DEVELOPMENT OF SAR BASED CLASSIFICATION TOOLFOR IDENTIFYING TRANSIENT GLACIER ZONES OF HIMALAYAN GLACIERS

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Synthetic Aperture Radar (SAR), Microwave Data Analysis Software (MIDAS), decision rule classification module

ABSTRACT
Monitoring of glacial zones provides information on prevailing weather conditions and various glacial parameters, like, wetness condition and stratigraphy, etc. Use of Synthetic Aperture Radar (SAR) data facilitates monitoring of glaciers independent from solar illumination and atmospheric conditions (to some extent). Radar Imaging SATellite-1 (RISAT-1) Medium Resolution SAR (MRS) data is used to develop dual-pol SAR signatures of transient glacial zones, namely, Debris Covered Ice Zone (DCIZ), Bare Ice Zone (BIZ), Super-imposed Ice Zone (SIZ), Wet Snow Zone (WSZ), Seasonal Frozen Percolation Zone (Seasonal FPZ). The two dimensional SAR backscattering signatures (HH and HV polarizations) of the glaciers zones define the linear decision rules. The conditional loop based logics, consist of linear equations, classify glaciated region in to different zones (level 1). Purely backscatter based classification result produces error by mixing DCIZ and seasonal FPZ due to overlapped signatures. Altitude thresholds of accumulation zone are employed to segregate the mixing (level 2). A module is integratedunder Microwave Data Analysis Software (MIDAS). MIDAS,is an in-house software, developed for analyzing microwave data and polarimetric signatures. Thecore module is written in C/C++, whereas, the Graphical User Interface (GUI) is written in TCL/TK. The module requires calibrated ortho-rectified sigma naught dual-pol SAR imagery in Geotiff (.tif) format. The glaciated area should be provided as shape file (.shp) format which will generate Area of Interest (AOI). A Digital Elevation Model (DEM) file is required for altitude threshold. The output classes are saved in separate files with Boolean values. The classification module is tested over the Himalayan region from west to east. The universal backscattering based classification result of level 1 is fully automatic. In level 2, altitude threshold is variable since formation of glacial zones depend up on the prevailing weather, which is highly variable from western to eastern Himalaya.

INTRODUCTION

Image classification and developing information classes based on prior knowledge of the classes or spectral behavior of the targets follows different classification methods. The maximum likelihood (MXL) classification technique is the most common classification method within supervised classification. However, MXL involves development of training classes. Classification of transient glacial zones in temporal scale involves changing in location and extension of the classes. Use of one set of training classes, therefore, is not possible for glacier zones classification.The training sites of MXL classification also not useful during the shifting of study sites. The training sites are not employed to classify glacial zones of diverse study areas. Decision rule classification technique involve in identification of signature characteristics of each classes and development of decisions for classifying the zones. The physical zones of glaciers form and evolve depending on the prevailing weather conditions. As determined by the physical characteristics, a glacier can be divided into five zones, namely the dry snow zone (DSZ), the frozen percolation zone (FPZ), the wet percolation snow zone (WSZ), the superimposed ice zone (SIZ), and the bare ice zone
(BIZ) (Benson 1962). To monitor the Himalayan glacial zones and their temporal changes, regular data analysis and output derivation are necessary. The yearly monitoring will help to develop data inventories and further will be used to study the health of the Himalayan glaciers and impact of climate change on it. SAR data have been used as primary input to get information of glaciers' transient zones and their metamorphosis over the time unobstructed by atmospheric conditions. The purpose of the work was to develop a classification method as a tool to analyze multi-temporal SAR data over multiple glaciers with more objective way.

Use of SAR data increases opportunity of collecting information of the glaciers without affected by cloud cover or solar illumination. The variation in backscattering of the radar signal is subjected to system parameters, like, signal frequency, polarization and target parameters, like, surface roughness, target's dielectric constant, orientation to the radar beam (Partington, 1998). Sensitivity of radar signal to liquid water allows to detect wet snow precisely.

Penetration capability of radar signal (some particular frequencies for some particular depth) also aids to study sub-surface properties of glaciers, mostly at accumulation region. To monitor the Himalayan glaciers, regular data analysis and output derivation are necessary. The yearly monitoring will help to develop data inventories and further will be used to study the health of the Himalayan glaciers and impact of climate change on it.

STUDY AREA AND DATA USED

ChhotaShigri glacier of Lahul and Spiti district of Himachal Pradesh state of India has been selected as Area of Interest (AOI). The 9.2 km long ChhotaShigri glacier is considered as a bench mark Himalayan glacier (Ramanathan, 2011). The boundary of the glacier has been derived from cloud free optical data and saved as shape file format (.shp).

Figure 1: RISAT-1 HH polarized image over ChhotaShigri glacier of Himachal Pradesh State of India (one of the study area). ‘R’ and ‘A’ denote range and azimuth direction of the SAR sensor. The image is filtered and calibrated (sigma naught).

DATA

RISAT-1 C band Medium Resolution SAR (MRS) data are used for this study. Multi-temporal SAR data from the year 2012 to 2015 are analyzed. The amplitude data are filtered using 5 X 5 gamma filter and sigma naught backscattering values are calibrated before classification. The calibrated filtered data of each date contains two image files (in .tif format), i.e., HH and HV polarization images. The other data which are required for classification is Digital Elevation Model (DEM) of the study area (in .tif format). The glacier boundary is considered as AOI and provided in .shp format for the classification process. The data are in Universal Transvers Mercator (UTM) projection.

METHODOLOGY

The glacial zones, identified by the classification system, are Debris Covered Ice Zone (DCIZ), Bare Ice Zone (BIZ) in ablation area and Super-Imposed Ice Zone (SIZ), Wet Snow Zone (WSZ), Seasonal Frozen Percolation Zone (seasonal FPZ) in accumulation area of the glacier. The decision rule classification algorithmcontains two-dimensional (co and cross polarization)backscattering information of each glacial zone and their relationship with other classes. Therefore, the classification method requires both polarizations, co and cross to differentiate the classes with accuracies. The algorithm has been developed by Kundu and Chakraborty, 2015. Figure 2 shows the pictorial representation of decision rule algorithm. Backscattering signature of some classes like, Debris covered Ice Zone (DCIZ) overlaps with Seasonal Frozen Percolation Zone (Seasonal FPZ), however, generation of SAR backscattering from these two classes are completely distinct. To minimize the error due to overlap of signatures, altitude thresholds are employed to segregate the mixed classes.

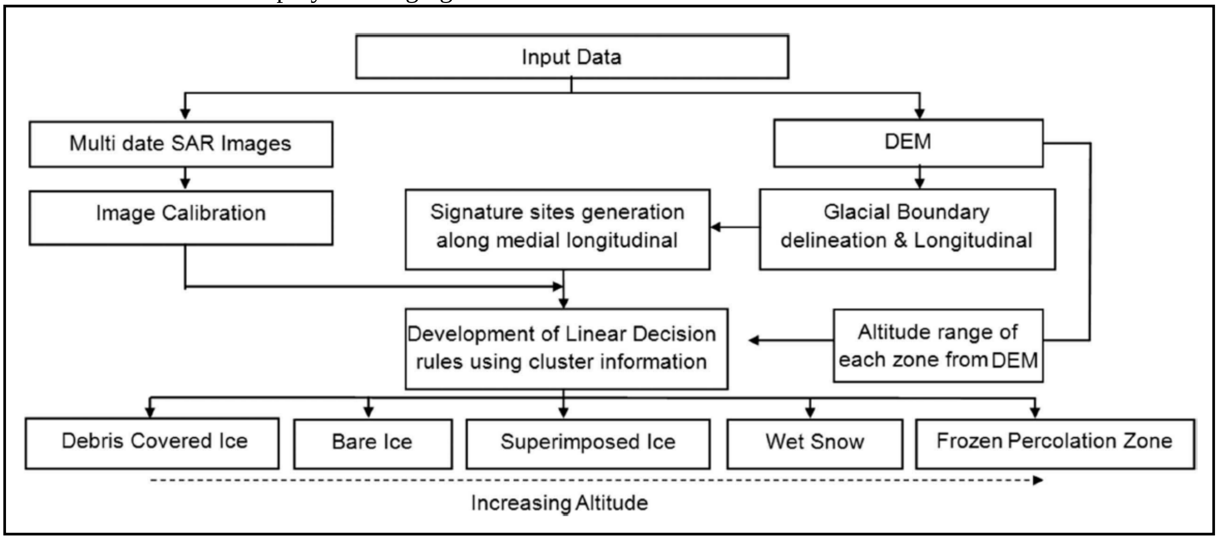

Figure 2: The logical diagram of decision rule based classification algorithm.

The decision rule classification module is integrated under Microwave Data Analysis Software (MIDAS). MIDAS, is an in-house software developed in Space Applications Centre, ISRO for analyzing microwave data and polarimetric signatures. The core module is written in C/C++, whereas, the Graphical User Interface (GUI) is written in TCL/TK. Figure 3 shows the logical diagram of the module.

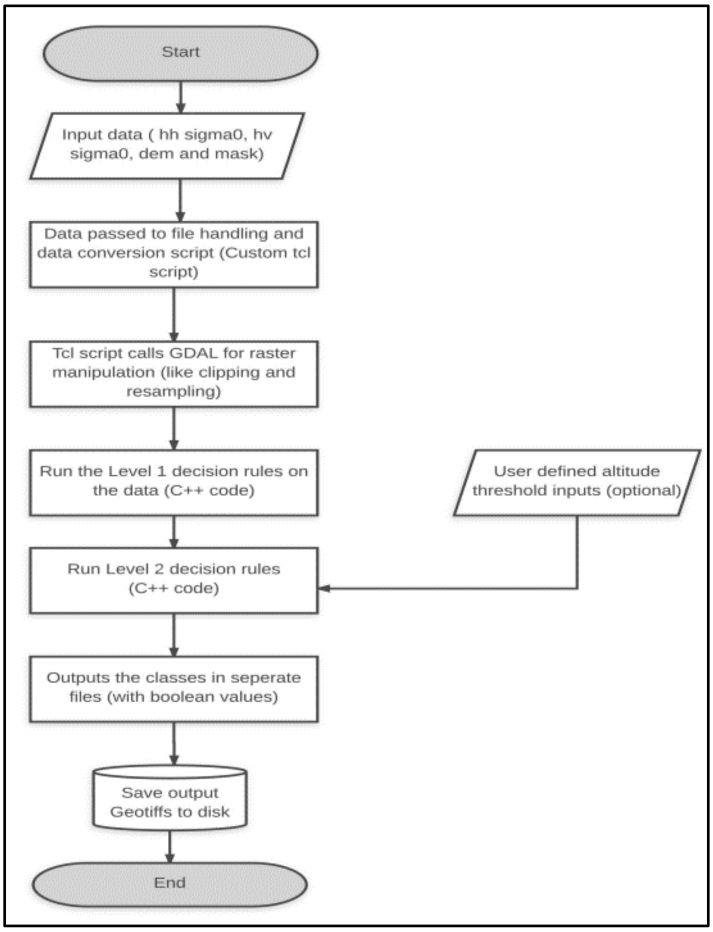

Figure 3: Conceptual diagram of classification module integrated in MIDAS software.

The module requires calibrated ortho-rectified sigma naught dual-pol SAR imagery in Geotiff (.tif) format. The glaciated area should be provided as shape file (.shp) format which will generate AOI. TheDEM file is called for altitude threshold. Before classification all input data, i.e., HH, HV, DEM and AOI files are passed through tcl script for file handling and data conversion. TCL script calls GDAL to clip and resample data (HH, HV and DEM) under raster manipulation program. The clipped and converted data are saved in disk.

The algorithm has two classification levels. The first level is completely based on SAR backscattering information. The result derived in first level of classification is further used in second level as primary input with DEM. The second level produces final result based on both backscattering and altitude information of glacial zones. The classification algorithm is written in C++ language.

The output classes are saved in separate files with Boolean values. The classification module is tested over the Himalayan region from west to east. The universal backscattering based classification result of level 1 is fully automatic. In level 2, threshold for three regions of the Himalaya, i.e., western, central and eastern, are stored in lookup table which linked with geographical locations of the AOI. However, all threshold values can be adjustable according to the needs of the user.

RESULT AND DISCUSSION

The classification resultsare generated over many glaciers throughout the Himalaya. The results (Figure 4a)showdistribution of glacial zones of different glaciers of Shyok valley of Indus basin. The outer boundary of wet snow zone (WSZ represented in magenta colour) provides existence of snowline at a particular altitude on that date. The similar classification module is executed over glaciated region of eastern Himalaya. The module only alters altitude threshold values as the zone changed. The Figure 4b shows the classified glacial zones of eastern Himalayan glacier. The glacial lake in front of the glacier is also classified. Backscattering of water bodies and WSZ are overlapped. The super-saturated snow with water molecules produces similar backscattering like waterbodies.

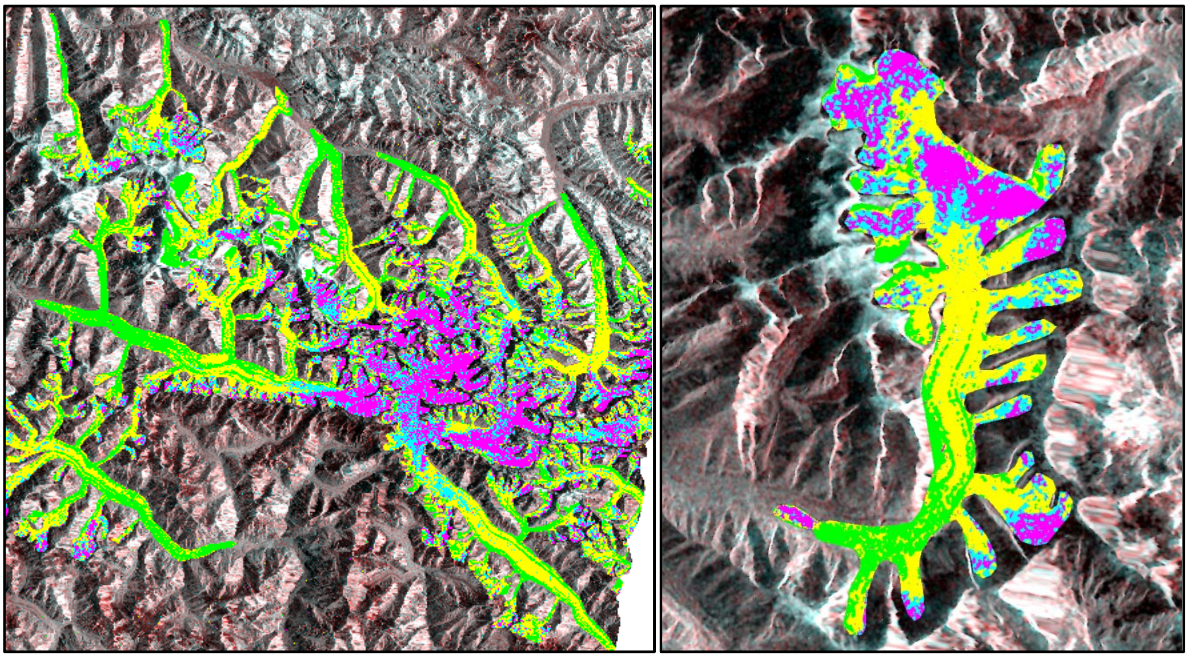

Figure 4: a) Glaciated region at Shyok valley of Indus basin; b) Glacier of eastern Himalaya near Arunachal Pradesh, India. The glacial zones are represented by colour as follows, green: Debris Covered Ice Zone (DCIZ), yellow: Bare Ice Zone (BIZ), cyan: Super-imposed Ice zone (SIZ), magenta: Wet Snow Zone (WSZ). Water in glacial lake is represented by magenta colour.

The lower boundary of the WSZ is considered as snowline. Continuous monitoring of snowline provides changes in altitude in different dates. The highest snowline altitude during the end of ablation season is considered as Equilibrium Line Altitude (ELA) of a glacier. This information is further used to derive mass balance of the glacier. Here, in this study, the average snowline altitude of glaciers of Shyok valley is 4855 during 30th July 2015 whereas, the glacier of eastern Himalaya has snowline at 5950 m during 14th July 2015.

CONCLUSION

The classification module is integrated under in-house software MIDASto make the algorithm more user friendly. The user only has to provide the dual-polarized SAR data, DEM and AOI. The module converts the input data according to the requirement. The classification consists of two parts. Part 1 classifies images according to the backscattering values and part 2 reclassify the level 1 result on the basis of altitude information derived from DEM. If the user requires only backscattering based classification, then user should execute up to level 1 classification.

The output results are generated in .tif format. For analyzing SAR data at temporal scale over the Himalayan region, the classification module helps to generate classified data which are used to monitor snowlines during ablation season and firnline during accumulation season of the Himalayan glaciers. The module can be used also over Karakoram region. However, it is currently spatially limited within Hindukush-Karakoram-Himalaya (H-K-H) region.

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