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Potential Uses of ERS-1 SAR Data For The Malaysian Coastal Zone

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Abstract

Satellite remote sensing using visible and infrared wavelengths is not very suitable in the tropics because of the cloud cover problem. Radar remote sensing can overcome this problem although it may not possess some of the advantages of sensing in the optical wavelengths.

This paper reports on the results of a study that has been carried out under the EC-ASEAN ERS-1 project, subproject MAL-2, to derive coastal zone information from the synthetic aperture radar (SAR) data of the ERS-1 satellite over the coastal areas of Terengganu and Sarawak (Malaysia). The PCI EASI/PACE and ErgoVista digital image processing software were used to analyse SAR PRI images. The digital image processing carried out include geo-referencing, filtering and calibration.

The University of Texas at Arlington Radiative Transfer Canopy Model (UTA) was used to derive backscatter values expected from different types of dominant vegetation which were then compared with the backscatter values obtained from the ERS-1 SAR data.

In the study, the radar bathymetry model implemented at TNO was used to assess a number of maritime features in the images potentially caused by topography of the sea bottom. The contrast profiles produced by the model were compared to profiles extracted from the ERS-1 images.

The ERS-1 data were also processed to obtain ocean wave spectra in order to derive information about ocean wavelength and direction using 2-dimensional Fourier Transform. The study also included visual interpretation of oil slicks, ships, ship wakes and some coastal features such as river outflows and fronts.

1.0 INTRODUCTION

Satellite remote sensing using the visible and the infrared wavelengths have been used very successfully in various applications related to earth resources studies and monitoring of the environment. This is also the case for applications related to the marine environment. For instance, useful results have been obtained in sea surface temperature, suspended sediment concentration, ocean colour and bathymetry studies. However, in some applications, there are limitations in the use of the optical wavelengths such as in studies related to sea bottom topography in turbid waters, ocean waves and oil slicks.

The use of radar remote sensing has many advantages in comparison with optical remote sensing techniques. By far the most important factor is the virtual insensitivity of radar to atmospheric conditions. This allows the regular collection of site observations independent of cloud cover or time of overpass. On the other hand, the interpretation of radar imagery over land and ocean are not as straightforward as that of the more commonly used visible and infrared remote sensors. Usually, special image processing techniques must be applied on the radar imagery to make it more readily interpretable. Furthermore, the interpretation of the backscattering process that underlies the radar image formation must be well understood with respect to the physical characteristics of the targets under observation and the specifics of the radar instrument.

The objective of this study is to develop a suitable methodology for mapping coastal features and land cover using multi-temporal ERS-1 SAR satellite data. The study includes shallow water bathymetry, wave spectra analysis, detection of oil slicks and mapping of natural and artificial features. Some modelling work for vegetation backscattering and bathymetry was also carried out in order for some comparisons to be made to the ERS-1 data. Through this study, local scientists were able to acquire knowledge and experience in the analysis of ERS-1 SAR digital data.

2.0 DATA PROCESSING & ANALYSIS

For this study, two test areas were selected. One area stretches from Kuala Terengganu to Dungun on the north-east coast of Peninsular Malaysia, and one near Kuala Baram on the north-west coast of Sarawak (Figure 1). Both areas are characterized by large outflowing rivers and are affected by coastal erosion and accretion during the monsoon season.

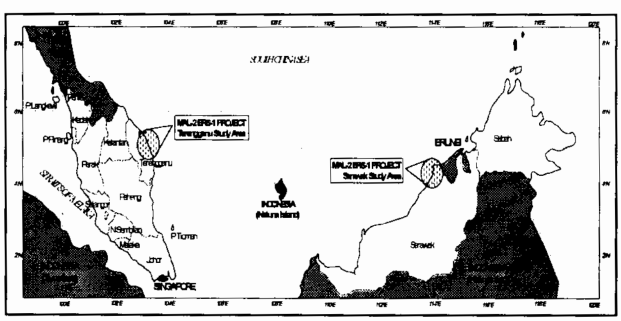

Figure 1 : Map of the MAL-2 study area.

During the duration of the study, several scenes of ERS-1 SAR PRI data were acquired and used. These data were received by the Bangkok receiving station and made available by ESRIN and Bangkok.

The data processing and analysis involved in this study include geo-referencing, filtering, calibration, vegetation backscattering, bathymetric signatures, ocean wave spectra and visual interpretation for oil slicks, ship and ship wakes.

2.1 DIGITAL IMAGE PROCESSING

Since ERS-1 PRI images has already undergone slant-to-ground range correction at the Processing and Archiving Facility, SAR multi-temporal images were registered to each other by applying a shift in the x and y direction. The geo-referenced images were co-registered with existing maps of the area for comparisons.

Various filters including Lee, Frost and Gamma MAP filter were used to reduce speckle noise from the images in order to compare the results visually for land areas.

In order to obtain absolute backscatter values from the ERS-1 SAR data, calibration was done by using the constant provided by ESRIN and Bangkok station.

2.2 VEGETATION BACKSCATTERING MODEL

In order to understand radar backscatter from vegetation, the University of Texas at Arlington (UTA) Radiative Transfer Canopy Model (Karam et al., 1992) was used to derive backscatter values expected from different types of dominant vegetation in the study area, viz. rubber, oil palm and paddy. The parameters used in the model were obtained from ground observations which included tree height, soil roughness, soil moisture, leaf radius, leaf density, leaf orientation, branch radius, branch density, trunk radius, trunk density, etc.

Backscatter values were also extracted from the ERS-1 SAR data in order to make comparisons. The results are shown in figures 2(a), 2(b), 2(c) and 2(d).

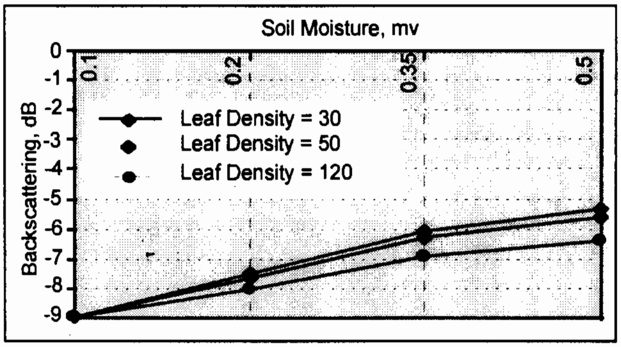

Figure 2(a) : Backscatter values for rubber derived from the UTA model

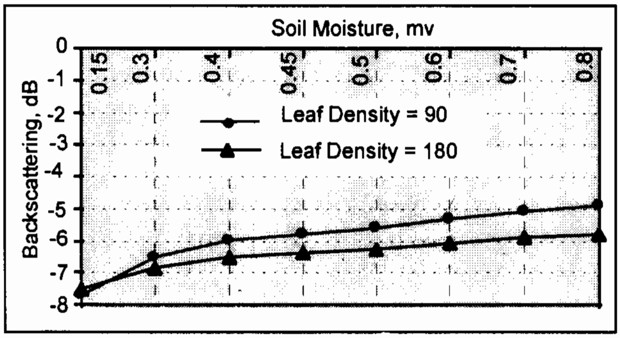

Figure 2(b) : Backscatter values for oil palm derived from the UTA model.

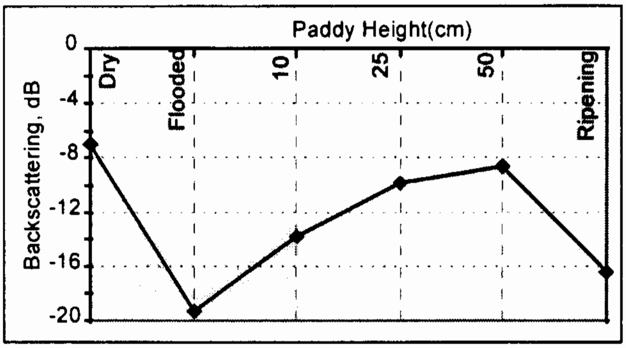

Figure 2(c) : Backscatter values for paddy derived from the UTA model.

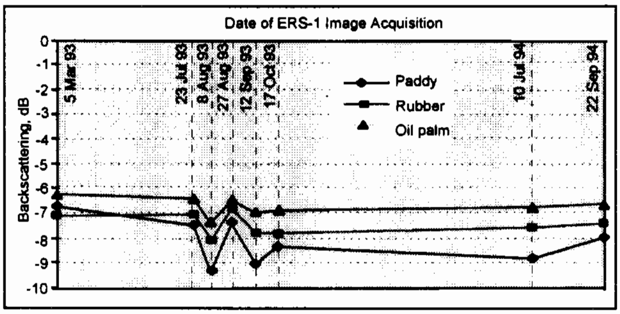

Figure 2(d) : Backscatter values for paddy, rubber and oil palm extracted from the multi-date ERS-1 data.

2.3 BATHYMETRY SIGNATURE MODEL

In the study, the radar bathymetry model implemented at TNO was used to assess a number of maritime features in the images potentially caused by topography of the sea bottom. This model is based on the action balance equation, weak hydrodynamic interaction theory and Bragg scattering (Vogelzang, 1989). The model which is suitable for shallow waters was run using estimated bathymetric profiles based on available hydrographic charts, and wind and current velocities and directions at the time of ERS-1 imaging.

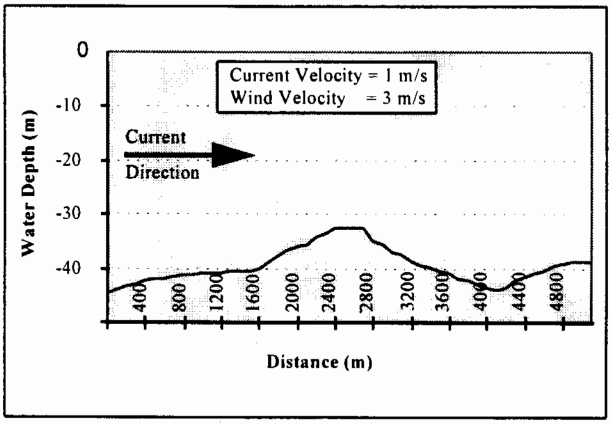

Figure 3(a) : Sea bottom profile and marine information in the study area.

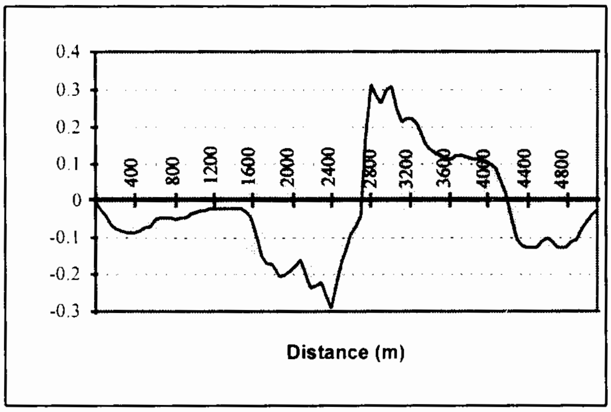

Figure 3(b) : Radar contrast derived from the model (wind and current velocities are 3.0 m/s and 1.0 m/s respectively during data acquisition).

The contrast profiles produced by the model were compared to profiles extracted from the ERS-1 images. The results are shown in figures 3(a), 3(b) and 3(c).

ERS-1 data has been demonstrated to provide ocean wave information in terms of wavelengths and directions. ErgoVista software was used to calculate wave spectra from PRI images. Single SAR image frames comprising of 512 x 512 image pixels was extracted. Since each pixel represents a 12.5 m x 12.5 m area, the entire image frame corresponds to a 6.4 km x 6.4 km patch on the ocean surface. The frame size provides a sufficiently large area that at least 10 cycles of very long surface waves, up to 640 m in length, can be included in a single image frame. They are also small enough that the ocean can be reasonably assumed homogeneous within a frame (Monaldo, 1991).

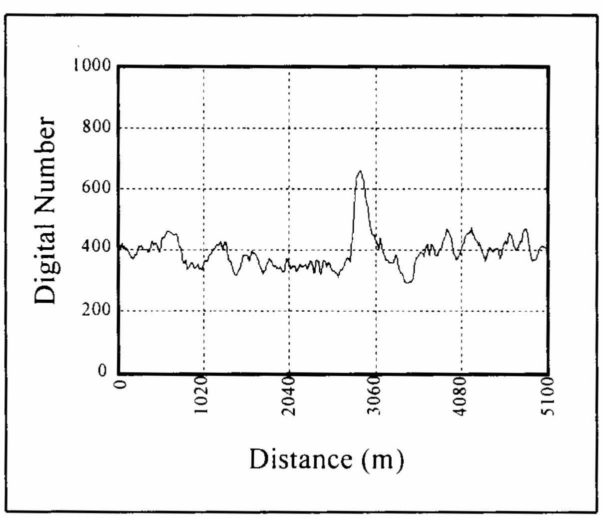

Figure 3(c) : Profile from ERS-1 data.

Ocean Wave Spectra

The wave spectra were calculated based on a 2-dimensional Fast Fourier Transform, with smoothing in the spectral domain and spatially averaging for noise reduction, and a correction for the stationary instrumental response function. The results are shown in figure 4. This process was repeated for other frames in the image.

2.4 VISUAL IMAGE INTERPRETATION

For visual interpretation, both single and geo-referenced multi-temporal images were used to recognise different types of vegetation and their changes especially in the coastal land areas using unfiltered and filtered images.

ERS-1 images were also used to detect oil slicks, ship and ship wakes and water fronts.

Georeferenced multi-temporal images were inspected for changes in the coastline due to erosion and accretion, which is known to occur in this area during the monsoon season.

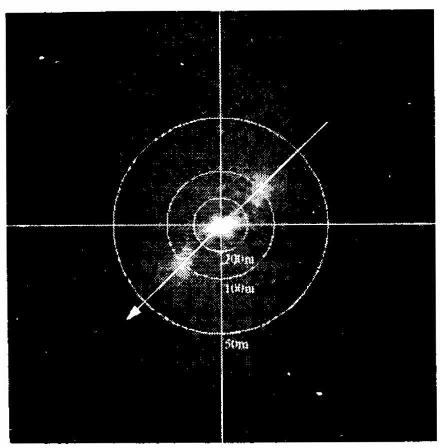

Figure 4 : Wave spectra derived from single frame on ERS-1 data acquired on 5 Mar 93. Circle and arrow represent ocean wavelength and direction respectively.

3. 0 RESULTS & DISCUSSIONS

From the single ERS-1 SAR image, it was difficult to delineate different types of vegetation. However, by using multi-temporal images, it was possible to detect temporal changes in the paddy crop due to different stages of growth.

Among the filters used, the Gamma MAP filter using 11x11 window produced the best visual results where point targets are clearly visible and land use boundaries are more distinct.

The vegetation backscatter simulation results show that rubber plantations have a fairly stable backscatter level of -7.0 dB (Figure 2(a)). The backscatter values obtained from ERS-1 data also show a fairly stable signal around -7.5 dB (Figure 2(d)). For oil palm plantations, the results from the model and the ERS-1 data show the same trends as for rubber with a fairly stable signal in the range of -6.0 to -7.0 dB (Figures 2(b) and 2(d)). As for paddy fields, the simulations show that the backscatter can be very low for flooded bare fields, but can be considerably higher as a result of wind or when the area is dry. When the plant grows the backscatter continously increases up to -8.0 dB and drops again when the plants ripen or turn yellow. The results obtained from the ERS-1 data range from -6.7 to -9.0 dB very low for flooded bare fields, but can be considerably higher as a result of wind or when the area is dry. When the plant grows the backscatter continously increases up to -8.0 dB and drops again when the plants ripen or turn yellow. The results obtained from the ERS-1 data range from -6.7 to -9.0 dB (Figures 2(c) and 2(d)). These results are acceptable considering the fact that the ERS-1 data used in the study were acquired during mid to end of the paddy season.

The radar contrast derived from the bathymetric signature model was quite consistent with the shape of the sea bottom profile obtained from hydrographic charts. However, the results obtained from ERS-1 data do not compare well with the above results (Figures 3(a), 3(b) and 3(c)).

From the ocean wave spectra analysis, the wavelength and direction of the ocean waves have been determined from the images (Figure 4). The dominant wavelength is about 200 m. The spectra show 180° ambiguity as the wave propagation direction is not resolved.

From the visual interpretation of the processed images, it was possible to locate oil slick areas which appear as dark patches because of the damping of the ocean wave due to the oil layer which reduce radar backscatter. Ship and ship wakes have also been identified on the image with the wakes trailing for several kilometers behind the ship. Water fronts where water from the rivers meet with the sea water is also clearly visible in the images.

So far, no coastal erosion or accretion sites could be unambiguously identified in the data set. This is partly due to the relatively short time base over which the data were collected and the limited spatial resolution. Also, the extraction of the exact location of the coastline from the SAR images proved to be difficult, due to the brightness variations of the sea surface with wind, the presence of waves, and the speckle. This issue is one which deserves further attention.

4. 0 CONCLUSIONS

From the work that has been carried out in the study, the ERS-1 SAR data has shown great potential in deriving information on land and sea areas. However, to operationalise the use of SAR data, market survey needs to be carried out in order to obtain user requirements. Also, suitable mechanisms should be made available in order to obtain timely data especially in sea areas which are dynamic in nature.

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REFERENCES

Karam, M.A., A.K. Fung, R.H. Lang and N.S. Chauhan, 1992, A microwave scattering model for layered vegetation, IEEE Transactions on Geoscience and Remote Sensing, Vol.GE-30, pp.767-784.

Monaldo, F.M., 1991, The consequences of sampling variability on the estimation of wave number and propagation direction from spaceborne SAR image spectra, IEEE Transactions on Geoscience and Remote Sensing, Vol.29, No.1, pp. 113-119.

Vogelzang, J., 1989, The mapping of bottom topography with imaging radar : A comparison of the hydrodynamic modulation in some existing models, Int. J. Remote Sensing, Vol.10, No.9, pp. 1503-1518.