SATELLITE REMOTE SENSING : APPLICATIONS OF ERS-1 SYNTHETIC APERTURE RADAR FOR DERIVING COASTAL ZONE INFORMATION

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ABSTRACT

The use of radar remote sensing in the microwave region of the electromagnetic spectrum has many advantages in comparison with optical remote sensing in the visible and infrared wavelengths. 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 is not as straightforward as 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.

This paper reports on some of the results of a study that has been carried out to derive coastal zone information from multi-temporal synthetic aperture radar (SAR) data of the ERS-1 satellite over the coastal areas of Terengganu, Malaysia. Digital image processing of the SAR data has been made that includes filtering, texture processing and Fast Fourier Transform (FFT) for ocean wave spectra generation. Some of the features that have been identified on the processed SAR data include oil slicks, ocean waves, river outflows, breakwaters, ship and ship wakes. Some land features such as natural forest, plantations and paddy fields can also be recognised.

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. Radar measurements are independent of cloud cover and illumination from the sun and therefore superior to measurements by optical systems in areas with a high probability of cloud coverage. The imaging mechanism for radar systems is quite different from those for optical sensors thus radar does not provide the same information. Spaceborne synthetic aperture radar (SAR) provide images of the earth's surface with a resolution of 20 - 30 meters which is sufficient for a wide range of applications.

SAR images of the ocean surface show a variety of signatures reflecting processes in the atmosphere, in the water body, and at the water surface. For the radar bands, microwave radiation is not affected by the atmosphere and does not penetrate into the water. Therefore, all signatures on SAR images are due to variations in the radar backscatter intensity from the water surface.

This paper reports on the study carried out by using multitemporal ERS-1 SAR satellite data for deriving coastal zone information in the coastal areas of Terengganu (Figure 1). The objectives of this study is to develop a suitable methodology for deriving coastal features and land cover using multi-temporal ERS-1 SAR satellite data. The study includes shallow water bathymetry, detection of oil slicks/spills, wave spectra analysis and mapping of natural and artificial features. However, in this paper, the results of the wave spectra analysis and the mapping of natural and artificial features are reported.

SATELLITE DATA USED

Multi-temporal ERS-1 satellite data (C-band, V V polarization) with a repeat cycle of 35 days, acquired on three different dates, i.e 5 March, 23 July and 27 August 1993 were used in the study. These data are the Precision Image (PRI) data received by the Thailand Ground Receiving Station and processed by ESRIN-ESA Italy. The PRI data covers an area approximately 100 by 100 km corresponding to 8000 by 8000 pixels of pixel size 12.5 by 12.5 m. For the purpose of the study, sub-scenes of about 1000 by 1000 pixels of the study area were made for convenient and fast processing. Figure 2(a) shows the land and sea areas of Kuala Terengganu whilst Figure 2(b) shows a 512 x 512 sub-scene of the 5 March 1993 ERS-1 SAR image covering the land areas.

FIELD OBSERVATIONS

Field work has been carried out at the Terengganu study area in order to get an overall idea of the study area in terms of land cover. Satellite Global Positioning System (GPS) was used to determine ground control points in order to carry out geometrical rectification of the satellite data. Hardcopies of the ERS-1 images were also used to interprete land cover types, infrastructure such as roads, tracks and settlements. Observations were also made in the sea for possible oil slicks/spills, sand banks, sand bars etc. Meteorological data were also obtained from the Kuala Terengganu Airport meteorological station at the time of satellite pass.

From the field observations, the main covertypes are oil palm, rubber, paddy (irrigated and non-irrigated), swamp forest and primary forest. As for the coastal features, beaches, sand bars, rivers and other features such as break waters were identified. During observations on the sea, oil slick areas were detected.

SATELLITE DIGITAL DATA PROCESSING

The ERS-1 SAR digital satellite data were processed with the PC-based PCI EASI/PACE and ErgoVista Image Analysis Systems available at the Centre for Remote Sensing UTM (PRSUTM). Suitable image dimensions were extracted convenient for rapid processing. The tasks described below have been carried out. Figure 3 shows the flow chart of the sequence of work involved in the study.

Speckle filtering

The coherent nature of radar backscattering causes the well-understood grainy appearance of SAR imagery (Hoekman, 1990). In speckle filtering, the knowledge on speckle formation is used to locally reduce this phenomenon in the radar image. In short, speckle can be reduced by averaging over an image window which is contained in a supposedly fully developed speckled target area. The well-known adaptive Lee-filter which is the most commonly applied speckle filtering technique has been used (Figure *4*).

More recently, an advanced adaptive SAR filtering technique has been used which takes into account the variation of the SAR intensity signal when edge-features and line-features or strong scatterers are present in the scene. This so-called Gamma Maximum A Posteriori (GMAP) filter has also been implemented in the study (Figure 5).

Texture processing

Texture is one of the important characteristics used to identify objects or regions of interest in an image. Unlike spectral features, which describe the average tonal variation in the various bands of an image, textural features contain information about the spatial distribution of tonal variations within a band.

One method of measuring texture mathematically is based on statistics derived from a co-occurrence matrix. A co-occurrence matrix shows the relationship between a given pixel to its specified neighbour. The co-occurrence matrix for a given window is dependent on the spatial relationship (i.e. direction and distance) of the reference pixel to its neighbour as well as the input data values, as the co-occurrence matrix is asymmetric. This means the co-occurrence matrix for a given window would be different for a neighbour below it then a neighbour to the left and two scan lines down. This characteristic makes co-occurrence matrices conducive to describing texture for radar imagery, which is affected by the flight path and angle at which it is scanned.

The texture of an image is related to the distance of the co-occurrence matrix elements to the diagonal elements. The amount of dispersion that the matrix elements have about the diagonal may be measured statistically through difference texture measures to characterize texture.

There are many different texture measures such as contrast, correlation, angular second moment, entropy etc (Hoekman, 1990). However, in this initial study, contrast and correlation texture measures have been used.

Geocoding

Geocoding is the process of transforming a SAR image into an image whose coordinates are based on geographical coordinate system. This involves slant to ground range conversion of the SAR images and registration to common geographical grid. ERS-1 PRI imagery has already undergone slant to ground range conversion at the Processing and Archiving Facility (PAF). However, in this study, the registration of the multi-temporal images were achieved by applying a shift in the x and y direction (Figure 6).

Ground control points (GCP) were used to tie the images to the ground coordinate system. More accurate georeferencing techniques (geocoding) make use of local topography to precisely correct pixel dimensions, especially in areas of relief. These techniques make use of detailed digital elevation models (DEM).

Ocean wave spectra generation

High resolution SAR has shown the potential of measuring ocean wave spectra. Using data from both spaceborne and a number of aircraft platforms, various investigators (Beal et al., 1983 and Shuchman et al., 1993) have demonstrated that spectral parameters such as wavelength and propagation direction extracted from SAR image spectra are generally consistent with independent measures of the ocean surface.

In this study, a single SAR image frame 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 (Beal et al., 1985).

The SAR intensity image was transformed using 2-dimensional Fast Fourier Transform to produce an image intensity-variance spectrum as a function of azimuth and wavelength. Since it is common practice to transform the viewing output from the frequency transforms into an optical image with the frequency 0 in the centre, this was implemented in this study. The power spectra images that were generated are shown in Figures 7(a) and 7(b).

RESULTS AND DISCUSSIONS

In the case of land use applications in the Terengganu study area, natural forest, plantations and rice fields can be recognised in the ERS-1 images. However, the boundary between the different landuse types are not very distinct. Rice fields show some temporal variations comparing the March and August 1993 images. However, more ground verifications have to be carried out to determine accurately the different land use types.

The GMAP filtered image shows the best visual results where point targets are clearly visible and land use boundaries are more distinct compared with other filtered images. Since this filter also preserves edge structures, linear features such as roads and field boundaries are significantly enhanced.

As for marine applications, a great variety of features are visible on the image. Possible oil slicks/spills which appear as dark patches can be identified on the image. However, this can only be confirmed if in-situ observations have been made during satellite pass. Ship, ship wakes, and coastal features such as break waters, beaches etc are also visible on the image. It has been found that the normal filtering techniques used in land areas are not so useful in marine applications.

In the power spectra images as shown in figures 7(a) and 7(b), it is possible to derive wave direction and wavelength. However, the ambiguity in the wave direction i.e. the 180 degrees difference has to be resolved.

SUMMARY

The initial results obtained in this study show the potentials of ERS-1 SAR data for land and marine applications in Malaysia. However, further processing of the data using multi-temporal images need to be carried out to realize the full potentials of the ERS-1 SAR data. This would include more detailed study on ocean wave spectra for wave directions, sea bottom topography, internal waves, oil spills and coastal features.

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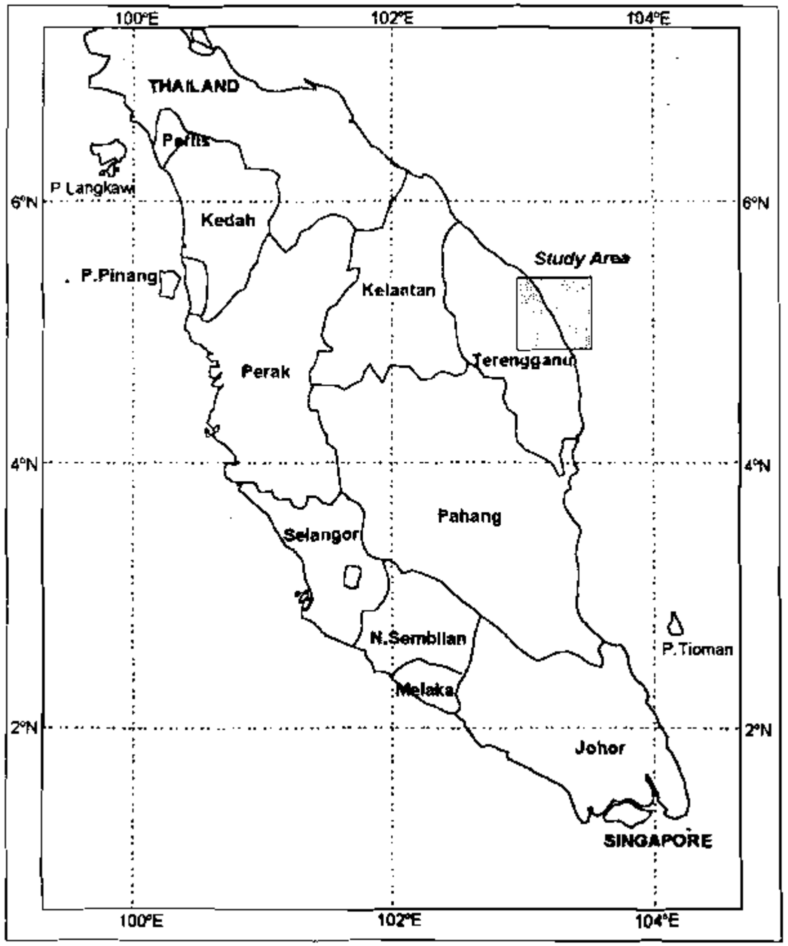

FIGURE 1 : Location Map of Study Area.

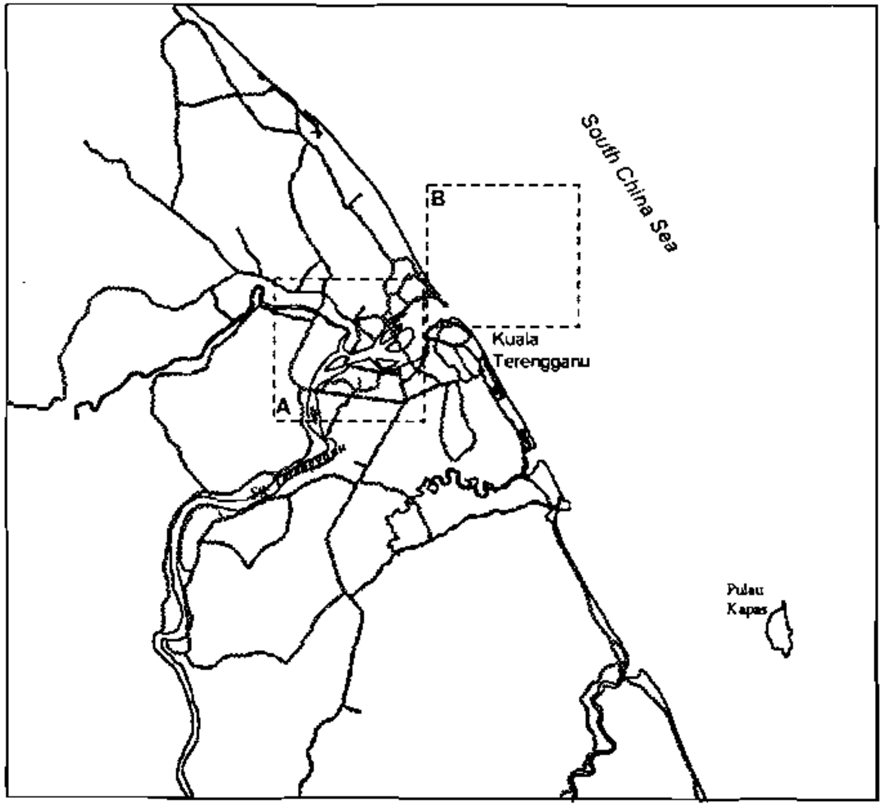

FIGURE 2(a) : Kuala Terengganu Study Area
(Box Indicates Land and Marine Study Areas).

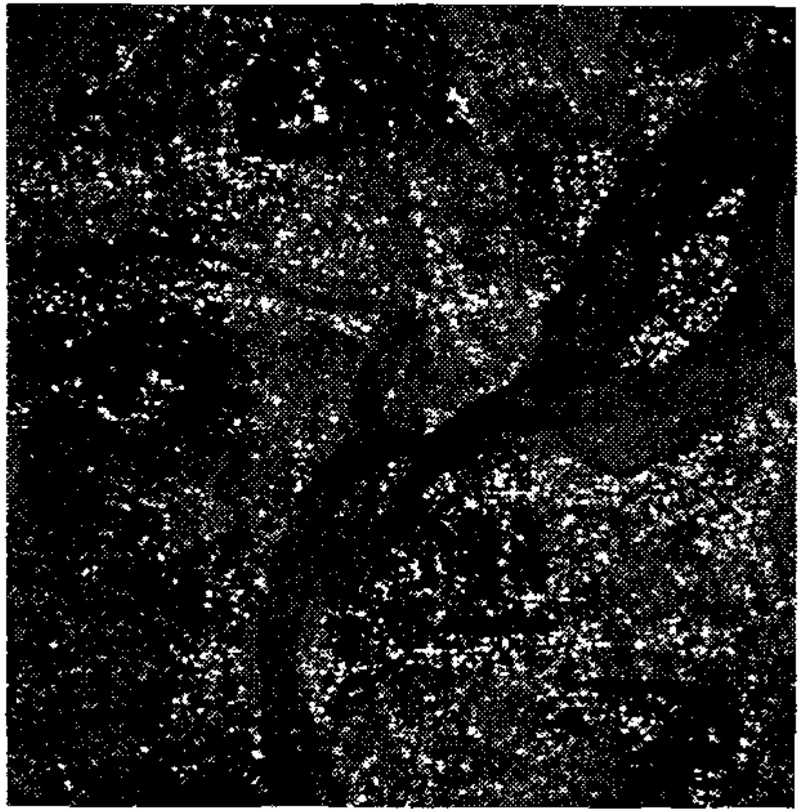

FIGURE 2(b) : ERS-1 SAR Image Acquired on 5 March
1993 Covering the Land Areas in Kuala Terengganu.

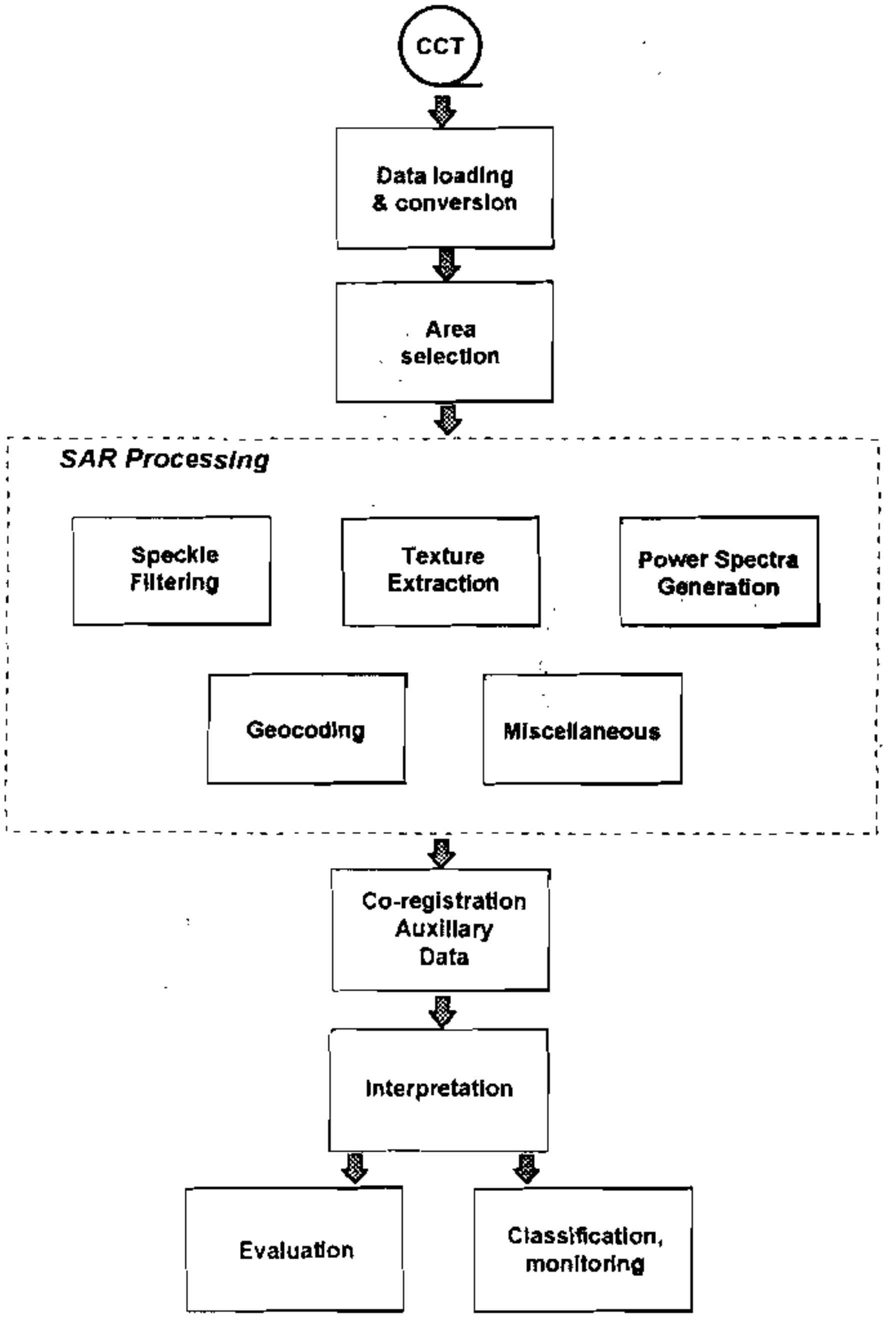

FIGURE 3 : Flow Chart of Work Sequence.

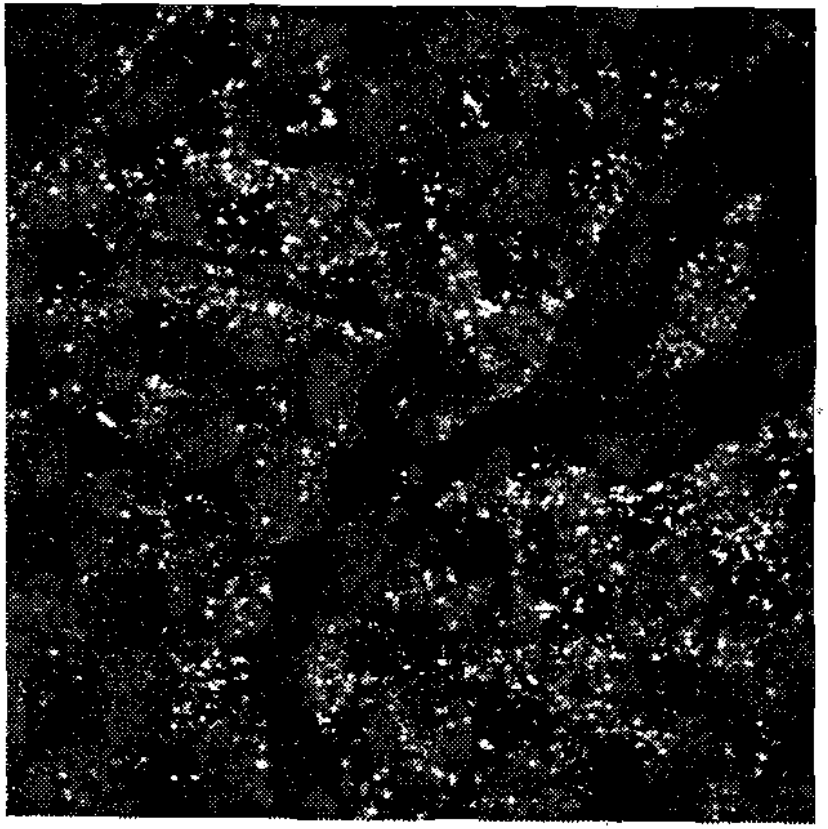

FIGURE 4 : 5 x 5 Lee Filtered Image of Kuala Terengganu Acquired on 5 March 1993.

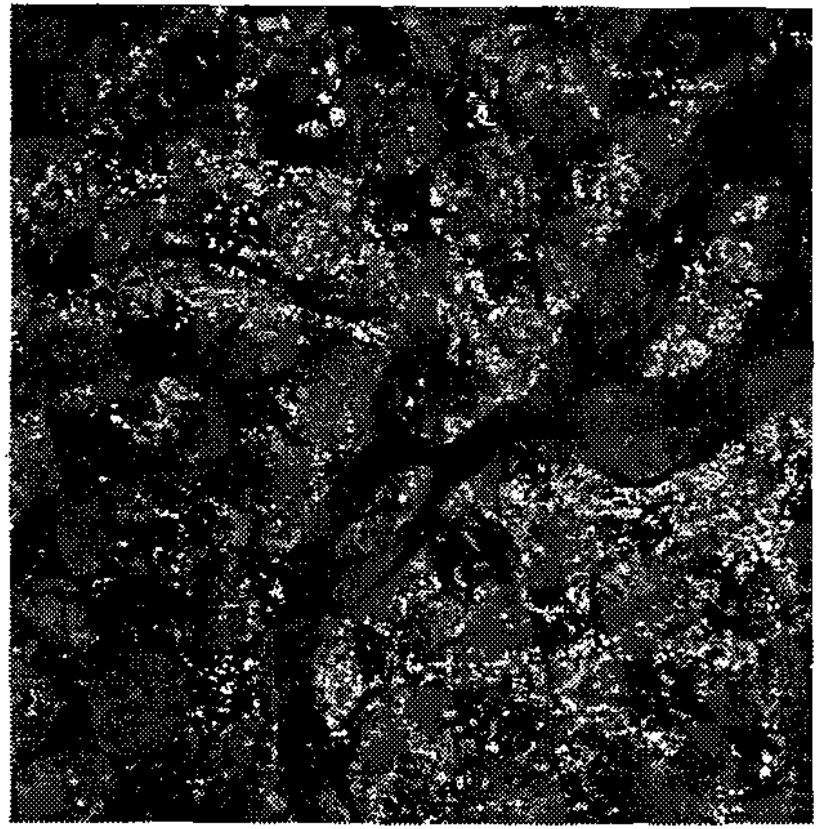

FIGURE 5 : 11 x 11 GMAP Filtered Image of Kuala Terengganu Acquired on 5 March 1993.

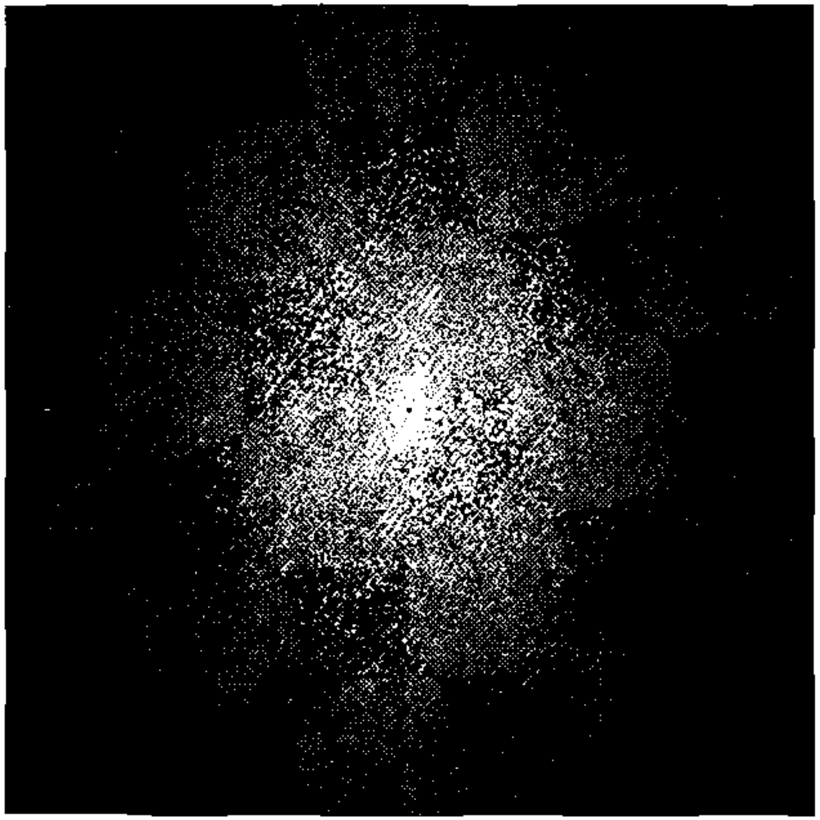

FIGURE 7(a) : Power Spectra Image of ERS-1 SAR Data.

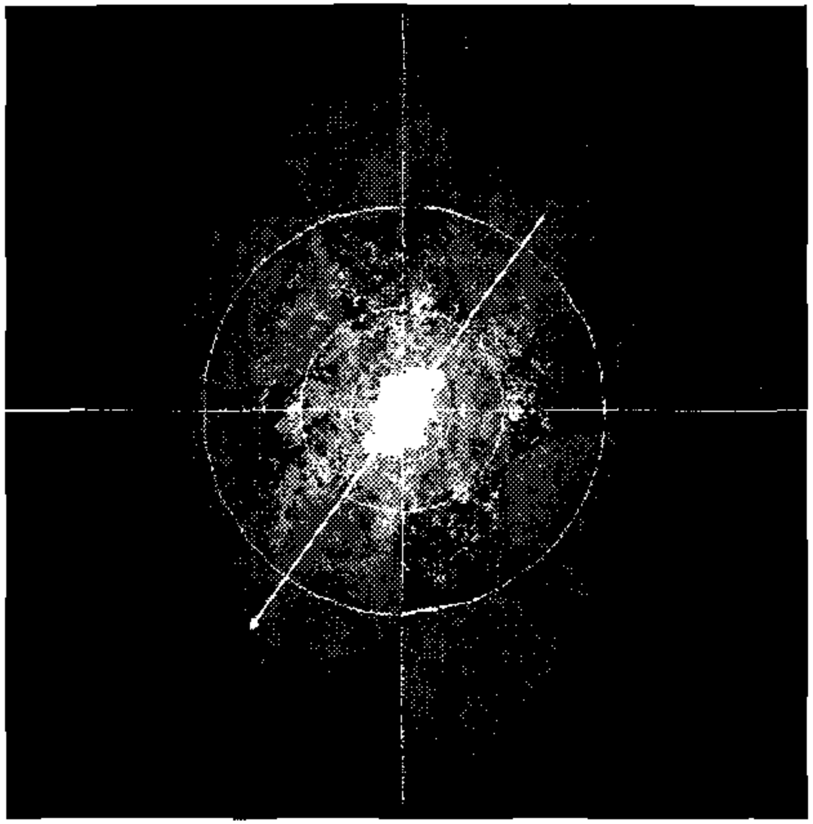

FIGURE 7(b) : Ocean Wave Spectra Image Showing Wavelengths (Outer circle=50 m, Middle circle=100 m, Inner circle=200 m).