Avalanche Feedback Information using Remote Sensing Satellite Data

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Abstract— Snow avalanches are natural hazards in snow covered mountains regions and can cause loss of human life and damage to infrastructure such as buildings and roads. Avalanche release depends on many different parameters i.e. terrain, ground cover and meteorological conditions of the region. Many areas of Indian Himalaya were affected by snow and avalanches due to high average annual snow accumulation and severe weather. In Himalaya, Knowledge of when and where avalanches are occur and how large they are, is not easy to obtain due to the inaccessible terrain, harsh climatic conditions and vast region. Observations of past and present avalanche activity are of great importance for avalanche forecasting as they are strong and reliable indicators of snow instability. To limit the number of future fatalities, it is desirable to develop a technique that detect the avalanches. Remote sensing satellite data has a potential to detect the avalanches. In the present study, we present a method to identify the avalanche debris using optical remote sensing data on the basis of change in reflectance after avalanche occurrence.

Key words: Avalanche, Himalaya, Sentinel-2, Optical Data, Reflectance

I. Introduction

Most of the part of Himalaya is covered by snow during winter season and the amount of snow plays important role in hydrological and climatological conditions of the region and can cause avalanches which is destructive for life and property [3, 4, 18]. Many regions of Indian Himalaya were affected by avalanches. In India mainly in three states i.e. Jammu and Kashmir, Himachal Pradesh and Uttarakhand, 11 major roads and 216 settlements lies under avalanche prone slopes [8]. In Western Himalayan region, approximately 3 % of the total population lives in avalanche prone areas and every fifth person traversing through the avalanche terrain is caught in an avalanche [2]. Avalanche accidents in the past have taken place due to ignorance and fatalistic attitude of the people towards avalanche phenomenon. To limit the number of future fatalities, it is essential to develop a technique that detect the avalanches. In 1969, Snow and avalanche study establishment (SASE) under Defence Research & Development organization is established to solve this problem and to increase socio economic growth of snow bound regions [7]. There are different types of avalanche forecast models used by experienced avalanche experts, but in Himalaya due to remote and inaccessible terrain, it can be dangerous or even impossible to obtain necessary field information on avalanche events manually. However, avalanche release information is crucial to secure life and property. Remote Sensing satellite has potential to detect the avalanches.

Previous Research regarding automatic detection of avalanche deposit carried by Buhler et al. in 2009 with the help of VHR (very high resolution) optical data collected by ADS40 instrument for a test site at Davos in Switzerland. The applicability ADS40 instrument is restricted by a) weather conditions and b) misclassifications due to other rough surfaces i.e artificial snow piles, wind modelled snowpack and sparsely vegetated area. The space borne SAR-Sensors (Sentinel-1, Radarsat 2), acquiring data with a spatial resolution of close to one meter, overcome the limitations imposed by weather conditions. Texture is used to segment and classify objects in image [1] and Grey Level Co-Occurrence Matrix (GLCM) based on Haar Wavelet Transform has been found very powerful tool for texture image segmentation [5, 13]. To detect the avalanche, Lato et al. in 2012 have suggested an object–oriented image interpretation approach that uses segmentation and classification methodologies by using VHR panchromatic optical remote sensing images. Digital Elevation models (DEM) and forest information is used to identify potential snow avalanche release areas [14]. Radar data is also found helpful to forecast the avalanche but its operational usage are limited due to its high acquisition costs, small ground swath, and uncertain data availability [15, 16, 18]. Sentinel-1A SAR satellite is powerful tool to develop an automate avalanche debris detection algorithm by performing change detection, unsupervised object classification and K-means classification [19, 20]. In the present study we present a method to identify the avalanche debris using optical remote sensing. Reflectance image (optical data) are used for identification of avalanche occurrence areas.

II. Study Area

Most of the part of Himalaya is covered by snow during winter season and the amount of snow plays important role in hydrological and climatological conditions of the region and can cause avalanches which is destructive for life and property. North West Himalaya has been categorized into various zones i.e. lower Himalaya (Pir-Panjal range), middle Himalaya (Great Himalayan range) and upper Himalaya (Karakoram Range) as shown in fig 1 to estimate the information of avalanche occurrence.

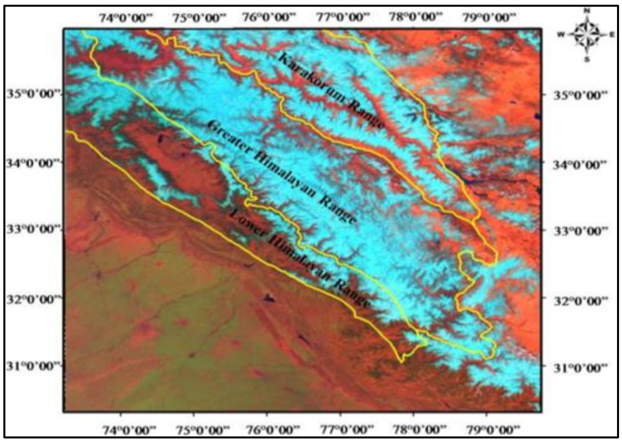

Fig. 1: Himalayan Ranges in NW Himalaya

III. SATELLITE DATA

In the present work, almost cloud free satellite images of Sentinel-2A (optical data) having resolution of 10 m has been used to detect the avalanches in the North West Himalayan region. The launch of the first satellite, Sentinel-2A, occurred 23 June 2015 and Sentinel-2B was launched on 7 March 2017 .The Sentinel-2 mission has the following capabilities:

- Multi-spectral data with 13 bands in the visible, near infrared, and short wave infrared part of the spectrum.
- Revisiting every 5 days under the same viewing angles.
- Spatial resolution of 10 m, 20 m and 60 m
- 290 km field of view.

In detail, the specifications of Sentinel-2A is given in Table 1

Sentinel-2A Bands	Central Wavelength (µm)	Resolution (m)	Bandwidth (nm)
Band 1-Coastel aerosol	0.443	60	20
Band 2-Blue	0.490	10	65
Band 3-Green	0.560	10	35
Band 4- Red	0.665	10	30
Band 5-Vegetation Red Edge	0.705	20	15
Band 6- Vegetation Red Edge	0.740	20	15
Band 7- Vegetation Red Edge	0.740	20	20
Band 8-NIR	0.842	10	115
Band 8A-Narrow NIR	0.865	20	20
Band 9-WaterVapour	0.945	60	20
Band 10-SWIR-Cirrus	1.375	60	90
Band 11- SWIR	1.610	20	90
Band 12-SWIR	2.190	20	180

Table 1: Bands of Sentinel -2A

IV. METHODOLOGY

A. *Description*

The methodology used in present work is shown in fig 2. We used images from Sentinel-2A as main source of data in this study. Based on reported avalanches, pre avalanche image from Sentinel-2A and Post avalanche image from Sentinel-2A satellite data were downloaded from Earth Explorer software. Firstly, digital numbers (DN) image is converted into radiance image and after that the reflectance of pre and post avalanche images is estimated by processing Sentinel-2A raw data by using QGIS and ERDAS IMAGINE software's and finally topographic corrections of pre and post avalanche are made. From DEM dataset, information about the slope, aspect according to the sun angle were generated for input to the topographic correction algorithms. On the basis of change in reflectance after avalanche occurrence from optical satellite images, avalanche is detected. The detailed Methodology explained in the following flow chart.

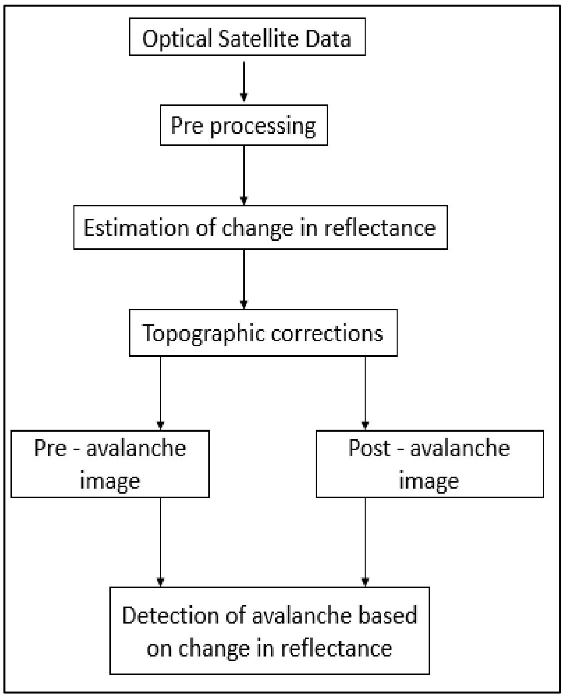

Fig. 2: Flow Chart of Methodology

V. RESULTS

A. *Reflectance with Topographic Corrections*

Optical satellite imagery in Himalaya terrain (Mountainous terrian) is affected due to sharp variations in the topographic parameters such as altitude, slope and aspect. The topographic variability causes a problem of differential illumination due to steep and varying slopes in rugged Himalayan terrain. So, effective removal or minimization of topographic effects is necessary in satellite image data of mountainous terrian. In present study, slope matching technique is used for topographic corrections which is best suitable for Himalayan terrain [6, 10, 11].

Terrain slope, aspect and illumination (IL) are the three important inputs required in topographic correction for Himalayan terrain. The slope values of the study area and aspect map is generated using DEM as shown in figure 3 (a) to 3 (c) and Topographic corrected Sentinel-2A scene using Slope Matching techniques is shown in figure 3 (d)

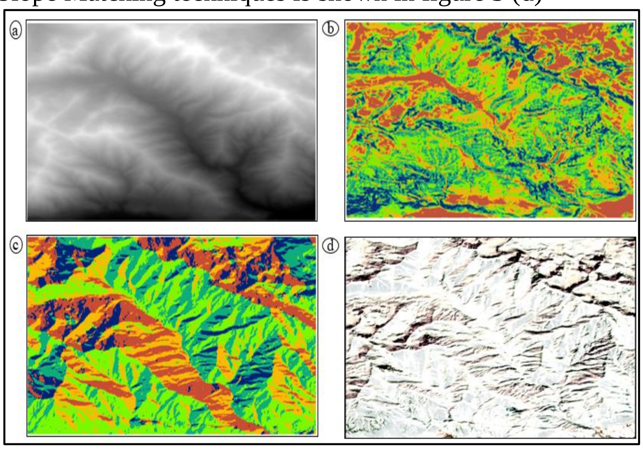

Fig. 3 (a): DEM, (b) Slope, (c) Aspect, (d) Topographic Corrected Sentinel- 2A Scene using Slope Matching Techniques

Result indicates that Maximum change in reflectance between pre and post avalanche activity is observed in the NIR band. Pre avalanche reflectance image has higher reflectance whereas post avalanche reflectance image shows lower reflectance due to contamination in NIR band as shown in figure 4 (a) and 4 (b) respectively. It is also observed that change in grain size is more dominant in comparison to the contamination in the snow due to avalanche

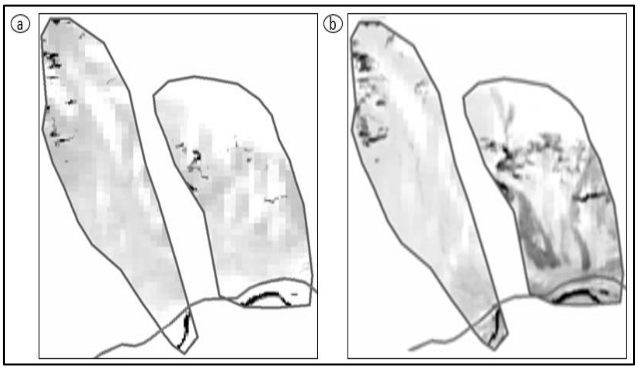

Fig. 4 (a): Pre avalanche Reflectance Image: NIR Band, (b) Post Avalanche Reflectance Image: NIR Band

VI. CONCLUSION

Avalanches form a threat to people travelling in mountainous regions as well as for infrastructure and buildings. Avalanche research is needed to get a more profound understanding of the avalanche activity in space and time, which is of great value for avalanche warning services. The snow conditions in the Himalaya are complex and require continuous monitoring of snow and meteorological parameters. The problems of avalanches, their prediction and control in the Himalayas have assumed great relevance and importance not only for the Army but also for the progress of the Himalayan States. In Himalaya, it is very difficult to collect the information of avalanche activity using manual methods due to the inaccessible terrain, harsh climatic conditions and vast region. Now, remote sensing satellite data based techniques are found useful to collect the information of rugged and inaccessible areas including snow cover. Remote sensors provides data with high spatial and temporal resolution.

In this study, Sentinel- 2A data having resolution of 10m has been used to detect the avalanches in the North West Himalayan region. Reflectance image of the pre and post avalanche area has been generated and analyzed. On the basis of change in reflectance after avalanche occurrence from optical satellite images, avalanche debris are detected.

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