EVALUATION OF THE SINGLE REFERENCE IMAGE SNOW-COVERED AREA ESTIMATION METHOD FOR THE BOREAL FOREST ZONE

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1. INTRODUCTION

Information regarding the extent of (wet) snow covered-area (SCA) during the spring melt season is nowadays extensively utilized for hydrological, meteorological and climate research purposes. There are several distinct methods for SCA estimation, based on different sensors and slightly varying methodologies. Optical sensors have been shown to provide accurate information about snow cover; that is, however, spatially and temporally limited during the snow-melt season due to the need for solar illumination and cloud-free conditions. Synthetic Aperture Radar (SAR) can be reliably utilized in all weather conditions to provide accurate information about snow-melt conditions. Different SCA estimation methodologies have been developed and are utilized for different geographical regions. However, global methods that function well in all different regions are lacking. A method developed for mountainous regions [1], utilizing a single reference image for SCA estimation, is investigated here for a test area dominated by boreal forest. Its performance is compared with a method developed specifically for the boreal forest zone, utilizing two reference images and a forest compensation procedure [2]. The investigation shows the difference between the methods and gives an indication of the usability of the single reference image method for the boreal forest zone. The evaluations are carried out using Radarsat-1 data for the snow-melt seasons of 2004-2007. The SCA estimation accuracies for the radar-based methods are determined using optical satellite based SCA data as reference.

2. THE EVALUATED SCA ESTIMATION METHODS

The single reference image SCA estimation method

The single reference image SCA estimation method is presented in [1]. It utilizes the difference in backscattering coefficients when dry snow or bare ground is compared with wet snow. A reference image acquired during dry snow or bare ground conditions is required. The evaluated image is compared with the reference and if an adequate difference in backscattering coefficient is observed the investigated sample is determined to consist of wet snow. The method is formulated as [1]

$$\begin{aligned} &if\ (\sigma^\circ_{obs} / \sigma^\circ_{ref}) < TR \rightarrow (then\ wet\ snow) \\ &else \qquad\qquad\quad\ \rightarrow (then\ dry\ snow\ or\ bare\ ground) \end{aligned} \tag{1}$$

where σ°_{obs} is the observed backscattering coefficient, σ°_{ref} is the reference backscattering coefficient and TR is the threshold for the SCA discrimination. Using the reference image, the observed image is classified into either wet snow or bare ground/dry snow areas. When the evaluation is done during the snow-melt season, as is the case here, the classification can be determined to have only two possible outcomes: bare ground or wet snow.

The TKK SCA Estimation Method

The Helsinki University of Technology (TKK)-developed SCA estimation method, used as a benchmark for the single reference image method, was developed for the boreal forest zone. It requires the knowledge of the forest-stem volume distribution of the target area. Furthermore, two reference images are needed for SCA estimation. One represents a wet snow situation at the beginning of the snow-melt season and the other describes a typical snow-free situation at the end of the snow-melt season. The effect of forest canopy on SCA estimation is minimized by a forest compensation procedure. The method uses ground-based weather station data to further improve estimation accuracy. A thorough introduction and evaluation for the method is given in [2].

3. RESULTS

The accuracy of SCA estimation was determined by using optical satellite data (Terra/MODIS-based SCA estimates) as a reference (ground truth data). The best attainable SCA estimation accuracy using a single reference image had an root-mean-square error (RMSE) of 0.176; the data set had 9020 samples. Evaluation of the same data set, with the method utilizing two reference images, showed an RMSE of 0.156 for SCA estimation. Additionally, the method using two reference images produces significantly less biased estimates. The SCA estimation accuracy with two reference images and the forest compensation procedure yields an RMSE of 0.151. The SCA estimation accuracy for the enhanced TKK method (with all the developed elements enabled) attains an RMSE of 0.123. The different steps and an in-depth analysis of the enhanced TKK SCA estimation method are presented in [2]. It can be concluded that the difference in SCA estimation accuracy when using a single or two reference images is notable. The difference in estimation accuracy is even greater when the single reference image method is compared with the enhanced TKK SCA estimation method.

4. CONCLUSIONS

The SCA estimation method utilizing a single reference image developed for mountainous regions was evaluated for a boreal forest dominated test area. The optimal threshold level for SCA estimation using a single reference image was between -0.0dB and -1.5dB, largely depending on the selected reference image. The optimal threshold level for the dry snow image that produced the best estimation accuracy was -0.4 dB; this yielded an RMSE of 0.176. The average RMSE for SCA estimation using a single reference image, when the optimal threshold level had been determined for each reference image, was 0.193. The accuracy is significantly weaker than that of the TKK method developed specifically for boreal forest regions. Accuracy of the TKK method, using the exact same dataset showed an RMSE of 0.123. The investigation shows that the single reference image method is usable for the boreal forest zone, although the accuracy is poorer than that of the method using two reference images.

5. REFERENCES

[1] T. Nagler and H. Rott, "Retrieval of wet snow by means of multitemporal SAR data", *IEEE Trans. Geosci. Remote Sens.*, vol. 38, no. 2, pp. 754-765, March 2000.

[2] K. Luojus, J. Pulliainen, S. Metsämäki, and M. Hallikainen, "Enhanced SAR-Based Snow-Covered Area Estimation Method for Boreal Forest Zone," *IEEE Trans. Geosci. Remote Sens.*, vol. 47 no. 3, March 2009.