Snow Information System with the usage of GIS in western Himalayas, India

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Abstract

The avalanche occurrence in northern Indian Mountains draws significance because of strategic reasons and tourism and poses serious problems for the military movements. This necessitates reliable avalanche forecasting, which in turn requires computer models to aid the forecaster in interpreting the data and issuing timely forecast. In order to be able to have a better overview of the avalanche situation, Geographical Information System (GIS) has been used such that spatial analysis can be done on the snow and meteorological conditions leading up to an avalanche. Keeping this in view, the author has developed a GIS based application software of Snow Information System (SIS) for spatial visualization and analysis of snow and meteorological conditions around the Kashmir valley in Jammu & Kashmir state. The author believes that in the future all this information will greatly aid in the avalanche forecasting, hazard analysis, zoning etc.

1. Introduction

Spatial variability in snow (e.g. depth, density, temperature, and hardness) is a characteristic feature of snow especially in mountainous region. This has profound implications for life in nivean regions. Macro-scale variations results from major storm systems and large geographical features. Small scale and short-time spatial variations in snow covers are the result of a combination of features including types of snowfall, changes arising from the redistribution of snow, atmospheric conditions during and following a snowfall and ground surface conditions like topography and vegetative cover. Peck(1964) cites that the influence of climatic factors or elements of the parent weather system must be recognized to interpret snow distribution and accumulation patterns adequately, e.g. extremely low temperatures over the region reduce the moisture holding capacity of the air to extremely low values thereby reducing snowfall amounts. Thus the absolute value of the depth of snowfall at a point would be representative of the depth in a very limited area. But in order to obtain the spatial distribution of snow cover, point measurements of precipitation serve as the primary source of information (data).

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In the absence of viable solution to the problem, information technology holds the key. A well sifted, logically expressed and visually presented information may speak volumes by itself. Thus a GIS application for understanding the variability of snow cover, which would ultimately help in avalanche mitigation is likely to prove quite helpful. Cartographic presentation of available information, delineation of zones quite similar to a particular area having specific terrain features and climatic conditions can be easily achieved through GIS software. Thus without even having to know the science of release mechanism of avalanches, a significant information of the stability state of snowpack can be obtained. The efforts of physically traversing through the terrain and identifying potential threat zones can be minimised to a large extent with the usage of GIS.

With many such features in-built in the GIS, the author has developed an application software of SIS for spatial visualization and analysis of snow and meteorological data collected at various observatory stations around Kashmir valley in the Jammu and Kashmir state.

2. Simulated Domain

The Kashmir Valley in Jammu and Kashmir State is approximately 80 km long and is of maximum width of about 25 km, extending from North-West to South-East. The average altitude of the Valley is about 1600 m above mean sea level. During winter months, generally the valley gets precipitation in the form of snow. The region of study was taken covering the Kashmir Valley and its adjoining areas i.e. 74^0 E to 76^0 E and 33^0 N to 35^0 N. This area covers 22 observatory stations scattered all around the valley.

3. Sample data and initial conditions

The source of information used for the topographic analysis of the area is the high resolution Digital Elevation Model (DEM) derived from US Geological survey's global elevation data set (Source USGS ftp site: ftp://edcftp.cr.usgs.gov/pub/data/gtopo30/global). The data included in the DEM are elevation and geographical coordinates. The elevation data is in regularly spaced grid with a resolution of 30 arc second (i.e. approximately 0.8-km) resolution over the selected domain. The shaded topography of the selected domain considered for simulation is shown in Fig 1. The observed snow and meteorological parameters e.g. fresh snow, standing snow, wind speed, wind direction, temperature etc were chosen for the initial development of the application software. A sample data of 23-Jan-2001 of the various observatory stations in the Kashmir valley is being used in this paper to show the overview of the software.

4. Spatial visualization and analysis

Cartographic presentation of information using digital elevation maps is one of the most tangible features of GIS. It helps in understanding the relationships between different types of spatial and attribute data that are geographically referenced. Once the data have been captured in a geographical data model, GIS gives the ability to perform efficient query, analysis and mapping on it.

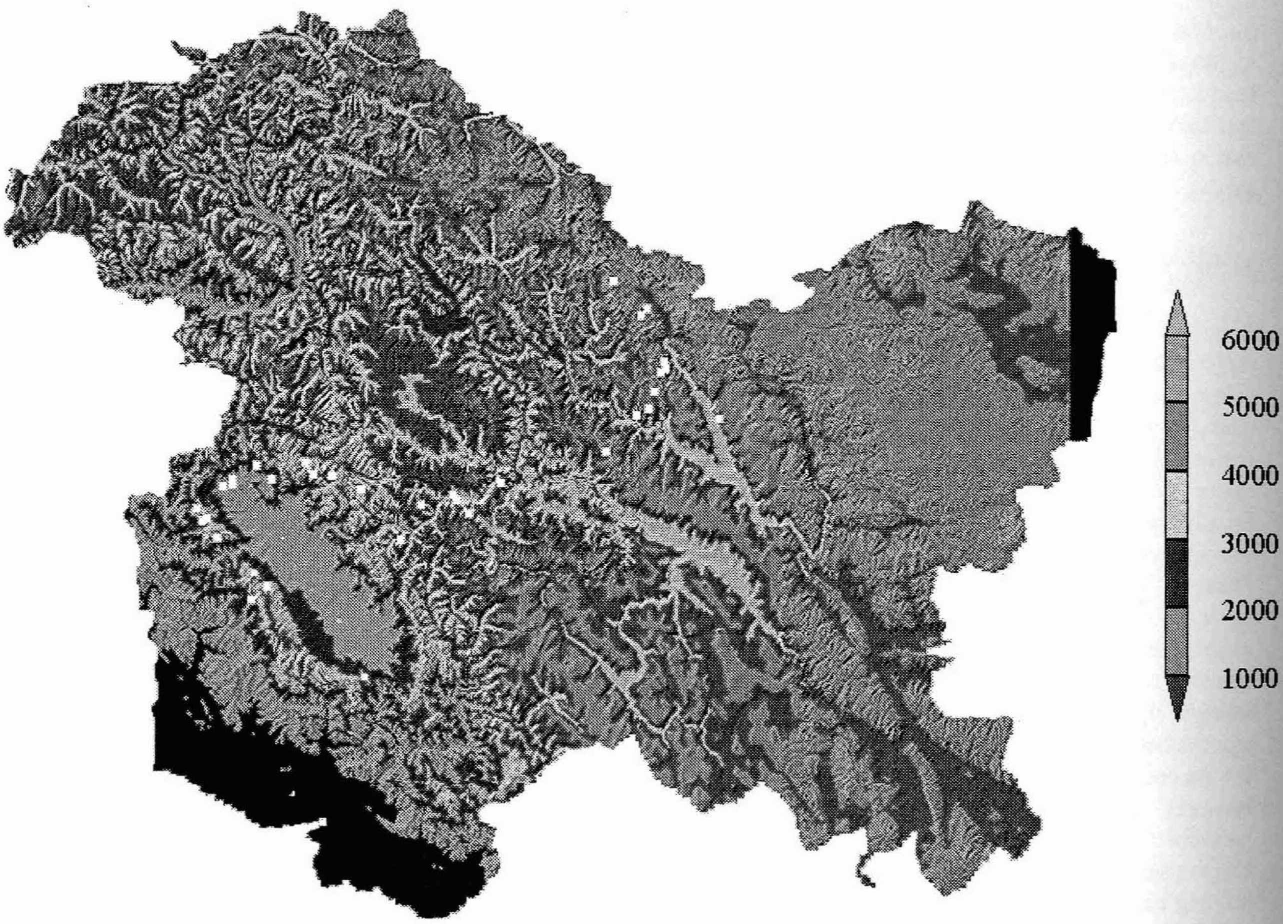


Figure 1: Kashmir vallley and adjoining areas

Author has used these GIS features to develop an application software of SIS for spatial visualization and analysis of snow and meteorological data collected at various observatory stations around

Kashmir valley in Jammu and Kashmir state. The significance of SIS in avalanche forecasting is shown in the chart below.

The software consists of the following subsystems :

- A data input subsystem : It collects and preprocesses data from various sources. This data is a collection of various snow and meteorological parameters for all the stations. Application software does data validation and correction and then it segregates the data of all the stations and puts them in their respective database files. Fig 2 shows a snapshot of this subsystem.

- A data storage and retrieval subsystem :

It organizes the data in a manner that allows retrieval, updating and editing. Data can be retrieved once user's task and needs have been identified and analysed. It follows that choice of data should relate directly to user needs. So it asks user for the specific date and time, of which the data is required for and selects the required data from the master database. The application software puts this data in a temporary database and transfers it to GIS(GeoMedia Pro) for further analysis. Fig 3 shows a snapshot of this subsystem.

- A data manipulation and analysis subsystem :

It performs tasks on the data, aggregates and disaggregates, estimates parameters and constraints and performs modeling functions. This subsystem contains menus for various snow and meteorological parameters e.g. fresh snow, standing snow, wind speed and wind direction, etc. The user can visualize and analyse any information by just selecting a particular menu item. For example if user wants to see the pattern of snowfall around the Kashmir Valley, they just have to click on fresh snow menu item and the software will show the values at the respective stations on the 3D terrain (DEM) itself, as shown in the Figure 4. The user can also edit the data and visualize the effect on the DEM itself. More details of any of the stations can be obtained by just clicking over the station for getting the finer resolution DEM of that area with all the avalanche sites, roads and

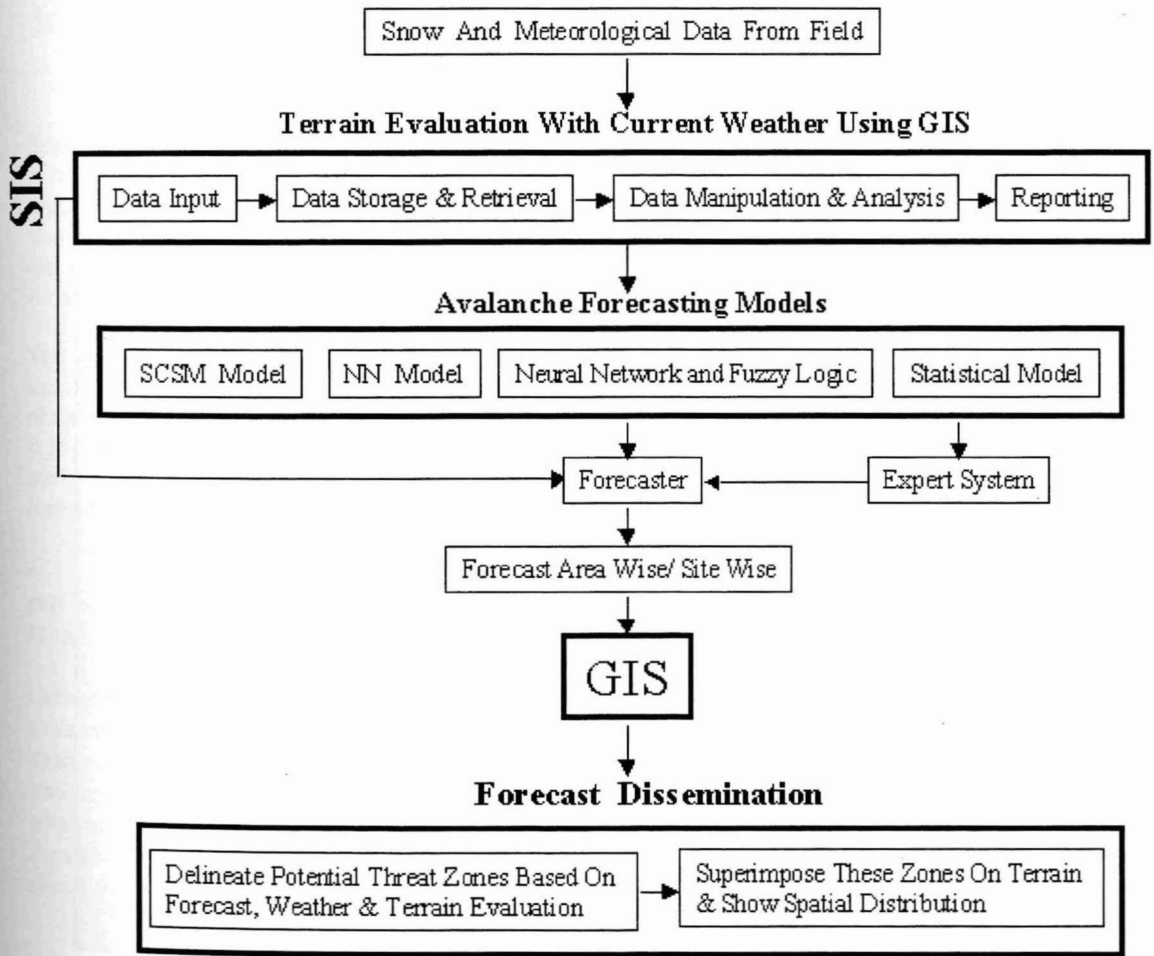
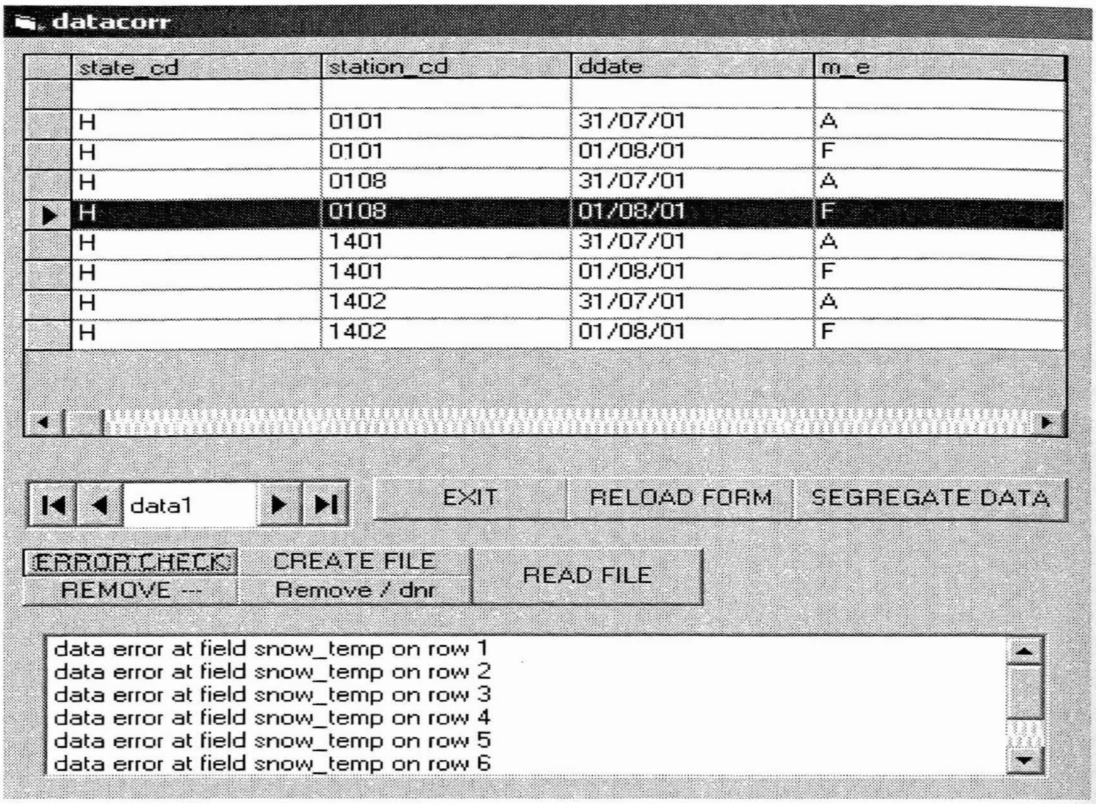
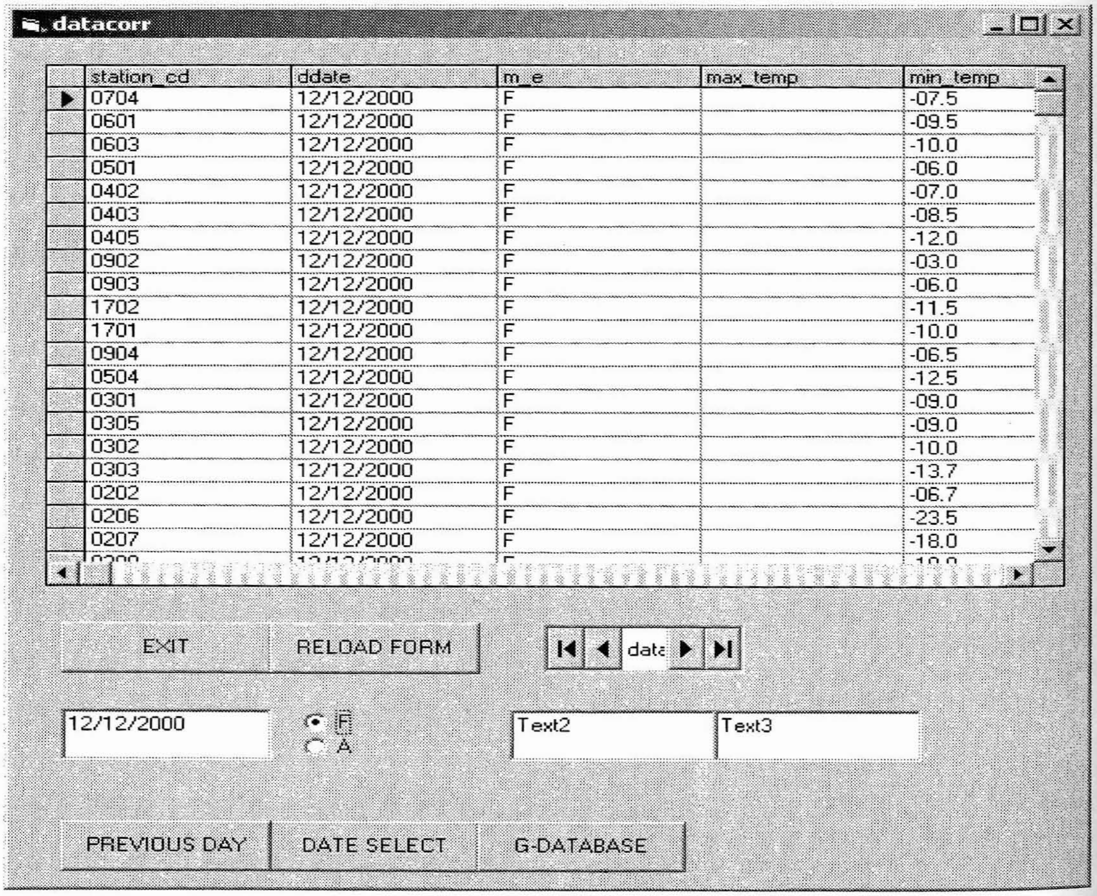


Chart 1: Significance of SIS in avalanche forecasting



state_cd	station_cd	ddate	m_e
H	0101	31/07/01	A
H	0101	01/08/01	F
H	0108	31/07/01	A
H	0108	01/08/01	F
H	1401	31/07/01	A
H	1401	01/08/01	F
H	1402	31/07/01	A
H	1402	01/08/01	F

Figure 2: Data input subsystem



station_cd	ddate	m_e	max_temp	min_temp
0704	12/12/2000	F		-07.5
0601	12/12/2000	F		-09.5
0603	12/12/2000	F		-10.0
0501	12/12/2000	F		-06.0
0402	12/12/2000	F		-07.0
0403	12/12/2000	F		-08.5
0405	12/12/2000	F		-12.0
0902	12/12/2000	F		-03.0
0903	12/12/2000	F		-06.0
1702	12/12/2000	F		-11.5
1701	12/12/2000	F		-10.0
0904	12/12/2000	F		-06.5
0504	12/12/2000	F		-12.5
0301	12/12/2000	F		-09.0
0305	12/12/2000	F		-09.0
0302	12/12/2000	F		-10.0
0303	12/12/2000	F		-13.7
0202	12/12/2000	F		-06.7
0206	12/12/2000	F		-23.5
0207	12/12/2000	F		-18.0

Figure 3: Data storage and retrieval subsystem

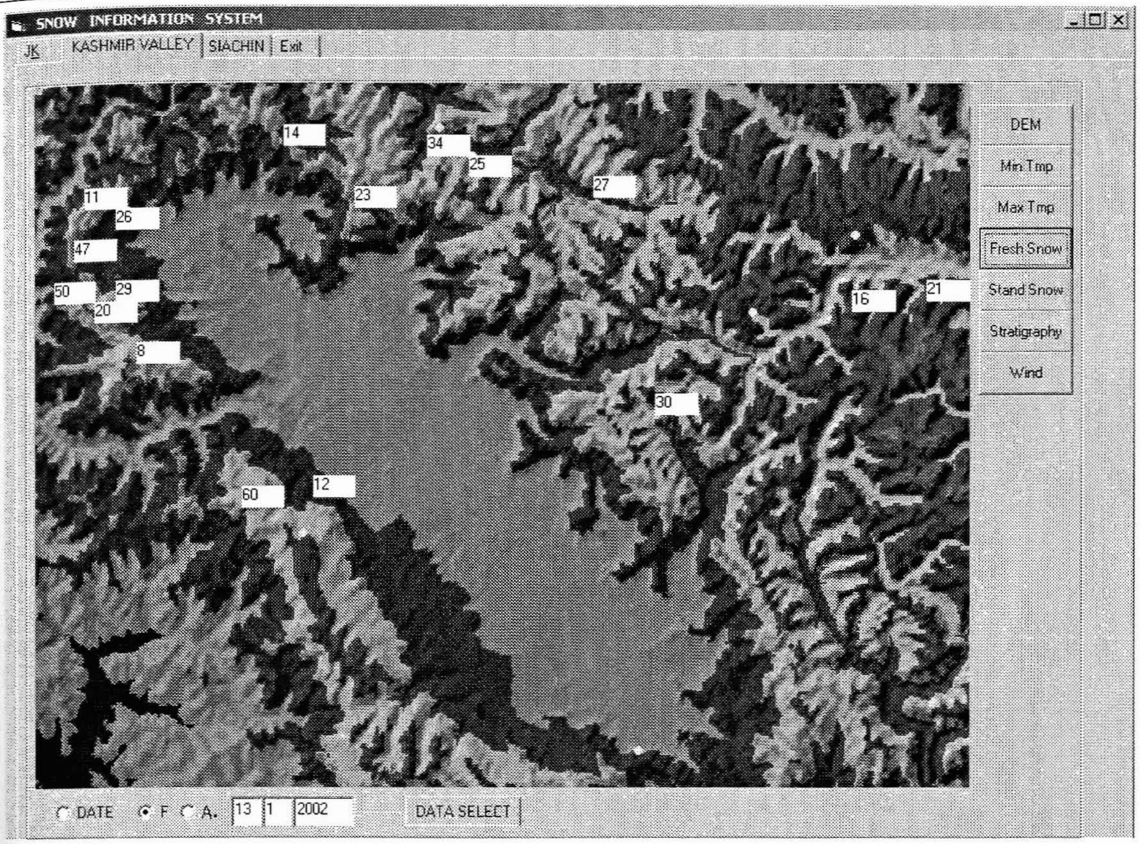


Figure 4: Fresh Snow Distribution around Kasmir Valley on 23-Jan-2001

drainage, etc as shown in fig 8. Further, the details of any avalanche site, which includes slope and aspect profile, avalanche accident report etc, can also be seen by just clicking over it. The forecaster can also see the fly through of the concerned area for more detailed analysis.

The software is being used for processing of snow and meteorological data collected from various observatories in Jammu & Kashmir state, and also it is being tested for continuous monitoring of the avalanche situation in a given area on short and long term basis.

- A reporting subsystem that displays all or part of the database in tabular, graphic or map forms.

Cartographic presentation of snow and meteorological parameters like fresh snow, temperature, standing snow and wind for all the stations over Kashmir valley on 23 – Jan - 2001 obtained using the application software is shown in Figures 4 - 5. The stratigraphic profile, which shows the various properties of the different layers of snowcover, can also be analysed for the selected observatory station as shown in figure 6.

5. Future scope

Data analysis is an important part of the decision making process. Thus a GIS application for understanding the spatial variability of snow cover which would ultimately help in avalanche mitigation is likely to prove quite helpful. GIS can be used for spatial analysis of the raster data set derived from the DEM like thematic layers of slope, aspect and elevation could be generated. Using all these layers of information, a new layer of information could be derived e.g. delineate all such areas having slopes exceeding 30° with southern aspect and have received more than 100 cm of snow and where past occurrences have been frequent. Such areas could thus be put under potential threat zones. This analysis would be helpful in providing every day the probability of avalanche occurrences for each formation zone in a defined area. A similar study has been done for CT-Axis area in Pir-Panjal range of Himalaya. Areas having altitude between 2500-3500 m,

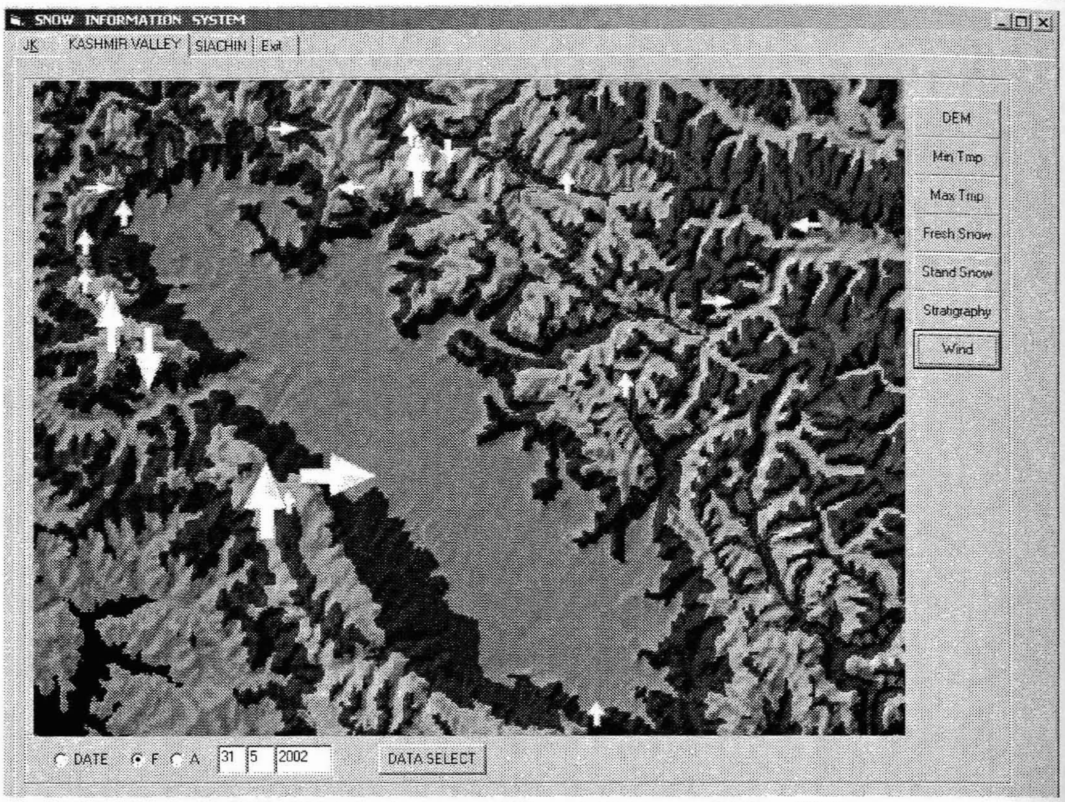


Figure 5: Wind Distribution around Kasmir Valley on 23-Jan-2001

aspect between ESE to WSW and slopes between 30° to 40° are delineated as high danger zones for avalanches as shown in Fig 8. This analysis could be further extended for risk assessment of individual avalanche sites.

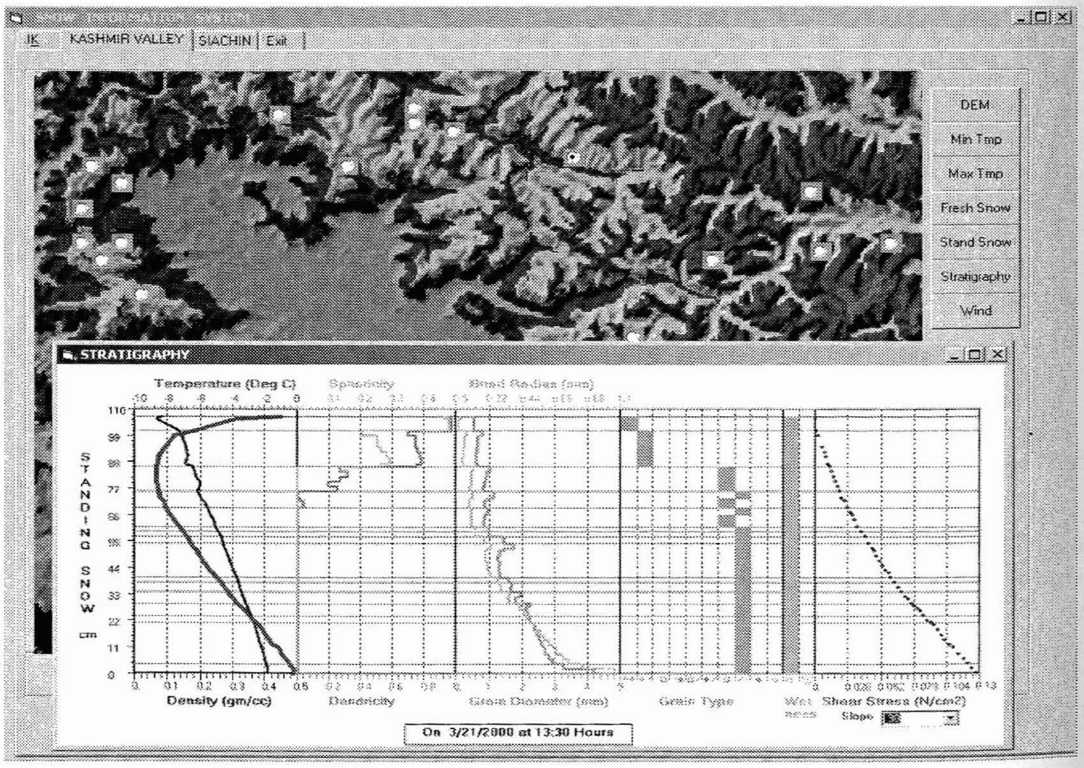


Figure 6: Straitigraphy Profile Of Selected Station on 23-Jan-2001

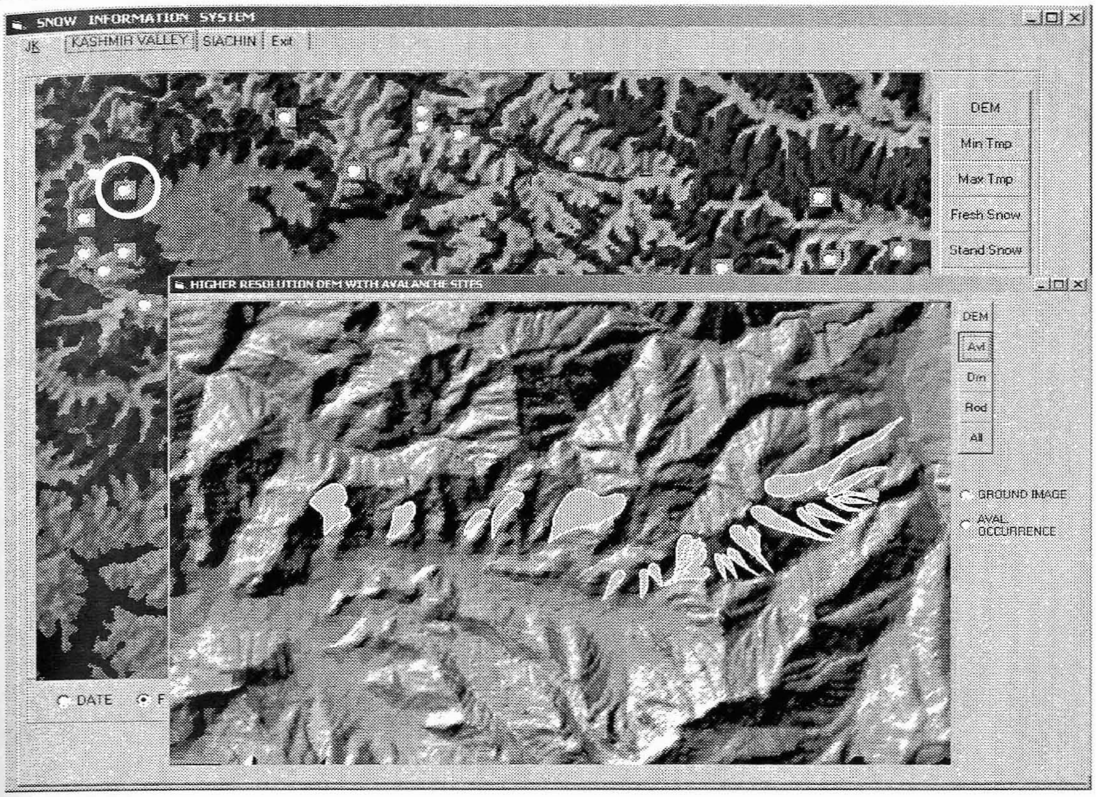


Figure 7: Higher Resolution DEM of the Selected Station With Avalanche Sites

Figure 8: Delineated higher danger zones in CT-Axis

6. Conclusion

Bringing out the usefulness of GIS application oriented avalanche forecasting, author has compared specific cases of the past where the additional information through GIS have helped in predicting potential threat areas. With the help of such SIS, a better view of the snow and avalanche situation existing at any time can be obtained for obtaining avalanche threat at any given time for a given area. Author perceives that GIS could be integrated with other avalanche forecasting models as well as satellite data to get to know the precise areas where avalanche occurrence could be menacing in the next few days.

7. Acknowledgements

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8. References

D.M. Gray and D.H. Male, 1981, "Handbook of snow"

Jagdish Bahadur, "Precipitation characteristics over high Himalayas', Advances in Tropical Meteorology, 400-407.

Loiselle M.C., Cowing D.J. and Keezer G.R., "Preliminary analysis of historical snow data using Geographical Information System", 81-88.

Magnusson M.M. and Baldursdottir H.B., "A relational database for snow avalanches".

Philips D.L., Dolph J. and Marks D., 1992, "A comparison of geostatistical procedures for spatial analysis of precipitation in mountainous terrain", Agriculture and Forest Meteorology, 58, 119-141.

Richard E.J. Kelly and Peter M. Atkinson, "Modeling and efficient mapping of snow cover in UK for remote sensing validation", Advances in remote sensing and GIS analysis.

Xu H., Bailey J.O., Barrett E.C. and Kelly R.E.J., 1993, "Monitoring snow area and depth with integration of remote sensing and GIS", International Journal of Remote Sensing, 14, 3259-3268.