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Snow Accumulation and Depletion Pattern of an Eastern Himalayan River Basin

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***Abstract*—Accumulation and ablation pattern of seasonal snow are important variables in snow hydrological studies. For any snow-dominated catchment, snow accumulation and ablation patterns vary with elevation zones. The present study deals with the zone specific average snow accumulation and ablation pattern of a snow covered river basin in Eastern Himalayan region. The satellite images (AWiFS/LISS-III) of the selected basin for the accumulation as well as ablation period (October – June) were obtained from National Remote Sensing Centre (NRSC), ISRO, Hyderabad, India. GIS software, ArcGIS and ERDAS were used to determine snow covered area (SCA) percentages of different elevation zones by using NDSI model.**

***Keywords*—Eastern Himalayan region, LISS III/AWiFS, Normalized Snow Difference Index (NDSI), Snow Depletion Curve (SDC), Snow Covered Area Percentage (SCA).**

I. INTRODUCTION

In mountain snow basins, seasonal snow cover extent is changed due to change in climate. Hydrological models are now increasingly used for predicting the climate affected runoff. Derivation of a quantitative estimate of the snow cover can estimate snowmelt runoff. The snow coverage is the main input variable for the wide variety of snowmelt runoff models. Readily available estimates of snowmelt runoff for a variety of climate change scenarios will support the planning of water management and the use of water resources, i.e. water power generation, irrigation and drinking water supply. Martinec and Rango (1989)employed a method to simulate the changed hydrological regime in mountain basins for any climatic change involving air temperature and precipitation.Rango and Martinec (1994) showed that in mountain snow basins, a change in climate will likely cause a change in the basin snow cover extent.

Snow cover depletion curve (SDC) indicates the snow coverage on each day of the melt and are commonly obtained by interpolating percentages of snow cover area for dates when cloud-free scenes are available. For preparation of snow cover depletion curve from snow cover extent, remote sensing and geographic information system (GIS) are used. Using remote sensing and GIS, snow covered percentage ofan area can be determined which is the maininput for preparation of SDC. Satellite remote sensing data are particularly well accepted for monitoring the snow-covered area over continuous space–time scales compared to the conventional in situ snow measurements. For measuring and observing snow cover, nowadays variety of space borne sensors with various spectral, spatial, and temporal resolutions are available that satisfactorily satisfy the needs of climatologists and hydrologists.

Gupta *et al*. (1982) has chosen the River Beas, in the northwestern part of India, to study the relation between snow-cover area and snowmelt runoff. Snow-cover area was mapped from the LANDSAT images for a number of years in various sub-catchments. Seidel *et al.* (1994) carried out seasonal and short-term runoff forecasts for two hydroelectric stations in the upper Rhine basin based on snow cover monitoring by Landsat and SPOT

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satellites. Kulkarni *et al.* (2006)showed that the NDSI value increases from 0 to 1. But the amount of change varies from constant to rapid. In the case of AWiFS scene in winter, a constant drop in area in the order of 3% was observed as threshold value changes from 0 to 0.4. After a threshold of 0.4, the drop in area (snow pixels) is moderate to rapid. Visual analysis suggests that all snow cover areas, including snow in forest and in mountain shadow, can be mapped if the threshold value is 0.4.

Negi*et al.* (2009) used a technique based on NDSI with vegetation information and NIR band reflectance for snow cover distribution in the Beas basin consisting of rugged terrain; snow under forest; and contaminated snow and patchy snow. A significant variation was observed between satellite estimated reflectance and field observed reflectance using spectra-radiometer due to topographic conditions, however, no variations were observed in the estimated NDSI values. Different methods based upon snow indices were attempted to find suitable index for mapping of snow cover and NDSI estimated using planetary reflectance was found the suitable index method. The present study has been undertaken to understand the average accumulation and depletion pattern in different elevation zones of a snow-covered river basin in Eastern Himalayan region.

II. METHODOLOGY

A. Study Area and Data Acquisition

Nuranang river basin (Fig. 1) with an area of 52 km^2 was selected as the study area. It is located at West Kameng district of Arunachal Pradesh, India. Nuranang River originates from Sela Lake and joins Tawang River as Nuranang fall at Jang. The altitude of the Sela lake is 4211 m above mean sea level (MSL) and it lies at 27^o 30’ 09” N and 92^o 06’ 17” E. Elevation of the basin ranges from 3143 m to 4946 m above MSL with an average slope of 51%. At upper elevation, climate is Alpine and at lower elevation, it is Temperate. Latitude ranges from 27°30’ N to 27°35’N, whereas longitude is in between 92° E – 92°7’ E. The entire basin is dominated by seasonal snow. Snow starts accumulating from October and ends at March. Melting of snow starts at February and completely depleted in June. Snow accumulation and ablation periods vary with years. Satellite images (LISS-III/AWiFS) for the five block periods (2005-06, 2006-07, 2008-09, 2009-10 and 2010-11) of snow accumulation and ablation (October to June) have been procured from National Remote Sensing Centre (NRSC), ISRO, Hyderabad, India. Digital Elevation Model (DEM) for the study area (3143-4946 m) was downloaded from (http://gisdatadepot.com/dem) (Fig. 1).

B. Snow Cover Mapping of Different Elevation Zones

Snow covered area (SCA) percentage is referred as the areal extent of snow-covered ground which is usually expressed as percentage of total area in a given region.The snow water equivalent (SWE) of the snowpack is important for hydrological modelling and runoff prediction. Snowmelt plays a major role in seasonal energy exchanges between the atmosphere and ground, affecting soil moisture and runoff, and thereby water resources. Snowfall as a fraction of total precipitation is important in hydro-climatic models and in monitoring climate change. The SCA percentage was estimated using GIS software: ERDAS and ArcGIS. In Himalayas, cloud cover is quite common. In the visible portion of the electromagnetic spectrum, snow and cloud, both appear bright white and create confusion in snow cover area estimation.

Mountain shadow also makes it difficult for the discrimination of snow covered areas under mountain shadow from snow free areas.

The normalized difference snow index (NDSI) is useful for the identification of snow as well as for separating snow from clouds. NDSI uses the high and low reflectance of snow in visible (Green) and shortwave infrared (SWIR) bands respectively and it can also delineate and map the snow in mountain shadows (Kulkarni et al 2002). Additionally, the reflectance of clouds remains high in SWIR band, thus NDSI allows discrimination of clouds from snow. NDSI ranges from −1 to +1. The NDSI was estimated using the following equation (Hall et al. 2002).

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$$\text{NDSI} = \frac{\text{Green Reflectance (B2)} - \text{SWIR (B5)}}{\text{Green Reflectance (B2)} + \text{SWIR (B5)}} \qquad (1)$$

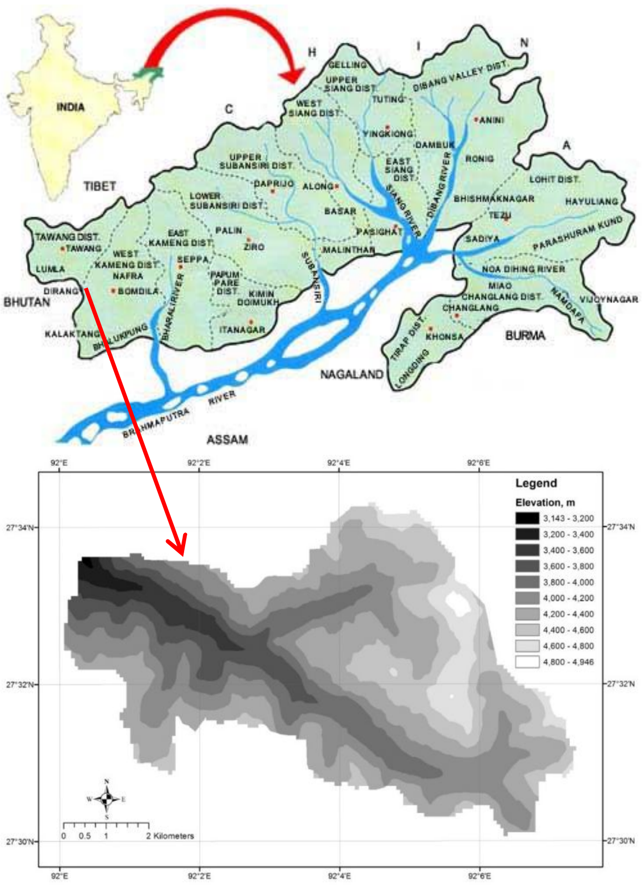

Fig. 1 Nuranang river basin, Arunachal Pradesh, India

NDSI value increases from 0 to 1. In the case of AWiFS scene in winter, a constant drop in area in the order of 3% is observed as threshold value changes from 0 to 0.4. After a threshold of 0.4, the drop in area (snow pixels) is moderate to rapid. (Kulkarni et al, 2006). An NDSI model was coded in ERDAS for discrimination of snow and cloud from the main imagery data of the study area (Fig. 2). The coding is based on the flowchart given by Kulkarni et al. (2006).In the NDSI model, the geo-rectified image was used as the input file. On execution of the model, the image obtained by 10 bit sensor is rescaled to 8 bit float image. In the next step, the DN value of each band is converted into radiance value. Further, the radiance value is converted into reflectance. In the end of the process, the NDSI image is obtained by executing the Eqn. 1. NDSI value greater than 0.4 was taken as snow plus water.

The snow cover area (SCA) of the project site was estimated using ArcGIS software for the whole basin (3143-4946 m), zone 1 (3143-3744 m), zone 2 (3744-4345) and zone 3 (4345-4946 m) using DEM images (Fig. 3) for

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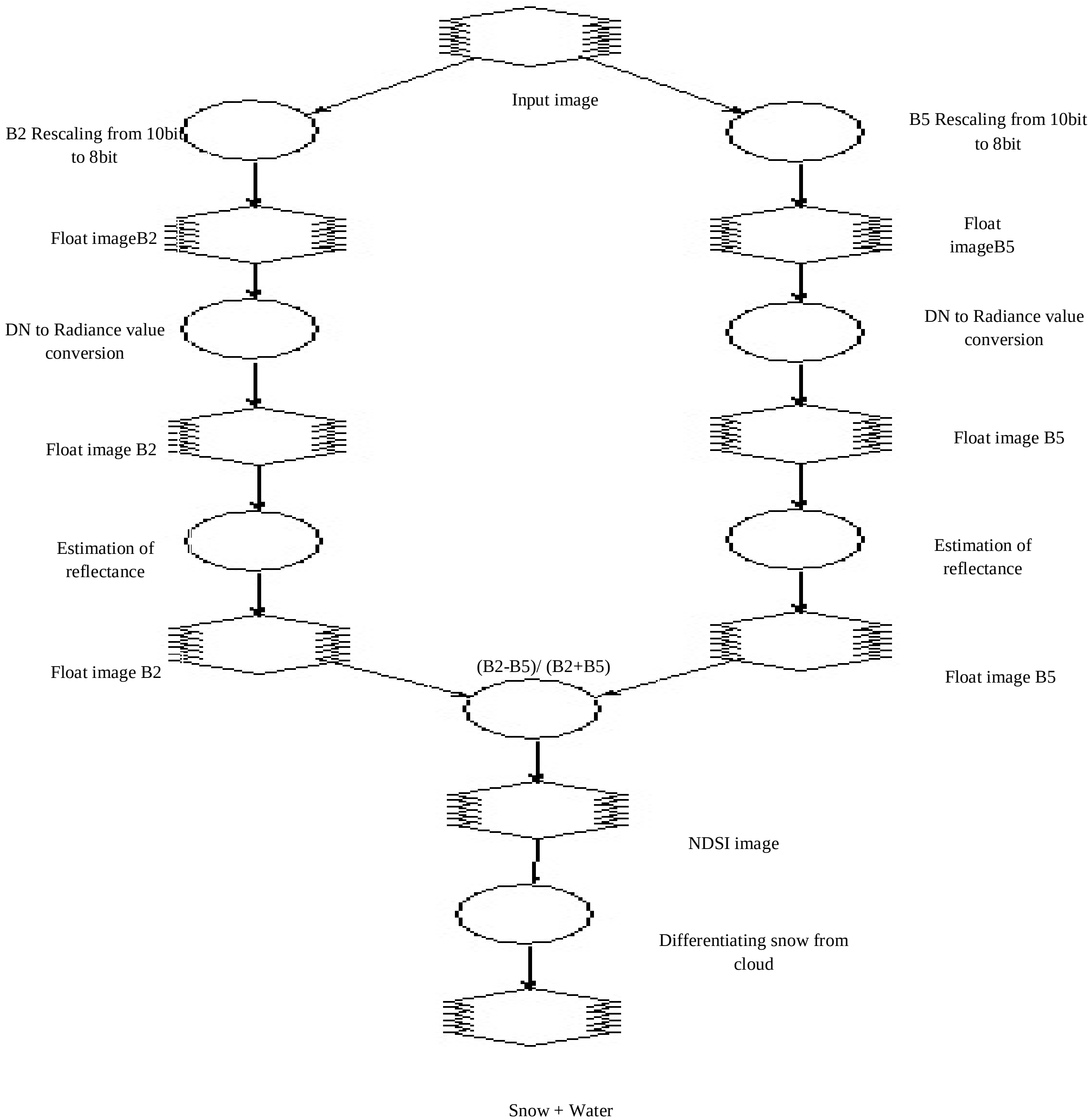

Fig. 2 NDSI Model

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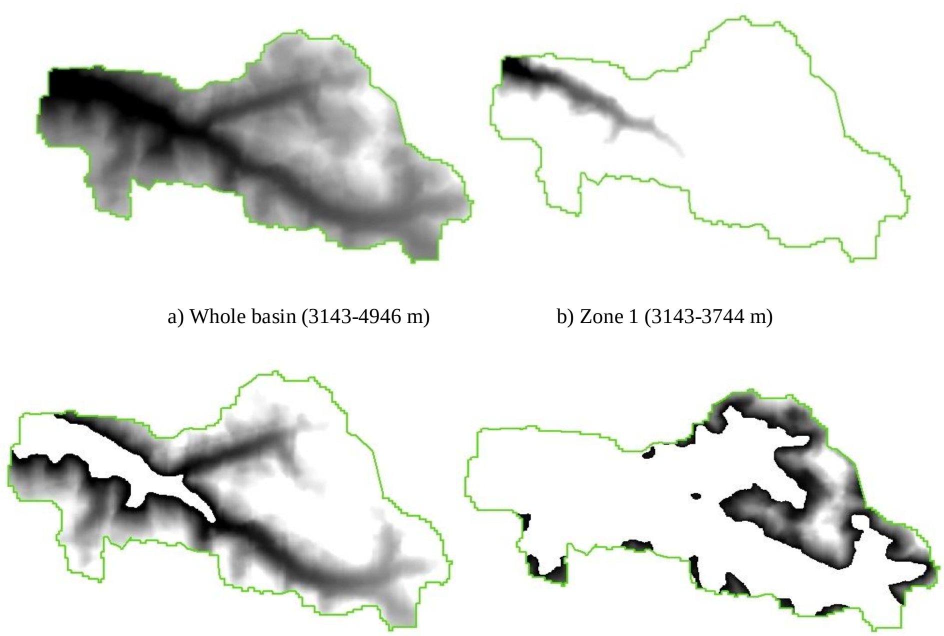
the corresponding zone by masking the DEMs in the NDSI images. Accumulation and ablation patterns of each elevation zones were obtained for each block years from snow cover area percentages.

III. Results and Discussion

A. Accumulation and depletion pattern of different elevation zones

From NDSI images, variations of snow cover percentages in accumulation as well as ablation months (Oct.-June)have been determined for block years of 2005-06, 2006-07, 2008-09, 2009-10 and 2010-11 for whole basin as well as different elevation zones (Fig. 4).In most of the block periods, two peaks have been observed while snow cover percentages are plotted against month (October to June) (Fig. 4). First peak is around November- January and Second peak is larger than first one and around March – April. Fig 5 shows the average depletion curves for whole



a) Whole basin (3143-4946 m) b) Zone 1 (3143-3744 m)

c) Zone 2 (3744-4345 m) d) Zone 3 (4345-4946 m)

Fig. 3 Digital elevation model for different elevation zones

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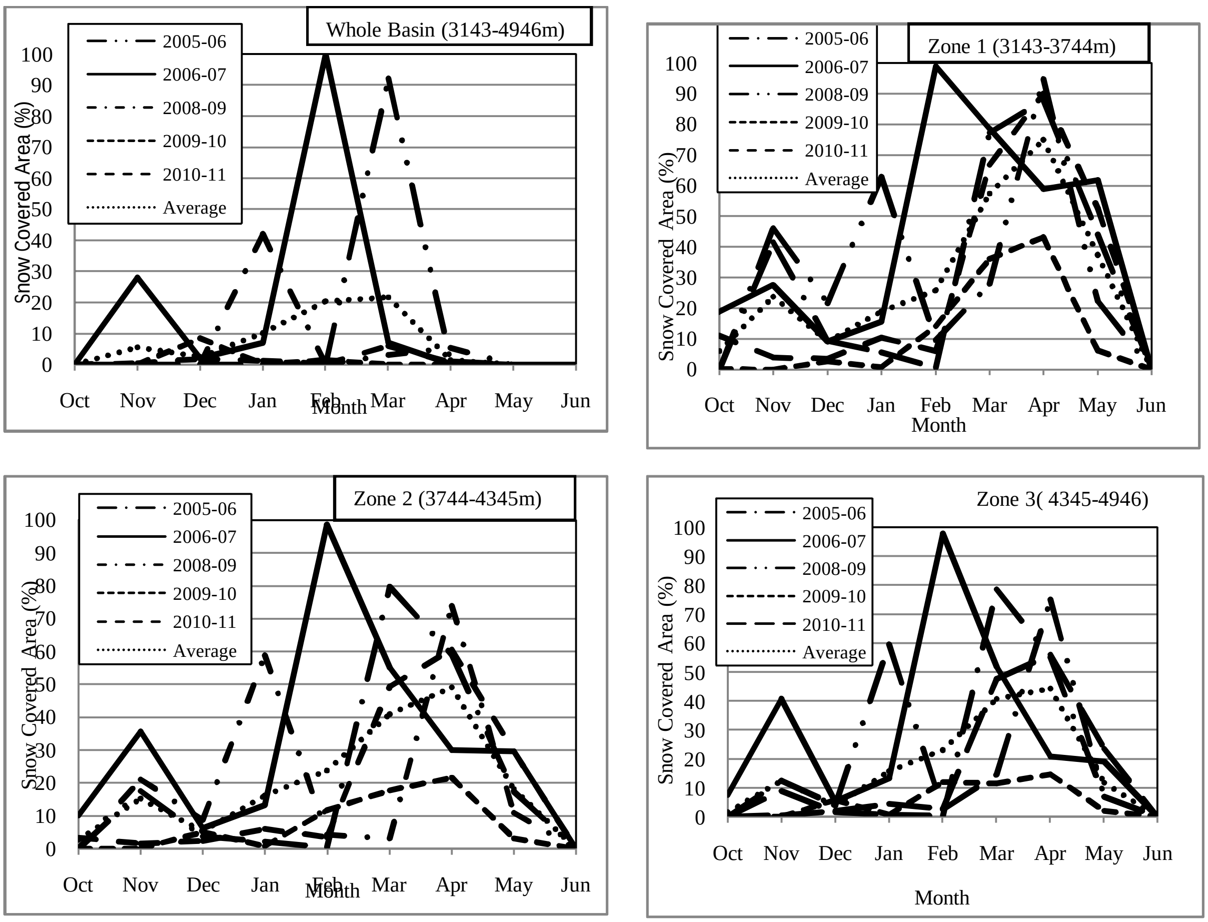

Fig. 4 Accumulation and depletion patterns for different zones

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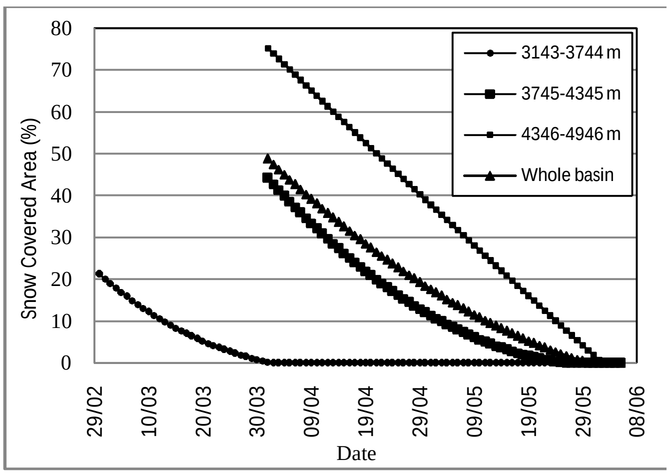

Fig. 5 Average depletion curves for different elevation zones

basin and different elevation zones. From Fig. 5 and Table 1, it can be noticed that, snow cover area percentage is highest in upper elevation zone and lowest in lower elevation zone. Average depletion curve for middle zone and whole basin lie in between average curves for upper and lower elevation zones. In lower elevation zone, depletion starts early, in the month of March; while for other elevation bands and whole basin, depletion start in the month of April.

IV. CONCLUSION

The temporal variation of snow coverage at different elevation zones in the Nuranang Basin of Eastern Himalayan region was successfully evaluated using remotely sensed satellite imagery of the LISS-III/AWiFS and GIS techniques. Snow accumulation and depletion pattern of the basin depends on the temperature variation of the basin. During winter months, average temperature initially decreases in the month of October/November but then increases in the month of December/January. Again temperature decreases during February/March. Variations of snow cover area percentages for individual block years also follow this unique trend as temperature. Average snow accumulation and depletion pattern of whole basin shows two distinct peaks: smaller peak is in the month of November and larger one in April.

Table 1. Average depletion pattern for different elevation zones

Elevation zone	Area, sq. km	Max. SCA (%)	Depletion starts
Zone 1 (3143 – 3744 m)	05.20	22	March
Zone 2 (3745 – 4345 m)	31.60	44	April
Zone 3 (4346 – 4946 m)	15.20	75	April
Whole basin (3143-4946 m)	52.00	49	April

REFERENCES

[1] Gupta, R.P., Duggal, A. J., Rao S. N., Sankar G., and Singhal, B. B. S. 1982 Snow cover area vs. snowmelt runoff relations and its dependence on geomorphology-a study from Beas catchment (Himalayas India). *Journal of Hydrology*, 58: 325–339.

[2] Hall, D.K., Riggs. G.A., Salamonson, V.V., DiGirolano, N. and Bayr, K.J. 2002 ModisSnowcover Products. *Remote Sensing Environmen*, 83: 181-194.

[3] Kulkarani, A. V., Srinivasulu, J., Manjul, S.S. and Mathur, P. 2002b Field based spectral reflectance to develop NDSI method for snow cover. *Journal of the Indian Soceity of Remote Sensing*, 30(1&2): 73-80.

[4] Kulkarani, A.V., Singh, S.K., Mathur, P. and Mishra, V.D. 2006 Algorithm to monitor snow cover using AWiFS data of RESOURCESAT-1 for the Himalayan Region. *International Journal of Remote Sensing*, 27(12): 2449-2457.

[5]Martinec, J. and Rango, A. 1989 Effects of climate change on snowmelts runoff patterns, remote sensing and large scale global processes. *In: Proc. Of the Battimore Symposium*, IAHS Publ. no. 186: 31-38.

[6] Negi, H.S., Kulkarani, A.V. and Semwal, B.S. 2009 Estimation of snow cover distribution in Beas basin, Indian Himalaya using Satellite data and ground measurement. *Jouranl of Earth System Science*, 118 (5): 525-538.

[7]Rango, A. and Martinec, J. 1994. Areal extent of seasonal snow cover in a change climate. *Nordic Hydrology*, 25(4): 233-246.

[8] Seidel, K., Brusch, W. and Steinmeier C. 1994 Experiences from real time runoff forecasts by snow cover remote sensing. *Proceedings IGARSS, Surface and Atmospheric Remote Sensing: Technologies, data analysis and interpretation*, IEEE, 4:2090–2093.