CHARACTERIZATION OF GLACIATED AREA USING HYPERSPECTRAL IMAGING

A DISSERTATION

Submitted in partial fulfilment of the

requirements for the award of the degree

of

Integrated Masters of Technology
in
GEOLOGICAL TECHNOLOGY

by

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DECLARATION OF AUTHORSHIP

I hereby solemnly declare that the work presented in this dissertation, titled **"Characterization of glaciated area using Hyperspectral Imaging"** in the partial fulfilment of the requirement for the reward of the degree of '**Integrate Masters of Technology'** in **Geological Technology** submitted in D**epartment of Earth Sciences, Indian Institute of Technology, Roorkee,** is an authentic record of my own work carried out during a period of June 2018 to May 2019 under the supervision of **Dr. Ajanta Goswami**, Professor, Department of Earth Science, I.I.T Roorkee. I have not submitted this matter embodied in this dissertation for the award of any other degree.

Date: Thursday, 16 May, 2019

Place: IIT Roorkee

Raveena Kumari

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Dr. Ajanta Goswami
(Supervisor)
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CERTIFICATE

This is to certify that the work presented in the dissertation thesis, entitled "**Characterization of Glaciated area using hyperspectral Imaging**" submitted by **Raveena Kumari** in partial fulfilment of requirements for award of the degree, **'Integrated Master of Technology'** in Geological Technology to the Department of Earth Sciences, Indian Institute of Technology Roorkee, is an authentic record of her work carried out during the period from June 2018 to May 2019, under the supervision of **Dr. Ajanta Goswami**, Professor, Department of Earth Sciences, Indian Institute of Technology Roorkee. I also certify that the above statement made by the candidate is correct to best of my knowledge.

Dated:

Place: Roorkee

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ABSTRACT

NASA's Earth Observing - 1 (EO-1) Hyperion satellite, launched in 2000, served as a stage to obtain hyperspectral images from the space. Hyperspectral imaging sensors provide valuable information to aid to the identification of geological and topographical features and other targets on the earth surface. The contiguous bands of narrow bandwidth helps in generating laboratory equivalent spectral signature and imaging techniques provides wider coverage area at a time. This advantage of hyperspectral imaging can be used in mapping mineral abundances over any area, thereby reducing tedious field data collection.

The present study takes Hyperion images to characterize glaciated area in Satopanth Glacier, Uttarakhand, India using Hyperion data and obtain spectral features of glacial rocks. Pre-processing of the data becomes mandatory for correct identification of the areas before applying atmospheric correction models and consists first of removing bad bands and noise prone bands which reduces the number of bands to 180 from 242 followed by destriping of bands using local techniques. After that FLAASH atmospheric correction model is applied which retrives a reflectance image which is further used for characterizing the study area.

Characterization of the area under study involved the use of MNF transform, followed by Pixel Purity identification. This was followed by end member collection which was used to characterize the study area.

By comparing spectral signatures generated using hyperspectral with the USGS library spectral data and with the field maps, it has been observed that hyperspectral data is in agreement with ground based and library data. Further it is recommended that spectral unmixing study may be carried to separate pixels and characterize different features and minerals on earth surface.

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1: INTRODUCTION

The Himalayan region has a huge glacial concentration and seasonal snow cover. As an important natural resource, snow cover and glaciers affect the flow of many north Indian perennial rivers, regional climate and many other development activities (Barnett et al. 2005). Due to elevated mountain ranges in Himalaya the snow cover forms avalanches in these mountain ranges, which affects safety of human life and property. In recent years, many studies have reported disturbance and withdrawal of these glaciers caused by the ongoing climate change (Yasunari etal. 2010; Kulkarni etal. 2011; Bolch etal. 2012).

Exploration of Himalayan terrain is useful for exploration of various minerals, climate studies, to study the flow of rivers, hydropower generation, snow cover mapping etc. The Himalaya has a rugged terrain and harsh climate, hence the traditional methods of geological exploration warrant tremendous investments of money, extended time and human capital that is not be entirely feasible (Drury et al. 2001).

The applications of remote sensing has supreme importance not only for geological studies of the developing countries, but also in decreasing risk in the field of geological and mineral exploration (Rooks et al., 2000). Thus, the advent of remote-sensing technology has helped in plummeting the risk and investment in exploring the geology of Himalayan terrain. The hyperspectral remote sensing has facilitated the better observation of different minerals, vegetation and snow cover characteristics. Therefore, main motive of this work is to support the field of mineral prospecting to providing geoinformation for geological and mineral prospect mapping which can be used to integrate spatial information to remotely sensed data sets.

Remote sensing is the observation of an object, a medium, a phenomenon or a process, with out ever coming in contact with it. In passive remote sensing, sensors record the object’s natural radiation whereas, in active remote sensing the device sends out signal to obtain information about the subject. By the latest progresses in remote-sensing field and launch of multiple satellites for the same, our knowledge of various domains of Earth Sciencs have been hugely improved.

In multi spectral remote sensing, the spectral bands are big in bandwidth, via which sensors record radiation and, are few in number. Hence it becomes difficult to attain precise information about the study area. But in hyperspectral remote sensing , the information is acquired in many continuous spectral bands ranging through out the EM spectrum. The spectral width of each band is around 10 nanometers. The wavelength region covered is from visible to infrared i.e. 300nm to 2500nm. As a result, a detailed and continuous spectral response is attained for each pixel.

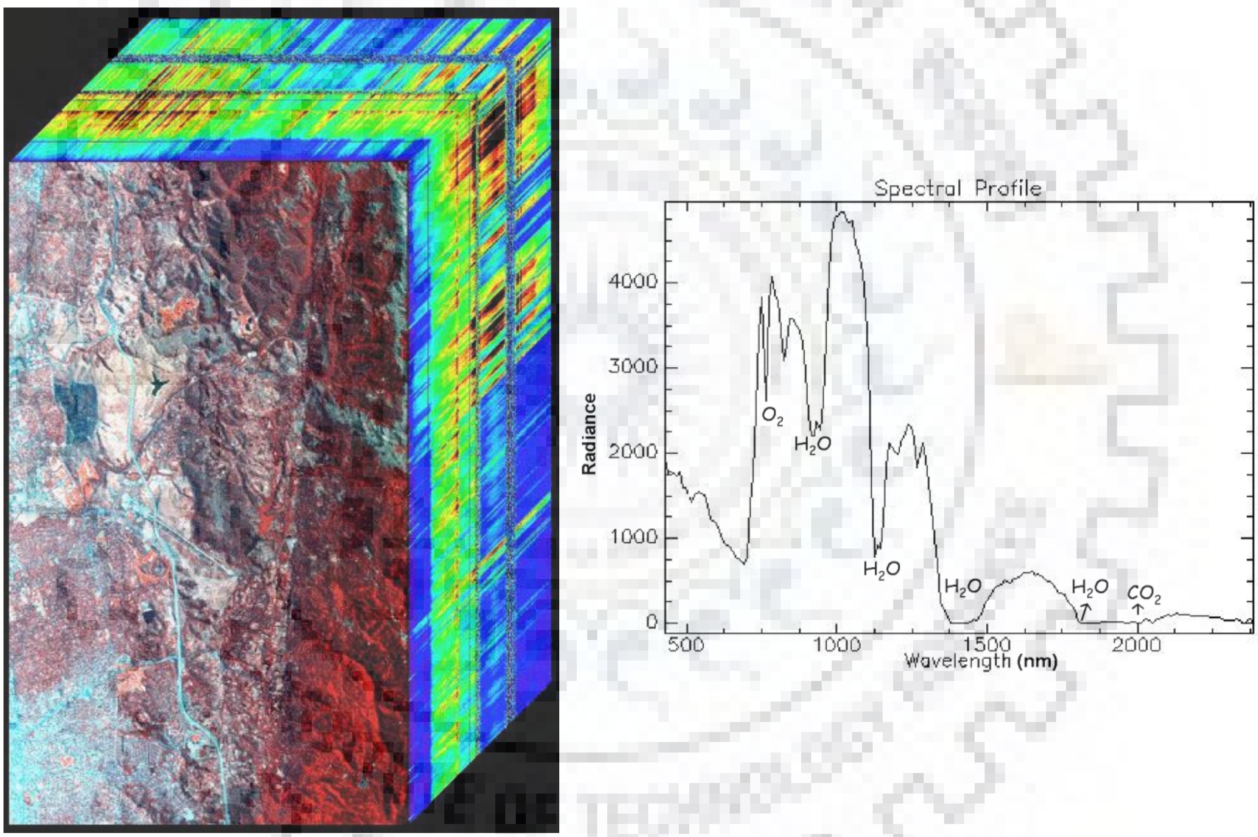


Figure 1.1 - Hyperion datacube and associated spectrum Source: https://eo1.usgs.gov/, accessed on 22/4/2019

1.1 Research Background

Earth Observing-1 (EO-1), launched by NASA as an New Millennium programme in 2000, poineered the acquisition of of spectra ranging form 400 to 2500 nms, to obtain hyperspectral images from the space. In comparision to other airborne sensors like AVIRIS, Hyperion offers better spatial resolution as well as similar quality of data under similar conditions. Although, motion of airborne sensors might affect quality of the data, a wide, humanly inaccessible area can be covered by space borne sensors.

Hyperspectral remote sensing puts quite high computational load in contrast with multispectral remote-sensing because generation of pixel wise spectra in hyperspectral image is uninterrupted. This makes the image processing and the analysis of data more complicated. The narrow bands in such hyprspectral sensors are prone to noise. This makes image interpretation difficult. During extraction of data resultant spectra contains both reflected and radiated noise. Noise is caused by many indepemdent factors like presence of atmospheric components like aerosols, gases etc., and also due to sensor induced chenges in the brightness.

A case has long been made for the documentation of geochemical variation on the Earth. National Geochemical Mapping Mission, which was initiated in 2001, aims to create a national database to study geochemical diversity in India by appropriate sampling and lab studies. For the various application and improtance in search of latent mineralization, it aims to produce geochemical maps delineating patterns and anomalies in the present elements. To validate the results generated using remote sensing techniques like hyperspectral imaging, the information attained from in situ ground measurements can be used.

1.2. RESEARCH OBJECTIVES

The this study, the prospects of space borne hyperspectral images, acquired using the Earth Observing-1 (EO-1) Hyperion sensor has been deployed for the classification of glaciated area and estimation of snow-cover in the Himalayan region. The following objectives are discussed in the present study:

- Assessment of the potential of remote sensing techniques in determining spectral signature for snow, glacial moraine, vegetation and glacial lake as well as the classifying mineral assemblage with an intent to extend the result in the vicinity if possible.
- Characterization of ice cover and surface mineralogy using hyperspectral data
- Collection of the image spectra in order to understand spectral signature of mineral assemblages.
- Delineation of glacier extent to Identify snow cover, glacial moraine, mixed snow, vegetation and glacial lakes
- Hyperspectral data analysis and classification of mineralogy in the study area.

2. STUDY AREA AND THE MATERIALS USED

2.1 Geology of Study Area

Satopanth Glacier is one of biggest glacier in Garhwal Himalays in Uttarakhand, India. It is located at an altitude of 4,600 metres (15,100 ft), above the mean sea-level (latitude 30044′682″ N and longitude 79021′468″ E). Satopanth Lake, which is 25 kilometers far from Badrinath, the popular Hindu shrine, is situated in middle of snow-capped glacial peaks. This lake is also considered to be of religious significance for local people. No published information was found regarding the Lake, except its location, type of the lake and water purity measurement data. The lake is lateral moraine dammed lake, and its occurrence is caused by the terminal moraine by preventing some of the melted water of glacier from leaving the valley. Commonly, such lakes are in shape of a long ribbon, but this lake is triangular in shape. With the support of satellite-images captured during 2011-2013 (Bhamdri et al. 2017), it was gathered that the lake remains beneath thick snow from September till the last of May or June. Normal temperature during summers remain around 8 to 12°C during the diurnal hours and 7 to -7 °C during night, whereas in winter season the temperature drops to -15 to -25 °C during day time and -30 to -35 °C during the night time.

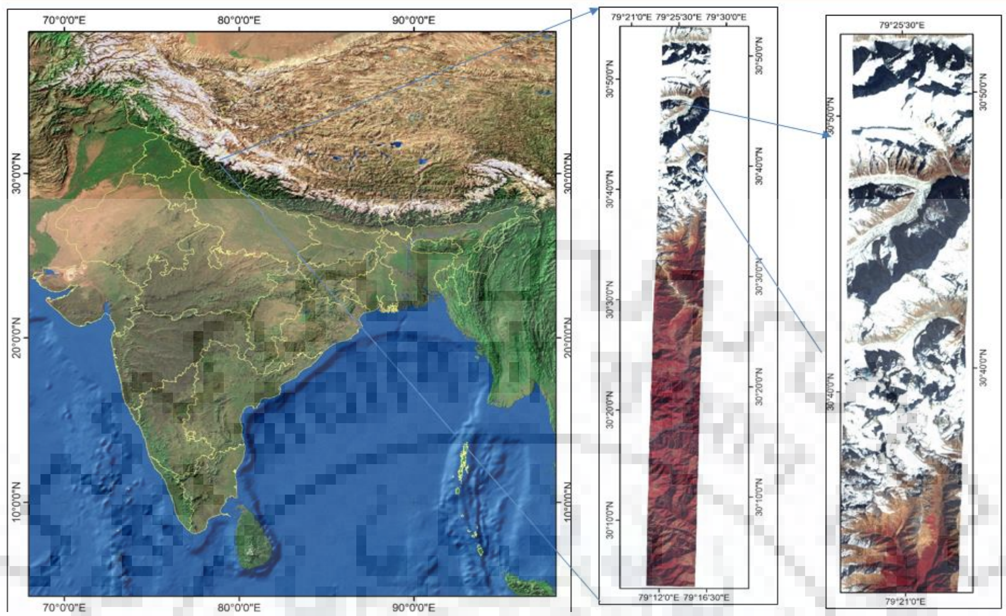


Figure 2.1 - Study Area

2.2. Dataset used

Earth Observing-1 (EO1) satellite data (Hyperion sensor) has been used for the present study. Hyperion data covers the entire spectral range of 400 nm to 2500 nm with 242 spectral bands. The spectral resolution is roughly 10 nm and the spatial resolution is around 30 nm from an orbit of 705 km. The Hyperion sensor of EO-1 satellite provides 242 spectral bands for a 7.5 kilometers wide swath and along 160 km path length. This satellite system has two scraping spectrometers, one in Visible and Near Infrared (VNIR range) (0.4 - 1.0 micrometers) and other in Short Wave Infra-red (SWIR) range (900- 2500nm).

Entity ID	EO1145039200333111OPF
Acquisition date	2003/11/27
Orbit path - Orbit row	145-39
Latitude	30.435000
Longitude	79.313000

Table 2.1 - Information about data acquired

2.3 Software used

The different softwares used in this project include: ENVI 5.0 and Hyperion tools. For processing and analysis of the Hyperspectral images Environment for Visualizing Images (ENVI) software was used. Hyperion tools were used for the removal of the hazy and uncalibrated data.

Spectral feature of snow, water, vegetation were extracted using Spectral Angle Mapper method in ENVI software.

2.4 Spectral Library

For the validation of data generated by processing of hyperspectral images, the spectral signature of the detected entities were compared with the spectral signatures from the USGS library.

ASTER (Advanced Space-borne Thermal Emission and Radiometer) library, also has archives containing the spectral feature for various minerals.

3. METHODOLOGY

The methodology adopted for this study has been devised for the primary objective of the work, which is to reduce the error in the data. A great challenge faced during this study was that in India, the work done in hyper spectral study is not much. The methodology adopted is given underneath.

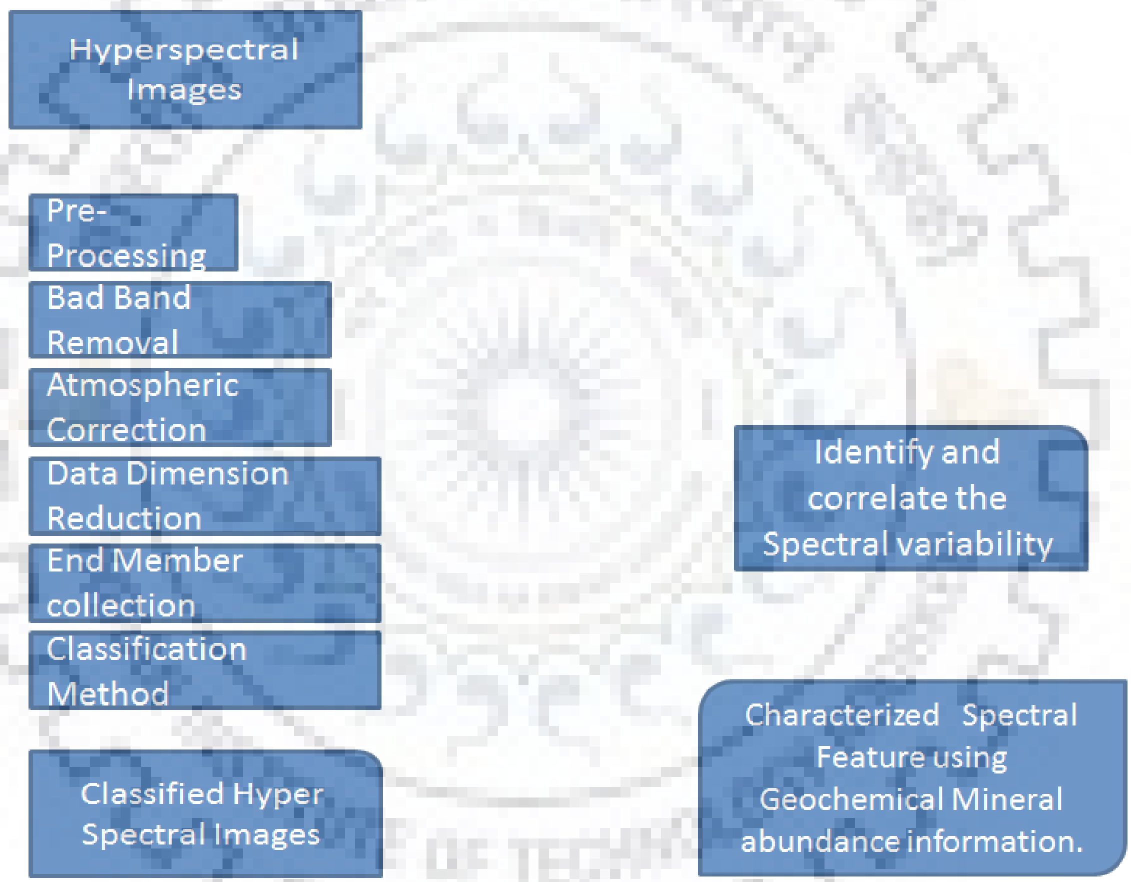


Figure 3.1 Methodology Flowchart

3.1 Pre-processing of the Data

Before further evaluation, Hyperion data needs to be pre-processed. This will be done using ENVI image processing software. The steps are as following:

3.1.1 Bad Band Removal

Present study has been conducted on the Earth Observing-1 hyperion data set. The data is downloaded from the archives of United States Geological Survey (USGS) website in both LIR (HDF) and L1T Geotiff format. EO-1 satellites has collected data ranging from 400 to 2500 nm.

Number of bands	242
Spectral Bandwidth	10 nm (nominal)
Spatial resolution	30 m
Sensor Altitude	705 km
Swath Width	7.75 km
Length of Path	160 km
Spectrometers	2 (VNIR, SWIR)
Digitization	12 bits

Table 3.1. - Hyperion Sensor Characteristics

For further processing HDF format data was used in Band Interleavd by Line (BIL) format. Geotiff data is georeferenced, hence it can be used as reference specially for collation with field data. During visual inspection of each Hyperion band one by one some serious radiomatic errors were revealed. Errors like severe stripping in some Short Wave Infrared bands as well as shift in sensitivity of some Hyperion detectors in opposite direction of track were found. It has mainly affected the bands in the VNIR region. Due to low ratio of signal to noise at both ends (430 nm and 2400 nm), heavy water absorption centre around 1400 nm and 1900 nm and the spectral overlap of the three types of detectors, a total of 62 bands were omitted and over-all 180 bands has to be used in analysis after the visual inspection. The detailed information about the dataset is in the table underneath:

Band No.	Spectral range (nm)	Status	Remark
1-7	356 - 436	No data	Not considered
8-57	436 - 711	Good quality	Considered
58-70	711 - 935	Black, no data	Not considered
71-76	900 - 1058	No data (data overlap)	Not considered
77-78	851 - 912	Contain less strips	Considered
79-98	912 - 942	Good quality	Considered
99-100	942 - 963	No data (data overlap)	Not considered
101-116	963 - 1124	Good quality	Considered
117-119	1124 - 1154	Contains less strips	Considered
120-126	1154 - 1346	Hazy data	Considered

127-140	1346 – 1457	Contains less strips	Considered
141-161	1457 – 1800	Hazy data	Considered
162-164	1800 – 1961	Good quality	Considered
165-169	1961 – 2022	Hazy + contains strips	Not considered
170-199	2022 – 2345	Hazy data	Considered
200-203	2345 - 2375	Hazy + contains strips	Not considered
204-221	2375 - 2405	Hazy data	Considered
222-242	2405 - 2577	White or No data	Not considered
223,224	2415, 2425	Moderate data	Considered

Table 3.2: Hyperion data : Individual Band Information

This L1R data has 242 bands, from which, only 196 are non zero (Dett etal. 2003; Ganesh et al. 2013; Smara et. al. 2014). If every band had been operating the spectral range from 358 nanometer to 2570 nanometee would have been covered with an overlap at 850 nm and 1052nm. However, either due to low sensitivity or due to no illumination, some bands remain uncalibrated. Resultantly, 180 out of 242 bands are selected for further processing. The eliminated are given in Table 4.2 data representation is clear.

3.1.2 Destriping

In some band of the data, vertical strips are observed which has to be removed to facilitate better pre-processing results from the data. The strips are visually identified using and has to be manually removed using Spectral Pixel Editor tool in ENVI. The values of the bad column is at zero, which is replaced by the average of values on either side.

Band Number	Band Column
94	102
99	198
116	16
165	6,114
169	123
190	146
200	248,249
201	248,249
203	137

Table 3.3: Bad columns of the bands

3.1.3 Atmospheric Correction of the Data

Radiation reflected from Earth surface passes through the atmosphere before reaching the sensors. Hence this contains the information, both of the earth surface as well as that of the atmosphere. To retrieve surficial reflectance properties, the atmospheric component have to be removed. For atmospheric corrections we only use FLAASH of ENVI.

FLAASH component of ENVI is built on the MODTRAN (Andarson etal. 1999; Cooley etal. 2002). It takes care of the parameters which influence atmosphere. Certain input parameters are required before using this model to generate Atmospherically corrected data.

To make atmospheric corrections in FLAASH some parameters are required as input , which are:

- Atmospheric model
- Water vapour retrieval
- Visibility
- Sensor type
- Spectral polishing
- Sensor altitude
- Sensor center
- Pizel size
- CO2 absorption model
- Flight date and time
- Aerosol model
- Spectral polishing
- Advanced parameters

Information about these parameters can be obtained from metadata file of the remote-sensing data on USGS website.

Scale factors

The scale factor for the input file during atmospheric correction has to be included in from of ASCII file. It can be created using simple notepad application. The scale factors are 400 and 800 for wavelength in nm, respectively for VNIR and SWIR bands.

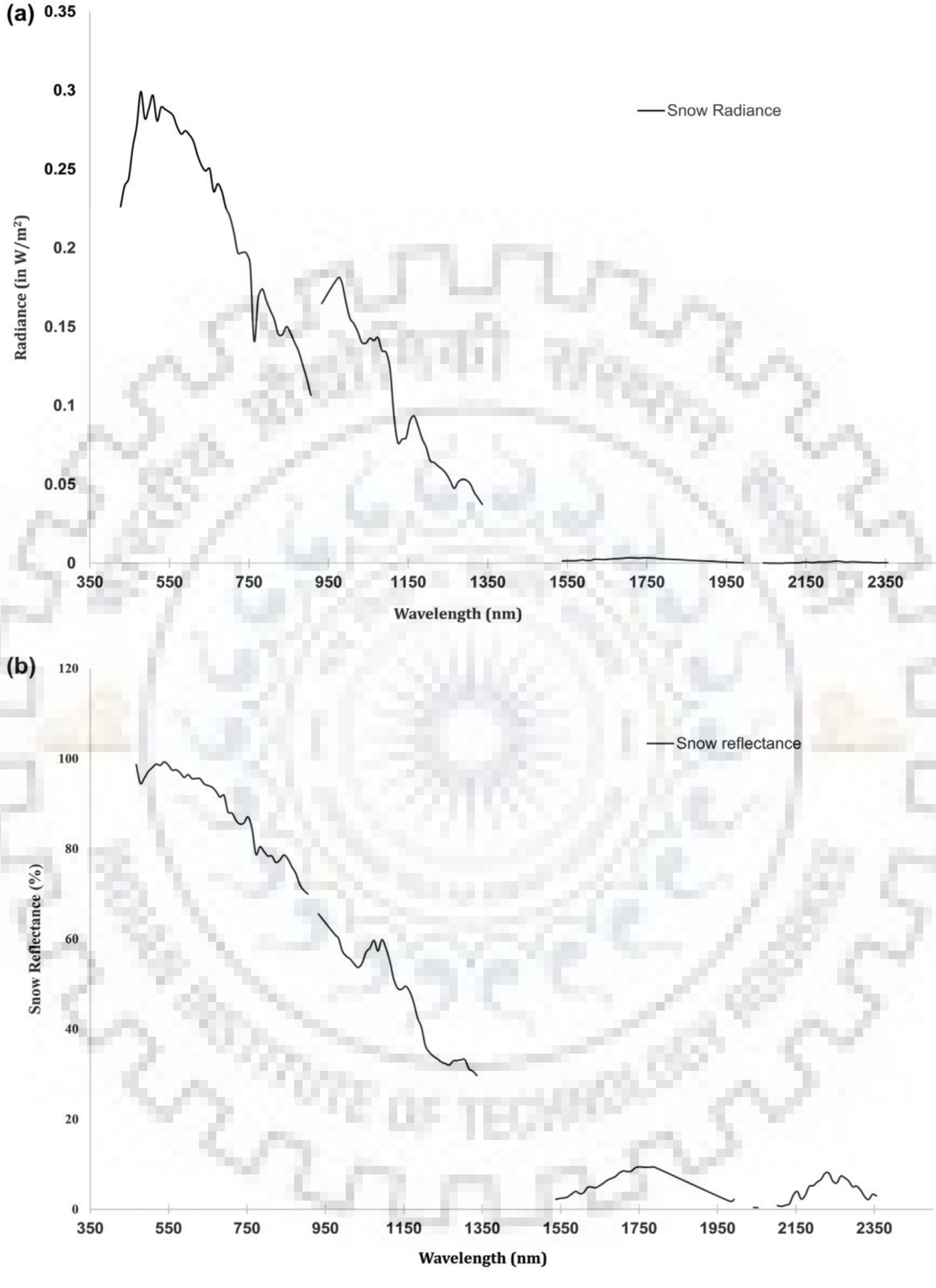


Figure 3.2 - Spectral signature of fresh snow before (a) and after (b) atmospheric correction.

Atmospheric correction was applied to ensure the comparison of Hyperion data with reference spectra and to improve the quality of image. Removing the effect of atmospheric component enabled the comparative analysis of field spectral signatures with laboratory spectra.

3.2 Hyperspectral Data Processing

To extract spectral signatures from data has to be processed to reduce noise. In contrast with multispectral, hyperspectral data contains more bands with narrower width. This increase in information due to more bandshas enabled us to decipher more characteristics of earth surfacebut it also has increased complexity and redundancy in data. The processing time has been increased greatly due to large size of data which is needed to be minimized before further processing of the data. The analysis of Hyperion data generally includes:

- Destriping and atmospheric correction
- Dimensionallity and noise reduction of data
- Extraction of pure and extreme pixels
- Identification of end members
- Spatial mapping of end members

3.2.1 Data Dimensionality Reduction

The great size of data created all through the Hyperspectral image-processing makes management and computationof data very complex. To improve analytical accuracy data dimensionality reduction is very necessary. In Hyperspectral analysis two methodologies are promising for dimensionality reduction.

1) Principal component analysis (PCA): It is is the most commonly used method by remote sensing community for reducing the dimensionality of the data. PCA projects the data from original dimension to other orthogonal axis which has a lower dimension. The outcome is a number of principal components in a descending order of information content. This method is used to produce uncorrelated bands, for separating noise components. It selects a small subset of the datum which is appropriate to isolate the several classes with required precision.

2) Minimum Noise Fraction transform: MNF transformation is a modified from of PCA. Nearby bands in EM spectrum are correlated, hence they can be used in reducing dimensionality of data. This approach of obtaining noise free data is a linear transformation. Since the neighbouring spectral bands are highly related, the dimensionality of the data can be abridged by using MNF Transformetion and holding the some of the noise-free components.

In this study , MNF transformation has been used to compute the characteristic dimensionallity of the image data and to separate out the noise in data and shrink the computational requirements for further processing (Broadman and Krue, 1994) .

3.2.2 Pixel Purity Index

This procedure is applied after dimentionality reduction of the satellite data to fix or locate the extremely pure pixels from data spectra. PPI method has been automated in ENVI software.

In this process, all the spectral points are repeatedly put on the random unit vector and the extreme spectral values (both, high and low) are noted. Also, the number of times each pixel is marked as extreme is also noted.

We also have to input two parameters - Thresold value and number of Iteration. Increasing the number of iterations is computationally intensive, but more effective in determining pure pixels. The result varies with change in number of iterations since the number of times the n-D scatter plot has been projected on the random unit vector changes. With increase in number of iterations we get more extreme pixels.

Threshold value is the measure of extremeness in the pixels, as measured from the ends of projected vector. For a larger Threshold value more pixels are marked as extreme, but the purity of pixels is compromised. A plot is also created after generation of PPI results to show the number of pixels that has been marked as extreme. The bright pixels represent spectrally pure pixels whereas dark pixels belong to a single element and are comparatively less pure.

3.2.3 N-d visualization for End-member selection

To locate and cluster the purest pixels n-D visualizer is used along with spatially subsetted MNF data. The data is significantly reduced using PPI and is projected on n-dimensional scatter plot. In this method, n represents the number of bands whereas the spectra corresponds to points. Generally, in n-dimensional visualizer, 2 or 3 spectral values are taken. Purest pixels are found at the tip of a corner in the data cloud generated by n-D visualizer. The pixels with extreme values are identified and marked as one class. Few classed are generated which have to be further tested in other dimenions to make sure that the points remain struck together in all the dimensions. The classes generated using this method are extracte to ROI file to find their spatial arrangement. The spectra generated using these classes are matched with that of spectral library datum to identify the mineral that can resemble with the class spectra.

3.3.4. Spectral Angle Mapper

SAM is an angle based supervised technique, used for classification of Hhyperspectral images. SAM determines the resemblance between a pixel and all of the reference spectra. This method is based on the calculation of the “spectral angle” between the pixel and the reference spectra.

There are other methods used for matching the measured spectra with reference spectra depending on the criteria adopted for measuring the similarity (or closeness) between the two spectra. These methods are distance-based and correlation-based measure.

SAM method is relatively quick and computationally less intensive. This classification method is not affected by topographic shading. However, it is susceptible to noise, hence pre-processing of the data is very important here.

To implement SAM, the data has to be reduced to apparent reflectance (True reflectance multiplied by gain factor due to topography, shadow etc). The dark noises including path radiance are removed so that zero reflectance values coincide with the origin.

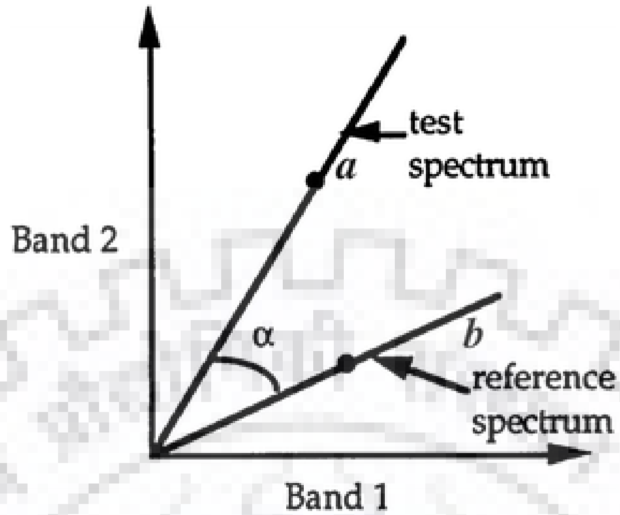


Figure 3.3 Spectral angle mapper

The resemblance of the any two spectral is derived by calculating the angle between the vectors representing the spectra in n-dimensional space. This method is widely used for spectral matching due to its independence from tropical shading. Smaller angles signify close matches to the ref. spectrum. The stated maximum angle is 0. 1 radian, above which the pixels are not classified. SAM classified image has been generated considering the part of the PPI image containing brighter pixels in the PPI image so that the proper end members can be classified in the SAM image.

4. RESULTS AND DISCUSSIONS

The results attained by following the recommended pre-processing steps in methodology described before are explained in the following section.

4.1 Pre-processing

4.1.1 Band Destripping

The hyperspectral image consists of large number of bands that can be read in ENVI image processing software. It was observed that some bands appeared completely black or white as they are uncalibrated and do not contain any useful information. The data content in each band is different. Removal of these bands is important for further processing. After observing all 242 bands of the data one by one, the uncalibrated bands are removed using spectral subset feature in ENVI software. All the chosen and removed bands are listed in Table 3.2.

Some images contain bad columns (mentioned in table 3.3) which are removed using "spatial pixel editor" feature in ENVI software. The data of bad column is replaced by average of two adjacent columns. This corrected image is used as input data for atmospheric correction.

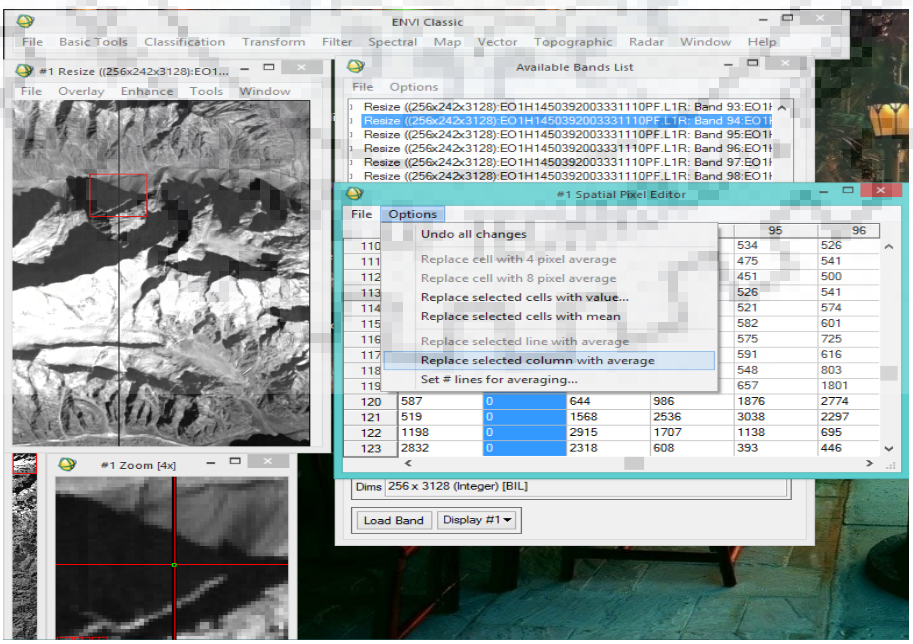


Figure 4.1 – Bad Band Removal

4.1.2 Atmospheric Correction

Since the data contains the information of surface as well as that of atmosphere, the components of aforementioned conditions has to be removed.

In order to understand the effect of atmosphere on the spectra, a sample of vegetation spectral profile is taken from the data used for this study.

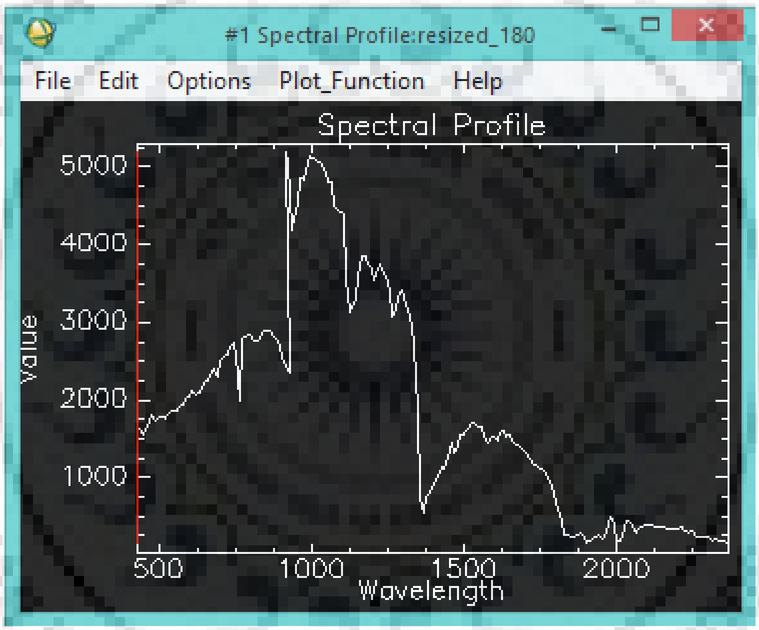


Figure 4.2 - Radiance spectra of vegetation over study area

In this image, the absorption effect of Oxygen, Carbon Dioxide and Water Vapour are evident in the image.

- Oxygen - The thin dip present at 750 nanometers is due to absorption of oxygen.
- Water vapour - The dips at 1375 nm and 1900 nm are caused by water vapour absorption. This has grossly distorted the surface radiance.

- Carbon dioxide - Weak absorption lines ant 1430 nm and absorptions between 1900 and 2055 nm are caused by CO_2 absorption.

FLAASH module of ENVI requires us to provide information about sensor, scene and atmospheric properties such as altitude, ground elevation, flight date, aerosol model, wavelength, azimuth and zenith for instruments and CO_2 mixing ratio to atmospherically correct the data. The wavelength data of input radiance image is read from a separate ASCII file as radiance scale factors.

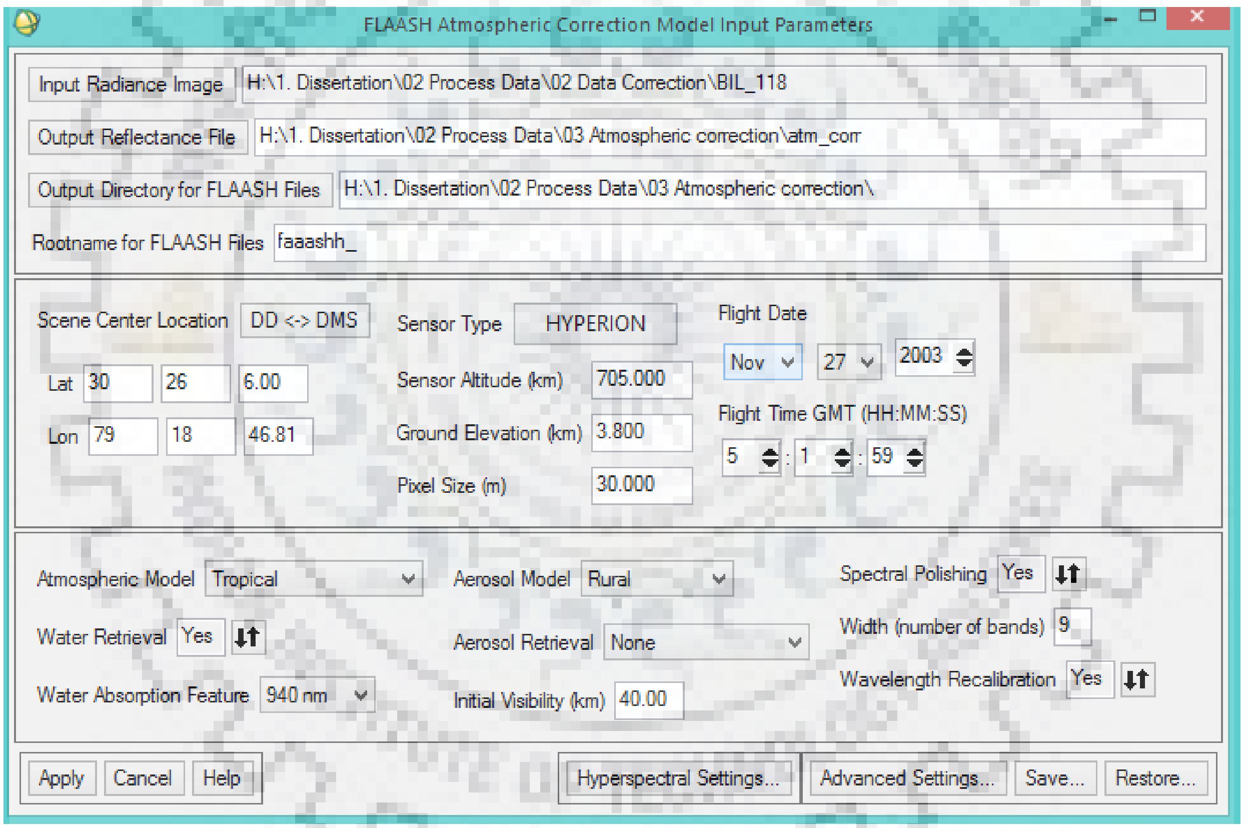


Figure 4.3 - FLAASH input dialogue box

To scale the reflactance values, Band math was applied to the atmospherically corrected data. The equation is applied on each pixel, so that the dimensions of every input band remain same.

The equation used here is -

(b1 le 0)*0 + (b1 ge 10000)*1 + (b1 gt 0 and b1 lt 10000)*float (b1)/10000

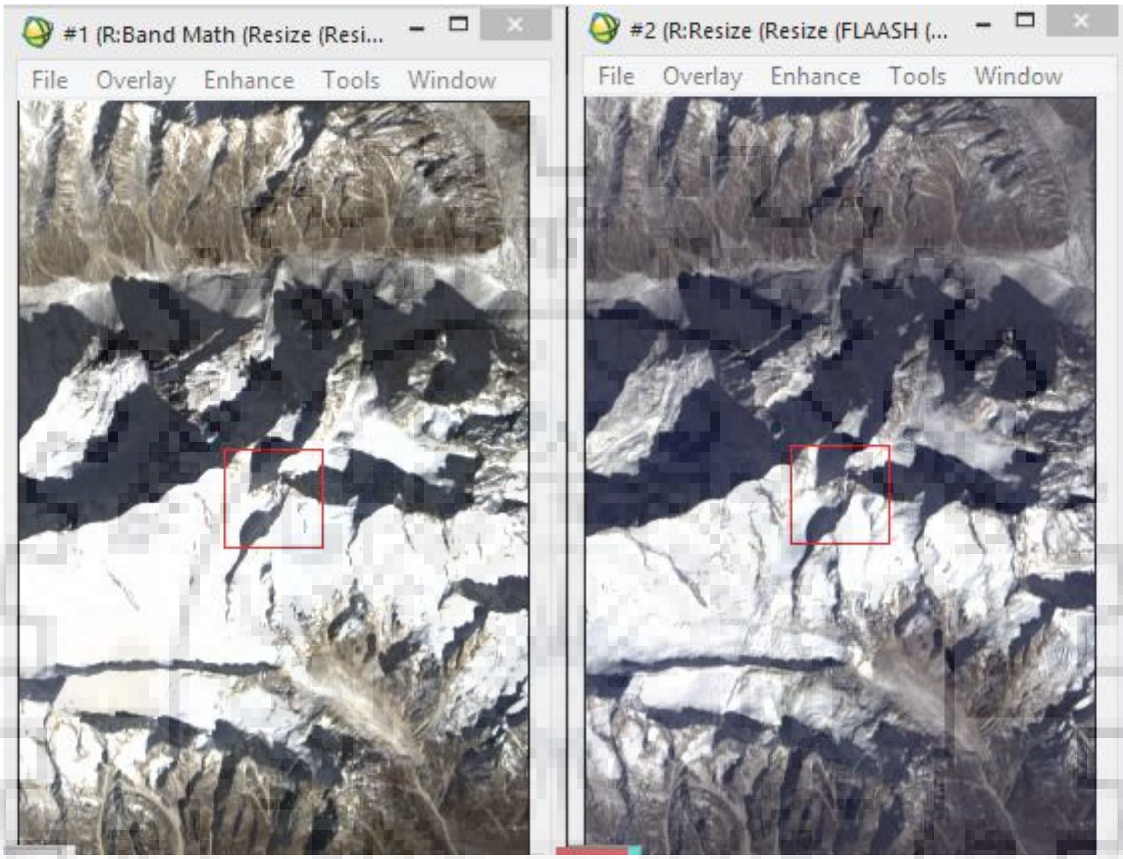


Figure 4.4 - Atmospheric correction results, before (left) and after (right) the Band math

4.2 Spectral Analysis Results

4.2.1 Minimum Noise Fraction Transform Results

To reduce the dimensionallity of the data, MNF transform is found to be more suitable. Forward MNF is applied to all 180 atmospherically corrected images and resultant plot is observed. As the number of bands increase in MNF, the eigenvalue decreases. To separate the bands that contained noise from the bands that contains useful data, eigenvalues are analysed. As output of MNF transform 40 MNF bands are obtained. After examining quality of these bands a spectral subset containing 10 bands is used for further study.

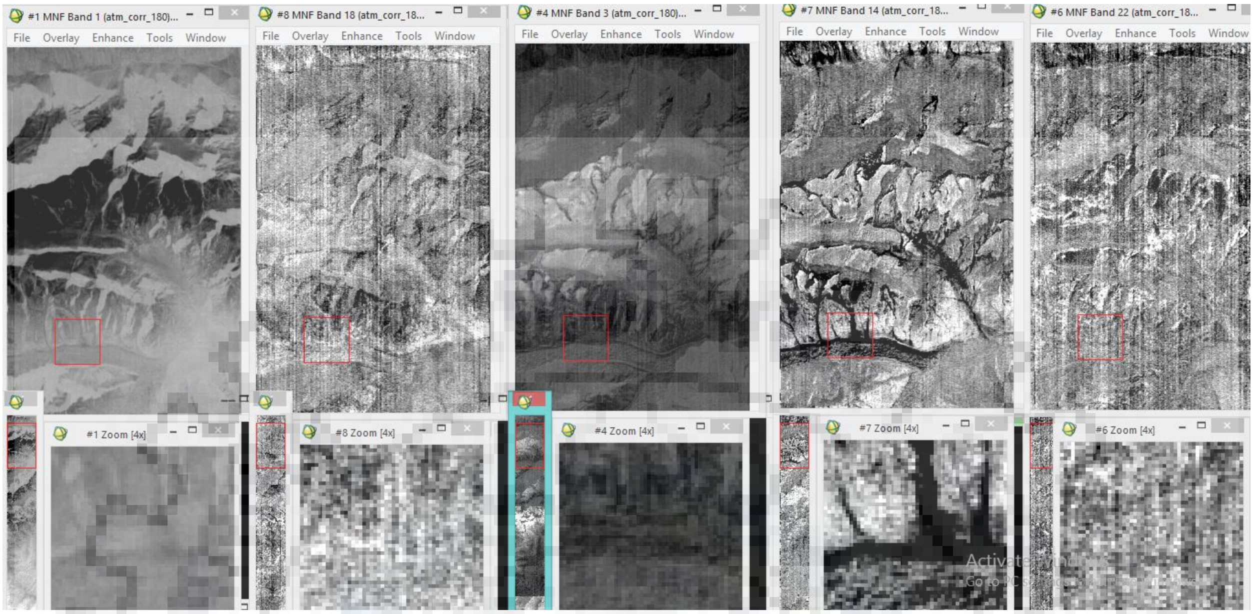


Figure 4.5 - MNF Transformed Band

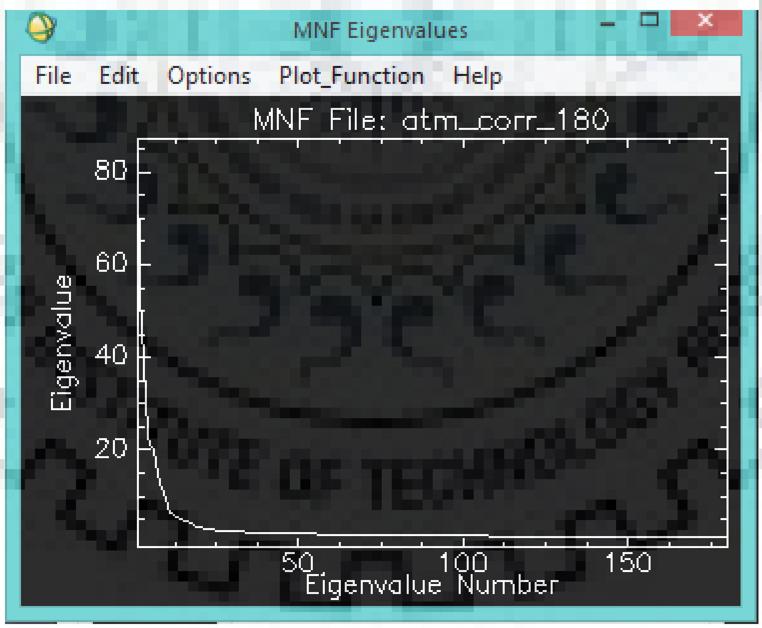


Figure 4.6 - Eigenvalue plot for MNF transform

Two separate statistics files are produced after the transformation : MNF noise statistics and MNF statistics. These files contain information unique to MNF and neglect the data usually found in ENVI stats files.

MNF results shows that band no 1 have highest eigenvalues (43.112623) and highest variance whereas values are decreasing with increasing band numbers. After analysing MNF plot and eigenvalues of bands initial 10 bands contains maximum variance therefore used for further processing and rest of the bands were discarded as they contain noise.

4.2.2 Pixel Purity Index

As mentioned earlier, finding of spectrally pure pixels, 10 MNF bands are used. Multiple combinations of threshold values and number of iterations were tested, (threshold values ranging from 1 to 2.5 and number of iterations ranging from 10000 to 30000), post which the results were stabilized. Higher threshold values make PPI to identify additional number extreme pure pixels but they might not necessarily be pure. The PPI curves tends towards horizontal line when extremes pixels are detected.

The pixel purity index image shown in figure 4.8 was obtained with 10 MNF bands using 30000 iterations and threshold value of 1.0. As mentioned earlier in methodology, the brighter areas indicate extreme pixels and intensity of brightness signifies the number of times that pixel was marked as extreme.

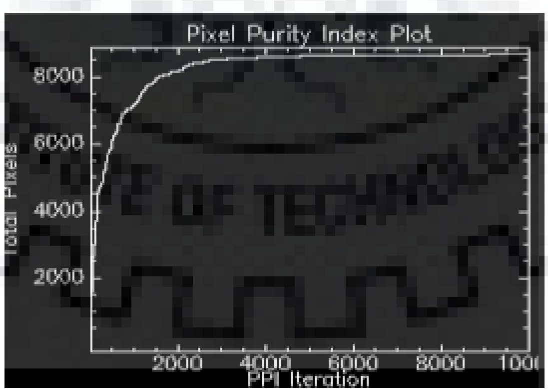


Figure 4.7 - PPI plot with threshold 1.0

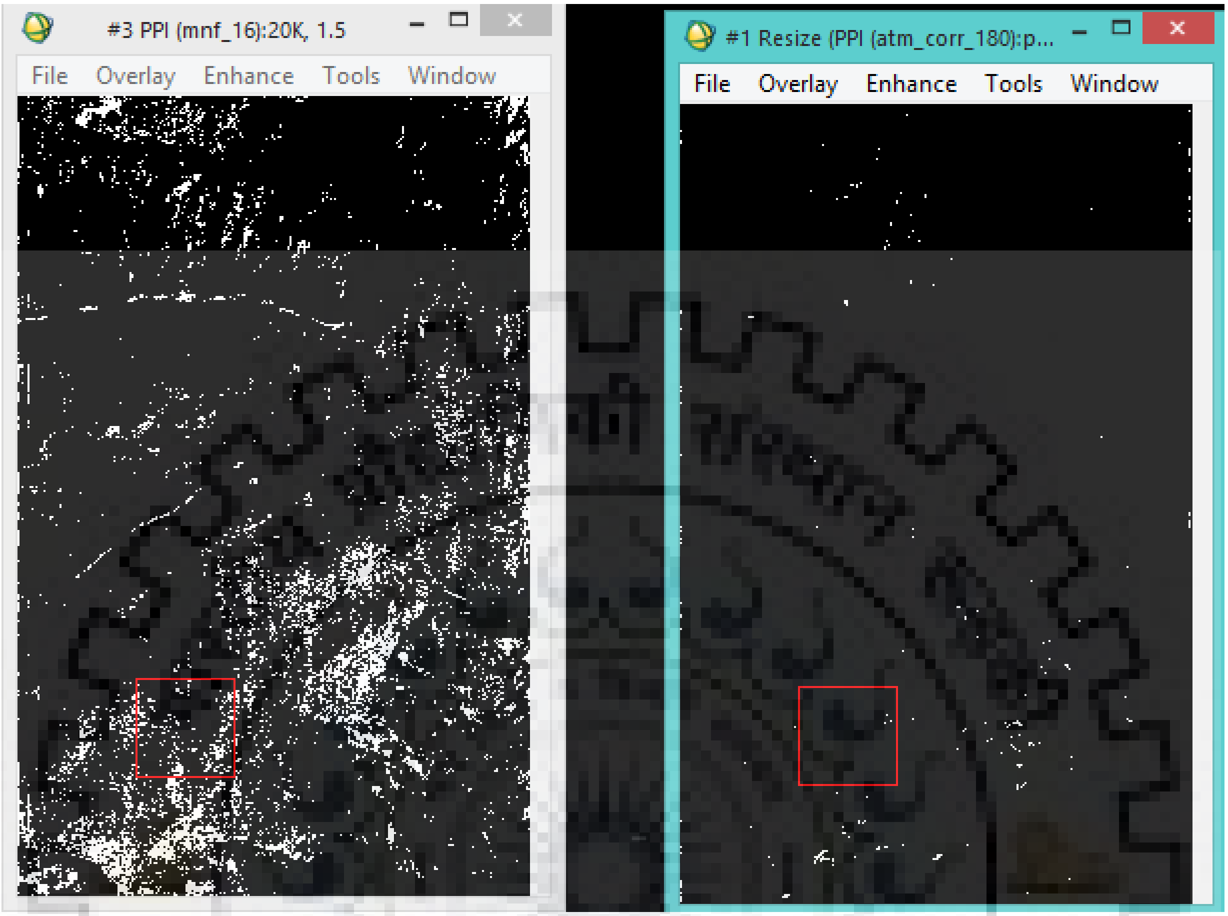


Figure 4.8 - PPI result (a)with threshold 2.5 (b) with threshold 1.0

4.2.3 N-dimentional visualizer

Selection of end-members can be obtained using any of the three ways:

1. Selecting end-members from a spectral library – either already available spectral library like that of USGS, ASTER or JPL

2. By using spectral library generated using data from field or laboratory data.

3. From the image using PPI results and n- Dimensional visualization (n-D)

For this study end members have been generated using he Pixel Purity Index (PPI) results and n-D visualizer in ENVI software. The pure pixels obtained through PPI were loaded in n-dimensional scatter plot and few classes were selected. The selected classes were matched with the USGS spectral library. Nine end members, having score more than 0.9 (Ice 0.927, glacial moraine 0.924 and vegetation 0.921etc.) were selected. These were verified from the USGS spectral library collection from the same area. The spectra were also generated for the field samples in the lab condition and they show good match with image spectra. These three end members for Glacial Ice, Glacial Moraine and Vegetation are used for classification

4.2.4 Endmember Identification

From n-D visualization the RoIs were generated, and are checked with the USGS library spectra. Due to presence of ice and snow, the classes generated are mostly belongs to ice.

In total nine classes are generated including vegetation, fresh snow, snow with debris, ice, ice with debris, water and shadow. All of these are sufficiently close to actual spectra of the same features according to Spectral Angle Mapper.

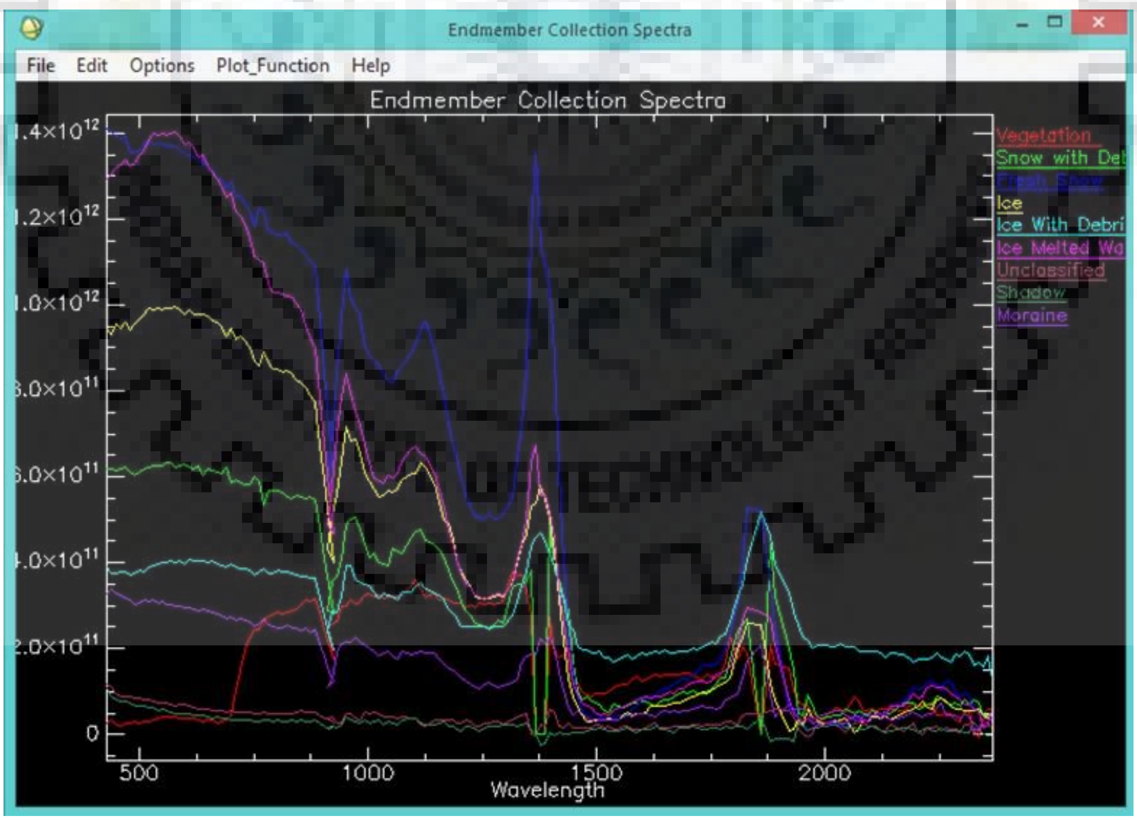


Figure 4.9 – Spectral profiles of all end members obtained

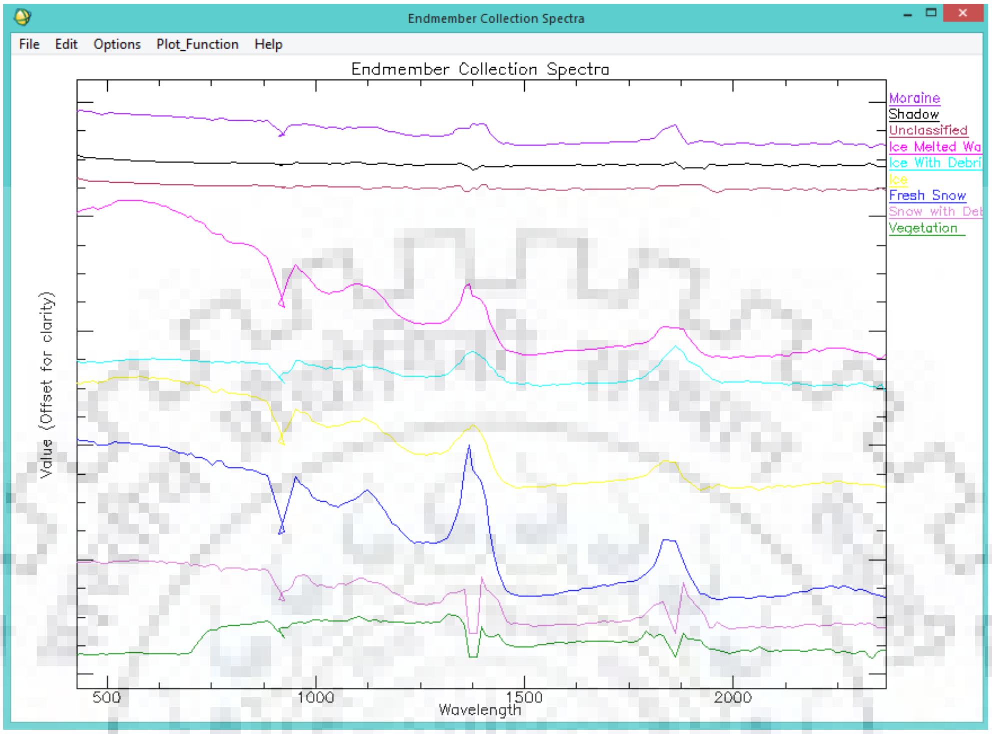


Figure 4.10 - Stacked plot of spectral signature of all end members

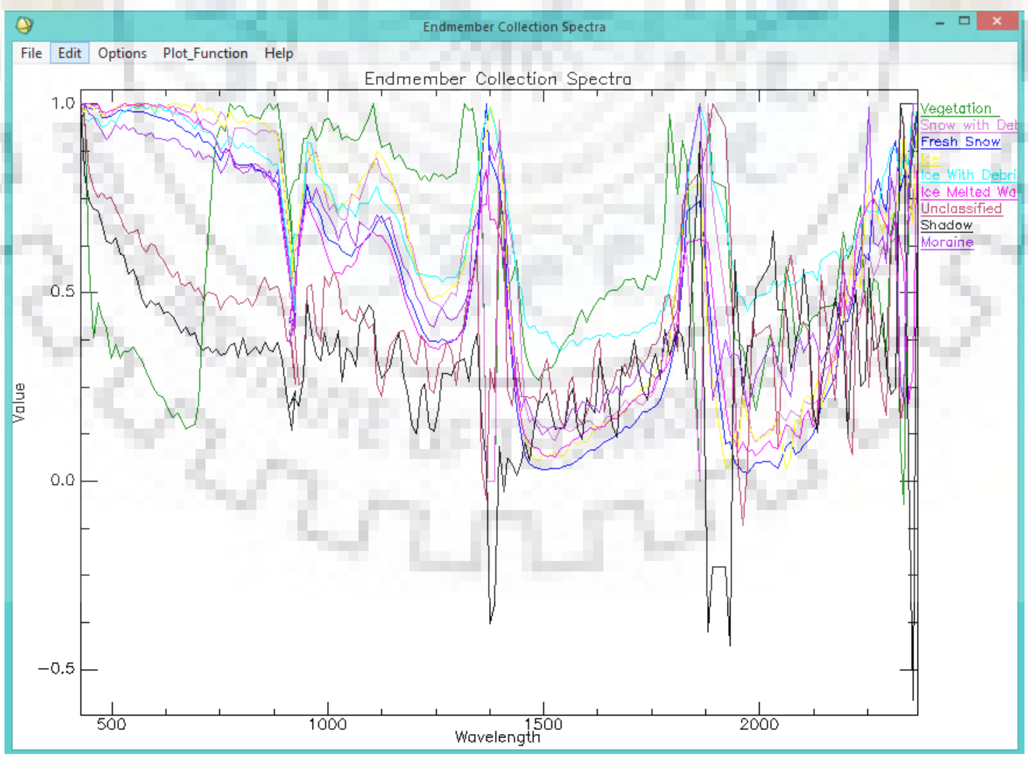


Figure 4.11 – Continnum removed spectral plot of all end members

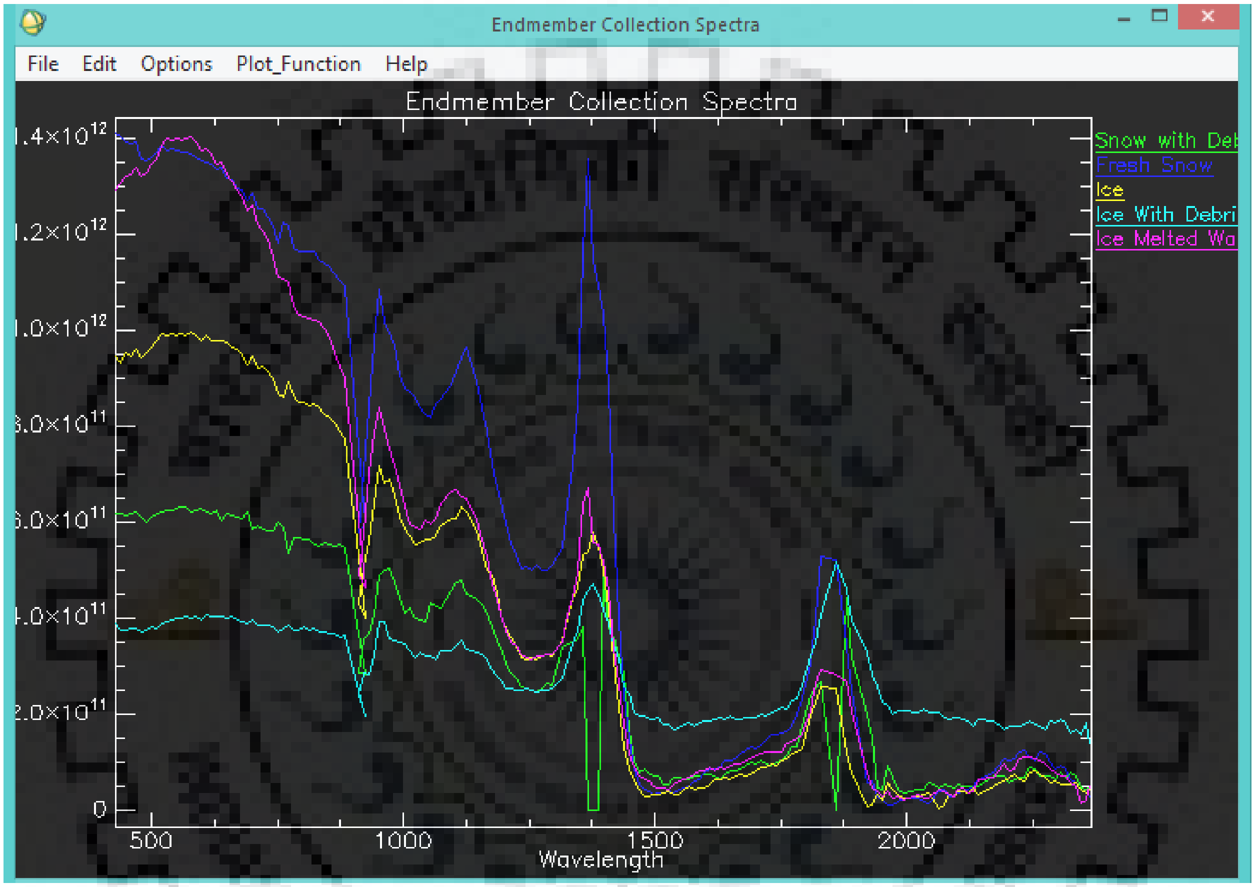
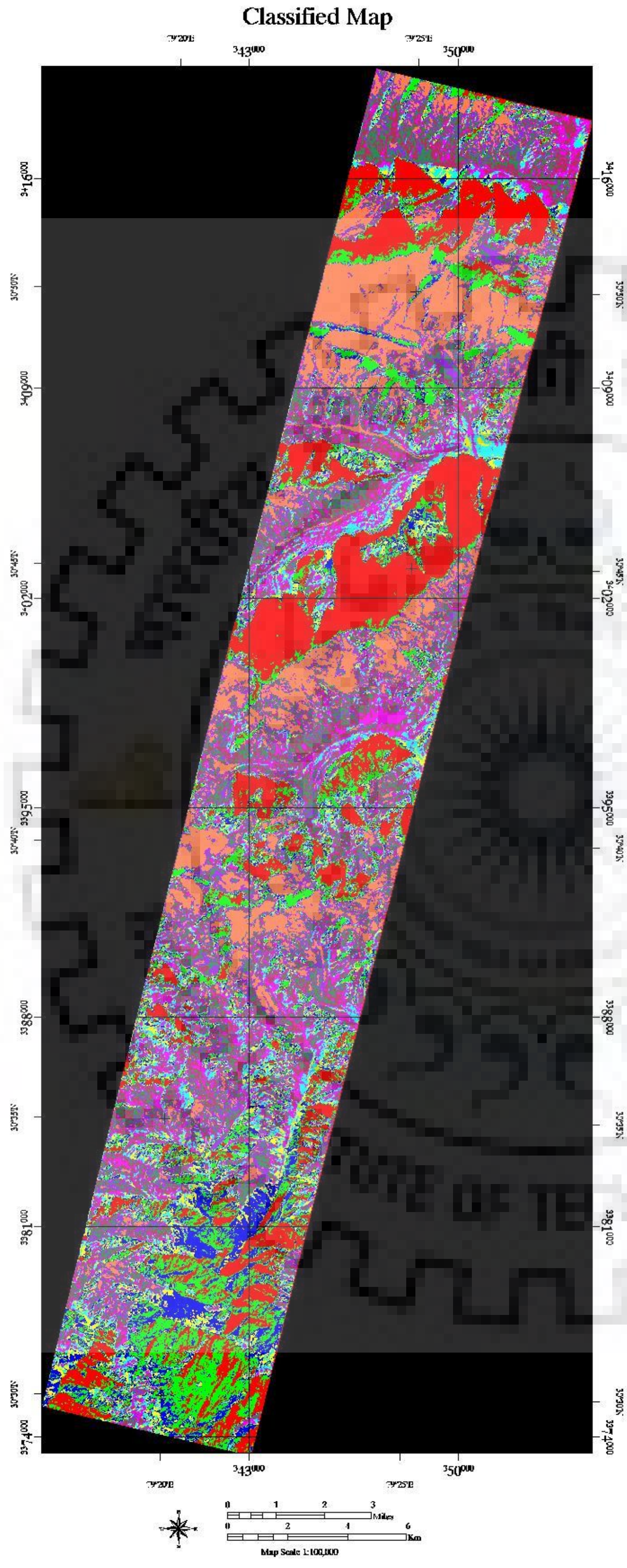


Figure 4.12 - Spectral profiles of all end members obtained

In figure 4.12, spectral profiles of all the end members containing either ice or snow are plotted. It can be observed that value of fresh snow maximum in visible range since it will have highest reflectance. Also, ice containing debris would have minimum reflectance value in visible range of spectra.

4.2.5 Spectral Angle Mapper

The Hyperion image was classified using the nine end members namely Ice, Glacial moraine, fresh snow, snow with debris, ice with debris, shadow, water, and vegetation. Individual mineral species are identified by the position, shape and strength of the absorption feature in SAM classification. For matching of the spectra with the spectral library, the combined score of SAM, BE, and SFF is used. The features with good score (>0.8) were taken as end members after close examination. The incidence of these minerals in study area is shown by Spectral Angle Mapper (SAM) classification.



The image was obtained using SAM classification method using all nine spectral signatures. As an output of Spectral Angle Mapper the classified image has been obtained. Geo-referencing of the classified map was done using ArcGIS software. This characterization of all the important features this area is accurate upto 5 meters.

Figure 4.13 – SAM classified and geo-referanced image of the study area. Different colours represent different endmembers.

5. CONCLUSION

The purpose of this study was to explore the prospectives of the Hyperion data to quantify and map various mineral and other geological feature and correlate sensor data with the geochemical data. After analysis of the hyperspectral data and comparing it with the USGS library data and the geological map of the study area, the study illustrates that the Hyperion data is useful for mapping of geological characteristics and various mineral zones. However Hyperion imagery has also its own limitations such as, low signal to noise ratio, presence of strips in some bands and the low spatial resolution. Due to these apparent strips in some bands, absorption dips for some minerals can not be observed in some bands. Also, the overlap between the Visible and Near Infrared (VNIR) and Short Wave Infrared (SWIR) focal planes some of the bands are rendered useless and are removed during pre-processing. Only 180 out of 242 bands were calibrated due to uncalibrated data.

On the basis of prior information of the area, a logical method of Hyperspectral remote sensing has been applied for processing of data. It has been useful in identifying important geological features like Ice, Snow, water, glacial moraine vegetation etc. These targeted glacial features were mapped using the Hyperion data with SAM method.

Multiple features of the spectrum like location of maxima or minima, near- horizontal flat intervals, inflexion points, distance between two peaks (consecutive minima/maxima), area below two consecutive minima/maxima can be extracted and studied for further interpretations. These spectral imaging methods and extracted feature after processing of hyperion data, can be further used to train data for machine learning classification models. Thus, spectral imaging can help us automate identification of the surface minerals and its abundance. This has an unexplored potential in the domain of mineral exploration based on spectral variability and hence can be adopted for further studies.

Further, it is recommended that the spectral unmixing techniques should be used to further quantifying mineral abundance. This, in result, will further improve the mapping capability using hyperspectral data.