Analysis of the Influence of Land Cover Conditions on SAR Backscatter Using Simultaneous SAR and TM Data

同時取得の SAR と TM データを用いた SAR 後方散乱に対する
土地被覆状況の影響の解析

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Abstract : Multitemporal SAR images are considered to be the practical data sources for monitoring of land cover changes in the tropical regions due to their capability of all weather data acquisition. In order to study the physical meanings of the change of SAR backscatter, regression analysis was performed between radar backscatter and soil wetness index (SWI) and perpendicular vegetation index (PVI) extracted from Landsat TM data, by using JERS-1 SAR and Landsat TM data acquired on the same day. The results suggest that the change of the radar backscatter is related to the changes of both soil moisture and of vegetation coverage conditions.

和文要旨

時系列の SAR 画像は、その全天候型という特徴から、熱帯地域での土地被覆変化のモニタリングのための有効なデータソースとしての利用が期待される。本研究では、SAR 画像における後方散乱強度の変化の物理的な意味を調べるため、同じ日に取得された JERS-1/SAR とランドサット TM 画像を用いて、SAR の後方散乱強度と TM データから抽出される土壤湿潤指数 (SWI) および植生指数 (PVI) との間で回帰分析を行なった。その結果、SAR の後方散乱の変化が土壌水分と植被状況の両者の変化に関係することを示唆する結果を得た。

1. Introduction

The synthetic aperture radar (SAR) data by the Japanese Earth Resources Satellite 1, JERS-1, are expected to be used effectively for the purpose of monitoring of land cover conditions in the tropical regions since the optical sensor data are difficult to obtain in a timely manner due to cloudy weather conditions while the SAR data can be obtained repetitively in any weather condition. The authors have conducted the preliminary analysis of the multitemporal SAR data at the Central Plain in Thailand and the results suggests that those data contain much information about the seasonal variations in SAR backscatter for various land cover types. However, the physical meanings of the varia-

tion in the SAR backscatter are still not so clear and the studies on the physical meanings of the changes of the SAR backscatter still seem quite important for practical use of multitemporal SAR images. The intention of this study is thus to investigate some physical meanings of the change of the SAR backscatter by a combined analysis with Landsat TM data and JERS-1 SAR data on the same day.

2. Examples of the seasonal changes of SAR backscatter

Plate 1 shows examples of three JERS-1 SAR images over a part of the Central Plain in Thailand. The data were acquired on March 16th, April 29th and September 8th in 1993, in the middle stage of the dry season, in the end of dry season and in the middle of the rainy season, respectively. The three SAR images were co-registered each other and a MAP filter¹⁾ was applied in order to remove speckle noise. Many types of the seasonal changes of the

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September 8th, 1993

JERS-1/SAR : MITI/NASDA retains ownership of data.

Plate 1 Multitemporal SAR images of the Central Plain of Thailand acquired on March 16th, April 29th and September 8th, 1993.

April 29th, 1993

Plate 2 Landsat TM image acquired on April 29th, 1993 (color composite of band 2,3 and 4).

backscattering intensity are seen in Plate 1 and the typical examples among them are summarized in Fig.1. In Fig.1 the change of the backscatter is represented by the Normalized Radar Cross Section (NRCS) which can be derived from the SAR level 2.1 product using the calibration coefficient given by National Space Development Agency of Japan (NASDA)²⁾.

The interesting changing patterns in Fig.1 are the patterns for two kinds of paddy fields (Paddy-1 and Paddy-2). The change for Paddy-1 is seen mainly in the central part of the images. It was confirmed by ground survey that in the middle of March the area is almost covered by dry bare soil with no vegetation. This area is known as a typical rice production area where tall rice is planted in the rainy season. These facts suggest a possibility that the increase of the SAR backscatter from March/April to September is caused by the increase of vegetation coverage.

The change for Paddy-2 is found mainly in the right side of the images. Plate 2 shows a Landsat TM image acquired on the same day (April 29th) as the SAR data. In this TM image, almost all areas to right side can be still identified as bare soil, where the brightness of color is different among the locations. This suggests that the increase of the backscatter from March to April is not caused by the change of vegetation coverage but by the change of soil condition. One possible change of the soil condition is the change of soil moisture since the difference of soil moisture appears as the difference of the brightness of color in TM images, although another possibility is that surface roughness is changed since the end of April is the season for land reclamation of the rice fields.

3. Combined analysis of SAR and TM

3.1 Soil wetness index (SWI) and perpendicular vegetation index (PVI) by TM

The parameters for indicating the differences in soil moisture and vegetation coverage can be estimated in the two dimensional plane composed by

the intensity of TM band 3 (visible-red) and band 4 (near infrared)^{3)~5)}. Fig.2 shows the result of the extraction of the two parameters; soil wetness index (SWI) and perpendicular vegetation index (PVI) from the TM data. The SWI is defined as the regression line derived from points regression of bare soils, shown as black squares in Fig.2. The SWI line indicates the degree of soil moisture content. Soil dryness index (SDI) is a soil parameter which is more often used, but in this case however, SWI was defined as the reverse feature of SDI for the convenience of comparison with the SAR backscatter.

The PVI is defined as the line perpendicular to the SWI line and indicates the degree of vegetation coverage. The maximum value of PVI corresponds to the averaged value of PVI for the areas fully covered by vegetation, which are indicated by black circles in Fig.2. Forest or orchard areas were selected as the fully covered vegetation. It should be noted that the absolute values of these two indexes are not important but only the directions of the two lines, which can be used as measures for soil moisture condition and vegetation coverage.

3.2 Regression analysis between SAR backscatter and SWI or PVI

Regression analysis was performed between SAR backscattering intensity and SWI and PVI using the JERS-1 SAR and Landsat TM image pair acquired on the same day (April 29th, 1993). The two images were co-registered each other and twenty pairs of the average values in 5 x 5 window areas for SAR and TM images which were sampled from the bare soil areas and the vegetated areas were used for the regression respectively. The samples were selected in a manner that they distribute randomly in a space but cover from low to high SWI/PVI values.

Fig.3 and 4 show the results from the regression analysis between SAR-NRCS and SWI and between SAR-NRCS and PVI respectively. In both figures, correlation is moderate, $R = 0.42$ for SWI and $R = 0.62$ for PVI. Fig.3 suggests a saturated condition of SAR-NRCS to SWI for dry bare soil since the NRCS value is limited to about -16 dB even if SWI

is very small and this situation makes correlation lower. Another reason for this relatively low correlation between SWI and NRCS is considered to be that the SAR backscatter is strongly affected by surface roughness and this surface roughness is much variable according to the variation of the surface condition of bare soil as described in chapter 2.

In Fig.4 there are seen relatively large variations of NRCS for large PVI samples, which is one of the factors decreasing correlation between PVI and NRCS. This variation is considered to be caused by the differences of vegetation types, that is, the SAR backscatter for grasses is lower than that for trees even the area is fully covered by vegetation.

Although the actual correlations for SWI and PVI were moderate due to various factors affecting to the SAR backscatter besides SWI and PVI, the results basically support the assumptions on the physical meanings of the SAR backscatter change described in chapter 2. From the regression analysis it is obvious that the SAR backscatter is related to both of soil moisture and vegetation coverage conditions and not uniquely to either of two. This fact is quite important for the interpretation of SAR multitemporal images.

4. Summary

Regression analysis was performed between SAR backscatter and soil wetness index (SWI) and perpendicular vegetation index (PVI) by using JERS-1 SAR and Landsat TM data acquired on the same day. The results suggest that the change of the SAR backscatter is related to the changes of both of soil moisture and vegetation coverage conditions. An detailed study with ground survey for the land cover condition in the rainy season is necessary to determine the physical meanings of SAR backscatter change and the use of multitemporal SAR images for monitoring of land cover change.

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Fig.1 Typical seasonal changes of the SAR backscatter.

Fig.2 Soil wetness index (SWI) and perpendicular vegetation index (PVI) derived from Landsat TM data acquired on April 29th, 1993.

Fig.3 Result of the regression analysis between SAR backscatter (NRCS) and SWI.

Fig.4 Result of the regression analysis between SAR backscatter (NRCS) and PVI.

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