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Determination of the NDSI index and cloud mask algorithm (The Case Study: Sepidan Region, Iran)

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Abstract. To investigate the hydrological balance in the hot seasons, the role of snow is very significance. Remote sensing technology has multiple applications in different studies including the studies in the context of snow and ice. In this paper, having applied the MODIS sensor images from TERRA satellite which has appropriate function in detection of snow level, we can estimate the snow level in the region by applying the snow map algorithm, then the application of cloud mask algorithm for the separation of cloud from snow and more precise detection of snow level were done. The comparison between the cloud mask algorithm with snow map algorithm (NDSI) showed that the snow level resulted from cloud mask is much lower than the level from snow map algorithm. It proves that cloud mask classifies higher number of pixels as cloud and snow map algorithm estimates the snow level higher than the real amount. In order to improve snow map algorithm we can apply the lands coverage maps to classify different surfaces. The precision of remote sensing algorithm, due to the difference in the spatial and spectral separation power of sensors, could not be compared. Especially the presence of cloud in the images which are moving phenomena makes the situation more difficult.

Keywords: Snow Cover, NDSI, MODIS, Remote Sensing.

1. Introduction

The majority of weather stations are located in accessible regions such as foothills; however the major part of snow cover are in the mountain heights and arduous regions where are rarely covered by weather stations. MODIS sensor has 36 bands, 11 bands are in visible light range, 9 bands in near-infrared range, about 6 bands in thermal infrared range, 4 bands in shortwave infrared range and 6 bands in thermal wave-infrared range. What makes this sensor different from its predecessors is the significant number of reflection and thermal spectral bands with shorter width, high gray levels, strip width and appropriate surveying time, strong and precise calibration during flight and various land resolution. In 1978, the inactive SMMR (scanning multi channel microwave radiometer) situated on Nimbus satellites, series 7, has been successfully used to detect the snow cover and even local resolution from 25 to 30 km in darkness and even under the cloud cover. DMSP satellite (Defense Metrological Satellite Program) entered into the realm of snow cover detection with microwaves sensors by launching the SSM/1 sensor (Special Sensor Microwave Image) in 1978. These sensors also give information about the water equal to snow, snow cover and snow depth (USACE, 1998; Hall et al 1998). With regard to the mentioned cases, we come to the conclusion that, in non-cloudy conditions, the medium accuracy of MODIS satellite images for the estimation of snow covered surface could be more than 80 percent (88 percent in Rio Grande and 82 percent in Turkey). Moreover, the

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estimated error of snowy-covered surface by the use of this sensor will increase at the beginning and at end of the snow period. Therefore, with this research method, the images taken from snow-covered surface would averagely have less than 20 percent of error. The techniques used to withdraw snow cover in snow map algorithm of MODIS sensor are efficient in regional and local scales. Snow map algorithm of MODIS sensor is designed to detect if there is snow in every 500m pixels of tropic (Hall et al, 2001). In snow map algorithm, normalized differential snow index (NDSI) is applied. Application of NDSI index for the detection of cloud/ snow is based on the fact that snow seriously reflects the visible radiations and this reflection is proportionally less in the mid-infrared wavelength. Whereas the cloud shows more reflections in the visible and mid-infrared ranges. So, the low value of this index shows the presence of cloud and its large quantities show the presence of snow (Dini, 2005). In this paper, we can recognize the snow level in the region by applying snow map algorithm and MODIS sensor images of TERRA satellite which has appropriate function in the detection of snow level. Then we can apply the cloud mask algorithm for separation of snow from cloud and precise detection of snow level.

2. The Study Area

Sepidan County with an area of 2859.14 km is located in the northwest of the province and has allocated half of the province area to itself. From the climate aspect, it has cold mountainous climate with mild and cool summers and cold and freezing winters. This county is one of the high rainfall regions of Fars province, in the south of Iran. In some years, its precipitation reaches to 1400 mm and the majority of its precipitation is snow, also its average annual rainfall is 700 mm. In the non-central regions, the majority of lands are plain and fertile and in the central region, the lands are rocky and mountainous.

3. Research method

In this paper, the cloud mask and snow map algorithms have been applied for snow cover detection and for the purpose of hydrological analysis of the data taken from MODIS sensor of TERRA satellite. Therefore, the data which is of a vast area, together with reasonable spatial resolution, and a significant spectral resolution is a desirable source for hydrological studies especially for monitoring snow cover. MODIS sensor usually detects the snow in the high regions more precisely than NOAA sensor and they could be compared to the land surveying data of SNOTEL sensor. Snow map algorithm was introduced in 1998. It has very low capacity from calculation aspect, but it is so simple from conceptual aspect which facilitates the comprehension of production quality for the user (Hall, 1998). The daily snow maps are provided by this algorithm across the world. In snow map algorithm the NDSI index is used. Since the snow map algorithm does not use the texture recognition functions, it is not completely able to distinguish all the clouds form the snow (However this problem could be solved by cloud mask algorithm). Snow has heterogeneous and extraordinary radiations in the visible and initial infrared bands. Since this reflection is almost equal in the whole visible spectrum the snow is seen in white color. The same occurs for cloud too and so in remote sensing images, it is difficult to differentiate the snow from cloud. In 3/55-3/93 micrometer spectral range it could be used for the recognition of snow from cloud. This range is sensitive to electromagnetic reflection range and thermal range too in a way that in this area the clouds consist of large ice crystals or large water drops are presented by the least reflection and are significantly brighter in comparison to the clouds consists of water drops and small ice crystals. Therefore they could be recognized and differentiated from darker surfaces such as snow. In order to prevent the classification methods based on the mathematical complications and high volume of calculations, firstly the algorithm recommended by Riggs (2001) was implemented and in the next stage the snow is recognized from other phenomena by application of NDSI index. The threshold value recommended by NASA for NDSI index is 0.4. Application of NDSI index to differentiate snow from cloud is based on the fact that snow severely reflects the visible radiations and proportionally this reflection is low in the wavelength of mid-infrared whereas the cloud has more reflection in the visible and mid-infrared ranges. So the low value of this index signifies the presence of cloud and proportionally its high values signifies the presence of snow. The images were used on Feb. 3 in 2009, 2010 and 2011 for this research. The conditions required for the application of snow map algorithm are as follows:

The pixels must be on the lands or the waters surrounded by lands.

The pixels must be photographed in the daylight (day images)

The pixels must not be covered by cloud (application of cloud mask algorithm)

Implementation of cloud mask algorithm

The above mentioned conditions test were implemented about all the images and the NDSI index was applied for the images. The gross snow has high NDSI but it will reduce in quantity when it is compounded with other materials (such as dust, smoke, etc). Figure 1 and 2 shows the statistical implementation of NDSI index. NDSI index in MODIS is the measured reflection in band 4 (0/545/565µm) and band 6 (1/628-1/652µm) as equation1:

$$NDSI = \frac{MODIS_{Band}\,4 - MODIS_{Band}\,6}{MODIS_{Band}\,4 + MODIS_{Band}\,6} = \frac{green - SWIR}{green + SWIR} \tag{1}$$

which is similar to the normalized differential vegetable index as equation2:

$$NDVI = \frac{MODIS_{Band}\,2 - MODIS_{Band}\,1}{MODIS_{Band}\,2 + MODIS_{Band}\,1} = \frac{NIR - red}{NIR + red} \tag{2}$$

As shown in figure 2, the pixels with values higher than 0.4 are selected as snow pixels. In a research performed in the Nevada and California mountains, the pixels which are 50 percent or more covered by snow will have a 0.4 value of NDSI index (Dini2005). Water may also have 0.4 value of NDSI index. The reflection of water in band 2 of TERRA sensor is lower than 0.11. So if we perform this condition along with the NDSI index the respective pixel will be known as snow. If the reflection of band 4 is lower than 10 percent, it will not be classified as snow and this factor will prevent the dark materials to be classified in the cloud category.

Required conditions:

1- NDSI index is equal to or higher than 0.4

2- Band 2 has reflections higher than 0.11 percent (0.841-0.867 mm)

3- Band 4 has reflections equal to or higher than 10 percent (0.54-0.665 mm)

Firstly the NDSI index was applied to separate the snow cover and water resources from other phenomena such as cloud. Before implementation of snow map algorithm as one of the preprocessing stages, the cloud mask algorithm was applied. The basis of the cloud mask is that if NDSI is equal to or higher than 0.4 and the reflection of band 6 is higher than 20 percent the pixel would be considered as snow. The image of the study area (A), Snow map algorithm (B) and Cloud mask algorithm (C) related to February from 2009 to 2011 are shown in figures 3 to 5.

4. Results

The images 3 to 5 which are related to the implementation of cloud mask show that the snow surface is lower compared to the situation in which the cloud mask is not implemented about them (Figures 3 to 5, A and B). As seen in figures 3 to 5, more pixels are classified as cloud and there is lower level of snow in the images of implementation of cloud mask. It proves that cloud mask classifies higher number of pixels as cloud and snow map algorithm estimates the snow level higher than the real amount. In order to improve snow map algorithm we can apply the lands coverage maps to classify different surfaces. The precision of remote sensing algorithm, due to the difference in the spatial and spectral separation power of sensors, could not be compared. Especially the presence of cloud in the images which are moving phenomena makes the situation more difficult.

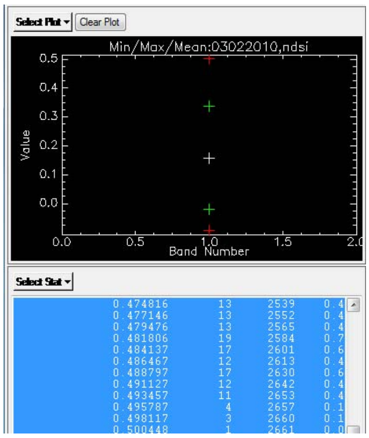


Figure 1: Statistical implementation of NDSI index snow pixels

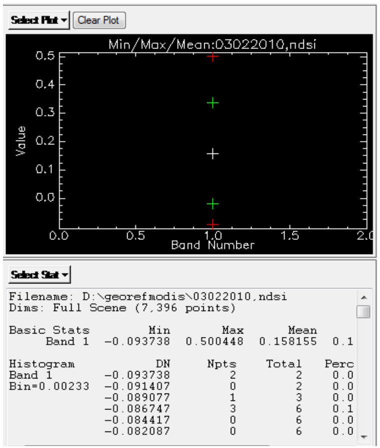
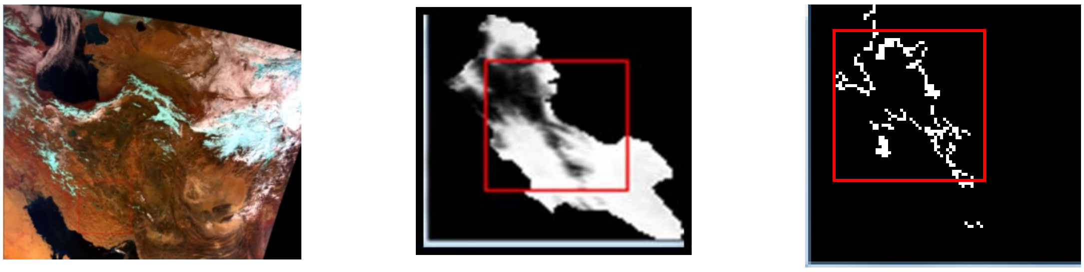


Figure 2: Selection of values higher than 0.4 to specify the

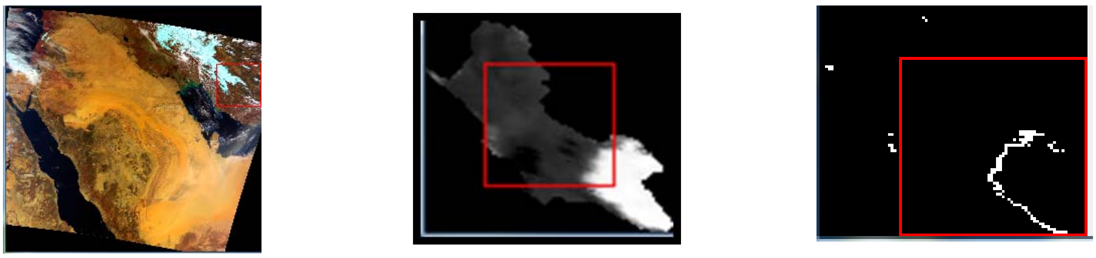


(A) (B) (C)

Figure 3: The image of study area (A), snow map algorithm (B) and Cloud mask algorithm (C) related to February 2009

(A) (B) (C)

Figure 4: The image of study area (A), snow map algorithm (B) and Cloud mask algorithm (C) related to February 2010



(A) (B) (C)

Figure 5: The image of study area (A), snow map algorithm (B) and Cloud mask algorithm (C) related to February 2011

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