Estimation of Snow Cover Area for Microwave SIR-C SAR Cerro Laukaru, Chile Dataset Using Statistical Parameters

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ABSTRACT: The microwave remote sensing is exceedingly useful, as it provides synoptic observation of the Earth's surface or planetary bodies. It retrieves the information regardless of day or night and the atmospheric conditions, propagation through ionosphere with minimum loss. This ability has been demonstrated under a variety of topographic and land cover conditions using both active and passive microwave instruments. One of the best active microwave remote sensing technology for imaging system is the Synthetic Aperture Radar (SAR) remote sensing. It has its own energy source for illumination. It receives the radiation reflected from the target on the ground surface. It generates a very high resolution imagery of the Earth or planetary bodies. In the present study Snow cover estimation can be obtained by using image classification technique. Because classification has become one of the very important task, after the availability of microwave SAR dataset from the satellites. This techniques is implemented on the basis of Entropy (H), Anisotropy (A) and Alpha (α) based parameters. The classification techniques used in the present work viz., H-alpha, Wishart H α and Wishart H A α classifier. The results of these three classifiers are analyzed and there implications on statistical parameters are compared. The statistical parameters includes Mean (m_a), Median, Standard Deviation (Sa), Coefficient Variance (CV), Equivalence Number of Looks (ENL). The overall process is applied on microwave L-band SIR-C SAR dataset of Cerro Laukaru, Chile. The dataset is useful for Snow cover estimation, as the large area is covered by Snow, also contains both the Dry and Wet type of Snow. Hence, the aim of the present work is to estimate the more accurate, reliable and skillful Snow cover area. The overall processing was done by using PolSARPro Ver. 5.0 software. In the present work the results of Wishart H Alpha classifier found to better compare to H Alpha and Wishart H A Alpha classifier. There are 5% to 7% difference in between Wishart H Alpha and Wishart H A Alpha classifier for dry and wet snow. The statistical parameters of these results are compared and from that also, it was found that the performance of Wishart H Alpha classification is better compared to the other classification. Hence, in overall class comparison, the Wishart H Alpha classifier shows a better response of classification compare to Wishart H A alpha and H Alpha classifier. Hence from the overall present paper work, it is concluded that the Snow cover estimation of microwave SAR dataset on the basis of statistical parameters analysis is the realistic and novel method.

1. INTRODUCTION

The microwave Synthetic Aperture Radar (SAR) is an active type of system, which acquired very high resolution images of the Earth or planetary bodies. It has the capability to sense the objects present on the Earth or planetary bodies during the day as well as at night time, though there is change in environmental conditions. It also penetrate through clouds, smoke, fog etc. (Lillesand and Kiefer 1999; OPN Calla 2009). The snow cover estimation using image analysis technique is one of the realistic application in snow mapping domain. Since last few decades many researcher work on microwave SAR dataset for snow mapping applications. Leshkevich et. al. (1995), work on ERS-1 data used for analysis of coastal ice cover using an unsupervised classification for detection and monitoring coastal ice present in that study region. The C band dataset used for snow cover mapping by Baghdadi et. al. (2001), reported that the overall accuracy is up to 86% and the result also vary due to changes in the type of polarization. Later Shi et. al. (1995) and Geldsetzer (2009) work on the C band dataset for improving the accuracy. They reported that the accuracy of snow cover mapping is up to 95%. The reason behind the accuracy assessment is the use of microwave band for satellite and the more important is the changes occurred in the statistical parameters. The image analysis can be done by using classification techniques. The unsupervised classification scheme based on two dimensional H/Alpha classifications introduced by Cloude and Pottier (1997). Then Lee et. al. (1999), proposed an unsupervised classification method for using H/Alpha classification technique. Hence in the present work the snow cover estimation is done by using the unsupervised classification techniques. This techniques is implemented on the basis of Entropy (H), Anisotropy (A) and Alpha (α) based parameters. Here the classification techniques used *viz.*, H-alpha, Wishart H Alphaand Wishart H A Alpha classifier.

In the present study microwave L-band SIR-C satellite SAR dataset is used. The objective of these work is to classify microwave SAR image for snow cover estimation using the above said classification techniques. The classified results analyzed on the basis of statistical parameters. The parameters includes Mean (m_a), Median, Standard Deviation (s_a), Coefficient Variance (CV), and Equivalence Number of Look (ENL). This paper will provide comparative simulation model results unsupervised classified microwave SAR images using PolSARPro Ver. 5.0 software. This software is freely available on the internet developed by ESA.

2. CLASSIFICATION TECHNIQUES

The classification of SAR image is to identify the different spectral classes present in it and their relation to some specific ground cover type. The classification technique used in this study is based upon polarimetric decomposition classification parameters such as Entropy (H), Anisotropy (A) and Alpha (α) and this classification procedure is carried out using decomposition theorem and the H A Alpha set of the coherency matrix (Cloude 1996, 1997; Shaikh et. al. 2016).

The information on the scattering degree of randomness is provided by entropy (H). The anisotropy (A) provides information on the relative importance of secondary mechanisms and the alpha (α) parameter indicates the nature of the scattering single or double bounce reflection or scattering over anisotropic media. This parameter cannot be interpreted separately from the entropy (Shaikh et al. 2018). The result of classification done here is based on the Wishart statistics of multilook coherency matrix.

In classification assessment the coherency matrix is calculated on the basis of eigenvalue and eigenvector *[T]*. The eigenvalue of *[T]* have direct physical significance in terms of the scattered component's power into a set of orthogonal unitary scattering mechanism. It can be given by the eigenvectors of *[T]*, where the radar backscatter themselves form the column of 3x3 matrix Ouarzeddine et. al. (2007). Hence, the arbitrary coherency matrix is written as,

$$\langle [T] \rangle = [U_3][\sum][U_3]^{-1} \tag{1}$$

$$= \sum_{i=1}^{i=3} \lambda_i u_i u_i^{*T} \tag{2}$$

where $[\sum]$ is a 3x3 diagonal matrix with nonnegative real elements and [$U3$] is a unitary matrix [9].

2.1 Unsupervised Classification

The classification of microwave SAR image is to identify the different spectral classes present in it and their relation to some specific ground cover type. The result of classification done here is based on H-alpha parameters and the Wishart classification based on the Wishart statistics of multilook coherency matrix. In the present work result from the H-alpha and Wishart H-alpha and Wishart H-A-alpha decomposition can be initializing as training sets of the unsupervised classifier is studied (Lee et al. 1999; 2004).

2.2 Wishart Classifier

The Wishart H A Alpha classification is a special type of H A Alpha classification. Here the coherency matrix of a pixel i of a multilook image knowing the class ωi, the Wishart complex distribution is given by,

$$p(\langle T_i\rangle / \omega_m) = \frac{N^{-qN}\exp(-tr(N[\sum_m]^{-1}\langle T_i\rangle))}{K(N,q)\left|\sum_m\right|^N} \tag{3}$$

Since, $\sum_m = E(\langle T_i\rangle \big| \langle T_i\rangle \varepsilon\omega_m)$

$$\sum_m = \frac{1}{N_m}\sum_{i=1}^{N_m}\langle T_i\rangle \tag{4}$$

where *Nm* is the pixel number of *ωm, K (N, q)* is the factor of standardization. Using Wishart classification method there is significant improvement in each iteration. When the number of pixel switching classes becomes smaller than a predetermined number the iteration end. After applying Wishart method the original class boundaries in the H and the alpha plane become less distinct with considerable overlap. The advantage of using Wishart method is its effectiveness in automated classification. It provides the interpretation based on scattering mechanism of each class (Lee et. al. 1994, 1998; Shenglong et. al. 2015). In the present work Wishart H-alpha and Wishart H-A-alpha classification techniques are used. The eight classes resulted from Wishart H-alpha classification and sixteen classes resulted from the Wishart H-A-alpha classification are to be studied.

3. STATISTICAL PARAMETERS

The microwave SAR dataset can be analyzed by using the statistical parameters (Gonzalez et. al. 2008; Gupta et. al. 2011; Kumar et. al. 2012) includes Mean (m_a), Median, Standard Deviation (s_a), Coefficient Variance (CV) and Equivalence Number of Look (ENL).

3.1 Mean

The average brightness of a region are defined as the sample mean of the pixel brightness's within that region. The average, m_a, of the brightness's over the pixels within a region (*R*) is given by equation (5),

$$m_a = \frac{1}{\Lambda}\sum_{(m,n)\in R} a[m,n] \tag{5}$$

Alternatively, we can use a formulation based upon the (unnormalized) brightness histogram, $h(a) = \Lambda * p(a)$, with discrete brightness values a. This gives by the equation (6),

$$m_a = \frac{1}{\Lambda}\sum_a a.h[a] \tag{6}$$

The average brightness, m_a, is an estimate of the mean brightness, u_a, of the underlying brightness probability distribution.

3.2 Standard Deviation

The unbiased estimate of the standard deviation, s_a, of the brightness within a region (R) with Λ pixels is called the sample standard deviation and is given by equation (7) & (8),

$$s_a = \sqrt{\frac{1}{\Lambda}\sum_{m,n\in R}(a[m,n]-m_a)^2} \tag{7}$$

$$s_a = \sqrt{\frac{\sum_{m,n\in R} a^2[m,n]-\Lambda m_a{}^2}{\Lambda-1}} \tag{8}$$

Using the histogram formulation gives the equation (9),

$$s_a = \sqrt{\frac{\left(\sum_a a^2.h[a]\right)-\Lambda.m_a{}^2}{\Lambda-1}} \tag{9}$$

Here also the standard deviation, s_a, is an estimate of σ_a of the underlying brightness probability distribution.

3.3 Coefficient Variance

The coefficient variance is a ratio of standard of deviation to the mean value for a given set of image. The dimensionless CV, is given by the equation (10),

$$CV = \frac{S_a}{m_a} X100\% \tag{10}$$

3.4 Equivalence Number of Looks (ENL)

Another good approach of estimating the speckle noise level in a SAR image is to measure the ENL over a uniform image region. A larger value of ENL usually corresponds to a better quantitative performance. The value of ENL also depends on the size of the tested region, theoretically a larger region will produce a higher ENL value than over a smaller region but it also trades off the accuracy of the readings. The formula for the ENL calculation is shown in equation (11),

$$ENL = \frac{NMV^2}{NS} \tag{11}$$

The significance of obtaining ENL measurement in this work is to analyze the performance of the filter on the overall as well as in smaller uniform regions.

4. STUDY AREA

The study area is located in Cerro Laukaru, Chile with latitude 48^0 56'13.20'' S to 49^0 42'07.20'' S and longitude 72^0 46' 44.40'' W to 74^0 07'01.20'' W. This is located near the Otzal an alpine valley. The large area is covered with terrain. Also the Snow is covered in this terrain area. The most of the river flowing through hills meets together at the lake. After melting Snow the water is flowing through these lakes. The selected area, region is used for snow cover mapping. There are two types of Snow cover, i.e., dry snow and wet snow. The fresh snow represented by dry snow and after formation of snow more than 10 inches makes into wet snow. The outline map and the region of the study area is shown in figure 1. The SAR dataset specification is shown in table 1.

Fig. 1: Outline map of Cerro Laukaru, Chile

Parameter	Specification
SAR Sensor	SIR-C
Microwave Band	L
Data Type	MLC (Multi Look Complex)
Incidence Angle	39.65^0
Polarization	Quad (HH, HV, VH, VV)
Date of Acquisition	04/12/1994

Table 1: SAR dataset specification

5. RESULT AND DISCUSSION

The microwave L band SIR-C dataset is initially import in the PolSARpro software and preprocessing like multilook, speckle filter etc. applied on original dataset. Later decomposition techniques applied on the preprocessed dataset and decomposition parameters like H A Alpha was generated which is very helpful for classification.

5.1 Unsupervised Classification Analysis

Here the unsupervised classification the H alpha, Wishart H alpha and Wishart H A alpha classifier is used. The H-alpha and Wishart H-alpha classifier automatically generated 8 number of classes, whereas the Wishart H A Alpha classifier automatically generated 16 number of classes. The Wishart classification method is significant in improving the effectiveness in the automated classification. Out of these numbers of classes, the four major classes choose and analyzed.
The four classes like dry snow, wet snow, water and terrain are selected for the present study. The figure 2 (a), (b), (c) shows H Alpha, Wishart H Alpha and Wishart H A Alpha classification results respectively.

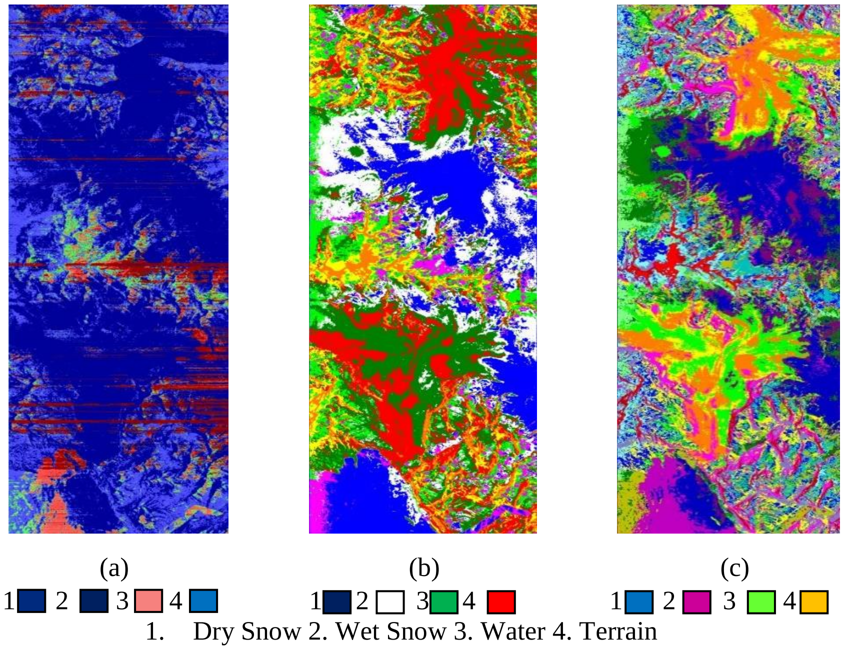

Fig. 2: Unsupervised classification for Cerro Laukaru, Chile SIR-C SAR image of (a) H Alpha (b) Wishart H Alpha (c) Wishart H A Alpha classifier

Table 2: Unsupervised classification for Cerro Laukaru, Chile SIR-C image

Class	Types of Unsupervised Classification		
	H Alpha (%)	Wishart H Alpha (%)	Wishart H A Alpha (%)
Dry Snow	60.6050	18.822	12.930
Wet Snow	00.0000	14.876	07.086
Water	03.7510	21.049	10.281
Terrain	20.1570	18.789	09.746
Other	15.4870	26.464	59.957

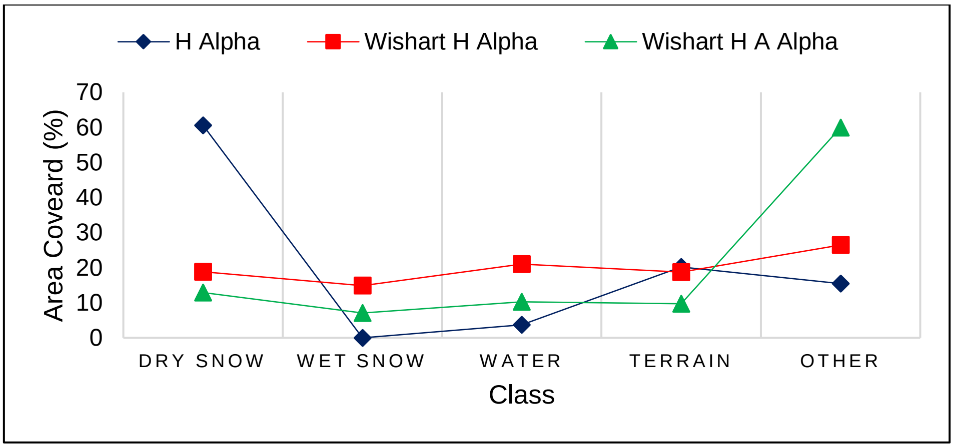

Fig. 3: Graph for comparison between classifications

The table 2 shows three unsupervised classification with area covered by four major class under studied. From the figure 3 comparison between classifications it is observed that, the results of H Alpha classifier show the maximum value of dry snow class compare to Wishart H Alpha and Wishart H A Alpha classifier. In case of wet snow class it shows zero value. Because here the both dry and wet snow class mixed with each other. The results of Wishart H Alpha classifier found to better compare to H Alpha and Wishart H A Alpha classifier. There are 5% to 7% difference in between Wishart H Alpha and Wishart H A Alpha classifier for dry and wet snow and 7% to 10% difference for water and Terrain class. Hence, in overall class comparison of Wishart classifier, Wishart H Alpha classifier shows a better response of classification compare to Wishart H A Alpha and H Alpha classifier.

5.2 SAR Statistical Parameter Analysis

The SAR statistical parameters include Mean, Median, Standard Deviation, Coefficient Variance and ENL. The total number of pixels DN's generated by unsupervised classification is 4712000. Using this the statistical parameters are calculated. The table 3 shows the SAR statistical parameter for H alpha, Wishart H alpha and Wishart H A alpha classification and its comparative graph is shown in figure 4. In the figure 4 the Wishart H A Alpha classifier shows a larger value of Mean and Median parameters compare to Wishart H Alpha and H Alpha classifier. So the removal of noise and average pixels are found to be better in Wishart H A Alpha classifier. But the Standard Deviation for Wishart H A Alpha is larger than the Wishart H Alpha. Due to this it shows mix classification. It also loss the snow cover information present in the image. Though the Coefficient Variance and ENL are nearly same for both Wishart classifiers. From the overall results it is found that the performance of Wishart H Alpha classification is better compared to the other unsupervised classification.

Table 3: SAR statistical parameter

Parameter	Types of Classification		
	H Alpha	**Wishart H Alpha**	**Wishart H A Alpha**
Mean	7.7667	3.9925	08.7803
Median	8.9980	3.0000	10.0000
Standard Deviation	1.6639	2.4505	04.9623
Coefficient Variation	0.3692	1.0544	00.8566
ENL	7.3381	0.8995	01.3627

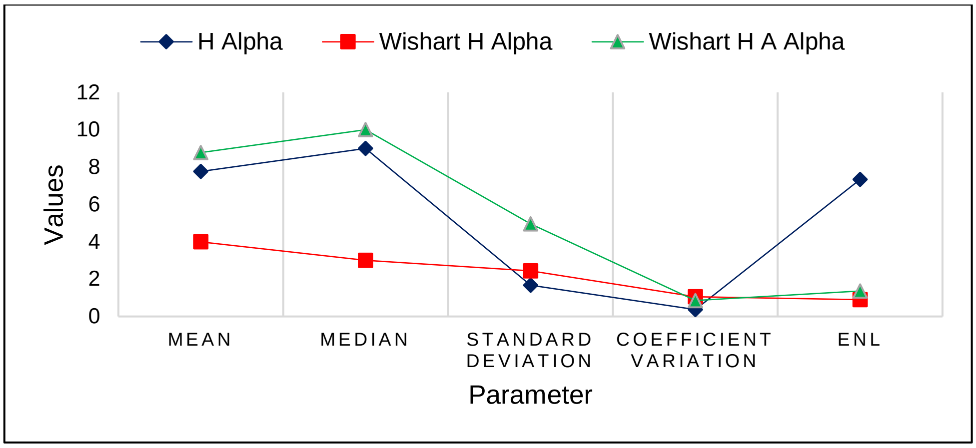

Fig. 4: Graph of SAR statistical parameter

6. CONCLUSION

The microwave L band SIR-C SAR data using unsupervised classification is successfully classified using PolSARpro software. The H-alpha, Wishart H-alpha and Wishart H-A-alpha techniques are used for unsupervised classification. The classification results are compared and for analyzed on the basis of statistical parameters. The dataset used in the present study is used for snow mapping application. The four major classes studied is Dry Snow, Wet Snow, Water and Terrain surface. In unsupervised classification Wishart H Alpha classifier found to be better performance for Dry snow and Wet Snow class compare to the H Alpha and Wishart H A Alpha classifier. The reason is that Wishart H Alpha has less Standard Deviation and less Coefficient Variance. Due to that there is minimum variation in pixels of each class. Another reason is that, it shows high ENL values implied to better performance. Hence from the overall work it is also concluded that the variation in the statistical parameter affects the accuracy of snow mapping estimation. In future the classification techniques used in this paper for snow mapping estimation using statistical parameter can be further applied to other microwave band dataset like C, X band etc. SAR dataset and other study area region.

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