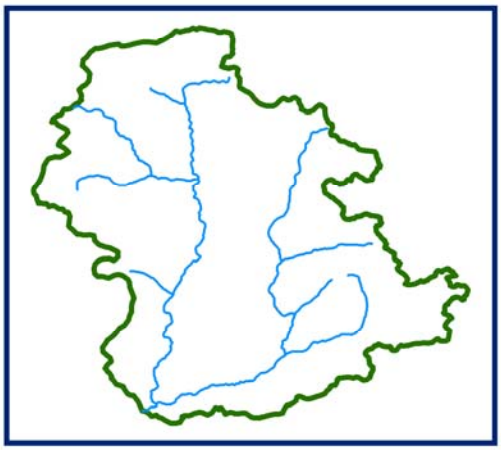


DATA NOT AVAILABLE

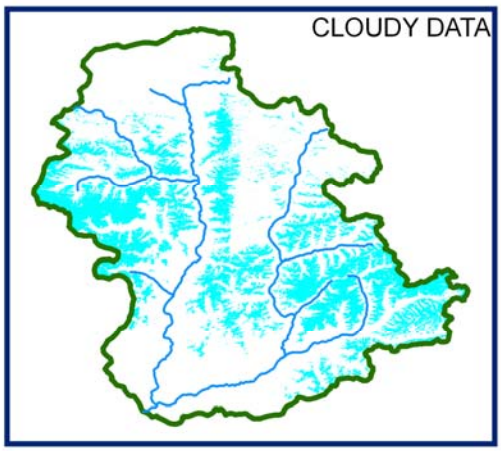
12 APRIL 2009



16 APRIL 2009



DATA NOT AVAILABLE



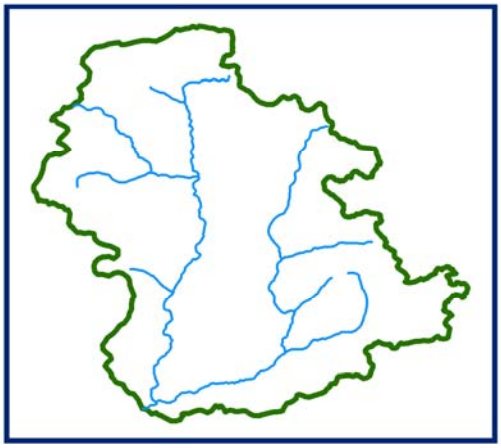
26 APRIL 2009

SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



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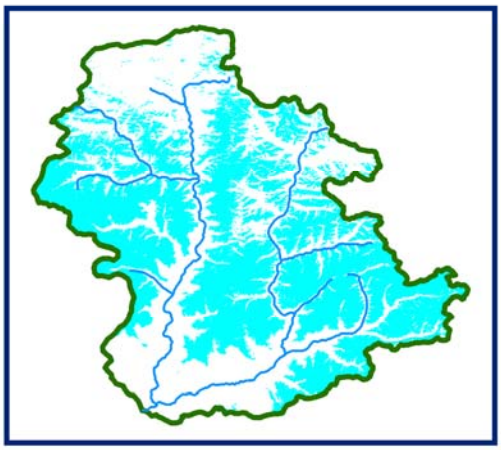
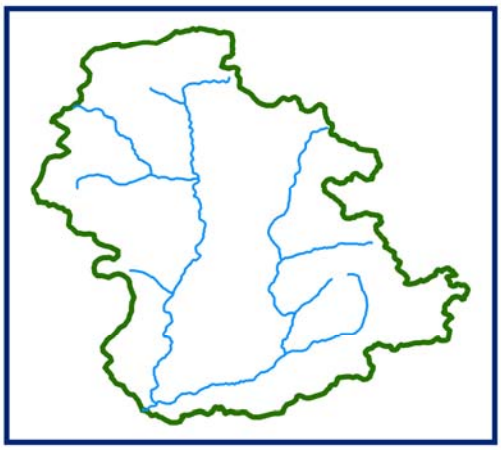


DATA USED
12 APRIL 2009

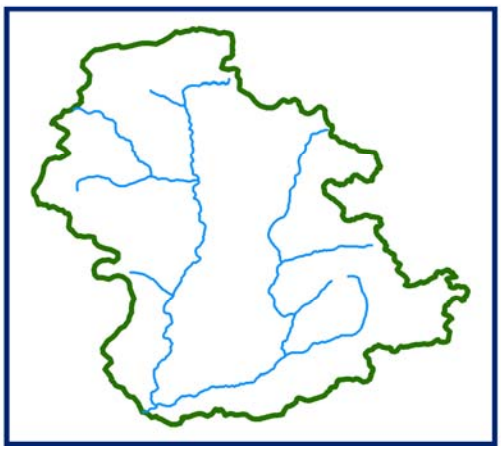


DATA USED
DATA NOT AVAILABLE

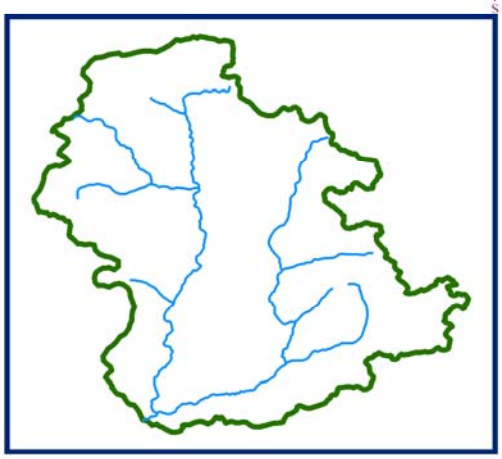
SNOW

0 10 20 40 60 80
Kilometers

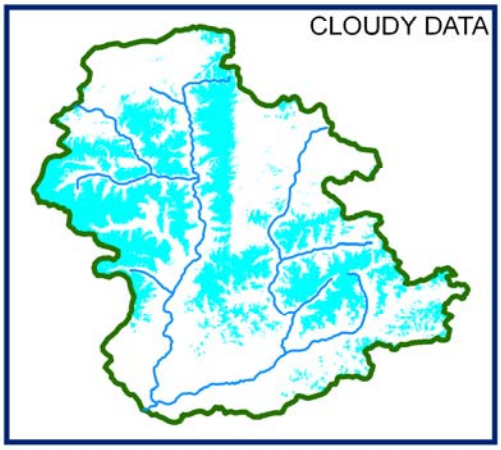
SNOW COVER MAP : TAWANG BASIN



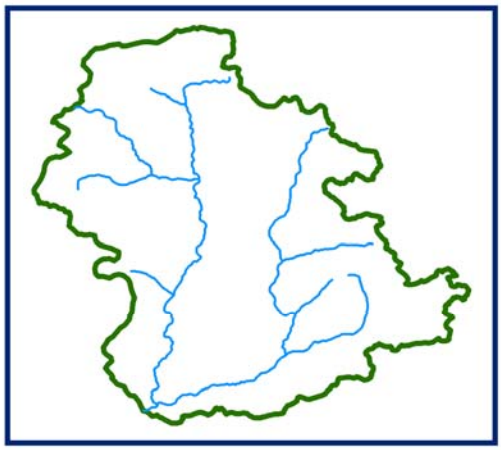
DATA NOT AVAILABLE



DATA NOT AVAILABLE



15 MAY 2009



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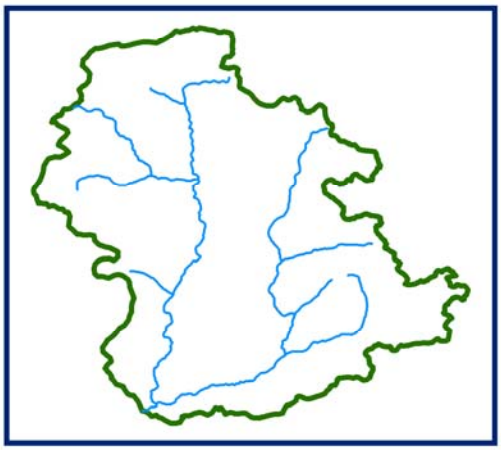

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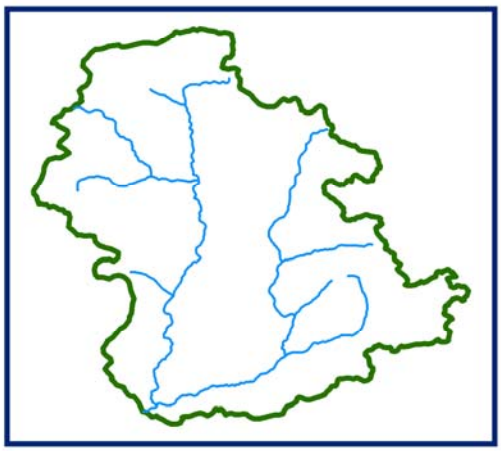


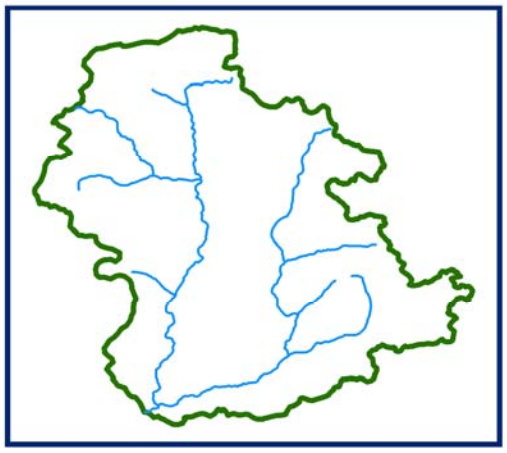
DATA NOT AVAILABLE

SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
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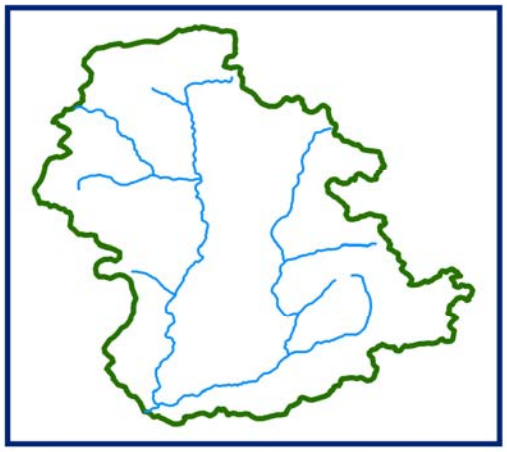

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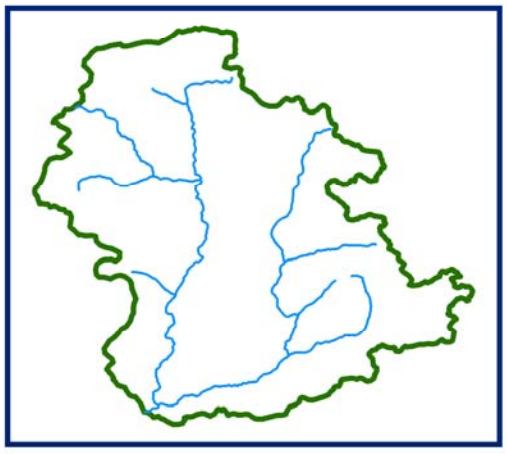
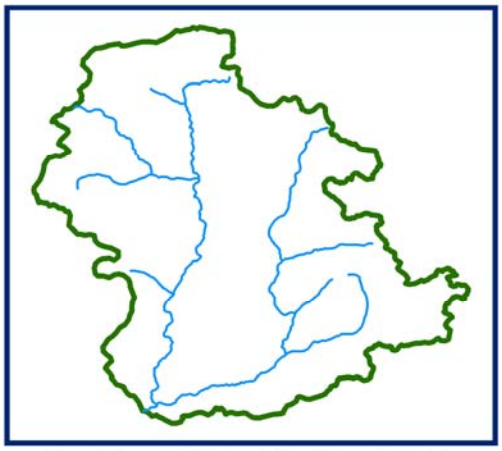


DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



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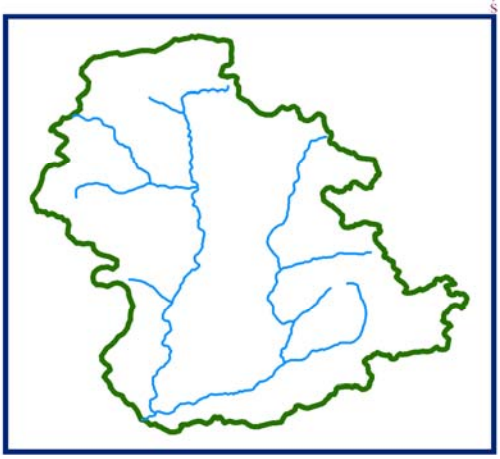
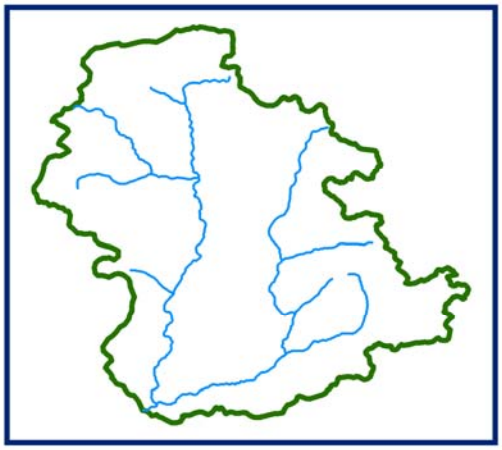


DATA NOT AVAILABLE



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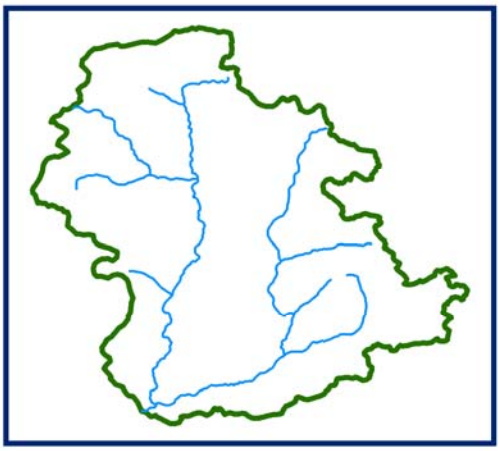

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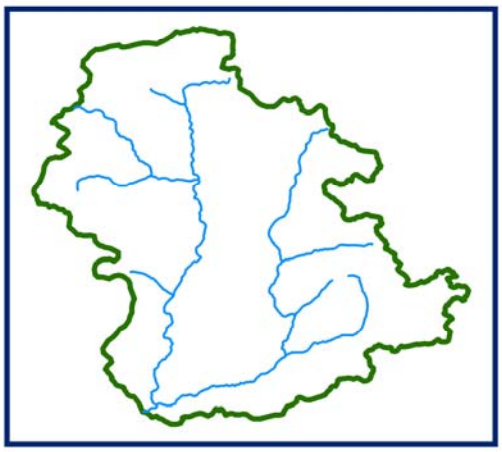

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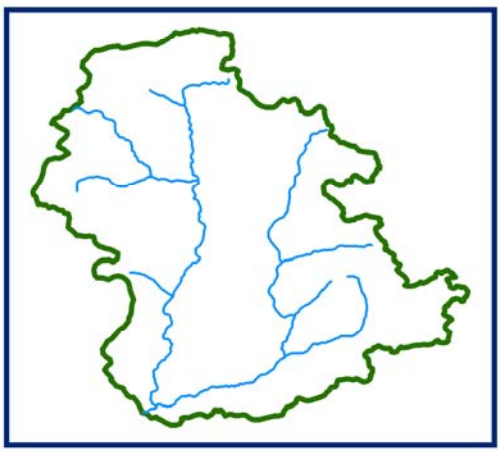


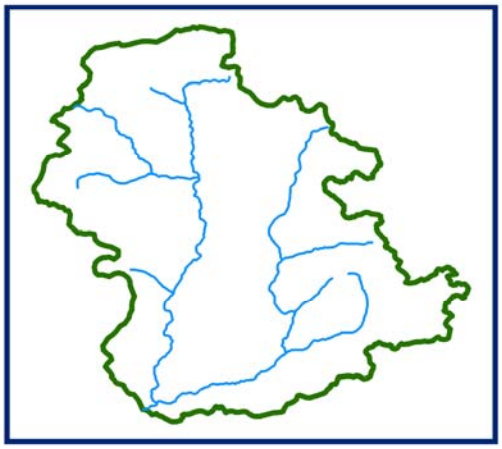
DATA NOT AVAILABLE

SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



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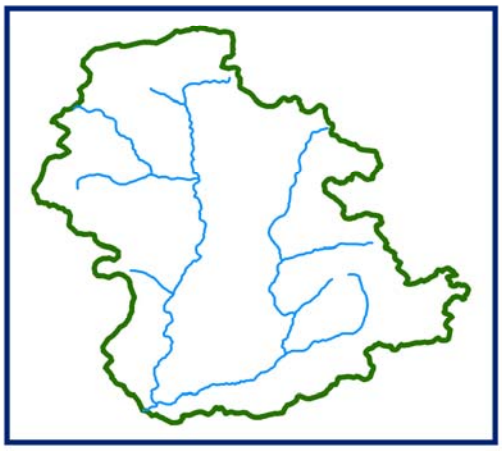

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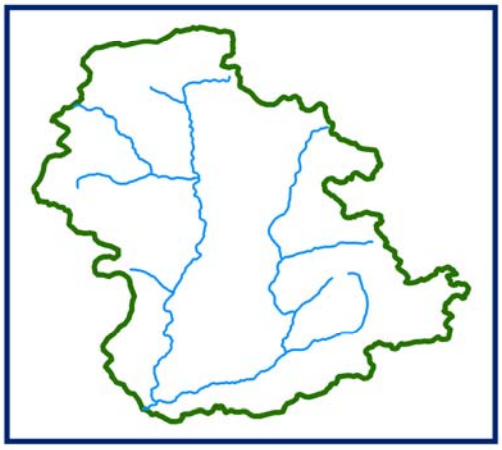

DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers