SNOW COVER MAPPING FROM MIXED SNOW-CLOUD NOAA IMAGERY

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ABSTARCT:

Although snow cover extent represents a critical factor in predicting snowmelt runoff, sufficient spatial and temporal resolution is not achieved by field observations. On the other hand, satellite images are readily available and provide exceptional spatio-temporal characteristics needed for snow mapping. In particular, NOAA satellite with AVHRR sensor provides daily images with 1.1-km spatial resolution, which may be quite suitable for snow mapping in large river basins. The snow cover area mapping based on satellite imagery has been mainly practiced using visual interpretation methods. Moreover, the presence of cloud in the images creates an obstacle in snow area delineation. In this article, a two-stage technique relying on feature reflectivity in AVHRR bands 2, 3, and 4 is proposed to classify ground, cloud, and snow. While visual interpretation is not required in this technique, the image classification is performed using image enhancement and multi-spectral analysis. ILWIS GIS served as the spatial data platform for imagery data manipulation and analysis. To examine the capabilities of the proposed technique, two of the available NOAA images corresponding to Jan. 9 and Feb 24, 1997, in an area of roughly 58000 km^2 located between (48,05-50,29) E longitude and (31,40-33,29) N latitude were selected. The results conferred overall with those of visual interpretation in areas where snow, cloud, and ground could clearly be identified. Furthermore, the results of applying the proposed technique on a third image dated May 18, 1998, was favorably compared with processing of the same-day LANDSAT/TM image with 28.5 m ground resolution. One major limitation of the technique is the inability to recognize the snow under the cloud cover.

1- INTRODUCTION

Snow cover is one of the most important hydrologic factors affecting energy balance, surface albedo and hydrometeorologic balance. In addition, spatial and temporal variation in snow extent could prove a useful indication of climate change (Simpson et al., 1998).
Ground monitoring of snow are normally based on point measurement, which is subjected to numerous problems especially in inaccessible mountainous regions. Therefore, satellite data could be a useful alternative for snow monitoring and snow cover mapping. The Third Symposium on Remote Sensing of Snow and Ice, organized by the International Glaciological Society, affirmed the strong potential of AVHRR (Advanced Very High Resolution Radiometer) images for studying sea ice and snow covered surfaces and

recommended its use for long term monitoring of polar processes (Steffen, et al., 1993). Therefore, the NOAA AVHRR data is a suitable alternative for preparing snow map time series. There are a few methods to interoperate satellite imaginary, which are reviewed by Engman and Gurney (1991). The usual method is eye interpretation using factors such as ground features, patterns, uniformity of reflectance, shadows and the consistency of images with time (Engman and Gurney, 1991).

Lucas et al. (1989) used unsupervised multispecteral classification for separation of snow and cloud in AVHRR images by using channel 1, 3 and 4. Cracknel (1997) emphasized on using AVHRR images to determine snow cover extent. He recommended the threshold methods in snow and cloud separation. Simpson and Gobat (1995) used AVHRR channel 2, 3, 4 and 5, to detect cloud. Simpson et al. (1998) used a multispectral-multistage method to separate snow and cloud in AVHRR images. They used channels 2, 3, 4 and 5 and proposed a three-stage algorithm. This method separates snow and cloud in the first stage and then, separate snow from clouds. Some pixels were coding as mixed pixels in tow previous stages and then divided in three parts using linear mixing model.

Tow stage algorithm is presented for snow/cloud separation in AVHRR scene by using channels 2, 3 and 4 in this article. While that algorithm is based on Simpson et al.'s method, there are some differences between the methods. Using a ratio of channel 3 to Square of channel 4 reflectance digital number and difference of channels 3 and 4 brightness temperature as second stage are the most difference between Simpson algorithm and our works. Histogram analysis using threshold is the other difference part with cluster analysis of Simpson method.

2. LOCATION OF STUDY AREA

The study area, Zagross high lands, is located in southwest of Iran. This area is bounded between 48° to 51° and 29' estern longitude and 30°, 30' to 33° and 39' northern latitude. This elevation ranges from 700 meters to 4420 meters above mean sea level.

3. SNOW-CLOUD ALGORITHM

The new multi-spectral, multistage snow and cloud detection has tow stages whit split and merges technique of AVHRR images channels 2, 3 and 4. Albedo of channel 2 (a_2), brightness temperature of channel 4 (T_4), a parameter, R, based on channel 3 and a_2 and finally brightness temperature difference (dT) of channel 3 (T_3) and channel 4 ((T_4) are the main parameters used in the first stage. Histogram analysis is used to determine thresholds, which are the digital number showing transition from one phenomenon to the other in the images. The threshold conditions are:

$$\begin{bmatrix} T_4 \leq T_{4th} \\ a_2 \geq a_{2th} \\ R \geq R_{th} \end{bmatrix} \quad \text{Snow and patches of cloud} \quad (1)$$

$$\begin{bmatrix} T_4 \leq T_{4th} \\ a_2 \geq a_{2th} \\ dT \geq dT_{th} \end{bmatrix} \quad \text{Cloud and patches of snow} \quad (2)$$

$$\begin{bmatrix} T_4 \rangle T_{4th} \\ a_2 \langle a_{2th} \\ R \langle R_{th} \\ dT \langle dT_{th} \end{bmatrix} \quad \text{Uncovered ground} \quad (3)$$

By application of above three sets of threshold conditions, three images are produced at the end of this stage. Then, the first and second images are merged together and prepared for the second stage.

In the second stage, channels 3 and 4 reflectance images are split based on the merged image of first stage. Then, the new channels 3 and 4 images are used for applying parameters based on T_3, and T4 differences(*dT*) and ratio of channel 3 digital number (R_3) and channel 4 digital number (R_4) as $\frac{R_3}{\sqrt{R_4}}$ (s). Threshold conditions are:

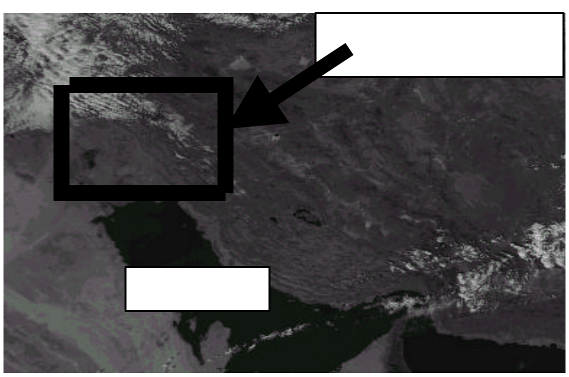
$$\begin{bmatrix} dT \le dT_{th} \\ s \le s_{th} \end{bmatrix} \quad \text{Snow} \qquad (4)$$

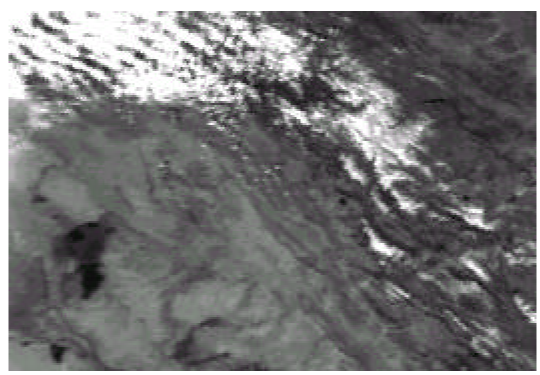
$$\begin{bmatrix} dT \rangle dT_{th} \\ s \rangle s_{th} \end{bmatrix} \quad \text{Cloud} \qquad (5)$$

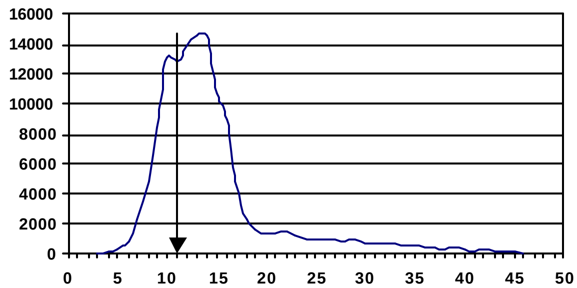
4. APPLICATION OF ALGORITHM IN SNOW SEASON

Two scene of NOAA AVHRR images is used for applying algorithm. The first one is Feb. 24, 1997 and the other one is Jan. 9, 1997.

Figures 1 and 2 show the research area windows corresponding to Feb. 24, 1997 AVHRR channel 2 images. Figures 3, 4, 5 and 6 respectively, show the frequency curve at a_2, T_4, *dT* and R in the first stage. The maps produced by the application of threshold conditions indicated in Equation (1) to (3) are shown on Figure 7, 8 and 9. Figure 7 is snow with the patches of the cloud, Figure 8 is cloud with the patches of the snow and Figure 9 shows the uncovered ground. Figures 7 and 8 are merged to form a new images and channel 3 and 4 are masked for the pixels in this merged images. The parameters dT and s are calculated from channel 3 and 4 masked images. Figure 10 and 11 show the frequency curves of dT and s based on these masked images. Figure 12 shows the snow map at the end of second stage.



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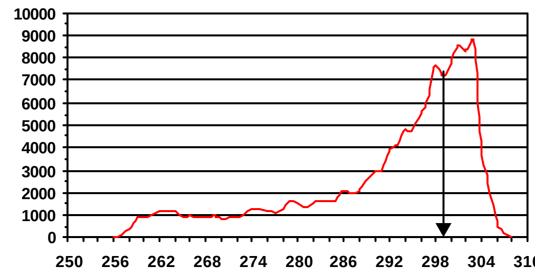
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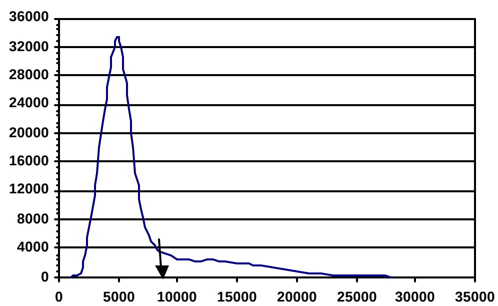
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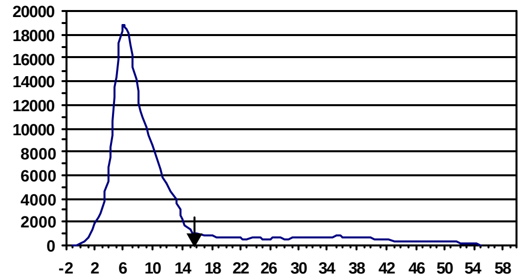
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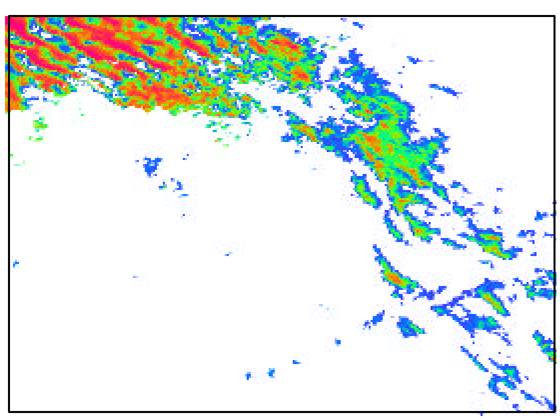
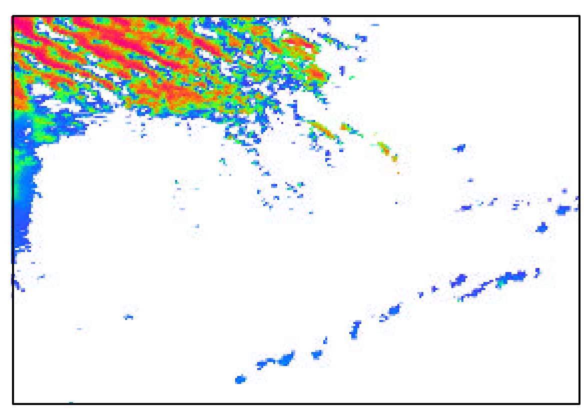
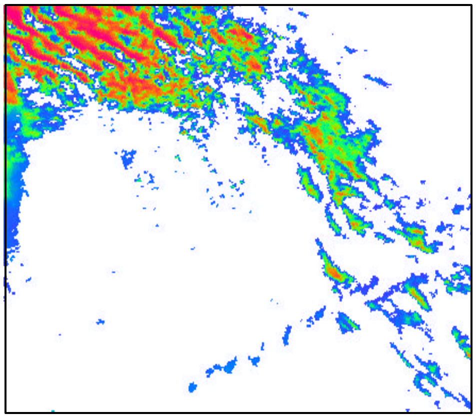
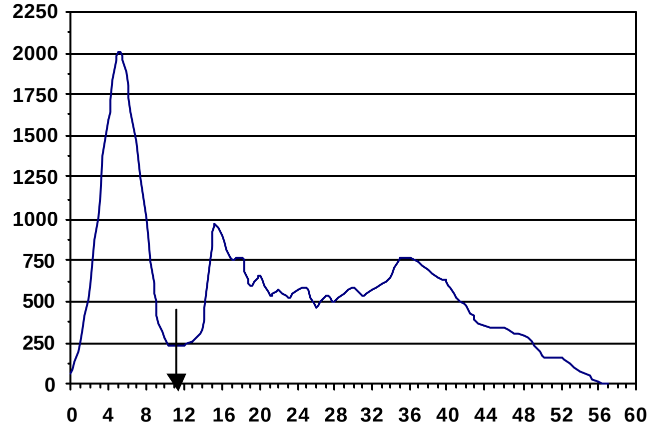
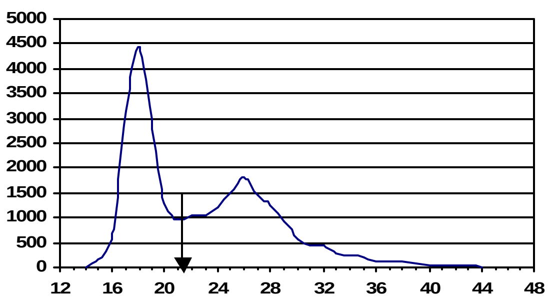
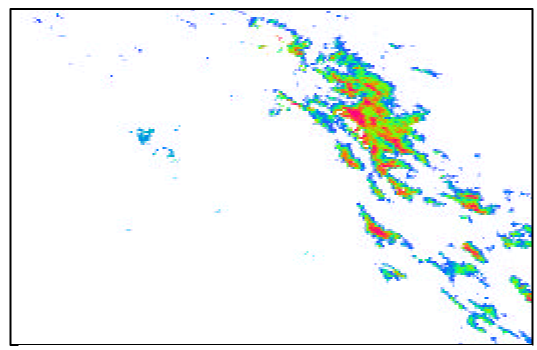




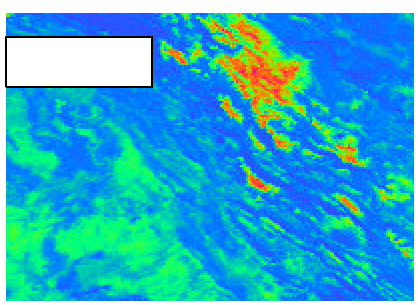


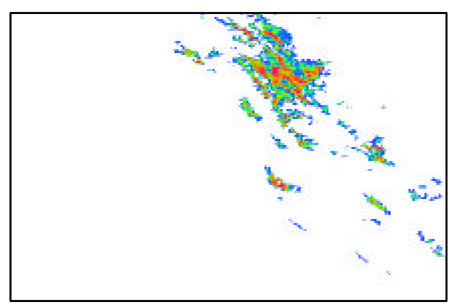






The algorithm is applied to January 9, 1997 AVHRR images in the study area. Figure 13 shows the final outcome of the proposed algorithm.

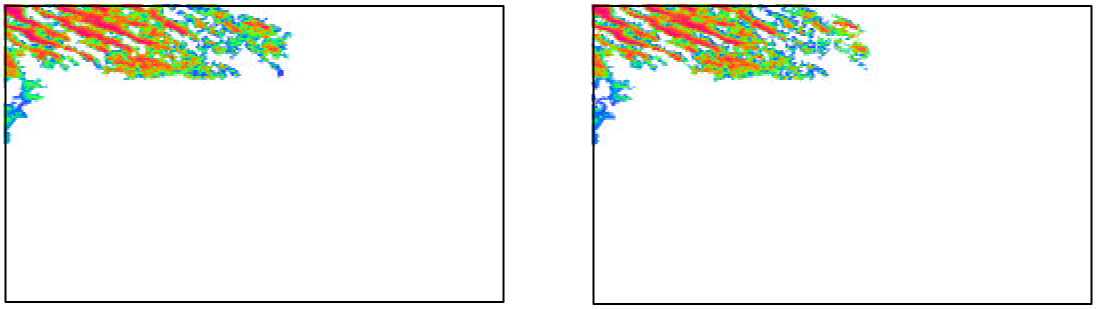


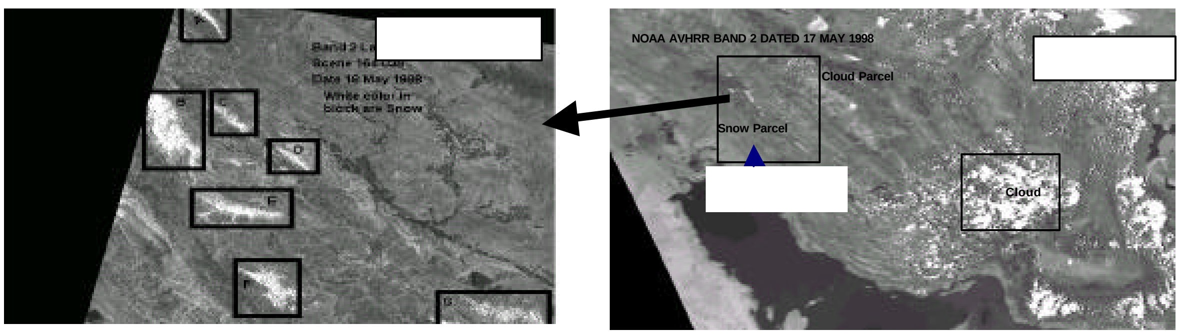


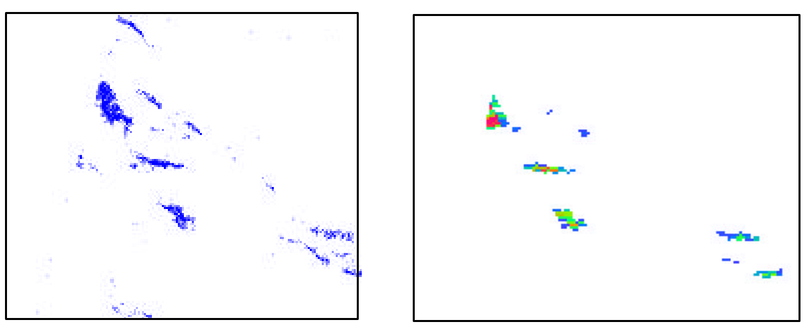
5. VALIDATION OF ALGORITHM

Validation of the algorithm is performed by comparing the result of snow and cloud maps produced by eye interpretation and on screen digitizing method of both NOAA and Landsat TM images of the same dates. In Figure 14 the 24 Feb. 1997 snow maps produced by eye interpretation method and the algorithm (model) are compared. Overlay of the two maps in GIS resulted in 93.6 percent agreement.

Figure 15 shows the cloud-free 18 May 1998 Scene No. 164-038 Landsat TM and corresponding 17 May 1998 AVHRR images. In Figure 16, maps prepared by the algorithm and eye interpretation Landsat image. Overlay of the two maps in GIS resulted in 88 percent agreement.







6. CONCOLUTION

The following conclusion can drawn from this study:

1-The two-stage algorithm using AVHRR channel 2, 3 and 4 can separate snow, cloud and uncovered ground.

2- Validation of the algorithm in comparison with eye interpretation shows 6.4 percent difference.

3- Validation of the algorithm in comparison with Landsat TM shows 12 percent difference in an image of end of snowmelt season.

REFFRENCES

1): Cracknell, P., 1997. The Advanced Very High Resolution Radiometer. Taylor and Francis Pub.

2): Engman, E.T., and Gurney, R.J., 1991. Remote Sensing in Hydrology. 1st Edit, Chapman and Hall, p. 225.

3): Lucas, R.M., Harrison, A.W. and Barrett, E.C., 1989. A Multispectral Snow Area Algorithm for Operational 7-Day Snow Cover Monitoring, Remote Sensing and Large Scale Global Processes. Proc. IAHS 3rd Int. Assembly, MD, IAHS Pub. No. 186, pp. 161-166.

4): NOAA (National Oceanic and Atmospheric Administration of U.S.A.), NOAA POD Guide, Online on Internet.

5): Simpson, J.J., and Stephan, R.Y., 1994. Reduction of Noise in AVHRR Channel 3 Data with Minimum Distortion. IEEE Transactions on Geoscience and Remote Sensing, Vol. 32, No. 2, pp. 315-328

6): Simpson, J.J., and Gobat, J.I., 1995. Improved Cloud Detection for Daytime AVHRR Scenes Over Land. Remote Sensing of Environment, No. 55, pp. 21-49.

7): Simpson, J.J., Stitt, J.R., and Sienko, M., 1998. Improved Estimates of the Arial Extent of Snow Cover from AVHRR Data. Journal of Hydrology, No. 204, pp. 1-23.

8): Steffen, K. Bindschalder, R., Casassa, G. Cosimo, J., Eppler, D., Fetterer, F., Hawkins, J., Key J., Rothrock, D., Thomas, R., Weaver, R., Welch, R., 1993. Snow and Ice Applications of AVHRR in Polar Regions: Report of a Workshop Held in Boulder, Colorado, 20 May 1992, Ann. Glaciol., 17, pp. 1-16.