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Classification of COSMO SkyMed SAR Data Based on Coherence and Backscattering Coefficient

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Abstract - A novel supervised classification approach is proposed for high-resolution dual-polarization (dual-pol) amplitude COSMO SkyMed images. Coherence, mean backscattering coefficient and backscatter difference images are generated, from which the False Color Composite (FCC) image is formed. A classification scheme based on maximum likelihood algorithm land cover classification is implemented on the false color composite image to classify the river, vegetation and the urban areas of Jharia, located in the state of Jharkhand in India using MATLAB 7.6 and ENVI 4.7.

Keywords - COSMO Skymed data, land cover classification; Coherence image, mean backscattering coefficient, False color composite image.

I. INTRODUCTION

The mapping of land cover and the monitoring of spatial and temporal variability of land surface parameters are important issues in the management of land and water resources. The improved spatial resolution and the reduced revisiting time of the new generation of spaceborne SAR systems, such as Cosmo-SkyMed, aroused an increasing interest in SAR data for land cover classification.

The Cosmo/SkyMed SAR constellation is currently operating with two spacecrafts and allows daily acquisition of the same area with a spatial resolution from 1 m to 20 m. The possibility to operate a SAR sensor allows obtaining information on the ground in all weather conditions in spite of severe cloud covers. In this logic, Cosmo/SkyMed could be an important tool to verify the reliability of land cover information provided that the nature of the remotely sensed signal in the microwave range at such a high resolution is investigated and understood in terms echoes reflected by surface targets[1].

The COSMO Skymed data used here for analysis is an Interferometric Synthetic Aperture Radar (InSAR) image of processing level, level-1A operating in the Stripmap (PING PONG) acquisition mode. The data captured is of cross polarized ie.(HH/HV) horizontal polarization. The images were captured with a time interval of one day in the month of june, 2011 over the area of Jharia with the geographic coordinates, whose

LL ranging from 23°50'22.81"N to 23°35'9.46"N, and 86°19'8.27"E and 86°33'14.37"E, located in the state of Jharkhand in India.

With supervised classification, the region of interests(ROI) are chosen from the water body, urban and the forest region based on the accuracy and resolution of the data. These ROIs are called "*training sites*". The image processing software system is then used to develop a statistical characterization of the reflectance for each information class. This stage is often called "*signature analysis*" and may involve developing a characterization as simple as the mean or the range of reflectance on each bands, or as complex as detailed analyses of the mean, variances and covariance over all bands. Once a statistical characterization has been achieved for each information class, the image is then classified by examining the reflectance for each pixel and making a decision about which of the signatures it resembles most. Maximum Likelihood classification(MLC) is one of the most powerful supervised classifier, which is applied on the false color composite image to delineate the land cover classes such as river, vegetation and urban areas. ENVI 4.7 and MATLAB 7.6 are used for the image processing.

II. METHODOLOGY

Complex images of the acquired consecutive pair was initially geometrically corrected and co-registered by taking image captured on 12th june 2011 as the

master image and image captured on 11th June 2011 as the slave image. The same geometrical image is further processed to generate coherence image and the backscatter image.

A. Coherence Image generation

Coherence can be calculated using the equation below,

$$\gamma_{hv} = \frac{\langle m_{hv} \cdot s_{hv}^* \rangle}{\sqrt{\langle m_{hv} \cdot m_{hv}^* \rangle \langle s_{hv} \cdot s_{hv}^* \rangle}}, \quad (1)$$

Where, γ_{hv} is the coherence of HV polarized image, m denotes the master image and s denotes the slave image of HV polarized image. Similarly, γ_{hh} is calculated for HH polarized image. The coherence should be estimated by ensemble average [2-4]. That means the expectation values should be obtained by using a suite of observations for every single pixel. Thus according to the eqn(1), coherence image as shown in figure.1, is generated from the complex co-registered images using a 3x3 window in MATLAB.

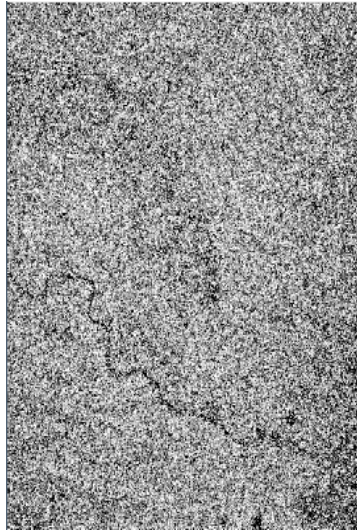


Fig. 1. Coherence image of HH polarization

B. Backscattering coefficient of COSMO Skymed data

Many researchers have observed important effects of structures like water body, on radar backscattering. For example, the polarization ratio of the average HH power to the average HV power is related to the shape and orientation of scatterers. The effects of scatterer orientation are reduced, by the like-polarization magnitude, the average of the backscattering coefficients for HH and HV may be used in image interpretations, or the normalized difference between HH and HV backscattering can be used as an index of stem-angle related canopy structure. The backscattering

coefficient, σ^0 of HH & HV polarized complex images are evaluated using a 3x3 window in MATLAB.

Steps involved in calculating backscattering coefficient:

1. Power image $P(i,j)$, evaluation of input image, $img(i,j)$,

$$P(i,j) = |img(i,j)|^2$$

2. Remove the Reference Slant Range R_{ref} , Range Spreading Loss Compensation Geometry,

$$Fact = R_{ref}^{2 * R_{exp}}, \text{ if } R_{slflag} \neq none$$

3. Remove the Reference Incidence Angle α_{ref} , Incidence Angle Compensation Geometry,

$$Fact' = Fact * \sin(\alpha_{ref}), \text{ if } Inc_{flag} \neq none$$

4. Remove the Rescaling Factor, F ,

$$Fact'' = Fact' \cdot 1/F^2$$

5. Apply the Calibration Factor with the condition, Calibration Constant Compensation Flag, $K_{flag} = 0$,

$$F_{tot} = Fact'' \cdot 1/K$$

6. Apply the total scaling factor,

$$\sigma^0(i,j) = P(i,j) * F_{tot}$$

To get back scattering coefficient, σ^0 in dB,

$$\sigma^0(r,c) = 10 * \log_{10}(\sigma^0(i,j)) \quad (2)$$

The parameters involved in the above equations are obtained from the metadata of the image which are given as the calibration factors. Eqn. 2 gives the resulting backscattering coefficient image, from which mean backscatter and backscatter difference images for the master and the slave images are generated. The mean backscattering coefficient is shown in the fig. 2.

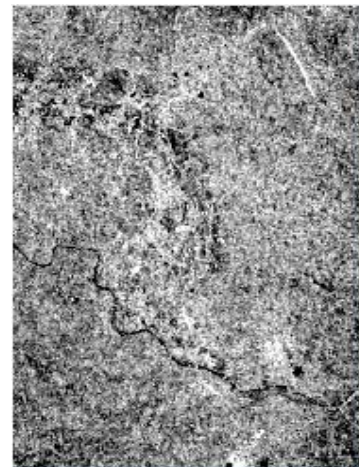


Fig. 2 : Mean Backscattering Image

C. Maximum Likelihood Classification

Maximum likelihood Classification is a statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class of highest probability[5-6]. The maximum likelihood classifier is considered to give more accurate results however it is much slower due to extra computations. On stacking the derived coherence layer, mean backscatter layer and the backscatter difference layer the false color composite(FCC) image is generated. Maximum Likelihood classification is applied on the FCC image and the land cover classes were delineated from the study area. Maximum likelihood Classification is a statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class of highest probability. The maximum likelihood classifier is considered to give more accurate results however it is much slower due to extra computations. On stacking the derived coherence layer, mean backscatter layer and the backscatter difference layer the false color composite(FCC) image is generated. Maximum Likelihood classification is applied on the FCC image and the land cover classes were delineated from the study area. Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless the probability threshold is specified, all pixels are classified. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). If the highest probability is smaller than a threshold specified, the pixel remains unclassified. Maximum likelihood classification is calculated by the discriminant functions for each pixel in the image from the equation (3)

$$G(x) = \ln p(\omega_i) - \frac{1}{2} \ln |\Sigma_i| - \frac{1}{2} (x - m_i)^t \Sigma_i^{-1} (x - m_i) \tag{3}$$

Where, $i = \text{class}$,

$x = n\text{-dimensional data}$ (where n is the number of bands)

$p(\omega_i) = \text{probability that class } \omega_i \text{ occurs in the image and is assumed the same for all classes,}$

$|\Sigma_i| = \text{determinant of the covariance matrix of the data in class } \omega_i$

$\Sigma_i^{-1} = \text{its inverse matrix}$

$m_i = \text{mean vector.}$

Morphological operations such as eroding and opening are further applied to the classified image in which the image appears more accurately classified. *Eroding* removes islands of pixels smaller than the

structural element (kernel) in a binary or gray scale image and *opening* smoothens the contours, eliminate small islands and sharp peaks or capes in an image as a result the image appears with more clear features.

III. RESULTS

The Figure 3 shows the FCC image_[2] of coherence, mean backscattering coefficient and backscatter difference images. Because of the coherence and the backscattering coefficient values, as the combination of both the values has the best efficiency to classify the pixels. Low coherence and low backscattering coefficient separates the water body from the vegetation and the urban areas which has a high values of these parameters. Therefore the water body appears dark due to low coherence values and the vegetation and urban regions appears in red and green due to the moderate and highest coherence values respectively. Figure 4 shows the resulting image of Maximum Likelihood classification, which further classifies these regions based on the probability of occurrence of these values for each pixels. On applying morphological operations to the classified image the continuity and accuracy of these classes is increased, this is shown in figure 5.

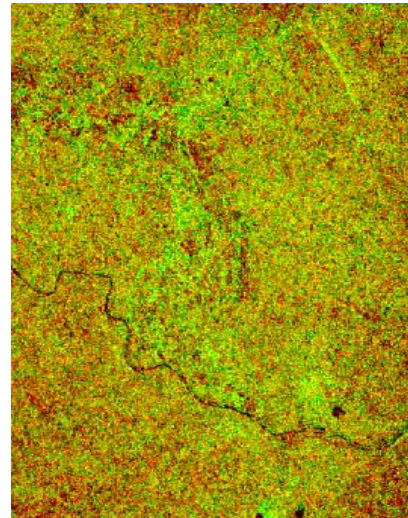


Fig. 3 : False Color Composite image

Here the image of size 670x940 was chosen from HH and HV polarized image and processed using ENVI and MATLAB 7.6.

Coherence and the backscattering coefficients calculations were done programmatically in MATLAB and the FCC image and the Classification image were generated using ENVI 4.7.Mapping[7] with respect to the Google Earth image is carried out to locate the river region, which is located accurately.

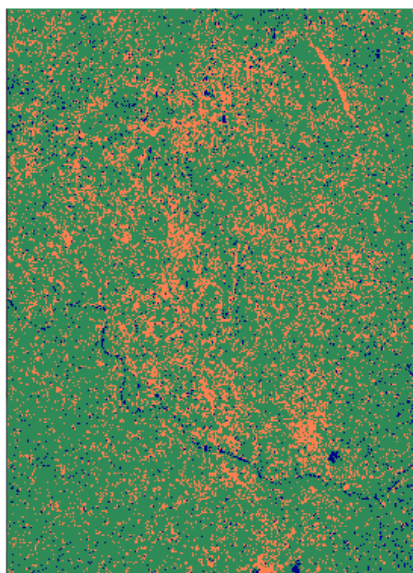


Fig. 4 : Resulting image of Maximum Likelihood classification

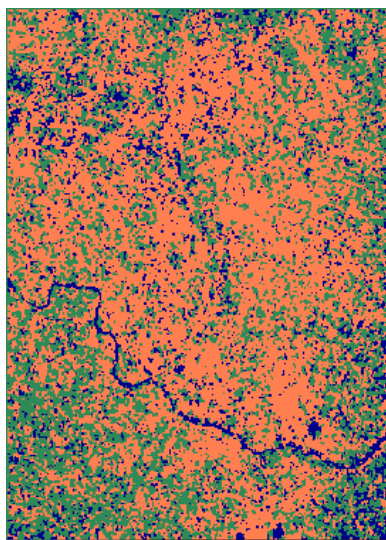


Fig. 5 : Resulting image on morphological operations

IV. CONCLUSION AND REMARKS

The classification algorithm implemented in this paper, results in delineating the land cover classes such as the water body, vegetation and the urban areas in a

better way. The high resolution COSMO SkyMed data gives a good classification result on this methodology discussed in this paper due to the accurate evaluation of coherence and the backscattering coefficients. Finally the resulting image has been mapped with the google earth image and the river body was mapped accurately.

V. ACKNOWLEDGMENT

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