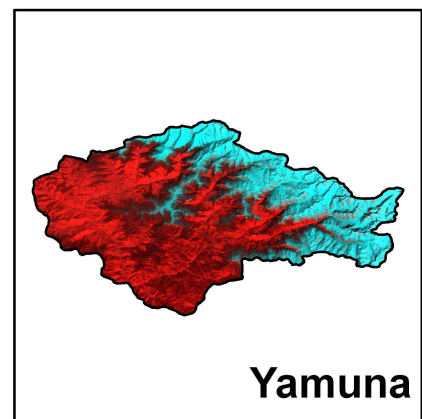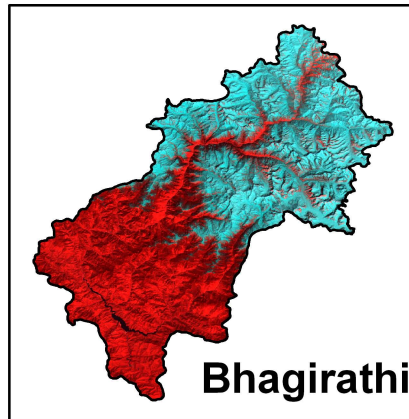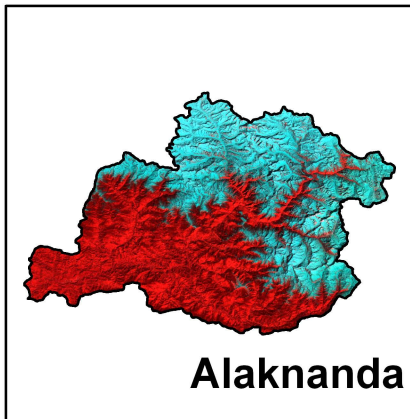# SNOW COVER ATLAS OF GANGA BASIN

Sub basins: Alaknanda, Bhagirathi and Yamuna

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

Year : 2010-11

Alaknanda

Bhagirathi

Yamuna

**Uttarakhand Space Application Centre
Dehradun - 248001**

&

**Space Applications Centre (ISRO)
Ahmedabad - 380015**

May 2012

SNOW COVER ATLAS OF THE GANGA BASIN

Sub-basins: Alaknanda, Bhagirathi and Yamuna

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

Year: 2010-11

**Uttarakhand Space application centre
Dehradun
and
Space Applications Centre (ISRO)
Ahmedabad-380015**

May 2012

SPACE APPLICATIONS CENTRE (ISRO), AHMEDABAD - 380015

DOCUMENT CONTROL AND DATA SHEET

Report Number	SAC/EPSA/MPSG/SGP/SN/ 68 /2012
Month and year of publication	May 2012
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	Team members
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 2010 to June 2011. 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

Authors

Space Applications centre (ISRO), Ahmedabad

B. P. Rathore

S. K. Singh

I. Bahuguna

A. S. Rajawat

Ajai

Uttarakhand Space Application Centre, Dehradun

Asha Thapliyal

Anju Panwar

M. M. Kimothi

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 2010 to June 2011 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:

$$Normalized\ Difference\ Snow\ Index(NDSI) = (band\,2 - band\,5)/(band\,2 + band\,5) \qquad ..(1)$$

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

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

5. Snow cover monitoring algorithm

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

6. Results and discussions

In this atlas, basin-wise snow cover statistics, maps, and seasonal depletion curves have been provided from October 2010 to June 2011. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. In the month of October to January there is not much snow fall was observed but in Bhagirathi snow fall was observed in the month of November and melting was observed in the month of December. January onward snow pattern was more or less same. Ablation starts from middle of April for the three basins.

Acknowledgements

References

Agarwal, K. G., Kumar, V. and T. Das, 1983, Melt runoff for a subcatchment of Beas basin. In Proceedings of the First National Symposium on Seasonal Snow Cover, New Delhi, India, April 28-30, 43 p.

Foster, J. L. and Chang, A. T. C., 1993, Snow cover, in Atlas of satellite observations related to global change. R. J. Gurney, C.L. Parkinson and J. L. Foster (eds.), Cambridge University Press, Cambridge, pp. 361-370.

Hall, D. K., Riggs, G. A. and Salomonson, V. V., 1995, Development of methods for mapping global snow cover using moderate resolution Image Spectroradiometer data. Remote Sensing of Environment, 54, pp. 127-140.

Kulkarni, A. V., Mathur, P., Rathore, B. P., Alex, S., Thakur N. and Kumar, M. 2002, Effect of global warming on snow ablation pattern in the Himalayas. Current Science, 83(2), pp 120-123.

Kulkarni A. V., Singh, S. K., Mathur, P. and Mishra, V. D., 2006, Algorithm to monitor snow cover using AWiFS data of RESOURCESAT for the Himalayan region. International Journal of Remote Sensing, 27(12), pp 2449-2457.

Kulkarni, A. V., Randhawa, S. S. and Sood, R. K., 1997, A stream flow simulation model in snow covered areas to estimate hydro-power   potential: a case study of Malana nala, H.P. Proc. of the First international Conference on Renewable Energy- Small Hydro, Hyderabad, pp 761-770.

Markham, B. L. and Barker, J. L., 1987, Thematic Mapper bandpass solar exoatmospheric irradiances. International Journal of Remote Sensing, 8(3), pp 517-523.

Singer, F. S. and Popham, R. W., 1963. Non-meteorological observations from satellite. Astronautics and Aerospace Engineering 1(3), 89-92.

Srinivasulu, J. and Kulkarni, A. V., 2004, A satellite based spectral reflectance model for snow and glacier studies in the Himalayan terrain. Proceedings of the Indian Academy of Science (Earth and Planetary Science), 113 (1), pp. 117-128.
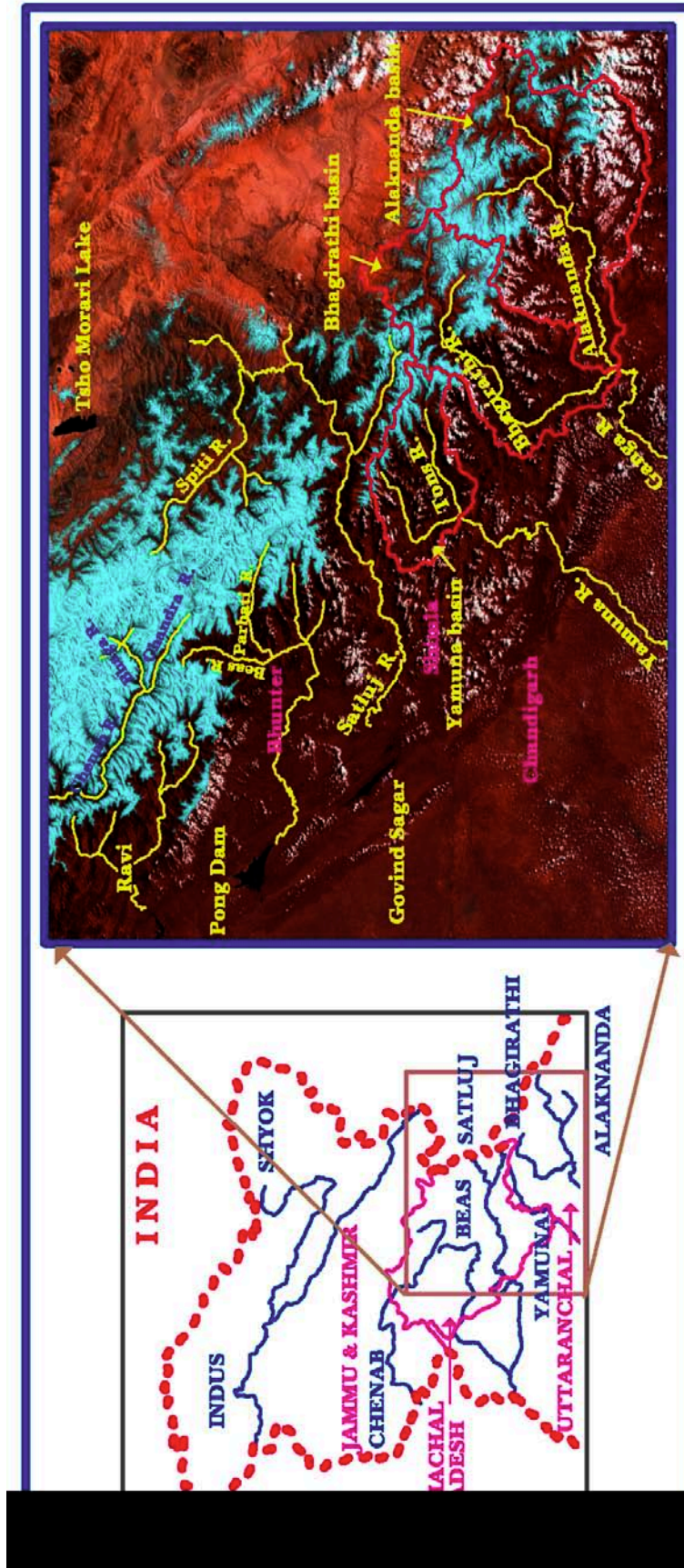
Figure 1: Location map of Alaknanda, Bhagirathi and Yamuna sub-basins (Part of Ganga basin)
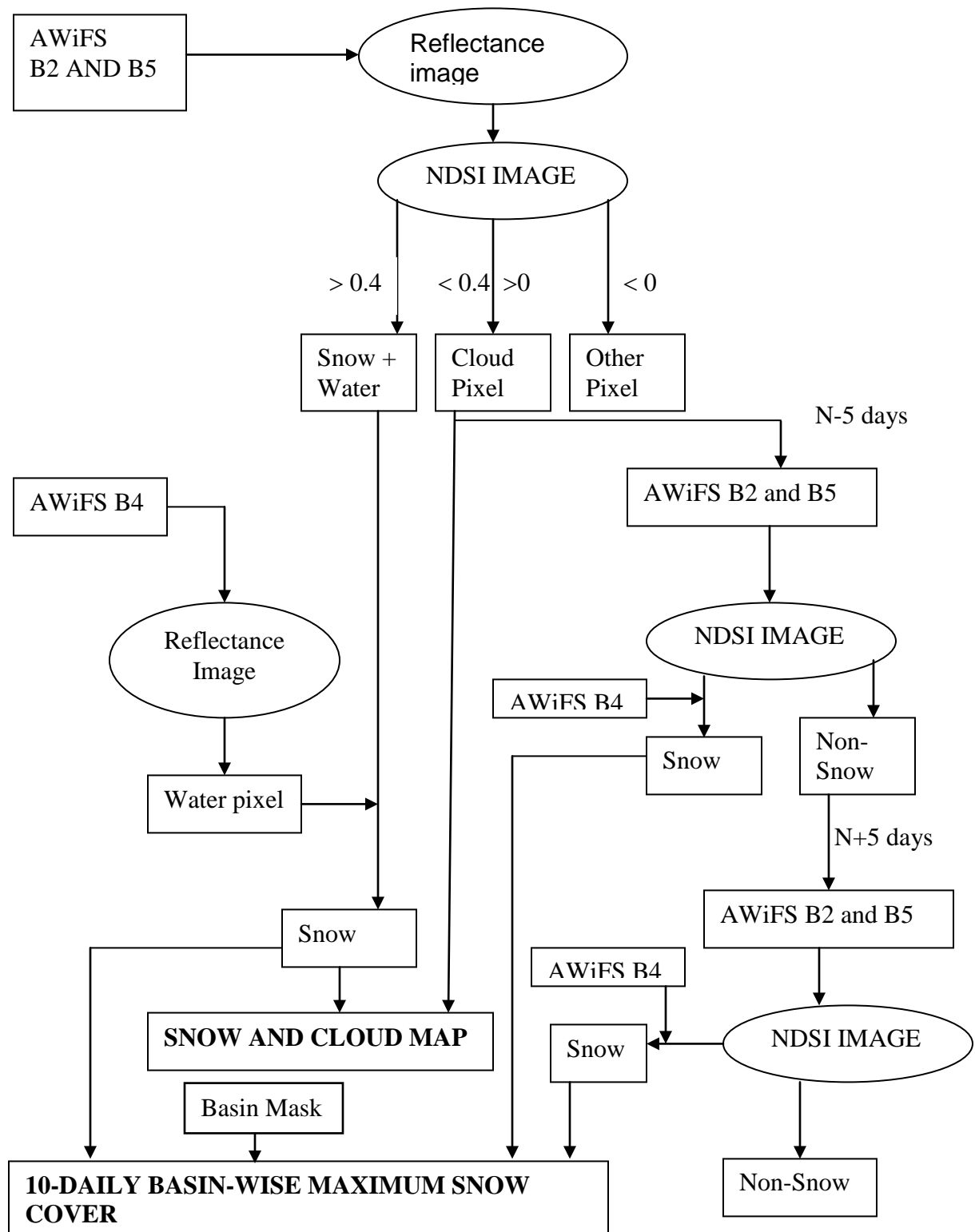
Figure 2: Algorithm for snow cover mapping using AWiFS data

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 2010							
1	03-Oct-2010	1707.98	15	5	18-Oct-2010	2328.08	21
2	04-Oct-2010	2791.05	25	6	23-Oct-2010	3913.91	35
3	08-Oct-2010	1736.29	16	7	27-Oct-2010	2066.96	19
4	09-Oct-2010	2459.01	22	8	28-Oct-2010	3432.31	31
November 2010							
10	02-Nov-2010	2847.55	26	13	20-Nov-2010	2187.46	20
11	06-Nov-2010	2665.08	24	14	21-Nov-2010	2899.19	26
12	11-Nov-2010	2304.33	21	15	26-Nov-2010	2389.86	22
13	16-Nov-2010	1576.04	14	16	30-Nov-2010	2257.08	20
December 2010							
17	05-Dec-2010	2115.36	19	21	19-Dec-2010	1869.16	17
18	10-Dec-2010	2071.69	19	22	19-Dec-2010	2596.08	23
19	14-Dec-2010	1234	11	23	24-Dec-2010	2235.95	20
20	15-Dec-2010	1929.43	17	24	29-Dec-2010	2839.79	26
January 2011							
25	03-Jan-11	2347.25	21	29	24-Jan-11	4619.53	42
26	12-Jan-11	4497.42	41	30	27-Jan-11	5062.34	46
27	17-Jan-11	5442.46	49	31	31-Jan-11	2816.58	44
28	22-Jan-11	5270.59	48				
February 2011							
32	1-Feb-11	4948.6	45	34	25-Feb-11	5610.32	51
33	05-Feb-11	3051.4	35				
March 2011							
35	16-Mar-2011	5531.08	50	37	30-Mar-2011	5021.44	45
36	26-Mar-2011	5170.03	47				
April 2011							
38	09-Apr-2011	4718.19	43	40	23- Apr - 2011	4972.13	45
39	18- Apr -2011	4841.21	44	41	28-Apr-2011	4665.59	42
May 2011							
42	03-May-2011	4158.71	37	44	17-May-2011	3503.01	32
43	12-May-2011	3950.85	36	45	22-May-2011	4151.82	37

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 2010
1	04-Oct-10	2802.30	25	3	28-Oct-10	3155.88	28
2	18-Oct-10	2519.88	23				
November 2010
4	02-Nov-10	3159.84	28	6	26-Nov-10	2747.70	25
5	16-Nov-10	2752.68	25				
December 2010
12	05-Dec-10	2940.49	27	14	24-Dec-10	2973.85	27
13	19-Dec-10	3238.23	29				
January 2011
16	03-Jan-11	2807.32	25	18	31-Jan-11	5527.57	50
17	17-Jan-11	5865.30	53				
February 2011
22	01-Feb-11	5171.93	47				
March 2011
23	16-March-11	5610.01	51				
April 2011
25	09-April-11	4852.20	44	27	23-April-11	4974.49	45
26	18-April-11	4842.00	44				
May 2011
31	03-May-11	4414.26	40	32	17-May-11	3762.16	34

Snow cover depletion curve

Alaknanda Basin(5 Daily): With Cloudy Data

Alaknanda Basin(5 Daily): Without Cloudy Data

Snow cover depletion curve
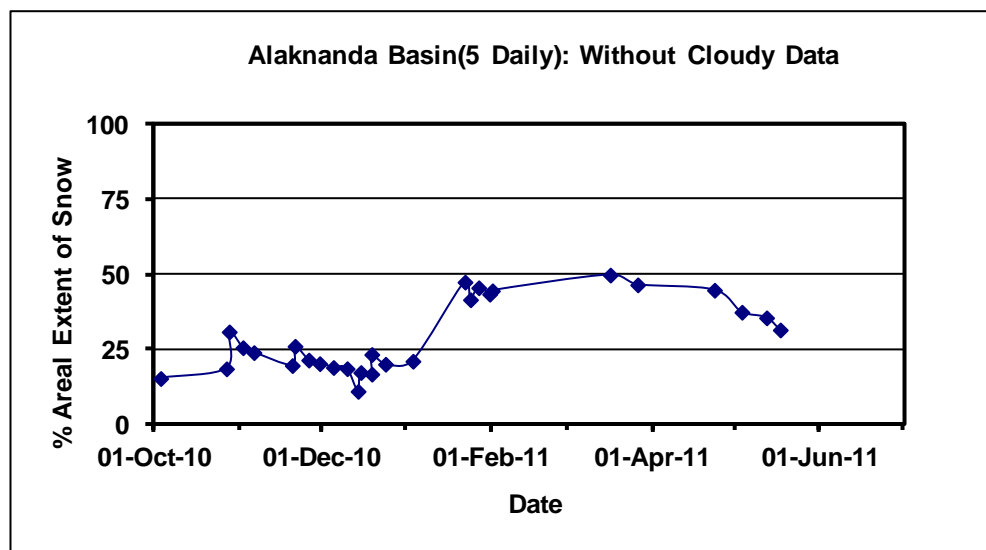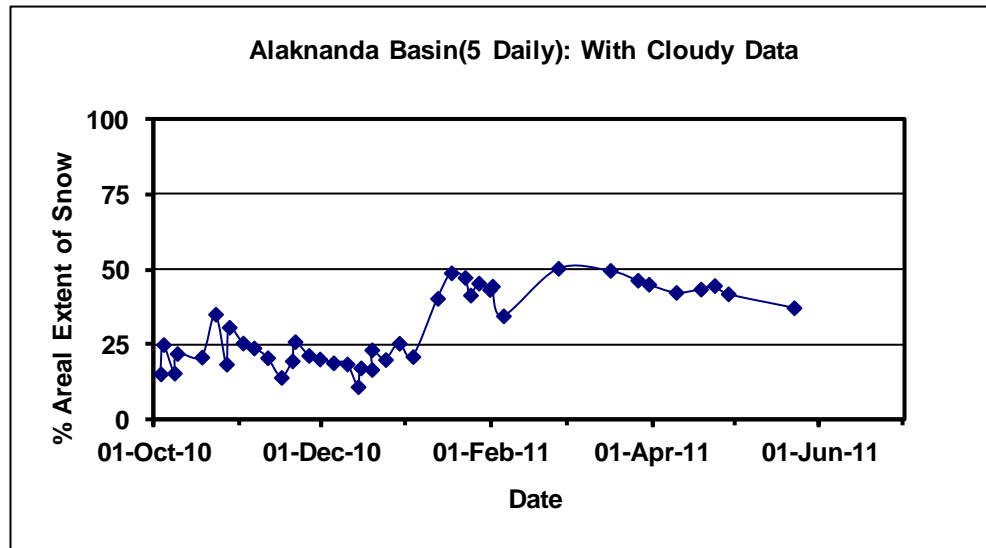
Alaknanda Basin (10 Daily)
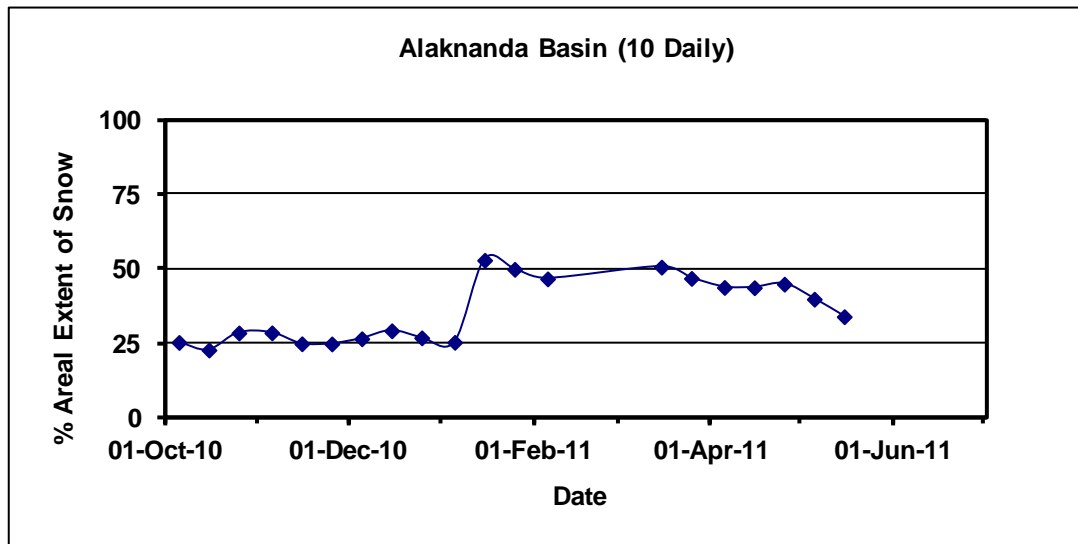
SNOW COVER MAP

SNOW COVER MAP : ALAKNANDA BASIN

CLOUDY DATA

04 OCTOBER 2011

CLOUDY DATA
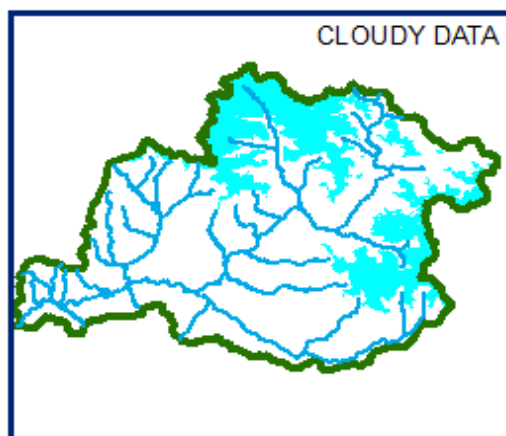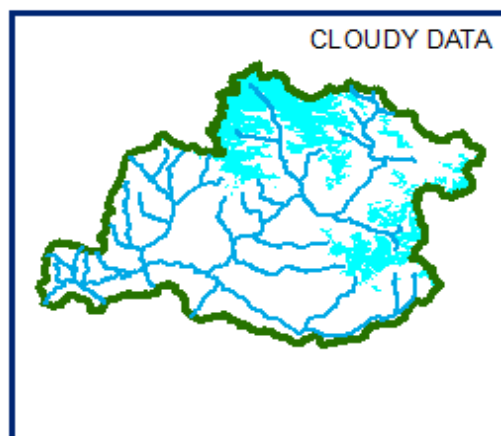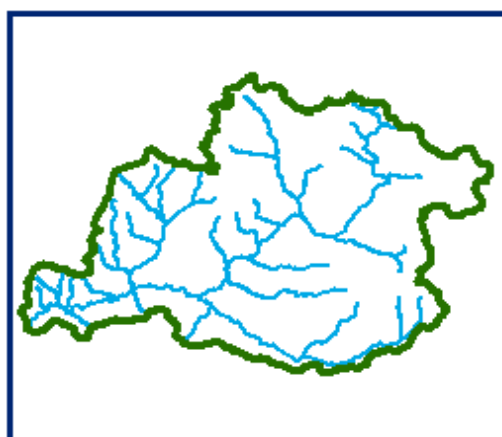
09 OCTOBER 2011

DATA NOT AVAILABLE

18 OCTOBER 2011

CLOUDY DATA
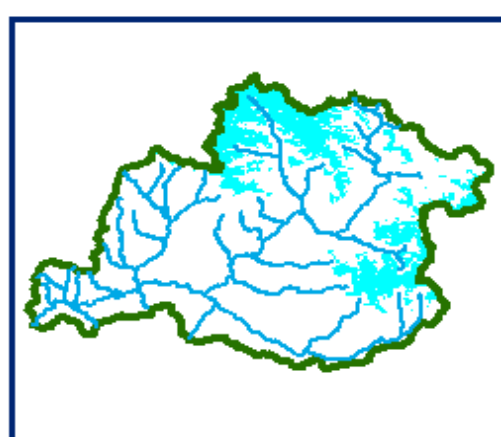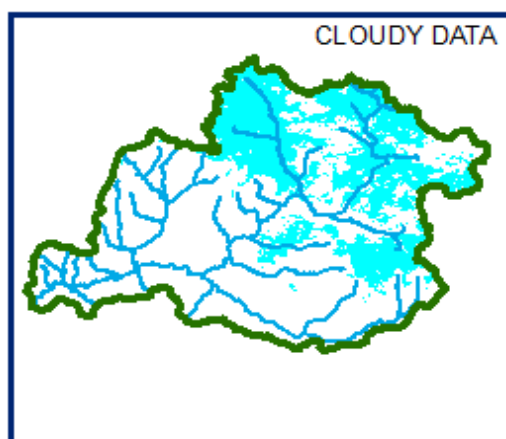
23 OCTOBER 2011

28 OCTOBER 2011

SNOW

0 20 40 80 120 160
Kilometers

12
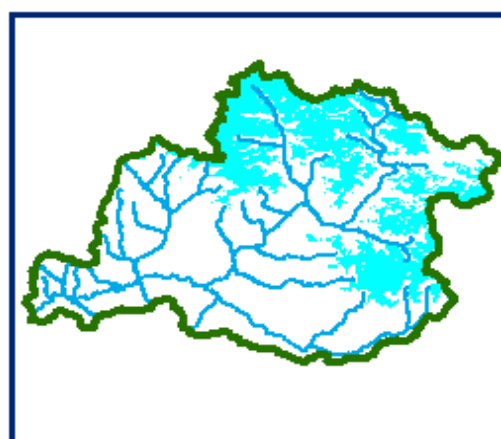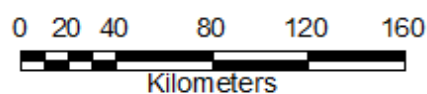
10 DAILY SNOW COVER MAP: ALAKNANDA BASIN
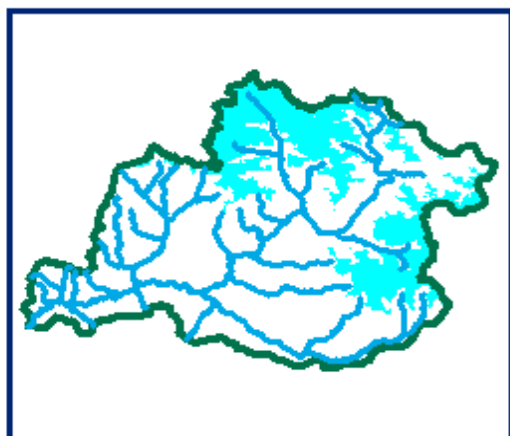
DATA USED
03 OCTOBER 2010
04 OCTOBER 2010
08 OCTOBER 2010
09 OCTOBER 2010
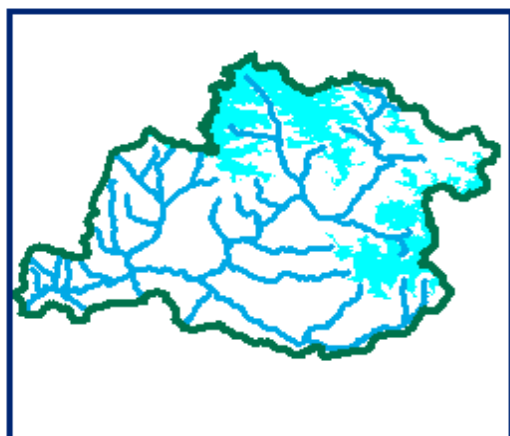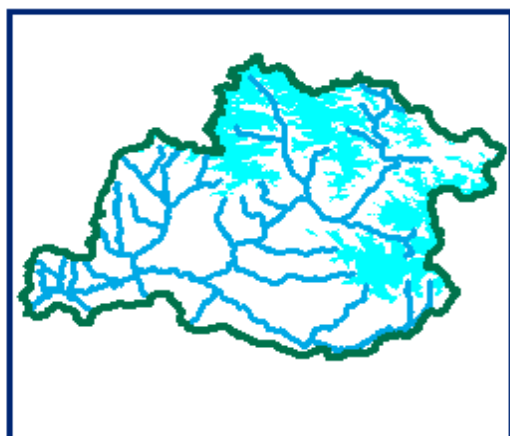
DATA USED
18 OCTOBER 2010

DATA USED
23 OCTOBER 2010
27 OCTOBER 2010
28 OCTOBER 2010

SNOW

0 20 40   80   120   160
Kilometers
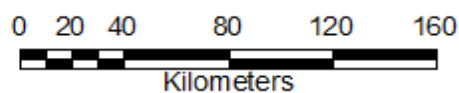
SNOW COVER MAP : ALAKNANDA BASIN
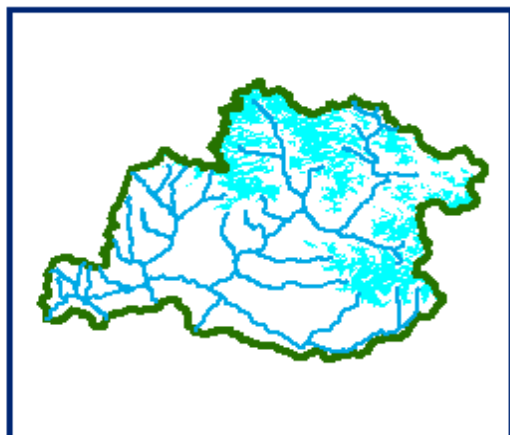
02 NOVEMBER 2011

06 NOVEMBER 2011

CLOUDY DATA

CLOUDY DATA
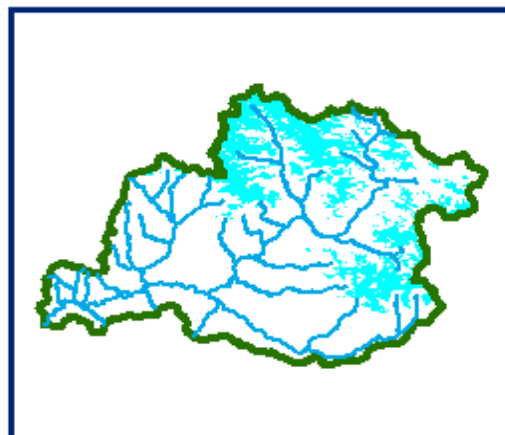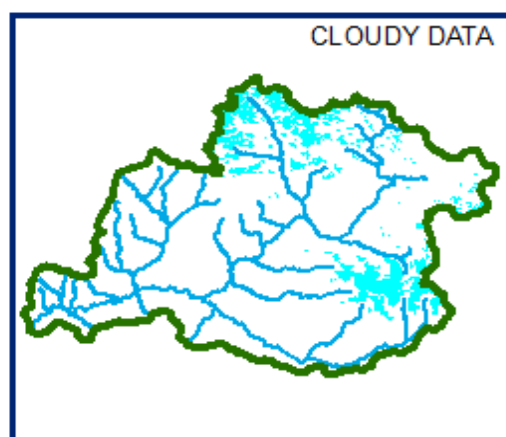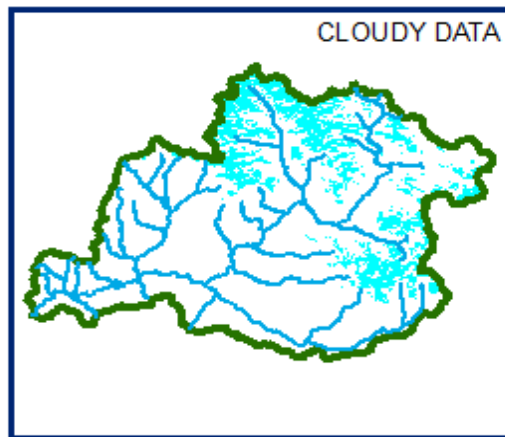
11 NOVEMBER 2011

16 NOVEMBER 2011
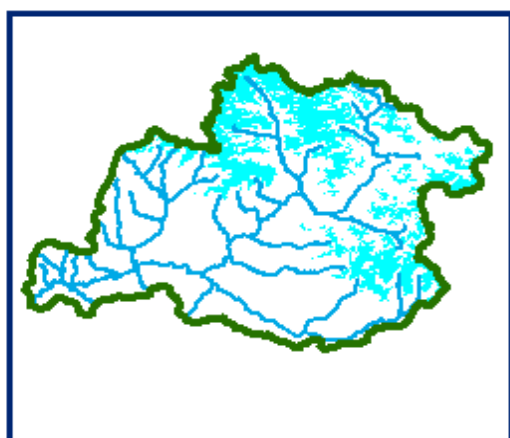
21 NOVEMBER 2011

30 NOVEMBER 2011

SNOW

0 20 40 80 120 160
Kilometers

14
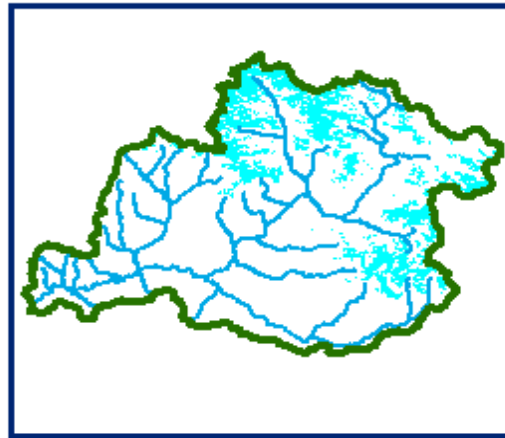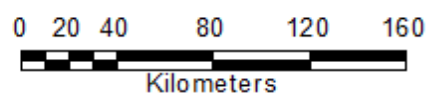
10 DAILY SNOW COVER MAP: ALAKNANDA BASIN
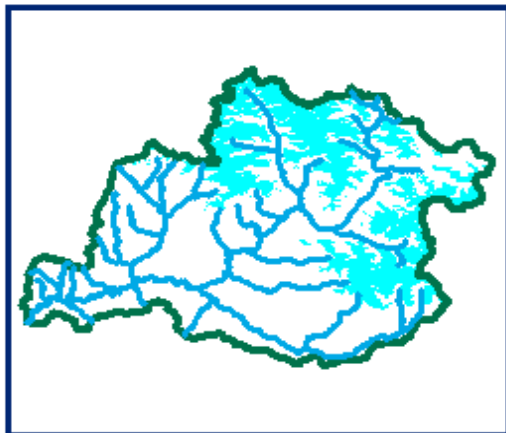
DATA USED

02 NOVEMBER 2010
06 NOVEMBER 2010
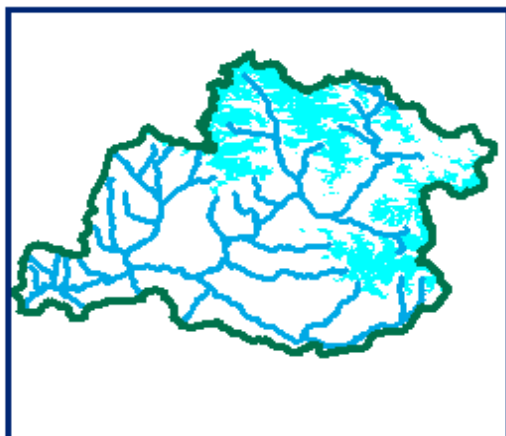
DATA USED

11 NOVEMBER 2010
16 NOVEMBER 2010
20 NOVEMBER 2010
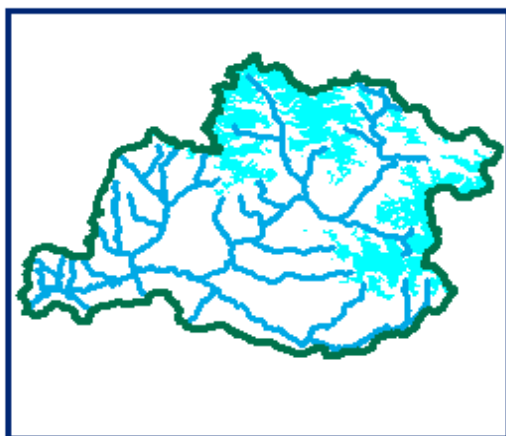
DATA USED

21 NOVEMBER 2010
26 NOVEMBER 2010
30 NOVEMBER 2010

SNOW

0 20 40   80   120   160

Kilometers
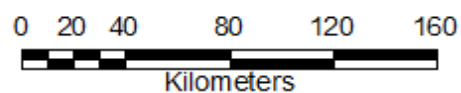
SNOW COVER MAP   :   ALAKNANDA BASIN
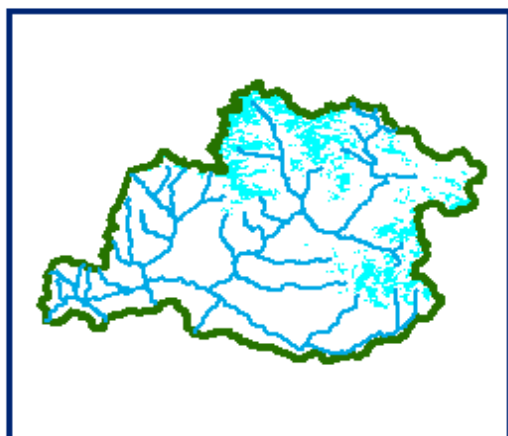
05 DECEMBER 2011
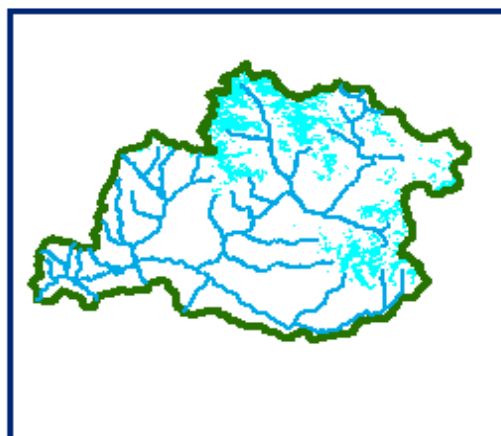
10 DECEMBER 2011
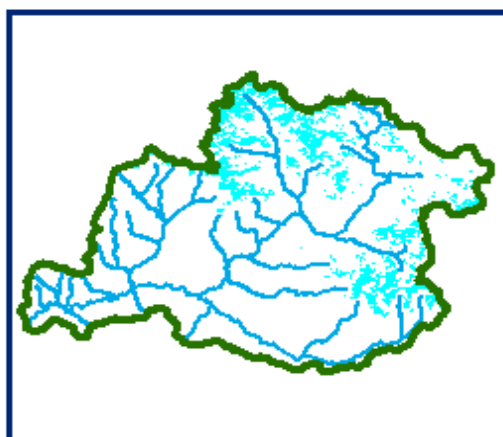
15 DECEMBER 2011

19 DECEMBER 2011

CLOUDY DATA
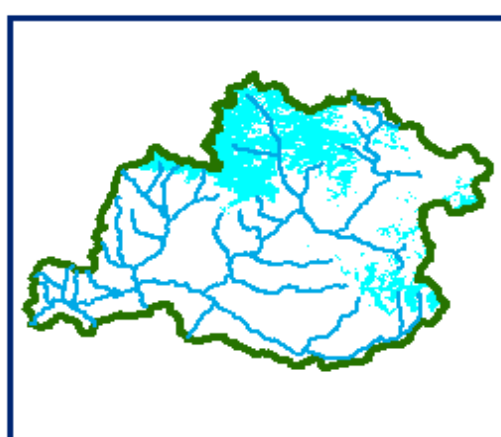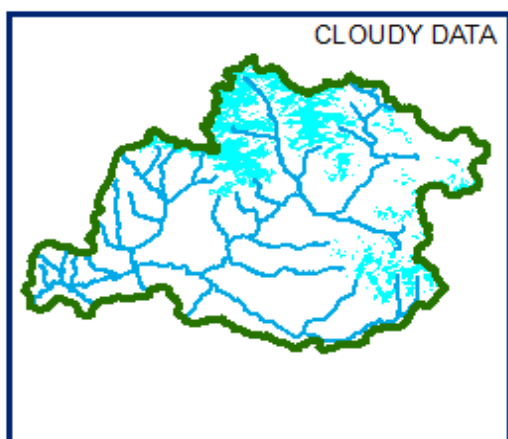
24 DECEMBER 2011

29 DECEMBER 2011

SNOW
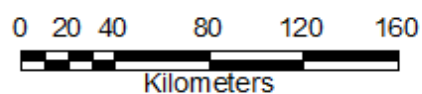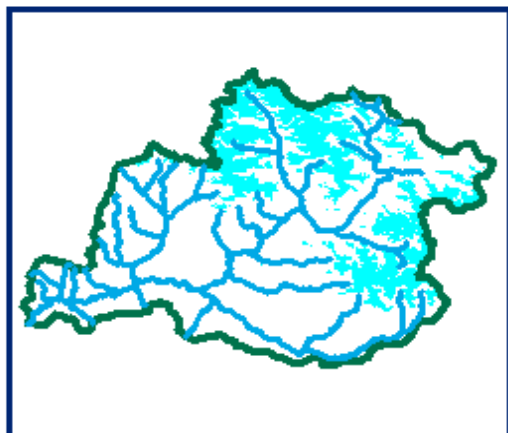
0 20 40   80   120   160

Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN

DATA USED
05 DECEMBER 2010
10 DECEMBER 2010

DATA USED

14 DECEMBER 2010
15 DECEMBER 2010
19 DECEMBER 2010

DATA USED
24 DECEMBER 2010
29 DECEMBER 2010

0   20   40   80   120   160

SNOW   Kilometers
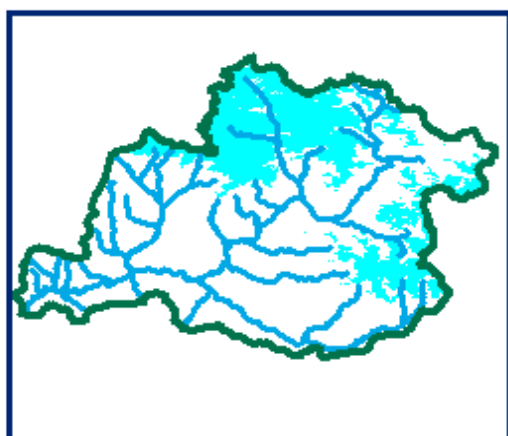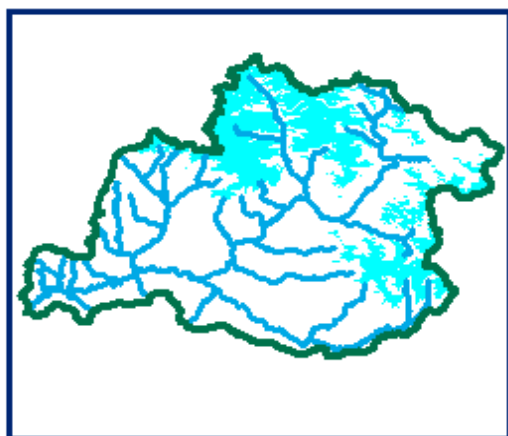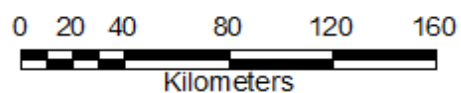
SNOW COVER MAP : ALAKNANDA BASIN

03 JANUARY 2011

DATA NOT AVAILABLE

CLOUDY DATA

12 JANUARY 2011

CLOUDY DATA

17 JANUARY 2011

CLOUDY DATA

24 JANUARY 2011

31 JANUARY 2011

SNOW

0 20 40 80 120 160
Kilometers

18

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN
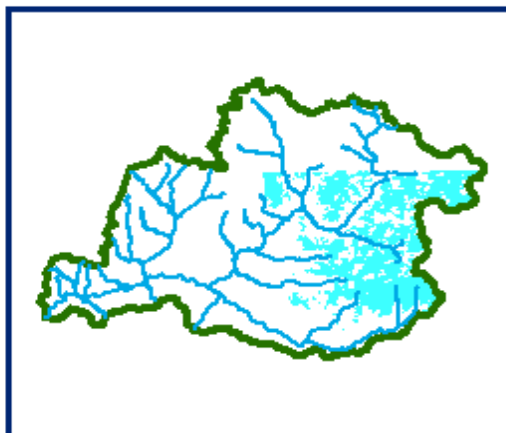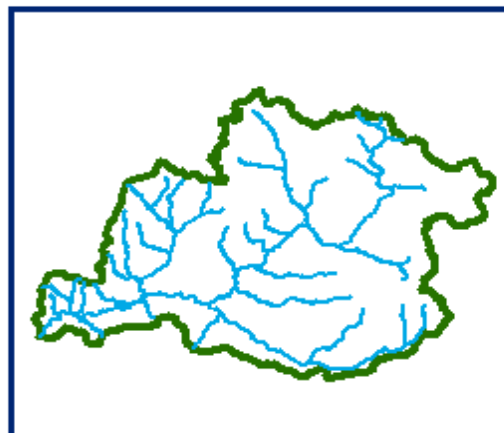
DATA USED

03 JANUARY 2011
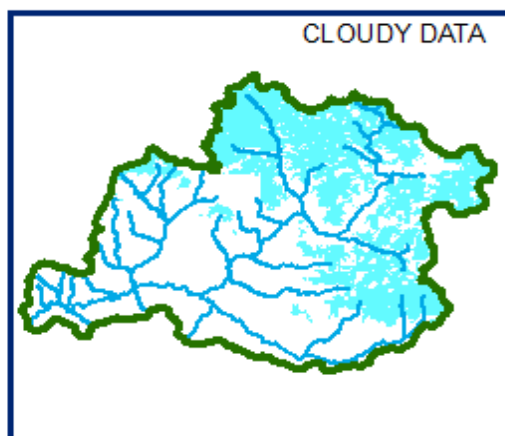
DATA USED

12 JANUARY 2011

17 JANUARY 2011
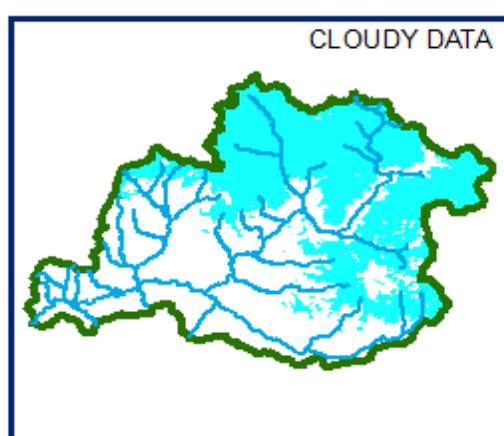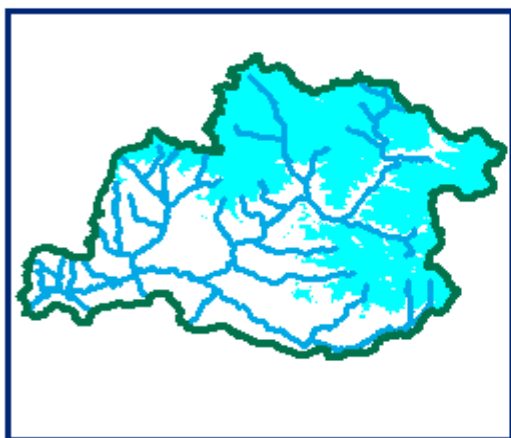
DATA USED

22 JANUARY 2011

24 JANUARY 2011

27 JANUARY 2011
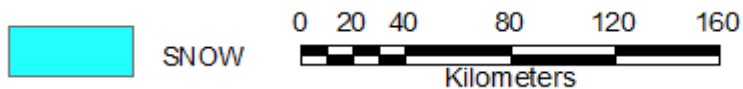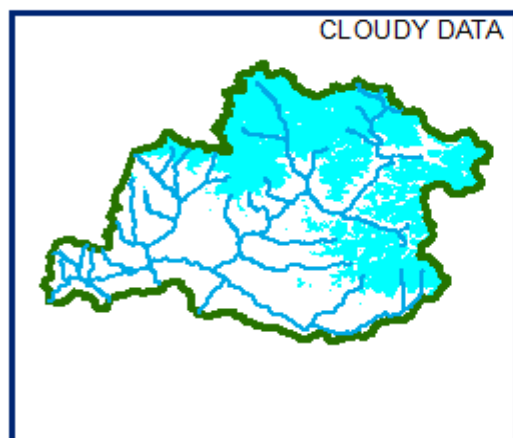
31 JANUARY 2011

SNOW

0   20   40   80   120   160

Kilometers

SNOW COVER MAP : ALAKNANDA BASIN

CLOUDY DATA

01 FEBRUARY 2011

CLOUDY DATA

05 FEBRUARY 2011

DATA NOT AVAILABLE

DATA NOT AVAILABLE

DATA NOT AVAILABLE

CLOUDY DATA
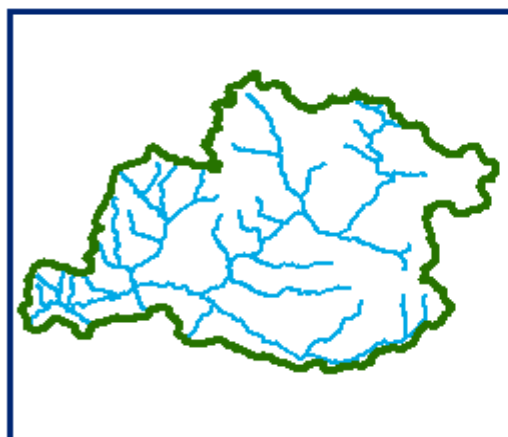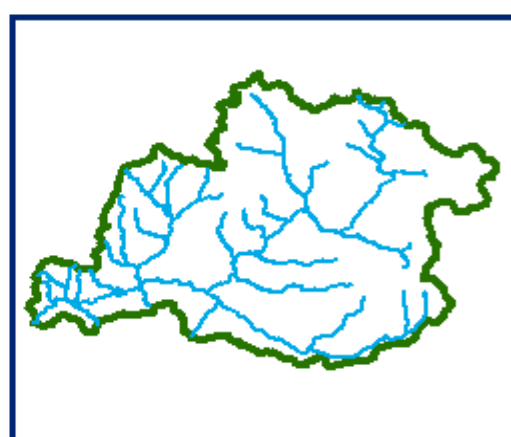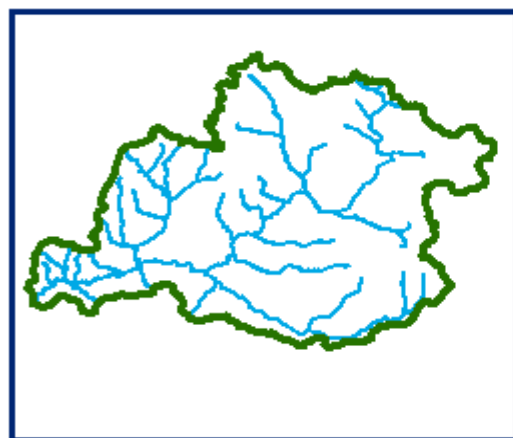
25 FEBRUARY 2011
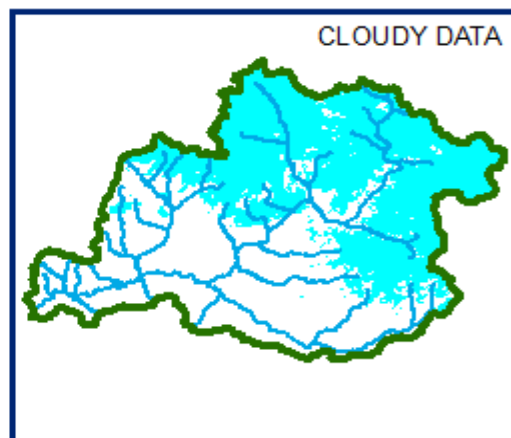
SNOW

0 20 40 80 120 160
Kilometers
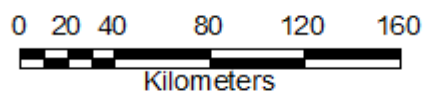
10 DAILY SNOW COVER MAP: ALAKNANDA BASIN
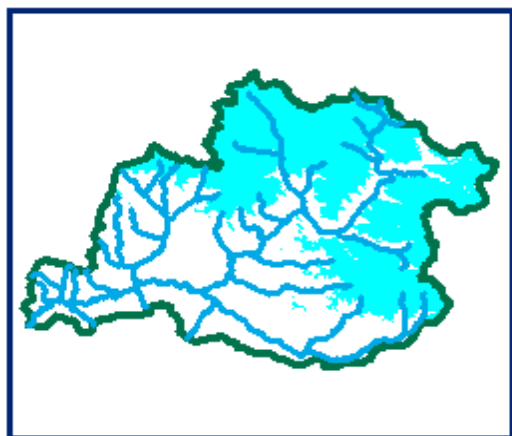
DATA USED

01 FEBRUARY 2011
05 FEBRUARY 2011
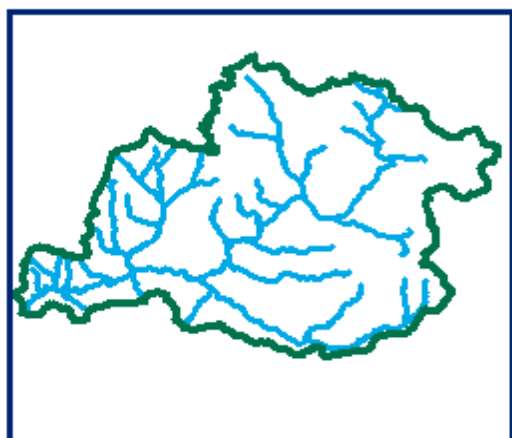
DATA USED
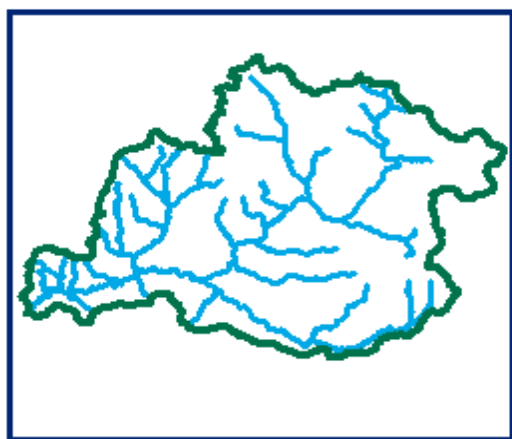
DATA NOT AVAILABLE

DATA USED

DATA NOT AVAILABLE

SNOW

0 20 40   80   120   160
Kilometers

SNOW COVER MAP : ALAKNANDA BASIN
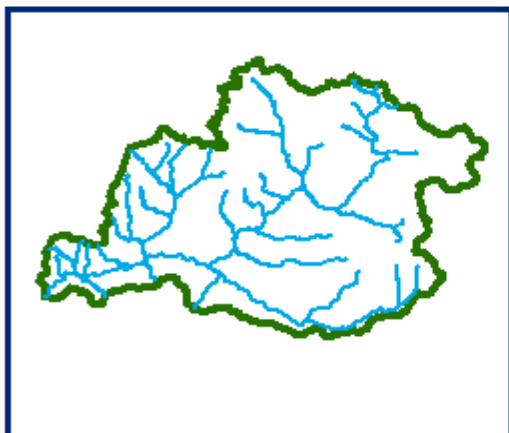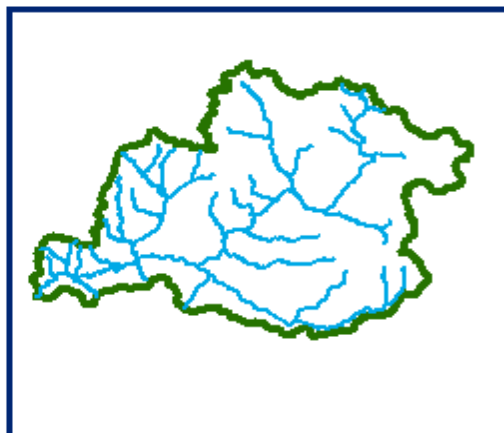
DATA NOT AVAILABLE
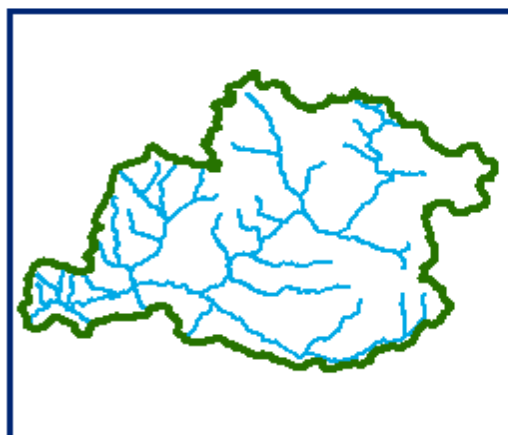
DATA NOT AVAILABLE
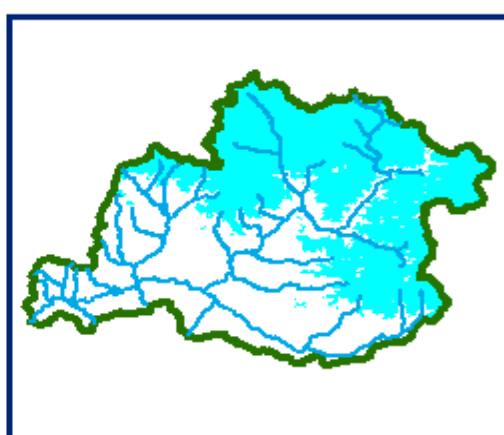
DATA NOT AVAILABLE

16 MARCH 2011

26 MARCH 2011
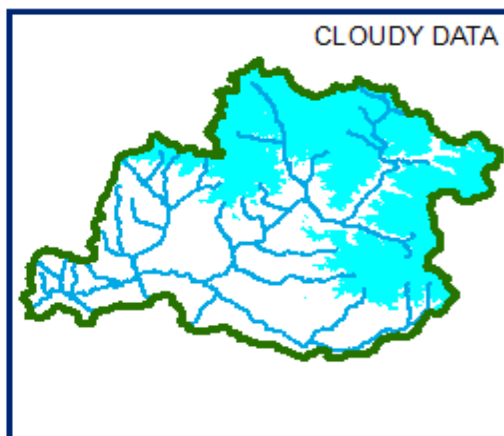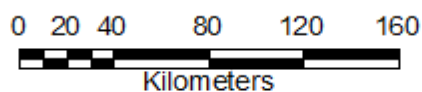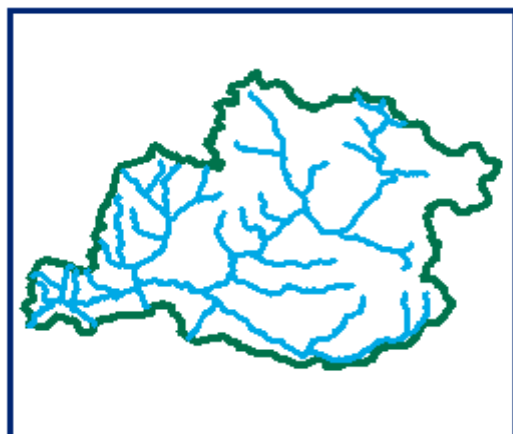
CLOUDY DATA

30 MARCH 2011

SNOW

0 20 40   80   120   160
Kilometers

22

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN

DATA USED
DATA NOT AVAILABLE

DATA USED
16 MARCH 2011

DATA USED
26 MARCH 2011

30 MARCH 2011

SNOW

0   20 40   80   120   160

Kilometers
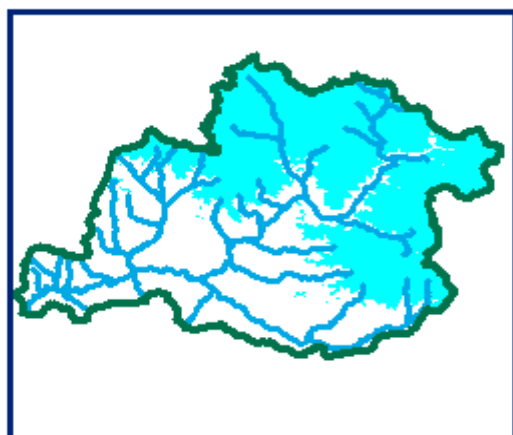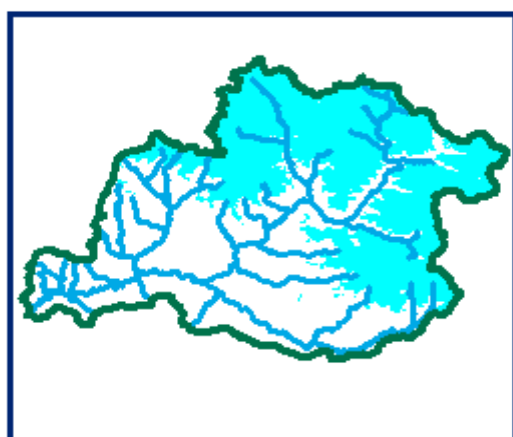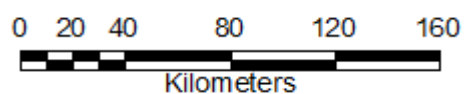
SNOW COVER MAP : ALAKNANDA BASIN
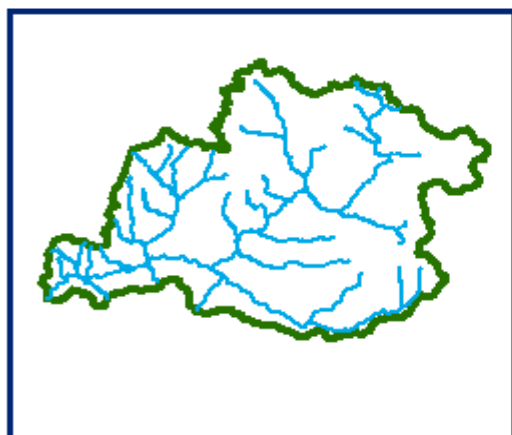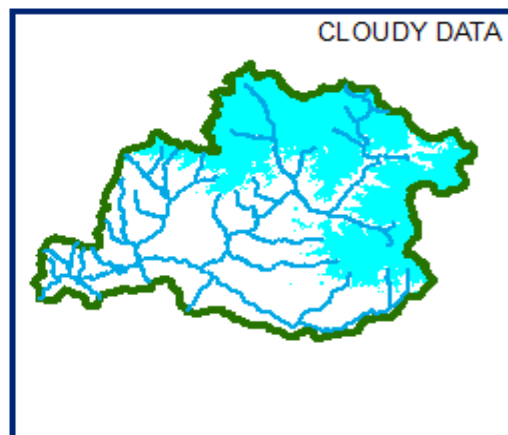
DATA NOT AVAILABLE

CLOUDY DATA

09 APRIL 2011
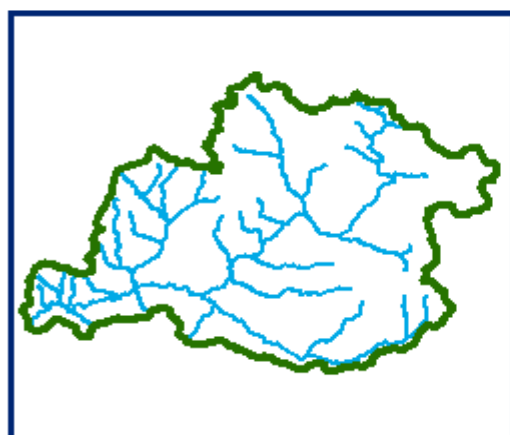
DATA NOT AVAILABLE
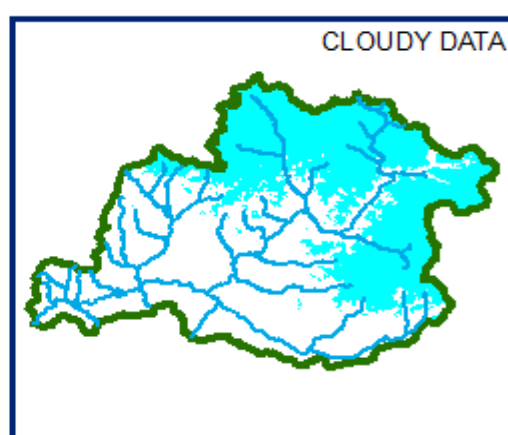
CLOUDY DATA

18 APRIL 2011
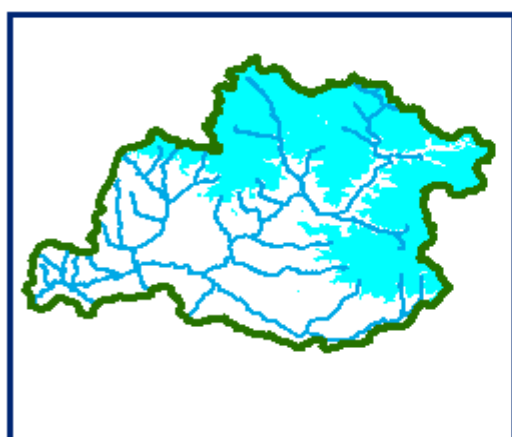
23 APRIL 2011
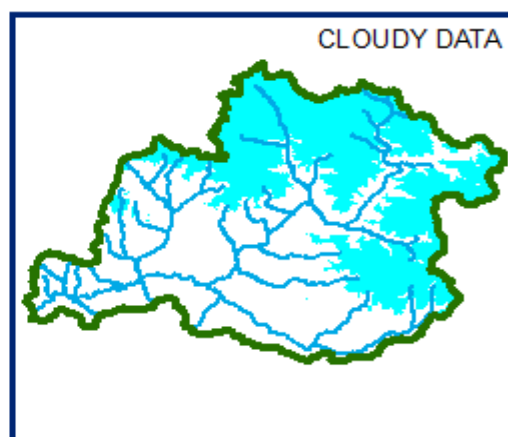
CLOUDY DATA

28 APRIL 2011

SNOW
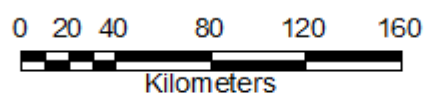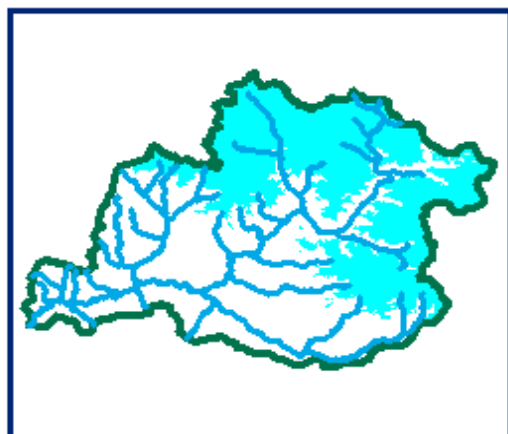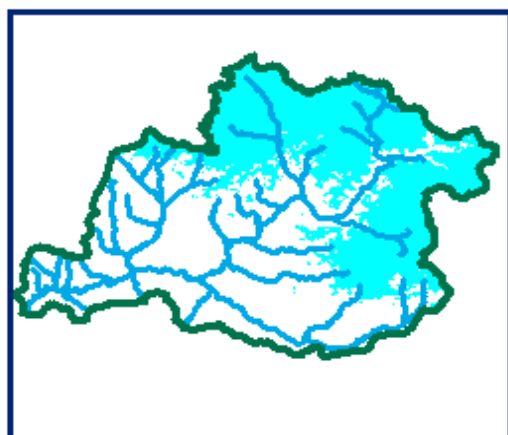
0 20 40   80   120   160
Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN

DATA USED
09 APRIL 2011

DATA USED
18 APRIL 2011

DATA USED
23 APRIL 2011
28 APRIL 2011

SNOW

| 0 | 20 | 40 | 80 | 120 | 160 |

Kilometers

25
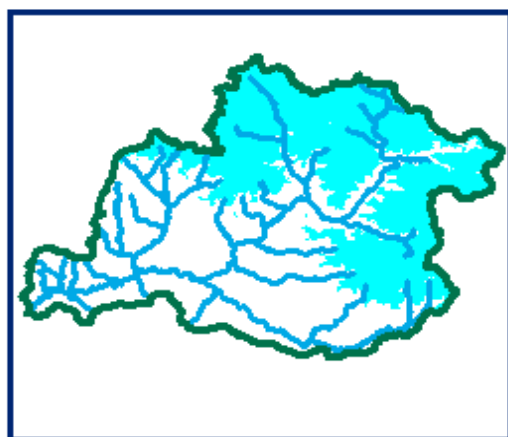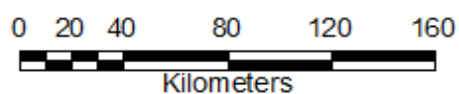
SNOW COVER MAP : ALAKNANDA BASIN
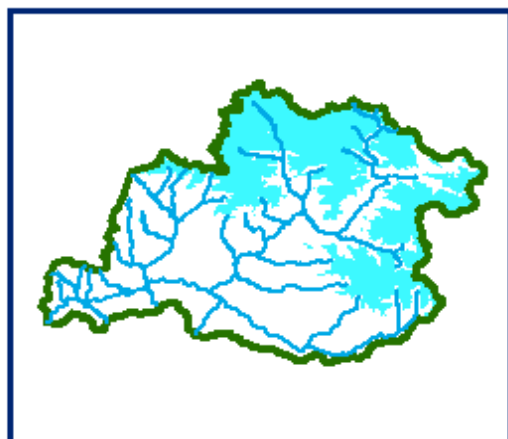
03 MAY 2011
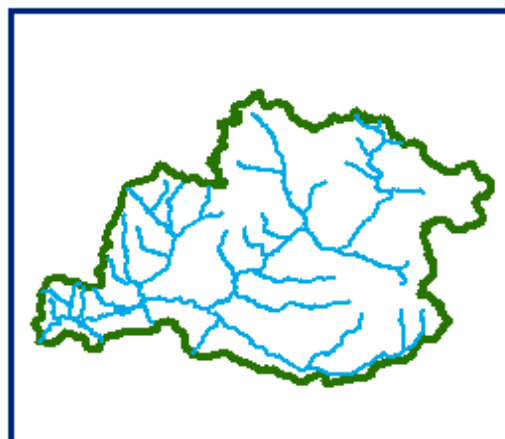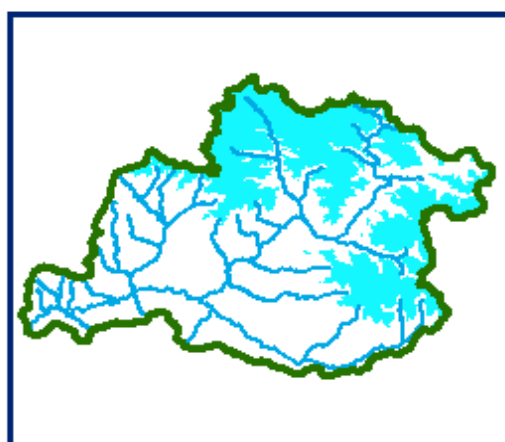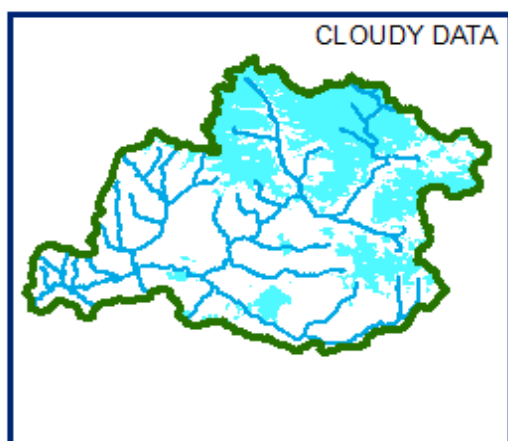
DATA NOT AVAILABLE

12 MAY 2011

17 MAY 2011

22 MAY 2011
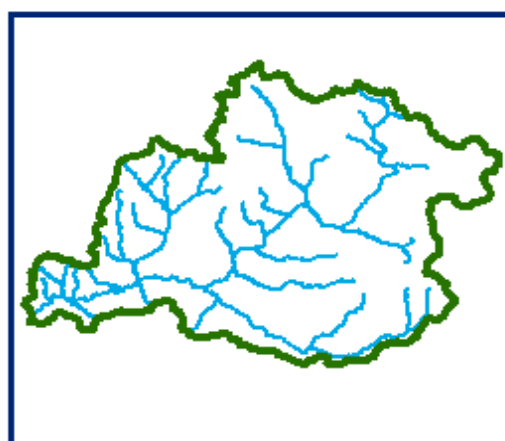
DATA NOT AVAILABLE
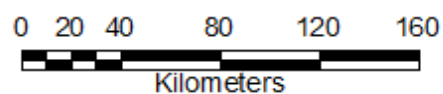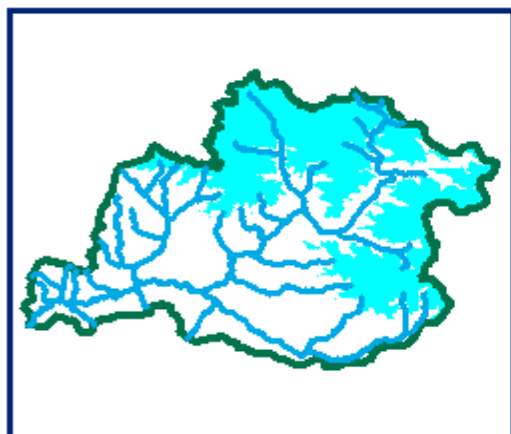
CLOUDY DATA

SNOW

0 20 40 80 120 160
Kilometers

10 DAILY SNOW COVER MAP: ALAKNANDA BASIN

DATA USED
03 MAY 2011

DATA USED

12 MAY 2011
17 MAY 2011

DATA USED

DATA NOT AVAILABLE

SNOW

0   20 40   80   120   160

Kilometers
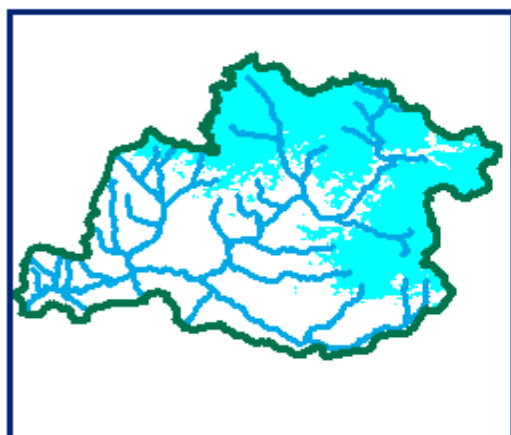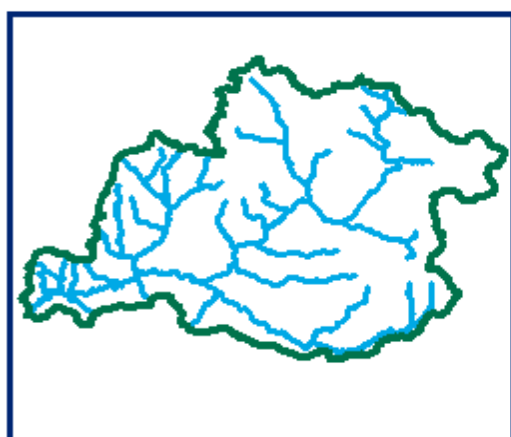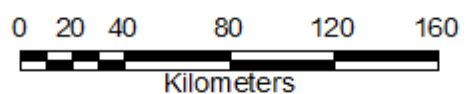
BHAGIRATHI BASIN

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 2010				
1	03-Oct-10	1956.77	26	6	23-Oct-10	2734.85	37
2	04-Oct-10	1920.08	26	7	27-Oct-10	2608.16	35
3	08-Oct-10	1788.72	24	8	27-Oct-10	2566.89	35
4	09-Oct-10	1810.97	24	9	28-Oct-10	2546.24	34
5	18-Oct-10	1732.15	23				
			November 2010				
10	06-Nov-10	1605.07	22	14	21-Nov-10	1976.66	27
11	15-Nov-10	1542.23	21	15	26-Nov-10	1594.25	21
12	16-Nov-10	1678.80	23	16	30-Nov-10	1479.13	20
13	20-Nov-10	1969.00	26				
			December 2010				
17	5-Dec-10	1436.75	19	21	15-Dec-10	1317.96	18
18	9-Dec-10	3279.54	15	22	19-Dec-10	1309.96	18
19	10-Dec-10	1368.45	18	23	24-Dec-10	1283.53	17
20	14-Dec-10	1329.11	18	24	29-Dec-10	3185.23	43
			January 2011				
25	02-Jan-11	3277.92	44	29	24-Jan-11	3315.96	45
26	03-Jan-11	3281.19	44	30	26-Jan-11	3653.39	49
27	12-Jan-11	3138.19	42	31	27-Jan-11	3678.66	49
28	22-Jan-11	3543.5	48	32	31-Jan-11	3269.49	44
			February 2011				
33	01-Feb-11	3603.87	48	35	25-Feb-11	3887.55	52
34	05-Feb-11	3374.58	45				
			March 2011				
36	15-Mar-11	3884.74	52	38	26-Mar-11	3672.35	49
37	16-Mar-11	3743.66	50	39	30-Mar-11	3649.17	49
			April 2011				
40	09-Apr-11	3560.71	48	42	23-Apr-11	3754.52	50
41	18-Apr-11	3766.69	51	43	28-Apr-11	3559.08	48
			May 2011				
44	03-May-11	3177.78	43	46	17-May-11	2680.08	36
45	12-May-11	3010.81	40	47	22-May-11	2675.24	36

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 2010				**November 2010**		
1	03-Oct-10	1984.44	27	4	06-Nov-10	2199.18	30
2	18-Oct-10	1830.78	25	5	16-Nov-10	1678.41	23
3	28-Oct-10	2378.56	32	6	26-Nov-10	1476.39	20
	December 2010				**January 2011**		
11	5-Dec-10	1460.57	20	14	03-Jan-11	4040.81	54
12	19-Dec-10	1367.41	18	15	12-Jan-11	4026.00	54
13	24-Dec-10	1799.01	24	16	26-Jan-11	3750.94	50
	February 2011				**March 2011**		
17	05-Feb-11	3305.06	44	18	26-March-11	3691.70	50
	April 2011				**May 2011**		
19	9-Apr-11	3522.90	47	22	03-May-11	3328.26	45
20	18-Apr-11	3612.79	49	23	12-May-07	2956.38	40
21	23-Apr-11	3558.63	48				

Snow cover depletion curve

Bhagirathi Basin(5 Daily): With Cloudy Data

Bhagirathi Basin(5 Daily): Without Cloudy Data
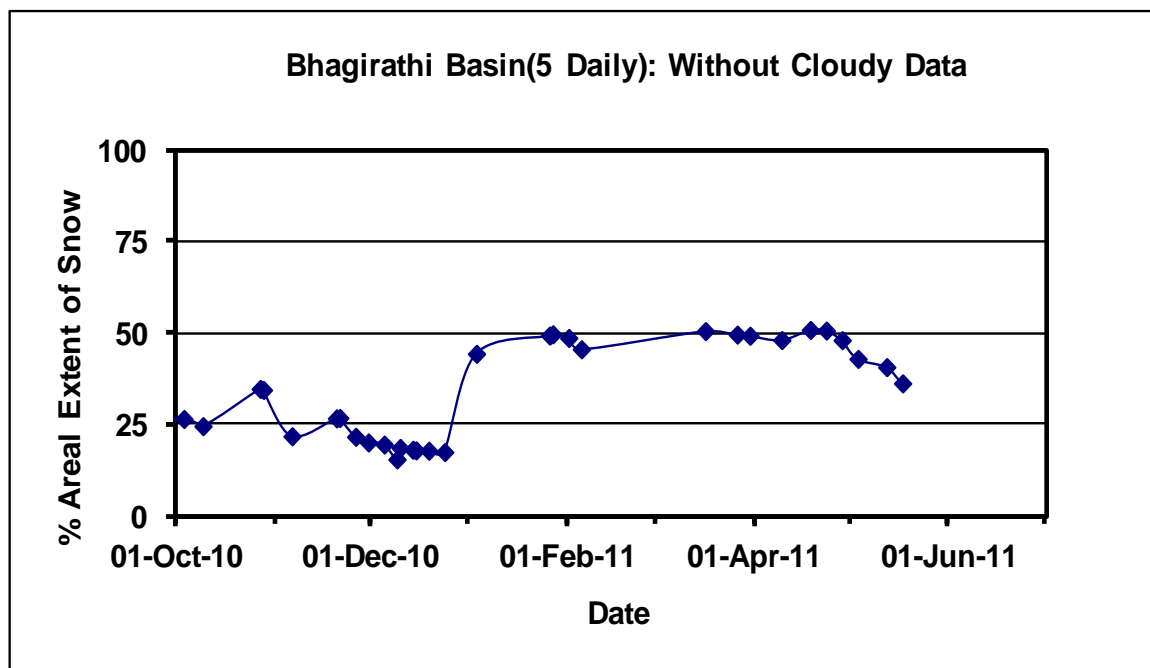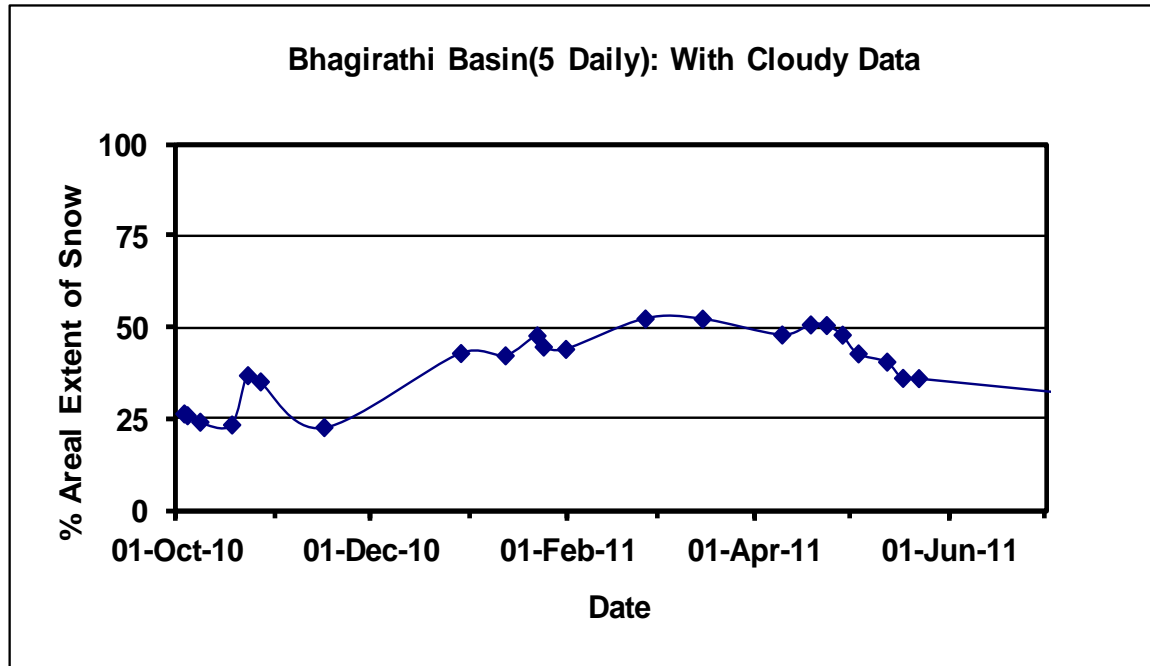
Snow cover depletion curve

Bhagirathi Basin (10 Daily)
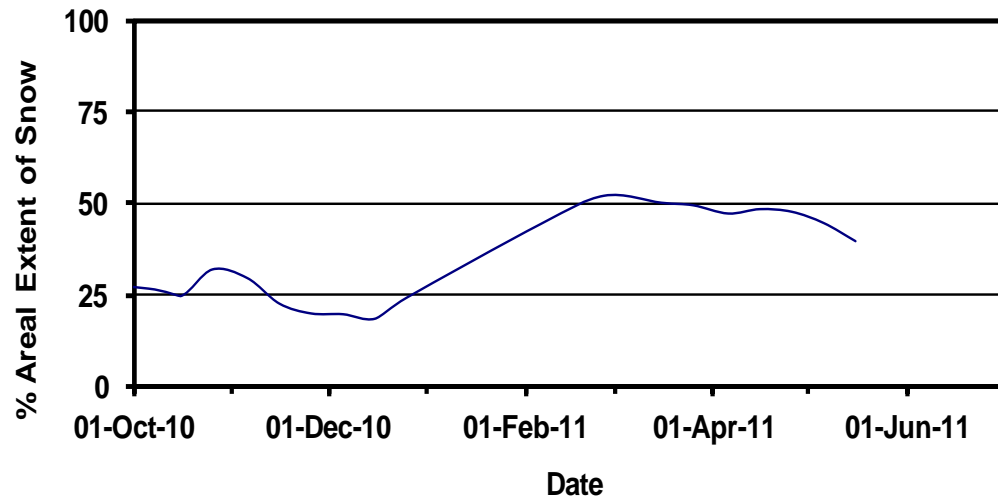
SNOW COVER MAP

SNOW COVER MAP   :   BHAGIRATHI BASIN

CLOUDY DATA
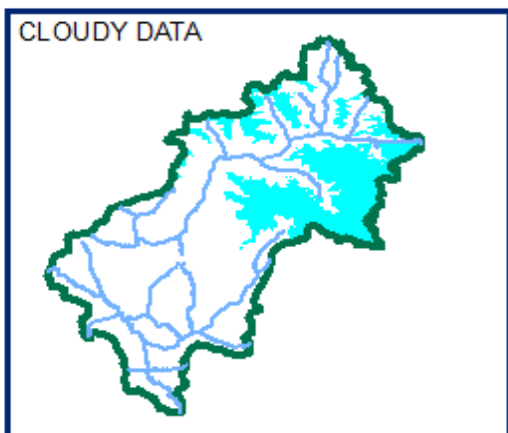
04 OCTOBER 2010
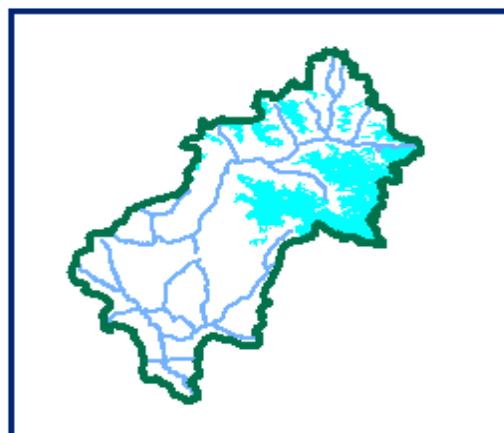
09 OCTOBER 2010
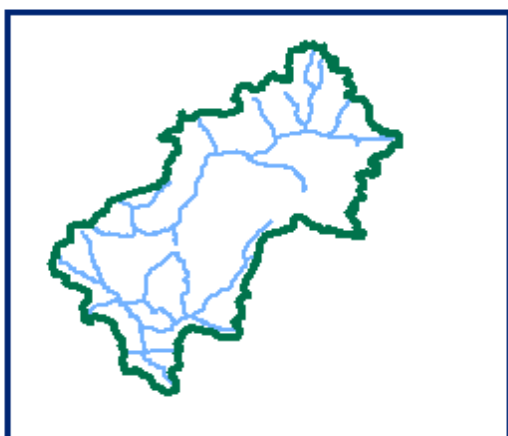
DATA NOT AVAILABLE
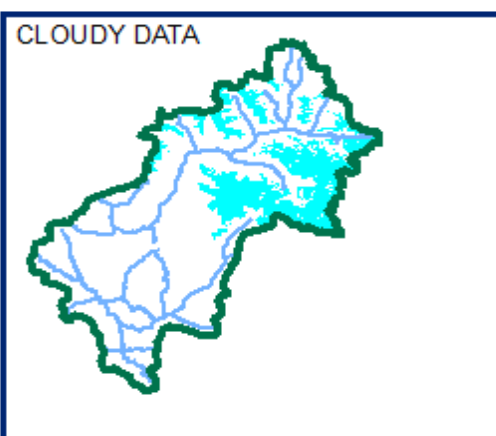
CLOUDY DATA

18 OCTOBER 2010

CLOUDY DATA
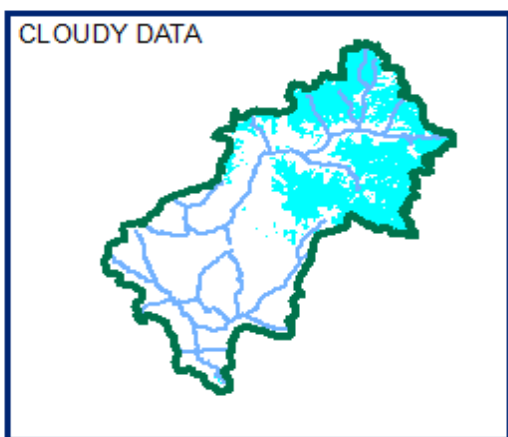
23 OCTOBER 2010
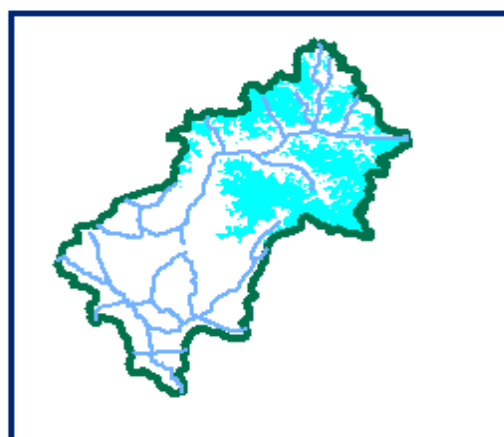
28 OCTOBER 2010
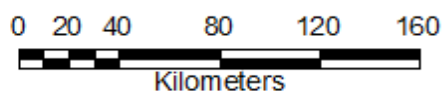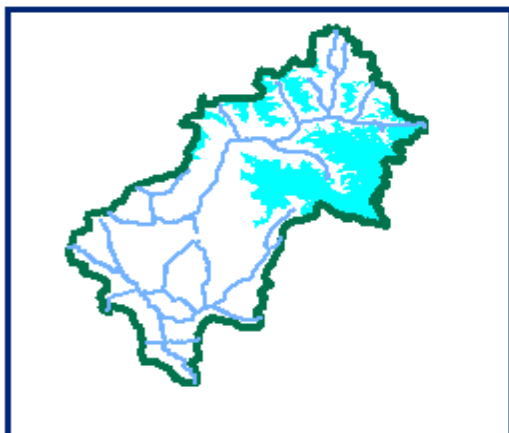
SNOW

0 20 40   80   120   160
Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN

DATA USED

03 OCTOBER 2010

DATA USED

18 OCTOBER 2010

DATA USED
23 OCTOBER 2010
27 OCTOBER 2010
28 OCTOBER 2010

SNOW

0   25   50   100   150   200
Kilometers
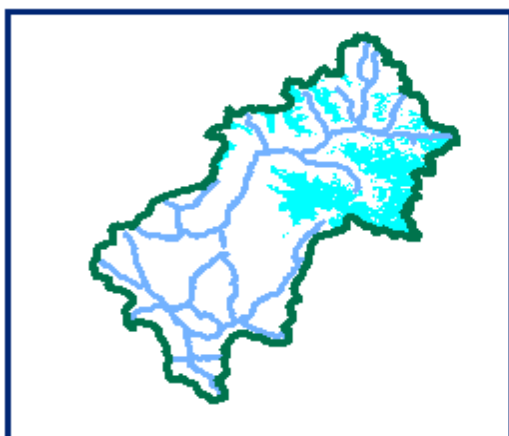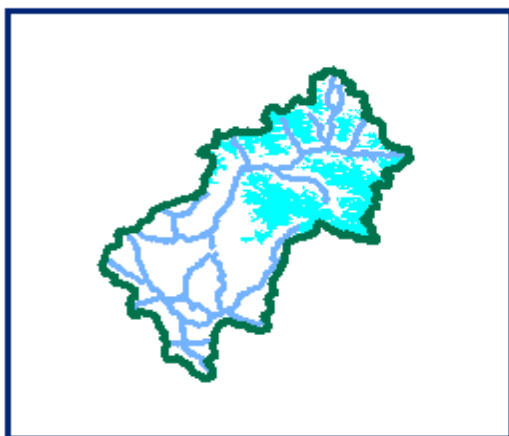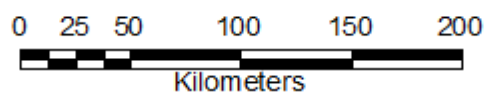
SNOW COVER MAP : BHAGIRATHI BASIN
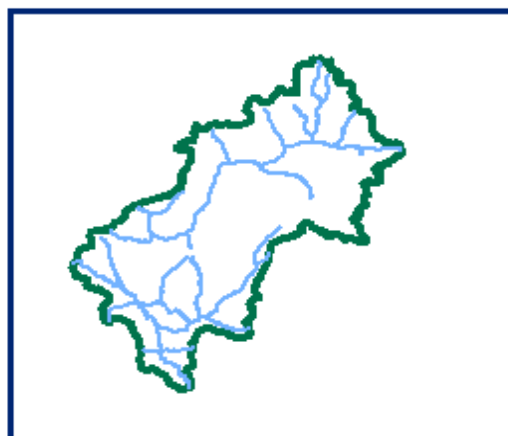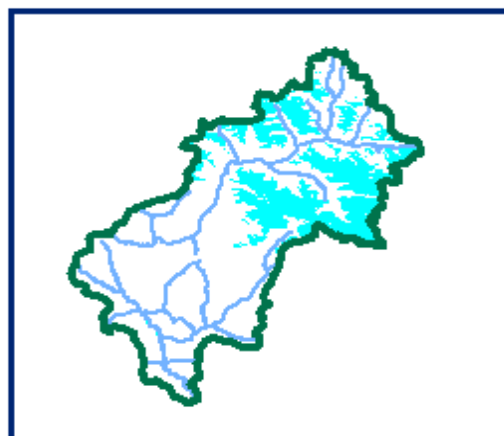
DATA NOT AVAILABLE
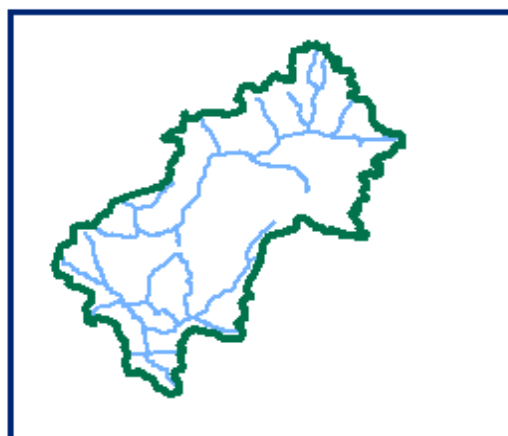
06 NOVEMBER 2010
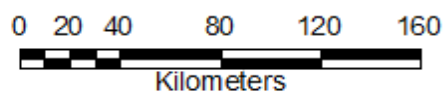
DATA NOT AVAILABLE
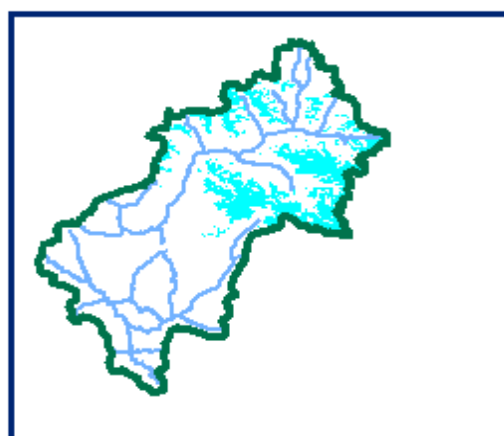
16 NOVEMBER 2010

21 NOVEMBER 2010

30 NOVEMBER 2010

SNOW

0 20 40   80   120   160
Kilometers
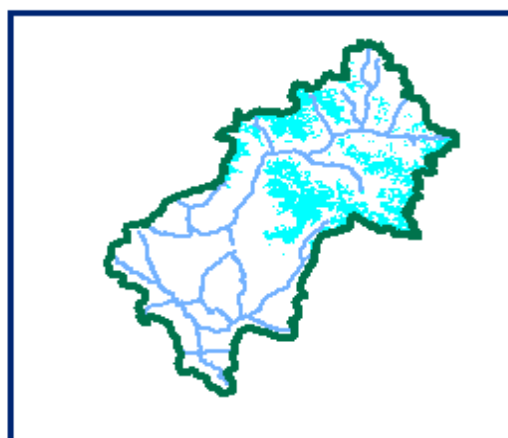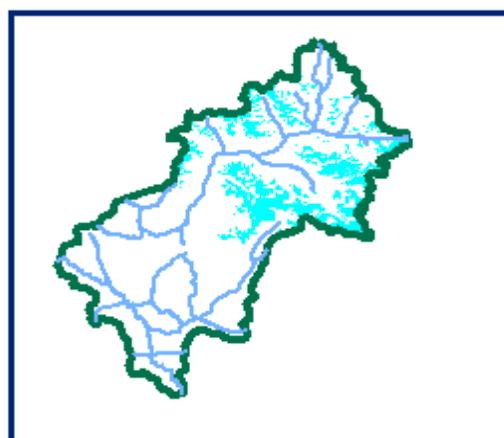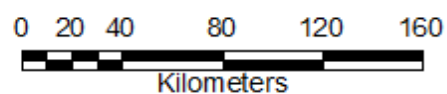
10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN
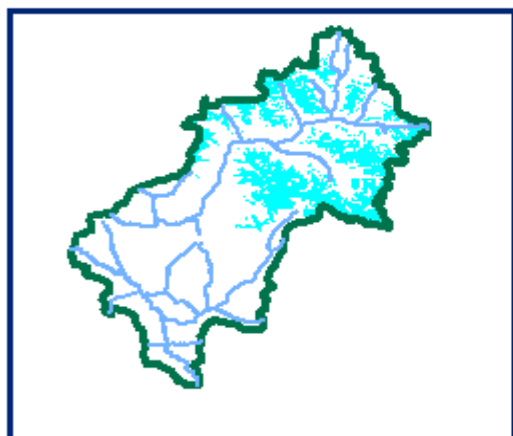
DATA USED
06 NOVEMBER 2010
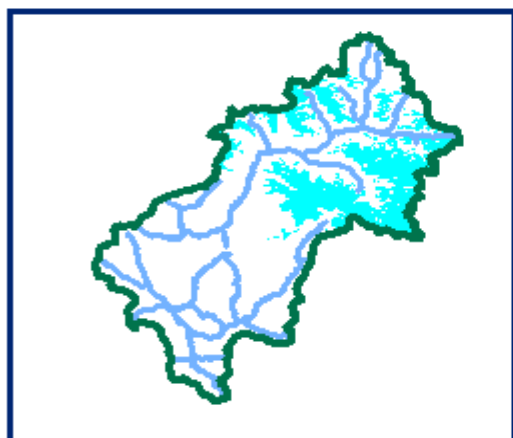
DATA USED
15 NOVEMBER 2010
16 NOVEMBER 2010
20 NOVEMBER 2010
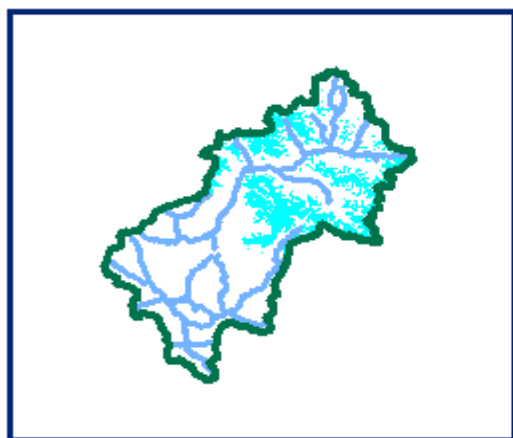
DATA USED

21 NOVEMBER 2010
26 NOVEMBER 2010
30 NOVEMBER 2010

SNOW

0   25   50   100   150   200

Kilometers

36
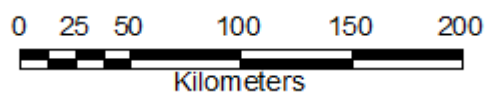
SNOW COVER MAP : BHAGIRATHI BASIN
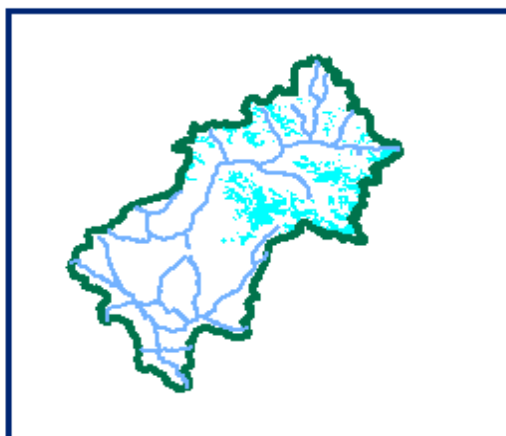
05 DECEMBER 2010
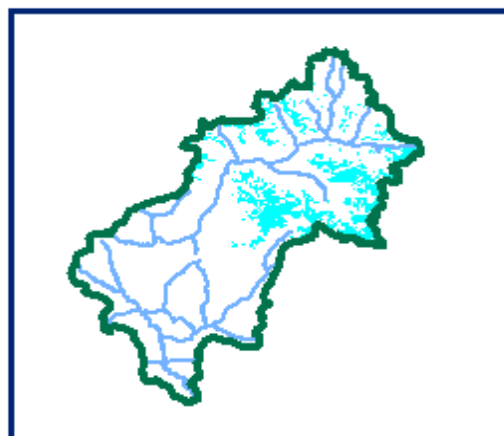
10 DECEMBER 2010
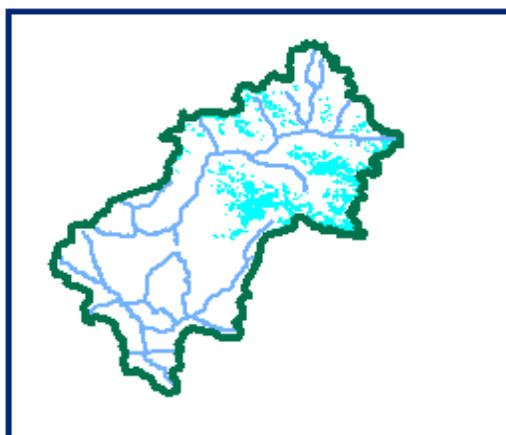
15 DECEMBER 2010
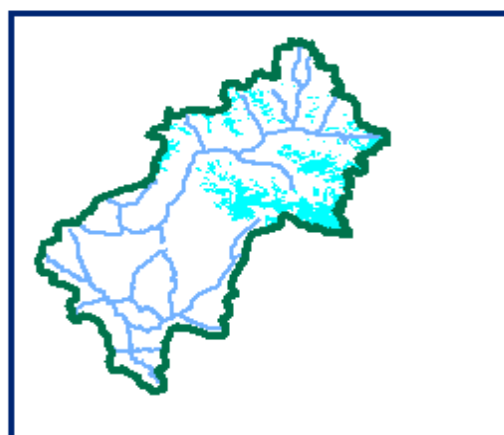
19 DECEMBER 2010

24 DECEMBER 2010

CLOUDY DATA

29 DECEMBER 2010

SNOW

0 20 40 80 120 160
Kilometers
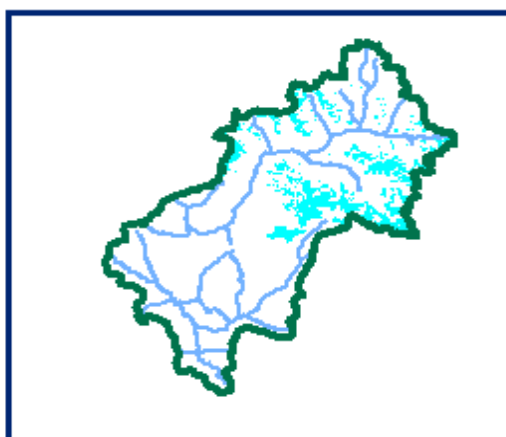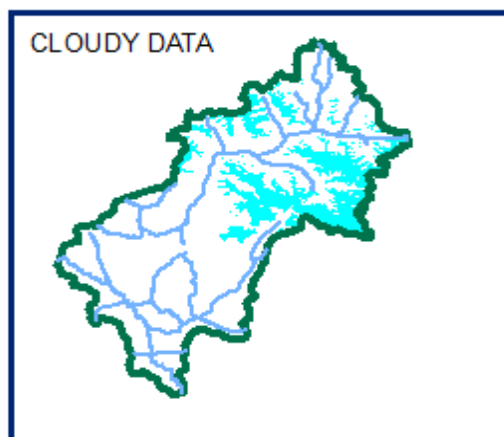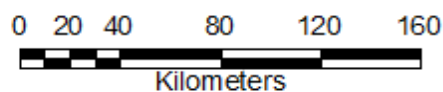
10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN
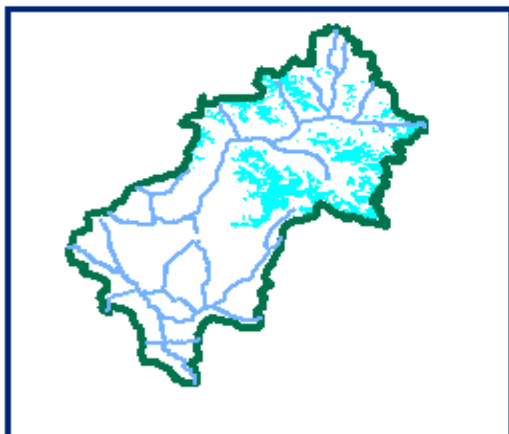
DATA USED

05 DECEMBER 2010
09 DECEMBER 2010
10 DECEMBER 2010
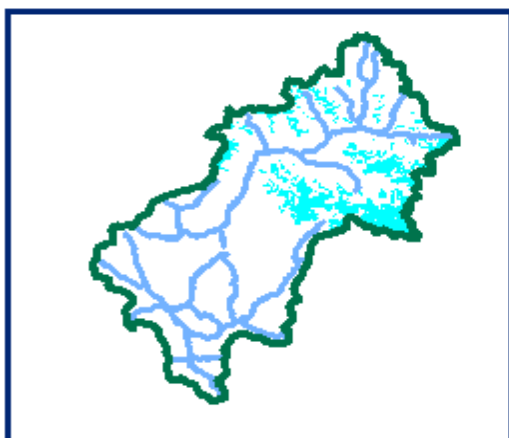
DATA USED

14 DECEMBER 2010

15 DECEMBER 2010

19 DECEMBER 2010

DATA USED

24 DECEMBER 2010

29 DECEMBER 2010

SNOW

0   25   50   100   150   200
Kilometers
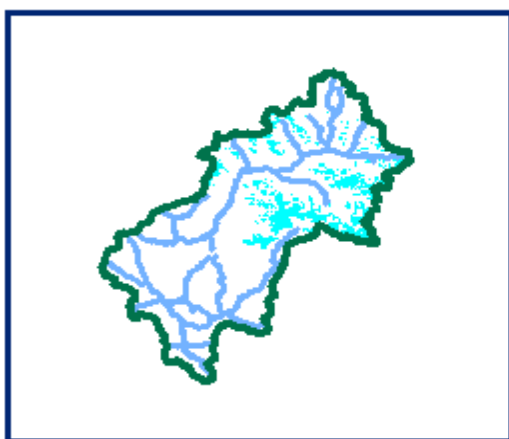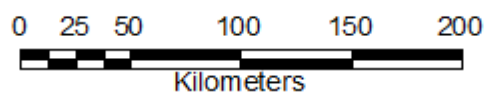
SNOW COVER MAP : BHAGIRATHI BASIN

03 JANUARY 2011
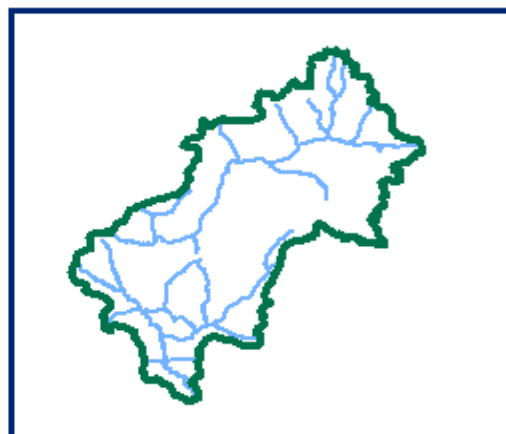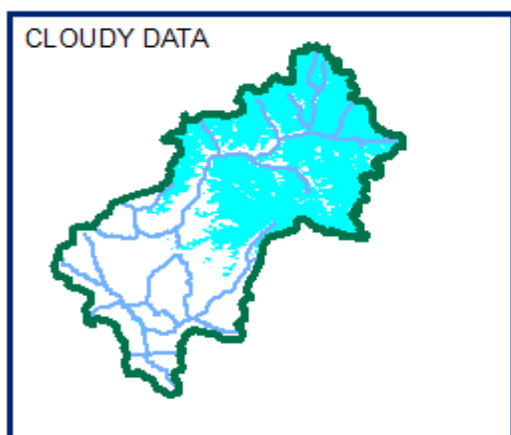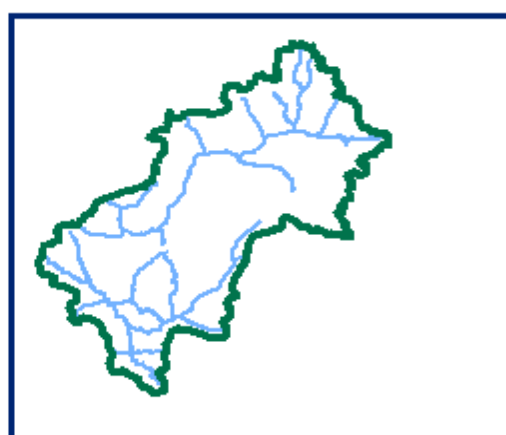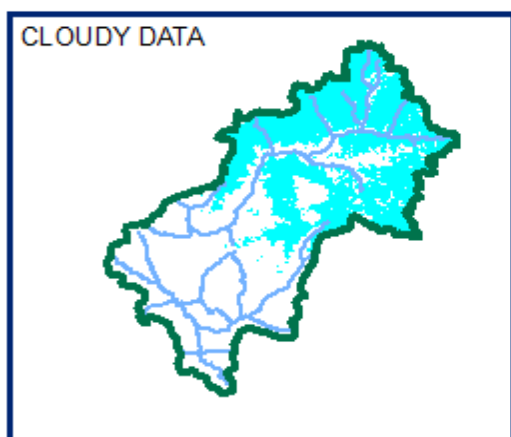
DATA NOT AVAILABLE

CLOUDY DATA

12 JANUARY 2011

DATA NOT AVAILABLE

CLOUDY DATA

24 JANUARY 2011

26 JANUARY 2011

SNOW

0 20 40   80   120   160
Kilometers
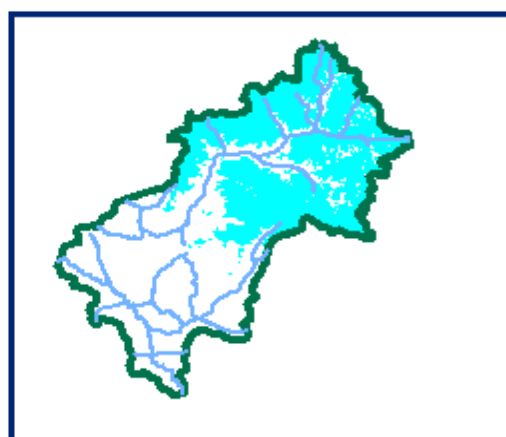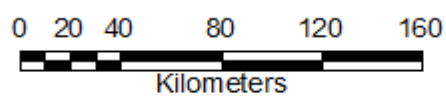
10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN
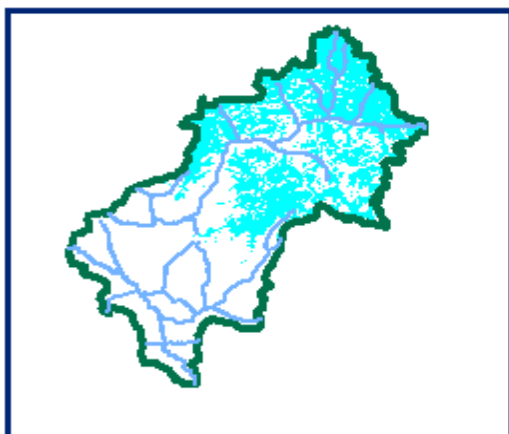
DATA USED
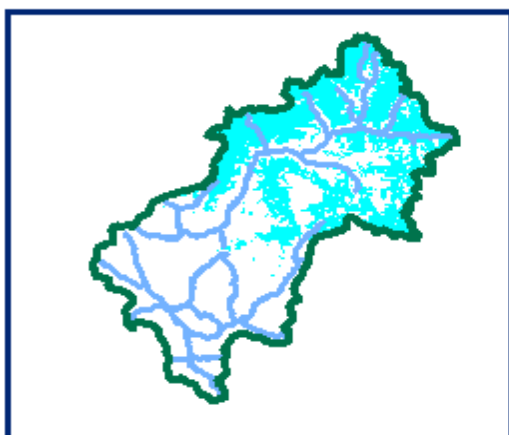
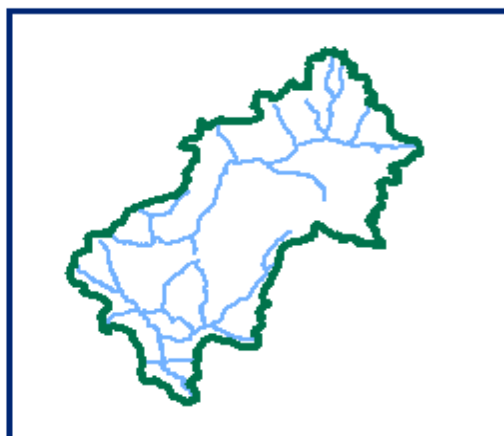**03 JANUARY 2011**

DATA USED
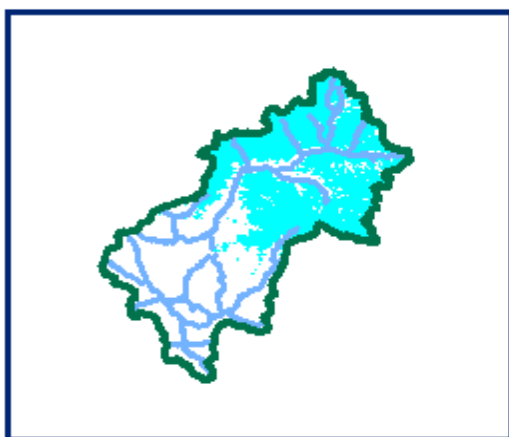
12 JANUARY 2011

DATA USED

24 JANUARY 2011
26 JANUARY 2011
27 JANUARY 2011
31 JANUARY 2011

SNOW

0   25   50   100   150   200
Kilometers

40
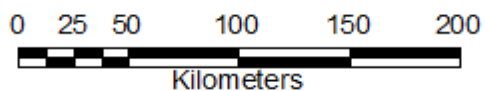
SNOW COVER MAP : BHAGIRATHI BASIN
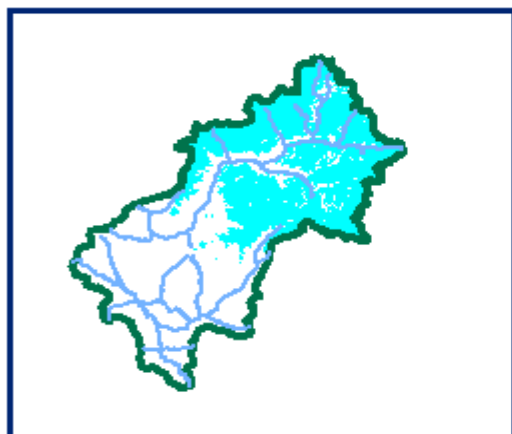
01 FEBRUARY 2011
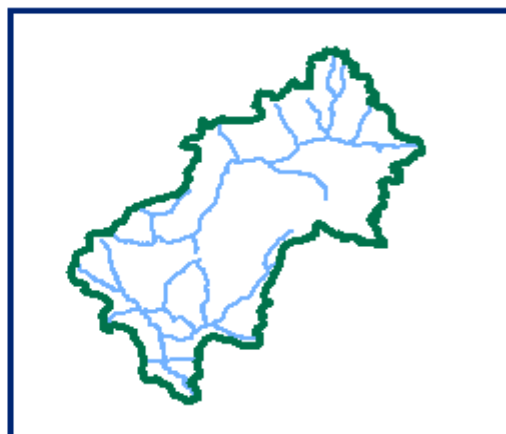
DATA NOT AVAILABLE
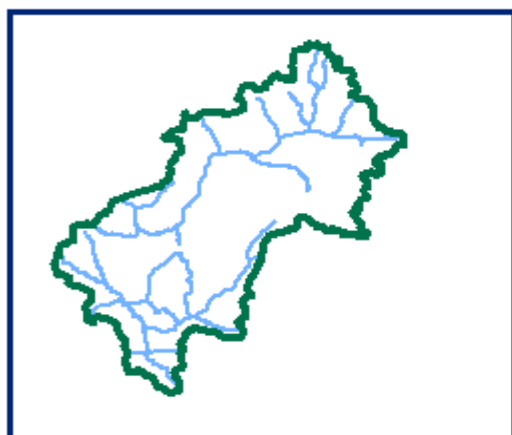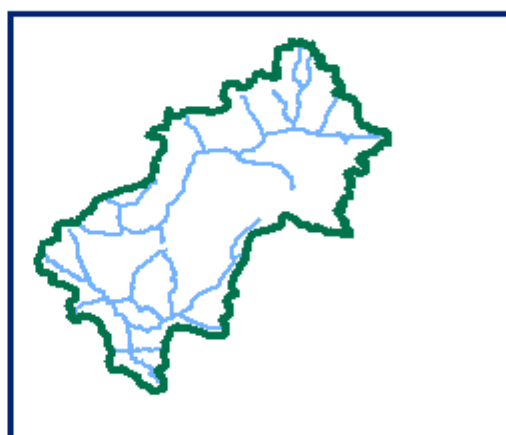
DATA NOT AVAILABLE
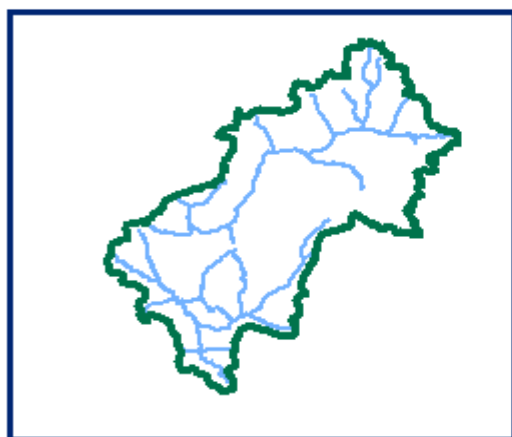
DATA NOT AVAILABLE

DATA NOT AVAILABLE

25 FEBRUARY 2011

SNOW

0 20 40 80 120 160
Kilometers
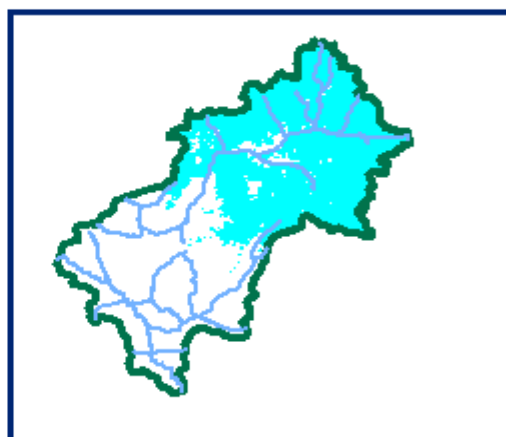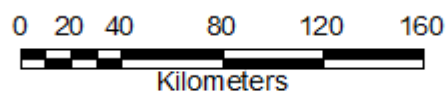
10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN
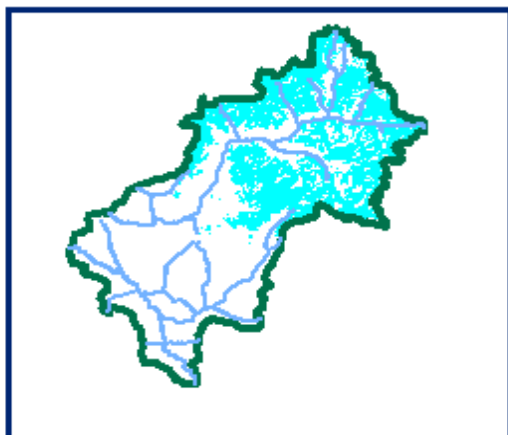
DATA USED

01 FEBRUARY 2010
05 FEBRUARY 2010
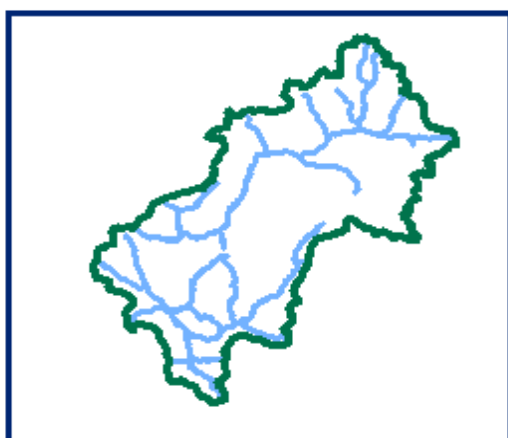
DATA USED

DATA NOT AVAILABLE
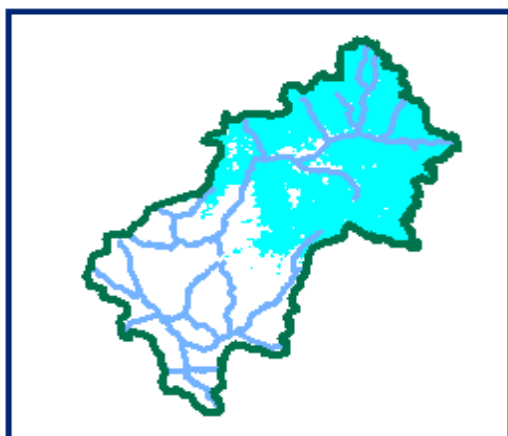
DATA USED

25 FEBRUARY 2010

SNOW
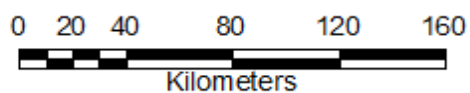
0 20 40   80   120   160
Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN
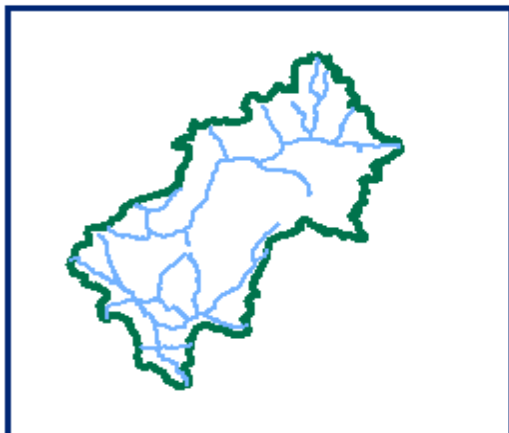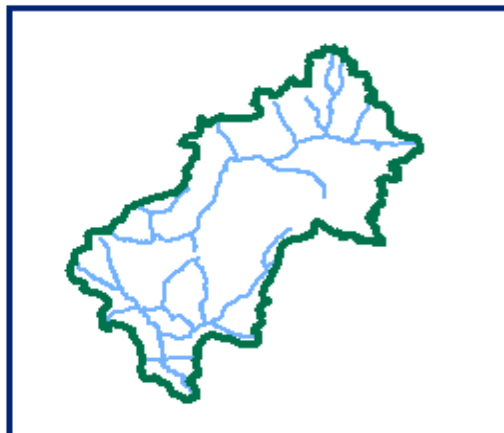
DATA NOT AVAILABLE
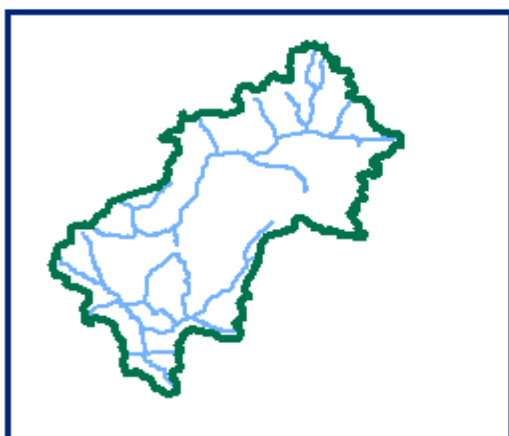
DATA NOT AVAILABLE
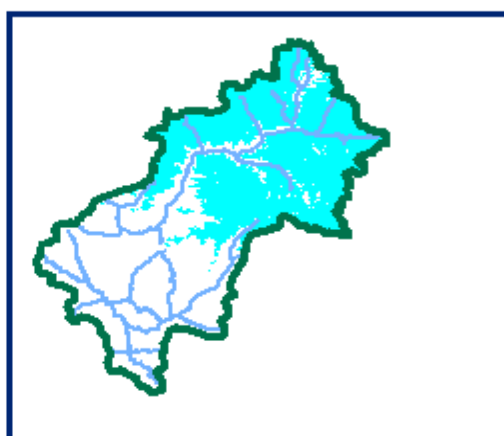
DATA NOT AVAILABLE
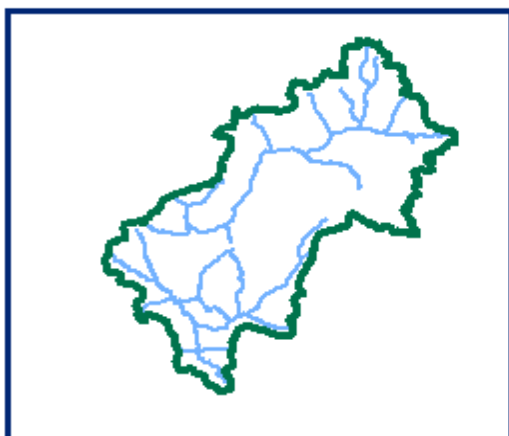
16 MARCH 2011

DATA NOT AVAILABLE

26 MARCH 2011

SNOW

0 20 40   80   120   160
Kilometers
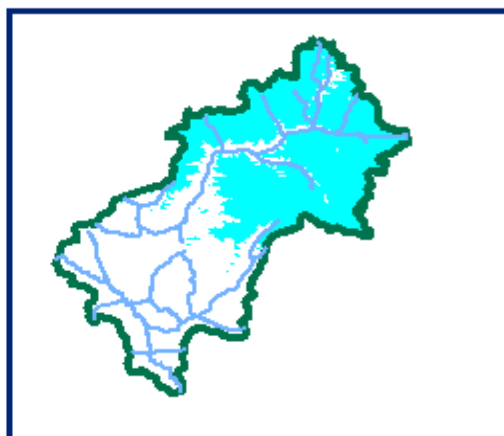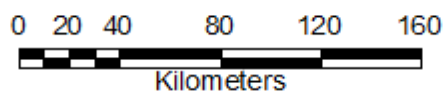
10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN
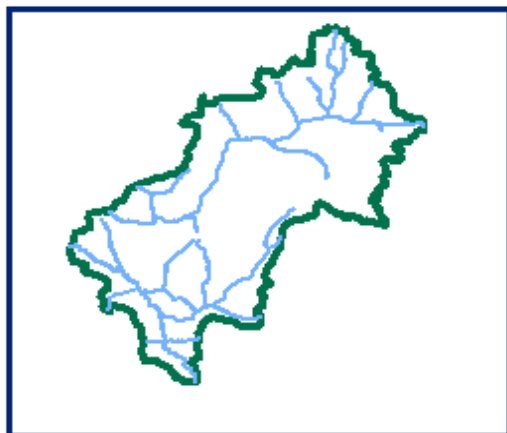
DATA USED
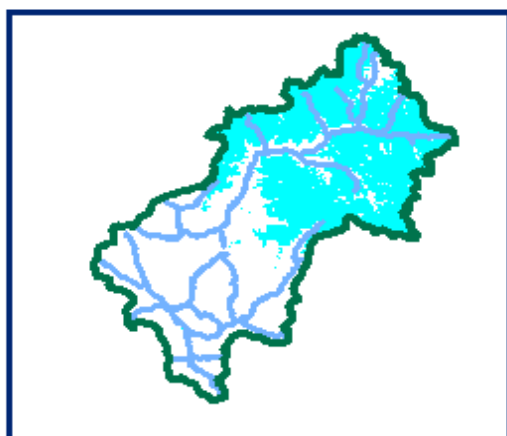
DATA NOT AVAILABLE

DATA USED

15 MARCH 2011

16 MARCH 2011
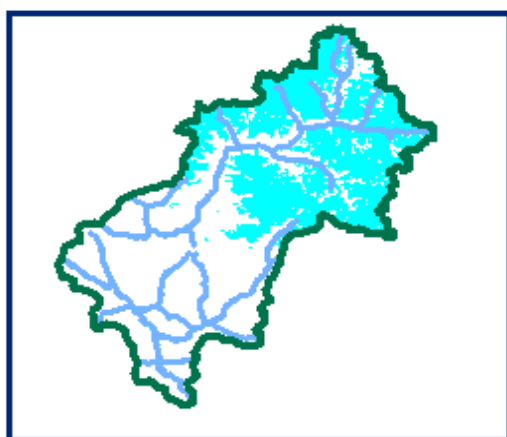
DATA USED

26 MARCH 2011

30 MARCH 2011

SNOW

| 0 | 20 | 40 | | 80 | | 120 | | 160 | |

Kilometers
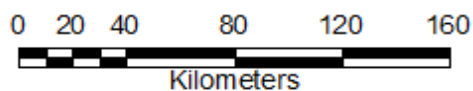
SNOW COVER MAP : BHAGIRATHI BASIN
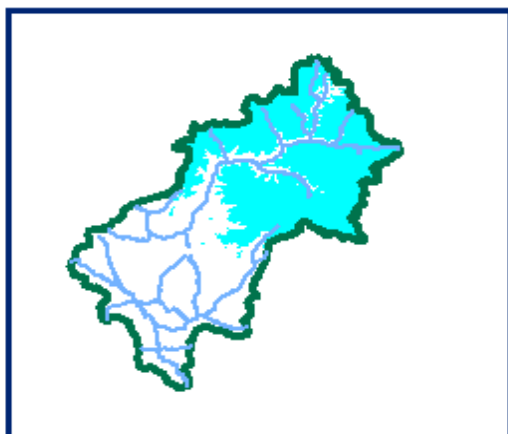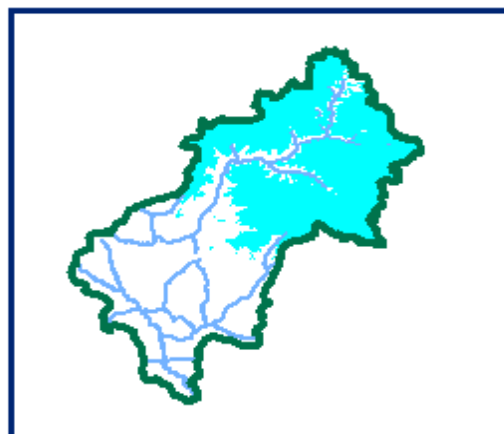
DATA NOT AVAILABLE

09 APRIL 2010
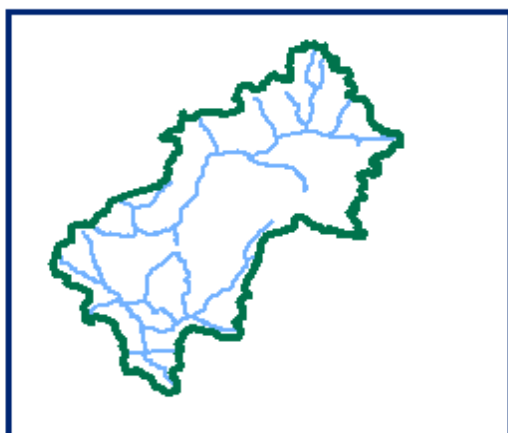
DATA NOT AVAILABLE
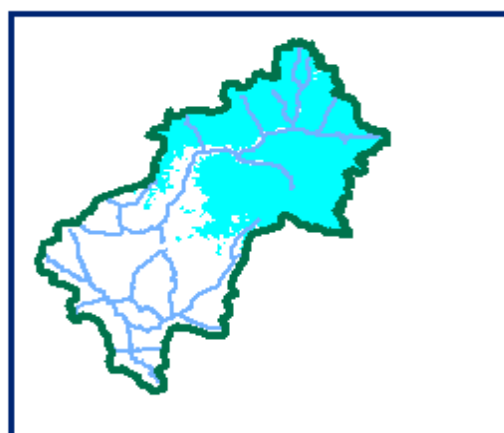
18 APRIL 2010

23 APRIL 2010

28 APRIL 2010

SNOW

0 20 40 80 120 160
Kilometers

45

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN

DATA USED

09 APRIL 2011

DATA USED

18 APRIL 2011

DATA USED

23 APRIL 2011
28 APRIL 2011

SNOW

0   20 40   80   120   160

Kilometers

SNOW COVER MAP : BHAGIRATHI BASIN

03 MAY 2011

DATA NOT AVAILABLE
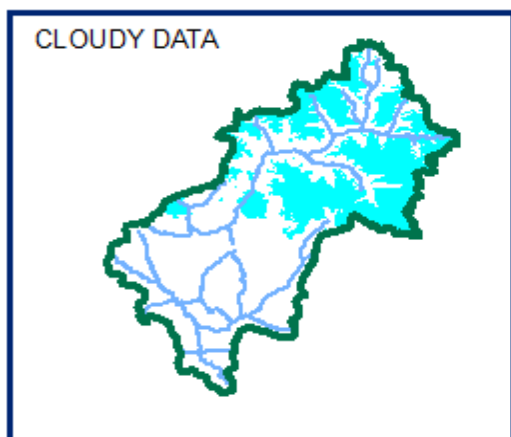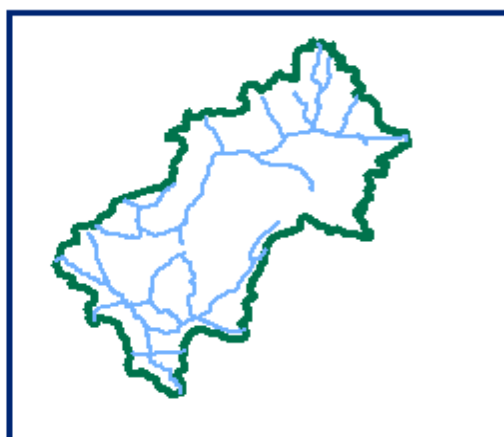
12 MAY 2011

17 MAY 2011

CLOUDY DATA

22 MAY 2011

DATA NOT AVAILABLE

SNOW

0 20 40 80 120 160
Kilometers

10 DAILY SNOW COVER MAP: BHAGIRATHI BASIN

DATA USED
03 MAY 2011

DATA USED
12 MAY 2011
17 MAY 2011

DATA USED
DATA NOT AVAILABLE

SNOW

0   20   40   80   120   160

Kilometers

48
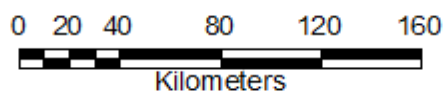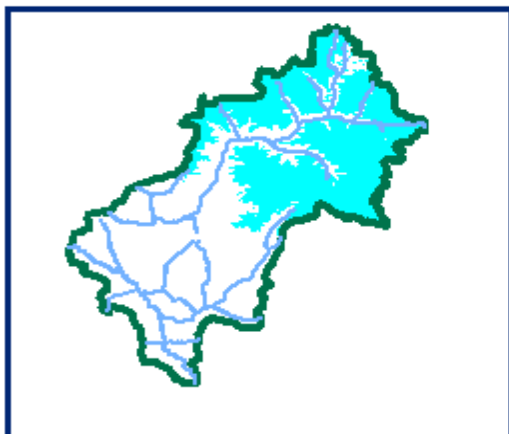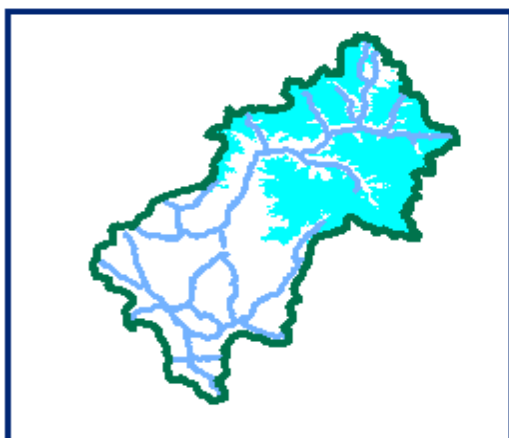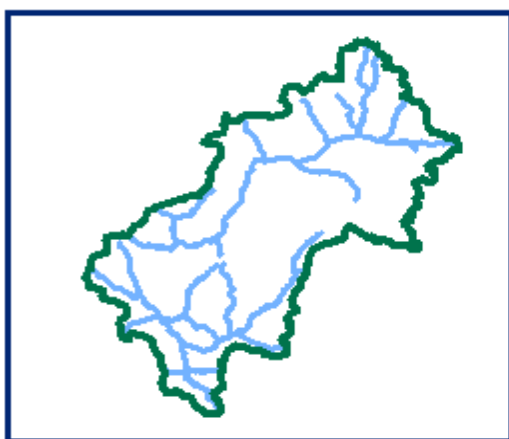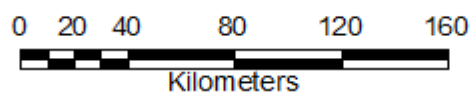
YAMUNA BASIN

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 2010							
1	03-Oct-2010	389.21	11	4	23-Oct-2010	306.10	9
2	08-Oct-2010	331.69	9	5	27-Oct-2010	527.82	15
3	18-Oct-2010	318.29	9				
November 2010							
1	06-Nov-2010	406.28	12	4	20-Nov-2010	599.69	17
2	15-Nov-2010	423.79	12	5	30-Nov-2010	418.56	12
3	16-Nov-2010	393.679	11				
December 2010							
1	05-Dec-2010	488.24	14	4	14-Dec-2010	249.7	7
2	9-Dec-2010	388.9	11	5	19-Dec-10	243.7	7
3	10-Dec-2010	277.91	8				
January 2011							
1	2-Jan-11	1484.1	42	5	26-Jan-11	972.27	28
2	3-Jan-11	1748.12	50	6	27-Jan-11	1323.52	38
3	12-Jan-11	801.93	23	7	31-Jan-11	925.274	26
4	22-Jan-11	532.73	15				
February 2011							
1	1-Feb-11	1343.37	38	2	5-Feb-11	1103.58	31
March 2011							
1	15-March-11	1386.85	39	4	26-March-11	1263.61	36
2	16-March-11	1377.39	39	5	30-March-11	1329.02	38
3	25-March-11	1332.43	38				
April 2011							
1	9-April-11	1269.51	36	3	23-April-11	1130.08	32
2	18-April	1170.62	33	4	28-April-11	909.64	26
May 2011							
1	3-May-11	872.66	25	3	17-May-11	648.25	18
2	12-May-11	895.24	25	4	22-May-11	614.29	17

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 2010				
1	3-Oct-10	356.04	10	2	18-Oct-10	332.087	9
				3	27-Oct-10	488.322	14
			November 2010				
1	6-Nov-10	496.845	14	3	30-Nov-10	418.06	12
2	20-Nov-10	645.71	18				
			December 2010				
1	9-Dec-10	501.89	14	3	24-Dec-10	447.517	13
2	19-dec-10	418.11	12				
			January 2011				
1	2-Jan-11	1714.46	49	3	22-Jan-11	1197.04	34
2	12-Jan-11	861.24	24				
			February 2011				
1	5-Feb-11	1161.52	33	2	19-feb-11	1169.24	34
			March 2011				
1	16-March-11	1334.48	38	2	25-March-11	1356.94	38
			April 2011				
1	9-April-11	1274.11	36	3	28-April-11	878.33	25
2	18-April-11	1176.62	33				
			May 2011				
1	3-May-11	939.28	27	2	12-May-11	864.53	25
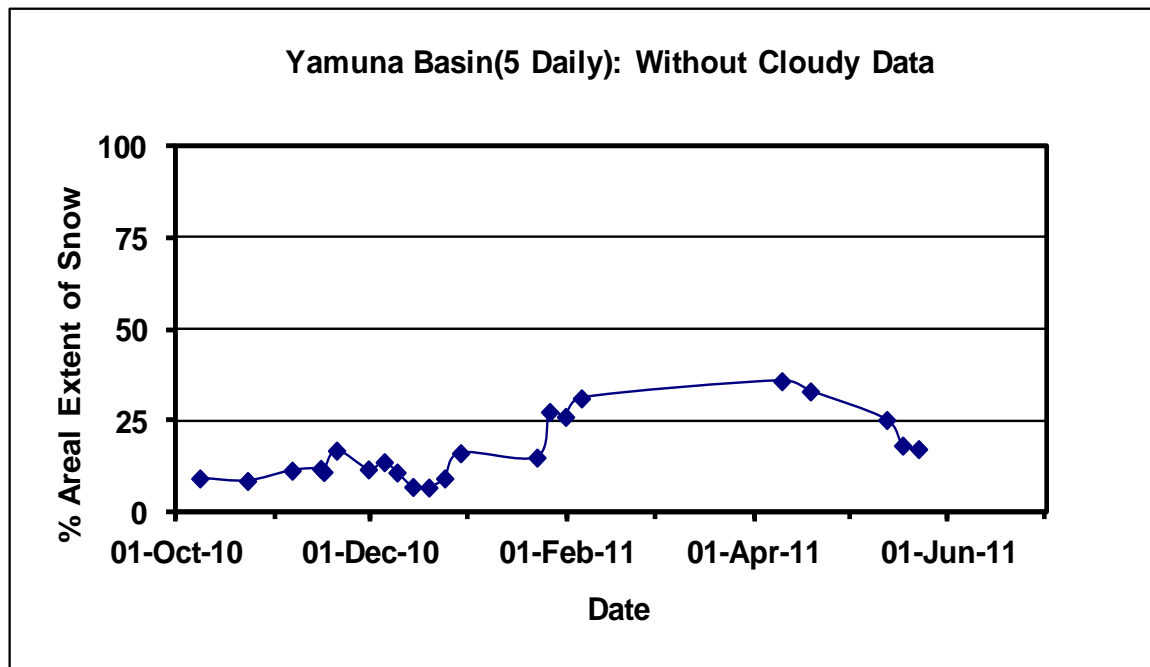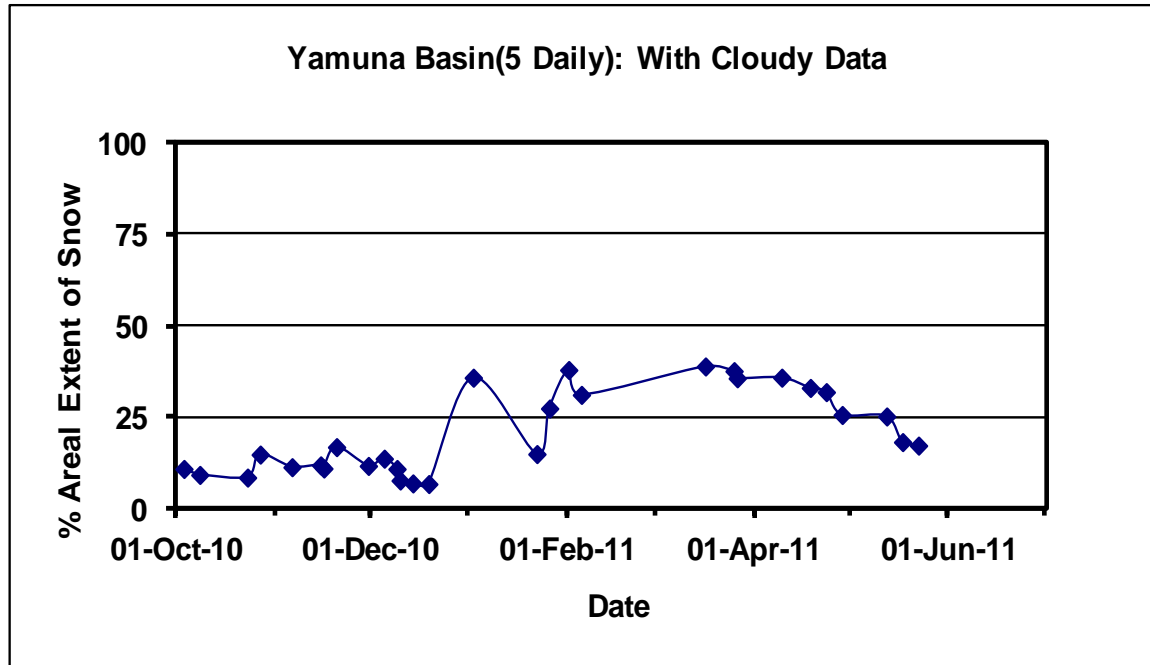
Snow cover depletion curve

Snow cover depletion curve

Yamuna Basin (10 Daily)
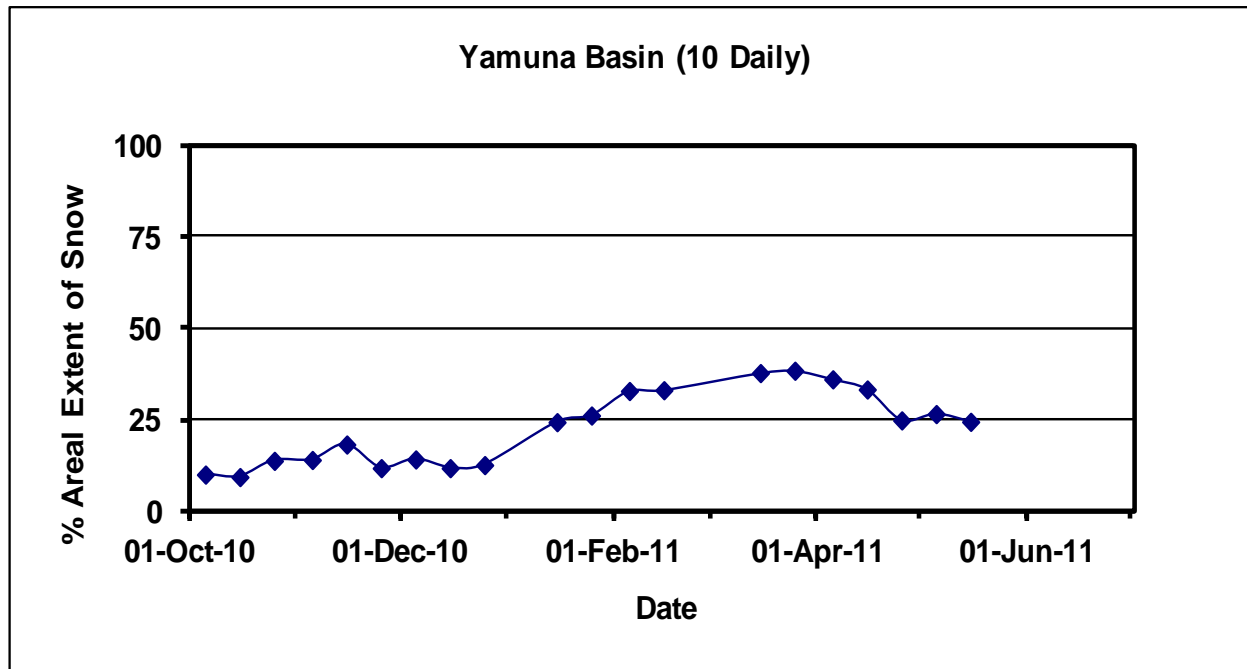
SNOW COVER MAP

SNOW COVER MAP   :   YAMUNA BASIN

CLOUDY DATA
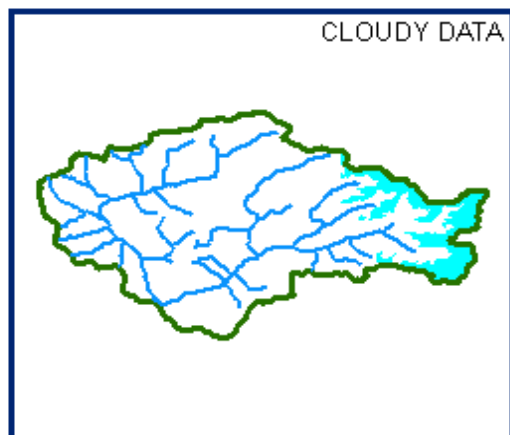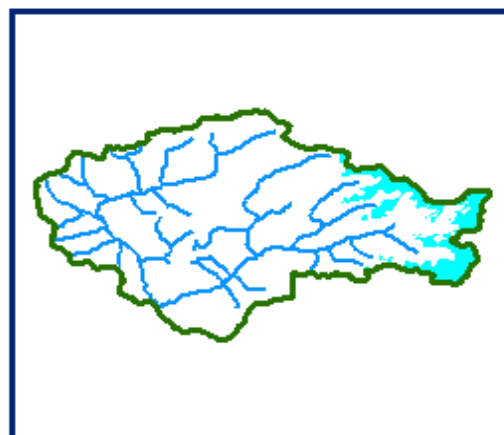
03 OCTOBER 2010
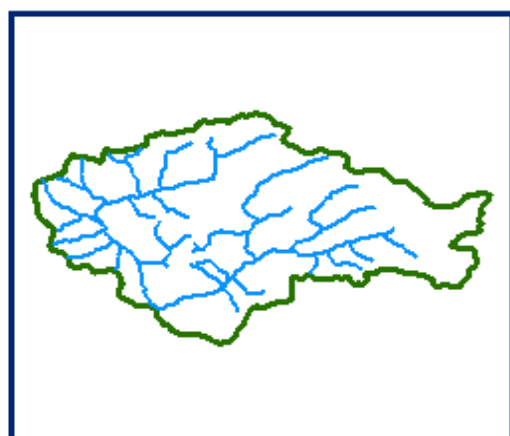
08 OCTOBER 2010

DATA NOT AVAILABLE
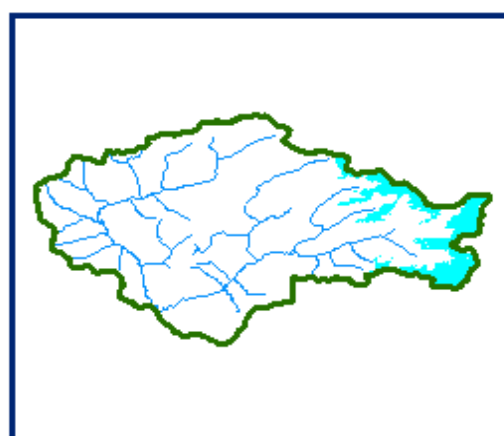
18 OCTOBER 2010
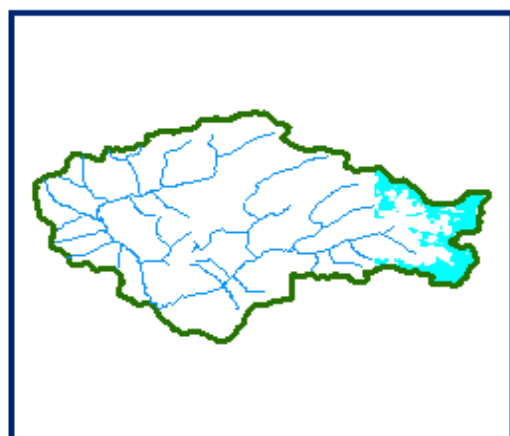
23 OCTOBER 2010
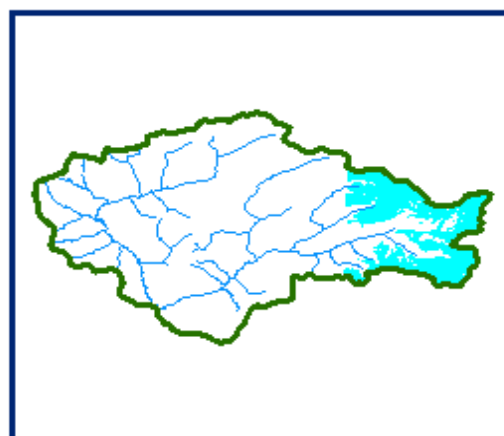
27 OCTOBER 2010

SNOW

0   15   30   60   90   120

Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN
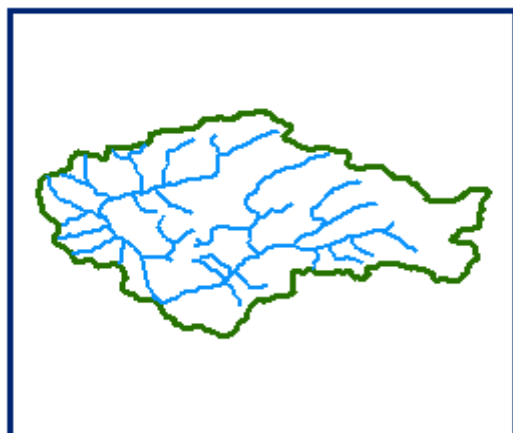
DATA USED
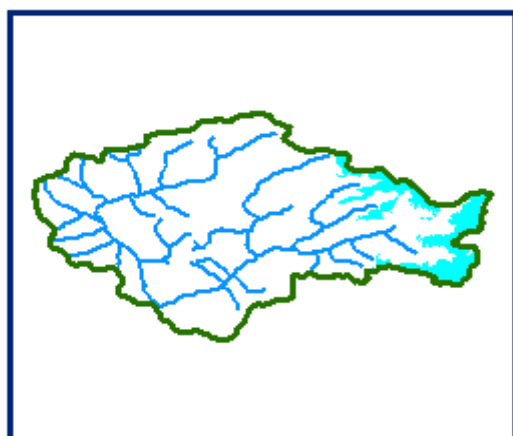
DATA NOT AVAILABLE

DATA USED

18 OCTOBER 2010
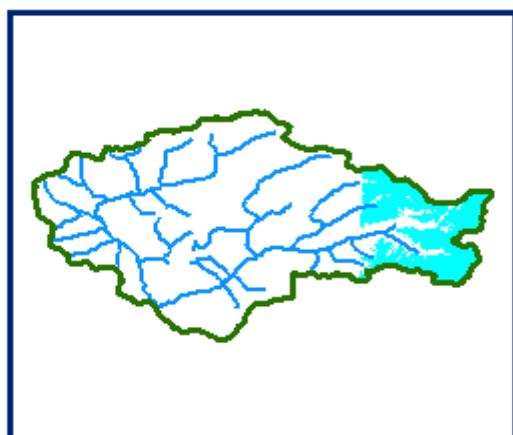
DATA USED

27 OCTOBER 2010

SNOW

```
0   15  30      60      90      120
```
Kilometers

SNOW COVER MAP   :   YAMUNA BASIN
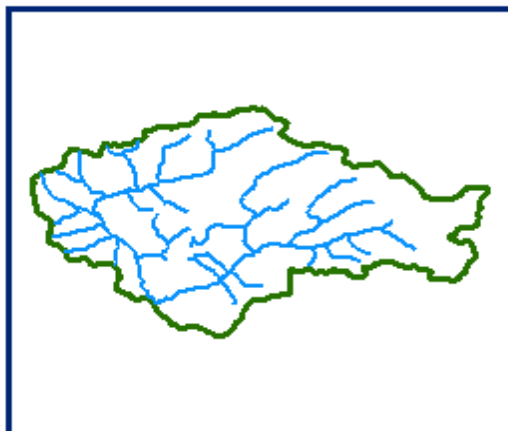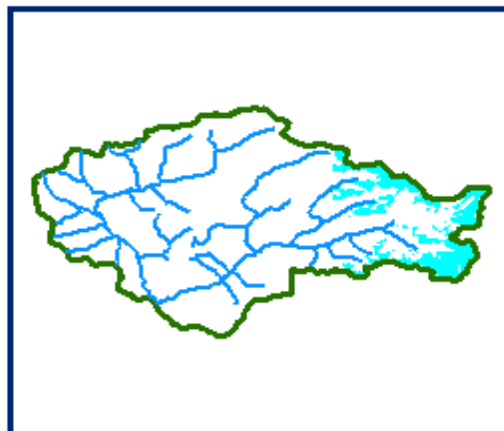
DATA NOT AVAILABLE
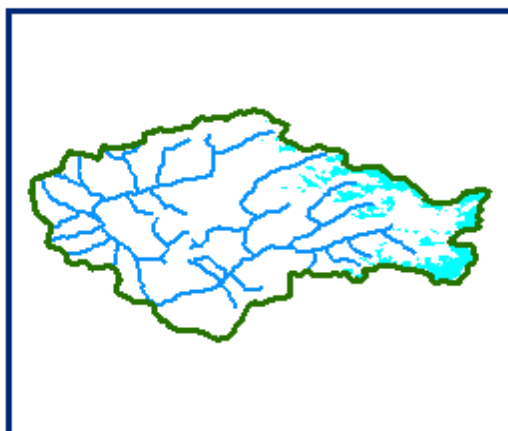
06 NOVEMBER 2010

15 NOVEMBER 2010
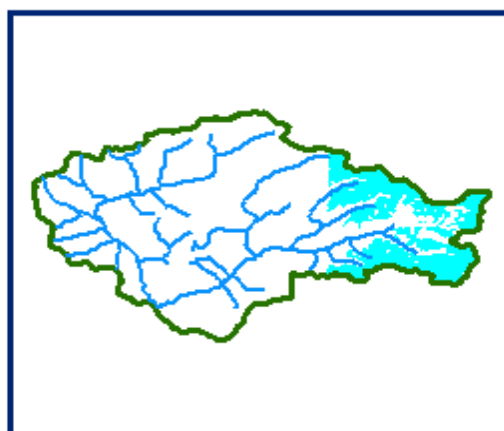
20 NOVEMBER 2010
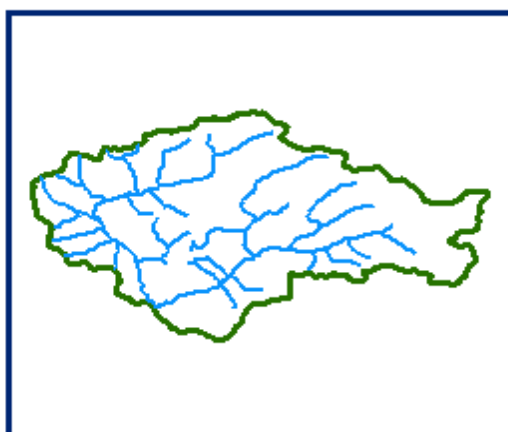
DATA NOT AVAILABLE

30 NOVEMBER 2010

SNOW

0   15   30   60   90   120

Kilometers
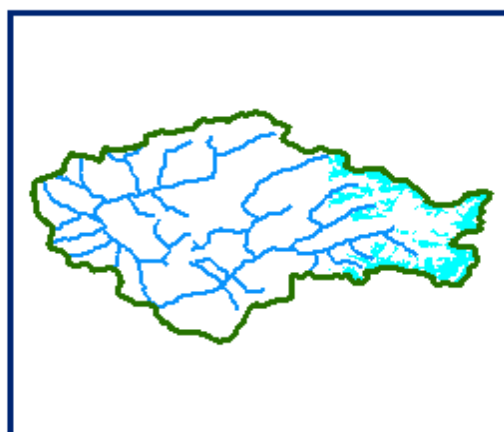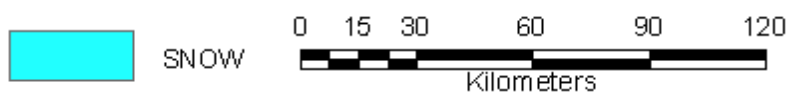
10 DAILY SNOW COVER MAP: YAMUNA BASIN
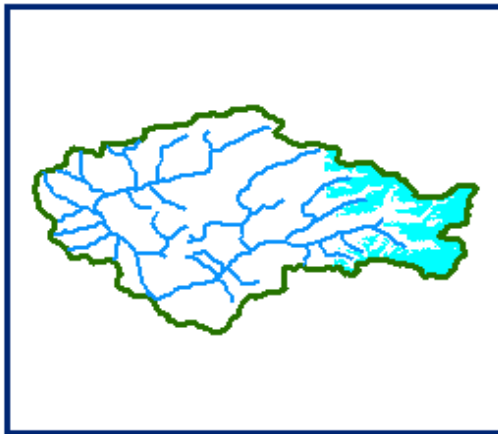
DATA USED
**06 NOVEMBER 2010**
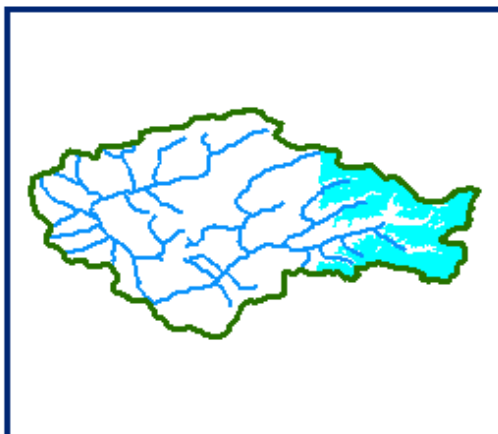
DATA USED
20 NOVEMBER 2010
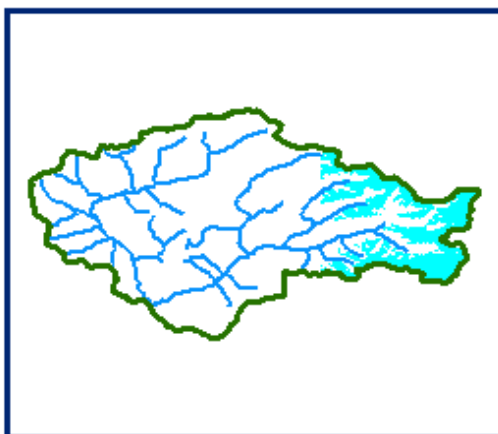
DATA USED
30 NOVEMBER 2010

SNOW

0   15   30   60   90   120

Kilometers

SNOW COVER MAP : YAMUNA BASIN

CLOUDY DATA

5 DECEMBER 2010

CLOUDY DATA
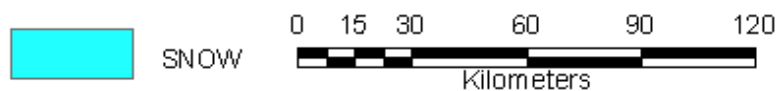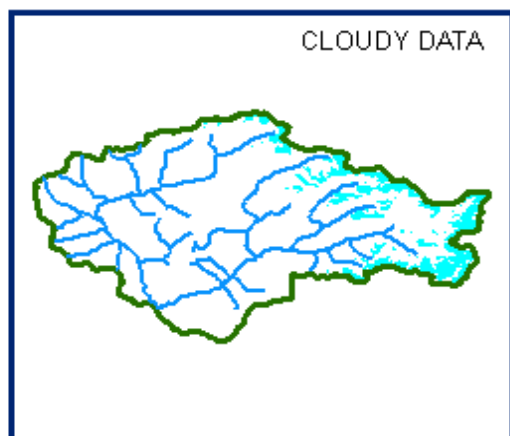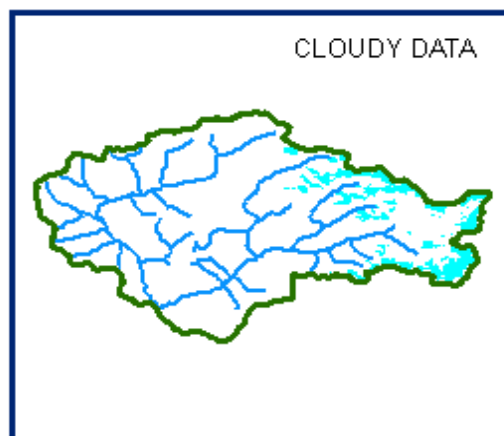
9 DECEMBER 2010

14 DECEMBER 2010
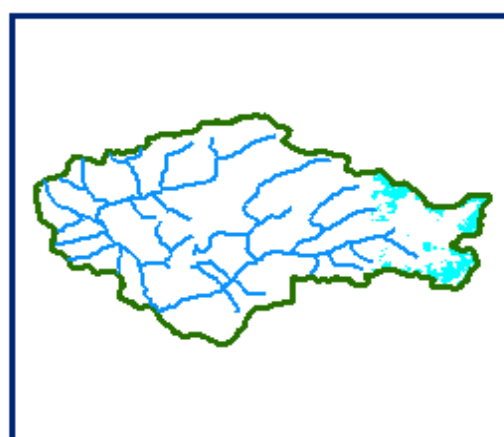
19 DECEMBER 2010
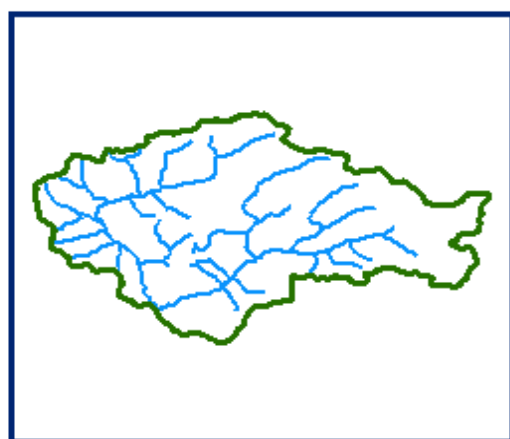
DATA NOT AVAILABLE

DATA NOT AVAILABLE

SNOW

0 15 30 60 90 120

Kilometers
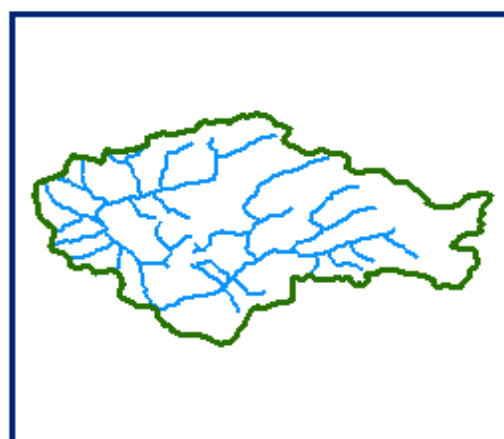
10 DAILY SNOW COVER MAP: YAMUNA BASIN
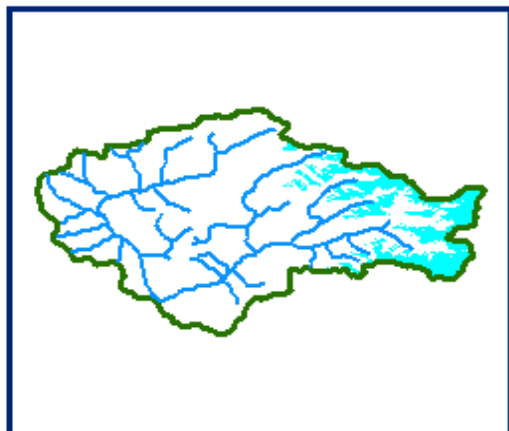
DATA USED
09 DECEMBER 2010
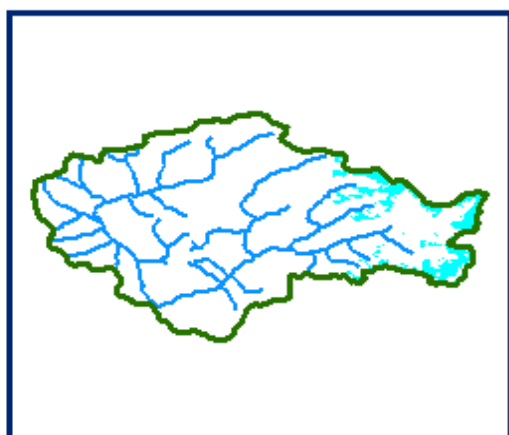
DATA USED
19 DECEMBER 2010

DATA USED
24 DECEMBER 2010

SNOW

| 0 | 15 | 30 | 60 | 90 | 120 |
Kilometers
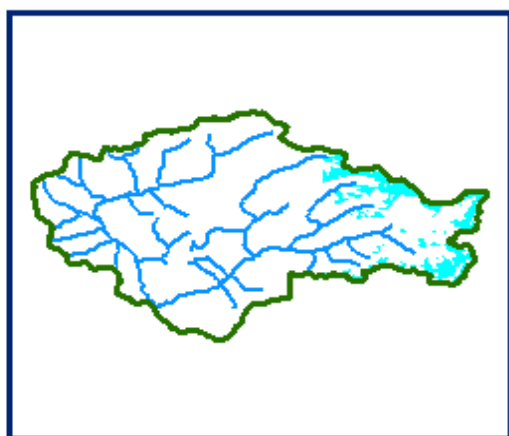
SNOW COVER MAP : YAMUNA BASIN
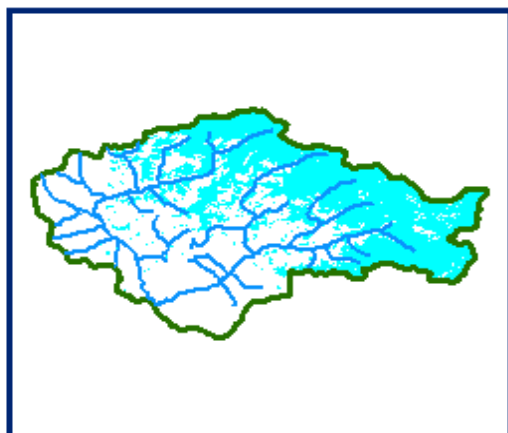
03 JANUARY 2011
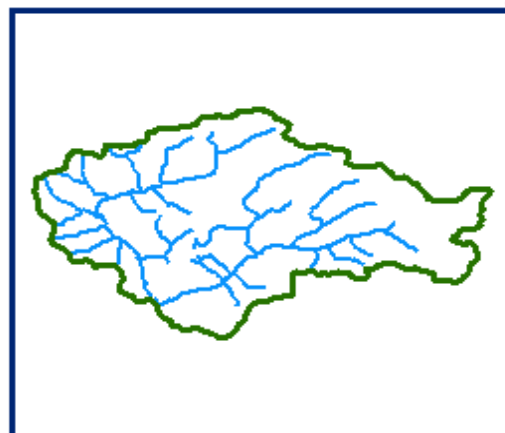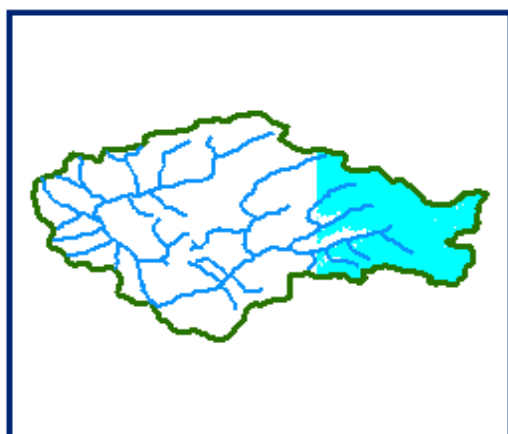
DATA NOT AVAILABLE

12 JANUARY 2011
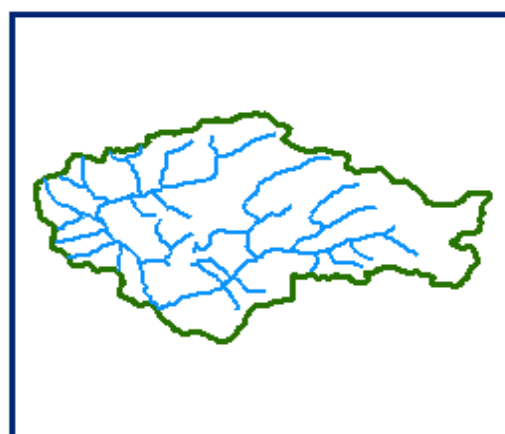
DATA NOT AVAILABLE

CLOUDY DATA

CLOUDY DATA

22 JANUARY 2011

26 JANUARY 2011

SNOW

0   15   30   60   90   120

Kilometers
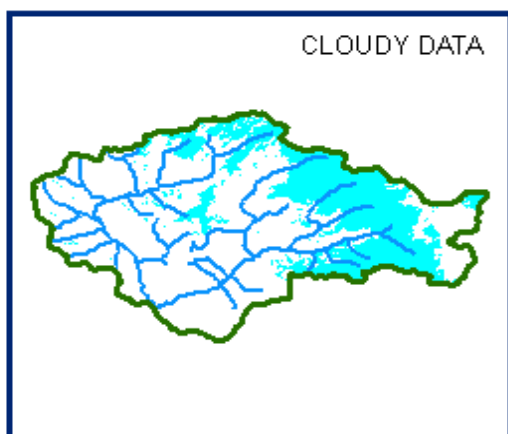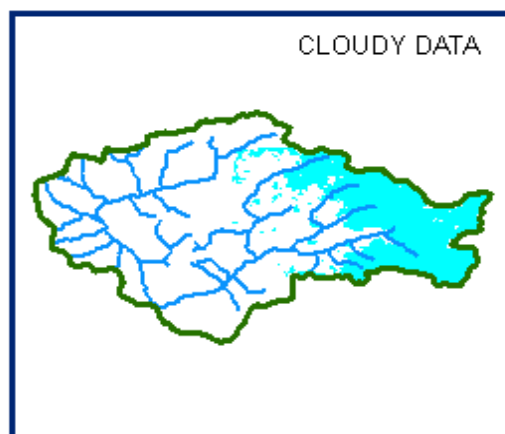
10 DAILY SNOW COVER MAP: YAMUNA BASIN
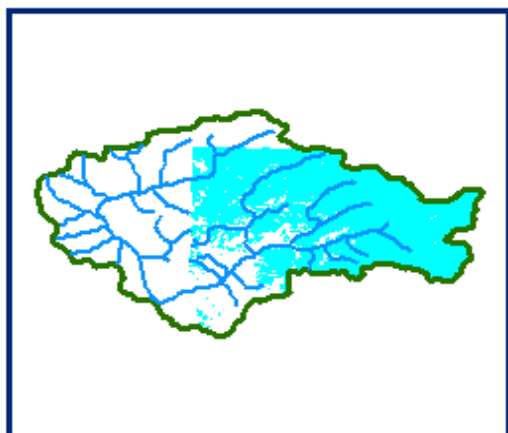
DATA USED
02 JANUARY 2011

DATA USED
12 JANUARY 2011

DATA USED
22 JANUARY 2011

SNOW

0   15   30   60   90   120

Kilometers
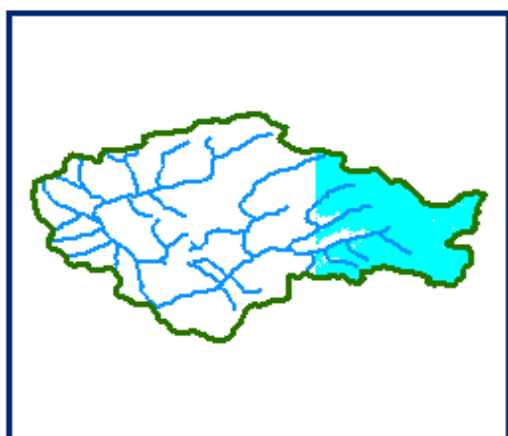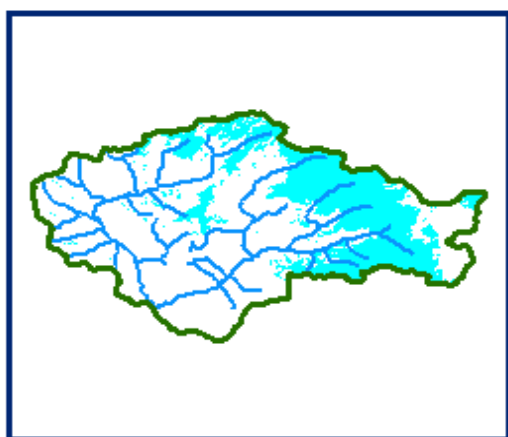
SNOW COVER MAP : YAMUNA BASIN

01 FEBRUARY 2011
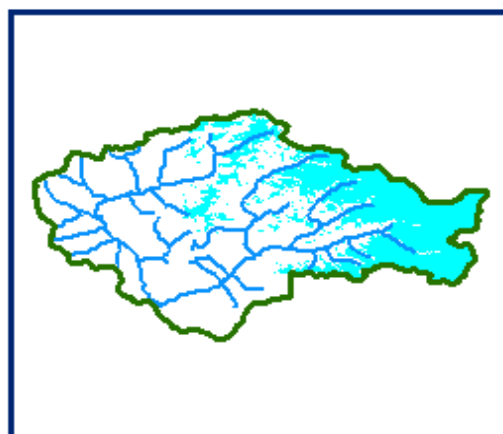
05 FEBRUARY 2011
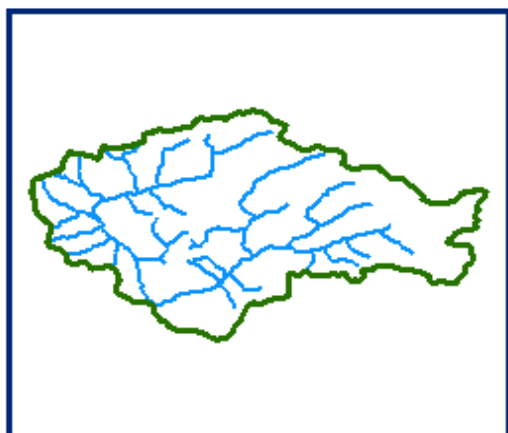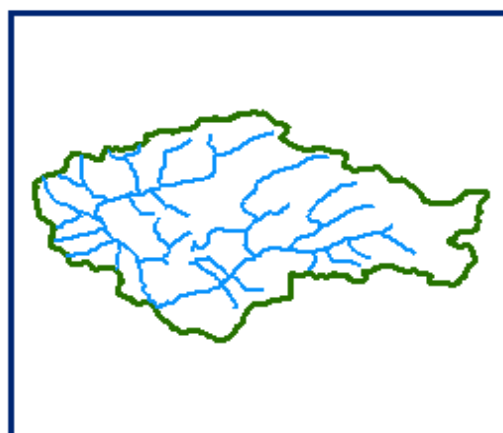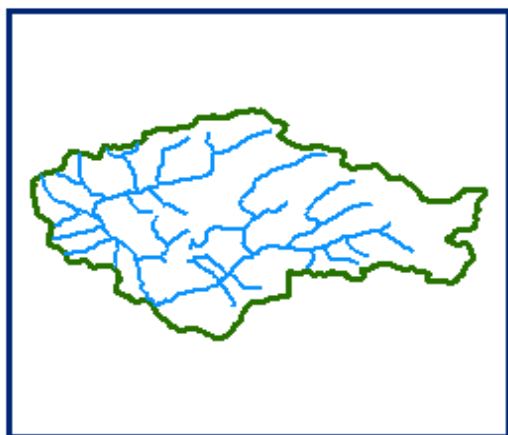
DATA NOT AVAILABLE

DATA NOT AVAILABLE

DATA NOT AVAILABLE

DATA NOT AVAILABLE

SNOW

0 15 30   60   90   120
Kilometers
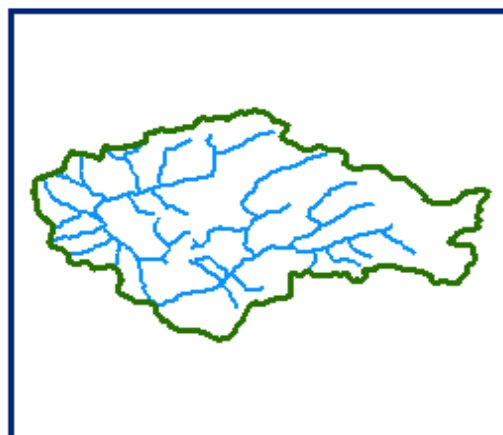
10 DAILY SNOW COVER MAP: YAMUNA BASIN
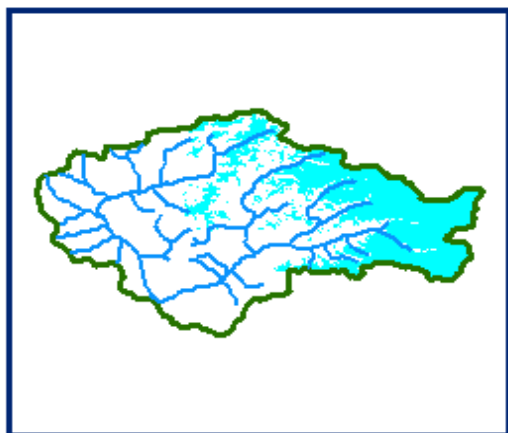
DATA USED
05 FEBRUARY 2011
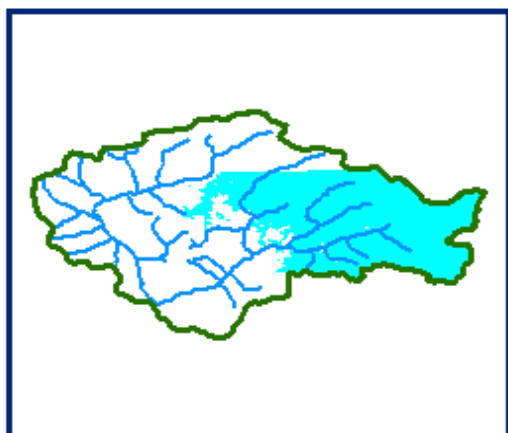
DATA USED
19 FEBRUARY 2011
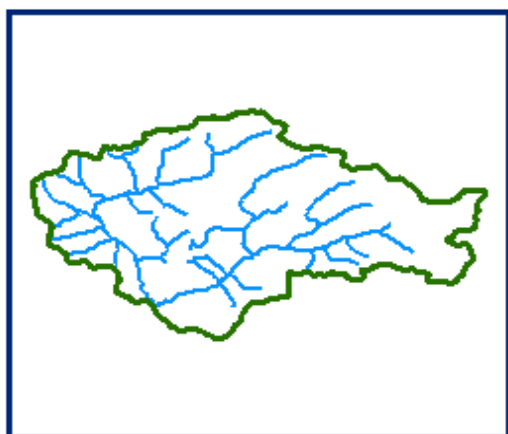
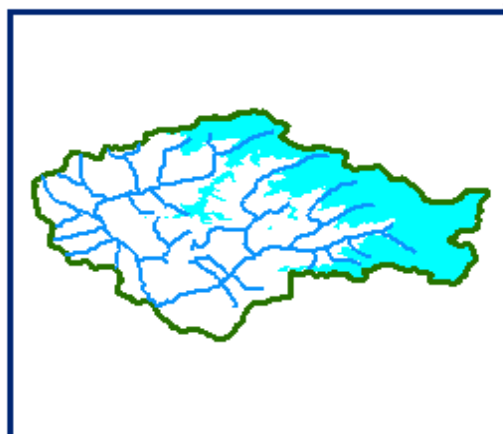DATA USED
DATA NOT AVAILABLE

SNOW

0   15   30   60   90   120
Kilometers

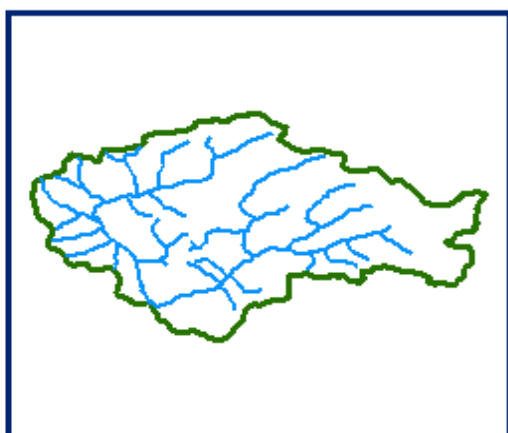SNOW COVER MAP : YAMUNA BASIN
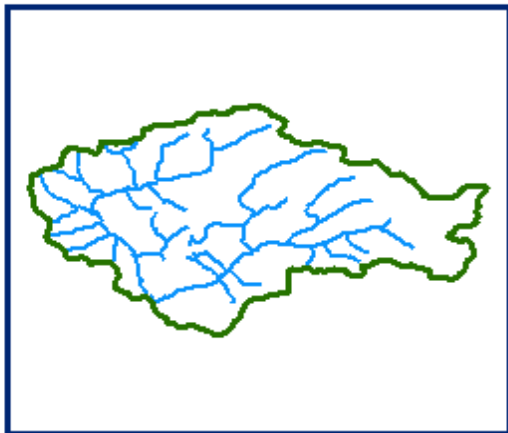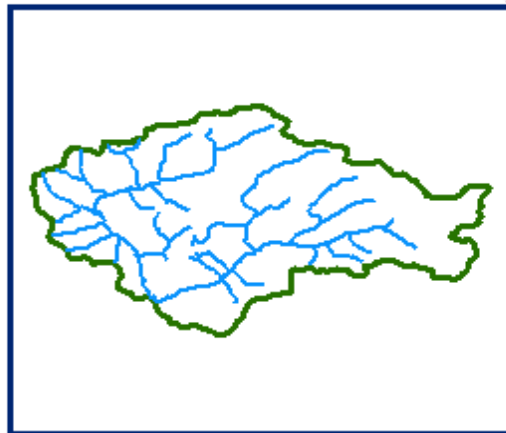
DATA NOT AVAILABLE
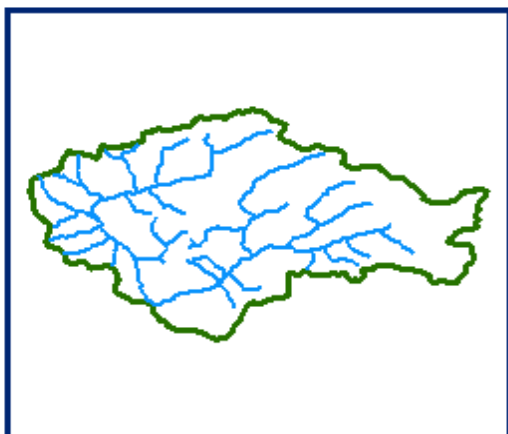
DATA NOT AVILABLE
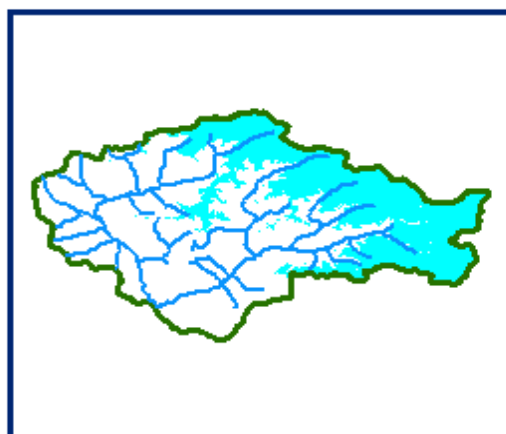
DATA NOT AVAILABLE

16 MARCH 2011

25 MARCH 2011
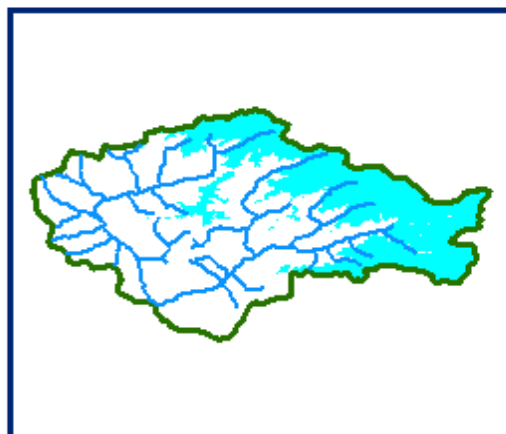
30 MARCH 2011

SNOW

0   15   30   60   90   120
Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN
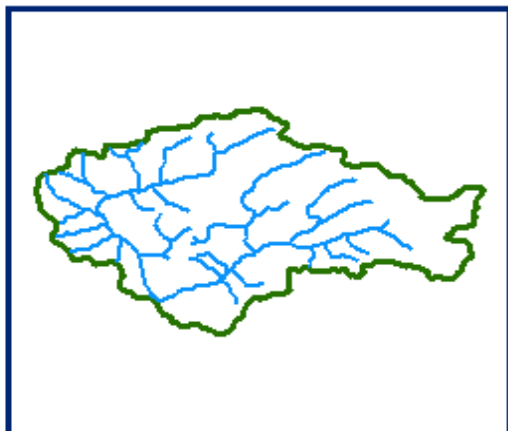
DATA USED
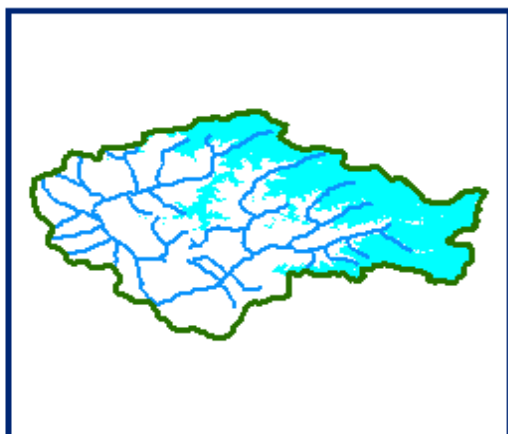
DATA NOT AVAILABLE

DATA USED
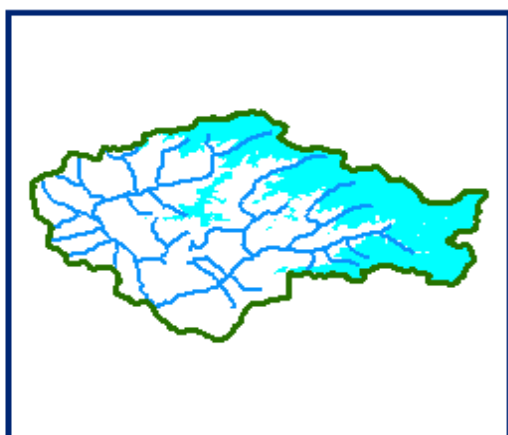
16 MARCH 2011

DATA USED

25 MARCH 2011

SNOW

0   15   30   60   90   120

Kilometers

SNOW COVER MAP : YAMUNA BASIN
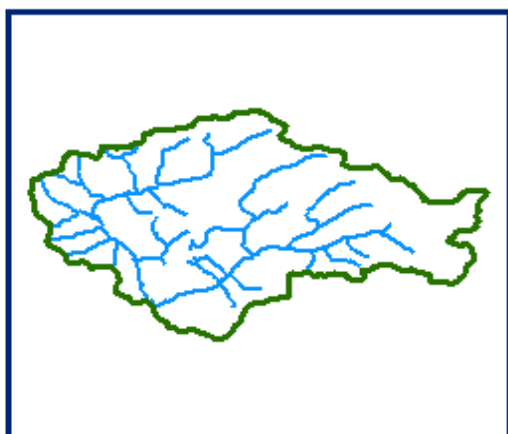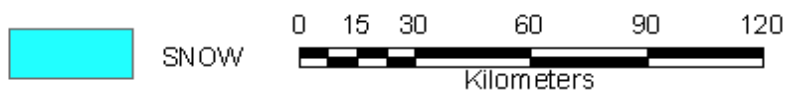
DATA NOT AVAILABLE

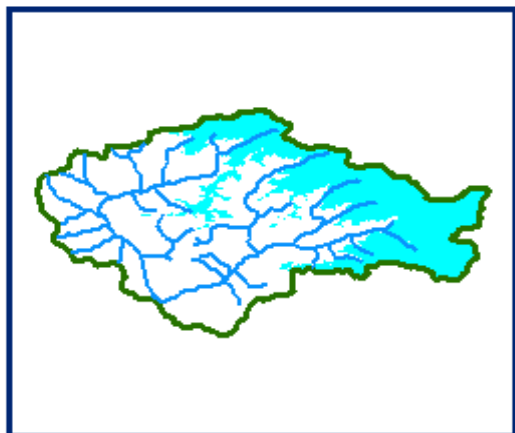9 APRIL 2011

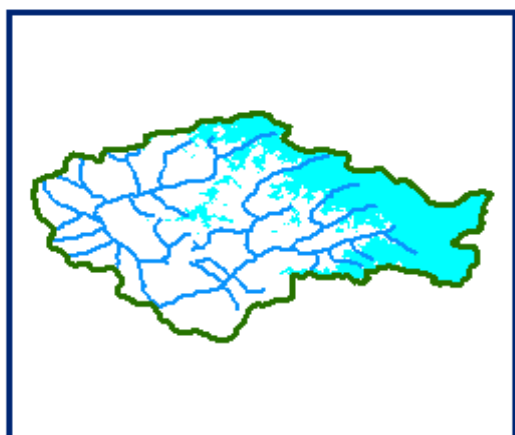DATA NOT AVAILABLE

18 APRIL 2011

23 APRIL 2011

28 APRIL 2006

SNOW

0   15   30   60   90   120
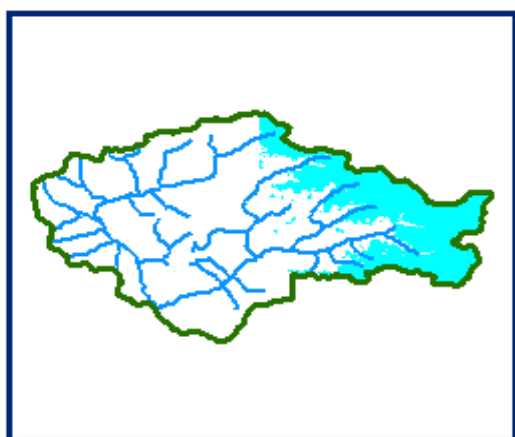Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN
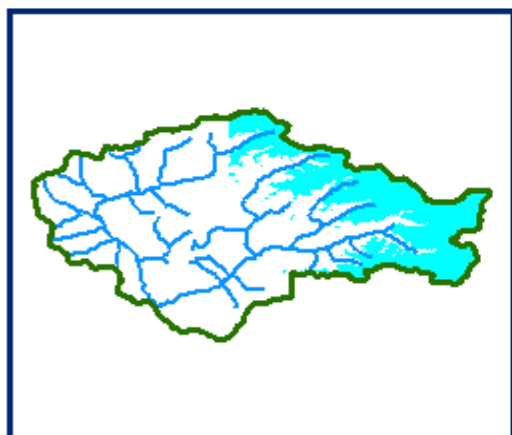

DATA USED
09 APRIL 2011

DATA USED
18 APRIL 2011

DATA USED
28 APRIL 2011

SNOW

```
0    15   30        60        90        120
                                          Kilometers
```
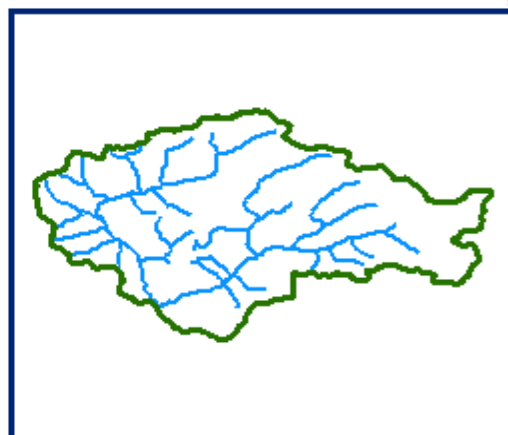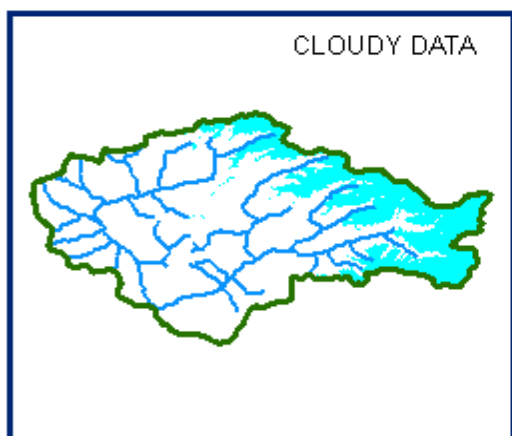
66

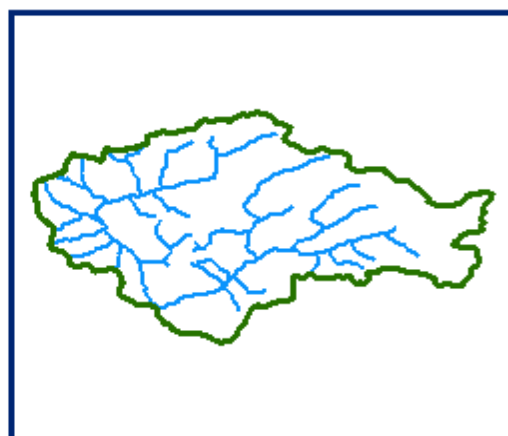**SNOW COVER MAP : YAMUNA BASIN**

03 MAY 2011
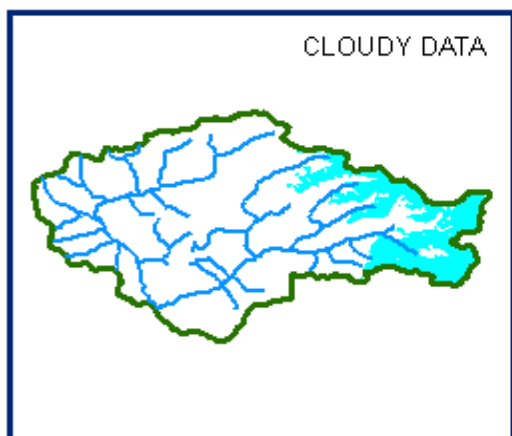
DATA NOT AVAILABLE

CLOUDY DATA

12 MAY 2011

CLOUDY DATA

17 MAY 2011

CLOUDY DATA

22 MAY 2011

DATA NOT AVAILABLE

SNOW
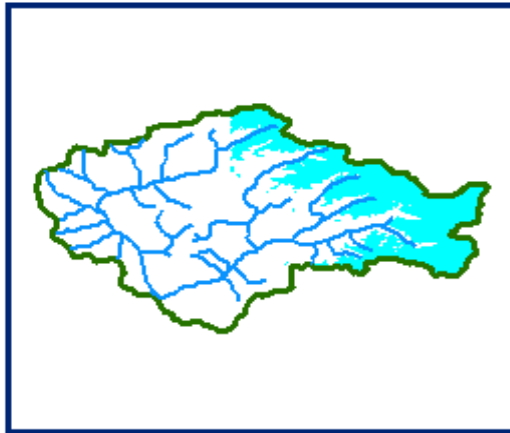
0 15 30   60   90   120
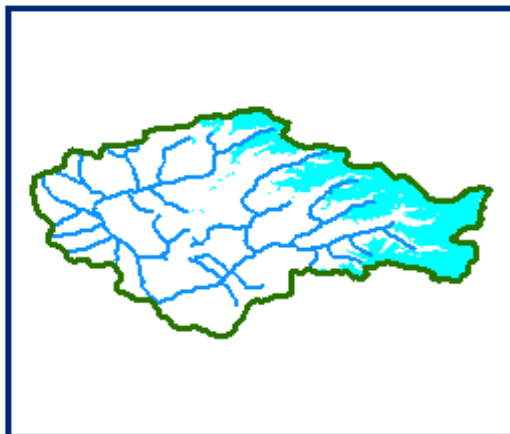
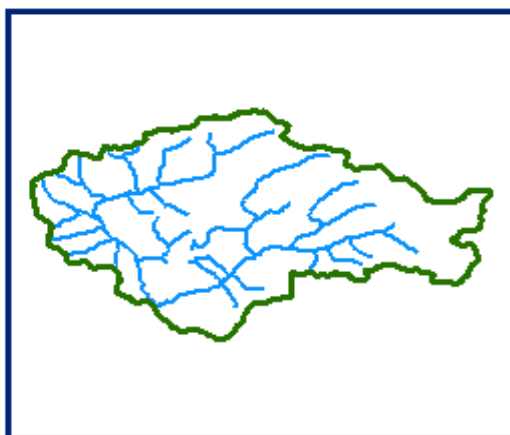Kilometers

10 DAILY SNOW COVER MAP: YAMUNA BASIN

DATA USED
03 MAY 2011

DATA USED
12 MAY 2011

DATA USED
DATA NOT AVAILABLE

SNOW

0   15   30   60   90   120

Kilometers