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Integration of Remotely Sensed Data, Meteorological Parameters and Topographical Details in Snowmelt-Runoff Modelling

Anjani K. Tangri & Sudhakar Shukla
Remote Sensing Applications Centre, U.P.
Sector-G, Janaki Puram, Kursi Road, Lucknow (INDIA)

SUMMARY

The capability to predict the possible discharge from a predominently snow cover watershed goes a long way in helping in proper management of various water resources related projects. The discharge is in turn largely depended upon numerous variable parameters viz the spatial extent of snow cover areas, the meteorological parameters and the topographical details. These variable parameters interact & are in turn depended upon each other. The present paper attempts to integrat these principal components to arrive at a meaningful snow cover-runoff model. This has been attempted in Alaknanda & Dhauliganga river watersheds upstream of Vishnuprayag in Chamoli district of Uttar Pradesh.

Multidate data from space borne platforms provide a synoptic & repetative coverage of the study area. This has been the helping tool in understanding and monitoring the spatial extent of snow covered areas. Conventional field surveys have helped in collecting the numerous meteorological and hydrological parameters. These have been suplemented to a great extent by data received from IMD & CWC. Survey of India topographical sheets have helped in retriving the topographical details.

A distinctive interplay of the numerous parameters eloborated above has been noted. In the ultimate analysis the pre-emptive approach at integration of remotely sensed data meteorological parameters and topographical details seems paramount in snowmelt runoff modelling.

1.0 INTRODUCTION :

The global warming phenomenon typical of the initial stages of interglacial periods through which the planet earth is presently passing has a direct bearing on the spatial extents of the snow covered areas. This increased melting has had an important implication on the snow covered areas in the Himalayas as well. The discharges in major river systems emenating from the Himalayas, depends to a large extent on the amount of snow-melt in higher reaches. This in turn is dependent upon the climatic variations.

The influence of the meteorological parameters and topogra py on the spatial extent of snow cover governs the quautum of discharge result- ing there upon. Hence a preamtive approach at knowing the three inter- dependent variable parameters viz the snow cover, the meteorological para- meters & topography go a long way in helping in predicting the discharge. This assu mes immense importance in maximum exploitation, optimum utilisa- tion of water resources as also in proper management of all water resources related projects.

The present state of art of the space borne sensors provides a vital tool in acquiring the knowledge about the spat ial extent of the snow covered areas in the otherwise inhospi table & inaccessaable terrain of the Himalayas. An attempt is here made to integrate the remotely sensed data with the conventional meteorological parmeters and topo details in attemp ting to predict the snow melt runoff.

2.0 BACK DROP :

The snow pack characteristics i.e. the density, snow thickness & its quality have a direct bearing on snow water equivalent (SWE)

$$SWE = \int_{o}^{Z} \rho s \cdot A \cdot dz \text{ ....(i)}$$

Where ρs is the specific gravity of snow.
A is the Snow Spread.
dz is the change is snow thickness.

For a watershed having an area of more than 250 square kms the variation in snow thickness could be considered negligible For a constant density of snow mass, it could be assumed that the snow water equivalent is directly proportional to the snow covered areas. (Rango & Solomanson 1975).

The aerial extent of snow covered areas depends to a large extent upon the meteorological and topographical parameters. Hence a close interdependence between these parameters has a direct bearing on the discharge .

3.0 DATA SOURCE :

Keeping the above relationship in view it is imperative to assess the different variable parameters. The establishment of discharge monitoring station with facilities for proper moni- toring of the various hydrological parameters of the emenating streams as also the numerous meteorological parameters is para - mount. Simultaneously the meteorological parameters over long periods of times for several preceding years were collected from Indian Meteorological department. Similarly the Central Water Commission provided the discharge data.

The numerous remote sensing satellites in orbit for example the LANDSAT series & the IRS series of satellites provided a synoptic & repetitive coverage of the areas. This helped in monitoring the temporal variations in the over all snow spread in the study area. SOI toposheets provided the topographical details.

4.0 CASE STUDY :

In order to attempt assessing the influence and inter-dependance of various meteorological parameters, spatial extent of snow spread and the discharge, the Alaknanda & Dhauliganga river watersheds upstream of Vishnuprayag in Chamoli district of Uttar Pradesh, India, was taken up for detailed investigations.

The terrain forming part of higher central Himalayas has a typical rugged Himalayan topography ranging in elevations from 2000 to almost 7000 meters above m.s.l..deep gorges & narrow valleys illustrate the juvenile state of Himalayan orogeny. The area is almost entirely snow covered during four to five winter months in an year. While the snow line receeds to 3600-3800 meters above m.s.l. during summer months. The higher reaches are perenially snow covered and are characterised by some of the important glaciers of Himalayas.

5.0 INPUT VARIABLES IN MODELISTIC APPROACH :

In the ultimate analysis of attempting an integration of numerous variable parameters in snow melt runoff modelling the data obtained from space borne platforms, the meteorological parameters as also the topographical details merit importance. A temporal monitoring of these parameters over extended periods of time has been attempted in the present exercise.

5.1 FIRST VARIABLE PARAMETER-SPATIAL EXTENT OF SNOW COVER:

For the study area having a total spatial extent of 4511.89 sq.kms, this parameter assumes the greatest importance. The variation in snow & ice thickness between the peak accumulation & ablation periods as also the variation in ice density could be considered negli ible keeping in view the large spatial extent of snow covered area in the watershed. The discharge resulting from snowmelt is directly proportional to the aerial extent of snow.

However determining this parameter from conventional field technique is rather impractical. The present state of art of the space borne platforms provides a ready tool towards this approach. Multidate satellite data over the study area enables the temporal monitoring of the spatial variations in snow cover. Data obtained from Landsat & IRS series of satellite have been visually & digitally analysed to determine this parameter. The following summarizes the data on percentage of snow covered areas in the watershed computed from the satellite data.

S.No.	Satellite	Date of Satellite pass	Percentage of snow covered area
Peak accumulation period			
1.	LANDSAT	10.4.86	88.73
2.	LANDSAT	21.4.87	84.52
3.	LANDSAT	15.4.88	82.49
4.	IRS-1A	14.4.89	93.58
5.	LANDSAT	21.4.90	74.56
Peak ablation period			
1.	LANDSAT	14.10.87	52.08
2.	LANDSAT	28.9.88	66.93
3.	LANDSAT	9.9.89	41.60
4.	LANDSAT	28.9.90	49.73

During the peak accumulation periods in different year, the total snow accumulated shows a gradual decline accept for the year 1989. However during the peak ablation periods the trend demonstrates a cyclicity in the total percentage of the snow covered areas in the watershed.

5.2 SECOND VARIABLE PARAMETERS - THE METEOROLOGICAL DATA :

Although the meteorological parameters in terms of temperature, humidity, wind velocity etc were determined by the conventional field techniques for certain duration of the study, the over all inputs interms of meteorological data over extended periods of time for the last couple of years has been based on IMD (Indian Meteorological Department) data.

The variations in temperature humidity & wind velocity during the peak accumulation & ablation in the study area have been graphically plotted. Although the duration of the data that has been taken into account is rather negiligible to impress upon the over all variations in the scenario, they navertheless demonstrate striking influence on the spatial distribution of snow covered areas. An approach incorporating data over extended periods of time would go a long way in better demonstrating the impact of meteorological parameters over the snowmelt runoff model.

5.3 THIRD VARIABLE PARAMETER-THE TOPOGRAPHICAL DETAILS:

This assumes immense importance in the context of rugged Himalayan topography where abundance of steep slopes & other topographical features principally govern the snow accumultation and ablation of snow. During the accumulation periods the retention of fresh snow over steep slopes is a later phenonmenon than its accumulation over gentle slopes at lower altitudes, but this phenonmenon stabilizes as a result of prolonged periods of snow accumulation However during the ablation periods the snow accumulated over steep slopes and ridges tends to melt off much faster or gets remove in avalanche, much before the snow accumulated on flat topped summits & valleys gets melted off. Thus topography plays an important role in governing the overall percentage of snow covered areas in the watershed.

6.0 INTERDEPENDANCE OF THE VARIABLE PARAMETERS :

6.1 As has been illustrated in the preceeding paragraph the topography plays an important role in snow accumulations & hence in the resulting melt water discharge from the system. The percentage of snow covered areas in the watershed when plotted against the pre-determined elevation zones demonstrates a possible relationship between them, which is distinctively different during the accumulation & ablatin periods.

The snow accumulation period data show an almost interdependence of snow cover percentage & elevation. With increasing elevation the percentage of snow cover area increases. This relation holds good in the zone where snow cover varies with seasonal variations. Beyond this zone the snow cover perrenially persists.

The snow cover percentage does not seem to be prima facie dependent upon the elevations during ablation periods. Here the topography seems to play a vital role as most of the snow accumulations are seen to occur along valley bottoms or the flat topped summits The steeply sloping valley walls do not retain snow. This phenomenon again holds good upto the zone emenable to annual snow accumulation & melting, beyond which the snow cover percentage seems to be governed by elevation.

6.2 Other than the humidity, wind velocity etc, the mean temperature plays an important role in governing the overall spatial extent of snow cover, there by also influenceing the resulting meltwater discharge from the system.

Immediately after the winter months the snow pack characteristics results in a relatively lesser amount of snow cover melt off as a result of variation in temperature. Due to the rise in temperature. There is a slow but steady decline in the over all percentage of snow covered areas.

The process is altogether different immediately after the summer months when peak ablation is in progress. The snow pack properties have by now changed immensely, as a result of which a slight rise in temperature results in enormous amounts of melt offs thereby demonstrating a strikingly fast decrease in the over all percentage of snow covered areas.

6.3 The topography & meteorological parameters no doubt have a bearing on the over all percentage of snow covered areas in a watershed, the overall snow precipitation & accumulation demonstrated by its spatial extent governs in principle the total discharge emenating out of the system. This exercise attains importance interms of its applicability in numerous water resources related projects. The capability to predict well in advance the quantum of available water out of a watershed on the basis of the spatial extents of the snow covered areas is crucially important. There has to be a direct bearing between the snow covered areas & the discharge, the intrinsic relationship is being worked out and is rather premature to be illustrated at this stage of work.

7.0 CONCLUSION :

Although the global warming is a universly accepted phenonmenon today, its impact over the snow line in the Himalayas is rather difficult to predict through the present exercise in hand which deals with just a meager amount of data over the last decade only. Nevertheless certain interesting relationships between the topographical & meteorological parameters over the over all percentage of snow covered areas has been highlighted. This does have a bearing on the resulting discharge from the system. The over all steady decline in the percentage of snow accumulations in the study area show certain reversals which could best be attributed to the minute pulses, so characteristic of the interglacial period.

8.0 ACKNOWLEDGEMENT :

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9.0 REFERENCES :

Baumgartner, M.F. Seidel, K. and Martinec J. (1987). Towards snowmelt runoff forecasts based on multisensor remote sensing information. IEEE Trans. Geosci. Rem. Sensing, V.GE-25, no. 6, pp. 746-750.

Dowdeswell, J.A. and McIntyre, N.F. (1986). The saturation of Landsat MSS detectors over large ice masses. Intl. J. Rem. Sensing, V.7, no.1, pp. 151-164.

Gray, D.M. and Male, D.H. (ed) (1981) Handbook of Snow-Principles, processes, management and use. Pergamon Press, Canada.

Landsat Thematic Mapper Data Applications - Illustrated Examples (1988). NRSA, Deptt. of Space, Govt. of India.

Rango, A. and Solomonson, V.V. (1975). Employment of satellite snow cover observations for improving seasonal run-off estimates. Workshop on operational applications of satellite snow cover observations, NASA SP 391, Washington DC, pp. 157-174.

Tangri, A.K., Shukla Sudhakar, Chaturvedi Shivendra (1991). Utility of Landsat - TM & IRS-1A LISS-II data in snow cover mapping in a part of U.P. Himalayas, India. 264, IGCP Meet Poona, December 11-12, 1991.

Tangri, A.K. & Srivastava, S.K. (1989). Assessment of the dynamics of spatial and temporal distribution of glaciers around Badrinath using satellite remote sensing technique, "First National Meet on Himalayan Glaciology" June 5th 1989, New Delhi.

Ventura, A.D., Rampini, A., Rabagliati, R., Rossi, G., and Barbero, R.S. (1986). Integration of remote sensing data into and information system. Proc. XX Intl. Symp. Rem. Sensing Environ., Nairobi, Kenya, 4-10 Dec., 1986 V-2, pp. 669-676.

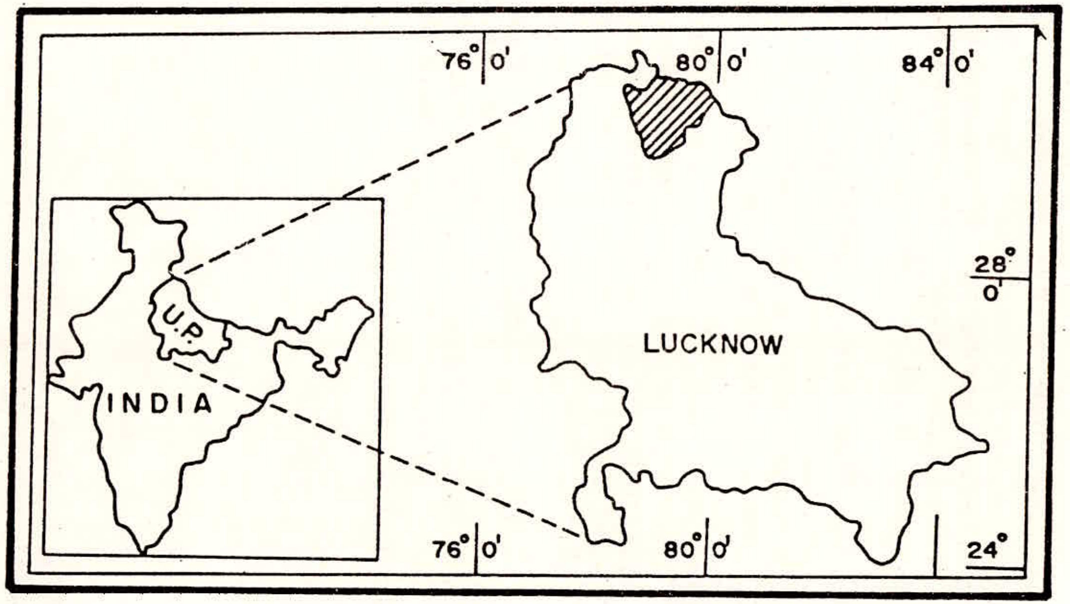
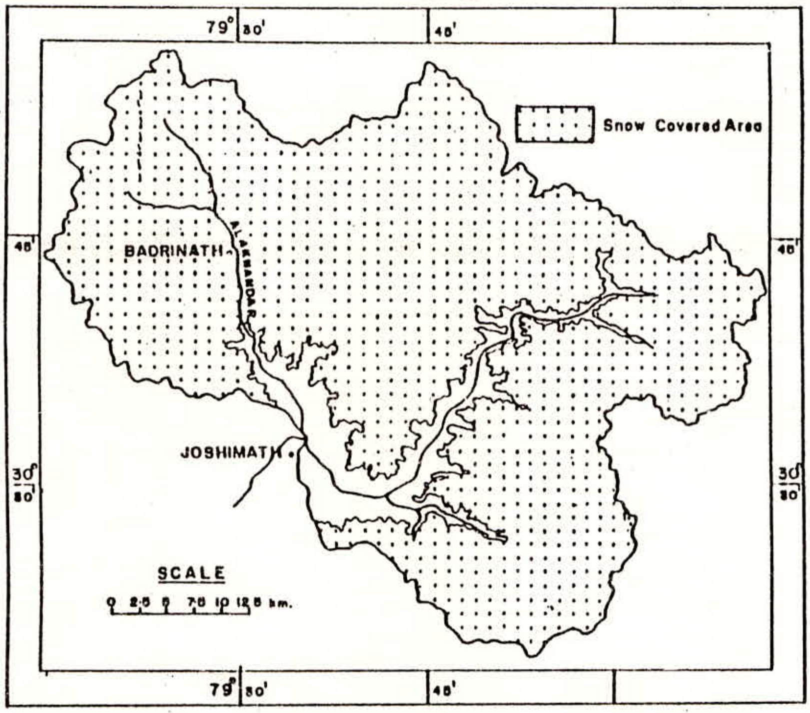
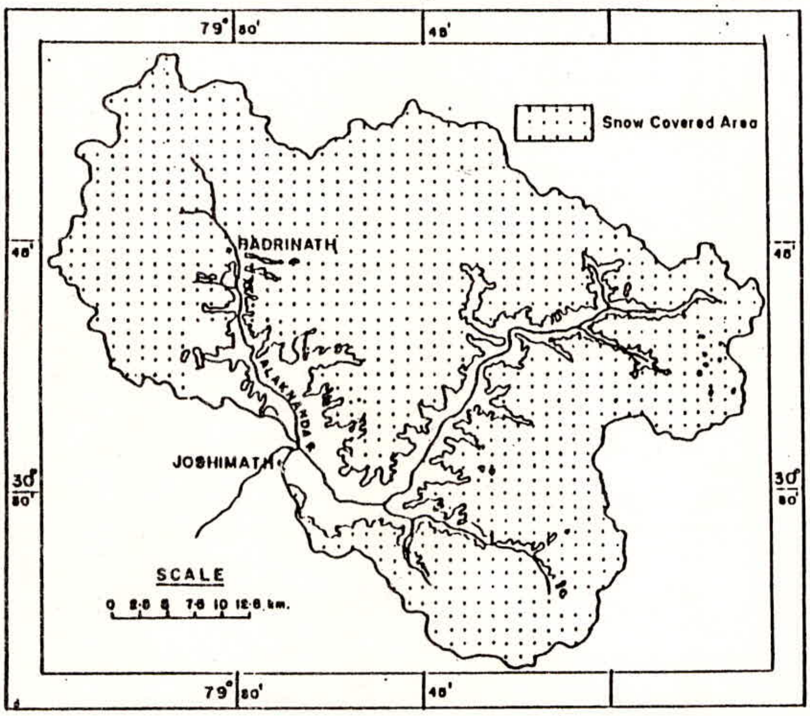


Fig. 1 :- Location of the study area ——

Fig. 2

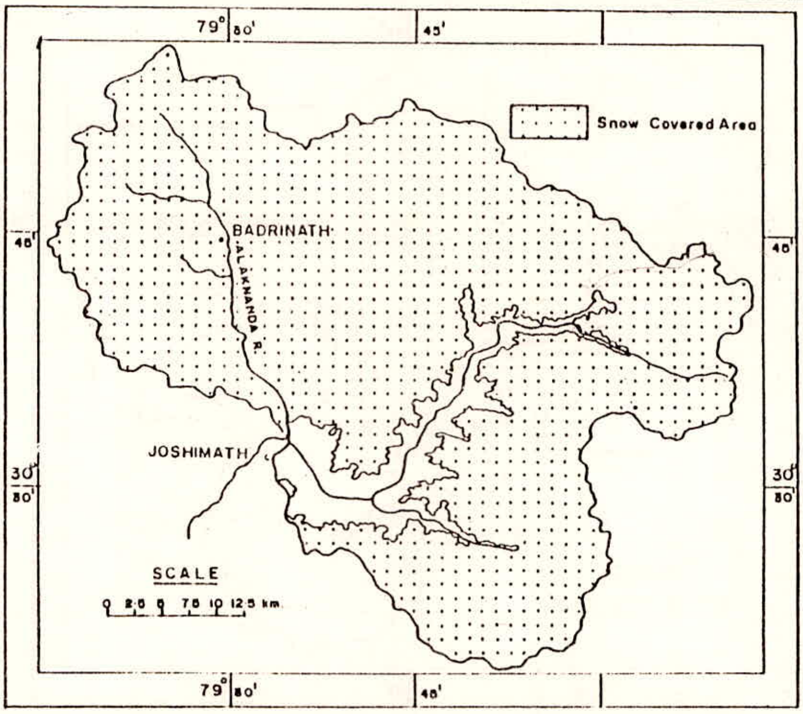


Distribution of snow cover in the study area as on 10th April 1986
(Interpreted from Landsat-TM-Scene No. 145-039)

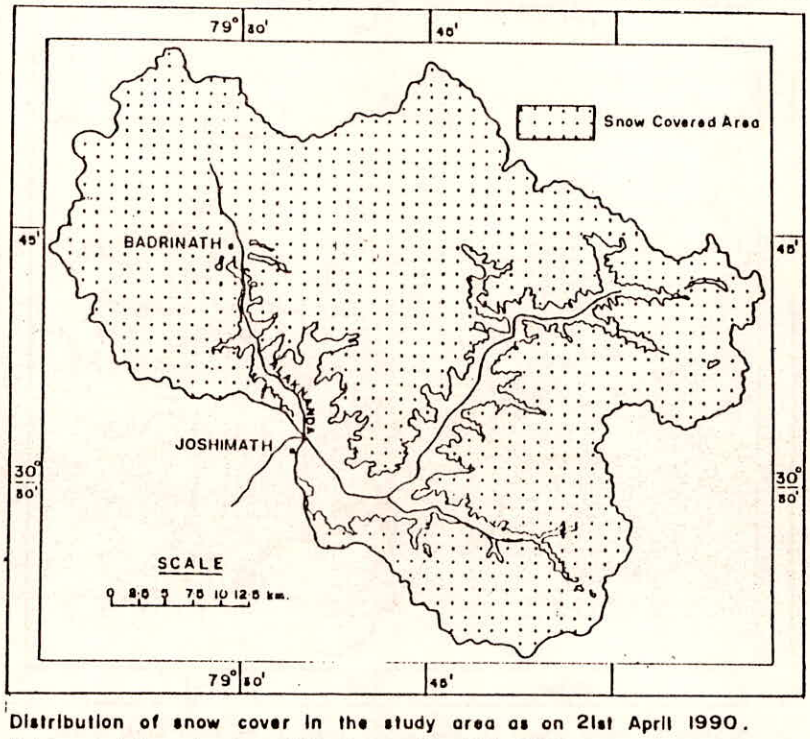


Distribution of snow cover in the study area as on 15th April 1988.
(Interpreted from Landsat-TM-Scene No. 145-039)

Fig. 3

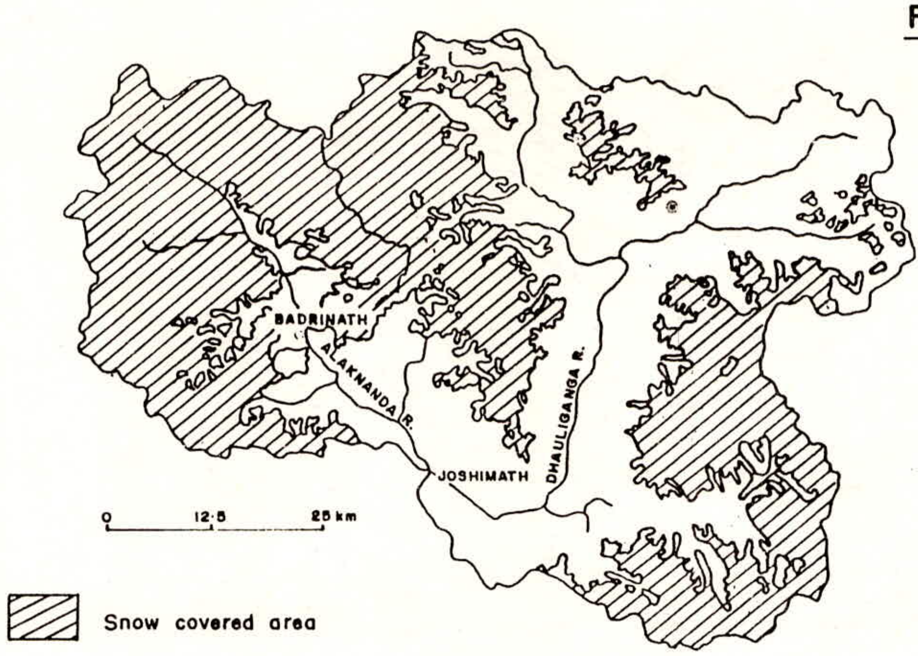


Distribution of snow cover in the study area as on 14th April 1989.
(Interpreted from IRS-IA Liss-II, Scene No. 27-46)

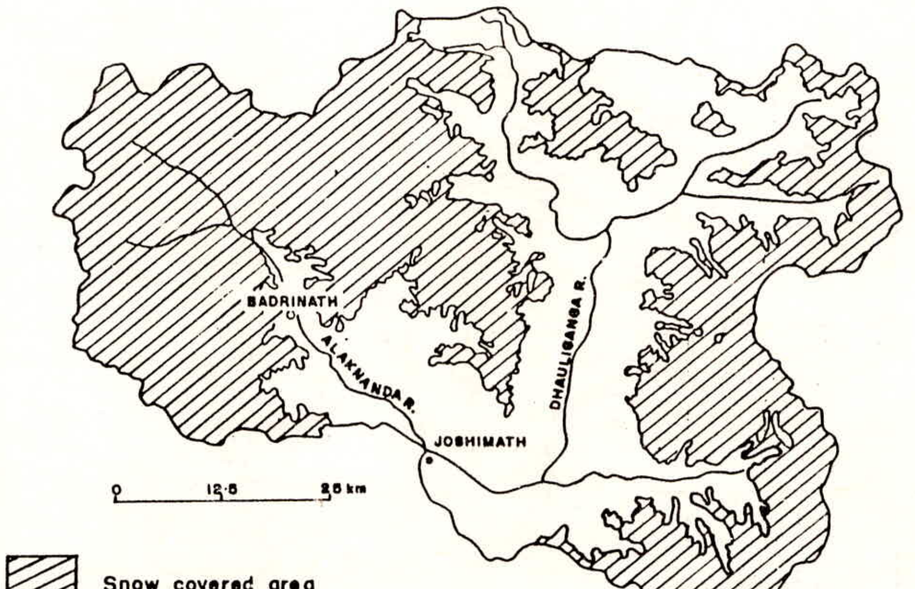


Distribution of snow cover in the study area as on 21st April 1990.
(Interpreted from Landsat-TM-Scene No. 145-039).

Fig. 4

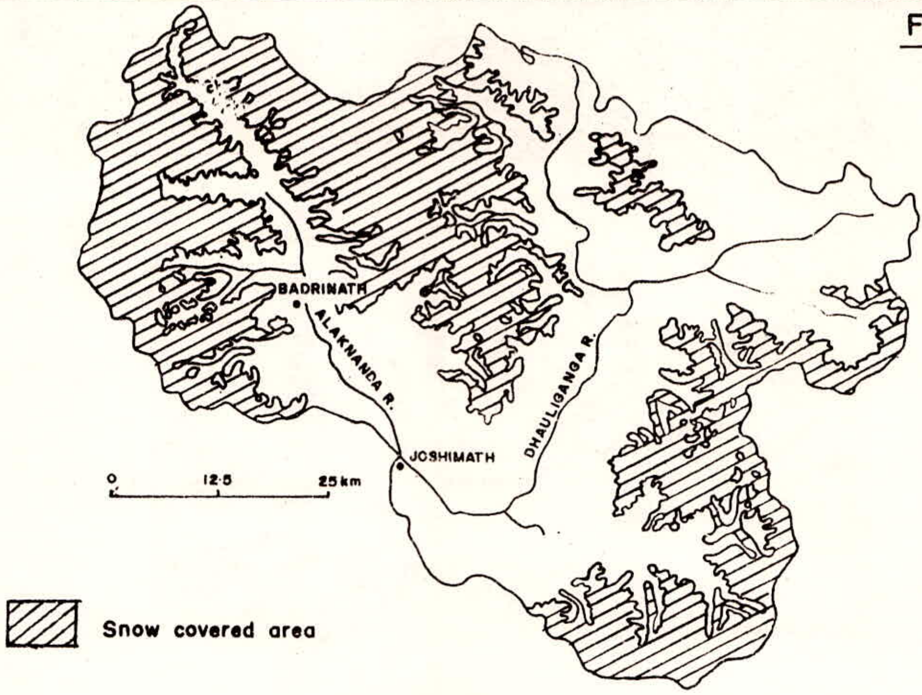


Spatial distribution of snow covered area as in October, 1987
(Interpreted from LANDSAT MSS scene no. 145-039 dt. 14·10·87)

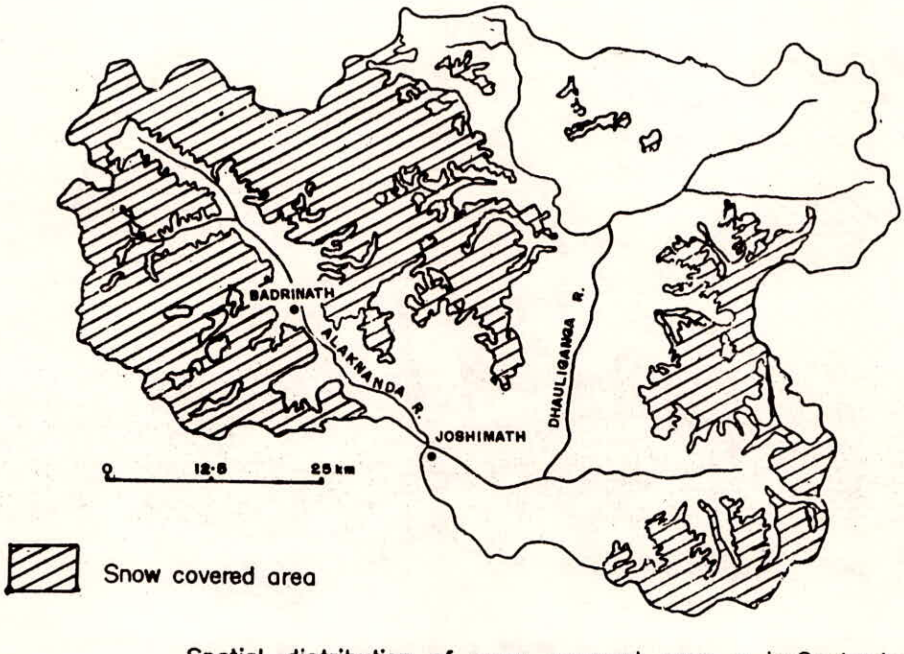


Spatial distribution of snow covered area as in September, 1988
(Interpreted from IRS - IA scene no. 27 - 46 dated 28·9·88)

Fig. 5

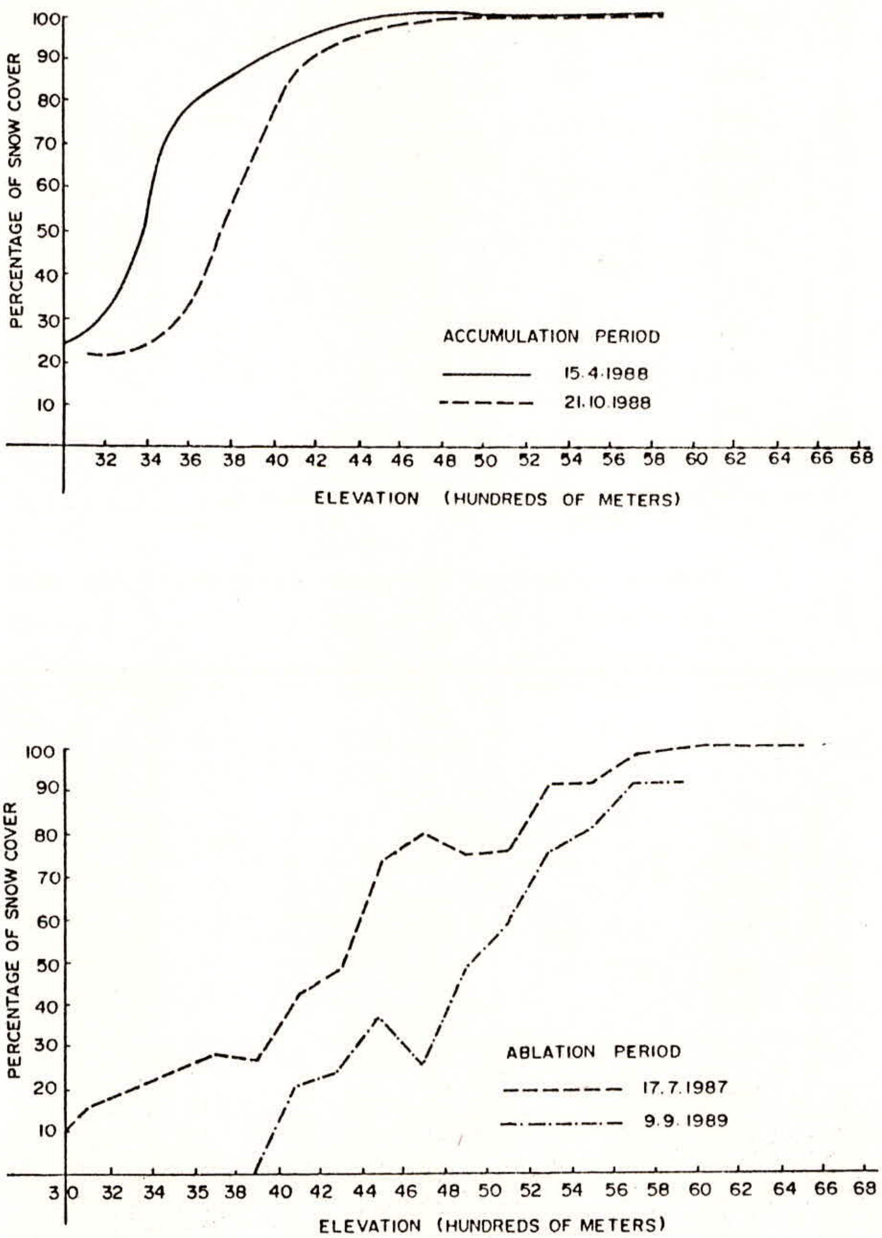


Spatial distribution of snow covered area as in September, 1989·
(Interpreted from LANDSAT TM scene no. 145-039 dt. 9·9·89)



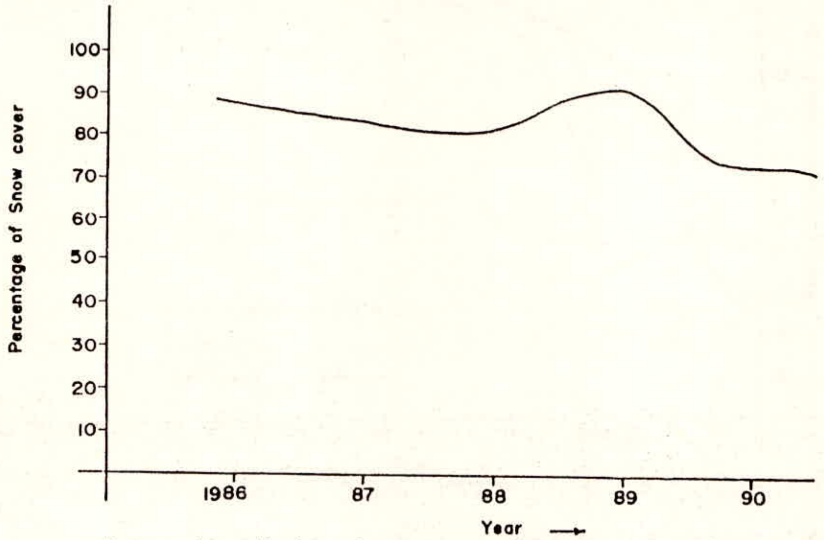
Spatial distribution of snow covered area as in Septembor 1990
(Interpreted from LANDSAT MSS scene no. 145-039 dt. 28·9·90)

Fig. 6

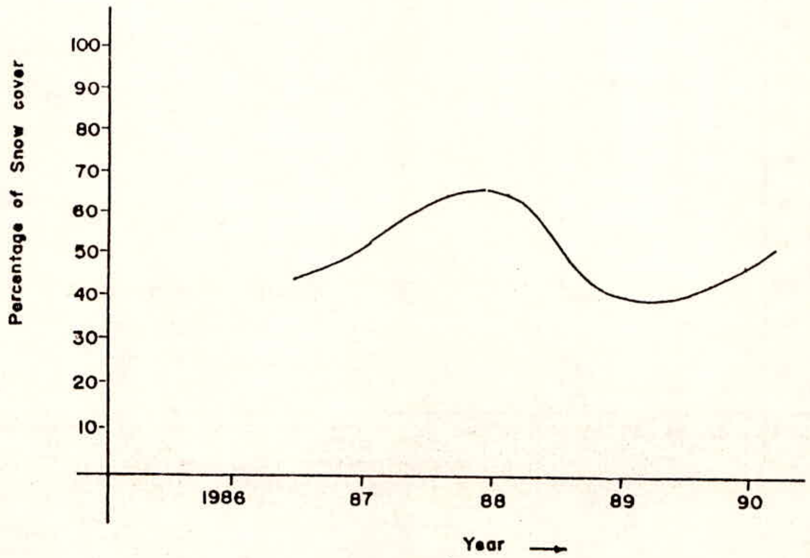


Relationship between percentage of snow cover and elevation in the study area

Fig. 7

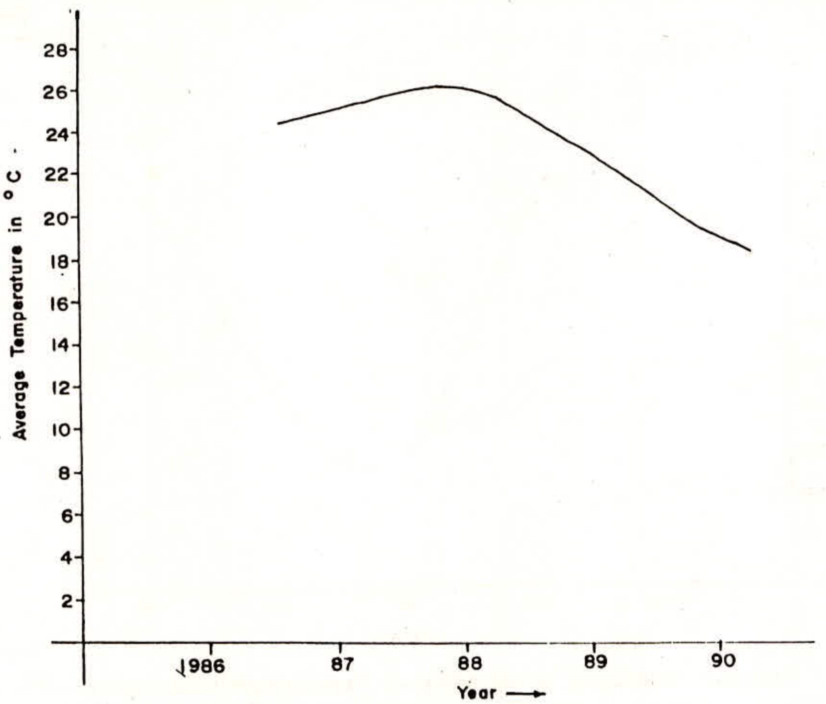


Temporal monitoring of snow cover in peak accumulation period

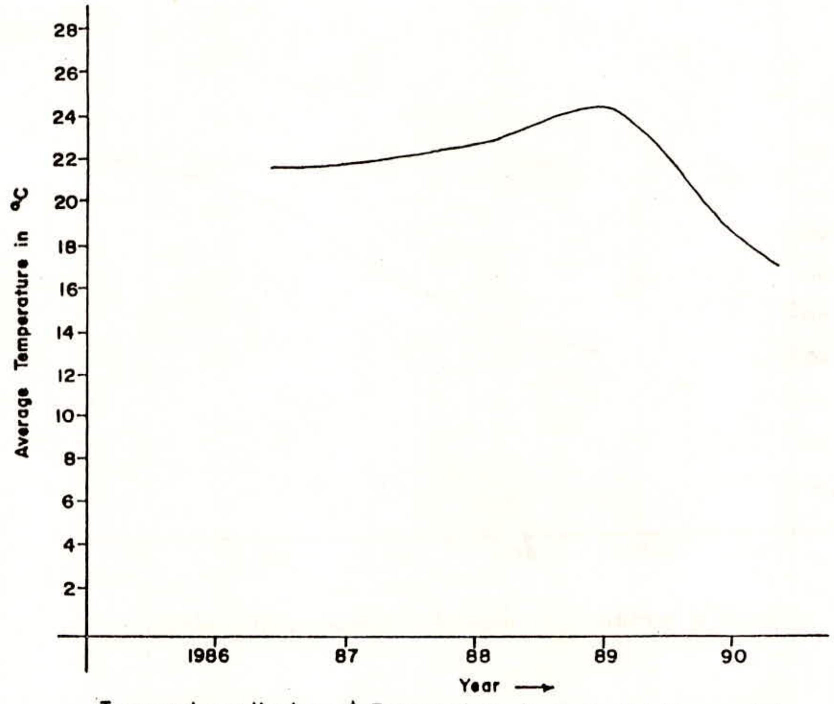


Temporal monitoring of snow cover in peak ablation period

Fig. 8

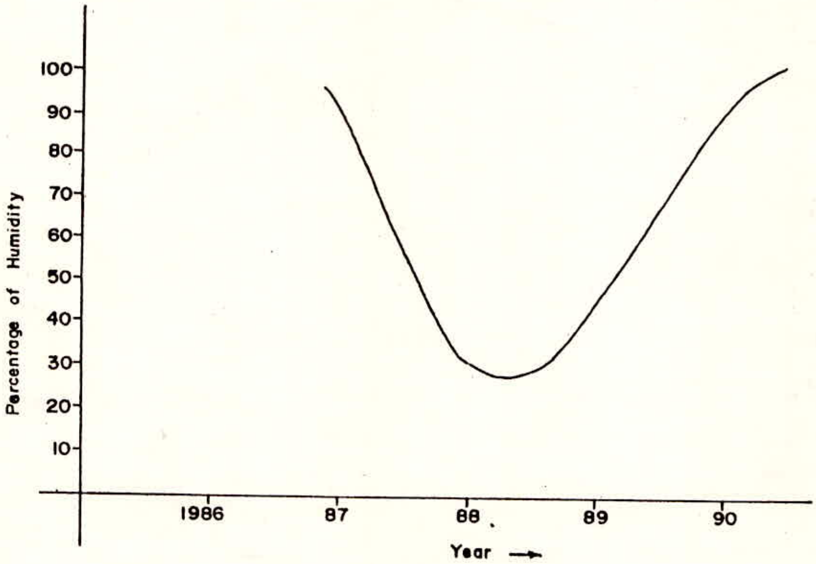


Temporal monitoring of Temperature in peak accumulation period

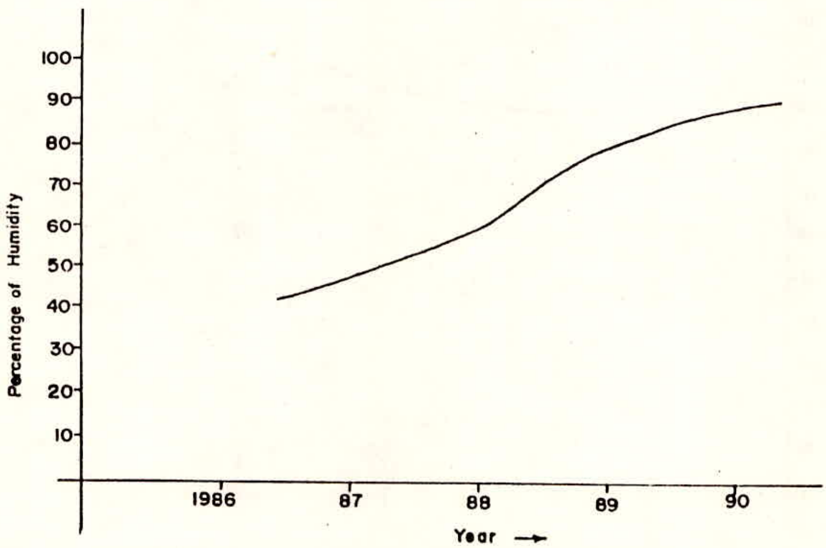


Temporal monitoring of Temperature in peak Ablation period

Fig. 9

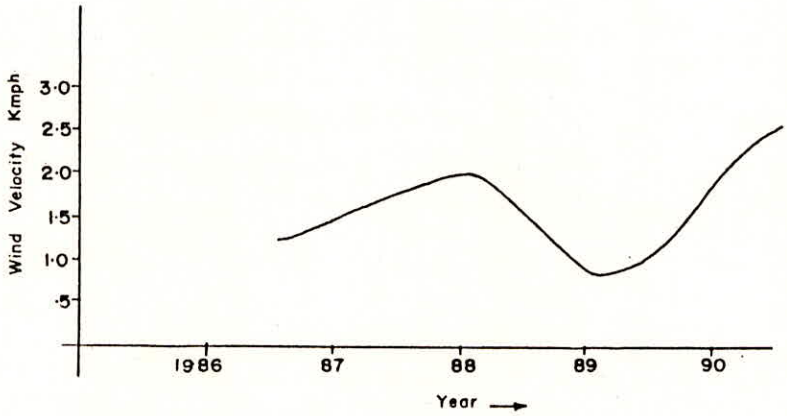


Temporal monitoring of Humidity in Peak accumulation period.

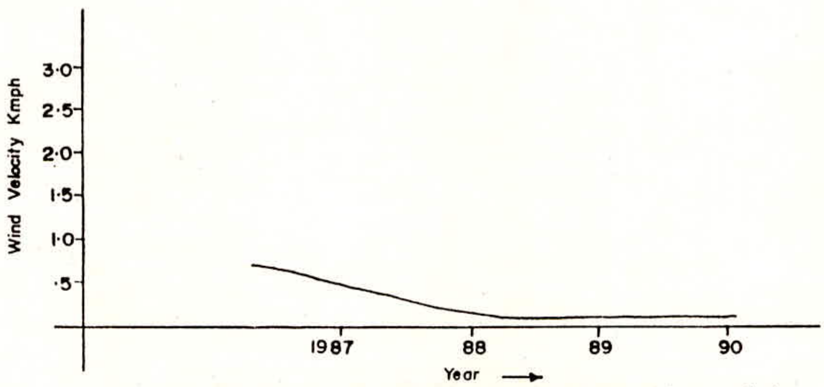


Temporal monitoring of Humidity in peak ablation period

Fig. 10

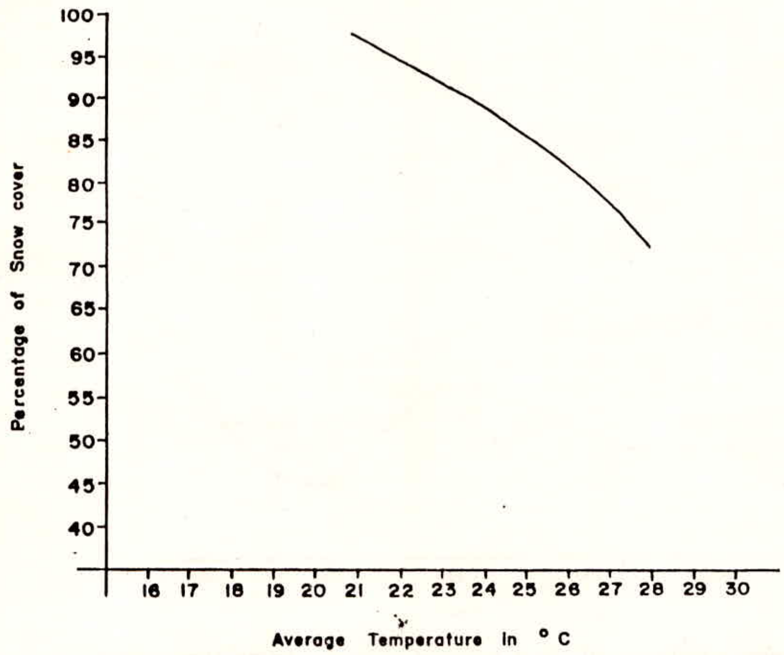


Temporal monitoring of Wind Velocity in peak accumulation period

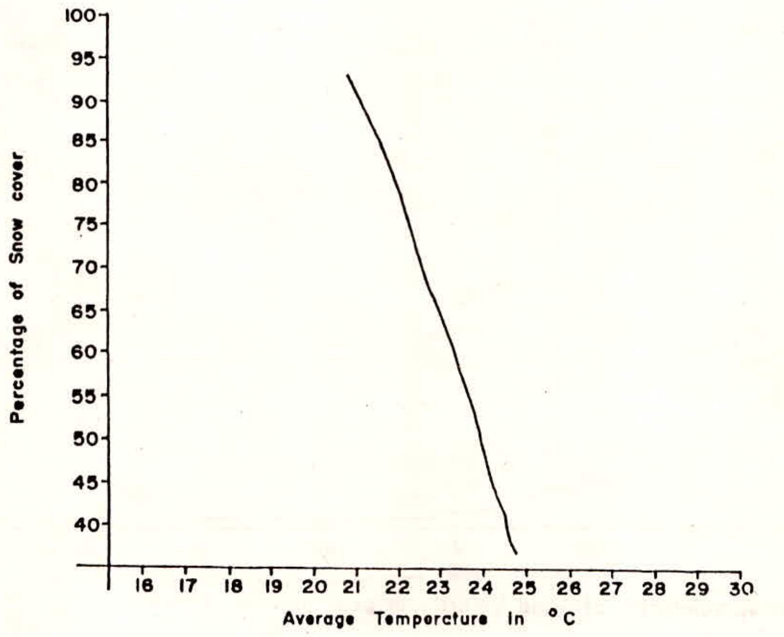


Temporal monitoring of Wind Velocity in peak ablation period

Fig. II



Interdependance of Snow cover and Temperature in peak accumulation period.



Interdependance of Snow cover and Temperature in peak ablation period.

DISCUSSION

S. M. SETH : What scale of toposheets have been used in the study to desire information about elevation etc.

AUTHOR(S) : Survey of India topographical sheets on 1:50,000 and 1:250,000 have been used to derive the above information.

S. M. SETH : How difference in scales and accuracy of information derived from imageries will effect the accuracy of the final outcome i.e. snowmelt runoff.

AUTHOR(S) : Since the spatial extent of snow spread in the catchment has a direct bearing on the resultant discharge, it is paramount to have an accurate assessment and delineation of snow cover areas. As such the scale and type of sensors as also a particular band combination is essential for achieving the desired level of accuracy. Any error in extracting the snowspread related information may lead to erroneous results about the snowmelt runoff.