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FLOOD MONITORING OF MEKONG RIVER DELTA, VIETNAM USING ERS SAR DATA

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KEY WORDS

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ABSTRACT

Successful launches of space borne high resolution microwave imaging radars in recent years added a new dimension of remote sensing technology to observe the Earth. With its all-weather and day-night time imaging capability, It has an interesting potential in the study of hydrological processes, especially in the tropical countries like Vietnam, where there is a limitation from using traditional optical imagery. Flood monitoring using SAR imagery has proven to be very successful. This study presented preliminary results of flood investigation in the Mekong River Delta (MKD), Vietnam based on analysis and interpretation of some ERS SAR PRI data, especially to monitor of changes from temporal flooding situations during the rainy season. A case study of flood monitoring in 1996 has been investigated. As a well known that in Vietnam, 1996 brought most serious damages from flooding into both of human and property. Five ERS-2 SAR PRI scenes of upper part of MKD acquired between June 1996 and February 1997 were processed into a set of multi-temporal images for interpretation and analysis, based on the knowledge in the changes of radar backscatter from surface, due to surface roughness, soil moisture and vegetation cover. The multi-temporal image revealed high variation in vegetation and soil surface roughness both in time and space, especially during the rainy season. A preliminary assessment of flood damages was focused to estimate affected paddy fields in the region.

INTRODUCTION

Every year, river and coastal flooding in the world results in major loss of life and property. The United Nations report showed the results of disasters statistics collected world wide during 30 years period (1963 – 1992) and found that floods killed more people than any other type of disaster (22% all of deaths) and caused the most damage (32% of the total bill). Vietnam is perhaps one of the most disaster-prone countries in the world and water-related disasters (e.g. flood, typhoon, erosion, inundation, seawater infiltration, etc.) are the most serious and high frequent in Vietnam, cause substantial suffering, severe losses of life and economic damage.

In Vietnam, one more reason made water disasters became increasingly serious is that almost all the population lives in areas susceptible to flooding. This is because Vietnam has developed the low-lying river deltas and coastal lands for wet-rice agriculture. As a result, over 70% of the population of Vietnam are at risk of water disasters, especially for flash floods (source: UNDP in Hanoi). These natural disasters have been aggravated also by inappropriate human activities.

The Mekong River is longest river in Southeast Asia, with overall length of 4,800km, flowing through China, Myanmar, Laos, Thailand, Cambodia and Vietnam before emptying in the South China Sea. The river is navigable south of Louangphrabang, Laos and provides water for an area covering approximately 800,000 km^2. The Mekong River Delta (MKD) in Vietnam (39,000km^2) occupies the lower 5% of the whole river basin area. This region is one of the most densely populated areas, with 16 million people living in the delta. The Mekong River Delta (MKD) collects entire water resources of Mekong River, and is subject to severe flooding each year. This occurs mainly during the rainy season, with worst flooding often occurs in September and early October.

In the past, there have been some projects for flood investigation in this area using optical remote sensing, but they were often limited by weather restrictions, because of cloud cover, especially in rainy season. In the contrary, Radar remote sensing systems can imaging Earth surface day or night time and independent from weather conditions. The

SAR data in frames covering an area of approximately 100 x 100 km, with high resolution and suitable to investigating large area, such as Mekong River Delta. The ERS SAR imagery is also very useful for flood studying because of its sensitivity to water surface and moisture content.
This study is aimed to explore the capabilities of Radar Remote sensing Technique in hydrology applications, particularly for imaging flooded areas and monitoring its changes. A total of 5 ERS-2 SAR scenes have been used for this study. The data was acquired at Singapore Ground Station on descending orbits. The ERDAS Imagine 8.3 software was used for digital image processing, and multi-temporal anlysis.

METHODOLOGY

The radar backscatter from the surface scattering is mostly governed by the roughness of the surface and the dielectric constant of the soil (related to its moiture content). The backscatter intensity that is retrieved from SAR data, is variable depending on the soil moisture and surface roughness. When land surface is inundated, low backscatter results from a water surface. For the enhancement of the flooded areas, a multi-temporal technique is normally used. This technique uses black and white radar images of the same area taken on different dates and assigns them to the basic (red, green and blue) colour channels to generate a colour composite. The resulting multi-temporal image clearly reveals changes on the Earth surface in of colours; the hue of the colour indicating the period in which the change occurred and the intensity of the colour depicts the degree of change.
The multi-temporal analysis of a series of SAR data sets before and during the rainy season is performed as follows:

- Visual interpretation of multi-temporal images to study radar scattering phenomena and hydrological processes.
- Use of image processing software, e.g. ERDAS IMAGINE for digital analysis. Some modules are well adapted to SAR images post-processing such as for data calibration; image registration; spatial filtering; temporal analysis, etc.
- Mapping of inundated area from multi-temporal image, obtained from above analysis, with integration to available Geographic Information System (GIS) data and ancillary data, such as topographic maps, land use maps, meteorological data, a flood report, etc.).

STUDY AREA

The Mekong River Delta (MKD) is located at from 8^o30'to 11^o00'N latitude, 104^o30'to 107^o00'E longitude. It covers 39,000km^2 including 12 provinces (Long An, Dong Thap, An Giang, Tien Giang, Ben Tre, Vinh Long, Kien Giang, Can Tho, Tra Vinh, Soc Trang, Bac Lieu and Ca Mau). Rice cultivation is the major agricultural activity in the MKD (approximately 2 million ha of paddy), known as the "rice bowl of Vietnam" (rice producing yield of MKD included about 51% of the total yield of the country) and it is largely supported by various agro-hydrological factors such as rainfall and irrigation. The annual average rainfall in MKD varies from 1400mm to 2000mm, with approximately 90 to 170 rainy days/year.
This study is limited investigating to the upper part of Mekong River Delta (10^0 07 to 11^0 16 N, from 104^0 81 to 105^0 90 E) including the two provinces An Giang, Dong Thap and small parts of Long An and Can Tho provinces. An Giang and Dong Thap with area of about 5,000 km^2 and more than 4 million of population are the two largest provinces of rice producing in the Mekong River Delta. The tropical climate is divided in two distinct seasons. The dry season, from December to April, and the rainy season, from May to November. Each year, flood often happen in this area. They occur between the end of August and mid November. In the rainy season of 1996, this area was serious affected by floods during a very long period.

DIGITAL PROCESSING

To achieve the objectives of this study, multi-temporal analysis and interpretation techniques were applied. Firstly, all images were digital processed for radiometric enhancement. For this process, ERDAS Imagine, version 8.3 was used. The visual interpretation and multi-temporal analysis are explained in next part of this report.

RESULTS AND DISCUSSION

This part discusses how land and water characteristics of study area (the upper part of Mekong River Delta, Vietnam as case study) can be investigated from ERS SAR images. Generally, main factors affecting SAR imaging of land cover are surface roughness, geometric shapes of large objects, moisture contents and also wind influence to water surface. Changes in these factors will produce different colors in multi-temporal images, which allowing for investigation of changes from surface roughness, water surface and land cover.

Two main characteristics considered were vegetation cover and water surface. As mentioned above, a multi-temporal technique is mainly used for ERS SAR interpretation, bases on understanding the changes of radar backscatter (σ^0) as a result of the dynamic changes from surface characteristics, visually represented by image color changes in composite image.

It is important to note that a combination of an equal quantity of the primary colors (red, green and blue – RGB) results in grey or white tonalities of a multi-temporal SAR image while black indicates a lack of signal in all three channels. Very rough surfaces are white whereas very smooth surfaces are black. It can be concluded (Table 1) that white target in a SAR multi-temporal image indicates high backscatter (very rough) for all three dates and black target indicates very smooth surface for each of the single images. The secondary colors, such as Magenta, Cyan, Yellow, etc. of SAR multi-temporal images are produced from primary colors (RGB) by their combination and depend on the backscatter intensity at different date. Generally, the secondary colors indicate the changes of surface's characteristics from one date to another date, or temporal changes.

For natural targets, e.g. vegetation or soil, a red color suggests a very rough surface in the earliest date that has radiometric reduced (smooth) surface in the subsequent dates, probably as a result of physical or morphological changes. Considering vegetation for example, blue surface means the target was possibly very young plant (sparse canopy), hence, smooth surface in the earliest date; but have matured into adult plant (dense canopy with a high roughness coefficient) by the last date. The secondary color, i.e. yellow, magenta and cyan result fom the combination of red and green; red and blue, and green and blue, respectively. The appearance of targets in any secondary color suggests a combined surface's effect from two dates. In fact, the secondary colors provide the most dynamic interpretation tools for change detection in SAR multi-temporal images.

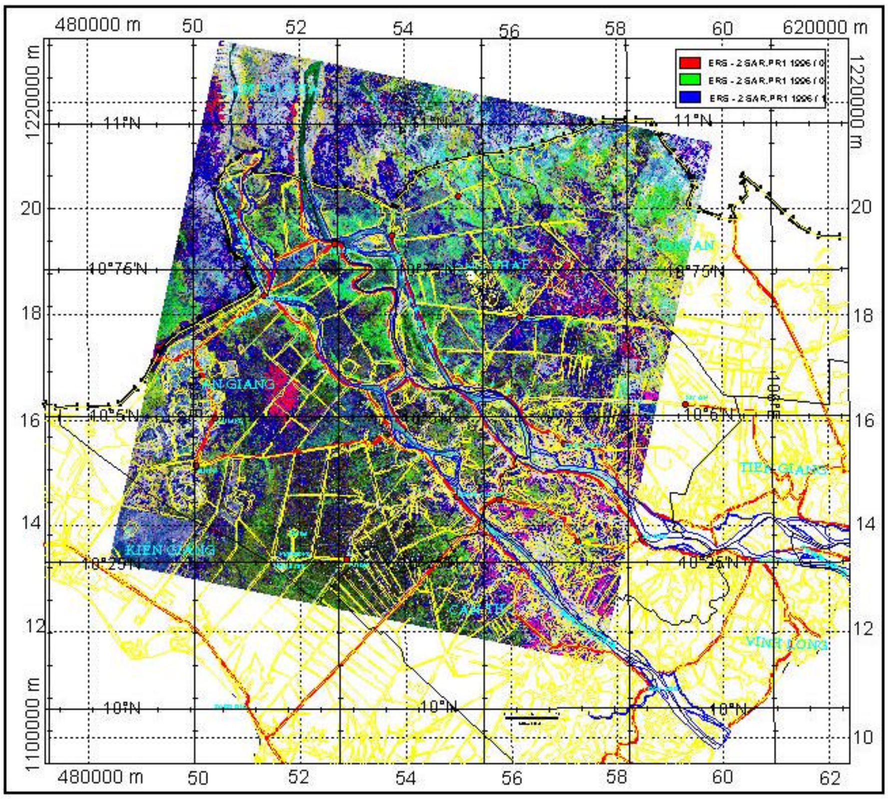

Figure 1. ERS SAR multi-temporal image of the An giang, MKD (Vietnam)
Red: 28JUN1996; Green: 02AUG1996: Blue: 06SEP1996

Figure 1 shows an ERS SAR multi-temporal image of full-sized image, composed from three ERS SAR PRI scenes dated 28JUN1996, 02AUG1996 and 06SEP1996. The image is a color composite with first scene assigned to the RED channel, the second to the GREEN channel and last to the BLUE channel. This is a relatively flat area, included main town Long Xuyen (at right-hand side of image) and a huge agricultural plain with different types of food plants, such as rice, corn, sugar-can, but mainly known as an area where most of the land use cover is rice cultivation fields. The image covers approximately 100 x 100 km ground area.

This composite image can be used to investigate the changes of the vegetation, particularly rice growth. As a known, the cycle between different growing states of rice plants is approximately of 35 to 55 days. A series of images acquired at three dates during a period from June 1996 to September 1996 is probably provide the means to study temporal changes of rice field. The results should however be interpreted with care and integrated with Geographic Information System information, ancillary data, etc.

Some vegetation types are not clearly distinguished from this multi-temporal image, but generally the secondary colors, such as yellow, magenta, cyan, and green indicate areas of major vegetation changes, during the period from June to September. Table 2 shows the impact parameters that could be identified in this composite image. Their appearance in different colors in the multi-temporal image is dependent on the contribution from their backscatter signals from different dates.

S/N	Parameters (Detected on the Multi-temporal Image)	Colour Combinations 1, 2, 3 Resulting Colour	Red 28JUN (1)	Green 2AUG (2)	Blue 6SEP (3)
1.	Changes of vegetation cover	Red Magenta/Purple Green Yellow Cyan Blue/Greenish	rough rough smooth rough rough smooth	smooth inundated rough inundated rougher rough	smooth rough inundated inundated rougher rougher
2.	Forest	Grey (a little change)	dry	moist	moist
3.	Settlement, roads, channels Steep mountain	White/Grey (no change)	dry	humid	humid
4.	Drainage network and Wet land	White/Grey (a little change)	No wind/ Smooth	windy rough	windy rough
5.	River networks	Green/Blue/Cyan (influence by wind speed)	No wind	windy	windy

Table 2. Impact Parameters and their colours in An Gi ang multi-temporal image (Red: 28JUN1996, Green: 02AUG1996, Blue: 06SEP1996)

The Red colour on this multi-temporal image represent very strong backscatter contributions from date 1, but weak backscattering from date 2 and date 3. It is likely to be due to vegetation, crop growing in the dry season and harvested in July (before date 2), after harvested, probably a field covered by water and weeds. The Magenta (the combination from Red and Blue) in the image probably shows low relief areas that are bare soil, or swamp using for fishery or shrimp feeding, not use for rice cultivation. The Green and Yellow in the image show that there are relatively high radar backscattering from dates 1 and very high from date 2 whereas low reflections from date 3. These portions could depict the paddy fields, as the beginning of crop in May/June and yellow/yellowish area probably corresponding to paddy fields areas affected from flood in both date 2 (02AUG1996) and date 3 (06SEP1996) either. While Green area may be corresponding to paddy fields areas affected only by flood in date 3 (06SEP1996). Different Green portions can be distinguished on the image and the higher green tonality (i.e. relatively higher radar backscatter from date 2) correspond to areas located close to drainage network or river basin, probably rice fields where earlier sowing occurred due to advantage of irrigation.

The Cyan color (combination from Green and Blue) of some rectangular areas in the lower-left hand of image is probably a vegetation with a long time crop cycle (maybe sugar-can), beginning before date 1 (28June1996), growing up until to the end of the monitored period. It was not affected by flood in both of last dates (date 2 and 3) as a continuous increase of radar backscatter from date 1, through date 2 and date 3 demonstrated. Either it is located at relatively higher relief, protected by embankment system or it is tall plant vegetation. There is a triangular area in the upper-part of image showing up as a combination of Blue, Light Blue and Greenish, meaning that there is a continuous increase of radar backscatter from date 1 to date 3 in this area. This suggested that the vegetation in this area was not likely to be affected by flood in both date 2 and date 3, due to coverage by high embankment systems or high relief topography.

The analysis of the ERS SAR data in combination with available ancillary data (topographic maps, land use maps, meteorological observations close to the time of data acquisition, etc.) can be used to derive parameters and information of the flood dynamic, particularly for floods caused by rainfalls of long duration. The multi-temporal approach is commonly applied for evolution monitoring (in terms of time and affected surfaces) by acquiring images during the flood event.

In a single date ERS SAR image, inundated areas are showed in black. Minimum radar echo is generally due to the fact that water bodies, with its smooth surface, act as specular reflectors of incoming radar signals, resulting in weak return towards to the sensor. This principle is used for mapping of inundated areas in single ERS SAR images during a rainy season. But rough water surface (influenced by strong wind, current flows) may return radar signal of varying strength, visible by different grey levels due to “Bragg resonance” effect. In the case of multi-temporal images, the inundated areas affected by strong wind are seen as various colours, which provided information about the surface wind conditions at the different observation dates. These factors must therefore be considered when interpreting multi-temporal SAR images for flood detection.

Figure 2 shows the upper part was extracted from full-size images for flood monitoring. This area covers approximately 25 x 25km ground areas, mostly covering Tan Chau district of An Giang province.

For monitoring of flood evolution, a multi-temporal image (Figure 2) produced from three ERS SAR images. The color composition is assigned as follows: Red channel: 02AUG1996, Green channel: 06SEP1996 and Blue channel: 20DEC1996. The temporal changes of the inundated areas at the different dates are shown by color differences.

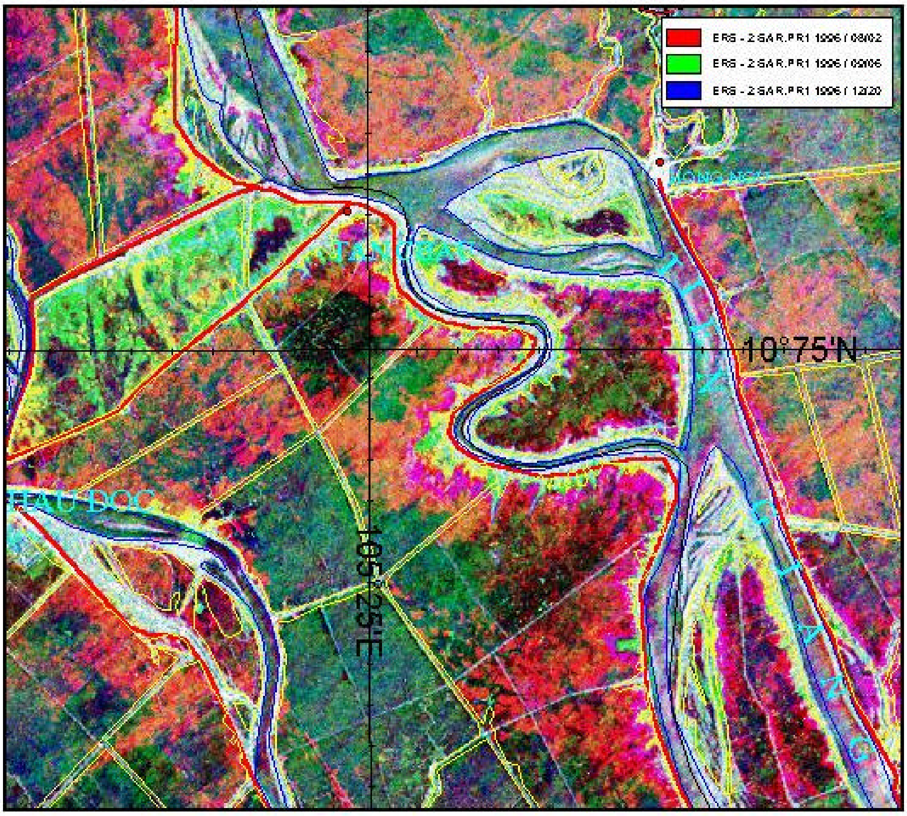

Figure 2. Flood monitoring during the during rainy season in MKD, Vietnam
(Tan Chau district, An Giang province with size 25 x25km)
(ERS SAR Multi-temporal image - Red: 02AUG96, Green: 06SEP96, Blue:20DEC96)

The town Hong Ngu and Tan Chau are clearly recognised in the multi-temporal image by white tonalities, originated by dominant corner reflector effect and the little changes of urban areas. Several other urban areas also distinguished in the image, located along a river. Strong radar backscattering is experienced in all of three dates (displayed in light grey levels) probably as a response to orchard surrounding settlement areas.

There is an area close to center of the scene displayed as very dark color, meaning that this area was inundated from 02AUG1996 until 20DEC1996. It may suggest that this area is and therefore was most severely affected by flood. The areas corresponding to a greenish color show that there is a weak radar return both at 1st date (02AUG1996) and at 3rd date (20DEC1996) but high radar return at 2nd date (06SEP1996). These areas are likely to be inundated only at 02AUG1996. The red and reddish colors suggest that the areas corresponding to these colors have weak radar backscattering in both 2nd and 3rd dates but strong radar backscattering from 1st date. These areas probably inundated at both dates 2nd date (06SEP1996) and 3rd date (20DEC1996) but very humid at 1st date (02AUG1996).

The areas corresponding to magenta color show that there is low radar backscattering on the 2nd date (06SEP1996) while high radar return on the 1st date (02AUG1996) and 3rd date (20DEC1996). It suggests that these areas were inundated only on the 06SEP1996. The areas corresponding to yellow color probably indicate inundated areas at 3rd date (20DEC1996) while non-flooded in 1st date and 2nd date.
The change of the flood is clearly visible in the multi-temporal image as color difference. It more clearly displayed in the areas along two margins of Mekong River as shown Figure 2. The magenta color indicates that flood extended was largest on the 06SEP1996 and had the most severe impact to the agricultural field at this time (i.e. in the middle of flood season).

CONCLUSION

The ERS SAR data is a powerful tool for the provision of in general weather independent information for flood management and monitoring. It also provides relevant land use and land cover information which can be enhanced with its integration into a Geographic Information System. Such a system is known to be an effective tool for land management.
ERS SAR data can be processed and analysed using different methods, but for almost applications, and especially for hydrology, the multi-temporal image technique is particularly powerful. SAR response to various land use and land cover features is a function of time. Multi-temporal SAR image can be used to discriminate the majority of these features. As discussed in this study, floods and agricultural land are main features detectable by this technique. The extensive pattern of agricultural land use (rice and other crops) in the Mekong River Delta shows a high temporal. Flooded areas at different time during the rainy season are distinguishable and the evolution of a flood can be monitored. ERS SAR data can image a large area at once (approximately 100 x 100 km), e.g. whole river catchment area can be captured in a single image. The utilization of this data for flood monitoring and damage assessment is therefore also very economic. The use of SAR imagery is still limited by periodicity of acquisition due to the inherent system repetition (for ERS-2 nominally, two to four coverage within 35 days) and the coverage of flood peak times is not always assured. Thus all available satellite systems (optical and radar) need to be considered to assure time-wise useful data access. The use multi-temporal SAR images is also partly difficult for flood detection in settlements, under high vegetation and in the case of open water in windy weather conditions.

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