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Development of New Thermal Ratio Index for Snow/Ice Identification

M Anul Haq, Kamal Jain, KPR Menon

Abstract— ***Existing methods and newly developed method of monitoring snow-covered areas by optical remote sensing were evaluated using the ASTER Satellite data of Satopanth and Bhagirathi Kharak Glaciers, and Landsat satellite data of Gangotri glacier, one of the largest ice bodies in the Indian Himalayas. Snow-covered areas were identified using two methods: (1) Normalized Difference Snow Index (NDSI) which uses visible and shortwave-infrared reflectance's, and (2) a newly proposed snow index called NDSTI which uses visible, thermal-infrared reflectance's. NDSTI can be achieved by the ratioing of significantly distinguishing bands and normalizing those values to a standardized range will provide a sensitive and comparable test of thermal character. The NDSTI is useful for the identification of snow and ice and for separating snow/ice and most water bodies. The NDSTI is a measure of the relative magnitude of the characteristic reflectance difference between the visible and TIR reflectance of snow. A comparison between NDSI vs. NDSTI has been attempted in current investigation.***

Index Terms— Accumulation, Classification, processing, Snow, Thermal

I. INTRODUCTION

Monitoring of glaciers actuates scientific interest for two main reasons. First, Glaciers change monitoring has been used for climatic change investigation. The surface area and volume of individual glaciers are monitored to estimate future water availability. Second, glaciers in Indian Himalayas, have been recognized as important water storage systems for municipal, industrial and hydroelectric power generation purposes. The glaciers are situated in remote areas and are very difficult to monitor through field measurement due to the rugged terrain and extreme climatic conditions. Remote sensing mapping techniques are particularly valuable for investigating inaccessible glaciers and their lakes. These enable preliminary assessments to be under-taken on a catchment-wide scale more cheaply and quickly than is possible with traditional field investigations. However, a traditional field survey cannot satisfy all of the necessary requirements, namely, wide coverage, frequency, and simultaneity of measurements. In this sense, satellite remote sensing has been used for monitoring snow-covered areas because it can satisfy these requirements. Many techniques have been proposed to monitor snow-covered areas using remotely sensed data for example [1-3]. The Normalized Difference Snow Index [4, 5] has been used internationally for identifying snow-covered areas. In our current investigation

We develop a newly proposed ratio index as Normalized Difference Snow Thermal Index (NDSTI). We compare the results of NDSI with our proposed ratio index NDSTI and found that NDSTI show better performance than NDSI.

II. STUDY AREA AND DATA SOURCES

We selected Gangotri Glacier in the Himalayas as our first study area. The Gangotri glacier, one of the largest ice bodies in the Garhwal Himalayas, is located in the Uttarkashi district of the state of Uttarakhand in India (See Fig 1). The area of the main trunk of the glacier **is** 62.412 sq km, Average width of the glacier is 1.847 km and glacier, lies between 79°4’ 46.13” E-79°16’ 9.45” E and 30°43’ 47.00” N-30°55’ 51.05” N (ETM+2000). It has varying elevation of 4082–6351 meters above sea level [6].An image of this region was procured by USGS New Earth Explorer Landsat TM 2000, Path/Row =146/039 on 21 October. This date is during the post-monsoon season, and ensures the minimum coverage of cloud and maximum exposure of the glaciers.

The second study area taken in current investigation is Satopanth and Bhagirathi Kharak Glaciers of Alaknanda Basin. These are the sources of the Alaknanda River, a major tributary of the Ganga. The glaciers are situated at the head of the Alaknanda valley in Chamoli District, Uttarakhand. The glaciers are located between lat. 30°42′55″–30°50′32″N and long. 79°13′55″–79°29′40″E (Figure 2). The Satopanth and Bhagirathi Kharak glaciers are approximately 13 and 18.5 km long with an average width of 750–850 m, covering an area of 21.17 and 31.17 sq. km respectively [7]. An image of this region was procured from NASA LPDAAC, Oct 2006. This date is during the post-monsoon season, and again ensures the minimum coverage of cloud and maximum exposure of the glaciers.

III. METHODOLOGY

Fresh dry snow appears white to the human eye. That is to say, it is highly reflective, with little variation over the range of wavelengths (approximately 0.4 to 0.65 µm) to which the eye is sensitive [8]. The reflectivity of new snow decreases as it ages in both visible and infrared region of spectrum, however the decrease is more pronounced in the curves of snow and ice Infrared. Decreasing reflectivity in the visible region can be attributed to the contaminants such as dust, pollen and aerosols. An advantage of using visible and near infrared data is the easy interpretation of the image.

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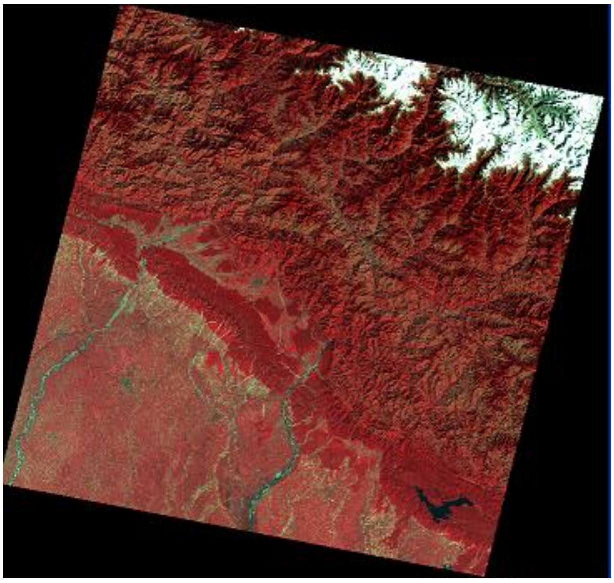

Fig. 1 Gangotri Glacier at top right corner: Landsat ETM+ image from 2000(432)

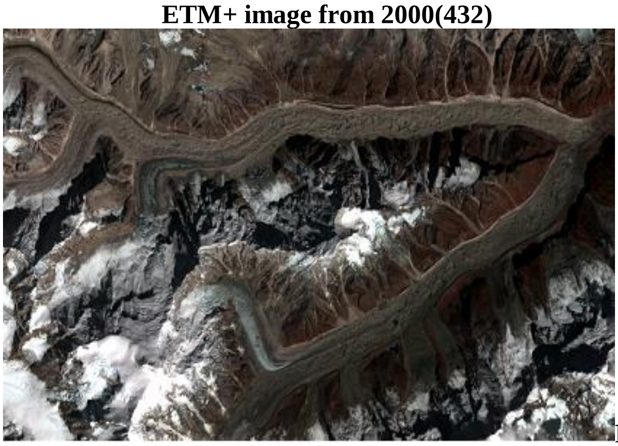

Fig. 2 Satopanth and Bhagirathi Kharak Glacier: ASTER Image from Oct 2006(321)

A commonly used remote sensing image processing technique is to divide the values of two different spectral bands by each other. A small ratio implies small change, while a large ratio means there is a greater spectral difference. This technique is used for many applications, such as identifying minerals in earth ores. However, for more sensitive comparisons, a more sophisticated technique is shown in Equation 1.

Band(x)-Band(y)/ Band(x) +Band(y)

Equation 1. The general Normalized Difference Index

This process is called a "normalized index," and results in values ranging from -1 to +1. The normalization allows for comparison of many different spectral bands. The procedure is used to identify vegetation based on the large difference in its absorption of the red and near-infrared bands. Because we posit a thermal inertia between roofs and pavements, we hypothesized that a reliable normalized difference thermal index could be derived.

Normalized Difference Snow Index (NDSI). The NDSI is defined as the difference of reflectance observed in a visible band (usually green) and the shortwave infrared (SWIR) band divided by the sum of the two reflectance. The index uses the spectral characteristics of snow/ice a high reflectance in the visible region and a strong absorption in the SWIR region [4,5,9,10,11].

The SWIR wavelength range of 1.55- 1.70 µm typical in many current spaceborne multispectral sensors has usually been used for the computation of the NDSI. The equivalent band at this wavelength for ASTER is Band 4 and Landsat Band 5, and hence this band has been used for the NDSI computation.

NDSI=VIS (Green)-SWIR/VIS (Green) +SWIR

Normalized Difference Snow Thermal Index (NDSTI). The newly proposed NDSTI is useful for the identification of snow and ice and for separating snow/ice from surrounding features. The NDSTI is defined as the difference of reflectance observed in a visible band (blue) and the Thermal infrared (TIR) band divided by the sum of the two reflectances. The index uses the spectral characteristics of snow/ice a high reflectance in the visible region and a strong absorption in the TIR region and does not depend on reflectance in a single band. The resampling of TIR band was performed with respect to visible band. The TIR wavelength range of 10.40–12.50 µm (Landsat Band 6) and 8.125-8.175 µm (ASTER Band 10) typical in many current spaceborne multispectral sensors has usually been used for the computation of the NDSTI as:

NDSTI= VIS (Blue)-TIR/VIS (Blue) +TIR

IV. RESULTS AND DISCUSSIONS

A pixel will not be mapped as snow if the reflectance in SWIR band is less than 10 %. This is required since very low reflectances cause the denominator in the NDSI to be quite small, and only small increases in the visible wavelengths are required to make NDSI value high enough to classify a pixel erroneously as snow [12].Such a criteria prevents pixels with very dark targets being mapped as snow. In our first study area, NDSI mapped the Ramganga reservoir (Kalagarh, Pauri Garhwal District) as snowy area (See figure 3). Same problem occurs in our second area that is Satopanth and Bhagirathi Kharak Glaciers. NDSI shows inconsistency to mapped Satopanth Lake and other glacial lakes as snow area, (See figure 5). On the other hand newly proposed NDSTI show good performance to map only snow/ice area and not include water bodies as snowy areas.

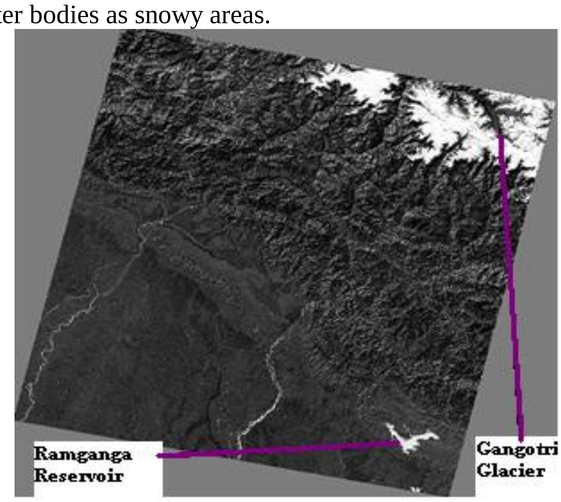

Fig. 3 Gangotri Glacier and Ramganga Reservoir after applying NDSI

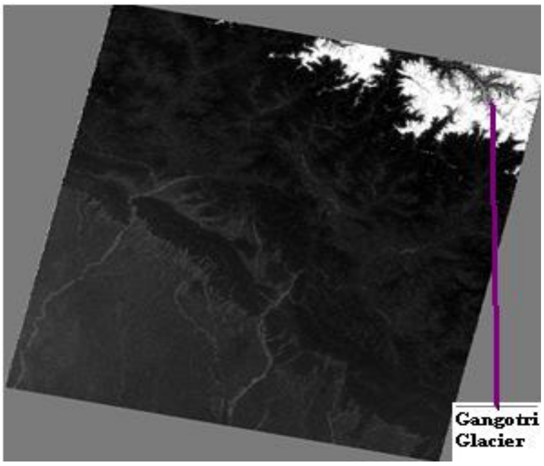

Fig. 4 Gangotri Glacier and Ramganga Reservoir after applying NDSTI

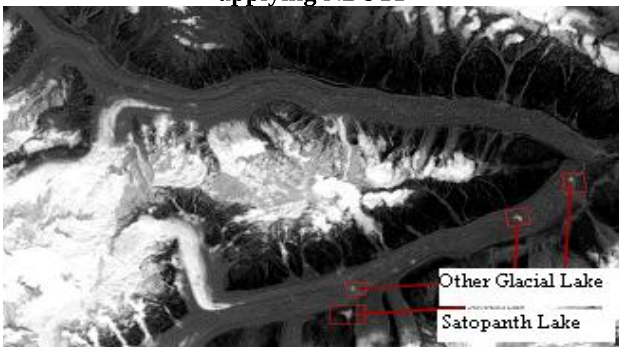

Fig.5 Satopanth and Bhagirathi Glaciers Image after NDSI

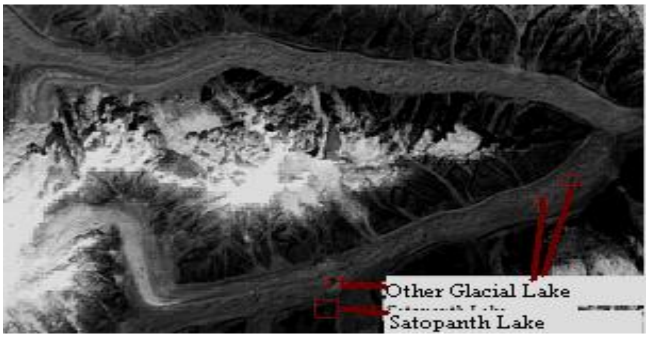

Fig.6 Satopanth and Bhagirathi Glaciers Image after NDSTI

V. ACCURACY ASSESSMENT

For the purpose of validating the classified output, a statistical error matrix-based approach was adopted [13]. ASTER Image of 2001 visible/near-infrared (VNIR) and thermal bands was used as reference. The test sample constituting 50 pixels per class (a total of 200 pixels) was collected following the equalized random samplings scheme. Reference class values to each point were given on the basis of analysis of spectral curves and visual interpretation. The overall accuracy was 93%, with values of individual accuracies (user's and producer's accuracies) ranging from 88% up to 96% (table 1). The Overall accuracy of NDSI was 86%, with values of individual accuracies (user's and producer's accuracies) ranging from 82% up to 88%.

VI. CONCLUSION

Objective methods for identifying snow-covered areas using optical remotely sensed data were evaluated by comparing two snow indices NDSI and newly Proposed NDSTI. The following conclusions were obtained in this study. The snow/ice discrimination defined in this study can objectively determine are robust threshold is identified using these indices. Thermal data have been used less than other remote sensing data for measuring snow characteristics. Since we should recognize snow radiation spectrum to determine temperature of snow. Despite all these limitations, thermal data are of great use to recognize the boundary between snowy zones and no-snowy zones (Rezaei, 2004).Using NDSI snow extent can be easily extracted, but surrounding water bodies can be mapped as snowy area (as in case of current study).When we compare the results driven from NDSI and NDSTI, we found NDSTI doesn't mapped water body as snow but due to coarser resolution of Landsat Thermal band it's not looking pleasant. Further improvements are expected when higher-resolution Thermal Images will available in future.

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