1. INTERFEROMATRY FOR COASTAL SPITE GEOMORPHOLOGY MAPPING

Dr. Maged Marghany and Prof. Dr. Mazlan Hashim
Department of Remote Sensing
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
81310 UTM, Skudai, Johore Bahru, Malaysia
Emails: maged@fksg.utm.my
:magedupm@hotmail.com

ABSTRACT

This study presents new approach for mapping coastal geomorphology changes from interferometric synthetic aperture radar (InSAR) data. Two RADARSTA-1 SAR standard beam data were processed to acquire digital elevation of surface spit topographic information from INSAR. Furthermore, Fuzzy B-spline model combined with InSAR model to obtain more precisely information. Fuzzy B-spline model implemented within unwrapped phase and the RADARSAT-1 SAR data backscattered power. The study shows that digital elevation of spit topographic map is produced with relative errors of $\pm$ 0.2 m rms. The rate change of spit is 3 m/year. The terrain slope estimated using cross-correlation phase is agreed with ones estimated from ground field data with R^2 of 0.86. This study also shows that the Fuzzy B-spline model is decreased problem of uncertainties of elevation height estimation. In conclusion, integration between INSAR procedures and Fuzzy B-spline model can be used as geomatica tool for mapping coastal geomorphology changes. In fact, combination between InSAR and Fuzzy B-spline reduced uncertainties to acceptable level of accuracy.

1.0 INTRODUCTION

Spit morphology plays tremendous role in maintaining perched of estuarine systems as well as spits are highly valued for both their aesthetic characteristics and leisure uses. However, spit along the coastal water of Malaysia has come under increasing pressure through sand mining development. In addition, growth of spit across the estuary might be impact ship navigation and coastal water hydrodynamic exchanges between ocean and estuary (Stanely 1985). However, advance application of remote sensing technology such as interferometric synthetic aperture radar (InSAR) for coastal geomorphology study is in a preliminary stage. Therefore, InSAR techniques are proved to provide precisely digital elevation model map (DEMs). In this context, mapping purposes, geomorphological studies based on aspect maps and slops are acquired highly accurate DEMs products. The key question is how to utilize InSAR technique in modeling rate change of spit geomorphology. The main objective of the present study is to determine the rate change of spite by using the combination between InSAR and Fuzzy B-spline algorithm.

2.0 METHODOLOGY
2.1 Study Area and Data Set

The study area is selected along the mouth river of Kuala Terengganu, Malaysia. According to Maged (2000) the coastline appears to be linear and orientated at about 45° along the east coast of Malaysia (Stanely 1985). In addition, spit locates across the largest hydrological communications between the estuary and the South China Sea i.e. mouth river of Kuala Terengganu (Maged 2000). Two RADARSAT-1 SAR images were acquired on November 23 1999 and March 30 2005. Both RADARSAT -1 SAR image are standard 2 with incidence angle of 27.49° and swath coverage of 7694. RADARSAT-1 SAR data are operated at C- band with HH polarization (Figure 1).
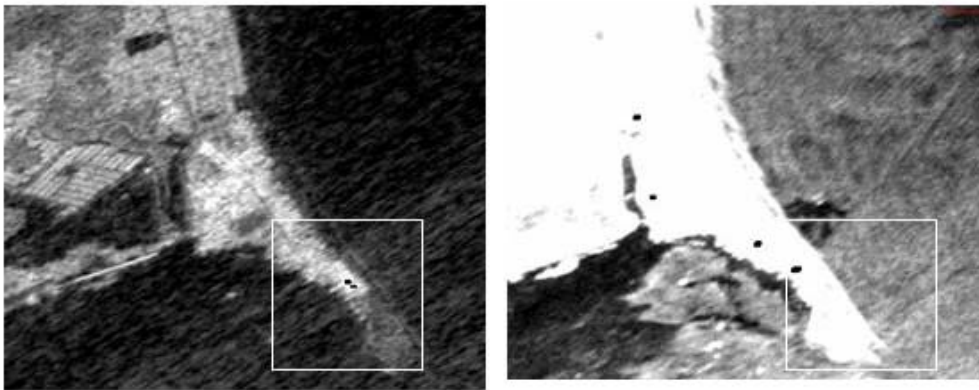
(a)   (b)

Figure 1. Selected Spit Area at (a) Master and (b) Slave images

2.2 Extraction of Spit Feature from RADARSAT-1 SAR

The change of image backscatter characteristics can assist to isolate the spit from the surrounding land covers and coastal water. Two RADARSAT-1 SAR Single Look Complex (SLCs) data used to generate the backscatter intensity images which performed by applying a focusing and multilooking methods (Zebker et al., 1994). Four steps used for preprocessing: (i) Gamma algorithm was used for speckle reduction, (ii) the intensity images were co-registered, (iii) These images then were geocoded, and (iv) finally, False Colour Composite (FCC) was produced in order to discriminate between spit and other surrounding environment classes.

2.3 Interferomatery Generation

Interferogram is produced by the product of the complex RADARSAT-1 SAR images of slave and conjugate of master image. This procedure is involved the average of the amplitude pixels and then calculate the difference of the phase values for each pixel located on RADARSAT-1 SAR images. Furthermore, utilization of multilook processing of range and azimuth bandwidth can reduce the amount of data and noise. Additionally, individual image is produced by dividing range and azimuth into sub-bands focusing each sub-band. Spectral frequency domain produced by convolution due complex multiplication of the two RADARSAT-1 SAR images.

2.4 Generation of a DEM from InSAR

DEMs are generated based on phase reconstruction from the two RADARSAT-1 SAR SLC images. This step might effect the quality of DEM if it committed any error. Fuzzy B- spline algorithm used to insure precisely information of DEM and overcomes uncertainties in phase reconstruction. Fusion technique is used to fed Fuzzy B-spline into 2-D least square phase unwrapping algorithm. Following Goldstein et al., (1988) integration between range, Doppler and interferomateric equations is employed to convert unwrapped phase into *x,y,z* coordinates. According to Tsay and Chen (2003), the quality of determine DEM is function of the accuracy of GCPs which collected using GPS during the RADARSAT-1 SAR pass over on March 30 2005 and topography map. Finally, height map is created and statistically compared with ground field data to acquire precisely spit's DEM.

3.0 RESULTS AND DISCUSSION

Figure 2 shows unwrapped interferogram where converted to interferomateric height by fusion with Fuzzy B-spline (Figure 3). The interferometric height consists of true elevation and a false height due to surface change. The time difference between two RADARSAT-1 SAR images is 6 years. The rate change of spit is 3 m/yr with maximum elevation height of 2.4 m. Table 1 shows a good agreement between InSAR DEM and ground data with r^2 of 0.86, *p* of 0.002 and rate of RMSE is $\pm$ 0.2 m. It is clear that rate of slope change is 1.5 m which considers as steep slope. It might be sand mining induced steep slope of spit. The increasing growth of spit across the estuary due to impact of sedimentation due to littoral drift. According to Maged (2003) net littoral drift along Kuala Terengganu coastal water is towards the southward which could induce growth of spit length. The high accuracy InSAR DEM could be generated due to fed Fuzzy B-spline into unwrapped phase. In fact, integration between Fuzzy B-spline and InSAR by using 2-D least square method has completely maintained the gradients on spit edges. Furthermore, Fuzzy B-spline increased the rate of unwrapped phase accuracy. Indeed, Fuzzy B-spline algorithm is able to keep track of uncertainty and provide tool for representing spatially clustered phase points. This advantage of Fuzzy B-spline is not provided in InSAR technique.
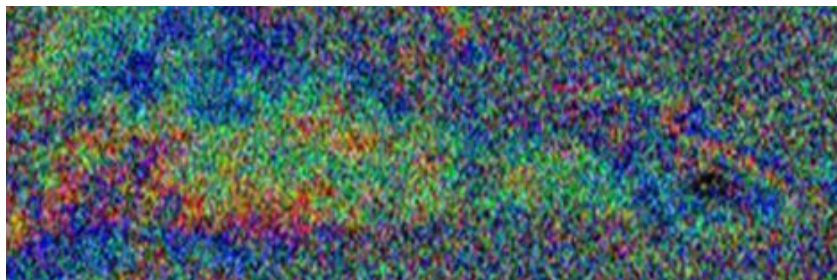

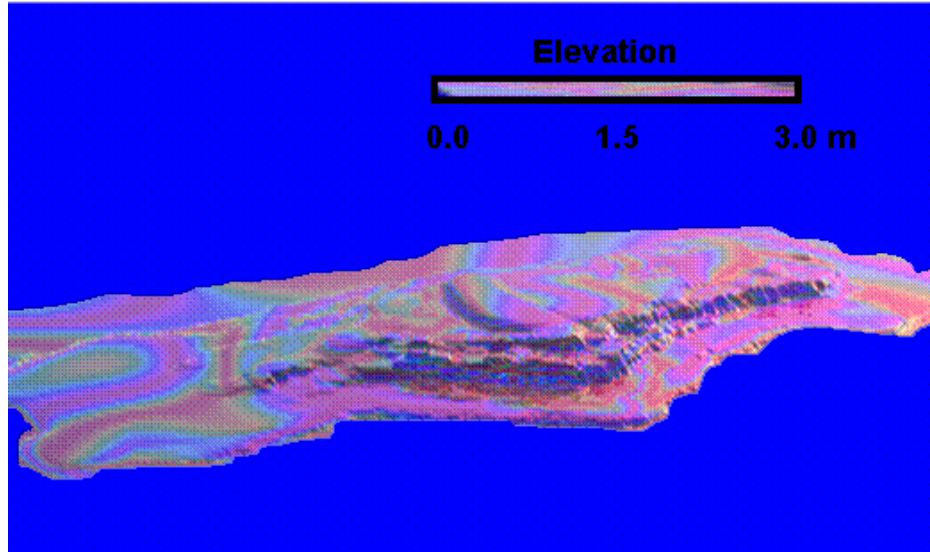**Figure 2. Unwrapped Interferogram of Spit Area**

Figure 3. Spit 's DEM extracted from Fusion of Fuzzy B-spline into Unwrapped Phase Interferogram.

Table 1: Significant Relationship between Ground Data and Fuzzy B-spline Interferomatery

Statistical Parameters	Values
R^2	0.86
P	0.002
RMSE	$\pm$ 0.2 m

4.0 CONCLOUSION

This work has demonstrated new approach for DEM generation based on InSAR technique. Feeding B-spline into phase by using 2-D least square method used as a new approach. Maximum height of spit is 2.4 and rate change of 3 m/yr within accuracy of 0.4 m/yr have been shown. This study also shows the increasing length of spit across the Terengganu estuary within 2 m. It can be concluded that the integration between Fuzzy B-spline and unwrapped phase intererogram can produce high accurate mapping of coastal geomorphology features such as spit.

REFERNCES

Goldstein, R.M. and H.A. Zebker, C.L. Wemer (1988) "Satellite Radar Interferometry: Two-dimensional phase unwrapping", *Radio Science,* 23,713-720.

Maged M., (2000). Wave spectra and shoreline change by remote sensing data. Ph.D. Thesis, Universiti Putra Malaysia, Serdang, Kuala Lumpur, Malaysia.

Massonet, D., and T. Rabaute, (1993). "Radar Interferometry: Limits and potential", *IEEE Trans. Geosci. Remote Sensing,* 3,455-464.

Stanely Consultants Inc., (1985). Malaysian national coastal ersoion study, Volume II. UPEN, Kuala Lumpur, Malaysia.

Zebker, H.A., C.L. Werner, P.A. Rosen, and **S.** Hensley, (1994) "Accuracy **of** Topographic Maps Derived from ERS-1 Interferometric Radar", *IEEE Trans. Geosci. Remote Sensing, 2* . 823-836,

Tsay, J.R. and H.H. Chen, (2003) " InSAR for DEM Determination in Taiwan by Using ERS Tandem Mode Data. Asian J. of Geoinformatics, 15:69-77

2. CANNY AND VELOCITY BUNCHING ALGORITHMS FOR MODELLING SHORELINE CHANGE USING MULTISAR DATA

Dr. Maged Marghany and Prof. Dr. Mazlan Hashim
Department of Remote Sensing
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
81310 UTM, Skudai, Johore Bahru, Malaysia
Emails: maged@fksg.utm.my
:magedupm@hotmail.com

KEYWORDS:RADARSAT-1 SAR,ERS-1, Velocity bunching, Canny algorithm, Shoreline change.

ABSTRACT

This paper introduces new method for simulating shoreline change from multi-SAR data. Edge detection algorithm such as Canny algorithm is implemented to identify shoreline. Automatic detection of sequence of shoreline derived from historical multi-SAR data (ERS-1 and RADARSAT-1 SAR data) used to estimate rate of shoreline change. In addition, velocity bunching model used to model the spectral energy of ocean waves from multi-SAR data. Then, rate of shoreline is simulated by using velocity bunching model. The study shows that: the maximum rate of erosion is -3.0 m/year along the coastal water of Kuala Terengganu, Malaysia. There is significant relationship between shoreline change rate estimated using Canny algorithm and ones modeled using velocity bunching model. The significant relationship is shown by high value of R^2 of 0.77.

1. INTRODUCTION

Recently there are tremendous studies have been conducted in automatic detection of coastline from various remotely sensing data (Maged 2002; and Liu and Jezek., 2004). Indeed, advance image processing tool of edge detection methods have been implemented to identify coastline. Maged (2002) and Liu et al., (2004) utilized edge detection algorithm such as Canny for coastline detection. Further studies have been simulated the shoreline change based on volume change of sediment transport by using ERS-1 images. Maged (2003) reported that shoreline change can be easily modeled from wave spectra information have extracted from SAR images. Analytical methods introduced by Vachon et al., (1993,1994 and 1995) of modeling significant wave height from SAR data based on quasi-linear and velocity bunching models have been implemented by Maged (2001, 2002 and 2003) to predict shoreline change from ERS-1 images. The aim of this work is to utilize Canny edge detection algorithm with velocity bunching model to simulate the rate change of shoreline from historical multi-SAR data (ERS-1 and RADARSAT-1 SAR data).

2. METHODS
2.1 Study Area

The study area is located in the coast of Kuala Terengganu, on eastern part of Peninsular Malaysia. This area is approximately 20 km along the north of Kuala Terengganu coastline, located between 5° 21' N , 103° 10' E and 5° 30' N, 103° 20' E). Sand materials make up the entire of this beach (Maged 2000). The east coast of Peninsular Malaysia is annually subjected to the northeast monsoon wind (November to January) (Stanley, 1985) under study showed that the mean and longer significant wave periods were 8 to 10 seconds. Significant wave heights maximum have reported by were 4 m and 2.4 m, respectively which are experienced in February and March However, during the southwest monsoon wave height was ranged between 0.4m -0.7m (Maged et al., 2002). During the inter- monsoon period (September to mid of November), the wave height was ranged between 0.37m to 1.6 m (Maged 2002).

2.2 Data Acquired

SAR data used in this study are involved ERS-1 and RADARSAT-1 SAR data. ERS-1 data in the C_{vv} band (12.5 m) is acquired on 12 December 1999. The in situ wave measurements data were obtained from Malaysian PETRONAS oil platform observation through Malaysian Meteorological Service. RADARSAT-1 SAR image is acquired on March 30 2005 with standard 2 mode. During its pass over in situ measurements collected by using AWAC wave rider buoy.

2.3 SAR Velocity Bunching Model

The velocity bunching MTF is the dominant component of the linear MTF for the ocean waves with an azimuth wave number (k_x). According to Vachon et al., (1994 and 1995), the velocity bunching can contribute to linear MTF based on the following formula

$$M_v = \frac{R}{V}\omega\left[\frac{k_x}{k}\sin\theta + i\cos\theta\right] \qquad (1)$$

where R/V is the scene range to platform velocity ratio, θ is ERS-1 and RADARSAT-1 SAR incidence angles (23° and 27.49°) and ω is wave spectra frequency which equal 2Π/K. To estimate the velocity bunching spectra $S_{vb}(k)$, we modified the algorithm that was introduced by Krogstad and Schyberg, (1991). The modification is to multiply the velocity bunching MTF by ERS-1 SAR and RADARSAT-1 SAR spectra variance of the azimuth shifts. This can be given by

$$S_{vb}(k) = [I_0 \sum_{n=1}^{\infty} \frac{\psi(k_x)^{2n}}{n!} S_{\zeta\zeta}^{*n} \psi(k)^2 e^{-K_x^2 \rho_{\zeta\zeta}}][M_v] \qquad (2)$$

where $S_{\zeta\zeta}$ is the SAR spectra variance of the azimuth shifts due to the surface motion, which induced by the velocity bunching effect in azimuth direction due to high value of R/V.

The relation between standard deviation of the azimuth shift and significant wave height can be given by

$$\sigma = (\frac{R}{V})(1 - \frac{\sin^2(\theta)}{2})^{0.5}(\frac{k_x g}{8})^{0.5} H_s \qquad \text{(Vachon et al., 1993)} \qquad (3)$$

where k_x is the azimuth wave number. Note that the mean wave period T_0 is equal to $2\pi(\langle\langle k_x\rangle g\rangle^{-0.5}$. Using equation 3 with equation 4, so the significant wave height can be given as

$$H_s = 0.6(\rho_{\zeta\zeta})^{0.5}[\frac{1+\theta^2/4}{R/V}]T_0 \qquad (4)$$

where θ is the ERS-1 and RADARSAT-1 SAR incidence angles and equation 4 is used to estimate the significant wave height which is based on the standard deviation of the azimuth shift.The significant wave height determined using velocity-bunching model then used to model the rate of volumetric sediment transport based on the depth of significant wave breaking by using the following formula derived from Maged (2003)

$$H_{Sb} = 0.4g^{1/5}[[(0.6\sqrt{\rho_{\zeta\zeta}}(\frac{1+\theta^2/4}{R/V})T_0)(T)]^2]^{2/5} \qquad (5)$$

According to Maged 2003, the along-shore sediment transport volume rate Q, is calculated as

$$Q = 1.1\rho g^{3/2}(H_{sb})^{5/2}\sin\alpha_b\cos\alpha_b \qquad (6)$$

where $\rho = 1020$ kg/m^3 for sea water and α_b is the breaking wave angle estimated from linear wave transformation model. The ambiguity of SAR wave spectra are resolved by using the sea direction in situ measurements. According to Maged (2002) the shoreline change rate based on volume change of sediment transport can be estimated by following equation

$$\int_{x_0}^{x} ydx = -\int_{t_0}^{t} 2hQdt \qquad (7)$$

where t is period of change and x is along shore distance and h the depth of closure (m).

2.4 Automatic Detection of Shoreline

According to Maged (2002) the shoreline of east Coast of the Peninsula of Malaysia is defined by the boundary between vegetation and the bar sandy area (beach). Following Maged (2002) Canny algorithm has applied to SAR images after performing linear filters by using Guassian and Lee algorithms. The Canny algorithm has applied as follows: The input of the SAR image intensity I, which is corrupted by noise. Let G be a Gussian with zero mean and standard deviation σ. The value of σ to be relied on the length of interesting connected contours, the noise level, and the localization-detection trade off. The Gaussian algorithm was applied and smoothens the image intensity to image Ji.e., J=I*G for each pixel (i,j):(a) compute the gradient components, J(x,y)(b) estimate the edge strength as given by

$$e_x(i, j) = \sqrt{J_x^{\,2}(i, j) + I_y^{\,2}(i, j)} \qquad (9)$$

The historical edge detection vectors then overlaid and the rate change *(R)* of shoreline estimated by given simple formula (Maged 2001)

$$R = \frac{x_n - x_0}{t_n - t_0} \qquad (10)$$

where x is the horizontal measured distance between initial vector (x_0) of ERS-1 image and second vector x_n of RADARSAT-1 SAR image over period t.

2.5 Field Work

Beach profile survey has been conducted during the RADARSAT-1 SAR pass over coastal water of Malaysia. Profile survey is carried out by using level and staff methods. Theodoliate is fixed on front between vegetation and sand. Then poles are fixed at every slope point. Furthermore, Global Position System (GPS) has used to collect geographical coordinates of selected 10 locations (Figure 1), where the interval distance between every location was 2 km. Additionally, the ground data information has used to acquire more precisely geomateric correction processing for multi-SAR data. Finally, accuracy validation is performed by comparing between multi-SAR and ground data.

3. RESULTS AND DISCUSSION

Figure 2 shows the significant wave height modeled by using velocity bunching model from ERS-1 and RADARSAT-1 SAR images. In December 1999 (ERS-1 SAR), significant wave heights are ranged between 1.2 to 3.2 m while in March 2005 (RADARSAT-1 SAR), significant wave heights are ranged between 0.2 to 0.7 m. Regression model shows that the significant wave heights modeled by velocity bunching are in good agreement with in situ data. The degree of correlation is a function of r^2 and probability (*p*). The relationship

between velocity bunching model and in situ data shows positive correlation as r^2 values for both ERS-1 and RADARSAT-1 SAR data are 0.69 and 0.73, respectively. According to Maged (2004) velocity bunching model produces precisely information of wave spectra. Indeed, it is able to solve the matter of non-linearity between SAR observed spectra and ocean wave spectra. On other words, it can be used to map SAR observed spectra into real ocean spectra. This result confirms that studies of Vachon et al., (1993) and Maged (2004). Figure 3 shows the result of Canny algorithm. It is interesting to notice that Canny algorithm is provided an automatic digitizing for shoreline. Furthermore, it is also clear that small texture details have detected. Indeed, Canny algorithm can perform pseudo-edge appearance. Additionally, the concave coastline is detected which is obvious along the coastline of Sultan Mohamed Airport. Maged (2002) stated that Canny algorithm produces pixel wide skeleton curves and able to extract the sequences of pixels along this curve. He concluded that each curve contains sequences of pixels is able to convert to vector layer by fitting piecewise line segments to it. In addition, Canny is able to produce a polyline is an approximation to the original pixel curve. Which could link pairs of polylines. Figure 4 shows the comparison between shoreline change rate simulated by velocity bunching and one based on historical vector layers extracted by Canny algorithm and ground data measurements. The different sorts of data are agreed that the high rate of erosion is recurred along the Mengabang Telipot coastline with maximum values of -3.0, -2.8, -2.6m/ yr obtained by velocity bunching model, Canny algorithm and ground beach profile surveying. Meanwhile, Sultan Mohamed airport is encountered high rate of erosion within maximum values of -2.4, -2.00, -1.93 m/yr modeled from velocity bunching model, Canny algorithm and ground beach profile data collection. The sedimentation events have been observed along mouth river of Kuala Terengganu and Batu Bourq within average values of 1.89 m/yr which are acquired from velocity bunching ,Canny algorithm and ground data. Table 1 shows significant relationship between Velocity Bunching model and Canny algorithm with R^2 of 0.70.

4.0 CONCLOUSION
This study has been demonstrated a new technique for modeling shoreline change based on velocity bunching model and Canny algorithm. It can be said that modification of sediment transport model based on velocity bunching model can be used to simulate rate change of shoreline from multi-SAR data. In fact, velocity bunching is provided a quantity information on significant wave height from SAR data such as ERS-1 and RDARSAT-1 SAR images. It can be concluded that integration between velocity bunching model and Canny algorithm is considered as usefual tool for modeling quantity of shoreline change pattern.

REFERENCES

Krogstad, H.E., and Schyberg, H. (1991). On Hasselman 's nonlinear ocean –SAR transformation. Proceedings of IGARSS'91, Espo, Finland, June 3-6, 1991. pp:841-849.

Liu, H., and K.C., Jezek (2004) Automated Extraction of Coastaline from Satellite Imagery by Integration Canny Edge Detection and Locally Adaptive Thresholding Methods. Int. J. Remote Sensing. 35:973-958.

Maged M., (2000). Wave spectra and shoreline change by remote sensing data. Ph.D. Thesis, Universiti Putra Malaysia, Serdang, Kuala Lumpur, Malaysia.

Maged M., (2001). TOPSAR wave spectra model and coastal erosion detection. Int. J. Applied Earth Observation and Geoinformation, (3)(4): 357-365.

Maged M., Ibrahim, Z., Genderen, J.V. (2002). Azimuth cut-off for significant wave height investigation along the coastal water of Kuala Terengganu, Malaysia. Int. J. Applied Earth Observation and Geoinformation. (4)(3): 147-160.

Maged M., (2002) Opertional of Canny Algorithm on SAR data for Modelling Shoreline Change. Photogram. Ferner. Geoinformation. 93, 93-102.

Maged, M. (2003) ERS-1 Modulation Transfer Function Impact on Shoreline Change Model. Int. J. Applied Earth Observation and Geoinformation. (4): 279-294.

Maged M. (2004) Velocity Bunching Model for Modelling wave Spectra along East Copast of Malaysia. J. Indian Society of Remot. Sensing, Vol 32. pp:185-198.

Stanely Consultants Inc., (1985). Malaysian national coastal ersoion study, Volume II. UPEN, Kuala Lumpur, Malaysia.

Vachon P. W., Olsen, R., Livingstone, C. and Freeman, N.G. (1988) Airborne SAR observations of ocean surface waves during LEWEX. IEEE Transactions on Geoscienceand Remote Sensing, 26: 549-562.

Vachon P.W., and Raney, R.K.   (1989). Estimation of the SAR system transfer function
through processor defocus. IEEE Transactions on Geoscienceand Remote Sensing, 26 (6): 702-708.

Vachon, P.W., and Raney, R.K., (1991). Resolution of the ocean wave propagation   direction in SAR imagery.IEEE Transactions on Geoscienceand Remote Sensing, 29 (91):105-112.

Vachon, P.W., Ghogal., A.S., and West,J.C. (1992). Airborne SAR measurements of ocean waves during SWADE. Proceeding of 15 th Canadian Symposium on Remote Sensing, 1-4 June 1992. Toronto: Canada. pp. 352-356.

Vachon, P.W., Raney,R.K., Krogstad, H.E., and Liu, A.K., (1993). Airborne synthetic aperture radar observations and simulations for waves-in-Ice. J. Geophysical Research, 98:16,411-16,425.

Vachon, P.W., Krogstad, H.E., and Paterson,J.S., (1994). Airborne and spaceborne synthetic aperture radar

observations of ocean waves. Atmosphere-Ocean. 32(10): 83-112.

Vachon P.W., Liu, A. K. and Jackson, F.C. (1995). Near-shore wave evolution observed by airborne SAR during SWADE. Atmosphere-Ocean, 2: 363-381.
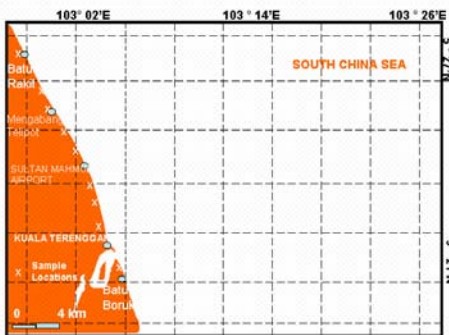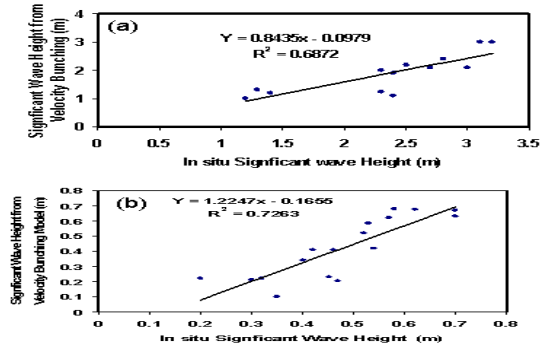
Figure 1. Location of Study Area

Figure 2 Signficant wave Height Modeled by Velocity Bunching Model (a) ERS-1 and (b) RADARSAT-1 SAR images
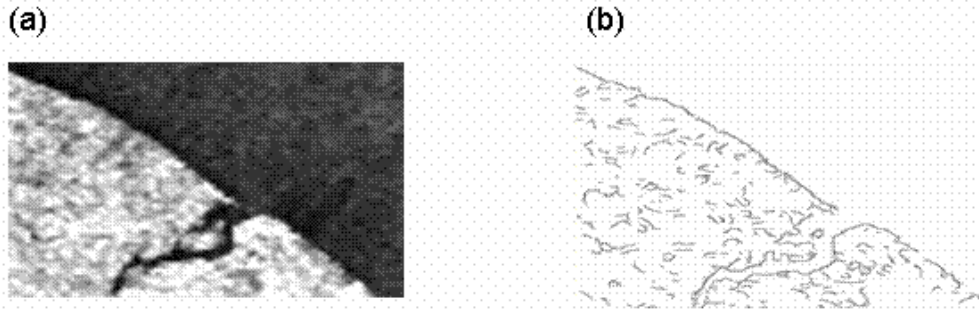

Figure 3. Example of Canny Algorithm (a) Raw SAR data (b) Output Result of Canny
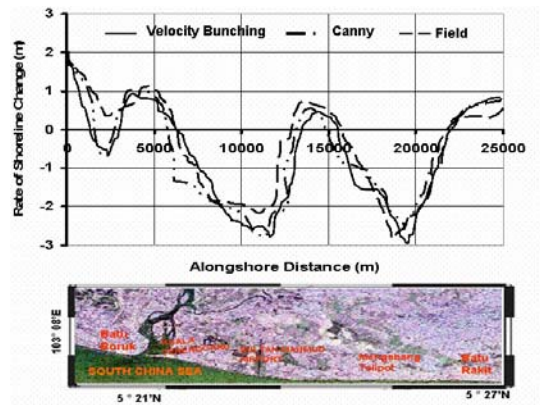

Figure 4. Rate Change of Shoreline from Canny, Velocity Bunching and Field data.

Table 1. Statistical Analysis between Velocity Bunching, Canny and Field Data

Methods	R^2
Velocity Bunching-Canny	0.70
Velocity Bunching-Field	0.68