

SNOW MAPPING OF ALAMCHAL GLACIER USING REMOTE SENSING DATA

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ABSTRACT:

Detection and determination of ice and snow characteristics using remote sensing data is a new method in obtaining hydrology parameters. In order to determine these characteristics the numbers of meteorological stations are not enough in the glacier and mountain regions. We suggest using remotely sensing data for removing these deficiencies. Snow is distinguished more than other objects in the land by its different reflectance. But snow and clouds have similar reflectance, therefore MIR bands are used to distinguish them. In this paper, the methods of extraction snow cover area, new snow, compressed snow from optical images are described. In this study we use Landsat and IRS_LISS (III) images.

1. INTRODUCTION

The hydrologists generally want to know how much water is stored in a basin in the form of snow. The hydrologists will also be concerned with the areal distribution of snow, its condition and the presence of liquid water in it. In general, all of these indicators of snow are difficult to measure and are variable from point to point, especially in the mountainous regions (Najafzadeh, Abrishamchi, Tajrishi, 2004). With the advances in sensor technology, the equipment that is durable to extreme weather and harsh winter conditions is provided. Even though successful applications of such systems exist, due to the calibration and updating of the stations, the manual snow surveys are still needed. Remote sensing (RS) and geographic information systems (GIS) are two new technologies that are being used increasingly in snow hydrology. They can be used for analyses of the measured snow and meteorological data, performing necessary up and/or down scaling processes, preparation of input variables to the hydrological models, determination of parameters required by these models and presenting the outputs of the model runs. Remote sensing offers the advantages of obtaining snow data like snow covered area and snow water equivalent to snowmelt runoff prediction in real time which is an important factor for a dynamic phenomenon like snow.

We should know reflectance of snow and ice in different regions of the electromagnetic spectrum to obtain hydrology parameters with remote sensing technology. To use remote sensing in hydrological applications, suitable images of the study site should be applied. Thus, we should define criteria to choose a sensor.

It is believed that a suitable integration between Remote Sensing, Geographical Information System and an appropriate hydrological model would provide accurate estimation for efficient water management, energy production and flood mitigation (Tekel, 2005).

In this paper, we consider remote sensing capability in gathering required parameters in hydrology.

To achieve this purpose, first, interaction of light with ice and snow in the electromagnetic spectrum are considered. Secondly, the criteria to choose a suitable sensor are explained. At the end, the results are discussed.

2. SNOW PROPERTIES IN THE ELECTROMAGNETIC SPECTRUM

It is necessary to consider interaction of light and snow in the electromagnetic spectrum to use remote sensing data in the management of water sources.

The most important regions of electromagnetic spectrum in studying snow and ice are Visible, Near Infrared, Thermal Infrared and Microwave. Figure 1 shows the electromagnetic spectrum and its intervals.

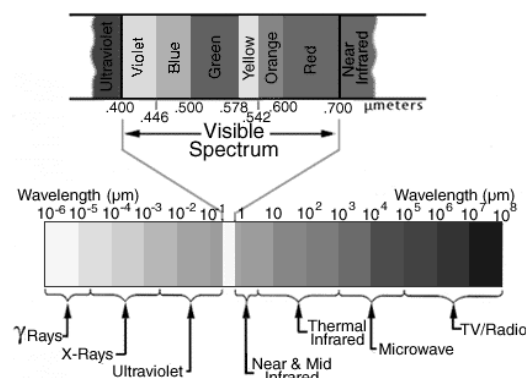


Figure 1. Electromagnetic spectrum and intervals

Furthermore, the behaviour of snow in Visible, Near Infrared, Thermal Infrared and Microwave intervals is described.

2.1 .Visible and Near Infrared

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 (Rees, 2006). 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. Even though, snow extent can be easily extracted, no information regarding the snow water content can be derived (Tekel, 2005).

2.2 .Thermal Infrared

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). Like visible and near infrared images, clouds limit the usability of thermal infrared images. If there are clouds, the temperature above them will be measured (Tekel, 2005).

2.3 .Microwave

Microwave regions and microwave's sensors can have most application attentive to climatological conditions. Actually the physical characteristics of the snowpack determine its Microwave properties. Properties affecting microwave response from a snowpack include: depth and water equivalent, liquid water content, density, grain size and shape, temperature, stratification as well as snow state and land cover. Since the response of snow varies with its state, regular monitoring may allow the detection of the onset of melt. Radiation measured at different wavelengths and at different polarizations enables the extraction of information related to snow depth and snow water equivalent. Superiority of microwave with respect to visible imagery is the independency of measurements from weather condition and illumination. Thus nighttime's data can also be used.

In large catchments, microwave images have been used to analyze snow cover and depth. However, their low spatial resolutions prevent their usability in mountainous basins (Tekel, 2005).

In addition, microwave's sensors can penetrate into snow and obtain information about it, but optical's sensors does not have this capability. Active microwave's sensors (for example SAR) have better spatial resolution than passive microwave sensors but requires more equipment. In hydrology application, a combination of passive sensors for mapping dry snow, water equivalent and onset of snowmelt and active sensors for mapping wet snow with areal resolution could guarantee the optimum information (Rott, Kunzi, 1983).

3. CHOICE OF REMOTE SENSING SENSOR

The reduced costs and large coverage areas make spaceborne remote sensing a more popular choice in hydrology application (Samantha, 2004). Main criteria in satellite platform selections are the spatial, temporal resolutions, the number of spectral bands, area of basin and climatological conditions for choice best sensor. In operational snow cover monitoring, satellites with high repetition rates are important for the advantage of obtaining a cloud free image. In this sense, Landsat and NOAA satellite images are more available than the aircraft data. Even though NOAA satellites can be used in small-scale area analyses due to the spatial resolution, many successful applications exist. Landsat can be used in small catchments areas. However, both NOAA and Landsat, which use a visible and near infrared region of electromagnetic spectrum, clouds are the main problem. Although thermal imagery cannot penetrate through clouds, they may be used in night passages during which there is the possibility of cloud free images.

A solution to the cloud problem is the microwave data either passive or active. Both can be acquired during night or day. Although the cloud problem is removed, interpretation of the images is much more difficult with respect to optical satellites. The difficulty of the microwave image interpretation arises due to the fact that the images are highly affected from surface and subsurface properties, such as temperature and electrical properties of the material under study (Tekel, 2005).

4. STUDY AREA

The AlamChal glacier is located in the vicinity of Kelardasht city in the north of Iran. AlamChal glacier is one of the important glaciers in Iran with an area of 4.8 km^2 with elevation ranging from 3700m to 4250m and its maximum length is 4.5 km and its maximum width is 2.25 km.

5. METHODOLOGY AND DATA

In this study, images of Landsat and IRS_LISS (III) were utilized and the processes were carried out using ENVI 4.0 software .The image of IRS_LISS could not be used for snow mapping due to the fact that its spectral bands were not appropriate for this application. By using the images of Landsat, the boundary between snowy zones and no-snowy zones was distinguished. To perform this, snow is extracted by using NDSI index and a 0.3 threshold.

$$NDSI = \frac{band2 - band5}{band2 + band5} \quad (1)$$

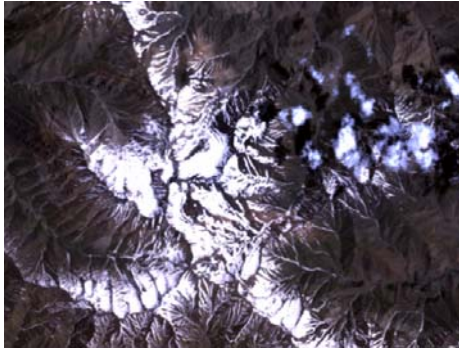


Figure 2. Landsat image in AlamChal

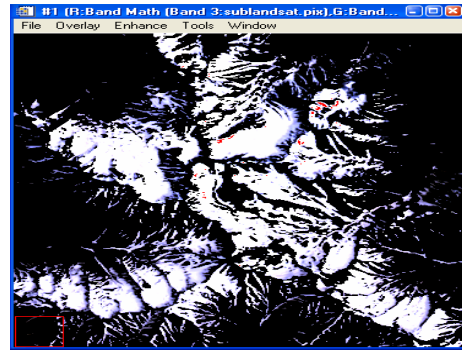


Figure 5. New snow

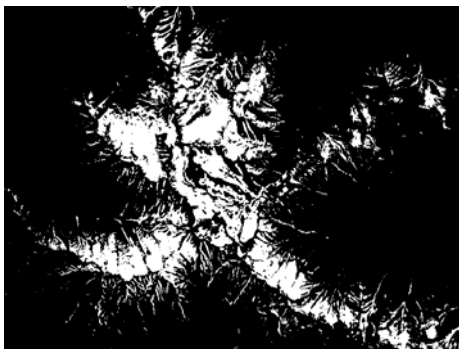


Figure 3. Snow Extraction with using NDSI index

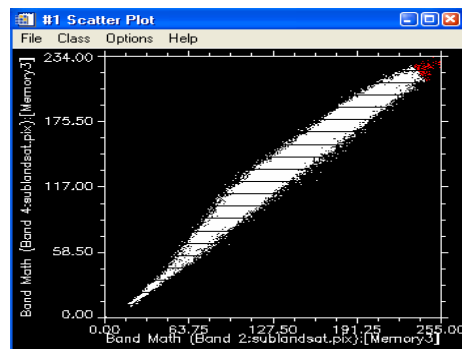


Figure 6. scatter plot 2, 4

Also we could obtain the area of snowy zones by using K_means unsupervised classification algorithm. The surface of snow covered areas was calculated 4.6 km² from Landsat images.

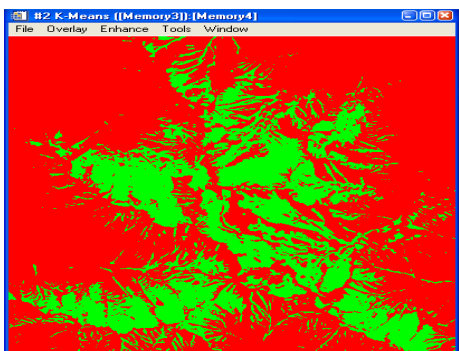


Figure 4. K_means classification

5.1 New snow extraction

As mentioned earlier, snow has high reflectance in the visible region and consecutively new snow has high reflectance in infrared region. To obtain new snow, scatter plot of 2,4 bands of Landsat was used. We chose the regions of band 2 where snow has high reflectance, and the regions of band 4 where new snow has high reflectance. In the figure below new snow with red regions is shown.

5.2 Compressed snow extraction

As discussed earlier, snow has very low reflectance in band 5 Landsat that is located in the middle of the infrared region and on the other hand snow has low reflectance in band 4. We chose the regions of band 4 that old snow has very low reflectance, and the regions of band 5 that snow has low reflectance in this band. In the figure below old and compressed snow with green regions is shown.

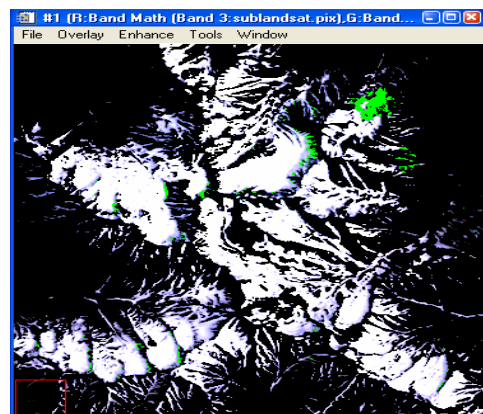


Figure 7. Compressed snow

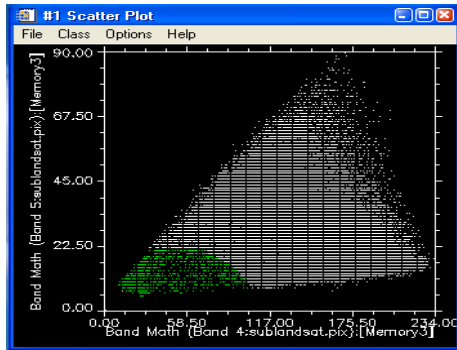


Figure8.Scatter plot 4, 5

6. RESULTS

The most important parameter obtained using remote sensing data is Snow Cover Area (SCA). The estimation SCA is very difficult using ground observation, but using satellite images to make the processing easier.

- Satellite images have high capability in snow cover mapping and calculating other hydrological parameters in the mountainous and glacier regions.
- For snow mapping in the large catchments, MODIS and NOAA images is suitable. But for small catchments Landsat images have good result because of higher spatial resolution than MODIS and NOAA images.

- To extraction of snow characteristics from optical images, usually optical sensors in the visible, NIR and MIR regions are used because snow has different reflectance than other objects in these regions.
- In hydrology application such as long-term and short-term runoff forecasts, a combination of passive sensor for mapping dry snow, water equivalent and onset of snowmelt and active sensors for mapping wet snow with high areal resolution could guarantee the optimum information.

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