# Rice Crop Monitoring Using ENVISAT-1/ASAR

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**Abstract:** Hiroshima Institute of Technology (HIT) is operating the direct down-link of ENVISAT-1/ASAR in Japan. This study focuses on the validation for rice crop monitoring by means of multi-temporal and multi-angle ASAR alternating cross polarization mode (VV/VH) images over several passes. In this study, the validation is performed by means of overlaying Sigma-Nought (σ0) images in the above each mode captured during the rice growing cycle with ground truth measurements such as height of crop, ratio of crop vegetation cover and leaf area index (LAI). As the result of this study, it is indicated that the growth process of rice crop can be estimated by means of multi-temporal and multi-angle ASAR alternating cross polarization data.
**Keywords:** ENVISAT-1/ASAR, Alternating cross polarization mode (VV/VH), Backscatter change during the rice growing cycle.

## 1. Introduction

Rice is the most important agricultural product in Japan and a lot of man-power is still necessary to monitor the rice crop in whole areas of Japan every year. Satellite remote sensing images, such as LANDSAT/TM or SPOT/HRV, have been expected to be used to monitor the rice crop so far. However, these optical sensors hardly have been able to get necessary data at a suitable timing due to cloud cover problem during rice planting season in Japan. Therefore, space-borne synthetic aperture radar (SAR) images might be practical data sources to realize rice crop monitoring by remote sensing in Japan.

According to high sensitivity of C-band radar image to surface roughness conditions, the backscatter intensity of RADARSAT(H/H) and ERS-1,2/SAR(V/V) images changes greatly from non-cultivated bare soil condition before rice planting to inundated condition just after rice planting [1]. But C-band SAR data tends to saturate backscatter from the early stage of the growth[2]. It is difficult to monitor the rice crop growth by only co-polarization SAR data.

In this study, the authors investigated the availability of monitoring by temporal change of alternating cross polarization (AP) mode (VV/VH) SAR backscatter including different incidence angle mode of ENVISAT-1/ASAR simultaneously with ground truth measurements in rice-planted fields.

## 2. Test Site and Test Data

The test sites were Higashi-Hiroshima City (Hachihonmatu-cho and Kurose-cho) and Aki-Takata City (Yachiyo-cho) in the western part of Japan as shown in Fig. 1. These regions have comparatively large paddy fields around Hiroshima City, and also the rice planting period is almost same. Fig. 2 shows ground photographs in each test site when rice ear was growing on August, 2005.

The test data were multi-temporal and multi-angle ASAR AP mode (VV/VH) images. All ASAR data were directory downlink by ground station of Hiroshima Institute of Technology (HIT). Table 1 shows ASAR data (19 scenes), taken from 4 June to 15 September in 2005. The image swath is IS2 to IS5, corresponding to center incidence angle from 22.8° to 37.6° .

The ground truth measurements were also performed simultaneously with ENVISAT-1/ASAR observation. In each ground truth data, physical parameters (height of crop, ratio of crop vegetation cover and leaf area index (LAI)) relevant to rice growth conditions were measured and also ground photographs were taken just above the rice crop by a digital camera as shown in Fig. 3. As for rice field on the beginning of June just after the planting, water was drawn in. Blade of rice crop grows well in July. Rice ear bore fruit at the beginning of August. Then the harvest started on August 17 in Kurose-cho.

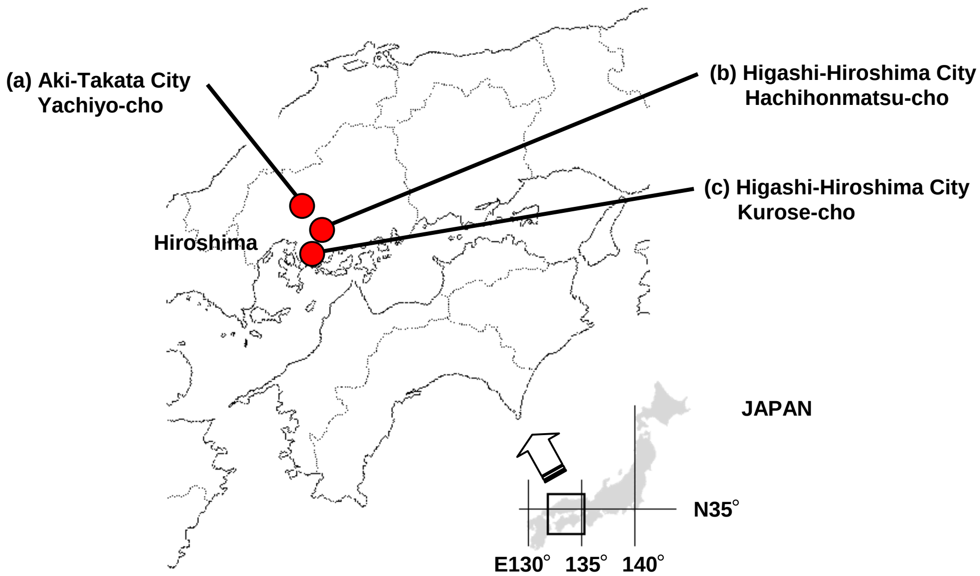
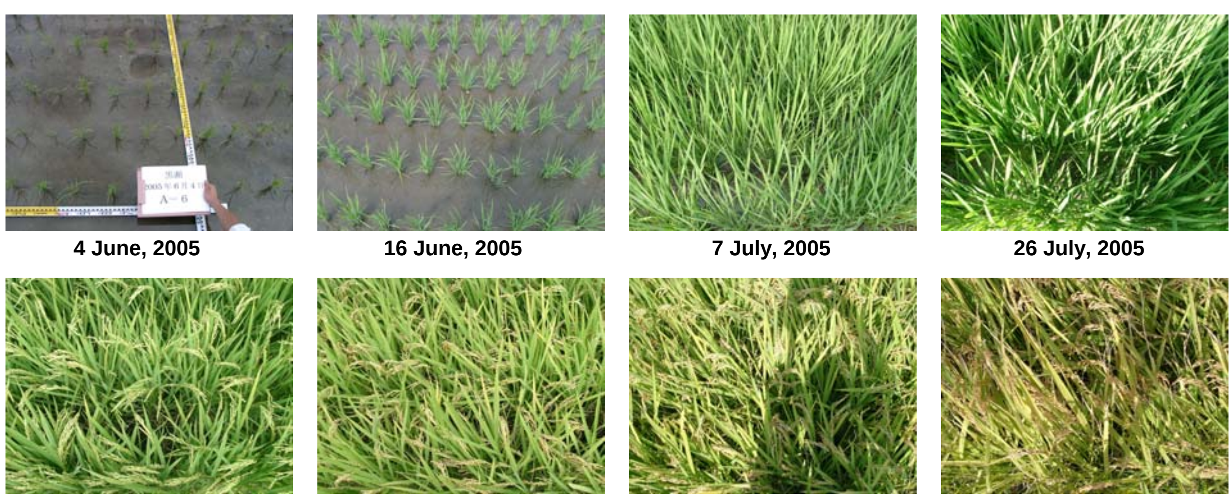



**Fig. 1. Test sites.**

**(a) Yachiyo-cho** **(b) Hachihonmatsu-cho** **(c) Kurose-cho**

**Fig. 2. Ground photographs in each test site.**



**4 June, 2005** **16 June, 2005** **7 July, 2005** **26 July, 2005**

**11 Aug., 2005** **26 Aug., 2005** **29 Aug., 2005** **15 Sep., 2005**

**Fig. 3. Ground photographs of rice growth process in Kurose-cho.**

**Table 1. ENVISAT-1/ASAR data used for the study.**

| Observation date | Polarization | Swath | Orbital path |
|---|---|---|---|
| 4-Jun-2005 | VV/VH | IS5 | Ascending |
| 4-Jul-2005 | VV/VH | IS4 | Descending |
| 6-Jul-2005 | VV/VH | IS3 | Ascending |
| 7-Jul-2005 | VV/VH | IS2 | Descending |
| 9-Jul-2005 | VV/VH | IS5 | Ascending |
| 20-Jul-2005 | VV/VH | IS5 | Descending |
| 22-Jul-2005 | VV/VH | IS2 | Ascending |
| 23-Jul-2005 | VV/VH | IS3 | Descending |
| 25-Jul-2005 | VV/VH | IS4 | Ascending |
| 8-Aug-2005 | VV/VH | IS4 | Descending |
| 10-Aug-2005 | VV/VH | IS3 | Ascending |
| 11-Aug-2005 | VV/VH | IS2 | Descending |
| 13-Aug-2005 | VV/VH | IS5 | Ascending |
| 24-Aug-2005 | VV/VH | IS5 | Descending |
| 26-Aug-2005 | VV/VH | IS2 | Ascending |
| 27-Aug-2005 | VV/VH | IS3 | Descending |
| 29-Aug-2005 | VV/VH | IS4 | Ascending |
| 12-Sep-2005 | VV/VH | IS4 | Descending |
| 14-Sep-2005 | VV/VH | IS3 | Ascending |
| 15-Sep-2005 | VV/VH | IS2 | Descending |

## 3. Data processing

### 3.1 Processing of ASAR Data

ENVISAT-1/ASAR data were processed by VEXCEL SAR Processor to make Precision Image (PRI) product, 2 look amplitude data (16-bit) with 12.5m pixel size. Then ASAR images were geometrically rectified in the local domain around each test site.

The radar backscattering coefficient( $\sigma^0$) was estimated as Eq. (1)

$$\sigma^{\mathbf{0}} = 10 \log_{10}(\boldsymbol{DN}^2 / \boldsymbol{K} * \sin \boldsymbol{I}) \qquad [\text{dB}] \qquad (1)$$

where

$\boldsymbol{DN}$ is digital number of an amplitude image pixel.
$\boldsymbol{K}$ is linear scaling factor.
$\boldsymbol{I}$ is incidence angle at the each pixel.

The average backscattering coefficient for a small area of interest was estimated as Eq. (2)

$$\sigma^{\mathbf{0}} = 10 \log_{10}( \Sigma (\boldsymbol{DN}^2)/\boldsymbol{n} / \boldsymbol{K} * \sin \boldsymbol{I_d}) \qquad [\text{dB}] \qquad (2)$$

where

$\boldsymbol{n}$ is number of pixels.
$\boldsymbol{I_d}$ is average incidence angle.

### 3.2 Comparison between ground truth data and SAR backscatter in rice fields

Fig. 4 shows the temporal variation of plant height during rice growing cycle. Plant height increases quickly until 70cm on the beginning of July. After that it grows up to approximately 90cm. Fig. 5 shows the relationship between backscattering coefficient and plant height. The correlation between $\sigma^0$ of V/V and plant height was high, however, it saturated with approximately -6dB. On the other hand, the correlation between $\sigma^0$ of V/H and plant height was lower than the case of V/V.

Fig. 6 shows the temporal variation of the ratio of crop vegetation cover. The ratio of crop vegetation cover was obtained from digital photograph taken in paddy field of test site. The ratio was calculated by making binary image classified into two categories such as rice plant and soil in paddy field. Fig. 7 shows the relationship between backscattering coefficient and the ratio of crop vegetation cover. The correlation between V/V backscatter and ratio of crop vegetation cover was high, however, it saturated with approximately -6dB. On the other hand, the relationship between V/H backscatter and ratio of crop vegetation cover was observed as a liner regression without the above saturation during the rice growing cycle.

Fig. 8 shows the temporal variation of the LAI. LAI was measured by plant canopy analyzer. Fig. 9 shows the relationship between backscattering coefficient and LAI. Both backscatter of V/V and V/H show the increasing of $\sigma^0$ until LAI became approximately 2.5, then those became saturated.

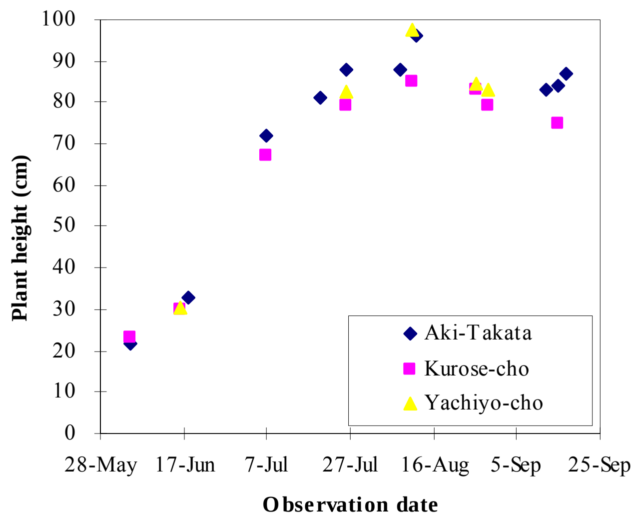



Fig. 4. Temporal variation of plant height.

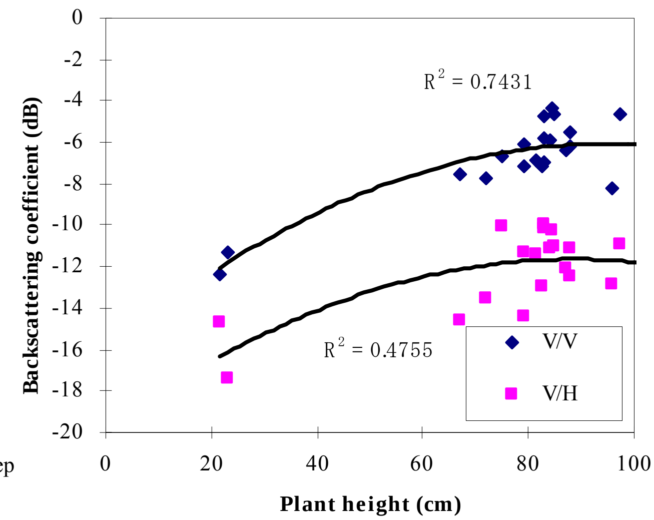



Fig. 5. Relationship between backscatter and plant height.

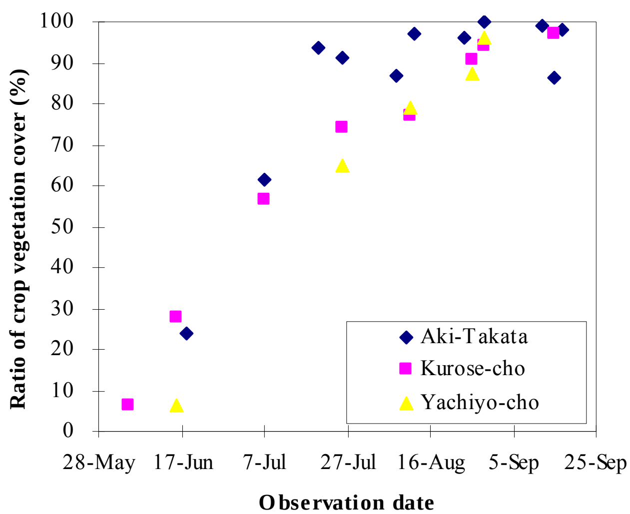



Fig. 6. Temporal variation of the ratio of crop vegetation cover.

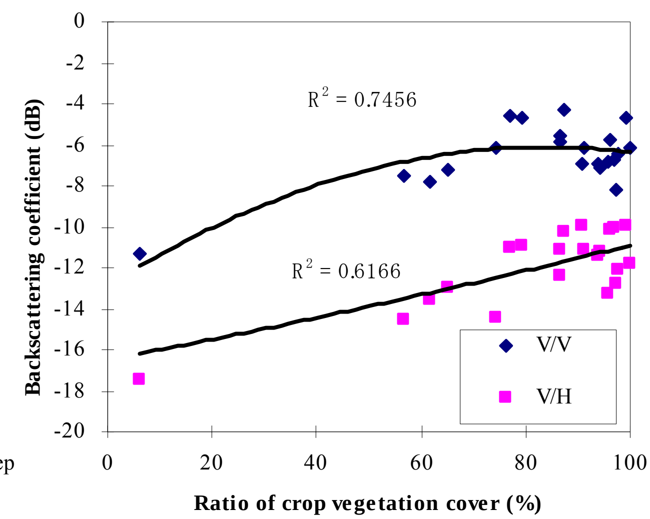



Fig. 7. Relationship between backscatter and ratio of crop vegetation cover.

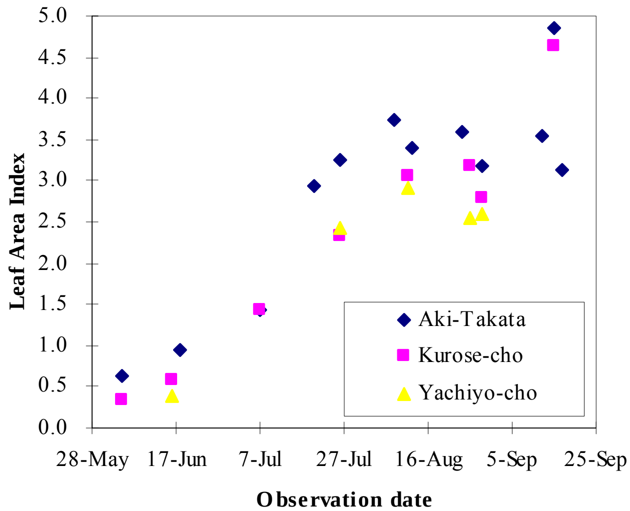



Fig. 8. Temporal variation of LAI.

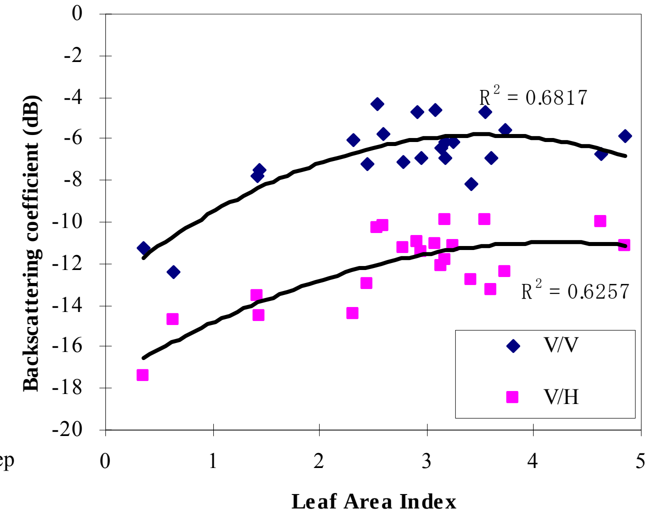



Fig. 9. Relationship between backscatter and LAI.

### 3.3 Extraction of temporal changes of SAR backscatter in rice fields

Fig. 10 shows the comparison of the backscatter of image swath (IS) from IS2 to IS5. As a preprocessing, test data were converted into averaged data set on each IS mode over three test sites. Differences of SAR backscattering coefficients were comparatively small in comparison with each incidence angle. However IS5 that the incidence angle is large tended to saturate compared with other IS on middle of Jul. In the rice crop monitoring by RADARSAT, high incidence angle mode (F3) was saturated compared with low incidence angle at early stage [3]. More detailed verification is necessary for this tendency.

Fig. 11 shows the temporal changing patterns of SAR backscatter by ENVISAT-1/ASAR in rice-planted area. Generally, the distribution of $\sigma^0$ of V/V is depicted higher than one of V/H. $\sigma^0$ of V/V shows a significant change of backscatter in an early period from the beginning of June to the beginning of July. $\sigma^0$ of V/V changed from -12 to -6dB approximately. After that, $\sigma^0$ of V/V remain to saturate until middle of September. On the other hand, $\sigma^0$ of V/H increased in linear during the rice growing cycle. $\sigma^0$ of V/H changed from about -17 to -11dB.

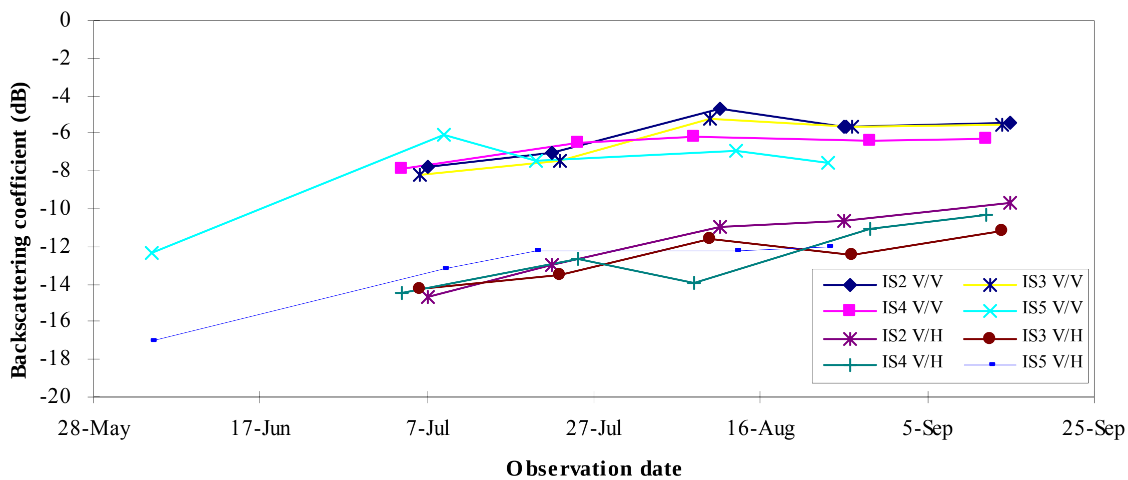



Fig. 10. Comparison of backscattering coefficients of image swath from IS2 to IS5.

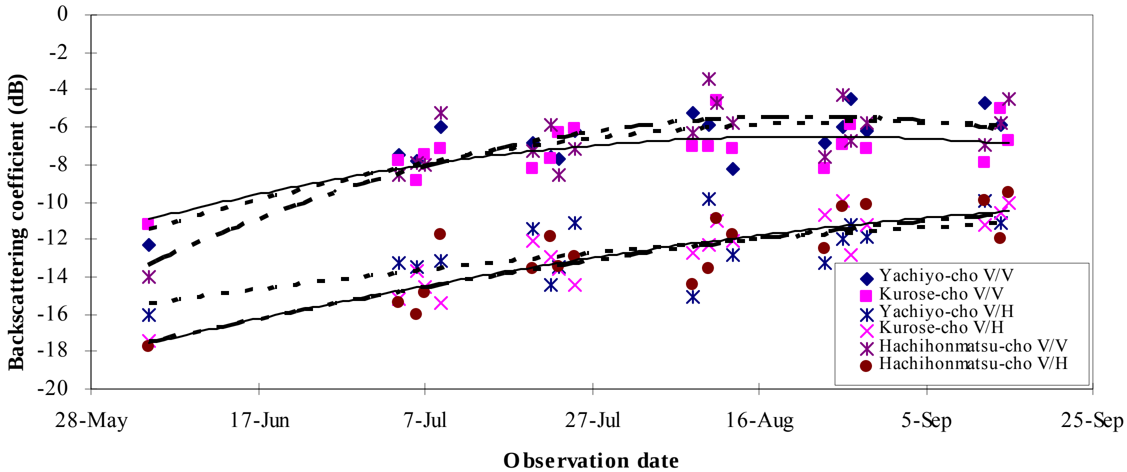



**Fig. 11. Temporal changes of SAR backscattering coefficient.**

## 4. Conclusions

Rice crop monitoring was attempted using multi-temporal and multi-angle ENVISAT-1/ASAR alternating cross polarization mode (VV/VH) images directory down-linked in HIT ground station. As for correlation between SAR backscattering coefficient and ground truth measurements (height of crop, ratio of crop vegetation cover and leaf area index (LAI)), correlation coefficients between V/V and ground truth measurements was higher than one of V/H, and also SAR backscattering coefficient of V/V was distributed that is higher than one of V/H. Differences of SAR backscattering coefficients were comparatively small in comparison with each incidence angle in this study.

On the other hand, backscatter of V/V polarization indicated saturation by -6dB in an early period. However, backscatter of V/H polarization was linearly measured during the rice growing cycle. This result shows the effectiveness of alternating cross polarization mode (VV/VH) for the rice crop monitoring during the growing cycle.

This study was able to verify the possibility of rice crop monitoring by using ENVISAT-1/ASAR VV/VH. The further study on rice crop monitoring by other alternating cross polarization modes (VV/HH, HH/HV) should be continued.

## Acknowledgement

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