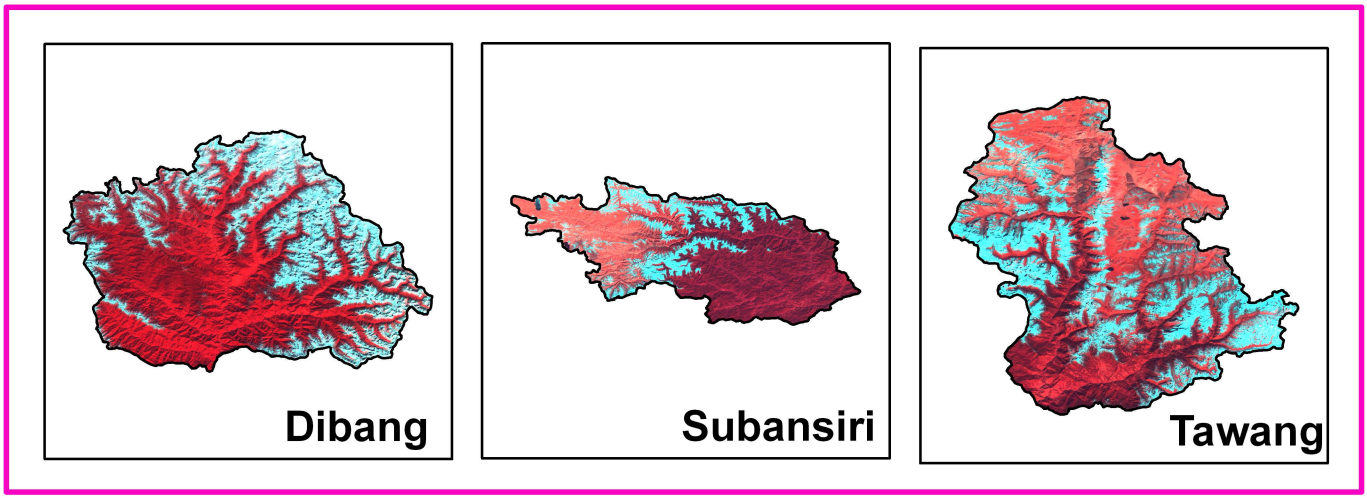
SNOW COVER ATLAS OF BRAHMAPUTRA BASIN

Sub basins: Dibang, Subansiri and Tawang

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

Year : 2011-12



State Remote Sensing Application Centre
Itanagar, Arunachal Pradesh - 791113

&

Space Applications Centre (ISRO)
Ahmedabad - 380015

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DOCUMENT CONTROL AND DATA SHEET

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Abstract	This atlas gives sub basin-wise distribution of snow cover in the Brahmaputra basin from October 2011 to June 2012. 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

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1. **Introduction**

Snow covers almost 40 per cent of the Earth's land surface during Northern Hemisphere winter. This makes albedo and areal extent of snow as important component of the Earth's radiation balance (Foster and Chang, 1993). In addition, large areas in the Himalayas are also covered by snow during winter. Area of snow can change significantly during winter and spring. This can affect stream flow for rivers originating in the higher Himalayas. All the rivers originating from higher Himalayas receive almost 30-50 % of annual flow from snow and glacier melt run off (Agarwal et al., 1983). In addition, snow pack ablation is highly sensitive to climatic variation. Increase in atmospheric temperature can influence snowmelt and stream runoff pattern (Kulkarni et al., 2002). Therefore, mapping of the areal extent and reflectance of snow are important parameter for various climatological and hydrological applications. In addition, extent of snow cover can also be used as input for numerous other applications.

Mapping and monitoring of seasonal snow cover using field methods are normally very difficult in a mountainous terrain, like the Himalayas. Therefore, remote sensing techniques have been extensively used for snow cover monitoring. Snow cover monitoring using satellite images were started by using the TIROS-1 satellite from April 1960 (Singer and Popham 1963). Since then, the potential for operational satellite-based mapping has been enhanced by the development of higher temporal frequency and satellite sensors with higher spatial resolution. In addition, satellites with better radiometric resolutions, such as NOAA have been used successfully for snow mapping (Hall et al., 1995). This is possibly due to the distinct spectral reflectance characteristics of snow in visible and near infrared regions. India has launched series of Indian Remote Sensing satellite (IRS) to study the different earth resources. Previously launched satellites have flown with many sensors having different spatial, temporal and spectral resolutions. Recently launched RESOURCESAT-1 satellite has three different sensors namely LISS III, LISS IV & AWiFS with different spatial, temporal and spectral resolutions as desired for different applications. AWiFS (Advanced Wide Field Sensor) is an advanced version of earlier Indian satellite sensor WiFS (Wide Field Sensor) with improved spectral and spatial resolutions maintaining the same repetivity. There are a series of other polar orbiting satellites, like Landsat, NOAA and MODIS etc., which have provided information on different aspects of

snow. Geo-stationary satellites also proved their utility in mapping/monitoring the snow-covered regions. Information generated from satellite observations has been extensively used for snowmelt runoff modeling (Kulkarni et al., 1997).

2. Study Area:

This Atlas gives distribution of snow cover in 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 2011 to June 2012 were used in this study.

4. Normalised Difference Snow Index (NDSI):

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

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

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

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 2011 to June 2012. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. In the Tawang river basin, shows accumulation and ablation of snow throughout the winter season. For example on November 8, 2011, 38 percent area was covered by seasonal snow. This was reduced to 12 percent by December 2, 2011 again it increases to 90 percent on January 3, 2012. Dibang sub-basin also shows accumulation and ablation of snow throughout the winter season and snow depletion pattern is similar. Subansiri sub-basin also shows accumulation and ablation of snow throughout the winter season but percentage areal extent snow is very less compare to Tawang and Dibang sub-basins.

Acknowledgements

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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.

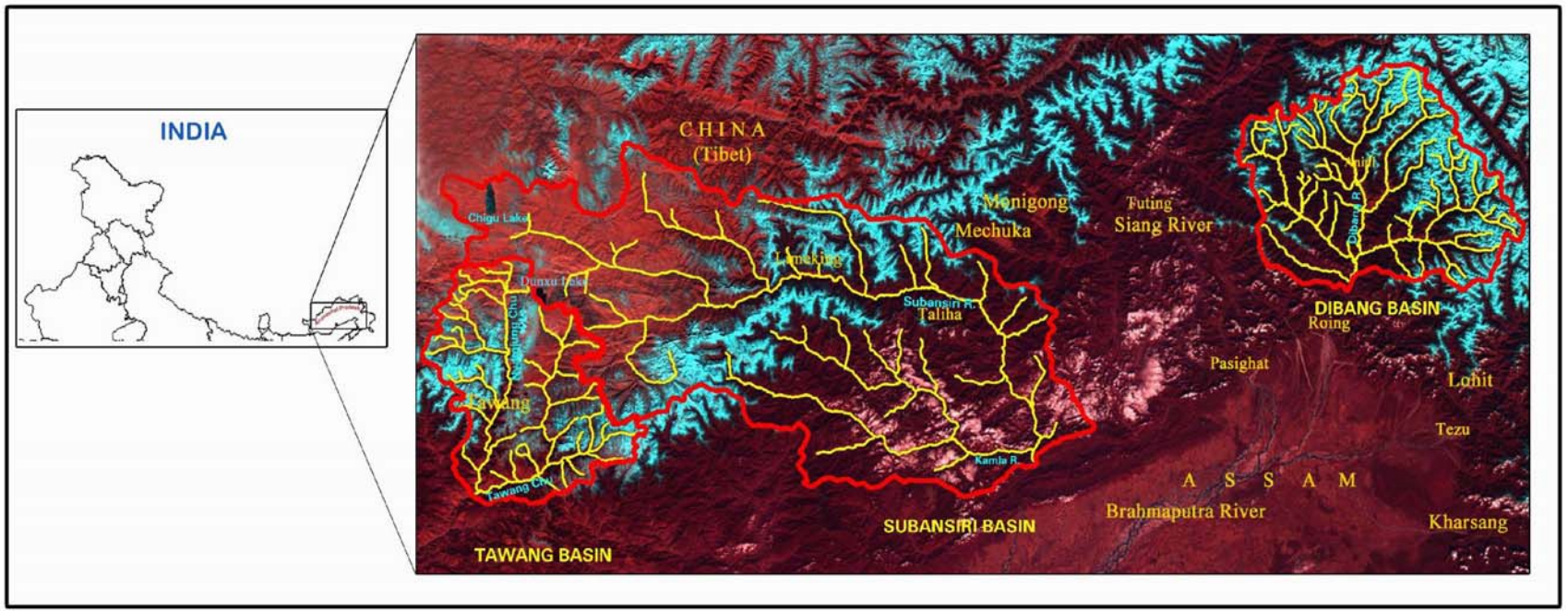


Figure 1: Location map of Dibang, Subansiri and Tawang sub-basins (Part of Brahmputra basin)

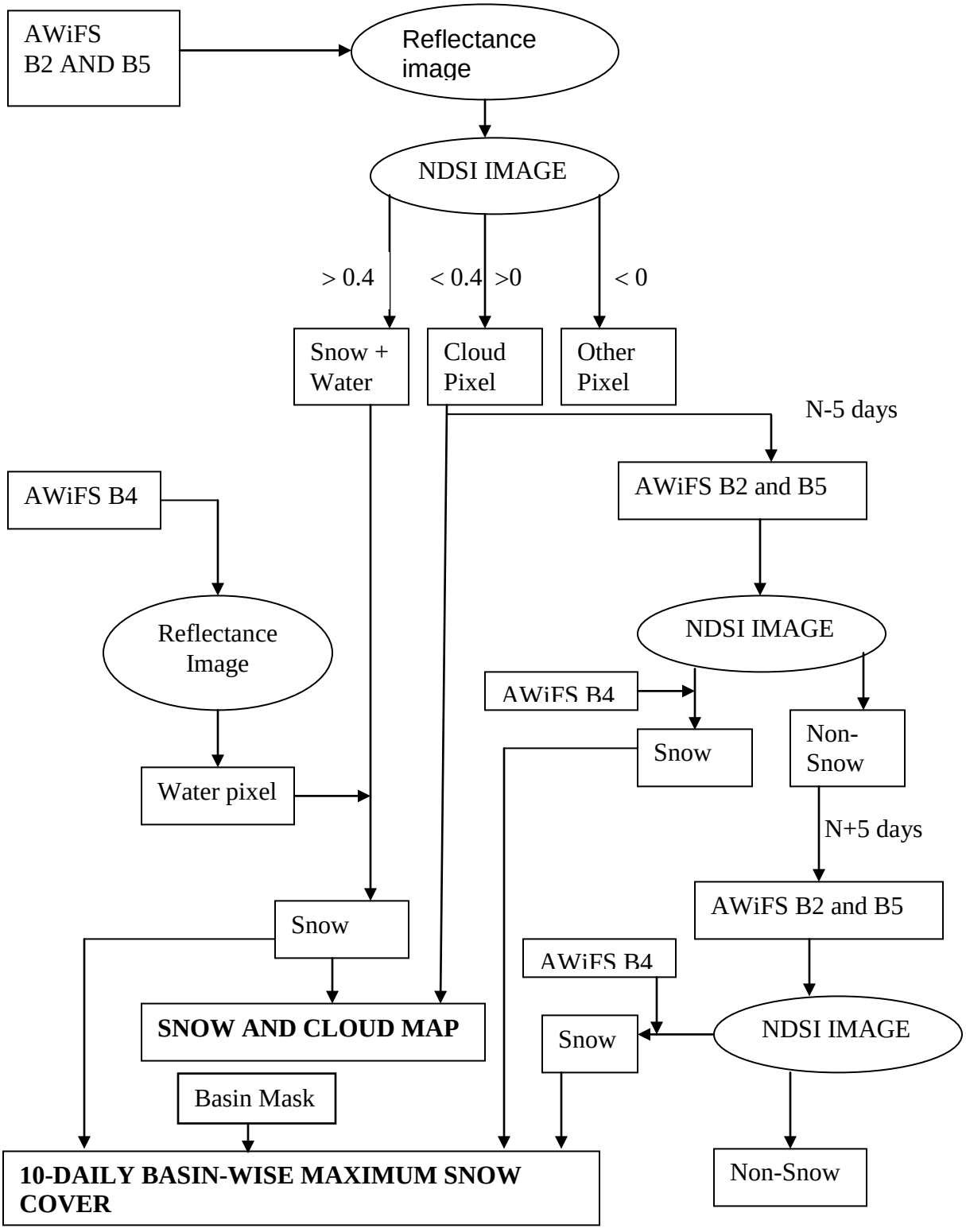


Figure 2: Algorithm for snow cover mapping using AWiFS data

DIBHANG BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: DIBANG **BASIN AREA: 9158 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2011							
1	1-Oct-11	DNA		5	26-Oct-11	DNA	
2	7-Oct-11	DNA		6	27-Oct-11	DNA	
3	11-Oct-11	82	1	7	30-Oct-11	DNA	
4	16-Oct-11	DNA		8	31-Oct-11	DNA	
November 2011							
9	4-Nov-11	1295	14	14	19-Nov-11	3907	43
10	5-Nov-11	DNA		15	23-Nov-11	DNA	
11	9-Nov-11	1874	20	16	24-Nov-11	DNA	
12	10-Nov-11	DNA		17	28-Nov-11	1840	20
13	14-Nov-11	DNA					
December 2011							
18	3-Dec-11	991	11	23	15-Dec-11	4276	47
19	4-Dec-11	DNA		24	18-Dec-11	1965	21
20	8-Dec-11	DNA		25	22-Dec-11	DNA	
21	9-Dec-11	DNA		26	23-Dec-11	DNA	
22	13-Dec-11	DNA		27	25-Dec-11	2927	32
January 2012							
28	3-Jan-12	7122	78	32	13-Jan-12	5741	63
29	6-Jan-12	DNA		33	16-Jan-12	5197	57
30	7-Jan-12	DNA		34	26-Jan-12	DNA	
31	10-Jan-12	DNA		35	30-Jan-12	DNA	
February 2012							
36	1-Feb-12	4432	48	40	18-Feb-12	DNA	
37	3-Feb-12	DNA		41	24-Feb-12	DNA	
38	5-Feb-12	DNA		42	25-Feb-12	DNA	
39	12-Feb-12	DNA		43	28-Feb-12	DNA	
March 2012							
44	5-Mar-12	DNA		46	7-Mar-12	DNA	
45	20-Mar-12	5269	58	47	25-Mar-12	4759	52
April 2012							
48	17-April-12	CLOUDYDATA					
May 2012							
49	7-May-12	5128	56	50	26-May-12	2881	31

June 2012							
51	7-June-12	DNA					

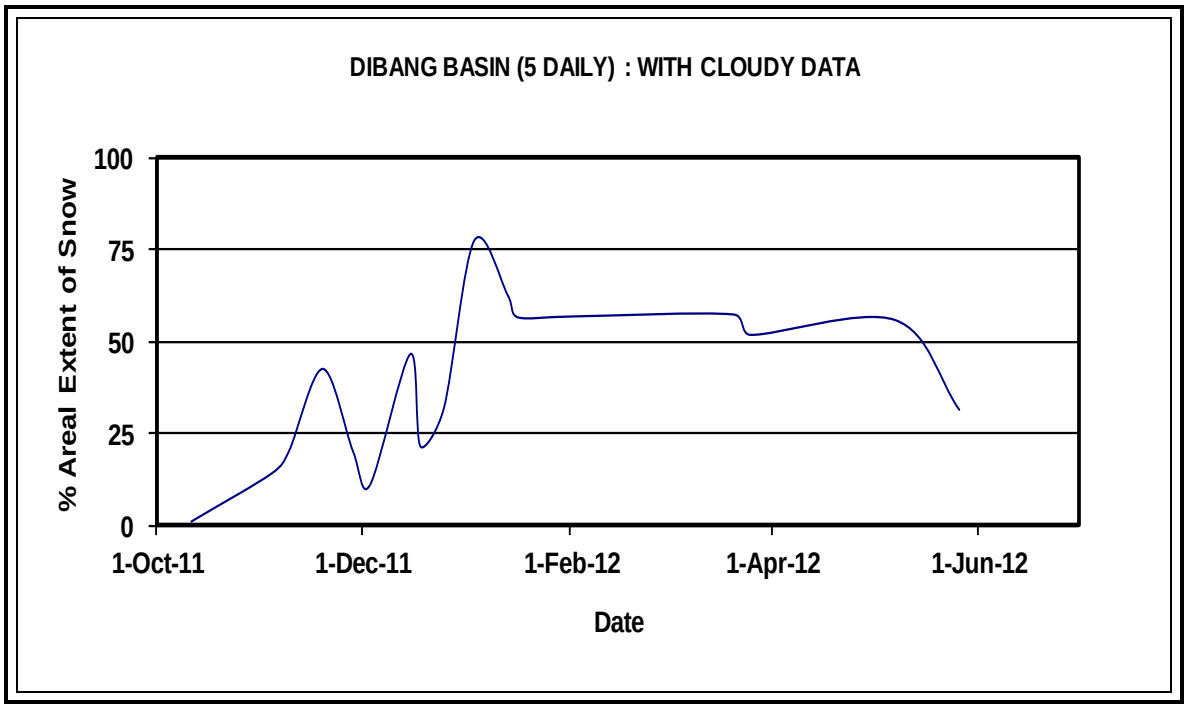
DNA- DATA NOT AVAILABLE
DNC-3BASINS NOT IN SCENE/HALF IN SCENE

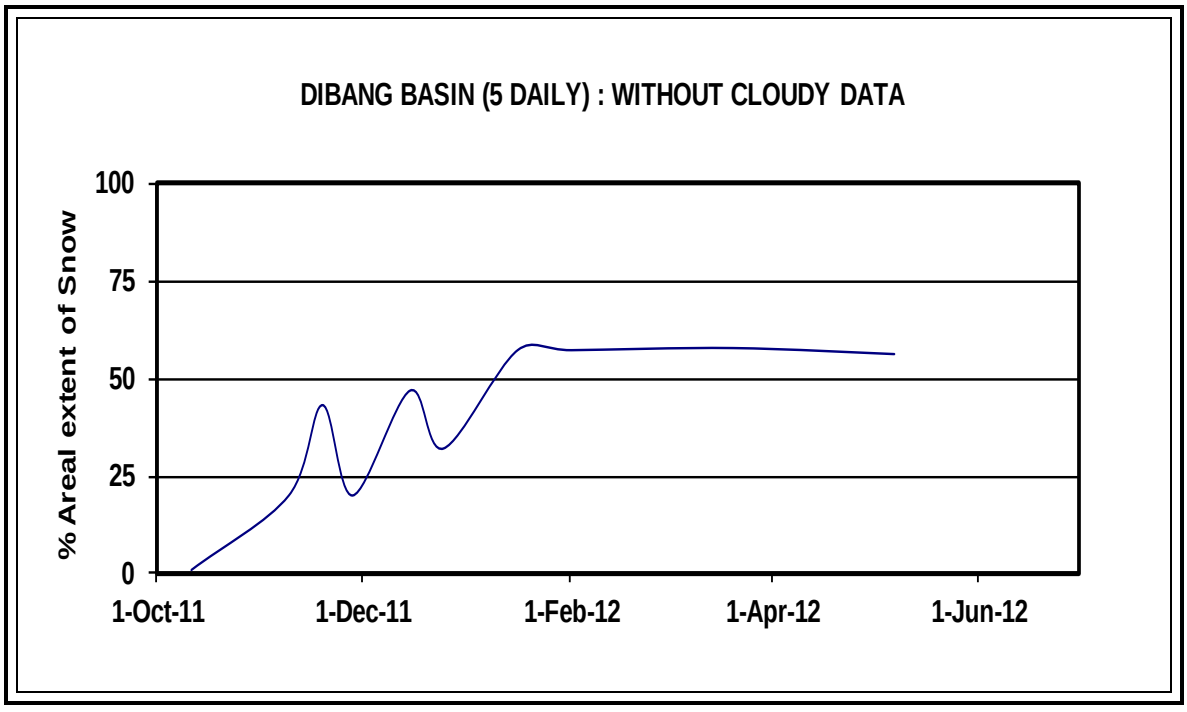
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: DIBANG **BASIN AREA: 9158 sq km**

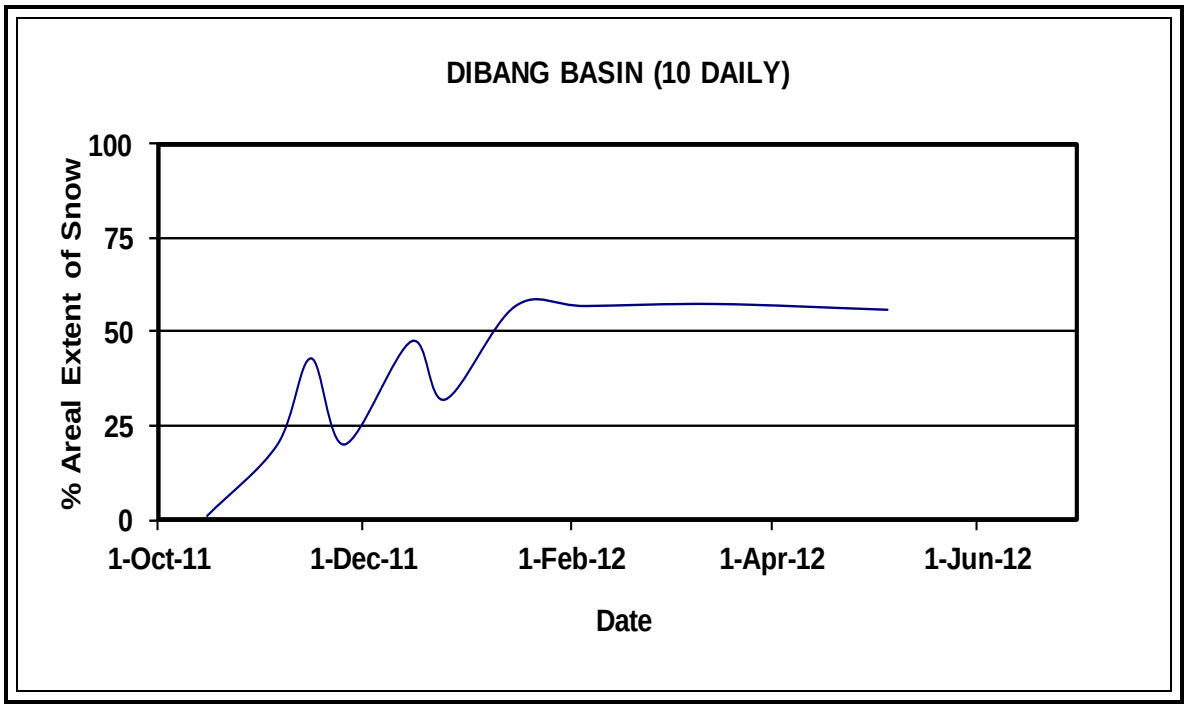
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2011				**November 2011**			
1	7-Oct-11	DNA		4	9-Nov-11	1831	20
2	11-Oct-11	82	1	5	19-Nov-11	3678	43
3	26-Oct-11	DNA		6	28-Nov-11	1831	20
December 2011				**January 2012**			
7	3-Dec-11	DNA		10	16-Jan-12	5220	57
8	15-Dec-11		47	11	23-Jan-12	DNA	
9	25-Dec-11		32				
February 2012				**March 2012**			
12	1-Feb-12	5220	57	15	10-Mar-12	DNA	
13	12-Feb-12	DNA		16	20-Mar-12	5269	58
14	24-Feb-12	DNA		17	30-Mar-12	DNA	
April 2012				**May 2012**			
				19	7-May-12	5128	56
18	17-Apr-12	CLOUDY DATA		20	17-May-12	DNA	
				21	26-May-12	CLOUDY DATA	
June 2012							
22	7-June-12	CLOUDY DATA					

Snow cover depletion curve



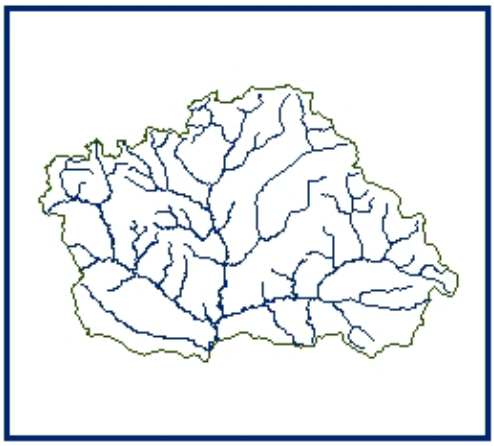


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : DIBANG BASIN



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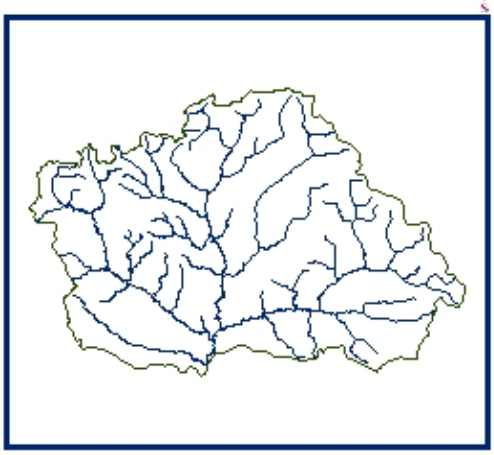

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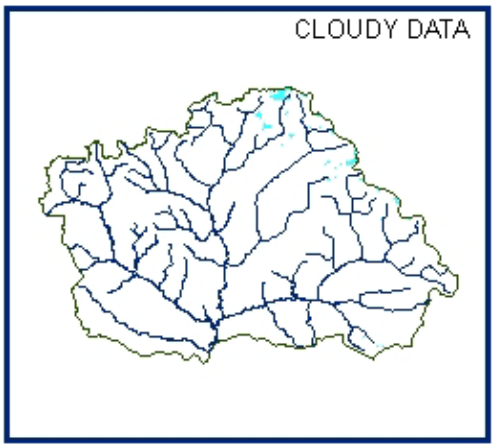

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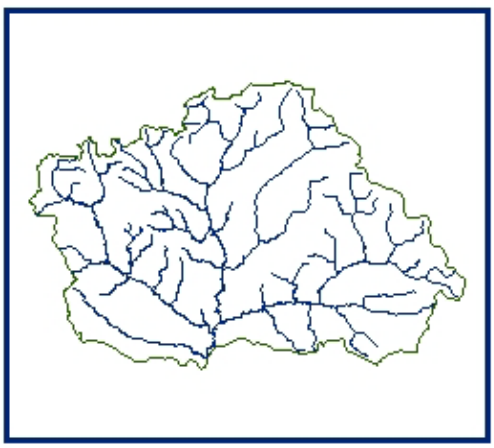

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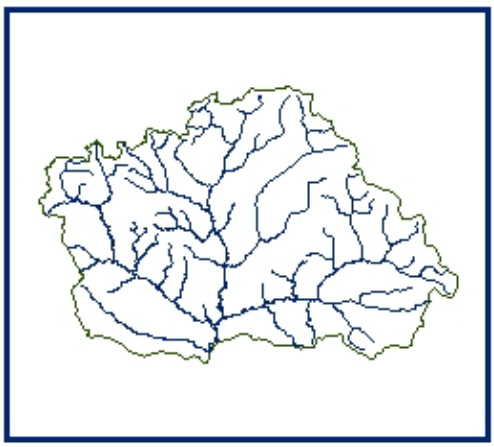

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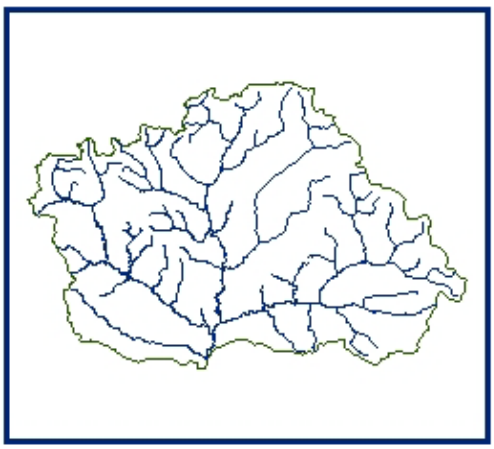

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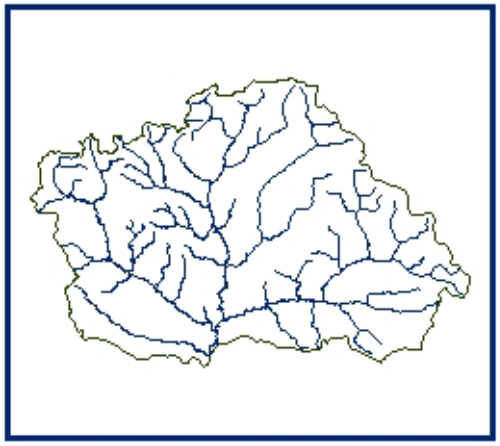
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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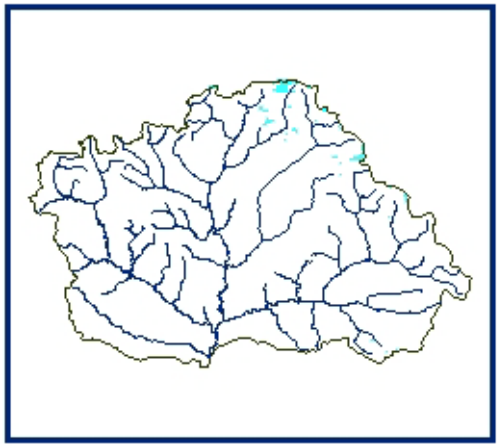

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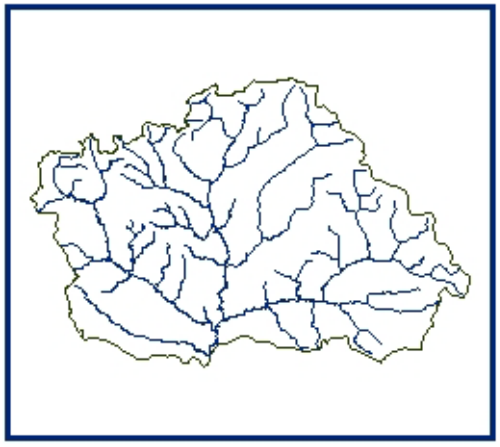

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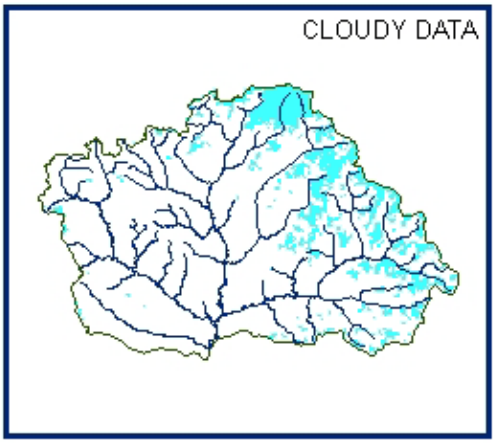
SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



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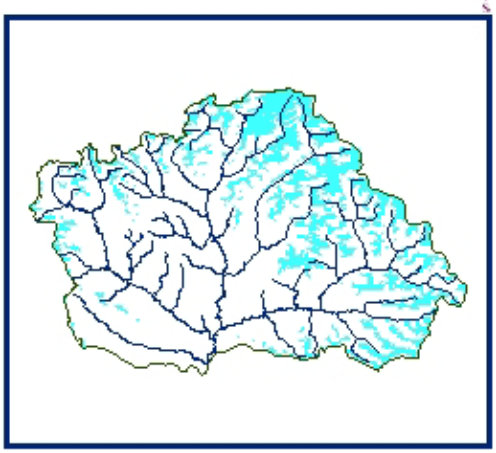

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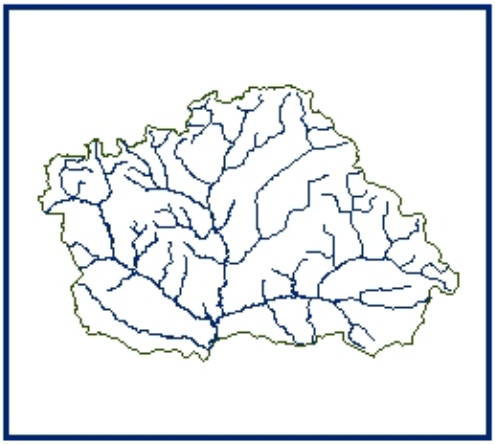

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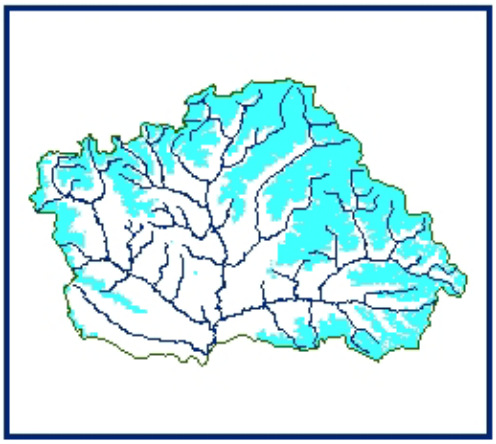

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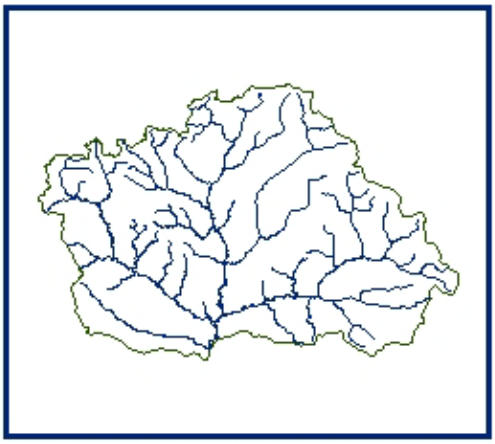

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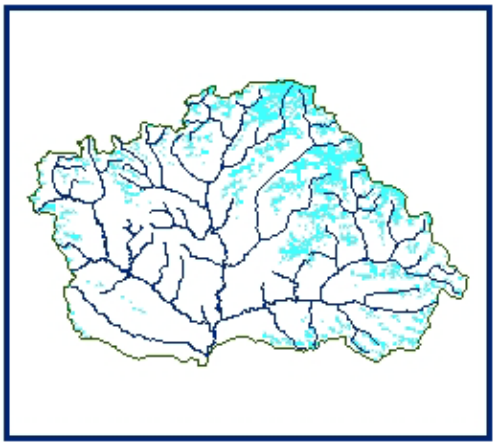


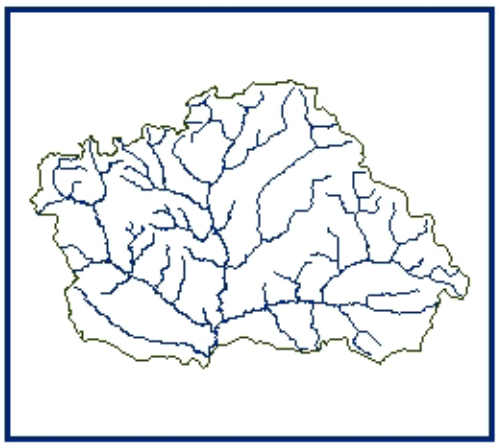
28 NOVEMBER 2011

SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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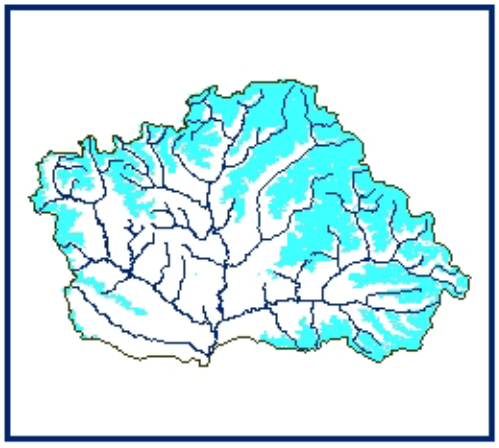

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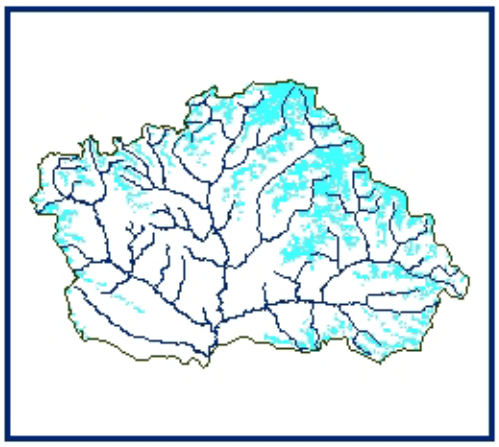

DATA USED
28 NOVEMBER 2011

SNOW

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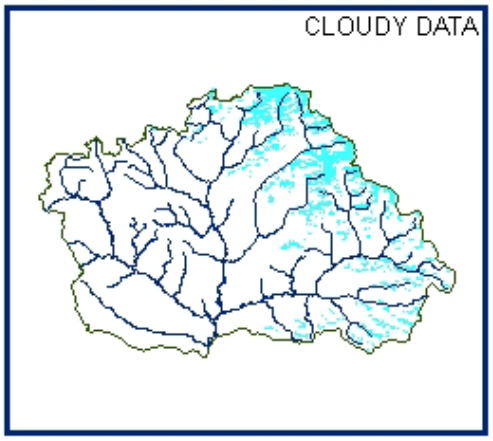
Kilometers

SNOW COVER MAP : DIBANG BASIN



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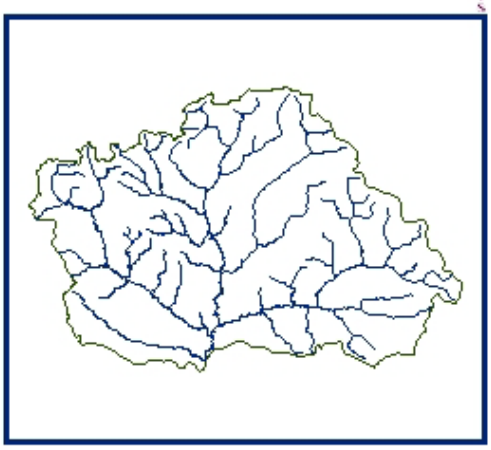

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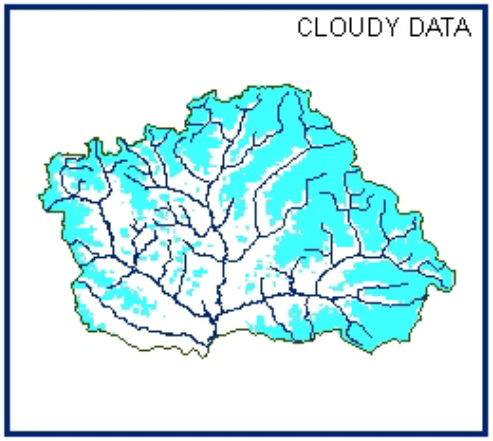

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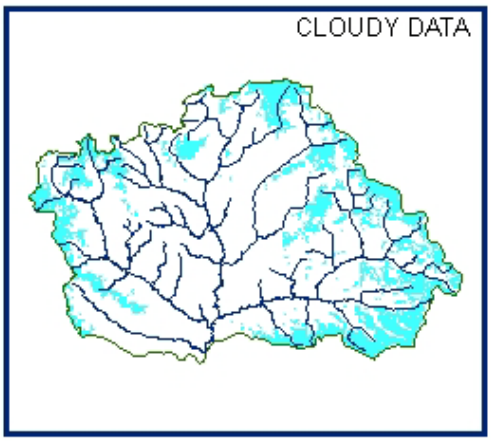

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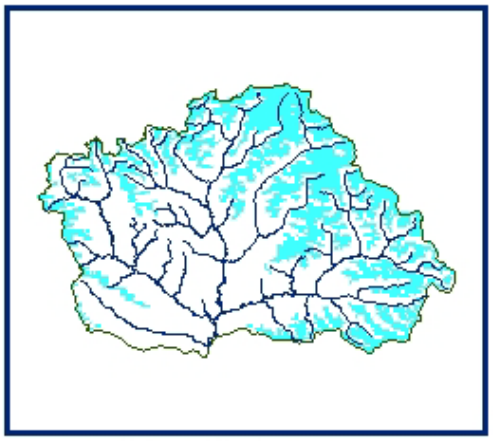
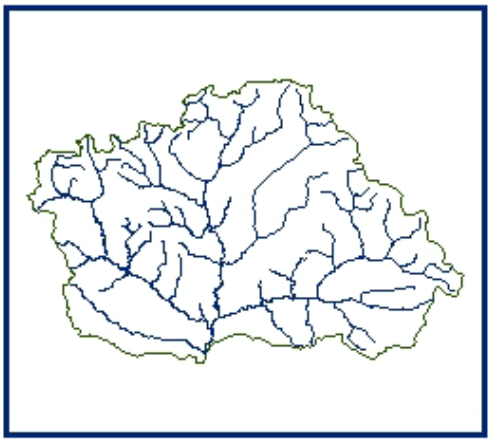


25 DECEMBER 2011



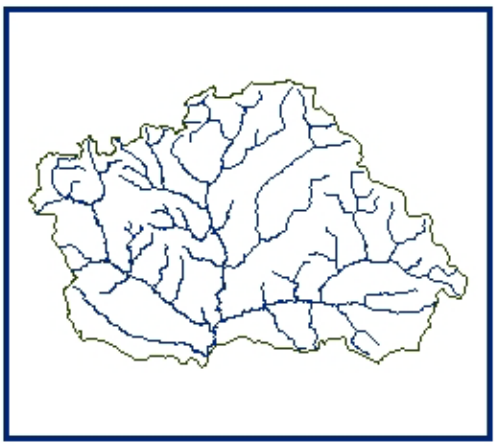
DATA NOT AVAILABLE

SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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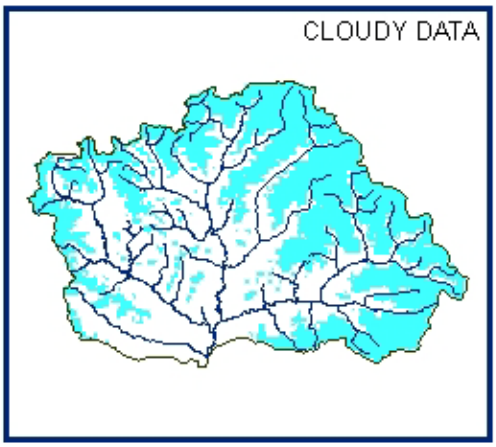

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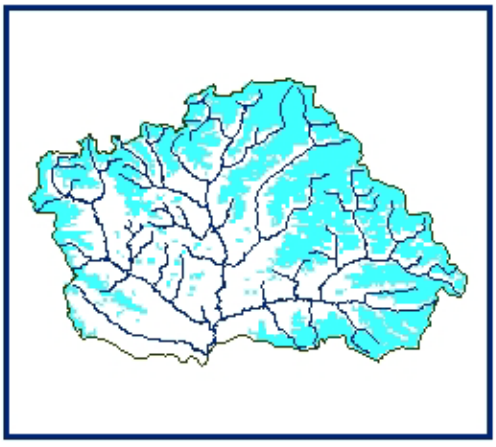

DATA USED
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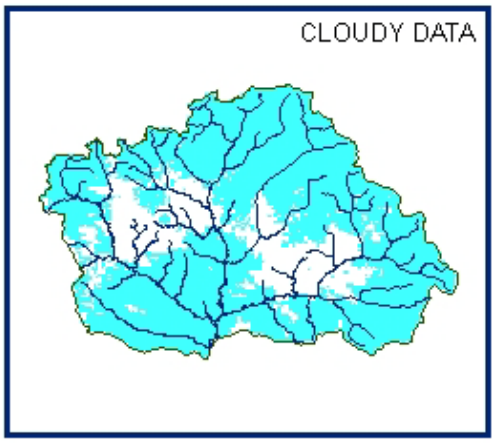
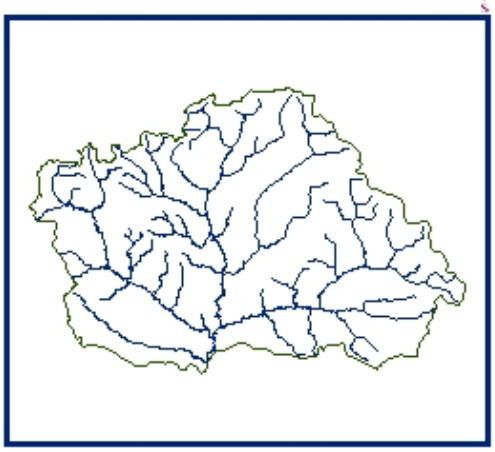
SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



03 JANUARY 2012



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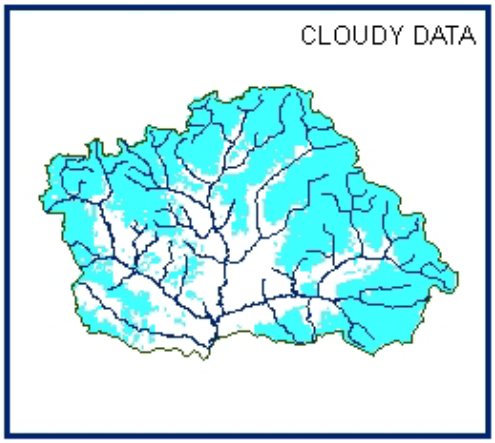
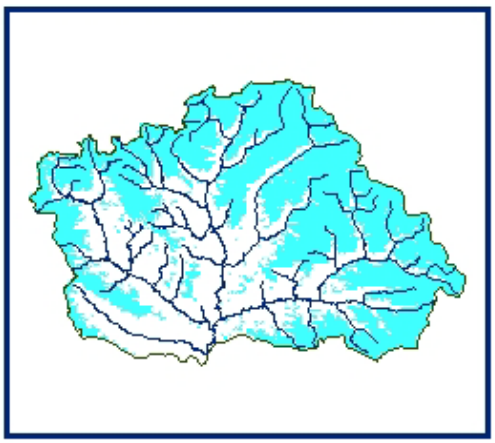
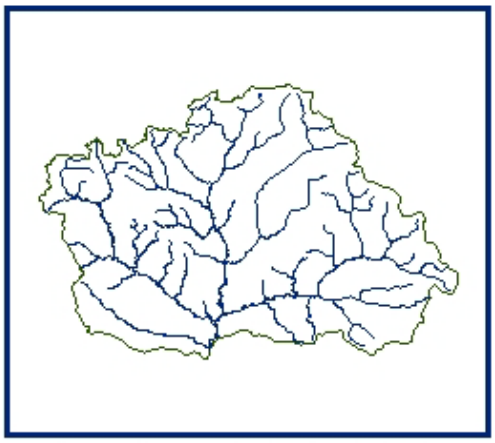


13 JANUARY 2012



16 JANUARY 2012



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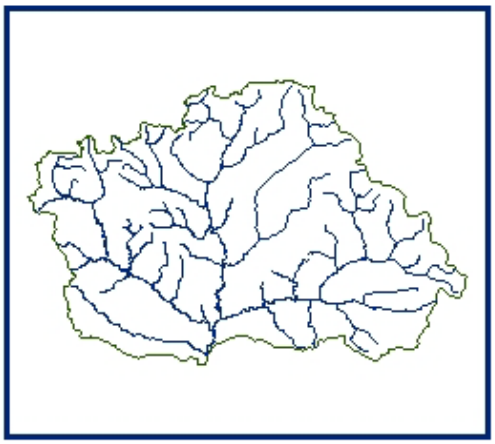

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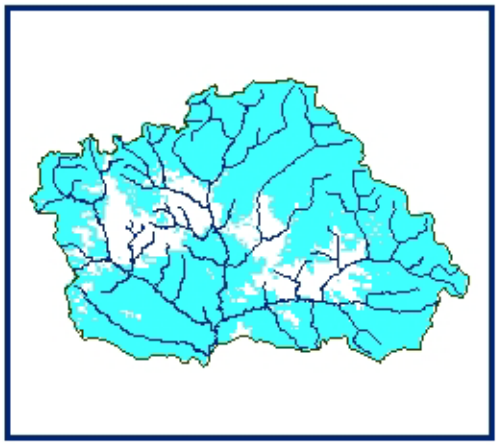
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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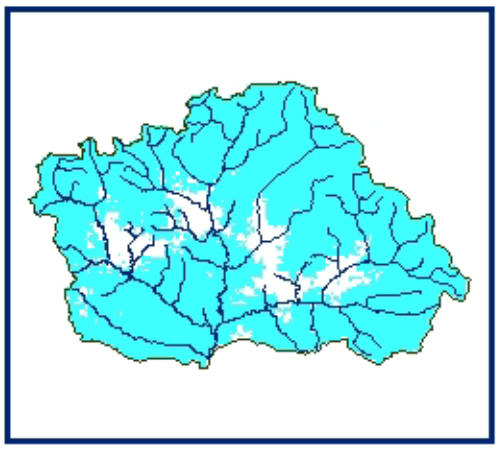

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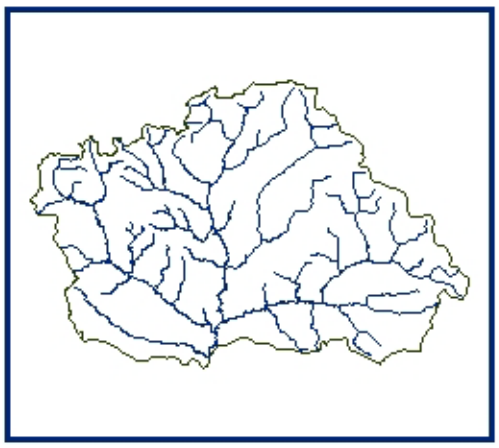

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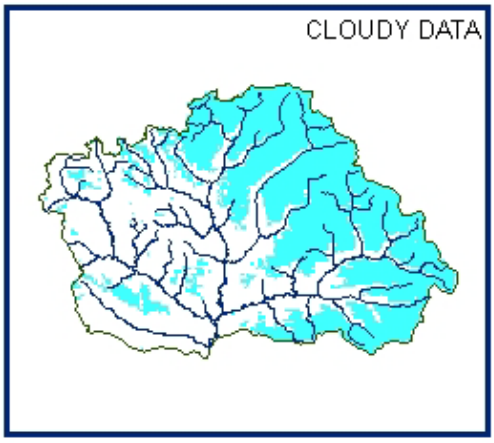
SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



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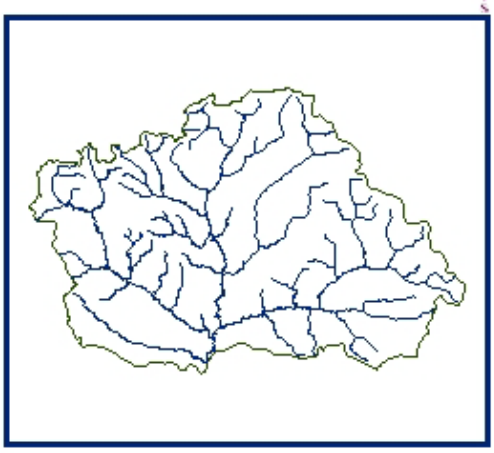

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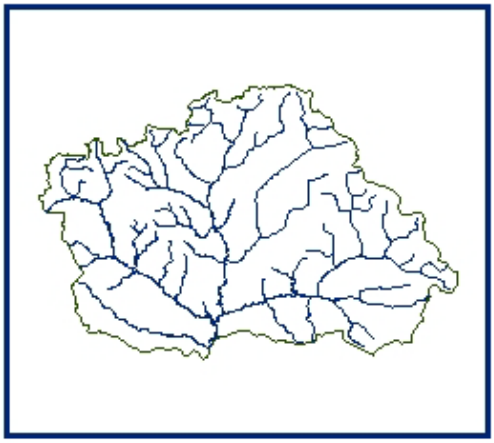

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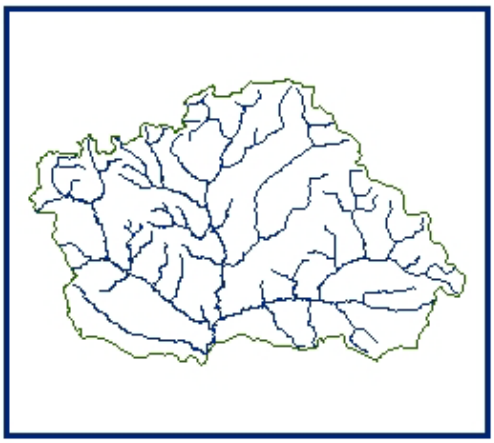

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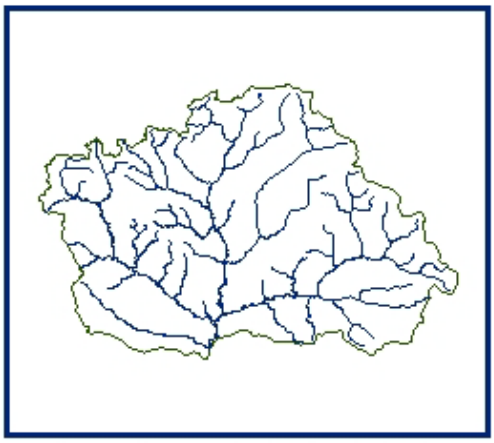

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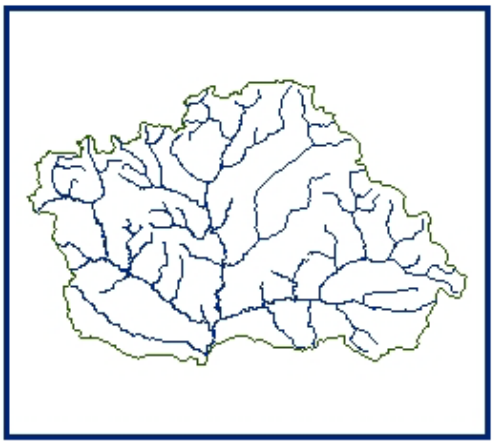

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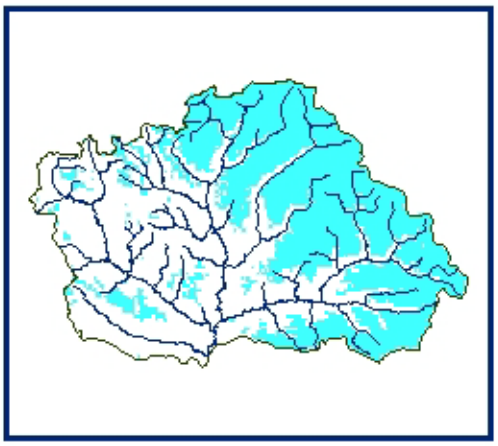
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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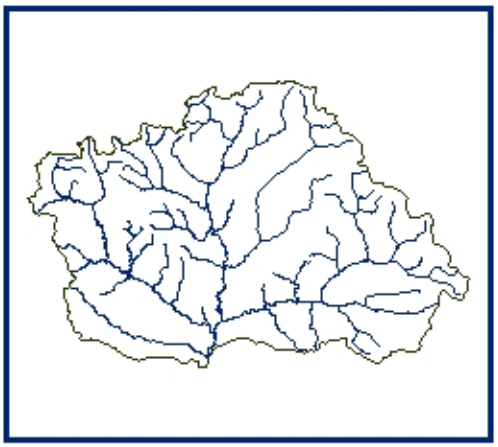

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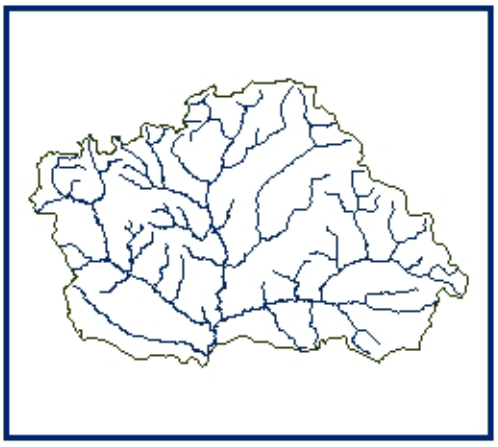

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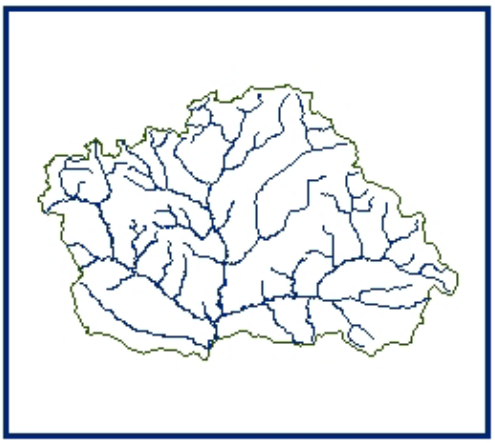
SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



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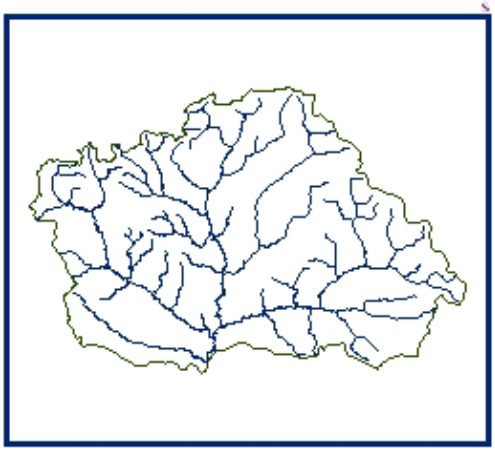

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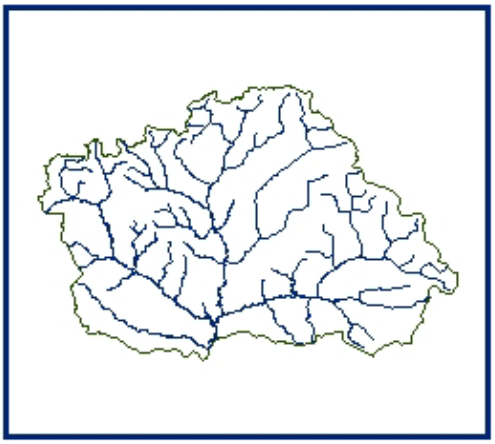

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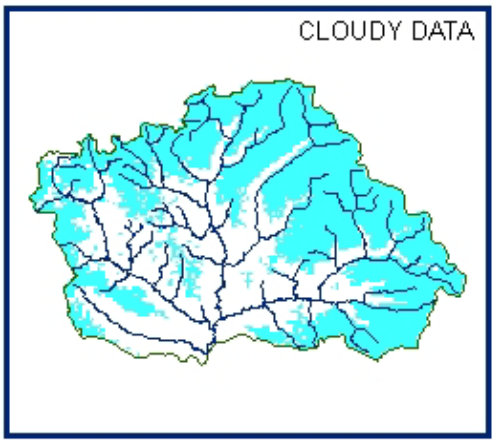

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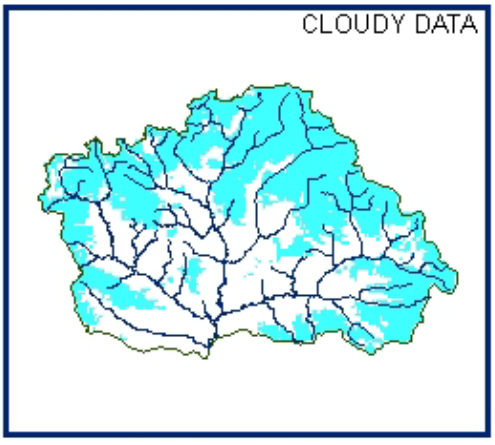

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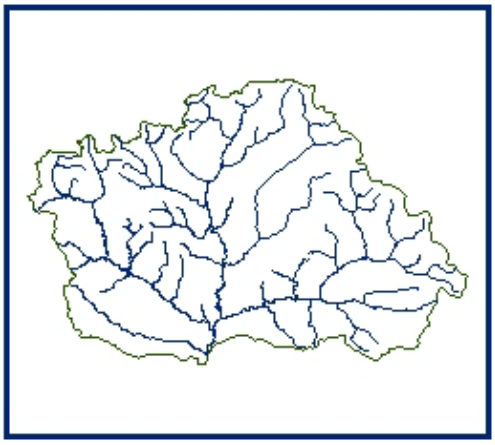

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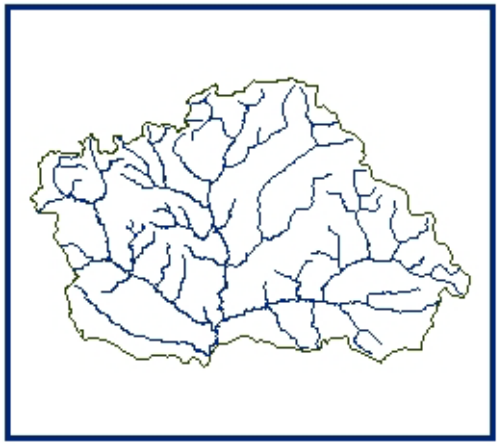
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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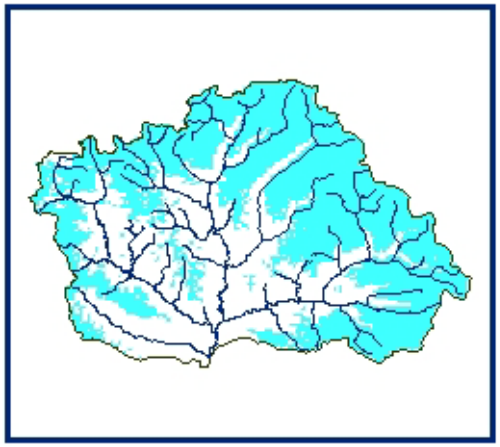

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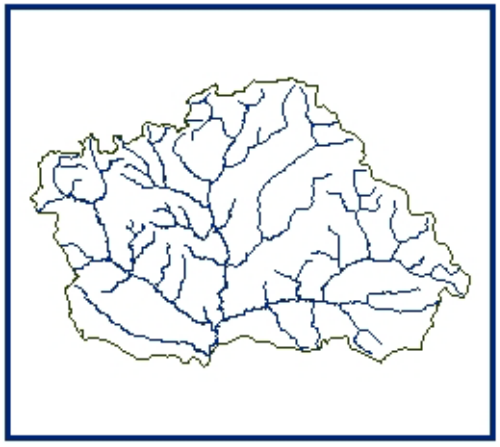

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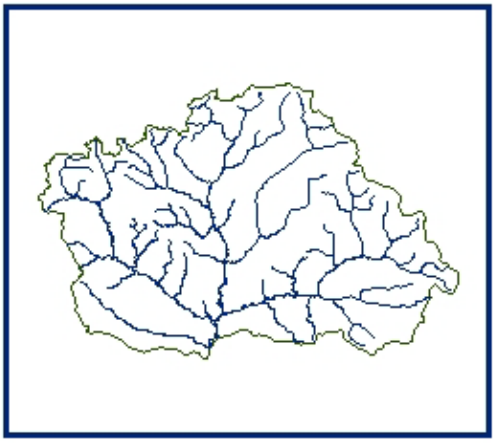
SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



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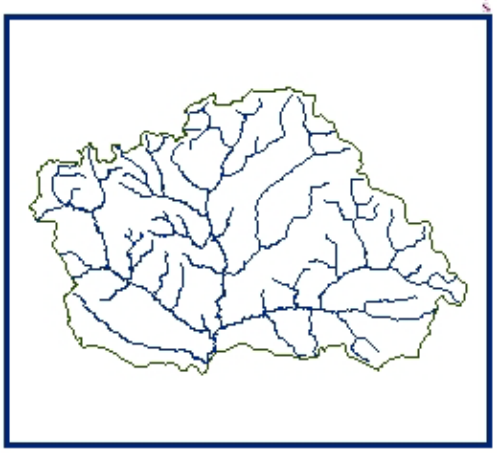

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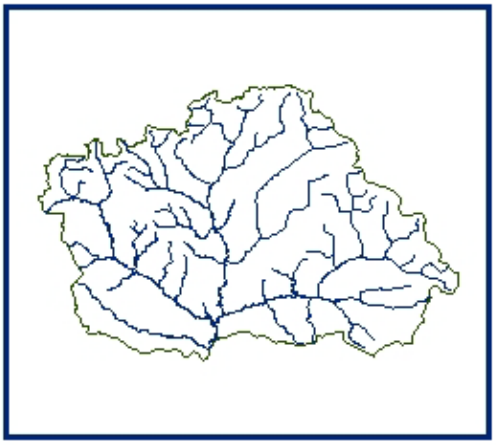

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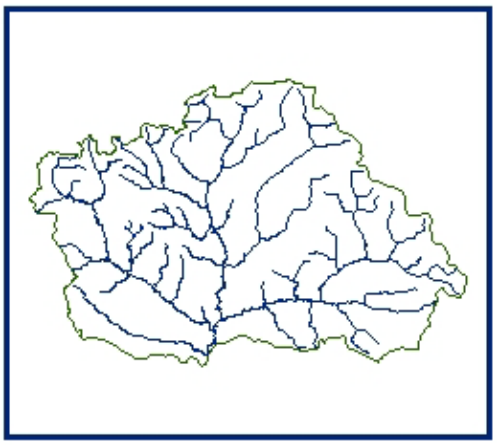

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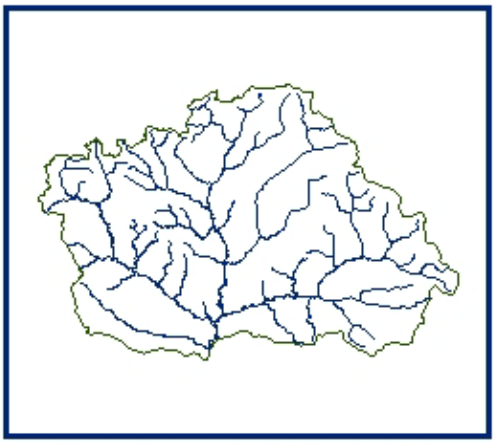

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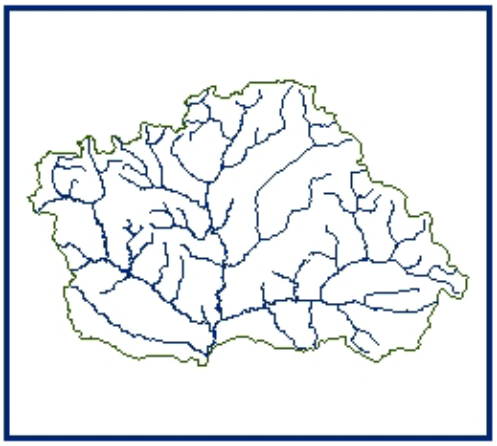

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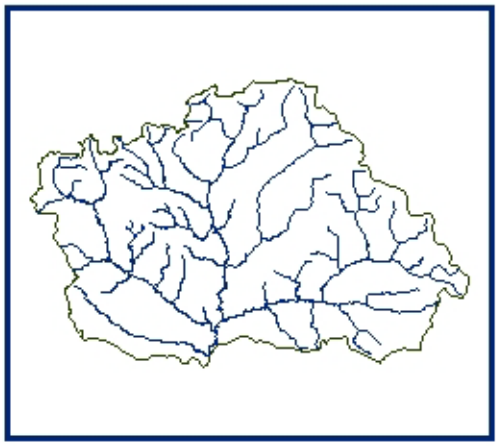
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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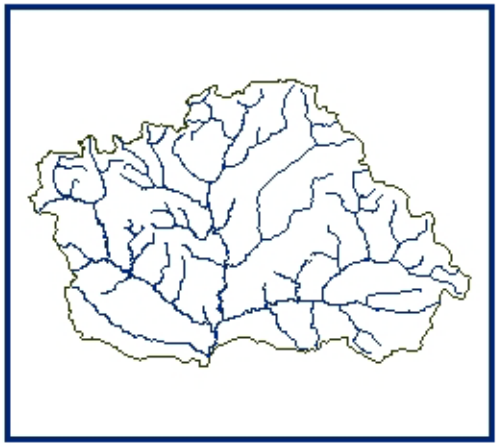

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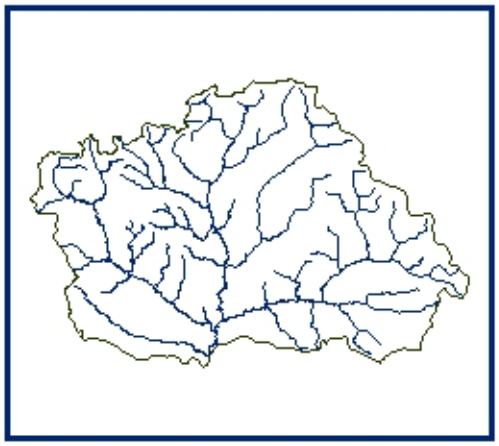

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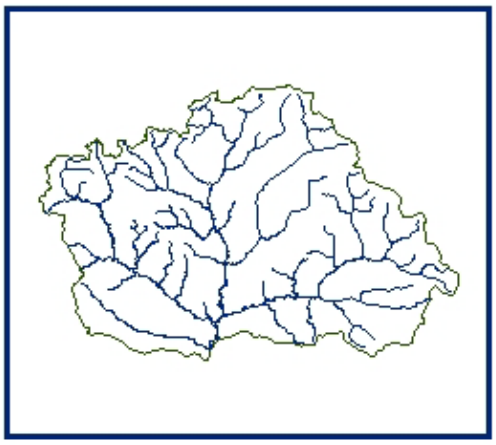
SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



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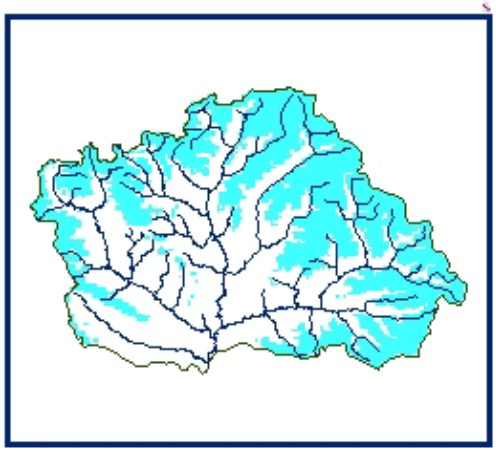
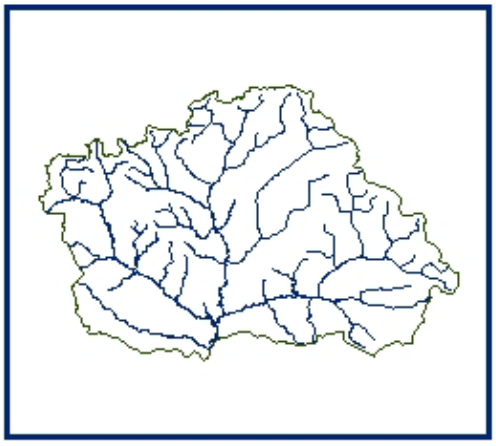


07 MAY 2012



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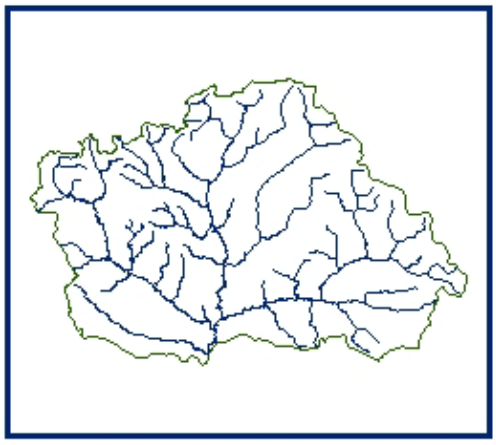

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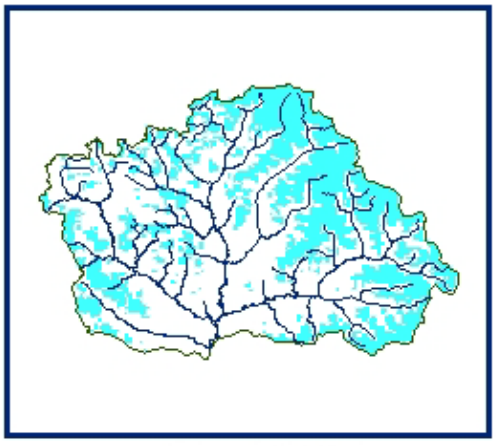
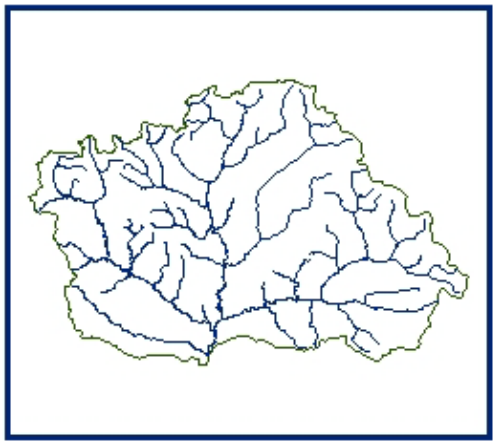


26 MAY 2012



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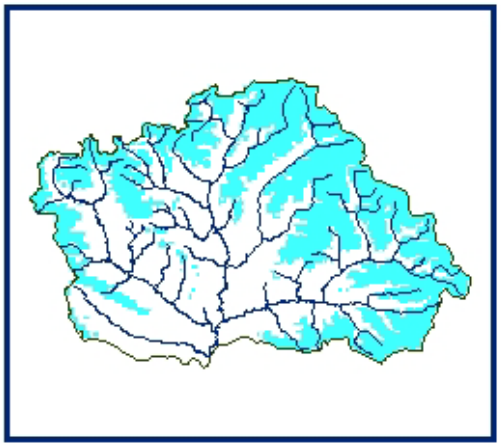
SNOW

0 15 30 60 90 120

Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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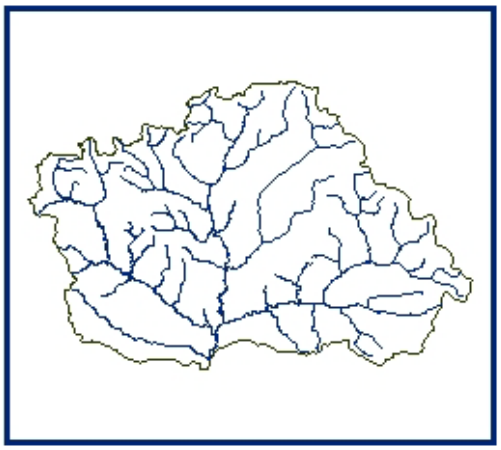

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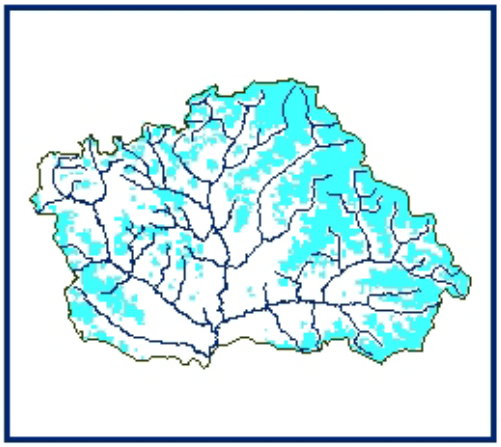
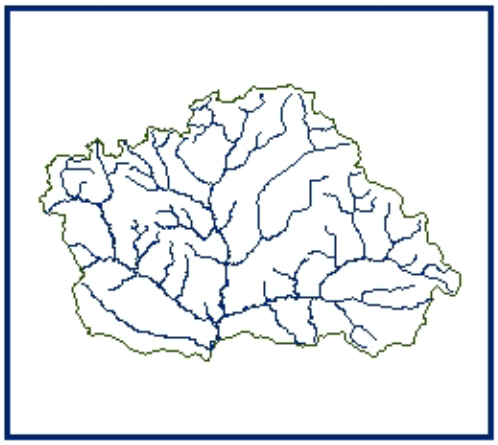


DATA USED
26 MAY 2012

SNOW

0 15 30 60 90 120
Kilometers

SNOW COVER MAP : DIBANG BASIN



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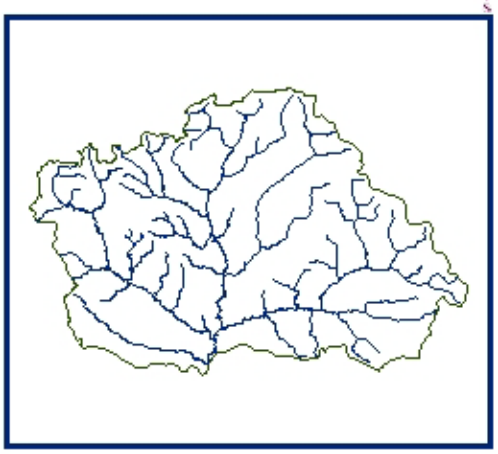

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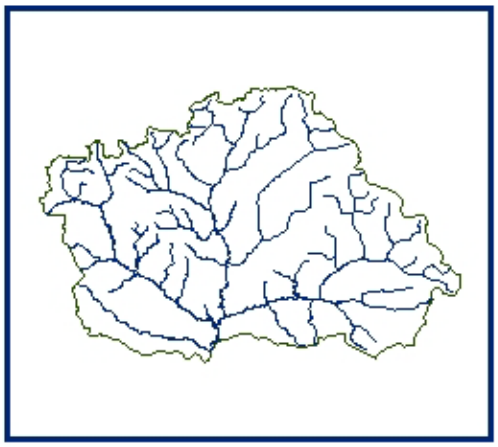

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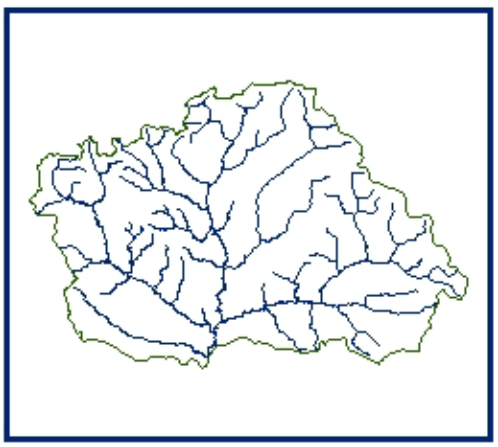

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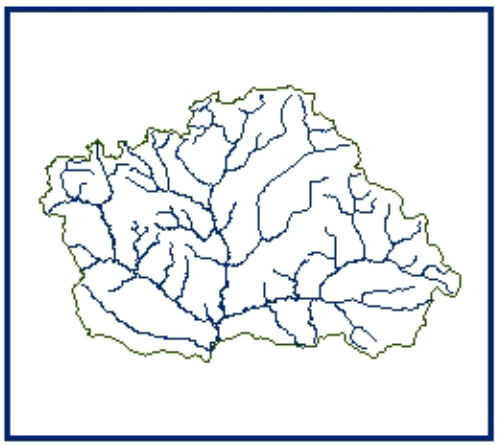

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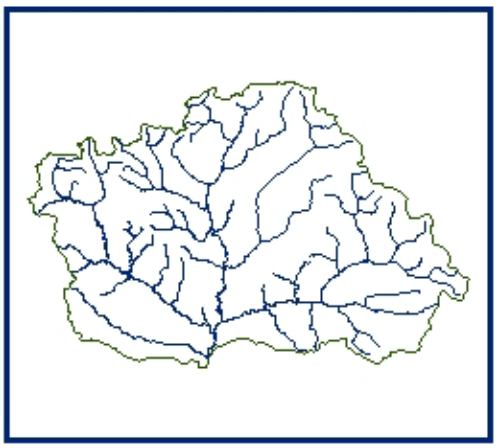


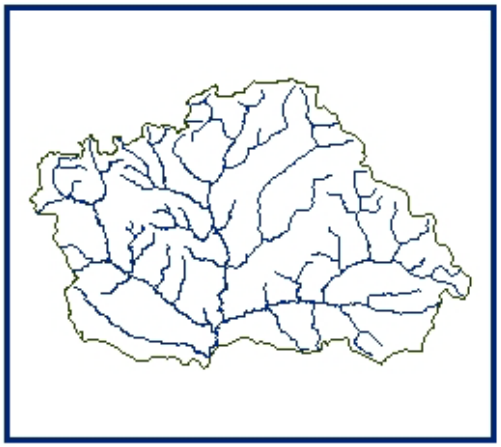
DATA NOT AVAILABLE

SNOW

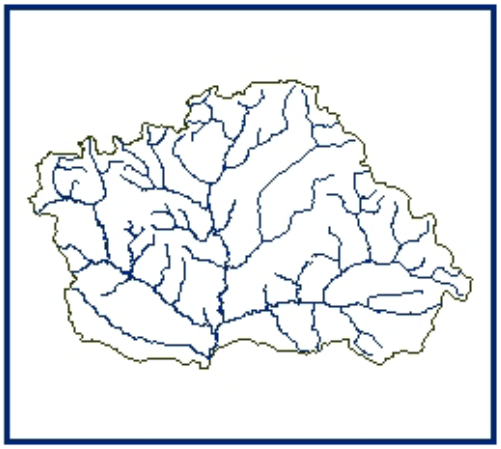
0 15 30 60 90 120

Kilometers

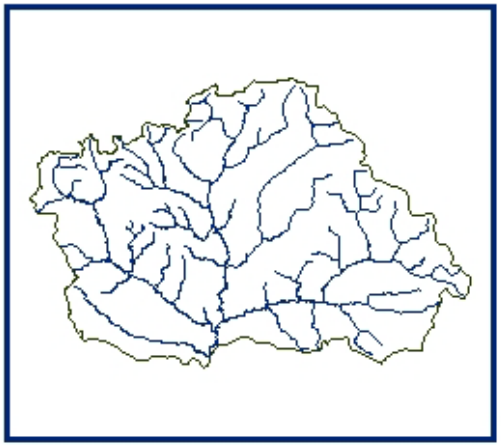
10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
DATA NOT AVAILABLE



DATA USED
DATA NOT AVAILABLE

SNOW

0 15 30 60 90 120
Kilometers

SUBANSIRI BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: SUBANSIRI **BASIN AREA: 25345 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2011							
1	1-Oct-11	DNA		5	25-Oct-11	1190	5
2	6-Oct-11	888	4	6	27-Oct-11	DNA	
3	11-Oct-11	652	3	7	30-Oct-11	DNA	
4	16-Oct-11	DNA		8	31-Oct-11	DNA	
November 2011							
9	4-Nov-11	2342	9	14	18-Nov-11	4821	19
10	5-Nov-11	DNA		15	23-Nov-11	3080	12
11	9-Nov-11	4515	18	16	24-Nov-11	DNA	
12	10-Nov-11	DNA		17	28-Nov-11	2570	10
13	14-Nov-11	DNA					
December 2011							
18	3-Dec-11	931	4	23	15-Dec-11	3319	13
19	4-Dec-11	DNA		24	17-Dec-11	1396	6
20	8-Dec-11	DNA		25	22-Dec-11	DNA	
21	9-Dec-11	DNA		26	23-Dec-11	DNA	
22	12-Dec-11	976	4	27	27-Dec-11	DNA	
January 2012							
28	3-Jan-12	CLOUDYDATA		32	13-Jan-12	7437	29
29	6-Jan-12	DNA		33	15-Jan-12	DNA	
30	8-Jan-12	CLOUDYDATA		34	22-Jan-12	5327	21
31	10-Jan-12	DNA		35	26-Jan-12	DNA	
				36	30-Jan-12	DNA	
February 2012							
37	1-Feb-12	3794	15	41	18-Feb-12	DNA	
38	3-Feb-12	3082	12	42	23-Feb-12	DNA	
39	8-Feb-12	DNA		43	25-Feb-12	3295	13
40	9-Feb-12	DNA		44	28-Feb-12	DNA	

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
March 2012							
45	5-Mar-12	5822	23	48	19-Mar-12	DNA	
46	10-Mar-12	5174	20	49	20-Mar-12	3580	14
47	14-Mar-12	DNA		50	25-Mar-12	4449	18
April 2012							
51	17-April-12	CLOUDYDATA					
May 2012							
52	7-May-12	2980	12	53	21-May-12	4470	18
June 2012							
54	7-June-11	CLOUDYDATA		55	13-June-11	CLOUDYDATA	

DNA- DATA NOT AVAILABLE

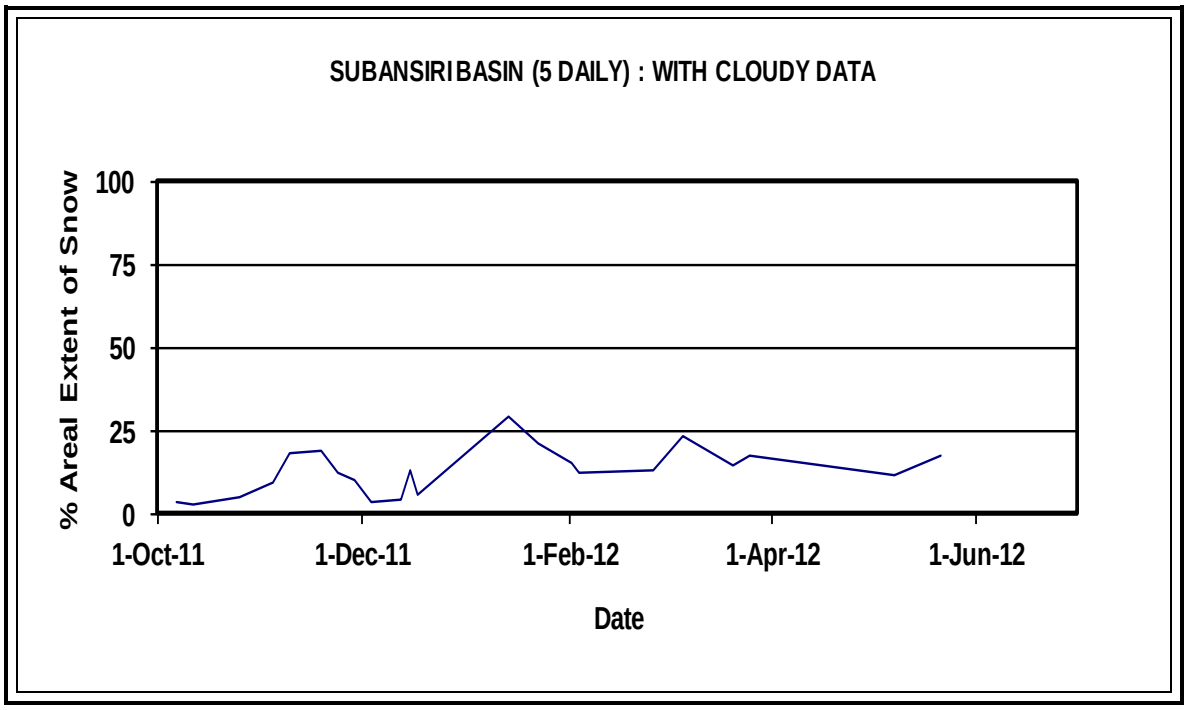
DNC-3BASINS NOT IN SCENE/HALF IN SCENE

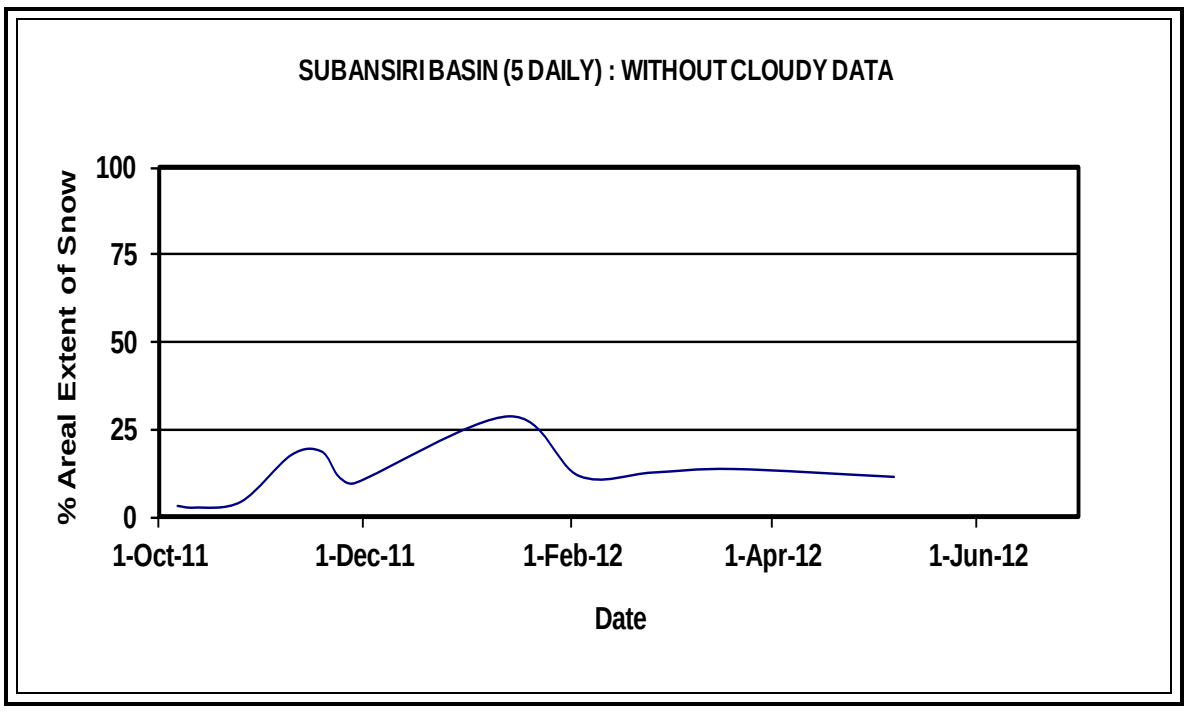
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: SUBANSIRI **BASIN AREA: 25345 sq km**

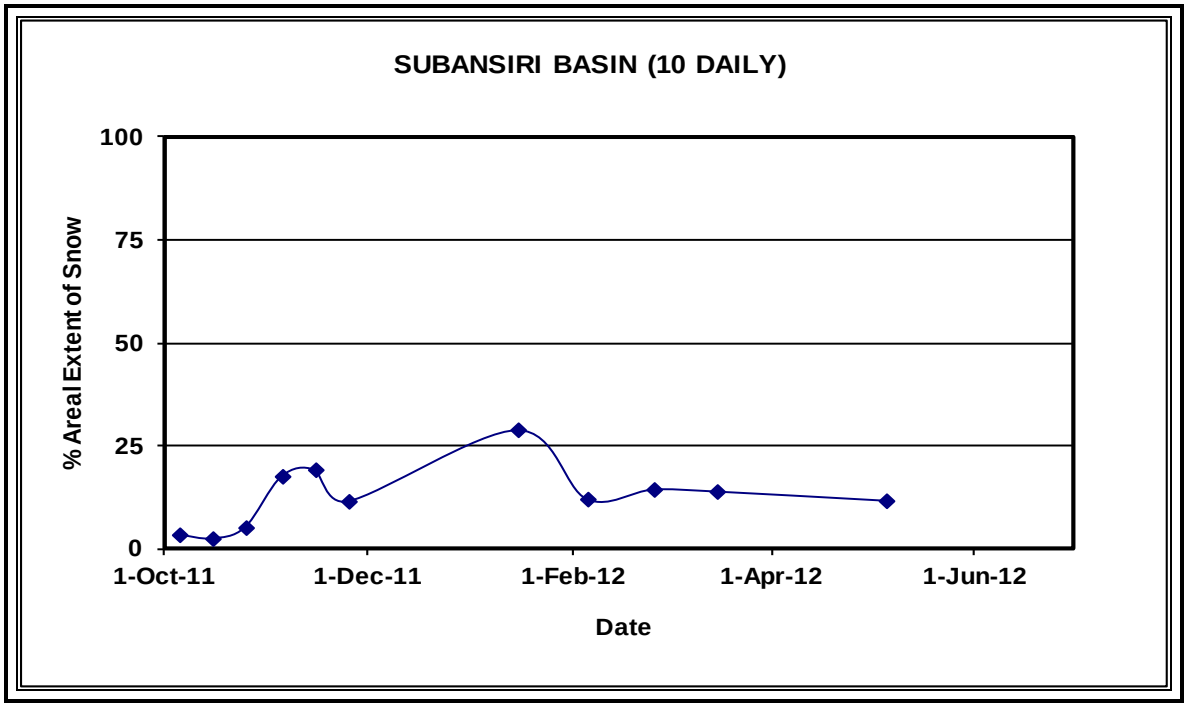
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2011				**November 2011**			
1	5-Oct-11	1014	4	4	9-Nov-11	4487	18
2	11-Oct-11	652	3	5	18-Nov-11	4893	19
3	25-Oct-11	1329	5	6	28-Nov-11	2947	12
December 2011				**January 2012**			
7	3-Dec-11	DNA		10	3-Jan-12	CLOUDY DATA	
8	12-Dec-11	CLOUDY DATA		11	13-Jan-12	7437	29
9	24-Dec-11	DNA		12	22-Jan-12	CLOUDY DATA	
February 2012				**March 2012**			
13	3-Feb-12	3082	12	16	10-Mar-12	CLOUDY DATA	
14	13-Feb-12	DNA		17	20-Mar-12	3548	14
15	25-Feb-12	3295	13				
April 2012				**May 2012**			
18	17-Apr-12	CLOUDY DATA		19	7-May-12	2980	12
				20	17-May-12	DNA	
				21	21-May-12	CLOUDY DATA	
June 2012							
22	7-June-12	CLOUDY DATA					

Snow cover depletion curve



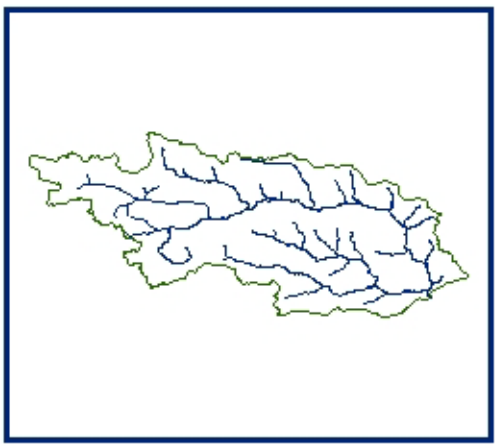


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : SUBANSIRI BASIN



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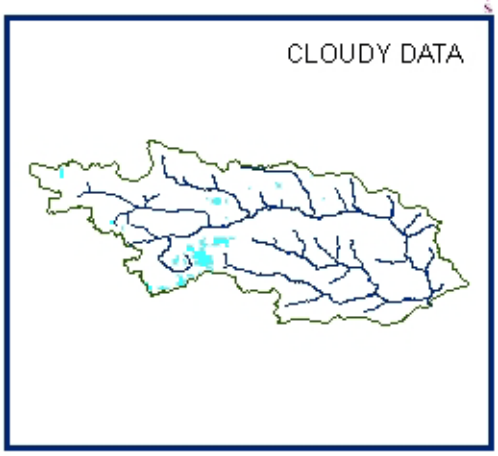
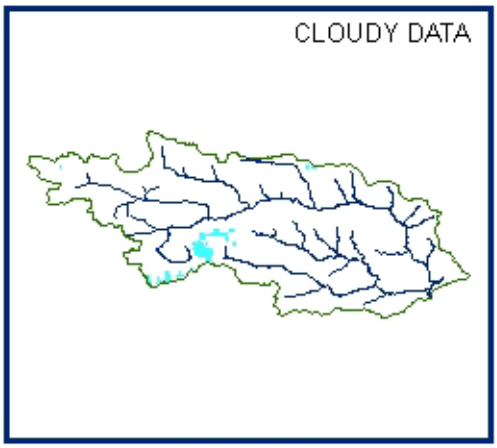
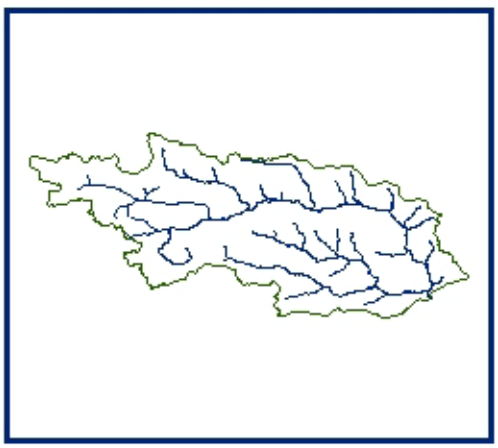


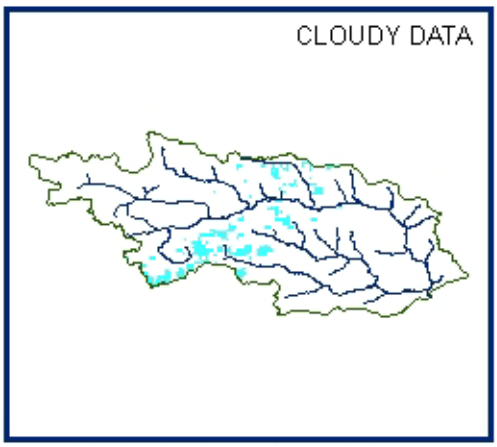
06 OCTOBER 2011



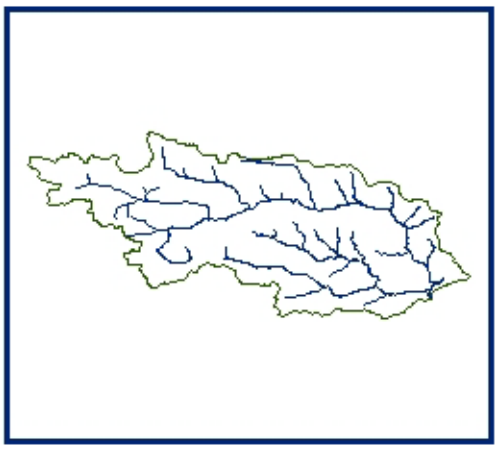
11 OCTOBER 2011



DATA NOT AVAILABLE



25 OCTOBER 2011



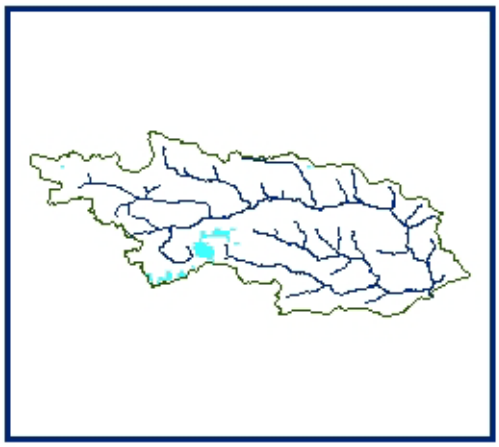
DATA NOT AVAILABLE

SNOW

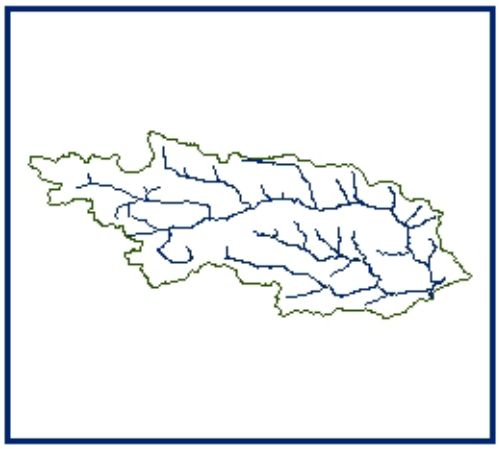
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
11 OCTOBER 2011



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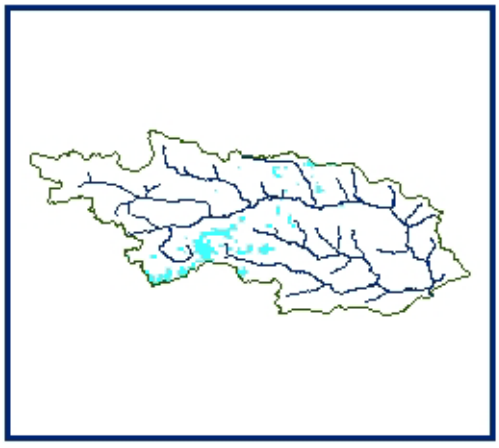
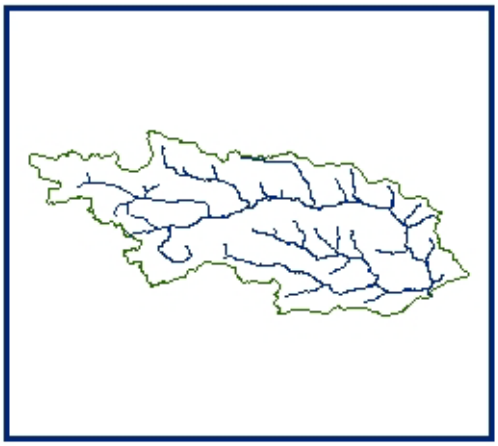


DATA USED
25 OCTOBER 2011

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SUBANSIRI BASIN



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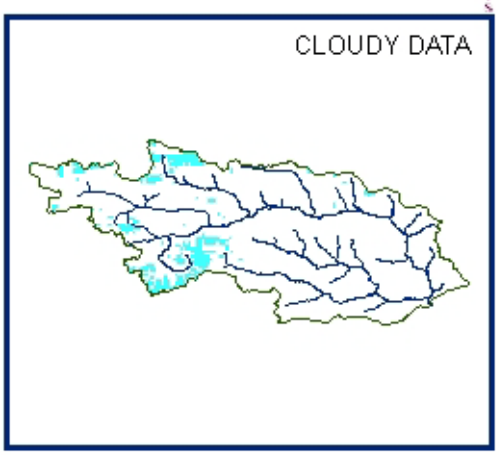
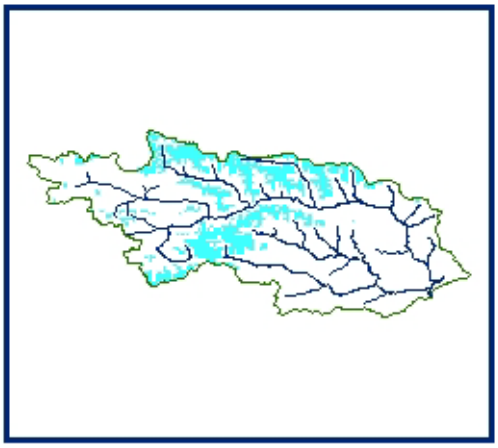
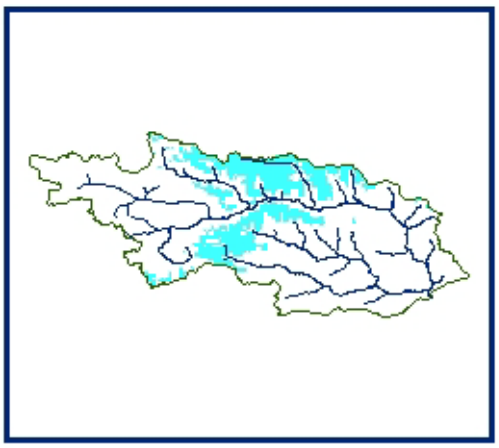


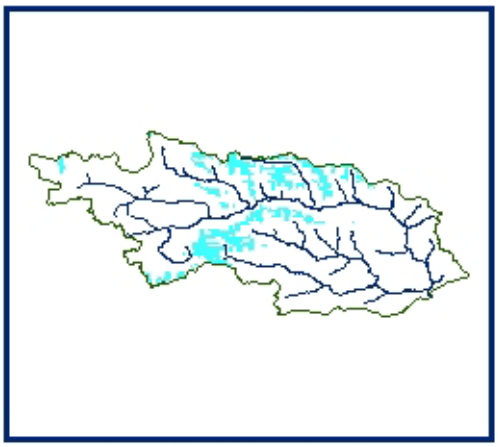
04 NOVEMBER 2011



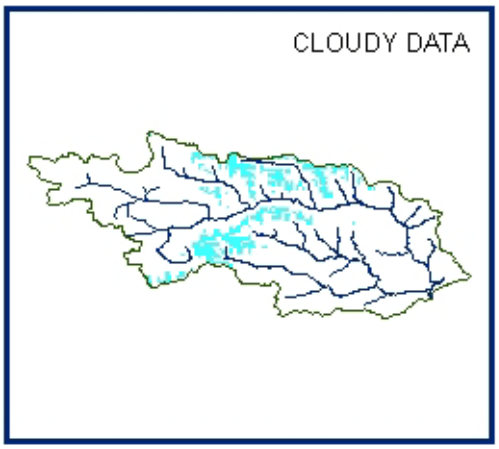
09 NOVEMBER 2011



18 NOVEMBER 2011



23 NOVEMBER 2011



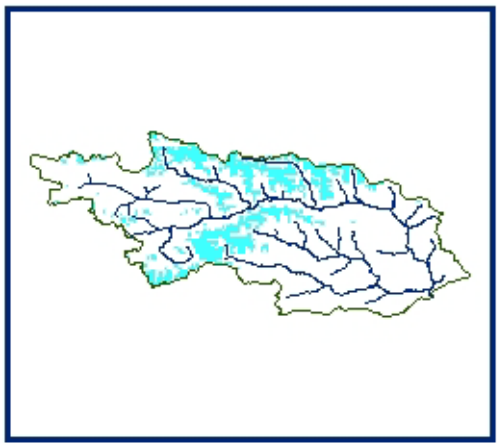
28 NOVEMBER 2011

SNOW

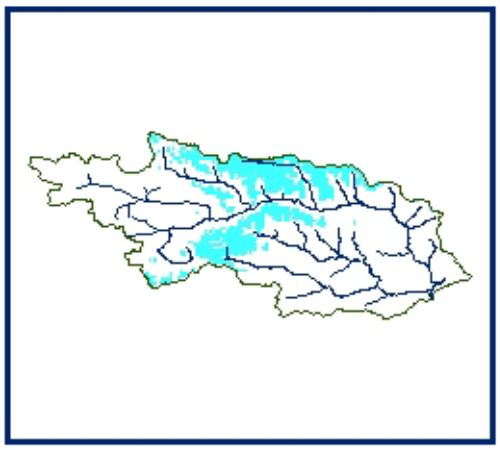
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
09 NOVEMBER 2011



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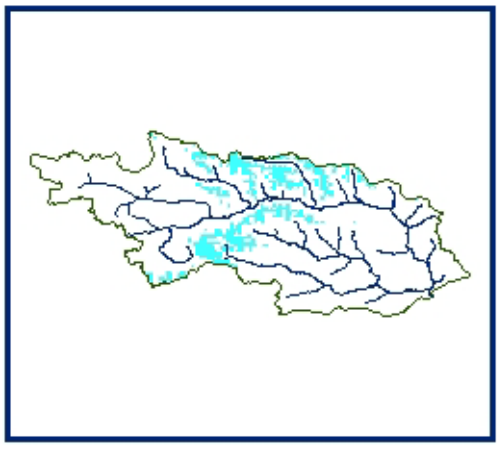
18 NOVEMBER 2011

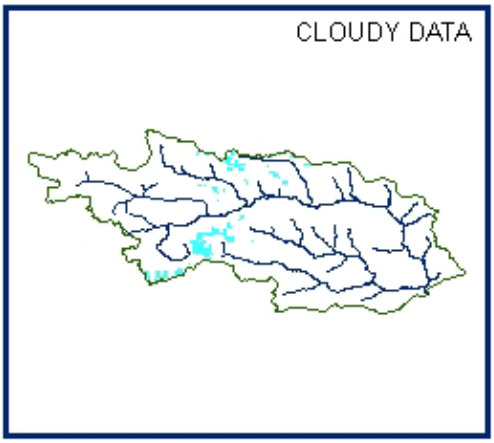


DATA USED
28 NOVEMBER 2011

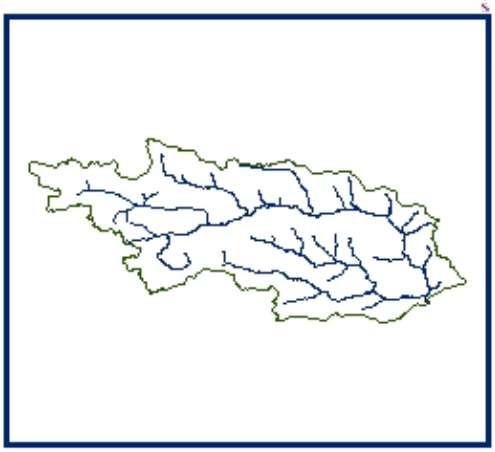
SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SUBANSIRI BASIN



03 DECEMBER 2011



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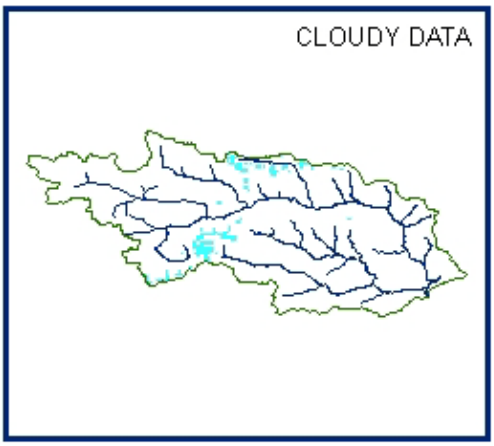
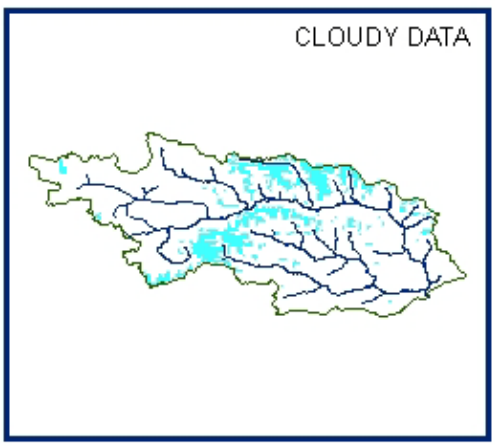
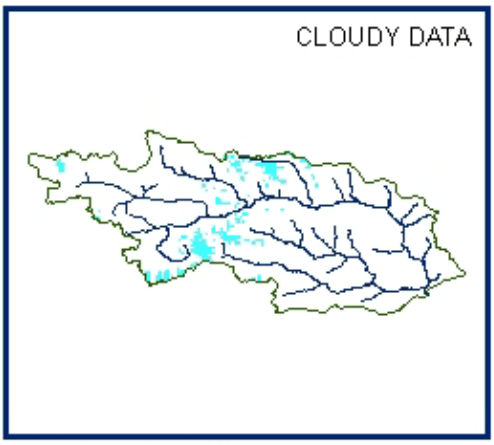


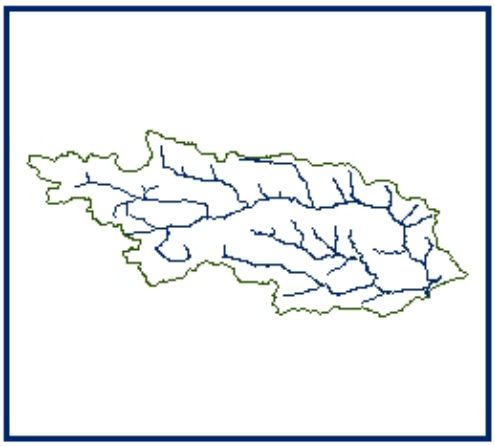
12 DECEMBER 2011



15 DECEMBER 2011



17 DECEMBER 2011



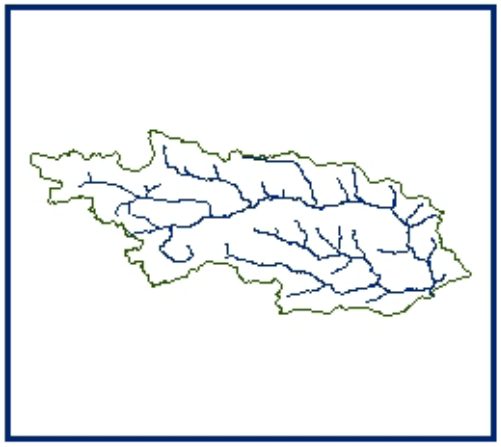
DATA NOT AVAILABLE

SNOW

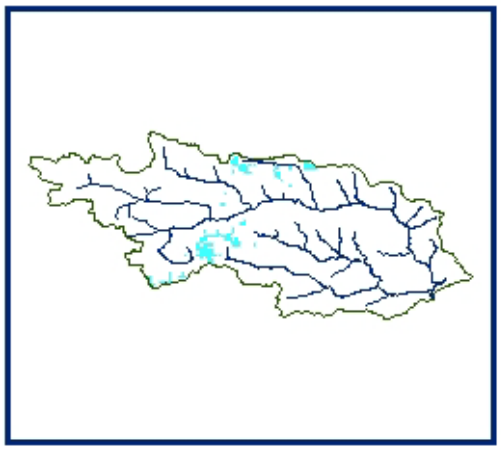
0 35 70 140 210 280

Kilometers

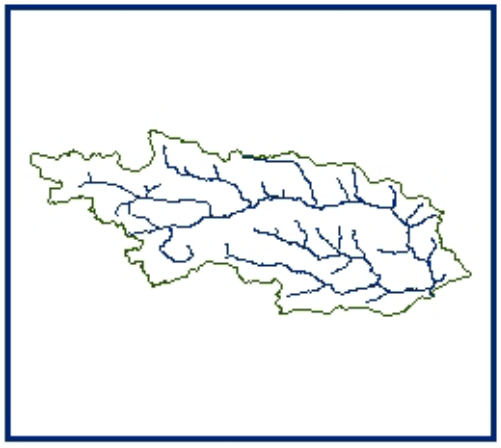
10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
12 DECEMBER 2011

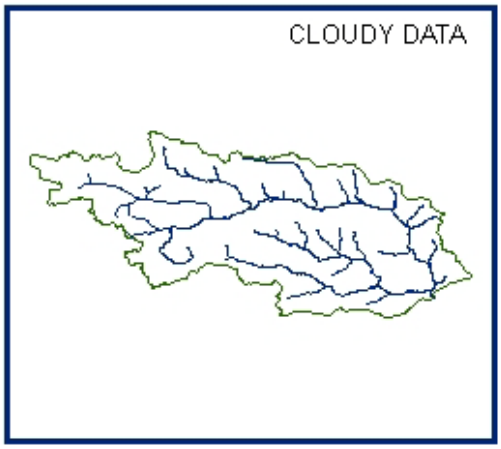


DATA USED
DATA NOT AVAILABLE

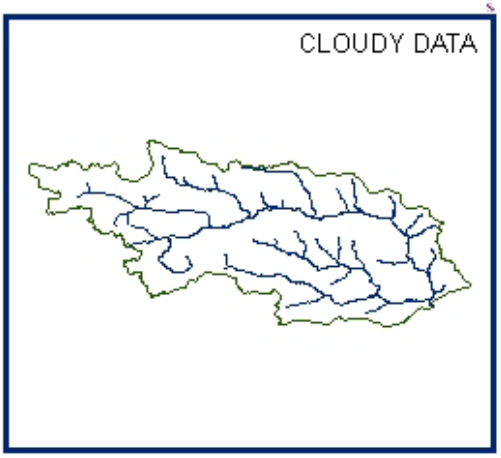
SNOW

0 35 70 140 210 280
Kilometers

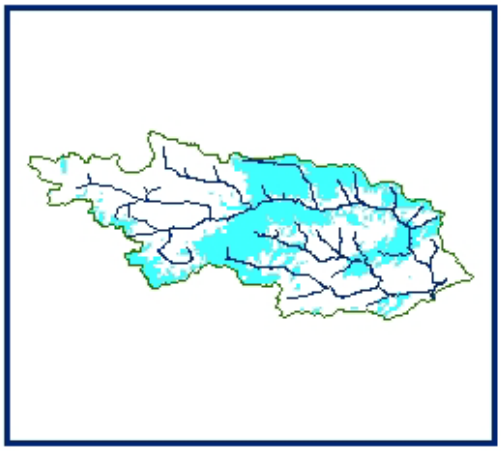
SNOW COVER MAP : SUBANSIRI BASIN



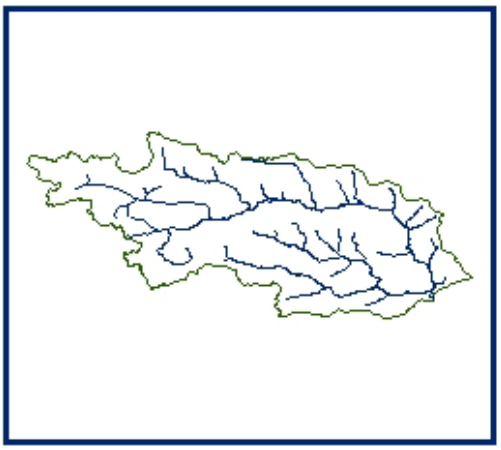
03 JANUARY 2012



08 JANUARY 2012



13 JANUARY 2012



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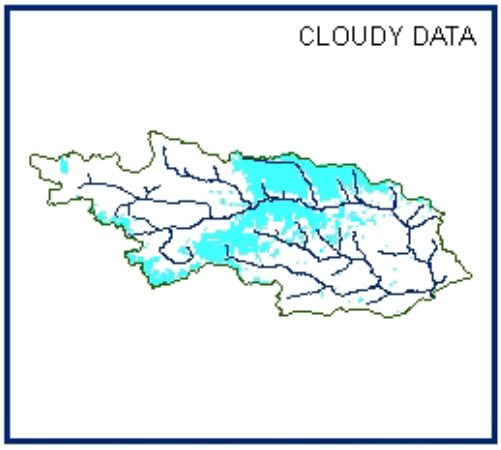
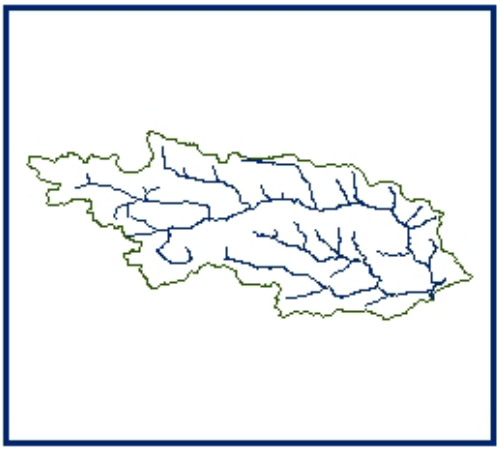


22 JANUARY 2012



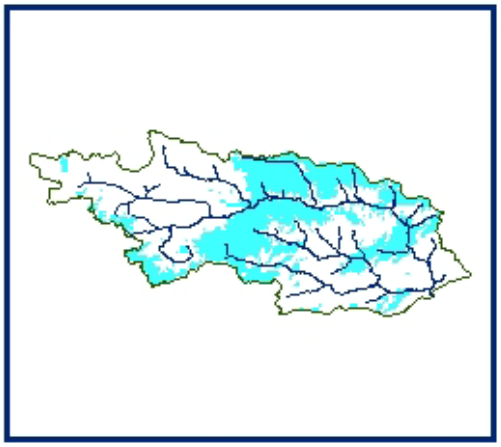
DATA NOT AVAILABLE

SNOW

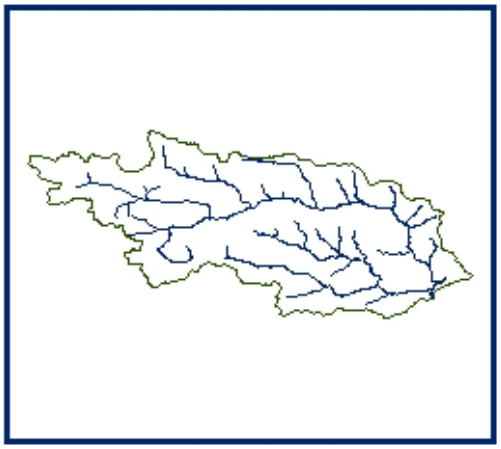
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
13 JANUARY 2012



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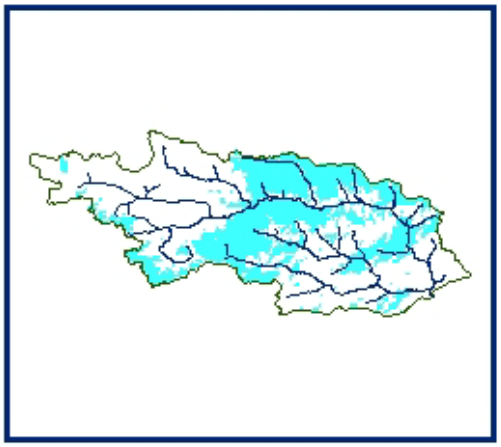
DATA NOT AVAILABLE

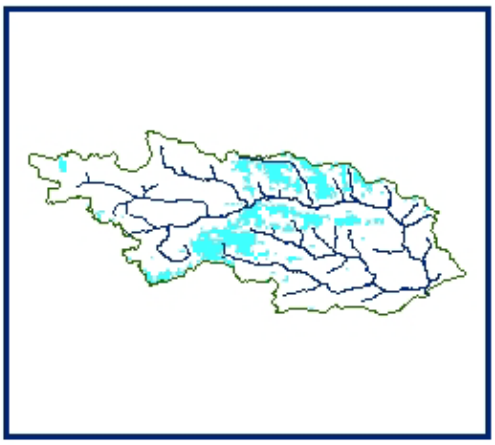


DATA USED
22 JANUARY 2012

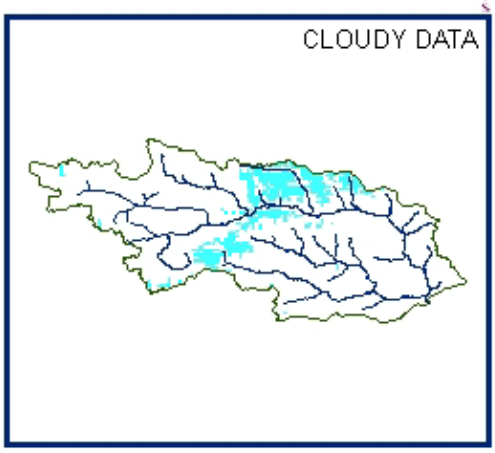
SNOW

0 35 70 140 210 280
Kilometers

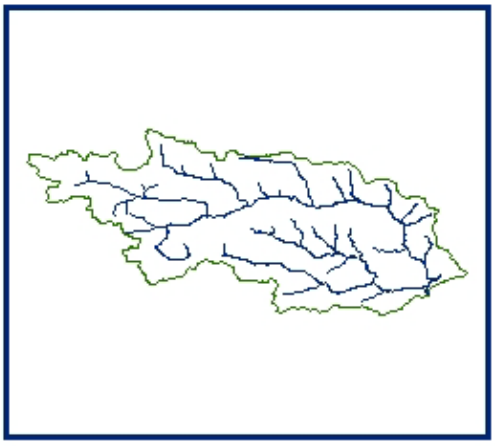
SNOW COVER MAP : SUBANSIRI BASIN



01 FEBRUARY 2012



03 FEBRUARY 2012



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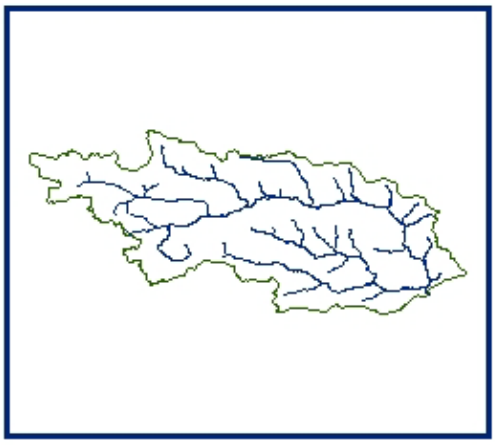
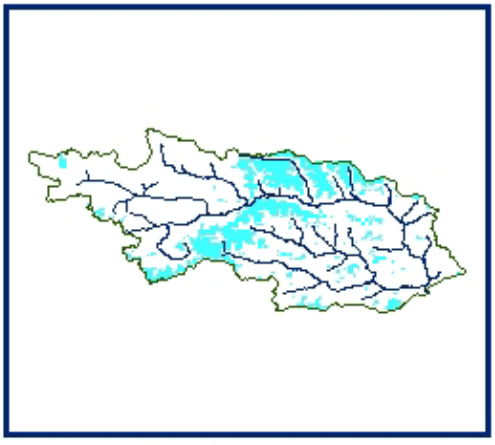
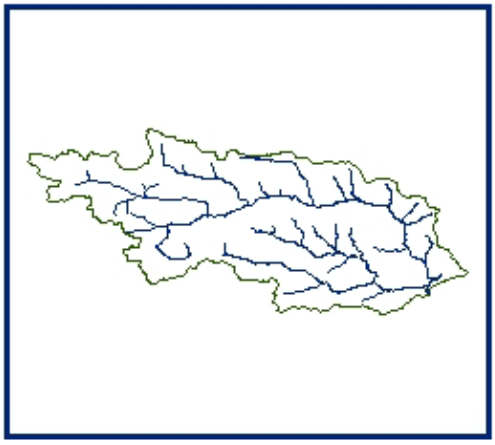


DATA NOT AVAILABLE



25 FEBRUARY 2012



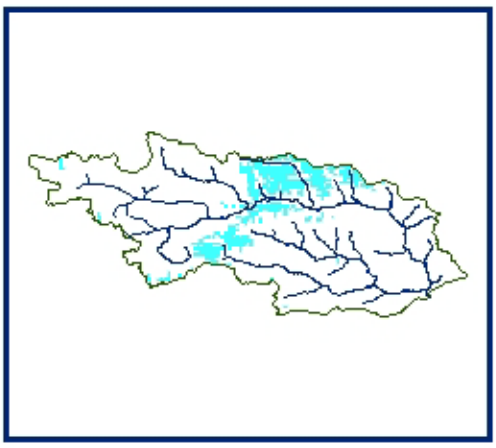
DATA NOT AVAILABLE

SNOW

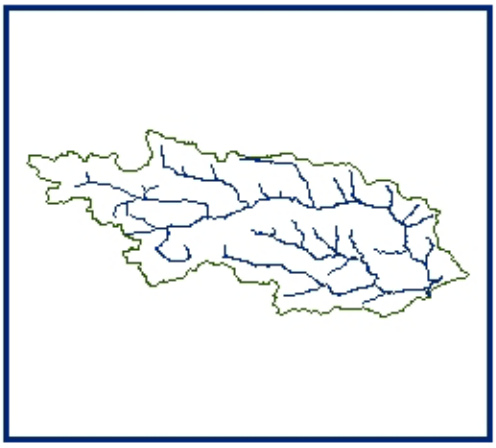
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
03 FEBRUARY 2012



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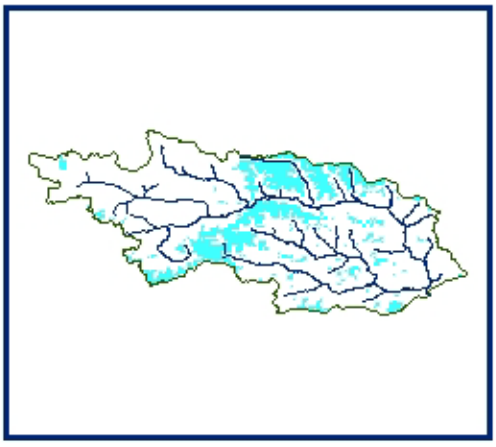
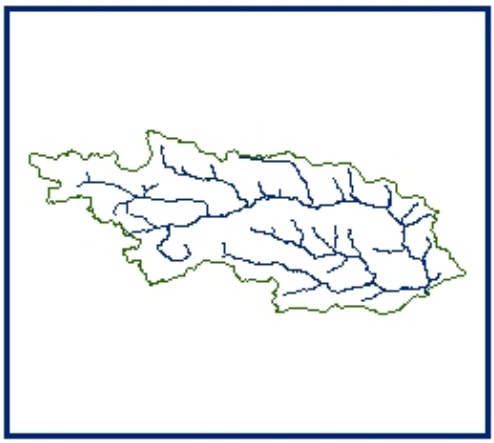


DATA USED
25 FEBRUARY 2012

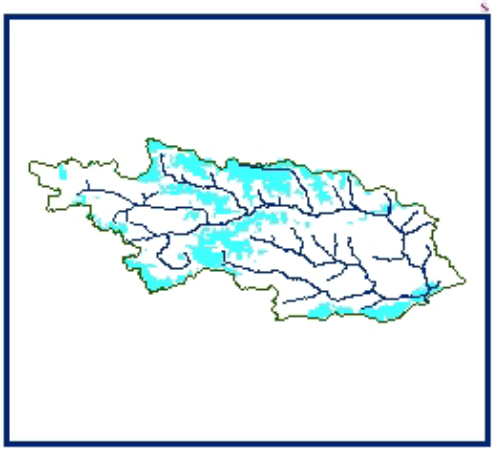
SNOW

0 35 70 140 210 280
Kilometers

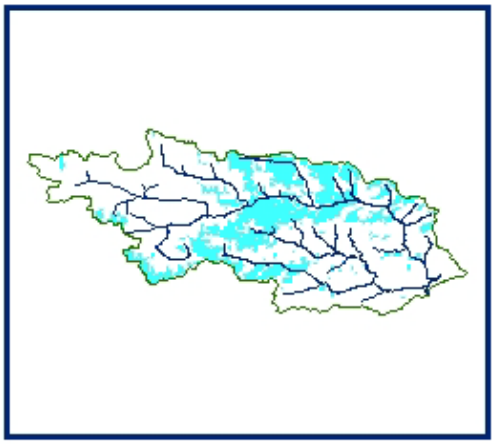
SNOW COVER MAP : SUBANSIRI BASIN



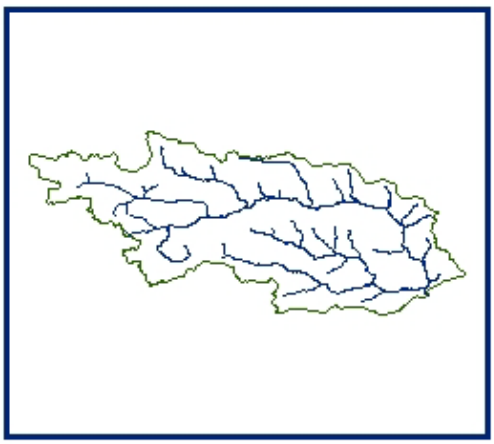
DATA NOT AVAILABLE



05 MARCH 2012



10 MARCH 2012



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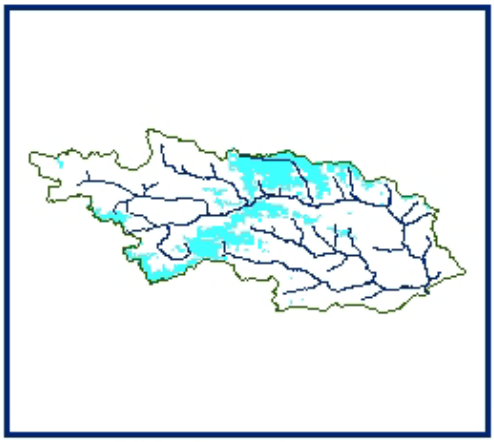
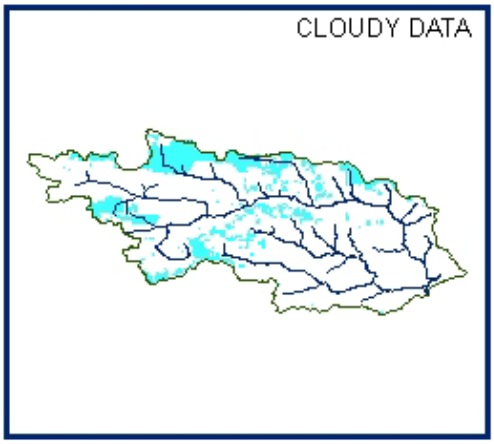


20 MARCH 2012



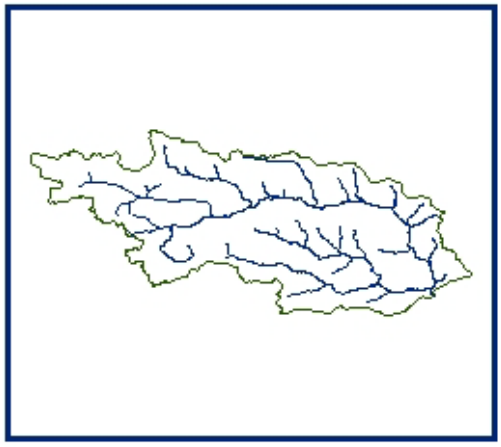
25 MARCH 2012

SNOW

0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



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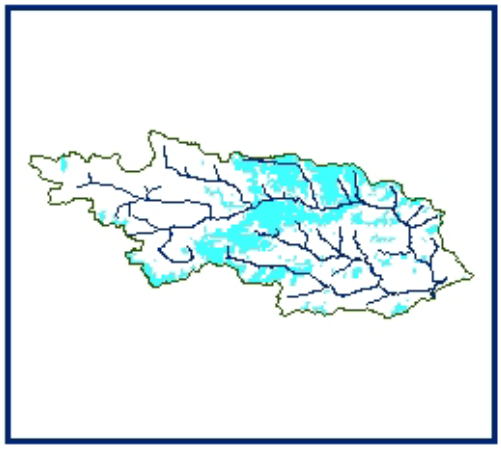
DATA NOT AVAILABLE



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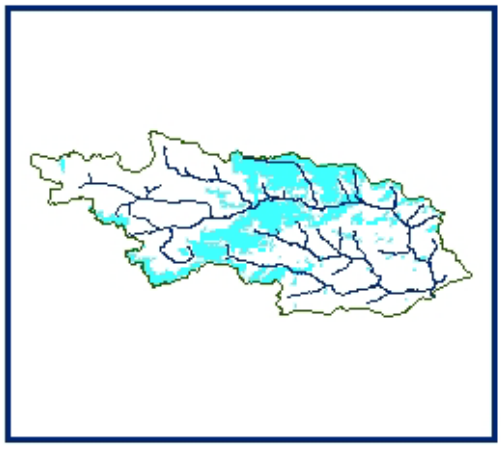
10 MARCH 2012

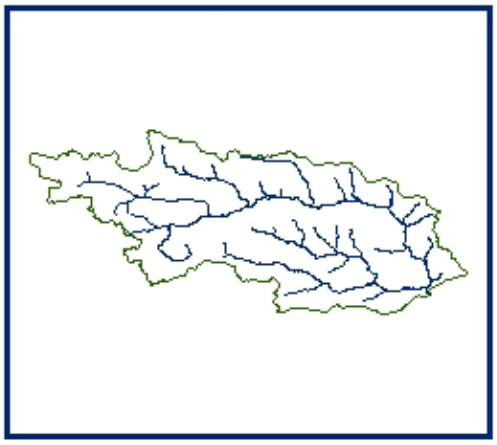


DATA USED
20 MARCH 2012

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SUBANSIRI BASIN



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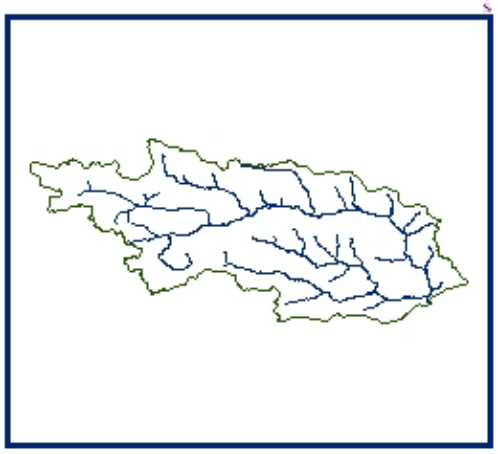

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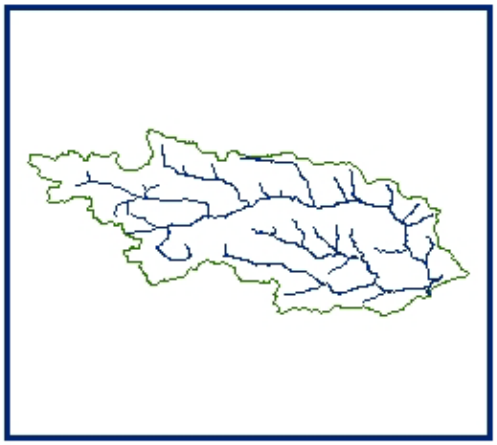

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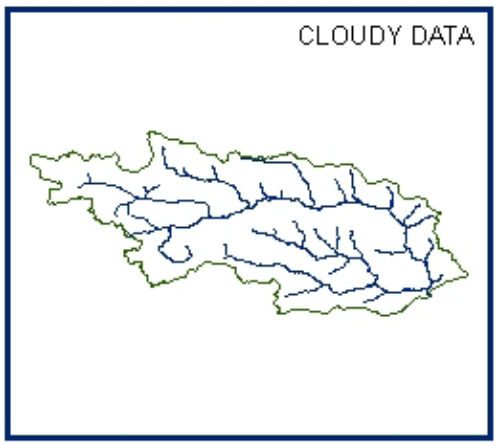
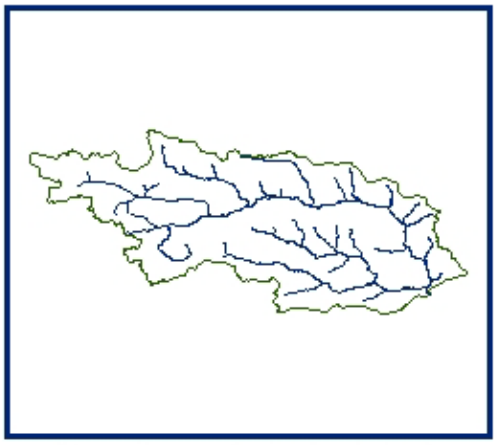


17 APRIL 2012



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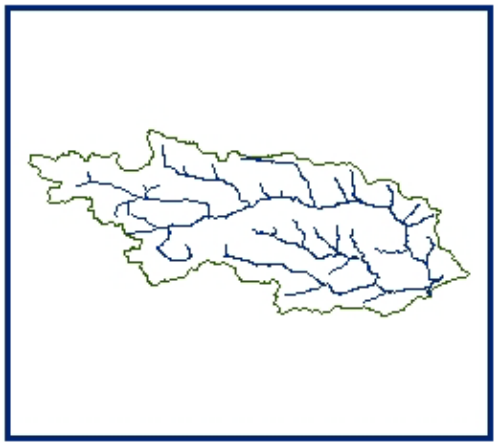


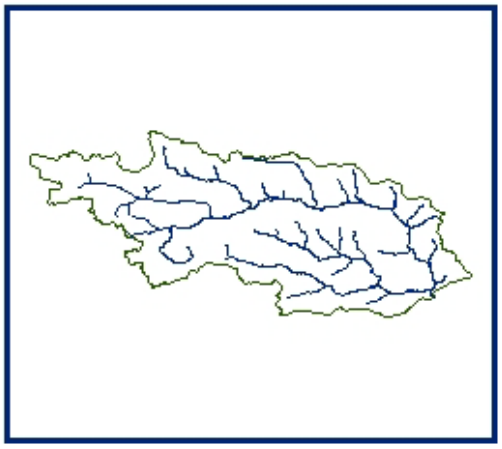
DATA NOT AVAILABLE

SNOW

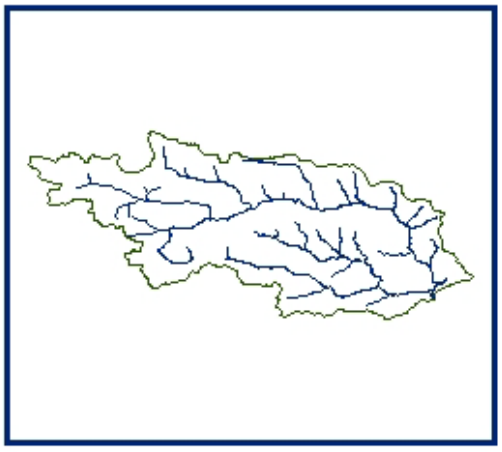
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



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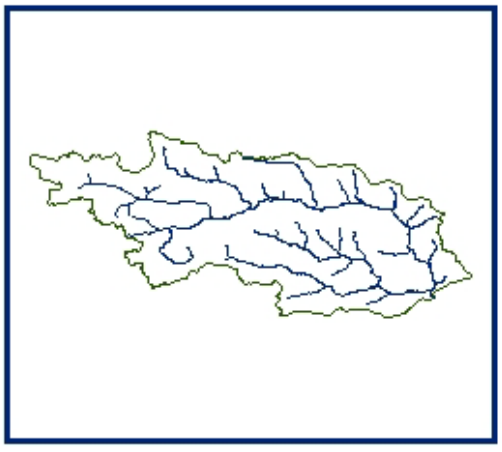
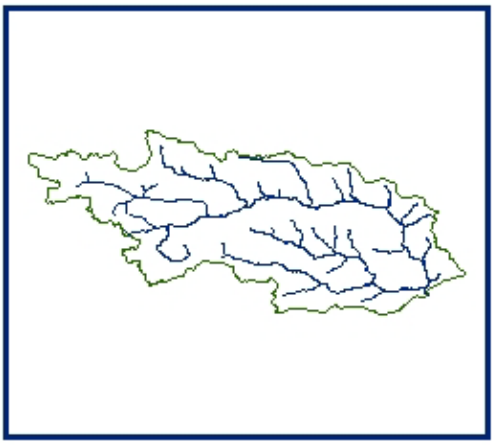


DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SUBANSIRI BASIN



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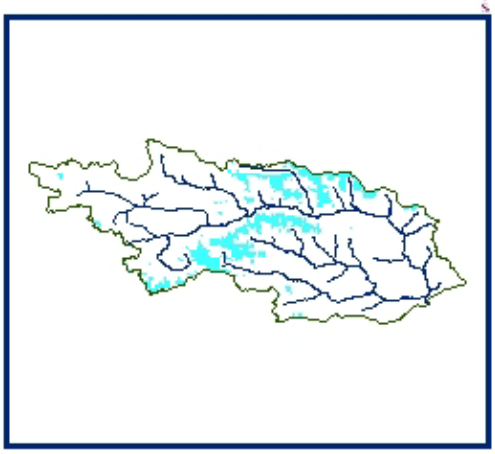
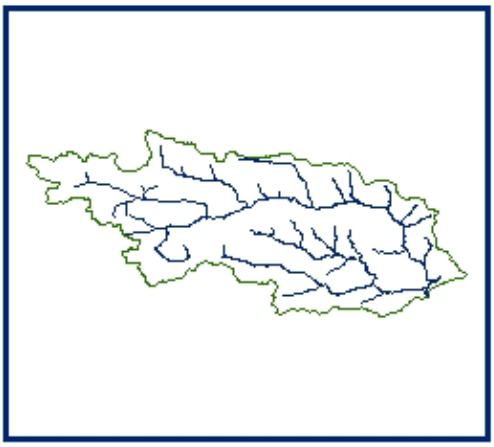


07 MAY 2012



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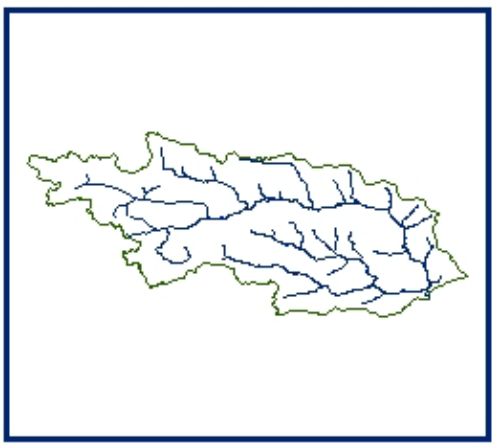

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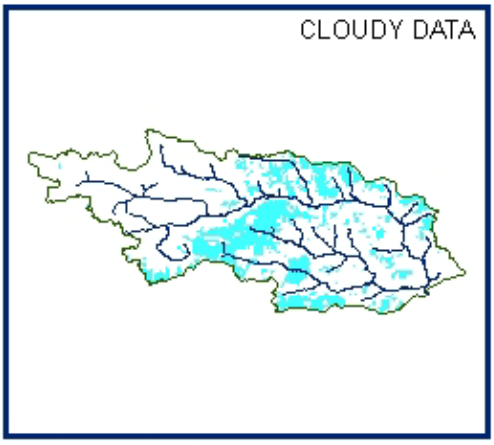
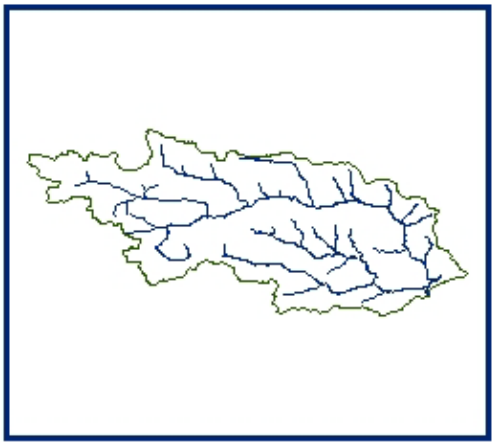


21 MAY 2012



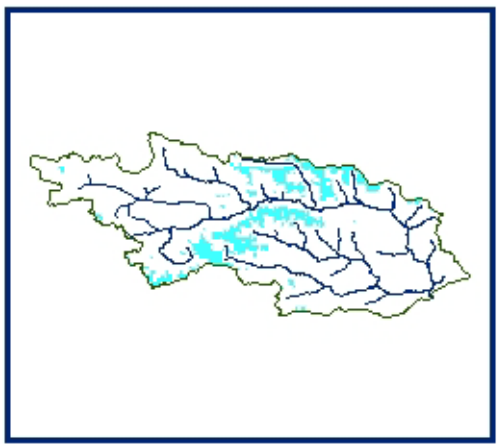
DATA NOT AVAILABLE

SNOW

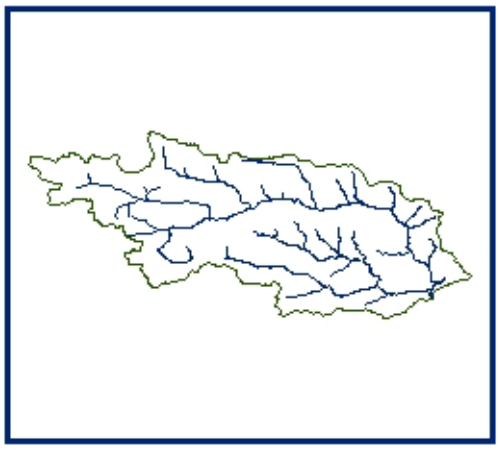
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
07 MAY 2012



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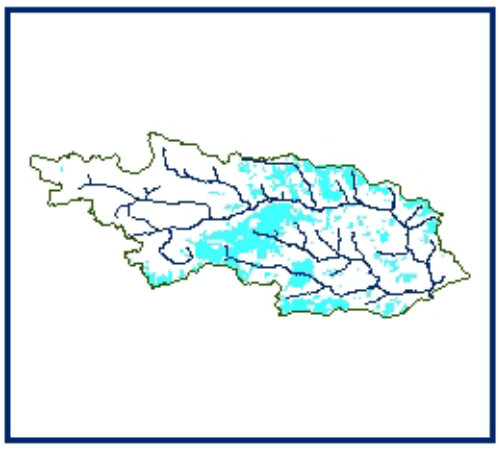
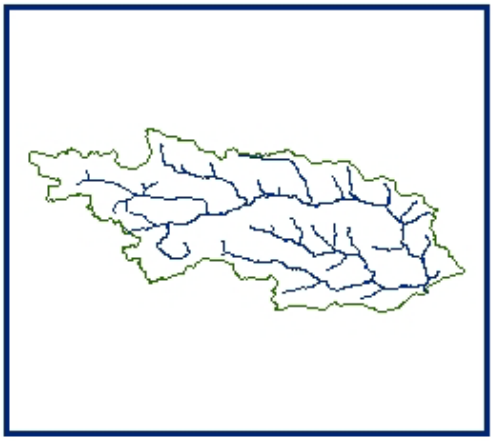


DATA USED
21 MAY 2012

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : SUBANSIRI BASIN



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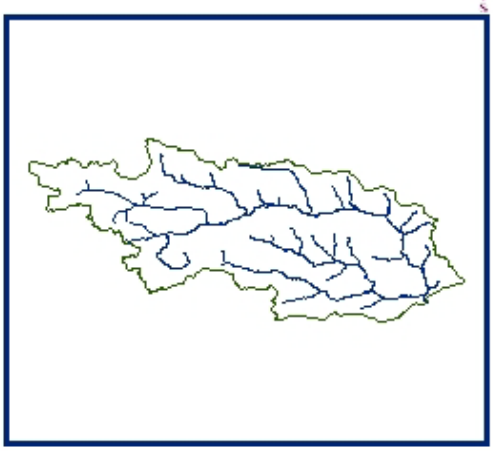

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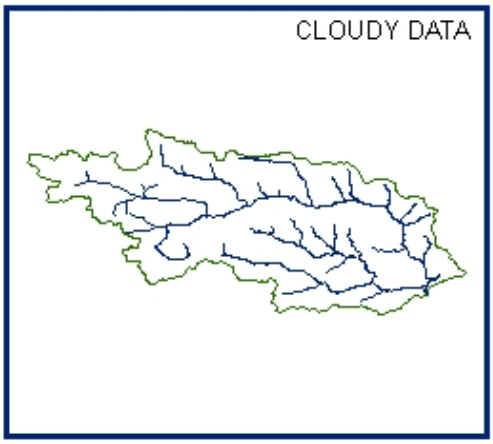
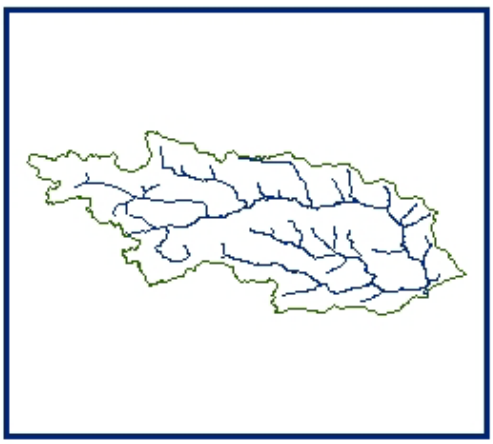


07 JUNE 2012



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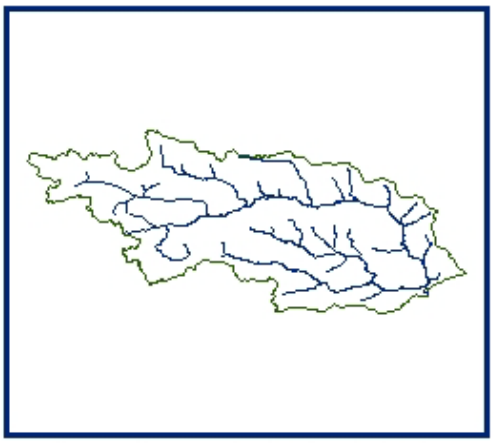

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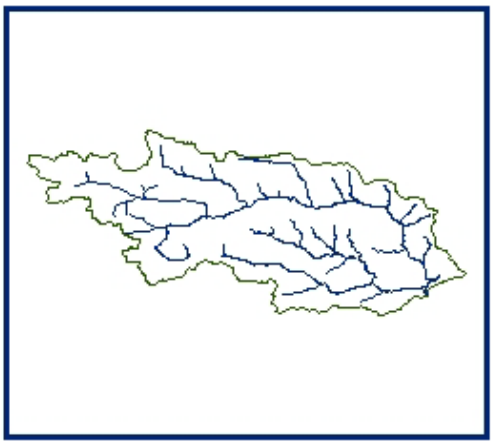


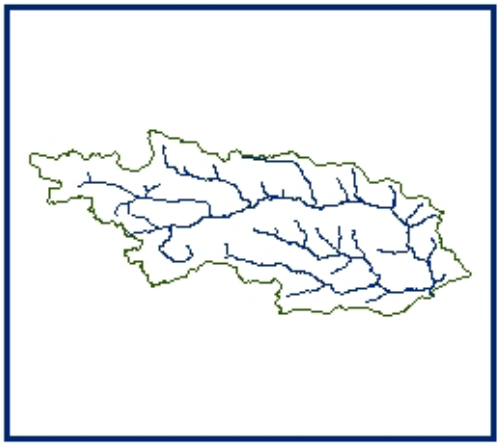
DATA NOT AVAILABLE

SNOW

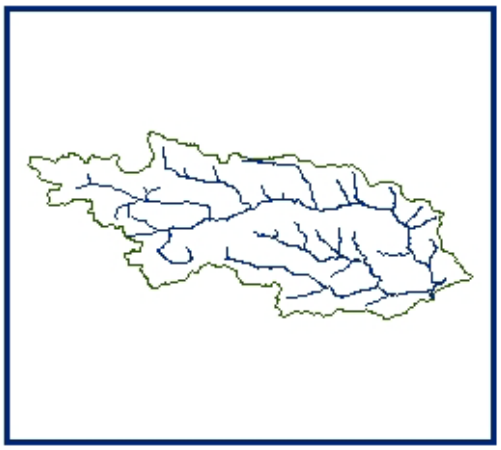
0 35 70 140 210 280

Kilometers

10 DAILY SNOW COVER MAP: SUBANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
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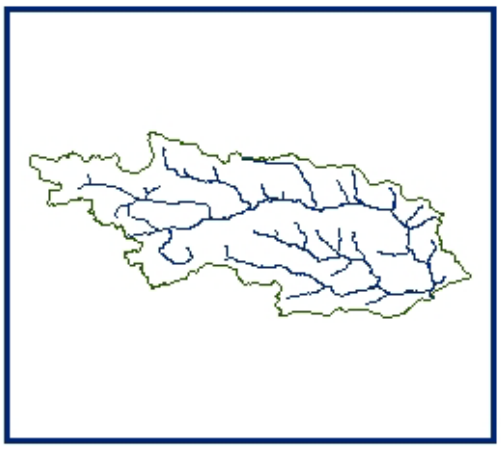


DATA USED
DATA NOT AVAILABLE

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 2011							
1	1-Oct-11	DNA		5	20-Oct-11	480	7
2	6-Oct-11	396	6	6	25-Oct-11	676	10
3	11-Oct-11	301	4	7	30-Oct-11	DNA	
4	16-Oct-11	DNA		8	31-Oct-11	DNA	
November 2011							
9	4-Nov-11	1936	29	14	18-Nov-11	2304	34
10	8-Nov-11	2575	38	15	20-Nov-11	1945	29
11	9-Nov-11	2002	30	16	23-Nov-11	1278	19
12	10-Nov-11	DNA		17	24-Nov-11	DNA	
13	14-Nov-11	DNA		18	28-Nov-11	913	14
December 2011							
19	2-Dec-11	816	12	25	13-Dec-11	DNA	
20	3-Dec-11	648	10	26	15-Dec-11	1076	16
21	7-Dec-11	628	9	27	17-Dec-11	885	13
22	8-Dec-11	DNA		28	19-Dec-11	1047	16
23	9-Dec-11	DNA		29	26-Dec-11	617	9
24	12-Dec-11	465	7				
January 2012							
30	3-Jan-12	6031	90	36	19-Jan-12	3143	47
31	5-Jan-12	DNA		37	22-Jan-12	3657	54
32	6-Jan-12	DNA		38	26-Jan-12	DNA	
33	8-Jan-12	5340	79	39	29-Jan-12	DNA	
34	10-Jan-12	DNA		40	31-Jan-12	2602	39
35	13-Jan-12	4304	64				
February 2012							
41	1-Feb-12	2394	36	44	18-Feb-12	DNA	
41	3-Feb-12	1763	26	45	24-Feb-12	1952	29
42	5-Feb-12	1792	27	46	25-Feb-12	1803	27
43	12-Feb-12	2514	37	47	28-Feb-12	DNA	
March 2012							
48	5-Mar-12	3924	58	52	20-Mar-12	3263	57
49	7-Mar-12	2541	38	53	24-Mar-12	2486	37

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
50	10-Mar-12	4035	60	54	25-Mar-12	1886	28
51	12-Mar-12	3115	46				
April 2012							
55	17-April-12	CLOUDY DATA					
May 2012							
56	6-May-12	2787	41	58	7-May-12	2519	37
57	15-May-12	DNA		59	21-May-12	1376	20
June 2012							
60	7-June-12	261	4	61	13-June-12	DNA	

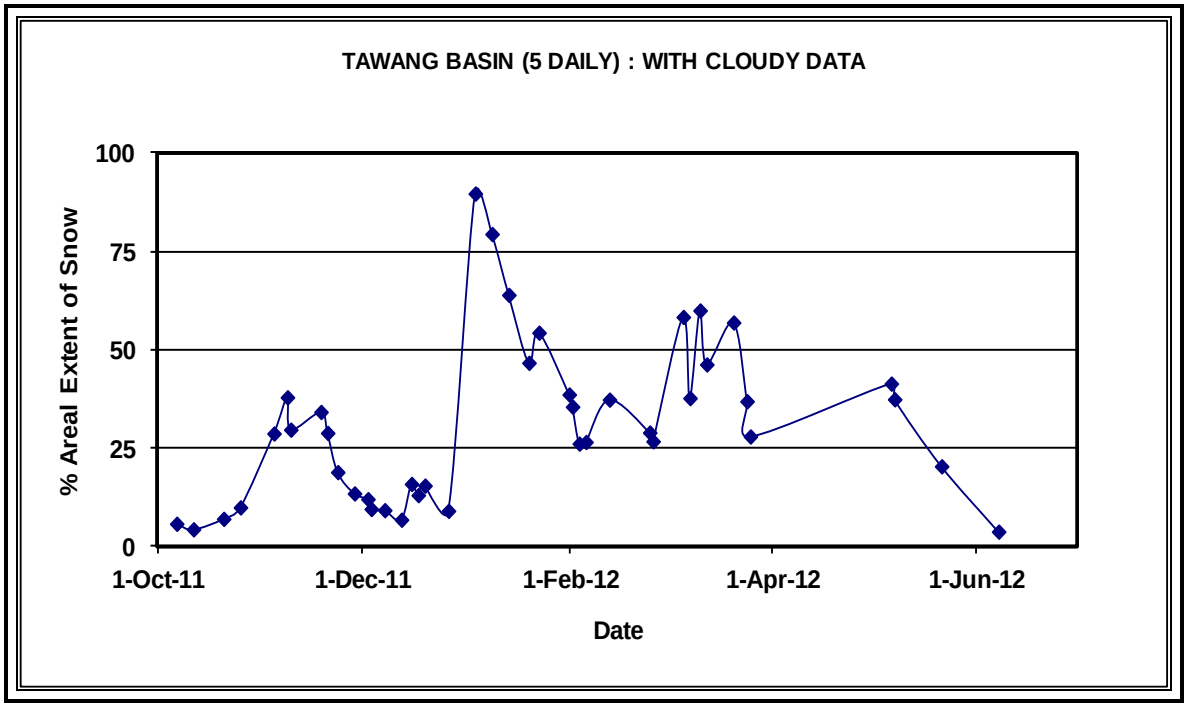
DNA- DATA NOT AVAILABLE
DNC-3BASINS NOT IN SCENE/HALF IN SCENE

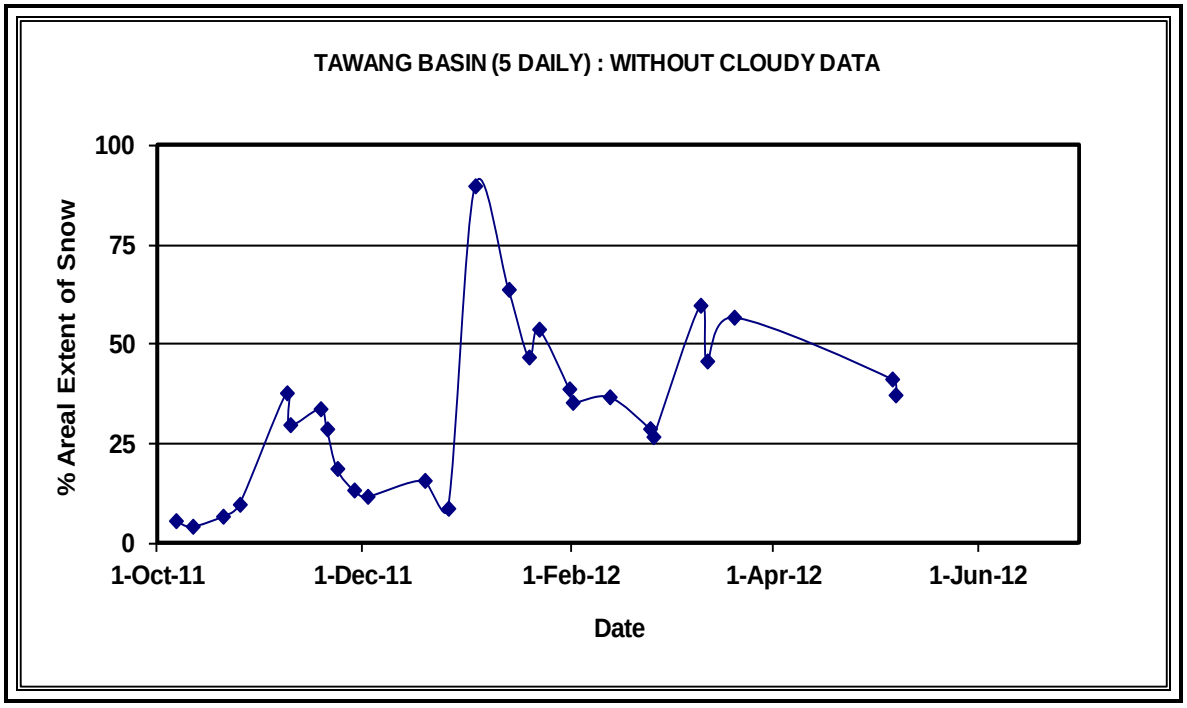
AREAL EXTENT OF SNOW (10 DAILY)

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

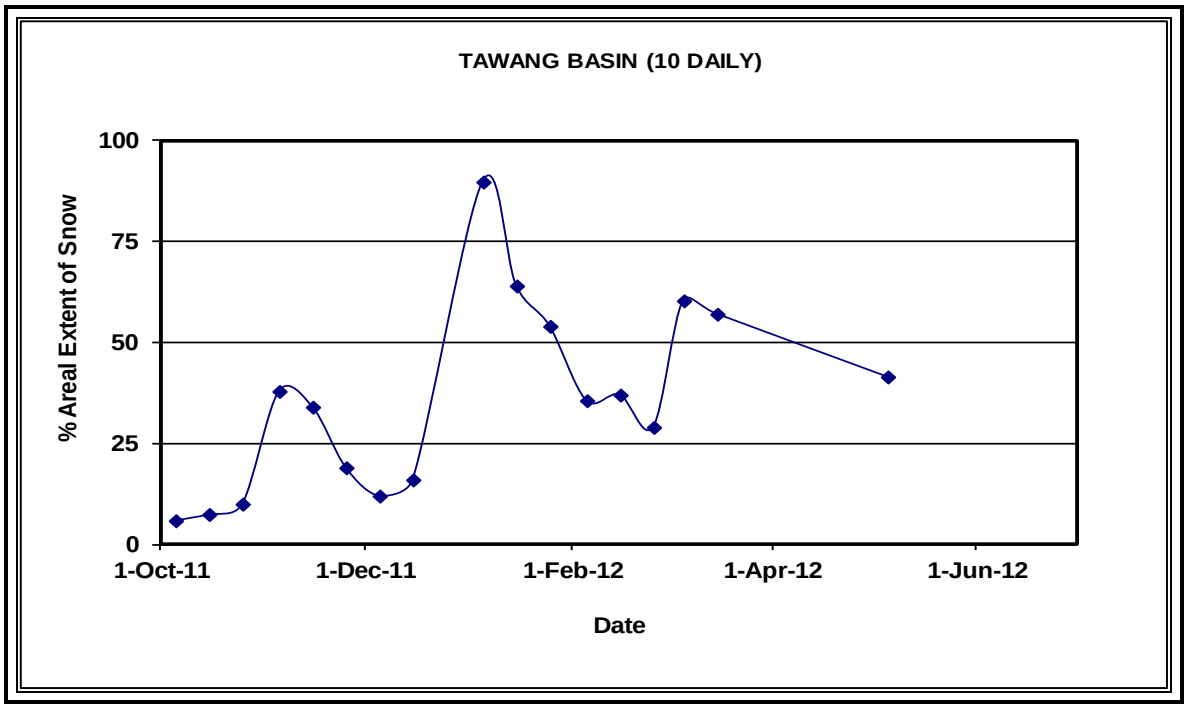
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2011				**November 2011**			
1	1-Oct-11	396	6	4	8-Nov-11	2556	38
2	20-Oct-11	471	7	5	18-Nov-11	2287	34
3	30-Oct-11	673	10	6	28-Nov-11	1278	19
December 2011				**January 2012**			
7	7-Dec-11	807	12	10	3-Jan-12	6053	90
8	17-Dec-11	1076	16	11	13-Jan-12	4304	64
				12	22-Jan-12	3632	54
February 2012				**March 2012**			
13	1-Feb-12	2395	36	16	10-Mar-12	4035	60
14	12-Feb-12	2488	37	17	20-Mar-12	3833	57
15	24-Feb-12	1950	29				
April 2012				**May 2012**			
18	17-Apr-12	CLOUDY DATA		19	6-May-12	2790	41
				20	15-May-12	DNA	
				21	21-May-12	CLOUDY DATA	
June 2012							
22	7-June-12	CLOUDY DATA					

Snow cover depletion curve



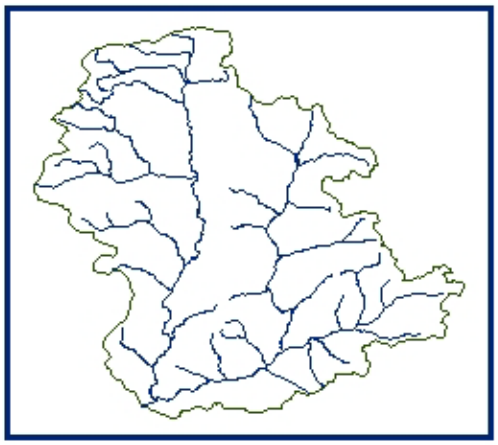


Snow cover depletion curve

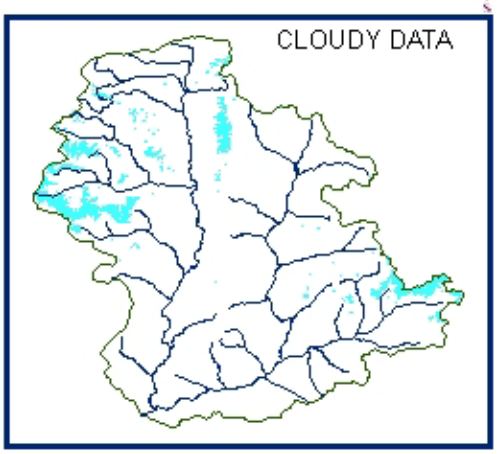


SNOW COVER MAP

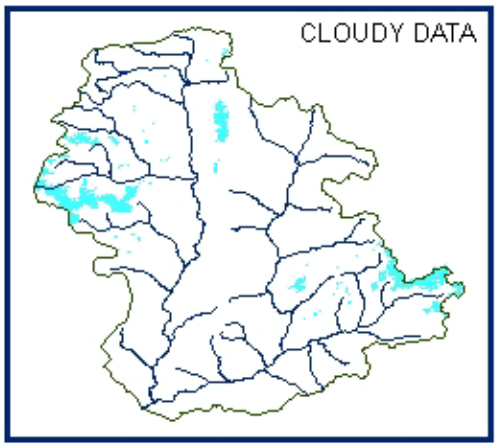
SNOW COVER MAP : TAWANG BASIN



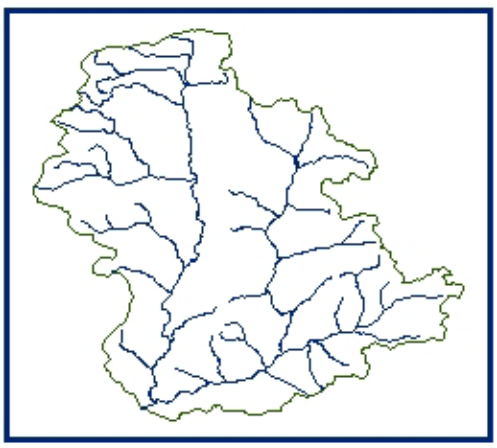
DATA NOT AVAILABLE



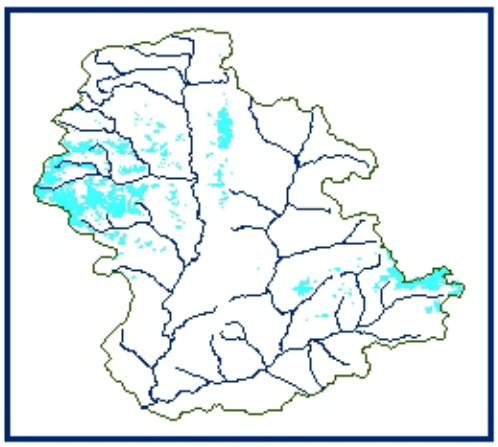
06 OCTOBER 2011



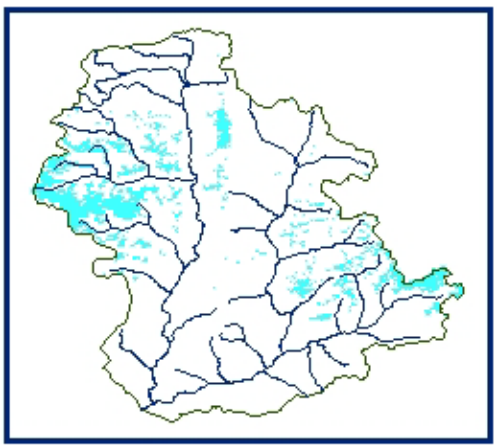
11 OCTOBER 2011



DATA NOT AVAILABLE



20 OCTOBER 2011



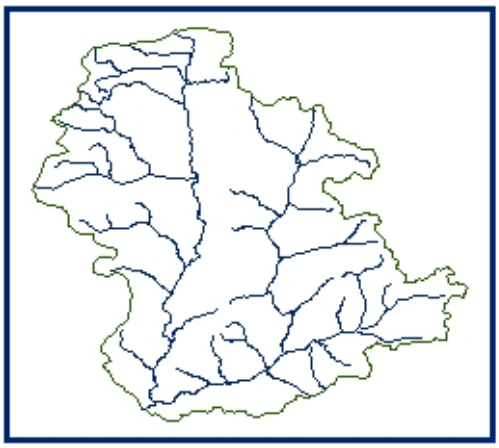
25 OCTOBER 2011

SNOW

0 12.5 25 50 75 100

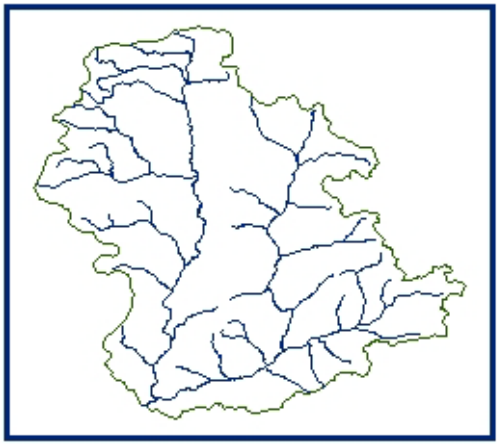
Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
DATA NOT AVAILABLE

DATA USED
20 OCTOBER 2011

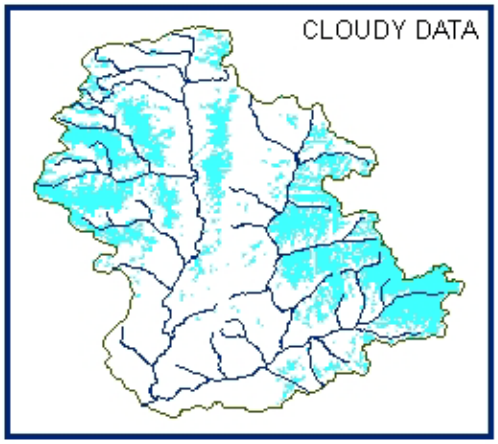


DATA USED
DATA NOT AVAILABLE

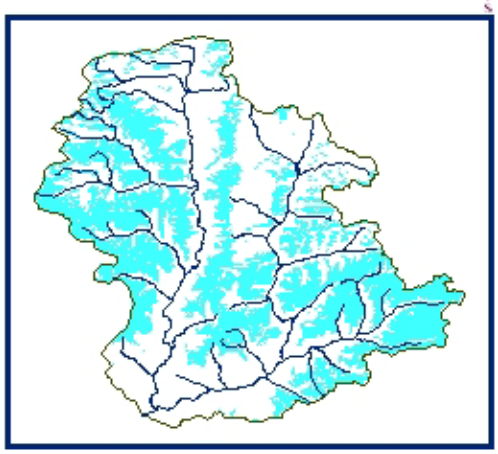
SNOW

0 10 20 40 60 80
Kilometers

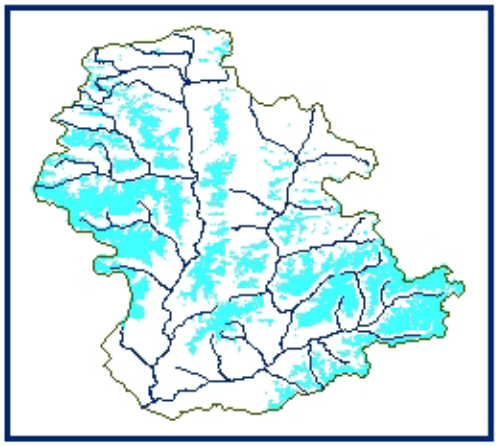
SNOW COVER MAP : TAWANG BASIN



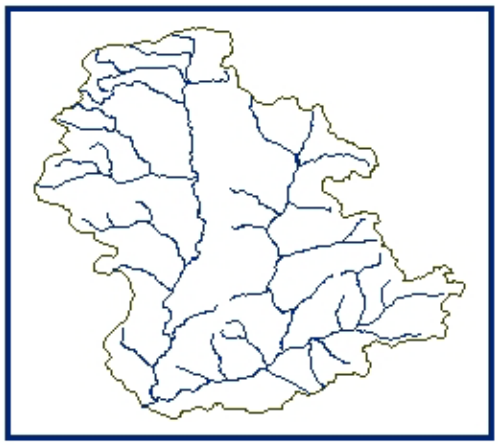
04 NOVEMBER 2011



08 NOVEMBER 2011



09 NOVEMBER 2011



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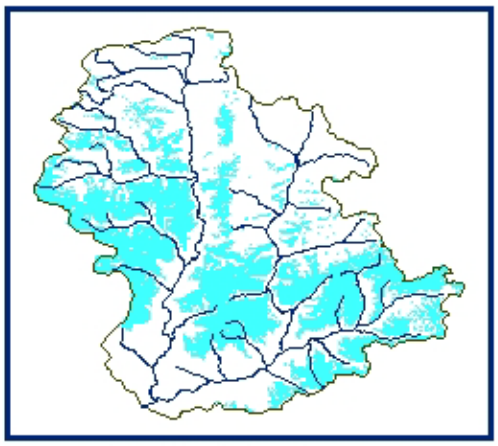
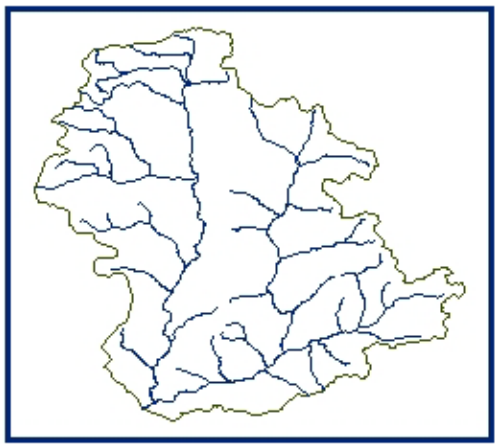


18 NOVEMBER 2011



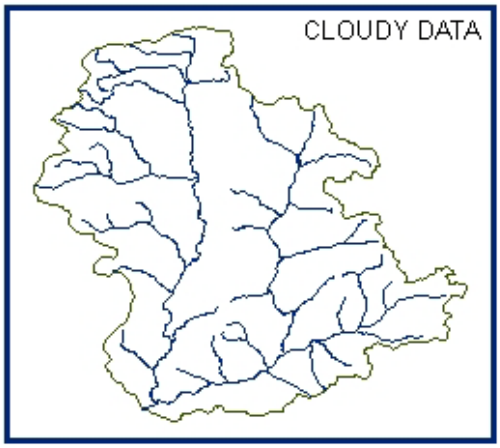
DATA NOT AVAILABLE

SNOW

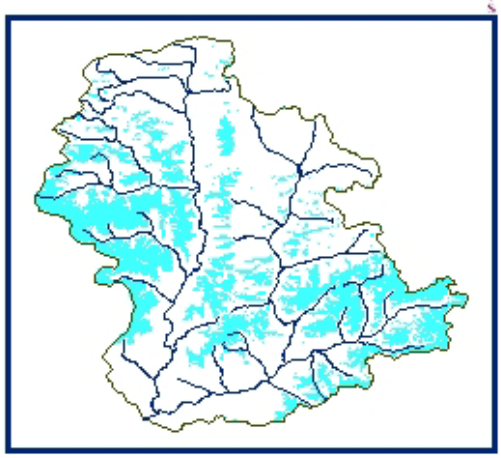
0 12.5 25 50 75 100

Kilometers

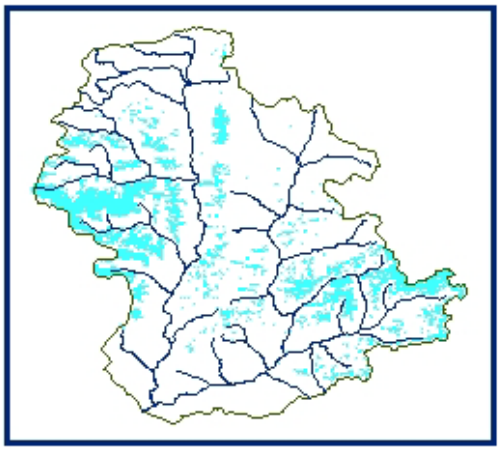
SNOW COVER MAP : TAWANG BASIN



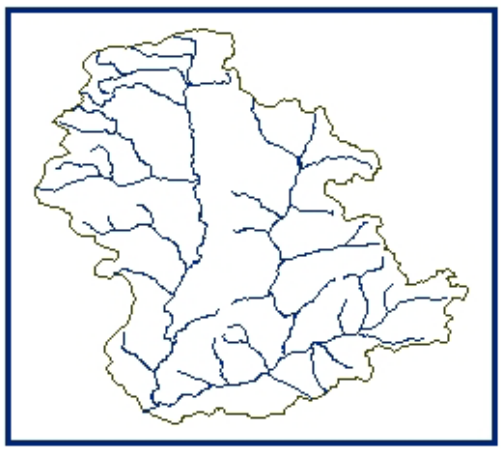
DATA NOT AVAILABLE



20 NOVEMBER 2011



23 NOVEMBER 2011



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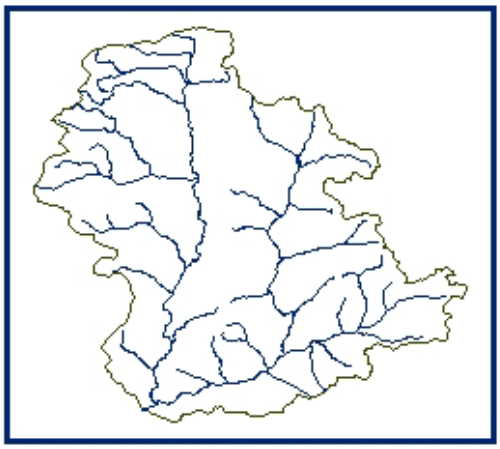
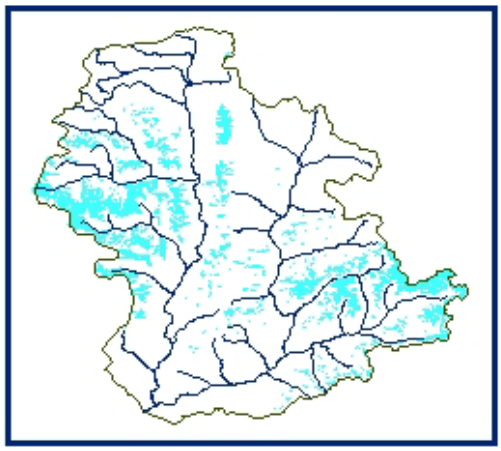


DATA NOT AVAILABLE



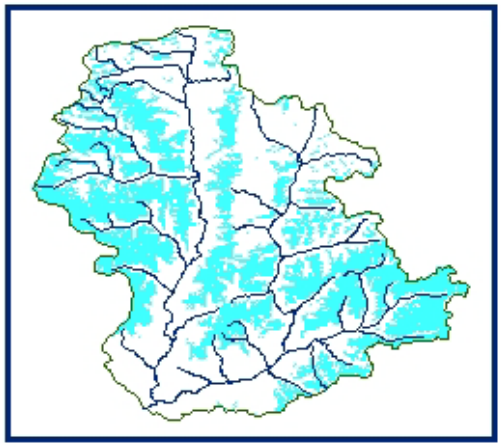
28 NOVEMBER 2011

SNOW

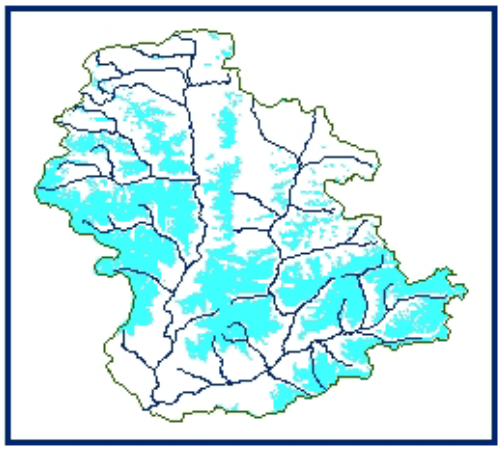
0 12.5 25 50 75 100

Kilometers

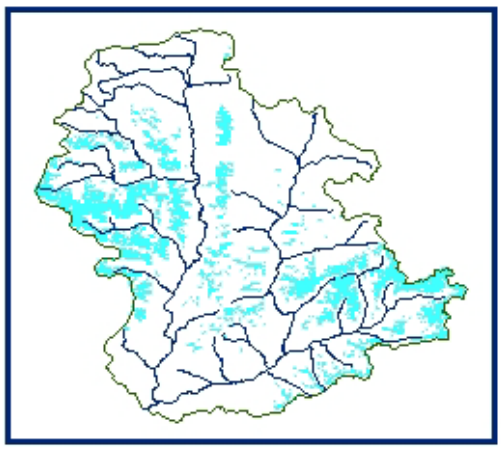
10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
08 NOVEMBER 2011



DATA USED
18 NOVEMBER 2011

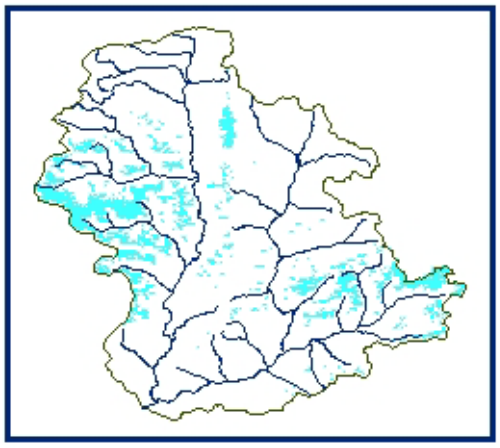


DATA USED
28 NOVEMBER 2011

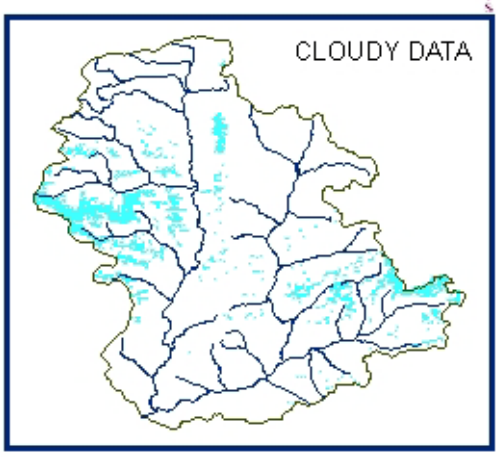
SNOW

0 10 20 40 60 80
Kilometers

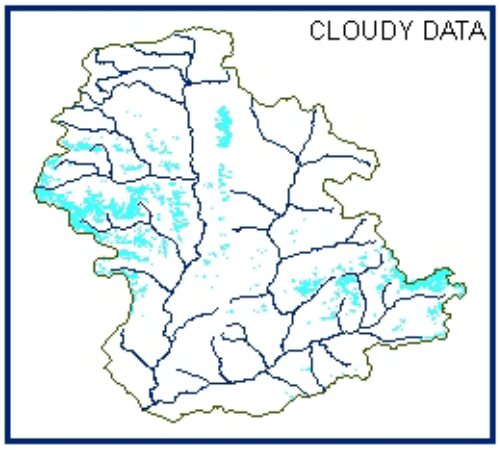
SNOW COVER MAP : TAWANG BASIN



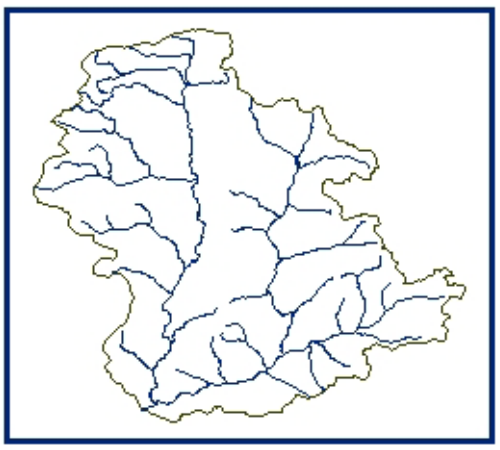
02 DECEMBER 2011



03 DECEMBER 2011



07 DECEMBER 2011



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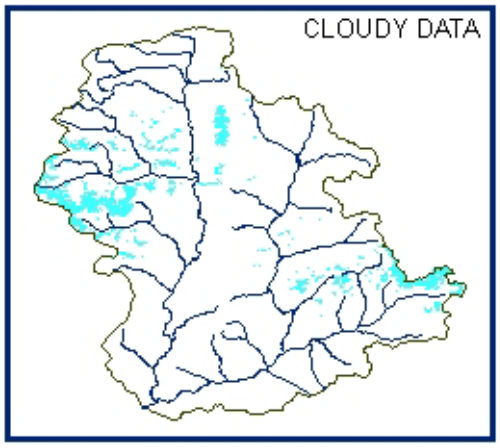
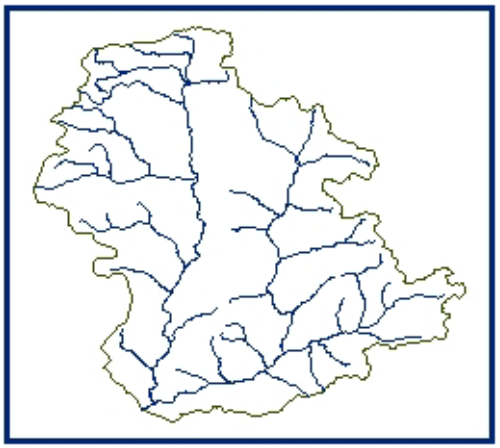


12 DECEMBER 2011



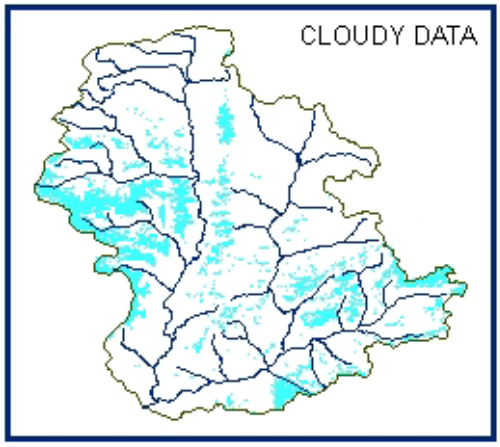
DATA NOT AVAILABLE

SNOW

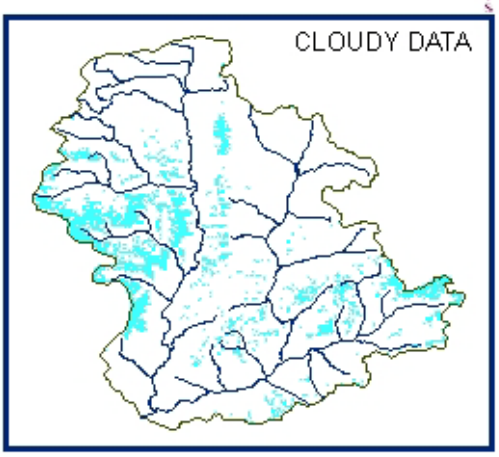
0 12.5 25 50 75 100

Kilometers

SNOW COVER MAP : TAWANG BASIN

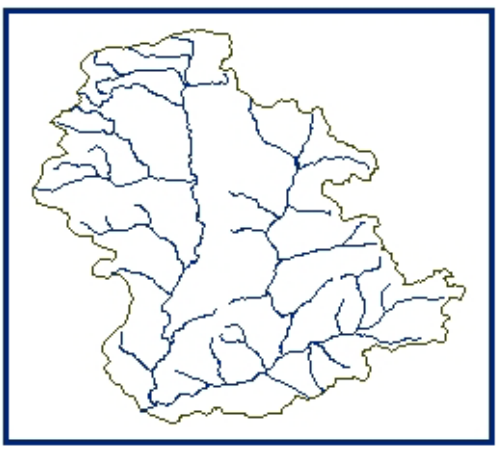


15 DECEMBER 2011



17 DECEMBER 2011

19 DECEMBER 2011



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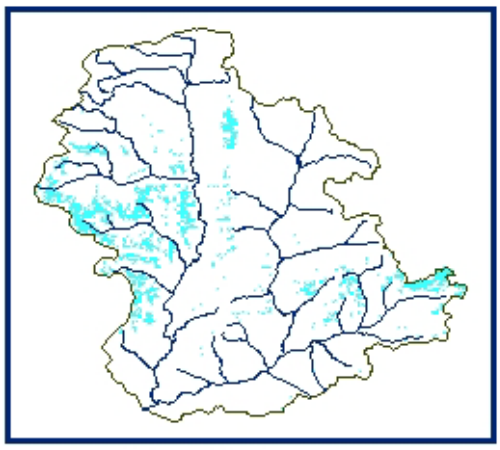
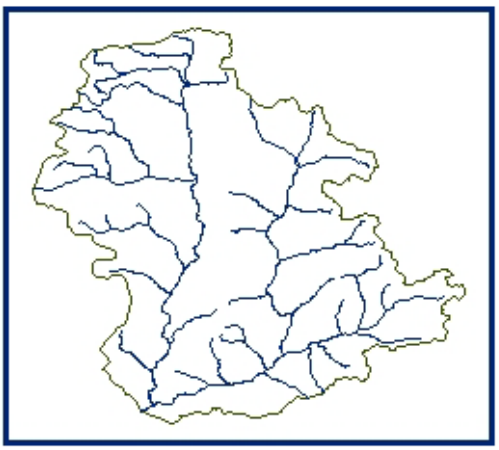


26 DECEMBER 2011



DATA NOT AVAILABLE

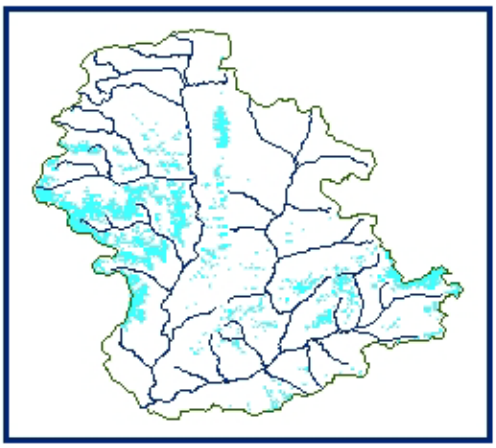
SNOW

0 12.5 25 50 75 100

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN

DATA USED
07 DECEMBER 2011



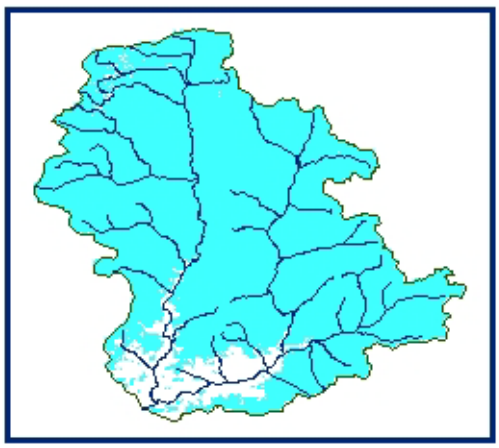
DATA USED
17 DECEMBER 2011

DATA USED
26 DECEMBER 2011

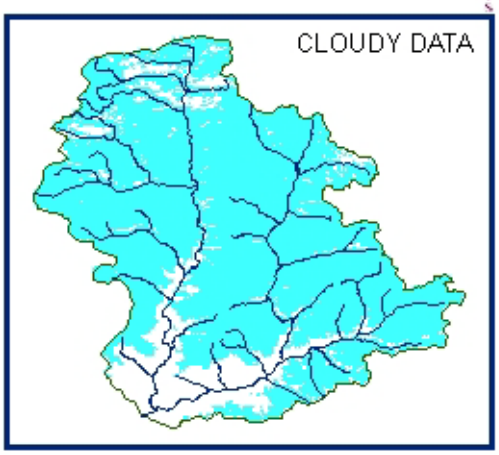
SNOW

0 10 20 40 60 80
Kilometers

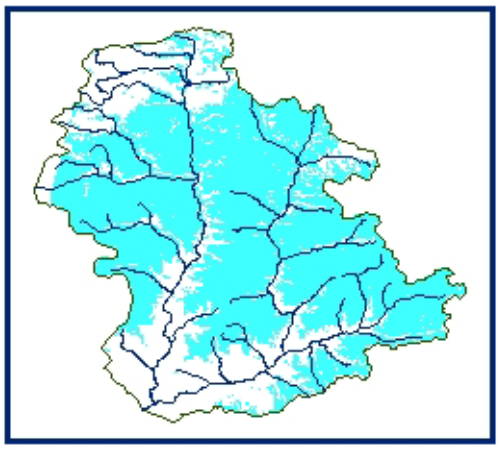
SNOW COVER MAP : TAWANG BASIN



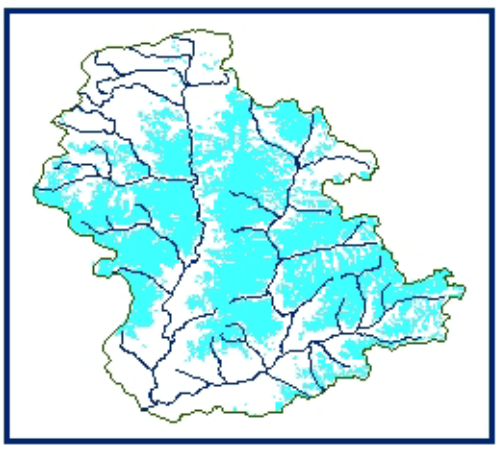
03 JANUARY 2012



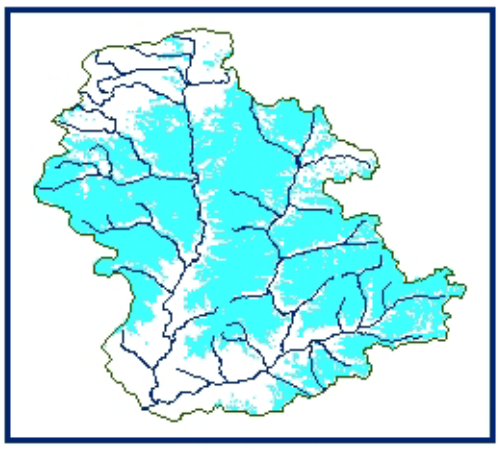
08 JANUARY 2012



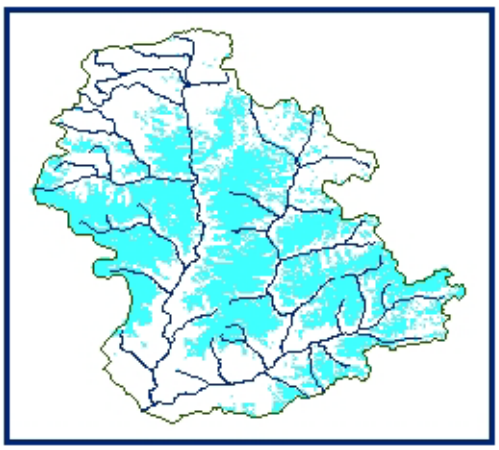
13 JANUARY 2012



19 JANUARY 2012



22 JANUARY 2012



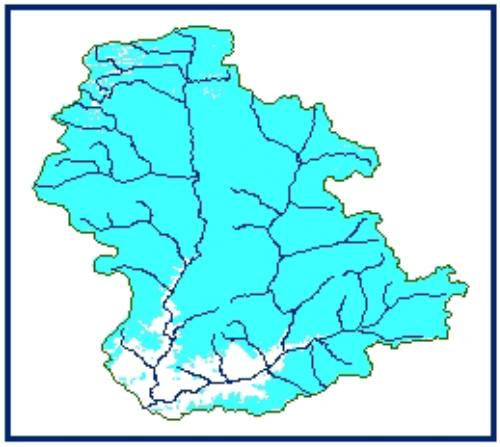
31 JANUARY 2012

SNOW

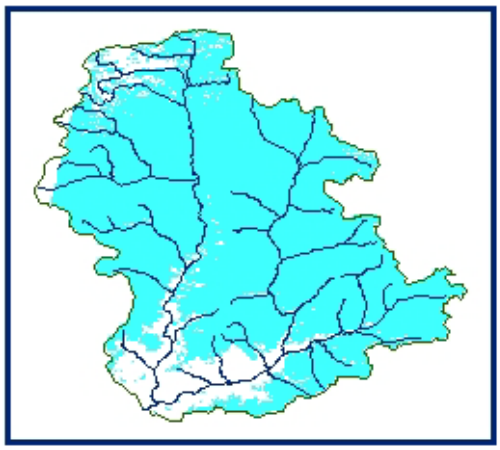
0 10 20 40 60 80

Kilometers

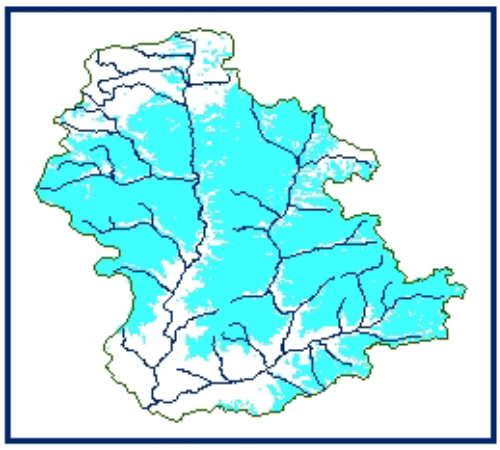
10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
03 JANUARY 2012



DATA USED
13 JANUARY 2012

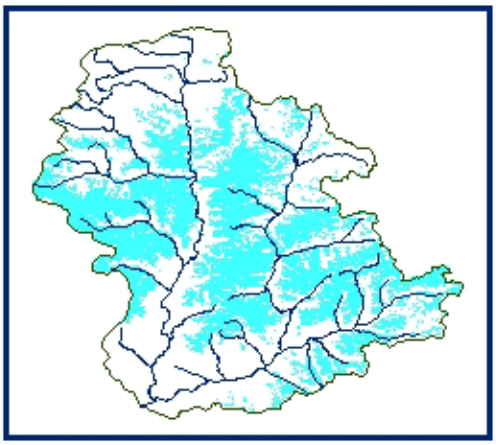


DATA USED
22 JANUARY 2012

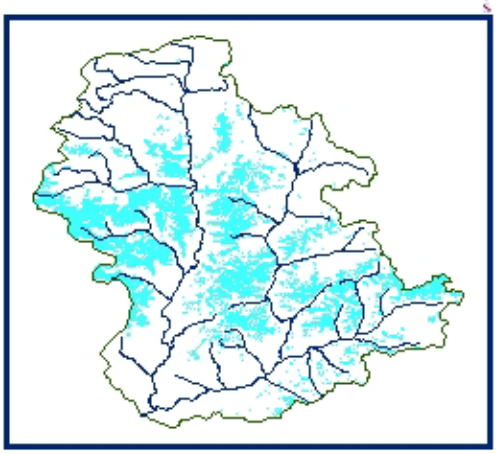
SNOW

0 10 20 40 60 80
Kilometers

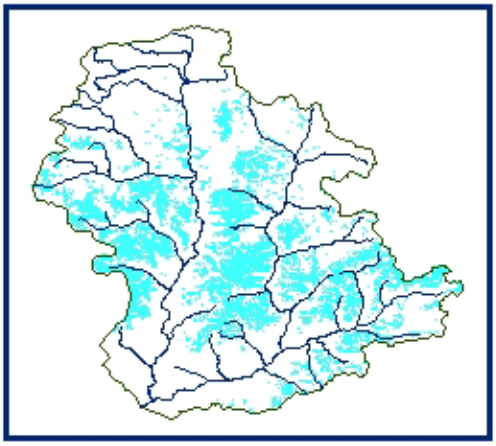
SNOW COVER MAP : TAWANG BASIN



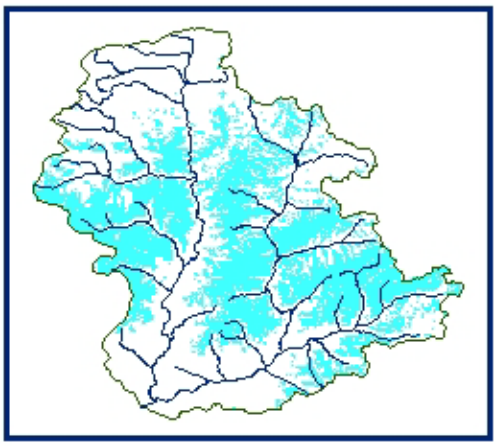
01 FEBRUARY 2012



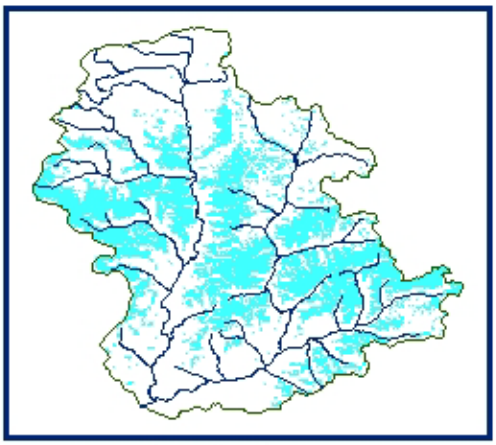
03 FEBRUARY 2012



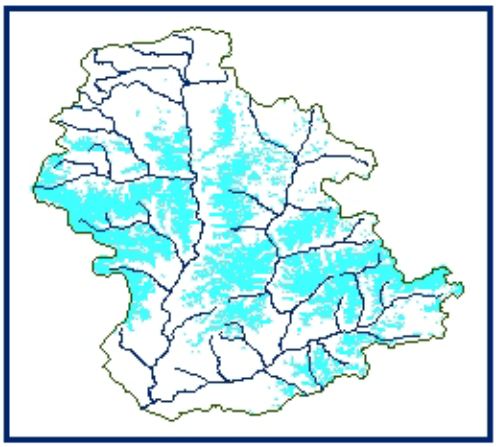
05 FEBRUARY 2012



12 FEBRUARY 2012



24 FEBRUARY 2012



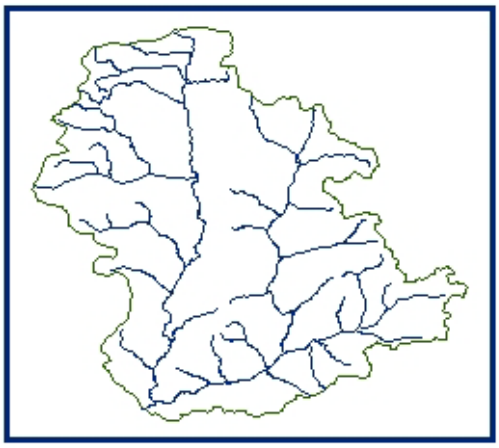
25 FEBRUARY 2012

SNOW

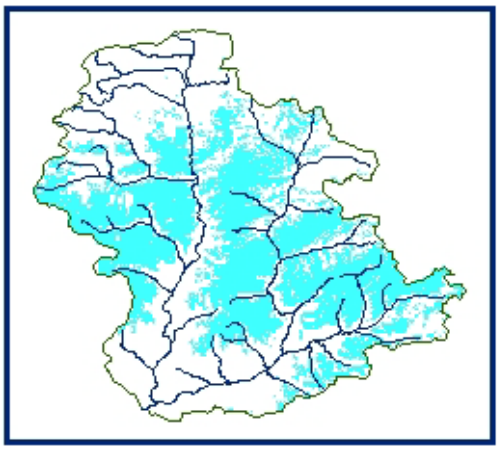
0 12.5 25 50 75 100

Kilometers

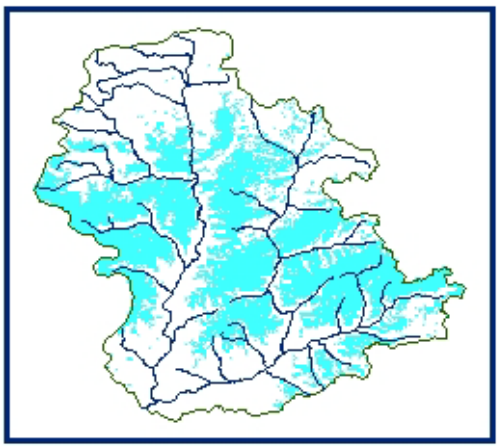
10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
12 FEBRUARY 2012

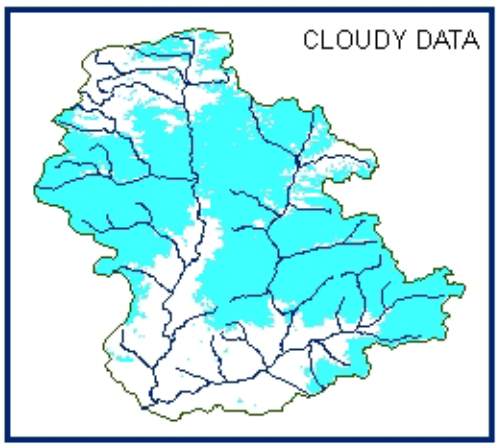


DATA USED
24 FEBRUARY 2012

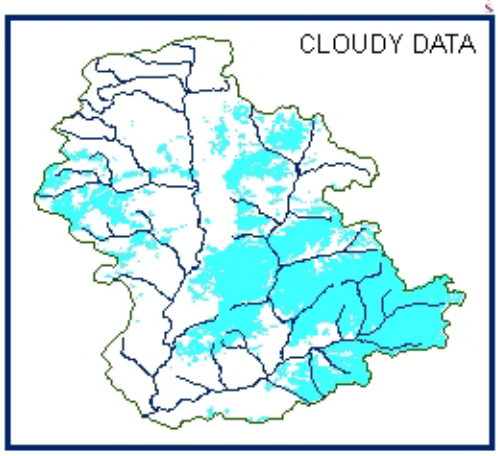
SNOW

0 10 20 40 60 80
Kilometers

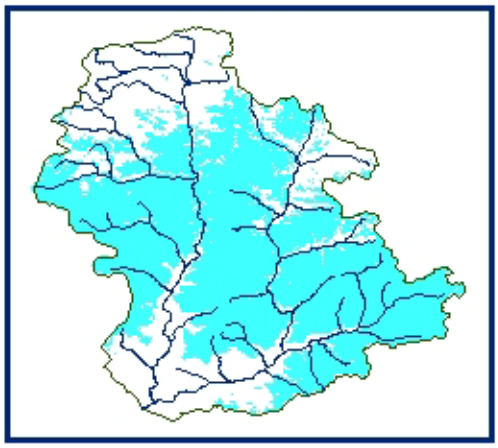
SNOW COVER MAP : TAWANG BASIN



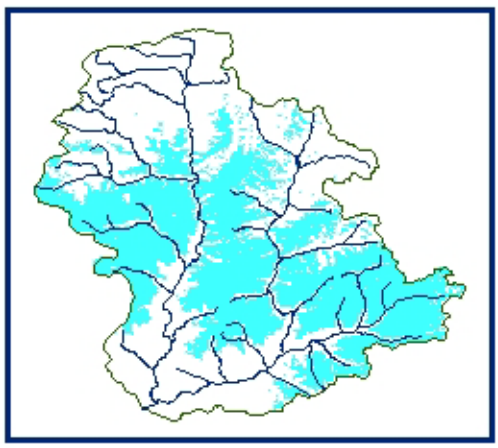
05 MARCH 2012



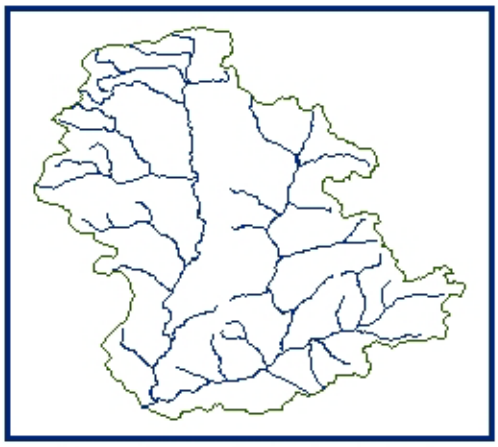
07 MARCH 2012



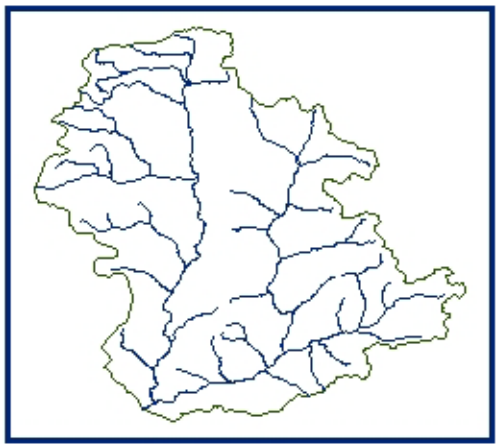
10 MARCH 2012



12 MARCH 2012



DATA NOT AVAILABLE



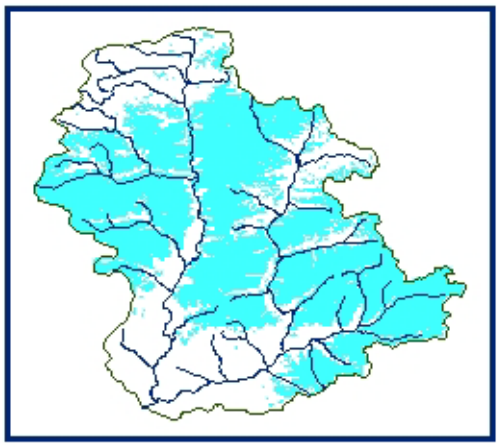
DATA NOT AVAILABLE

SNOW

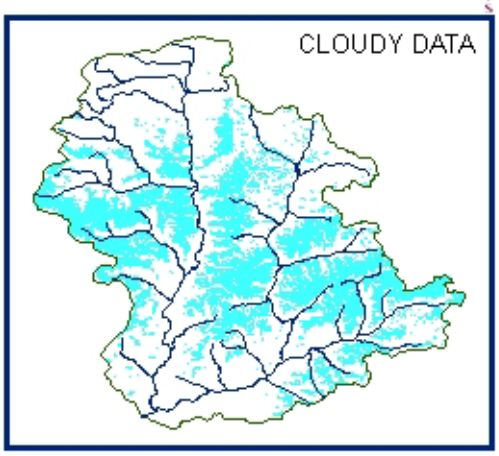
0 12.5 25 50 75 100

Kilometers

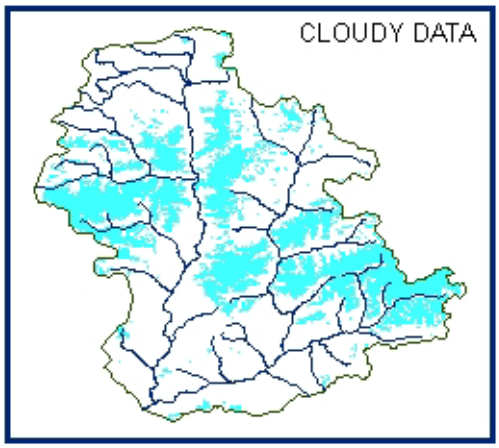
SNOW COVER MAP : TAWANG BASIN



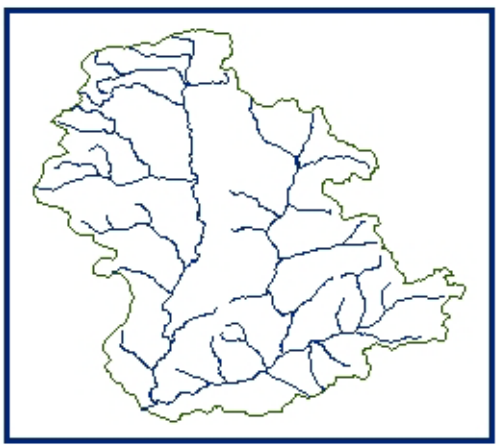
20 MARCH 2012



24 MARCH 2012



25 MARCH 2012



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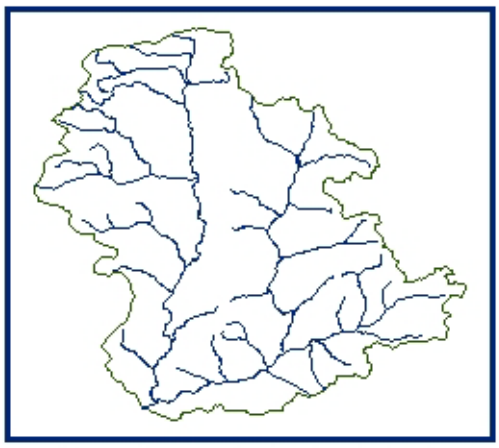

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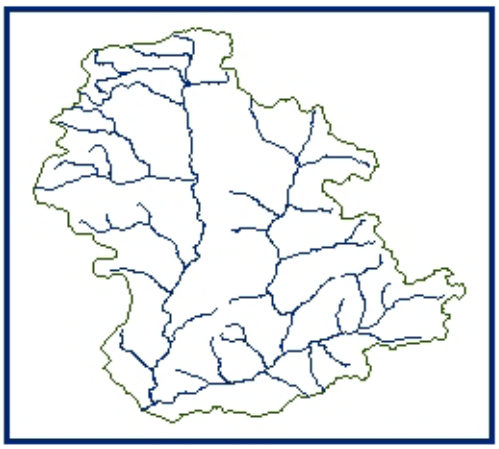


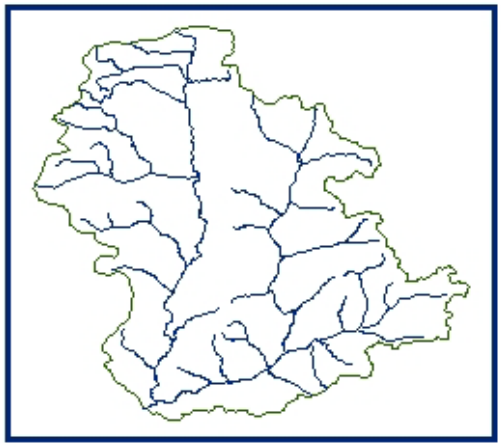
DATA NOT AVAILABLE

SNOW

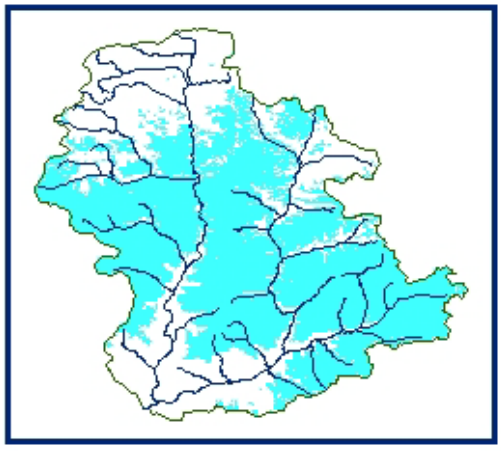
0 12.5 25 50 75 100

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
DATA NOT AVAILABLE



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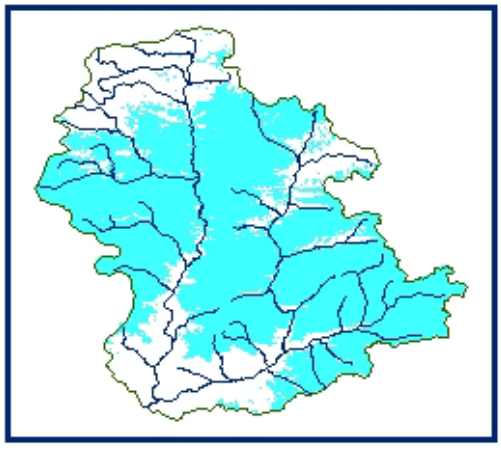
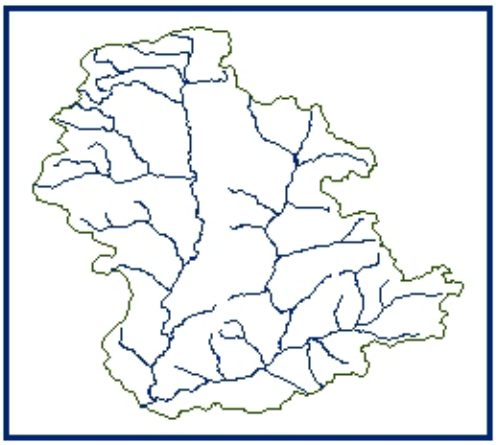


DATA USED
20 MARCH 2012

SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



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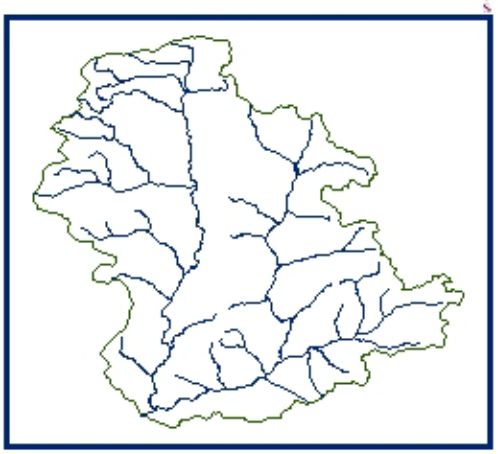

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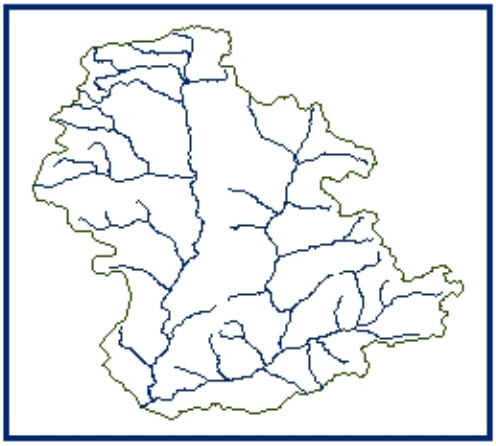

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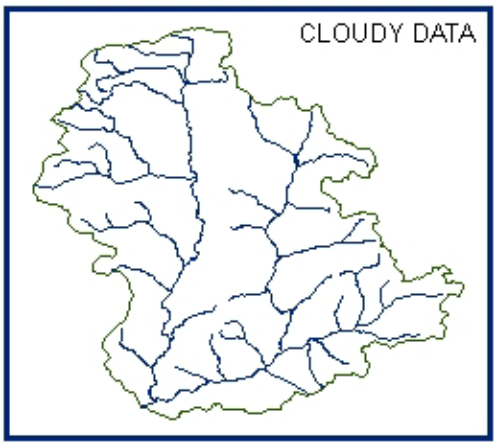
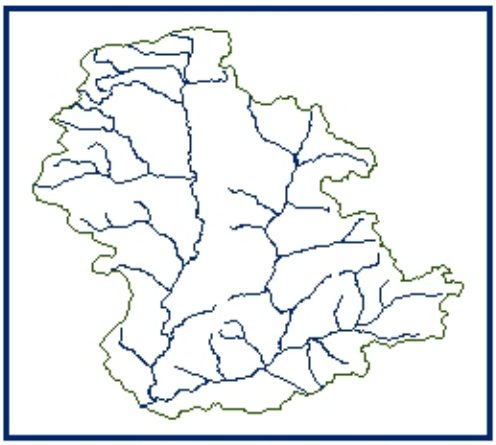


17 APRIL 2012



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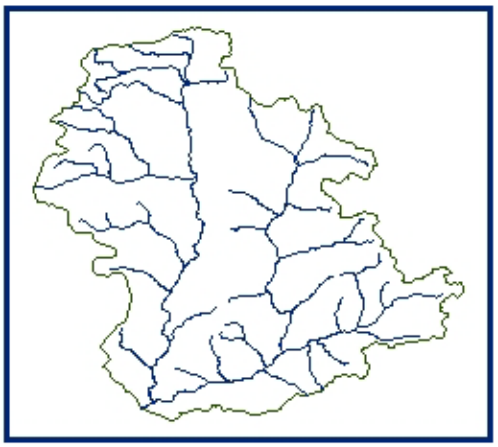


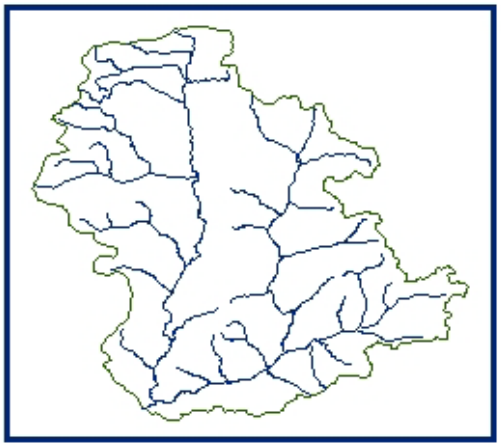
DATA NOT AVAILABLE

SNOW

0 12.5 25 50 75 100

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
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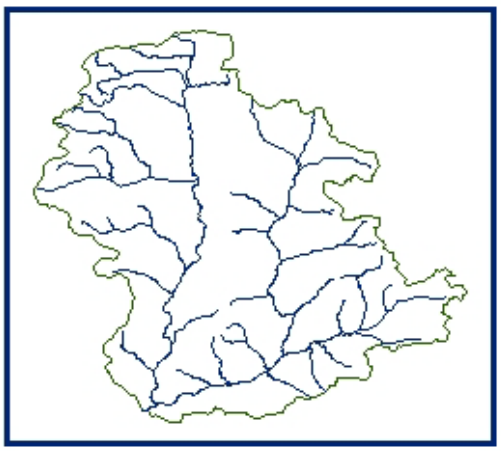

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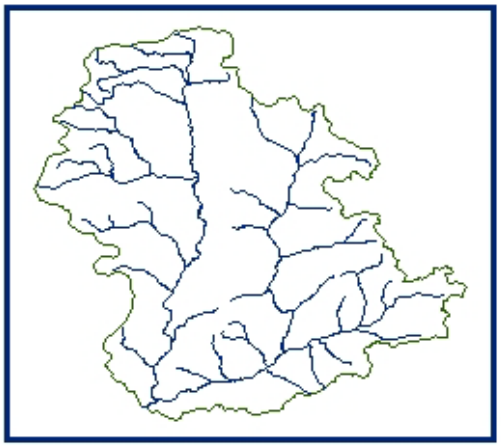
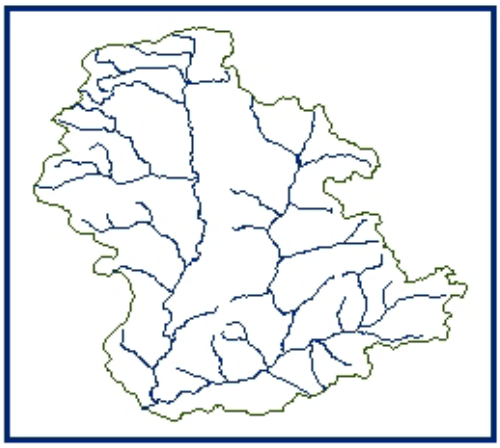


DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



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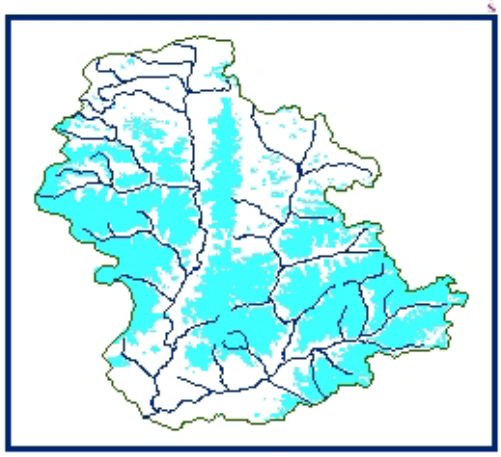
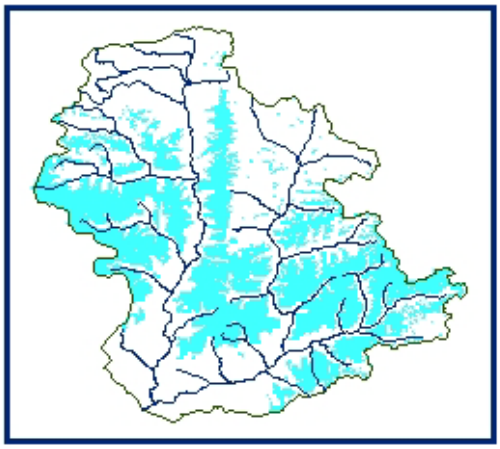
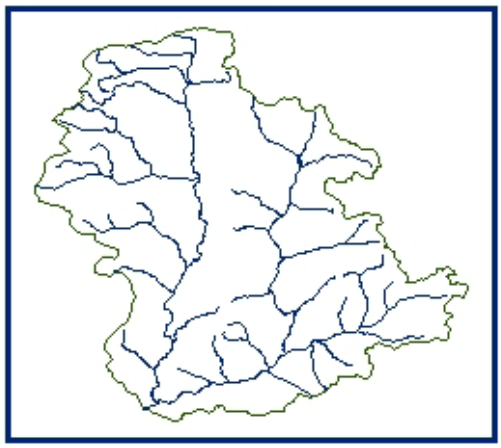


06 MAY 2012



07 MAY 2012



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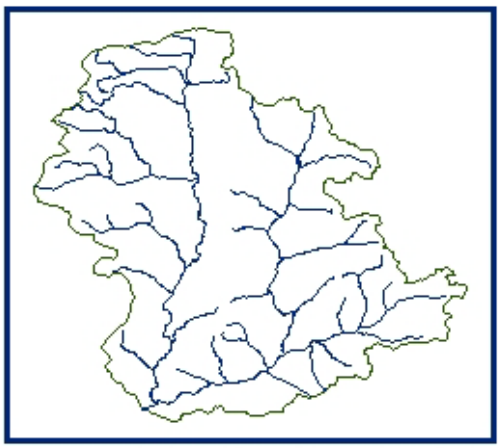

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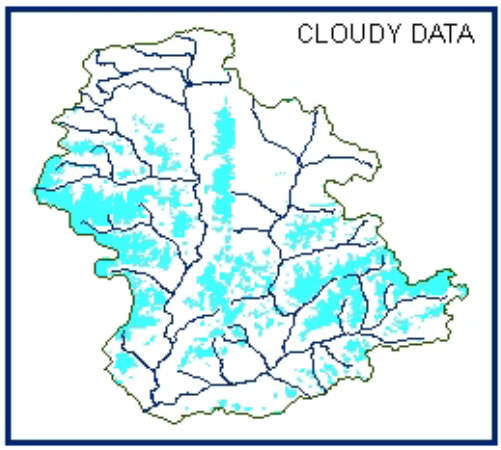


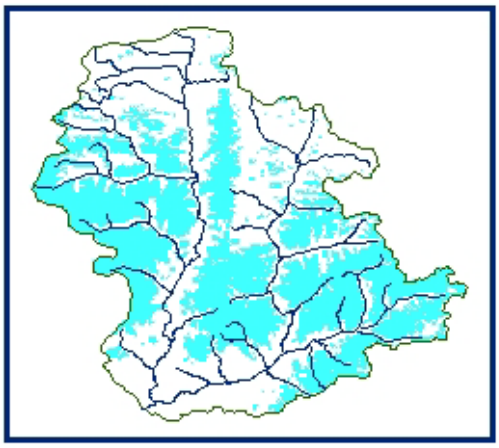
21 MAY 2012

SNOW

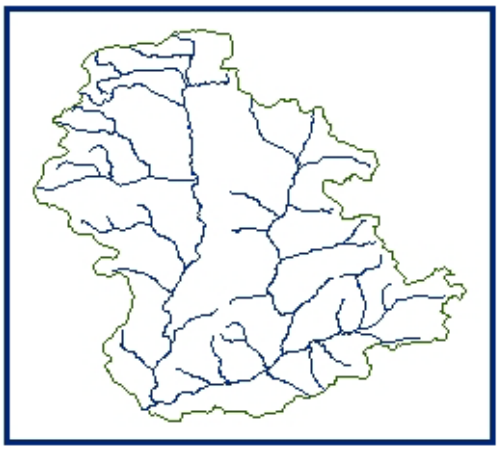
0 12.5 25 50 75 100

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
06 MAY 2012



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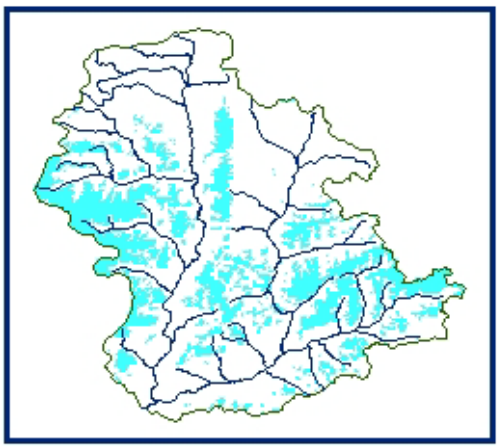
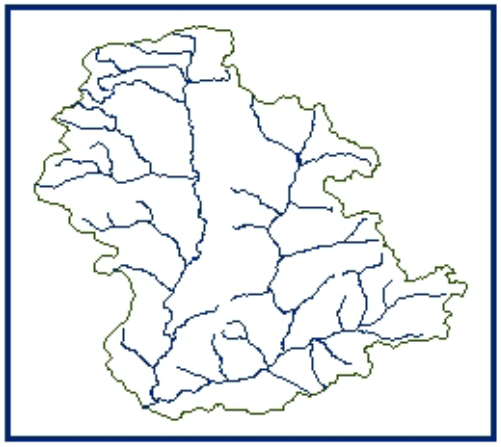


DATA USED
21 MAY 2012

SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



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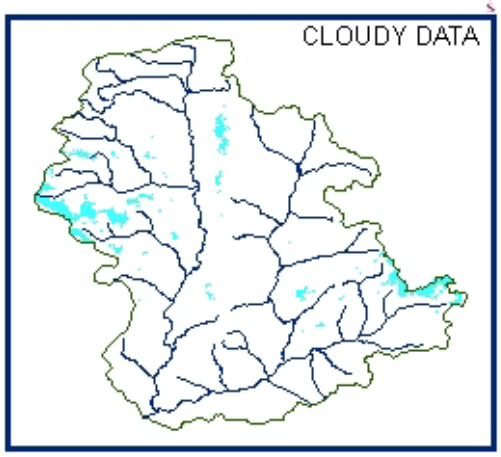
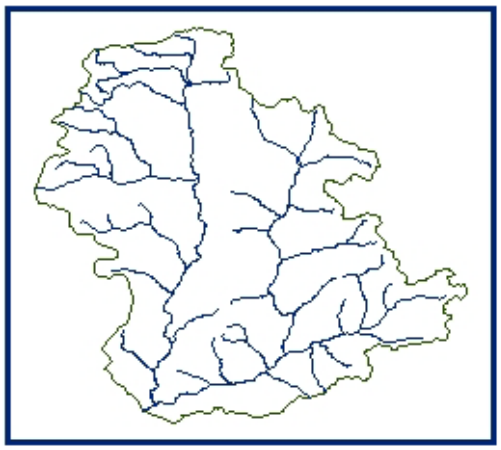


07 JUNE 2012



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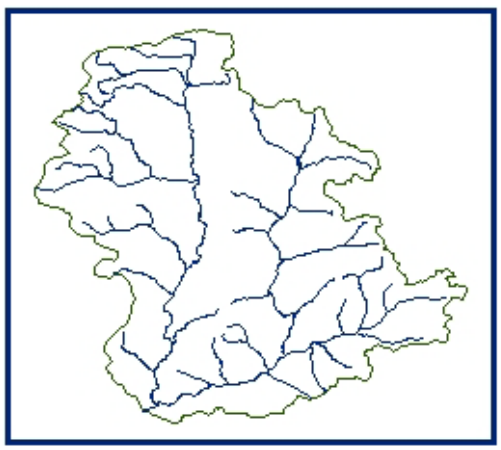

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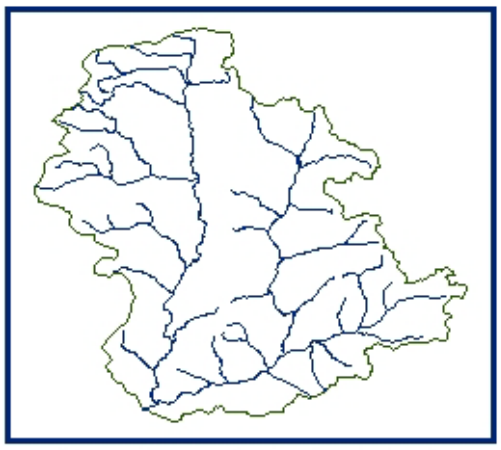

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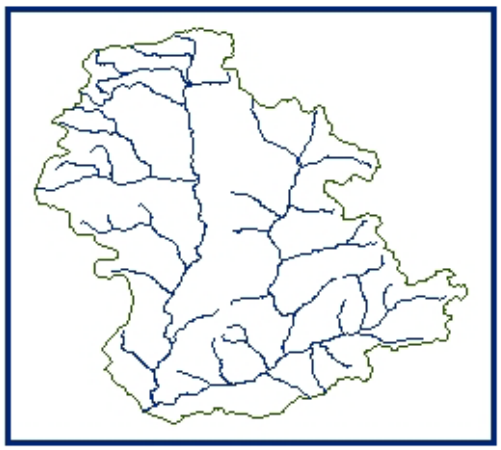


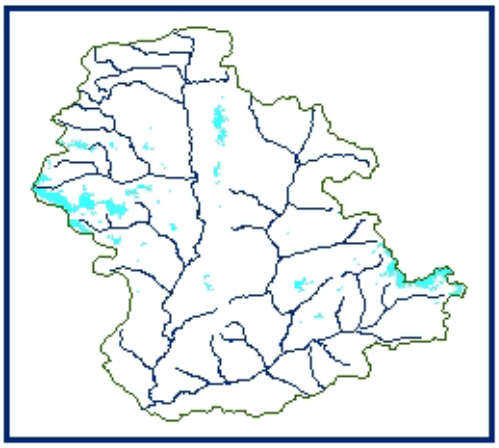
DATA NOT AVAILABLE

SNOW

0 12.5 25 50 75 100

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



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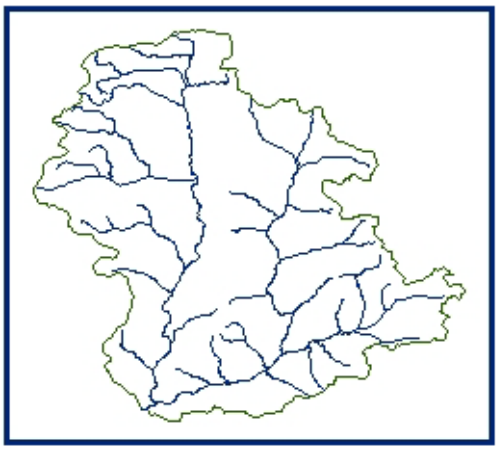
07 JUNE 2012



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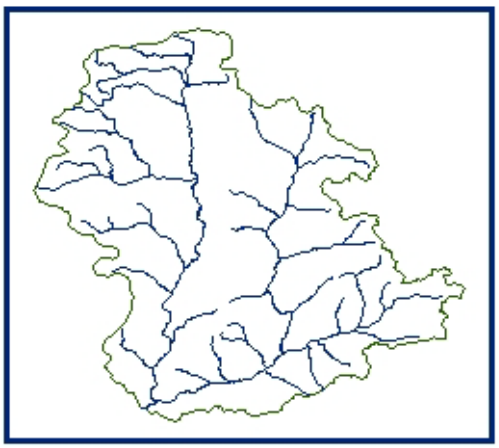

DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers