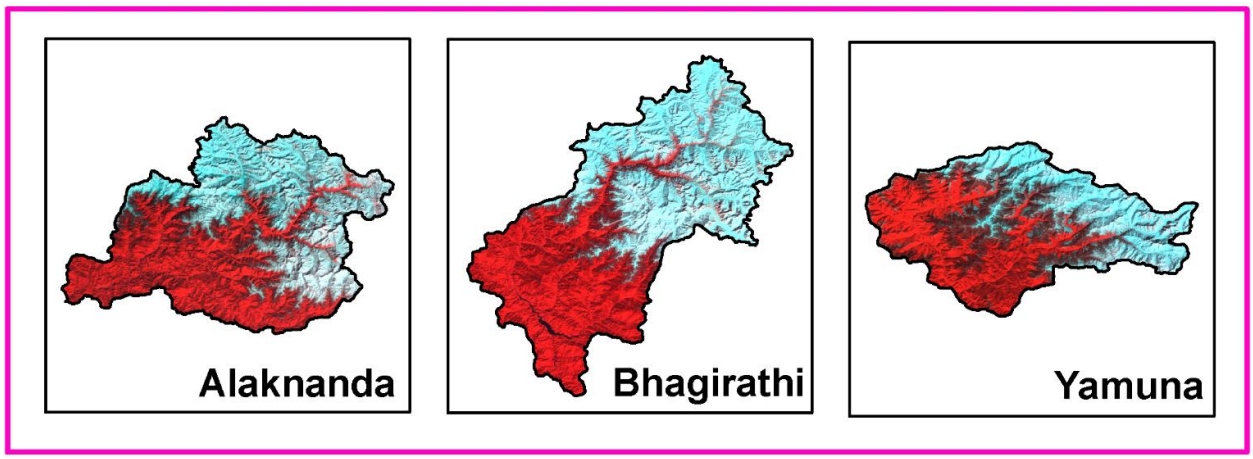
SNOW COVER ATLAS OF THE GANGA BASIN

Sub-basins: Alaknanda, Bhagirathi, and Yamuna

(Integrated *Studies of Himalayan Cryosphere*

A Project of Indian Space Research Organisation)

Year 2015-2016



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Originating Unit	Cryosphere Sciences Division, Geo-Sciences, Hydrology, Cryosphere Sciences and Applications 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 Ganga basin from October 2015 to June 2016. The sub-basins included in this report are Alaknanda, Bhagirathi and Yamuna. 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, Alaknanda, Bhagirathi and Yamuna basins.
Security Classification	Unrestricted
Distribution	Among concerned

CONTENTS

1. **Introduction**

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

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

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

2. Study Area:

This Atlas gives distribution of snow cover in three sub-basins of the Ganga basin. These are Alaknanda, Bhagirathi and Yamuna sub basins. Locations of these basins are shown in Figure 1.

3. Data used:

AWiFS data from October 2015 to June 2016 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 2015 to June 2016. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. From October to December there was not much snow fall was observed, accumulation starts from November and melting was observed from till first week of December in all the three sub-basins. Again accumulation starts from mid of January till March end. Maximum snow cover was observed in the month of February in all the three sub-basins. Yamuna sub-basin ablation starts in early March. Fluctuation in snow cover was more in Yamuna sub-basin. It may be due to lower altitude.

Acknowledgements

This investigation was carried out under Integrated studies of Himalayan Cryosphere, at Space Applications Centre (ISRO), Ahmedabad. The authors are grateful to Shri Tapan Misra, Director, Space Applications Centre, Ahmedabad for continuous guidance and encouragement during the investigation. Authors would like to thank Dr. Rajkumar Deputy Director, EPSA, SAC for their suggestions and comments on the manuscript.

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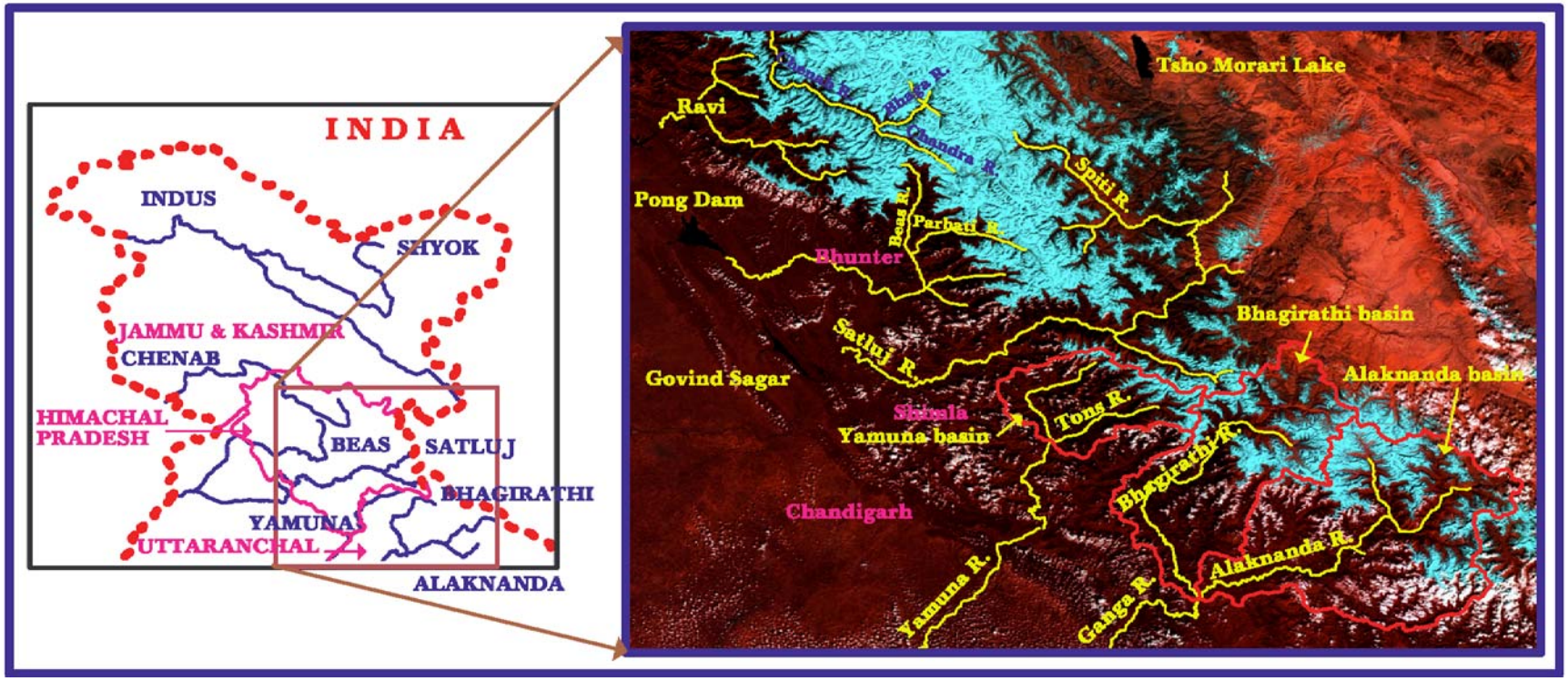


Figure 1: Location map of Alaknanda, Bhagirathi and Yamuna sub-basins (Part of Ganga basin)

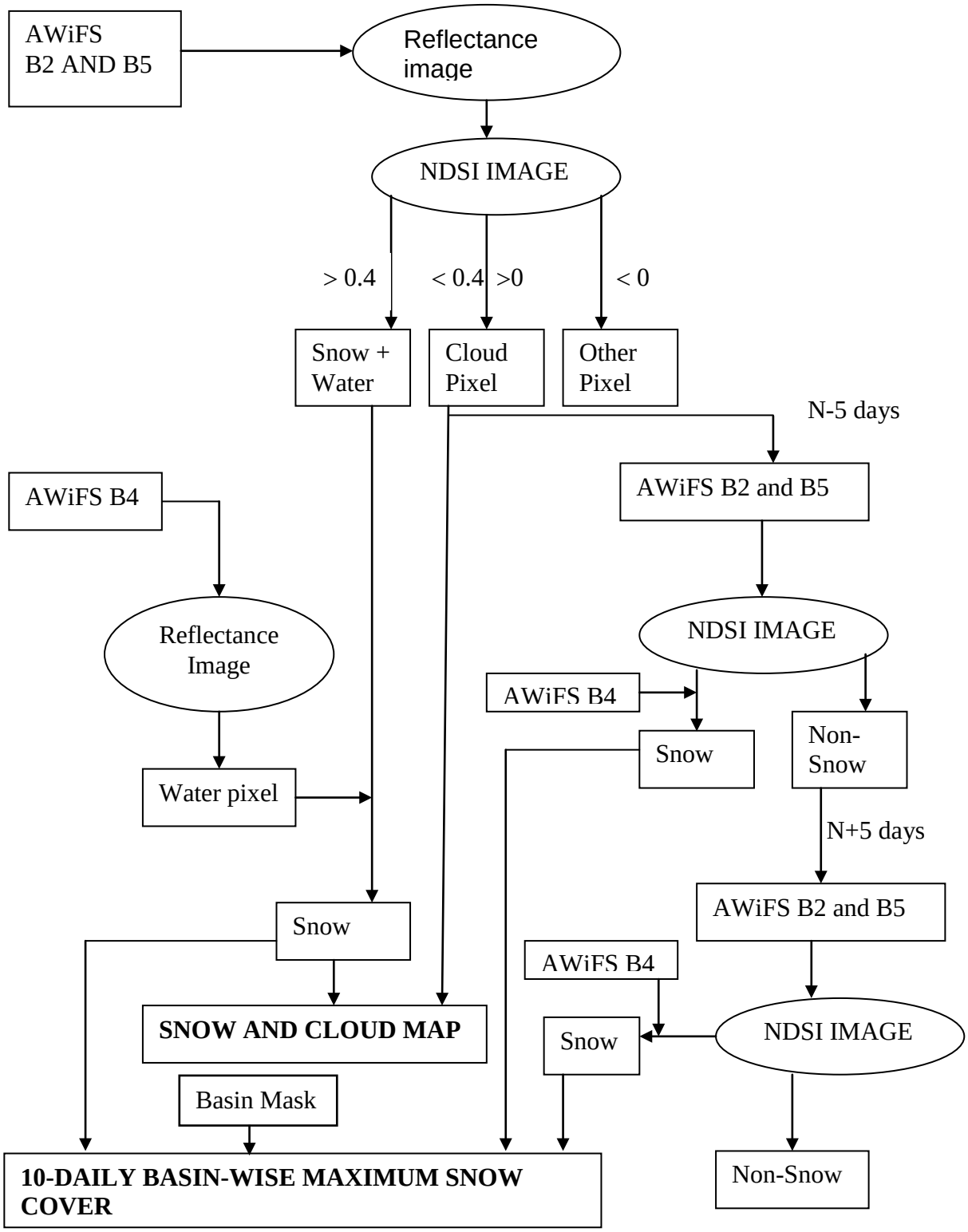


Figure 2: Algorithm for snow cover mapping using AWiFS data

ALAKNANDA SUB-BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: ALAKNANDA **BASIN AREA: 11090 sq km**

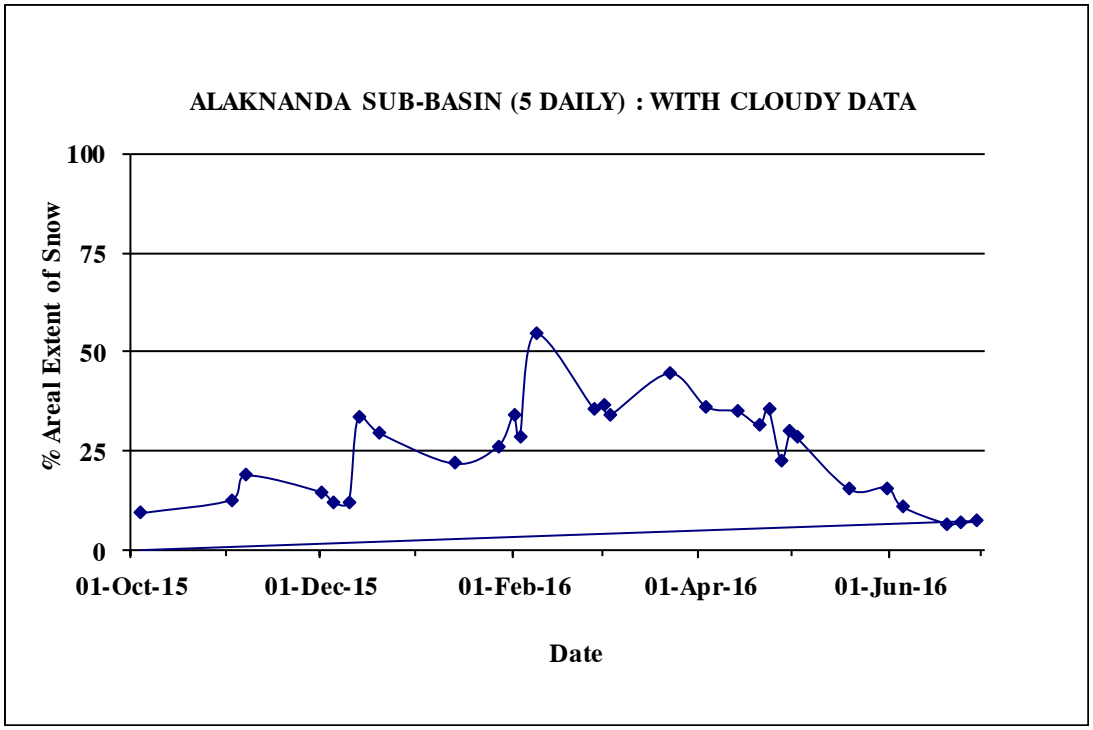
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2015							
1	04-Oct-2015	1035 (C)	9				
November 2015							
2	02-Nov-2015	1405(C)	13	**3**	07-Nov-2015	2094	19
December 2015							
4	01-Dec-2015	1630	15	**7**	13-Dec-2015	3707	33
5	05-Dec-2015	1335	12	**8**	20-Dec-2015	3278	30
6	10-Dec-2015	1352(C)	12	**9**			
January 2016							
10	13-Jan-2016	2425 (C)	22	**11**	27-Jan-2016	2913 (C)	26
February 2016							
12	01-Feb-2016	3783	34	**14**	08-Feb-2016	6072	55
13	03-Feb-2016	3161	29	**15**	27-Feb-2016	3953 (C)	36
March 2016							
16	01-Mar-2016	4045	36	**18**	22-Mar-2016	4963	45
17	03-Mar-2016	3785	34				
April 2016							
19	03-April-2016	4027	36	**22**	23-April-2016	3942 (C)	36
20	13-April-2016	3893	35	**23**	27-April-2016	2530 (C)	23
21	20-April-2016	3513 (C)	32	**24**	30-April-2016	3340	30
May 2016							
25	02-May-2016	3173	29	**27**	31-May-2016	1755 (C)	16
26	19-May-2016	1707 (C)	15				
June 2016							
28	05-June-2016	1220 (C)	11	**30**	24-June-2016	760 (C)	7
29	19-June-2016	748 (C)	7	**31**	29-June-2016	821	7

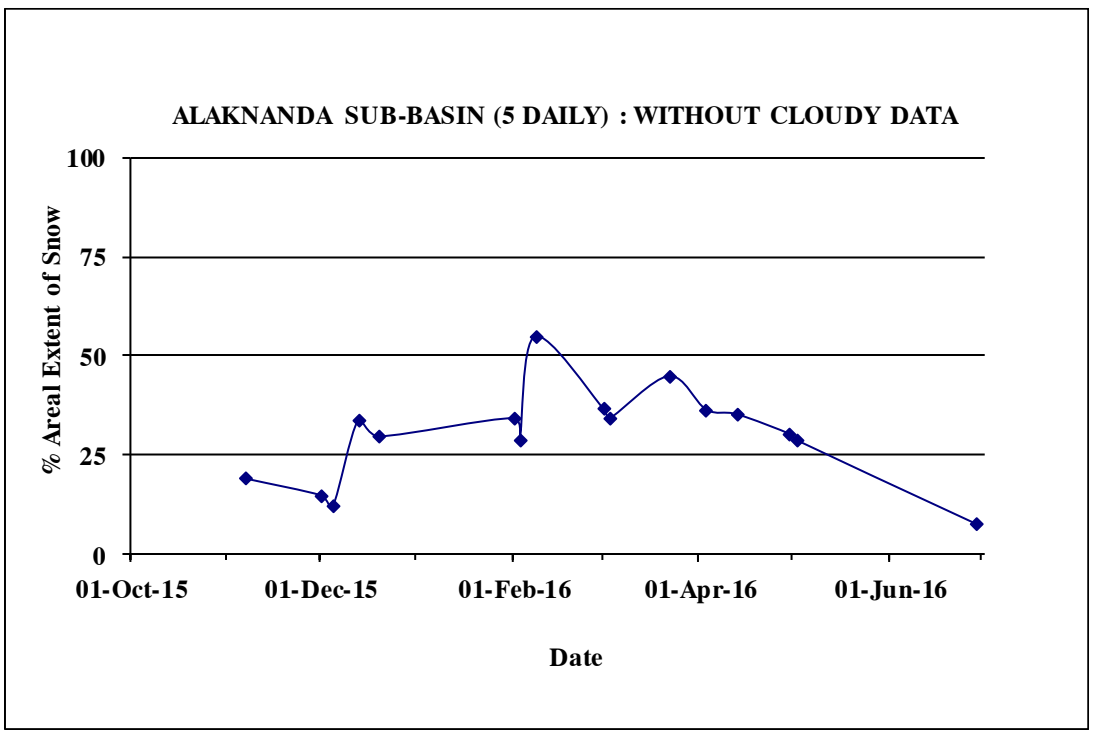
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: ALAKNANDA **BASIN AREA: 11090 sq km**

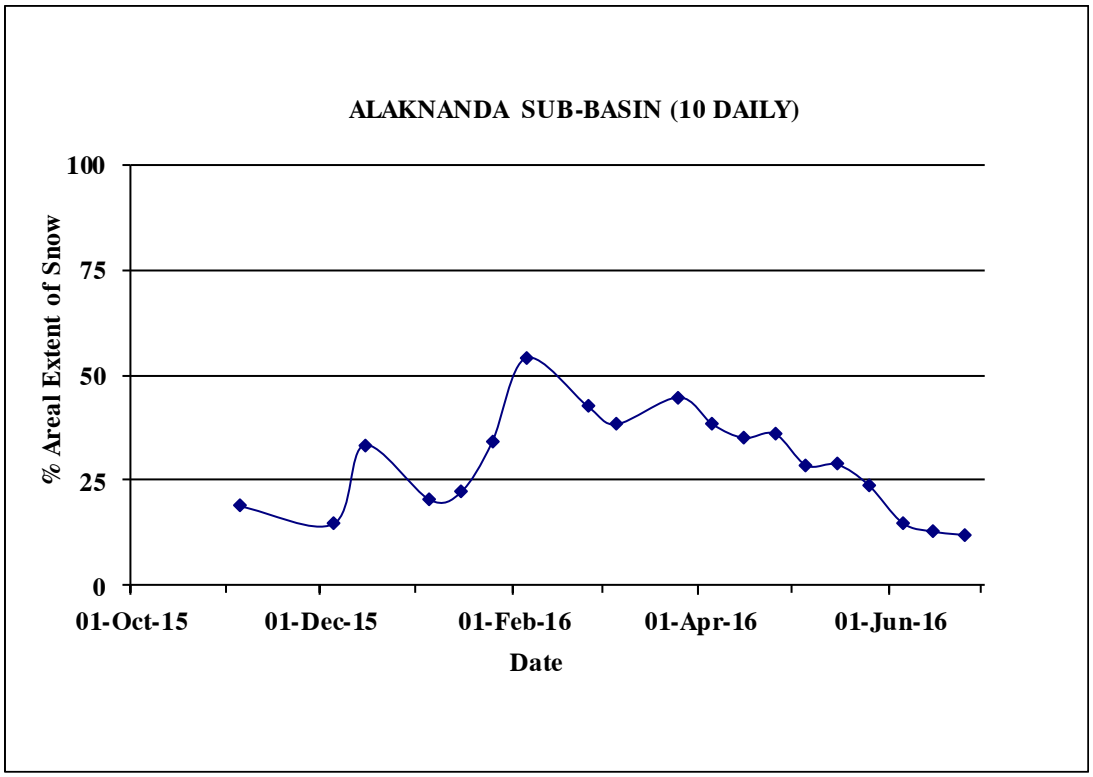
S. No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2015							
November 2015							
1	05-Nov-2015	2095	19				
December 2015							
2	05-Dec-2015	1631	15	**3**	15-Dec-2015	3706	33
January 2016							
4	05-Jan-2016	2266	20	**5**	25-Jan-2016	3770	34
	15-Jan-2016	2464	22				
February 2016							
6	05-Feb-2016	5998	54	**7**	25-Feb-2016	4710	42
March 2016							
8	05-Mar-2016	4254	38	**9**	25-Mar-2016	4963	45
April 2016							
10	5-Apr-2016	4249	38	**12**	25-Apr-2016	4002	36
11	15-Apr-2016	3893	35				
May 2016							
13	05-May-16	3175	29	**15**	25-May-16	2661	24
14	15-May-16	3195	29				
June 2016							
16	05-June-16	1659	15	**18**	25-June-2016	1339	12
17	15-June-16	1429	13				

SNOW COVER DEPLETION CURVE



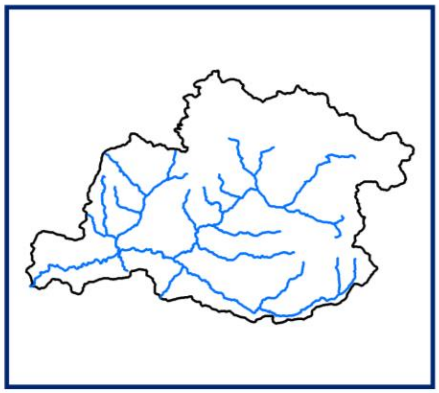


SNOW COVER DEPLETION CURVE



SNOW COVER MAP

SNOW COVER MAP : ALAKNANDA SUB-BASIN



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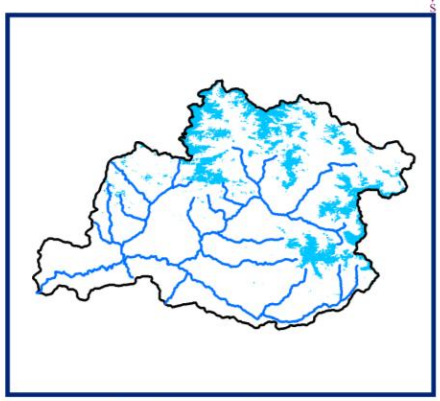

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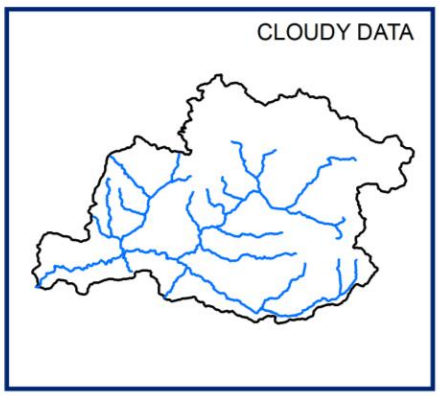

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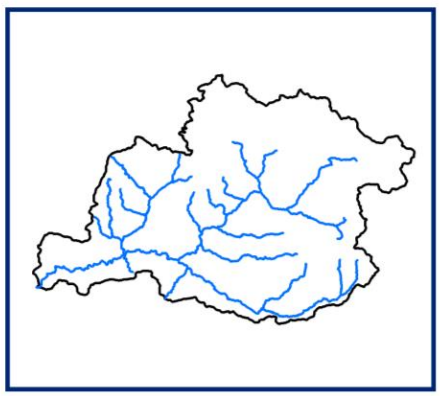

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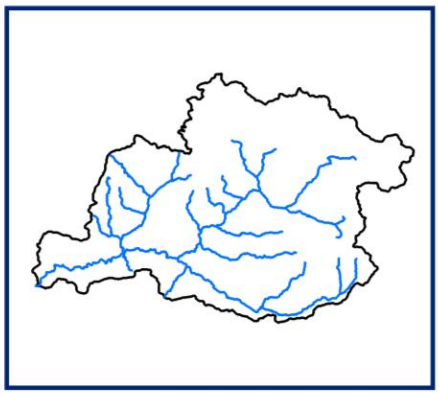

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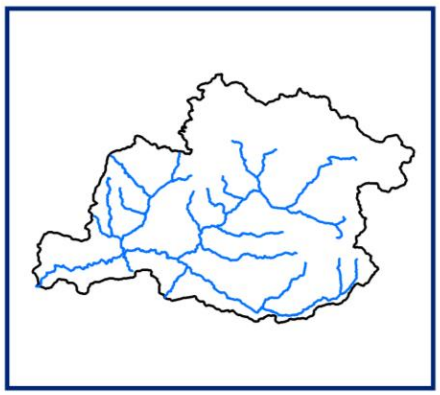

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SNOW

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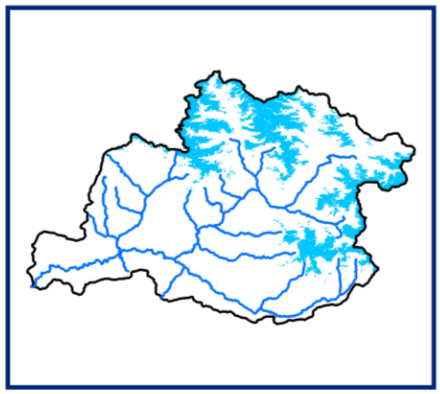
Kilometers

SNOW COVER MAP : ALAKNANDA SUB-BASIN



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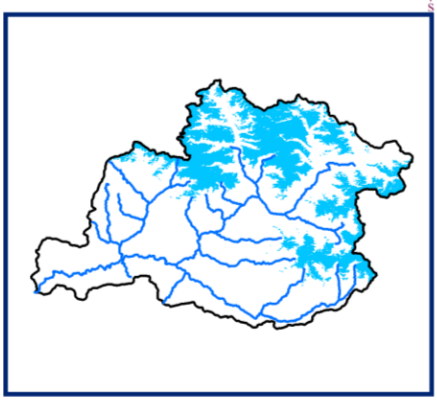

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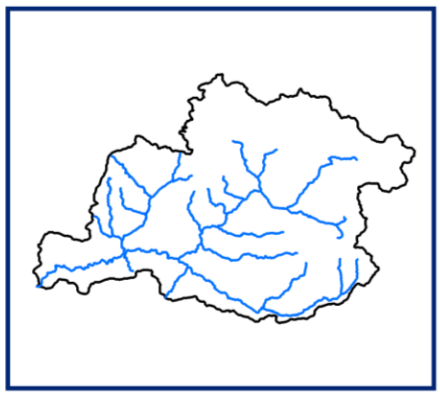

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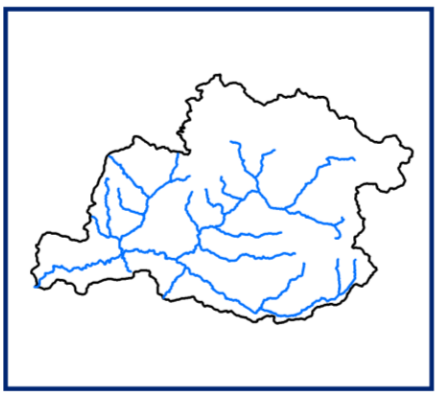

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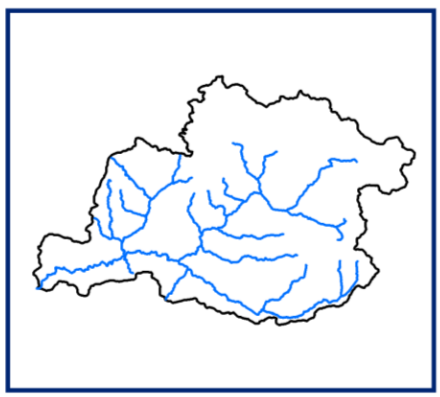

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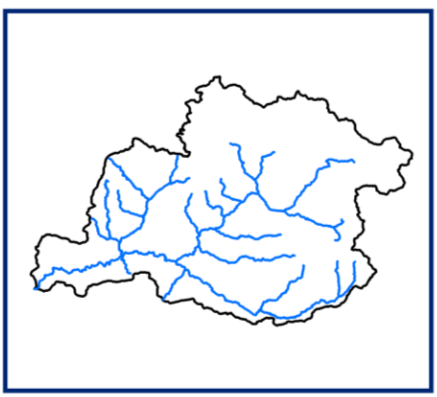

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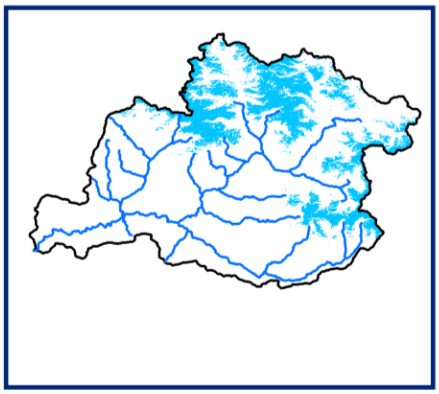
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



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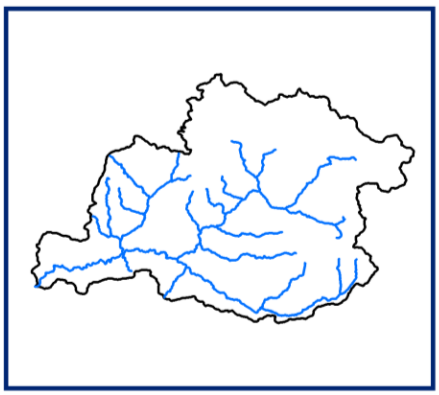

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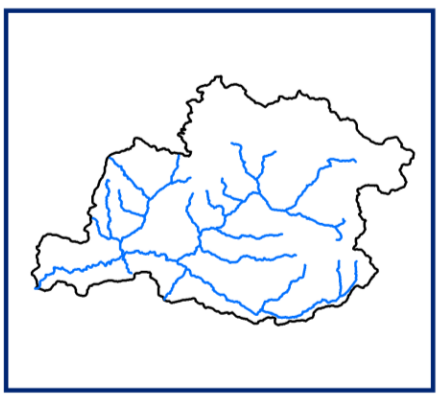

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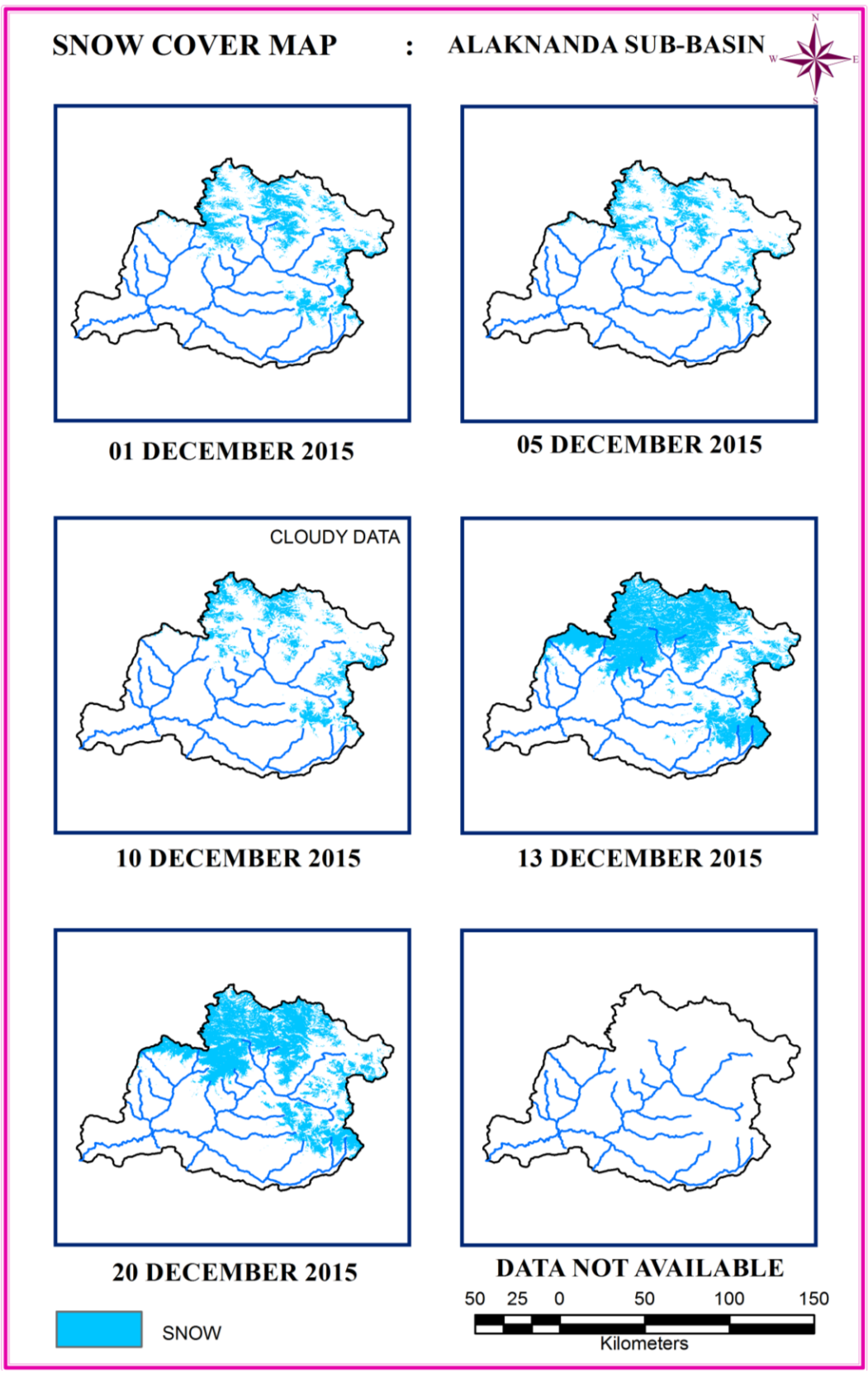
SNOW COVER MAP : ALAKNANDA SUB-BASIN
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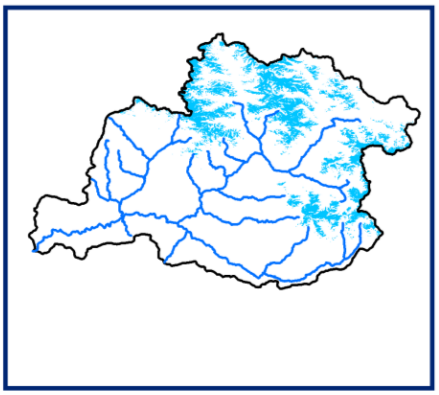
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



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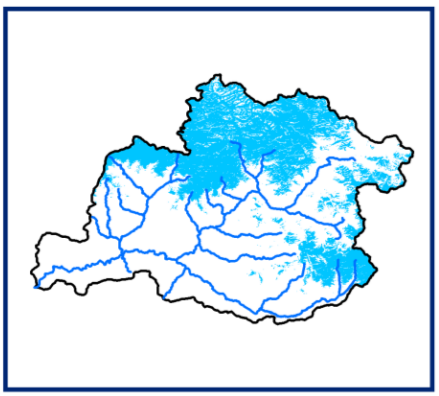

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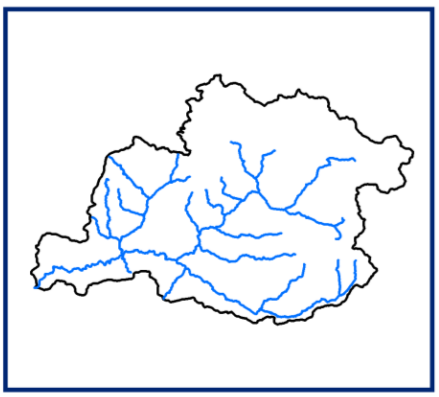

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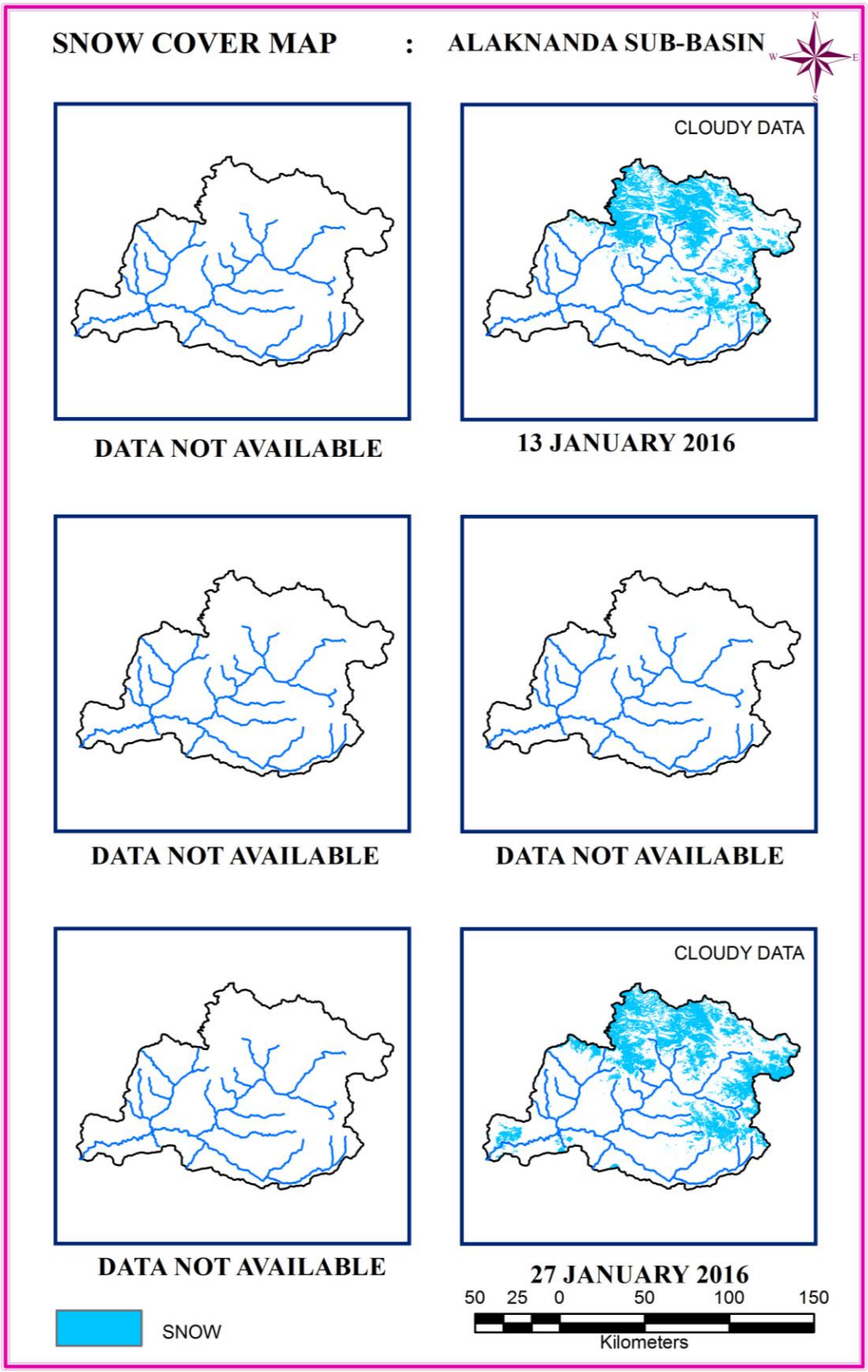
SNOW COVER MAP : ALAKNANDA SUB-BASIN
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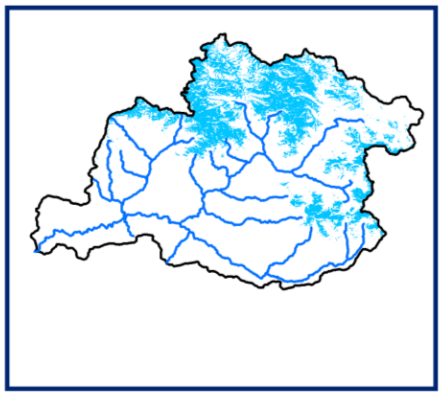
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



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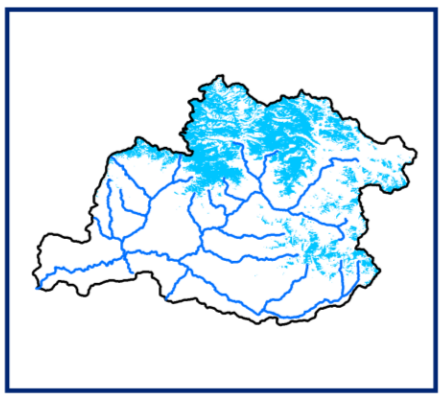

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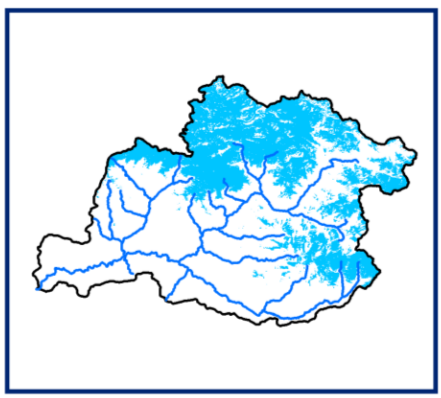

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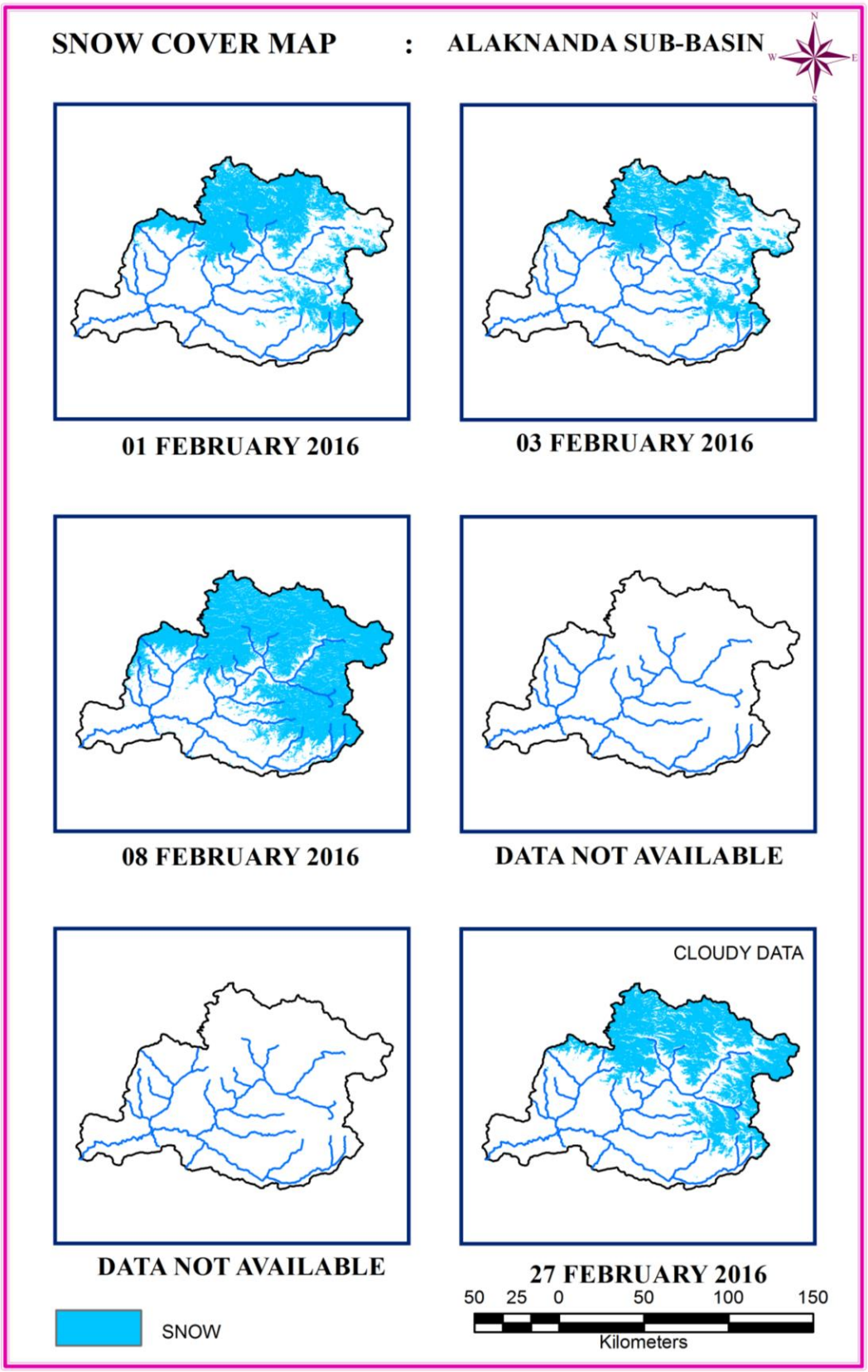
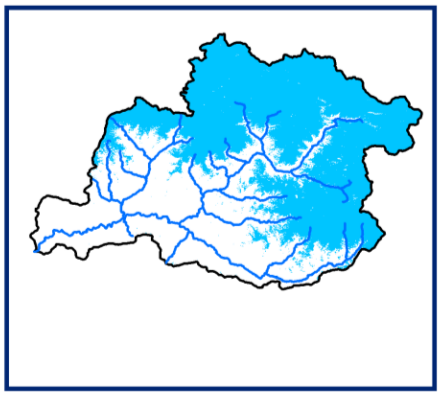
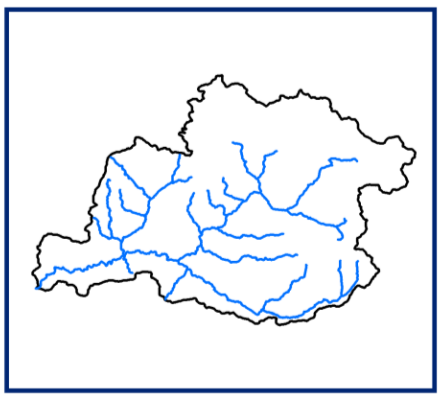
Kilometers


SNOW COVER MAP : ALAKNANDA SUB-BASIN
N
W
E
S
01 FEBRUARY 2016
03 FEBRUARY 2016
08 FEBRUARY 2016
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
27 FEBRUARY 2016
SNOW
50 25 0 50 100 150
Kilometers

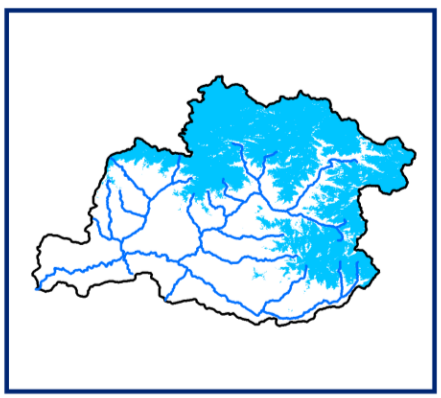
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



DATA USED
05 FEBRUARY 2016



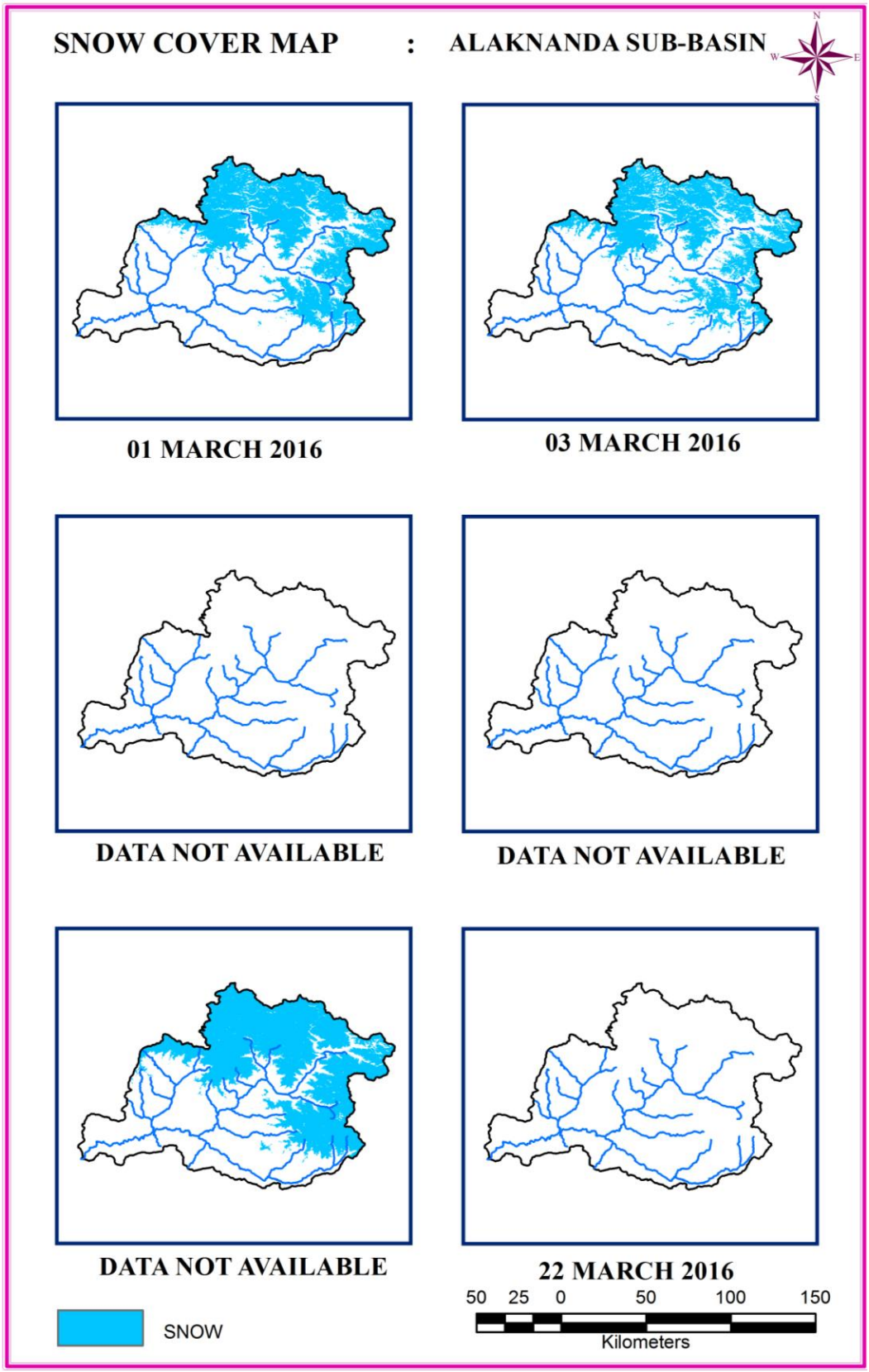
DATA NOT AVAILABLE



DATA USED
25 FEBRUARY 2016

SNOW

40 20 0 40 80 120
Kilometers


SNOW COVER MAP : ALAKNANDA SUB-BASIN
N
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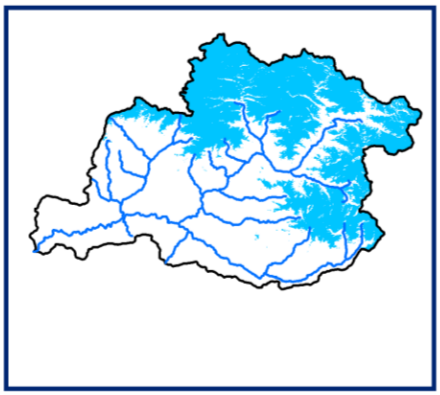
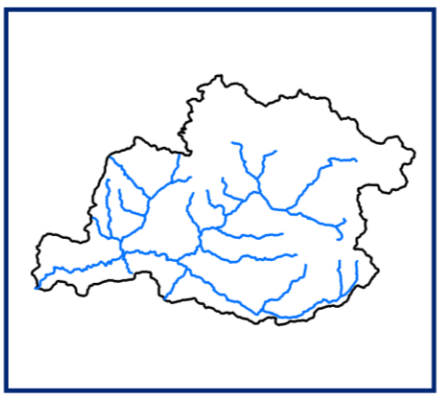
01 MARCH 2016
03 MARCH 2016
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
22 MARCH 2016
SNOW
50 25 0 50 100 150
Kilometers

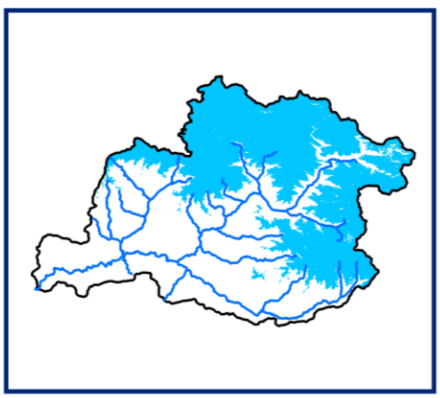
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



DATA USED
01 MARCH 2016
03 MARCH 2016



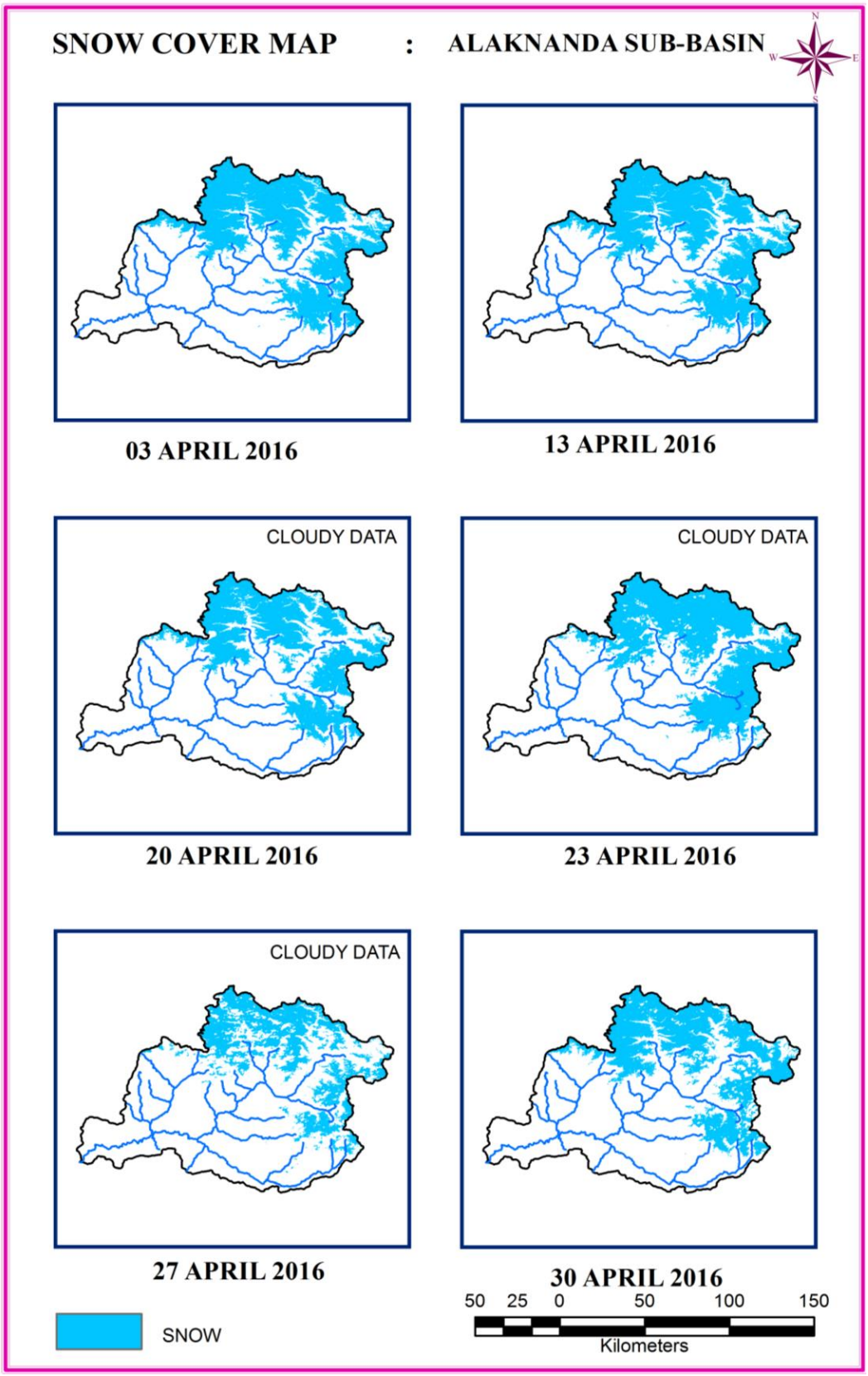
DATA NOT AVAILABLE



DATA USED
25 MARCH 2016

SNOW

40 20 0 40 80 120
Kilometers


SNOW COVER MAP : ALAKNANDA SUB-BASIN
N
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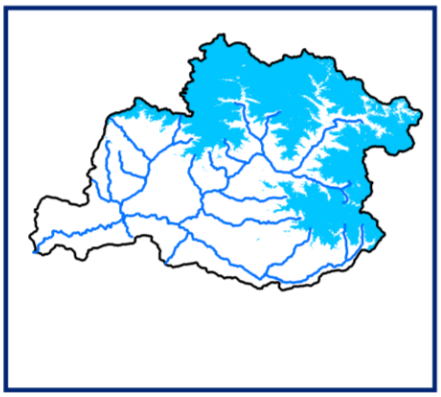
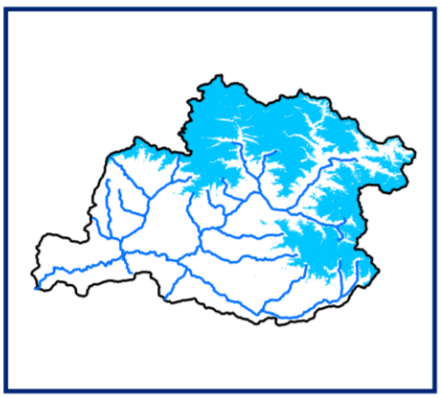
03 APRIL 2016
13 APRIL 2016
CLOUDY DATA
20 APRIL 2016
CLOUDY DATA
23 APRIL 2016
CLOUDY DATA
27 APRIL 2016
30 APRIL 2016
SNOW
50 25 0 50 100 150
Kilometers

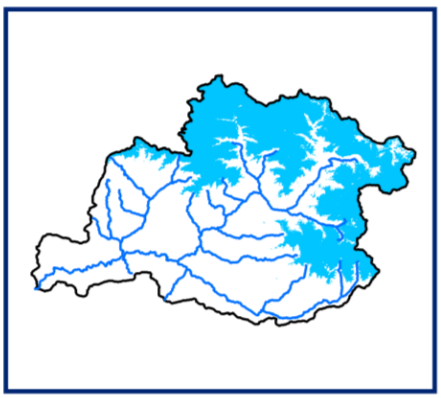
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



DATA USED
05 APRIL 2016



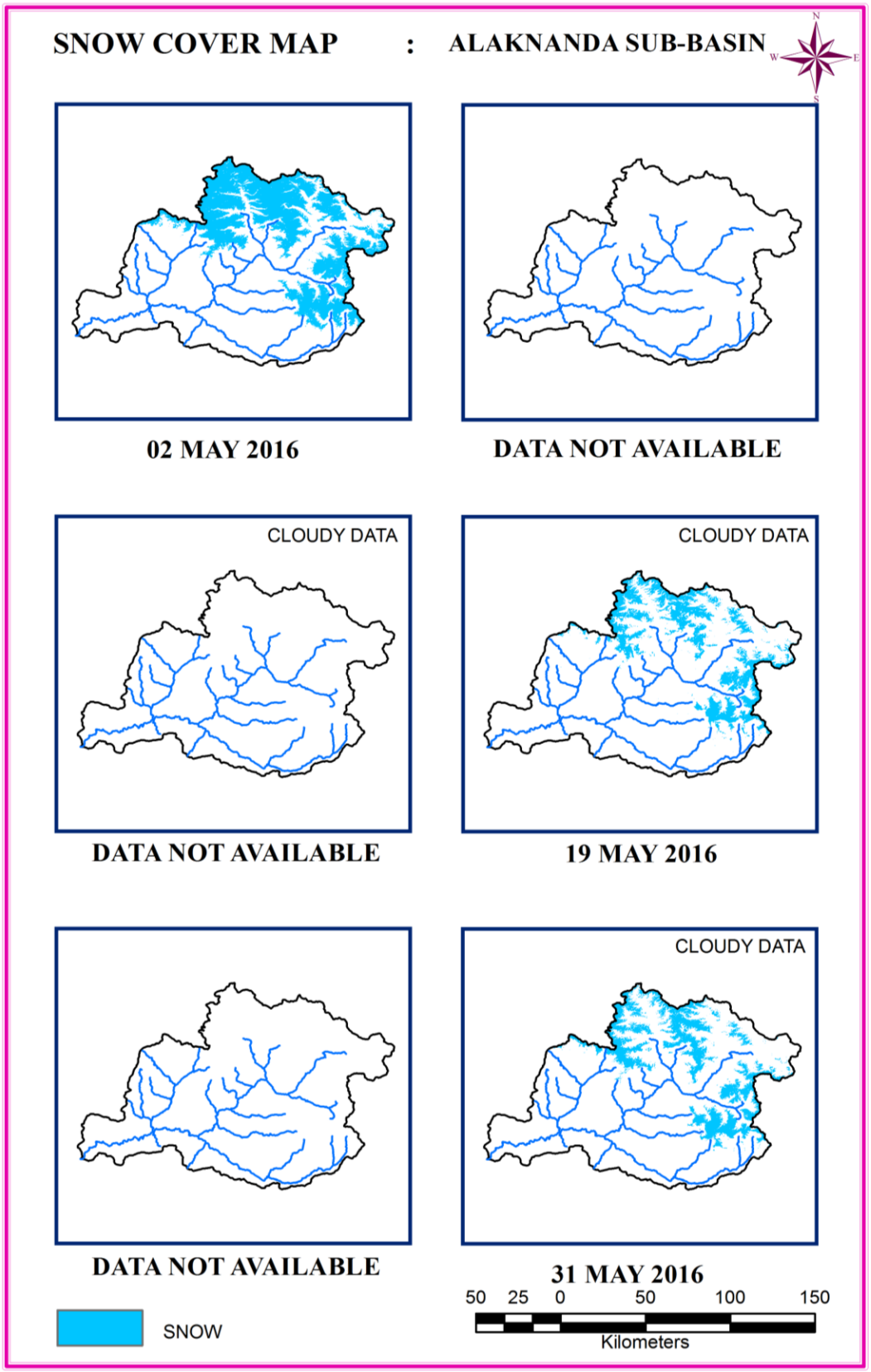
DATA USED
13 APRIL 2016
20 APRIL 2016



DATA USED
23 APRIL 2016
27 APRIL 2016
30 APRIL 2016

SNOW

40 20 0 40 80 120
Kilometers


SNOW COVER MAP : ALAKNANDA SUB-BASIN
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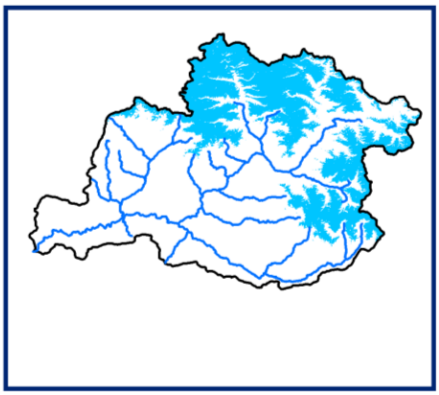
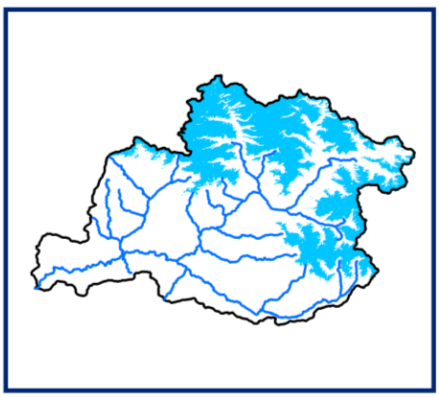
02 MAY 2016
DATA NOT AVAILABLE
CLOUDY DATA
DATA NOT AVAILABLE
CLOUDY DATA
19 MAY 2016
DATA NOT AVAILABLE
CLOUDY DATA
31 MAY 2016
SNOW
50 25 0 50 100 150
Kilometers

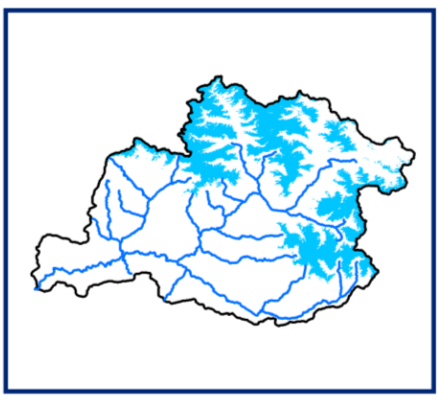
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



DATA USED
05 MAY 2016



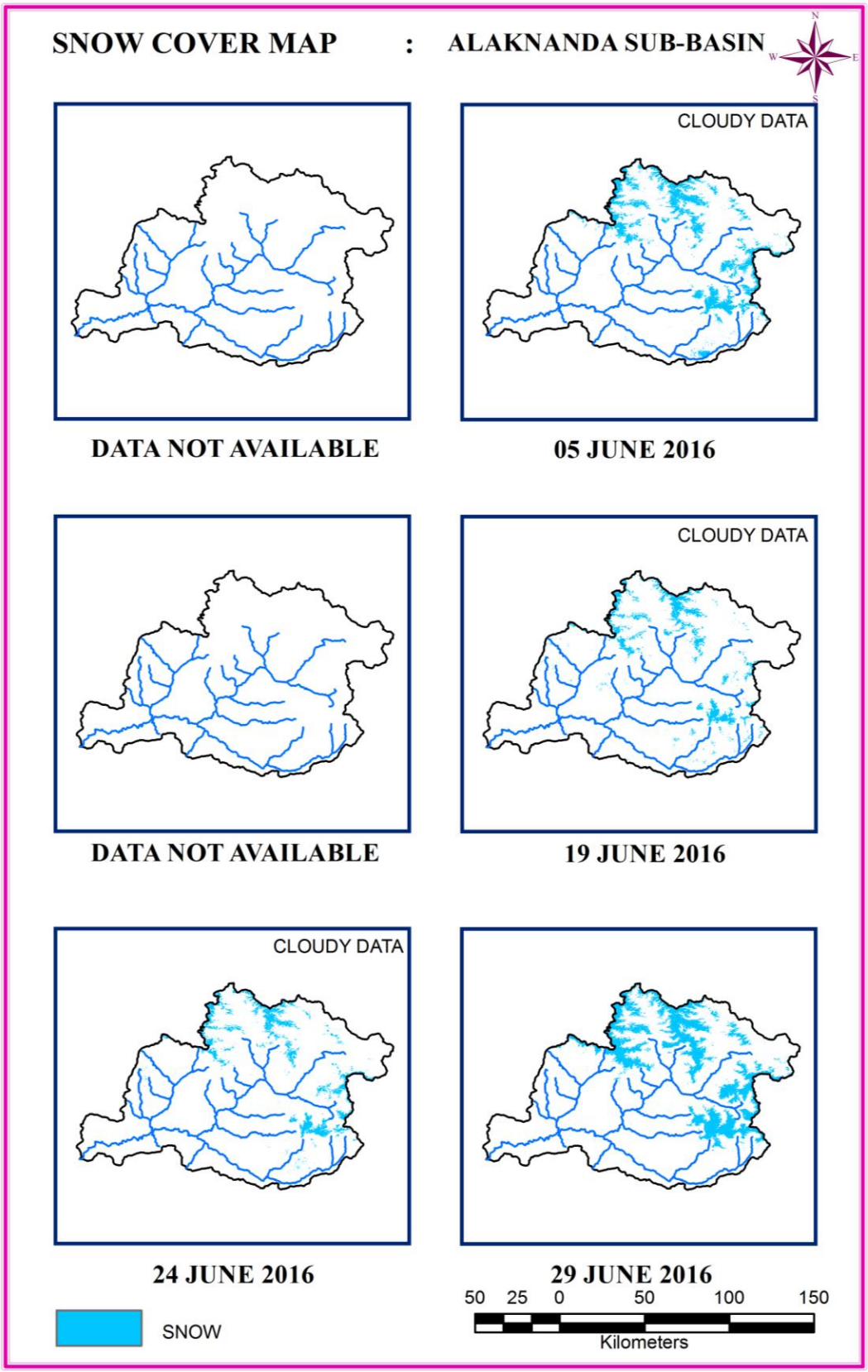
DATA USED
15 MAY 2016



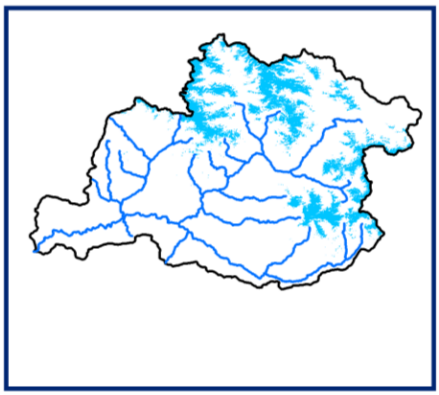
DATA USED
25 APRIL 2016

SNOW

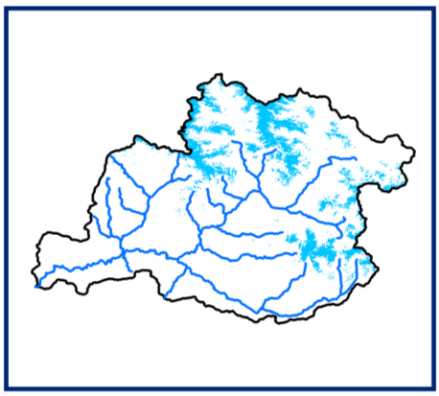
40 20 0 40 80 120
Kilometers


SNOW COVER MAP : ALAKNANDA SUB-BASIN
N
W
E
S
CLOUDY DATA
DATA NOT AVAILABLE
05 JUNE 2016
CLOUDY DATA
DATA NOT AVAILABLE
19 JUNE 2016
CLOUDY DATA
24 JUNE 2016
29 JUNE 2016
SNOW
50 25 0 50 100 150
Kilometers

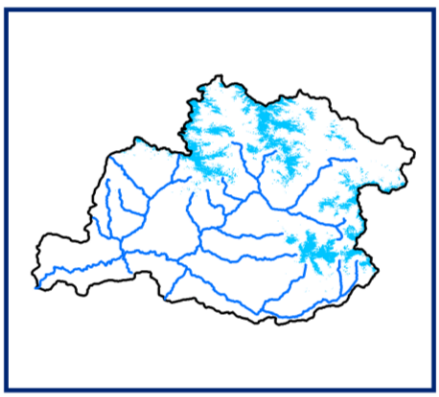
10 DAILY SNOW COVER MAP : ALAKNANDA SUB-BASIN



DATA USED
05 JUNE 2016



DATA USED
15 JUNE 2016



DATA USED
24 JUNE 2016
29 JUNE 2016

SNOW

30 15 0 30 60 90
Kilometers

BHAGIRATHI SUB-BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: BHAGIRATHI **BASIN AREA: 7438 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2015							
1	04-Oct-15	1011	14	**2**	30-Oct-15	1114	15
November 2015							
3	02-Nov-15	971	13	**5**	07-Nov-15	1073	14
4	06-Nov-15	1548	21				
December 2015							
6	01-Dec-15	1111	15	**9**	13-Dec-15	2650	36
7	05-Dec-15	843	11	**10**	20-Dec-15	2085	28
8	10-Dec-15	1259 (c)	17				
January 2016							
11	03-Jan-16	1473	20	**13**	13-Jan-16	1482 (c)	20
12	06-Jan-16	1918	26	**14**	27-Jan-16	1819 (c)	24
February 2016							
15	01-Feb-16	2688	36	**18**	10-Feb-16	2938 (c)	39
16	03-Feb-16	2130	29	**19**	27-Feb-16	2740	37
17	08-Feb-16	4691	63				
March 2016							
20	01-Mar-16	2718	37	**22**	22-Mar-16	3696	50
21	03-Mar-16	2456	33				
April 2016							
23	03-Apr-16	3025	41	**26**	23-Apr-16	2963	40
24	13-Apr-16	3053	41	**27**	27-Apr-16	2368	32
25	20-Apr-16	2922	39	**28**	30-Apr-16	2598	35
May 2016							
29	02-May-16	2492	34	**31**	19-May-16	1418 (c)	19
30	17-May-16	1742	23	**32**	31-May-16	1224	16

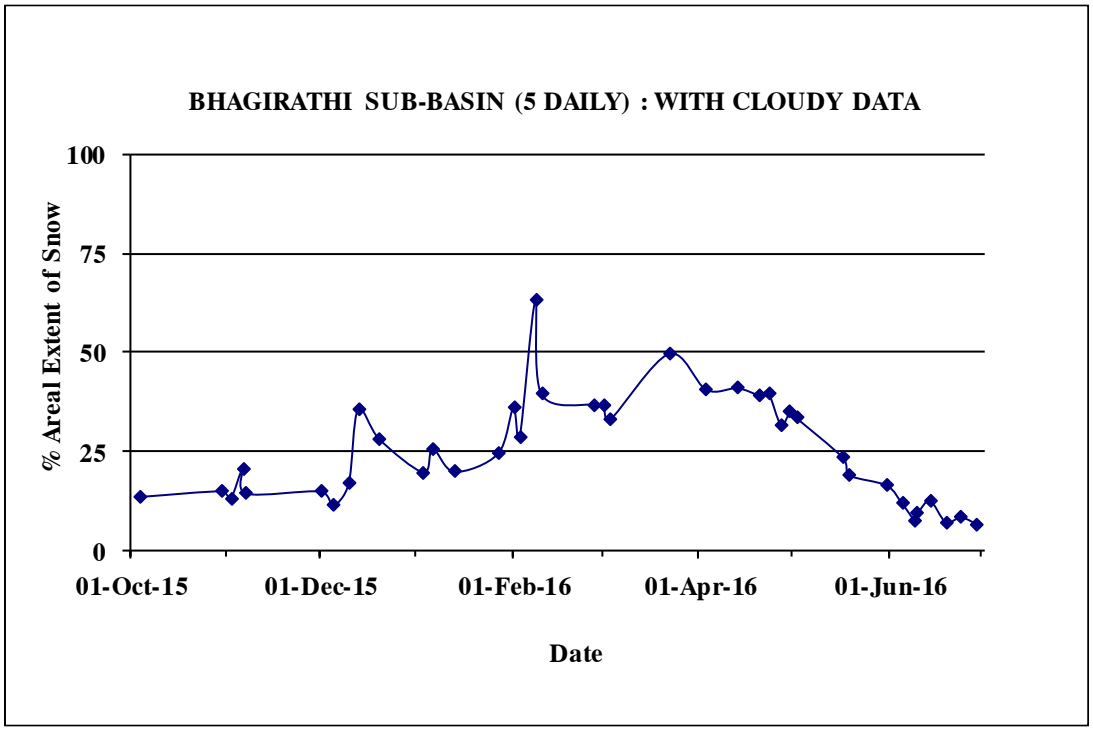
June 2016							
33	05-Jun-16	886	12	**37**	19-Jun-16	541 (c)	7
34	09-Jun-16	576 (c)	8	**38**	24-Jun-16	622	8
35	10-Jun-16	702 (c)	9	**39**	29-Jun-16	502 (c)	7
36	14-Jun-16	934 (c)	13				

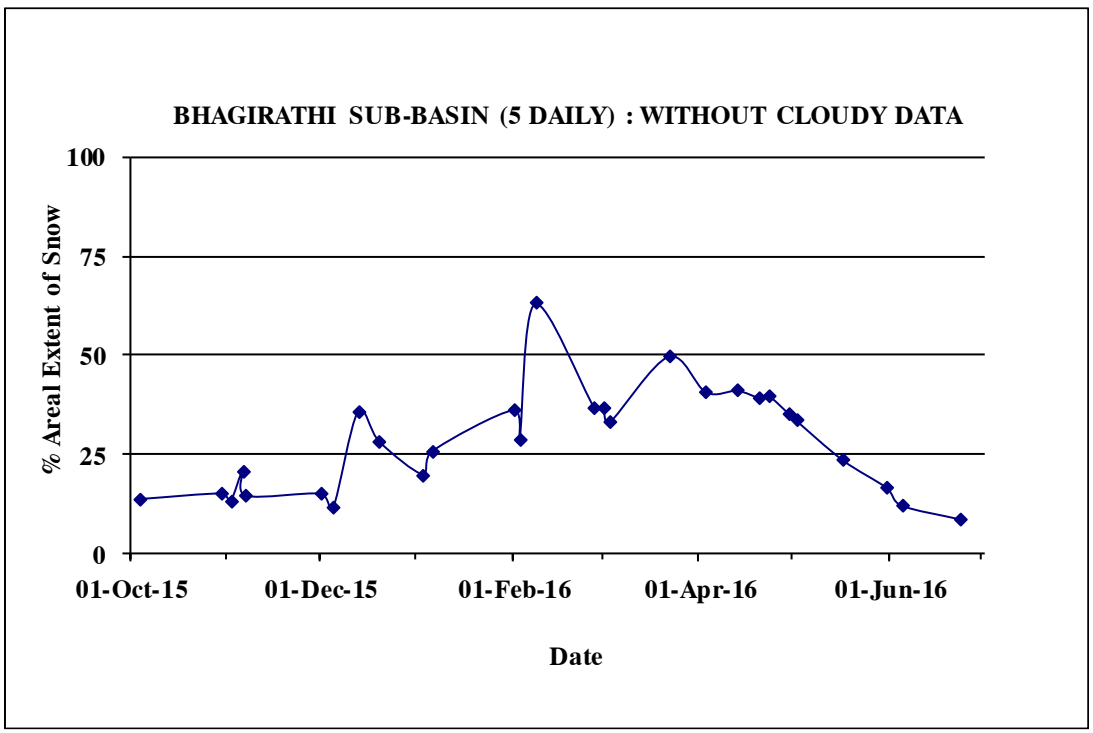
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: BHAGIRATHI **BASIN AREA: 7438 sq km**

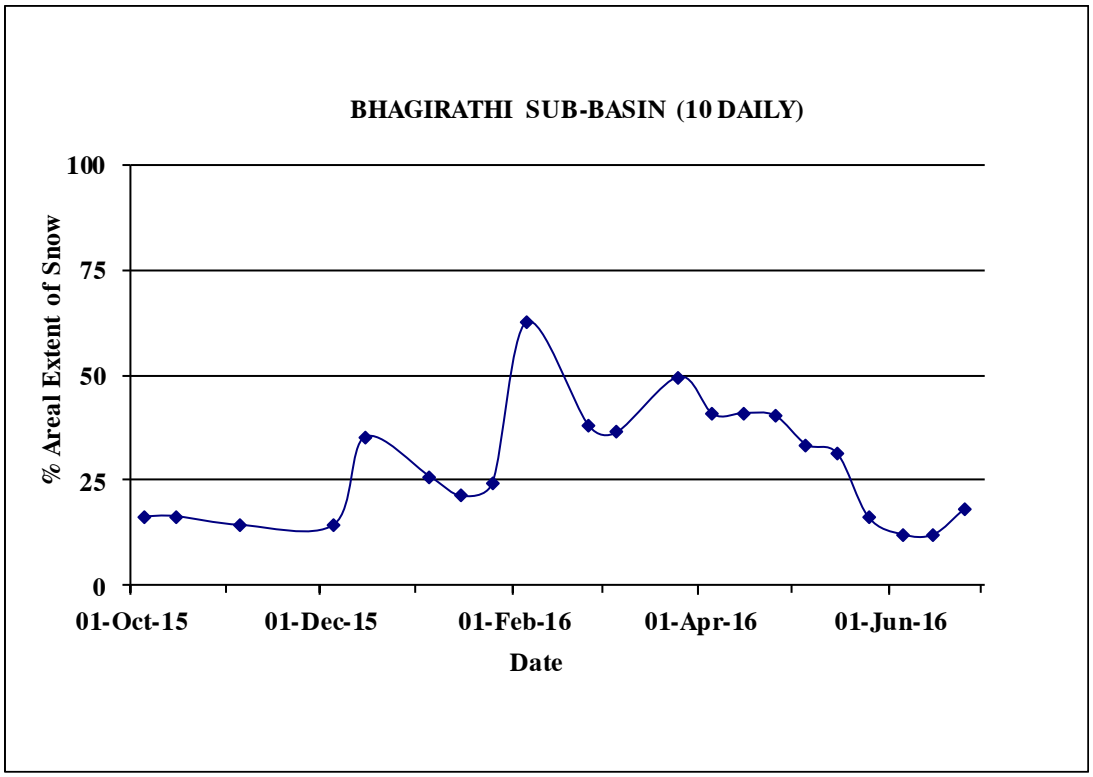
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2015				**November 2015**			
1	05-Oct-15	1223	16	**3**	05-Nov-15	1072	14
2	15-Oct-15	1227	16				
December 2015				**January 2016**			
4	05-Dec-15	1080	15	**7**	05-Jan-16	1919	26
5	15-Dec-15	2622	35	**8**	15-Jan-16	1583	21
6	25-Dec-15				25-Jan-16	1814	24
February 2016				**March 2016**			
9	05-Feb-16	4647	62	**10**	05-Mar-16	2703	36
11	25-Feb-16	2818	38	**12**	25-Mar-16	3684	50
April 2016				**May 2016**			
13	05-Apr-16	3020	41	**16**	05-May-16	2486	33
14	15-Apr-16	3043	41	**17**	15-May-16	2328	31
15	25-Apr-16	2995	40	**18**	25-May-16	1209	16
June 2016							
19	05-Jun-2016	904	12				
20	15-Jun-2016	906	12				
21	25-Jun-2016	1363	18				

SNOW COVER DEPLETION CURVE

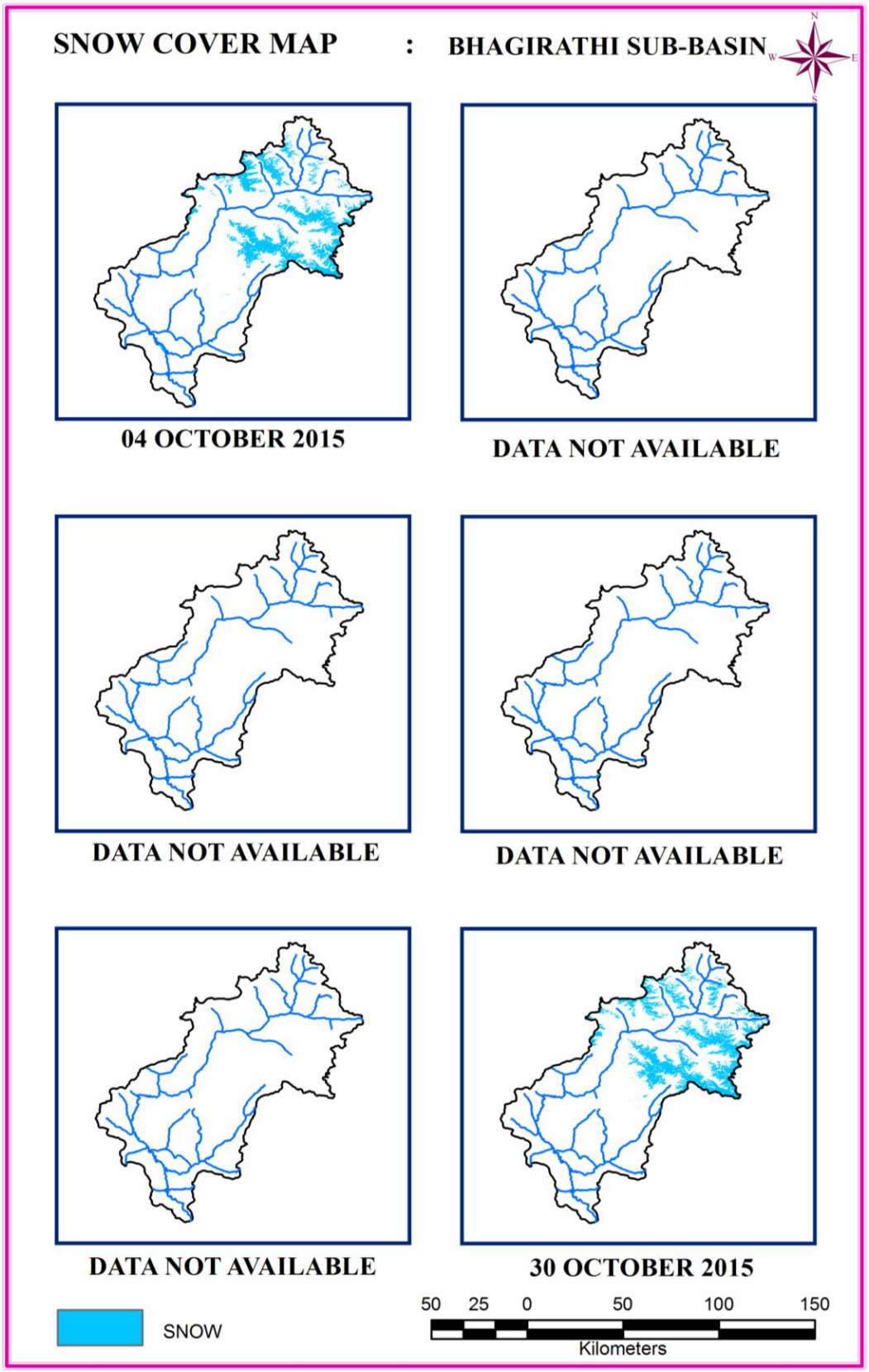




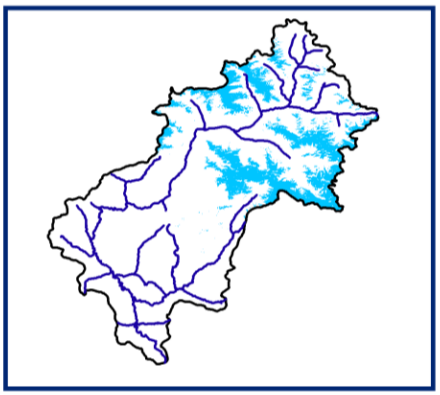
SNOW COVER DEPLETION CURVE



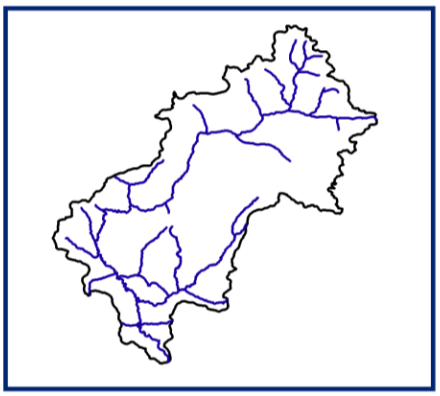
SNOW COVER MAP


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
W
E
S
04 OCTOBER 2015
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
30 OCTOBER 2015
SNOW
50 25 0 50 100 150
Kilometers

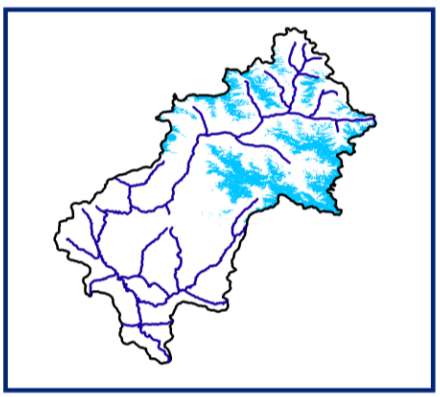
10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN



DATA USED
05 OCTOBER 2015



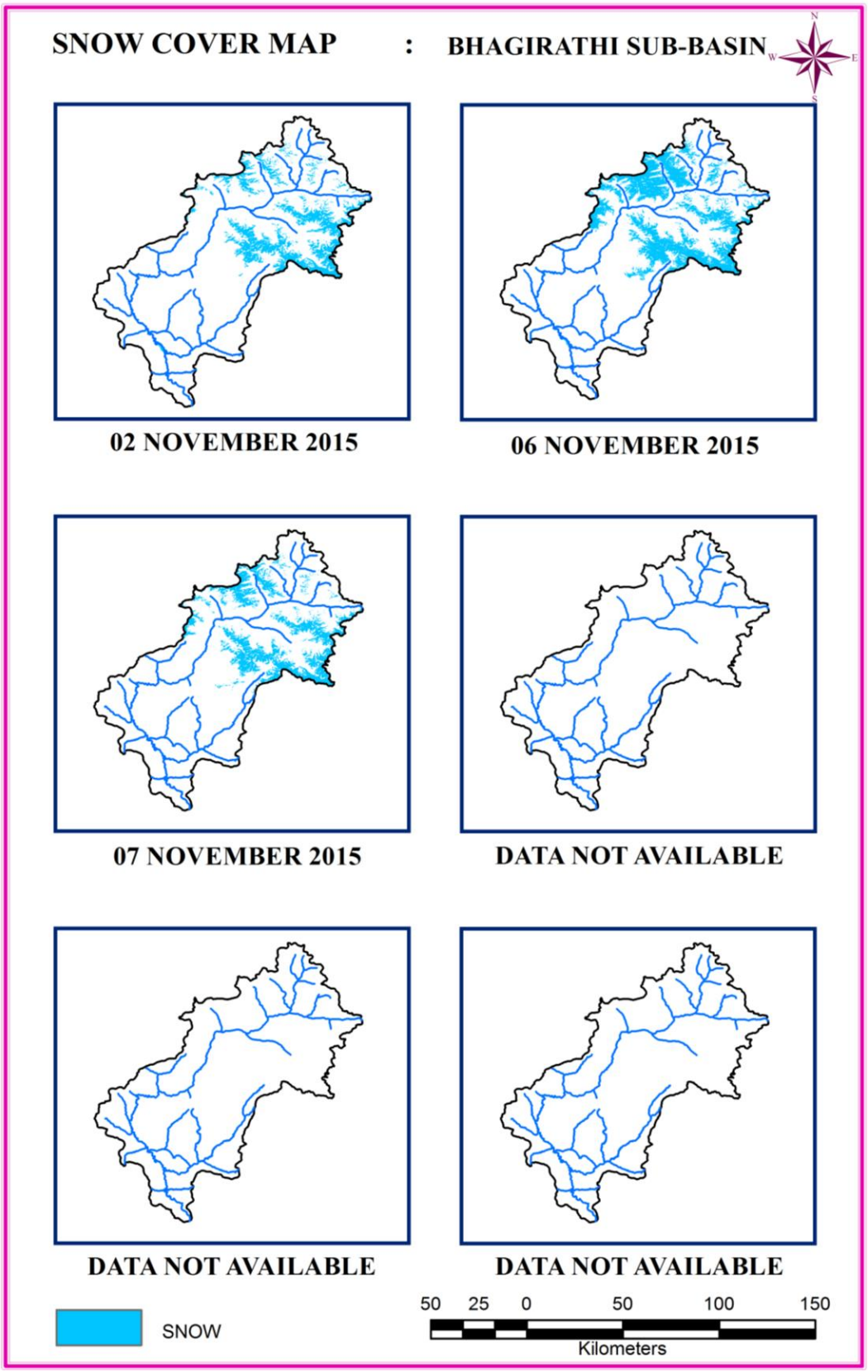
DATA NOT AVAILABLE



DATA USED
25 OCTOBER 2015

SNOW

50 25 0 50 100 150
Kilometers


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
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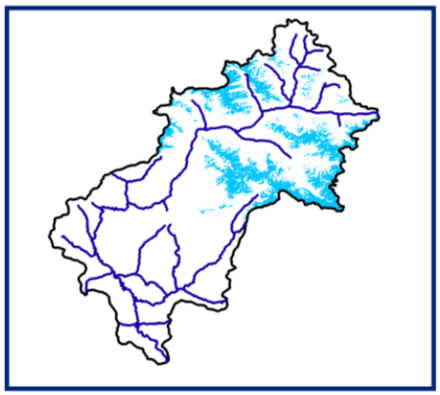
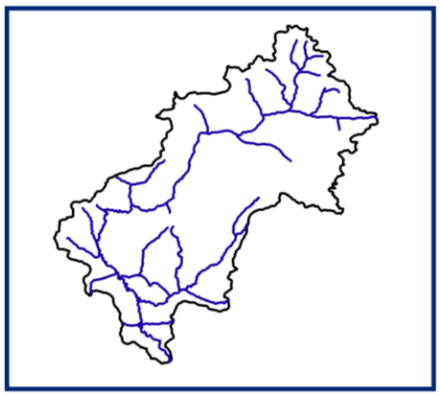
S
02 NOVEMBER 2015
06 NOVEMBER 2015
07 NOVEMBER 2015
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
SNOW
50 25 0 50 100 150
Kilometers

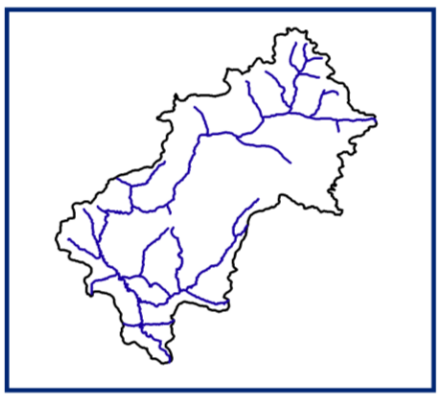
10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN



DATA USED
05 NOVEMBER 2015



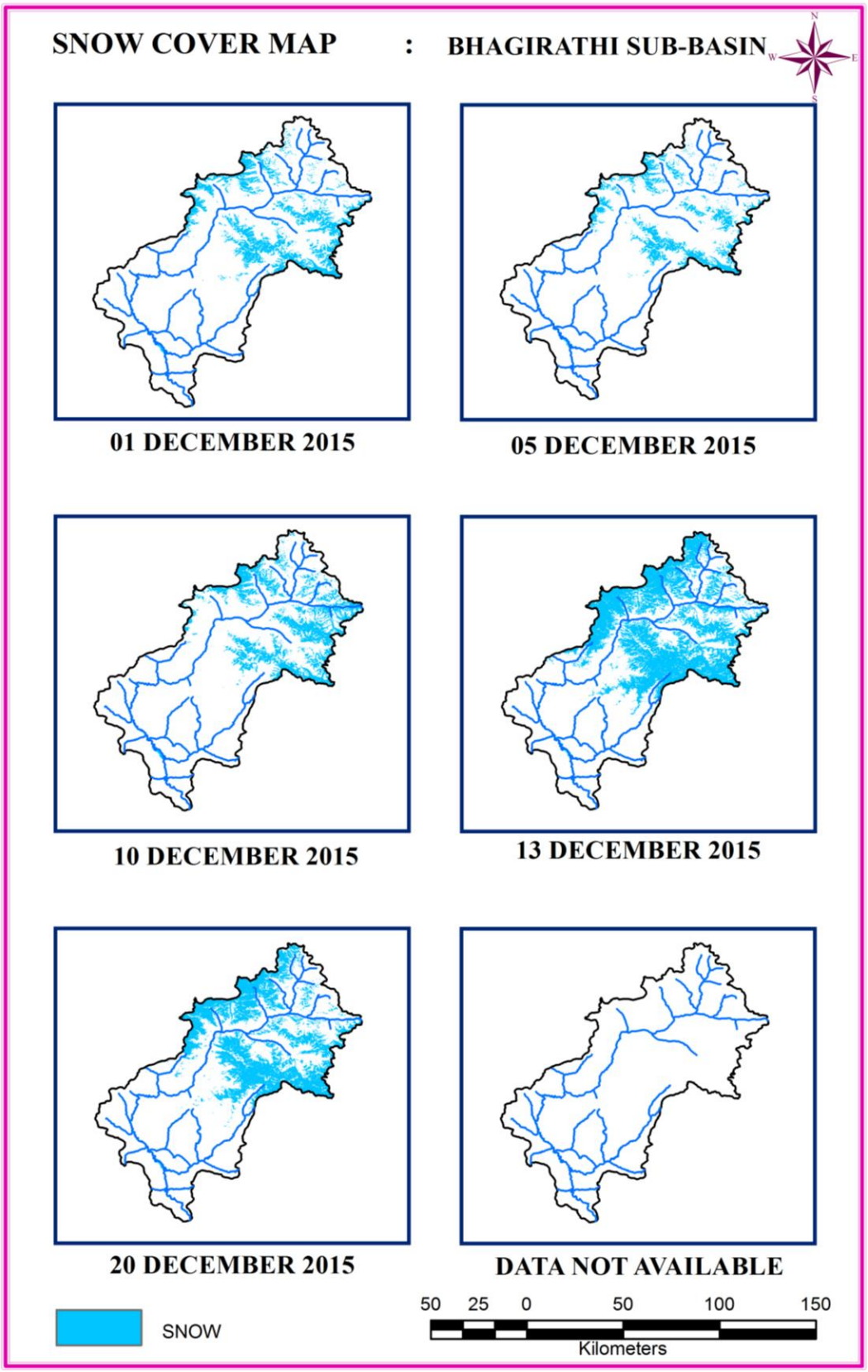
DATA NOT AVAILABLE



DATA NOT AVAILABLE

SNOW

50 25 0 50 100 150
Kilometers


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
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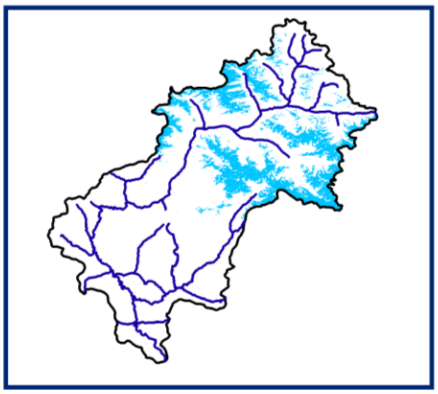
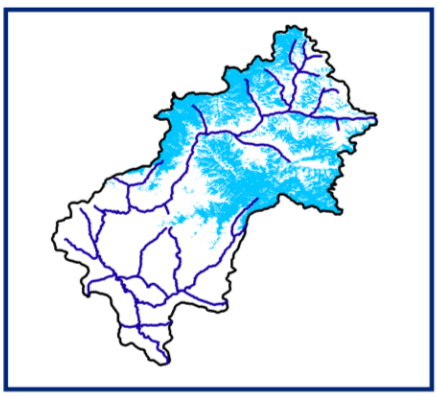
01 DECEMBER 2015
05 DECEMBER 2015
10 DECEMBER 2015
13 DECEMBER 2015
20 DECEMBER 2015
DATA NOT AVAILABLE
SNOW
50 25 0 50 100 150
Kilometers

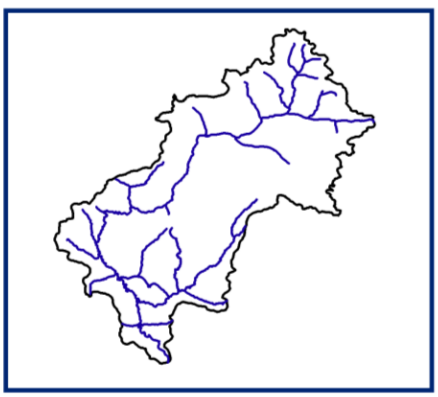
10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN



DATA USED
01 DECEMBER 2015
05 DECEMBER 2015
10 DECEMBER 2015



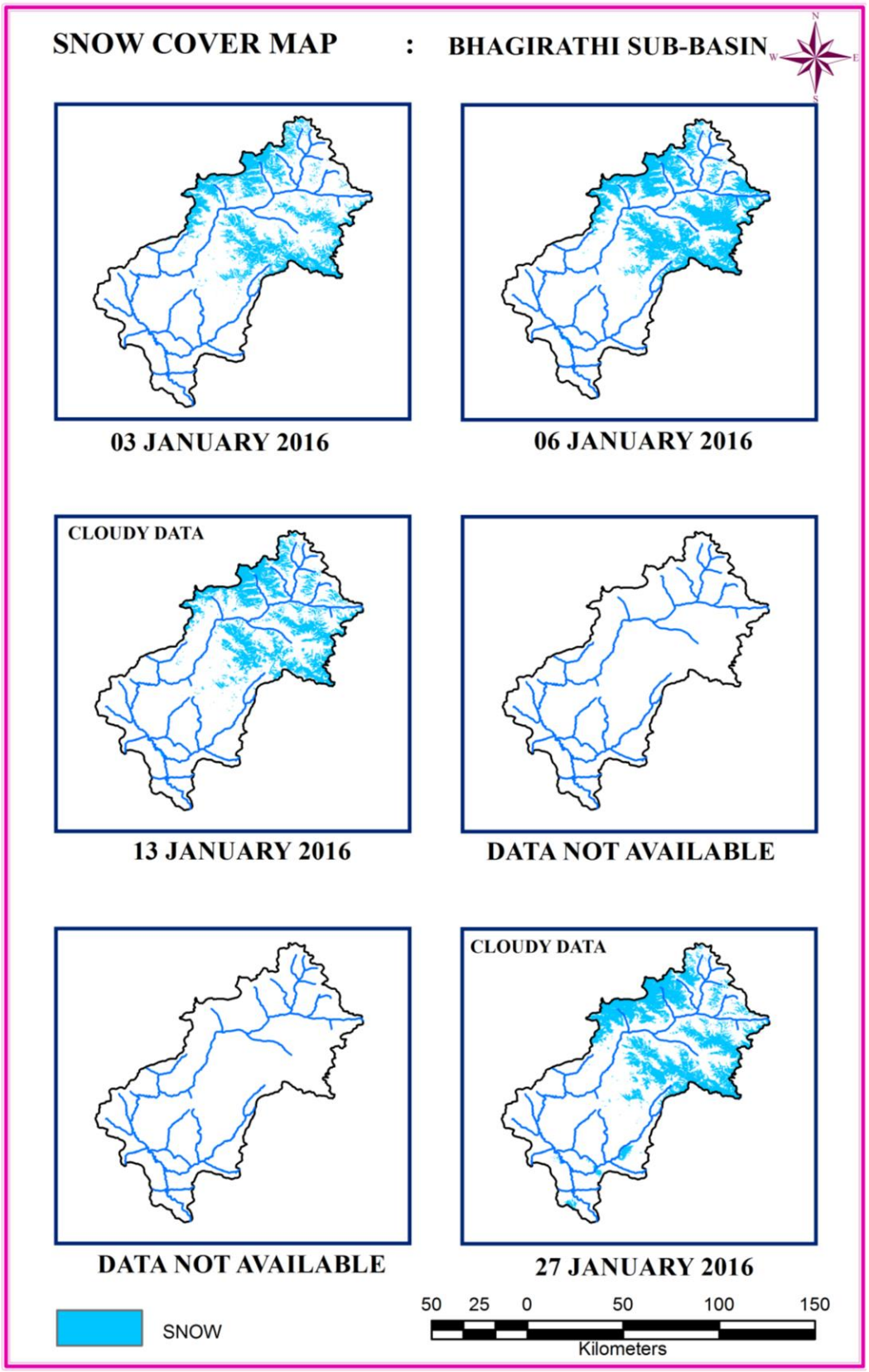
DATA USED
13 DECEMBER 2015
20 DECEMBER 2015



DATA NOT AVAILABLE

SNOW

50 25 0 50 100 150
Kilometers


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
W
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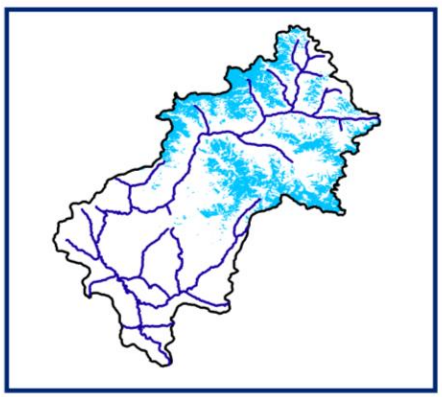
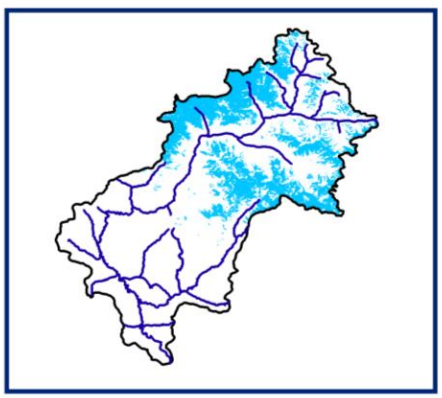
S
03 JANUARY 2016
06 JANUARY 2016
CLOUDY DATA
13 JANUARY 2016
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
27 JANUARY 2016
SNOW
50 25 0 50 100 150
Kilometers

10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN

DATA USED
03 JANUARY 2016
06 JANUARY 2016



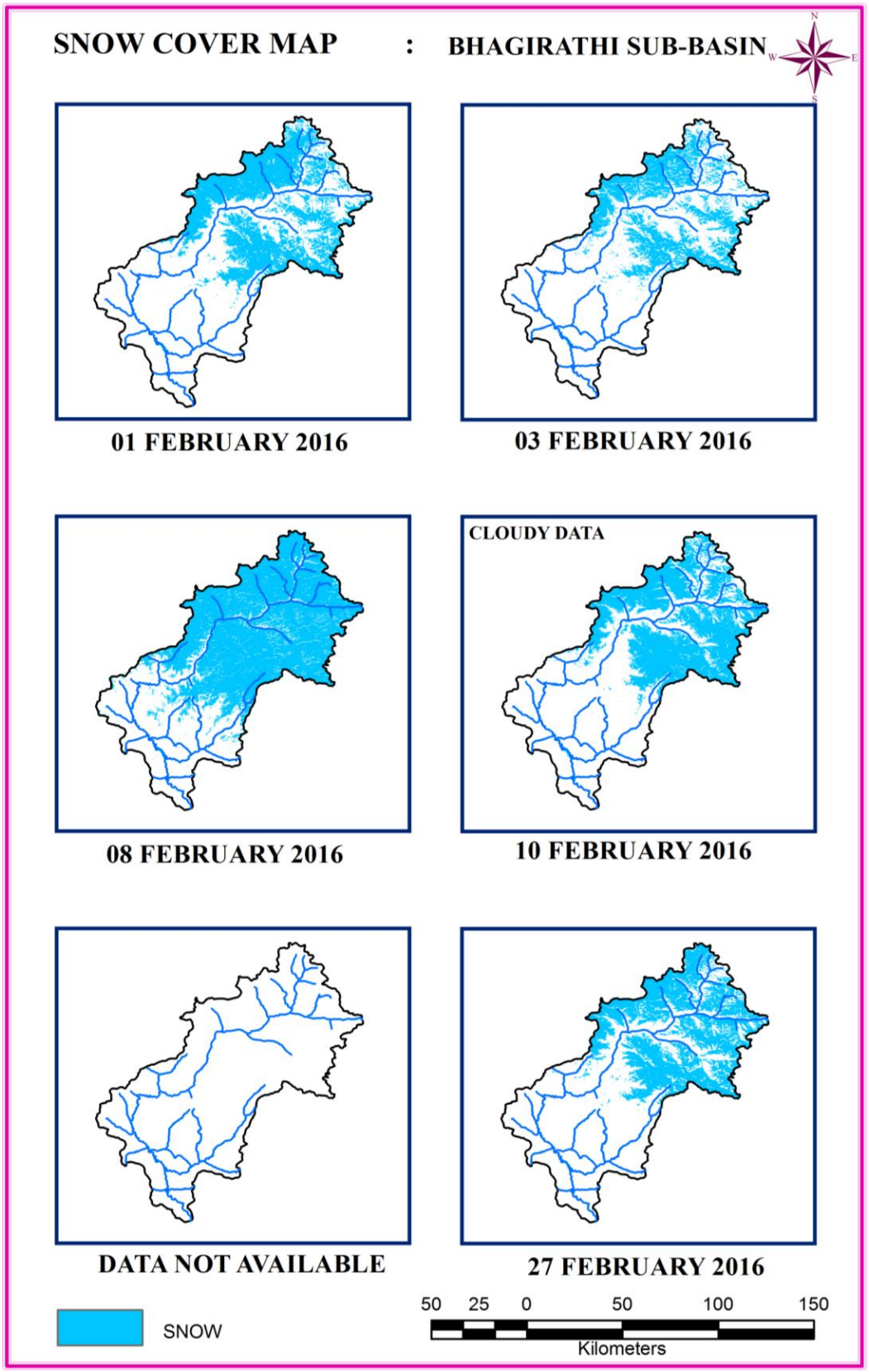
DATA USED
15 JANUARY 2016



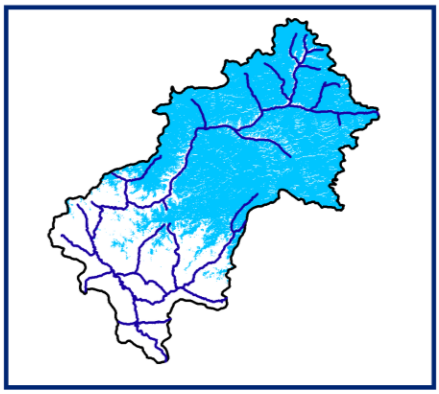
DATA USED
25 JANUARY 2016

SNOW

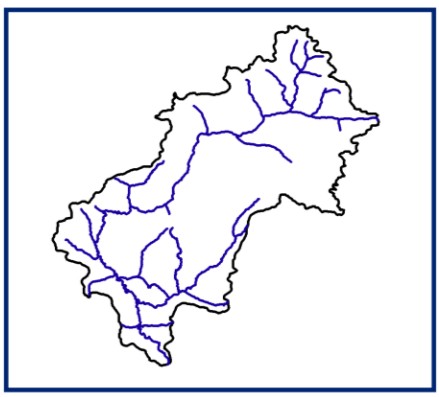
50 25 0 50 100 150
Kilometers


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
W
E
S
01 FEBRUARY 2016
03 FEBRUARY 2016
08 FEBRUARY 2016
CLOUDY DATA
10 FEBRUARY 2016
DATA NOT AVAILABLE
27 FEBRUARY 2016
SNOW
50 25 0 50 100 150
Kilometers

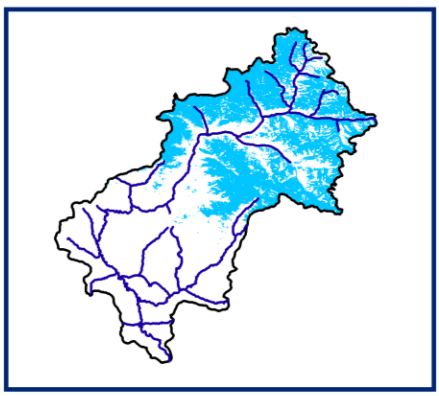
10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN



DATA USED
01 FEBRUARY 2016
03 FEBRUARY 2016
08 FEBRUARY 2016



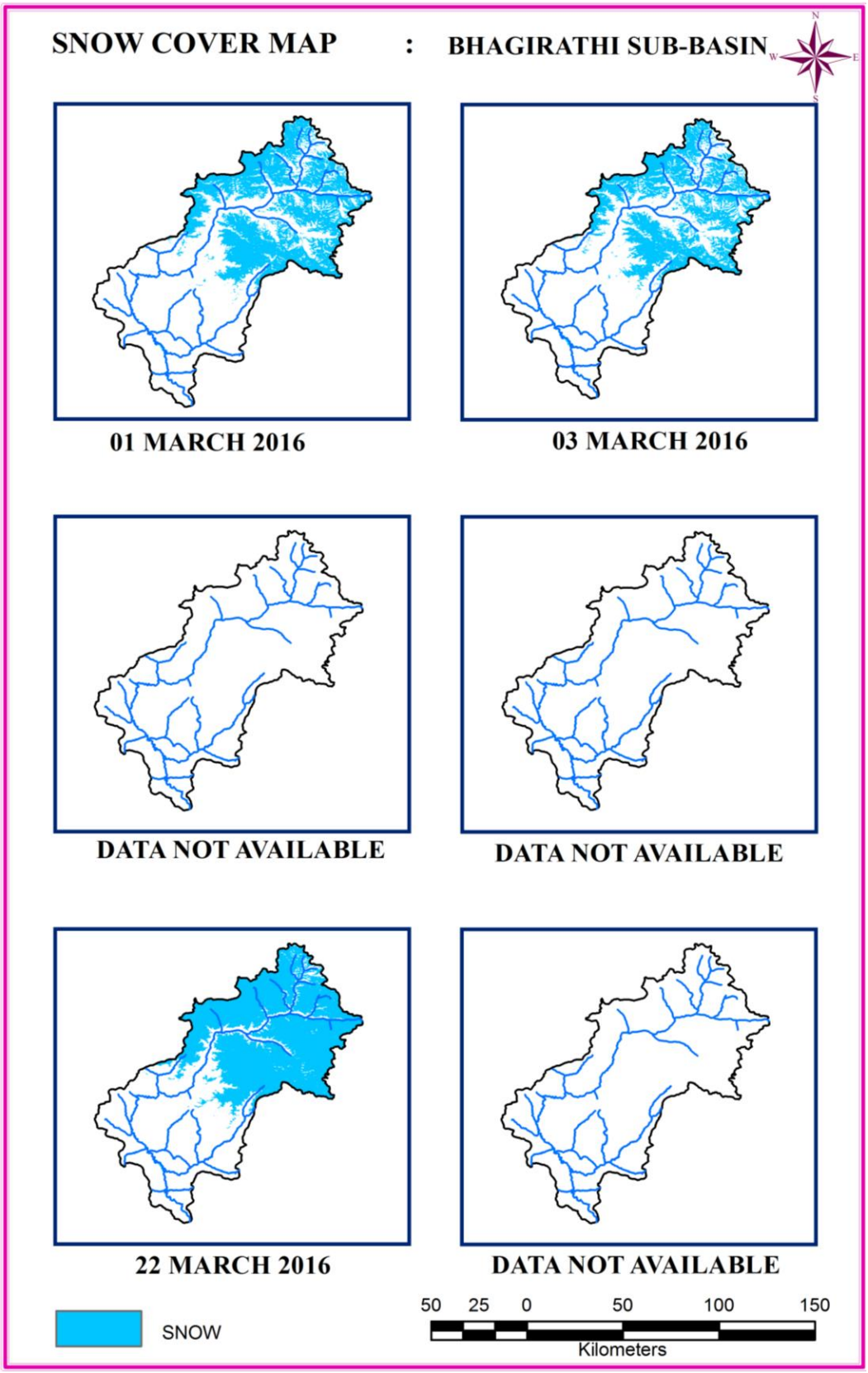
DATA NOT AVAILABLE



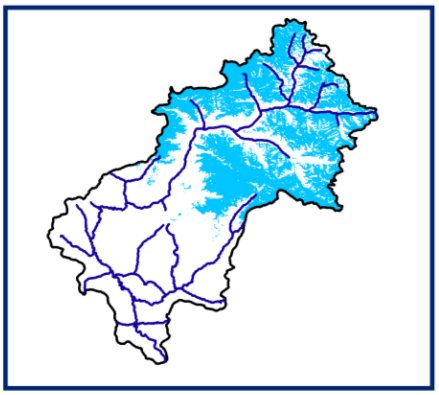
DATA USED
25 FEBRUARY 2016

SNOW

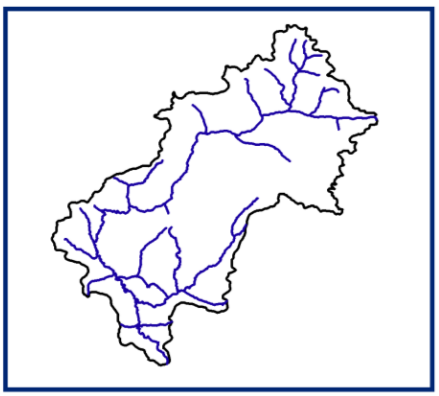
50 25 0 50 100 150
Kilometers


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
W
E
S
01 MARCH 2016
03 MARCH 2016
DATA NOT AVAILABLE
DATA NOT AVAILABLE
22 MARCH 2016
DATA NOT AVAILABLE
SNOW
50 25 0 50 100 150
Kilometers

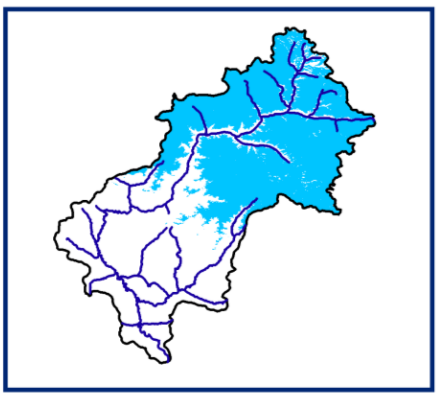
10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN



DATA USED
01 MARCH 2016
03 MARCH 2016



DATA NOT AVAILABLE

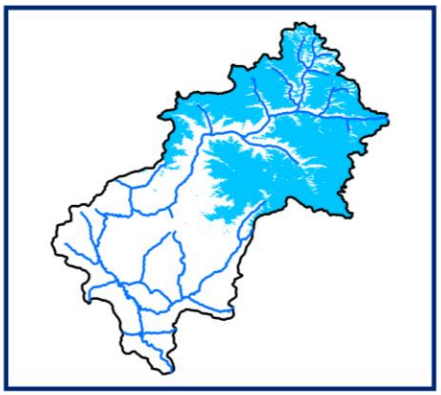


DATA USED
25 MARCH 2016

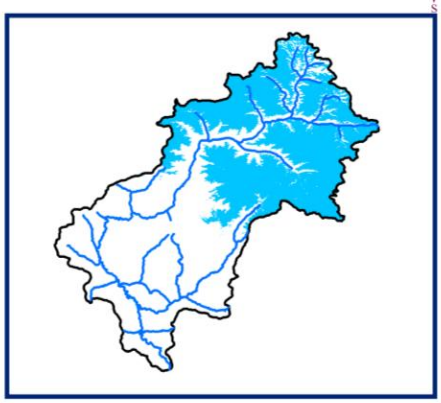
SNOW

40 20 0 40 80 120
Kilometers

SNOW COVER MAP : BHAGIRATHI SUB-BASIN

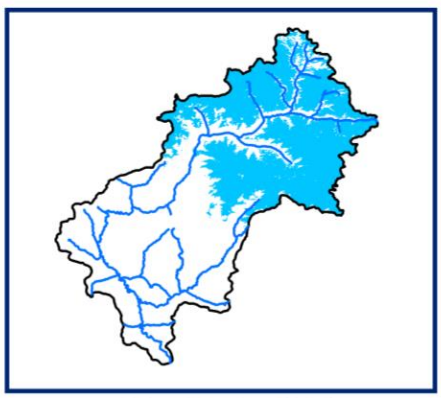


03 APRIL 2016

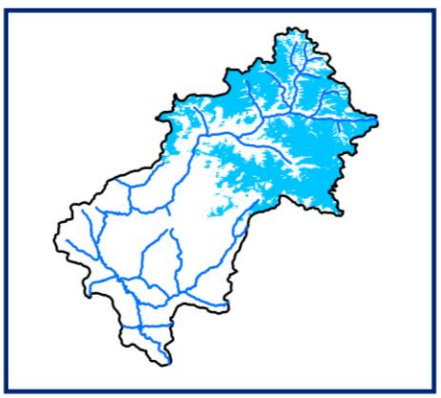


13 APRIL 2016

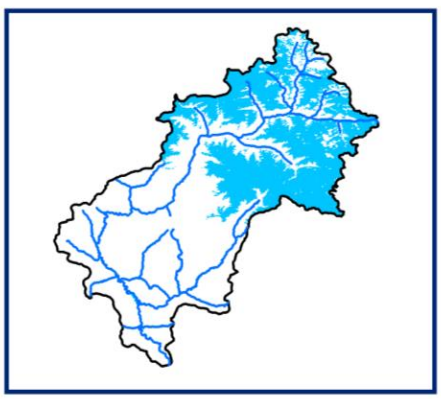
20 APRIL 2016



23 APRIL 2016



27 APRIL 2016



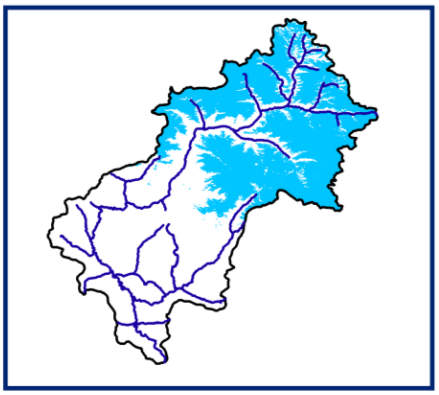
30 APRIL 2016

SNOW

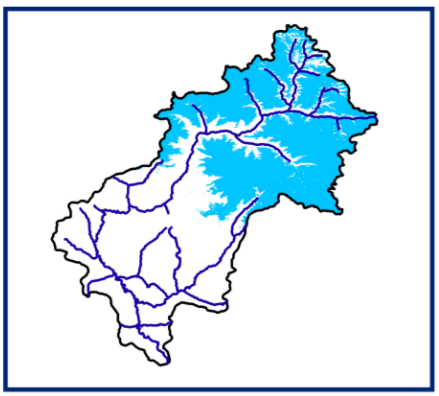
50 25 0 50 100 150

Kilometers

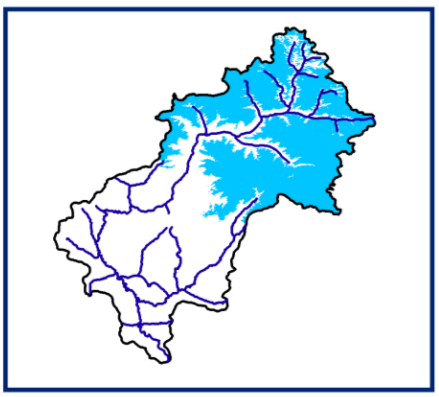
10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN



DATA USED
05 APRIL 2016



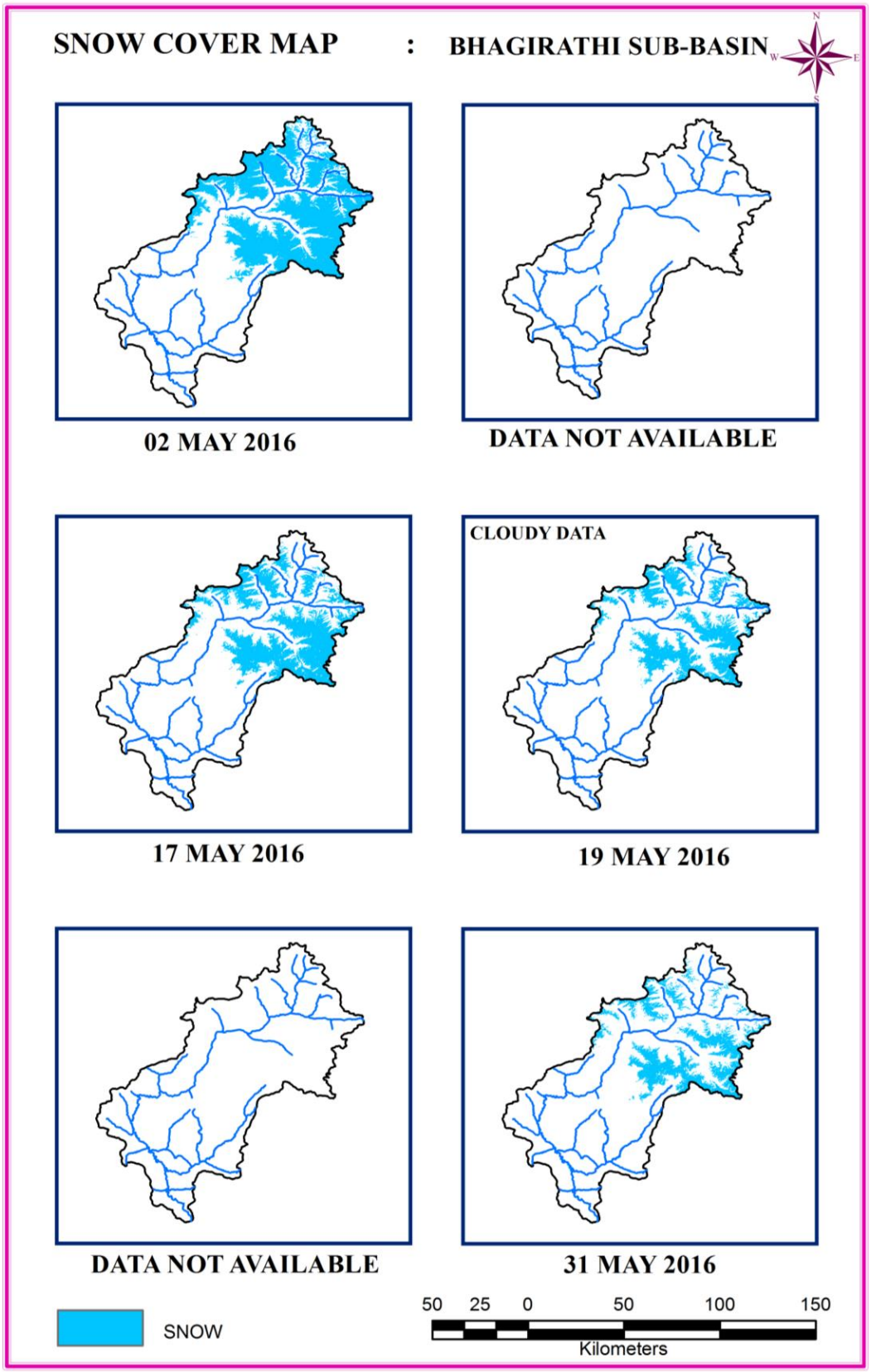
DATA USED
13 APRIL 2016
20 APRIL 2016



DATA USED
23 APRIL 2016
27 APRIL 2016

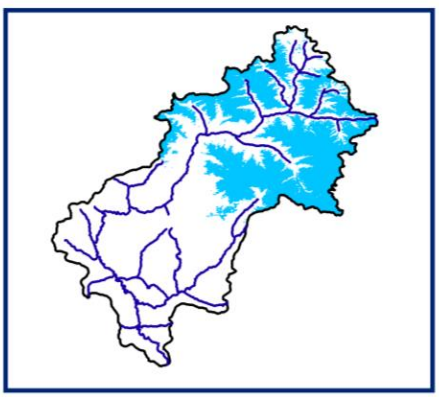
50 25 0 50 100 150
Kilometers

SNOW


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
N
W
E
S
02 MAY 2016
DATA NOT AVAILABLE
17 MAY 2016
CLOUDY DATA
19 MAY 2016
DATA NOT AVAILABLE
31 MAY 2016
SNOW
50 25 0 50 100 150
Kilometers

10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN

DATA USED
05 MAY 2016

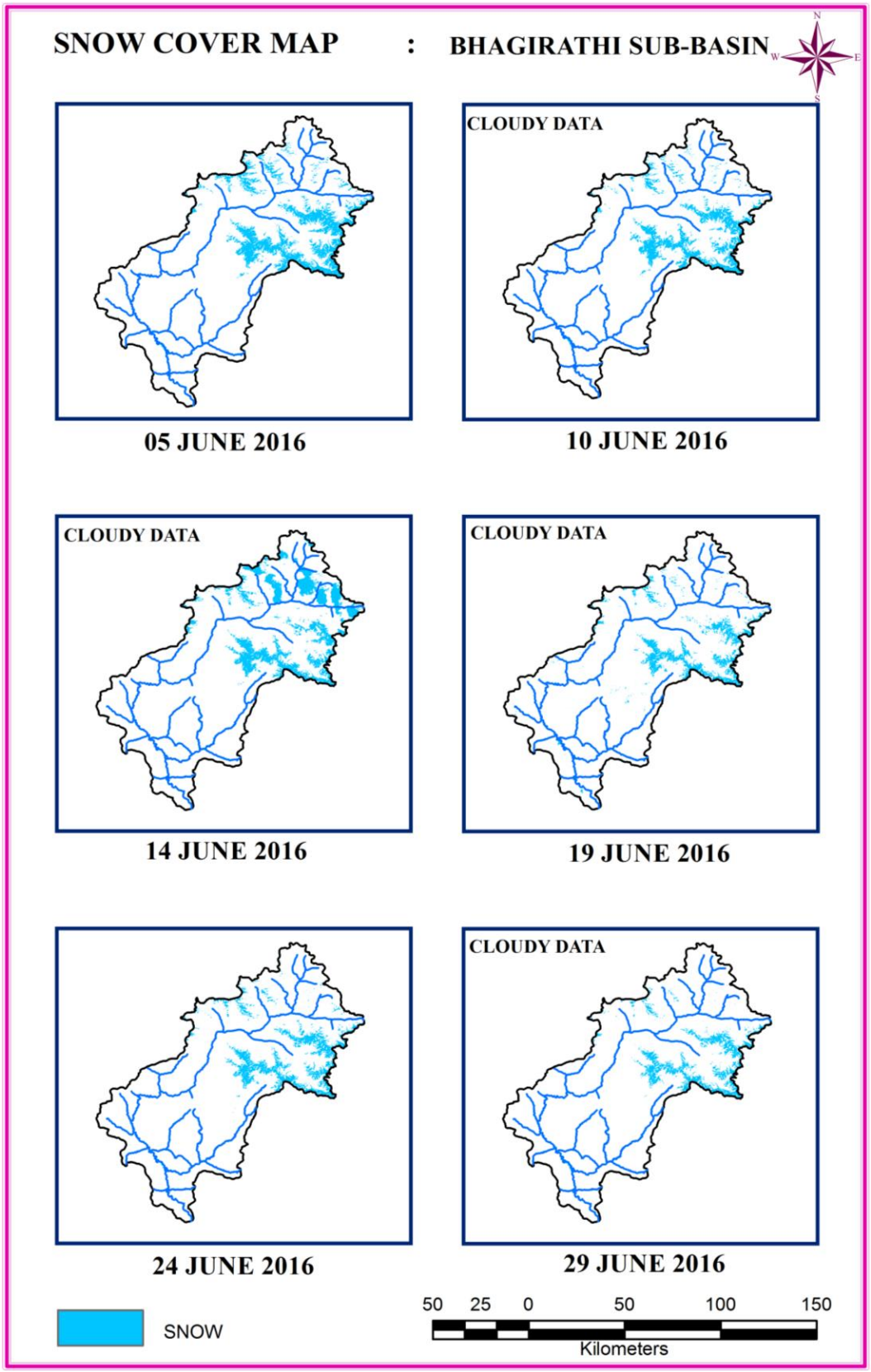


DATA USED
17 MAY 2016
19 MAY 2016

DATA USED
25 MAY 2016

40 20 0 40 80 120
Kilometers

SNOW


SNOW COVER MAP : BHAGIRATHI SUB-BASIN
CLOUDY DATA
05 JUNE 2016
10 JUNE 2016
CLOUDY DATA
CLOUDY DATA
14 JUNE 2016
19 JUNE 2016
CLOUDY DATA
24 JUNE 2016
29 JUNE 2016
SNOW
50 25 0 50 100 150
Kilometers

10 DAILY SNOW COVER MAP : BHAGIRATHI SUB-BASIN

DATA USED
05 JUNE 2016
10 JUNE 2016

DATA USED
14 JUNE 2016
19 JUNE 2016

DATA USED
24 JUNE 2016
29 JUNE 2016

40 20 0 40 80 120
Kilometers

SNOW

YAMUNA SUB-BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: YAMUNA **BASIN AREA: 3527 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2015							
1	04-Oct-2015	249 (c)	7	3	30-Oct-2015	240	7
2	28-Oct-2015	214 (c)	6				
November 2015							
4	01-Nov-2015	213	6	13	06-Nov-2015	569	16
5	02-Nov-2015	201	7	14	07-Nov-2015	424	12
December 2015							
8	01-Dec-2015	663	19	11	10-Dec-2015	276 (c)	8
9	05-Dec-2015	427	12	12	13-Dec-2015	1483	42
10	07-Dec-2015	355	10	13	20-Dec-2015	1041	30
January 2016							
14	03-Jan-16	803	23	16	13-Jan-16	688 (c)	20
15	06-Jan-16	794 (c)	23	17	27-Jan-16	763 (c)	22
February 2016							
18	01-Feb-16	1291	37	21	10-Feb-16	1316 (c)	37
19	03-Feb-16	1154	33	22	17-Feb-16	1285	36
20	08-Feb-16	2958	84	23	27-Feb-16	1020	29
March 2016							
24	01-March-16	1067	30	26	22-March-16	1346	38
25	03-March-16	942	27				
April 2016							
27	03-April-16	950	27	30	23-April-16	823 (c)	23
28	13-April-16	991	28	31	27-April-16	550 (c)	16
29	20-April-16	888	25	32	30-April-16	768	22
May 2016							
33	02-May-16	694	20	35	19-May-16	456 (c)	13
34	17-May-16	511	14	36	31-May-16	480	14

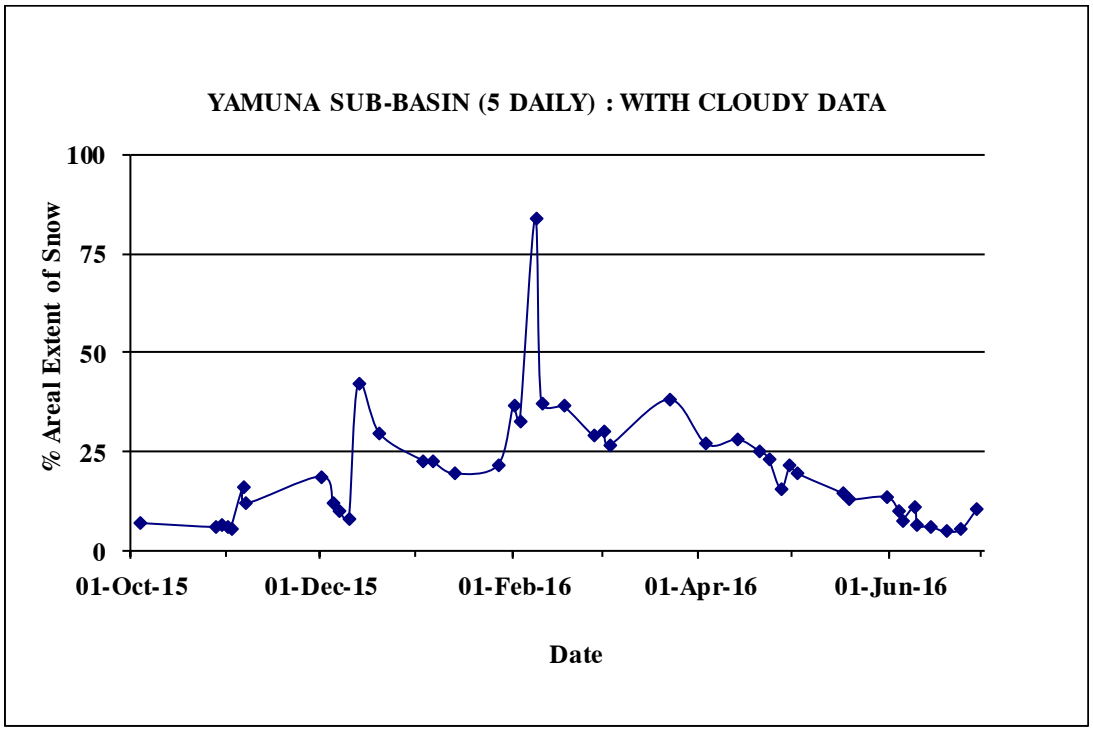
June 2016							
37	04-June-16	347 (c)	10	41	14-June-16	219	6
38	05-June-16	275 (c)	8	42	19-June-16	172 (c)	5
39	09-June-16	391 (c)	11	43	24-June-16	194	6
40	10-June-16	228 (c)	6	44	29-June-16	370 (c)	10

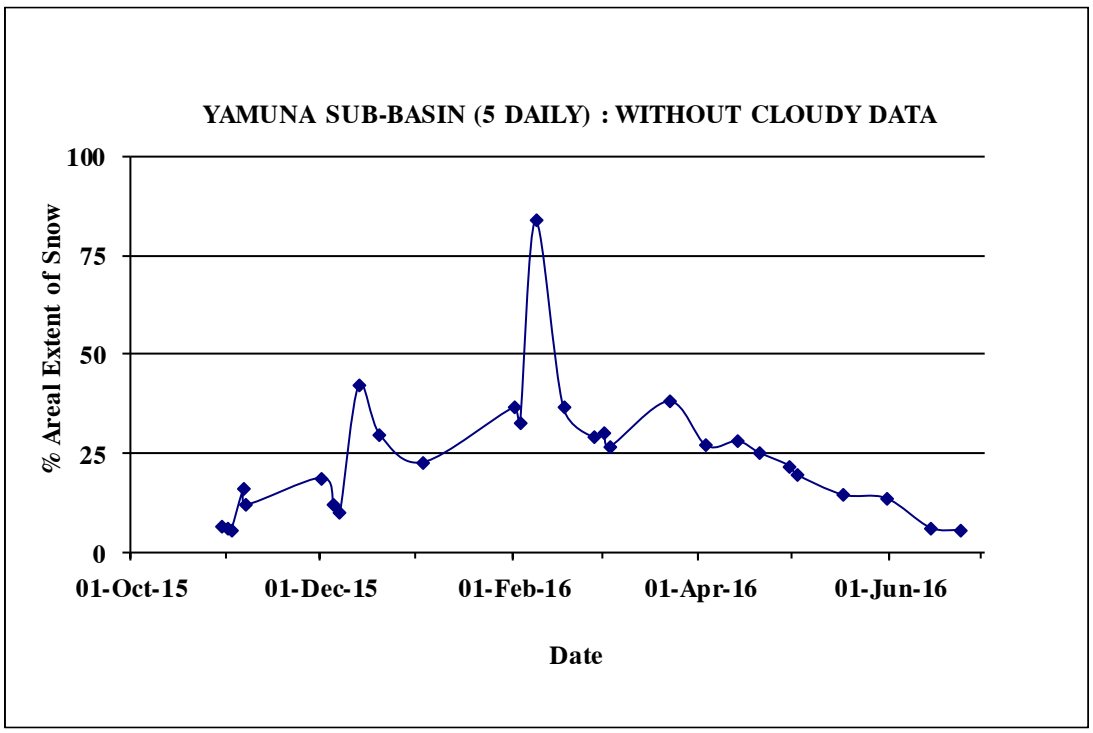
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: YAMUNA **BASIN AREA: 3527 sq km**

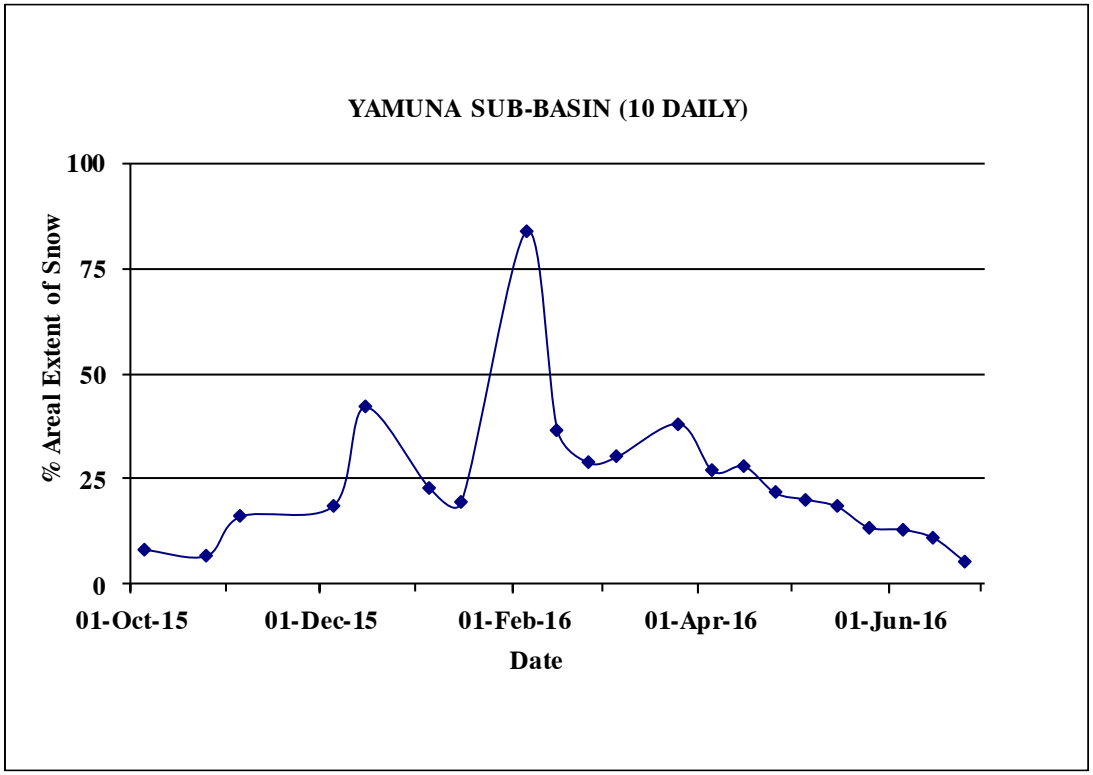
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2015							
1	5-Oct-15	293	8	2	25-Oct-15	241	7
November 2015							
3	5-Nov-15	570	16				
December 2015							
4	5-Dec-15	662	19	5	15-Dec-15	1485	42
January 2016							
6	5-Jan-16	803	23	7	15-Jan-16	689	20
February 2016							
8	05-Feb-16	2958	84	10	25-Feb-16	1020	29
9	15-Feb-16	1286	36				
March 2016							
11	5-March-16	1067	30	12	25-March-16	1346	38
April 2016							
13	5-April-16	949	27	15	25-April-16	768	22
14	15-April-16	991	28				
May 2016							
16	5-May-16	712	20	18	25-May-16	480	14
17	15-May-16	653	19				
June 2016							
19	5-June-16	460	13	21	25-June-16	194	6
20	15-June-16	391	11				

SNOW COVER DEPLETION CURVE

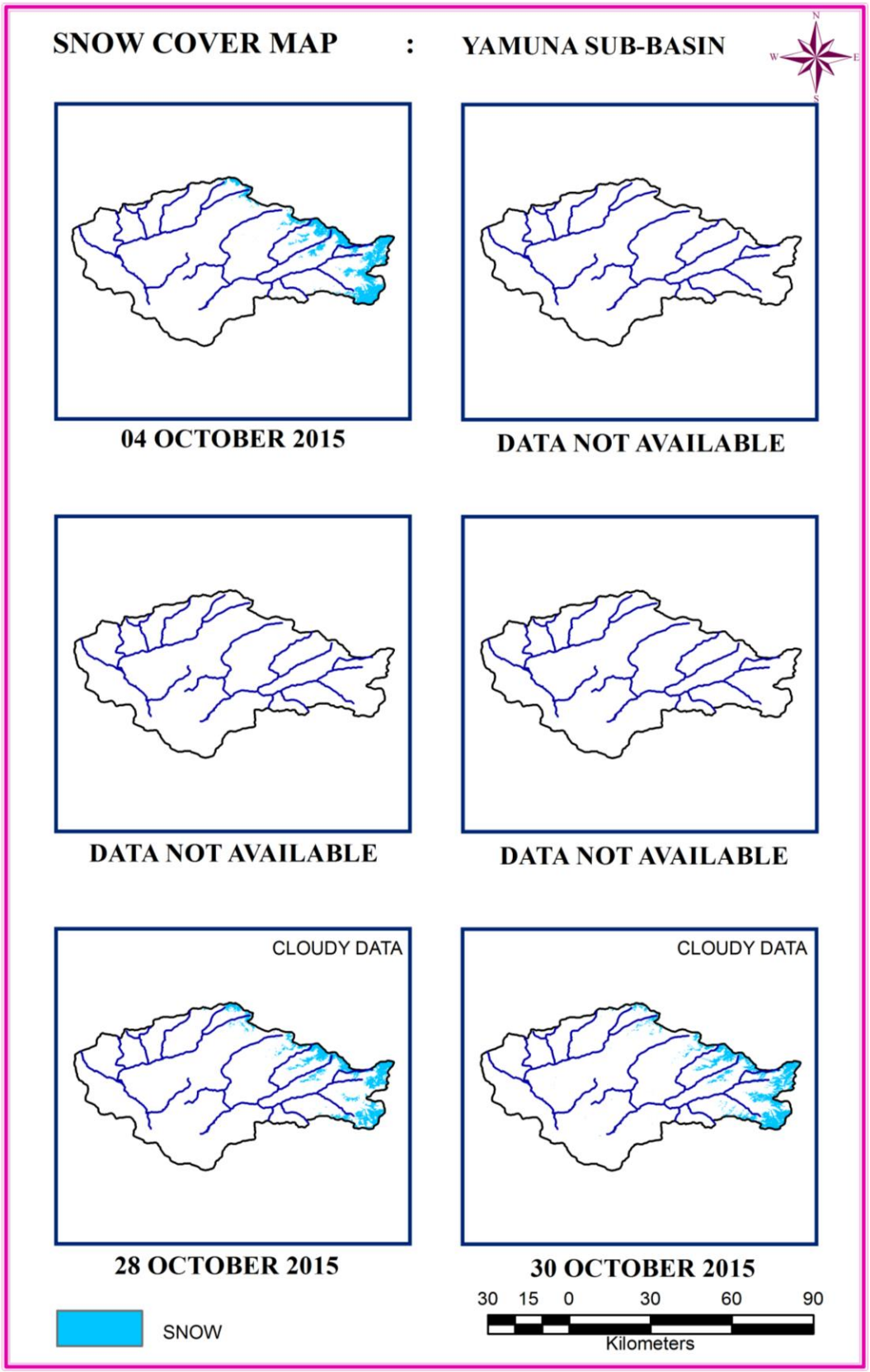




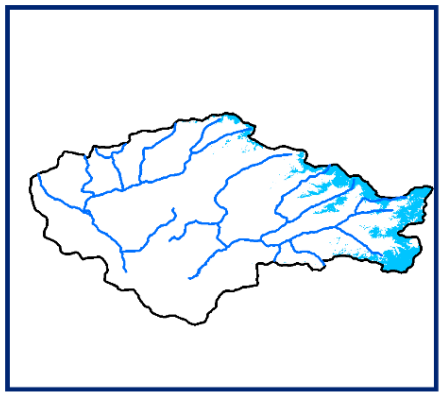
SNOW COVER DEPLETION CURVE



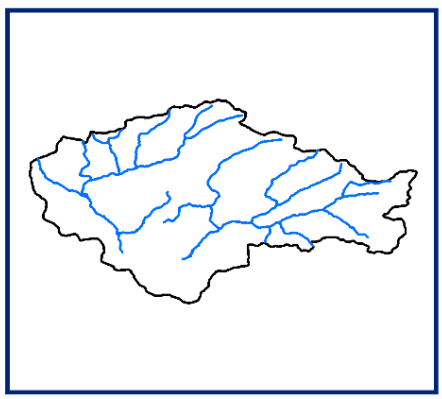
SNOW COVER MAP


SNOW COVER MAP : YAMUNA SUB-BASIN
N
W
E
S
04 OCTOBER 2015
DATA NOT AVAILABLE
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
CLOUDY DATA
28 OCTOBER 2015
30 OCTOBER 2015
30 15 0 30 60 90
Kilometers
SNOW

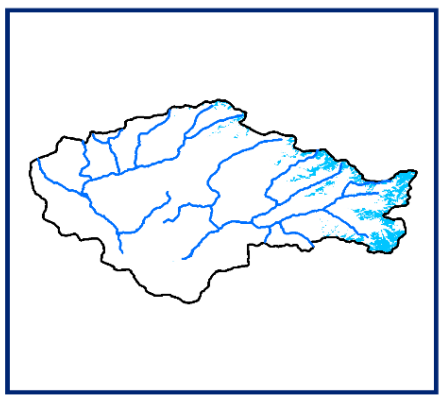
10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



DATA USED
05 OCTOBER 2006



DATA NOT AVAILABLE

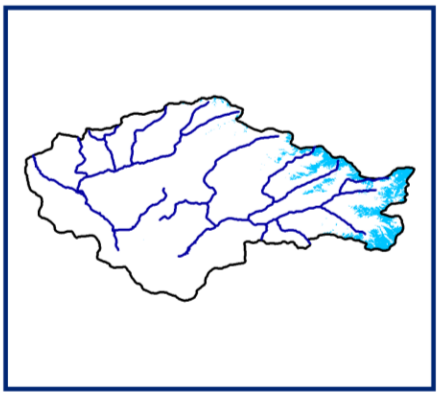


DATA USED
28 OCTOBER 2015
30 OCTOBER 2015

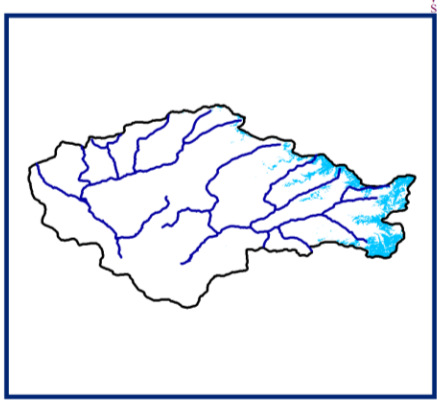
SNOW

30 15 0 30 60 90
Kilometers

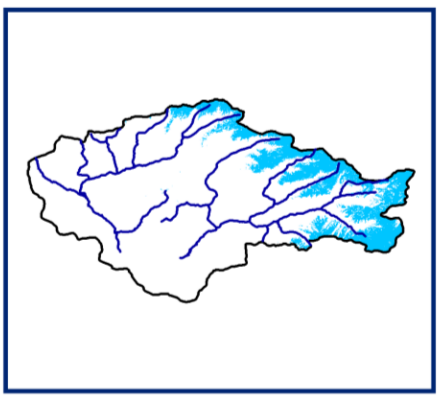
SNOW COVER MAP : YAMUNA SUB-BASIN



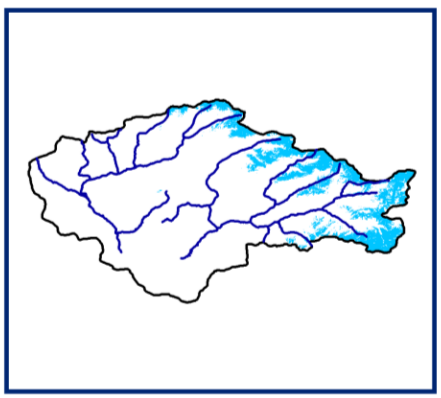
01 NOVEMBER 2015



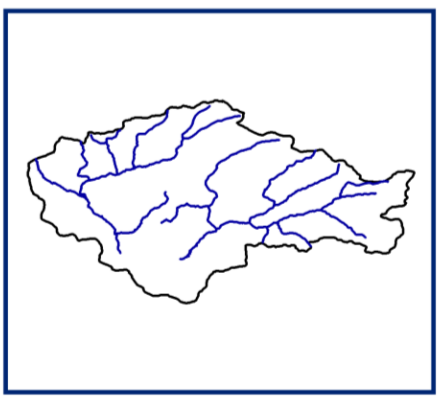
02 NOVEMBER 2015



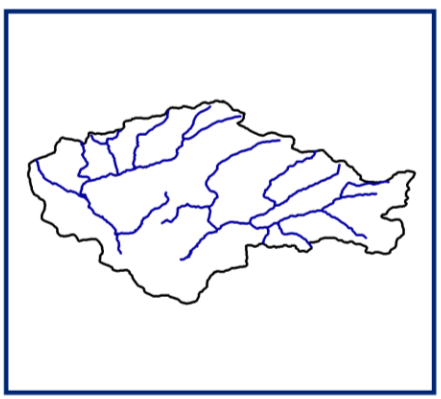
06 NOVEMBER 2015



07 NOVEMBER 2015



DATA NOT AVAILABLE



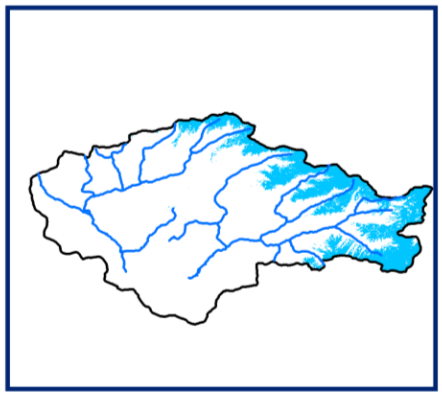
DATA NOT AVAILABLE

SNOW

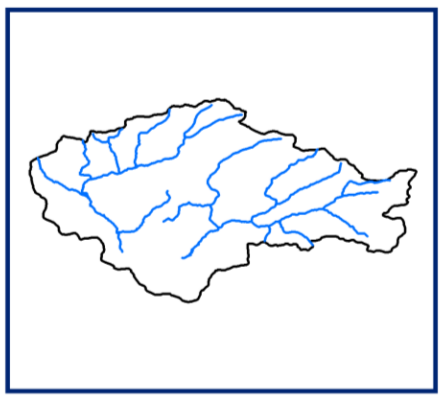
30 15 0 30 60 90

Kilometers

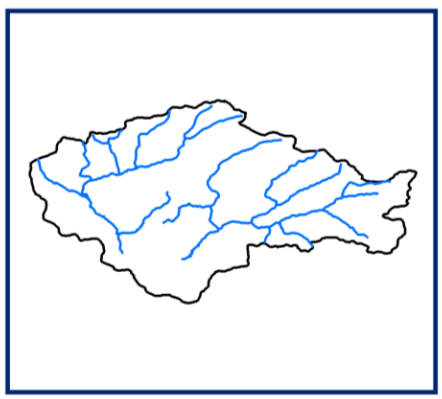
10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



DATA USED
01 NOVEMBER 2015
06 NOVEMBER 2015
07 NOVEMBER 2015



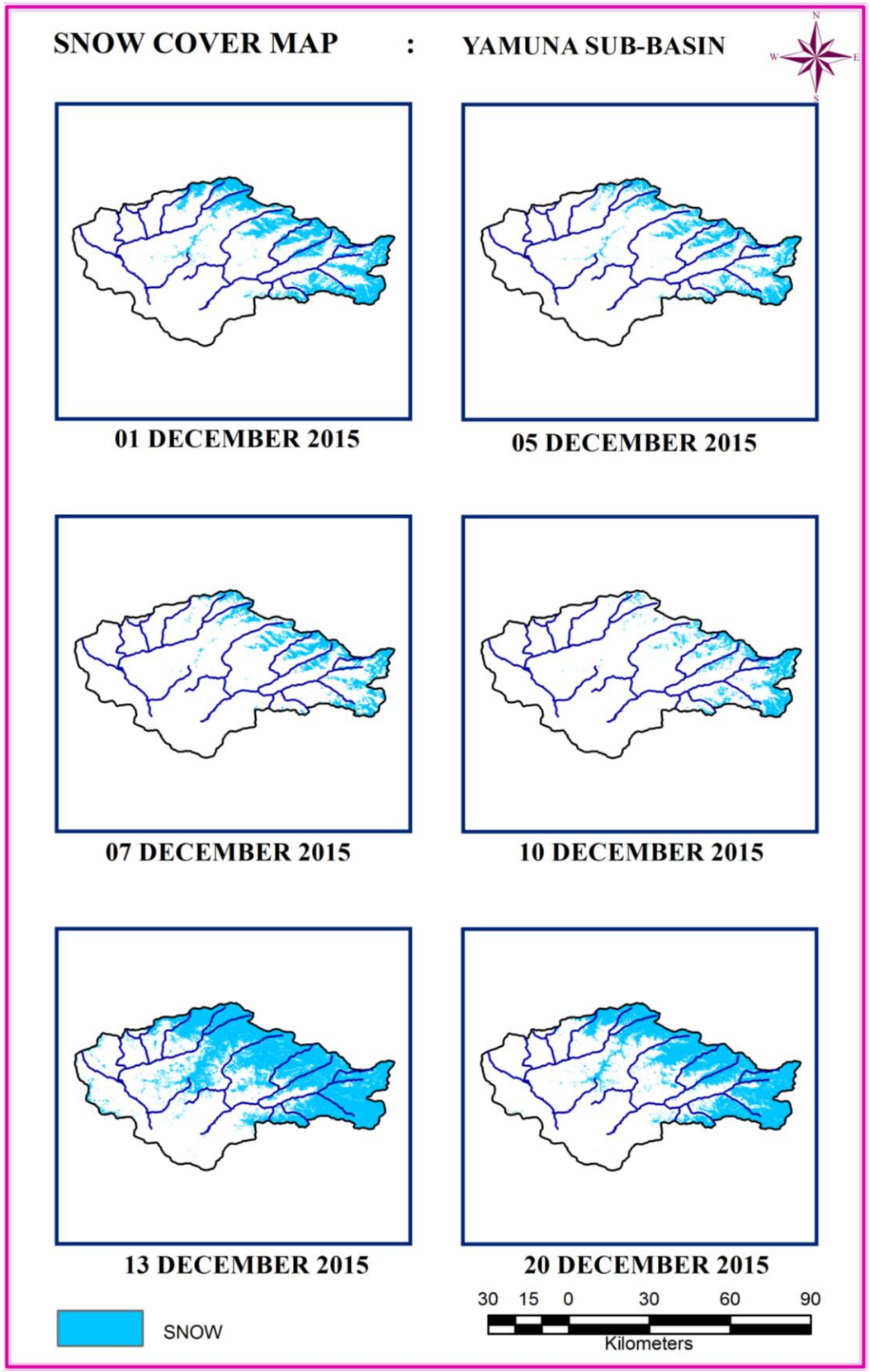
DATA NOT AVAILABLE



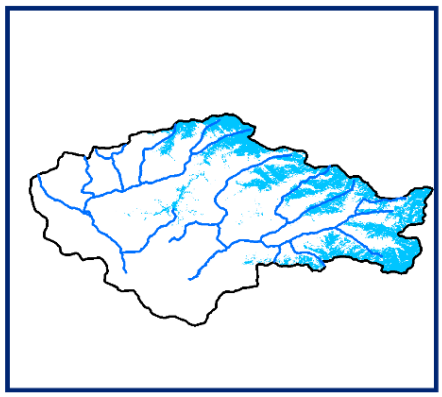
DATA NOT AVAILABLE

SNOW

30 15 0 30 60 90
Kilometers


SNOW COVER MAP : YAMUNA SUB-BASIN
N
W
E
S
01 DECEMBER 2015
05 DECEMBER 2015
07 DECEMBER 2015
10 DECEMBER 2015
13 DECEMBER 2015
20 DECEMBER 2015
SNOW
30 15 0 30 60 90
Kilometers

10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



DATA USED
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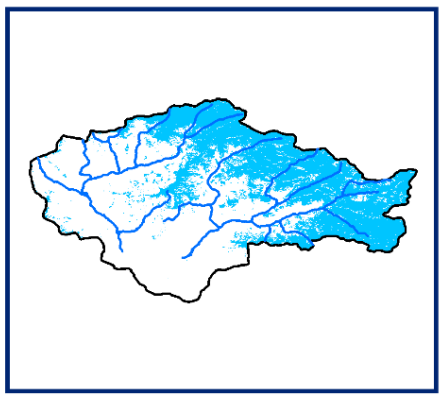
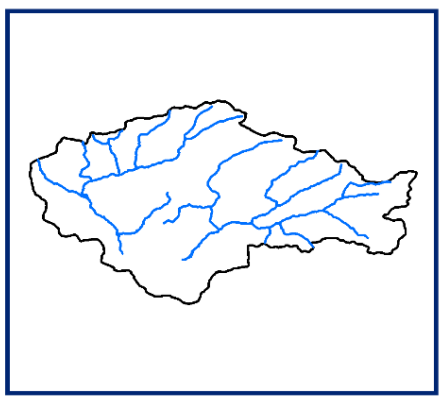
05 DECEMBER 2015
07 DECEMBER 2015



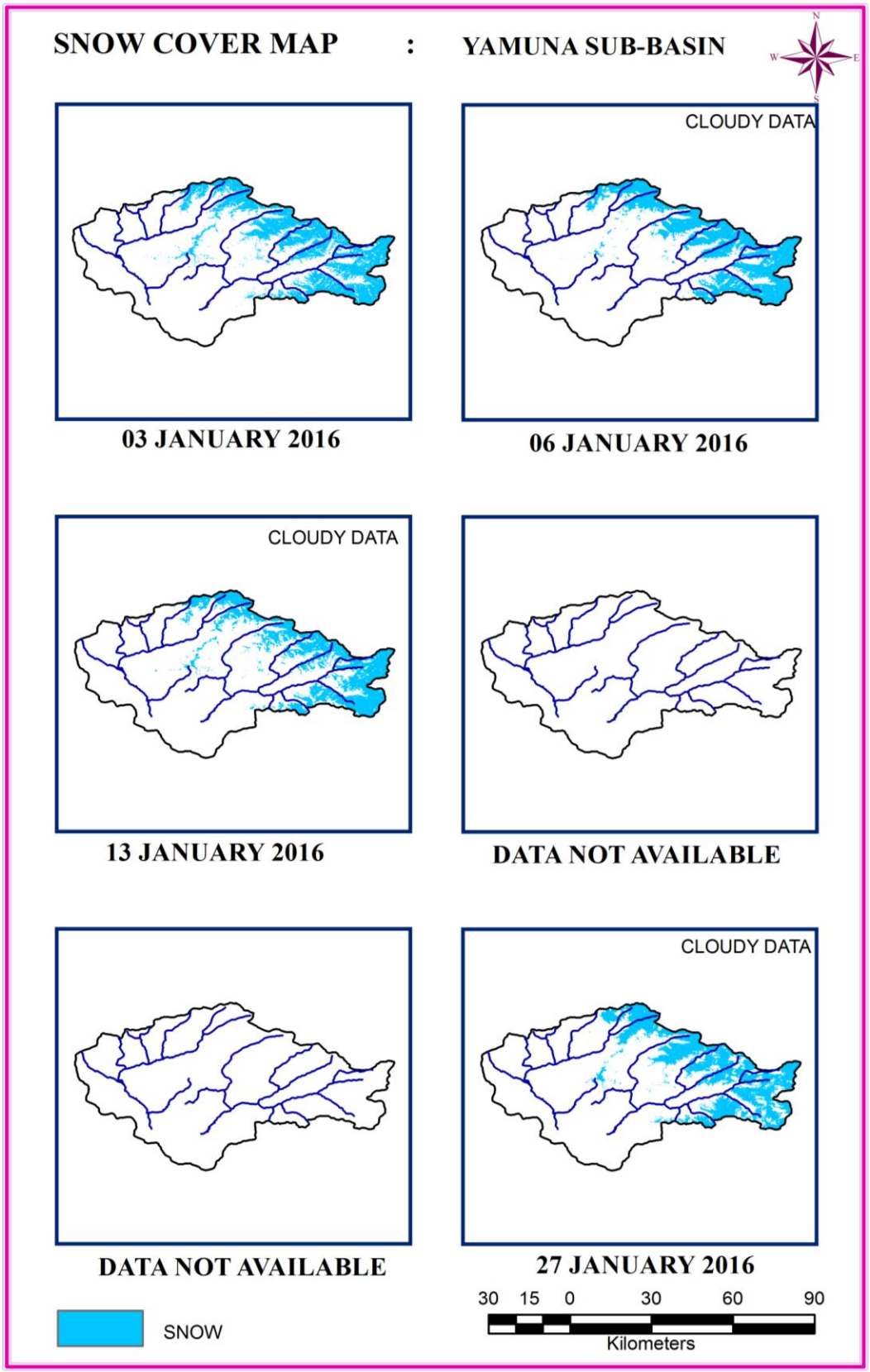
DATA USED
13 DECEMBER 2015
20 DECEMBER 2015



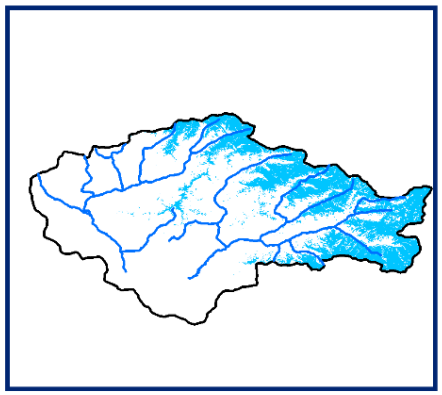
DATA NOT AVAILABLE

SNOW

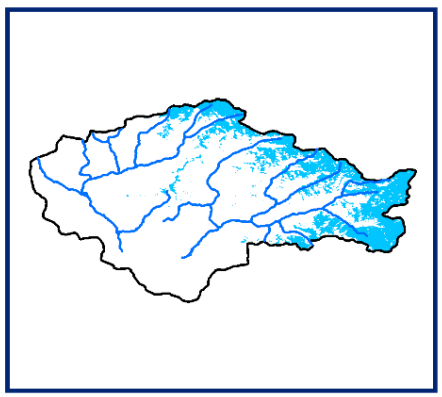
30 15 0 30 60 90
Kilometers


SNOW COVER MAP : YAMUNA SUB-BASIN
N
W
E
S
CLOUDY DATA
03 JANUARY 2016
CLOUDY DATA
06 JANUARY 2016
CLOUDY DATA
13 JANUARY 2016
DATA NOT AVAILABLE
DATA NOT AVAILABLE
CLOUDY DATA
27 JANUARY 2016
SNOW
30 15 0 30 60 90
Kilometers

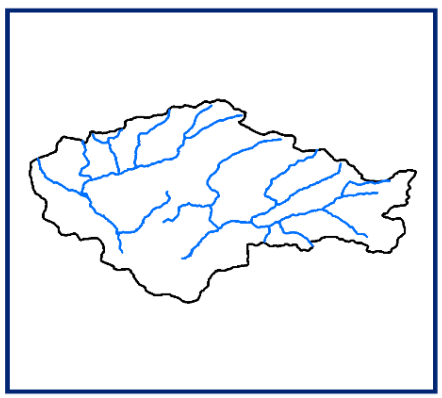
10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



DATA USED
03 JANUARY 2016
06 JANUARY 2016



DATA USED
15 JANUARY 2016

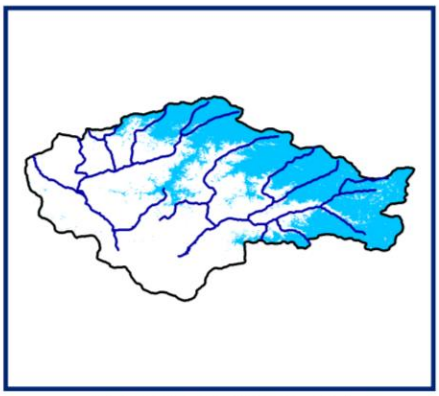


DATA NOT AVAILABLE

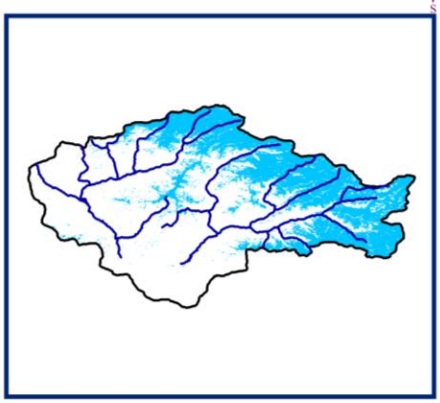
SNOW

30 15 0 30 60 90
Kilometers

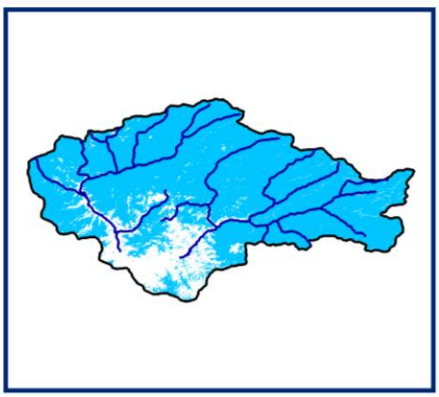
SNOW COVER MAP : YAMUNA SUB-BASIN



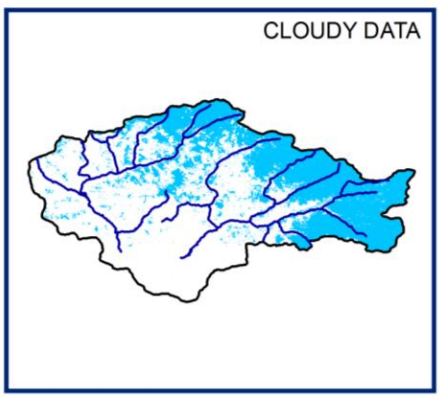
03 FEBRUARY 2016



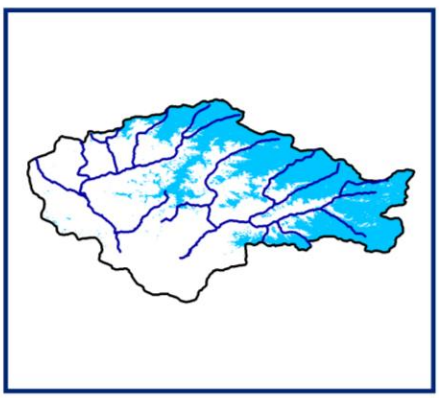
03 FEBRUARY 2016



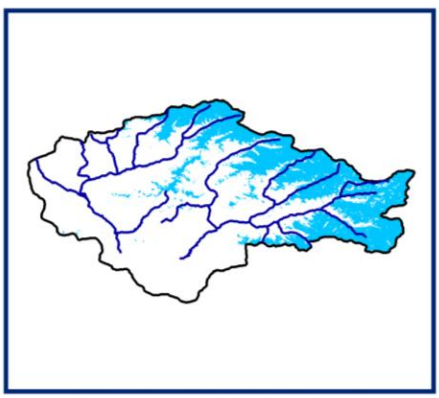
08 FEBRUARY 2016



10 FEBRUARY 2016



17 FEBRUARY 2016



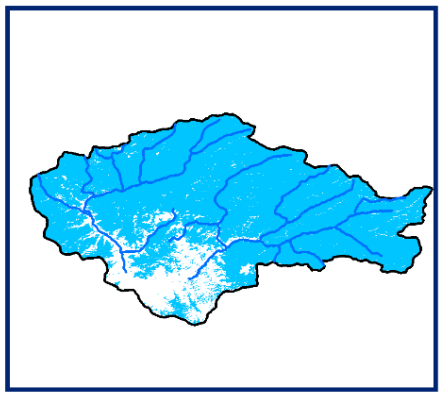
27 FEBRUARY 2016

SNOW

30 15 0 30 60 90

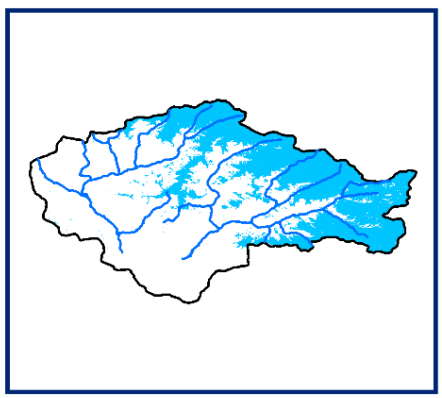
Kilometers

10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



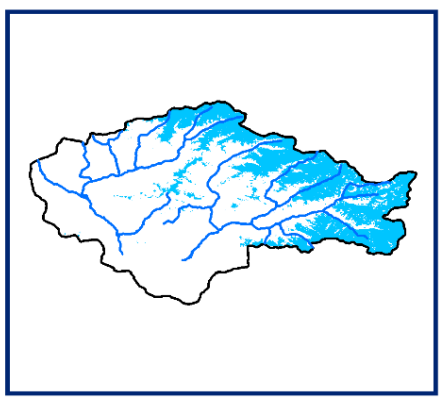
DATA USED

01 FEBRUARY 2016
03 FEBRUARY 2016
08 FEBRUARY 2016



DATA USED

15 FEBRUARY 2016



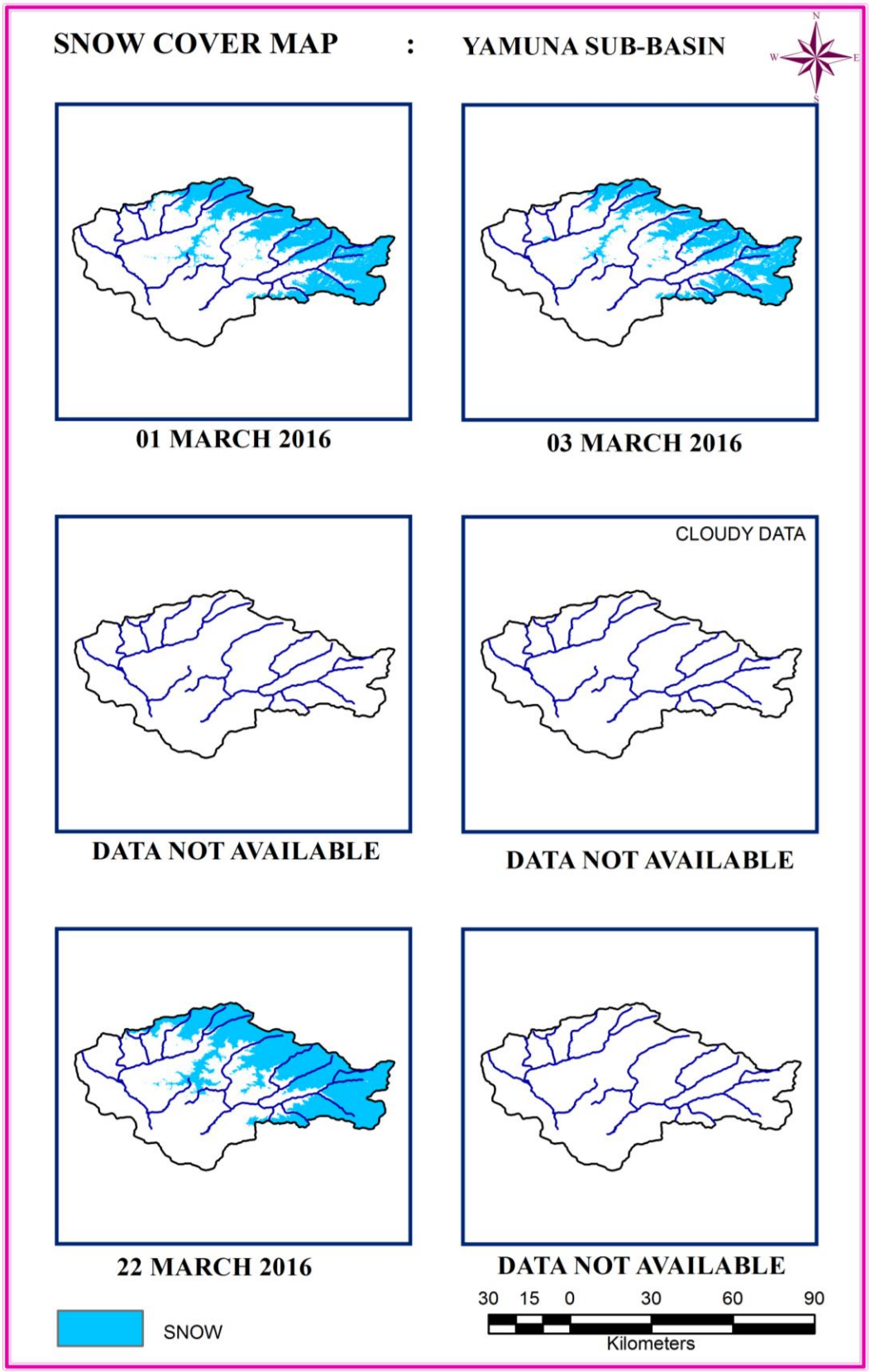
DATA USED

25 FEBRUARY 2016

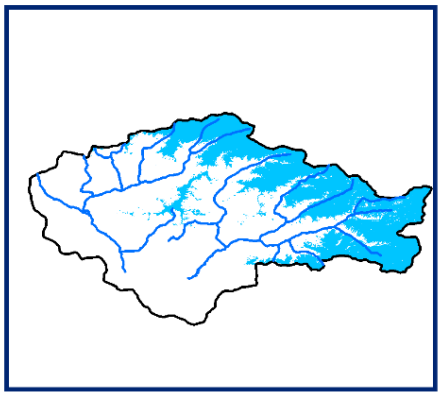
SNOW

30 15 0 30 60 90

Kilometers

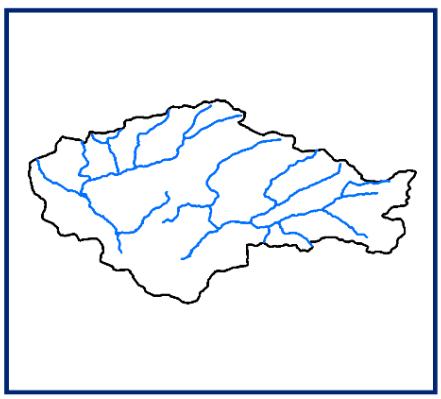

SNOW COVER MAP : YAMUNA SUB-BASIN
N
W
E
S
01 MARCH 2016
03 MARCH 2016
DATA NOT AVAILABLE
CLOUDY DATA
DATA NOT AVAILABLE
22 MARCH 2016
DATA NOT AVAILABLE
SNOW
30 15 0 30 60 90
Kilometers

10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN

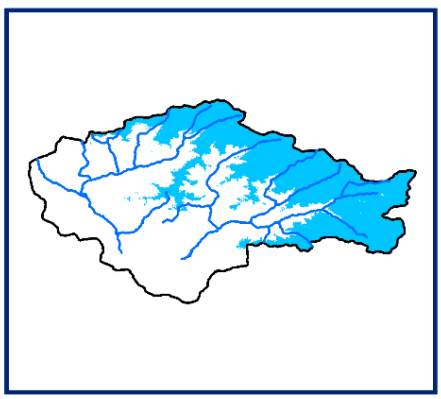


DATA USED

01 MARCH 2016
03 MARCH 2016



DATA NOT AVAILABLE



DATA USED

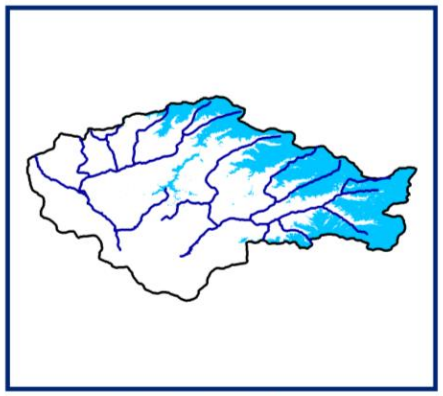
25 MARCH 2016

SNOW

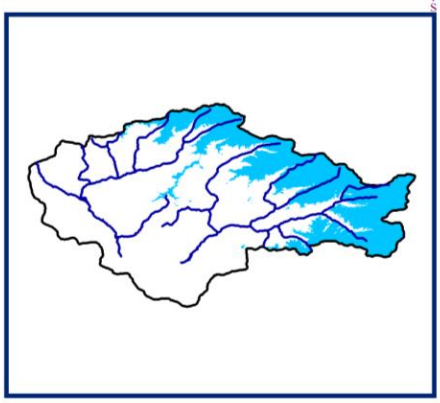
30 15 0 30 60 90

Kilometers

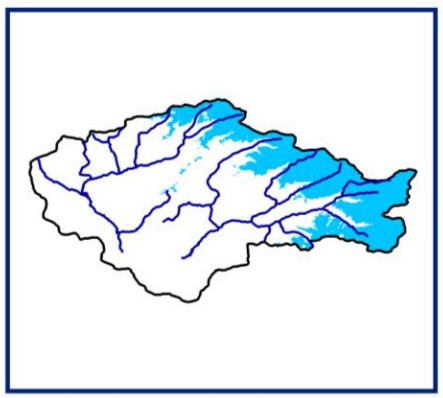
SNOW COVER MAP : YAMUNA SUB-BASIN



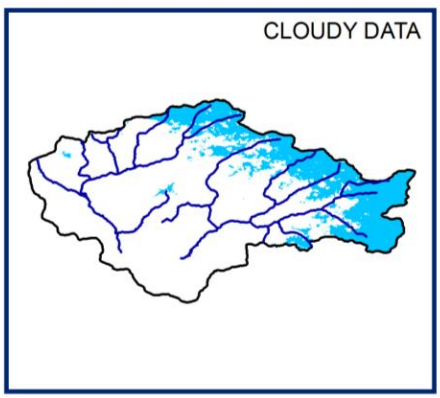
03 APRIL 2016



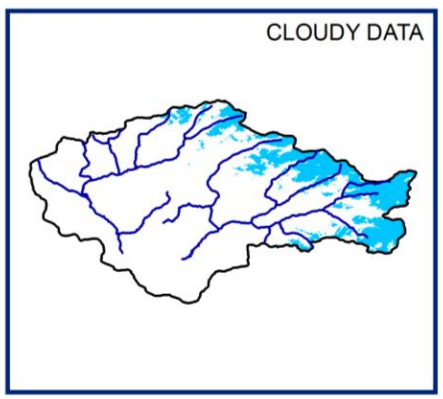
13 APRIL 2016



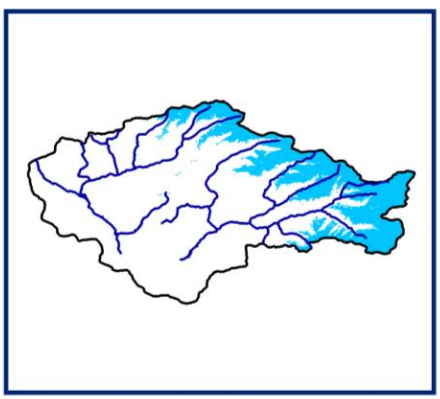
20 APRIL 2016



23 APRIL 2016



27 APRIL 2016



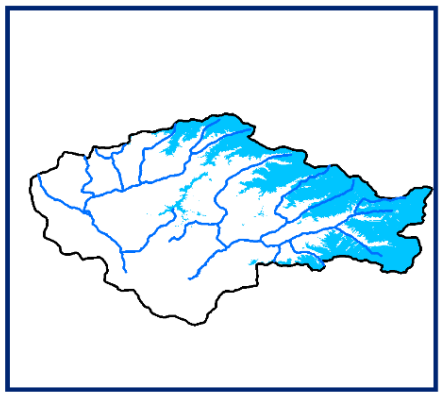
30 APRIL 2016

SNOW

30 15 0 30 60 90

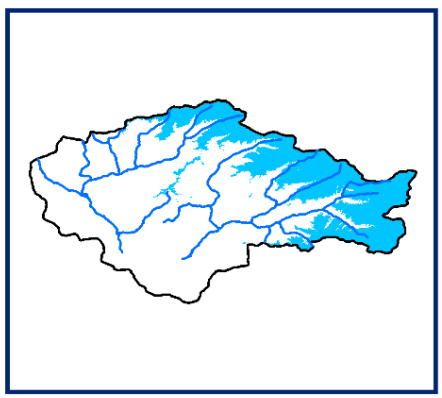
Kilometers

10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



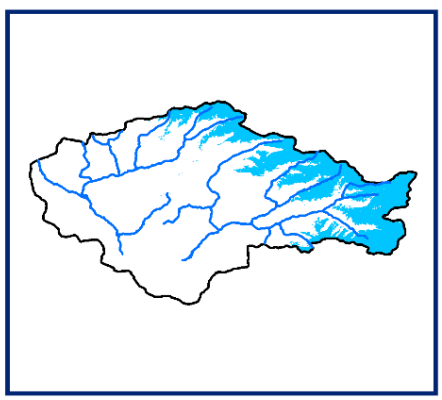
DATA USED

05 APRIL 2016



DATA USED

13 APRIL 2016
20 APRIL 2016



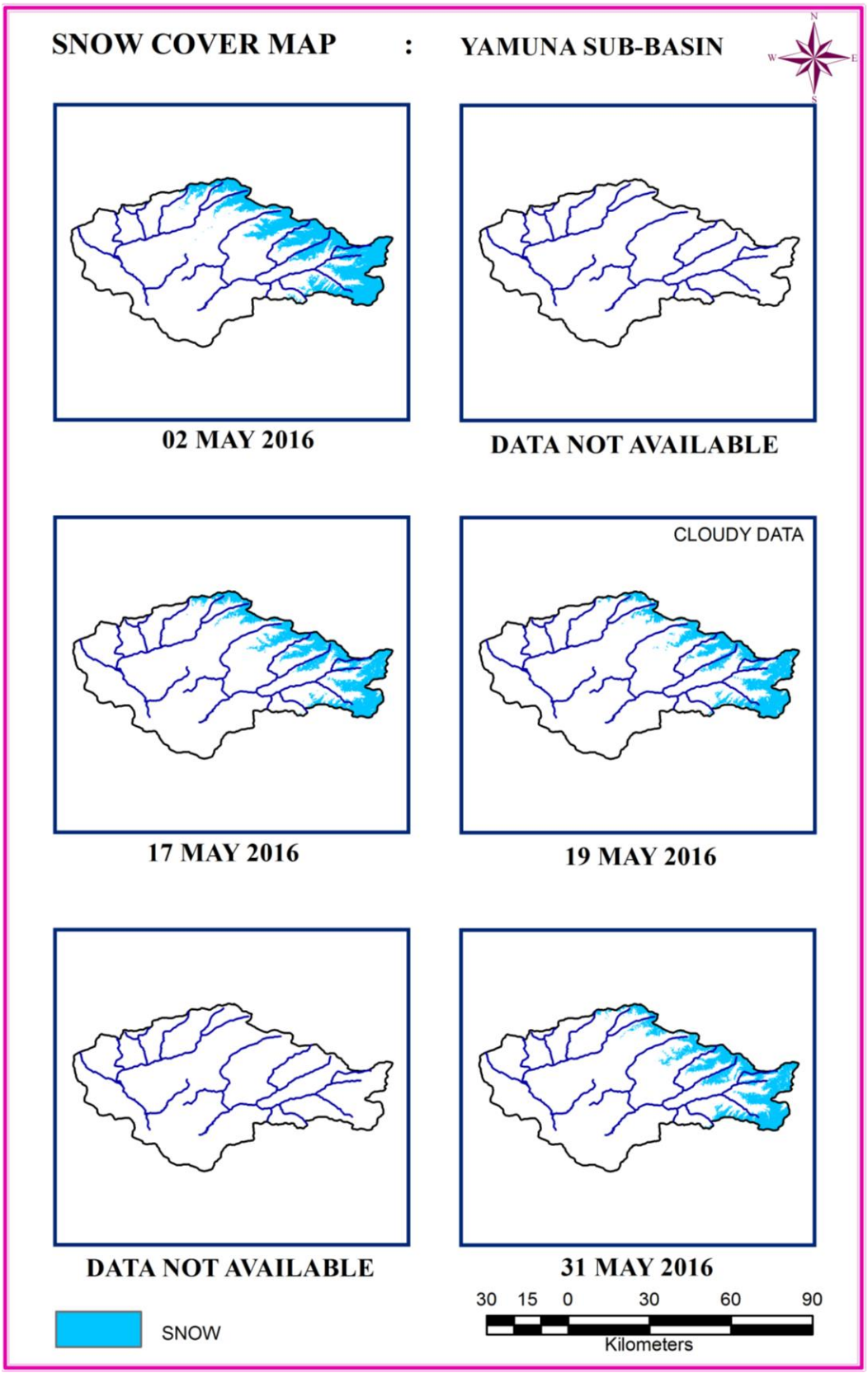
DATA USED

23 APRIL 2016
27 APRIL 2016
30 APRIL 2016

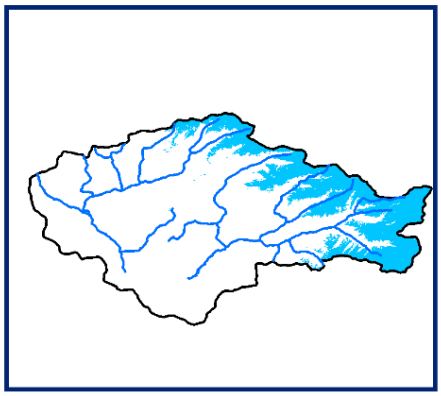
SNOW

30 15 0 30 60 90

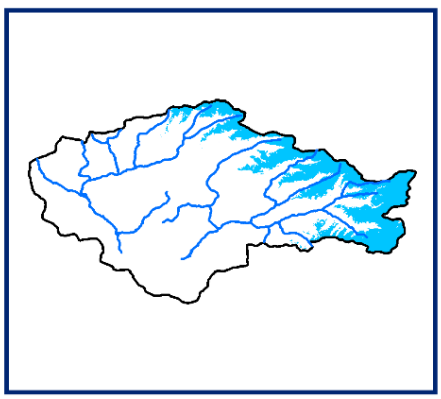
Kilometers


SNOW COVER MAP : YAMUNA SUB-BASIN
N
W
E
S
02 MAY 2016
DATA NOT AVAILABLE
CLOUDY DATA
17 MAY 2016
19 MAY 2016
DATA NOT AVAILABLE
31 MAY 2016
SNOW
30 15 0 30 60 90
Kilometers

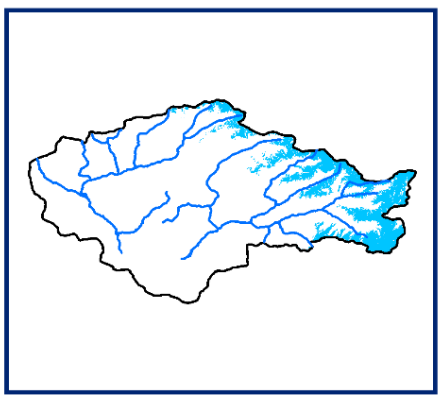
10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



DATA USED
05 MAY 2016



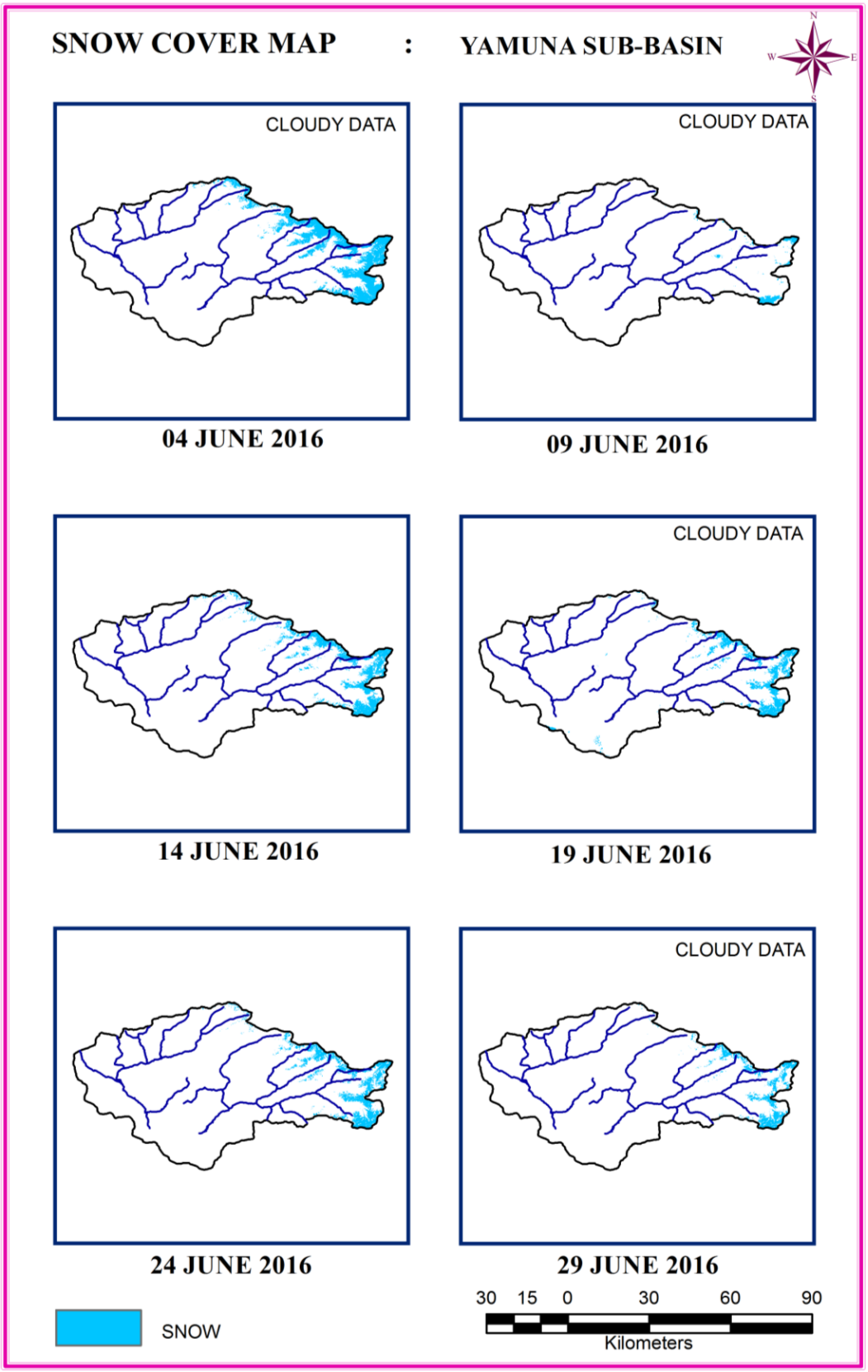
DATA USED
17 MAY 2016
19 MAY 2016



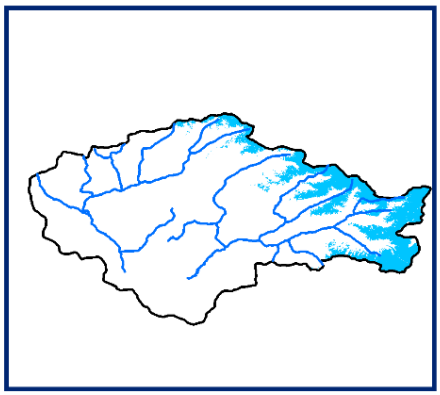
DATA USED
25 MAY 2016

SNOW

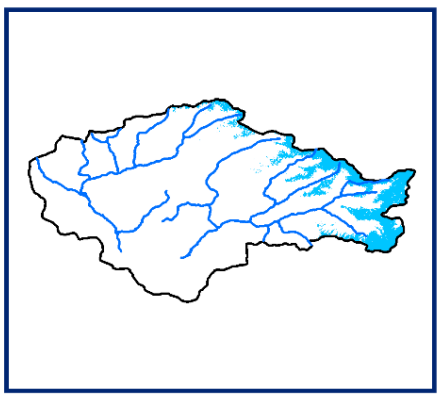
30 15 0 30 60 90
Kilometers


SNOW COVER MAP : YAMUNA SUB-BASIN
N
W
E
S
CLOUDY DATA
04 JUNE 2016
CLOUDY DATA
09 JUNE 2016
14 JUNE 2016
CLOUDY DATA
19 JUNE 2016
24 JUNE 2016
CLOUDY DATA
29 JUNE 2016
SNOW
30 15 0 30 60 90
Kilometers

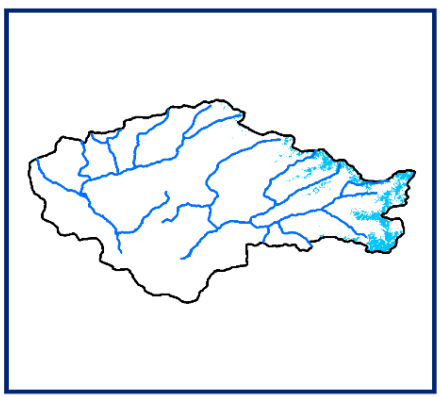
10 DAILY SNOW COVER MAP : YAMUNA SUB-BASIN



DATA USED
04 JUNE 2016
05 JUNE 2016
09 JUNE 2016



DATA USED
14 JUNE 2016
19 JUNE 2016



DATA USED
24 JUNE 2016
29 JUNE 2016

SNOW

30 15 0 30 60 90
Kilometers