AIRSAR ALONG TRACK INTERFEROMETRY FOR SHORELINE CHANGE MODELING

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Abstract

This study is introducing a new approach for modeling shoreline change. AIRSAR data with L and C bands utilized to model shoreline change. Based on the phase information in along track interferometry, the quantitative information such as current velocity and swell wave height have been modeled. The phase information in ATI SAR images can be transferred to interferometric velocities, which are the sums of the orbital velocity of current, the phase velocity of Bragg wave and the orbital velocity of swell. These information have been used to model the volume change of longeshore transport.

The result shows that wave spectra swell are less than 100 m of wavelength. The shoreline change rate obtained from phase information is ranged from –0.0125 m/day to 0.5 m/day. In conclusion, along track interferometry method cold be used to detect small change of shoreline change over short period which may be less than one day. This method could be used as an automatic tool for quick detection of shoreline change and modeled the factors could be induced this change

Key words: Along – Track Interferometry (ATI)- Phase interferometry, Swell and Shoreline change.

1.0 Introduction

Airborne along track interferometry (ATI) applications for coastal process studies has not been recognized yet. This is because of the fact that interferometric SAR technique for oceanic application is relatively new and has not a full visibility in oceanic graphic community yet. The purpose of this study is to present interferometry technique for mapping shoreline change. In this paper it is shown how observation from AIRSAR interferometry can be used to model shoreline change. Here we demonstrate how the quantitative information of swell and current can be used for shoreline change model form single AIRSAR data. According to Vachon et al., (1999) Airborne along track interferometry (ATI) has the potential of measuring ocean surface currents and waves with high spatial resolution. According to Fabrizio et al., (2002), two antenna SAR system should be used with ATI technique. The short time lag between complex SAR images is produced by the along –track baseline between the two antenna due to that each antenna received backscatter signal with different time. The phase difference between the images induces the mean short-term Doppler shift of the scattering from the ocean surface to be measured on pixel by pixel basis. In other words, the phase information along track interferometry (ATI) SAR images considers as measure of the Doppler shift of the backscattered signal and line of sight velocity scatterers. Duk et al., (2002) pointed that the interferometric velocity is the sum of the ocean surface currents, phase velocities of Bragg waves and the orbital motion of the water particles.

The question is how this phase difference can be used to model the shoreline change from a two complex polarized AIRSAR images. There are few studies have been realized the potential of SAR for modeling coastal erosion (Maged, 1999; 2000; 2001). These studies stated that quasi-linear transform can be used to predict shoreline change based on significant wave height simulation. Maged (2001) found that modulation transfer function has limitation for modeling shoreline change. The modulation transfer function based on quasi-linear model able to model the sedimentation along the range direction. The velocity bunching can model the erosion only along the azimuth direction.

2.0 Data Acquired

The sea wave truth data was collected from ship observation and wave rider buoy from Malaysian PETRONAS platform on 6 December 1996 (during which time the airborne AIRSAR/TOPSAR passed over the study area). The platform observations were obtained through the Malaysian Meteorological Service. These data included wave height and wave direction. These data were observed at PETRONAS oil platform at 5° 02 ' N and 105° 23' E in the month of December 1996. These data were used for wave spectra modulation with TOPSAR data.

2.1 Modeling Shoreline Change from ATI

Duk et al., (2002) proposed method to model swell wave height simply from orbital velocity with the angular velocity. We intend to use this model to derive changes in shoreline change. This model exploits the fact that waves can induce volume change of sediment transport. This model concerns with modeling the radial component of the surface velocity, then model the swell wave height. The quantities information of swell wave height can be used to model volume change of sediment transport based on longshore current.

The ocean surface current is measured by the surface Doppler velocity which is the sum of-sight velocities. The radial surface Doppler velocity measurements U_d cann be expressed as

$$U_d = f(u_c, u_b, u_w) \qquad (1.0)$$

where u_c , u_b and u_s are the surface current, phase velocity of Bragg-resonant wave and the orbital velocity of the swell, respectively. The Bragg-wave phase velocities depend on radar frequency, while ocean surface current velocity is steady over relatively wide area regardless of radar frequency. The difference of Bragg-resonant wave phase velocities induce difference between C-band and L-band averaged velocities. This can be explained mathematically as

$$\langle U \rangle^L - \langle U \rangle^C = [2\alpha(\vartheta_w) - 1](\omega^L - \omega^C) \qquad (2.0)$$

where α represents the respective proportion of approaching and receding Bragg-resonant wave spectra density contribution to radar echo and φ is wind direction
(Dua et al., 2002).

The wave height can be given by

$$H = 2.\frac{u}{\sqrt{\sin^2 \phi + \cos^2 \theta \cos^2 \phi}}\omega^{-1} \qquad (3.0)$$

where ϕ,θ, and ω are the flight direction, incidence angle and wave frequency respectively. U is the amplitude of the radial velocity.

The breaker heights are used to simulate longshore sediment transport rates, Q, as the volumetric rate of sand movement parallel to the shoreline. According to Komar (1976) this can be empirically derived as

$$Q = 1.1\rho g^{3/2} H_{sb}^{5/2} \sin\alpha_b \cos\alpha_b \qquad (4.0)$$

where ρ is the density of sea water (1020 kg/m^3), g is 9.8 m/s and α_b is the breaking wave angle. Using a mass conservation cross-shore transport model, the conservation of sand along a infinitely small length of shoreline, δx , can lead to a definition of the shoreline position, *y,* as

$$\frac{dy}{dt} + 2H_{\max}\frac{dQ}{dx} = 0 \qquad (5.0)$$

where t is the period in time, $2H_{\max}$ is the depth of closure (m) and Q is the longshore sand transport rate.

3.0 Results and Discussion

Figure 1 shows the interferogram spectrum where the intensity peak appears to be truncated at azimuth wave number of about 0.015 rad/m. Figure 2 shows the estimated swell wavelength from using 2-D Fourier transform of the interferometry velocity equation 3. It observed that the swell propagated with wavelength less than 100 m. This swell tend to move along the azimuth direction. Figures 1 and 2 agreed that a shifting of peak intensity spectra along the azimuth direction. These results are similar to Vachon et al., (1997). This swell are converged by high spectra energy along the shoreline of Airport. The normalized interferogram spectra along the convergence zone is 1.4 dB (Figure 3b). The phase of the interferogram wave refraction spectra confirms that the swell tends to converge along the Airport shoreline (Figure 3c). The shoreline can be distinguish from normalized interferogram spectra. This may be due to that Doppler spectra filters out the effect of certain scattering mechanisms, so enhancing the visibility of shoreline and swell convergence and divergence along the shoreline. It is clear that the convergence area located along the azimuth direction. This may be because of the ATI can imagine the highest spectra velocity by acquiring interferogram from different azimuth viewing angle. Figure 3c shown a phase change as approaching onshore. This is because of the fact that the scatter elevation varies from the reference, a differential phase is introduced into the interferogram which induced phase change following the topography of sea. The radial velocities which used to model the wave height depends on radar frequency. The change of horizontal current velocities are based on the change of the ocean bottom topography. This induces different change in the Bragg phase velocities. These results are agreed with Duk et al., (2002). The shoreline rate change is was less than 0.5 m/day (Figure 4). This occurred along airport shoreline. This can be due to the concave shape of Airport shoreline.

4.0 Conclusion

It can be concluded that ATI SAR provide a good map for swell wave refraction propagation. The swell wave height can be estimated from the amplitude of the radial velocity. The rate of erosion occurred along the convergence zone with rate less than 0.5 m/day.

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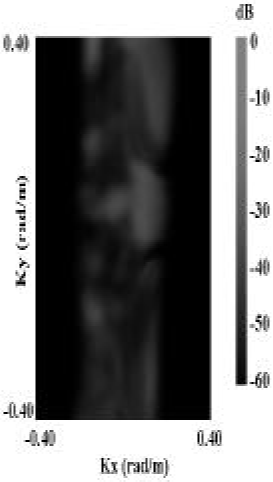

Figure 1. Interferogram Complex Spectra of the difference between L and C bands

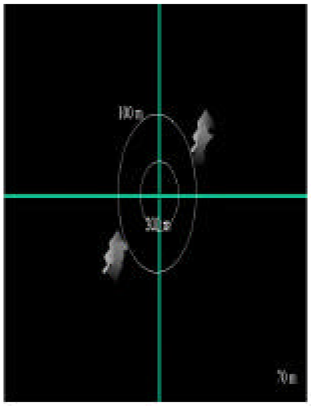

Figure 2. Swell wave spectra estimated from 2-D Fourier transform of the interferometry velocity.

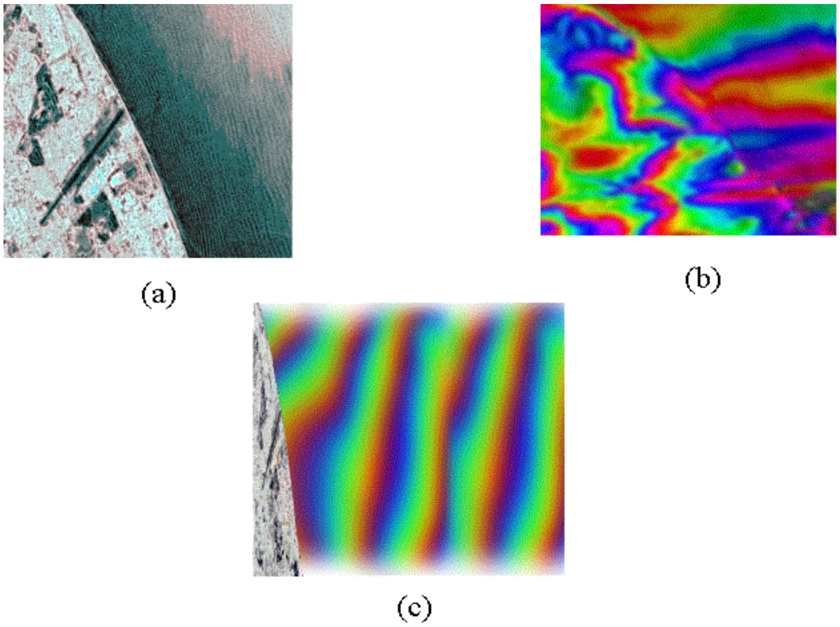

Figure 3 (a) composite image of L and C-band (b) Interferogram (c) Interferogram phase of wave refraction.

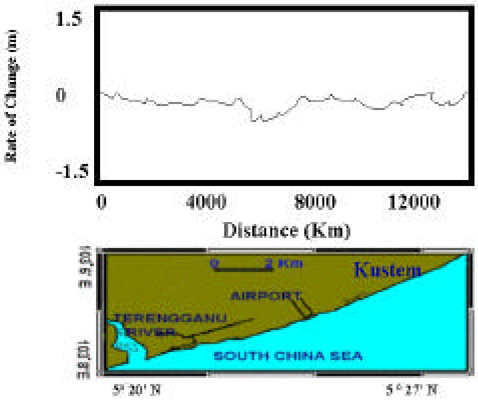

Figure 4. Estimated Shoreline Change Rate per Day from Interferogram Phase