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Study on Calibration of Sea Wave Height Using Synthetic Aperture Radar Image Based on Grey Level Co-occurrence Matrix: Case on Multi Polarization P Band

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Abstract— **Indonesian** ***archipilago had 70% sea area of its total area. Due to safety factor in sea transportation fishery and tourism, sea wave height in all area in Indonesia must be known. Lack of the information on the height of sea wave caused lot of accident in sea transportation or fishery especially in East Indonesia. This research proposed an introduction to calibration system of the height of sea wave using the feature texture of the Synthetic Aperture Radar (SAR)image. The feature texture were extracted by using grey level cooccurence matrix (GLCM) with zero degree obsevation. The research object was the Sinthetyc Apperture Radar (SAR) image P band of Kalimantan's coastal. The image had full polarization such as horizontal horizontal, horizontal vertical, vertical horizontal and vertical vertical. The result showed four features were extracted, contrast, correlation, energy and homogeneity. The homogeneity had highest accuracy compare to test image and it could be used as a calibrator of sea wave height.***

Keywords— GLCM, sea wave, SAR, texture

I. Introduction

This paper proposed the new method to calibrate the height of sea wave in Kalimantan Island or Borneo in Indonesia based on grey level co-occurrence matrix (GLCM). In the previous research the feature texture of Synthetic Aperture Radar (SAR) image of certain area of West Jakarta could be extracted. These features were contrast, correlation, energy and homogeneity. We extracted four areas such as housing area, grass area, tree area and water area. This previous study worked on L Band Multi polarization SAR Image [1]. In this research we worked on P band multi polarisation SAR image and we focus on sea area of East Kalimantan Island. The results of this research was very important for us due to Indonesia is an archipelago country where the sea transportation was a highest priority. The objective of this research was to have the four feature texture, as mentioned before, of the East Kalimantan sea area and to compare these features between different polarizations of P band SAR image. We do hope the results would be used in early warning system on the sea wave height.

As an archipelagic country Indonesia consists of 70% of sea areas and 30% of the land area. Indonesia has five big islands and thousands of small islands. Total area of the sea was 3,257,483 km^2 and lands was 1, 369, 65 km^2 . The mode of transportation between two islands in Indonesia still used ferry or speedboats. In Indonesia there are many inter-island crossing locations including Merak – Bakauheuni to connect Java and Sumatra island, Banyuwangi – Gilimanuk to connect Java and Bali island, as well as in other areas such as Lembar, Pagimana, Belawan and others. This research focus on inter-island crossing between East Kalimantan and Centre Sulawesi or between Balikpapan city and Palu city in the East Indonesia. Accidents on crossing between these two islands have several times happened. These accidents caused by very high sea wave. Accidents occurred on ferries and fishing boats which has lots of death victim and wounded. The last terrible accident was occurred in the middle of December 2015 in Bone bay, Sulawesi east Indonesia, ferry hit by 3 to 5 meters sea wave height and the dead victim were more than 60 died and more than 100 wounded.

For monitoring the state of the sea or the height of wave, there were two methods such as measure from the beach and measure on the surface of the sea by using certain type of gage [2]. There were other method to measure the height of sea wave by using the wind velocity, this method was known as Gumbel method [3]. Here in this research we proposed the new method by using the feature texture on SAR image. Indonesia has been using satellites Jers-1 and ERS-1 in 1986 to create the image of East Kalimantan and Irian Jaya and in 1989 extended coverage to Sumatra with a total area of 899 000 km 2, this area is 47% of the land surface area of Indonesia[4]. As we know SAR image consists of the return signal that is mostly influenced by the roughness of the surface of the sea. The roughness of the sea was proportional to sea wave height and it caused the texture on the SAR image. In this preliminary research we just extracted the features texture of P band multi polarization SAR image of the sea between East Kalimantan and Centre Sulawesi.

II. Texture Analysis

Analysis on the characteristic textured SAR image can be done with the structural approach or statistical approaches. Texture can be said to be a descriptor that can provide information about the regularity, roughness and smoothness. Structural approach can be performed on images that have certain structural components.

Examples for the image tile floor has rectangular structural component. SAR images do not have a structural component; we could so use a statistical approach. Tomita described a statistical approach is divided into three levels such as:

a. The first level: by calculating the average, maximum and minimum.
b. The second level: by counting Grey Level Co-occurrence Matrix (GLCM), Semi-variogram, or Autoregresi.
c. The third level: by counting the cover or run length interval.

Naddler also described three levels statistic such as:

a. Imaged-based: characteristic obtained directly from the image.
b. Model-based: characteristics obtained by creating a model of texture.
c. Transform based: transform image to another domain which included based transform is a Fourier transform, Wavelet, and CLCM

Analysis using Grey Level Co-occurrence Matrix will produce some texture characteristics of the image such as energy, entropy, correlation, dissimilarity, inverse different moment, inertia, cluster shade, cluster Prominence, homogeneity [5],[6], but not all characteristics could be used, in some studies using only the four features such as contrast, correlation, energy and homogeneity. GLCM is a method that is widely used for texture analysis in the SAR image. Here for the example suppose we have 5 x 5 pixels image depicted on Figure 1. There are four degrees of grey level from 0,1,2, and 3.

1	2	0	3	1
1	2	0	3	2
2	3	0	0	2
1	3	0	2	1
2	2	1	0	3

Figure 1. 5 x 5 pixels image .

If the distance pixels are selected one to the right and the direction angle co-occurrence 0° then the matrix can be formed as follows:

1. Determine the degrees of grey, sorted from minimum to maximum in the example was from 0 1 2 3.
2. Form m x n framework matrix where m = n was the number of degrees of greylevel, elements of the frame matrix F is $f_{i,i}$, where $f_{i,I}$ was the number of occurrences with a degree of grey level. In the first row $f_{i,I}$ or $a_{1,j}$ were the number of pixels 0 followed by 0, 0 followed by 1 , 0 followed by 2 and 0 followed by 3. In the second row $f_{2,j}$ were the number of pixels 1 followed by 0, 1 followed by 1 , 1 followed by 2 and 1 followed by 3.

Frameworks matrix form depicted on Figure 2 below.

	0	1	2	3
0	1	0	2	3
1	1	0	2	1
2	2	2	1	1
3	2	1	1	0

Figure 2. Framework matrix

1. Create a co-occurrence matrix C, divide each element of the matrix F with n where n is the number of all elements of the matrix F, it was 20. The matrix C depicted in Figure 3 below.

$$\begin{matrix} 1/20 & 0 & 2/20 & 3/20 \\ 1/20 & 0 & 2/20 & 1/20 \\ 2/20 & 2/20 & 1/20 & 1/20 \\ 2/20 & 1/20 & 1/20 & 0 \end{matrix}$$

Figure 3. Co-occurrence Matrix.

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From this matrix C may be calculated four features texture such as:

1. Contrast.

$$\sum_{i=1}^{n}\sum_{i=1}^{n}(i-j)c_{i,j}$$

2. Correlation.
   m is a meant of matrix element C

$$\sum_{i=1}^{n}\sum_{i=1}^{n}(i-m)(j-m)c_{i,j}$$

3. Energy.

$$\sum_{i=1}^{n}\sum_{j=1}^{n}c_{i,j}$$

4. Homogeneity

$$\sum_{i=1}^{n}\sum_{j=1}^{n}c_{i,j}/1+(i-j)^2$$

III. METHODOLOGY

First step we crop a small part of image 10 x 10 pixels in each polarization from 5 areas. These 5 areas were the same coordinates for each polarization. These 5 small images were extracted and the results were 4 GLCM features as mentioned before such as contrast, correlation, energy and homogeneity. Next step crop a small part of image 10 x 10 pixels in each polarization but on the different coordinates with the 5 images cropped before, and continue to extract the 4 GLCM features. The 4 GLCM features as results from test images than would be compared to the results of references images. If these test results still in the range of reference image, it has been accepted otherwise it has been rejected in this research we crop 8 small images to be tested. The all step of this research was depicted on Figure 4.

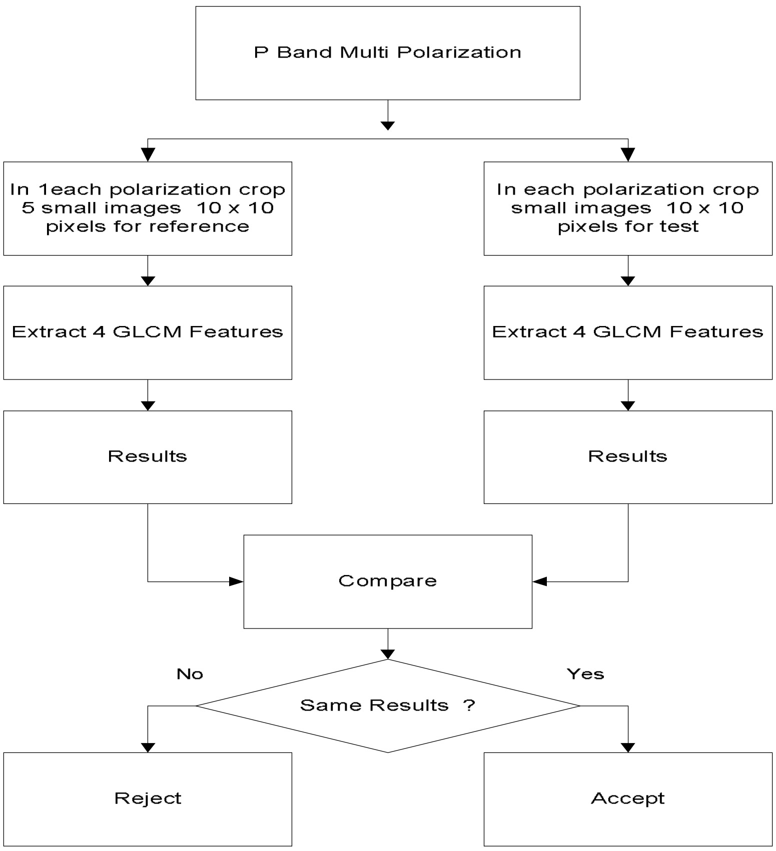

Figure 4. Experiment's diagram

IV. DISCUSSION

The object in this research was the P Band multi polarization SAR images acquired from East Kalimantan.The polarization were horizontal-horizontal (HH), horizontal-vertical (HV), vertical-horizontal (VH) and vertical -vertical (VV). The size of this images 512 x 128 pixels, these images depicted on Figure 5, Figure 6, Figure 7 and Figure 8.

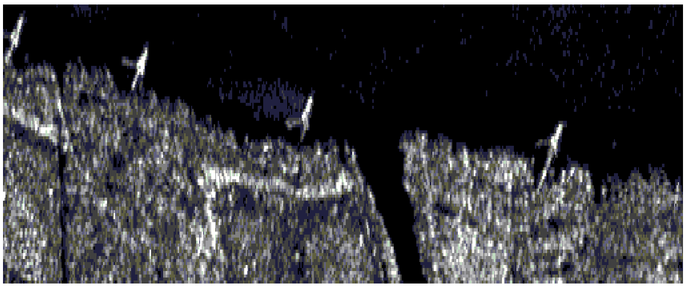

Figure 5. P-HH SAR image.

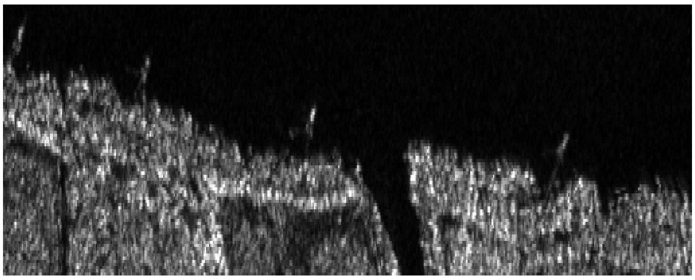

Figure 6. P-HV SAR image.

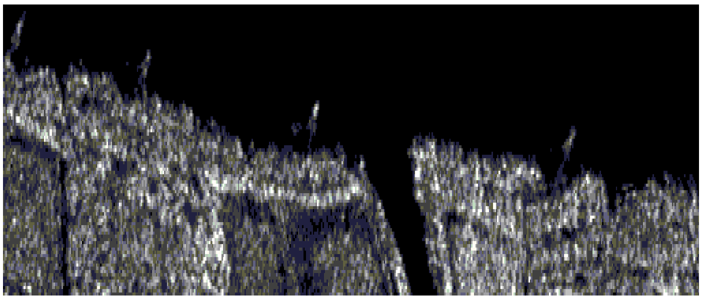

Figure 7. P-VH SAR image.

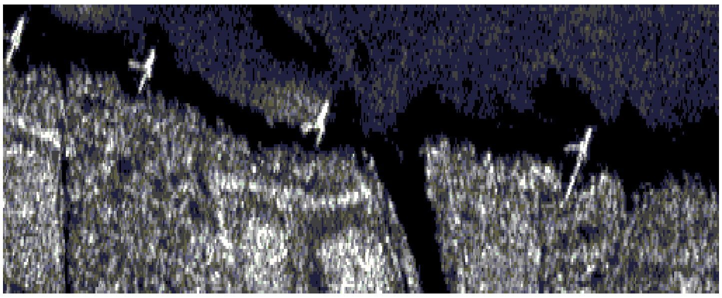

Figure 8 . P-VV SAR image.

The test images was taken from each polarization by cropping into 10 x 10 pixels image on the different coordinates. We cropped 8 images from each polarization, thus we had totally 32 image to be extracted. The results were contrast, correlation, energy and homogeneity. We thus had 8 contrast , 8 correlation, 8 energy and 8 homogeneity in P-HH, 8 contrast , 8 correlation, 8 energy and 8 homogeneity in P-HV, 8 contrast , 8 correlation, 8 energy and 8 homogeneity in P-VH, and 8 contrast , 8 correlation, 8 energy and 8 homogeneity in P-VV

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4.1.Features extracted .

4.1.1.P- HH

The feature texture of five location from P-HH image, named HH1 to HH5, were described in Table 1. These feature were contrast (con), correlation (cor), energy (en) and homogeneity (hom). Observation angle was 0°.

TABLE I - FEATURE TEXTURES OF P-HH

	CON	COR	EN	HOM
HH1	2.4444	0.3656	0.0548	0.5669
HH2	0.5669	0.3141	0.0627	0.0627
HH3	2.2778	0.3873	0.0573	0.5609
HH4	1.2667	0.6184	0.0617	0.6481
HH5	2.1778	0.0227	0.9141	0.9611

The mean value of these feature texture described in Table 2.

TABLE 2 - MEAN OF FEATURE TEXTURES OF P-HH

NO	FEATURES	MEAN
1	Contrast	1.7467 ± 0.6640
2	Correlation	0.5199 ± 0.1380
3	Energy	0.2301 ± 0.0144
4	Homogeneity	0.5599 ± 0.1998

The span of these features was from 1.0827 to 2.4107 for contrast, 0.3819 to 0.6579 for correlation, 0.2157 to 0.2445 for energy and 0.3601 to 0.7597 for homogeneity. The values of features in order were contrast, homogeneity, correlation and energy; and the values of differences between minimum and maximum in order were contrast, homogeneity, correlation and energy. Based on span and differences of these HH features we chose homogeneity as a robust feature.

4.1.2.P- HV.

In horizontal vertical polarization the features were described in Table 3. The observation angle was 0°. The 10 x 10 cropped image were named HV1 to HV5.

TABLE 3 - FEATURE TEXTURES OF P-HV

	CON	COR	EN	HOM
HV1	0.9778	0.3120	0.2415	0.7356
HV2	1.1222	0.6328	0.2244	0.7546
HV3	0.7546	0.7546	0.0763	0.6054
HV4	1.6667	0.5766	0.0711	0.6120
HV5	2.6111	0.3091	0.0528	0.5313

The mean value of these features were described in Table 4

TABLE 4 - MEAN OF FEATURE TEXTURES OF P-HV

NO	FEATURES	MEAN
1	Contrast	1.4265 ± 0.5669
2	Correlation	0.5170 ± 0.1651
3	Energy	0.1322± 0.0797
4	Homogeneity	0.6647 ± 0.0778

We then counted the span and the difference of each feature. The span of these features was from 0.8598 to 1.9934 for contrast, 0.3519 to 0.6821 for correlation, 0.0525 to 0.2119 for energy and 0.5869 to 0.7425 for homogeneity. The value of features in order were contrast, homogeneity, correlation and energy; and the value of differences between minimum and maximum in order were contrast, homogeneity, correlation and energy. Based on span and differences of these HH features we chose homogeneity as a robust feature. This value order was same as P-HH's value.

4.1.3.P-VV.

Features extracted from P-VV was described on Table 5. The five 10 x 10 test images named VH1 to VH5. We kept the observation angle was 0°.

TABLE 5- FEATURE TEXTURES OF P-VV

	CON	COR	ENERGY	HOM
VH1	0.5313	0.6472	0.7010	0.7010
VH2	0	Na	1	1
VH3	0.5444	Na	0.9780	0.9903
VH4	0	Na	1	1
VH5	0	Na	1	1

The mean value of these features were described in Table.6.

TABLE 6 - MEAN OF FEATURE TEXTURES OF P-VV

NO	FEATURE	MEAN
1	Contrast	0.2551 ± 0.2181
2	Correlation	undefined
3	Energy	0.9358 ± 0.0939
4	Homogeneity	0.9382 ± 0.0949

Features extracted of P-VV SAR image was different compare to P-HH and P-HV. In this extraction correlation was undefined. The value of features in order were homogeneity, energy and contrast; and the value of differences between minimum and maximum in order were homogeneity, energy and contrast. Despite of un consistent result, on the other side it has consistent results such as homogeneity, its span and difference were robust.

4.1.4.P-VH.

Features extracted from P-VH was described on Table 7. The five 10 x 10 test images named VV1 to VV5 like in the previous polarization. We kept the observation angle was 0° like in the previous step.

TABLE 7 - FEATURE TEXTURES OF P-VH

	CON	COR	EN	HOM
VV1	0.9903	0.6289	0.8121	0.9460
VV2	1.0889	0.6990	0.9141	0.9806
VV3	0.5444	Na	0.9780	0.9903
VV4	11.9778	0.1834	0.5269	0.7861
VV5	2.8667	0.3657	0.4314	0.4314

The mean value of these features were described in Table.8.

TABLE 8- MEAN OF FEATURE TEXTURES OF P-VV

NO	FEATURE	MEAN
1	Contrast	3.4936 ± 3.3937
2	Correlation	undefined
3	Energy	0.7325 ± 0.2026
4	Homogeneity	0.8269 ± 0.1743

Case on vertical - vertical (VV) polarization was really different compare to horizontal – horizontal (HH) and horizontal-vertical (HV), but similar to vertical- horizontal (VH). Homogeneity still the had robust value compare to other features. From Table 2, Table 4, Table 6 and Table 8 we could assume that homogeneity could be considered or nominated as features to calibrate the sea wave height. We extracted 10 test images in each polarization and we compared to span of each polarization and we got the result depicted in Table 9.

TABLE 9- ACCURACY OF TEST IMAGES

NO	POLARIZATION	CON	COR	EN	HOM
1	P-HH	12.5	0	0	0
2	P-HV	0	50	62.5	100
3	P-VH	0	0	0	0
4	P-VV	0	0	0	100

In HH polarization only had 1extracted feature; it was contrast, match to span which has 12.5% accuracy. HV polarization had two extracted features; there were correlation and energy, match to span which had 50% and 62.5% accuracy. VH polarization had no extracted feature match to span. VV had only 1 extracted feature; it was homogeneity which had 100% accuracy. We considered that homogeneity was the features that could be used as a standard to calibrate the texture on sea wave and it means the sea wave height. These results presented in Table 9 had been done for observation 0°. As mentioned before the observation angle could be another angle such as 45°, 90° and 135°. We have to pursuit this research by using another angle and we could chose the most robust feature of P band and the most important step would be extracting the feature of SAR image taken from certain area provide by date and height of the sea wave to make a calibration table.

V. CONCLUSIONS

Regarding all Table as a result of these research we thus could make a conclusion that homogeneity was the most robust feature in the observation angle 0° and could be considered as a calibrator.

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