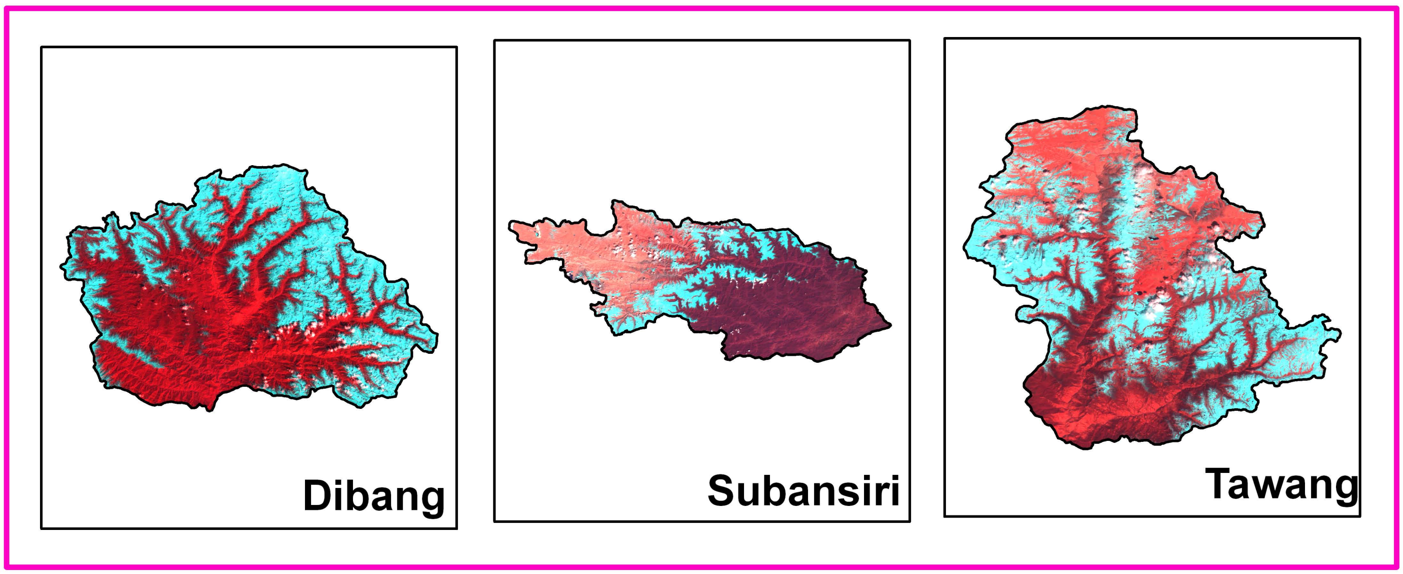
SNOW COVER ATLAS OF BRAHMAPUTRA BASIN

Sub basins: Dibang, Subansiri and Tawang

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

Year : 2009-10



Space Applications Centre (ISRO)
Ahmedabad - 380015

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DOCUMENT CONTROL AND DATA SHEET

Report Number	SAC/RESA/MESG/SGP/SN/ 76 /2012
Month and year of publication	December 2012
Title	Snow cover Atlas of Brahmaputra basin
Type of Report	Scientific Report
No. of pages	76
No. of figures, Charts & Tables	56, 9 & 6
Authors	B. P. Rathore, S. K. Singh, I. Bahuguna, A. S. Rajawat and Ajai
No. of References	9
Originating Unit	Geo Sciences Division, Marine, Geo and Planetary Sciences Group, Earth, Ocean, Atmosphere, Planetary Sciences and Applications area, Space Applications Centre (ISRO), Ahmedabad-15
Abstract	This atlas gives sub basin-wise distribution of snow cover in the Brahmaputra basin from October 2009 to June 2010. 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 2009 to June 2010 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:

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

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 2009 to June 2010. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. In the Tawang river basin, accumulation and ablation pattern of snow is not prominent up to February 08, 2010. For example on March 04, 2010, 59 percent area was covered by seasonal snow. This was reduced to 31 percent by May 01, 2010. May onwards data was cloudy. 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

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

References

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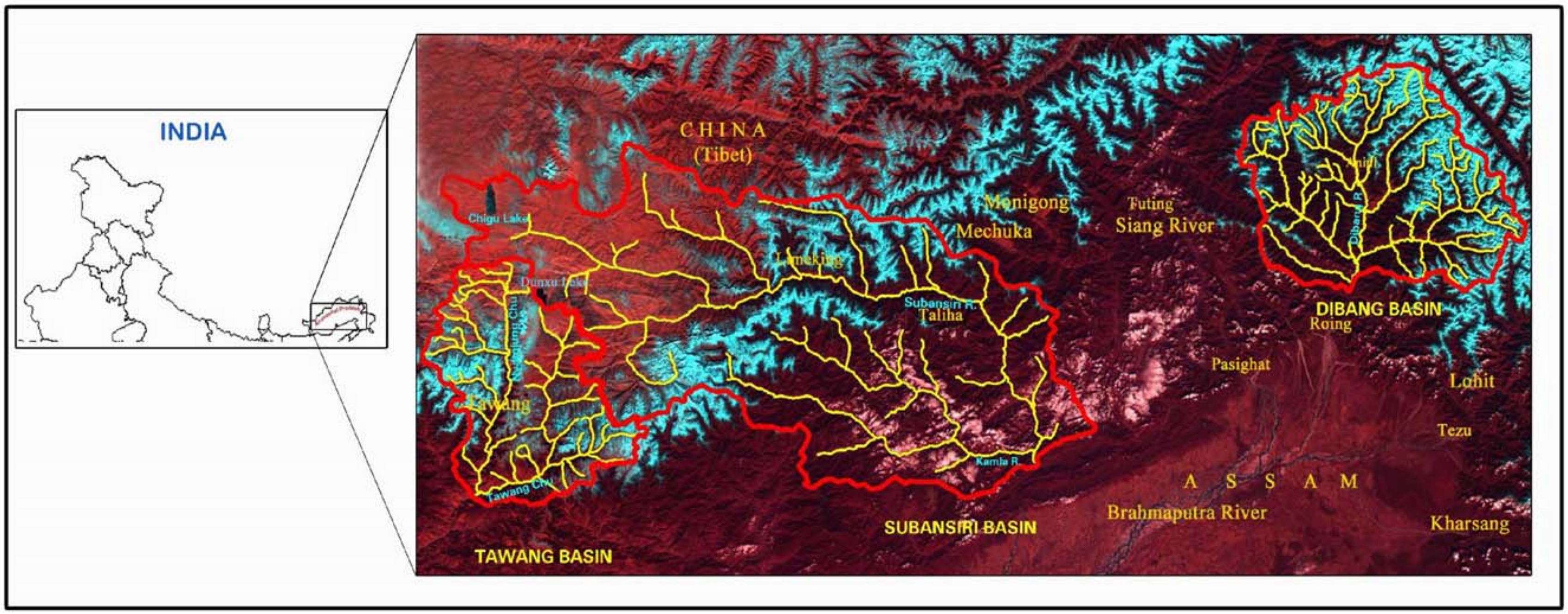

Figure 1: Location map of Dibang, Subansiri and Tawang sub-basins (Part of Brahmputra basin)

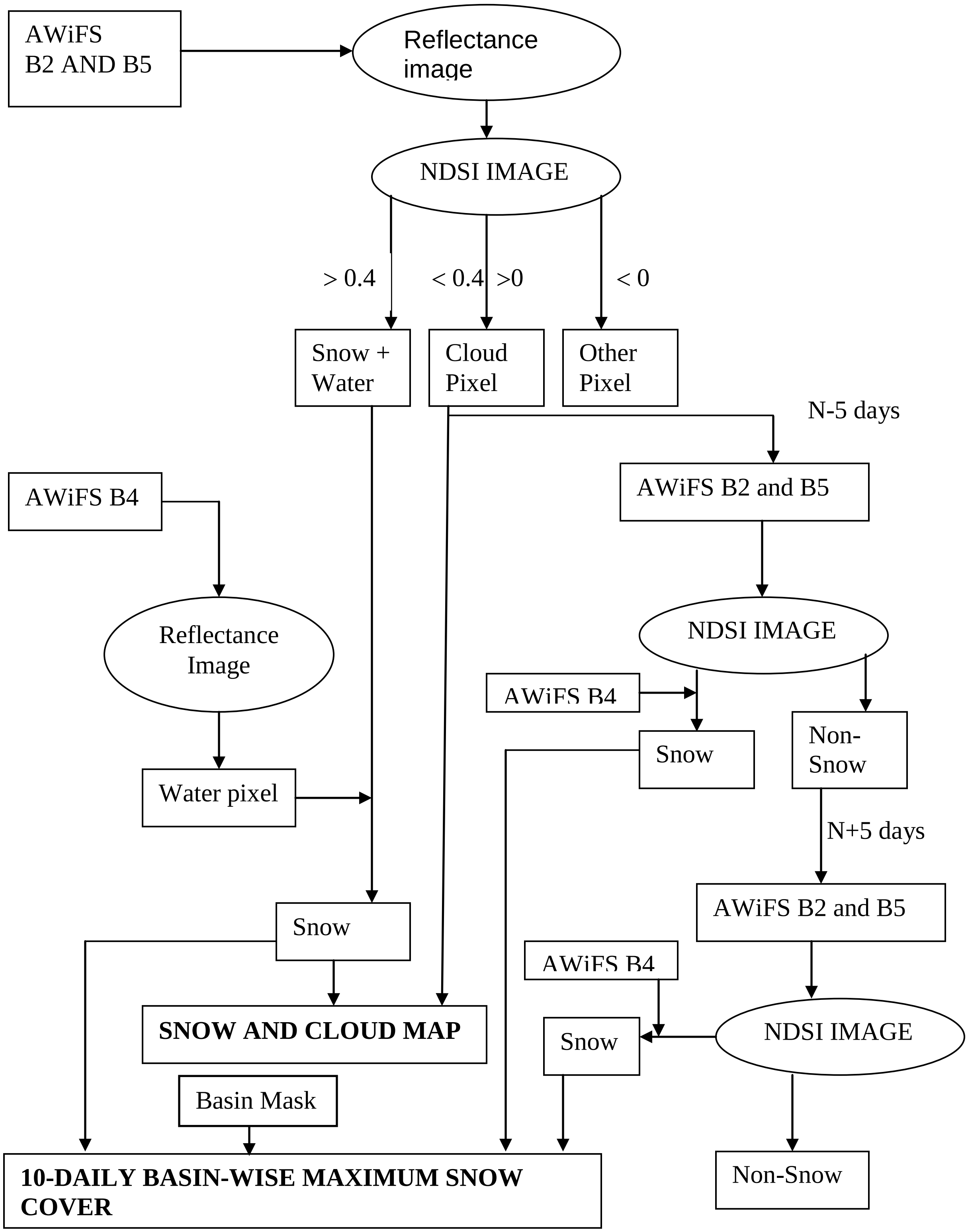

Figure 2: Algorithm for snow cover mapping using AWiFS data

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DIBHANG BASIN

AREAL EXTENT OF SNOW (5 DAILY)

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

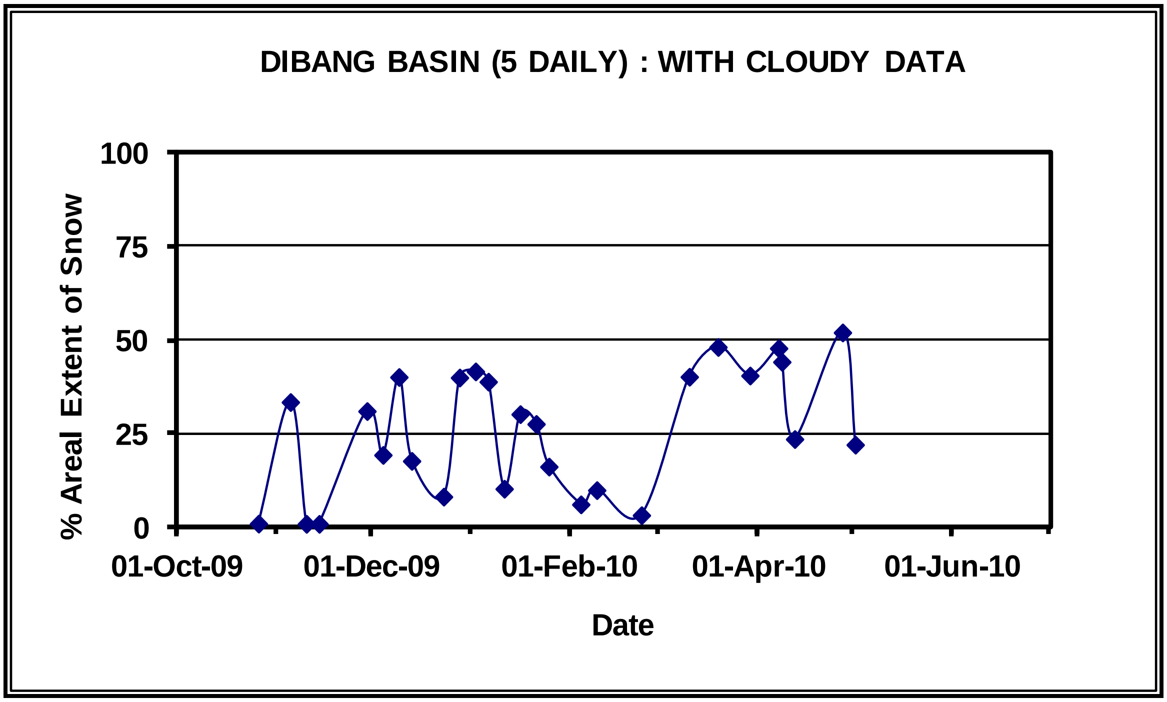
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2009							
1	26-Oct-09	97	1				
November 2009							
2	5-Nov-09	3072	33	4	14-Nov-09	65	1
3	10-Nov-09	16	1	5	29-Nov-09	2851	31
December 2009							
6	4-Dec-09	1778	19	9	22-Dec-09	907	10
7	9-Dec-09	3685	40	10	23-Dec-09	758	8
8	13-Dec-09	1632	18	11	28-Dec-09	3672	40
January 2010							
12	2-Jan-10	3821	42	15	16-Jan-10	2776	30
13	6-Jan-10	3571	39	16	21-Jan-10	2536	28
14	11-Jan-10	951	10	17	25-Jan-10	1493	16
February 2010							
18	4-Feb-10	569	6	20	23-Feb-10	304	3
19	9-Feb-10	917	10				
March 2010							
21	10-Mar-10	3692	40	23	29-Mar-10	3721	41
22	19-Mar-10	4419	48				
April 2010							
24	7-Apr-10	4389	48	27	27-Apr-10	4775	52
25	8-Apr-10	4056	44	26	12-Apr-10	2167	24
May 2010							
28	1-May-10	2029	22				
June 2010							

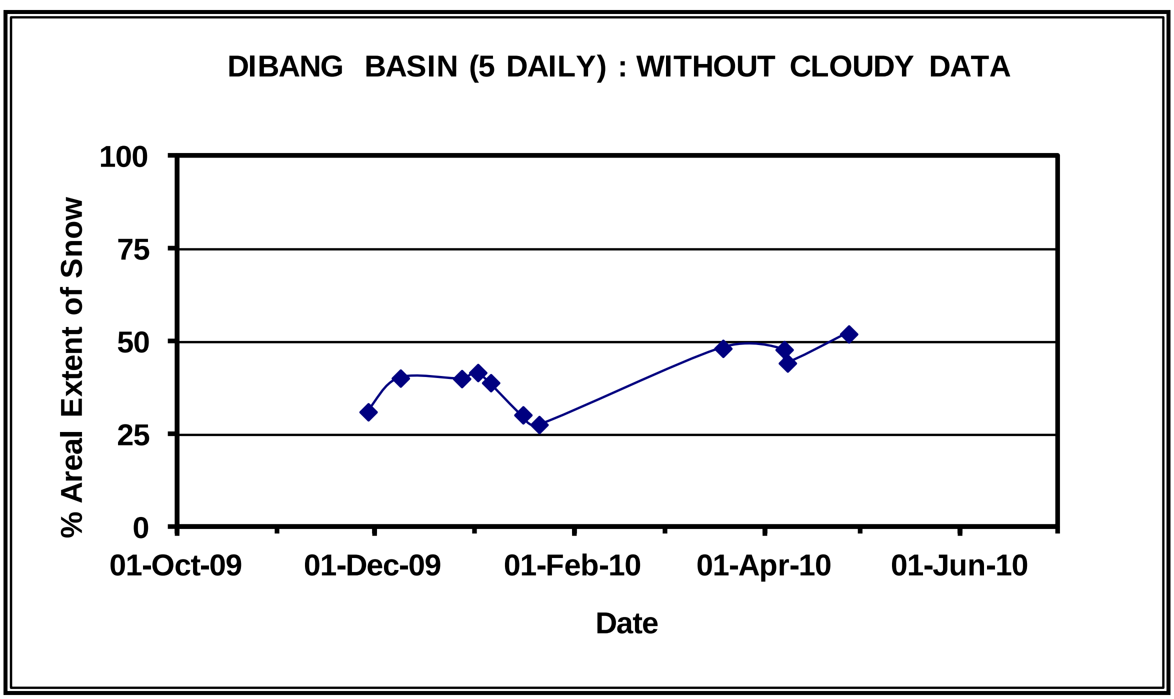
AREAL EXTENT OF SNOW (10 DAILY)

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

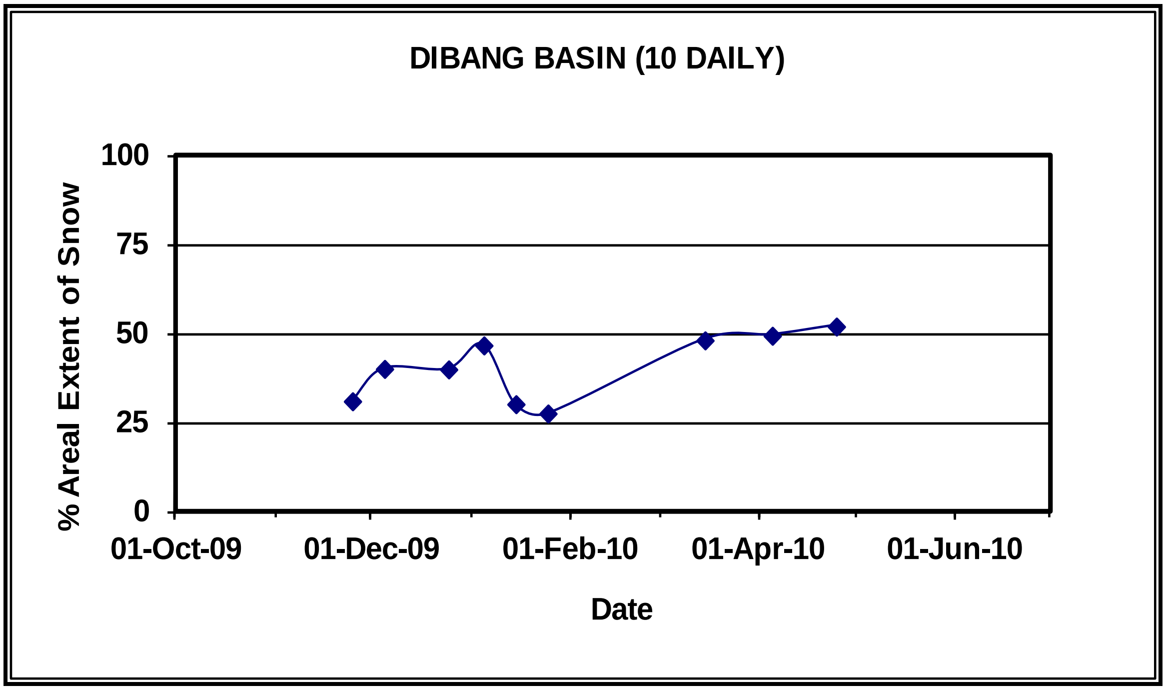
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2009				**November 2009**			
				1	25-Nov-09	2851	31
December 2009				**January 2010**			
2	59-Dec-09	3685	40	4	5-Jan-10	4290	47
3	25-Dec-09	3672	40	5	15-Jan-10	2776	30
				6	25-Jan-10	2536	28
February 2010				**March 2010**			
				7	15-Mar-10	4419	48
April 2010				**May 2010**			
8	5-Apr-10	4538	49				
9	25-Apr-10	4775	52				
June 2010							

Snow cover depletion curve

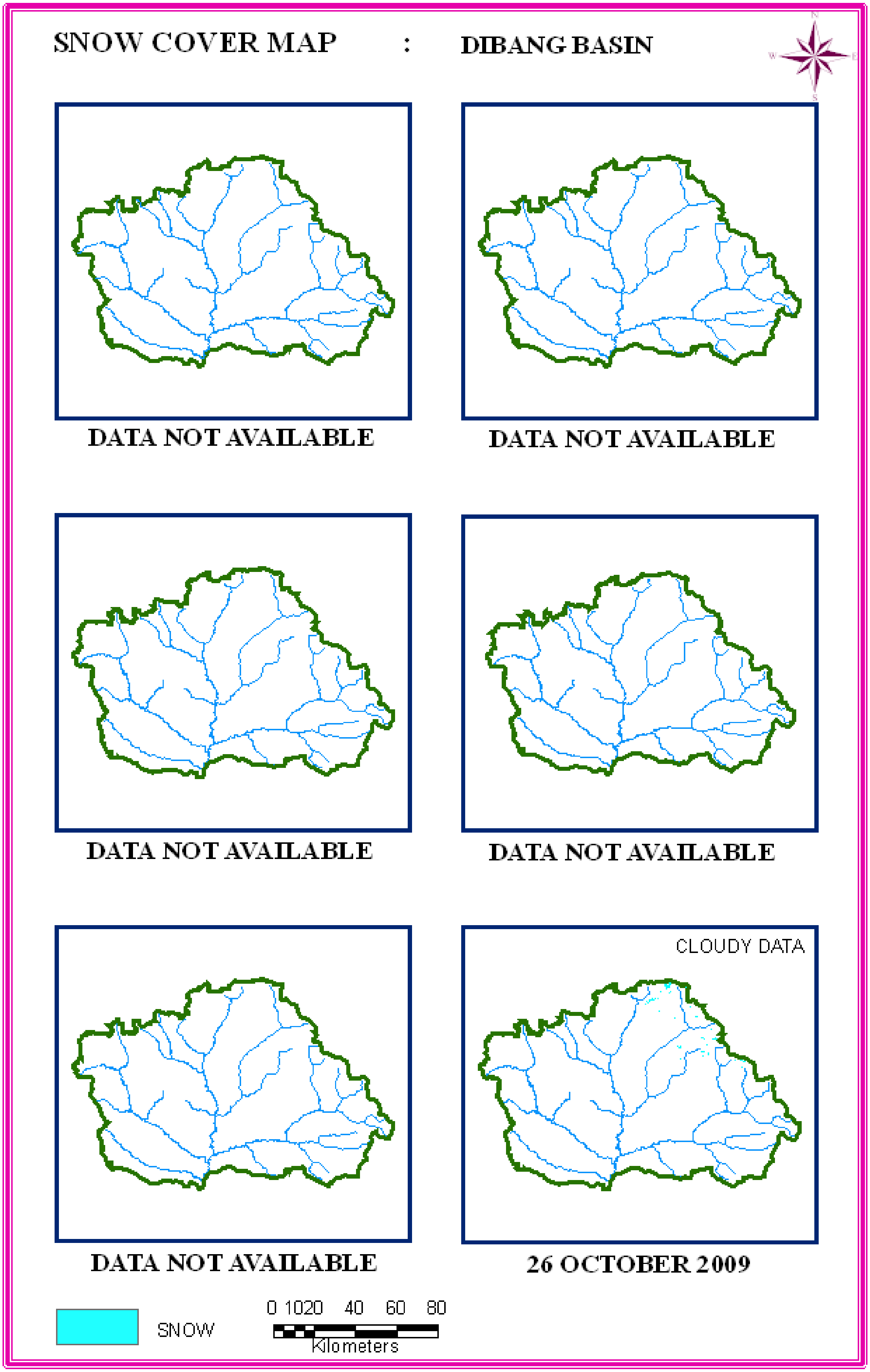




Snow cover depletion curve



SNOW COVER MAP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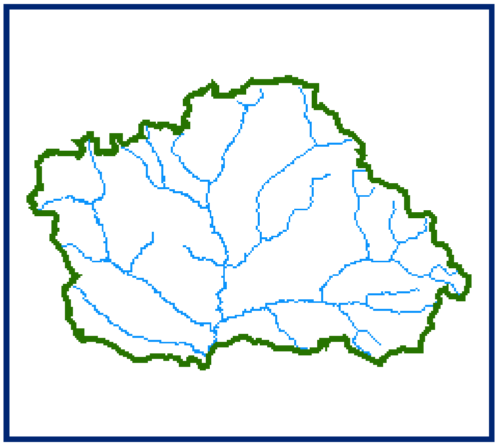
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
26 OCTOBER 2009
SNOW
0 10 20 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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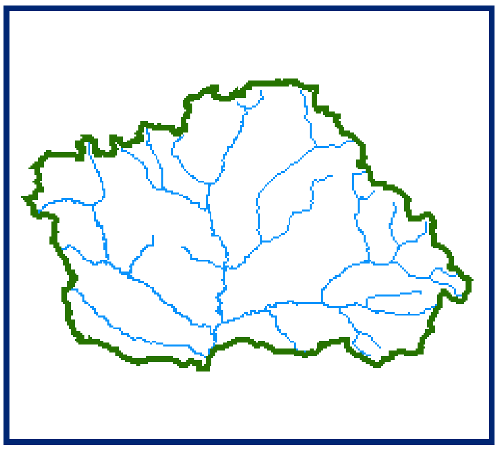

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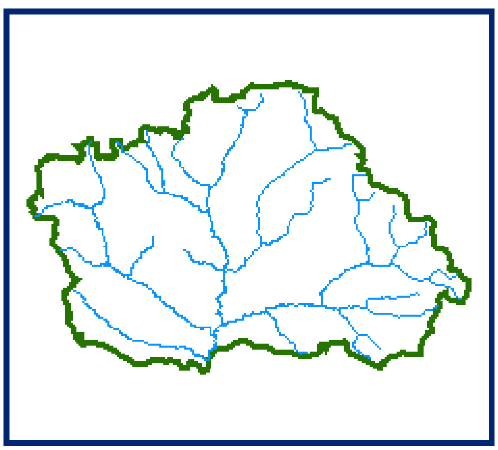

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SNOW

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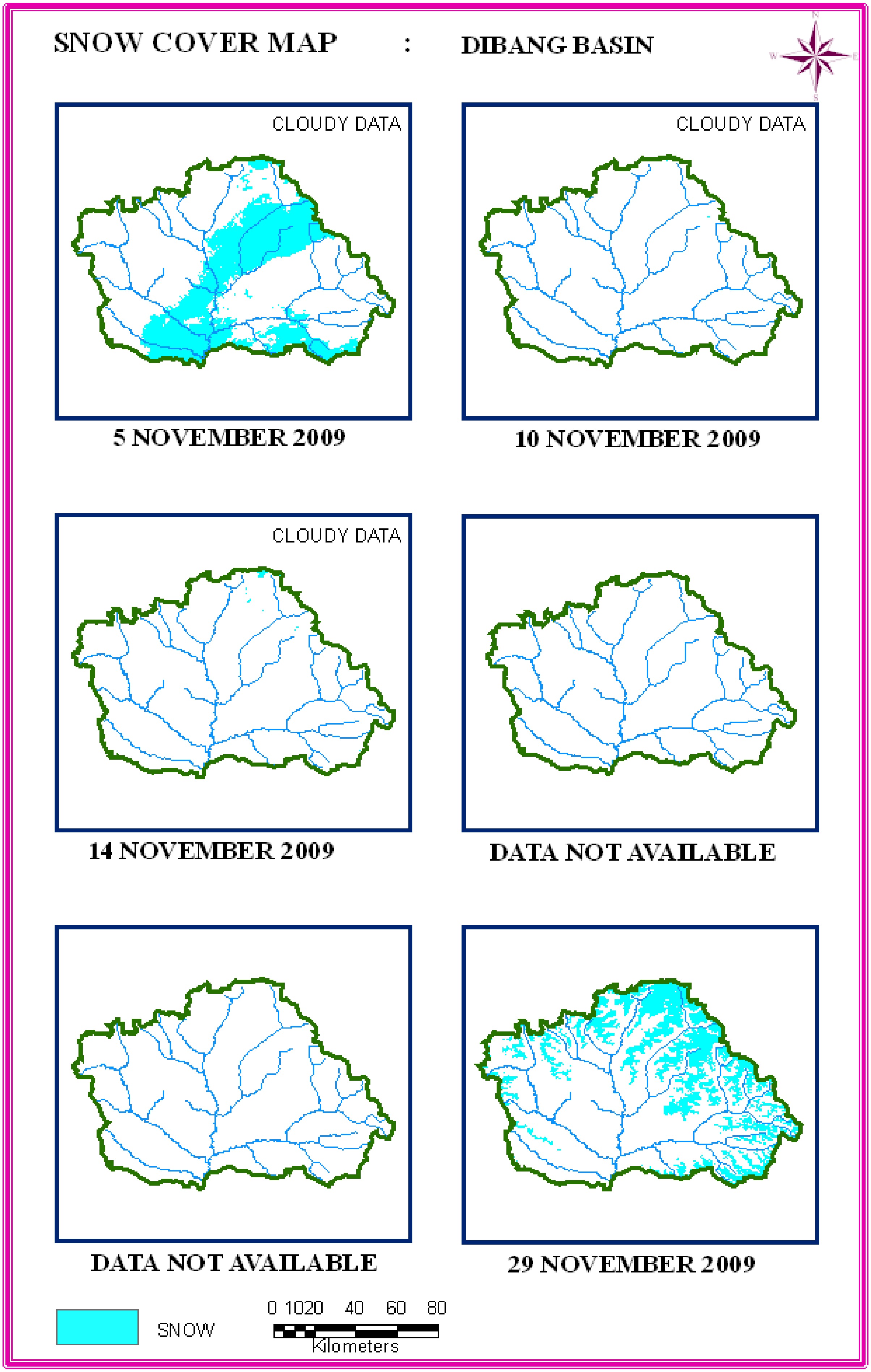
Kilometers


SNOW COVER MAP : DIBANG BASIN
CLOUDY DATA
5 NOVEMBER 2009
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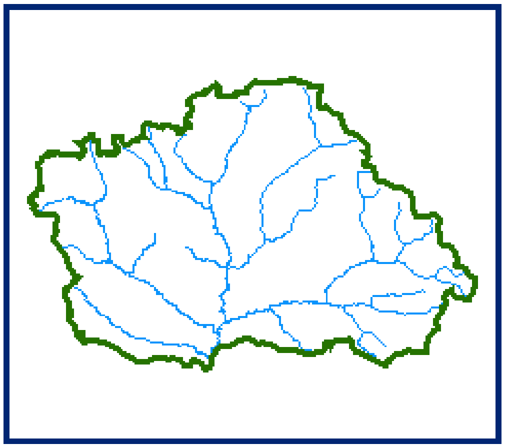

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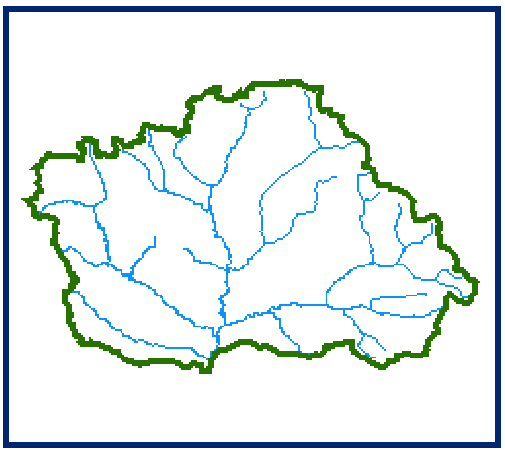

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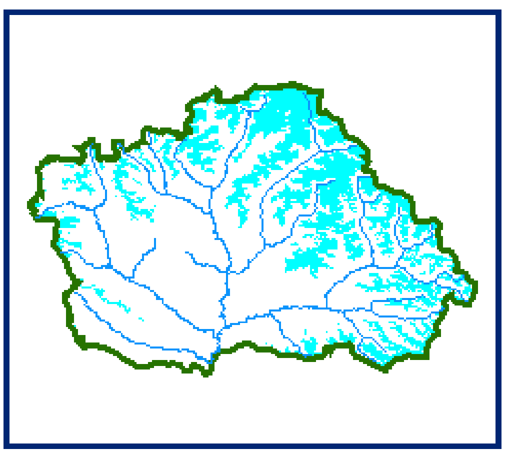

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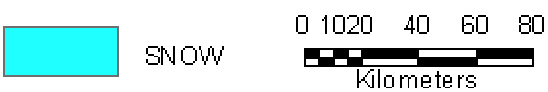

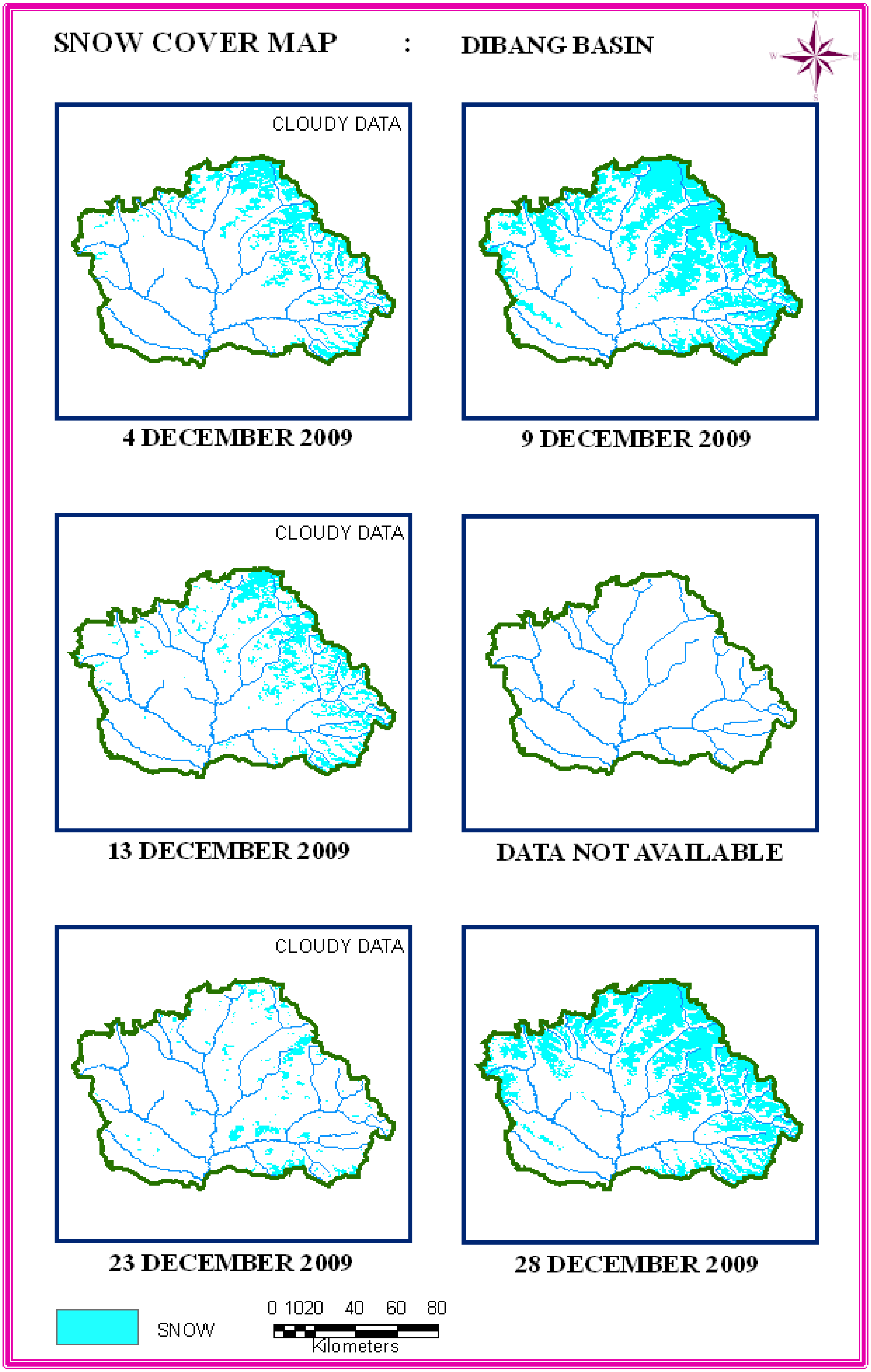
SNOW COVER MAP : DIBANG BASIN
CLOUDY DATA
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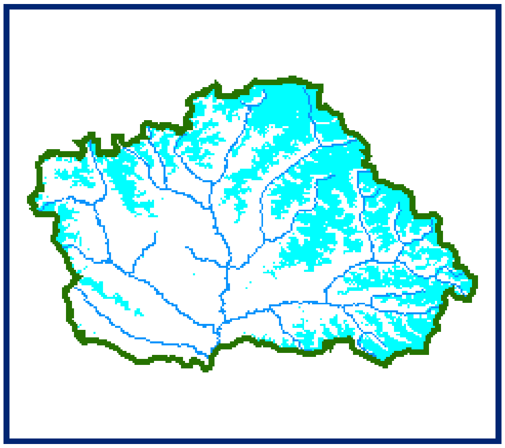

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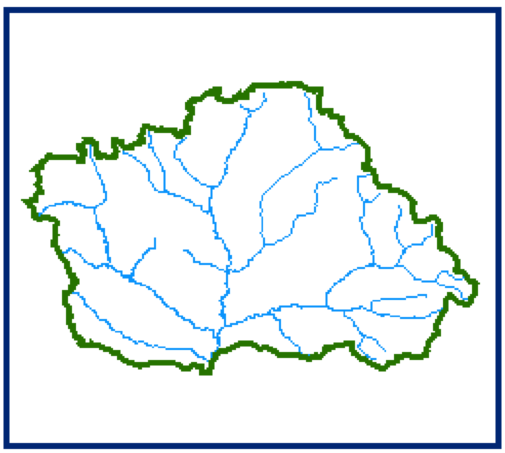
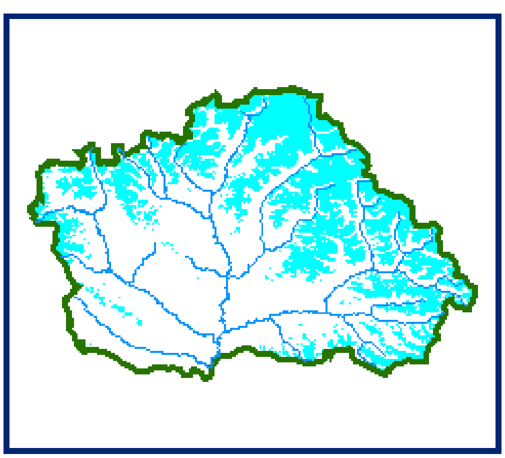
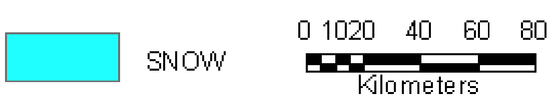
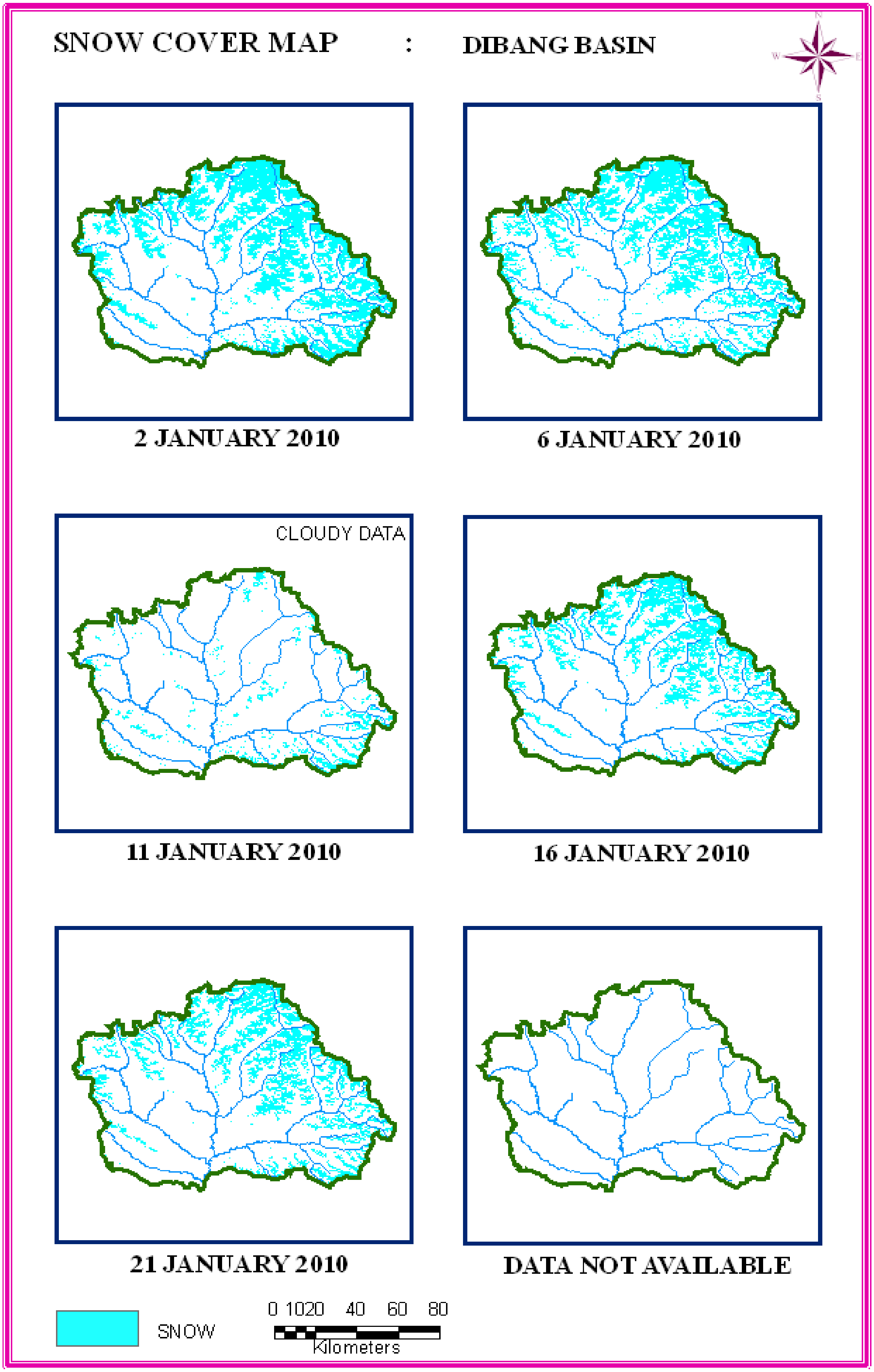


DATA USED
DATA NOT AVAILABLE

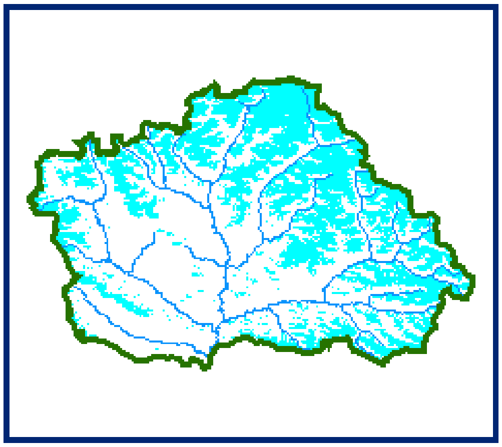


DATA USED
28 DECEMBER 2009




SNOW COVER MAP : DIBANG BASIN
2 JANUARY 2010
6 JANUARY 2010
CLOUDY DATA
11 JANUARY 2010
16 JANUARY 2010
21 JANUARY 2010
DATA NOT AVAILABLE
SNOW
0 10 20 40 60 80
Kilometers

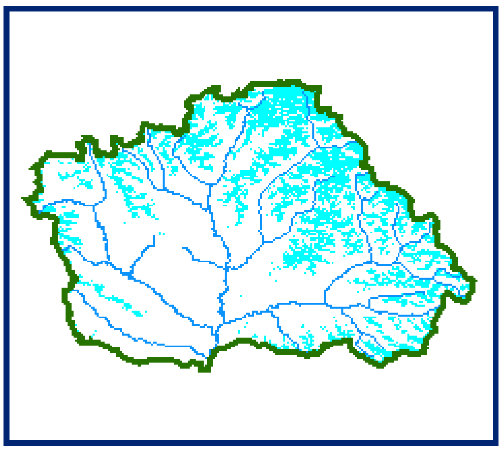
10 DAILY SNOW COVER MAP: **DIBANG BASIN**



DATA USED

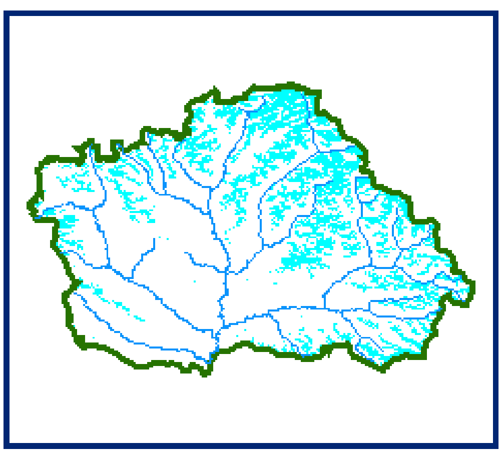
2 JANUARY 2010

6 JANUARY 2010



DATA USED

16 JANUARY 2010



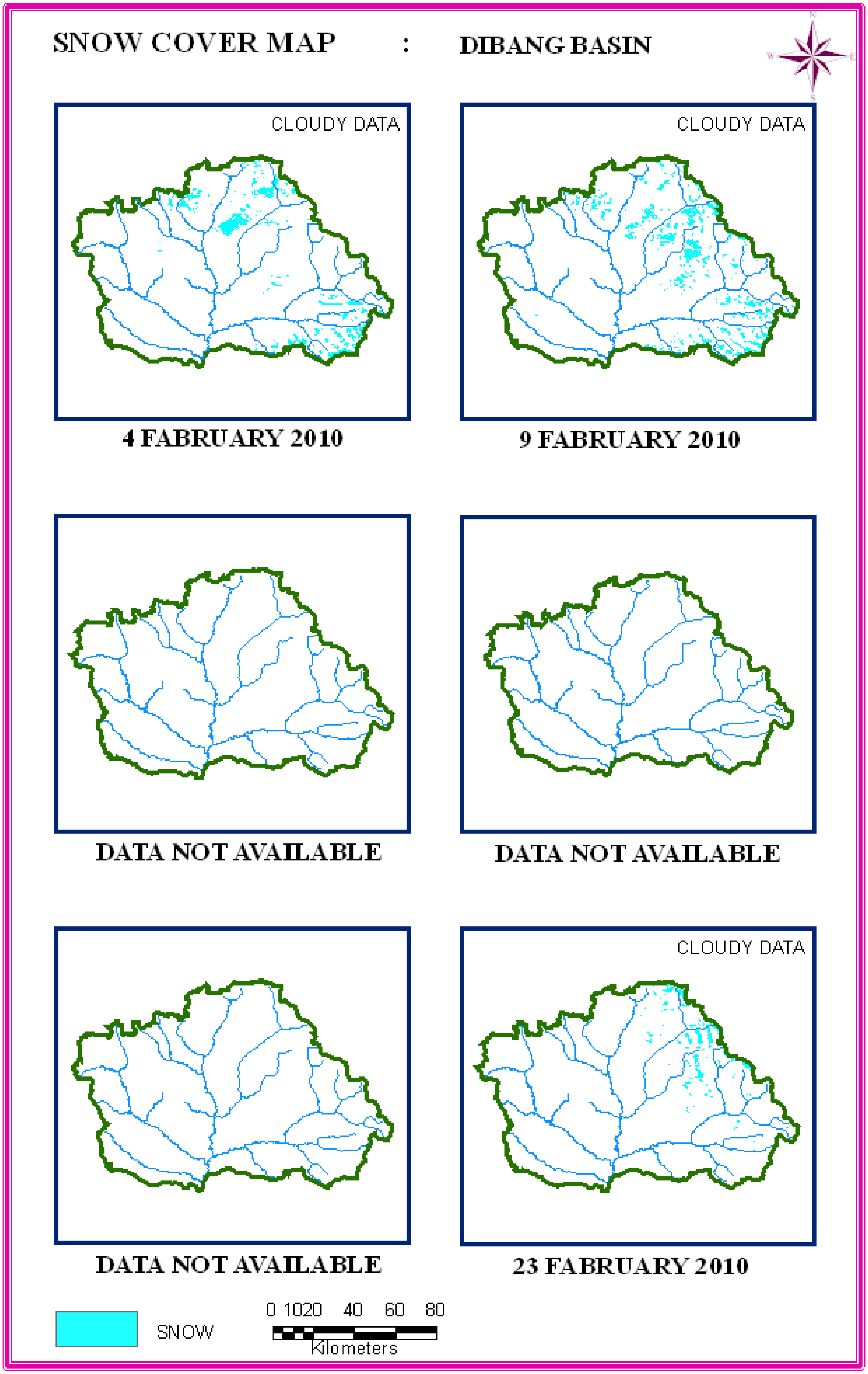
DATA USED

21 JANUARY 2010

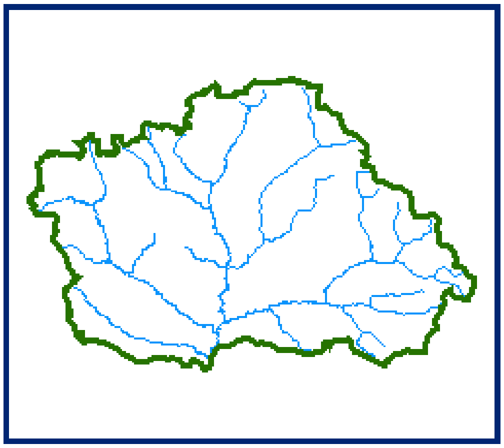
SNOW

0 10 20 40 60 80

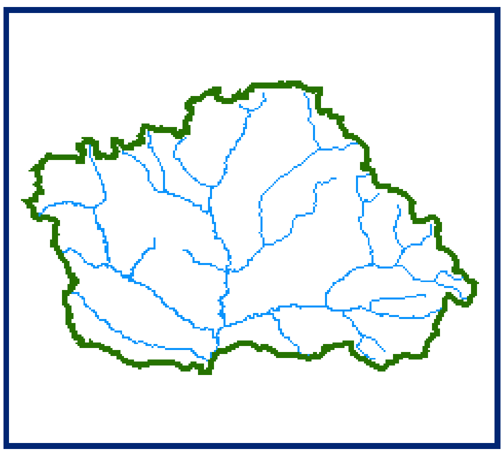
Kilometers


SNOW COVER MAP : DIBANG BASIN
CLOUDY DATA
4 FABRUARY 2010
CLOUDY DATA
9 FABRUARY 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
23 FABRUARY 2010
SNOW
0 1020 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED
DATA NOT AVAILABLE



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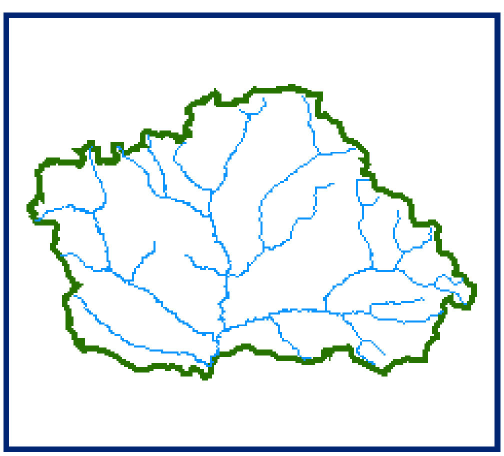
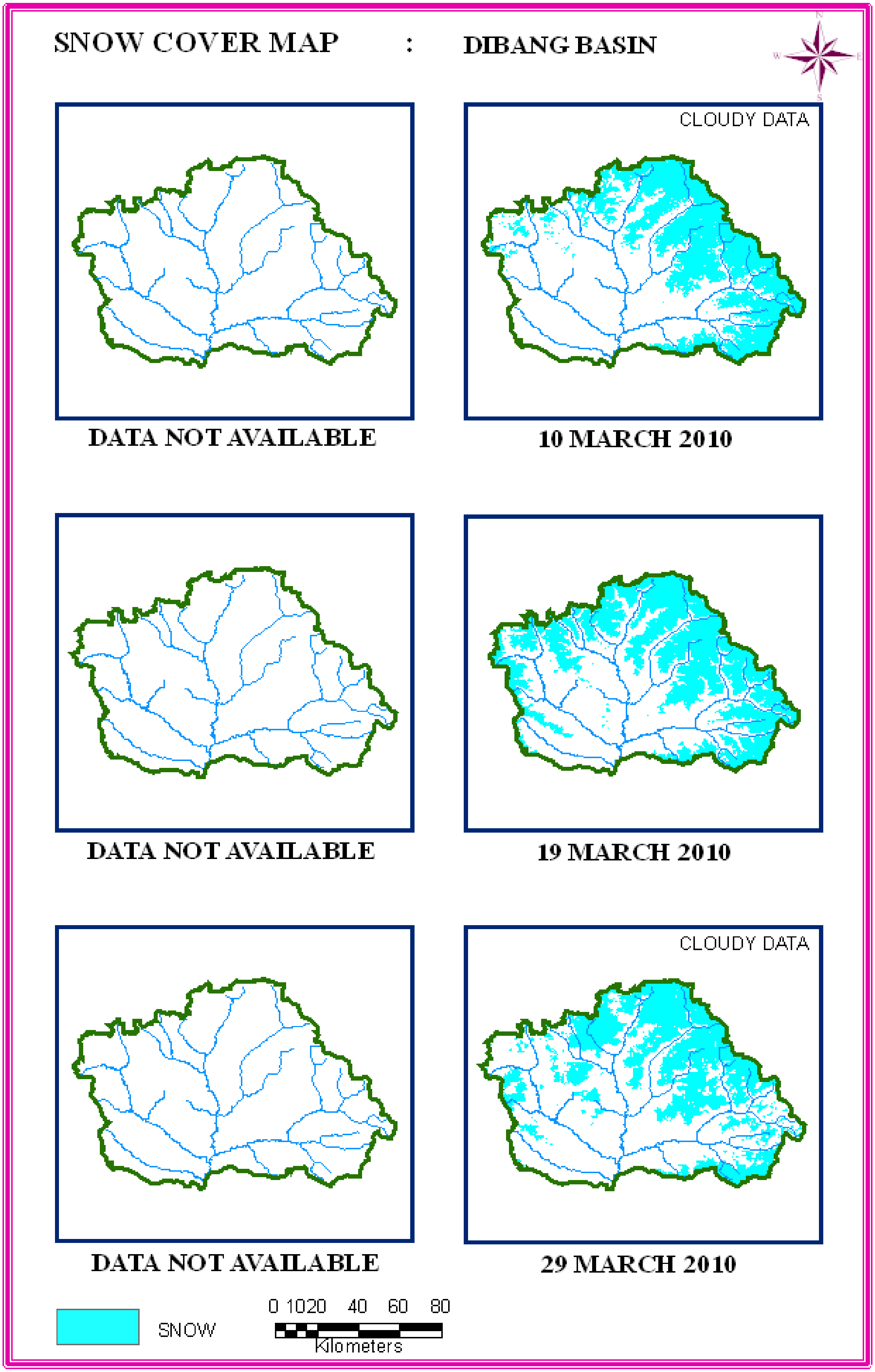


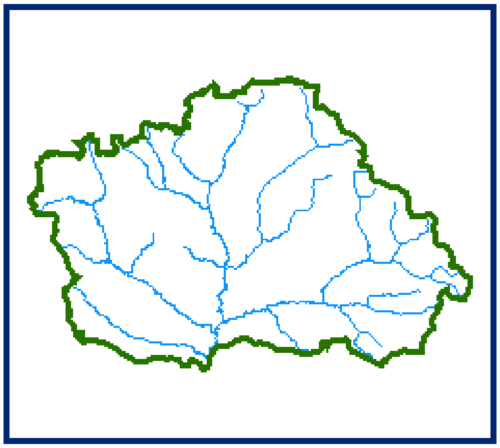
DATA USED
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers


SNOW COVER MAP : DIBANG BASIN
DATA NOT AVAILABLE
CLOUDY DATA
10 MARCH 2010
DATA NOT AVAILABLE
19 MARCH 2010
DATA NOT AVAILABLE
CLOUDY DATA
29 MARCH 2010
SNOW
0 1020 40 60 80
Kilometers

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



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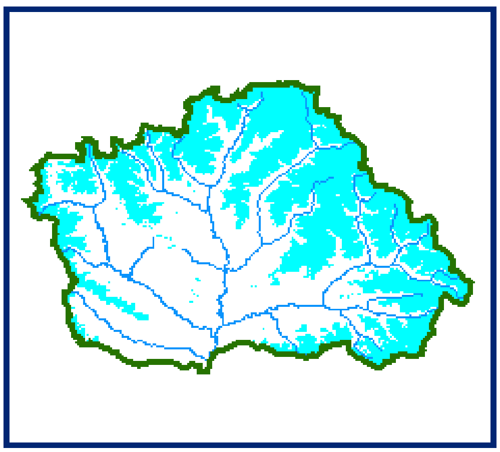
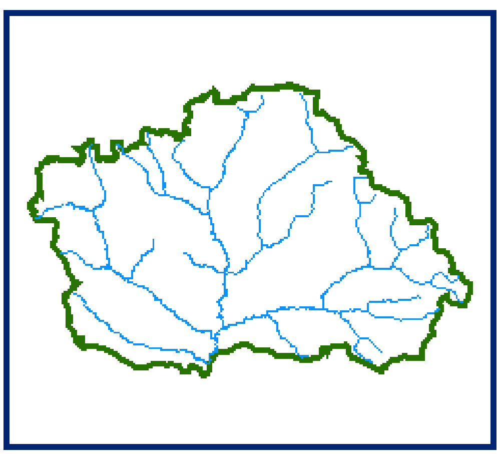


DATA USED

19 MARCH 2010



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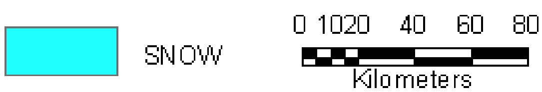
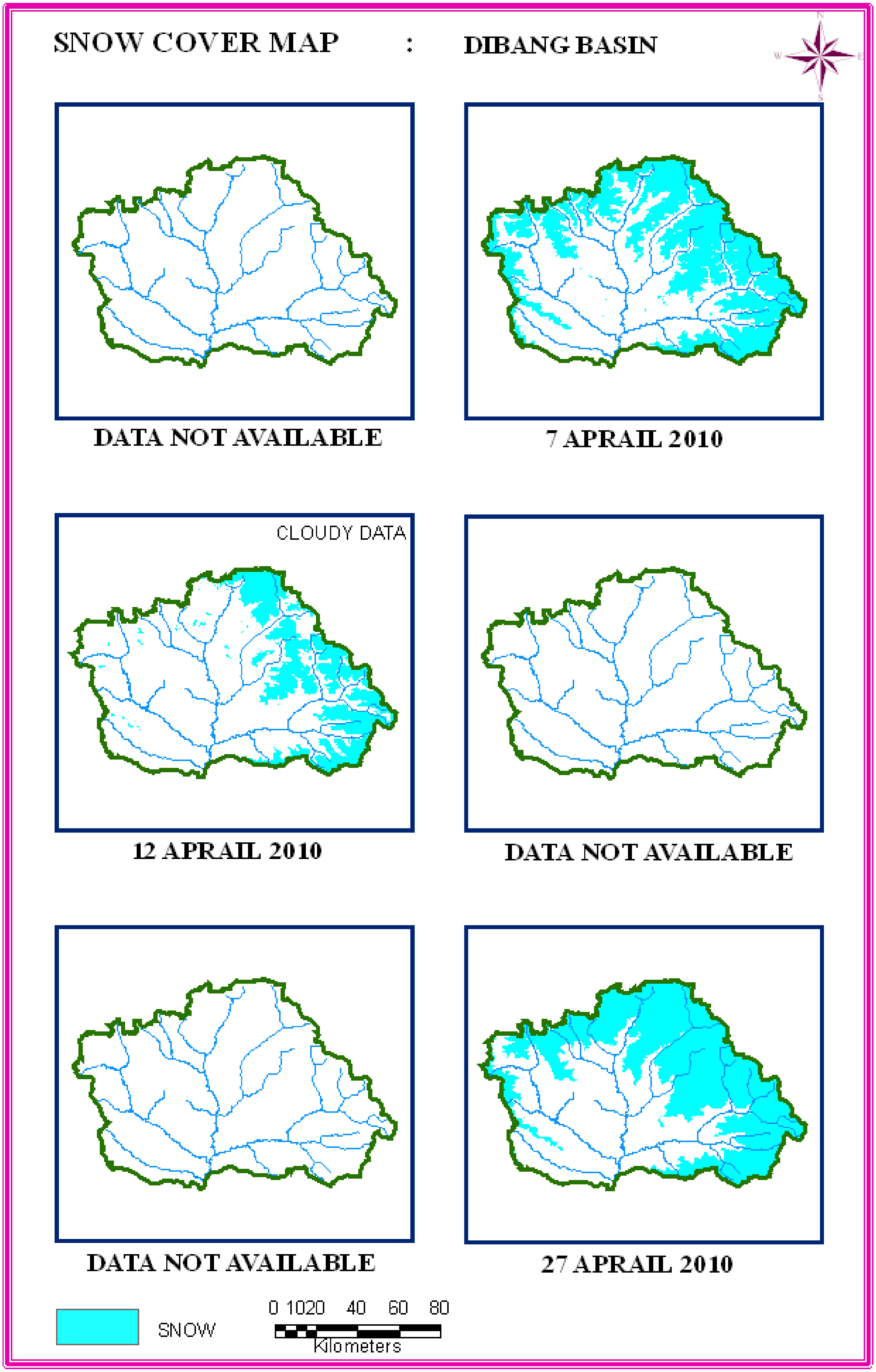
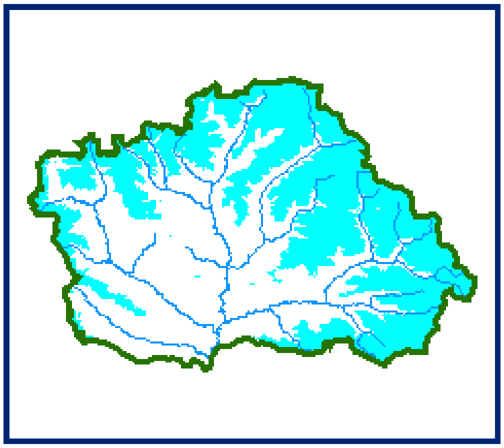



SNOW COVER MAP : DIBANG BASIN
DATA NOT AVAILABLE
7 APRAIL 2010
CLOUDY DATA
12 APRAIL 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
27 APRAIL 2010
SNOW
0 1020 40 60 80
Kilometers

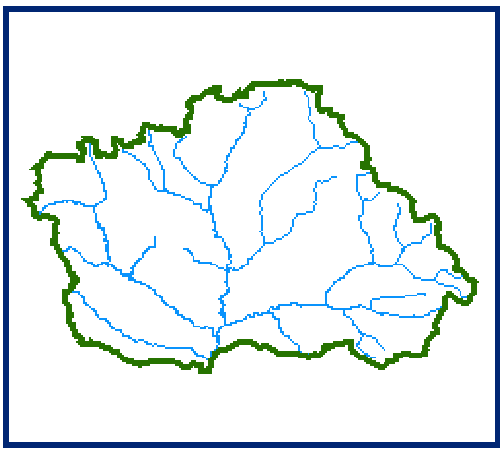
10 DAILY SNOW COVER MAP: DIBANG BASIN



DATA USED

7 APRAIL 2010

8 APRAIL 2010



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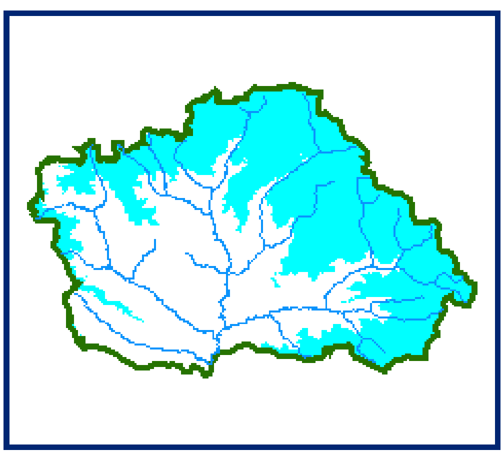


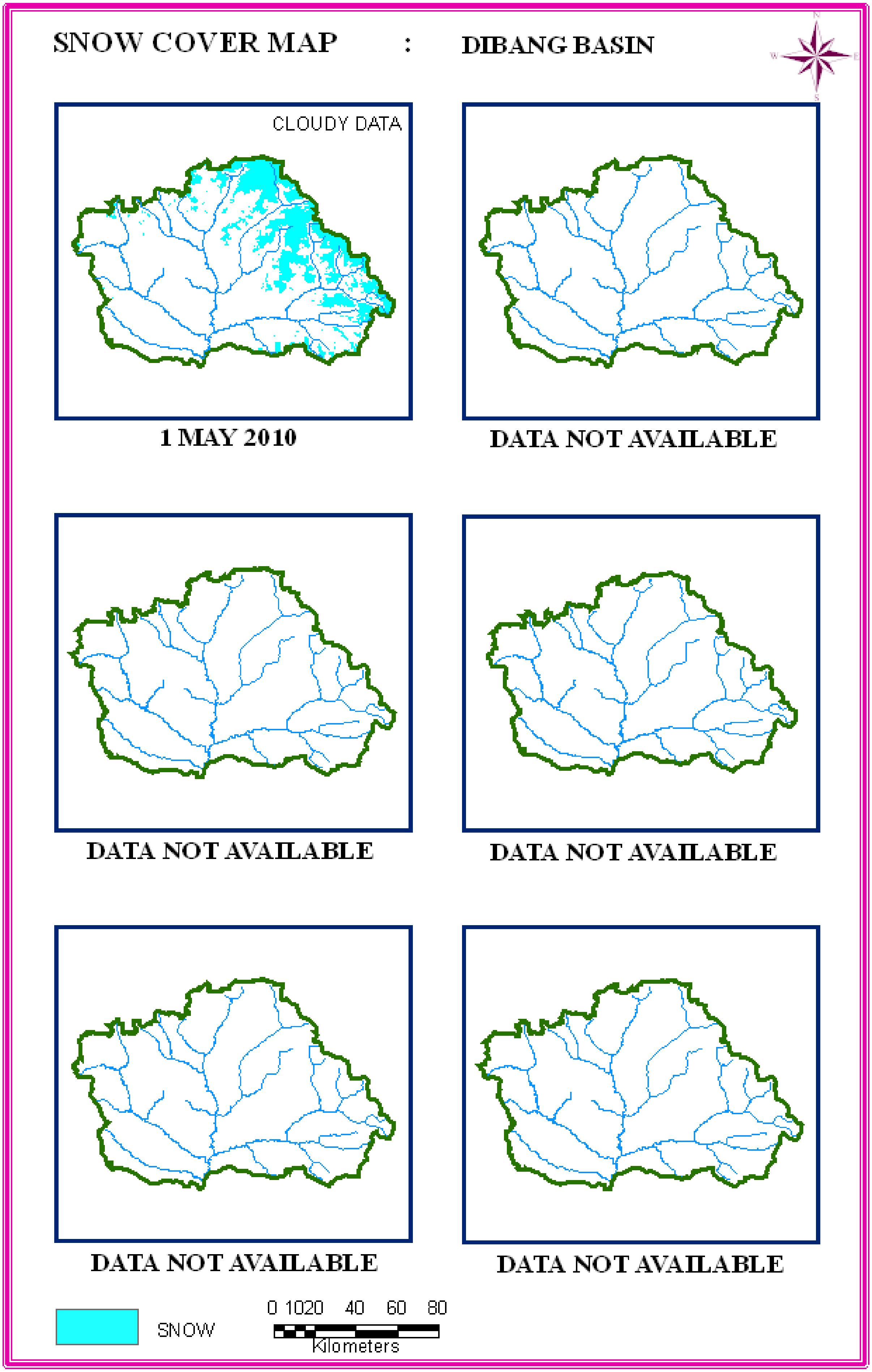
DATA USED

27 APRAIL 2010

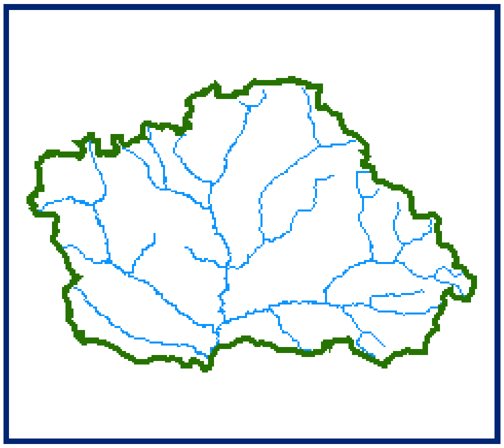
SNOW

0 10 20 40 60 80

Kilometers


SNOW COVER MAP : DIBANG BASIN
CLOUDY DATA
1 MAY 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
SNOW
0 1020 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: DIBANG BASIN



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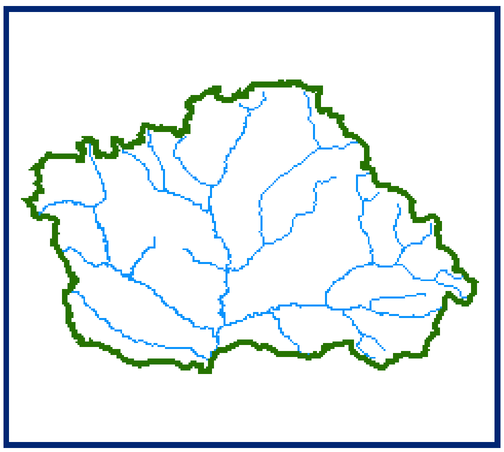

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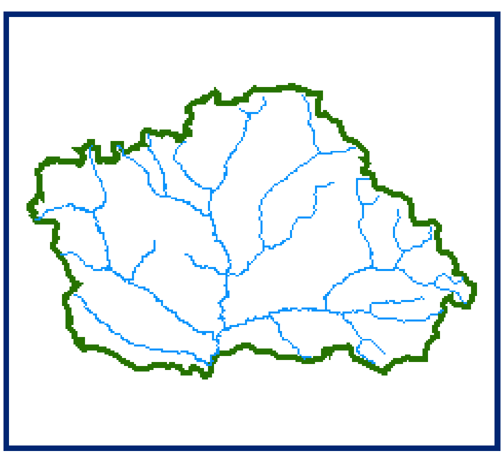


DATA USED

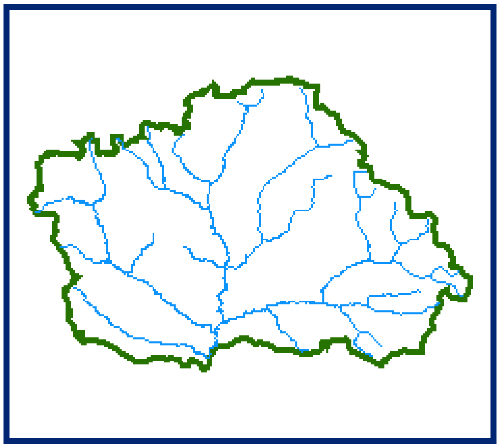
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80

Kilometers

SNOW COVER MAP : DIBANG BASIN



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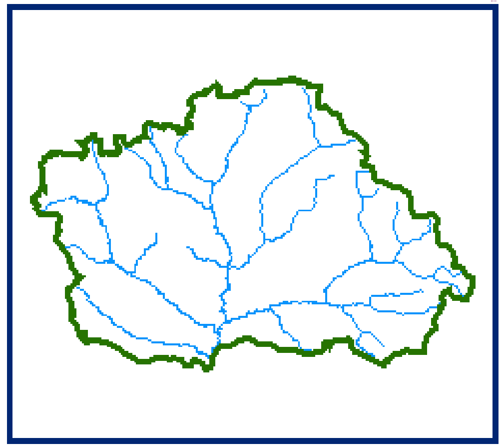

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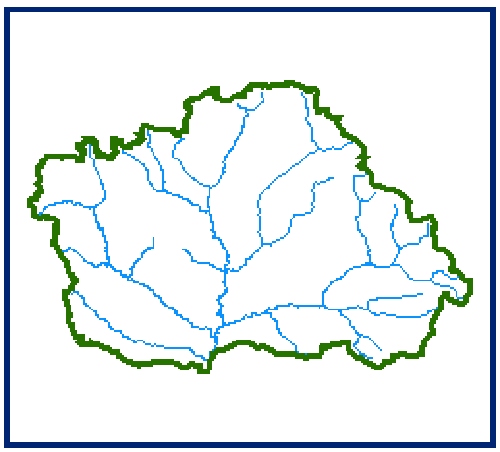

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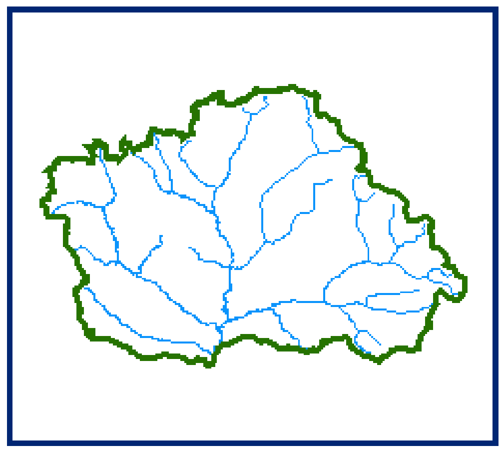

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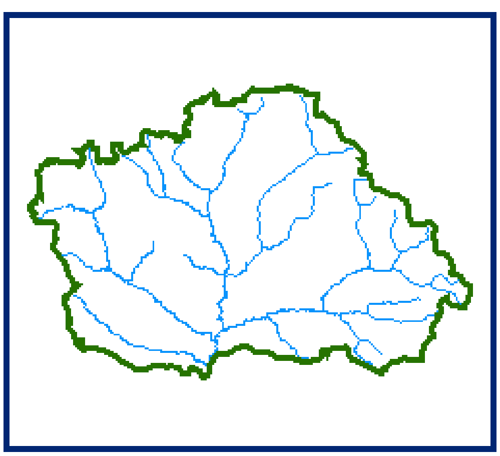

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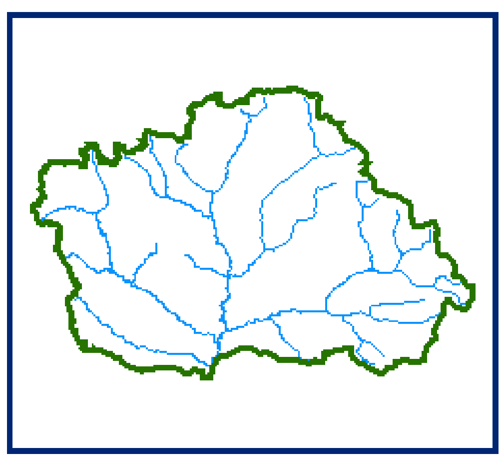

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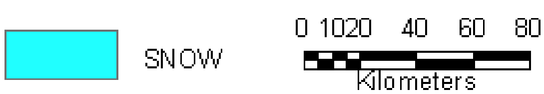
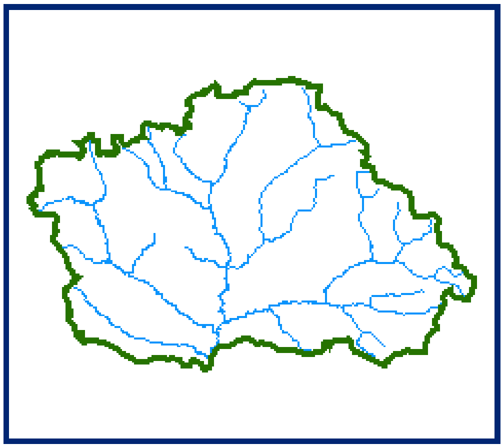


10 DAILY SNOW COVER MAP: **DIBANG BASIN**



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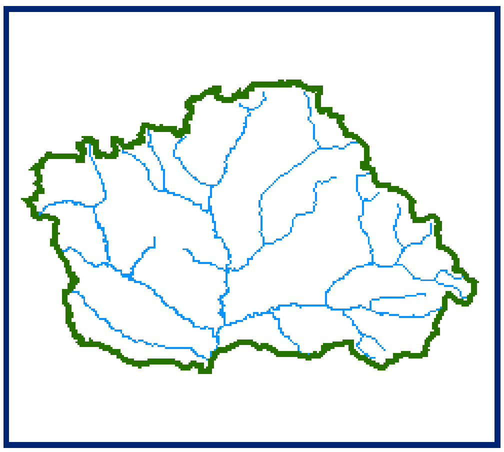

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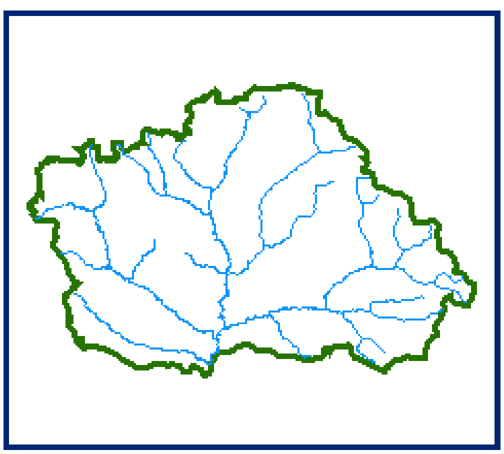


DATA USED

DATA NOT AVAILABLE

SNOW

0 1020 40 60 80

Kilometers

SUBANSIRI BASIN

AREAL EXTENT OF SNOW (5 DAILY)

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

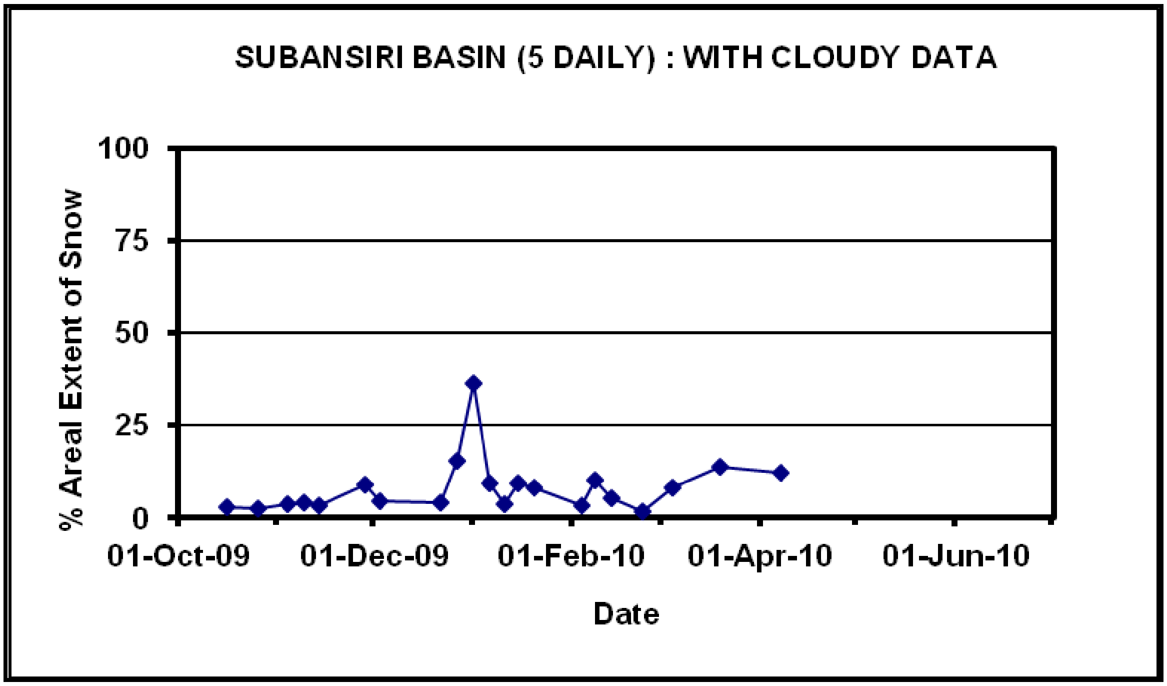
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2009							
1	16-Oct-09	713.7	3	2	26-Oct-09	681.6	3
November 2009							
3	4-Nov-09	966.0	4	5	14-Nov-09	820.3	3
4	9-Nov-09	1074.6	4	6	28-Nov-09	2264.7	9
December 2009							
7	3-Dec-09	1162.8	5	9	27-Dec-09	3900.7	15
8	22-Dec-09	1019.2	4				
January 2010							
10	1-Jan-10	9193.4	36	13	15-Jan-10	2372.2	9
11	6-Jan-10	2371.0	9	14	20-Jan-10	2044.2	8
12	11-Jan-10	936.1	4				
February 2010							
15	4-Feb-10	784.4	3	17	13-Feb-10	1320.9	5
16	8-Feb-10	2618.5	10	18	23-Feb-10	399.2	2
March 2010							
19	4-Mar-10	2051.01	8	21	7-Apr-10	3095.6	12
20	19-Mar-10	3505.9	14				
April 2010							
May 2010							
June 2010							

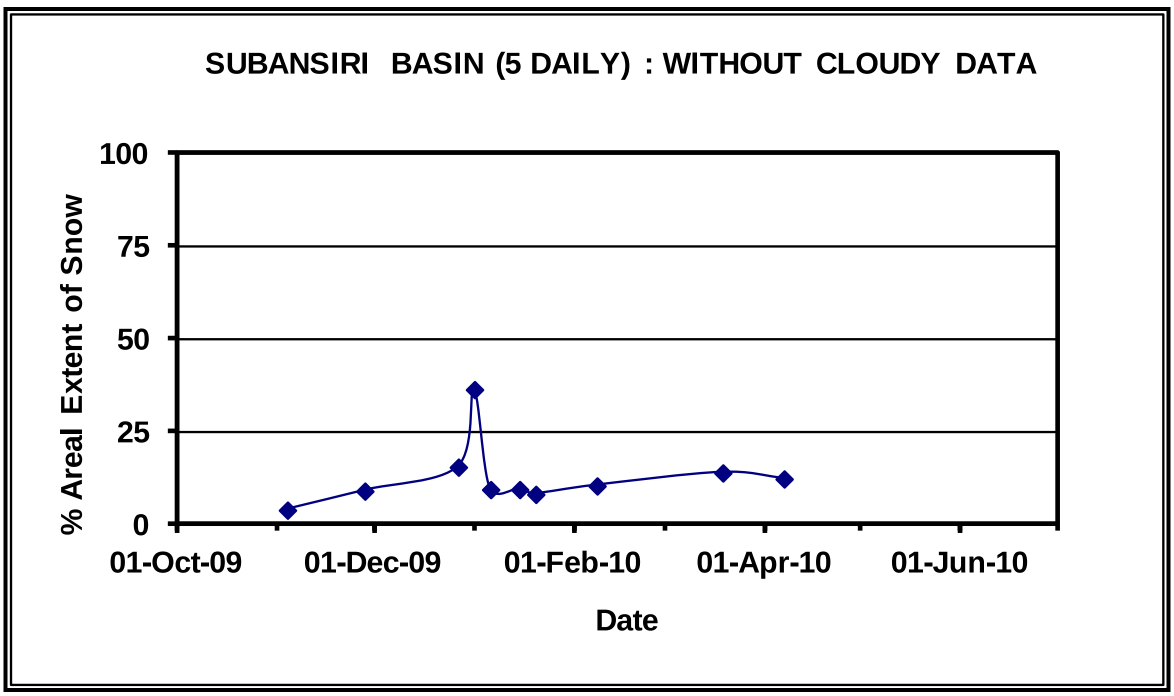
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: SUBANSIRI **BASIN AREA: 25329 Sq km**

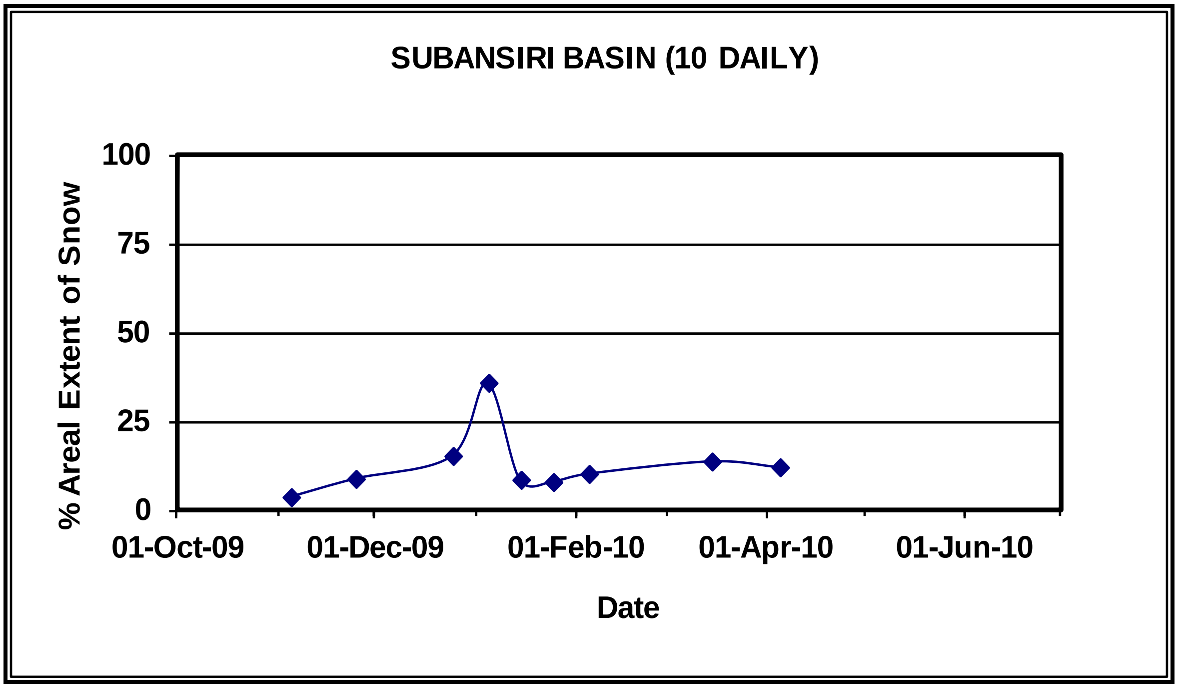
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2009				**November 2009**			
1	4-Nov-09	966.01	4				
2	28-Nov-09	2264.73	9				
December 2009				**January 2010**			
3	27-Dec-09	3900.80	15	4	1-Jan-10	3969.23	16
				5	15-Jan-10	2200.87	9
February 2010				**March 2010**			
6	8-Feb-10	2618.50	10	7	19-Mar-10	3505.94	14
April 2010				**May 2010**			
June 2010							

Snow cover depletion curve

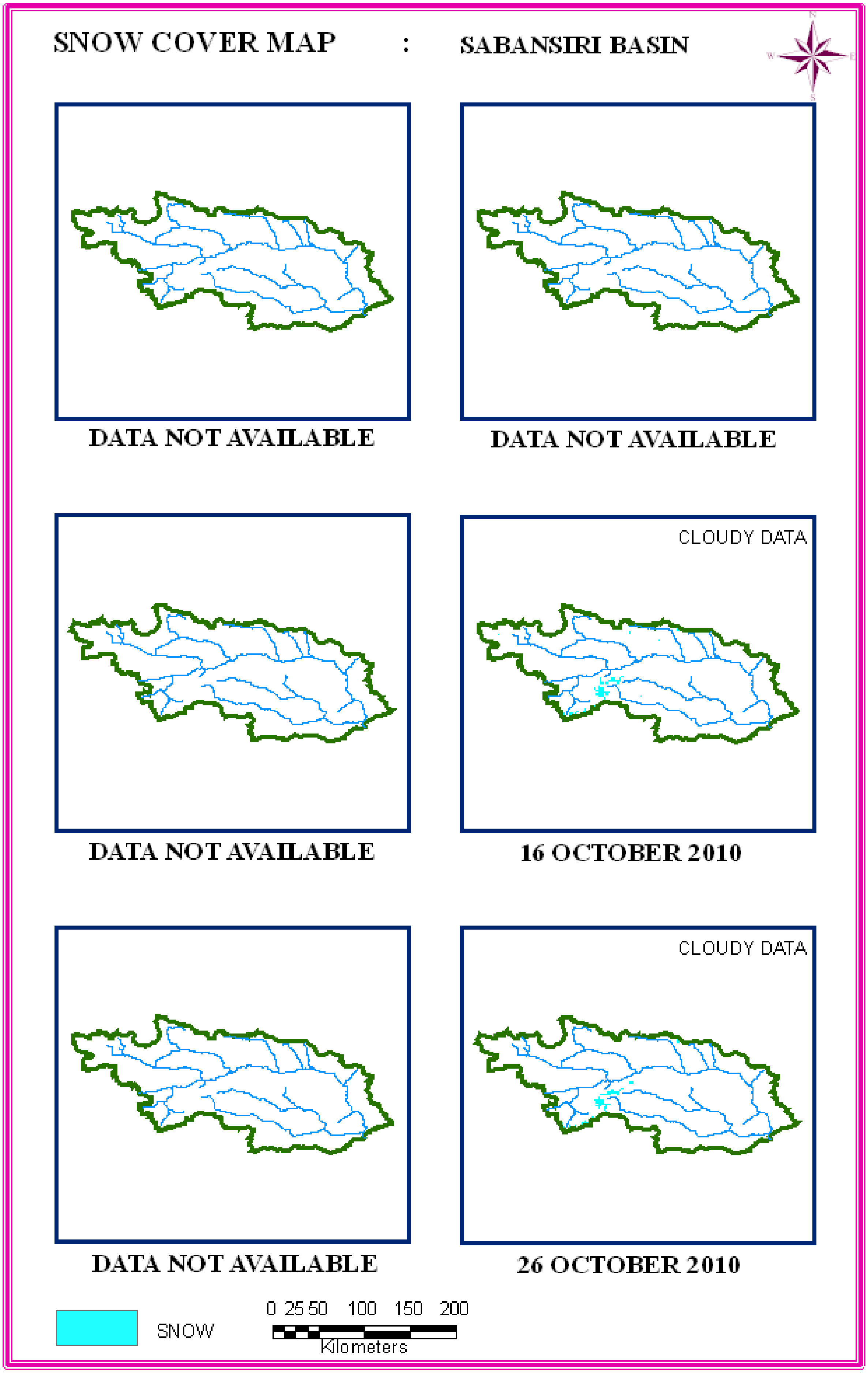




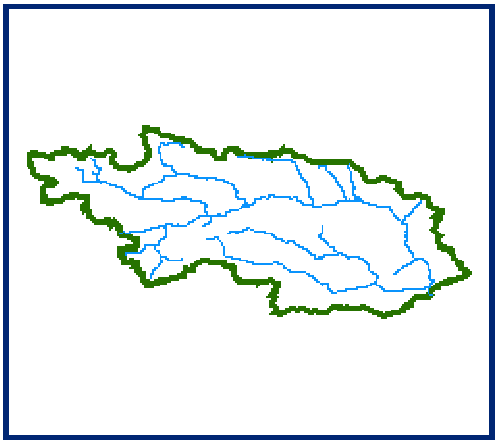
Snow cover depletion curve



SNOW COVER MAP


SNOW COVER MAP : SABANSIRI BASIN
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
16 OCTOBER 2010
DATA NOT AVAILABLE
CLOUDY DATA
26 OCTOBER 2010
SNOW
0 25 50 100 150 200
Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED

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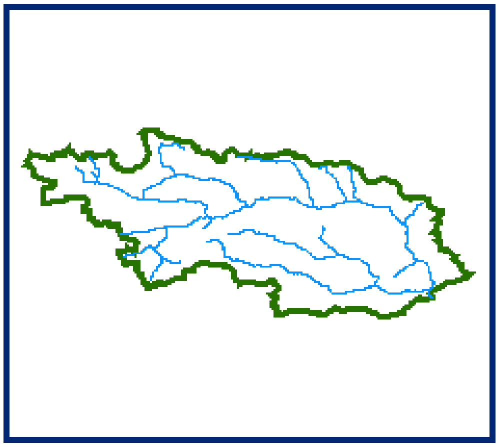

DATA USED

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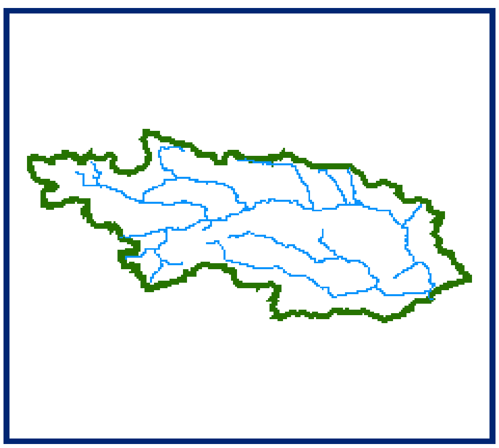


DATA USED

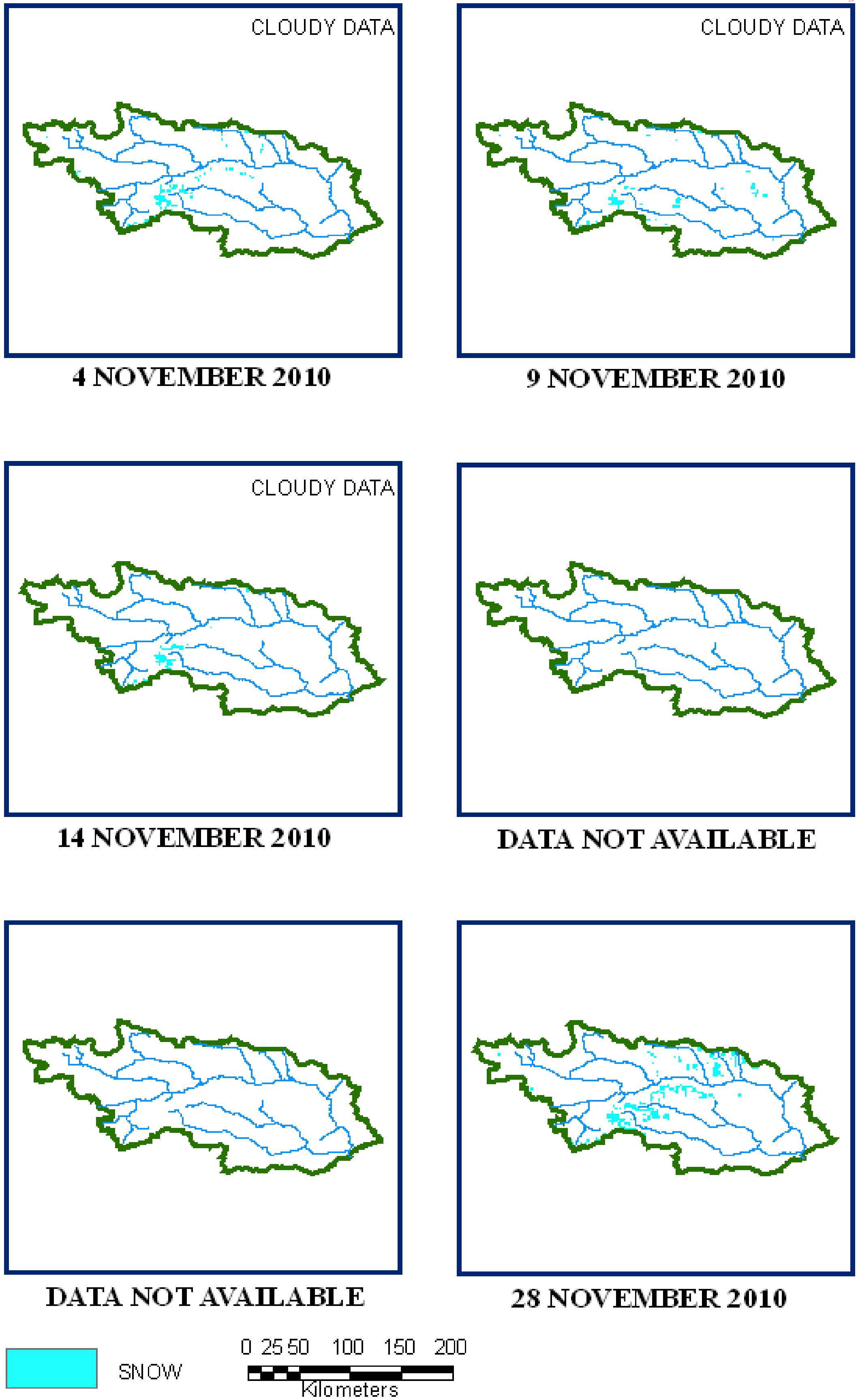
DATA NOT AVAILABLE

SNOW

0 25 50 100 150 200

Kilometers

SNOW COVER MAP : SABANSIRI BASIN



4 NOVEMBER 2010

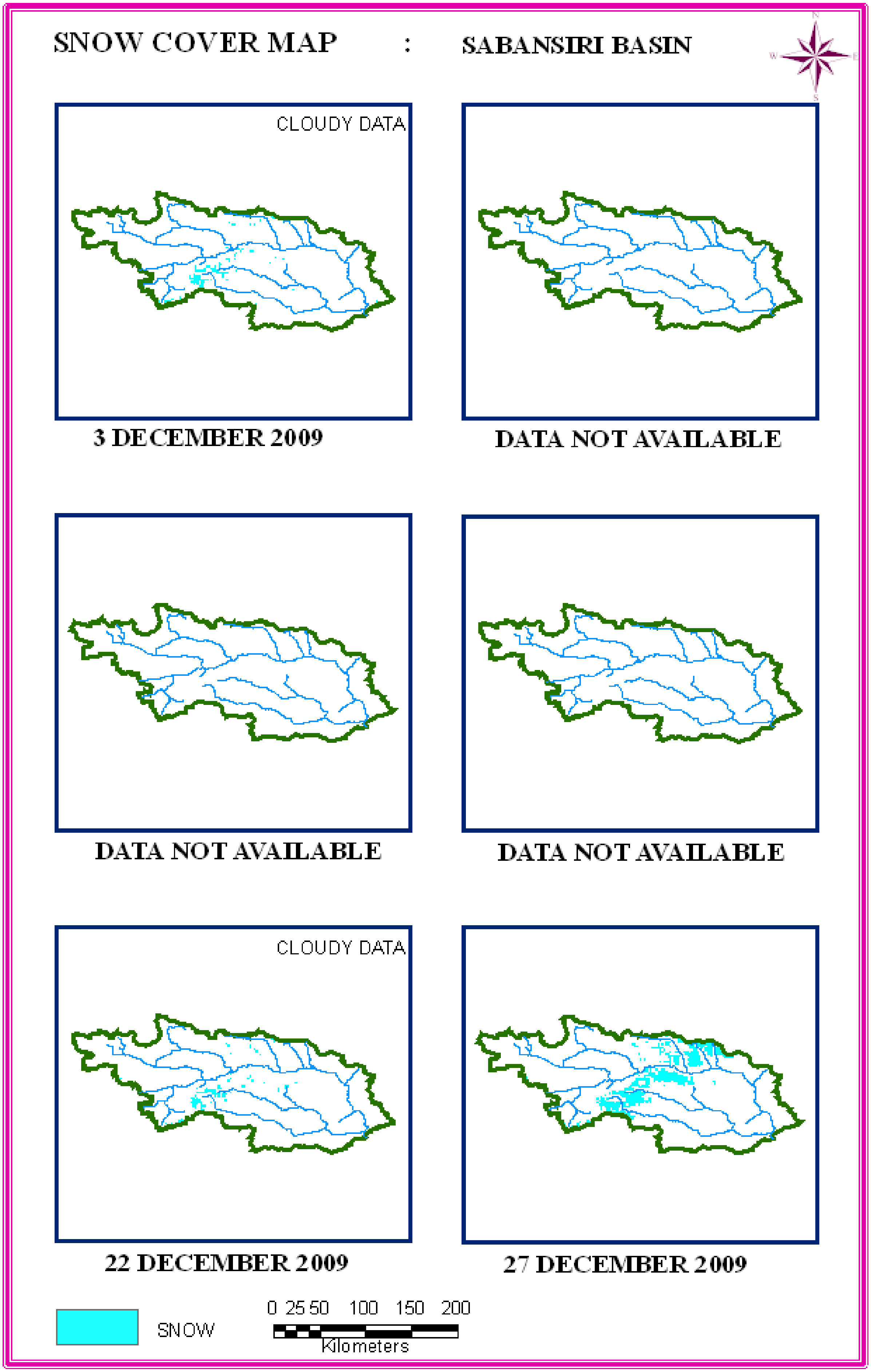
9 NOVEMBER 2010

14 NOVEMBER 2010

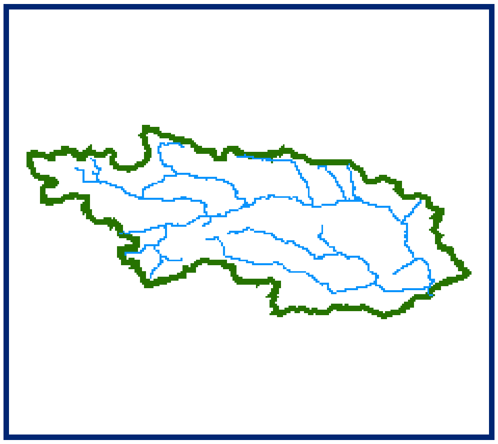
DATA NOT AVAILABLE

DATA NOT AVAILABLE

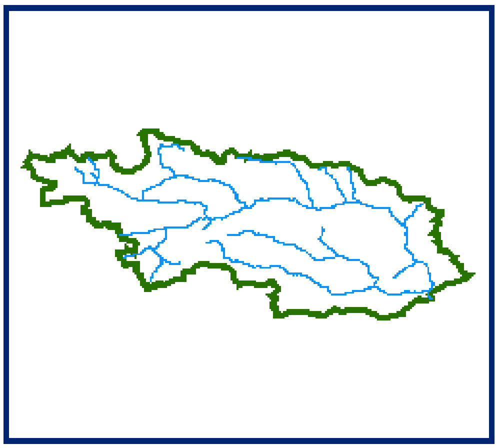
28 NOVEMBER 2010


SNOW COVER MAP : SABANSIRI BASIN
CLOUDY DATA
3 DECEMBER 2009
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
22 DECEMBER 2009
27 DECEMBER 2009
SNOW
0 25 50 100 150 200
Kilometers

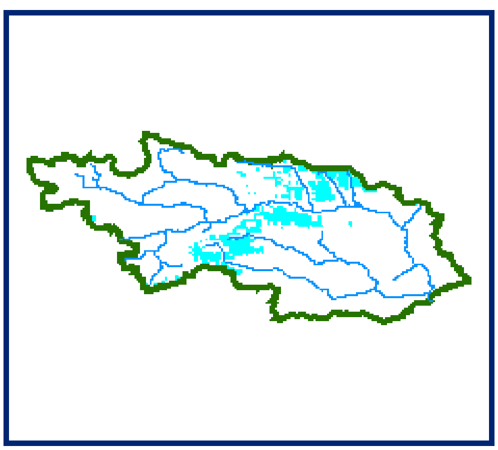
10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED
DATA NOT AVAILABLE



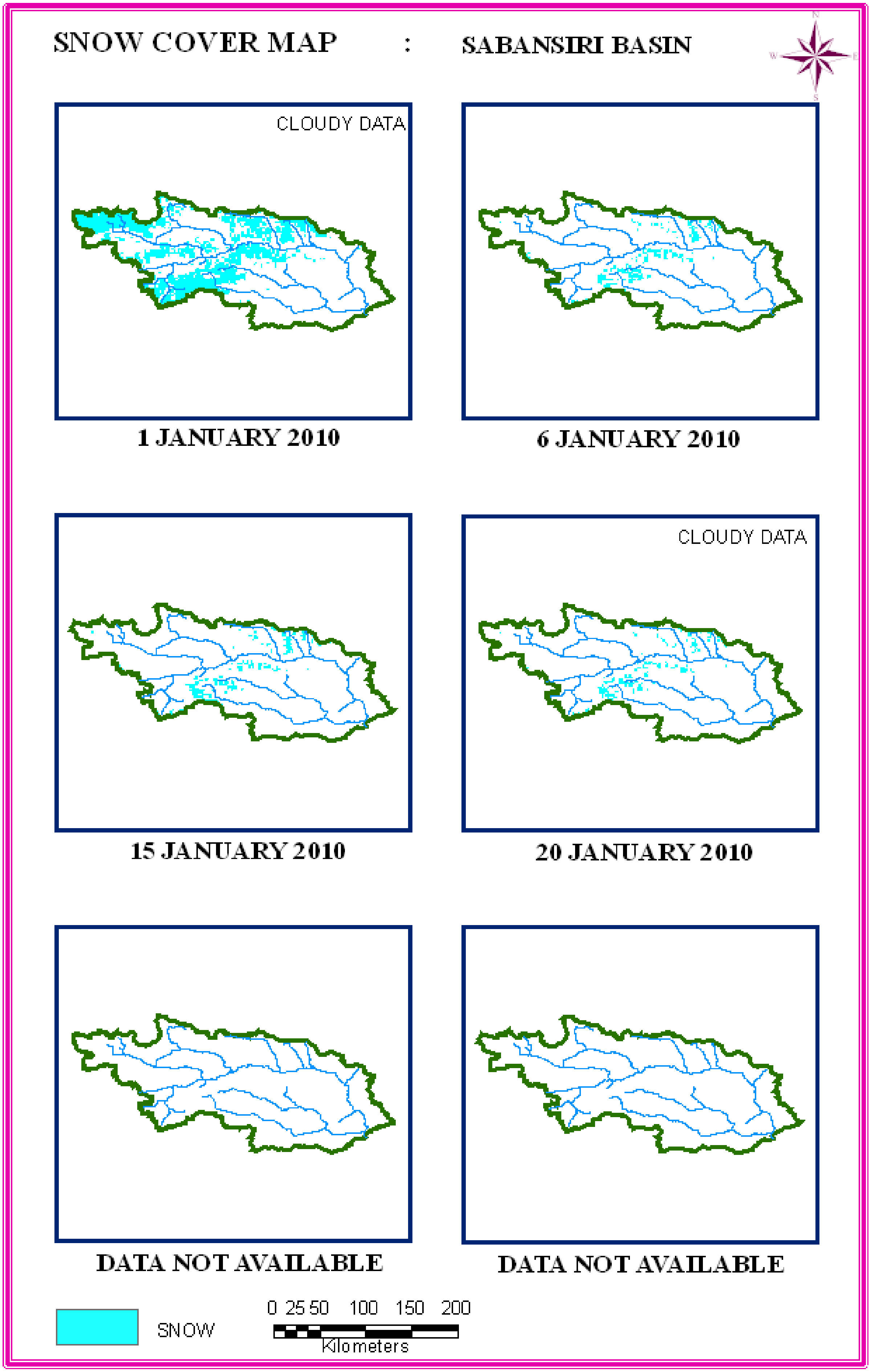
DATA USED
DATA NOT AVAILABLE



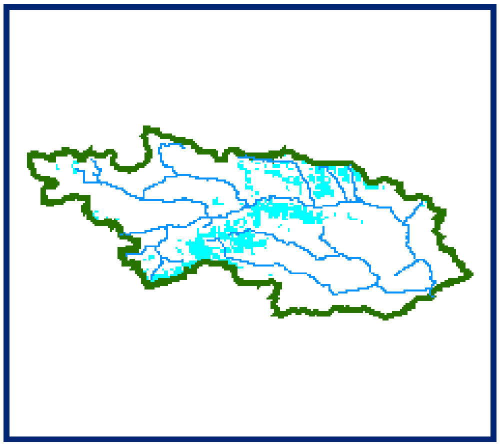
DATA USED
27 DECEMBER 2009

SNOW

0 25 50 100 150 200
Kilometers


SNOW COVER MAP : SABANSIRI BASIN
CLOUDY DATA
1 JANUARY 2010
6 JANUARY 2010
15 JANUARY 2010
CLOUDY DATA
20 JANUARY 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
SNOW
0 25 50 100 150 200
Kilometers

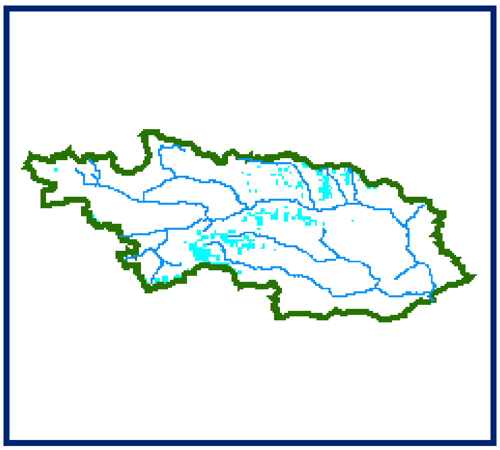
10 DAILY SNOW COVER MAP: SABANSIRI BASIN



DATA USED

1 JANUARY 2010

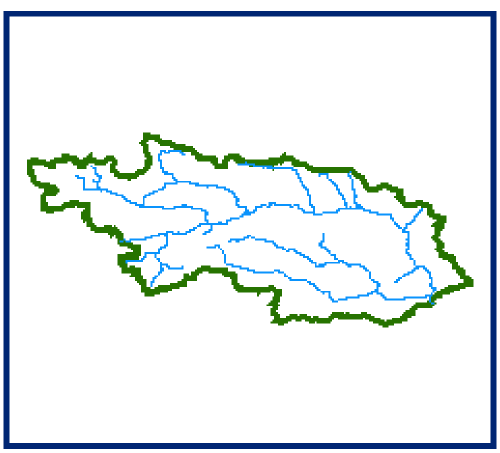
6 JANUARY 2010



DATA USED

15 JANUARY 2010

20 JANUARY 2010



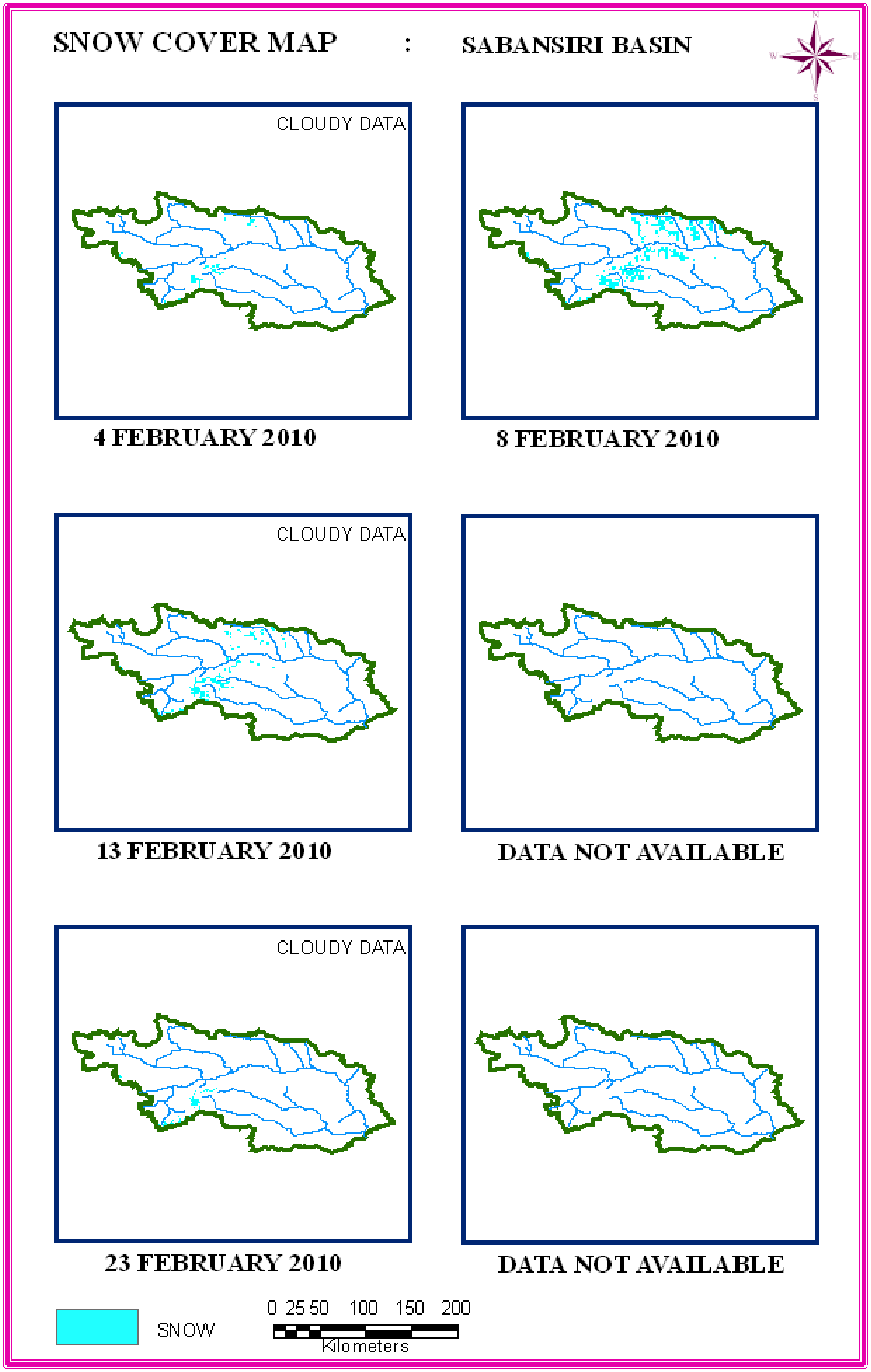
DATA USED

DATA NOT AVAILABLE

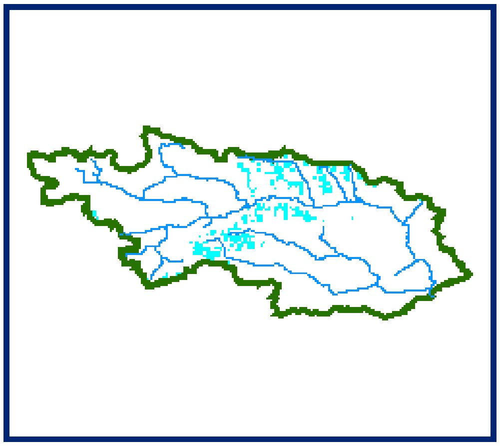
SNOW

0 25 50 100 150 200

Kilometers

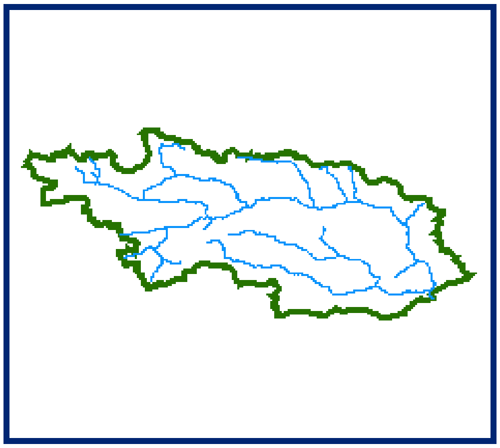

SNOW COVER MAP : SABANSIRI BASIN
CLOUDY DATA
4 FEBRUARY 2010
8 FEBRUARY 2010
CLOUDY DATA
13 FEBRUARY 2010
DATA NOT AVAILABLE
CLOUDY DATA
23 FEBRUARY 2010
DATA NOT AVAILABLE
SNOW
0 25 50 100 150 200
Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



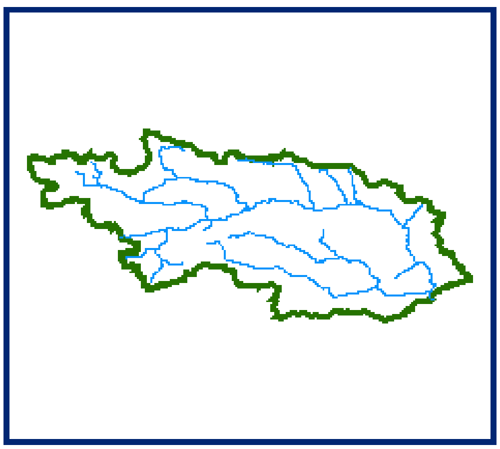
DATA USED

8 FABRUARY 2010



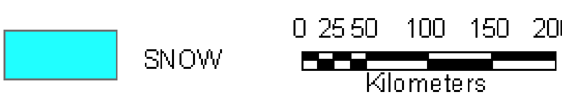
DATA USED

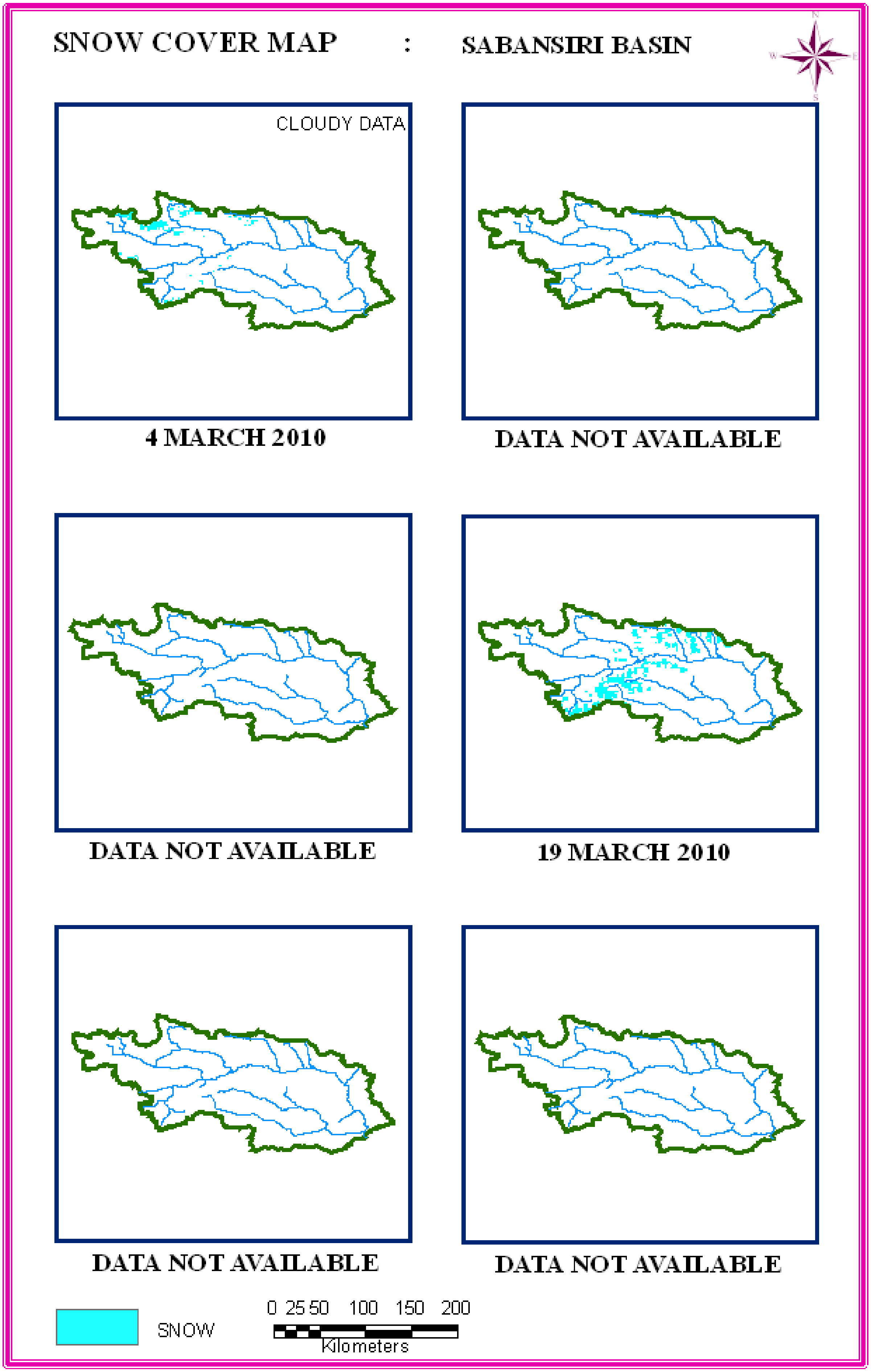
DATA NOT AVAILABLE



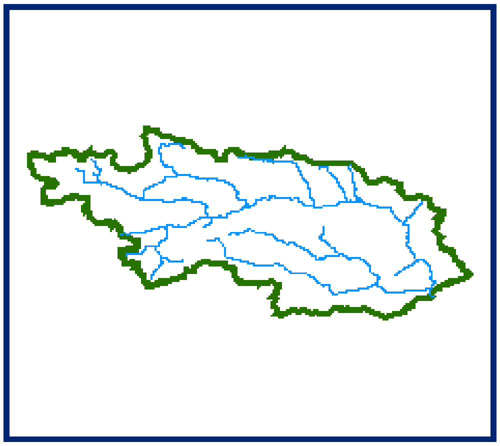
DATA USED

DATA NOT AVAILABLE




SNOW COVER MAP : SABANSIRI BASIN
CLOUDY DATA
4 MARCH 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
19 MARCH 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
SNOW
0 25 50 100 150 200
Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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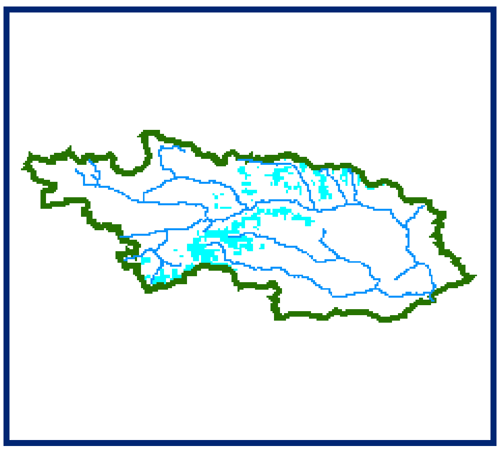
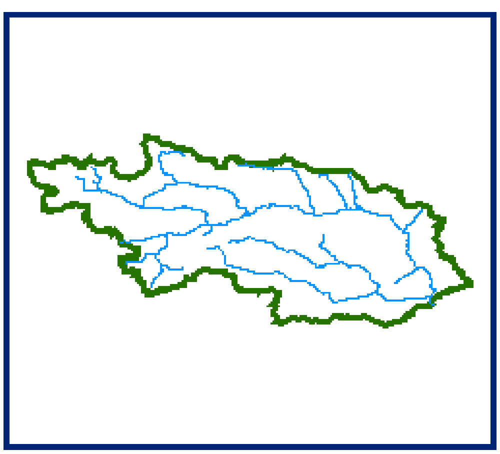


DATA USED

19 MARCH 2010



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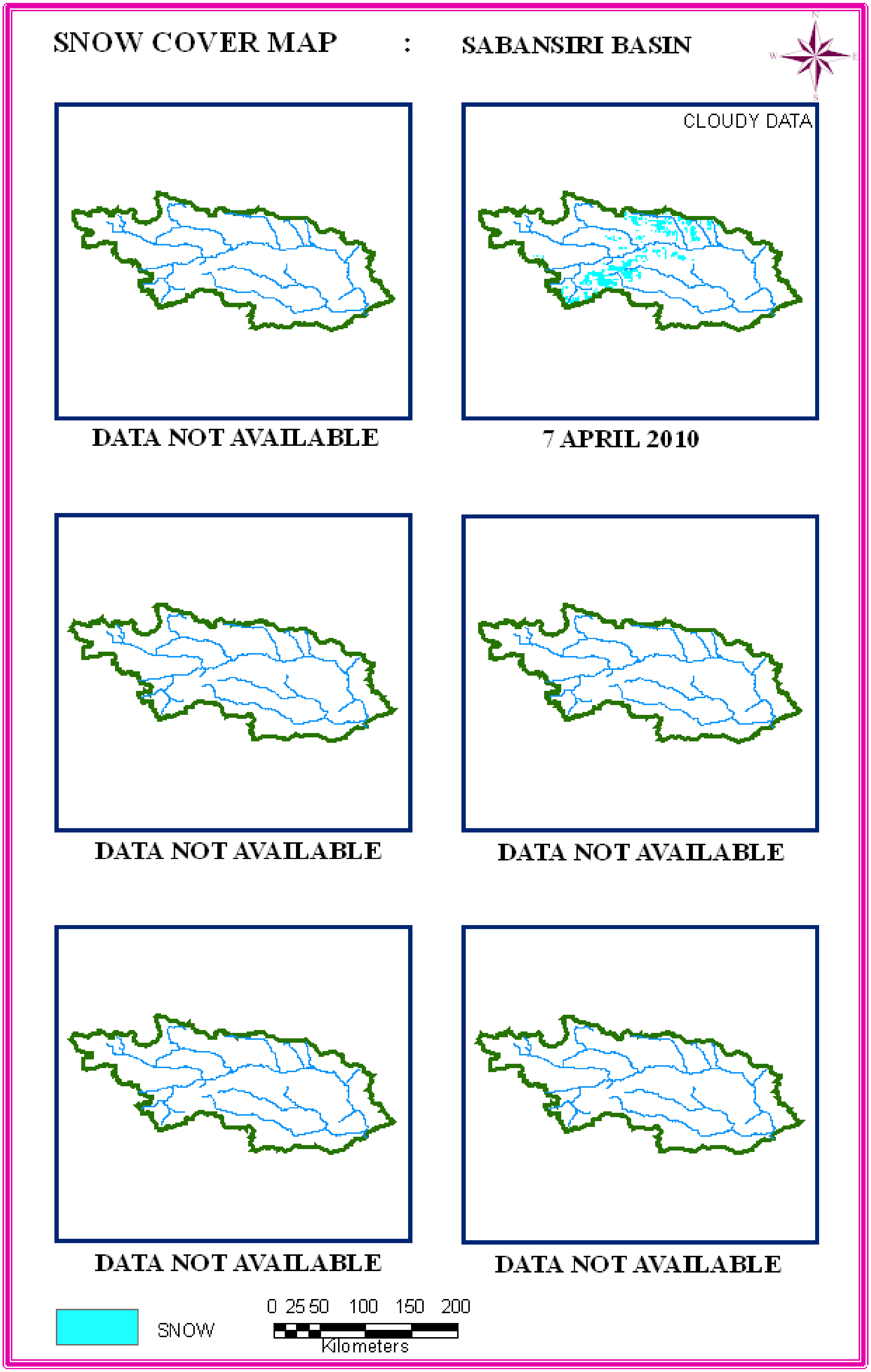
DATA NOT AVAILABLE

SNOW

0 25 50 100 150 200

Kilometers


SNOW COVER MAP : SABANSIRI BASIN
CLOUDY DATA
DATA NOT AVAILABLE
7 APRIL 2010
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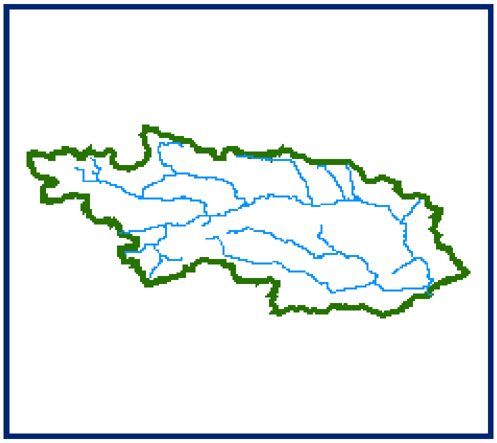
DATA NOT AVAILABLE
SNOW
0 25 50 100 150 200
Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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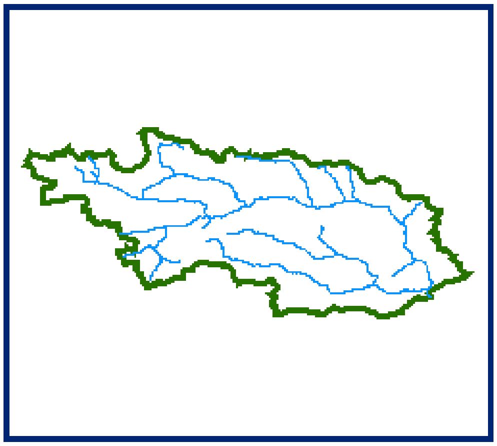

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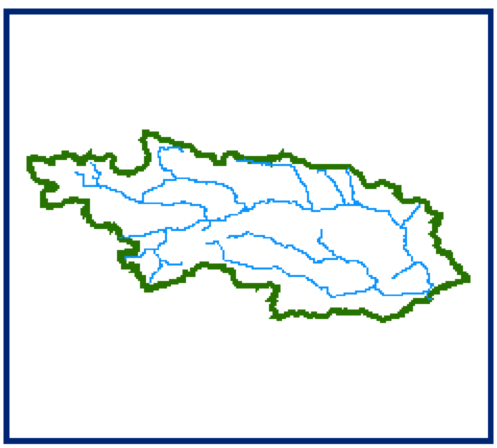

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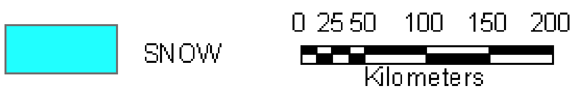
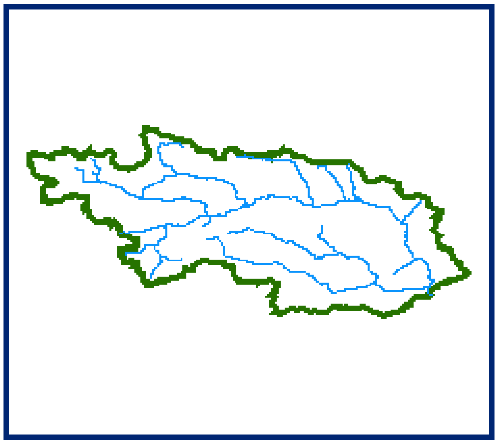


SNOW COVER MAP : SABANSIRI BASIN



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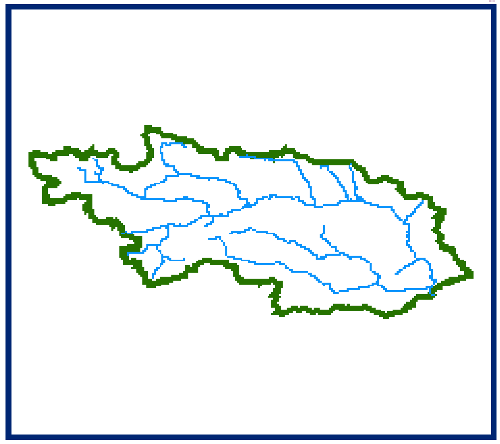

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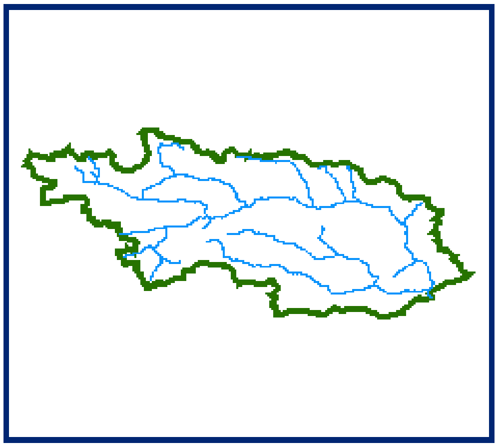

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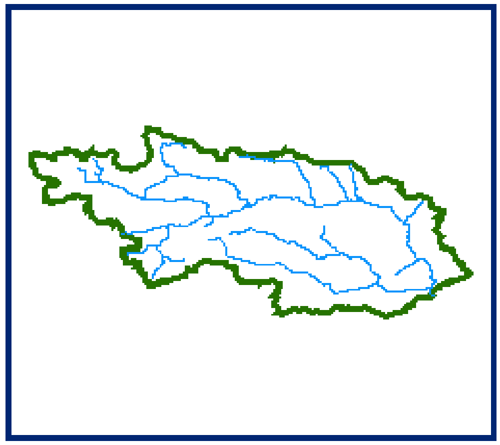

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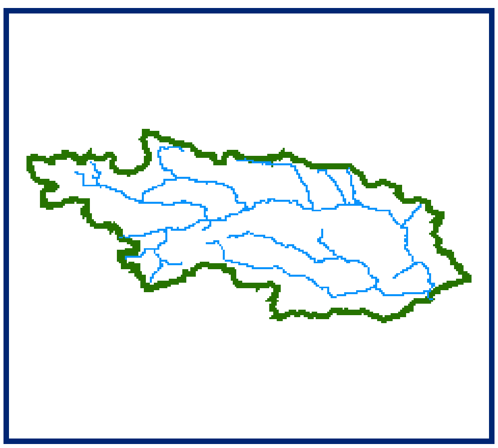

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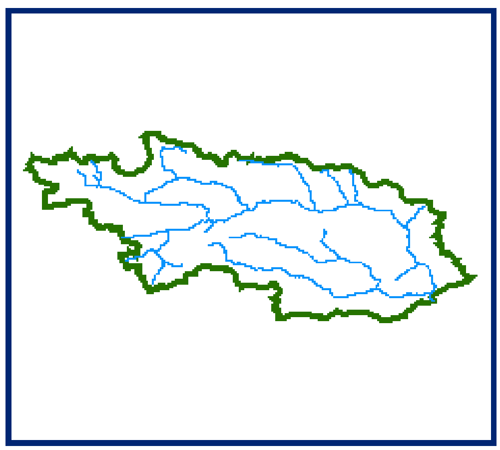

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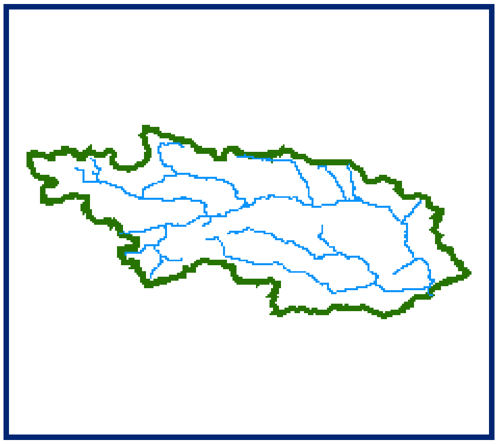
10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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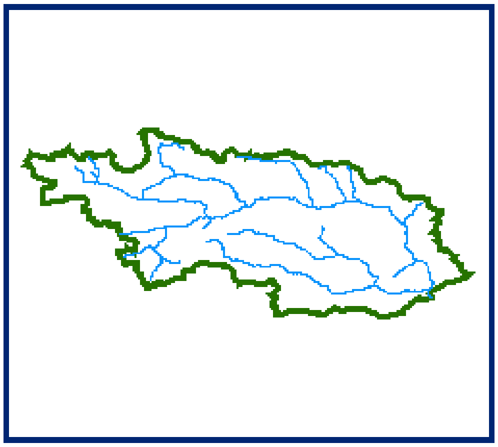

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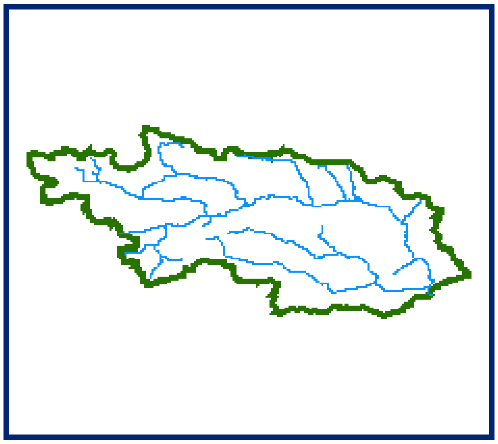

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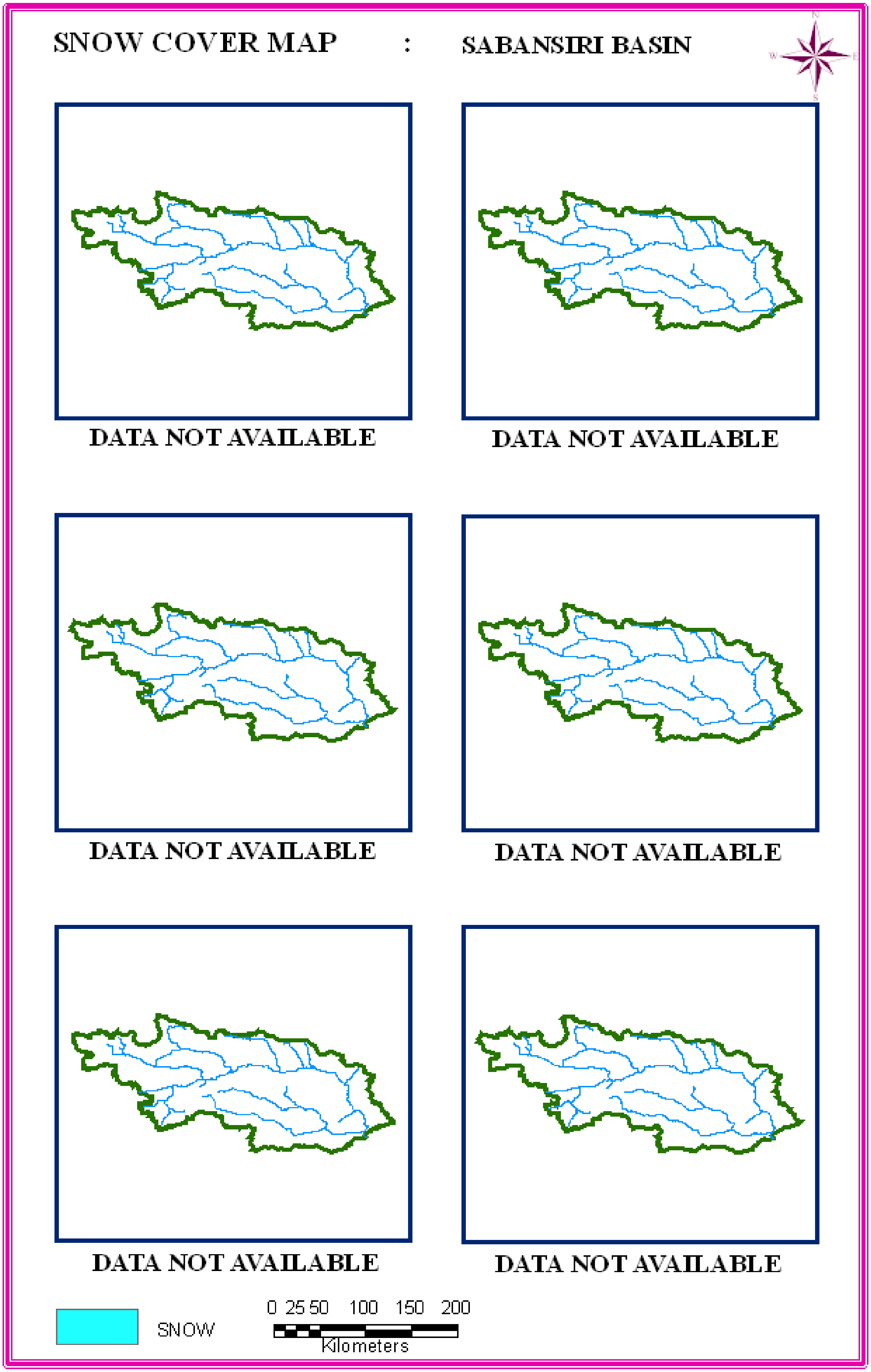
SNOW

0 25 50 100 150 200

Kilometers


SNOW COVER MAP : SABANSIRI BASIN
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DATA NOT AVAILABLE
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DATA NOT AVAILABLE
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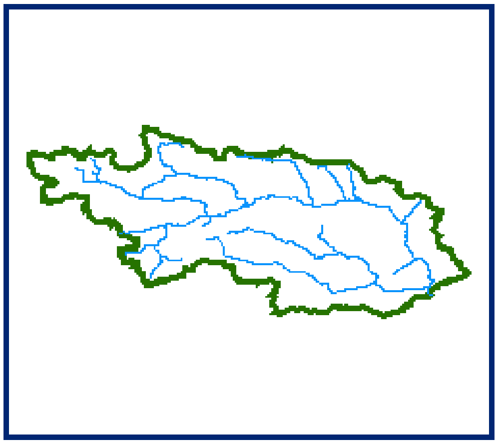
DATA NOT AVAILABLE
SNOW
0 25 50 100 150 200
Kilometers

10 DAILY SNOW COVER MAP: SABANSIRI BASIN



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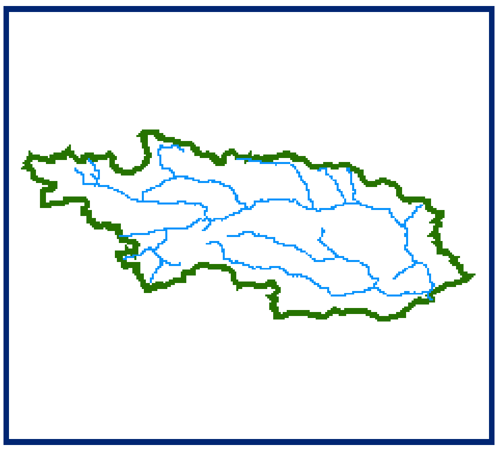

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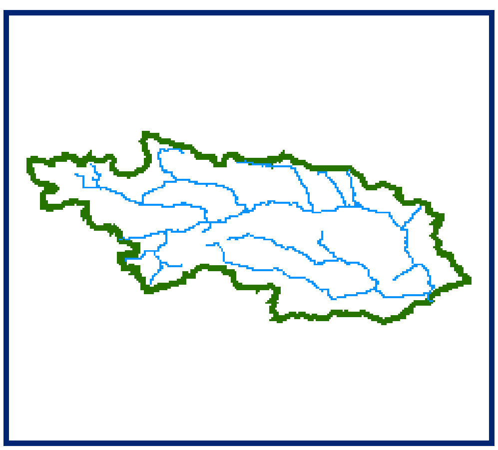


DATA USED

DATA NOT AVAILABLE

SNOW

0 25 50 100 150 200

Kilometers

TAWANG BASIN

AREAL EXTENT OF SNOW (5 DAILY)

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

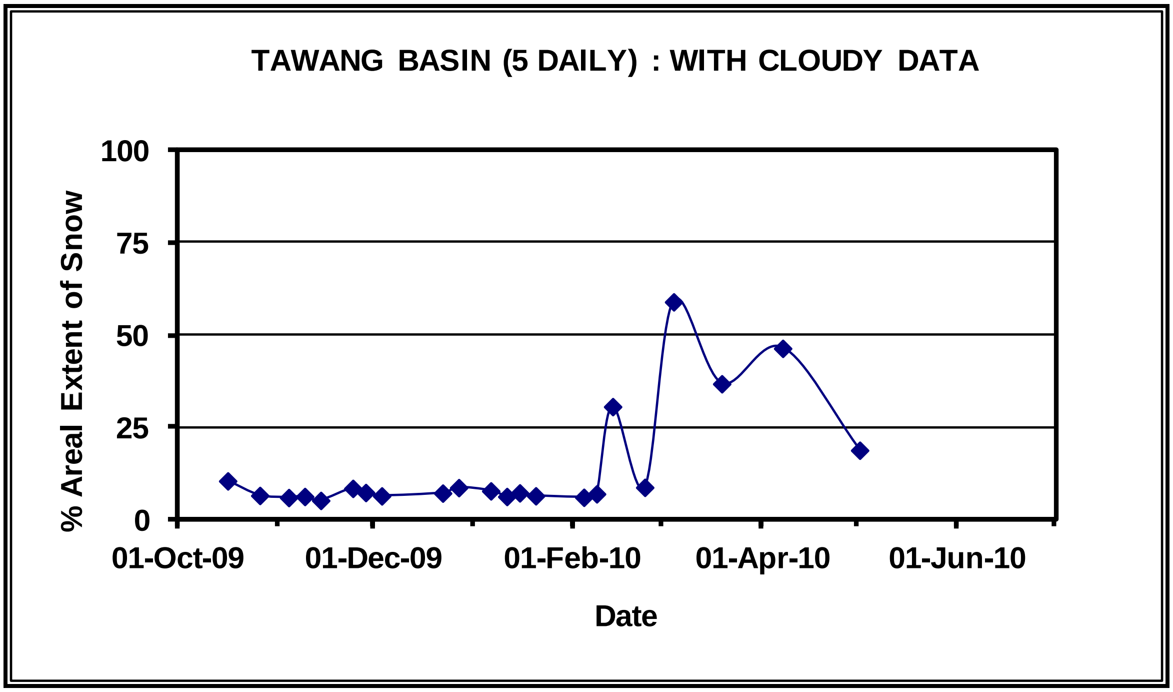
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2009							
1	16-Oct-09	710	11	2	26-Oct-09	445	7
November 2009							
3	4-Nov-09	407	6	6	24nov09	574	9
4	9-Nov-09	426	6	7	28-Nov-09	498	7
5	14-Nov-09	354	5				
December 2009							
8	3-Dec-09	437	6	10	27-Dec-09	587	9
9	22-Dec-09	488	7				
January 2010							
11	6-Jan-10	528	8	13	15-Jan-10	492	7
12	11-Jan-10	426	6	14	20-Jan-10	438	7
February 2010							
15	4-Feb-10	411	6	17	13-Feb-10	2061	31
16	8-Feb-10	474	7	18	23-Feb-10	593	9
March 2010							
19	4-Mar-10	3307	49	20	19-Mar-10	2477	37
April 2010							
21	7-Apr-10	3122	46				
May 2010							
22	1-May-10	1268	19				
June 2010							

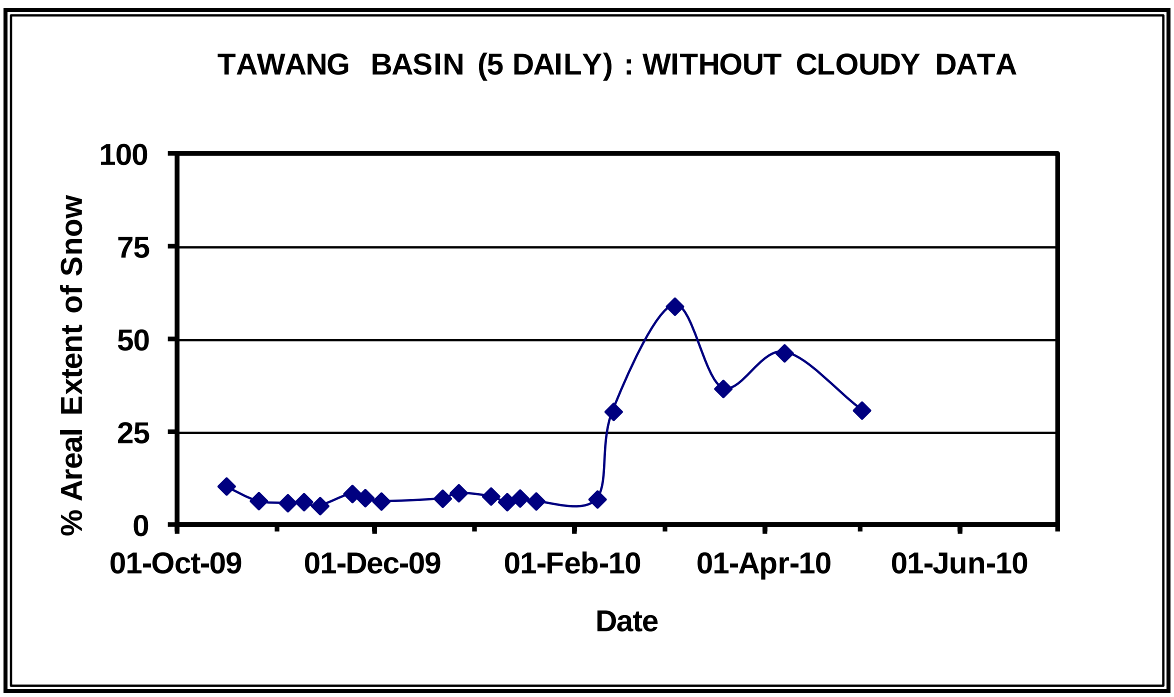
AREAL EXTENT OF SNOW (10 DAILY)

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

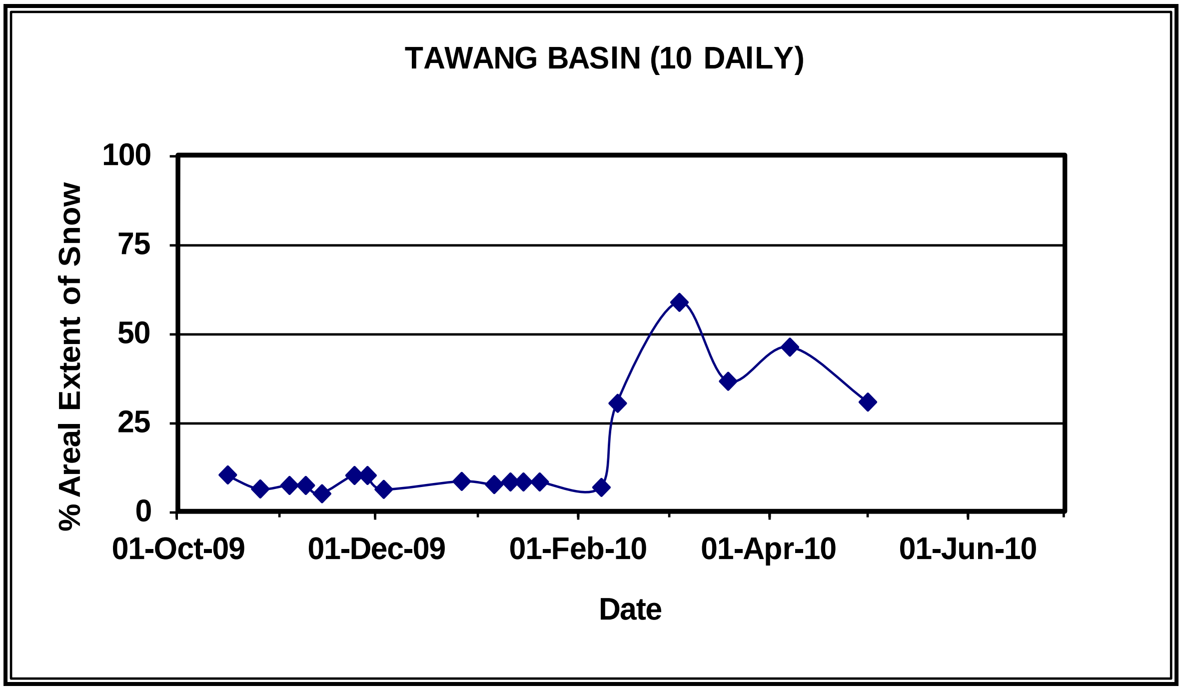
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2009				**November 2009**			
1	16-Oct-09	710	11	3	4-Nov-09	511	8
2	26-Oct-09	445	7	4	14-Nov-09	354	5
				5	24-Nov-09	699	10
December 2009				**January 2010**			
6	3-Dec-09	437	6	8	6-Jan-10	528	8
7	27-Dec-09	587	9	9	15-Jan-10	577	9
February 2010				**March 2010**			
10	8-Feb-10	474	7	12	19-Mar-10	2477	37
11	13-Feb-10	2061	31				
April 2010				**May 2010**			
13	7-Apr-10	3122	46	14	01-May-10	2061	31
June 2010							

Snow cover depletion curve



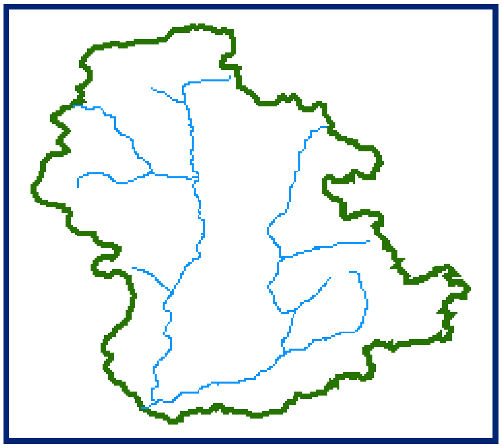


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : TAWANG BASIN



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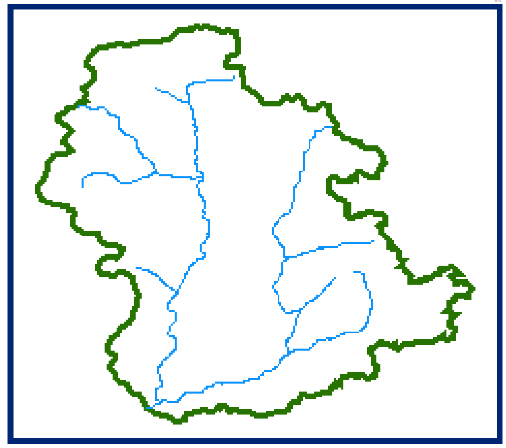

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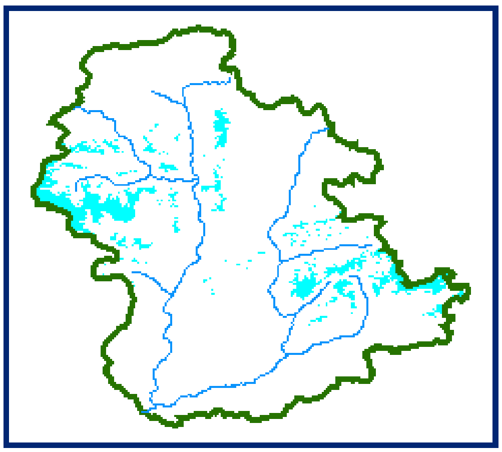
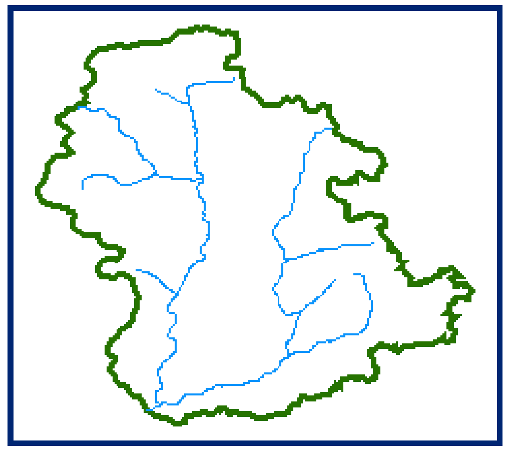


16 OCTOBER 2009



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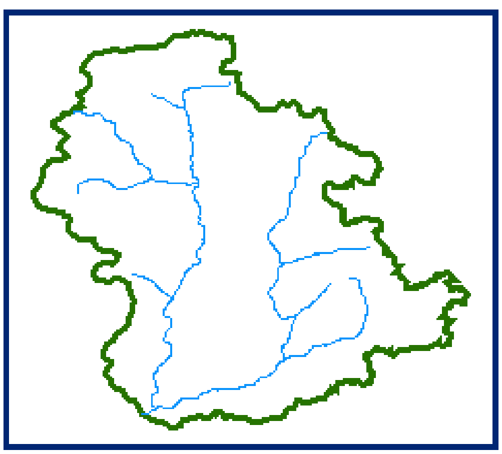

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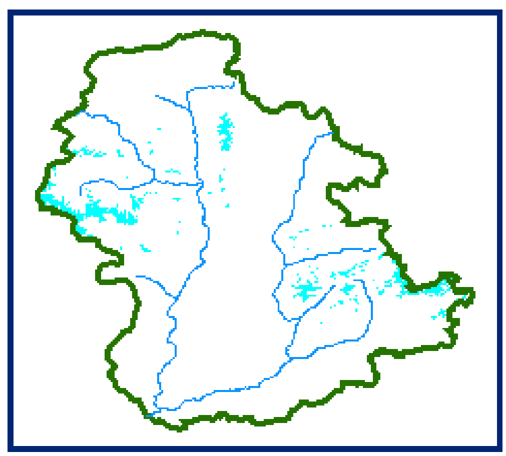


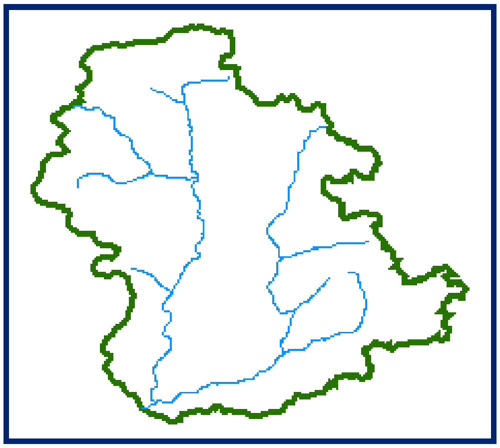
26 OCTOBER 2009

SNOW

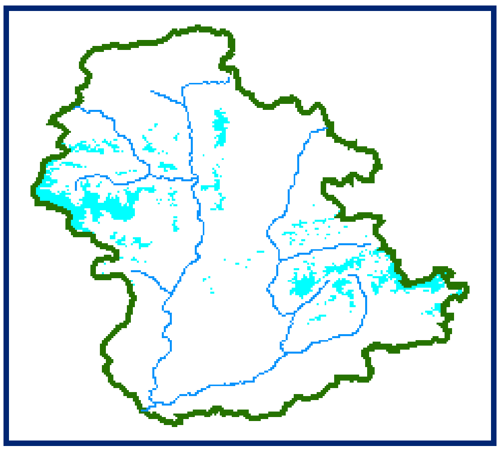
0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
16 OCTOBER 2009



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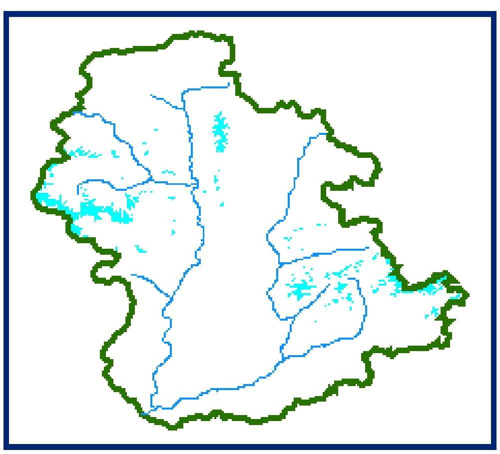

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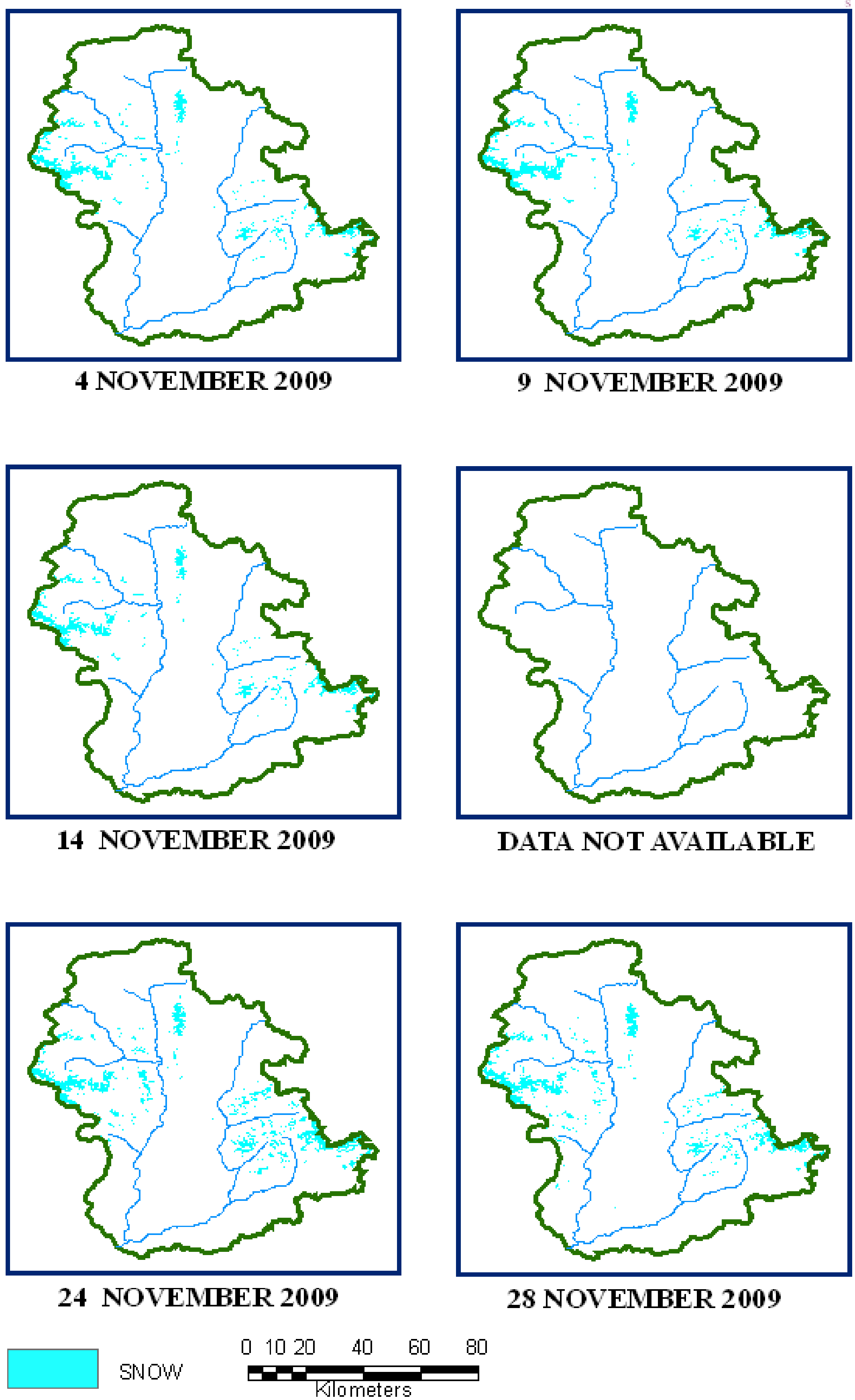
16 OCTOBER 2009

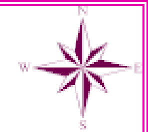
SNOW

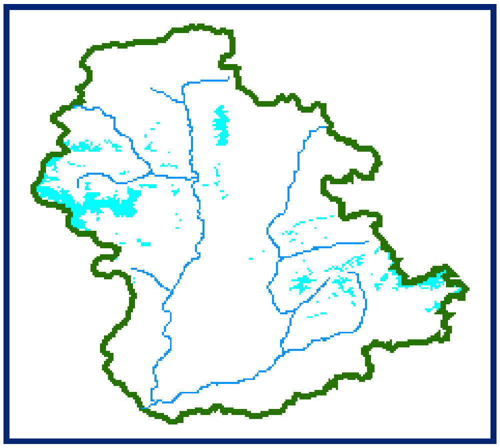
0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



10 DAILY SNOW COVER MAP: TAWANG BASIN





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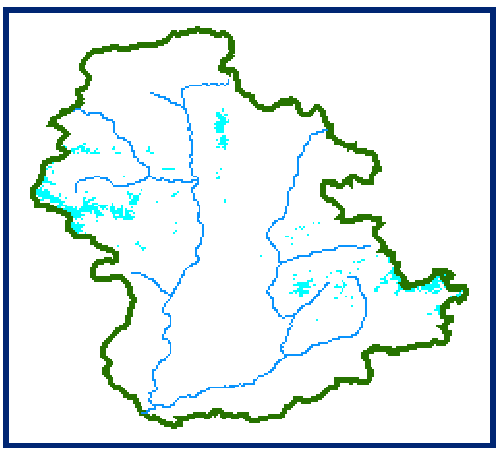
4 NOVEMBER 2009

9 NOVEMBER 2009



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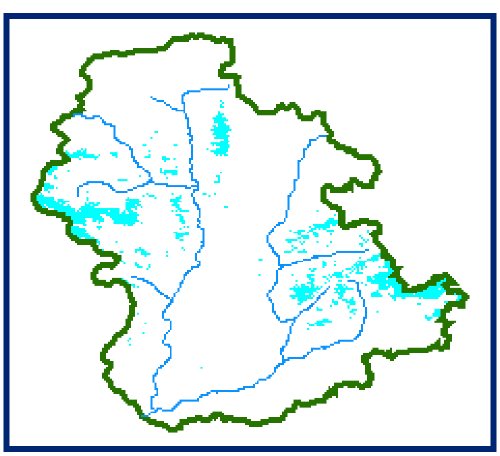
14 NOVEMBER 2009



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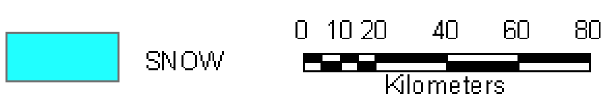
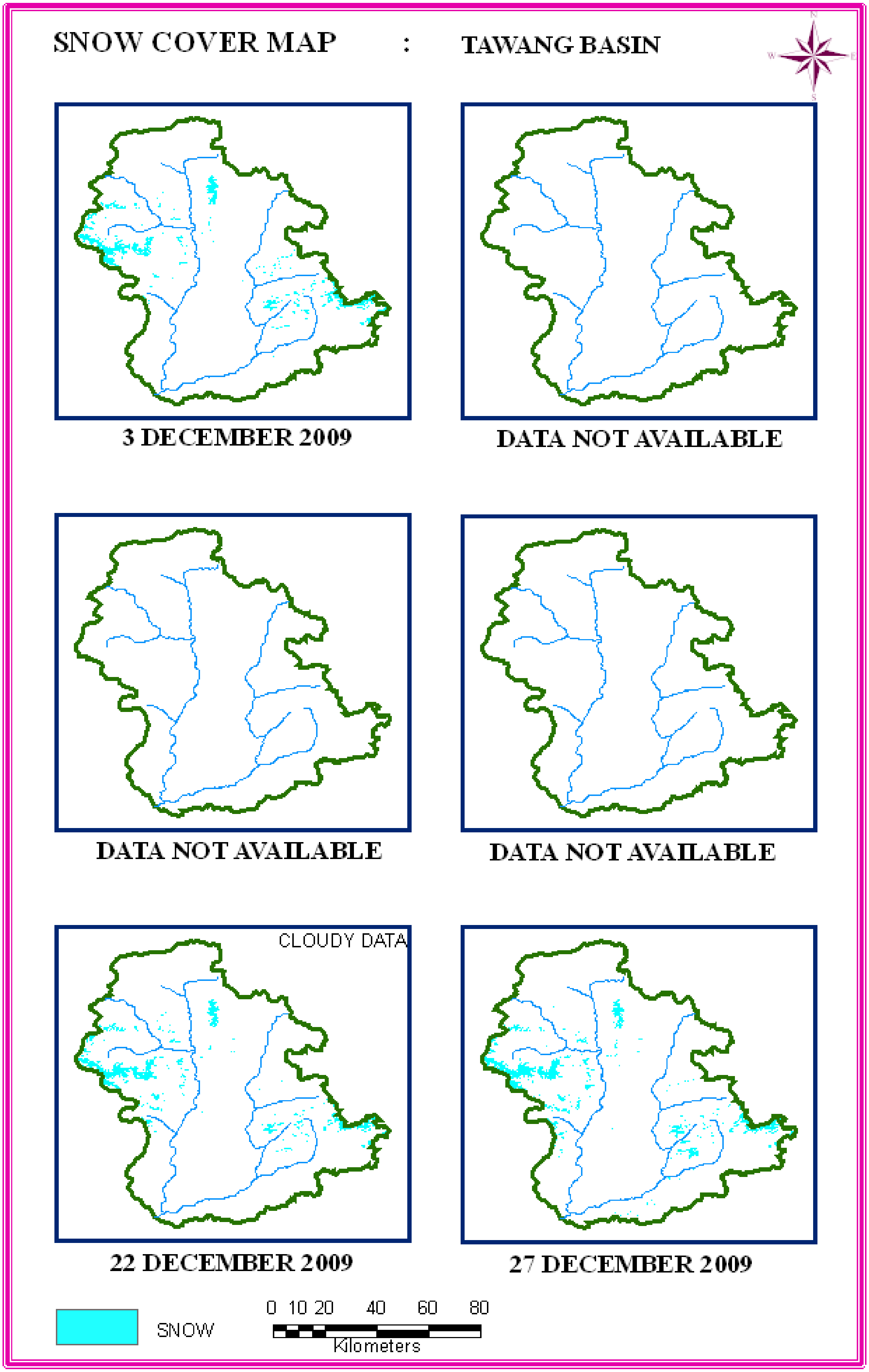
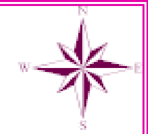
24 NOVEMBER 2009

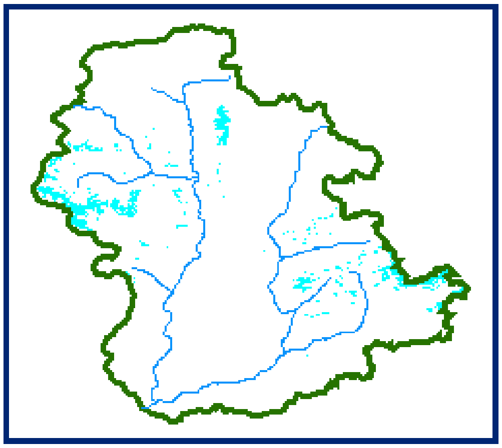
28 NOVEMBER 2009




SNOW COVER MAP : TAWANG BASIN
3 DECEMBER 2009
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
22 DECEMBER 2009
27 DECEMBER 2009
SNOW
0 10 20 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN





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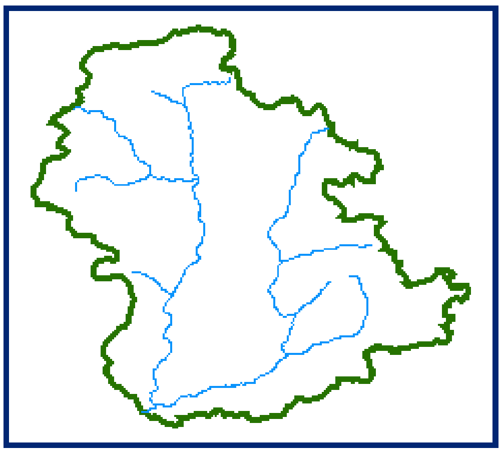

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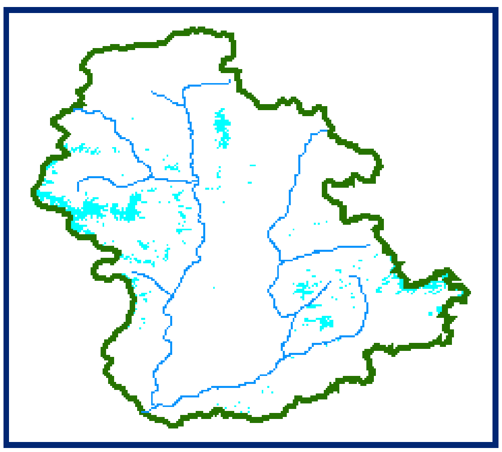

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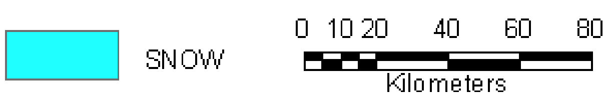
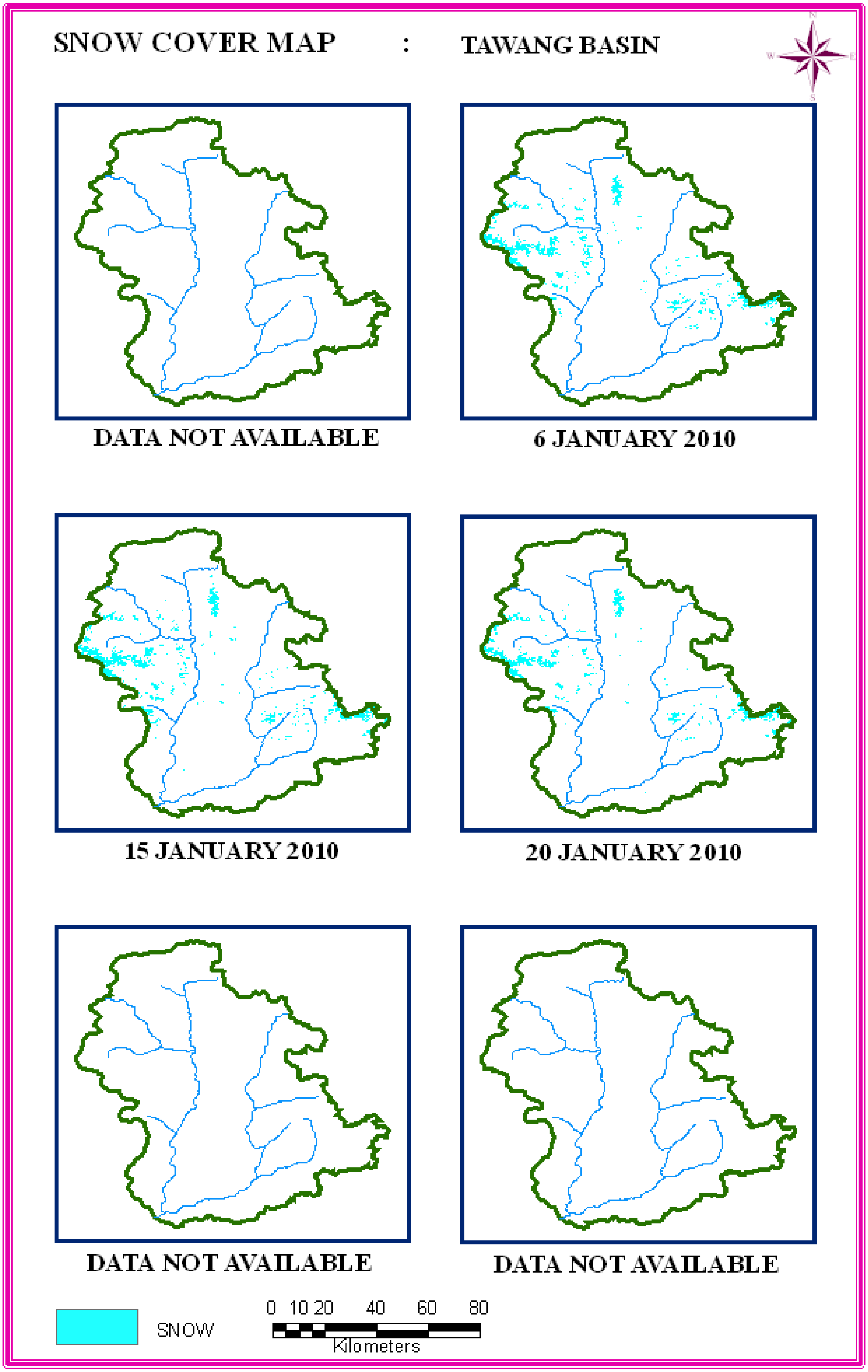
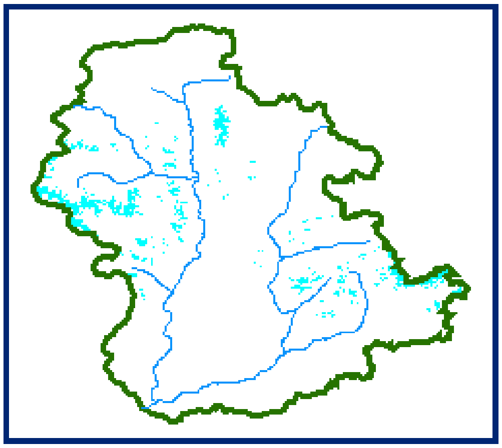



SNOW COVER MAP : TAWANG BASIN
DATA NOT AVAILABLE
6 JANUARY 2010
15 JANUARY 2010
20 JANUARY 2010
DATA NOT AVAILABLE
DATA NOT AVAILABLE
SNOW
0 10 20 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



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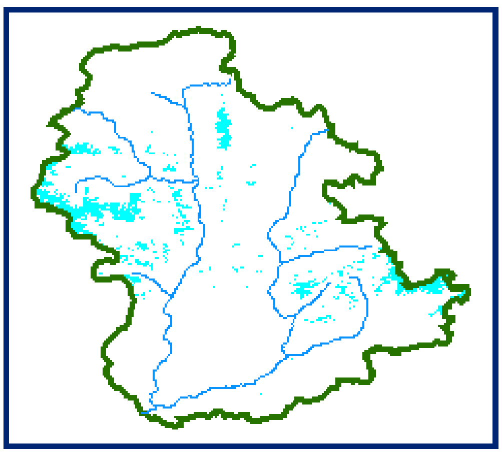

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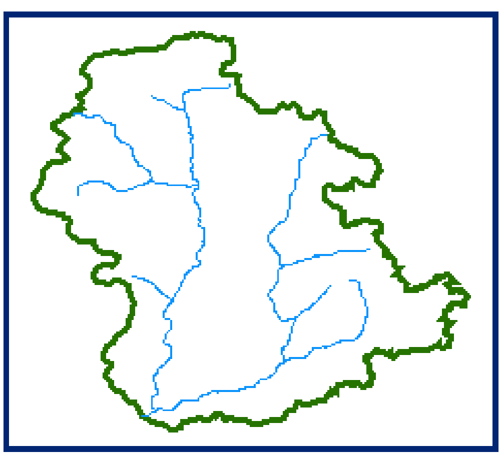
11 JANUARY 2010

15 JANUARY 2010

20 JANUARY 2010



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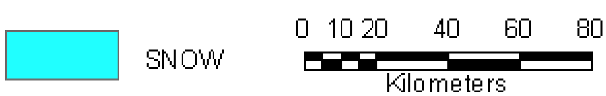
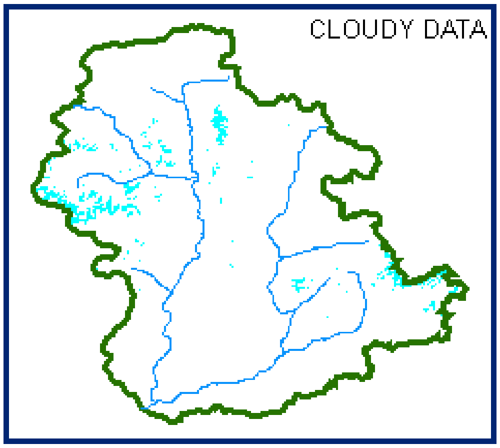
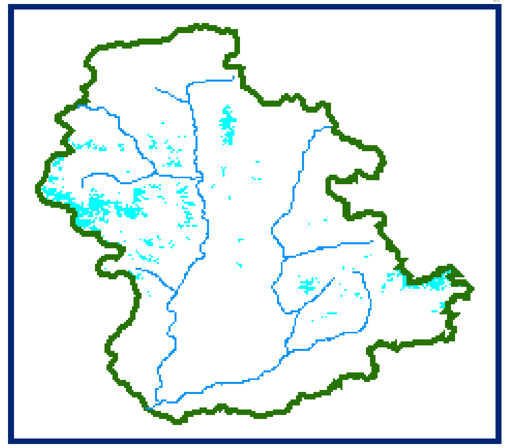


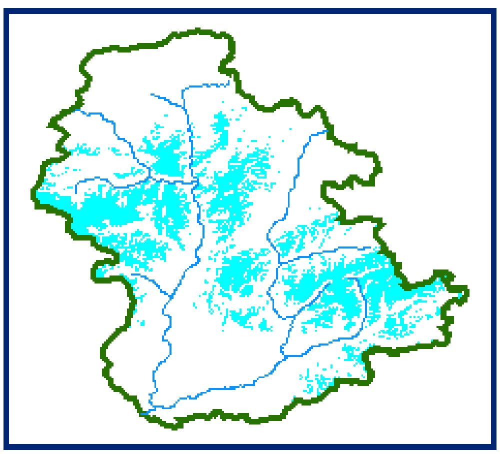
SNOW COVER MAP : TAWANG BASIN



4 FABRUARY 2010



8 FABRUARY 2010



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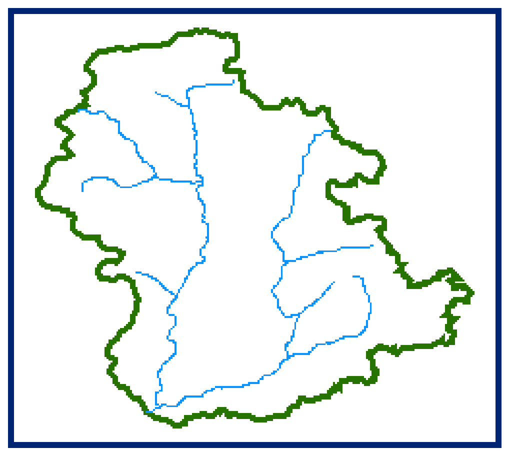

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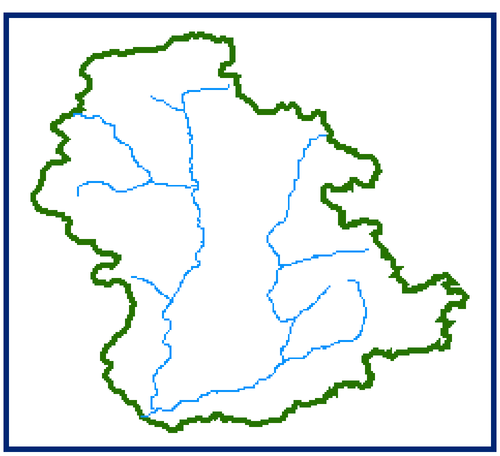

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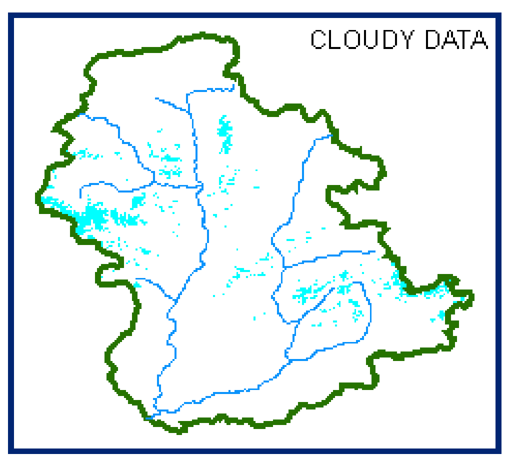
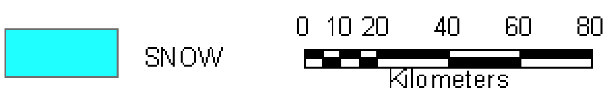
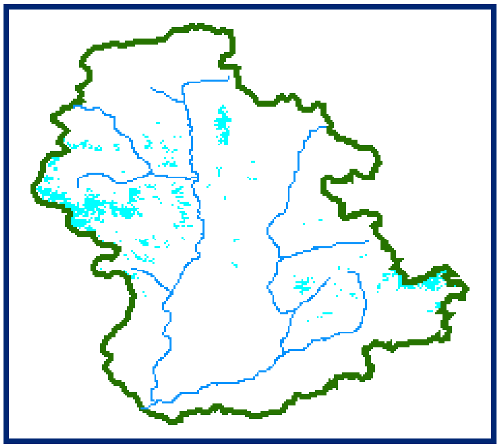


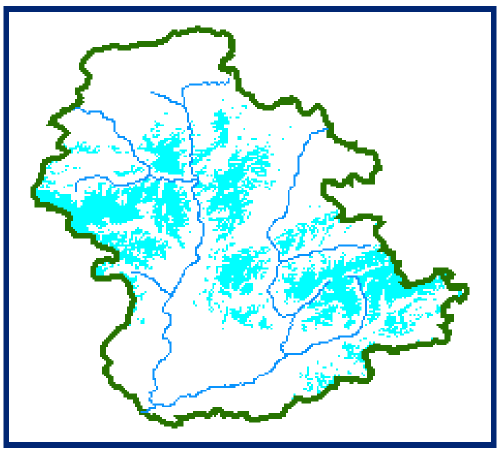
27 FABRUARY 2010



10 DAILY SNOW COVER MAP: TAWANG BASIN



DATA USED
8 FABRUARY 2010



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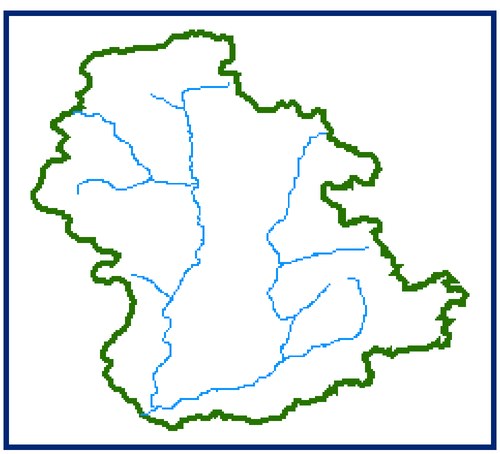
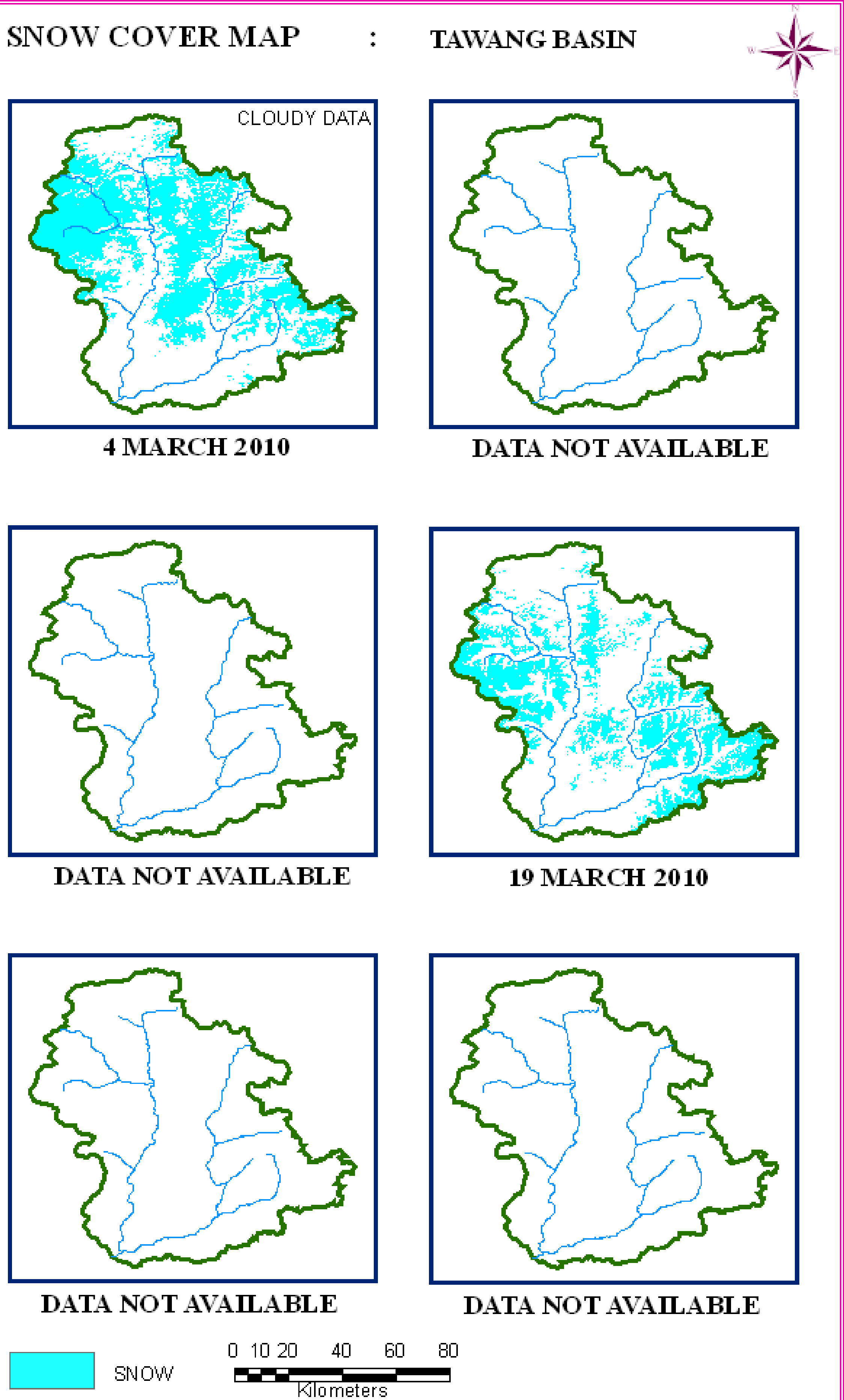


DATA USED
DATA NOT AVAILABLE

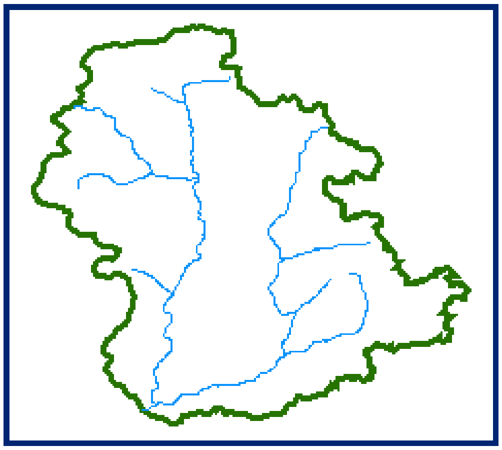
SNOW

0 10 20 40 60 80
Kilometers

SNOW COVER MAP : TAWANG BASIN



10 DAILY SNOW COVER MAP: TAWANG BASIN



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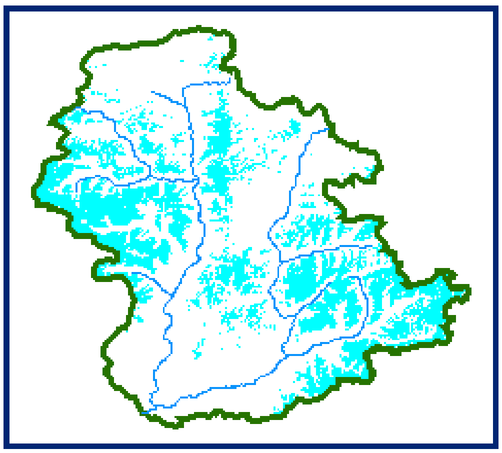

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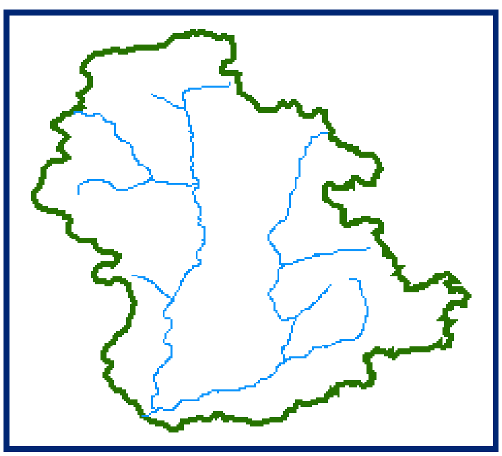

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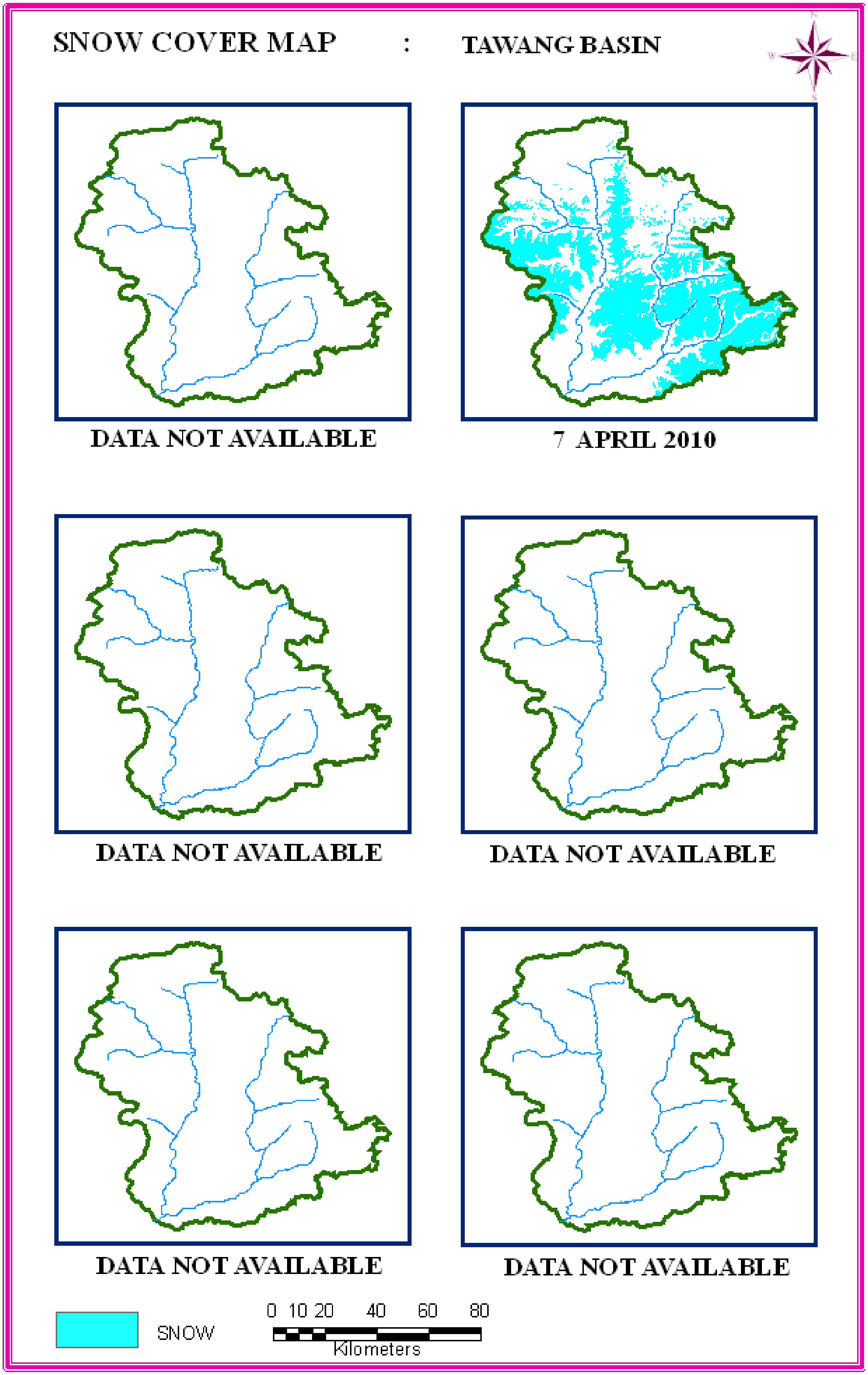
SNOW

0 10 20 40 60 80

Kilometers


SNOW COVER MAP : TAWANG BASIN
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7 APRIL 2010
DATA NOT AVAILABLE
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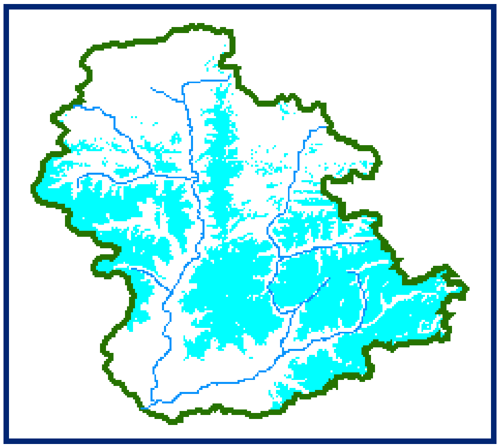
DATA NOT AVAILABLE
SNOW
0 10 20 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN



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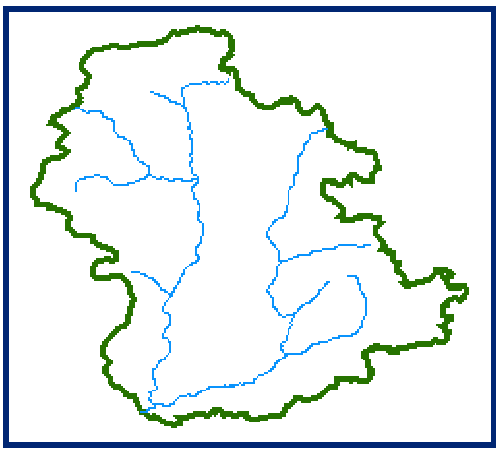

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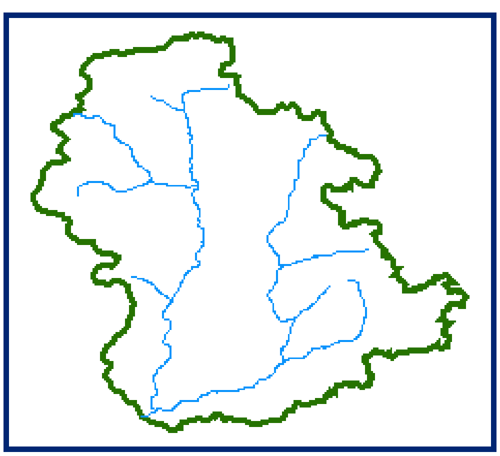

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SNOW

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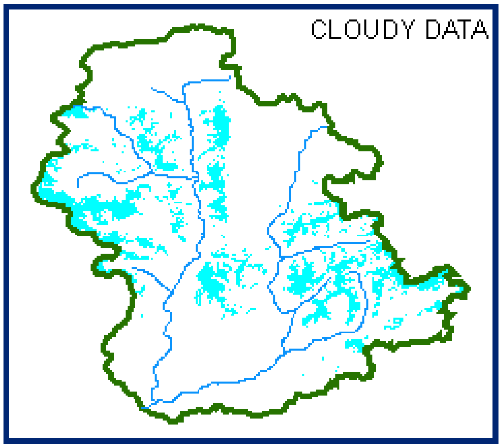
Kilometers

SNOW COVER MAP : TAWANG BASIN



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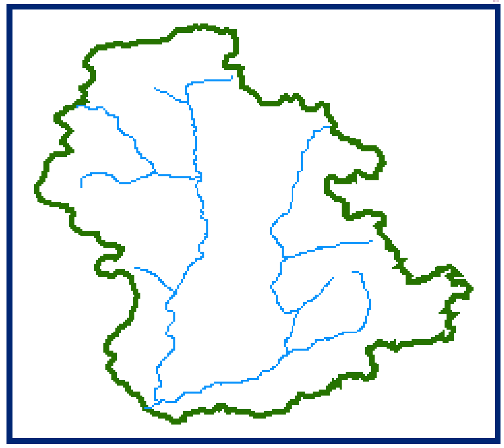

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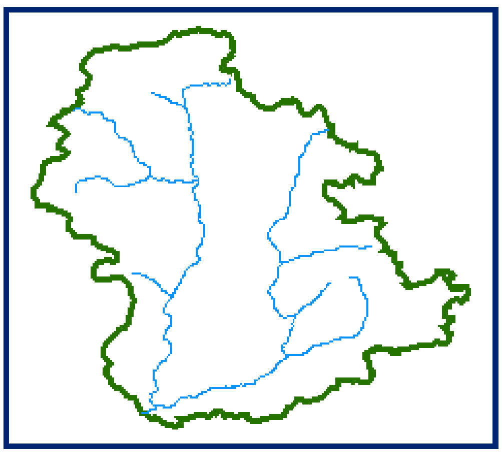

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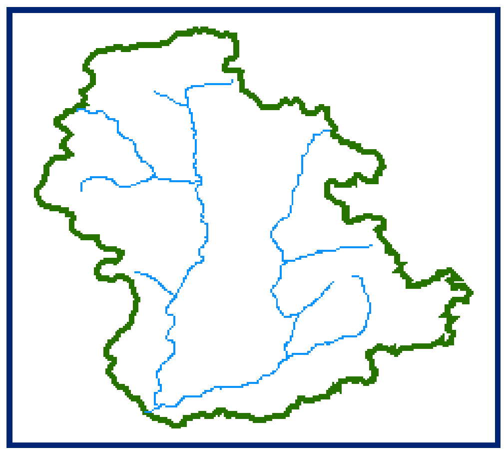

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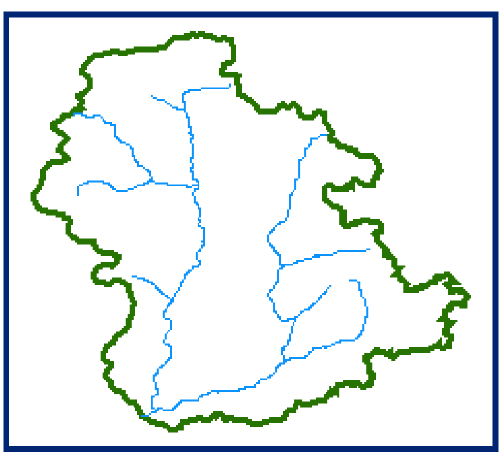

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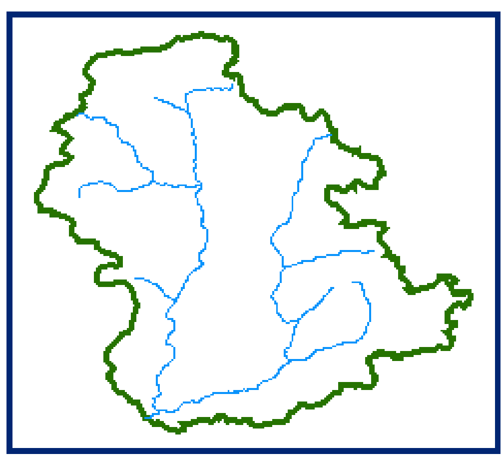

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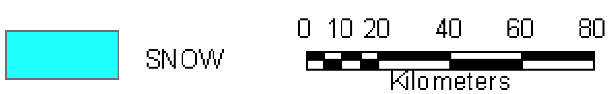
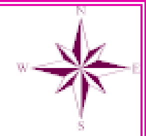
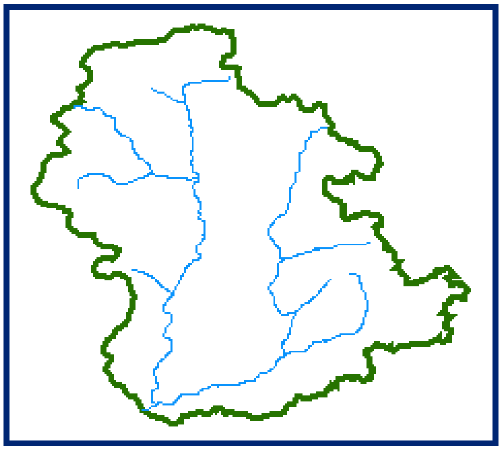


10 DAILY SNOW COVER MAP: TAWANG BASIN





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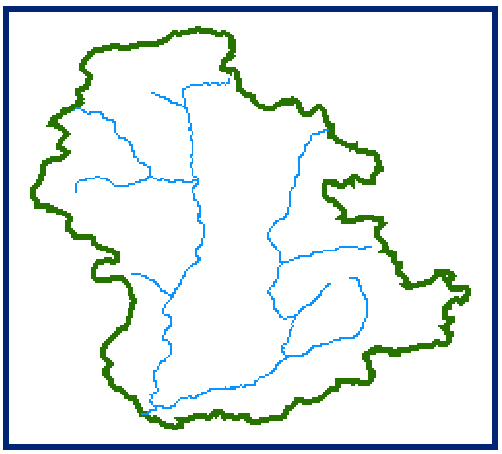

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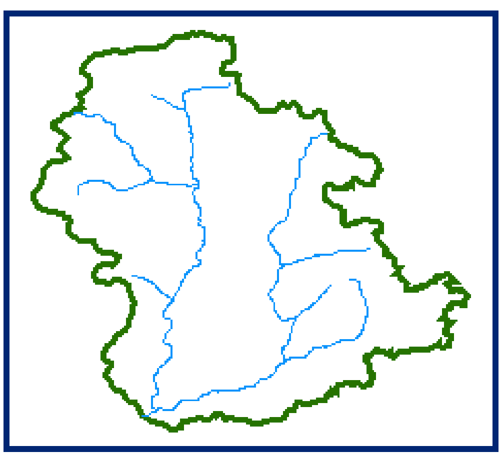

DATA USED

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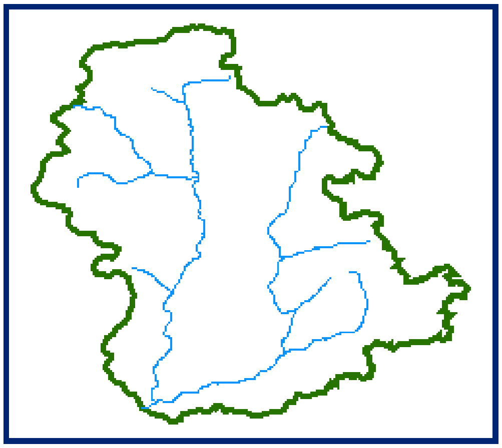
SNOW

0 10 20 40 60 80

Kilometers

SNOW COVER MAP : TAWANG BASIN



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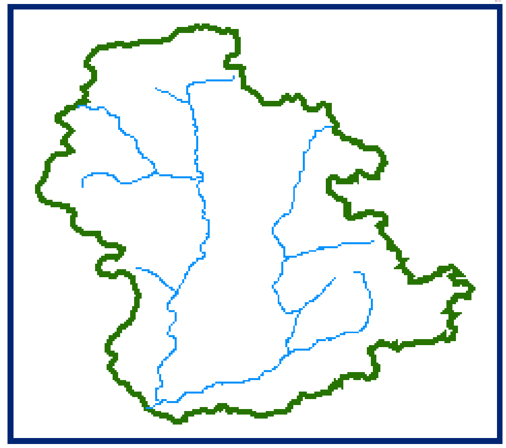

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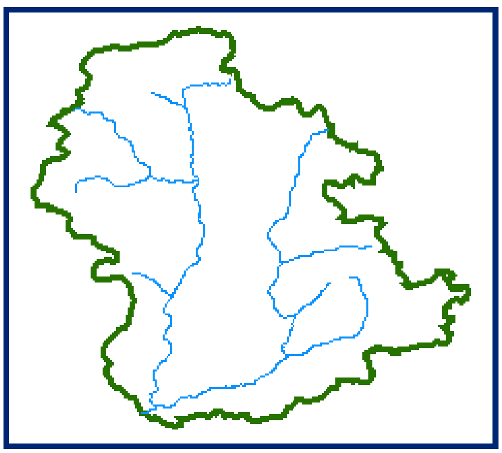

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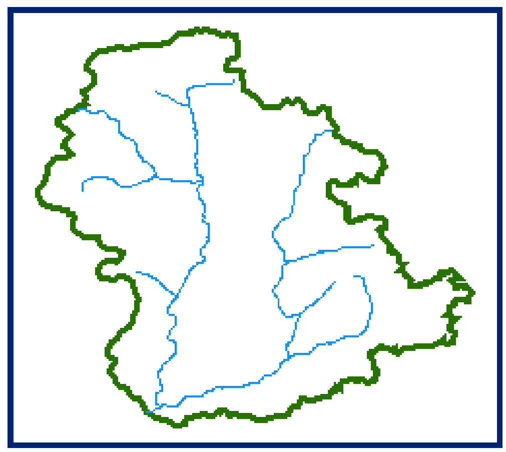

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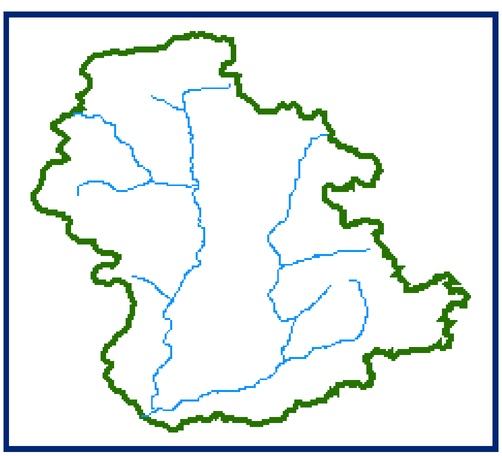

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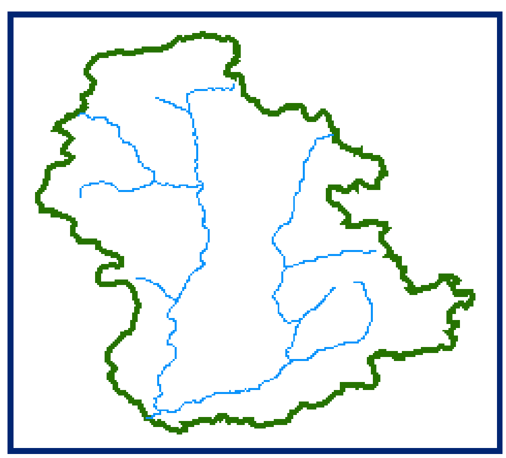
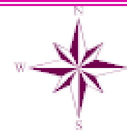


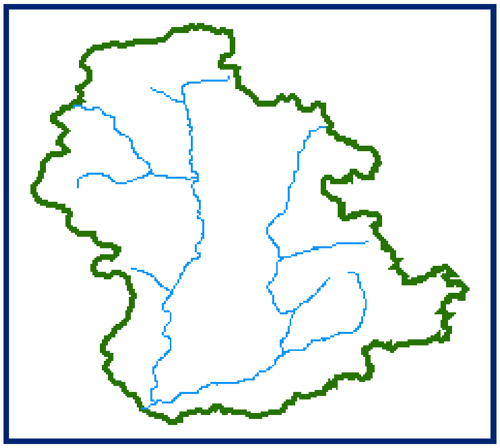
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80
Kilometers

10 DAILY SNOW COVER MAP: TAWANG BASIN





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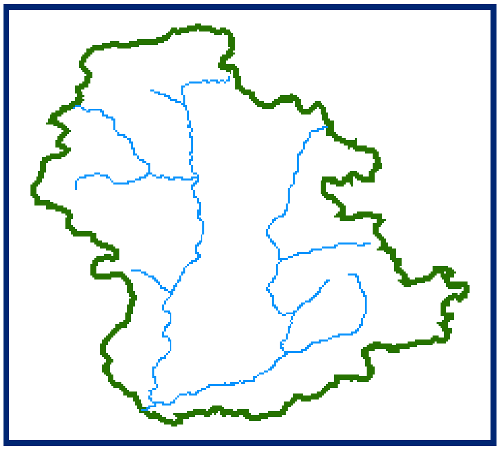

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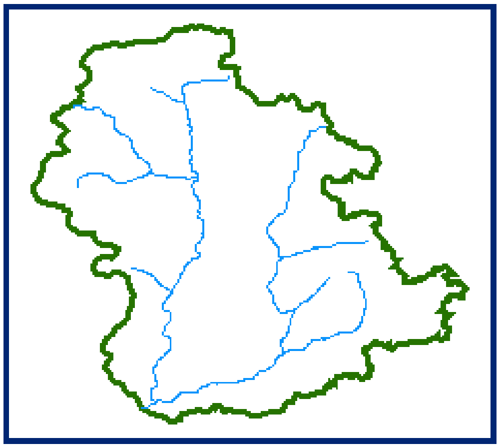

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