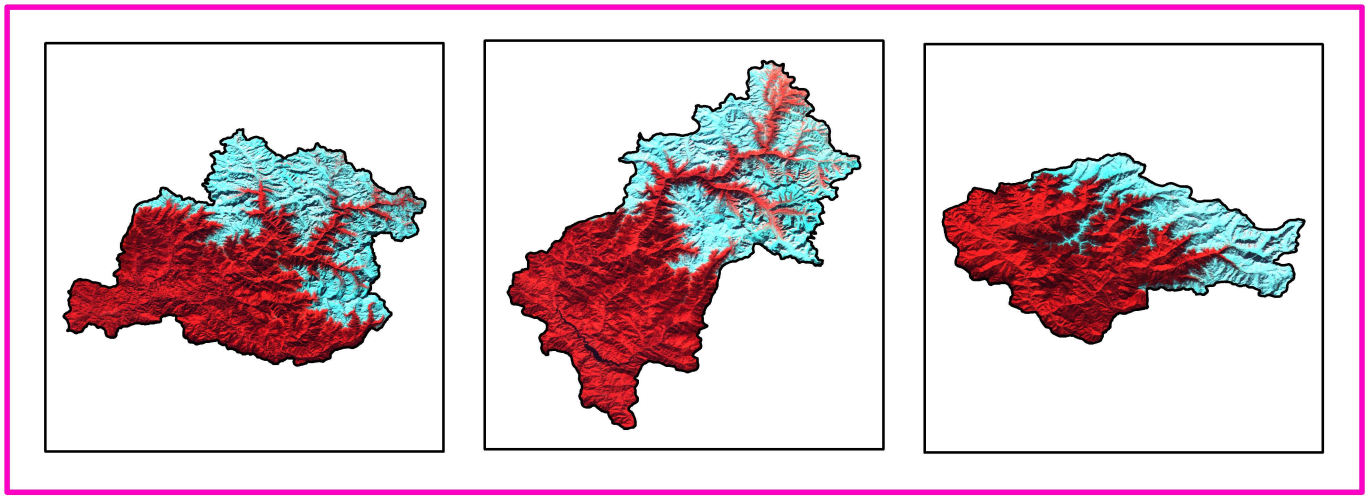
SNOW COVER ATLAS OF GANGA BASIN

Sub basins: Alaknanda, Bhagirathi and Yamuna

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

Year : 2008-09



Space Applications Centre (ISRO)
Ahmedabad - 380015

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DOCUMENT CONTROL AND DATA SHEET

Report Number	SAC/EPSA/MPSG/GSD/SGP/SN/ 81 /2013
Month and year of publication	January 2013
Title	Snow cover Atlas of the Ganga 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 subbasin-wise distribution of snow cover in the Ganga basin from October 2008 to June 2009. The subbasins 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 subbasins 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 2008 to June 2009 were used in this study.

4. Normalised Difference Snow Index (NDSI):

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

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

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

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

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

5. Snow cover monitoring algorithm

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

6. Results and discussions

In this atlas, basin-wise snow cover statistics, maps, and seasonal depletion curves have been provided from October 2008 to June 2009. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. In the Yamuna river basin, this includes Tons, shows accumulation and ablation of snow throughout the winter season. For example on November 25, 2008, 40 percent area was covered by seasonal snow. This was reduced to 12 percent by December 15, 2008. Bhagirathi and the Alaknanda sub-basins also shows accumulation and ablation of snow throughout the winter season and snow depletion pattern are similar.

Acknowledgements

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

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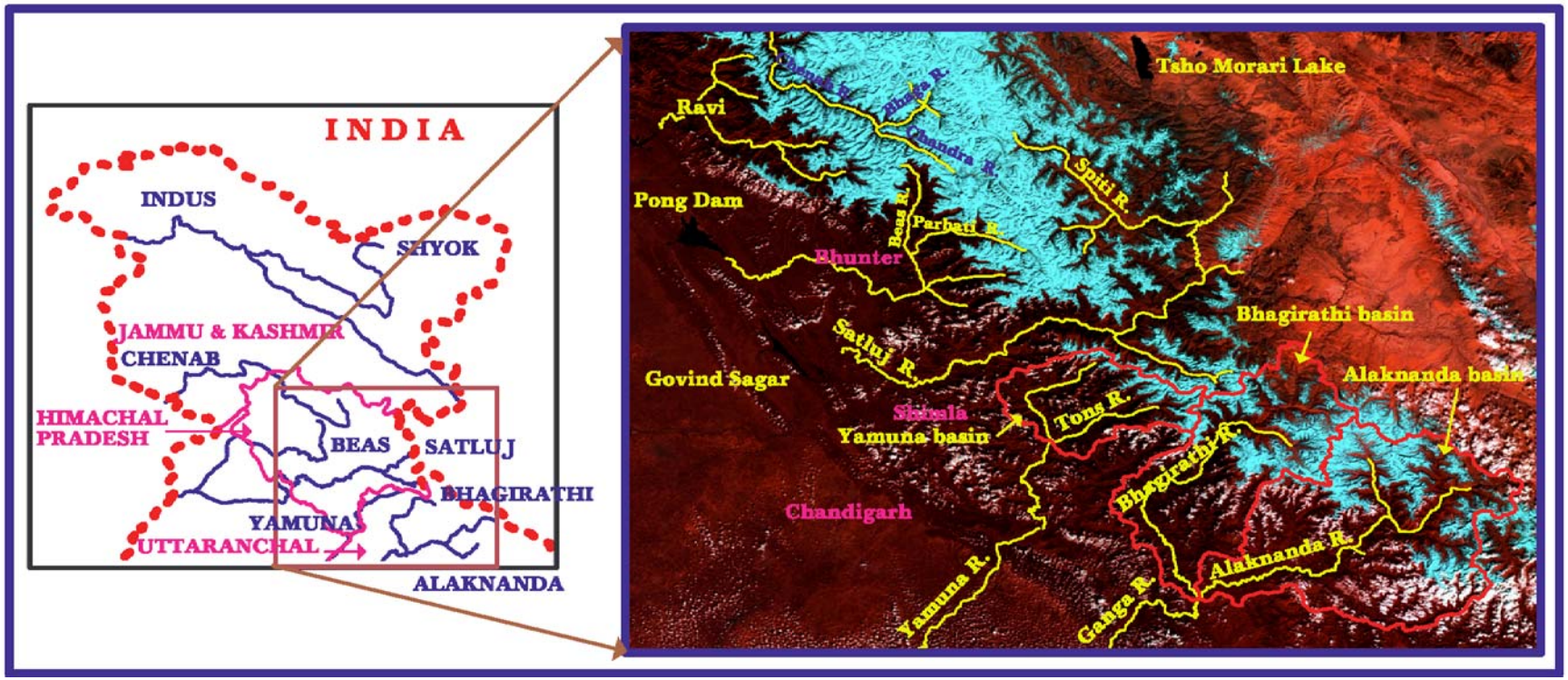


Figure 1: Location map of Alaknanda, Bhagirathi and Yamuna sub-basins (Part of Ganga basin)

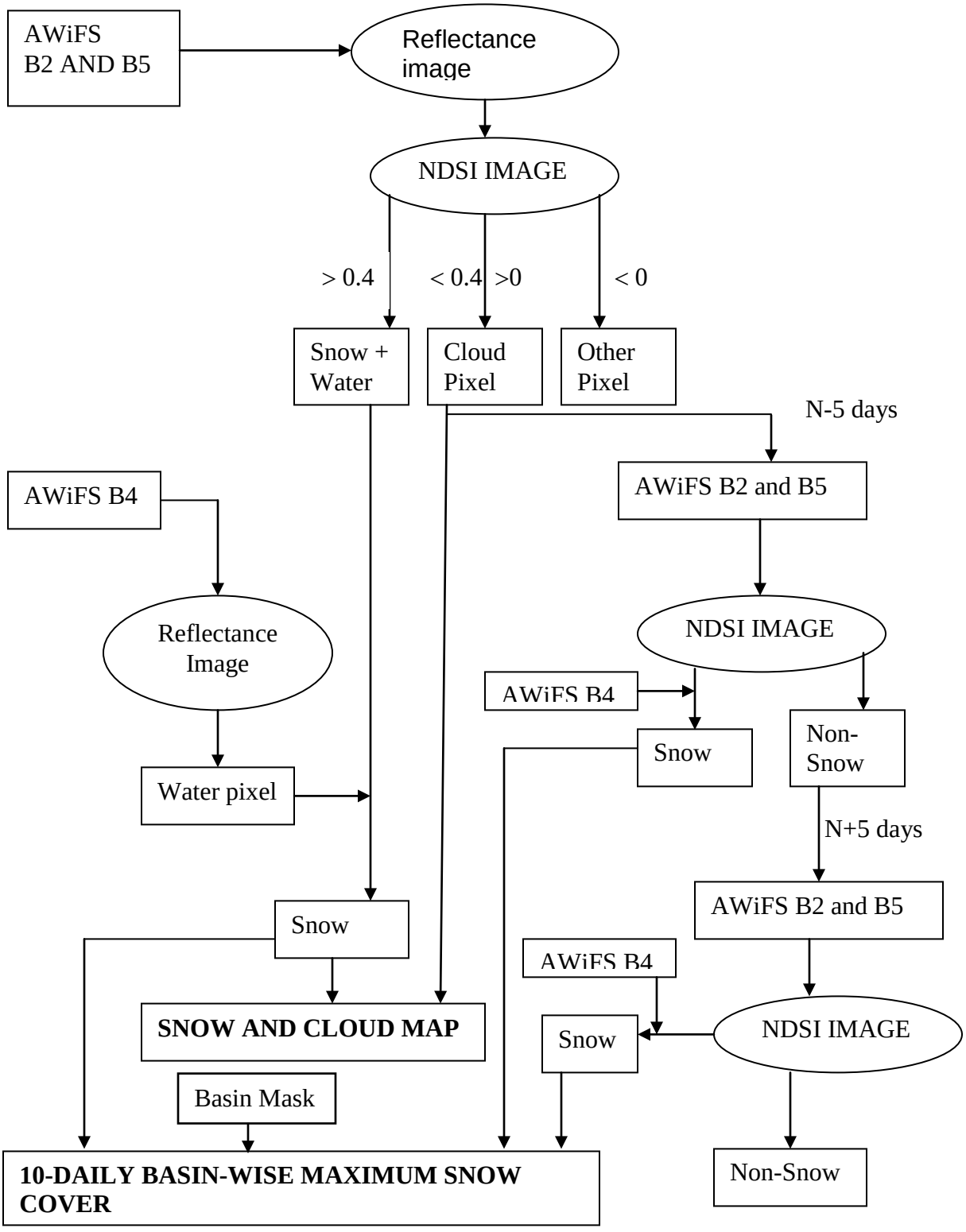


Figure 2: Algorithm for snow cover mapping using AWiFS data

ALAKNANDA 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 2008							
1	4-Oct-08	2824	25	3	23-Oct-08	2723	25
2	19-Oct-08	2639	24				
November 2008							
4	7-Nov-08	2316	21	7	16-Nov-08	2169	20
5	11-Nov-08	2298	21	8	17-Nov-08	2054	19
6	12-Nov-08	2149	19	9	21-Nov-08	5170	47
10	26-Nov-08	3346	30				
December 2008							
11	1-Dec-08	3180	29	15	15-Dec-08	2527	23
12	5-Dec-08	2595	23	16	24-Dec-08	2536	23
13	6-Dec-08	2368	21	17	25-Dec-08	4782	43
14	10-Dec-08	2819	25	18	29-Dec-08	4559	41
19	30-Dec-08	4234	38				
January 2009							
20	8-Jan-09	5569	50	21	27-Jan-09	4313	39
22	27-Jan-09	4321	39				
February 2009							
23	1-Feb-09	3252	29	25	16-Feb-09	3042	27
24	15-Feb-09	4840	44	26	16-Feb-09	3166	29
27	25-Feb-09	3720	34				
March 2009							
28	7-Mar-09	2965	27	31	21-Mar-09	6813	61
29	12-Mar-09	3633	33	32	26-Mar-09	5470	49
30	21-Mar-09	6827	62	33	31-Mar-09	4715	43
April 2009							
34	4-Apr-09	4431	40	37	14-Apr-09	3977	36
35	10-Apr-09	5034	45	38	19-Apr-09	3724	34
36	14-Apr-09	3982	36	39	28-Apr-09	3297	30
40	29-Apr-09	2468	22				

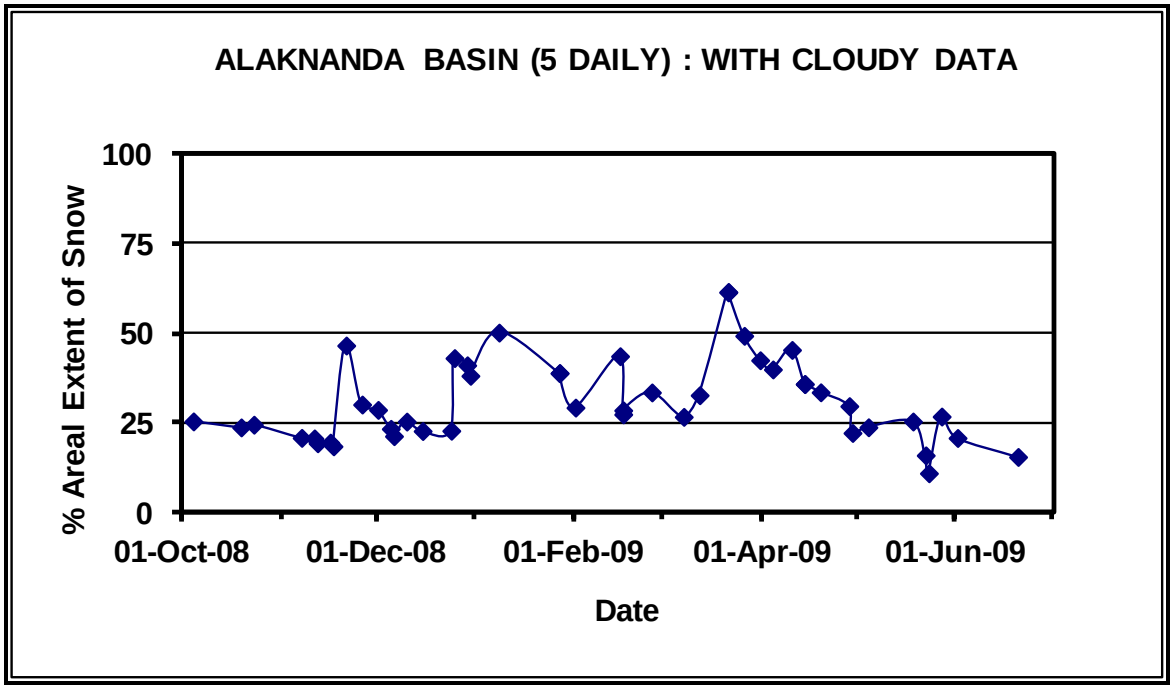
S. No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
41	4-May-09	2643	24	43	22-May-09	1775	16
42	18-May-09	2821	25	44	23-May-09	1221	11
45	27-May-09	2975	27				
June 2009							
46	1-Jun-09	2312	21	47	20-Jun-09	1726	16

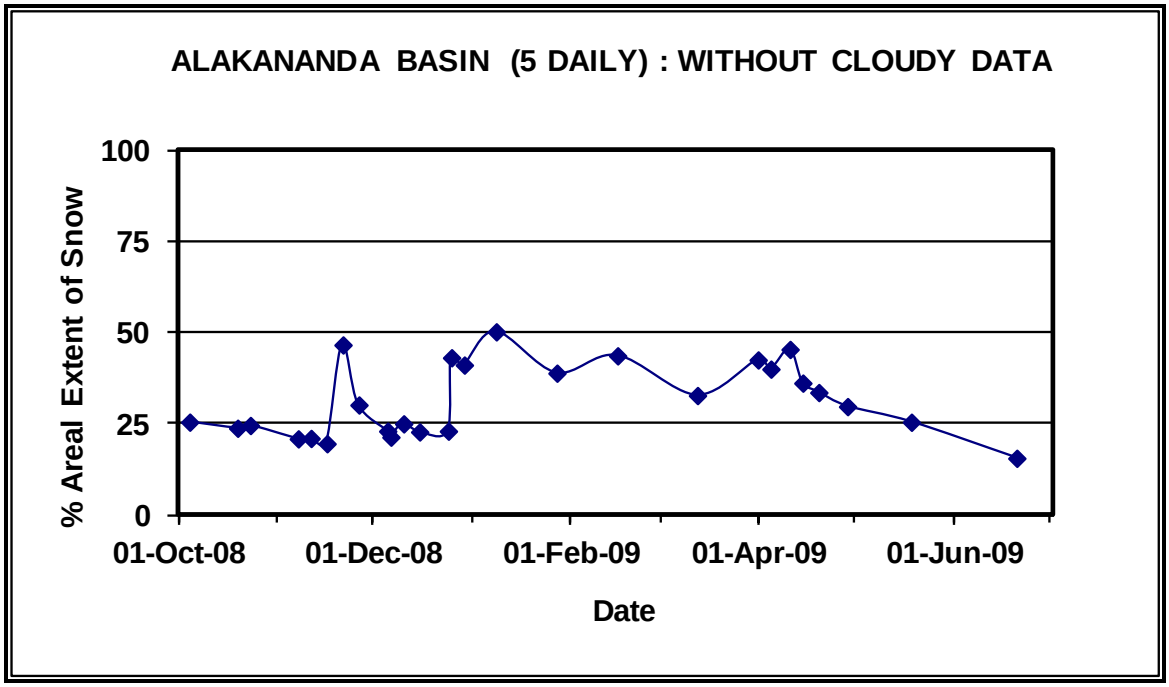
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: ALALNANDA **BASIN AREA: 11090 Sq km**

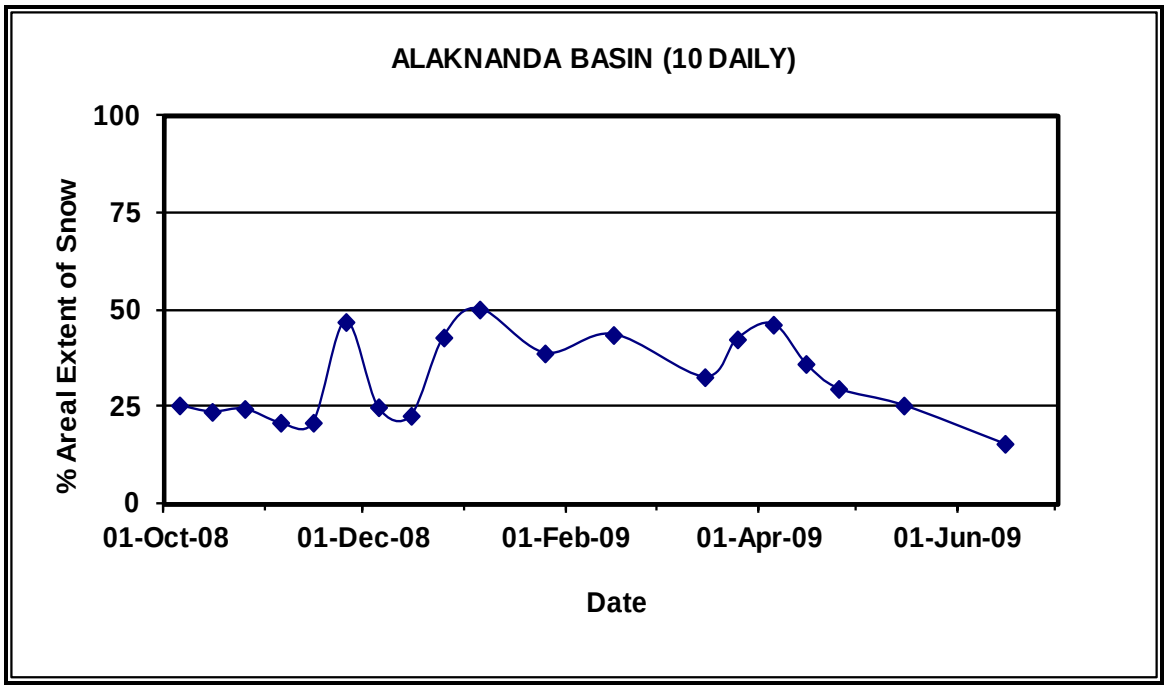
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
1	5-Oct-08	2824	25	2	7-Nov-08	2329	21
2	19-Oct-08	2639	24	3	11-Nov-08	2329	21
2	25-Oct-08	2723	25	4	26-Nov-08	5212	47
December 2008				**January 2009**			
5	5-Dec-08	2773	25	8	8-Jan-09	5569	50
6	15-Dec-08	2527	23	9	27-Jan-09	4313	39
7	24-Dec-08	4769	43				
February 2009				**March 2009**			
10	15-Feb-09	4840	44	11	5-Mar-09	3633	33
				12	31-Mar-09	4715	43
April 2009				**May 2009**			
13	4-Apr-09	5135	46	16	18-May-09	2821	25
14	14-Apr-09	4011	36				
15	28-Apr-09	3297	30				
June 2009							
17	15-Jun-09	1726	16				

Snow cover depletion curve



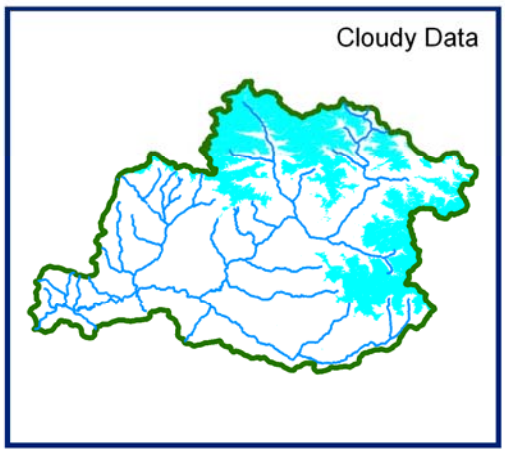


Snow cover depletion curve



SNOW COVER MAP

SNOW COVER MAP : ALAKNANDA BASIN



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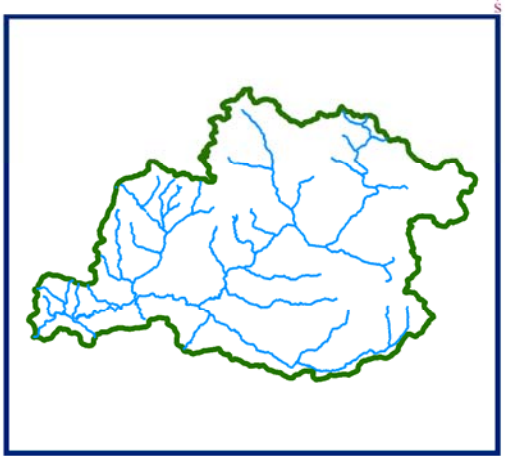

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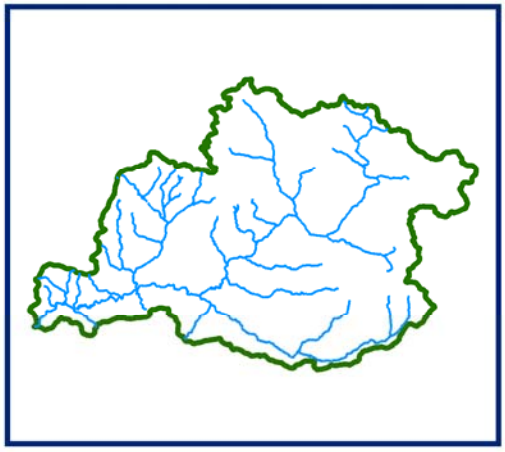

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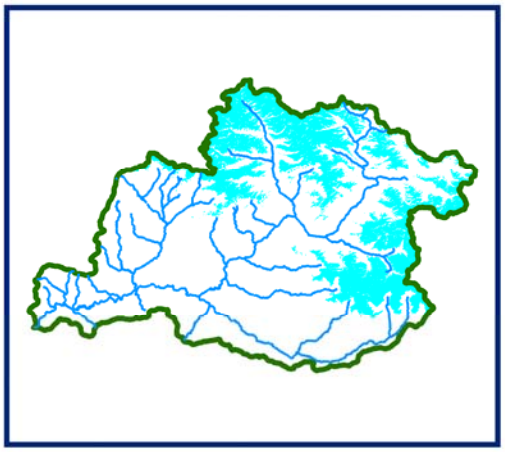

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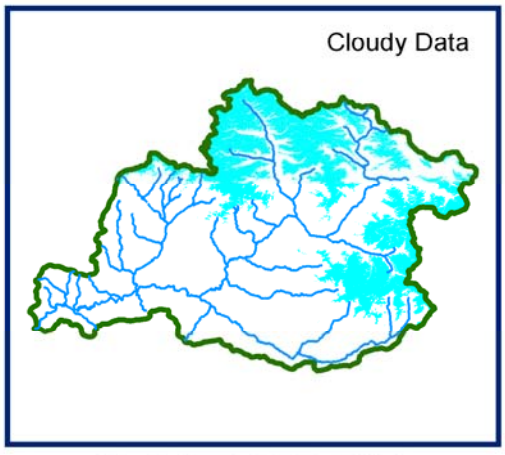

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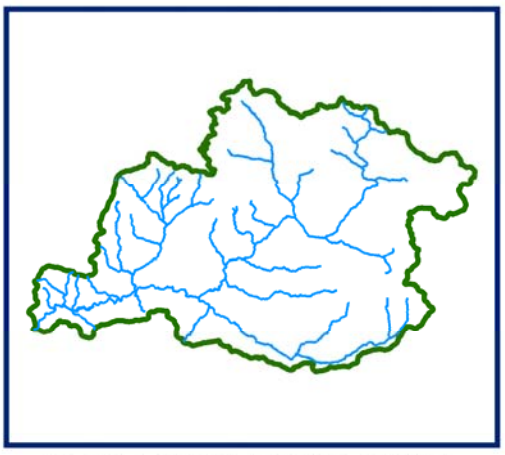

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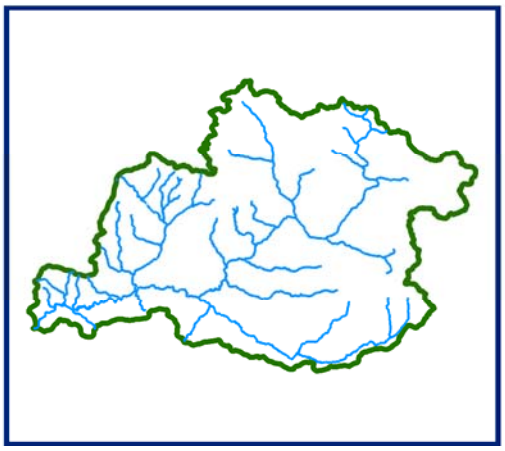
SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



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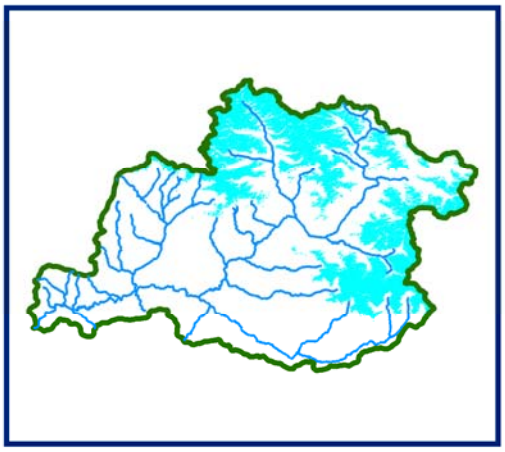

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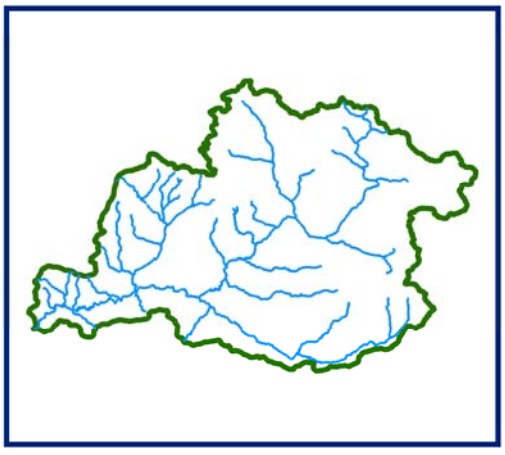

DATA USED

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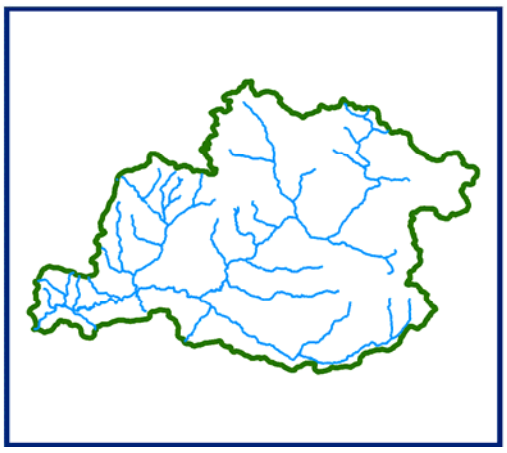
SNOW

0 5 10 20 30 40

Kilometers

SNOW COVER MAP : ALAKNANDA BASIN



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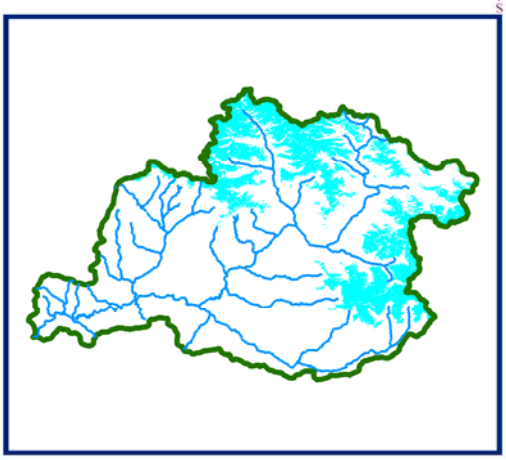

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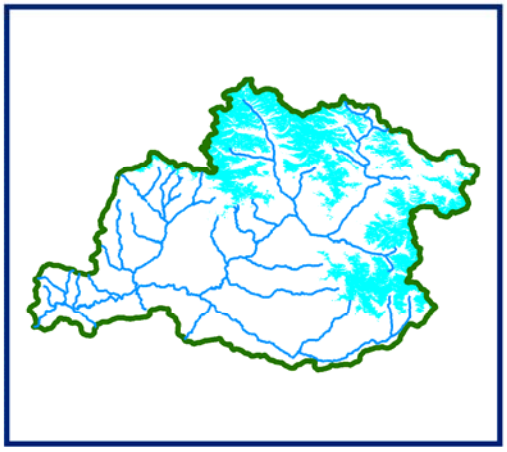

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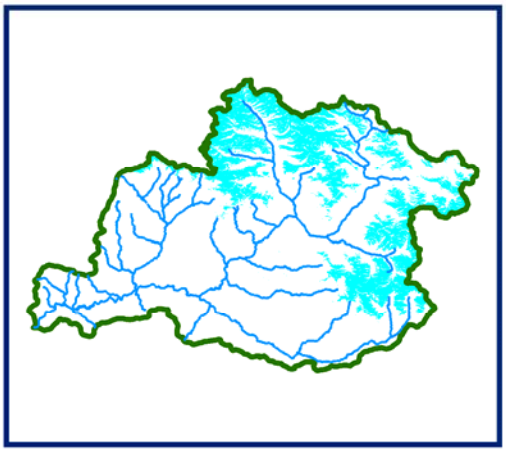

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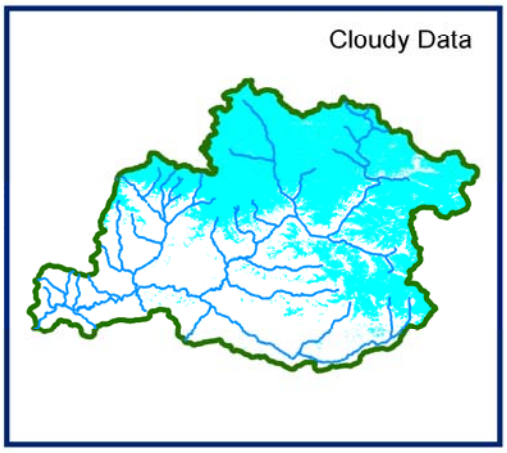

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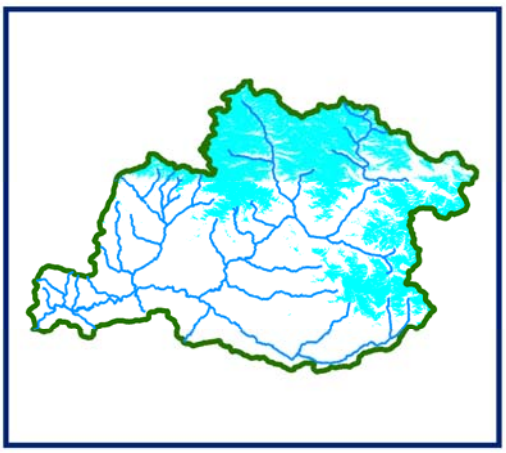


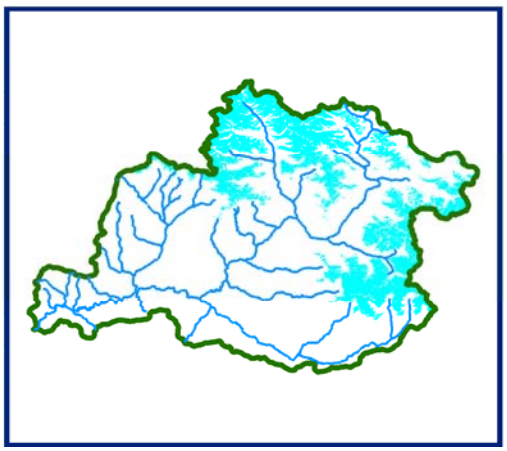
26 NOVEMBER 2008

SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



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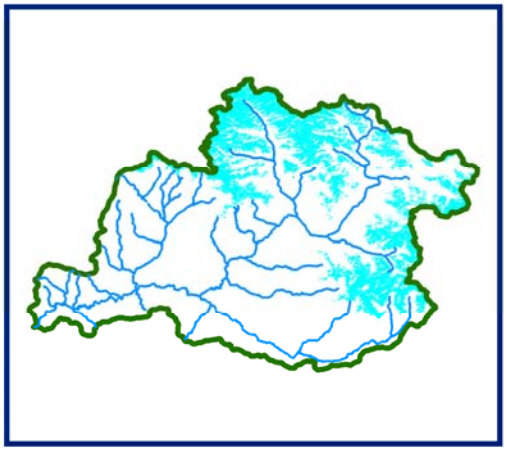

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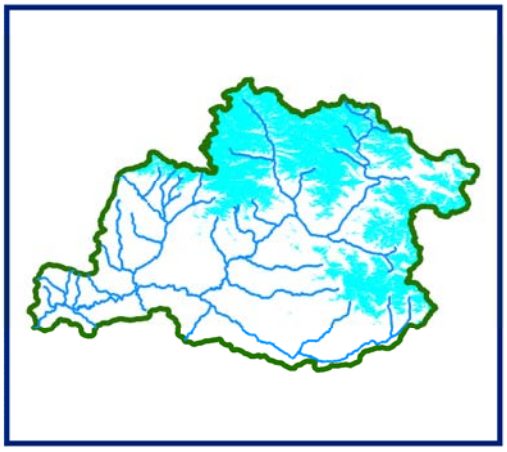

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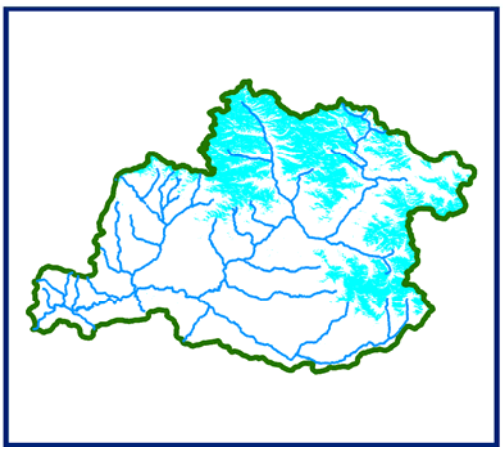
SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : ALAKNANDA BASIN



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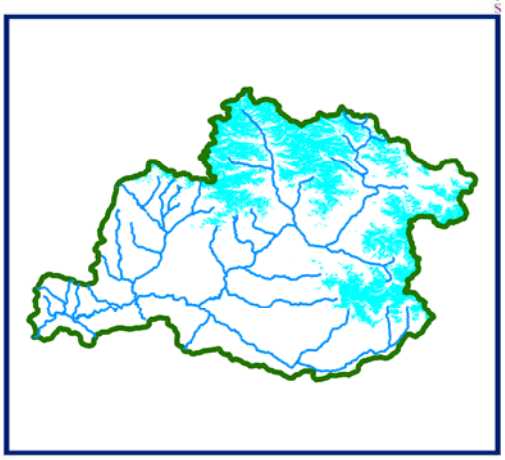

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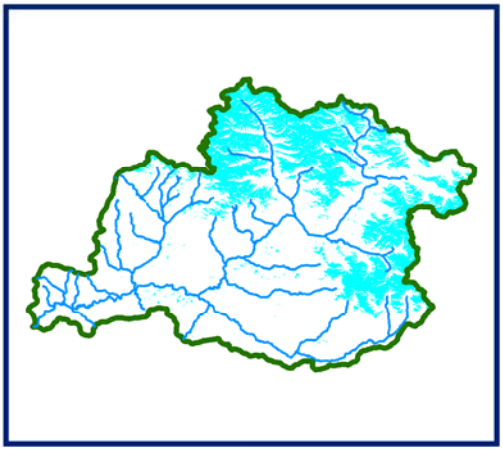

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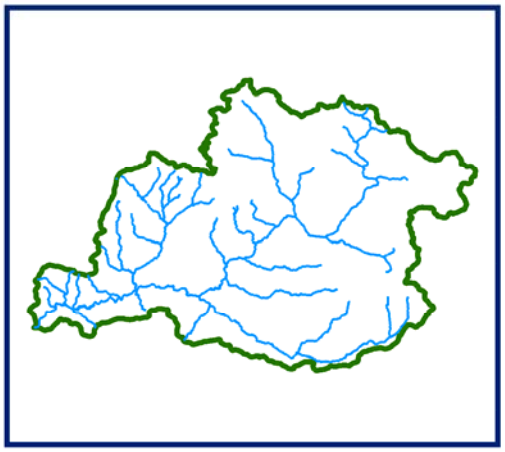

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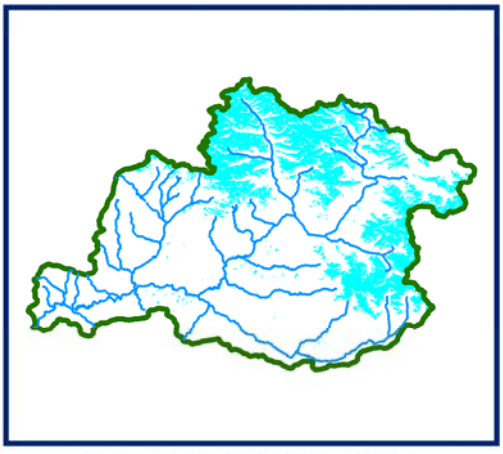

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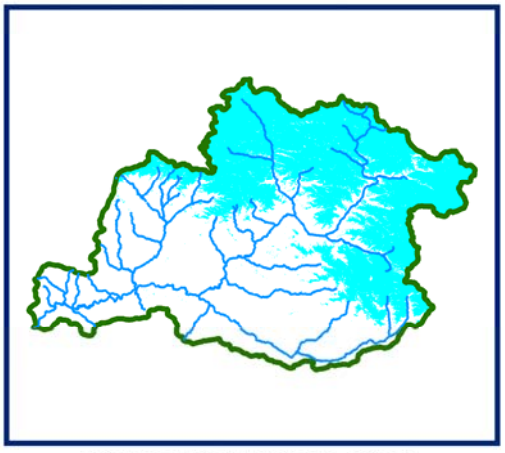


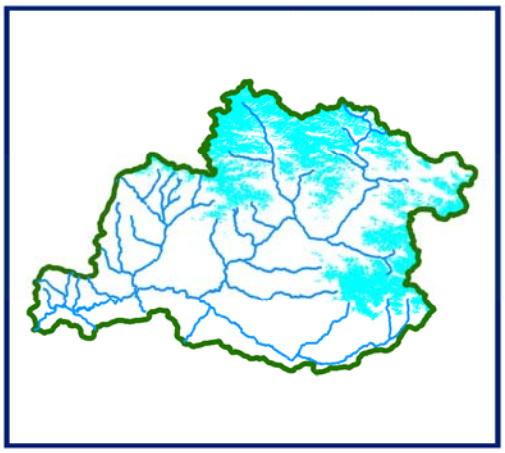
29 DECEMBER 2008

SNOW

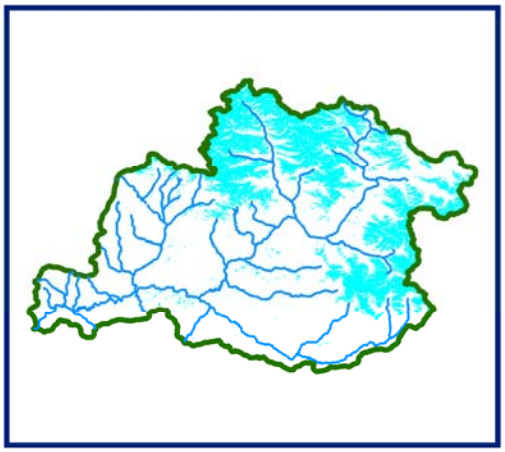
0 10 20 40 60 80

Kilometers

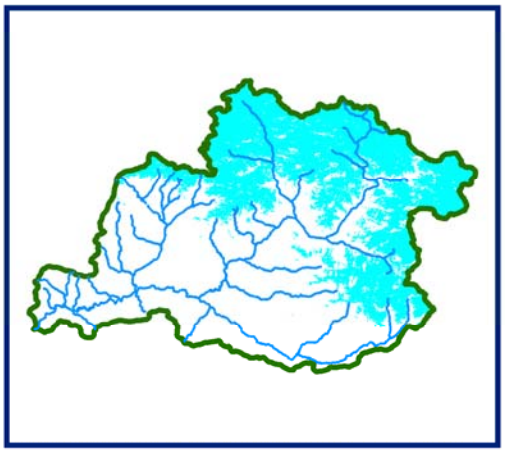
10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



DATA USED
05 DECEMBER 2008
06 DECEMBER 2008



DATA USED
15 DECEMBER 2008

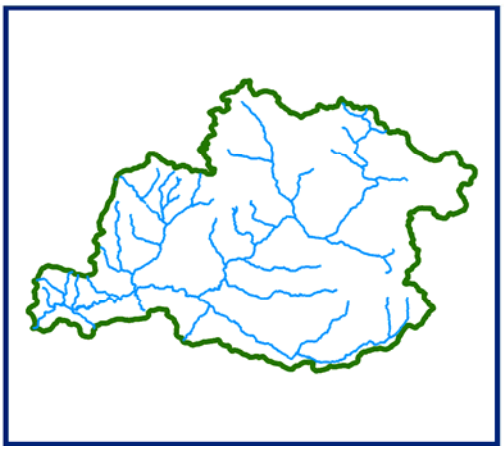


DATA USED
24 DECEMBER 2008
29 DECEMBER 2008

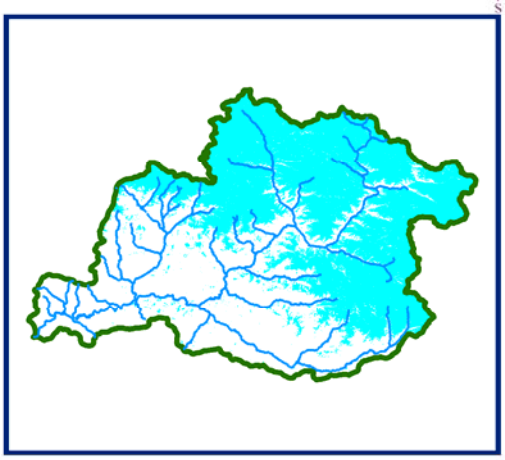
SNOW

0 5 10 20 30 40
Kilometers

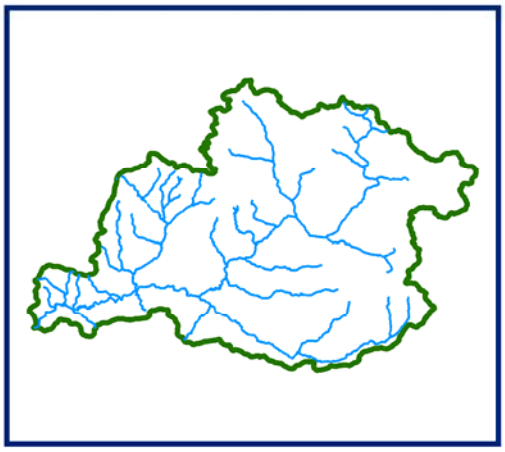
SNOW COVER MAP : ALAKNANDA BASIN



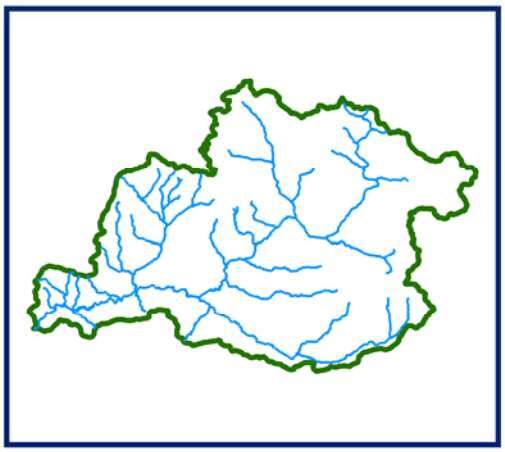
DATA NOT AVAILABLE



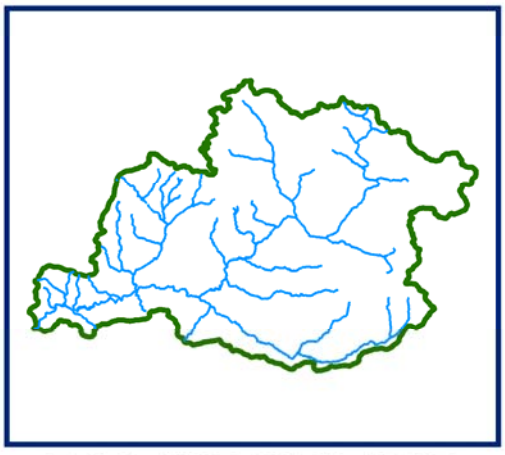
08 JANUARY 2009



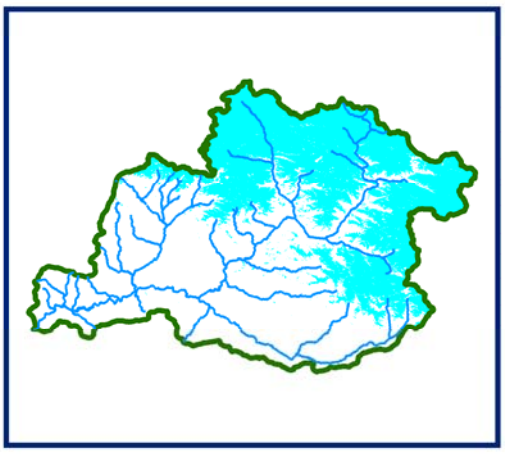
DATA NOT AVAILABLE



DATA NOT AVAILABLE



DATA NOT AVAILABLE



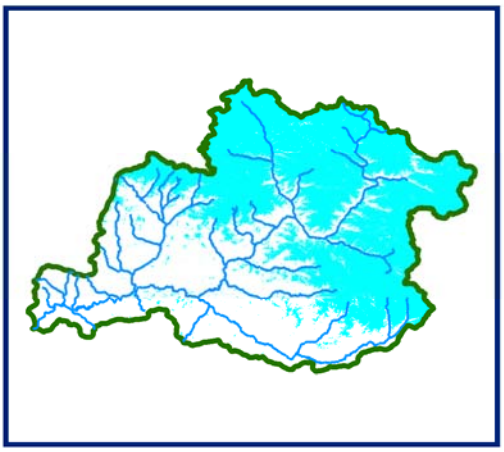
27 JANUARY 2009

SNOW

0 10 20 40 60 80

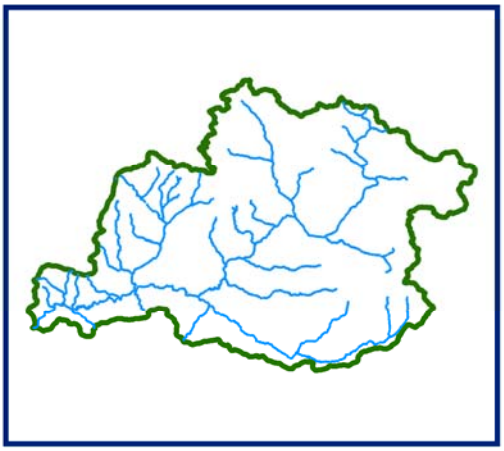
Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



DATA USED

08 JANUARY 2009



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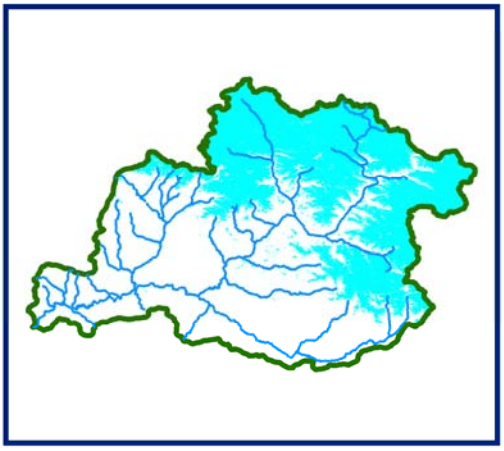


DATA USED

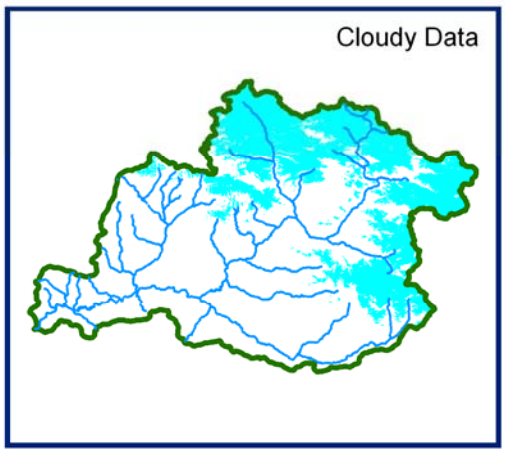
27 JANUARY 2009

SNOW

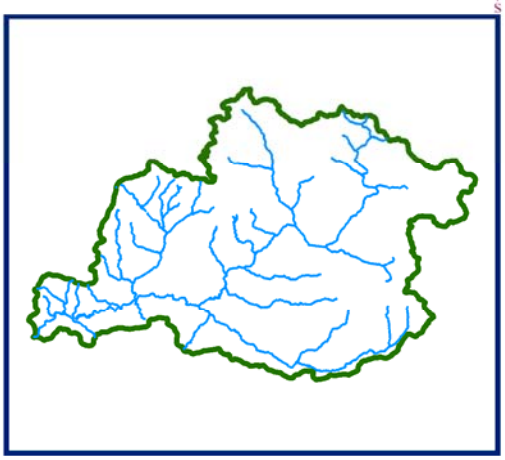
0 5 10 20 30 40

Kilometers

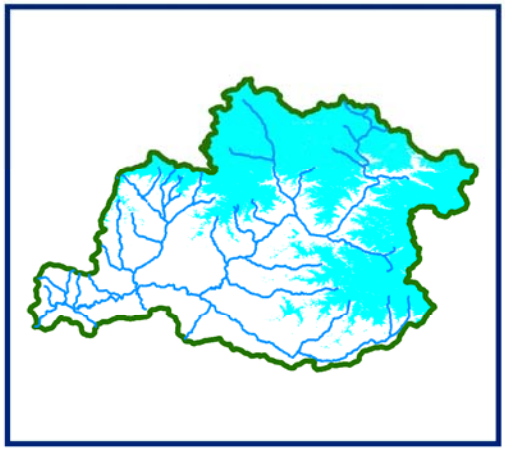
SNOW COVER MAP : ALAKNANDA BASIN



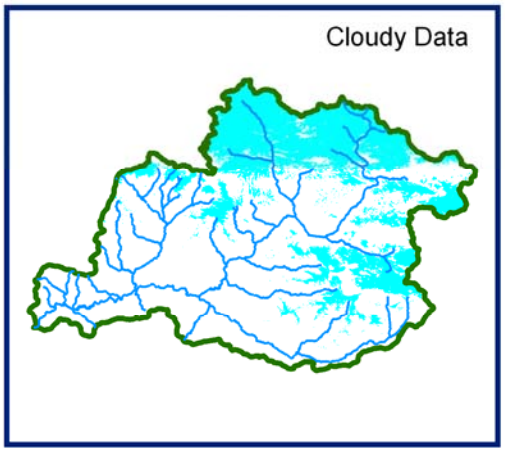
01 FEBRUARY 2009



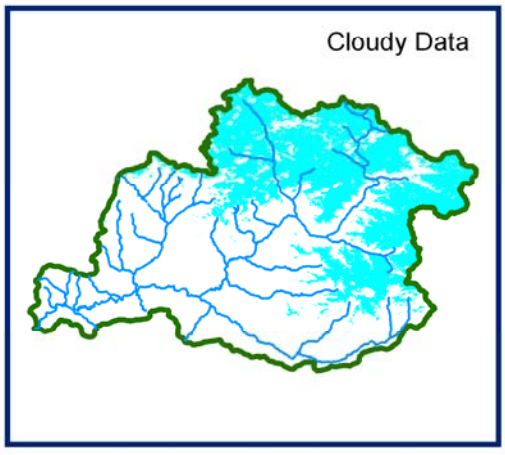
DATA NOT AVAILABLE



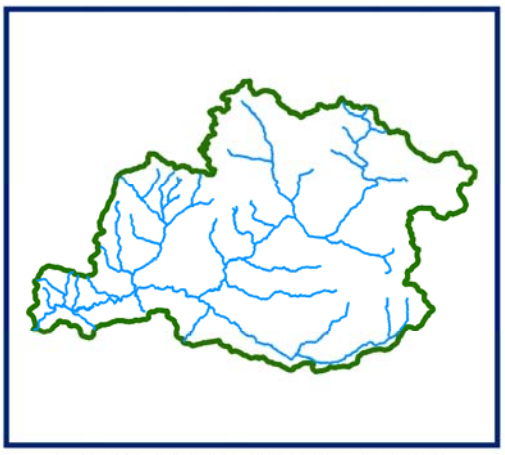
15 FEBRUARY 2009



16 FEBRUARY 2009



25 FEBRUARY 2009



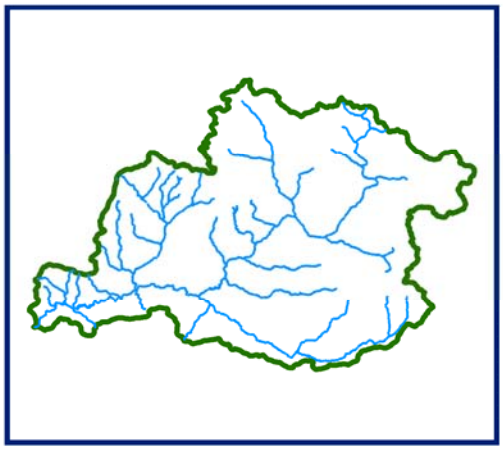
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80

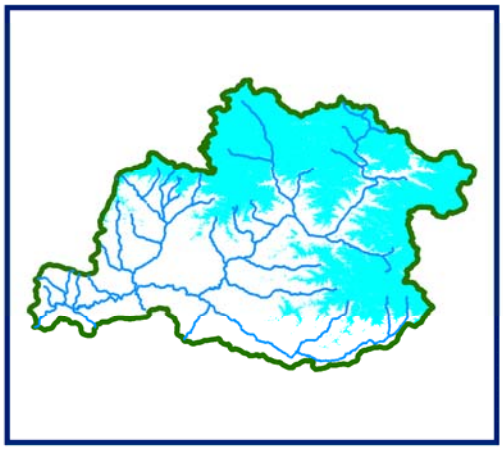
Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



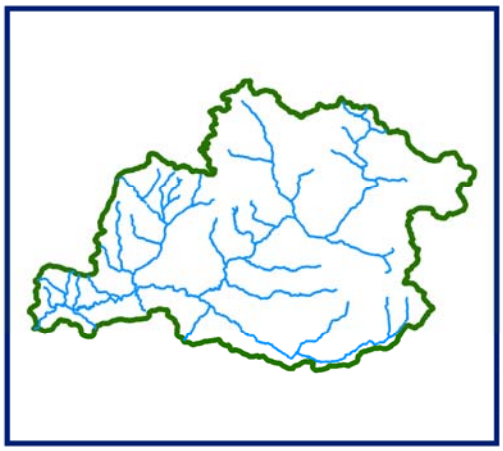
DATA USED

DATA NOT AVAILABLE



DATA USED

15 FEBRUARY 2009



DATA USED

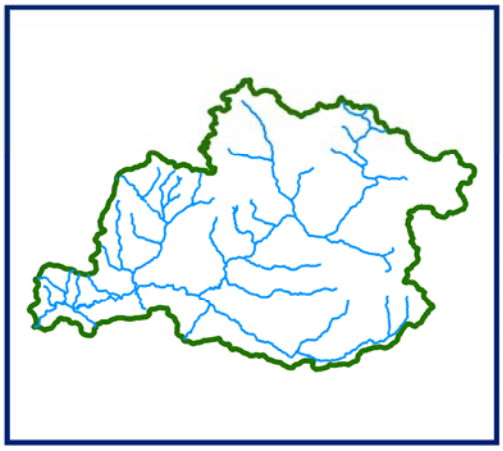
DATA NOT AVAILABLE

SNOW

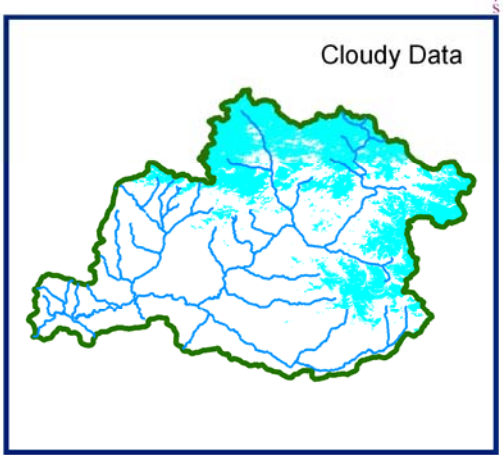
0 5 10 20 30 40

Kilometers

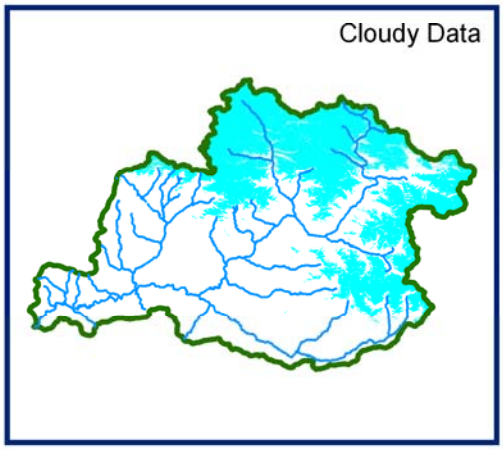
SNOW COVER MAP : ALAKNANDA BASIN



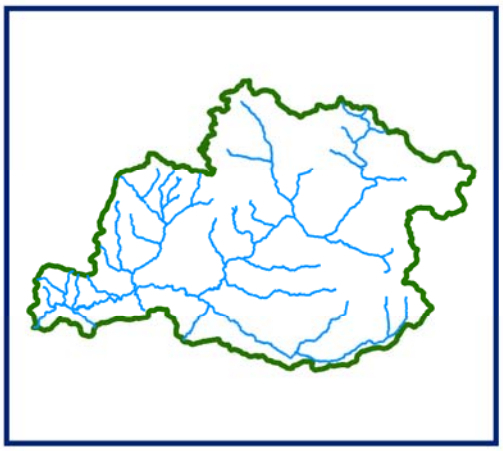
DATA NOT AVAILABLE



07 MARCH 2009



12 MARCH 2009



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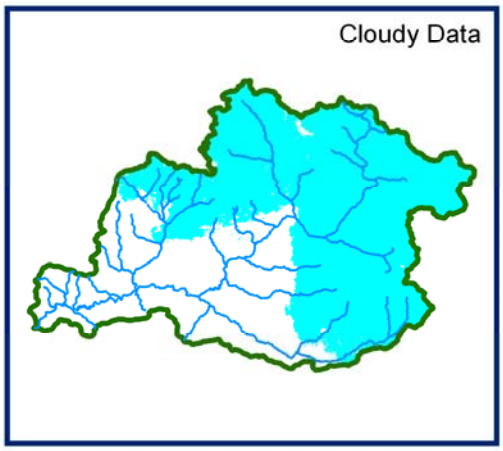
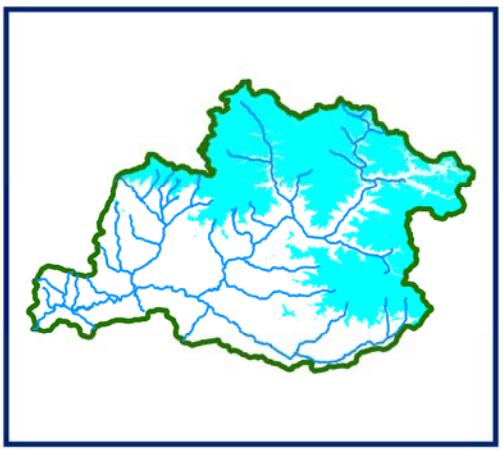


21 MARCH 2009



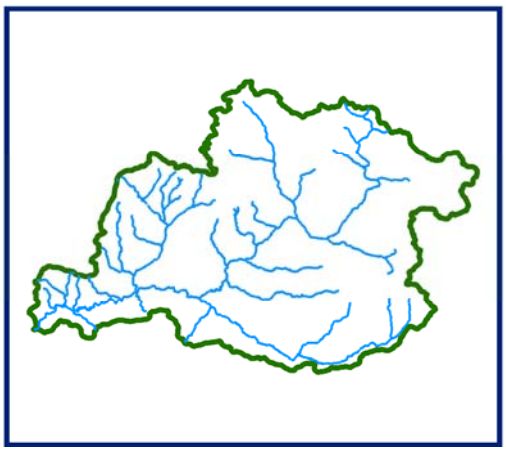
31 MARCH 2009

SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



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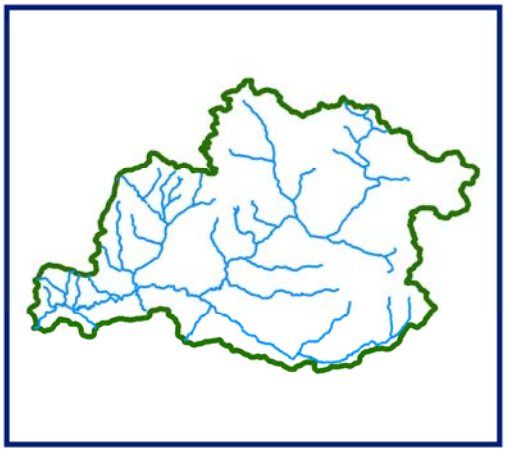

DATA USED
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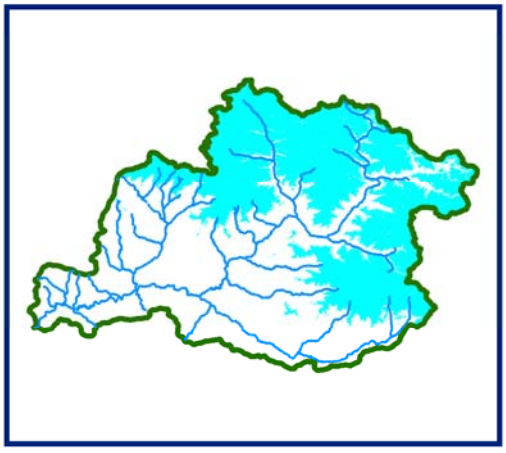
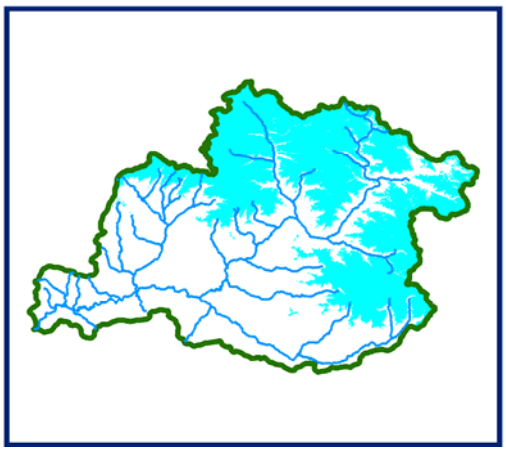


DATA USED
31 MARCH 2009

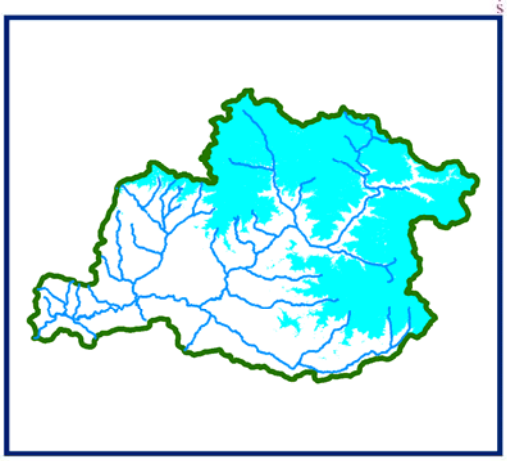
SNOW

0 5 10 20 30 40
Kilometers

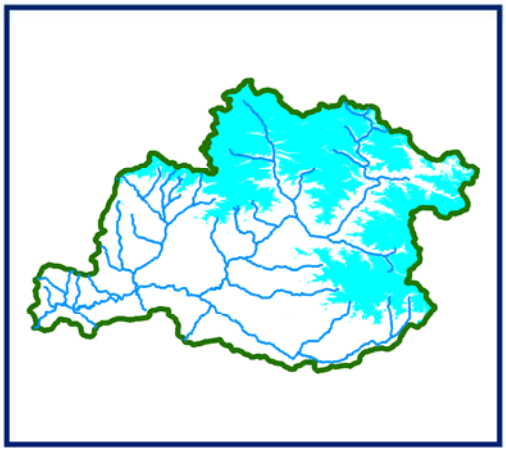
SNOW COVER MAP : ALAKNANDA BASIN



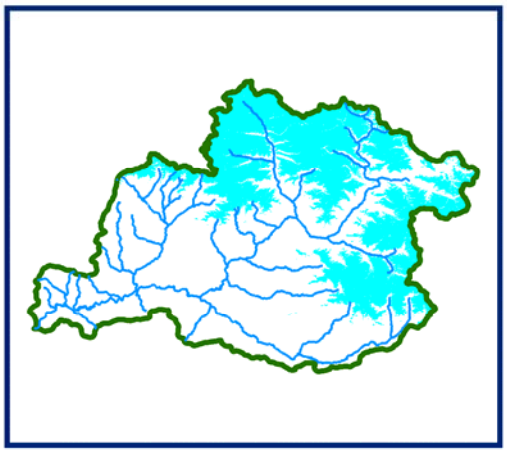
04 APRIL 2009



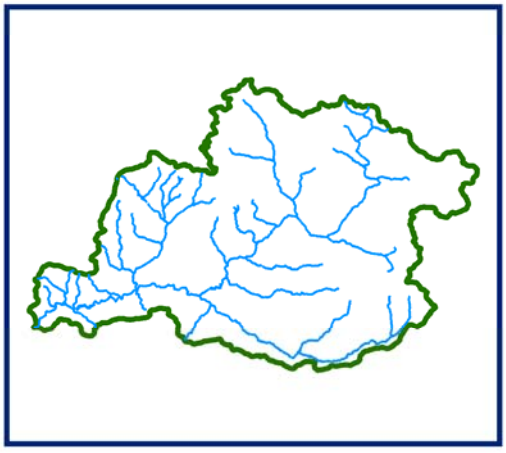
10 APRIL 2009



14 APRIL 2009



19 APRIL 2009



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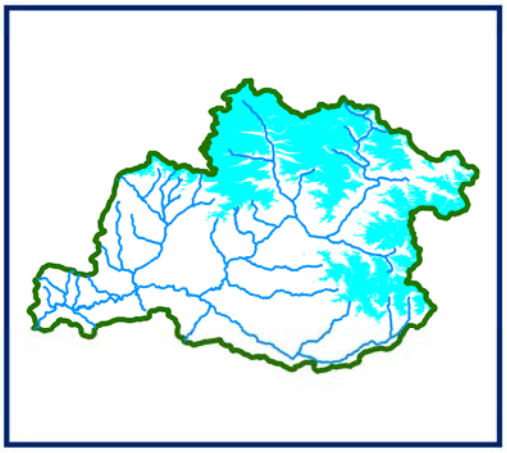


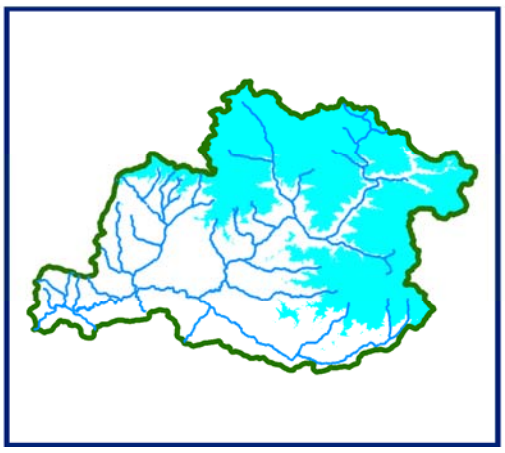
28 APRIL 2009

SNOW

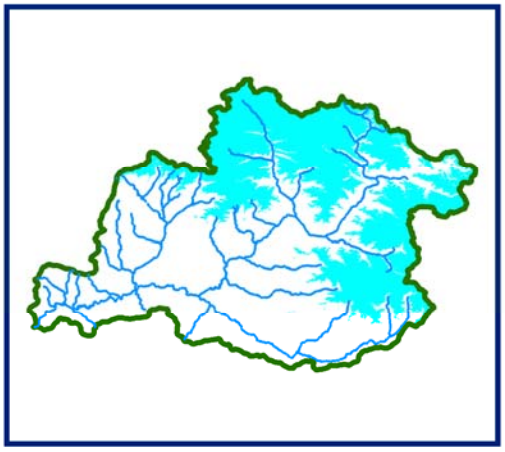
0 10 20 40 60 80

Kilometers

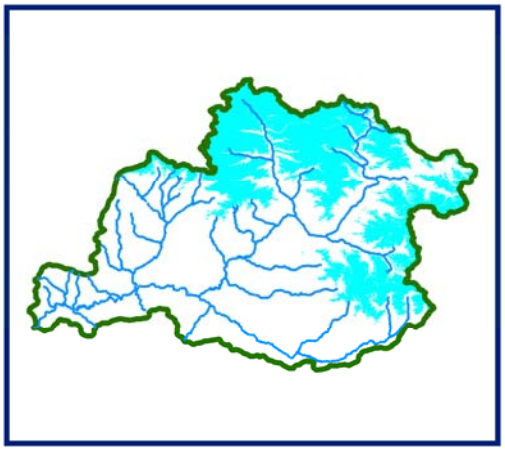
10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



DATA USED
04 APRIL 2009
10 APRIL 2009



DATA USED
14 APRIL 2009
19 APRIL 2009

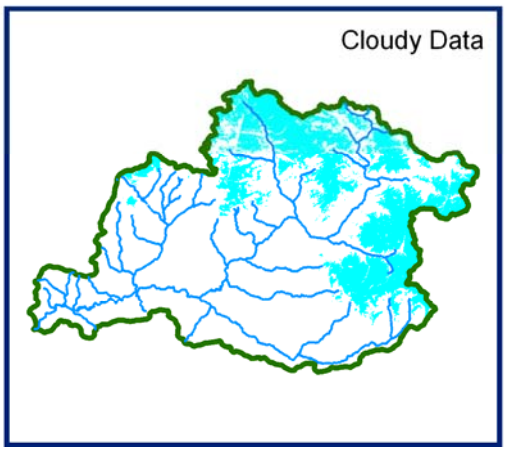


DATA USED
28 APRIL 2009

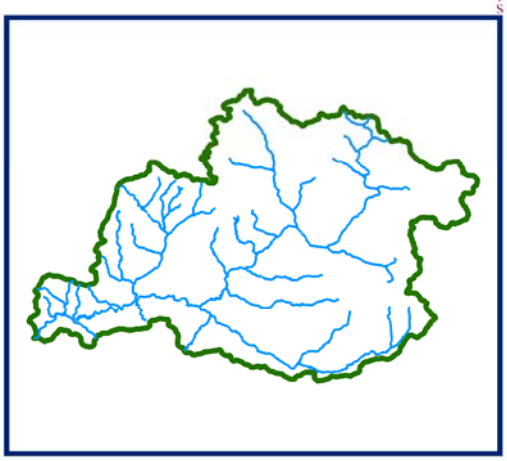
SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : ALAKNANDA BASIN



04 MAY 2009



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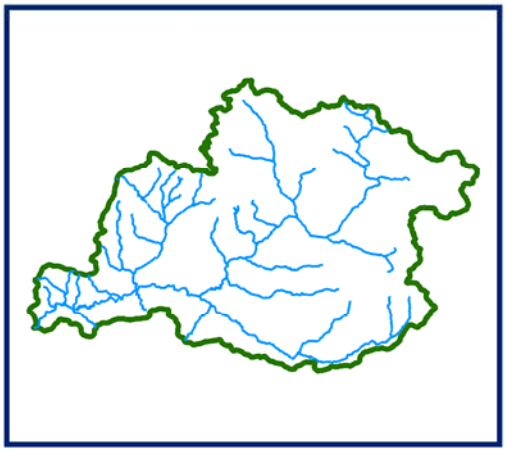

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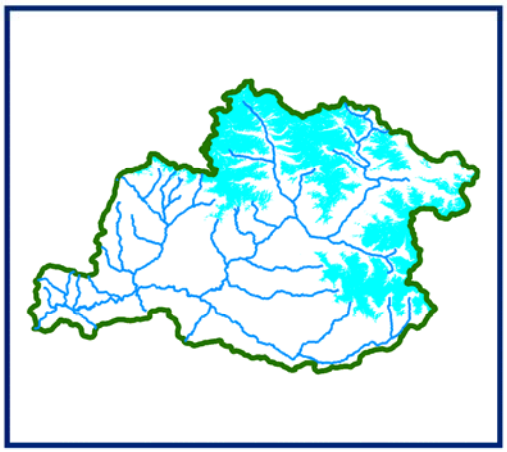
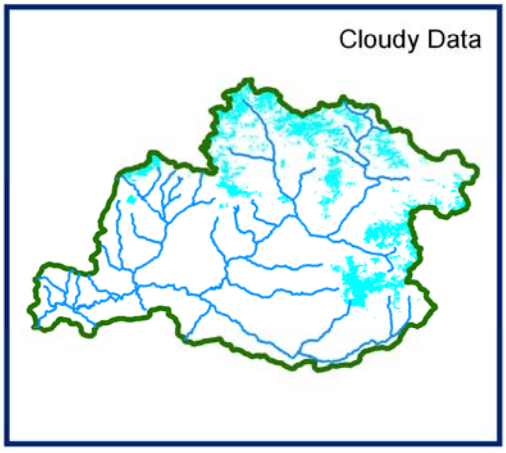
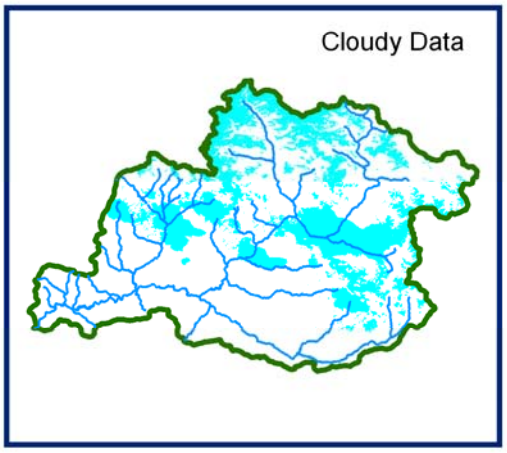


18 MAY2009



23 MAY 2009



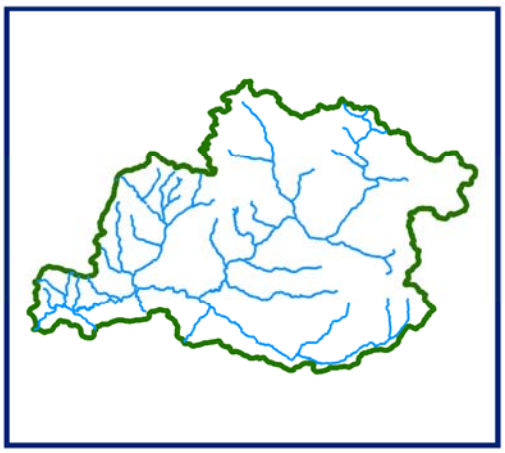
27 MAY 2009

SNOW

0 10 20 40 60 80

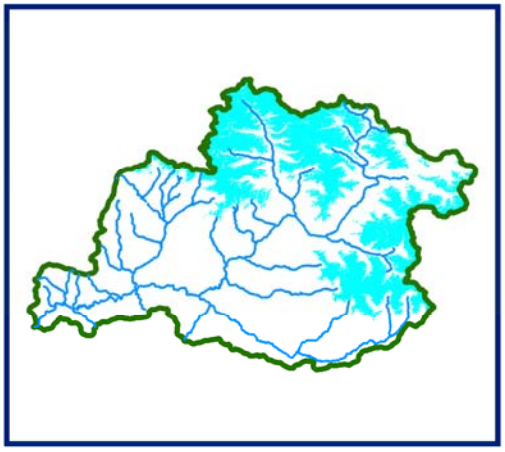
Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



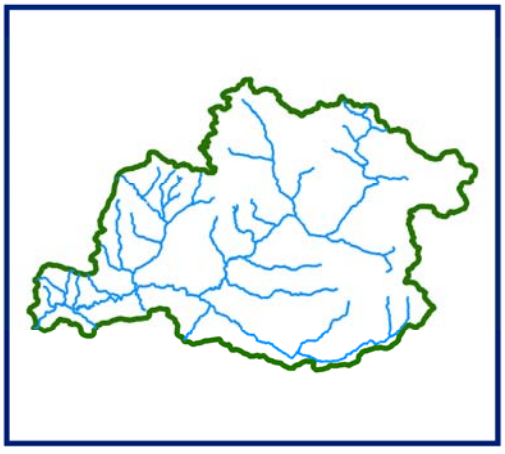
DATA USED

DATA NOT AVAILABLE



DATA USED

18 MAY 2009



DATA USED

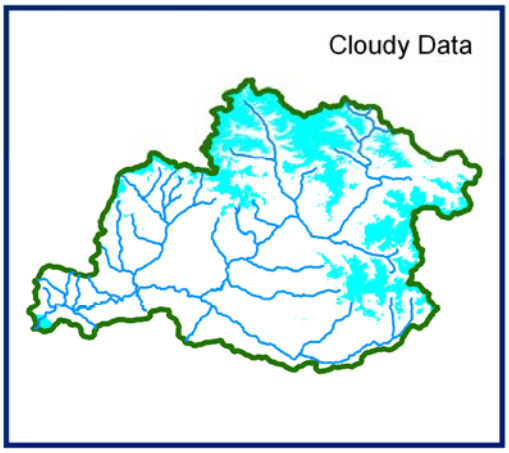
DATA NOT AVAILABLE

SNOW

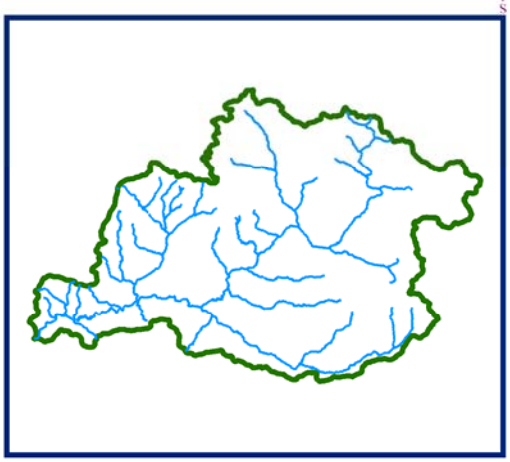
0 5 10 20 30 40

Kilometers

SNOW COVER MAP : ALAKNANDA BASIN



01 JUNE 2009



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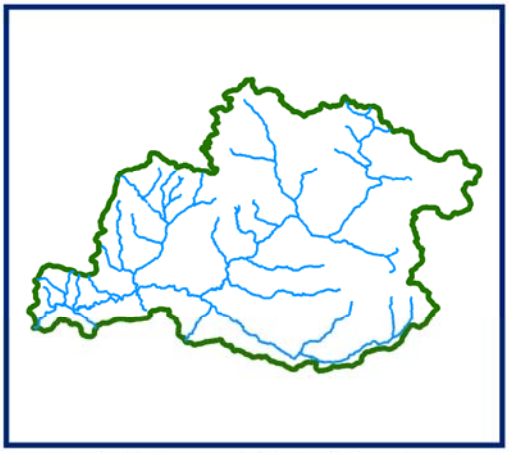

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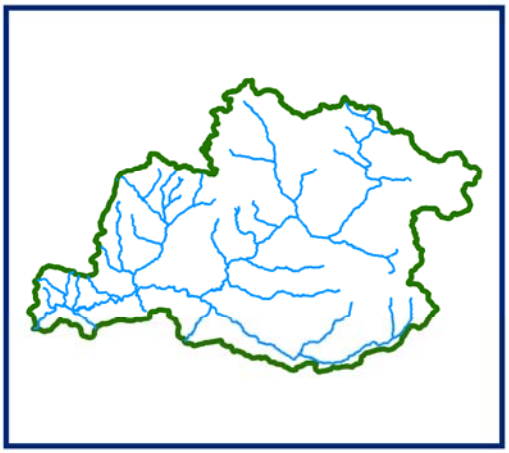

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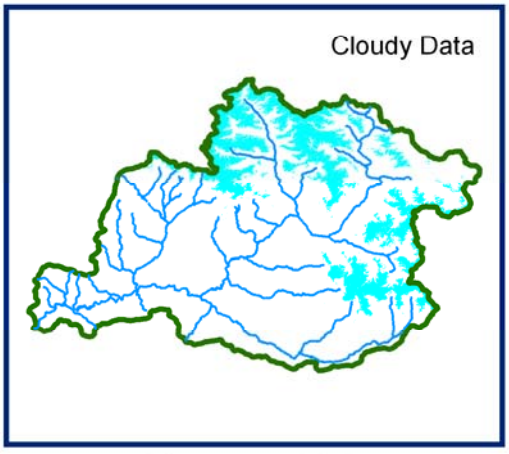

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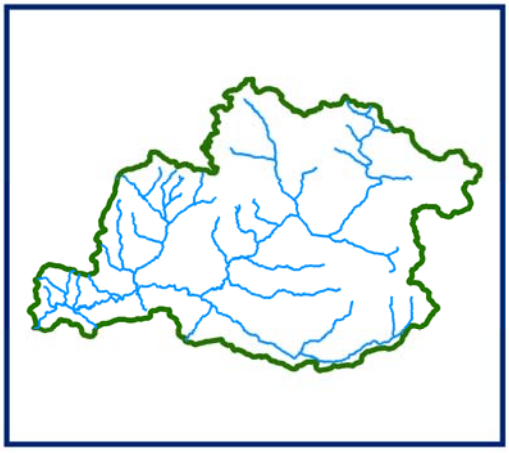


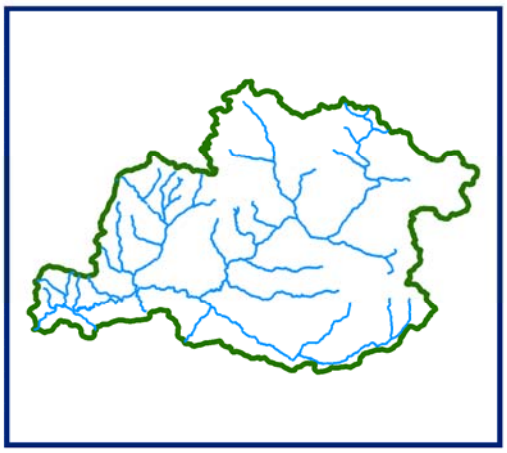
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN



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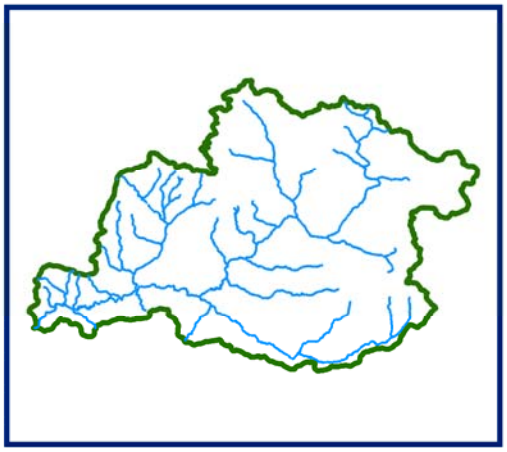
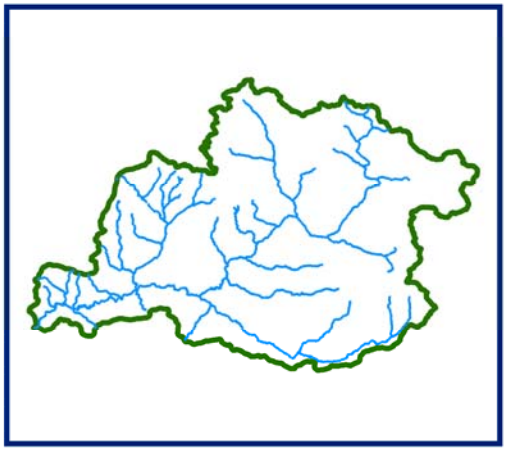
DATA NOT AVAILABLE



DATA USED
DATA NOT AVAILABLE



DATA USED
DATA NOT AVAILABLE

SNOW

0 5 10 20 30 40
Kilometers

BHAGIRATHI 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 2008							
1	4-Oct-08	1970	26	2	23-Oct-08	1724	23
November 2008							
3	1-Nov-08	1599	21	7	12-Nov-08	1380	19
4	6-Nov-08	1601	22	8	16-Nov-08	1402	19
5	7-Nov-08	1480	20	9	21-Nov-08	4016	54
6	11-Nov-08	1504	20	10	26-Nov-08	2449	33
December 2008							
11	1-Dec-08	1779	24	15	15-Dec-08	1646	22
12	5-Dec-08	1692	23	16	24-Dec-08	1635	22
13	6-Dec-08	1554	21	17	25-Dec-08	3612	49
14	10-Dec-08	2054	28	18	29-Dec-08	3521	47
19	30-Dec-08	3410	46				
January 2009							
20	8-Jan-09	3767	51	21	27-Jan-09	3360	45
22	27-Jan-09	3360	45				
February 2009							
23	1-Feb-09	2742	37	25	16-Feb-09	3015	41
24	15-Feb-09	3560	48	26	25-Feb-09	3323	45
March 2009							
27	7-Mar-09	2536	34	30	21-Mar-09	3544	48
28	12-Mar-09	2797	38	31	26-Mar-09	3466	47
29	21-Mar-09	3540	48	32	31-Mar-09	3223	43
April 2009							
33	4-Apr-09	3141	42	34	14-Apr-09	2982	40
35	14-Apr-09	2975	40	36	19-Apr-09	2802	38
37	23-Apr-09	2924	39	38	28-Apr-09	2564	34
39	29-Apr-09	2047	28				

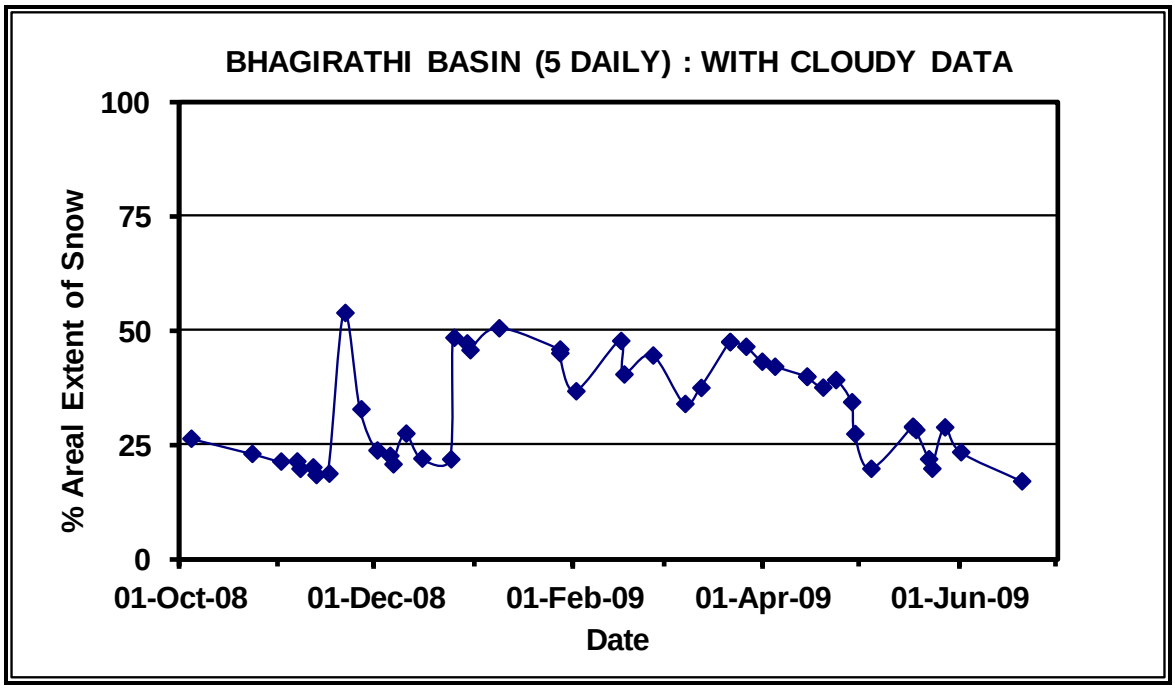
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
40	4-May-09	1481	20	43	18-May-09	2111	28
41	17-May-09	2166	29	44	22-May-09	1638	22
42	17-May-09	2157	29	45	23-May-09	1482	20
46	27-May-09	2155	29				
June 2009							
47	1-Jun-09	1751	24	48	20-Jun-09	1277	17

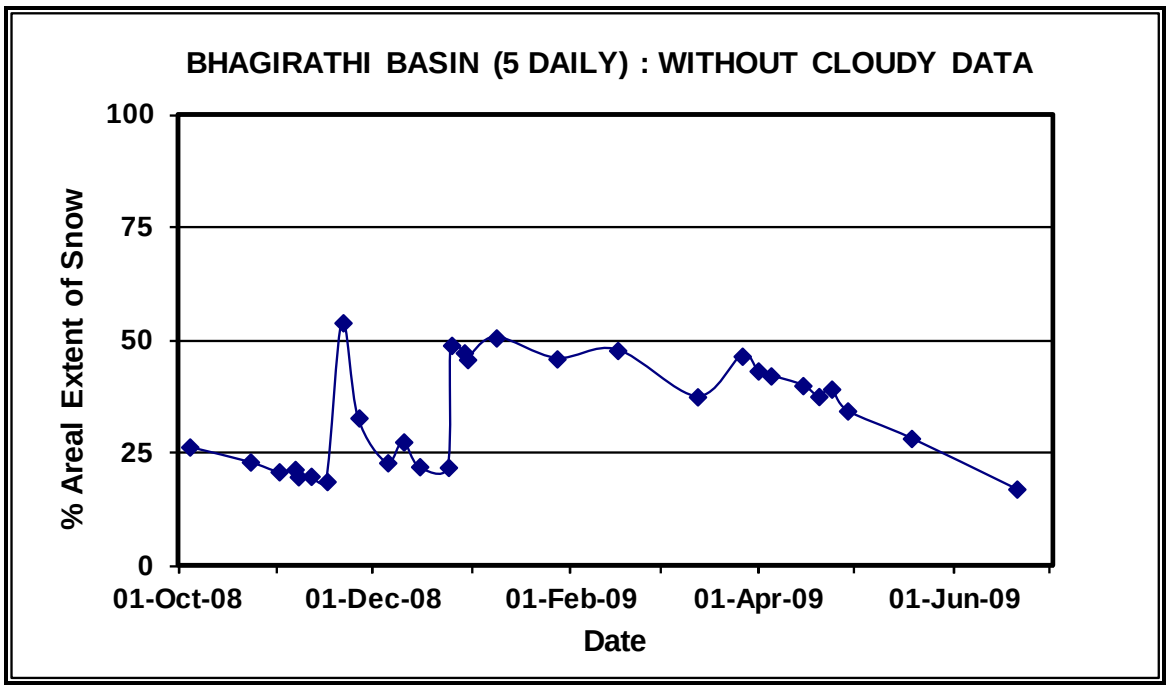
AREAL EXTENT OF SNOW (10 DAILY)

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

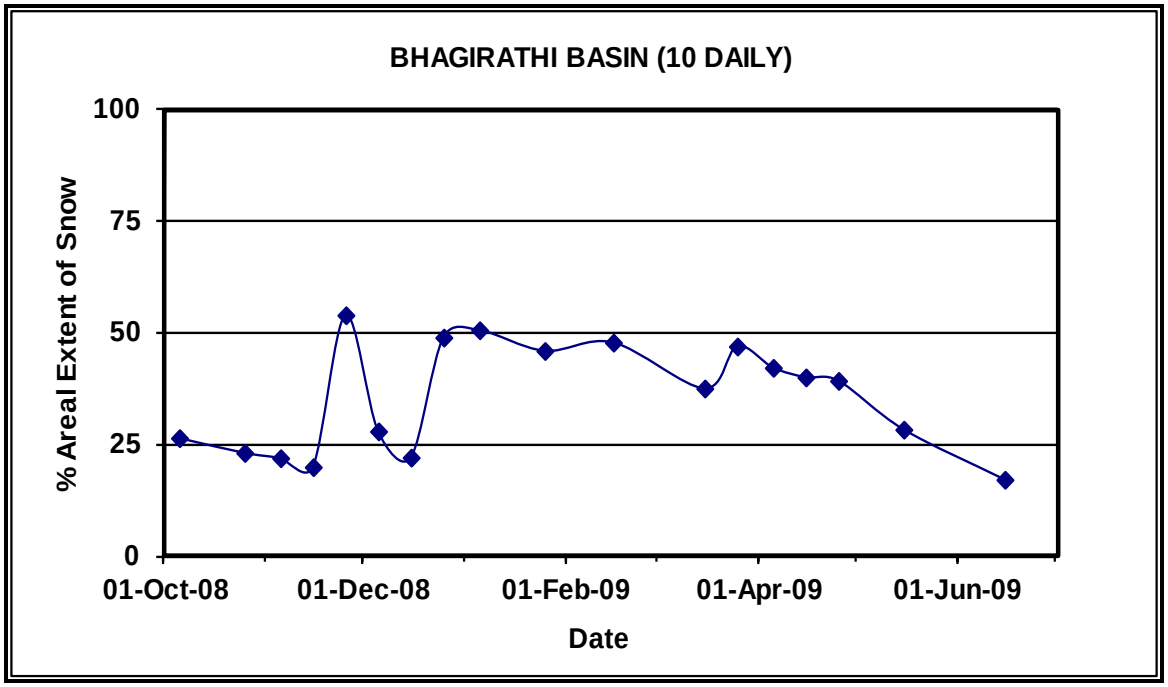
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
1	4-Oct-08	1970	26	3	1-Nov-08	1636	22
2	23-Oct-08	1724	23	4	11-Nov-08	1488	20
				5	21-Nov-08	4017	54
December 2008				**January 2009**			
6	5-Dec-08	2083	28	9	8-Jan-09	3767	51
7	15-Dec-08	1646	22	10	27-Jan-09	3421	46
8	25-Dec-08	3645	49				
February 2009				**March 2009**			
11	15-Feb-09	3560	48	12	12-Mar-09	2797	38
				13	31-Mar-09	3496	47
April 2009				**May 2009**			
14	05-Apr-09	3141	42	17	18-May-09	2111	28
15	15-Apr-09	2982	40				
16	25-Apr-09	2924	39				
June 2009							
18	20-Jun-09	1277	17				

Snow cover depletion curve



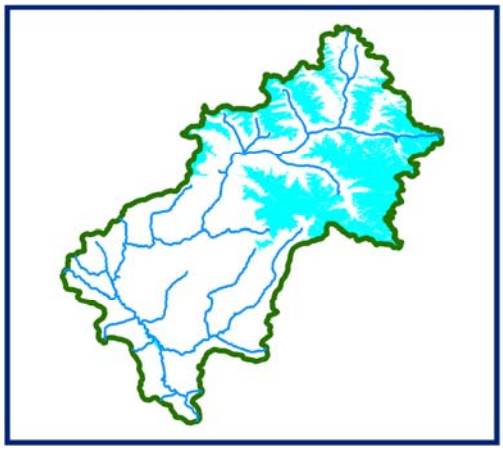


Snow cover depletion curve

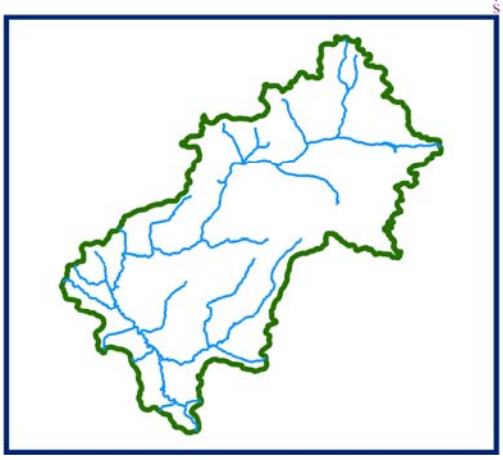


SNOW COVER MAP

SNOW COVER MAP : BHAGIRATHI BASIN



04 OCTOBER 2008



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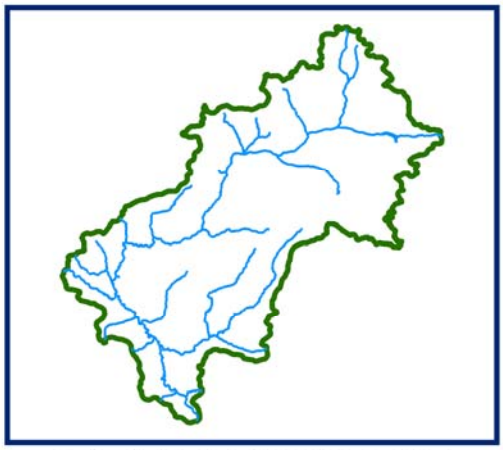

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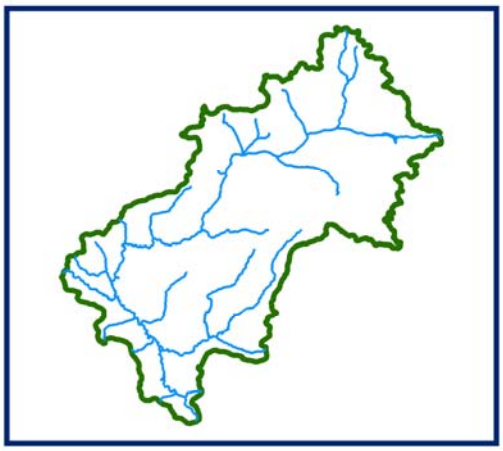

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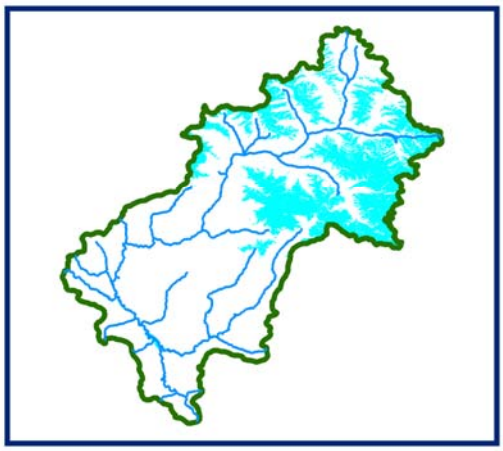
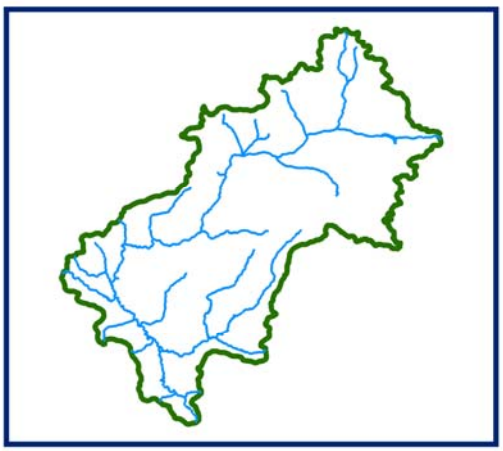


23 OCTOBER 2008



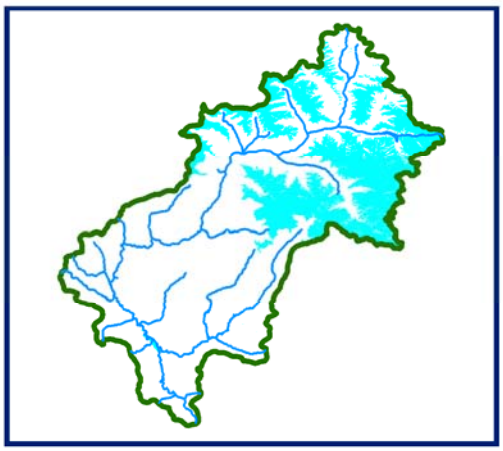
DATA NOT AVAILABLE

SNOW

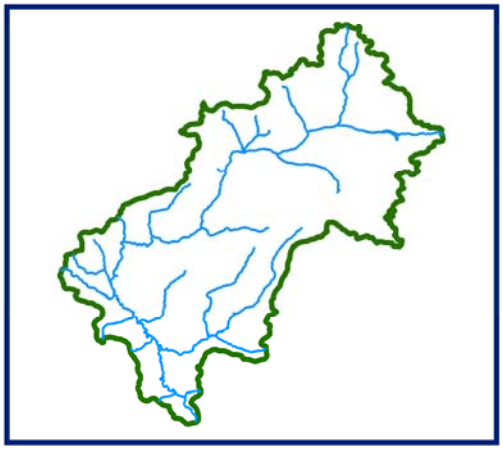
0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



DATA USED
04 OCTOBER 2008



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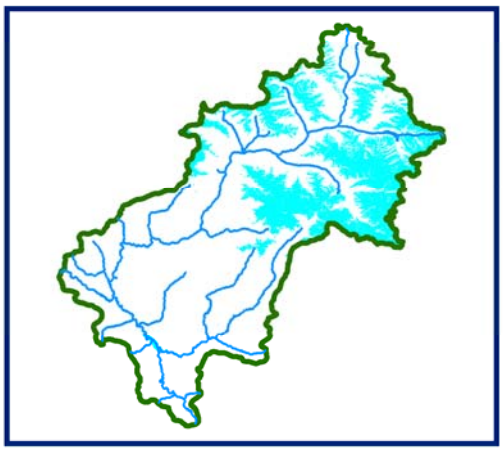
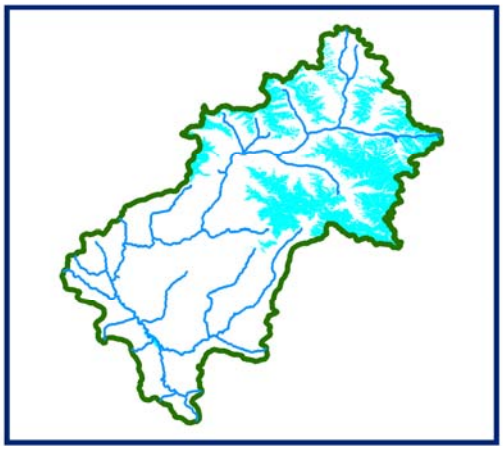


DATA USED
23 OCTOBER 2008

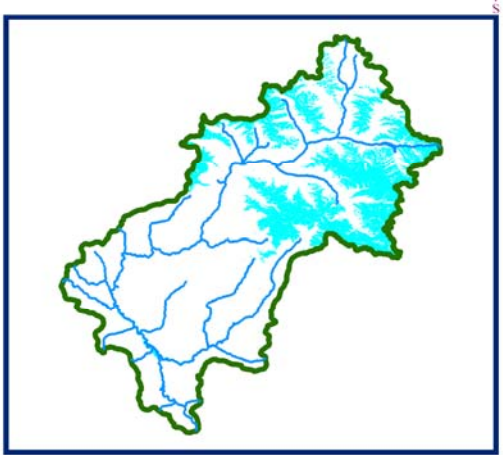
SNOW

0 5 10 20 30 40
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



01 NOVEMBER 2008



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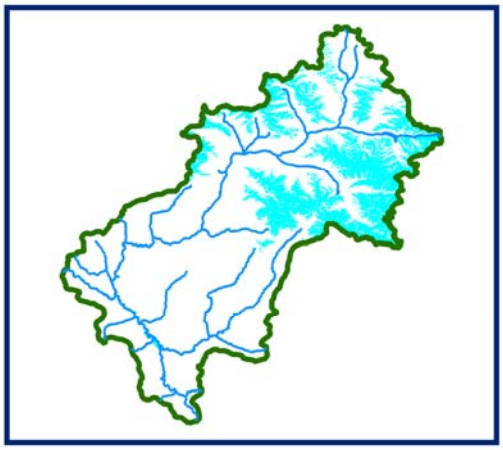

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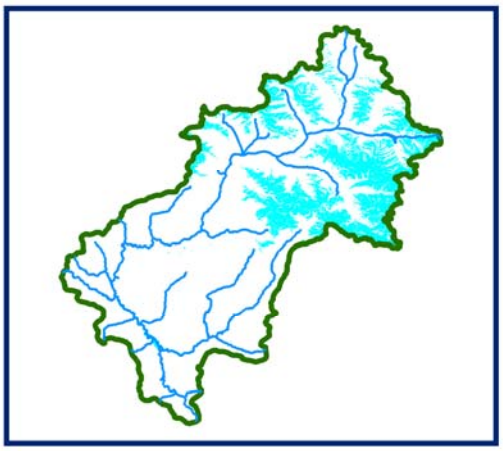
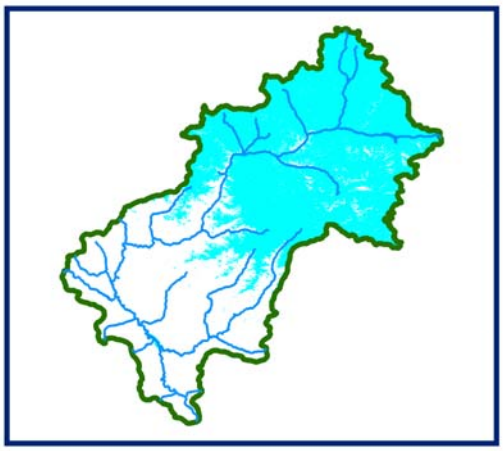
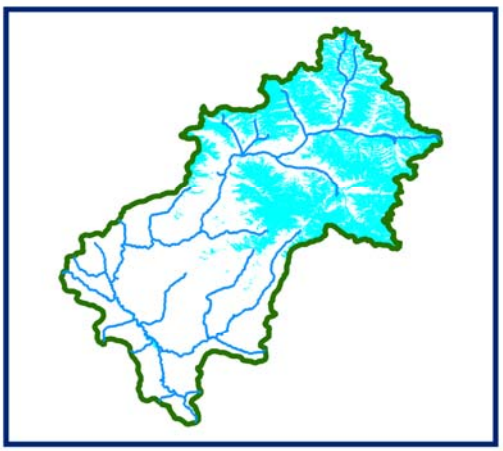


16 NOVEMBER 2008



21 NOVEMBER 2008



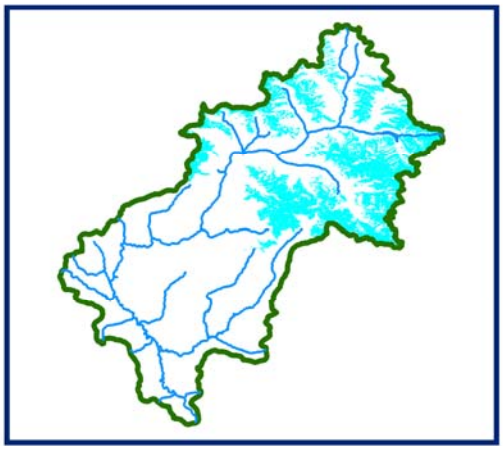
26 NOVEMBER 2008

SNOW

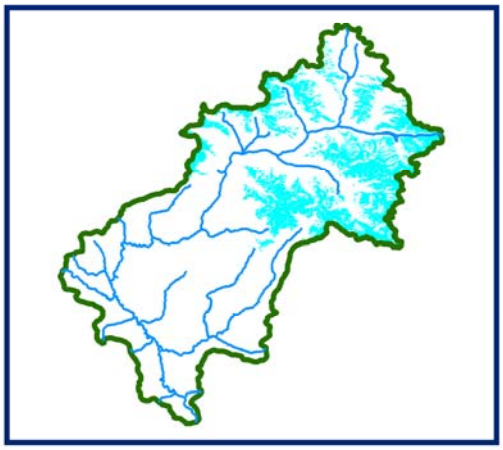
0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



DATA USED
01 NOVEMBER 2008
06 NOVEMBER 2008



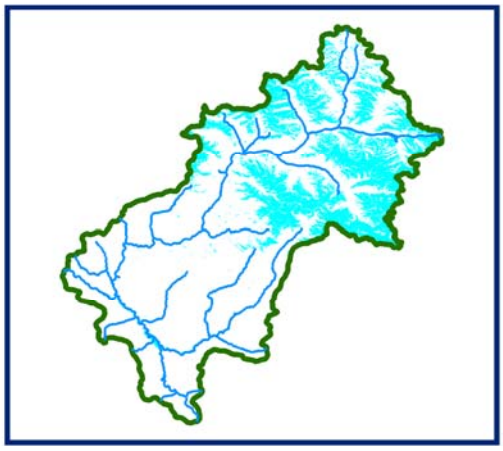
DATA USED
11 NOVEMBER 2008
16 NOVEMBER 2008

DATA USED
21 NOVEMBER 2008
26 NOVEMBER 2008

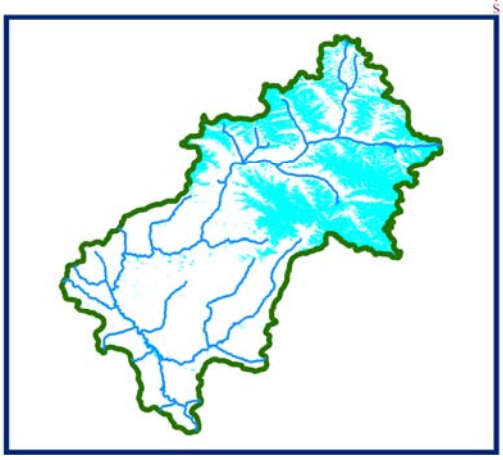
SNOW

0 0.5 1 2 3 4
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



05 DECEMBER 2008



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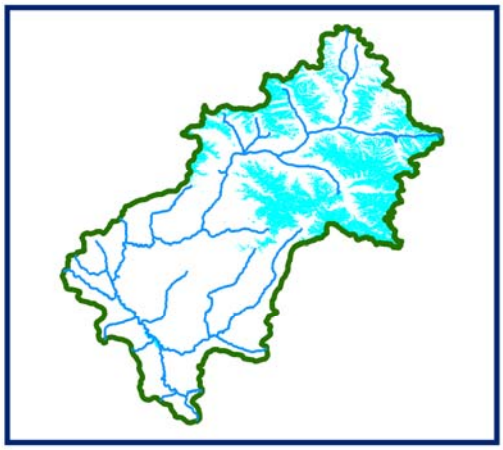
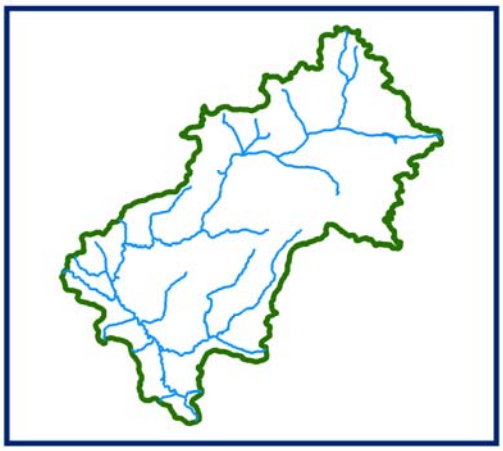


15 DECEMBER 2008



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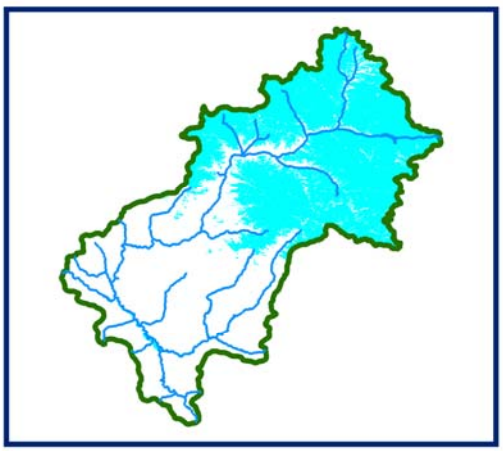
25 DECEMBER 2008



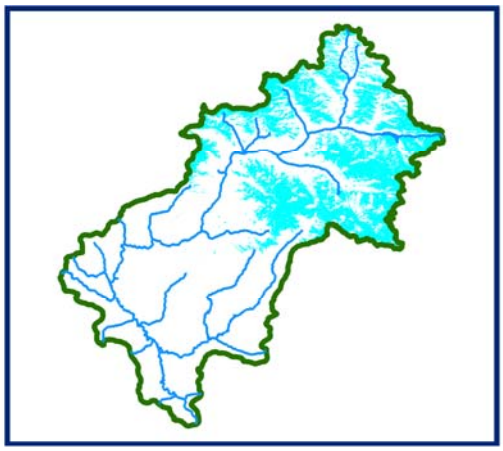
30 DECEMBER 2008

SNOW

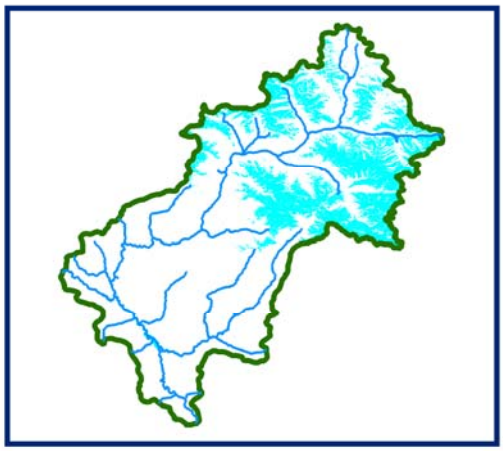
0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



DATA USED
05 DECEMBER 2008
10 DECEMBER 2008



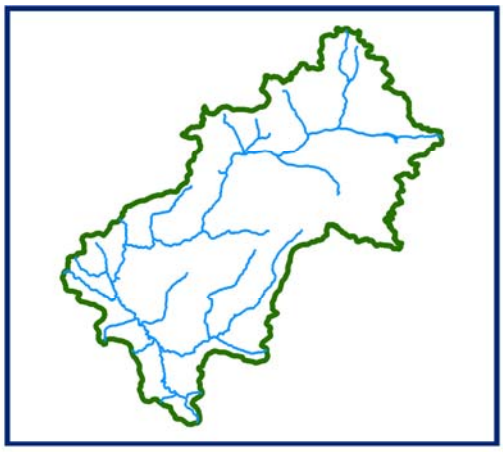
DATA USED
15 DECEMBER 2008

DATA USED
25 DECEMBER 2008
30 DECEMBER 2008

SNOW

0 9 18 36
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



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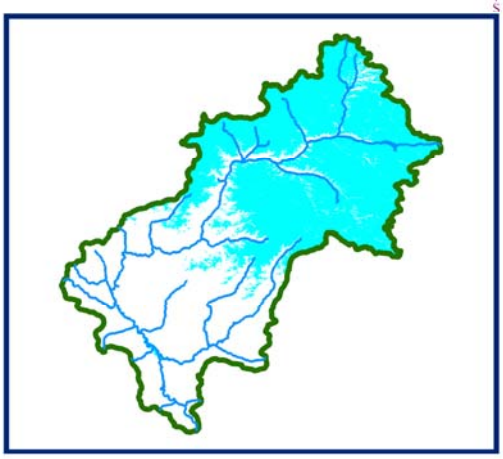
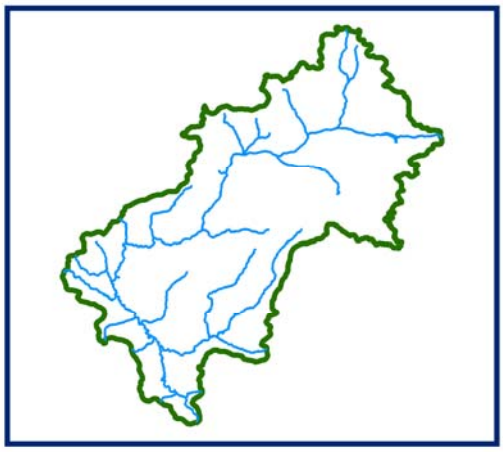


08 JANUARY 2009



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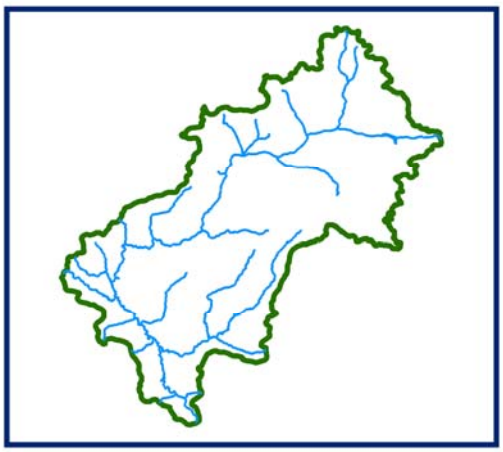

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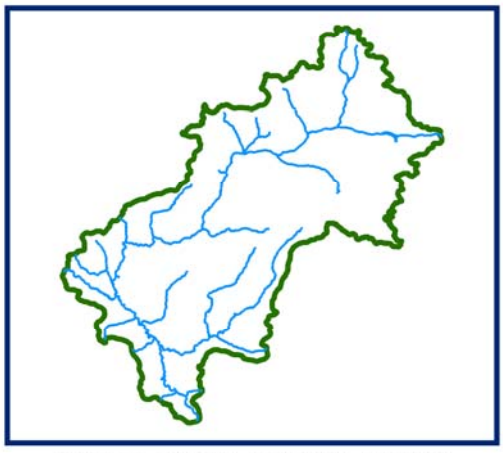

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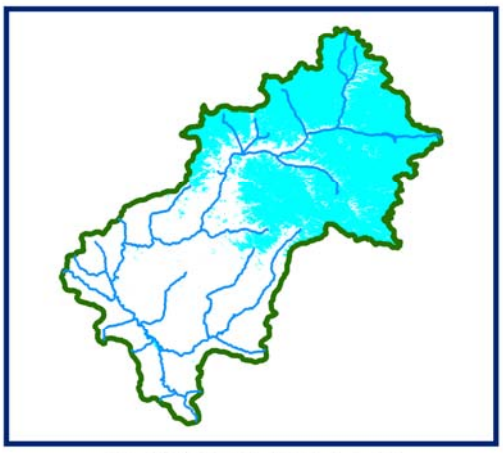


27 JANUARY 2009

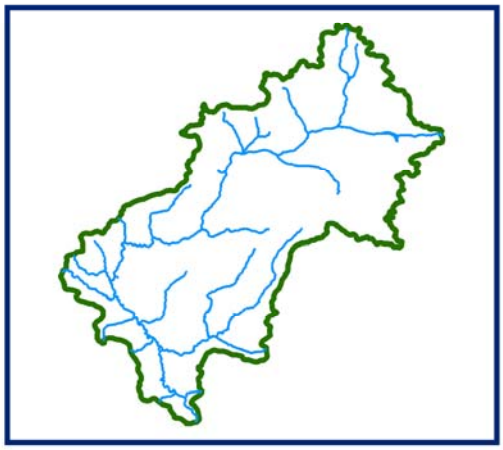
SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN

DATA USED
08 JANUARY 2009



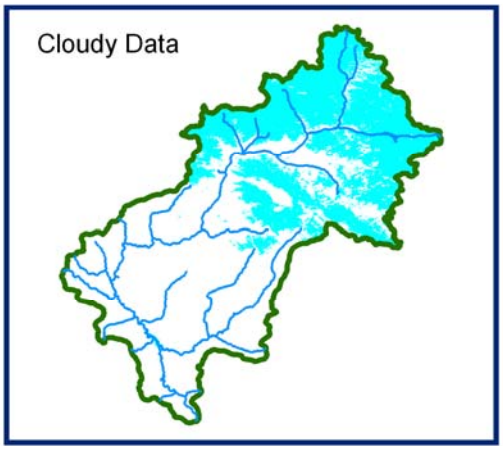
DATA USED
DATA NOT AVAILABLE

DATA USED
27 JANUARY 2009

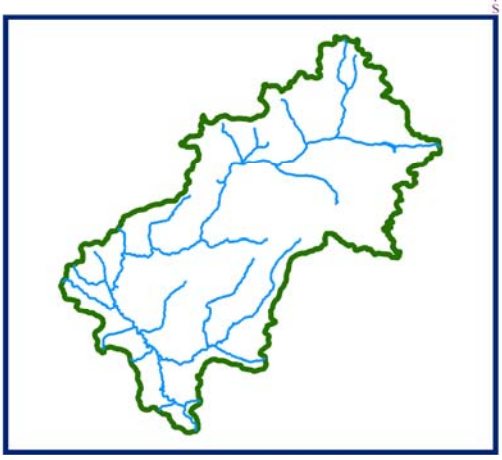
SNOW

0 9 18 27 36
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



01 FEBRUARY 2009



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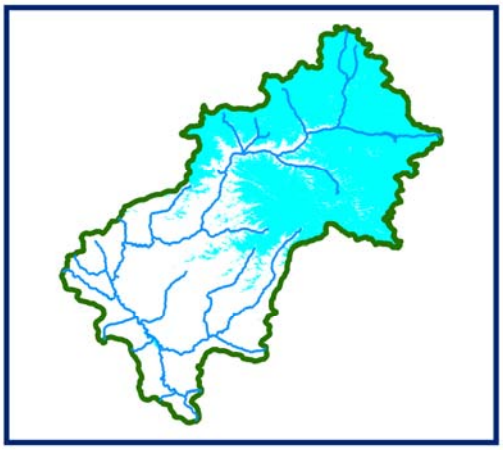

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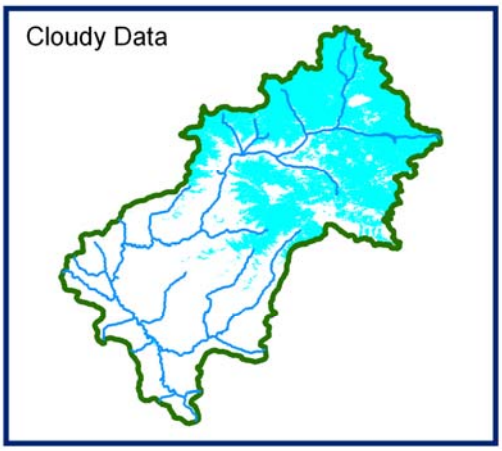
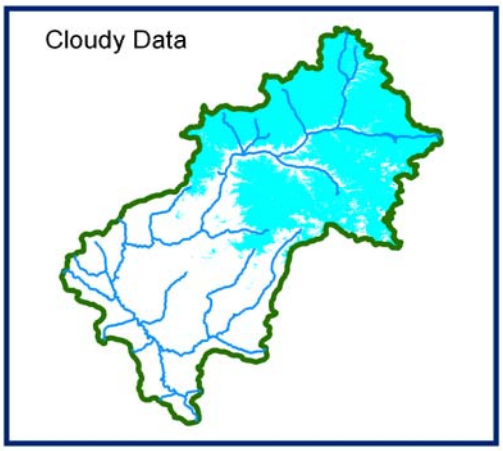
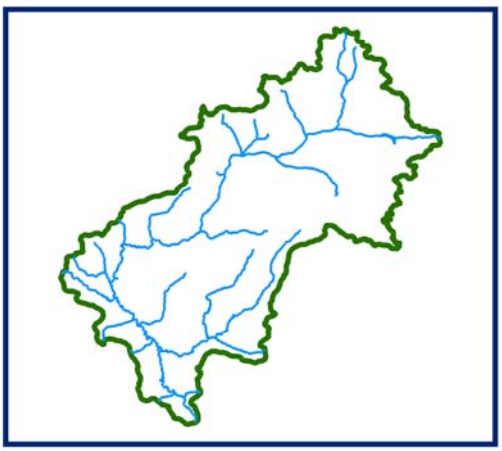


16 FEBRUARY 2009



25 FEBRUARY 2009



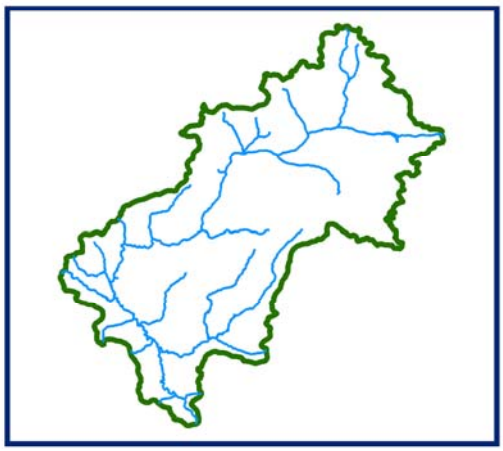
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN

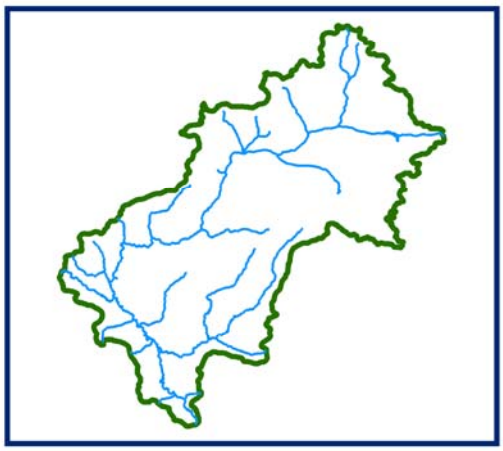


DATA USED

DATA NOT AVAILABLE

DATA USED

15 FEBRUARY 2009



DATA USED

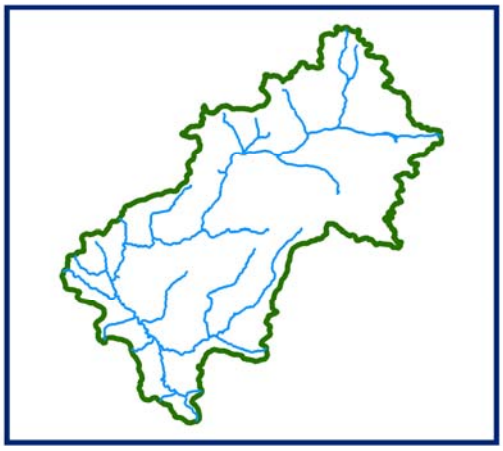
DATA NOT AVAILABLE

SNOW

0 9 18 36

Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



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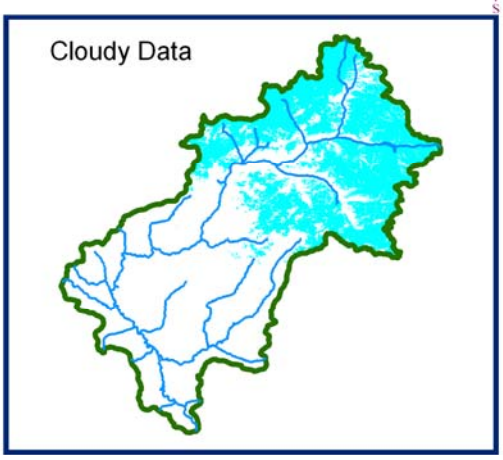
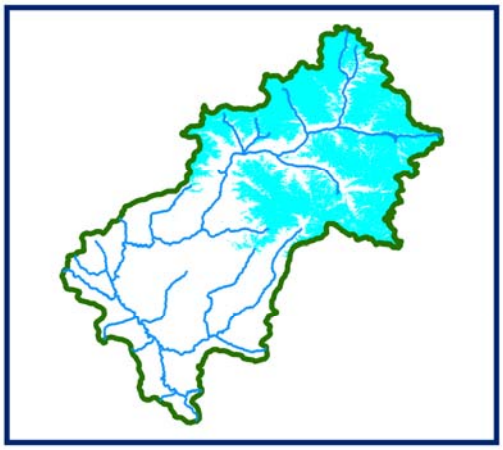
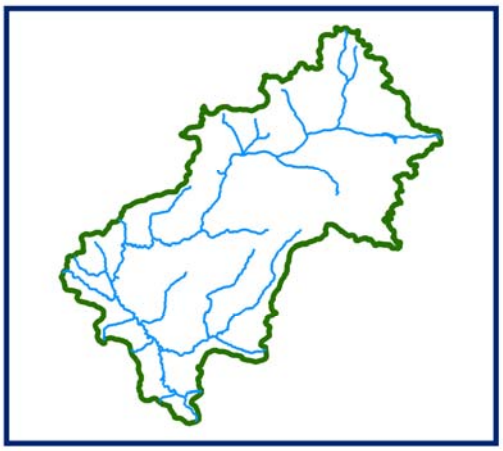


07 MARCH 2009



12 MARCH 2009



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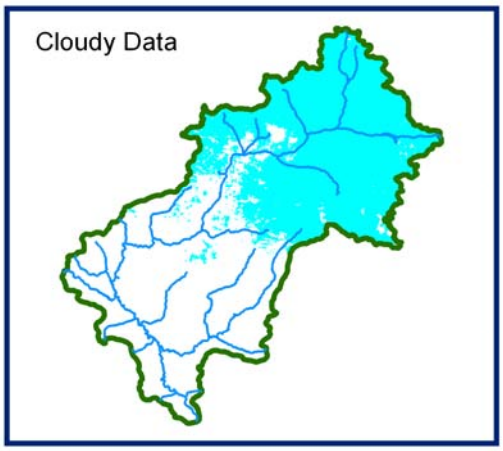
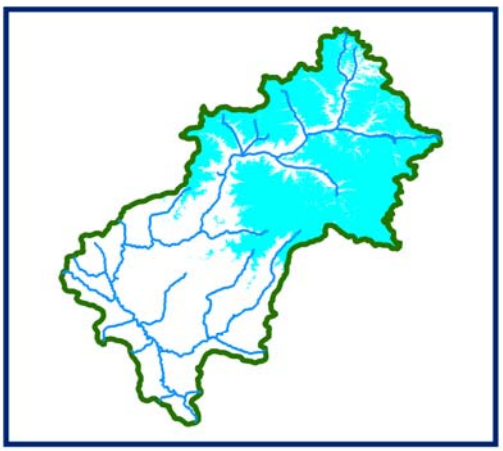


21 MARCH 2009



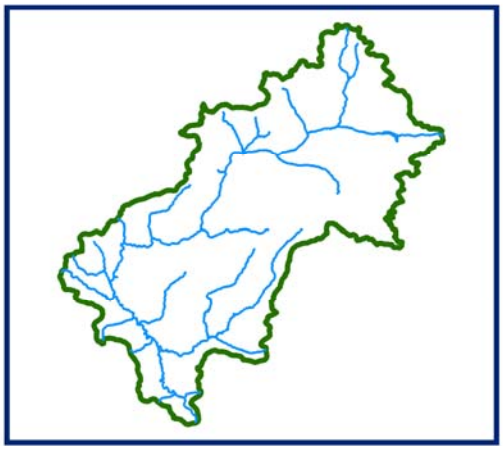
31 MARCH 2009

SNOW

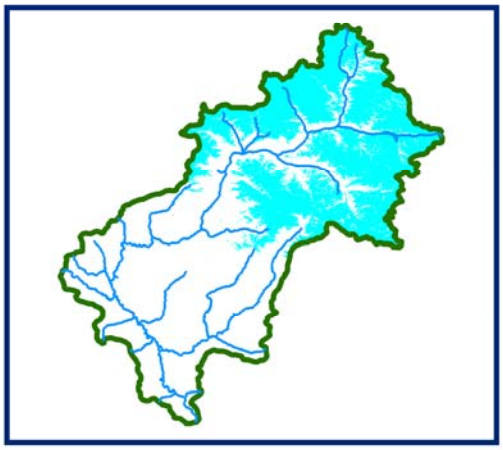
0 10 20 40 60 80

Kilometers

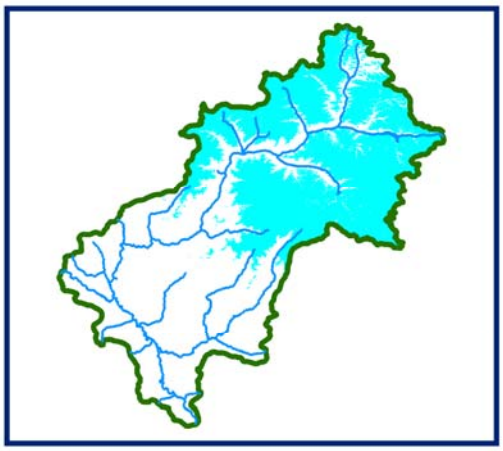
10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
12 MARCH 2009

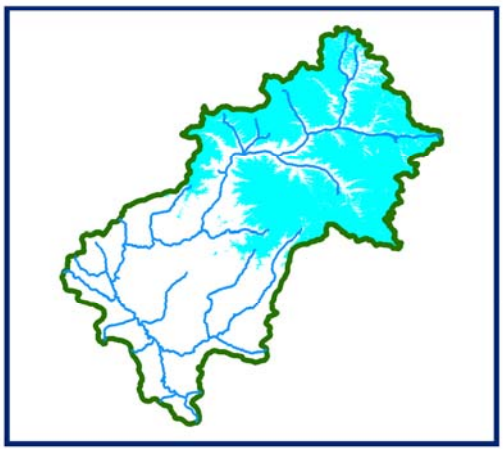


DATA USED
31 MARCH 2009

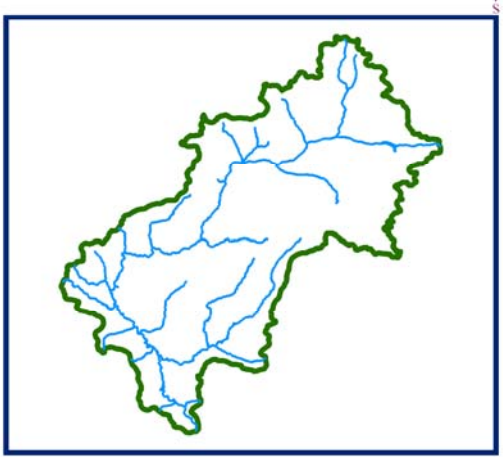
SNOW

0 4.5 9 18 27 36
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



04 APRIL 2009



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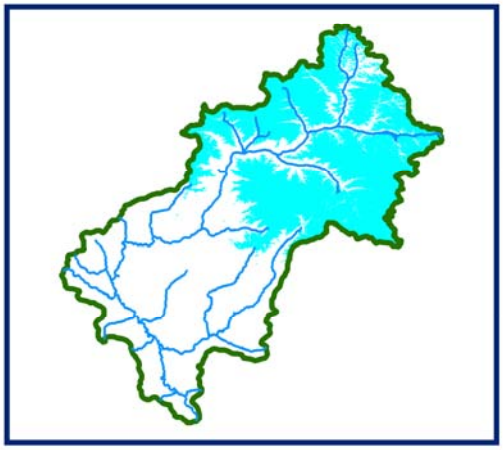
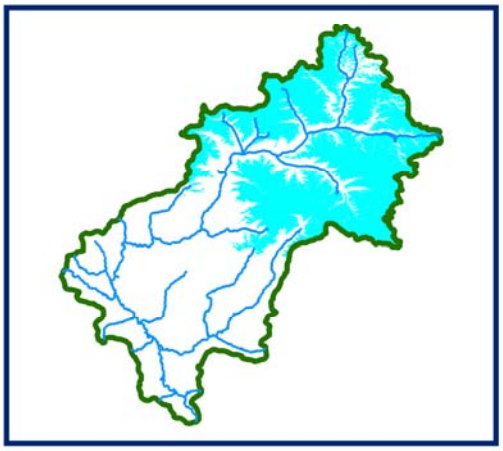
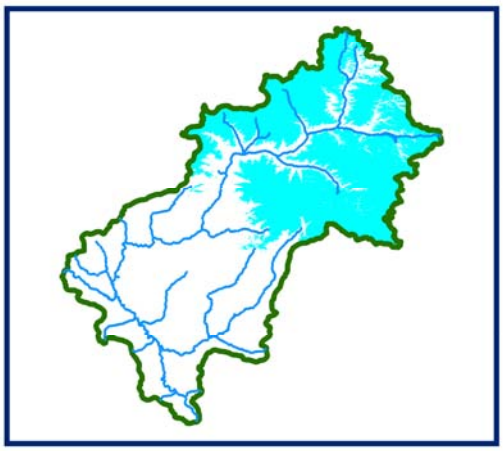


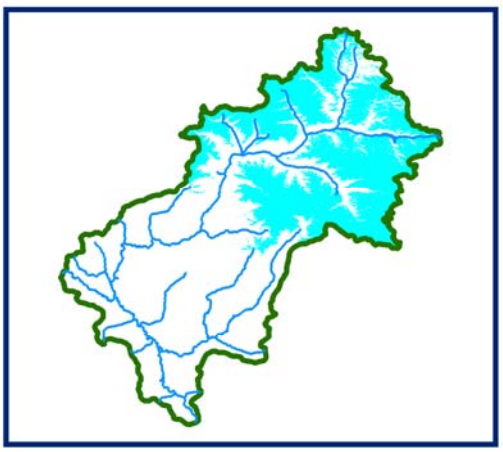
14 APRIL 2009



19 APRIL 2009



23 APRIL 2009



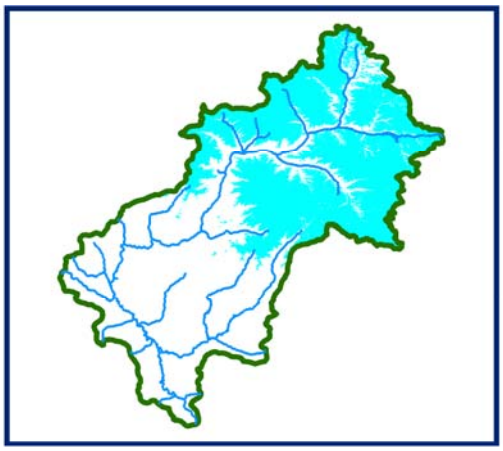
28 APRIL 2009

SNOW

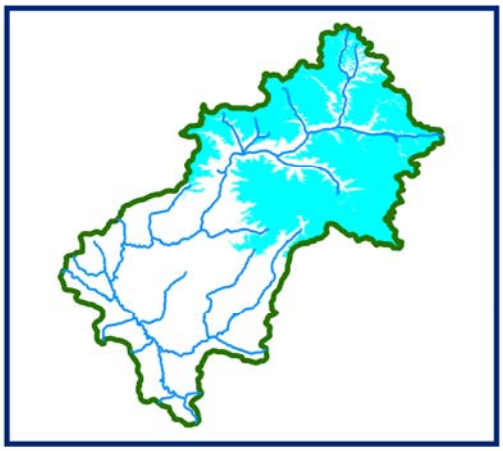
0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



DATA USED
04 APRIL 2009



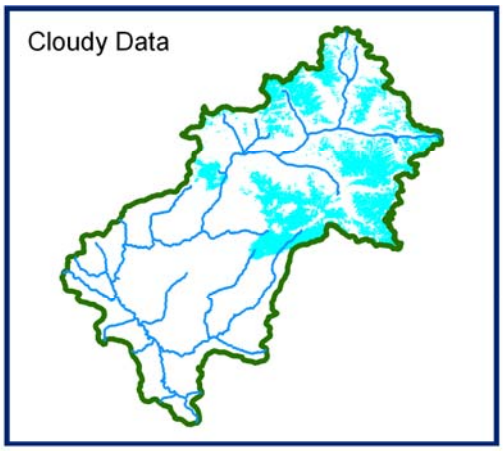
DATA USED
14 APRIL 2009
19 APRIL 2009

DATA USED
23 APRIL 2009
28 APRIL 2009

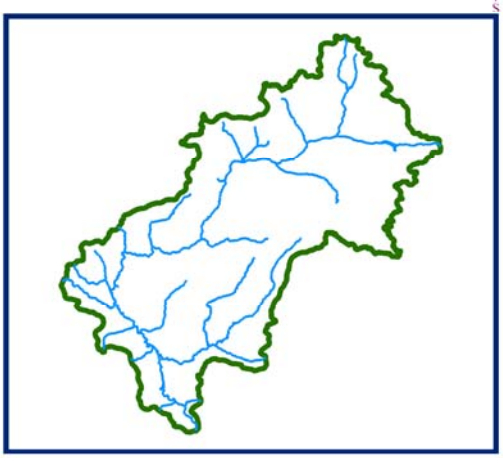
SNOW

0 9 18 27 36
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



04 MAY 2009



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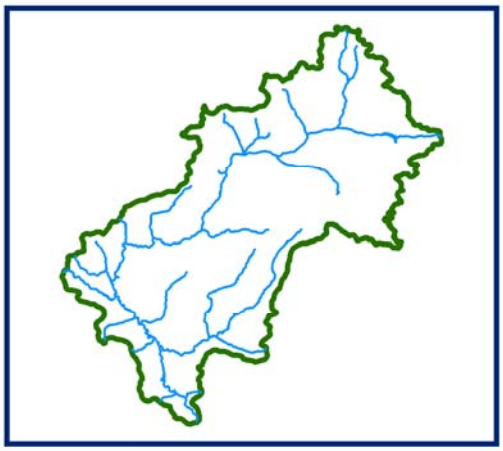

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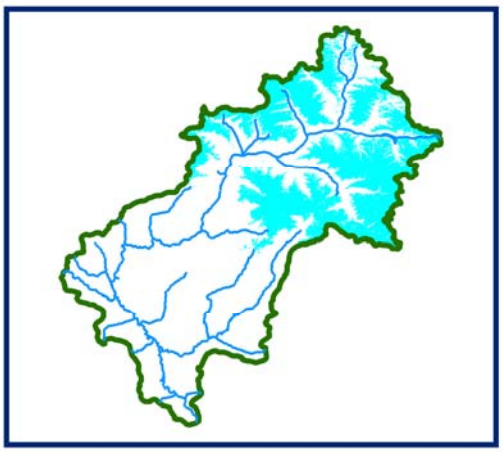
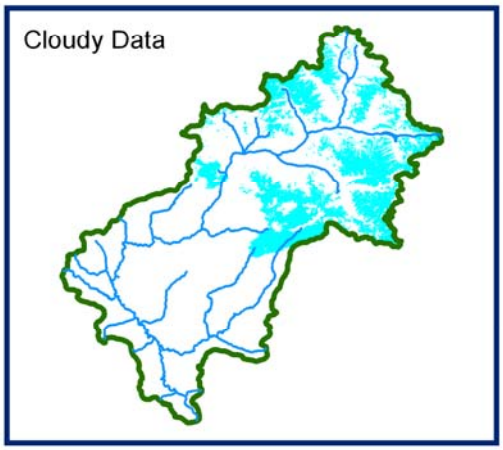
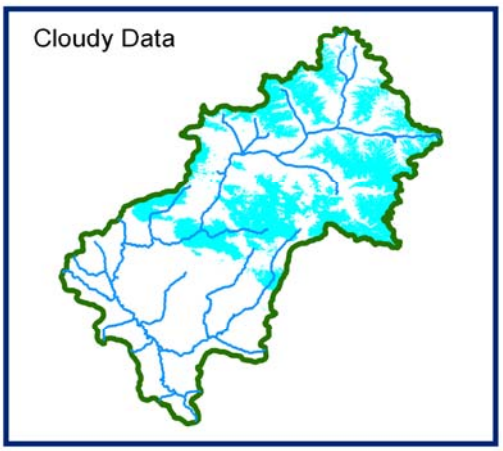


18 MAY 2009



23 MAY 2009



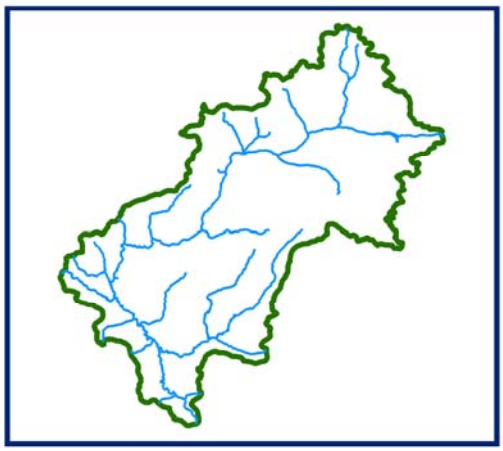
27 MAY 2009

SNOW

0 10 20 40 60 80

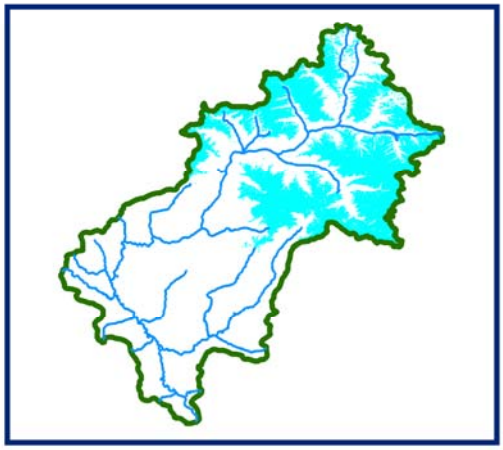
Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



DATA USED

DATA NOT AVAILABLE



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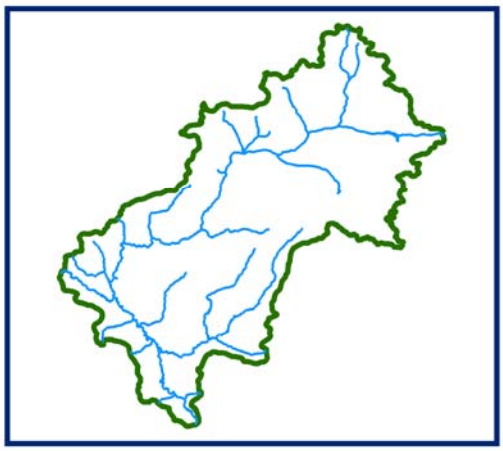
18 MAY 2009



DATA USED

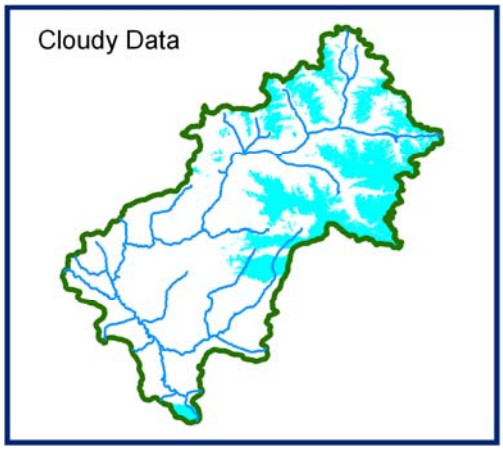
DATA NOT AVAILABLE

SNOW

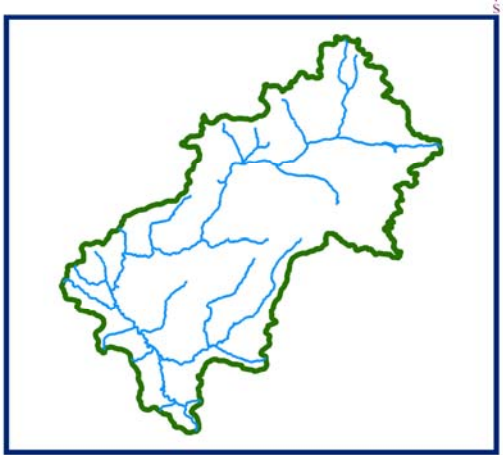
0 4.5 9 18 27 36

Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN



01 JUNE 2009



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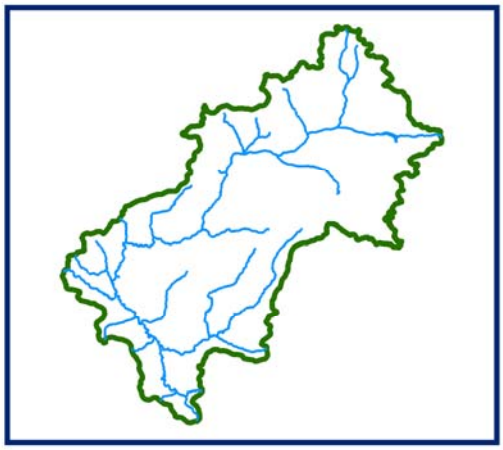

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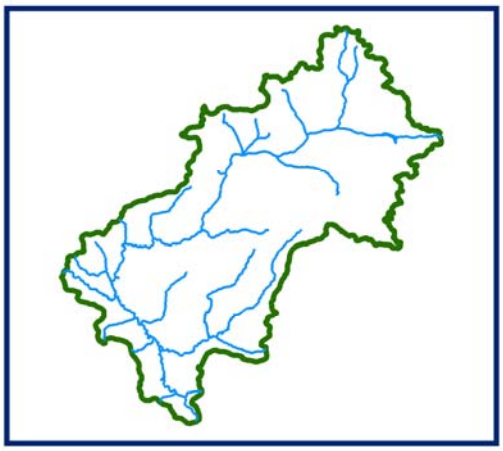

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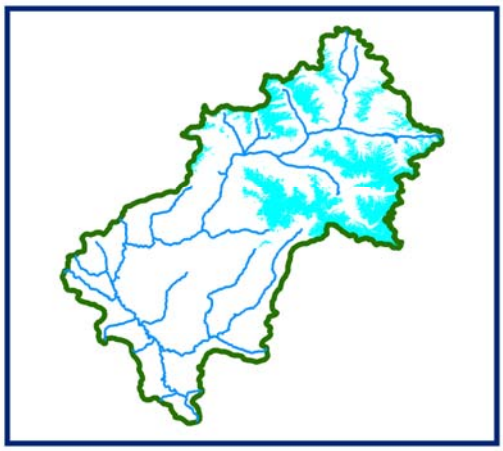
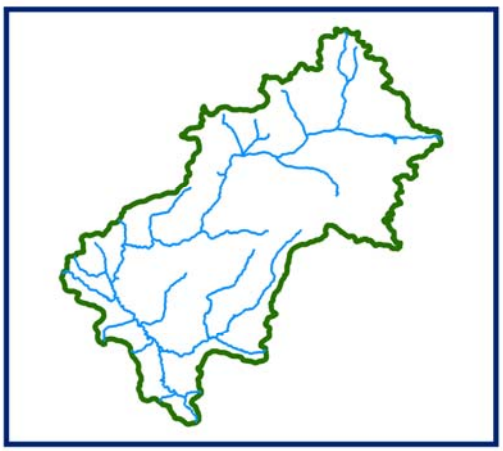


20 JUNE 2009



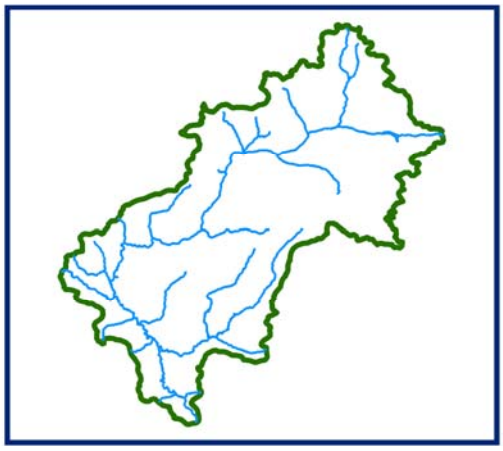
DATA NOT AVAILABLE

SNOW

0 10 20 40 60 80

Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN



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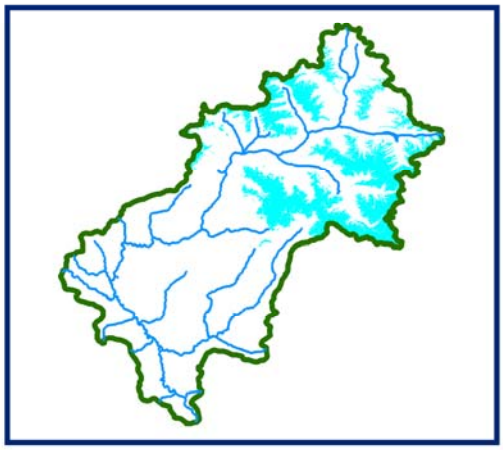

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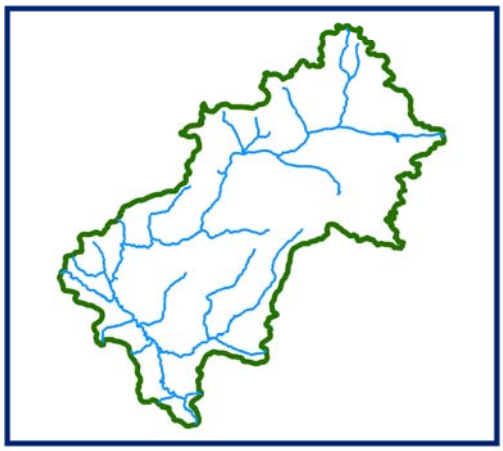
20 JUNE 2009



DATA USED

DATA NOT AVAILABLE

SNOW

0 9 18 36
Kilometers

YAMUNA BASIN

AREAL EXTENT OF SNOW (5 DAILY)

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

S. No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008							
1	4-Oct-08	520	15	3	23-Oct-08	493	14
2	13-Oct-08	428	12	4	27-Oct-08	493	14
November 2008							
5	1-Nov-08	396	11	8	11-Nov-08	348	10
6	6-Nov-08	365	10	9	16-Nov-08	345	10
7	7-Nov-08	353	10	10	21-Nov-08	1402	40
11	26-Nov-08	658	19				
December 2008							
12	1-Dec-08	451	13	15	15-Dec-08	435	12
13	5-Dec-08	455	13	16	24-Dec-08	445	13
14	10-Dec-08	554	16	17	25-Dec-08	1168	33
18	29-Dec-08	1148	33				
January 2009							
19	8-Jan-09	1577	45	21	27-Jan-09	810	23
20	12-Jan-09	1308	37	22	27-Jan-09	794	23
February 2009							
23	1-Feb-09	969	27	25	15-Feb-09	1363	39
24	5-Feb-09	770	22	26	25-Feb-09	1251	35
March 2009							
27	7-Mar-09	696	20	30	21-Mar-09	1632	46
28	11-Mar-09	915	26	31	26-Mar-09	1162	33
29	21-Mar-09	1629	46	32	31-Mar-09	1026	29
April 2009							
33	4-Apr-09	960	27	37	19-Apr-09	822	23
34	14-Apr-09	919	26	38	23-Apr-09	789	22
35	14-Apr-09	928	26	39	28-Apr-09	670	19
36	18-Apr-09	880	25	40	29-Apr-09	670	19

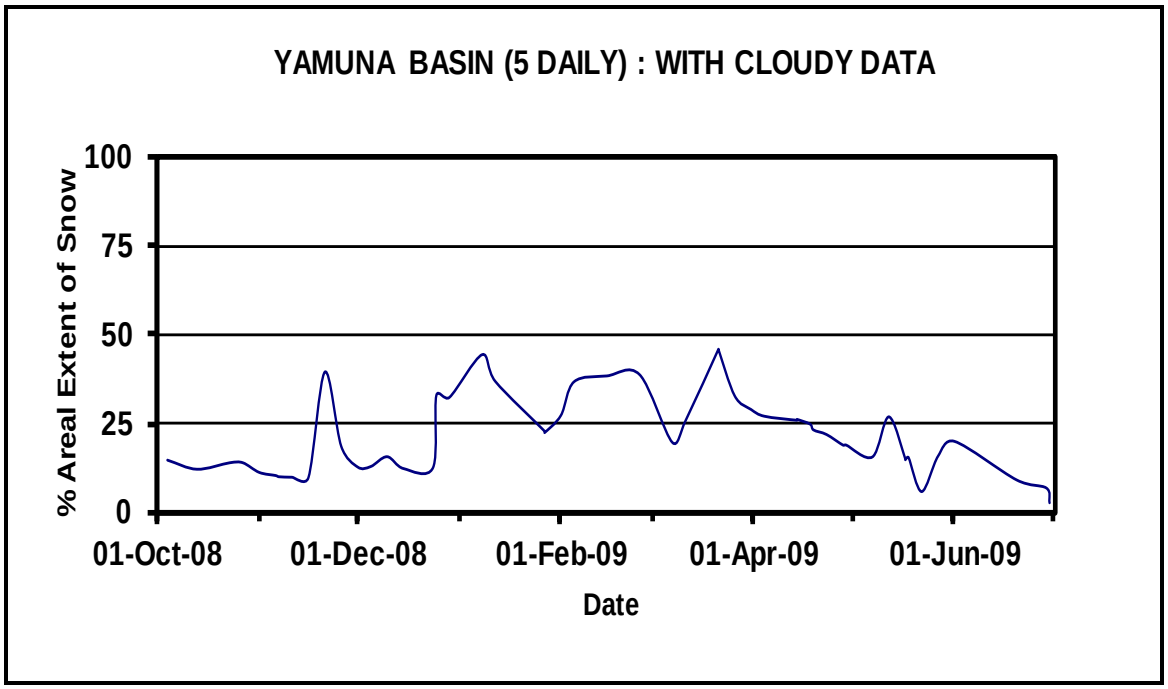
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2009							
41	7-May-09	552	16	44	17-May-09	523	15
42	12-May-09	953	27	45	18-May-09	545	15
43	17-May-09	532	15	46	22-May-09	204	6
47	27-May-09	560	16				
June 2009							
48	1-Jun-09	708	20	50	29-Jun-09	240	7
49	20-Jun-09	320	9	51	30-Jun-09	92	3

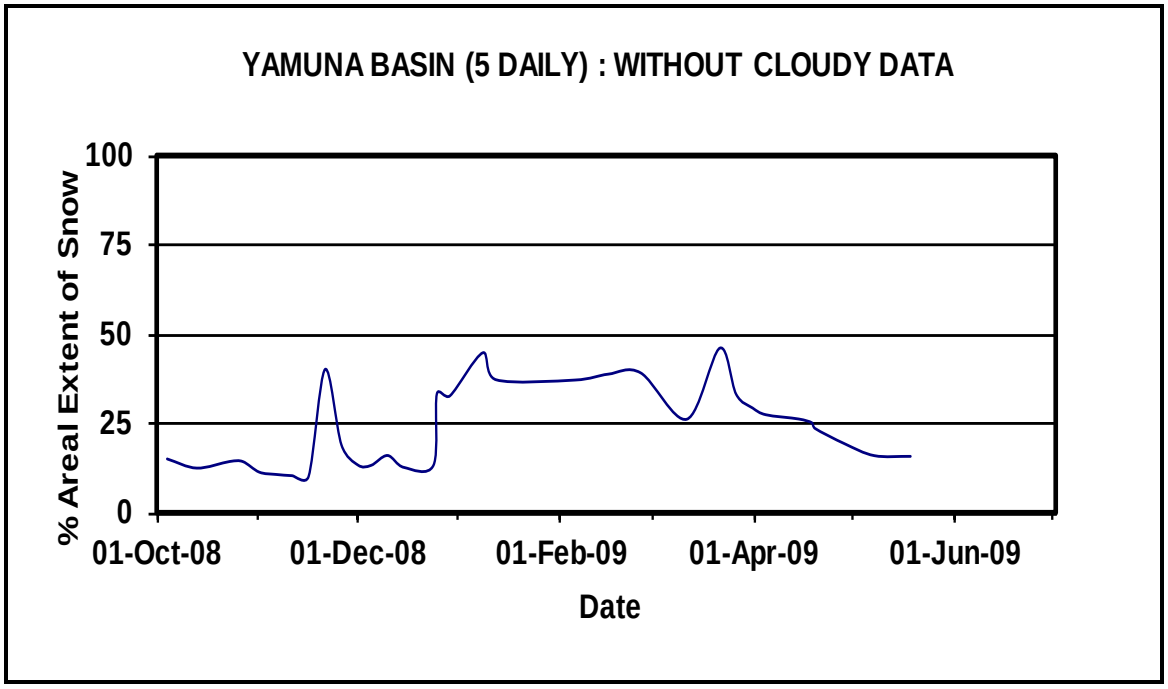
AREAL EXTENT OF SNOW (10 DAILY)

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

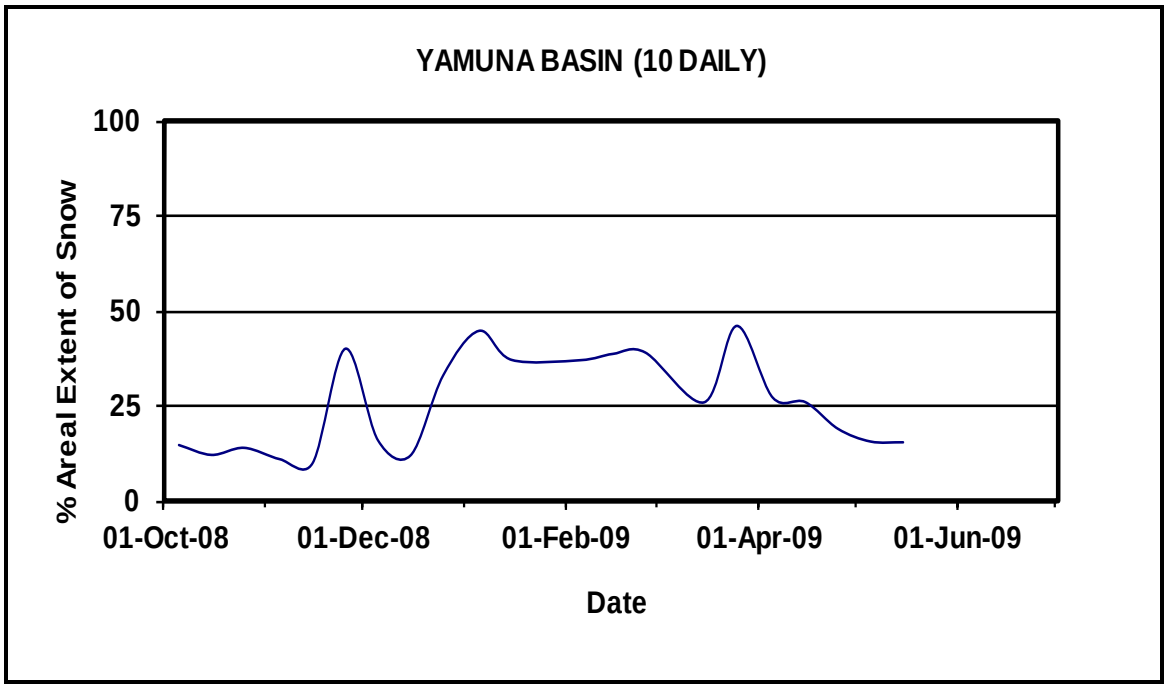
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2008				**November 2008**			
1	4-Oct-08	520	15	4	1-Nov-08	388	11
2	13-Oct-08	428	12	5	11-Nov-08	353	10
3	23-Oct-08	494	14	6	21-Nov-08	1411	40
December 2008				**January 2009**			
7	1-Dec-08	564	16	10	8-Jan-09	1577	45
8	15-Dec-08	423	12	11	12-Jan-09	1308	37
9	24-Dec-08	1164	33				
February 2009				**March 2009**			
12	5-Feb-09	1305	37	14	11-Mar-09	915	26
13	15-Feb-09	1363	39	15	21-Mar-09	1169	46
13	25-Feb-09	1376	39				
April 2009				**May 2009**			
16	4-Apr-09	960	27	19	7-May-09	552	16
17	14-Apr-09	915	26	20	18-May-09	545	15
18	28-Apr-09	670	19				
June 2009							

Snow cover depletion curve



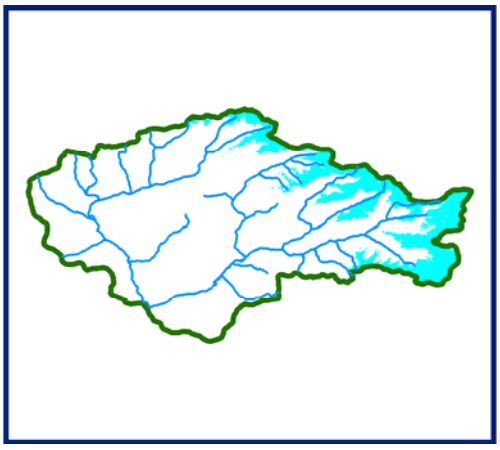


Snow cover depletion curve

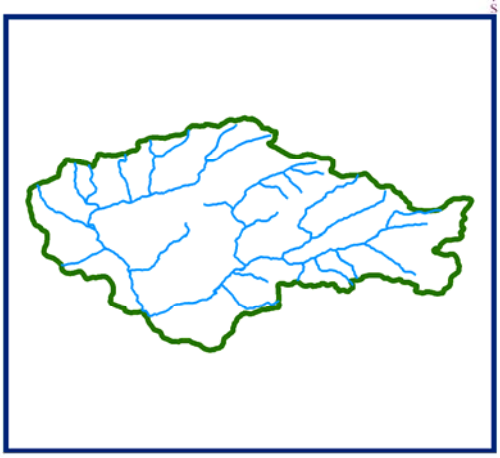


SNOW COVER MAP

SNOW COVER MAP : YAMUNA BASIN



04 OCTOBER 2008



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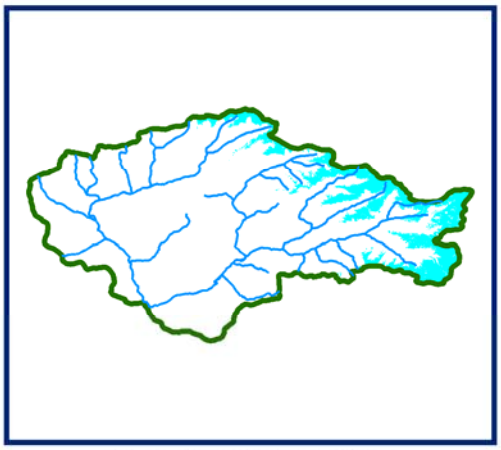
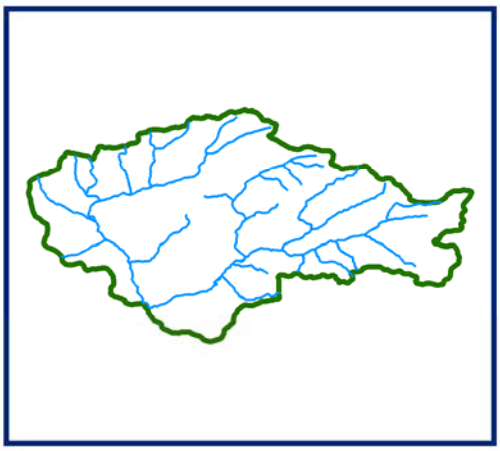


13 OCTOBER 2008



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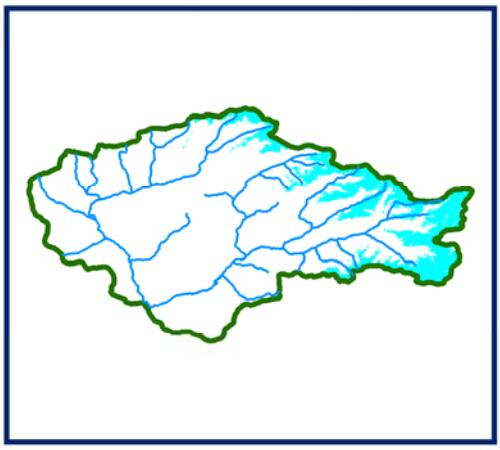
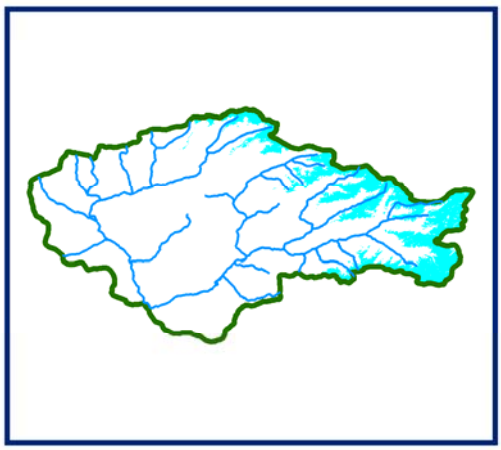


23 OCTOBER 2008



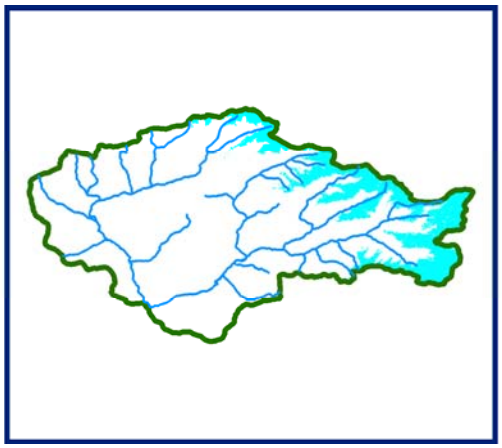
27 OCTOBER 2008

SNOW

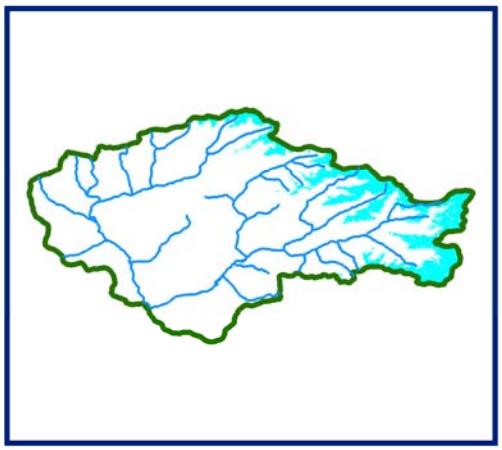
0 5 10 20 30 40

Kilometers

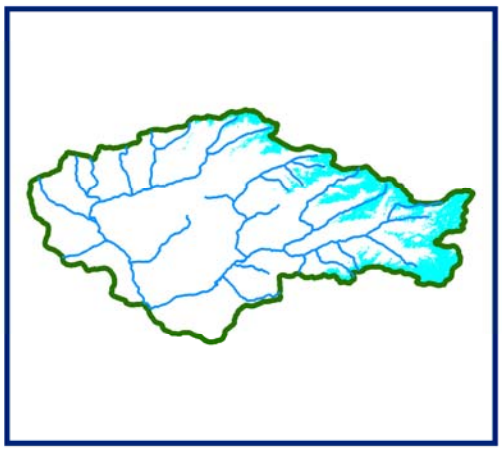
10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
04 OCTOBER 2008



DATA USED
13 OCTOBER 2008

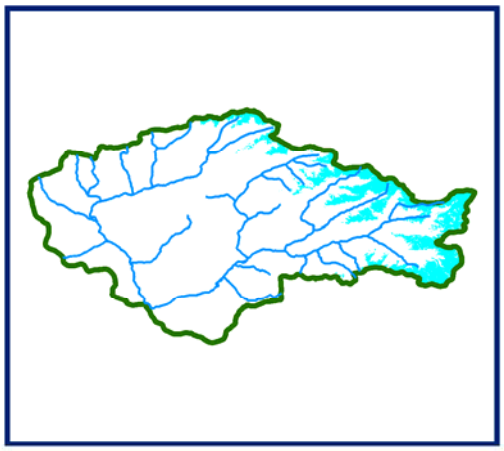


DATA USED
23 OCTOBER 2008
27 OCTOBER 2008

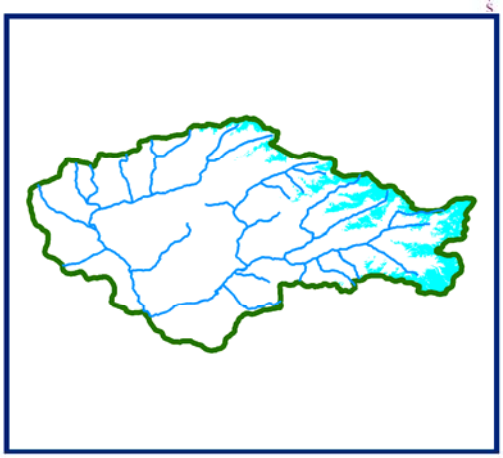
SNOW

0 35 70 140 210 280
Kilometers

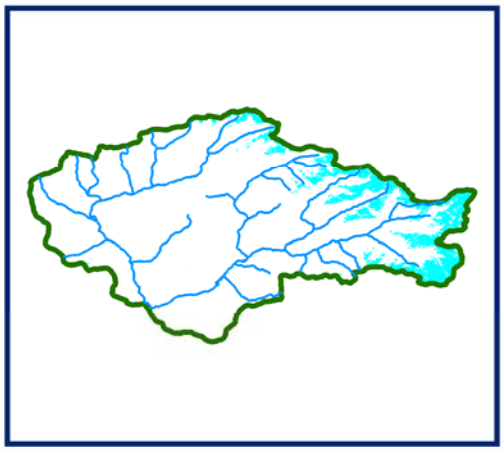
SNOW COVER MAP : YAMUNA BASIN



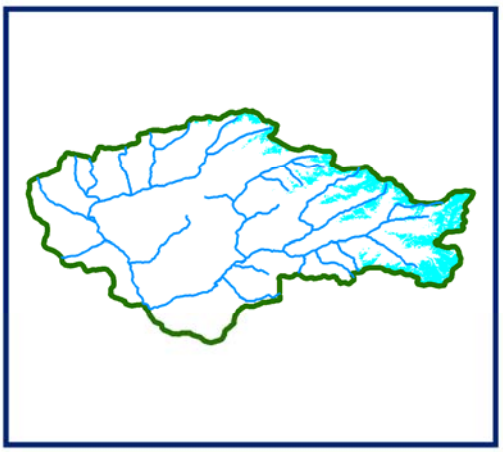
01 NOVEMBER 2008



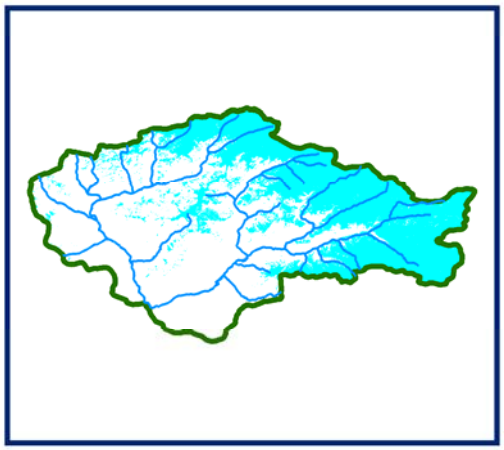
06 NOVEMBER 2008



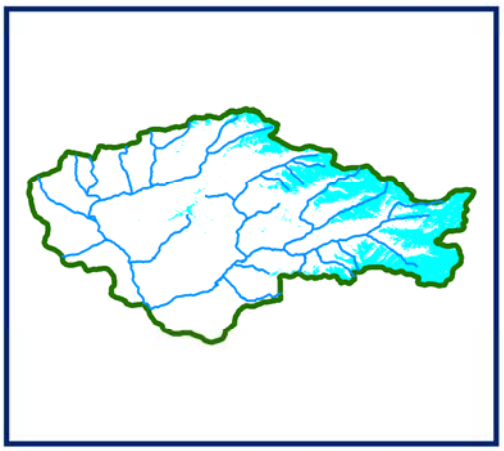
11 NOVEMBER 2008



16 NOVEMBER 2008



21 NOVEMBER 2008



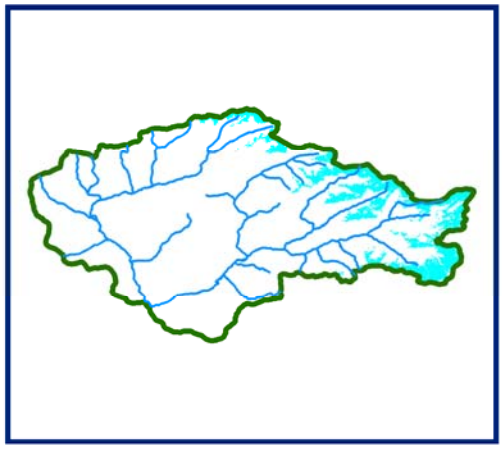
26 NOVEMBER 2008

SNOW

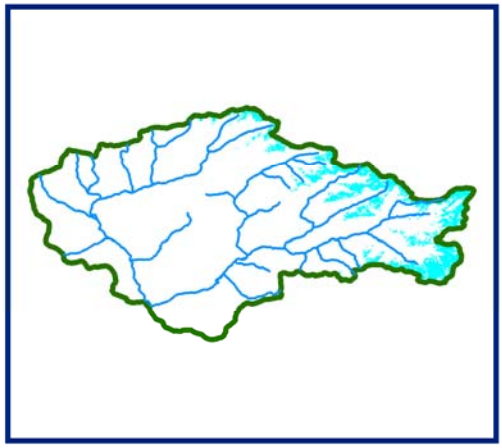
0 5 10 20 30 40

Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
01 NOVEMBER 2008
06 NOVEMBER 2008



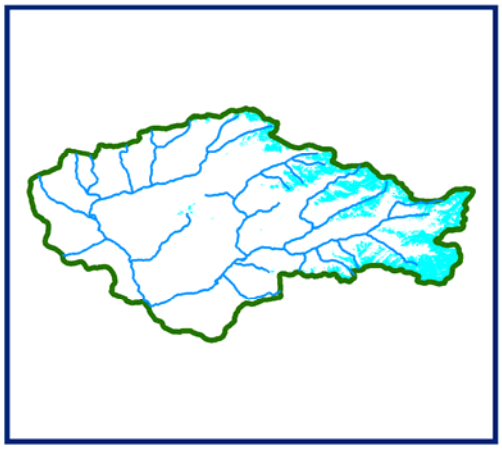
DATA USED
11 NOVEMBER 2008
16 NOVEMBER 2008

DATA USED
21 NOVEMBER 2008
26 NOVEMBER 2008

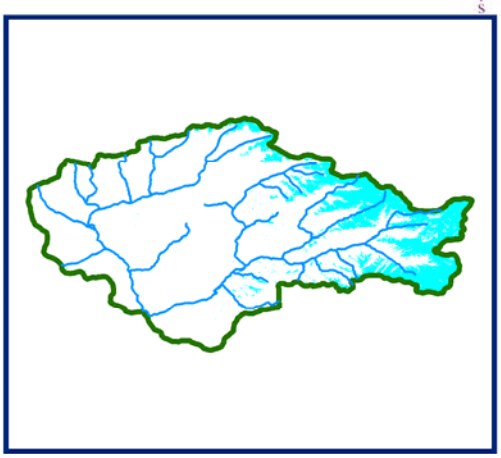
SNOW

0 142128
Kilometers

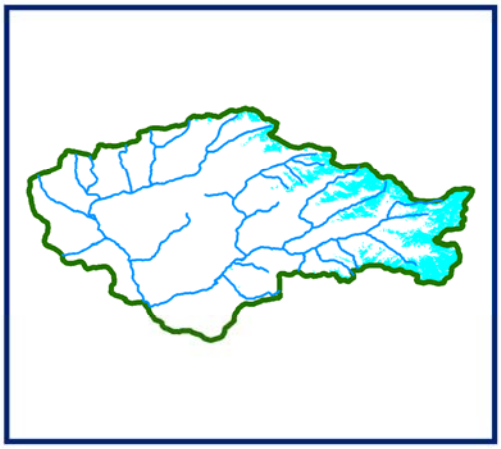
SNOW COVER MAP : YAMUNA BASIN



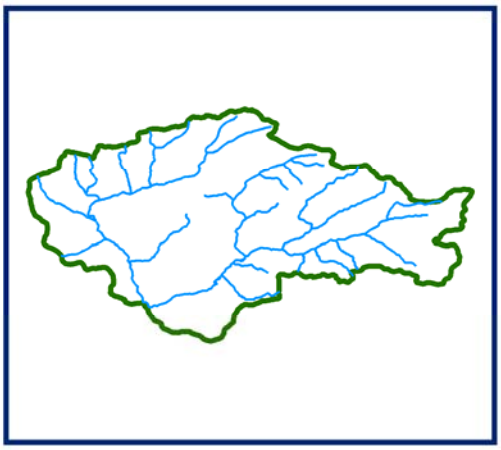
01 DECEMBER 2008



10 DECEMBER 2008



15 DECEMBER 2008



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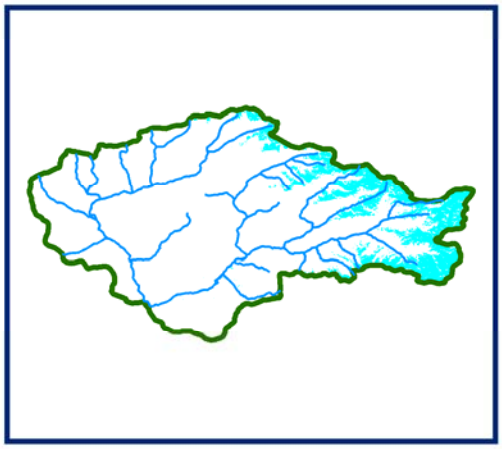
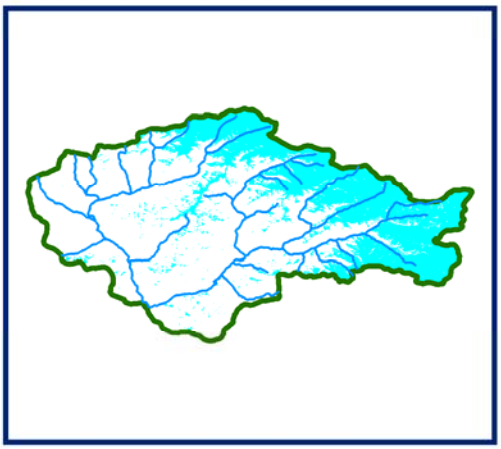


24 DECEMBER 2008



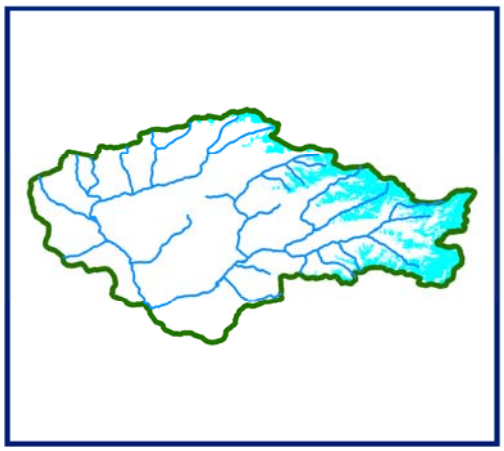
29 DECEMBER 2008

SNOW

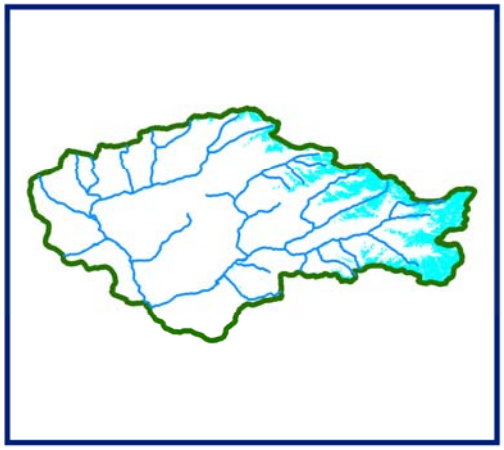
0 5 10 20 30 40

Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
01 DECEMBER 2008
10 DECEMBER 2008



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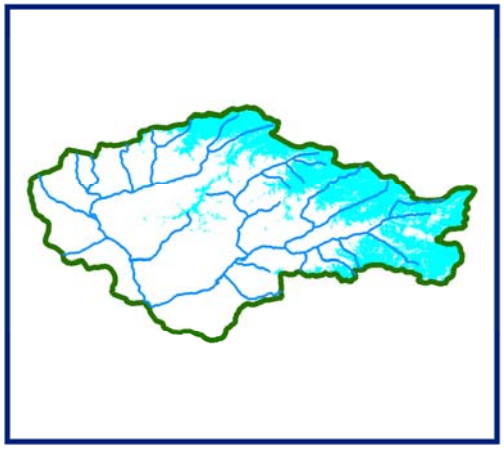
15 DECEMBER 2008

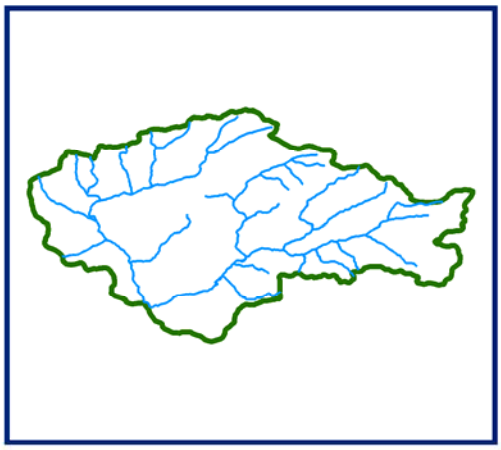


DATA USED
24 DECEMBER 2008
29 DECEMBER 2008

SNOW

0 71 142128
Kilometers

SNOW COVER MAP : YAMUNA BASIN



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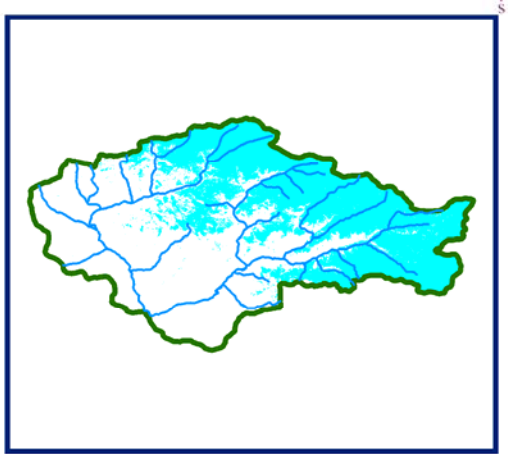
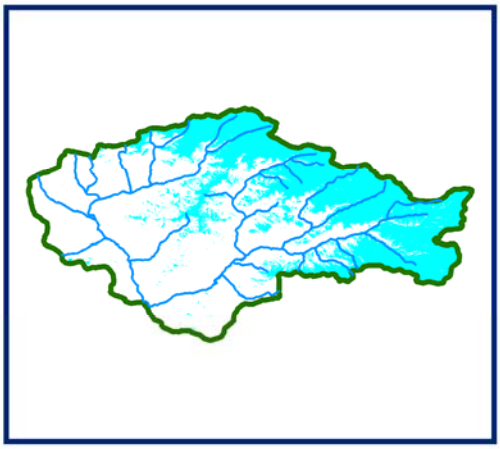
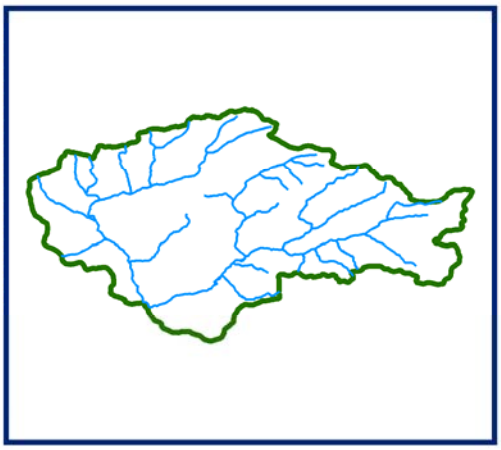


08 JANUARY 2009



12 JANUARY 2009



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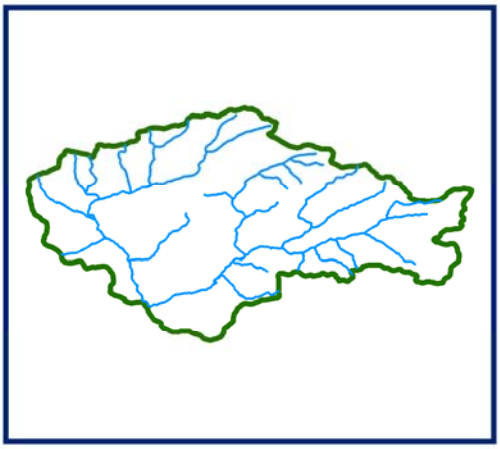

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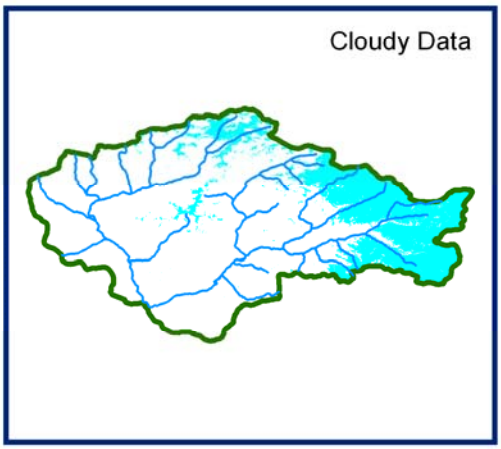


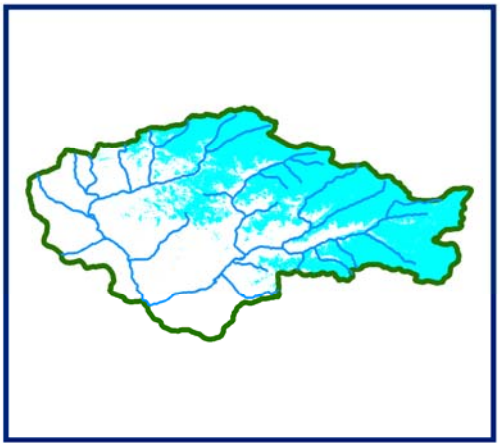
27 JANUARY 2009

SNOW

0 5 10 20 30 40

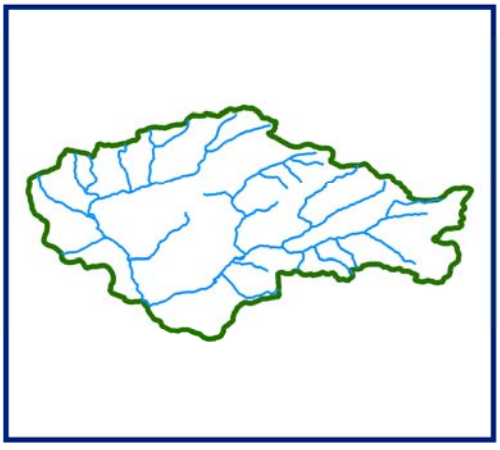
Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
08 JANUARY 2009

DATA USED
12 JANUARY 2009

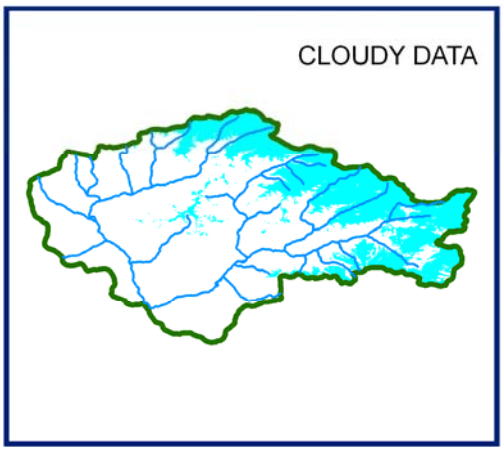


DATA USED
DATA NOT AVAILABLE

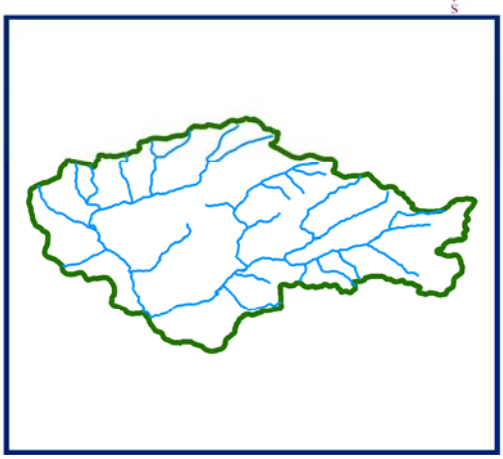
SNOW

0 3.5 7 14 21 28
Kilometers

SNOW COVER MAP : YAMUNA BASIN



01 FEBRUARY 2009



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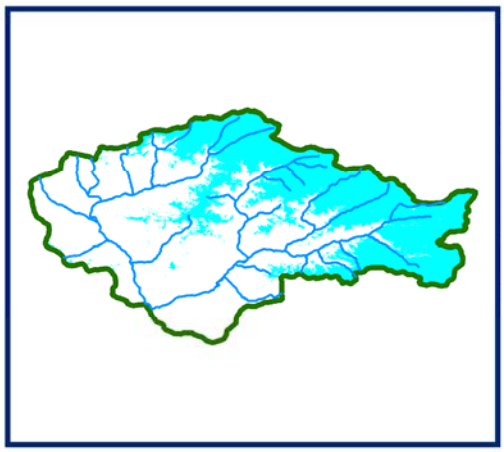

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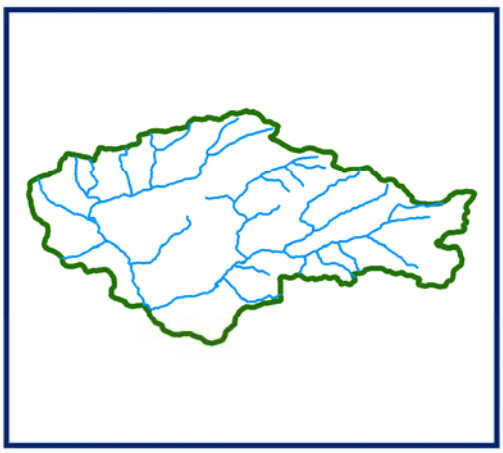

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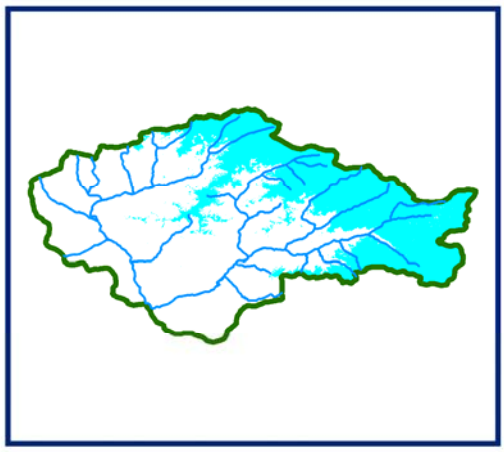
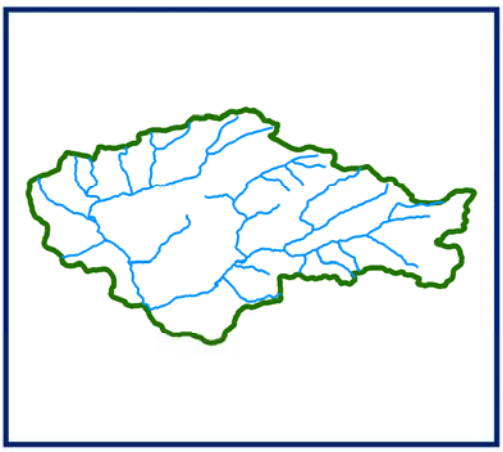


25 FEBRUARY 2009



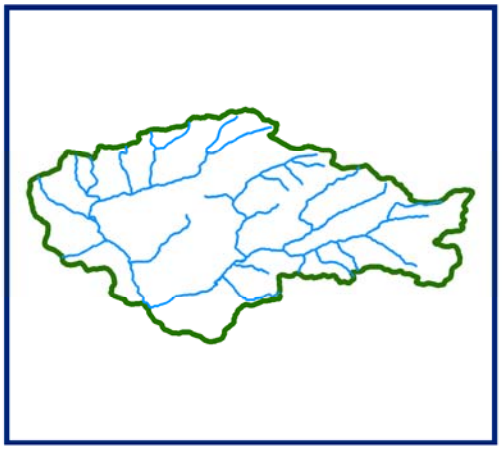
DATA NOT AVAILABLE

SNOW

0 5 10 20 30 40

Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN

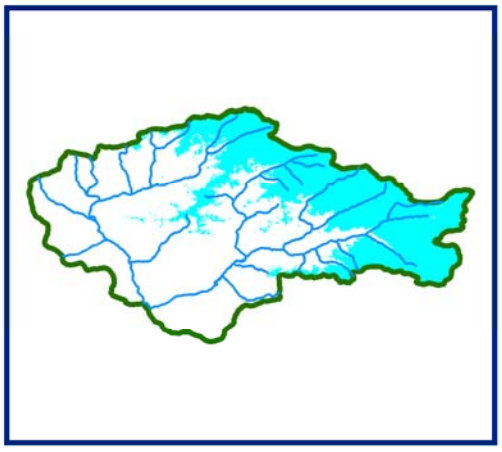


DATA USED

DATA NOT AVAILABLE

DATA USED

15 FEBRUARY 2009



DATA USED

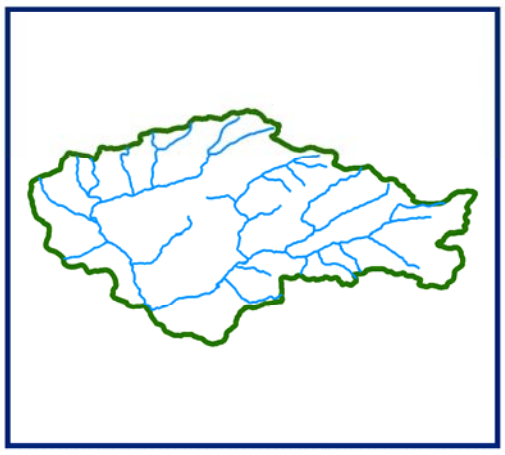
25 FEBRUARY 2009

SNOW

0 71 142128

Kilometers

SNOW COVER MAP : YAMUNA BASIN



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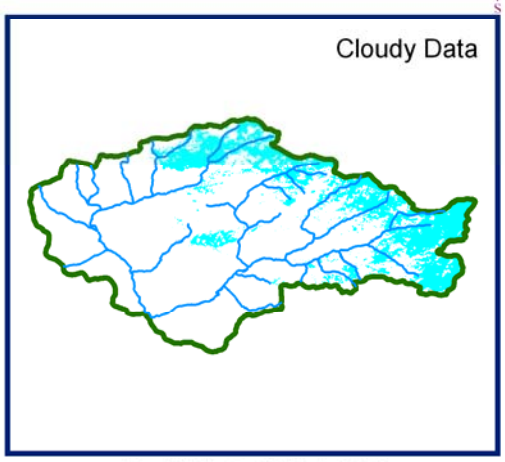
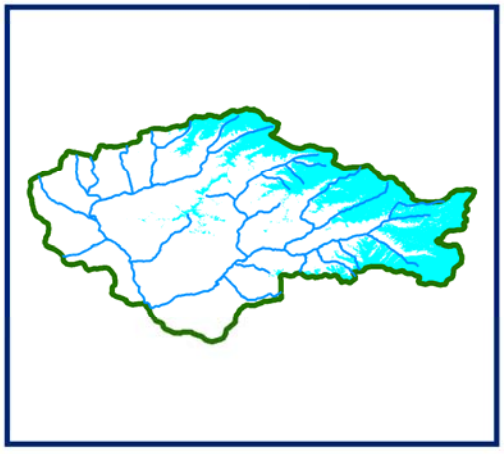
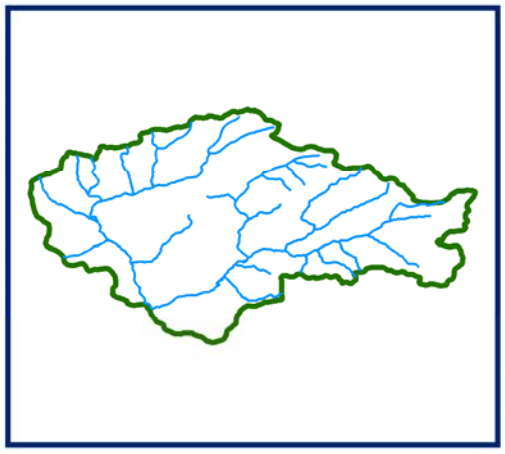


07 MARCH 2009



11 MARCH 2009



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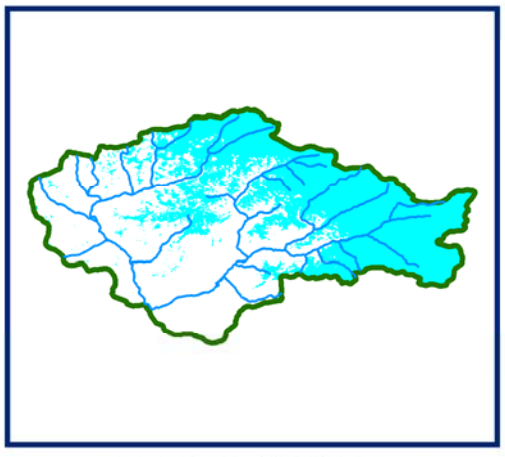
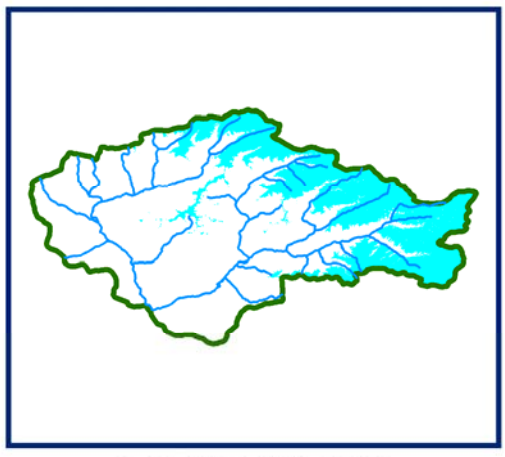


21 MARCH 2009



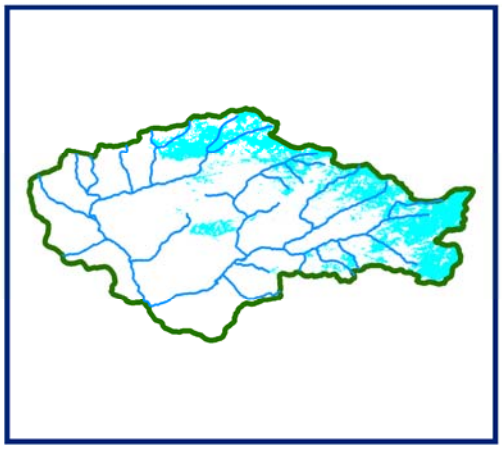
31 MARCH 2009

SNOW

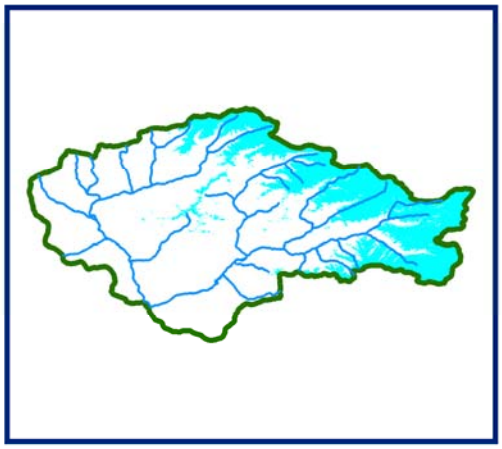
0 5 10 20 30 40

Kilometers

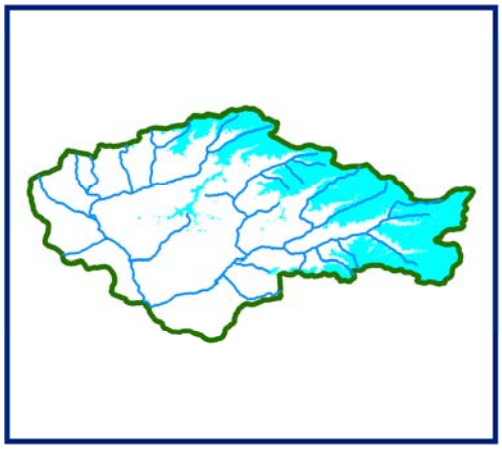
10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
07 MARCH 2009



DATA USED
11 MARCH 2009

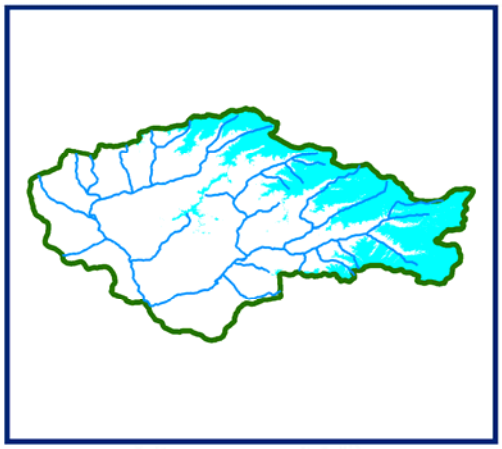


DATA USED
21 MARCH 2009
31 MARCH 2009

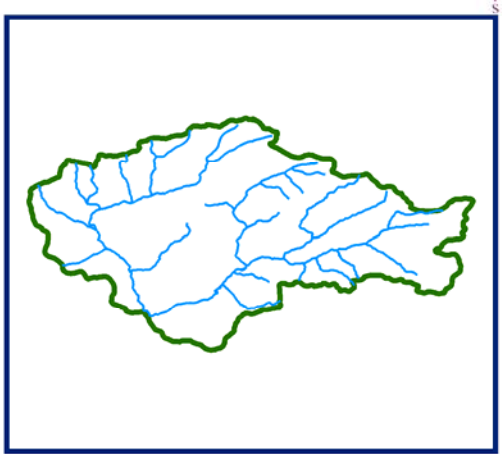
SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : YAMUNA BASIN



04 APRIL 2009



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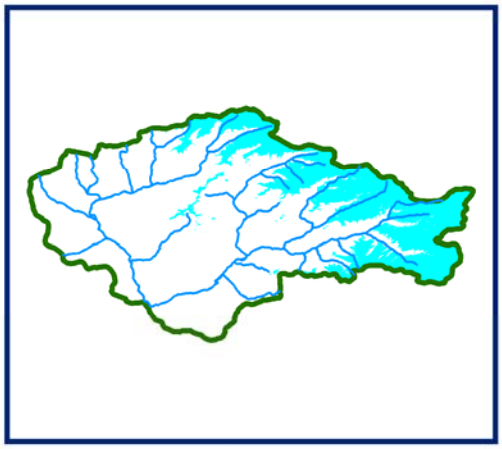
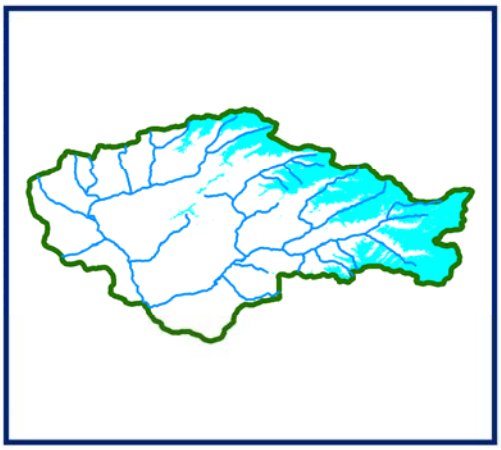
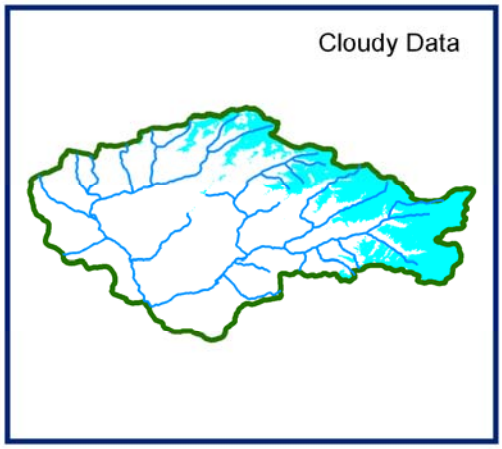


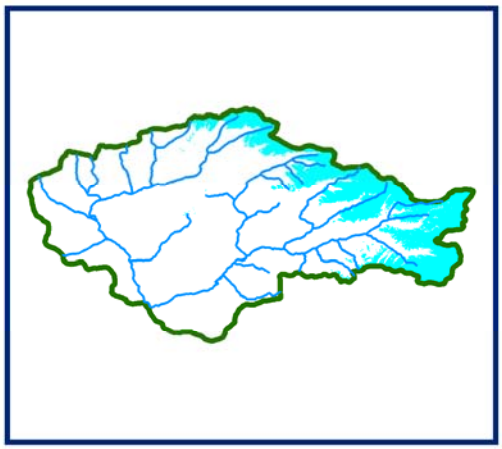
14 APRIL 2009



19 APRIL 2009



23 APRIL 2009



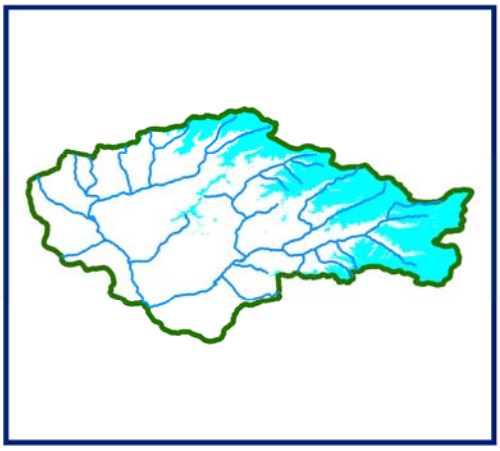
28 APRIL 2009

SNOW

0 5 10 20 30 40

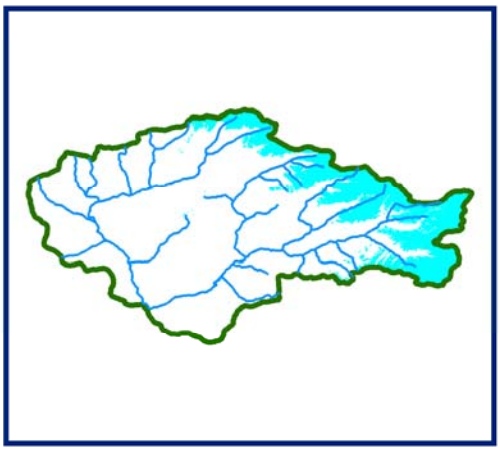
Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
04 APRIL 2009

DATA USED
14 APRIL 2009
19 APRIL 2009

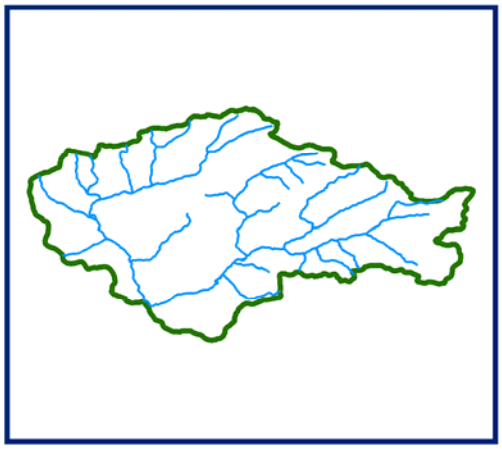


DATA USED
28 APRIL 2009

SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : YAMUNA BASIN



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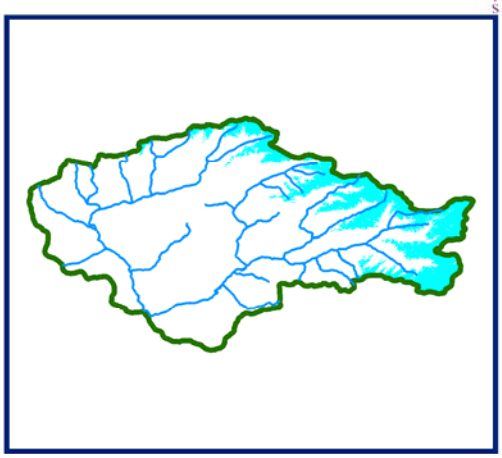
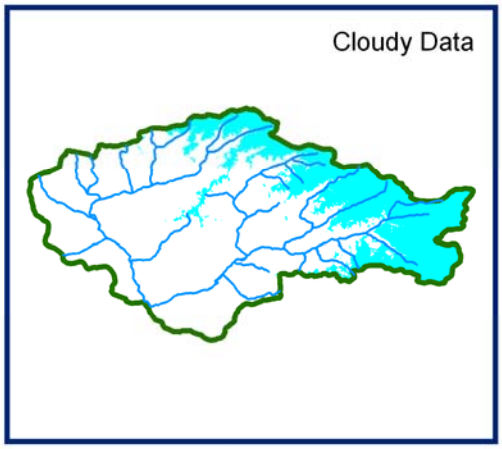
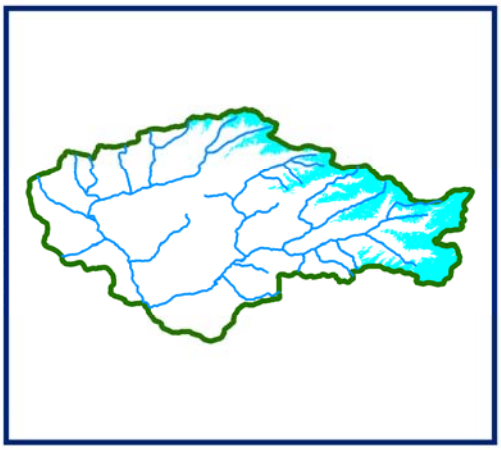


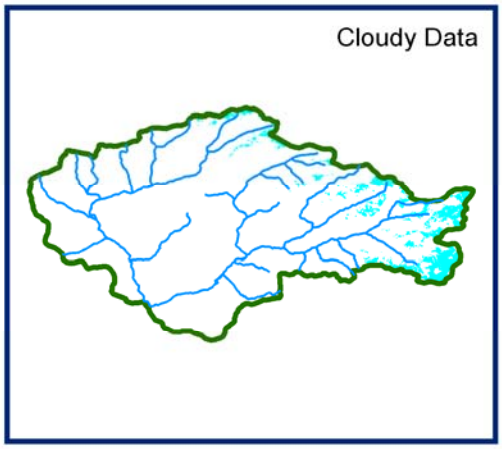
07 MAY 2009



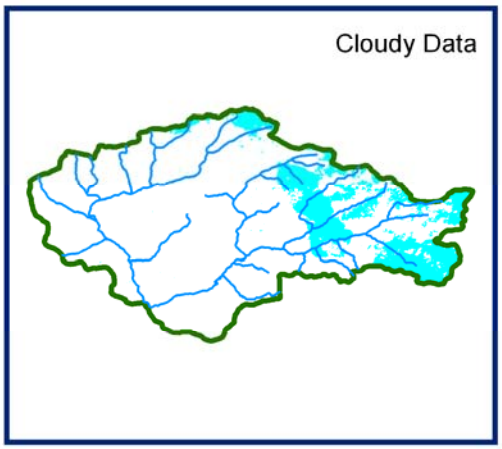
12 MAY 2009



18 MAY 2009



22 MAY 2009



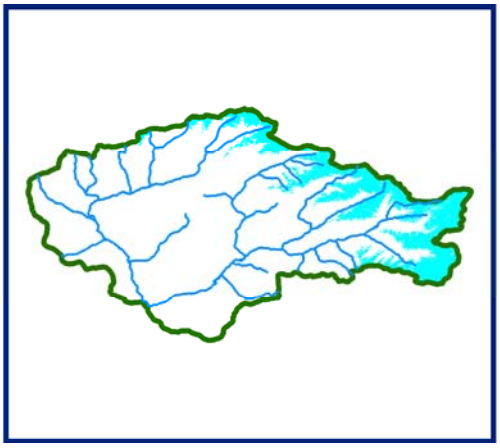
27 MAY 2009

SNOW

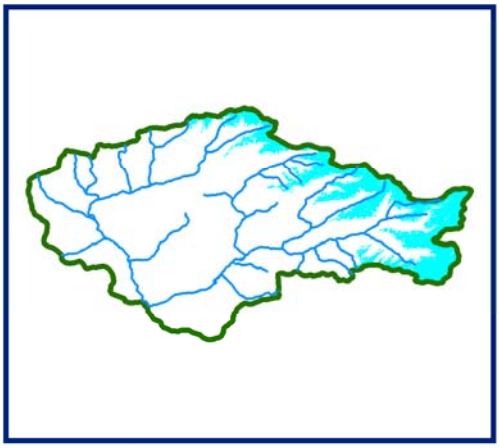
0 5 10 20 30 40

Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
07 MAY 2009



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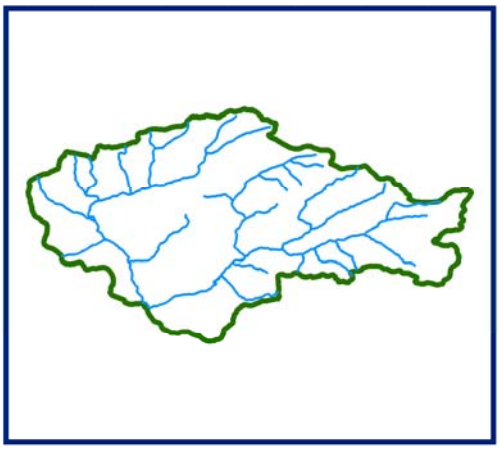
18 MAY 2009

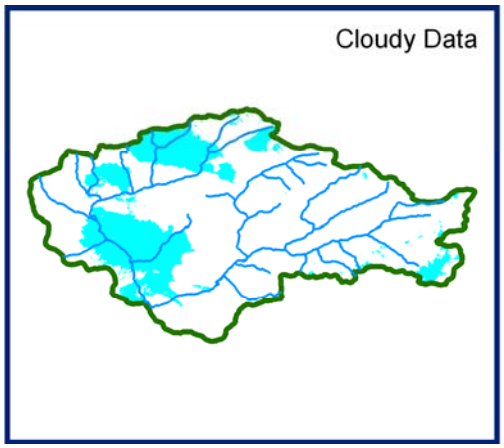


DATA USED
DATA NOT AVAILABLE

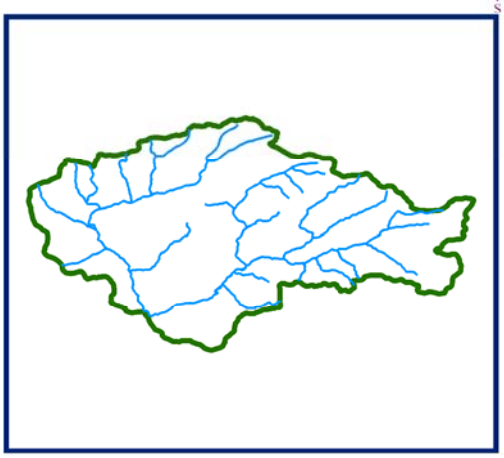
SNOW

0 35 70 140 210 280
Kilometers

SNOW COVER MAP : YAMUNA BASIN



01 JUNE 2009



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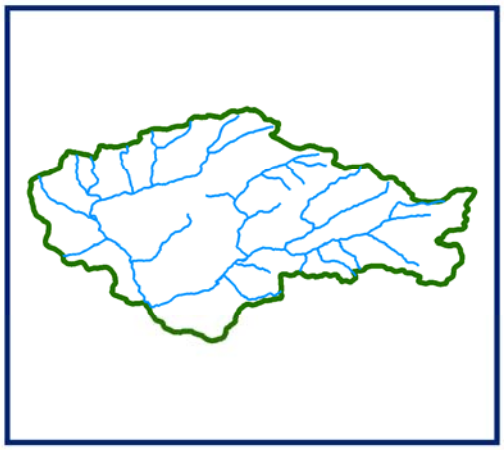

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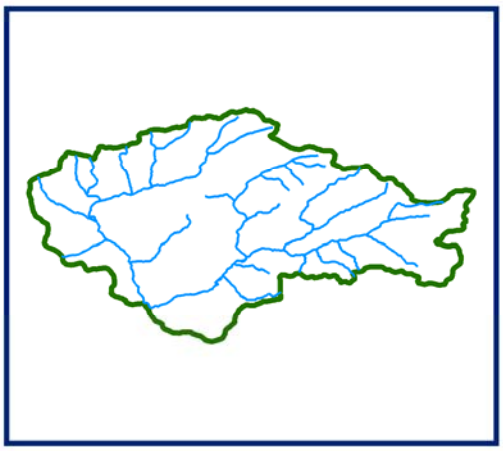

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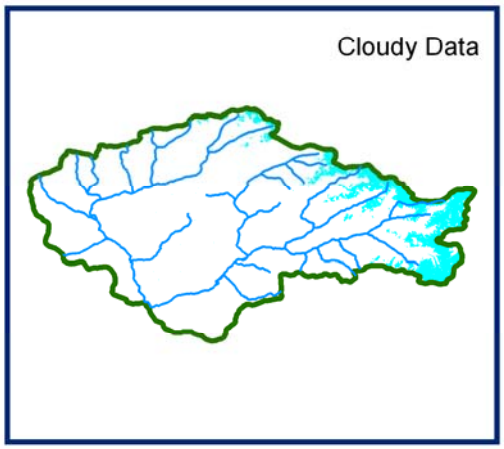

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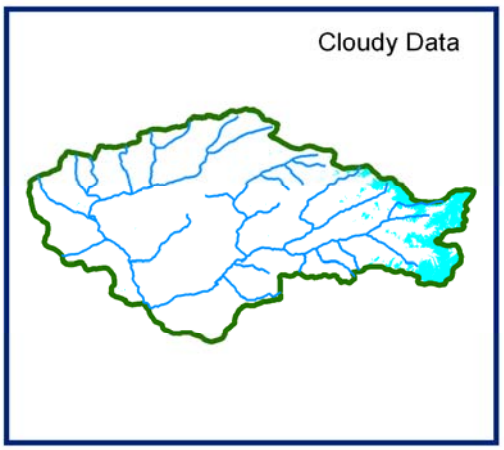
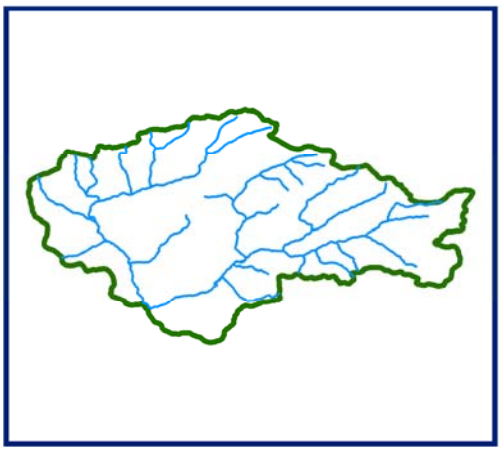


29 JUNE 2009

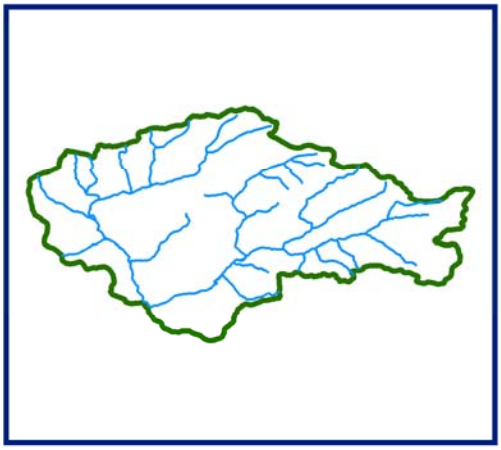
SNOW

0 5 10 20 30 40
Kilometers

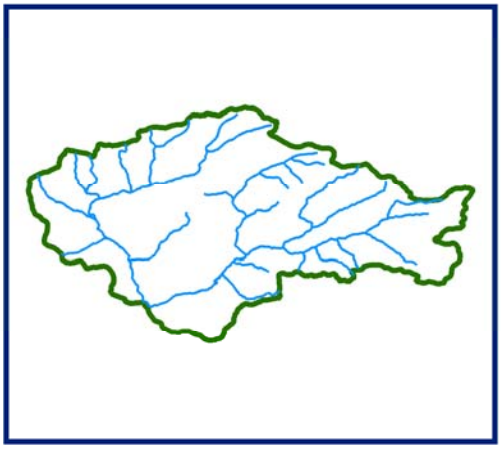
10 DAILY SNOW COVER MAP: YAMUNA BASIN



DATA USED
DATA NOT AVAILABLE



DATA USED
DATA NOT AVAILABLE



DATA USED
DATA NOT AVAILABLE

SNOW

0 35 70 140 210 280
Kilometers