OPERATIONALIZATION OF SAR POLARIZED DATA FOR ASSESSMENT OF COASTAL EROSION

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ABSTRACT

This study introduces a new approach for operationalization of SAR polarized data on coastal erosion studies. Polarized TOPSAR and ERS-1 data are used for this purpose. ERS-1 data was acquired on the 8th August 1993 and polarized TOPSAR data was acquired on the 6th December 1996. A quasi-linear model and a new model based on the Canny algorithm were used to model shoreline changes. Digitized vector layers of shoreline change were used to examine the accuracy of the model results. This study shows that the results of the Canny algorithm has a good correlation with the results from the quasi-linear model. The Canny algorithm can successfully be used for automatic detection of shoreline change. In conclusion, the integration between the quasi-linear model and the Canny algorithm model enables further operationalization of SAR data for coastal erosion studies.

1.0 INTRODUCTION

Coastal erosion studies from space are still in an early stage. Most studies that have been done by using remotely sensed data are restricted to the application of classical methods of shoreline identification based on digitizing and overlaying methods. These methods induce high rates of error and require a lot of time to process the data. In this process, the sum of thematic errors and digitizing errors account for the low accuracy of the interpretation results. This often results in inadequate solutions of the problems for coastal engineers and decision makers. For instance, Raj (1982); Mazlan et al., (1989), and Frighy et al., (1994) used different historical data of satellite imagery, aerial photography and topographic maps for coastal erosion studies. Most of these studies found an unrealistic high rate of erosion of more than 50 m/year. For instance, Frighy et al., (1995) found the rate of erosion in the Nile Delta to be –70.8 m/year. However, if this rate really had occurred, it would have caused the destruction of all the infrastructures, such as roads and bridges near the coastal waters. Furthermore, Frighy et al., (1995) stated that there is a significant relation between shoreline change, estimated from Landsat TM, aerial photography and ground surveys with a correlation coefficient (r) of 0.93. This can not be considered as a significant result, due to the fact that a significant statistical test such as ANOVA or the t-test have not been performed. In addition, the low resolution of the Landsat data (30 m) only justifies its use in coastal erosion studies with changes that are larger than this pixel size. As a matter of fact, the resolution of this sensor is unable to capture beach profiles at a width less than the pixel size (< 30m). The high resolution of SPOT PAN (10 m) and radar data such as from ERS-1 (12.5 m), Radarsat (12.5 m) and AIRSAR/TOPSAR (ca. 10 m) enables us to solve this type of problem.

Another critical problem often observed in coastal erosion studies is the misunderstanding of the dynamic relation between waves, tides and current movements with sediment transport. This was obvious in the study of El-Reay et al. (1995). El- Reay et al. (1995) stated that the high rate of erosion along the Rossate (branch of the Nile river delta, Egypt) is due to sea level rise. However, the problem of coastal erosion along the Rosseta is due to wave effects (Komar, 1976).

Recently, Maged (1999) used a new approach for coastal erosion studies. A radon transformation was used to detect shoreline changes. Maged (1999) compared the results of radon transformation with the results of classical methods of shoreline identification by the digitizing and overlaying method. He found that the error is significantly lower while using the radon transformation. However, radon transformation can not be applied to concave shorelines since it can only deal with linear features in the images. Maged‘s study (1999) could not fully explain this type of shoreline change as it appeared to be concave in some places. So the conclusion might be that radon transformation is not suitable to apply to these non-linear features but only to straight shorelines.

The operationalization study of coastal erosion models could be new method for coastal erosion detection. This method will be useful for rapid detection and illustrative for educational purposes. In order to make the coastal erosion model operational, the integration between wave spectra effects and automatic detection of shoreline (over time and space) should be recognized. The aim of this study is to introduce a new approach for operational use of polarized SAR data in coastal erosion studies.

2.0 Methodology

2.1Study Area

The study area is located in the South China Sea between 5° 21’ N to 5° 27 ‘ N and 103° 10’ E to 103° 15’ E. This area lies in the equatorial region and is dominated by two monsoon seasons (Maged, 1994). The southwest monsoon lasts from may to September while the northeast monsoon lasts from October to March. The monsoon winds effect the direction and magnitude of waves. Strong waves are prevalent during the northeast monsoon when prevailing wave direction is from the north (December to February), while during the southwest monsoon (May to September), the wave direction is from the south (Maged 1999).

2.2 Data Acquired

SAR data used in this study include ERS-1 and AIRSAR/TOPSAR data. ERS-1 data in the Cvv band (12.5 m) was acquired on 8^{th} August 1993. AIRSAR/TOPSAR data with composite polarization in the L band was acquired on 6^{th} December 1996.

2.3 Shoreline Change Model

In ease of shoreline detection, the shoreline of the East Coast of the Peninsula of Malaysia is defined by the boundary between the vegetation and the bare sandy area (beach). This definition will be helpful for determining the shoreline from polarized SAR data. It is well known that SAR data contain speckled noise which induces limitation on the visual interpretation of SAR images. Linear filters, such as Gaussian filtering and Lee filtering could be applied to enhance the image for visual interpretation. The Canny algorithm has been used for shoreline detection. It provides a way of edge detection of the shoreline, as close as possible to the true edges. This has been examined by manual digitizing and overlaying of shoreline maps derived from the radar imagery. The Canny filtering algorithm was applied as follows:

The input of the image intensity is **I,** which is corrupted by noise. Let **G** be a Gaussian with zero mean and standard deviation **s**. The value of σ to be used depends on the length of interesting connected contours, the noise level, and the localization-detection trade off. The Gaussian filtering was applied and smoothens the image intensity to image **J** i.e., **J= I * G**. For each pixel **(j,j)**: (a) compute the gradient components, $\mathbf{J_x}$ and $\mathbf{J_y}$, (b) estimate the edge strength as given by

$$E_x\ (i,j) = \sqrt{}\ J^2_x\ (i,j) + J^2_y\ (i,j) \qquad (1)$$

and (**e**) estimates the orientation of the edge normal as given by

$$e_0(i,j)= \arctan J_y/ J_x \qquad (2)$$

The output is a strength image, Es, formed by the values $\mathbf{e_s}$ **(i,j)** and orientation image, $\mathbf{E_0}$ formed by the values $\mathbf{e_0}$ **(i,j)**. The shoreline edge pixels will be vectorized automatically after Canny algorithm has been performed. Canny algorithm was performed to two SAR polarized images in order to identify the rate of shoreline change.

2.4 Wave Spectra effects and Shoreline Changes

Wave spectra are derived from polarized SAR data by applying two dimensional Fourier Transformation. The wave spectra derived from polarized SAR data were mapped into the real wave spectra by using a forward quasi-linear model. This model was simplified by Vachon et al. (1994) as follows

$$Sq = h\ (Kx;Kc)\ S(L)\ S(k) \qquad (3)$$

where **Sq** is a quasi-linear transform function, **kx** is wave number in azimuth direction; Kc is the cut-off wave number, as a function of wind speed. **S (k)** is SAR polarized wave spectra while **S (L)** is a real wave spectra measured in situ.

Then, shoreline change detection was model by volume change of sediment transport equation developed by Maged (1999) as given by

$$dv = {}_{t0}\int^{t}\ V(S\ q)\ dt \qquad (4)$$

The shoreline change as function of the volume of sediment transport rate can be given by

$$dy = dv\ dt/dx \qquad (5)$$

where **dx** is the distance change along the shoreline. The negative value of **dy/dt** will indicate an erosion event, while the positive value of **dy/dt** will indicate a sedimentation event. The linear regression model will apply between equation 5 and 1 to determine the ratio of accuracy between the two methods introduced above.

3.0 RESULTS AND DISCUSSION

Figure 1 shows the automatic detection of shoreline by using the Canny algorithm. Figure 2 shows that vector layers extracted by the use of the Canny algorithm coincided with vector layers digitized manually. This explains that the Canny algorithm provides edge detection for shorelines as possible as close to the true. It is obvious that the Canny algorithm can detect the concave shoreline. This is clearly demonstrated along the coastline of Sultan Mohamed Airport, as this area tends to be concave. This is because of the fact that the Canny algorithm produces pixel wide skeleton curves. Then a sequence of pixels along the curve was extracted from the two images. In addition, the sequence of pixels for each curve is converted to a vector pattern by fitting piecewise line segments to it. This induced polyline was an approximation to the original pixel curve. This could be attributed to the fact that the Canny algorithm links pairs of polylines. Therefore it would be easier to detect the concave shoreline feature (Figure 2). The rate of shoreline change is finally determined by overlaying the two vector layers from different periods that were extracted by using the Canny algorithm.

Figure 3 shows the wavelength spectra modelled from TOPSAR L band data and ERS-1 C-band data. It is obvious that the wavelength spectra are variable between August 1993 and December 1996 (Table 1).

Table 1: Ocean Wavelength extracted from SAR Polarized data

Sensor Type	Ocean Wavelength
ERS-1 (August 1993)	25 m -100 m
TOPSAR (December 1996)	20 m- 170 m

The ocean wave spectra information shown in Table 1 has been used to model significant wave height as described in Vachon et al. (1994). The significant wave height was then used to model the change in sediment volume transport, in order to detect shoreline change. Figure 4 shows that the rate of shoreline change peaks that have been modeled with the Canny algorithm coincide with the results from the quasi-linear model and the vector data (August 1993 and December 1996). It is obvious that there is a significant relation between the rate of shoreline change that was modeled with the Canny algorithm and the volume of change of the sediment transport (Figure 5).

The statistical significant t-test shows that a rate of significant difference is noticed between volume change of sediment transport and vector data obtained by manual digitizing. The rate of significant difference decreased with the ones that were automatically extracted by using the Canny algorithm and volume change of the sediment transport model. This could be attributed to some of the errors introduced by manual digitizing. This error could be the reason for the low accuracy rate. However, all the methods agreed on a high rate of erosion along the Sultan Mahmed Airport coastline of less than I m/year. This result is similar to the result of Maged (1999) and Maged (2000). However this study does not agree with the study of Mazlan et al. (1989). This is because of the fact that Mazlan et al. (1989) defined the shoreline as the zone of high tide. This definition is not valid because of the fact that the tidal zone is a dynamic area in which the tide change its cycle between low and high tide. This could not be used as a basic reference for the shoreline.

Table 2. Significant Differences T-test of Canny Algorithm with Quasi-linear and Vectors Layers

Model Type	DF	Ts	T	Differences	p	Significant
Quasi-linear	20	1.45	1.2	0.2	0.13	non-sig.
Vectors layers	20	2.32	3.2	0.0003	0.0002	Sig.

4.0 CONCLUSION

The Canny algorithm can be used for automatic detection of shoreline change from remotely sensed data. Operational use of remote sensing for an assessment of coastal erosion could be done by the application of wave spectra effects on volume change of sediment transport directly from radar data. This method should be integrated with automatic detection of shoreline change by using the Canny algorithm.

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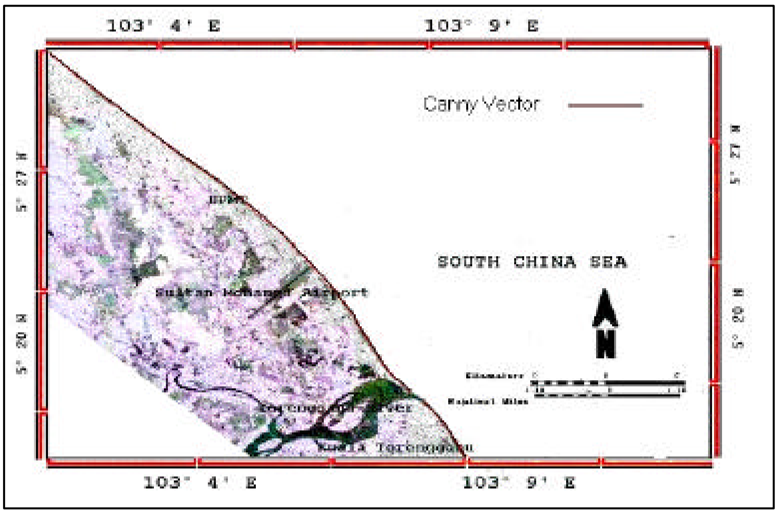

Figure 1. Output of Canny Algorithm

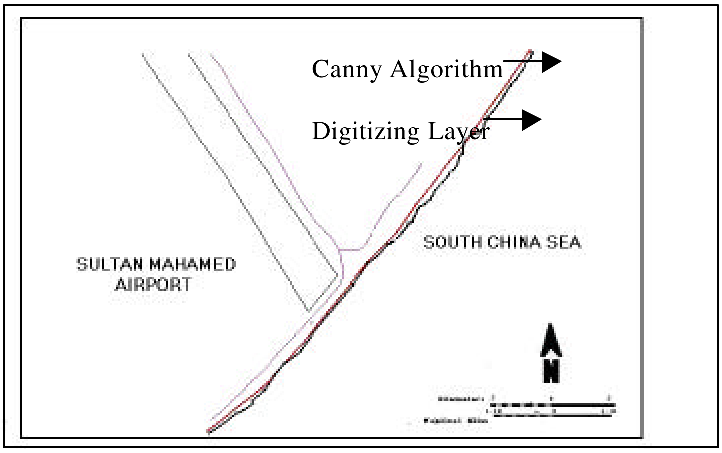

Figure 2. Vector Layers of Canny Algorithm and Digitizing

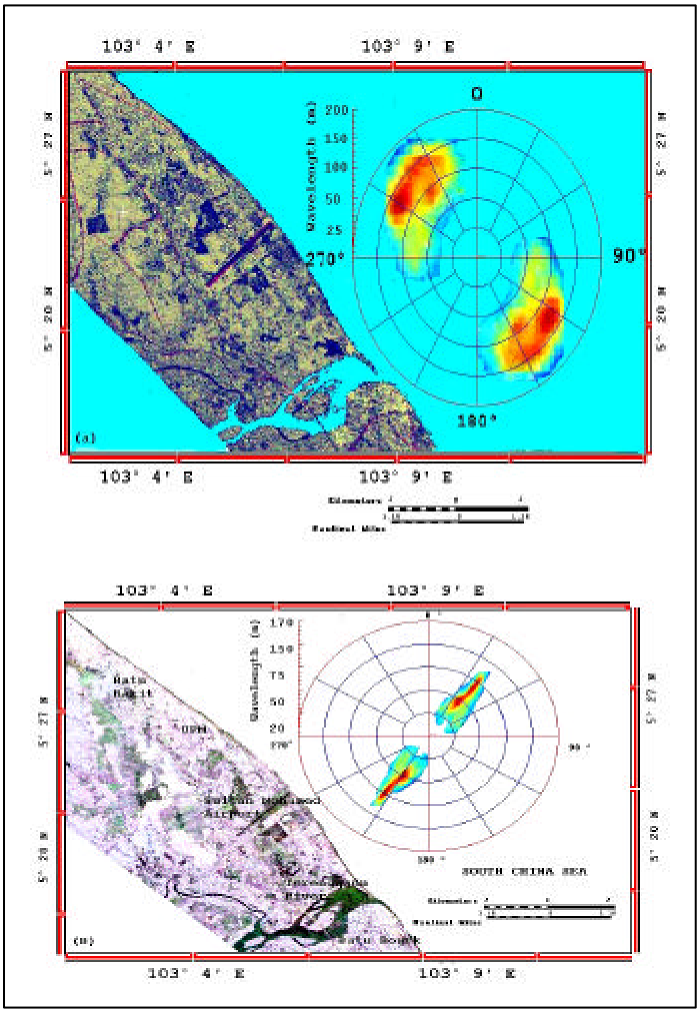

Figure 3. Wave Spectra Derived from ERS-1 and TOPSAR data, respectively.

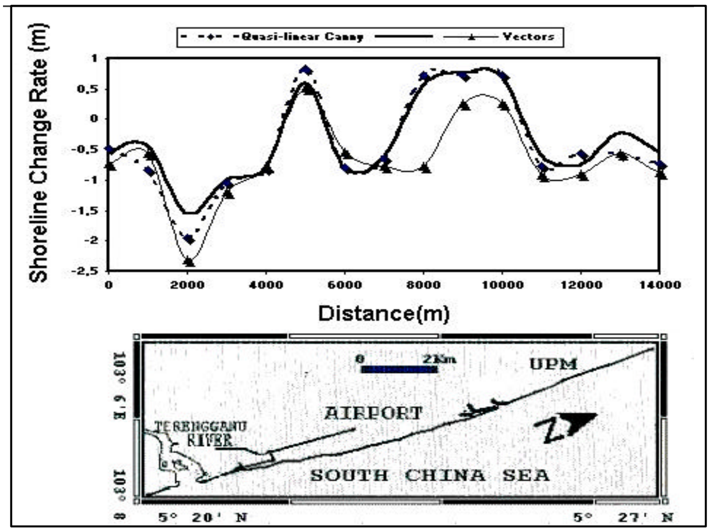

Figure 4. Shoreline Change Models

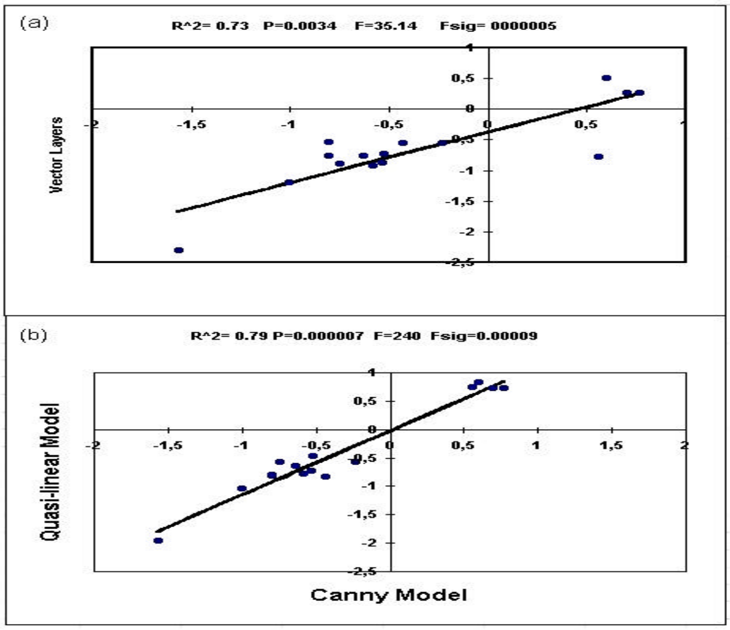

Figure 5. Regression Model between Canny Model (a) Digitizing and and Quasi-linear Model