Polarimetric Decomposition in Calibrated Radar Image for Detecting Vegetation Object

Dekomposisi Polarimetrik dalam Citra Radar yang terkalibrasi untuk Deteksi Obyek Vegetasi

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ABSTRACT – Radar imagery have some certain characteristic, pattern, feature or behaviour for specific vegetation. We have to determine what is the product processing level for data before take ALOS PALSAR data as an input. Determining process can give us information if the data has been slope corrected, reprojected, radiometric calibrated, etc. After have specific information which is qualified to be process further like digital number conversion to Gamma or Sigma Nought. Gamma Nought mostly used for change detection application for example like deforestation monitoring and forest change. Gamma nought also can be tested and validated for its high effectivity and stability for forest monitoring. Polarimetric decomposition method applied for some quad polarization radar image, in this research methods of decomposition are Sinclair, Pauli and Freeman-Durden. Comparison of the result from different method will be test and analyze further for the best method for classification. Some unsupervised classification is applied for checking classes separability.

Keywords: Polarimetric Decomposition, Calibration, Forest Monitoring, Polarization, Gamma/Sigma Nought

1. INTRODUCTION

There are two types of remote sensing satellite sensors namely optic and radar sensor. The optic sensor cannot preserve a clear imagery if the clouds, smoke or haze covers the earth surface. Cloud cover, smoke, haze and other atmospheric pollutants are among of the obstacles to acquire clear imagery from optical satellite data particularly acquisition of visible bands (red, green and blue band). According to research from Dirk H. Hoekman, et al in his paper with title "PALSAR Wide-Area Mapping of Borneo: Methodology and Map Validation" that for certain areas in Indonesia, such as Kalimantan (Borneo island in Indonesia), persistent cloud cover in many tropical areas prevents optical sensors from making regular reliable image acquisitions and high cloud cover is predominant almost all of the year. In such area the use of optical imagery for...
a land or forest fire is intensive includes hot spot detection and burnt area mapping. However, the result of burned area mapping by optical imagery frequently is in low quality due to cloud cover and haze pollution.

The comparison between C and L band radar imagery will be done based on previous studies (Comparative Study on C and L Band SAR for Fire Scar Monitoring, Nakayama,S., Maximilians,L.). For those reason we need to approach some research to develop technique or method to maximize forest classification and mapping using radar images. X, C and L-band from radar image provide another benefit for forest degradation by blazing of fire. Huge rage of fire cause removal of large canopies where this condition can be persistent detected by SAR image. We can use two date acquisition before and after fire disaster to compare Radar C band image while optical imagery is only detect forest degradation temporarily. These temporary conditions happen because of the pattern are disappearing due to forest regrowth.

2. METHODOLOGY

Before take ALOS PALSAR data as an input firstly we have to determine what is the product processing level for data that we have selected, for example ALOS PALSAR product levels are 1.0, 1.1 or 1.5. SAR Radiometric Calibration is a critical preprocessing step for subsequent classification processing based on absolute backscatter values (Terrain Slope Correction and Precise Registration of SAR Data for Forest Mapping and Monitoring, Z.-S. Zhou). Gamma Nought mostly used for change detection application for example like deforestation monitoring and forest change. (Shimada. M, et al., 2012). Gamma nought also regarded has high effectivity and stability for forest monitoring and land cover classification.

According to (Lavalle, M., 2009)) that derivation of sigma, beta and gamma nought can be calculated by formula (1).

\[
\sigma_{ij}^0 = K \cdot D N_{ij}^2; \quad \beta_{ij}^0 = \frac{\sigma_{ij}}{\sin(\alpha_{ij})}; \quad \gamma_{ij}^0 = \frac{\sigma_{ij}}{\cos(\alpha_{ij})}; \quad ..........................................................(1)
\]

\[i = 1,2 ... L; j = 1,2 ... M .\]

where K= absolute calibration constant, \(D N_{ij}^2\) is pixel intensity value at image line i and column j, \(\sigma_{ij}^0\) is sigma nought (backscattering coefficient) at image line i and column j, \(\beta_{ij}^0\) is beta nought (brightness) at image line i and column j, \(\gamma_{ij}^0\) is gamma nought at image line i and column j, \(\alpha_{ij}\) is incident angle sigma nought at image line i and column j, and L, M are number of lines and columns in the product

Average backscattering coefficient for an area of interest can be derived as an average of \(\sigma_{ij}^0\) over \(N = N_a \times N_r\) pixels within the distributed target as shown by formula (2).

\[
\sigma_{avg}^0 = \frac{1}{N} \sum_{i=1}^{N_a} \sum_{j=1}^{N_r} \sigma_{ij}^0 ..........................................................(2)
\]

To obtain sigma nought to dB is shown by formula (3).

\[
\sigma^0[dB] = 10 \cdot \log_{10}(\sigma^0) = 20 \cdot \log_{10}(DN) + K[dB] ..........................................................(3)
\]

We can see from this Figure 1 how sigma, beta and gamma nought can be described also they are related to incidence angle theta. This picture only valid for one object or 1 pixel unit column and row i,j and according to Shimada with ASF software and ALOS level 1.1 product that Normalized Radar Cross Section can be calculated.
\[
\sigma^0 = 10 \log_{10}(I^2 + Q^2) + CF - A \tag{4} 
\]

or
\[
\sigma_{1.1}^{0, product} = 10 \cdot \log(DN^2) + CF - A \tag{5} 
\]
Sigma nought value also can be calculated as following formula
\[
\sigma_{1.5}^{0, product} = 10 \cdot \log(DN^2) + CF \tag{6} 
\]

With I is real number and Q is imaginary parts also for A is conversion factor of 32.0.
DN= Amplitude Digital number from image
\sigma^0= Sigma Nought
CF= Calibration Factor (-83 after January 7 2009)
\langle . . \rangle = Averaging 3x3 size kernel window (Convolution Filter 3x3)

**Polarimetric Decomposition**

a. Pauli Decomposition is calculated from following formula
   - Red band: an absolute value from HH-VV which mean even bounce
   - Green band : an absolute value from HV+VH which mean rotated bounce
   - Blue band : an absolute value from HH+VV which mean odd bounce
   Where this decomposition can visualize dominant scattering mechanism in different areas of the scene, for example man made object like building will looked red (this condition happen because even bounce return will dominate).

b. Sinclair Decomposition is a simple decomposition that combines all four polarizations into a single RGB image. Green channel is consist of the average of cross polarization which cannot be equal due to noise matter.

c. Freeman-Durden Decomposition is a model based approach which attempts to fit the combination of three simple scattering mechanisms to the polarimetric SAR observation, without utilizing any ground truth measurements. This decomposition can be assigned into
   - Red band: Double bounce component (scatter from a pair orthogonal surface with different dielectric constant)
   - Green band : canopy component (scatter from a cloud of randomly oriented dipoles)
   - Blue band : Rough Surface component (Bragg scatter)

3. **RESULT AND DISCUSSION**

3.1 Result
**Radar ALOS data for quad polarization level 1.1**

Figure 2 is ALOS PALSAR Level 1.1 with scene id ALPSRP062077060 which taking place in Cirebon Regency with acquisition date 25 th March 2007 and it is still not projected and calibrated. Beam mode is PLR 21.5, data type complex real 32 and the product is single look complex. The ASF software will produce in output data type multi look amplitude.
After calibrate this ALOS PSR 1.1 2007/03/25 then four polarization results can be viewed in Figure 3. ASF can produce sigma, beta, gamma, amplitude or power value from these kind of SAR data, next figure will show that ALOS image converted into sigma nought value.

Process with ASF ALOS data raw digital number become sigma value and the description of above figure from the left to right are ALPSRP062077060-P1.1__A_SIGMA-AMP-HH, HV, VH and VV. This scene still not geometric corrected but the software estimated center scene location in latitude and longitude: -6.444800, 107.722000.

3.1.1 Radar data for ALOS PALSAR quad polarization level 1.5
ALOS data for (HH, HV, VH and VV) in Riau Regency (Figure 4), Sumatera Island Indonesia on 26th April 2009 and the first figure is still not converted to radar backscatter coefficient.
After converted from Amplitude into sigma nought value in desibel unit then we can see the result in Figure 5 below.

Using SNAP software convert to sigma nought for every band and digital number for each band has change to desibel. This change can be seen in next statistic report (Figure 6) where the histogram, minimum, maximum, mean and standard deviation value displayed.
Figure 6. Sigma Nought (a) HH, (b) HV, (c) VH and (d) VV

Figure 7 is polarimetric decomposition with Sinclair method and the color is produced in lexicograph color coded.

Figure 7. ALOS Sinclair Polarimetric Decomposition and Alibrated

3.1.2 Radar data for sentinel 1 C band with VV polarization

SNAP display the Sentinel 1 C- band in Sigma Nought value in left image and for the right image is displayed in amplitude value.

Figure 8. Sentinel 1 Before Calibrated (a) and After (b)
Sentinel 1 radar image with VV polarization has been calibrated with the output sigma nought, the radar sentinel is Interferometric Wide and the acquisition date on 5th February 2015 in Aceh Regency, North Sumatera Indonesia. Figure 8 is one of the third from the real image size and it is not yet reprojected, that is why the picture is still not north map oriented.

3.1.3 Radar data for ALOS PALSAR Level 1.5 with HH polarization.

Figure 9 are visualization of ALOS Level 1.5 with scene id ALPSRP050697120, north map oriented and 50N NUTM. The region area is banjarmasin South of Kalimantan and image acquistion date on 6th January 2007. Beam mode is Fine Beam Single 34.4 HH, data type is Gamma (db) in integer 16, format is CEOS L1, high resolution and single polarization.

![Figure 9. ALOS before calibrated formula ENVI applied (a) and after (b)](image)

After applying formula of calibration to get new value then the scene image change into the next image, Figure 10 is the image before formula calibration applied (left image) and after calibrated (right image).

![Figure 10. Before (a) and after (b) Calibration Formula Applied](image)

Figure 11, the left image is statistic report for ALOS PALSAR HH L1.5 before calibration process and for the right image is after process. We can see minimum and maximum value has change from 0 to -114.230560 and 65535 to 13.852707.
Figure 11. Statistic Report Before Claibrated (a) and After (b)

Figure 12. Unsupervised Classification ISO

Unsupervised Classification with ISO-Data method is produce the classification result which have retrieve purely from the backscatter coefficient itself. This process condition is the state where the computer has self organized for each unique pattern characteristic. By setting in its deafult value used by ENVI such as number of class minimum 5 and the maximum 10, maximum iteration 1 time, changing treshold 5 percent, maximum class standar deviation 1 unit, maximum class distance 5 units and maximum number of merge pairs are 2. This classification still using ALOS data pure machine computation and the condition still not affected by human analysis. As you can see in Figure 12, water classes still mix with land or vegetation object.

3.2 Discussion

L-Band HV polarization is more sensitive to vegetation rather than L-Band HH, Figure 13 below is ALOS PALSAR with HH polarization in the left image and HV for the right image.
Also according to (Shimada, M. 2009) HV is not sensitive to the vertical structures of the tree regrowth after clear cut and to rough surfaces. This sensitivity behaviour is very important to detect deforested area. Image with HV polarization can detect fire scars more sensitive than HH polarization. Cross polarization (HV or VH) is very sensitive to vegetation objects. Figure 14 is ALOS PALSAR with combination Band HH, HV and Ratio (HH and HV) in Riau Area, Sumatera Island, Indonesia (2009).

Comparative decomposition (Sinclair, Pauli, Cloude-Pottier, Freeman-Durden, Yamaguchi) produce best analysis to determine which polarization will give a best object detection. Figure 15 consist of four composition from left side (2) HH, HV, ratio then (4) Sinclair, (7) Pauli and (8) Freeman-Durden Decomposition. From the each picture we can see image that give an optimum classification result. Below is the picture of ALOS data quad polarization in Riau Regency, Sumatera Island Indonesia on 26th April 2009.

Fine Beam Single and Dual frequently used for forest monitoring because its polarization, HV is more sensitive to forest clear cut monitoring than HH. HV is not too sensitive to the vertical structures of the tree regrowth after clear cut and rough surfaces. HH slightly sensitive to vertical structure and wet condition of the soil which is very important for recognizing a deforested area. HV also show greater sensitivity than HH for detecting fire scar. Some examples indicate that HV or Fine Beam Dual has better performance rather than Polarimetry (PLR), like detect a fire scars object. Two possible reasons are that the HV of FBD has a lower Noise-equivalent Sigma Zero than the HV of PLR, since the latter is contaminated by the Range Ambiguity of a like component (because of the twice-larger Pulse Repetition Frequency (PRF) of PLR as compared with that of FBD), and that the larger change in Normalized Radar Cross Section (NRCS) appears with larger incidence angles, for which PLR is limited by its small angle 21.5° from nadir while the FBD is operated with an off-nadir of 34.3°. PALSAR is operationaly monitoring deforestation and surface deformation, also required much more computation time rather than JERS because of longer azimuth time. (Shimada, M. 2009).
4 CONCLUSION

Calibration formula to derive gamma nought and polarimetric decomposition is an efficient tools to determine vegetation object. This object like forest, deforest or burnt forest area will be easily analyzed by using Sinclair method for its decomposition. Copolarization and cross polarization have their own capabilities in detect several vegetation object.

5 REFERENCE


