Images Difference of ASAR Data for Rice Crop Mapping in Fuzhou, China

WANG Xiaoqin, SHI Xiaoming, LING Feilong

Key Laboratory of Spatial Data Mining & Information Sharing of Ministry of Education, Spatial Information Research Center of Fujian Province, Fuzhou University, 523 Gongye Road, Fuzhou 350002, China

© Wuhan University and Springer-Verlag Berlin Heidelberg 2010

Abstract This paper introduces ENVISAT ASAR data application on rice field mapping in the Fuzhou area, using multi-temporal ASAR dual polarization data acquired in 2005. The procedure for ASAR data processing here includes data calibration, image registration, speckle reduction and conversion of data format from amplitude to dB for backscatter. The backscatter of rice increases with the rice growing stages, which was much different from other land covers. Based on image difference techniques, 6 schemes were designed with ASAR different temporal and polarization data for rice field mapping. Difference images between images in the early period of rice crop and growing or ripening period, are more suitable for rice extraction than those difference images between different polarizations in the same date. The most accurate result of late rice extraction was achieved based on the difference of HH polarization data acquired in October and August. Therefore, for rice field mapping, the temporal information is more important than polarization information. The data during the early growing season of rice is very important for high accuracy rice mapping.

Keywords ENVISAT ASAR; rice crop mapping; images difference; Fuzhou

CLC number P237.3; TP79

Introduction

Rice area monitoring is of particular significance in China and many other Asian counties, as the crop is grown in the rainy season, and occupies one of the largest share of the food grains. The conventional methods for rice monitoring are based on ground-collected statistics, which have been proved to be time consuming, inaccurate and expensive. Space-borne remote sensing offers an effective alternative to these traditional methods through operational, weather independent systems utilizing synthetic aperture radar technology. These techniques allow an efficient mapping and monitoring of rice crops over large areas at regular and frequent intervals.

Since the launch of the European ERS-1/2 satellites, Japanese JERS-1 satellite and the Canadian RADARSAT satellite, a number of studies have shown the usefulness of SAR data for the detection of rice crop. The radar backscatter coefficient of rice fields appears to have a significant temporal variation, so most of the studies use multi-temporal SAR data for rice field mapping. Taking advantage of the strong temporal variation of radar backscatter of paddy fields, Le Toan et al. (1997) used the multi-temporal information of ERS-1 SAR data for rice crop mapping. Ribbes et al. (1998) assessed the
use of RADARSAT-1 data for rice field mapping and monitoring based on the significant temporal variation of radar backscatter coefficient of rice fields, and compared with the ERS data. Shao et al. (2001) examined the backscatter behavior of rice fields, as a function of time using multi-temporal RADARSAT-1 data and produced a rice-type distribution map with different life spans. As a result of the limitation of SAR data sets, the majority of researches were carried out by using the single polarization SAR data. Some studies have shown that the accuracy of rice mapping will be better when using multi-polarization SAR data.

The advanced SAR (ASAR) on board ENVISAT as the preceding SARs on ERS-1/2 has multi-polarization capability, which provides more polarization information than those of ERS-1/2. Therefore, using the multi-temporal ASAR data, the accuracy for rice crop classification may be improved. Ling et al. (2006) and Wang et al. (2008) used multi-temporal ASAR Alternating Polarization Mode products (VV and VH) acquired in 2004 for early rice mapping in Fuzhou. Chen et al. (2007) used the combination of ASAR HH and HV polarization data between two acquisition dates to monitor rice crop growth in Guangdong Province, China.

In this paper, temporal variations of ASAR data with VV and HH polarization were analyzed in 2005 late rice growth season in Fuzhou, Fujian Province, China. A methodology based on image difference for rice crop mapping is proposed.

1 Study area and dataset analysis

1.1 Test site characteristic

The study area lies in Fuzhou, downstream of the Minjiang River and the east coastal zone of Fujian Province in southeastern China (Fig.1(a)), with an area of 11968 km². It lies between 117°34′-119°05′ E and 24°22′-25°56′ N, belonging to the subtropical region. The main land use types are arable land, garden plots, forest and urban area. The warm climate (the average annual temperature is 19.6 °C) and abundant precipitation are propitious to various crop types characteristic of warm and humid sub-tropical regions. Rice is one of the most stable crop types.

In Fuzhou, there are two crop cycles yearly, early season rice (spring) and late season rice (autumn). In this paper, we focus on the late season rice. Seedlings of autumn rice were transplanted in rice fields filled with water at the early part of August, then harvested at the end of November to early December.

1.2 Data description

The Envisat ASAR data are the main satellite data resource used in this study. Three pairs of ASAR data acquired on 5th August (20050805), 9th September (20050909) and 14th October (20051014) 2005 were used for the late season rice mapping. The data are all C band, same incidence swath from 19.2° to 26.7°, and VV&HH polarization data from ascending orbit with 25 m resolution. Fig.1(b) was the ASAR composition image of the study area.

According to the rice growth calendar, 5th August is in the early growth stage and the rice fields are flooded. Images acquired on 9th September, and 14th...
October respectively are in rice well growing and ripening stages correspondingly. 1:50000 DEM data, geocoded ETM+ data acquired in 2000 and the CCD image of CBERS-02 (the 2nd China-Brazil Earth Resource Satellite) acquired in 2005 are also used for ASAR data processing and analysis.

2 Methodology

Analysis and classification of satellite images, particularly SAR, require powerful processing techniques to achieve satisfactory classification results. The whole process include ASAR data pre-processing, backscatter coefficient analysis and image difference schemes designing.

2.1 ASAR data pre-processing

Multi-temporal ASAR image preprocessing includes raw data input to the image processing software, radiometric calibration, image registrations, speckle suppression, and conversion of data format from amplitude to DB.

In order to be able to compare images from different dates and for quantitative measurement, radiometric calibration should be applied first. Because further steps like image registration and speckle suppression have to be processed, we took the linear scale and not DB scale as the calibration result.

SAR analysis often requires registration of images of the same scene. Two common methods were taken: image correlation matching and using ground control points (GCPs). All images acquired were in the same mode, with no rotation, skewing, etc. involved. Hence, registration between the images can be achieved simply by shifting the image frame along the azimuth and range direction. Image co-registration was done by correlation matching first, then by using GCPs to register these ASAR images to a geocoded ETM+ image of 2000.

Filtering reduces the effects of speckle and improves visual interpretation, but more importantly improves the accuracy of the estimate of backscatter at each pixel. For handling the multi-temporal ASAR data, a multi-channel filtering has been used [17]. The idea of filtering is to linearly combine N images from the same scene to produce N speckle reduced images. Multi-channel filtering represents a better preservation of edge and texture features than other filters. After multi-channel filtering, a Gamma-Map filter with 3×3 window was applied next in order to improve the radiometric resolution.

If quantitative measurement of radar brightness over point and distributed targets is the objective, the output of the calibrated result should be given in decibels (DB). The data can be converted from linear ($\sigma^0$) to decibels $\sigma$ (DB) by the following formula:

$$DB = 10.0 \times \log_{10}(\sigma^0)$$

2.2 Backscatter coefficient analysis

The temporal behaviors of VV and HH backscatter for some typical land covers are shown in Fig.2. Four land cover types were considered, which were rice field, urban area, water and forest. The backscatter behaviors of the four land cover types were different. For rice fields and urban area, the values of HH polarization were bigger than those of VV polarization; while for water and forest, the values of HH polarization were lower than those of VV polarization.

Urban area had the highest backscatter and changed little. Water bodies have low backscatter. However, due to wind effect, it had various backscatter coefficients. The backscatter of forest is low and temporally stable, while backscatter of rice is temporally variable.

The backscatter of rice in both polarizations increases as time goes by, which matches the regulation of rice growing. In the early growing stage, the backscatter values of both VV and HH were lowest in the four land covers, but the values increased rapidly after that stage and larger than those of water and forest. The backscatter increased more rapidly during early

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig2}
\caption{Temporal behaviors of backscatter of typical land covers from ASAR data}
\end{figure}
growing stage from August to September than the growing stage from September to October. The values of HH polarization increased more than those of VV. It has very low backscatter at the early growing season, but has higher backscatter at other growing periods. For VV polarization, from $-13.777 \text{ DB (Aug.)}$ to $-8.521 \text{ DB (Sep.)}$ to $-7.857 \text{ DB (Oct.)}$, and for HH polarization, from $-13.575 \text{ DB (Aug.)}$ to $-7.700 \text{ DB (Sep.)}$ to $-6.298 \text{ DB (Oct.)}$. The difference between HH polarization of August and October is the most significant. The temporal change of rice field from early stage to other stage is most different with other land covers. Therefore, whether the data during rice early growing season could be acquired is very important for rice mapping.

### 2.3 Difference schemes of backscatter coefficient

In order to map rice fields from SAR data, Le Toan et al. (1997) developed a more robust methodology based on the temporal variation of the backscatter of rice fields compared to other land-cover types, using ERS-1 SAR data. The methodology is based on image difference technique and used to quantify the temporal changes between several SAR acquisitions.

The image difference technique was adopted in our study. In this study, 6 schemes of change difference image were designed with ASAR different temporal and polarization data (see Table 1). The difference images were derived from the difference between each pair of ASAR images. For example, in Scheme 1, the difference image was the difference of VV polarization acquired in September and August. We experimented with not only the difference images of different date with same polarization (Scheme 1 to 4), but also the difference images of the same date with different polarization (Scheme 5 and 6).

#### Table 1  Six schemes of difference image

| Scheme No. | 1  | 2  | 3  | 4  | 5  | 6  |
|------------|----|----|----|----|----|----|
| Difference image | 09VV-08VV | 09HH-08HH | 10VV-08VV | 10HH-08HH | 08HH-08VV | 09HH-09VV |

The results indicate that the rice fields are distinct in difference images (Fig.3). Rice fields in the difference images between 09VV and 08VV (Fig.3(a)), 09HH and 08HH (Fig.3(b)), 10VV and 08VV (Fig.3(c)), 10HH and 08HH (Fig.3(d)), 08HH and 08VV (Fig.3(e)), 09HH and 09VV (Fig.3(f)), are quite distinct. In Figs.3(a), (b), (c) and (d), the rice fields were very bright, but mixed up with some water. While in Fig.3(e) and Fig.(f), the rice fields were not very bright, and were mixed up with urban and dry land, it is not

![Fig.3  Difference images with distinct rice areas](image-url)
serious for rice extraction.

From the above analysis, it was found that difference images with same polarizations between images in early period rice and growing or ripening period of rice, were more suitable for rice extraction than those difference images between different polarizations in the same date. Therefore, for rice field mapping, the temporal information is more important than polarization information.

3 Results and discussion

3.1 Rice field mapping

Our study area has a hilly terrain, and most of the rice fields are in quite small sizes. Besides, some other land covers (such as urban, dry land and water) were mixed up with rice in the difference images. It is impossible to derive the rice crop using only the difference image. Thus, HH and VV polarization images with the same date of difference images, as well as the slope information calculated from DEM were also used here.

The principle is to threshold the difference image to identify image pixels that change by more than the threshold value. The selection of threshold values depends on the nature and magnitude of the expected changes\textsuperscript{[5]}. For rice fields, the threshold must be optimized considering the data acquisition and local crop calendar constraints. The threshold of difference images varies from 1DB-2DB to 10DB-11DB. For the different polarization with the same date, the thresholds were small, but for the same polarization with different date, the thresholds were much bigger. For data acquired in August and October, a threshold of 11DB was used.

Once the different thresholds were built, according to the difference image, HH & VV polarization images and the slope information, the rice field/non-rice field map could be easily derived. The rice field thematic images with the six schemes of difference images are shown in white and non-rice area in transparent in Fig.4, in which the background is the VV polarization image.

3.2 Accuracy assessment and discussion

The accuracy assessment of rice field extraction was carried out based on the visual interpretation from the CCD image of CBERS-02 acquired on December 15th and survey records. The spatial resolution of CBERS-02 CCD is 19.5 m. The producer’s accuracy and the user’s accuracy are generated from the error matrix, and the Kappa coefficient expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification.

For the six different schemes, the different accuracy of rice field extraction are listed in Table 2. From Table 2, it was found that the result from the difference image of 10HH and 08HH was the best, in which, the highest Kappa coefficient reached 0.9321, and the producer’s and user’s accuracy were both larger than 85%. The others are lower. The lowest Kappa coefficient is from the result of difference image of 09HH and 09VV, only 0.6034.

From the above analysis, it also showed that the temporal information is more important than polarization information for rice field mapping. The image difference technique of same polarization with different date is a good solution for rice crop mapping, especially the difference image calculated between the ripening stage and early stage is most suitable.

The results confirm that C-band SAR data appear to be a very promising alternative to optical remote sensing data in developing an operational system for monitoring rice growth in cloudy and rainy Southern China, where regular optical remote sensing data are difficult to acquire.

4 Conclusion

The aim of this study is to assess the procedure of Envisat ASAR data for rice field mapping in Fuzhou area. The procedure includes the pre-processing phases and the methodology for rice field mapping. Every phase within the pre-processing is indispensable, especially for quantitative measurement, none can be neglected. The methodology of threshold for rice field mapping, based on the backscatter temporal change and difference scheme, has been successfully applied to ASAR data according to the fact of the study area. Difference image with same polarization between images in the early period of rice and grow-
ing or ripening period of rice, shows significant changes of rice crop. At present, the results appear promising with a satisfactory agreement, compared to the survey records and optical images. Furthermore, this study appears very promising in providing quantitative information on rice growing areas and besides, the application on rice mapping studied here is applicable to other places in South China. The use of different kinds of SAR data (e.g. PALSAR data) can be foreseen for these purposes.

Fig. 4 Rice field mapping (white area) using different difference images

Table 2 Accuracy of the extraction of rice field with different schemes

| Scheme          | Producer’s accuracy | User’s accuracy | Kappa coefficient |
|-----------------|---------------------|-----------------|-------------------|
| 09VV-08VV       | 89%                 | 79%             | 0.8980            |
| 09HH-08HH       | 82%                 | 76%             | 0.8263            |
| 10VV-08VV       | 88%                 | 77%             | 0.8688            |
| 10HH-08HH       | 94%                 | 87%             | 0.9321            |
| 08HH-08VV       | 85%                 | 75%             | 0.9123            |
| 09HH-09VV       | 61%                 | 50%             | 0.6034            |

Acknowledgements

The authors would like to thank ESA for the ASAR data. This work was carried out in the framework of the MOST and ESA cooperative programme—Dragon Programme.

References

[1] Holecz F, Dwyer E, Monaco S (2000) An operational rice field mapping tool using spaceborne SAR data [C]. ERS-ENVISAT Symposium, Goteborg

[2] Kurosu T, Fujita M, Chiba K (1995) Monitoring of crop rice from space using the ERS-1 C-band SAR [J]. IEEE Trans. on Geoscience and Remote Sensing, 33(4): 1092-1096

[3] Kurosu T, Fujita M, Chiba K (1997) The identification of rice fields using multi-temporal ERS-1 C band SAR data [J]. Int. J. of Remote Sensing, 18(14): 2967-2984

[4] Chakraborty M, Panigrahy S, Sharma S A (1997) Discrimination of rice crop grown under different cultural practices using temporal ERS-1 synthetic aperture radar data [J]. ISPRS Journal of Photogrammetry & Remote Sensing, 52: 183-191

[5] Le Toan T, Ribbes F, Wang L F, et al. (1997) Rice crop mapping and monitoring using ERS-1 data based on experiment and modeling results[J]. IEEE Trans. on Geoscience and Remote Sensing, 35(1): 41-56

[6] Ribbes F, Le Toan T (1998) Mapping and monitoring rice crop with RADARSAT data [C]. IGARSS’98, Seattle
[7] Panigrahy S, Manjunath K R, Chakraborty M, et al. (1999) Evaluation of RADARSAT standard beam data for identification of potato and rice crops in India [J]. *ISPRS Journal of Photogrammetry & Remote Sensing*, 54: 254-262.

[8] Ribbes F, Le Toan T (1999) Rice field mapping and monitoring with Radarsat data [J]. *Int. J. of Remote Sensing*, 20(4): 745-765.

[9] Shao Y, Fan X (2001) Rice monitoring and production estimation using multitemporal RADARSAT [J]. *Remote Sensing of Environment*, 76: 310-325.

[10] Chakraborty M, Manjunath K R, Panigrahy S, et al. (2005) Rice crop parameter retrieval using multi-temporal, multi-incidence angle Radarsat SAR data [J]. *ISPRS Journal of Photogrammetry & Remote Sensing*, 59: 310-322.

[11] Choudhury I, Chakraborty M (2006) SAR signature investigation of rice crop using RADARSAT data [J]. *Int. J. of Remote Sensing*, 27(3): 519-534.

[12] Shao Y, Liao J, Fan X, et al. (2002) Studies on rice backscatter signatures in time domain and its applications [J]. *Journal of Remote Sensing*, 6(6): 440-450 (in Chinese).

[13] Zeng Q, Ma H, Zhang T (2000) Simulation and analysis for the microwave backscattering coefficient of rice [J]. *Journal of Remote Sensing*, 4(1): 14-21 (in Chinese).

[14] Ling F, Wang Q, Wang X (2006) Identification of rice crop using ENVISAT ASAR in Fuzhou, Fujian Province, China [C]. Proceedings of the 2005 Dragon Symposium - Dragon Programme Mid-Term Results, Santorini, Greece.

[15] Wang X, Wang Q, Shi X, et al. (2008) Rice field mapping and monitoring using ASAR data based on principle component analysis [J]. *Transactions of the CSAE*, 24(10): 122-126 (in Chinese).

[16] Chen J, Lin H, Pei Z (2007) Application of ENVISAT ASAR data in mapping rice crop growth in southern China [J]. *IEEE Geoscience and Remote Sensing Letters*, 4(3): 431-435.

[17] Quegan S, Yu J (2001) Filtering of multichannel SAR images [J]. *IEEE Transactions on Geoscience and Remote Sensing*, 39(11): 2373-2379.