Chapter 6

SNOW PHYSICAL PARAMETERS AND CHANGE DETECTION ANALYSIS

6.1 Introduction

Himalaya is one of the youngest folded mountainous formations of the world, characterized by a complex geologic structure, snowcapped peaks, large valley glaciers, deep river gorges and rich soil and vegetation. A complex interplay of climatic and geological processes led to resource degradation in Himalayan ecosystem (Jodha 2001). Changes in ecosystems are generally affected by the level and type of land surface parameters such as land covers which includes: snow, water, grassland, forest, and bare soil (Assefa 2004). Extraction of surface parameters has world-wide concern to understand its impact on radiation balance, local climate, global climate change, biogeochemistry, diversity and abundance of terrestrial species. Thus an accurate representation of surface parameters and biophysical attributes (soils, elevation, topography-slope and aspect, etc.) of the landscape within Himalaya is required. In the last three decade, considerable advancement in space technology providing a numerous satellite platforms to study complex physical processes of the earth-atmosphere system (Rogan et al. 2004). And one of the best basic characteristics of remote sensing is the extensive use of quantitative algorithms for estimating earth surface variables (Liang 2004). The accurate estimation of surface variable using coarse resolution satellite sensor is challenging task due to mixing of various heterogeneous land features in a pixel. Sub-pixel classification techniques using multispectral data have been reported by many authors (Nolin et al. 1993; Rosenthal et al. 1996; Simpson et al. 1998; Metsamaki et al. 2002; Haertel et al. 2005) to improve the accuracy of classification for many applications in the field of earth surveys. However for certain applications there is a limit in the spatial and spectral resolution of satellite sensor which restricts the usefulness of multispectral data (Mishra et al. 2010).

6.1.1 Objectives

To get full advantages of spatial and spectral resolution, multispectral and hyperspectral imagery of AWiFS, MODIS and Hyperion provides opportunities to extract more detailed information than traditional data. The main objective of the present paper is to extract snow physical parameters such as snow cover area (SCA), snow classes (dry, moist, wet), grain size,
snow surface temperature (SST) and albedo as well as change detection among these parameters. The part of this work is focused on three key issues (a) potential of Hyperion data for land cover classification (b) estimation of land cover characteristics at sub pixel level (c) multi-temporal input to ecological modeling.

6.1.2 Data description

Present study carried out with three different satellites viz. AWiFS, MODIS and Hyperion. These satellites have their own potential to explore the specific land surface parameter. In the present work only Hyperion data is used to extract grain size. AWiFS used to measure SCA, snow classes and albedo whereas MODIS are used to measure snow surface temperature (SST), SCA and snow classes. To analysis change detection in snow bound region all these three satellites are used. These parameters are extracted from different parts of the Himalaya.

6.2 Snow Physical Parameters

6.2.1 Albedo

Albedo is a critical snow physical parameter that affects the earth’s climate system directly by altering the energy balance at the ground surface and indirectly by controlling the ecosystem processes. Spatial variability of snow surface albedo has immense importance in study of geomorphology, hydrology and climate dynamics. This paper describes and examines the retrieval of snow albedo by using multi-spectral AWiFS on board IRS-P6 of RESOURCESAT-1 for period between October 2012 and May 2013. The spectral reflectance is computed by converting digital numbers which is achieved by performing atmospheric correction on the images. This is validated with ground data using Spectroradiometer and satellite derived snow albedo has been verified with in-situ observation during the satellite pass over the area using pyronometer and Automated Weather Station (AWS).

6.2.1(a) Site description

The analysis is carried out for study area lies between latitude of 32°10’0” N to 32°30’0” N and longitude of 77°0’0” E to 77°20’0” E as shown in the Figure 11. It is a part of Beas basin comprises of mountainous terrain in Pir-Panjal range lies in district Kullu of Himachal Pradesh (India). The altitude varies from 2000 m to 5000m with a mean value of 3200m. The majority of the slopes inclination lies in the range of 30-35 degree. The area is generally bowl shaped having
southern aspect. The area is thickly forested covered maximum with coniferous trees in the lower altitude along the valley.

Figure 11. Study area – Beas basin (Dhundi)-H.P in AWiFS image to retrieve albedo

6.2.1 (b) Narrow band reflectance to broad band albedo

The approach to convert narrow band reflectance (NBR) to broad band albedo (BBA) for Advance Very High Resolution Radiometer (AVHRR) using two channels proposed by (Song et al. 1999) is adopted to derive a new algorithm for AWiFS multi-spectral data. The surface integrated albedo, a, in any wavelength band, $\Delta \lambda$, is defined as the ratio of integrated reflected energy, $\sum E_{s_{\Delta \lambda}} \rho_{\Delta \lambda}$, to integrated downward irradiance, $\sum E_{s_{\Delta \lambda}}$, at the solar zenith angle, $\theta_z$ and can be expressed as (Liang et al. 2003):

$$
a = \frac{\sum E_{s_{\Delta \lambda}} \rho_{\Delta \lambda}}{\sum E_{s_{\Delta \lambda}}} \cdot \frac{1}{\Delta \lambda}\n_{---------- (6.1)}
$$

Where $E_{s_{\Delta \lambda}}$ the incoming solar energy and $\rho_{\Delta \lambda}$ is the surface reflectance in wavelength band, $\Delta \lambda$. Precise estimation of broad band albedo from narrow band reflectance of remotely sensed data can be obtained when following three factors are accounted for (Brest 1987) (i) spectral reflectance characteristics of the surface of interest (ii) the spectral distribution of the irradiance (iii) wavelength region of the discrete spectral bands. AWiFS sensor has four narrow spectral wavelength bands (Table 5) and to convert these spectral reflectance in visible (VIS)
\(\lambda = 0.52 \mu m - 0.59 \mu m \) and \(0.62 \mu m - 0.68 \mu m\), \(0.77 \mu m - 0.86 \mu m\) and \(1.55 \mu m - 1.7 \mu m\) to the total broad band albedo in the solar spectrum \((0.3 - 2.5 \mu m)\), a better perception is required in the relationship between the reflectance characteristics of the narrow bands and broad band for snow surfaces. In present paper, we have divided the solar spectrum into three sub-regions: the visible (VIS) sub region \((0.350 \mu m - 0.7 \mu m)\); near infrared (NIR) sub-region \((0.7 \mu m - 1.5 \mu m)\) and short wave infrared (SWIR) sub-region \((1.5 \mu m - 2.5 \mu m)\). The reason to choose these sub-regions are due to (i) all AWiFS narrow spectral bands are consistent with these solar sub-regions (ii) spectral reflectance characteristics of snow surface have almost unique trends and donot overlap with each other in these sub-regions. We have considered only three instead of four spectral bands of AWiFS because of almost comparable narrow band reflectance in both the visible bands. It is very important here to examine the relationships between AWiFS band 1 and the VIS sub-region; AWiFS band 2 and the NIR sub-region; AWiFS band 3 and the SWIR sub-region. The equation 6.1 for total broad band albedo considering solar irradiance in the three sub-regions (VIS, NIR, and SWIR) can be represented as:

\[ a = \frac{\Sigma E_{s\Delta \lambda 1} \rho_{\Delta \lambda 1} + \Sigma E_{s\Delta \lambda 2} \rho_{\Delta \lambda 2} + \Sigma E_{s\Delta \lambda 3} \rho_{\Delta \lambda 3}}{\Sigma E_{s\Delta \lambda}} \]  

\[ \Delta \lambda_1: 0.35 \mu m - 0.7 \mu m; \Delta \lambda_2: 0.7 \mu m - 1.5 \mu m; \Delta \lambda_3: 1.5 \mu m - 2.5 \mu m. \]

Where the wave band \(\Delta \lambda\) represents complete solar spectral region \((0.35 \mu m - 2.5 \mu m)\); \(\Delta \lambda_1, \Delta \lambda_2\) and \(\Delta \lambda_3\) correspond to three sub-regions of the solar spectrum i.e. \(\Delta \lambda_1: 0.35 \mu m - 0.7 \mu m; \Delta \lambda_2: 0.7 \mu m - 1.5 \mu m\) and \(\Delta \lambda_3: 1.5 \mu m - 2.5 \mu m\). \(E_s\) and \(\rho\) is solar irradiance and reflectance in different wave bands as discussed above.

The broad band reflectance \(\rho_{\Delta \lambda 1}, \rho_{\Delta \lambda 2}\) and \(\rho_{\Delta \lambda 3}\) in equation 6.2 are different as compared to narrow band reflectance in corresponding AWiFS spectral bands and require some correlation to be established between them. We assume here that the broad band reflectance in VIS \((\rho_{\Delta \lambda 1})\), NIR \((\rho_{\Delta \lambda 2})\) and SWIR \((\rho_{\Delta \lambda 3})\) channel represented by each term in the numerator of equation 6.2 can be parameterized by corresponding narrowband reflectance in AWiFS bands accompanied by suitable alteration factors \(f_1\) and \(f_2\) (Song et al. 1999), respectively with the following equation given below:
\[ a = \frac{f_1^{-1} \rho_{\Delta \lambda} E_{\Delta \lambda} + f_2^{-1} E_{\Delta \lambda} \rho_{\Delta \lambda} + f_3^{-1} E_{\Delta \lambda} \rho_{\Delta \lambda}}{\sum E_{\Delta \lambda} / \Delta \lambda} \]  \hspace{1cm} \text{(6.3)}

Where subscripts v, n and s represents the VIS, NIR and SWIR narrow wavelength bands of AWiFS sensor respectively. Comparison of equation 6.2 and equation 6.3 gives estimation of \( f_1, f_2 \) and \( f_3 \).

\[ f_1 = \frac{\rho_{\Delta \lambda_{v}} E_{\Delta \lambda_{v}}}{\sum E_{\Delta \lambda_{v}} \rho_{\Delta \lambda_{v}}} \] \hspace{1cm} \text{(6.4a)}

\[ f_2 = \frac{\rho_{\Delta \lambda_{n}} E_{\Delta \lambda_{n}}}{\sum E_{\Delta \lambda_{n}} \rho_{\Delta \lambda_{n}}} \] \hspace{1cm} \text{(6.4b)}

\[ f_3 = \frac{\rho_{\Delta \lambda_{s}} E_{\Delta \lambda_{s}}}{\sum E_{\Delta \lambda_{s}} \rho_{\Delta \lambda_{s}}} \] \hspace{1cm} \text{(6.4c)}

The physical interpretation of conversion factors in equation (6.4a, 6.4b, & 6.4c) can be understood clearly. It quantifies the ratio of the reflected radiations within the narrow spectral bands of AWiFS to the reflected radiations of the corresponding broad band in VIS, NIR and SWIR region. Various authors have reported that linear relationship exists between broad band albedo and narrow band reflectance for NOAA-AVHRR, MODIS and METEOSAT data. The AWiFS reflectance channels in VIS, NIR and SWIR narrow bands are used to estimate surface albedo by using the following linear combination:

\[ a_{\text{AWiFS}} = C_1 R_1 + C_2 R_3 + C_3 R_4 + d \] \hspace{1cm} \text{(6.5)}

Here \( C_1, C_2 \) and \( C_3 \) are empirical coefficients, \( R_1, R_3 \) and \( R_4 \) are narrow band reflectance in AWiFS spectral channels and \( d \) is an offset difference. Combining equation 6.3, 6.4a, 6.4b, 6.4c and 6.5 estimates coefficients as:

\[ C_1 = w_1 f_1^{-1} \] \hspace{1cm} \text{(6.6a)}

\[ C_2 = w_2 f_2^{-1} \] \hspace{1cm} \text{(6.6b)}

\[ C_3 = w_3 f_3^{-1} \] \hspace{1cm} \text{(6.6c)}

\[ d = 0 \] \hspace{1cm} \text{(6.6d)}

Here \( w_1, w_2 \) and \( w_3 \) are the percentage of solar radiation within the wave bands of AWiFS channels \( B_1, B_2 \) and \( B_4 \) respectively. The values of \( f_1, f_2 \) and \( f_3 \) are calculated using the in-situ
observations of spectral reflectance and spectral irradiance in equation (6.4a, 6.4b and 6.4c) recorded at the time of satellite pass.

6.2.2 Snow cover area (SCA)

Large areas of Himalayas covered with seasonal snow during winter and it significantly changing during summer which affects the stream flow of many rivers originating from Himalayas. This necessitates the efficient time series monitoring of seasonal snowcover over the rugged mountainous region throughout winter and summer for weekly/monthly.

Hyperspectral MODIS imagery of the entire Himalaya (LHZ, MLZ and UHZ) lies between 31\(^0\)00'00" N to 35\(^0\)00'00" N latitude and 73\(^0\)00'00" E to 80\(^0\)00'00" E longitude (Figure 5) for the period between October-September of the years 2000 to 2013 has been used in the present study to estimate SCA. On the other hand, multispectral AWiFS imagery of Beas basin located between 31\(^0\)44'00" N to 32\(^0\)32'00" N latitude and 77\(^0\)00'00" E to 77\(^0\)55'00" E longitude in Kullu district of Himachal Pradesh (India) for the period between October-June for the years 2010 to 2013 used in the present study to estimate SCA. Elevation of Beas catchment rises northward from 1100 m near Bhuntar to 4000 m. Generally the study area has an average 4000 mm annual monsoon rainfall which contributes about 39-71% in the Beas river basin (Singh et al.2009), daily mean minimum temperature ranges between -15°C and 0°C in January and maximum between 20°C to 30°C in June and area receives moderate to heavy snow fall above 2400 m altitude. The entire basin has three permanent field observatories of Snow and Avalanche Study Establishment (SASE) located at varying altitudes i.e. Bahang (2003 m) and Solang (2440 m) and Dhundi (3080 m).

Snow and cloud reflectance is higher in optical region than other land features such as vegetation, rock, and water. However, snow reflectance is lower as compared to vegetation, rock and cloud in SWIR region (Kulkarni et. al.2002c). Snow appears white in visible and black in SWIR region in the satellite imagery. This higher reflectance of cloud in SWIR region helps in discriminating snow and cloud (Diets et al. 2012). Thus to find Radiometrically corrected (atmospheric +topographic) reflectance from digital satellite data, conversion of digital numbers into radiance known as sensor calibration is essential and estimate by using equation 4.14 and 4.15. These specified characteristic of snow is effectively used by Weighted Normalized Difference Snow Index (WNDSI) for snow cover mapping (equation 5.6) and used in the present study to estimate SCA which is validated with meteorological parameters.
6.2.3 Grain Size

Snow is a highly unstable and porous material which is composed of frozen water (ice) and air. It undergoes constant change due to ambient conditions and becomes essential matter in earth’s climate system. In this section, one of the snow physical parameters (i.e. snow grain size) has been estimated using spectral angle mapper (SAM) method and validated with existed grain index (GI) method. Study was carried out with Level 1_A: L1G/L1T data (geometric and terrain corrected) of Hyperion sensor dated 25 November 2003.

The study area is located in north of greater Himalayan range, lies between 34°43′00″ N to 34°53′00″ N latitude and 77°46′00″ E to 77°54′00″ E longitude at Ladakh district of Jammu & Kashmir, India (Figure 12).

![Study area on India map and Hyperion satellite image to retrieve snow grain size](image)

**Figure 12.** Study area on India map and Hyperion satellite image to retrieve snow grain size

The study area has low humidity and an average annual precipitation around 116 mm per year. This region is almost entirely above 3000 m above sea level thus winters are extremely cold. Due to high altitude zone this area is mostly glaciated and shows no vegetation. The average winter temperature in this region is about −20 °C with extremes as low as −40 °C and summer is pleasantly warm 20 °C.

The analysis procedure consists of Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) atmospheric correction code derives its physics-based algorithm from the Moderate Resolution Transmittance (MODTRAN4) radiative transfer code as well as topographic correction to retrieve surface reflectance. The spectral reflectance of different types of snow grain size, vegetation-mixed snow and boulder-mixed snow has been collected in field,
using optical spectroradiometer and compared with satellite derived spectra. The study reveals a good agreement between the grain size classes i.e. fine, medium and coarse and quantitatively retrieved grain sizes using SAM theory.

6.2.3 (a) Grain size mapping by Grain Index

The snow grain size estimated using grain index (GI) method proposed by (Negi et al. 2010) based on the field collected hyperspectral reflectance data:

\[
GI = \frac{\text{Reflectance}(590 \text{ nm}) - \text{Reflectance}(1050 \text{ nm})}{\text{Reflectance}(590 \text{ nm}) + \text{Reflectance}(1050 \text{ nm})} \quad \text{------- (6.7)}
\]

In the present study, Hyperion band number-24 (589.62nm) with bandwidth of 10.65nm and band number-90 (1043.59 nm) with bandwidth of 11.04 nm, were used in equation 6.7. Further, by the inversion of grain index, fine, medium and coarse grain size snow map was generated (Figure 41) using the threshold values 0.0-0.17, 0.17-0.26 and 0.26-0.35 respectively (Negi et al. 2010). The above relation was only valid for snow cover pixels.

6.2.3 (b) Grain size mapping using SAM

A physically-based classification spectral angle mapper (SAM) method was used in present study for the grain size retrieval. The algorithm determines the spectral similarity between the two spectra (i.e. the pixel spectra to known/reference spectra) by calculating the angle between two vectors representing these spectra (Kruse et al. 2003). To evaluate the selected methodology and classification results, the selection of endmembers based on “Spectral Hourglass” processing scheme (Kruse et al. 2003) were implemented. This Procedure includes the generation of Minimum Noise Fraction (MNF) images for data dimensionality estimation and reduction by decorrelating the useful information and separating noise (Green et al. 1988), Pixel Purity Index-Mapping (PPI) for the determination of the purest pixels in an image (as potential endmembers) utilizing the (uncorrelated) MNF-images and finally the extraction of endmembers utilizing the n-Dimensional-Visualizer tool.

6.2.4 Snow Surface Temperature (SST)

Numerous studies have been carried out on land surface temperature (LST), sea surface temperature (SST) and its application in different areas (Haefliger et al. 1993; Lindsay et al. 1993; Wan et al. 1996; Key et al. 1997; Qin et al. 1999; Hall et al. 2001; Hall et al. 2004). In case of snow surface temperature, most of the work has been carried out for sea ice surface temperature (IST), mainly for the Polar Regions i.e. Antarctica and Arctic regions. In this
section, an algorithm is implemented for the retrieval of snow surface temperature from MODIS thermal data for snow-avalanche studies in North-West Himalaya.

In the present study, MODIS imagery of North-West Himalaya of Indian region taken as study area. Study carried out with MODIS thermal IR band-31 (10.780\(\mu\)m -11.280\(\mu\)m) and band-32 (11.770\(\mu\)m-12.270\(\mu\)m) data were used, because 10.5\(\mu\)m-12.5\(\mu\)m window region has maximum transmittance and noise equivalent temperature difference is also very low (0.05Kelvin) in these channels. The technique followed here would essentially be valid for a non-cloudy region. Six cloud free scenes from January to April of the year 2013 were selected in the present study. Digital elevation model (DEM) of 1 km resolution is also used for the delineation of different altitude zones.

6.2.4 (a) Methodology

Multi-date MODIS data were imported and preprocessed using ERDAS Imagine software. First the scaled integer (SI) values were converted into radiance values using header information of the satellite data i.e. radiance scale and radiance offset.

Radiance = Radiance Scale \(\times\) (SI – Radiance Offset) \hspace{1cm} (6.8)

According to black body radiation principle, the spectral radiance \(R_\lambda\) emitted from ground surface as a black body can be described by Planck’s radiation spectral equation (Ulaby et al. 1990)

\[
R_\lambda = \frac{2hc^2}{\hbar^5[e^{hc/\lambda kT} – 1]}
\]

Where
- \(R_\lambda\) spectral radiance of a black body (Wm\(^{-2}\)Sr\(^{-1}\)\(\mu\)m\(^{-1}\))
- \(h\) Planck’s constant (Joule.sec)
- \(c\) velocity of light (m/sec),
- \(\lambda\) Wavelength (\(\mu\)m),
- \(k\) Boltzmann’s constant (Joule/Kelvin)
- \(T\) Brightness Temperature (Kelvin).

If there is no attenuation through the atmosphere, in the process of transferring the emitted spectral radiance \(R_\lambda\) from the surface, the brightness temperature of the ground surface can be determined, by inversion of Planck’s equation as
\[ T = \frac{c_2}{\lambda \ln(\frac{c_1}{\lambda^2 R_\lambda} + 1)} \]  
\text{------ (6.10)}

Where

\[
C_1 = 2hc^2 = 1.191066 \times 10^{-16} \text{ W.m}^2
\]
\[
C_2 = \frac{hc}{k} = 1.438833 \times 10^{-2} \text{ m.K}
\]

Snow bound area can be considered as a homogeneous surface as it consist only snow on the top surface and it can be considered as a black body as emissivity of snow/ice is approximately 0.98 or 0.99 in IR part (10.5\( \mu \text{m} \) to 12.5\( \mu \text{m} \)) which is close to 1. Similarly, sea ice emissivity is also considered as 1 for the estimation of sea surface temperature (Key et al. 1997; Joseph 2000; Oerlemans 2000; Hall et al. 2001). Hence, the emissivity is taken as unity in equations 6.8 and 6.9. The following linear equation was used for the estimation of snow surface temperature (SST):

\[ T_S = a + b T_{31} + c (T_{31} - T_{32}) \]  
\text{------ (6.11)}

Where, \( T_{31} \) and \( T_{32} \) Brightness temperatures in Band 31 and Band 32 estimated using equation (6.10). \( a, b \) and \( c \) are the coefficients for atmospheric effects. Regression analysis gives us the ability to summarize a collection of sampled data by fitting it to a model that will accurately describe the data (Dale 2005). The estimation of coefficients \( a, b \) and \( c \) for North-West Himalayan region has been carried out of regression model (equation 6.11) by least square method and the values are as follows:

\[ a = 22.20189692, b = 0.9272294273 \text{ and } c = -3.3071281612 \]

Using the values of \( a, b \) and \( c \) in the model, SST images were derived. Date-wise comparison of Ts derived from MODIS imagery (January to April 2013) and observed from AWS for all the stations of North-West Himalaya.

### 6.3 Change detection in snow bound region

Land cover is the assemblage of biotic and abiotic components on the earth’s surface and has direct concern with ecology. The sensitivity of the earth’s climate as well as ecological system depends on land cover changes. It is very difficult to detect changes in physical properties of snow as well as in snowcover based on ground measurement techniques for inaccessible areas. Hence the change detection using satellite data together with ground based measurement
data can assist in solving these problems. The change detection analysis using satellite data requires careful attention to both remote sensor system and environmental characteristics.

Change detection analysis for snow cover requires qualitative as well as quantitative information. Qualitative information includes general changes i.e. where and what kind of snow is changing in an image. Quantitative information provides increased and decreased class information from one date to another date. For avalanche occurrence information, satellite data is only the tool due to its revisit and field of view of remote areas. It is very helpful in avalanche forecasting models as well as for avalanche forecaster in assessing avalanche danger. Thus, post-classification change detection along with spectral change vector method has been used for aforementioned objectives.

6.3.1 Study area

AWiFS, MODIS and Hyperion images are used in the present study for change detection analysis in snow bound region. The study area for AWiFS imagery lies between 32.100 N to 32.250 N latitude and 77.000 E to 77.200 E longitudes in Kullu district of Himachal Pradesh (India) as shown in Figure 10, commonly known as Beas catchment area. In this study area, there are 12 registered avalanche sites (MSP2 to MSP13) along Manali-South Portal (MSP) axis (link road to proposed Rohtang tunnel) and 22 registered avalanche sites (A0 to A19) along existing Manali-Rohtang axis (SASE avalanche atlas). Whereas for MODIS imagery the study area lies between 33.5759 N to 34.9133 N latitude and 73.5418 E to 75.5504 E longitudes commonly known Kashmir valley of J&K district (India). The selective study area is also the part of Lower Himalayan. For Hyperion image the study area is located in the Karakoram Range of upper Himalayan Zone lies between 35042’7’’N-35048’13’’N and 76020’5’’E-76020’6’’E. The majority of the slopes inclination lies in the range of 55-60 degree.

6.3.2 Methodology

Initially post-classification change detection method is used for AWiFS and MODIS images. The area of each class was calculated using classified images. From the area of each class of date-2 image the area of each class of date-1 image was subtracted correspondingly, which provides the increased or decreased class information. Again from the classified images the change matrix was calculated, which provides how much area of each class is changing into another classes between two dates. Change pixels are again recoded into five classes, which shows where and what type of changes have been occurred in the change matrix images.
Finally the spectral change vector method has been used which represents the direction of the surface change from the first date to the second date (Jenson 1996). The direction of the change vector identifies the type of change occurred i.e. it specifies for each pixel whether the change is positive or negative in each band. Thus for n bands, 2n types of changes or sector codes are possible. Here only two bands i.e. Visible (band1 for AWiFS and band-4 for MODIS) and SWIR (band 4 for AWiFS and band-6 for MODIS) were considered. It can be observed very well that the reflectance of snow remains always high in visible and very low in SWIR band than any other object (except water=0%).

Therefore the four possible change sector codes for a pixel measured using two bands are;

<table>
<thead>
<tr>
<th>Sector code</th>
<th>Visible band</th>
<th>SWIR band</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Where –ve is decreased and +ve is increased reflectance in each band between two dates. Whereas For Hyperion image the analysis procedure consists of Fast Line-of-sight Atmospheric Analysis of Spectral Hyper cubes (FLAASH) atmospheric correction code derives its physics-based algorithm from the Moderate Resolution Transmittance (MODTRAN4) radiative transfer code as well as radiometric (atmospheric + topographic) correction to retrieve surface reflectance. Thereafter statistical models of supervised classification such as spectral angle mapper (SAM), support vector machine (SVM), and maximum likelihood (MLH) were implemented (equation 5.8, equation 5.9 and equation 5.10) for change detection analysis.