AN OPTIMUM TOTAL NUMBER OF CLASSES OF THE UNSUPERVISED WISHART CLASSIFER FOR FULLY POLARIMETRIC SAR IMAGE DATA

Hiroshi Ohkura[a], Motoo Ukawa[b] and Yoshio Yamaguchi[c]

[a] Professor, Department of Global Environment Studies, Hiroshima Institute of Technology, 2-1-1 Miyake, Saeki-ku, Hiroshima, 731-5193, Japan; Tel: +81-82-921-5462; E-mail: h.ohkura.x3@it-hiroshima.ac.jp

[b] Principal Senior Researcher, Volcano Research Department, National Research Institute for Earth Science and Disaster Prevention, 3-1 Tennodai, Tsukuba, Ibaraki, 305-0006, Japan; Tel: +81-29-863-7536; E-mail: ukawa@bosai.go.jp

[c] Professor, Faculty of Engineering, Niigata University, 8050 Ikarashi 2-no-cho, Nishi-ku, Niigata, 950-2181, Japan; Tel: +81-25-262-6752; E-mail: yamaguch@ie.niigata-u.ac.jp

KEY WORDS: SAR, Polarimetry, Unsupervised classification, Volcano

ABSTRACT: An optimum total number of classes of the unsupervised classifier is derived for fully polarimetric SAR image data. The classifier is based on the ISODATA method with the Wishart distance. The optimum total number is fixed by inspecting results with which two sets of different initial clusters converged. Filling in the details, we vary the total number N of classes of each set simultaneously, and the optimum number is the N which makes the concordance rate of the converged results maximum. In order to evaluate this methodology, we check whether the characteristics of the converged classes can be interpreted by the four-component scattering model. For the fully polarimetric SAR image of ALOS PALSAR, the characteristics can be clearly interpreted by the model.

1. INTRODUCTION

Fully polarimetric SAR (POLSAR) image data of earth observation satellites, which are widely supplied to people of remote sensing, have increased to those of ALOS PALSAR, RADARSAT-2 and TerraSAR-X. Because POLSAR data has much more information than the single polarimetric one, excellent methods for the POLSAR data to classify terrain and land use have been proposed (Lee, 1999, Lee, 2004, Xu, 2005, Cao, 2007).

Lee et al. proposed the k-means method with the Wishart distance as an unsupervised classifier (Lee, 1999). This classifier is useful when supplemental information of the analyzing area is inadequate and in case of emergency. However it is difficult to fix the total number of classes or clusters for each image data because we cannot find out the optimum number a priori. In this report, we develop the k-means method to the ISODATA method and propose a robust method to fix the optimum total number of the class.

2. WISHART DISTANCE

The Wishart distance d defines distance between coherency matrices T of pixels of the POLSAR image data. The distance d between an ensemble $\langle T \rangle$ of the coherence matrix of n pixels and the matrix V_m which is a cluster mean of the mth class is expressed by the following equation(Lee 1999).

$$d\left(\langle T \rangle, V_m\right) = \ln\left|V_m\right| + \mathrm{Trace}\left(V_m^{-1}\langle T \rangle\right) \quad (1)$$

3. AN OPTIMUM TOTAL NUMBER OF CLASSES

Since the ISODATA method is based on an iteration algorithm, a converged result is not necessarily the best one which represents characteristics of the image data optimally. To search the optimum result, we evaluate the converged results and fix an optimum number of classes. A criterion for the evaluation is whether two different initial clusters of the same total number of classes converge on a same result.

The two different initial classes are made up as followings.

1) By using the same method Lee et al. introduced (Lee, 1999), we divide the three dimensional space to N subspaces which is defined by the three axes of "the entropy", "the average of the alpha angle" and "the total power". Each pixel of the image is segmented into the classes according to the subspace which the pixel belongs to (Figure 1).

2) After extracting some number of pixels from the whole image by random sampling, we put them in the N classes using the hierarchical clustering based on the Ward method (Figure 2).

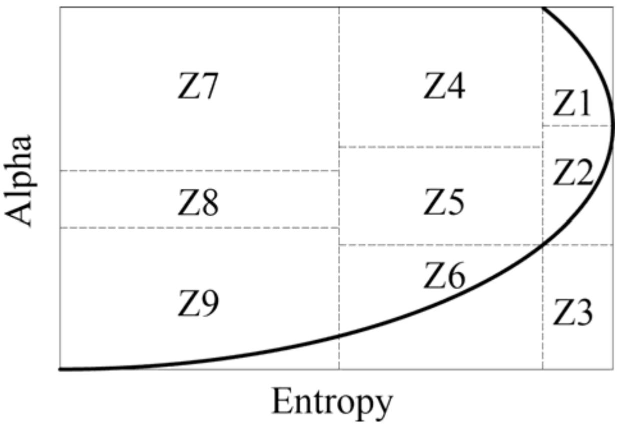

Figure 1. Initial clusters by domain segment-ation of the H-α plane (N=9).

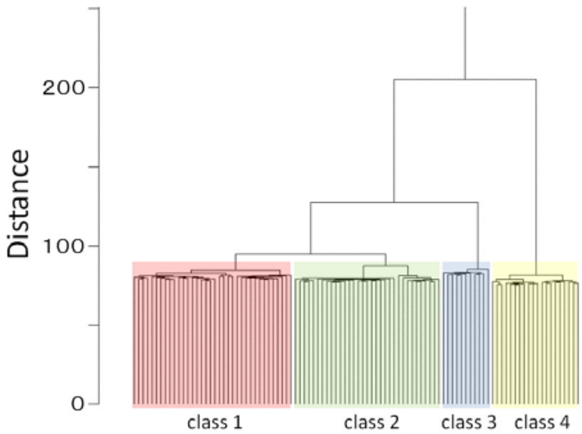

Figure 2. Initial clusters by the hierarchical clustering based on the Ward method (N=4).

We vary the total number N of classes of each initial set simultaneously, and the optimum number Nc is the N which makes a concordance rate of converged results maximum. The concordance rate C is defined by the following equation.

$$C = \frac{1}{N_p} \sum_{i=1}^{N} \max_{j=1,N} \left(M_i \cap S_j \right) \tag{2}$$

where Np is the total number of pixels, subscripts i and j represent the i th class and the j th class respectively, and M and S are two sets of classified results corresponding to the two initial classes respectively.

In addition, to keep the total numbers of classes of M and S at same number, following two points are modified from the general IODATA method.

1) "Merging of classes" and "splitting of a class" are executed at every iteration.

2) "Removal of minimum clusters and isolated members" is not executed.

The modification 2) is for not missing changes of a very small domain at the time of the time series analysis.

4. APLICATION TO IMAGE DATA OF ALOS PALSAR

We analyzed the POLSAR image data of ALOS PALSAR of Shinmoe-dake volcano in Kyushu, Japan on June 10, 2009 by the proposing classifier. A study area is a rectangle of about 30 km× about 30 km putting the volcano at the center (Figure 3).

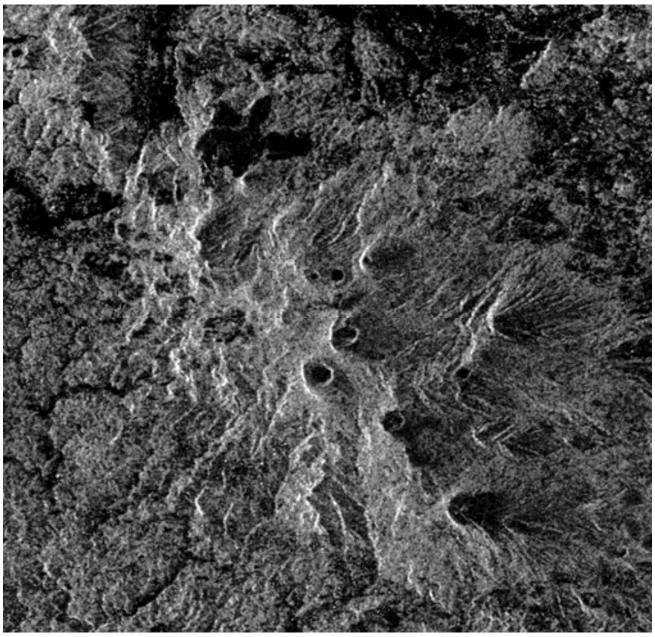

Figure 3. The original SAR image (total power) of the Shinmoe-dake.

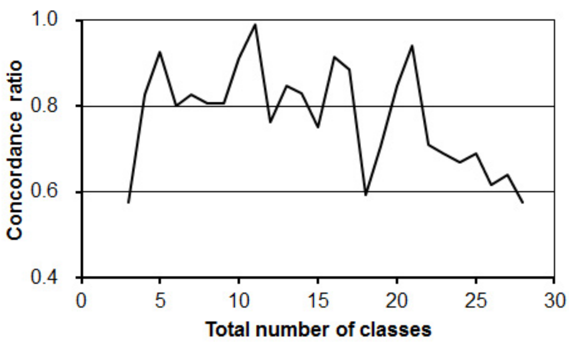

Figure 4. Concordance ratio versus the total number of classes.

Figure 4 shows variation of the concordance rate C versus the class number N. When N is 11, C becomes the maximum value of 0.99, and as N increases more, C trends toward decrease. This shows that the optimum total number of classes Nc is 11. Figure 5 is the classified result of the optimum total number.

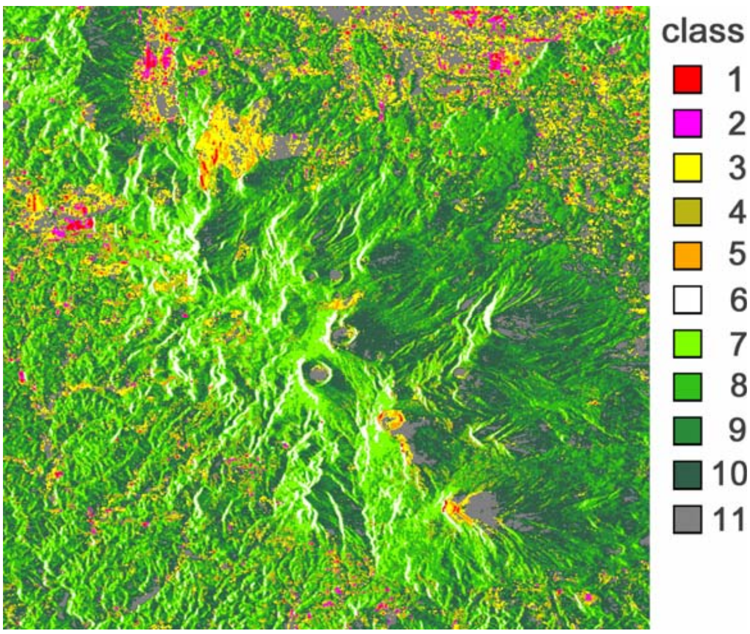

Figure 5. The clustering result of 11 classes.

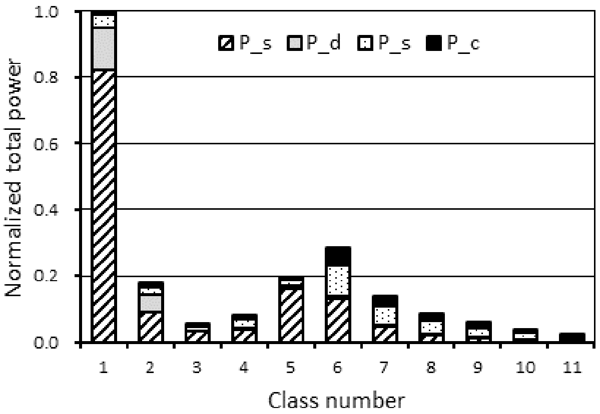

Figure 6. Normalized total power of the 11 classes.

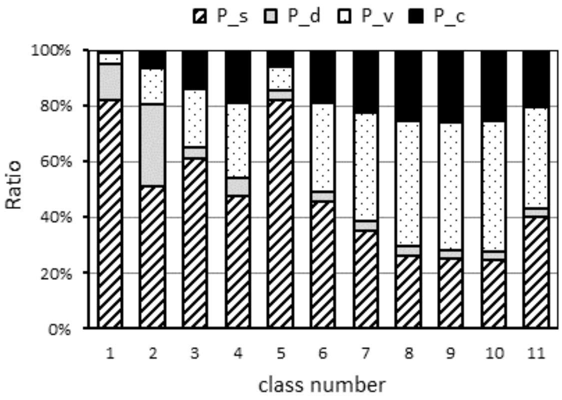

Figure 7. The ratio of the four components of the classes

Figure 6 and Figure 7 show the total power of each class and the power component of the four-component scattering model (Yamaguchi, 2005). Characteristics of the converged classes of the number Nc can be clearly interpreted with these figures.

Class 1 has the largest value of total power Tp. Eighty percent of the Tp is occupied by surface scattering power P_s. This class represents targets whose backscatter Radar Cross Section (RCS) is extremely large and this targets spread across urban areas. Class 2 has the fourth largest Tp, and the ratio of double-bounce scattering power P_d is larger than other classes. This class represents an urban area. Class 3 has small Tp. Sixty percent of the Tp is occupied by the P_s, and represents a bare area and a grass field. Class 4 has little smaller Tp. The deviation of the four power components is small. Trees, grass land and buildings coexist in the area of this class. Class 5 has the third largest Tp. Eighty one percent of the Tp is occupied by the P_s. This class represents targets whose surface faces to the satellite or where reflection of an odd number of times occurs. Those targets appear throughout and around urban areas. Class 6 has the second largest Tp and represents the area of layover on a mountainous area. Class 7 has the large value of Tp and has the slightly larger ratio of volume scattering power P_v. This class represents the forest on the slope facing to the satellite. Class 8, 9 and 10 have the largest ratio of the P_v (about 45 percent) and the composition rate of the four-components is almost identical among these classes. However values of Tp decrease in turn from the class 8 to the class 10 because these classes appears in the same order from the higher to lower part of the slopes which face back to the satellite. As descending to a lower slope, the incident angle increases and the value of Tp decreases. Class 11 has the lowest value of Tp. This class represents a water surface, a paddy field and the shade portion of the RADAR wave such as at the back of the mountain ridge and inside of the crater.

5. CONCLUSIONS

An optimum total number of classes of the unsupervised classifier with the Wishart distance can be derived for fully polarimetric SAR image data. The optimum total number is fixed by inspecting results with which two sets of different initial clusters converged. We vary the total number N of the classes of each set simultaneously, and the optimum number Nc is the N which makes the concordance rate of the converged results. Characteristics of the converged classes of ALOS PALSAR image data can be clearly interpreted by the four-component scattering model.

ACKNOWLEGEMENTS

This research was accomplished by the activity of the Group of Analysis of Satellite Data, the Coordinating Committee for Volcanic Eruption Prediction, Japan.

REFERENCES

Cao, F., Hong, W., Wu, Y. and Pottier, E., 2007. An unsupervised segmentation with an adaptive number of clusters using the SPAN/H/α/A space and the complex Wishart clustering for fully polarimetric SAR data analysis. IEEE Trans. GRS, 45(11), pp.3454-3467.

Lee, J., Grunes, M., Ainsworth, T., Du, L. and Schuler, D., 1999. Unsupervised classification using polarimetric decomposition and the complex Wishart classifier. IEEE Trans. GRS, 37(5), pp.2249-2258.

Lee, J., Grunes, M., Pottier, E. and Famil, L., 2004. Unsupervised terrain classification preserving polarimetric scattering characteristics. IEEE Trans. GRS, 42(4), pp.722-731.

Yamaguchi, Y., Moriyama, T., Ishido, M. and Yamada, H. 2005. Four-component scattering model for polarimetric SAR image decomposition. IEEE Trans. GRS, 43(8), pp.1699-1706.

Xu, F. and Jin, Y., 2005. Deorientation theory of polarimetric scattering targets and application to terrain surface classification. IEEE Trans. GRS, 43(10), pp.2351-2364.