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DEVELOPMENT AND VALIDATION OF A BRDF MODEL FOR ICE MAPPING FOR THE FUTURE GOES-R ADVANCED BASELINE IMAGER (ABI) USING ARTIFICIAL NEURAL NETWORK

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Abstract— Information on ice cover extent over seas is crucial for ship navigation. Ice cover can also show interannual fluctuations and reflects climate variations. Ability of satellites to provide global observations at high temporal frequency has made them the primary tool for the ice cover monitoring. This study is a part of GOES-R Cryosphere application group effort to develop new, and improve existing, applications for the future GOES-R Advanced Baseline Imager (ABI). In this paper, a new approach was developed to minimize the effect of both observation and illumination angles on the ice mapping accuracy. A Bidirectional Reflectance Distribution Function (BRDF) was developed to simulate the reflectance of ice and water over the Caspian Sea. The ultimate objective of this research is to develop a daily ice concentration map. The estimation of the reflectance of water and ice is a step toward the achievement of this goal. The Northern region of the Caspian Sea has been selected for algorithm development and calibration. Artificial Neural Networks (ANN) have been used to simulate reflectance values for both water and ice from solar, azimuth and satellite angles. Data collected by SEVIRI instrument onboard of Meteosat Second Generation (MSG) satellite have been used as a prototype. The approach used in the algorithm development includes daily cloud-clear image compositing. The simulated reflectances were compared to observed values and have shown a satisfactory agreement. This implies that the BRDF model coupled with ANN technique can be used to simulate reflectance values.

Satellite observations in the visible and infrared spectral bands have also been used for ice mapping (Kwok et al. 1995). A widely used approach to the atmospheric correction of satellite observations over water consists in the use of physically-based models which explicitly account for the Rayleigh and aerosol scattering as well as water vapor, ozone and other atmospheric gases absorption.

Application of this approach to ice cover identification and mapping from geostationary satellites may not be effective. First, accurate information on aerosol characteristics and large scale distribution is not generally available. Second, the existing atmospheric correction models can provide reliable results only for solar or satellite zenith angle below about 60 deg. The latter limitation is serious since low-solar elevation conditions are typical for observations over ice covered areas. Besides that, areas affected by seasonal and perennial ice are located above 45-50 deg N and hence corresponding view angles for geostationary satellites at zenith angles exceed 50 deg. Therefore, in this study we have used an empirical approach to the atmospheric and angular correction.

In this approach in order to characterize bidirectional properties of the top of the atmosphere reflectance we have used a linear combination of functions depending on observation geometry angles (solar-satellite relative azimuth along with solar and satellite zenith angles). This simplified approach cannot adequately represent bidirectional effects for all possible geometries. However, observation geometries involved in ice identification and mapping from geostationary satellites are limited to high solar zenith and satellite zenith angles, generally over 50 deg. Thus for this particular application, the use of an empirical approach may be appropriate.

$$R_{obs} = f(ARZ; SOL; SAT; \cos(ARZ); \cos(SOL);$$
$$\cos(SAT); \sin(ARZ); \sin(SOL); \sin(SAT))$$

where: SAT is the satellite angle; ARZ is the azimuthal angle and SOL is the solar angle and Robs is the observed reflectance.

Figure 1 The Caspian Sea (http://en.wikipedia.org/wiki/Caspian_Sea)

This study is a first attempt to apply a Bidirectional Reflectance Distribution Function (BRDF) model for ice cover mapping. Moreover, an Artificial Neural network technique has been also utilized for model calibration and application. Artificial neural networks have been widely utilized in remote sensing applications (Benediktsson et al. 1990; Paola; Schowengerdt 1995). Multi-layer perceptron trained by backpropagation algorithm is the most common neural network used for image classification. This type of neural network has been successfully applied to image processing and has shown a great potential in the classification of different types of remotely sensed data. In contrary to traditional techniques such as regression analysis, neural network uses its complex configuration to find the best nonlinear function between the input and the output data without any constraint of linearity or prespecified non-linearity (Ghedira et al. 2007; Ghedira et al. 2005).
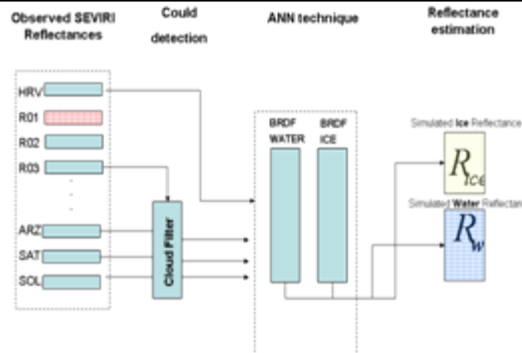

Figure 2 Flowchart of ice and water reflectance estimation

The cloud discrimination potentials of the near-infrared channel can be also seen in **Figure 3**. This figure shows the reflectance of the four optical channels at 11:45 am local time. These data were collected on January 23rd 2007.
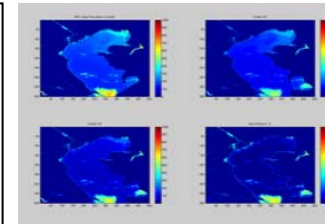

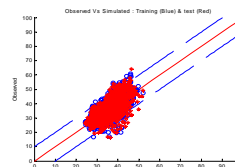**Figure 3 Reflectance of four optical channels**

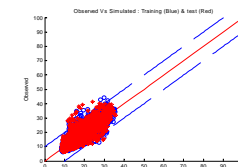**Figure 4 Observed and simulated ice reflectances**   **Figure 5 water reflectances**

simulations were carried out, according to the flowchart of Figure 2. Cloudy pixels were detected and eliminated. Then, the neural network was trained. The primary goal of this training step is the estimation of the weights connecting the nine input-layer nodes (angles + trigonometric transformations) to the 20 hidden nodes, and then the ones connecting hidden nodes with the output layer containing the observed reflectance. Two separate neural networks with same structure have been trained to simulate ice and water reflectances.

Figures 4 and 5 show the simulated reflectances for ice and water respectively. Firstly, these results illustrate a satisfactory agreement between simulated and observed reflectances. The root mean squared errors (RMSE) for both ice and water, summarized in table 1, are non significant. However, RMSE values were systematically higher when ice reflectances are simulated. This can be explained by the fact that ice reflectance are highly affected by ice features such as roughness, thickness and presence of fractional ice. RMSE obtained with simulated water reflectances can be generated by the variation of water reflectance due to the atmospheric effect as well as to water properties such as high concentration in sediments, presence of river deltaic deposits and presence of fractional ice. In future work, the simulated reflectances will be used to retrieve these features.

Overall, the simulated performances are acceptable and very encouraging. This implies that a combination of BRDF model and ANN allows simulating ice and water reflectances.

In this research, the SEVIRI instrument onboard Meteosat Second Generation (MSG) satellite was used as a prototype for the future GOES-R ABI. A neural-network-based model has been used to simulate water and ice reflectances over the Caspian Sea. Pixels geometry defined by the three solar, azimuthal and satellite angles were the primary input to the model. The developed ice detection and mapping algorithm have been tested over the Caspian Sea. The obtained acceptable results have shown that a neural-network-based BRDF model has an interesting potential for ice mapping and monitoring from geostationary platforms.