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Avalanche Hazard Mitigation in Western & Central Himalaya-II

Technology Focus focuses on the technological developments in the organisation covering the products, processes and technologies. This issue of *Technology Focus* highlights technologies in the area of *Avalanche Hazard Mitigation in Western & Central Himalaya* developed by *Snow and Avalanche Study Establishment (SASE), Chandigarh.*

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Readers may send their suggestions to
The Editor, *Technology Focus*
DESIDOC, Metcalfe House
Delhi-110 054
Telephone: 011-23902403, 23902472
Fax: 011-23819151; 011-23813465
E-mail: director@desidoc.drdo.in; techfocus@desidoc.drdo.in; technologyfocus@desidoc.deldom
Internet: www.drdo.gov.in/drdo/English/index.jsp?pg=techfocus.jsp

From the Desk of Guest Editor

November-December 2018 issue of Technology Focus was dedicated to various techniques/methods of predicting snow avalanches and mitigating avalanche hazard using control structures in Indian Western and Central Himalaya. Avalanche prediction and hazard mitigation require different types of supporting databases related to terrain, meteorology, snow cover, avalanche flow parameters, network of roads/routes/tracks in avalanche prone areas , etc, at spatial level. This database is generated through remote sensing and GIS technology, modeling & simulation, insitu ground observations and through various types of instrumentations.

Snow and Avalanche Study Establishment (SASE) is potentially using remote sensing and GIS technology. Multi-spectral, Hyper-spectral, Photogrammetry, Synthetic Aperture Radar and various other optical and microwave satellite data have been used in extraction of snow cover and terrain information from inaccessible remote areas of Himalaya. High resolution satellite images and digital elevation models are being used for mapping avalanche sites affecting roads/routes/tracks along Line of Control (LOC), in border areas of Western Himalaya. Number of avalanche hazard data cards and digital avalanche atlases of different sectors in J&K and H.P. have been developed. A virtual reality centre has been developed for avalanche related training to the troops in 3D environment. SASE imparts regular training to troops on avalanche safety and rescue measures and has produced a valuable training material including multimedia CDs, posters and handouts for the benefit of troops.

One of the core expertise of SASE is snow and avalanche physics. SASE is simulating snow cover and avalanches using snow cover simulation models and avalanche dynamics models. These models are helpful in estimation of various snow cover and avalanche flow parameters. Experiments using infrasonic acoustic waves have been conducted to predict failure of snowpack. Cold laboratory established by SASE at Manali and Field Research Station Patsio (3800 m elevation) provide unique set of scientific research capabilities and resources to facilitate the snow and avalanche research round the year. Instruments have been developed to assess the snow cover properties in the field.

This issue of Technology Focus is dedicated to technologies/methods/techniques involved in generation of various types of databases related to terrain, meteorology, snow cover, avalanches, etc., and the database thus generated is being used in prediction and mitigation of avalanche hazard in Western and Central Himalaya.

NAREST KUMAR

Outstanding Scientist
& Director, SASE

Databases related to snow cover parameters, terrain parameters, meteorology, avalanche flow parameters and settlements are essentially required to predict avalanches and to estimate avalanche hazard. This database is generated through satellite data, digital elevation models, *in situ* observations using various type of instruments, modelling & simulations, etc. This issue of *Technology Focus* is dedicated to remote sensing and GIS technology for snow cover and terrain database generation and product development; snow cover and avalanche: modelling and simulations; *in-situ* observation network and instrumentations in Central & Western Himalaya.

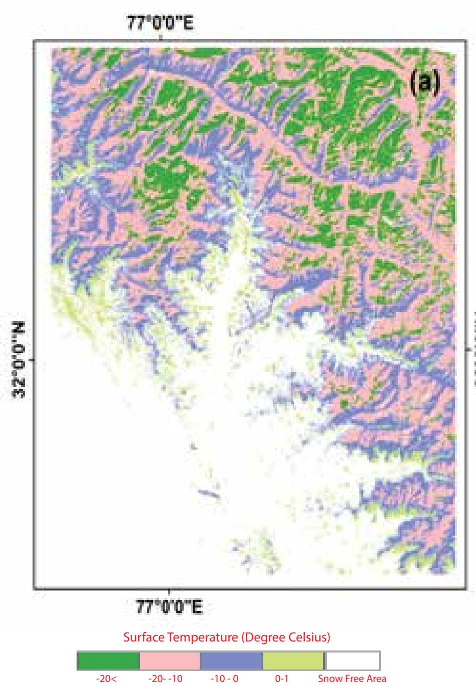
Remote Sensing and GIS Technology for Snow Cover Information Extraction, Terrain Visualisation and Product Generation

Remote Sensing and Geographic Information System (GIS) technology has number of applications in snow and avalanche research. In the rugged and inhospitable conditions of Himalaya, it's not possible to collect snow cover and terrain related data using ground observations at high temporal and spatial resolution. In such scenario, remote sensing and GIS technology provide an effective alternative to collect the snow cover and terrain related information of larger areas at high spatial and temporal resolution. Snow and Avalanche Study Establishment (SASE) has strong foundation and extensive understanding of the remote sensing and GIS technology and is fully equipped with the state-of-the-art software and hardware facilities to use this technology in avalanche hazard mitigation. The labrotary has developed various algorithms to extract snow cover parameters using multi-spectral, hyper-spectral and microwave remote sensing. Developed digital avalanche atlases in GIS environment are having information of avalanche terrain and avalanche activities. Visualisation and avalanche forecast dissemination tools using remote sensing and GIS have been developed. A brief about remote sensing and GIS technology is given to extract various snow cover parameters and generation of products which are used in avalanche hazard mitigation in Himalaya.

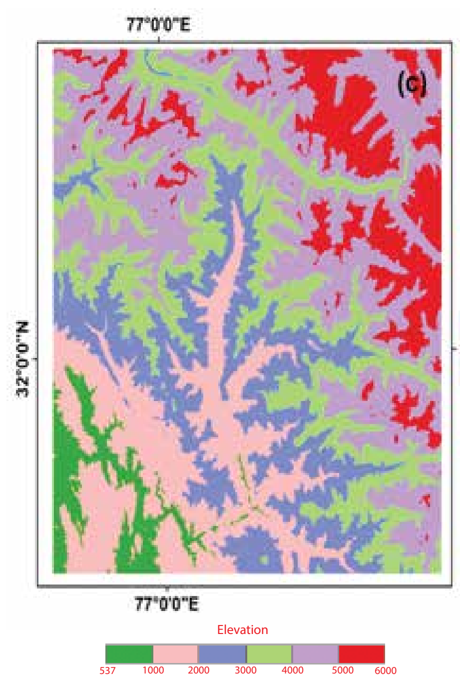
Snow Cover Parameters Extraction using Multi-spectral, Hyper-spectral and Microwave Remote Sensing Data

Estimation of Snow/Ice Surface Temperature using Landsat-8 Data

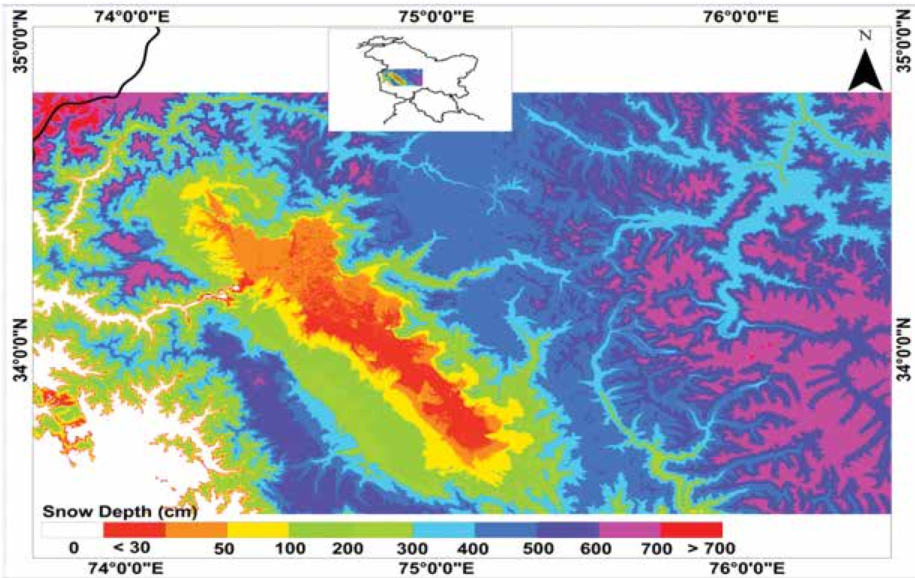
SASE has developed an automated method for retrieval of snow/ice surface temperature (SST) using Landsat-8 thermal data and the method was validated using wireless sensor network data in Beas River Basin, India. Digital number (DN) values of thermal data were converted into top of atmospheric (TOA) radiance. Surface radiance has been estimated from TOA radiance using a single channel method. The estimated surface radiance was then converted into SST. Cloud free Landsat-8 data has been used to



Landsat-8 derived snow surface temperature distribution map of Beas river basin for 23 January 2017.



Elevation map of Beas river basin.



Spatial snow depth map of maximum snow depth during past four decades using developed algorithm.

estimate SST. SASE has established a wireless Sensor network (WSN) in an avalanche prone slope in Beas river basin, India. Landsat-8 retrieved SST has been compared and validated with recorded SST at WSN stations. The mean absolute error (MAE) and root mean square error (RMSE) between estimated and recorded SST has been observed as ~ 1.1˚K and ~ 1.5˚K.

Mapping Snow Depth in Lower and Middle Himalaya in J&K

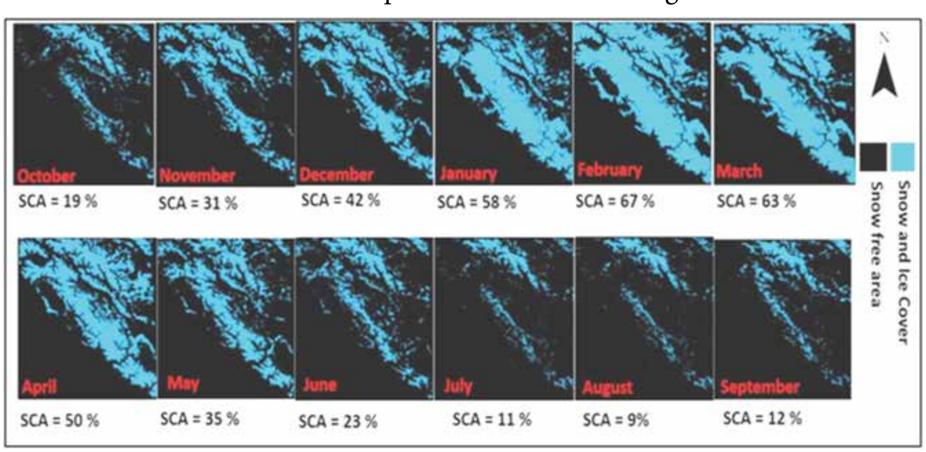
An algorithm is developed for generation of snow depth maps in lower and middle Himalayas in India. The model uses discrete point data supplemented with remotely sensed derived information data to create snow depth maps at spatial resolution of 0.5 km. *In situ* snow depth observations at different locations, moderate resolution imaging spectroradiometer (MODIS) images and shuttle radar topographic mission (SRTM) digital elevation model (DEM) form the database. The algorithm is based on the dependency of snow depth on elevation above mean sea level, which is later adjusted through the *in situ* snow depth observations to represent the local and regional characteristics of the snow distribution. The algorithm was validated using automatic weather stations (AWSs) data in the study area.

Estimation of Spatial and Temporal Variation of Snow Cover Area During Past Decade

MODIS sensor data has been used to estimate spatial and temporal variation of Snow cover area (SCA) in Western Himalaya. Ten days maximum snow cover product has been generated for the one and half decade. Snow cover has least area during the month of August and maximum area during the month of February. SCA in North-West Himalaya varied from approximately 13,180 square km (August, 2001) to 2,11,000 square km (February, 2004) during past one and half decade.

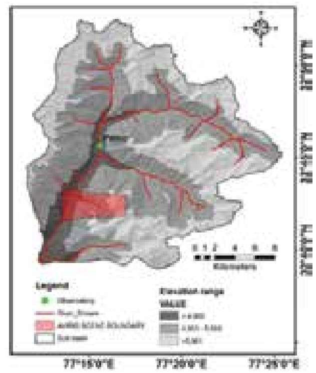
Snow Surface Features Mapping using Hyper Spectral Remote Sensing

Airborne visible infrared Imaging spectrometer–next generation (AVIRIS-NG) was flown for first time over snow bound regions of North-West Himalayas in February, 2016 under collaborative program of ISRO and NASA. The sensor provided hyperspectral images at 4-8 m spatial resolution in 430 narrow contiguous spectral bands in VNIR and SWIR (380-2510 nm) spectral range at 5 nm resampled spectral resolution. Spectral properties of snow at nm resolutions using hundreds of bands is helpful for retrieving snow physical properties, e.g., optical snow grain size, snow albedo, impurities (type and amount) in snow, etc. This data was processed to assess the state of surface snow with respect to wetness content. Exhaustive field measurements were done to estimate *in situ* snow water content using snow fork in synchronisation with high resolution spectral-radiometer (for hyperspectral measurements). Based on analysis of ground data, a new ratio method was proposed to discriminate dry and wet snow using hyper spectral data, which may be used as input for avalanche hazard mitigation, hydrology and climatology applications.

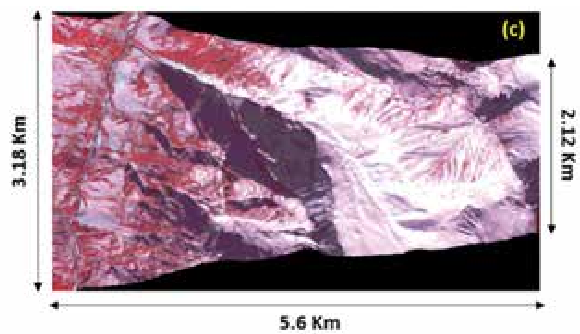


Spatial and temporal variation of snow cover area .

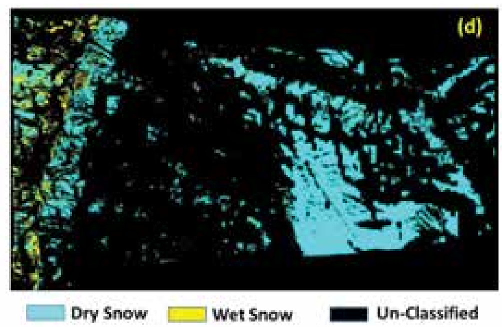
Study area in Middle Himalayas.



Corresponding DEM showing sub-basin boundaries and altitudinal variation in area .



Airborne Hyper spectral image shown as FCC .

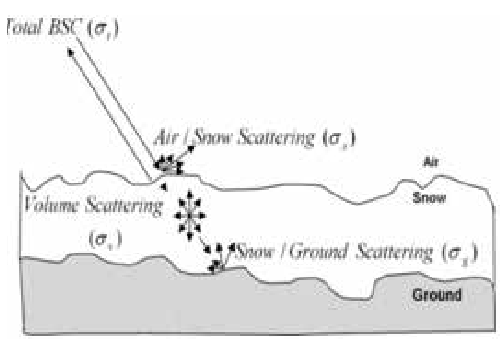


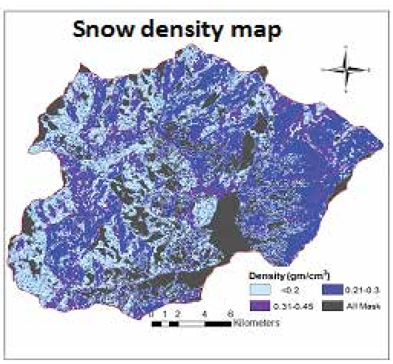
New method based classified wetness image..

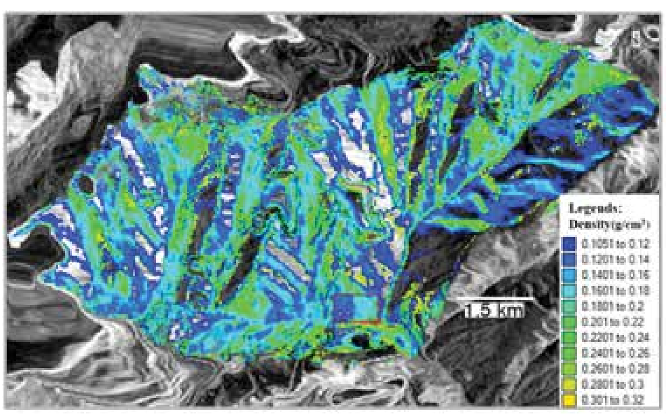
Estimation of Snow Cover, Snow Density and Snow Wetness Using Synthetic Aperture Radar (SAR)

SASE has developed methodologies using multi-frequency and multi-polarisation SAR data for estimation of SCA, snow density and snow wetness. SCA was estimated using single polarisation and multi-date images as well as using radar snow index (RSI).

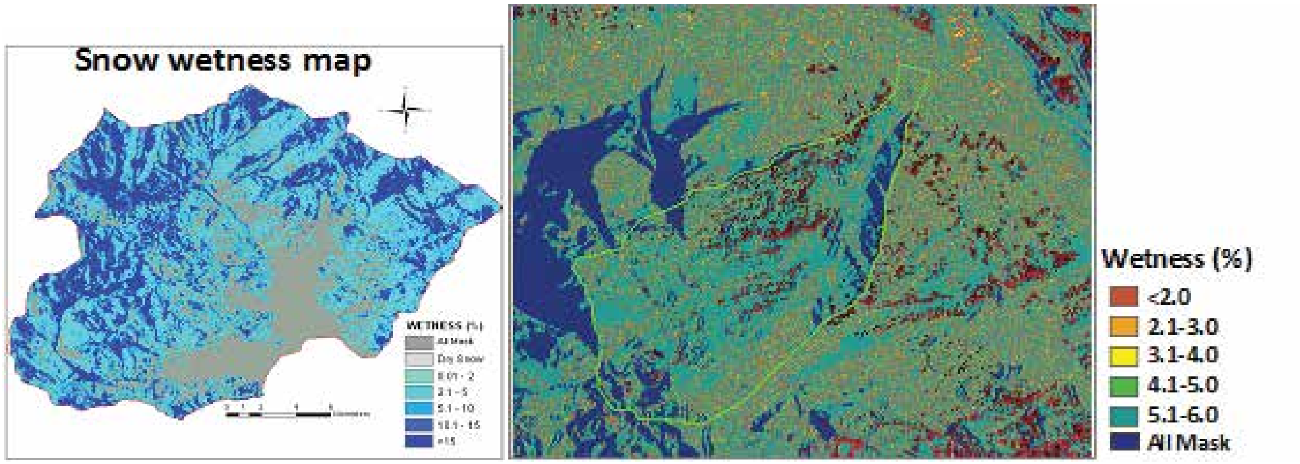
Snow density has been retrieved from multi-frequency (C-Band and X-Band) SAR data. Snow density is an important parameter for avalanche forecaster for calculation of additional load to trigger snow avalanches. Integral equation model (IEM) and generalised volume scattering based modeling techniques has been used to generate snow density map using dual and full polarimetric SAR data.







Snow density retrieval a) Modeling based on surface and volume scattering mechanism
b) Snow density map of Beas river sub-basin, Manali (H.P.) using Dual-Pol. C-band, 30 m SAR data based on IEM model and
c) Generalised volume scattering model based on Full-pol. X-band, 1 m SAR data.



Snow wetness map using IEM model C-band SAR (Left) for sub-basin Beas river, Manali (H.P.) India and high resolution X-band SAR (Right) for avalanche site near Dhundi Observatory (H.P.)..

Seasonal snowpack has variable wetness and it can be dry, moist or wet based on its water content. As the winter progresses, forecasting avalanches during early summer especially in the on-set of melt season required inputs about the moisture levels of snowpack. Methodologies have been developed based on IEM model for moisture estimation at spatial scale (30m-1m) using multi-frequency (C-Band and X-Band) SAR data.

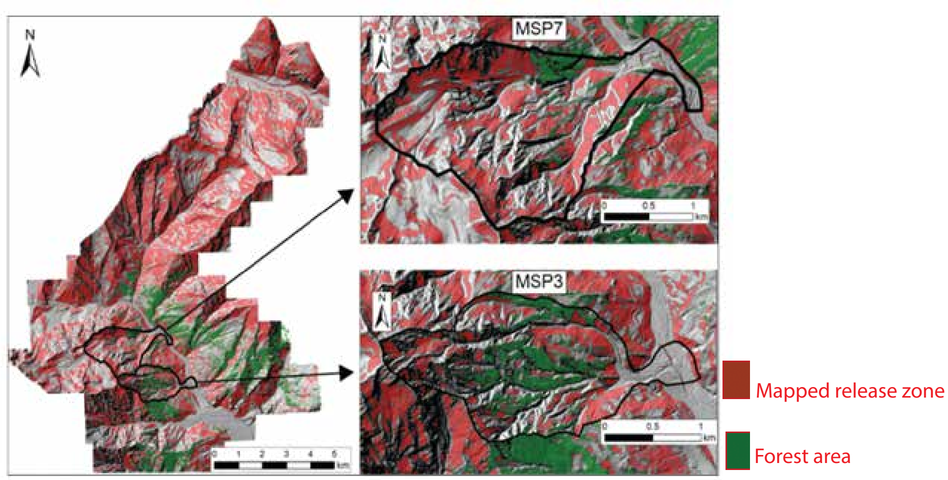
Mapping Potential Avalanche Release Zones using Aerial Photogrammetry Data

The release mechanism of snow avalanches mainly depends upon terrain, meteorological parameters, snowpack parameters and their interactions. Avalanche release information is required for numerical simulation of avalanche events to estimate avalanche flow parameters and hazard mapping. Hazard mapping help in suggesting appropriate measure to protect important roads/ buildings/railway line/transmission line, etc. By far the most reliable way to identify avalanche release areas is using historic avalanche records and field investigations accomplished by avalanche experts in the formation zones. But both methods are not feasible for Himalayan region due to the rough terrain, its vast extent and cold climate. Hence, alternate method of mapping potential avalanche release zones has been developed using aerial photogrammetry data.

Terrain Visualiation and Products Generation

Development of Avalanche Information System

Avalanche information system has been developed using remote sensing and GIS technology for Indian Karakoram Himalaya. High spatial resolution (0.5 m) PLEIADES satellite images, DEM of ASTER GDEM V2 (30 m) and Cartosat (10 m) have been used for the development. Terrain parameters, e.g., slope, aspect, elevation, etc. have been derived using DEM. Avalanche sites in avalanche prone areas have been identified using terrain parameters and snowfall information. Camp locations, pedestrian routes, avalanche sites along pedestrian routes, etc. have been digitised using appropriate GIS vector features, e.g., point, line, polygons. Past avalanche accidents along pedestrian routes, past avalanche occurrences, climatology of the region etc. have been mapped in GIS environment.



Potential snow avalanche release zones near Manali (H.P.) at 1m spatial resolution.

Remote sensing and GIS technology proved to be very useful for development of avalanche information system in digital form. The developed digital avalanche information system is being used for avalanche forecasting and mitigation of avalanche hazard in the Karakoram Himalaya.

LAN based Dynamic WebMap Platform for Geospatial Data Visualisation, Snow Situation Awareness and Avalanche Forecast Dissemination

LAN and browser based dynamic WebMap platform was developed in GIS environment. It maps the SASE's Area of Responsibility–J&K, H.P. and Uttarakhand by superimposition of satellite imagery in GIS. The user can directly access it on his computer on a web browser (IE, Chrome, Firefox, Safari, etc.) with no additional software or hardware requirement. It can be used for visualisation of locations and registered avalanche sites over high resolution satellite base imagery.

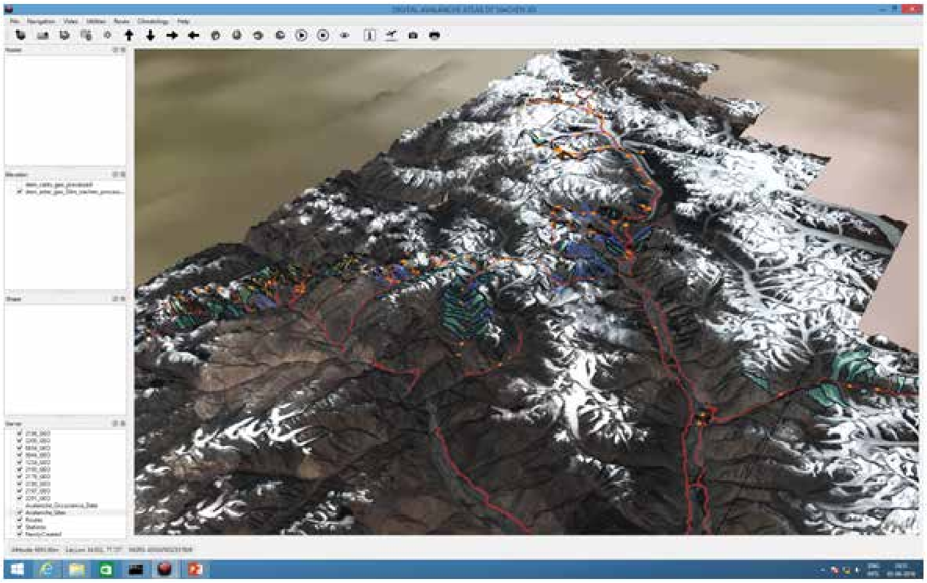
The latest satellite imagery is also updated so that the current status of each route, location and avalanche site vis-à-vis the near real time snow deposition is known. Currently the satellite imagery of MODIS having spatial resolution of 250 m and frequency daily; Landsat-8, having spatial resolution 30 m and frequency 7-9 days, Sentinel 2 having spatial resolution 20 m and frequency 15 days, is being updated regularly.

The platform also serves as daily avalanche forecast dissemination system. A user can view avalanche warning for three consecutive days around the date of his choice. For easy comprehension, the 5 avalanche warnings namely, unlikely, low danger, medium danger, high danger and all-round danger have been assigned colour codes which are displayed along with warning table on the map. The routes, locations and avalanche sites get colour-coded dynamically as per the prevalent avalanche danger.

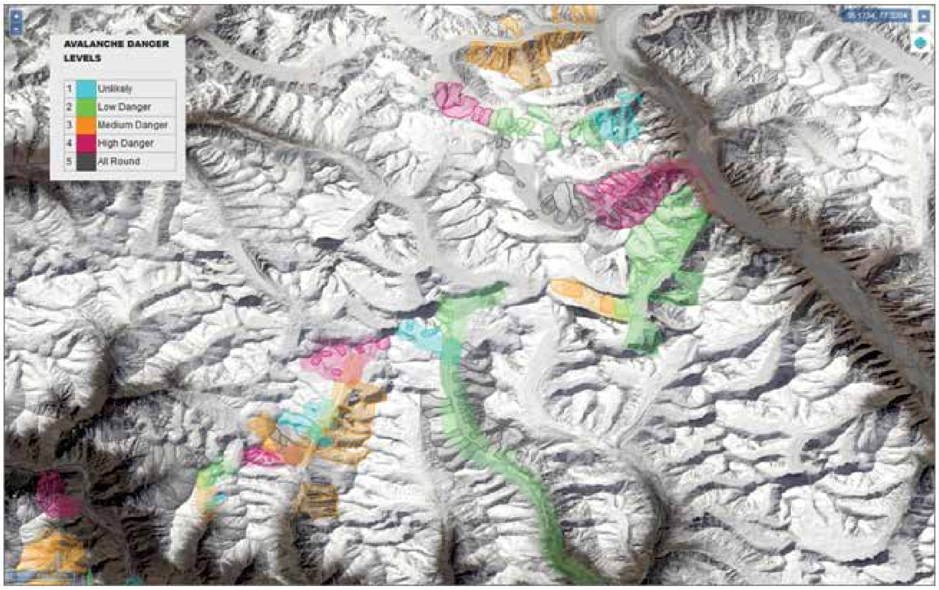
The platform is developed using three open source software; Geoserver for generation and display of dynamic map tiles and layers; MySQL for database of issued avalanche forecasts, Wordpress (Customised) for website frontend. Use of all open source software and free satellite data ensures that the platform remains updated and there is no recurring cost of its operation.

GPS-based Real-time Avalanche Path Warning and Navigation System

A portable avalanche warning and navigation system was developed by SASE. It is capable of providing



GUI of the avalanche information system.



LAN based dynamic WebMap platform.

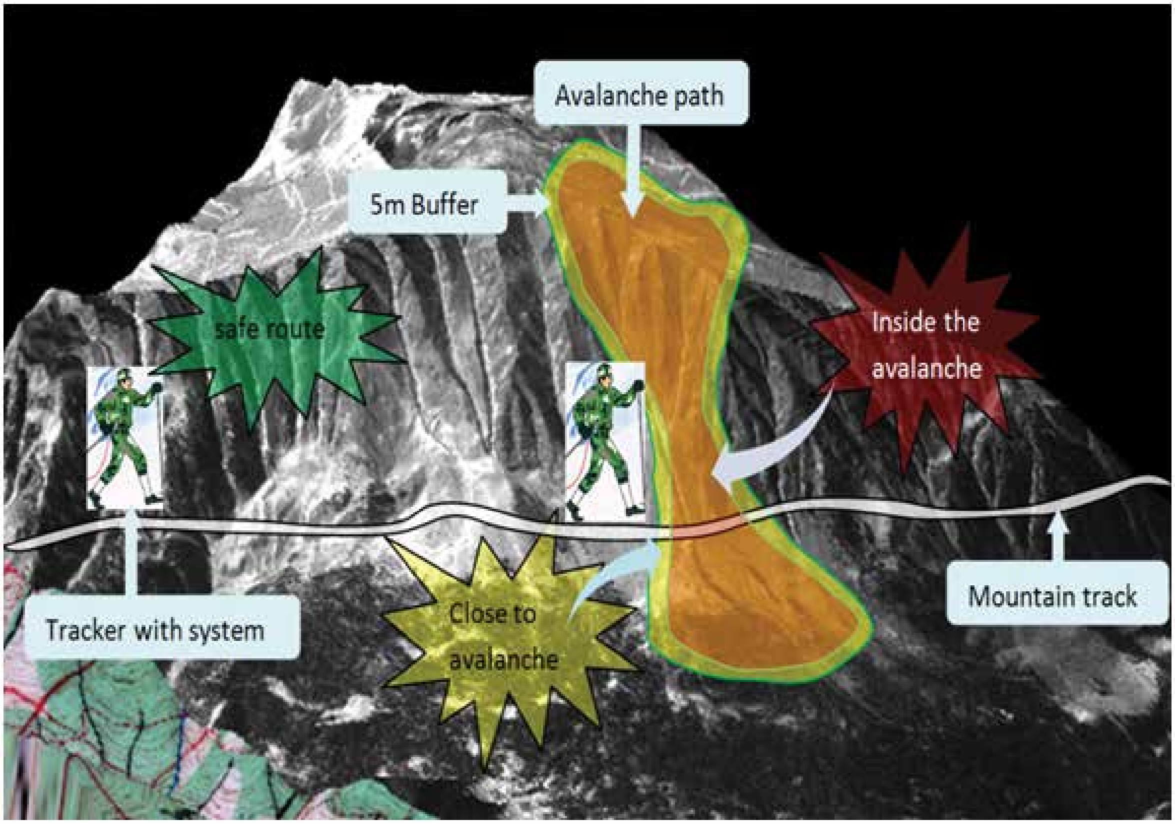
near real time safe navigation and warning to troops in avalanche-prone regions under all weather and terrain conditions. It can also provide near real time meteorological data with high spatial and temporal resolution to increase the accuracy of avalanche prediction. The system uses a hand held GPS with a positional accuracy of 2-5 m and a customised application has been developed for visualisation of maps, navigation, positioning, tracking and issuing avalanche path warning. Based on registered avalanche path data inputs, this application updates the traveller at pre-defined time intervals on whether the current position of the traveller is inside or outside of an avalanche path. The warning information is displayed to traveller on entering an avalanche prone area, in the form of text and voice messages. In numerous track tests, the system has demonstrated a high level of accuracy and repetition in locating registered avalanche sites in open slopes bare lands but accuracy deteriorated in the narrow valleys forested areas.

Development of Web-geospatial Platform for Analysis and Visualisation of Avalanche Hazard

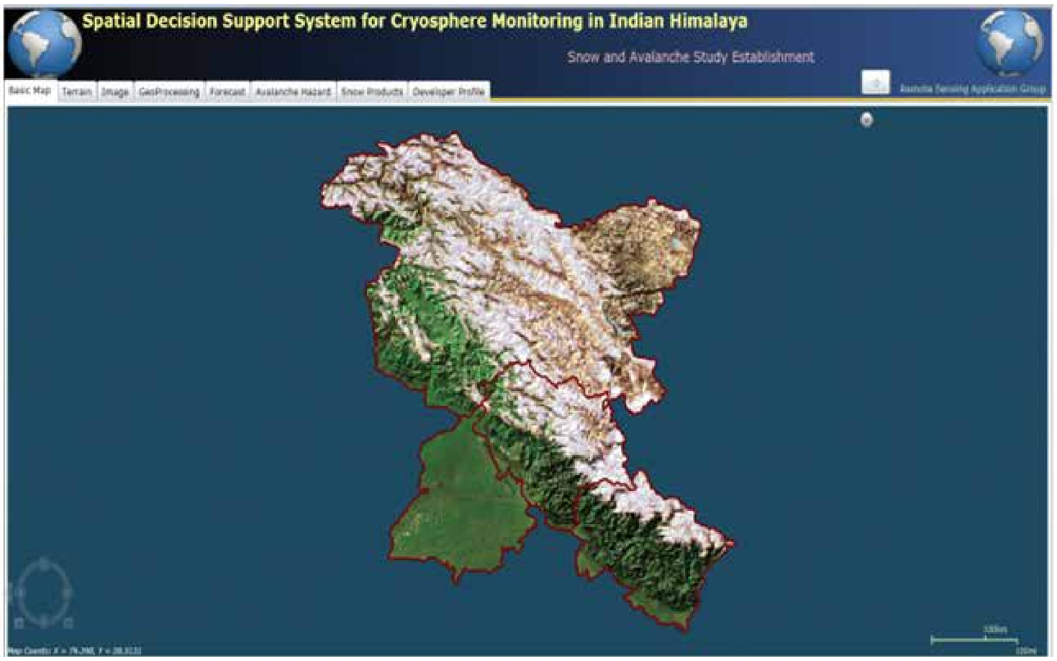
A web GIS-based geospatial platform is in the process of development to provide an integrated platform for avalanche researchers, operational snow and avalanche service providers, decision makers and users to access, visualise, analyse and manipulate the information related to snow and avalanches. This system is capable of handling of multi-source and multi-temporal data required for decision support. It has 3-tier client server architecture and geospatial data support is provided through various GIS services. Some of the important modules of the system are map, terrain, vector data, snow products, avalanche hazard, geo-processing and forecast.

Snow Cover and Avalanche Physics: Modeling and Simulation

Snow is a porous sintered material consisting ice grains, air, small amount of impurities and sometimes liquid water. The physical and mechanical properties of snow are directly influenced by the metamorphosing snow microstructure and thus evolve simultaneously during metamorphism. Snow physics and mechanics, snow cover and avalanche simulations are core research areas of SASE. Numerical analysis of physical and mechanical characteristics of snow, snow cover and avalanche simulations and experimental investigations are briefed.



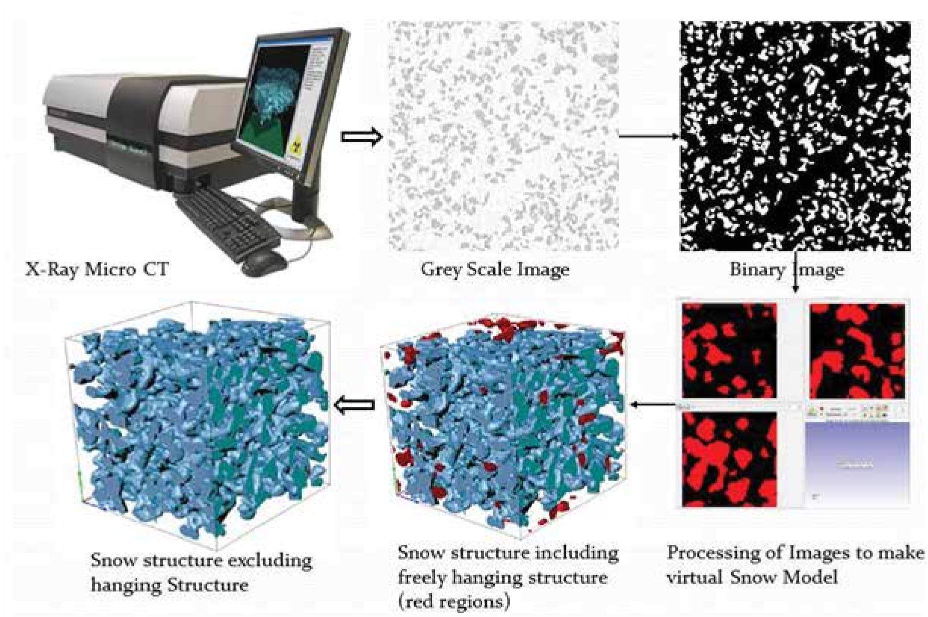
Schematic of navigation using proposed system, tracker is informed regularly about the route status in the form of one of these three conditions (a) Safe route (b) Close to avalanche path and (c) Inside the avalanche path (warning).



Web-geospatial platform for spatial decision support system.

Computational Snow Mechanics

Rheological models, various concepts from powder metallurgy and damage based elasto-plastic constitutive behaviour of ice are being used to take into account of various phenomenon at microstructure level in snow. In the ongoing investigations, spanning over last decade, SASE has prepared a large database of mechanical characteristics (elastic moduli, viscosity, compressive, shear and tensile strength) of typical Himalayan snow. SASE has also evolved image and finite element method (FEM) based methodology to extract constitutive behaviour from 3D microstructure of snow. Snow is foam like structure with matrix of ice. For each snow layer arrangement of ice network, i.e., matrix is different and hence the response also varies. Therefore for complete understanding of snow behaviour, micro-mechanical analysis and multistate modelling approaches were adopted. 3D microstructure is obtained using X-ray micro CT scanning. FEM is utilised to obtain mechanical



Sequence of processes involved to generate 3D structure of snow for FE analysis.

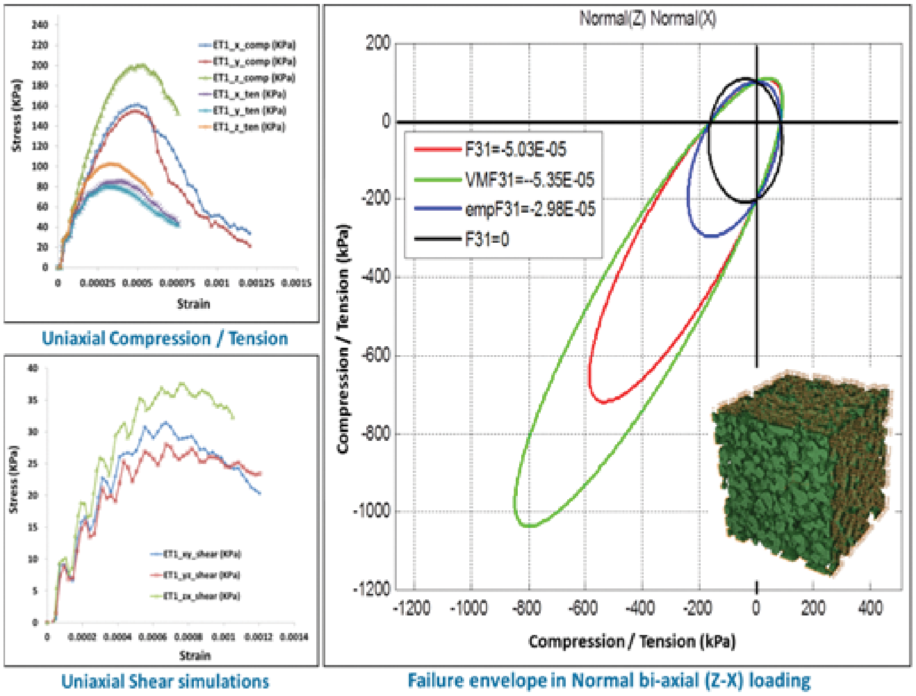
response of different snow layers. The complete failure envelope for snow is determined using FEM and has potential in estimation of avalanche hazard.

Snow-pack Stress Analysis and Failure Mechanism

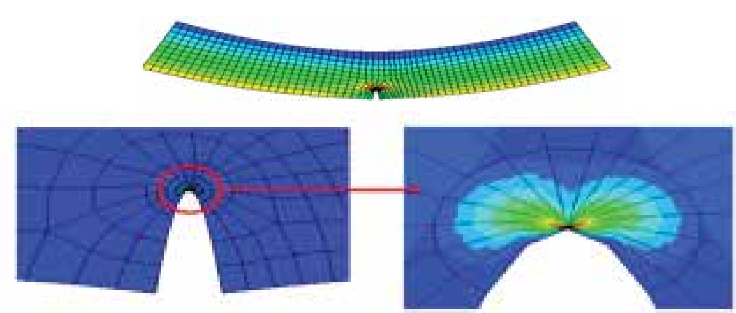
Experimental investigations have been conducted to obtain the strength and fracture mechanical properties from crack propagation studies on snow. Finite element simulations of stresses around the crack tip and its comparison with experimental results furnish an invaluable basis for validation of failure mechanism. Initially the snow was analysed considering it as a continuum as shown.

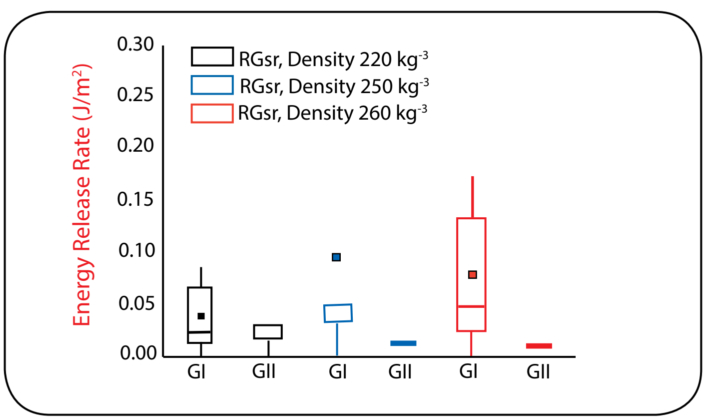
Characterisation of Snow Acoustic Properties

Impedance tube is a device used for the measurement of reflection, absorption, transmission and impedance of a porous material such as snow. A broadband stationary random signal is used as excitation source placed at one end of the long impedance tube. The sample under test is placed on the other end of the tube. The incident and the reflected signals are recorded with the help of two fixed microphones mounted near wall of tube at some known positions. Based on microphone data, different acoustical properties of snow are calculated. Figure shows the typical acoustic absorption characteristics for longitudinal waves propagating through pores of snow samples.

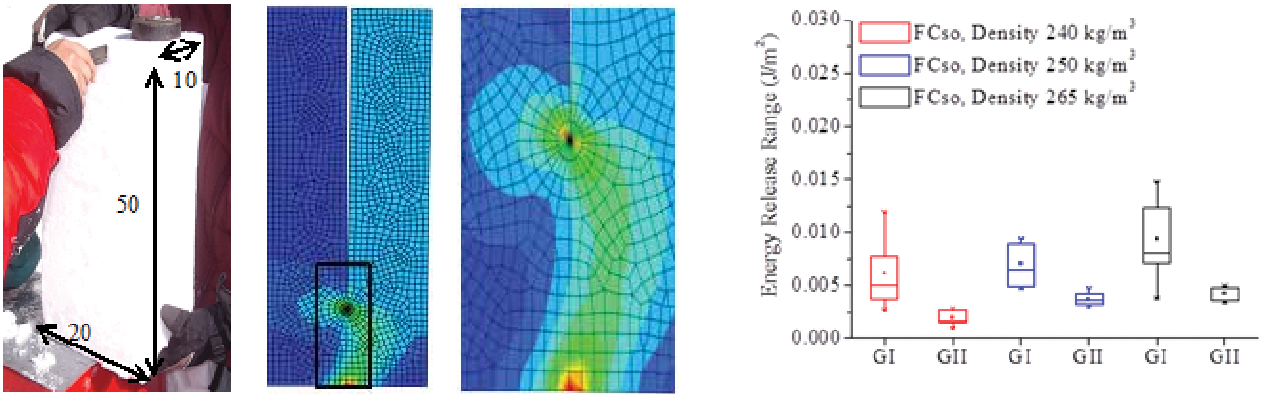


Failure envelope in normal bi-axial loading.

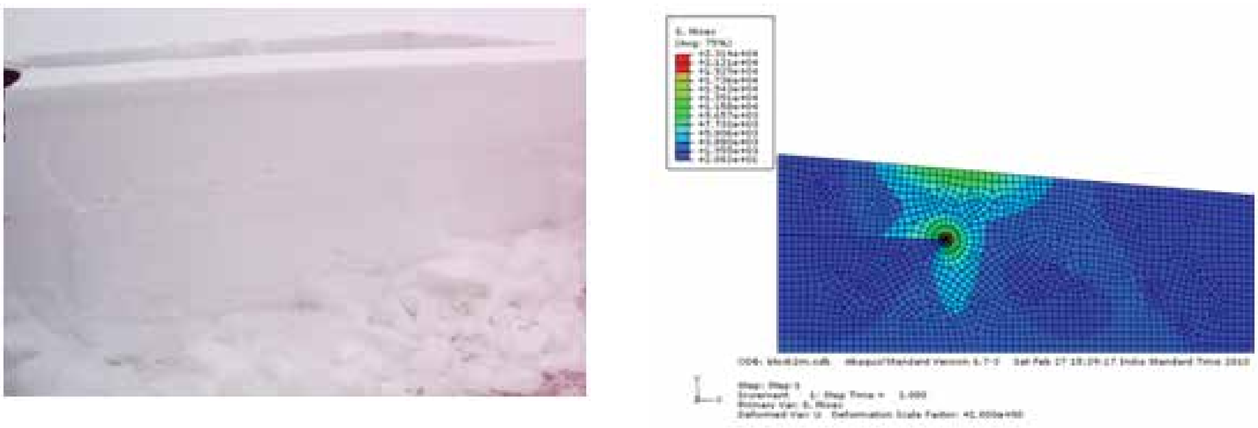




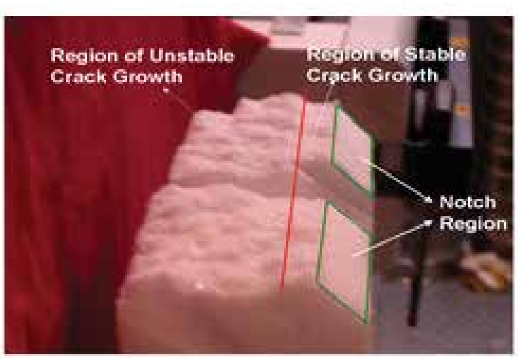
Determination of fracture energy release rate for a snow layer.



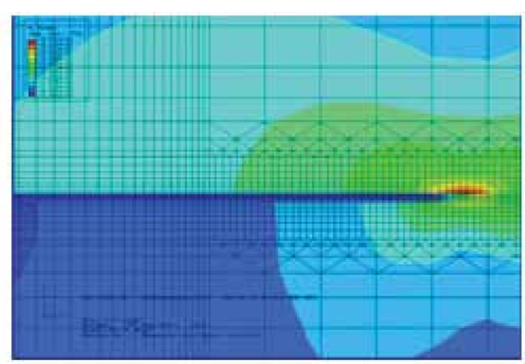
Determination of interfacial snow fracture energy release rate for interface involving FCso snow.



Numerical simulation of stress intensity around the crack tip at critical crack length for Propagation Saw Test (PST).

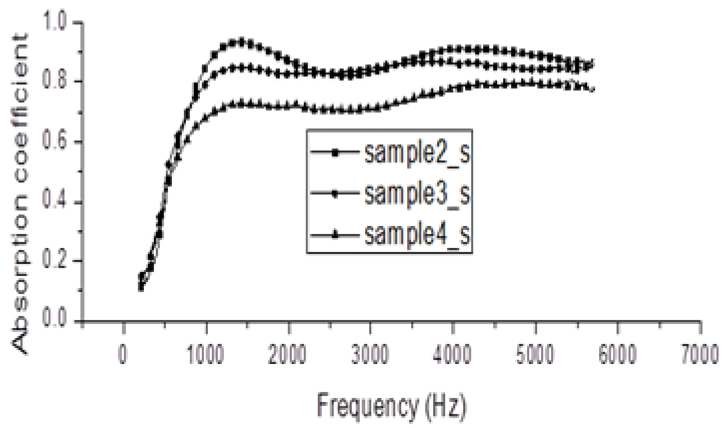


Beam notch test for crack propagation and fracture.



FEM simulation of stresses near the crack tip.

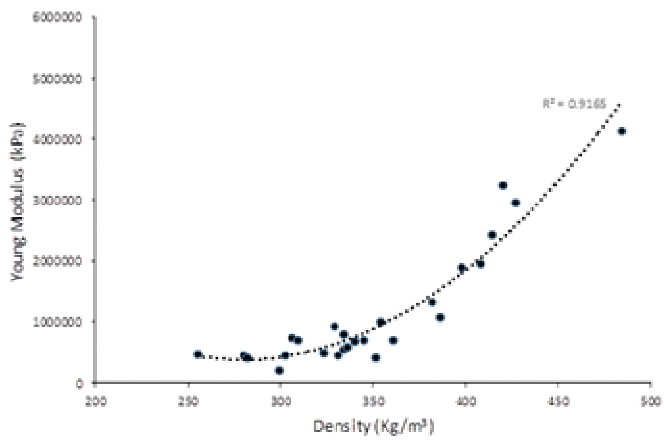
In P&S wave velocity measurement system the velocity of longitudinal and transverse waves in ultrasonic range is measured. In this system, a pulser is used to excite the transmitting transducer to send ultrasonic wave through the snow which is captured by another transducer at other end. Based on the time of arrival the velocity of the longitudinal wave are measured which is further used for the mechanical characterisation of snow under test.



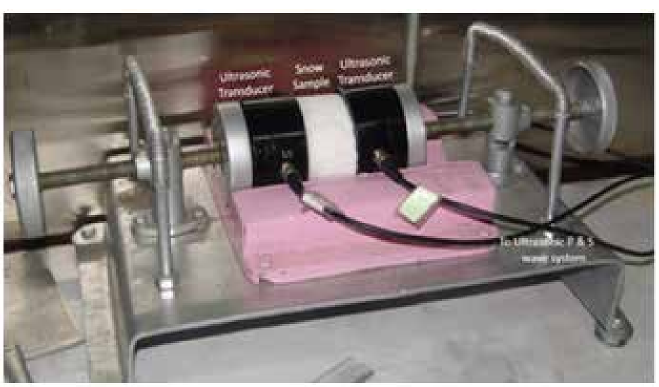
Absorption coefficient of snow.

Spatial Variability and Weak Layer Studies

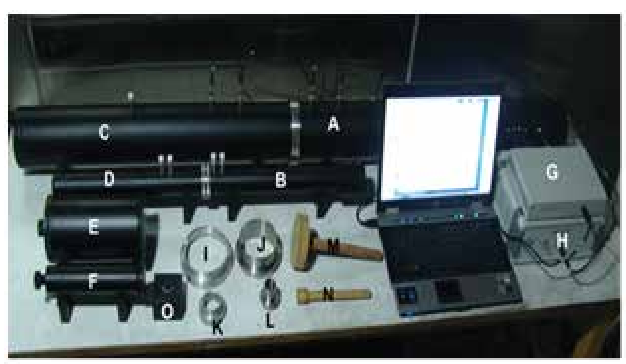
The snow cover distribution is inherently non-homogeneous due to local climatic and topographic differences. The knowledge of spatial variability of snow cover properties and underlying weakness is essential for the understanding of avalanche formation mechanism. Slab avalanches usually occur due to failure of a weak layer or an interface underlying a strong slab. Hence the mechanical properties of snow layers are of prime importance to determine the snow pack stability. In this direction, SASE has initiated an extensive programme at Field Research Stations Patsio (3800 m) and Dhundi (3050 m) for characterising the internal snow-pack structure using high resolution snow micropen (SMP). The SMP interacts with snow at microstructural level and the signal of penetration resistance offered by snow indicates about the microstructure as well as the mechanical properties of snow. The SMPSTRAT software has been developed for snow



Youngs Modulus of snow.



P&S wave velocity measurement system.



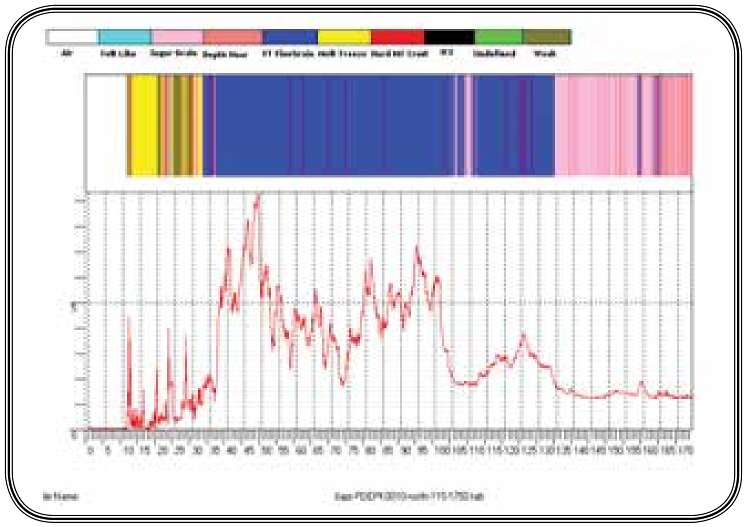
Impedance tube system.

characterisation, determination of mechanical properties, analysis of spatial and temporal variability and density inversion.

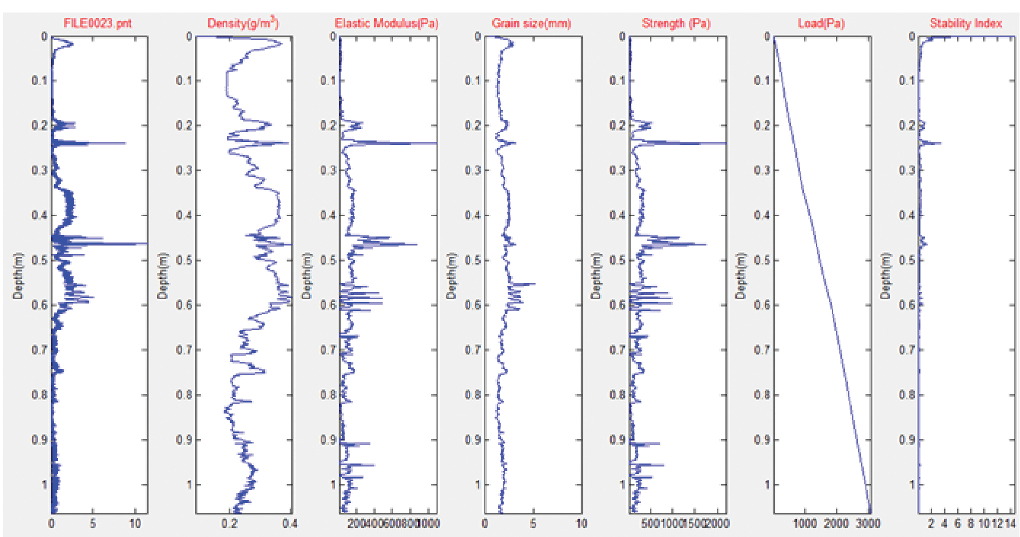
Snowpack Evolution Modelling

Knowledge of current state of snowpack structure and it's mechanical stability in space and time is very important for avalanche forecasting. Conventional method to assess the state of the snowpack is manual snow pit profiling, which is subjective, destructive in nature and time and labour intensive. Additionally, SASE has a large area of operation and limited resources. A process based approach is developed, where simulated snow profiles are generated by modelling energy exchange, heat and mass transfer processes, etc., occurring inside the snowpack. Such a snow cover evolution model-SNOWPACK (developed at ISAR SLF Switzerland) has been implemented at SASE, which can simulate hourly snow-profiles from snow-met data from a network of automatic weather stations. The model run in standalone mode and the entire process from data acquisition to result generation has been made automatic. Web-based tools to download and visualise snowpack profiles and stability indices have been implemented on intranet.

Snow MicroPen.



Layering information using SMPSTRAT.



Snow parameter interface for evaluation of snow parameter from a SMP profile using SMPSTRAT.

Neural Network based Snow Cover Model HIM-STRAT

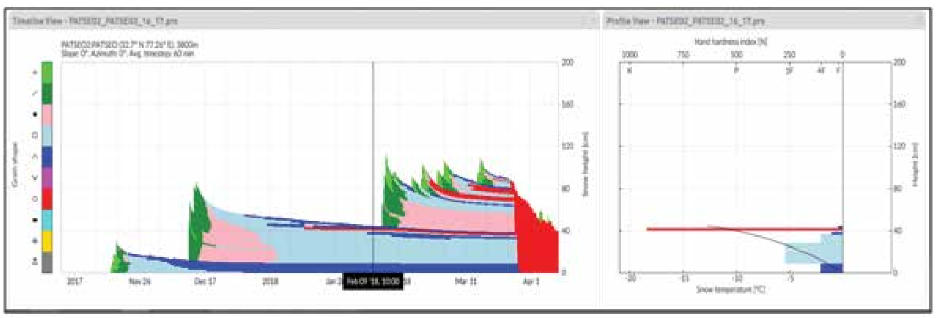
The snow cover model HIM-STRAT has been developed to integrate in the ensemble avalanche forecasting. This model gives snowpack stability index and other snow pack parameters such as RAM hardness, temperature, density, thickness and shear strength of different snow pack layers. It also provides information about the level of avalanche danger and possibility of avalanche occurrence.

Real Time Avalanche Monitoring using Infrasonic Sensor Array

Accurate manual recording of avalanches is not possible due to uncertainties involved in avalanche formation and difficulties associated with vast rugged terrain. An avalanche while descending on a slope generates infrasonic sound waves which travel far from their origin and can be detected by the sensitive microphones.

The technology was explored in this direction for the development of automatic real time avalanche detection system. In this system infrasonic microphone arrays are installed at two field stations namely, Dhundi (3050 m) in Pir Panjal range and Patsio (3800 m) in Great Himalaya range with each system consists of 04 infra-mics in a star configuration (01

Tool chain for operational implementation of SNOWPACK.



Outcome of simulations for station Patseo in Great Himalaya for the winter season 2017-18.

Validation with manual pit profile for 09 February 2018.

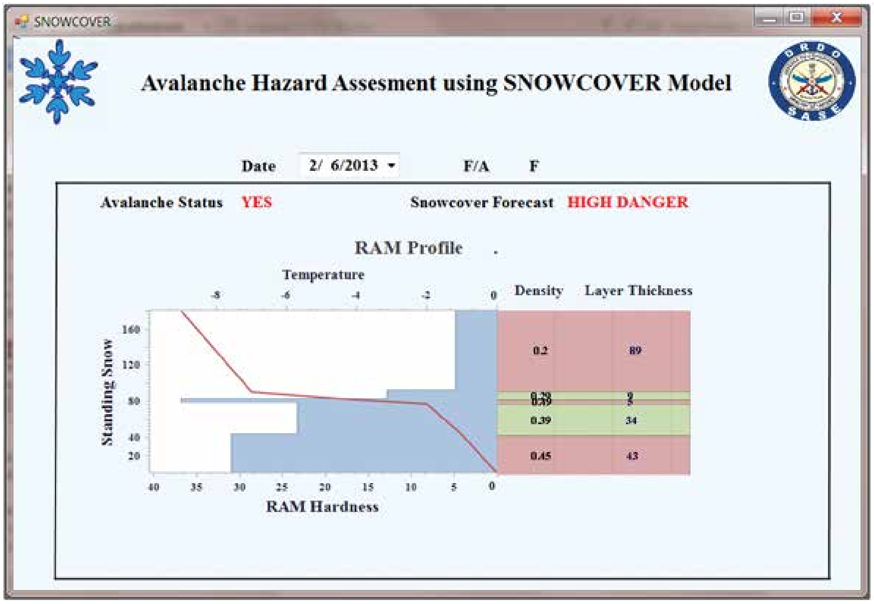
Mic at centre and 03 Mics at 30 m radius with an angular separation of 120°). The data is acquired by DAQ centrally and processed in realtime by a PC. Both the systems detected several avalanche events.

A signal processing utility Infralocator has been developed and tested. It is capable to detect and localise the avalanche activity based upon threshold classification. The system is useful for auto recording of avalanche phenomenon which can be used for validation of avalanche forecast, avalanche hazard mitigation and management of transportation in avalanche prone areas.

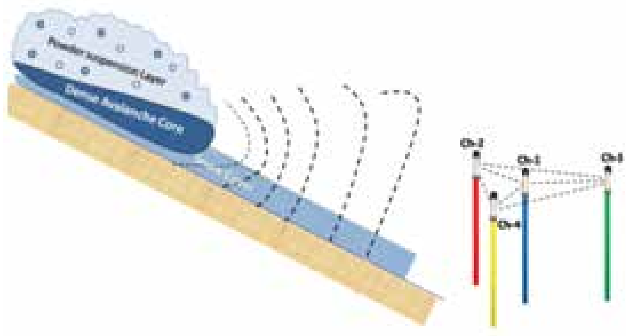
Snowpack Stability Assessment using Acoustic Emission Technology

Acoustic emissions are feeble acoustic signatures produced by materials during the microscopic deformation/failure processes which finally may result into catastrophic failure of the snowpack in the form of avalanche. SASE is working on acoustic emission (AE) behaviour of snow through various laboratory and field based studies. Innovative experimental techniques were developed to tackle the challenges such as the highly attenuating character of snow, the extremely weak signal strengths, the sensor-to-snow coupling (due to the fragile surface of snow), to get the efficient signal transmission and the interferences caused by extraneous noise. Extensive laboratory work is being carried out to model and correlate various AE characteristics such as amplitude, count, energy, hit duration and frequency with the damage mode and the fracture process occurring within snow.

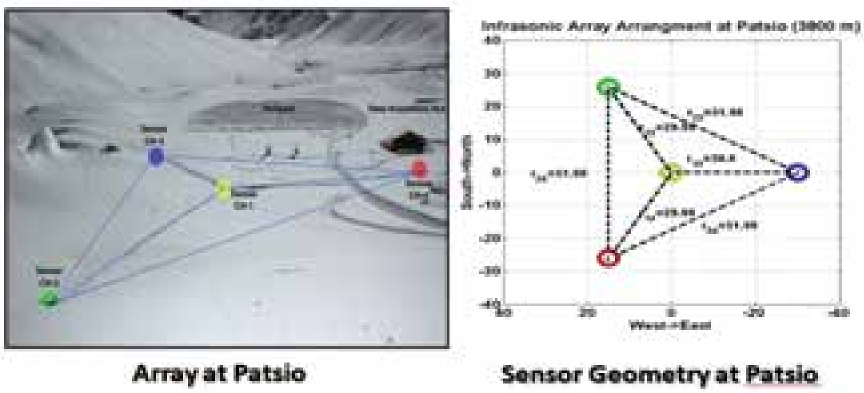
SASE has installed a multi-channel acoustic emission system in an experimental avalanche slope at Patsio in Great Himalayan range (altitude of 3800 m asl). The system



Snow cover model HIM-STRAT.



Schematic of infrasound generated by avalanche and captured by Infrasonic Array.



Actual installed array at Patsio.

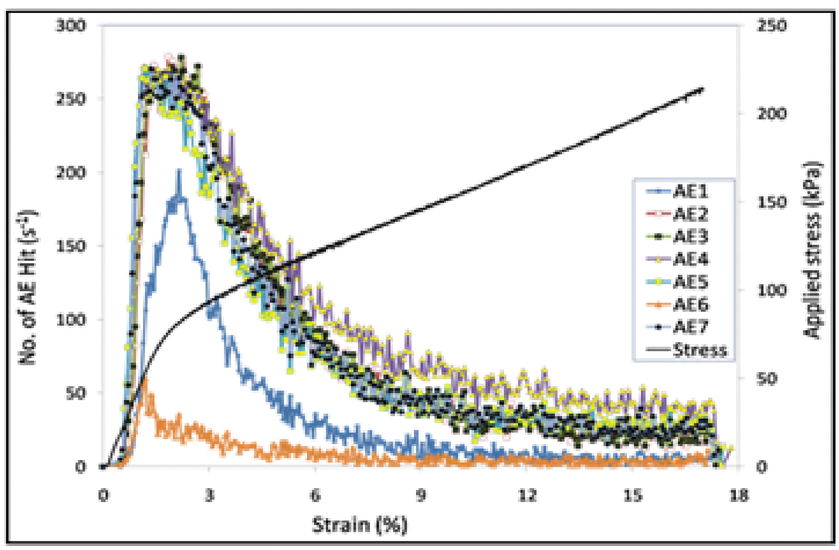
records the acoustic emission activity from natural snowpack lying on a slope prior to an avalanche activity. This information thus recorded is vital to assess the stability of the snowpack. The data collected is useful for development of automated avalanche warning system in near future.

Avalanche Flow Simulation

A software has been developed for simulation of avalanche flow. It solves mass and momentum conservation equations in two dimensional space. As these equations are depth averaged in third direction, they are also two dimensional. Terrain data (x, y, z coordinate information) of the avalanche sites are extracted from DEM. Using this data a grid in two dimensional space is created. Resolution of the grid depends upon resolution of DEM. Each grid/cell has its own elevation. Slope angle of each grid/cell is estimated.

Parameters used in avalanche simulation are flow height, flow velocities in x and y directions and friction parameters 'mu' and 'xi'. Values of these parameters are estimated for each grid/cell and stored in the form of a matrix. Initial values of flow height and flow velocities are separately stored in matrices and used in the software as initial conditions.

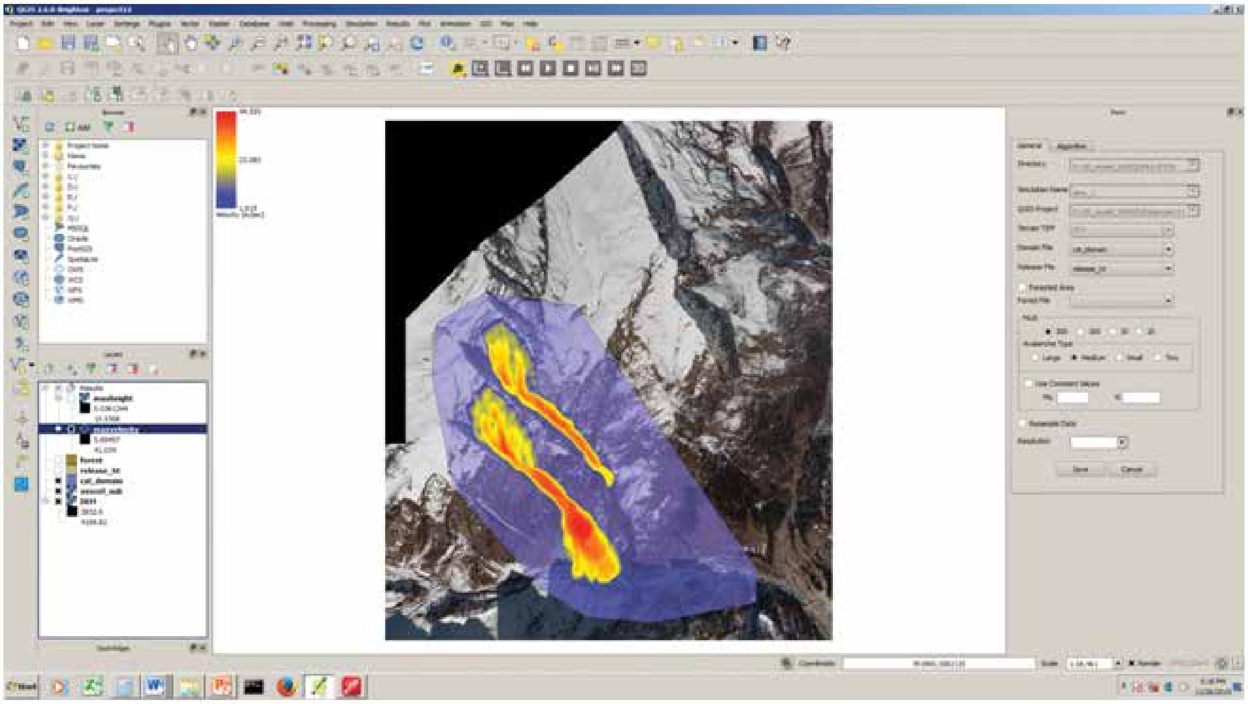
Avalanche simulation software estimates flow height and flow velocity at different time steps at each grid/cell and stores them in different matrices for viewing during post processing. The flow simulation software has three major components: (a) Pre-processor (to generate input data for main program) (b) main program (carries avalanche dynamics calculations) and (c) viewer and post processor (to visualise results of the main program). Avalanche flow simulation software is being operationally used in SASE and has applications in assessment of avalanche threat on various settlements, highways/property in avalanche prone areas.



AE Response of snow and performance of multi-sensor coupling.

High Altitude Observations Network and Instrumentations

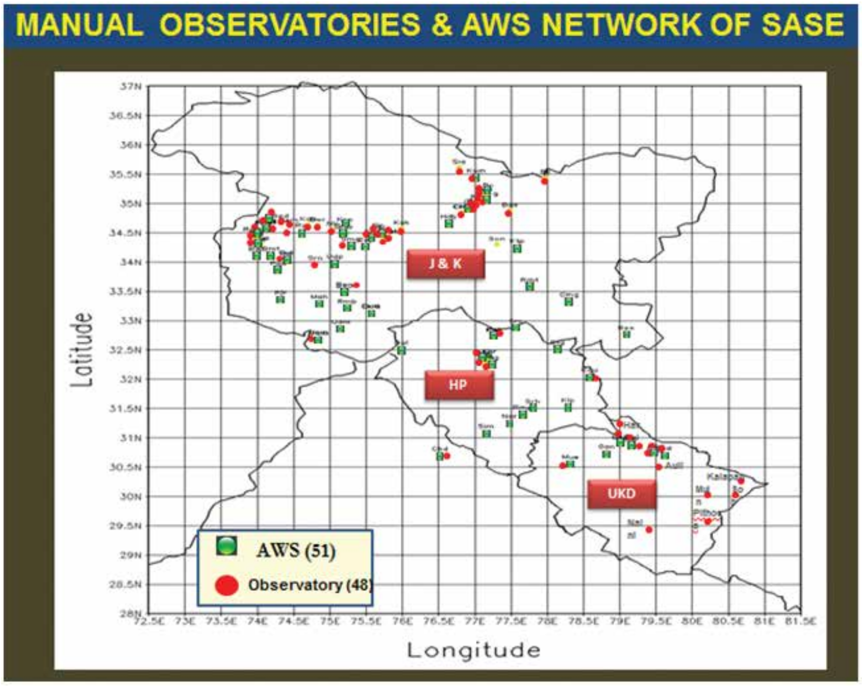
SASE has installed 48 observatories and 51 automatic weather stations (AWS) in the snow bound regions of J&K, H.P. and UK states at various elevation levels from 1800 m to 5500 m from mean sea level. Snow and meteorological parameters are recorded at these observation locations and received at RDC SASE, Chandigarh daily. Data include snowfall, rainfall, air temperature, surface temperature, relative



Avalanche flow simulation using software.

humidity, wind speed and direction, radiation, snow layer information, snow density, etc.

The data thus received are used as input in avalanche prediction, snow cover and avalanche simulation models. Network of manned observation locations and AWSs are also shown.



Wireless Sensor Network

SASE has established Wireless sensor network (WSN) on an avalanche slope in the PirPanjal Range in H.P. The network covers an area of approx. 400,000 sq m from an altitude of 2890 m to 3350 m. The base station of the WSN was setup at Dhundhi Field Research Station of SASE, which is approx. 20 Kms from Manali. 35 nos. of wireless nodes are installed around the avalanche site. Total 128 snow and meteorological sensors recording 14 different parameters, viz., ambient temperature, relative humidity, wind speed and wind direction, atmospheric pressure, snow surface temperature, snow depth,

Snow meteorological observatory of SASE at Dhundi (H.P.) near Rohtang Tunnel.

Two different sites of the WSN.

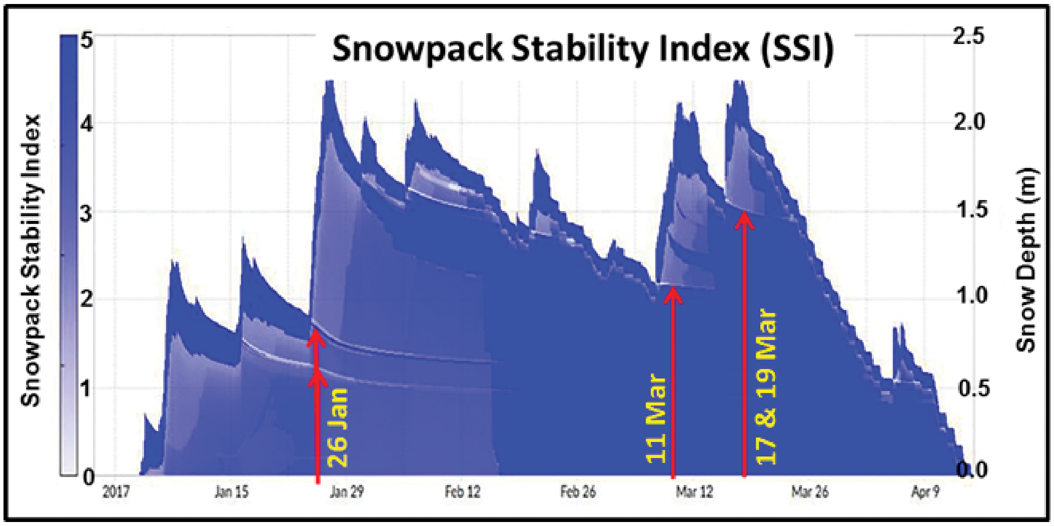
precipitation, soil water content, glide, creep, snowpack temperature, shortwave and long wave radiation, etc. are integrated to the nodes. Data of these parameters are received from the sensors wirelessly at regular intervals at the base station. A broadband connectivity has been setup to transfer the data from the base station to RDC SASE, Chandigarh. A system of geophones and camera has also been installed for acquisition of seismic signals and visual images of avalanche events and the data received wirelessly at the base station.

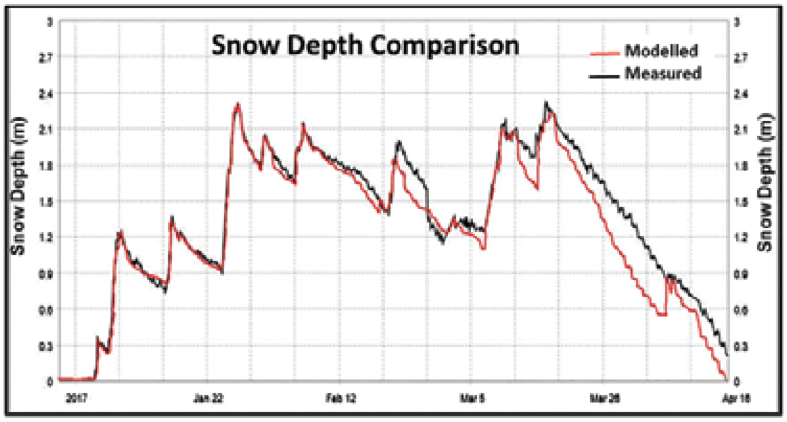
The snow-met data acquired through the WSN was utilised for estimation of snowpack stability of the avalanche slope. The inhouse developed snowpack stability assessment models generate outputs like snowpack stability index, snowpack temperature profile, density profile, snow grain type and size, snow hardness and many other parameters as function of time and snow height. The model outputs have been validated against the data from the WSN and results obtained are in good agreement. The snowpack stability index (SSI) of one of the sites with avalanche events (2017) marked in red. A sharp fall in SSI from a higher value is indicative of an impending avalanche event.

The system of geophones and camera, installed for acquisition of acoustic signals emanating during avalanching was able to record earthquake and avalanche events. To segregate different types of avalanches, a large database of such events is needed, but still the avalanche events could be identified from the shape and magnitude of the seismograms and frequency ranges of the acoustic signals.

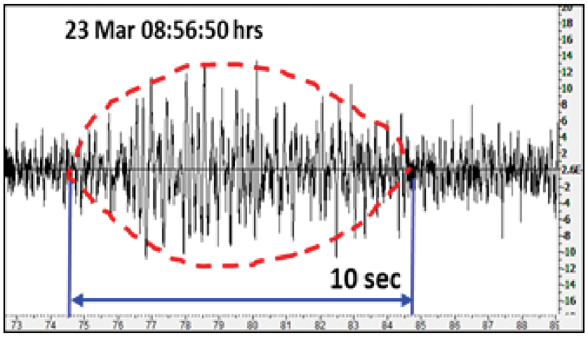
Parallel Probe Snow Profiler

Parallel probe snow profiler (PPSP) is an indigenously developed state-of-the-art multi-parameter probing device to record speedily the vertical distributions of liquid water content

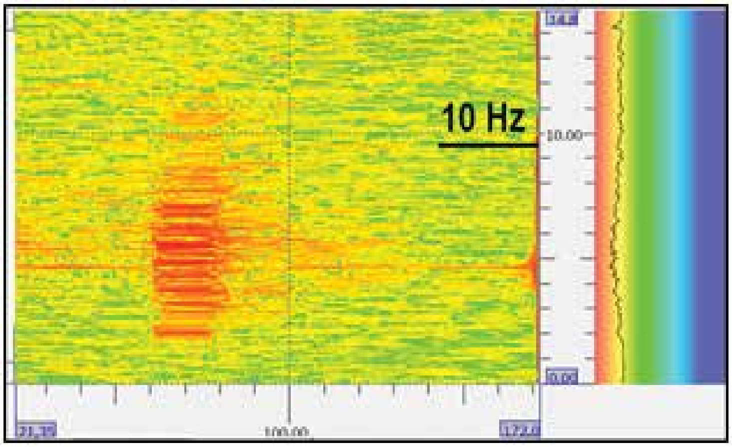




Comparison of modelled and measured snow depth at one of the WSN site. The comparison shows high accuracy of the model output.



A typical spindle shaped seismogram (Left) of a direct action fresh snow avalanche (2018).



Spectrogram showing frequency excursion of the event.

(LWC) or liquid water saturation (LWS), temperature and penetration hardness in porous materials like snow and soil corresponding to different depth positions. It uses hall-effect sensors in measurements. In this device two parallel probes are allowed to penetrate into the medium (saturated or non-saturated) up to depths of 2 m in the steps of 5 mm. PPSP v 2.0 onwards are wirelessly as well as manually operated device with line-off sight operation range up to 300 m. The PPSP is controlled with the help of a handheld remote control device and the data is retrieved/stored in the handheld memory (8 GB, expandable up to 32 GB) that can be interfaced to a PC Laptop via a USB port.

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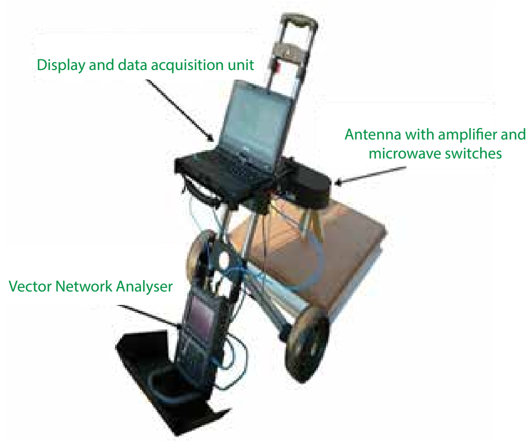
Parallel probe snow profiler.



Trolley mounted set-up of SFCW RadarParallel probe snow profiler.

The data can be displayed on the monitor in realtime both in the text as well as in the graphical formats. The probe has been tested in different Himalayan ranges. PPSP facilitate fast collection of stratigraphic information from a large snow cover area. 3D profiling of the area is also available in the later versions of the instrument. It has several applications in the area of snow and avalanches, remote sensing data validation, soil science, agriculture, landslides, hydrology, geology, etc.

Stepped Frequency Continuous Wave Radar

Stepped frequency continuous wave (SFCW) Radar system has been developed by SASE for snow applications. The vector network analyser (VNA) based ultra wide band SFCW radar system is capable of gathering snowpack depth profile in snow bound regions in a non-destructive manner.

The fully polarimetric SFCW radar consists of VNA, antenna sub-system for full polarimetric measurements (one transmit and one receive orthogonal linear polarised quad ridged antennas) and a control, data acquisition, processing and display platform. The SFCW radar covers a frequency range from 2 GHz to 18 GHz and can be operated in the temperature range of -10 °C to 40 °C. The system is capable of measuring the magnitude and phase of the received signal in two orthogonal polarisations and the full scattering matrix is displayed for the sub-surface. Any sweep band within the specified frequency range can be selected.

The output RF power over the band is adequate to penetrate at least 1m of snowpack (average density 300 kgm^{-3}) to provide the scattering coefficients and reflection profile.

Instrumented Avalanche Rod

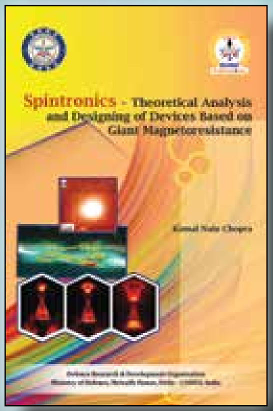
Instrumented avalanche rod is a multi-purpose rod and used in investigation of snow stability during movement of personnels. The instrument is integrated with the load cell, magnetic depth sensors, thermocouple, GPS and avalanche victim detector (AVD). Mechanical tools like snow-shovel, ice axe, etc., can be attached to the rod for multiple applications. The instrument used to collect snow layer information which helps in assessment of layer stability and safe movement in avalanche prone areas. Integrated AVD in the rod can help in rescue operations of avalanche accidents.

Instrumented avalanche rod.

DRDO Monograph Series

Spintronics – Theoretical Analysis and Designing of Devices Based on Giant Magnetoresistance

Dr Kamal Nain Chopra



In this monograph, the basic principles of the generation of carrier spin polarisation, spin dynamics, and spin-polarised transport have been discussed. Spintronics as spin-based electronics, main issues in semiconductor spintronics, magnetic semiconductors, diluted magnetic semiconductors and alloys of a nonmagnetic semiconductor have been discussed briefly. The topics like 'spinning electrons' in semiconductor components, advantages of the property of spin for spintronic devices, and some concepts connected with spintronics have been dealt with for bringing clarity to the readers. A review of the recent experimental results of the researchers has been presented to apprise the readers with the likely applications. Various concepts discussed include spin transfer, spin transfer torque, spin-pumping force and spin currents, tunneling anisotropic magnetoresistance, and tunnel magnetoresistance in semiconductor magnetic tunnel junction, spin-dependent magnetoresistance in all-semiconductor heterostructure, and magnetic induced and current induced switching. Some fundamental studies like magnetic tunneling junctions, their types, and structures have been included. Some new functions not possible with the conventional electronics and possible in spintronics have been described. Applications of spintronics in various fields including research and quantum computers, and the fabrication of the spintronics devices have also been described at length. Materials selection for the device fabrication, results of the experimental studies useful for the designing of the materials with custom made characteristics required for the spintronics devices, and some important experimental breakthroughs useful for spintronics have been presented very briefly for the benefit of the designers the researchers and the academicians, which can help them to develop the understanding of the topics of their interest.

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