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Visualization of Flood Monitoring in the Lower Reaches of the Mekong River

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ABSTRACT

One of the most useful SAR data utilization is the natural hazard monitoring because SAR enable to acquire the data even under the storm or the darkness. The purpose of this study is easily to understand the flood monitoring of JERS-1 SAR by visualized method. The study area, which is annually covered by flooding water for a long period, is situated at the lower reaches of the Mekong River. This condition, however, is convenient to JERS-1/SAR observation because of having 44-day repeat cycle for the targeted area. All of eight scenes, which were obtained from July 5, 1997 to May 9, 1998, were used in this study. On the power images the flooding areas are shown as the dark part, which means low back-scattering coefficient. The process of this method is as follows; 1). Register the two images using more than 10 Ground Control Points (GCPs). 2). Select the pixels less than -13.4dB. 3). Subtract the Digital Number (DN) between the registered pixels. 4). Assign the rainbow colors to each pixel derived from the subtraction. 5).Detect the flooding area on the colored images. Ground truth was carried out to verify the result of image analysis. This study is showing that L-band, HH polarization microwave of JERS-1/SAR is effective to identify the flooding area and, even 44-day interval. This visualized method is clearly indicating that the flooding water does not directly come from the river bank but gradually from upstream and spread to the huge low land area.

KEYWORDS: flood monitoring, Mekong River, JERS-1/SAR, subtraction

1. INTRODUCTION

The characteristics of remote sensing are correcting the data from extensive area with equivalent quality in a short time. Furthermore, it is very important to observe the same area repeatedly. This is useful for monitoring the global environmental problem as we understand. The observation by optical sensor is applied for this purpose, however, it is hampered by weather condition in many cases. When composed to JERS-1, Synthetic Aperture Radar (SAR) could minimize the obstacle such as clouds, rainfall and darkness. So, it is applicable for the monitor on flood, landslide, volcanic activity and topographic deformation by earthquake etc. It could also possible to apply for monitor on deforestation and desertification.

There are several studies about flood monitoring using SAR data. Hess et al. (1990) reviewed radar detection of flooding beneath the forest canopy. Hess et al. (1995) showed that HH polarization in L-band is the most optimum for the delineation between flooded forest and non-flooded forest using SIR-C. Honda et al. (1997) estimated flood areas in the central plane of Thailand using JERS-1/SAR and Landsat TM data. Pope et al. (1997) showed that the best radar parameter for flood monitoring in marsh is C-band phase difference. Adam et al. (1998) made a flood map with the speckle-reduced scenes using RADARSAT data. Ping et al. (1999) detected the flooding areas in the lower reaches of Mekong River using ERS and RADARSAT data. These data summarized that SAR is useful to monitor flooding area. In this study we used 8 scenes of JERS-1/SAR data acquired in every repeat path (44 days) during the period from July 5, 1997 to May 9, 1998, in order to extract the flood area and some difference of ground conditions.

2. OUTLINE OF THE STUDY AREA

2.1 Location and geographic aspect

The study area is covering approximately 75 km^2 in the lower reaches of the Mekong River in southern part of Vietnam (Fig.1). The area is located in 30 km southwest from Ho Chi Min City, the largest city in Vietnam. The study area is flat alluvial lowland, and the area is submerged by flooding water for three to four months annually. It is clearly divided into rainy and dry seasons in a year caused by monsoon. The rainy season is from May to October, and dry season is from November to April in general. Annual precipitation is approximately 1,400-1,500mm and average temperature is 25-29°C.

Most of un-paved roads and paths are not accessible in rainy season. A lot of branches of the Mekong River and irrigation systems are the most important traffic network for the local communities. While the study area in question is affected by strong tidal range, because it is about 50km away from sea Especially, during rainy season, it is the heaviest influence caused by flood and tidal currents.

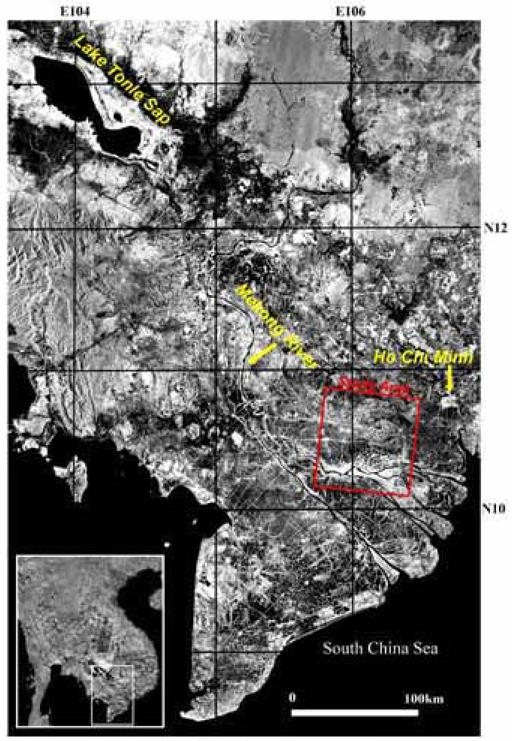

Fig.1 Location map of study area

2.2 Topography and Geology

The study area lies in lowland mostly, which is composed of alluvial materials transported by the Mekong River. And most of the study area is below one or two meters high above sea level. Natural levees have several kilometers in width along the Mekong River. These levees are two to three meters higher than the surrounding lowland. Most of the study area are covered by Holocene sediment. Some outcrops of the upper Pleistocene sediments, which is composed of sand and gravel with yellow-gray in color in the bottom part, are found to be small hills sporadically in northern part of the study area. Sometimes local people inhabit in those areas to avoid the flooding affection.

2.3 The type of flood occurrence

It is well known that flooding water during August to November covers the study area annually. Flooding water does not come from the main stream of the Mekong River to the study area, but from the tributaries or canals in the upper reaches of Mekong River. The flood flows down very slowly to the lowland. There is one-month difference on the highest level of water in the Mekong River at two points, which are located at 100km and 2400km from the mouth of the Mekong River approximately (Oya et al., 1984).

3. THE METHOD OF PROCESSING

3.1 Data applied for the study

JERS-1/SAR acquired 27 data over this area during his mission. In 1997 the flood monitoring was intended to perform JERS-1/SAR data observation. The eight scenes were acquired in every 44 days by his suspension in 1998. Date of acquisitions were as follows; Jul.5, Aug.18, Oct.1, Nov.14, Dec.28 1997, Feb.10, Mar.26, May 9 1998. Each data is generated by 16 bit signals with 12.5m pixel ground resolution in level 2.1 (power image level). The data are converted to sigma-0 for correlating the back scattering on the image.

3.2 Method to extract flooding area

The difference of back scattering is shown on the image as the brightness of gray in color. The darker parts indicate that the conditions of the surface ground are very smooth such as water surface. The method required for monitoring is to extract the area submerged by flood between two images in an orbital current. Comparison with the same pixel on two images, decreasing of back scattering is indicating the inundated area affected by flooding on the surface ground. Generally, back scattering in different time is shown in an image assigned the colors to Red, Green, Blue. However, that image is difficult to identify the small areas of flooding. So we proposed subtraction method in this study.

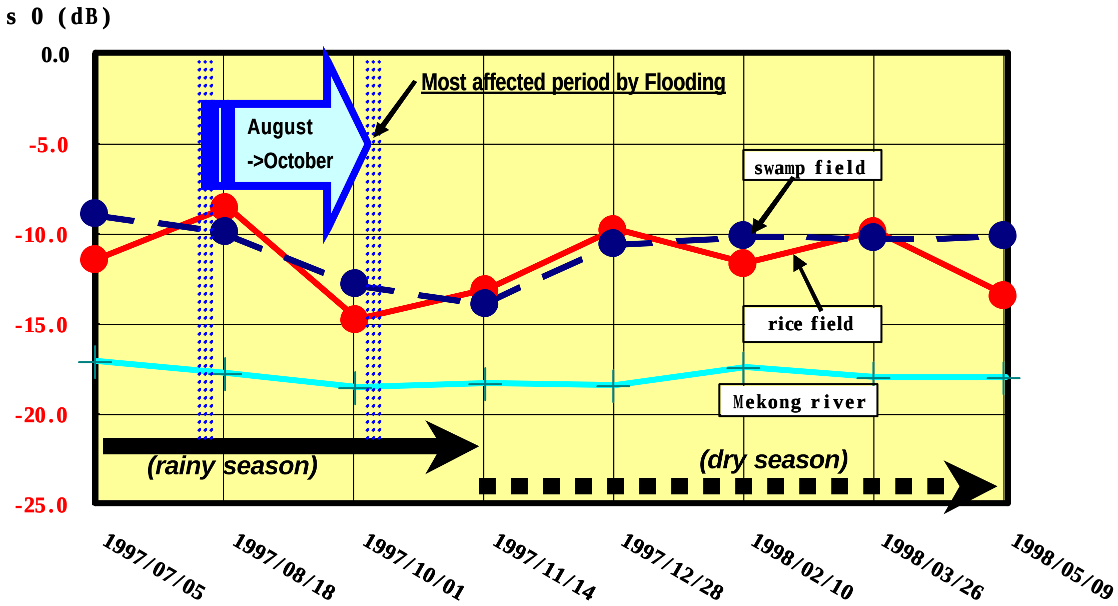

Fig.2 Seasonal variations of backscatter on the images

On the basis of the seasonal variations of back scattering on the images, the relevant threshold of inundated area was determined as –13.4 in dB (Fig.2). We extracted the pixels having below the threshold in the images firstly. And then "Subtraction" was done for this purpose, which is simple subtraction between the digital numbers (DN) of the former and latter image data acquired after 44 days. The following subtraction gave the difference of digital value between correspondent pixel in two images.

$$S_{DN} = F_{DN} - L_{DN} \quad (1)$$

Where;
S_{DN} : Digital number after subtracting
F_{DN} : Digital number on the former image
L_{DN} : Digital number on the latter image

The result of subtraction is shown in gray scale at first. After that it is converted to rainbow color to identify the submerged area clearly. However, there are no changed areas in the result image of subtraction. In that case, it is shown by gray in color to overlay the pixel data of former image on the pixel data which S_{DN} are shown within ±25 in digital value on the images. The surface condition of the area is indicated as follows;
(1) back scattering is low value. (river, irrigation canal, pond, swamp and submerged area by flood.)
(2) back scattering is high value (road, bridge, house, forest, city and village)
In order to determine the threshold value of masking image, we performed at following thresholds; ±15, 20, 25, 30 in digital values on the images. Most suitable threshold was ±25 for this purpose in this area.

4. EVALUATION

4.1 Processed data and image interpretation

Fig.3 is the result of processed data with "Subtraction" thought out here. The colors, which are shown as green yellow and red in the image, indicate the flooding area during observed period. The area shown from blue to magenta on the image is indicating the area dried up from flood for the same period. On the other hand, river, ponds, villages and natural levees were shown by similar back scattering by the "Subtraction" because there is no changes of surface condition. According to the result of this processed data, the flood occurred in the western part of the image (Fig. 3-A), as shown in red, yellow and green color. After that, the flood gradually spread to the eastern part of image (Fig. 3-B). The whole of area on the image (Fig. 3-c) was submerged by October 1st, as shown red yellow and green in color. And the western part in the image is shown as black color due to continuous submergence. Submergence continues till November (Fig. 3-C). After that submerged area was changed to dry areas shown by magenta and blue (Fig. 3-D). The most affected area is located at 5 km south of Ap Bac in the central part on the image. Periodical monitoring has been continued in this point using an installed water gauge. The area was inundated for 3 to 4 months with 1.5 to 2.5m in depth.

During dry season, color changes on the images could be indicated rice farming, such as water supply, draining,

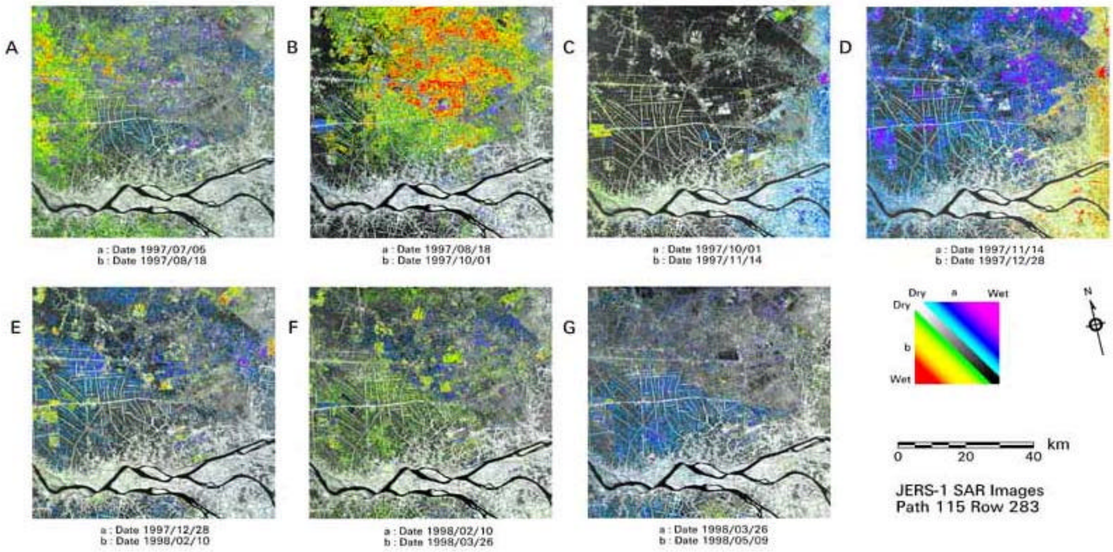

Fig.3 Transition of flooding water in study area

planting and growth of crop, etc. We found following characteristic areas on the each image. The name of those area are My Tho, Ap Ba Pho and Sung Hieu area. Two enlarged images of those areas are shown on Fig. 4. Characteristics of My Tho area are showing different color changes and different color cycle on each image. Ap Ba Pho area also shows same characteristics. However, there shows different shape of changes. Sung Hieu area shows higher back scattering on each image. The ground conditions of these areas were checked by ground truth.

4.2 Discussion of results with ground truth

To verify the generated image and the interpretation, the ground truth was carried out twice in dry (March) and rainy (October) seasons in 1999. We could observe the strong affection by flooding and rice farming conditions between the ground truth data.

1) My Tho area :

My Tho is covering about 5 x 10km that is located in the western part of the study area (Fig.4). By ground truth, we found that there is a rice-producing area on a large-scale. It is possible to harvest the rice in three or four times in a year because of ripening within 90 days. In addition, local farmer is well organized in order to make rice. This area has two kinds of characteristics as follows; a) different color changes in each images and b) different cycle of color changes from surrounding area. These characteristics were investigated by ground truth.

a) was related to the different growth of rice planting as shown by Rosenqvist (1999). Therefore, the change of color is showing homogeneous change on each image. The paddy field is normally filled with water for eight weeks in this region. In the end of the period, rice plant grows by 10 or 20 cm above the water. Even though there are dense rice plant, some pulse might be favorable for forward scattering on the water because of having strong penetration.

b) was related to the different time of sowing caused by flooding. In 1997 the time of sowing was delayed by flooding because there was strong flooding in August 1997. Therefore, there was different cycle of color changes in that area. It might be possible to

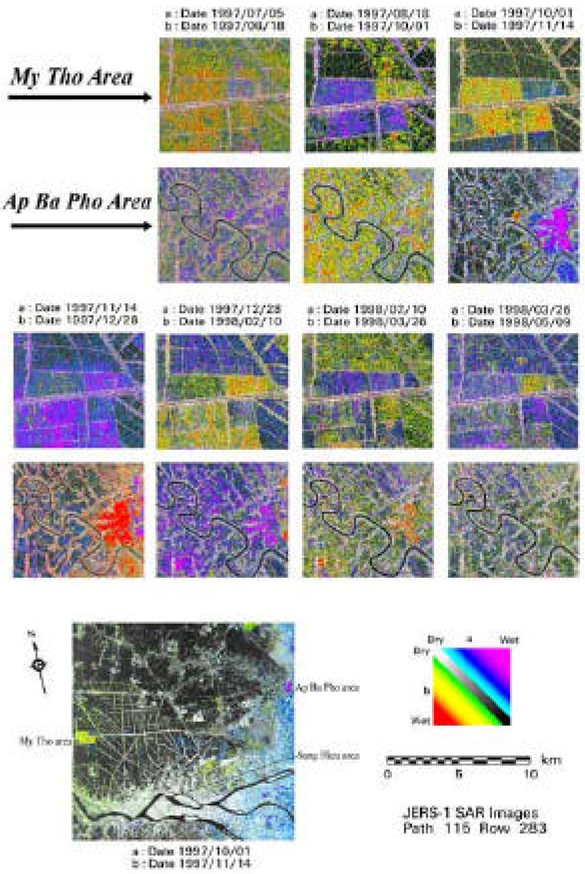

Fig.4 Seasonal variations in My Tho, Ap Ba Pho, Sung Hieu area

detect the growth change of rice plant by using this method.

2) Ap Ba Pho area :

Ap Ba Pho is covering about 2 x 4km that is located in the eastern part of the study area. It is almost flat plain and wide paddy field as My Tho. However flooding water does not come to this area frequently. This area has also two kinds of characteristics as My Tho area does. Those characteristics were also confirmed as same reasons in My Tho area. While we can recognize the different shape of color on image, which is showing irregular form as ameba-shaped, the reason was different and irregular sizes of paddy field. This area is separated into small fields, which are about 50-100m wide and 300-500m long with irregularly.

3) Sung Hieu area :

Sung Hieu is located in the lower part of the study area (Fig.4). There are many houses, trees and roads in this area that faces the Mekong River. Huge sediments transformed by the Mekong River formed natural levees, and ground surface of natural levees is higher than surrounding lowland. Accordingly, people move to these areas and there are many villages with highly-dense population because there is no covered by flooding water. This area is shown by brighter color in each image, because the back scattering from the area become stronger than other areas.

4.3 Comparison with other data

We can not compare directly this result with other data in the same period. But we referred two maps of the water level by flooding water which were made by South Vietnam Geological Mapping Division (SVGMD). The submerged area in the image (Fig..3-C: period is the longest) mostly correspond to the limited line of 0.5m depth on the contour of the map in 1994. And we tried to apply this method for the 88 days interval data in order to detect the flooding area. However, the detected area by using 88 days data might be incorrect in some area based on ground truth data. Moreover, we made transition map of flooding water in next path. And we arranged images as Fig.5. Fig.5 is showing the transition of flooding water clearly. It moved from the west to the east during July to October. And the water was staying the whole of images until November. Drying up was starting from the east rather than west on December. We can recognize the changes by different color in the images.

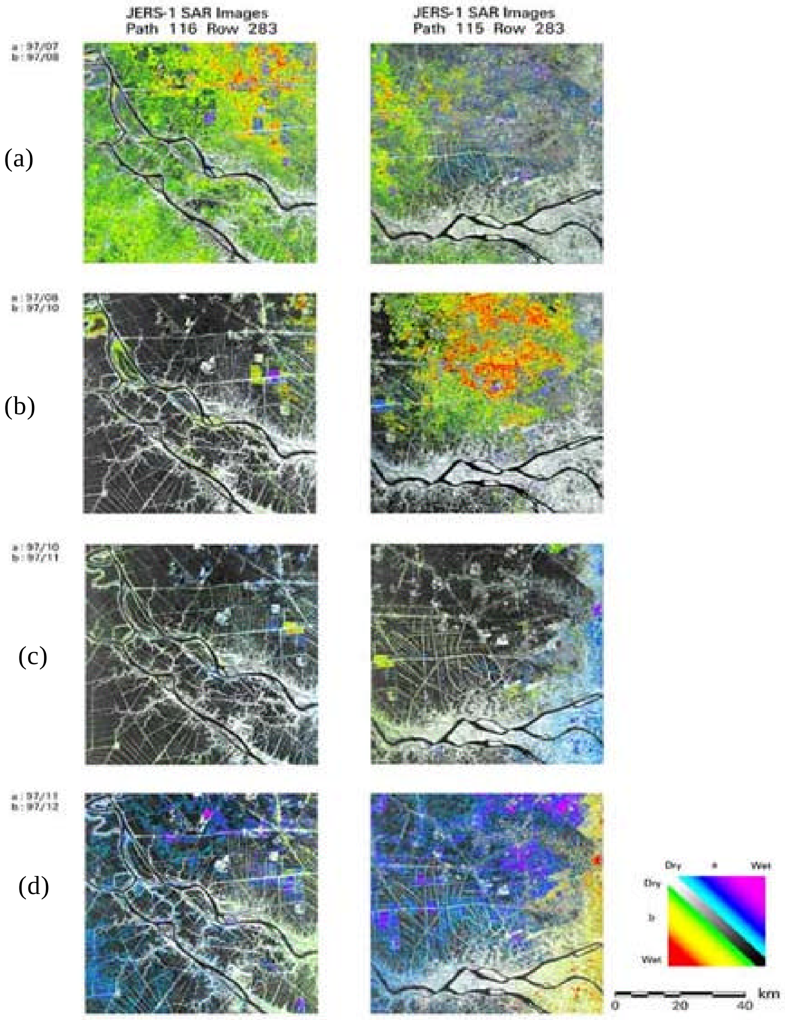

Fig.5 Transition of flooding water in study area

4. CONCLUSIONS

In this study, transition of flooding area is clearly extracted by the colored images resulting from the "subtraction" of multi temporal JERS-1/SAR data. The transition of flooding area is shown that expansion from the west to the east on Fig.3-A,B or Fig.5-(a), and submergence continued until next recurrent date (Fig.3-C or Fig.5-(c)). After that, we can identify the dry-up areas on Fig.3-D or Fig.5-(d). Thus JERS-1 repeat path each 44 days, that enables us easily to understand the outline of flooding area transition in this study area. It is successfully observed flooding even by 44 days interval data because the speed of flooding water is slowly. Moreover, the water filled in the paddy field might be favorable for forward scattering off the water surface due to the L-band penetration. However, there is a difficulty of dividing a flooding area into a paddy field because changes in same colors are recognized. In that case, it is possible to discriminate the shapes and cycles of color changes in each image. L-band SAR is applicable to flood observation. However, it is not enough to apply to the flood monitoring yet. Therefore, in more detail, study for the relationship between flood and topography is required using by DEM data. And more effective method to monitor the flooding is to determine the complicated signals of back scattering from the water surface, plants and rice. More frequent data acquisition for them could help to understand more detailed flood mechanism.

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