HOLOGRAPHIC INTERFEROMATERY FOR MODELLING RATE CHANGE OF SHORELINE FROM AIRSAR DATA

Maged Marghany, Mazlan Hashim and Arthur P. Cracknell

Department of Remote Sensing
Faculty of Geoinformation Science and Engineering
Universiti Teknologi Malaysia
81310 UTM, Skudai, Johore Bahru, Malaysia
Email: *maged@fksg.utm.my,*
magedupm@hotmail.com,
mazlan@fksg.utm.my,
cracknellarthur@hotmail.com

Abstract

This work is introducing a new approach for modeling shoreline change rate from AIRSAR Cvv-band. The hologram algorithm has been applied to simulate the wave spectra propagation pattern. In addition, Doppler frequency and azimuth cut off models are used to model longshore current movement and rate change of sediment transport volume. The results show that the phase information of AIRSAR hologram image can be used to simulate the wave refraction pattern. Furthermore, the Shoreline change rate is less than -0.5m /day which indicates an erosion event with accuracy error of ± 0.05 m/day.

Keywords. *Holographic, AIRSAR, Doppler frequency, and azimuth cut-off.*

1. Introduction

It is well known that the holographic interferometric can be defined by two wave-fronts are traveling and passing a given point where the total intensity is given by the algebraic sum of the intensities of the individual wave-fronts. In this context, when the phases of the two wave fronts are the same, the intensity is the sum of the incident intensities, but when the phase of the two wave-fronts is 180 degrees apart of the intensity is zero. Thus, when two plane wave fronts of different intensities are superimposed, the intensity varies periodically between the maximum value and the minimum value. This intensity variation is known as a fringe pattern and is in the form of a series of planes of uniform intensity which are parallel to the plane that bisects the angle between the two wave-fronts [5].

According to above prospective, this study is exploiting a holographic interferometry in modeling shoreline change rate. The technique is used coherent polarized radar cross section backscatter in which surface deformation can be measured from the behavior of the sea surface roughness variations in AIRSAR data. In this context, holographic interferometric will be used to extend the methods of classical interferometric to investigate much wider range of the behavior of wave spectra propagation and their effects on shoreline deformation. Through this technique we will be able to establish systematic tool to detect wave refraction pattern. These measurements are effected at sensitivities roughly of the order magnitude of the wavelength of polarized radar cross section backscatter. The main hypothesis is that the wave refection pattern detection can be determined by the shape or signature of the fringe anomaly.

2. Model

The hologram interferometric model for estimating shoreline change rate is consisted of three sub-models. The purpose of first sub-model is to determine the swell wave height by using Along Track Interferometry AIRSAR (ATInAIRSAR) technique. This technique is well known and have approached by several researchers [1]. Second sub-model aims to generate the holographic interferometry from the information of two wave spectra which detected by ATInAIRSAR technique. In addition, the azimuth cut-off variations along the fringe patterns will be estimated. As azimuth cut-off contains the wave height information which could be used to estimate the shoreline change rate. Finally, third sub-model

purposes the possible effects of fringe pattern azimuth cut-off on modeling shoreline change pattern.

2.1 Estimation of Wave Height

Duk et al., [1] proposed method to model swell wave height simply from orbital velocity with the angular velocity. We intend to use this model to derive the shoreline change rate. 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.

Following Fabrizio et al., [2], the radial surface Doppler velocity measurements U_d can be expressed as

$$U_d = f(u_{c,b,w}) \qquad (1)$$

where $u_{c,b,w}$ are the surface current, phase velocity of Bragg-resonant wave and the orbital velocity of the swell, respectively. The wave height as function of radial velocity can be given by

$$H = \frac{2U_r}{\omega \sqrt{\sin^2 \phi + \cos^2 \theta \cos^2 \phi}} \qquad (2)$$

where ϕ, θ, and ω are the flight direction, incidence angle and wave frequency respectively. U_r is the amplitude of the radial velocity. The orbital velocity U_r in slant range which determines the along track interferometric phase can be given using the Fourier representation as follows:

$$U_r = 2\,\mathrm{Re}[\int 0.5\sqrt{F_k}\,(\omega(\sin\theta \frac{k_y}{|K|} - i\cos\theta). \qquad (3)$$

$$e^{ik_x}\,dk)$$

where ω is wave frequency, θ is incidence angle, k_y is the range wave number and F is two dimensional ocean wave spectrum.

2.2 Hologram Interferometric

According to Maged [5] the wave pattern in first image happened to have a crest along the face of the shoreline plane, and the wave at the second image coming in an angle ϑ similarly has crest at similar points along the shoreline due to the coherence time difference is less than 1 sec. These correspond to points where interferometry maxima will occur. We assumed that the two waves will remain in-phase at there points through will overlap trough and maxima will remain fixed at different point along the shoreline . Similarly, between these points, trough overlaps crest and minima exist. The relative phase ϑ' of these two waves, which varies from point to point along the shoreline can be written as function of distance x. The phase spectra can be given as the two amplitudes of the radial velocities variation $U_{r_1} and U_{r_2}$ superimposed and interfere to form an interferometry intensity variation along the shoreline which may be given by

$$P(U_r) = 0.5\{(U_{r_1} + U_{r_2}) + U_{r1}U_{r_2}\cos(\vartheta_2 - \vartheta_1)\}\tau \qquad (4)$$

The amplitude transmission profile of the processed hologram can be made proportional to $P(U_r)$. In that case, the final energy wave, $\zeta(x,y)$ is proportional to the production of $P(U) * E_R(x,y)$ where $E_R(x,y)$ is the reconstruction of swell wave. The final wave pattern will be appeared due to the hologram interferometry may be written as

$$E_R(x,y) = 0.5U_r(U_{r_1}^2 + U_{r_2}^2)\cos(2\pi\omega + \vartheta) + \qquad (5)$$
$$0.5U_r U_{r_1} U_{r_2}\cos(2\pi\omega + 2\vartheta - \vartheta_0) + 0.5U_r U_{r_1} U_{r_2}\cos$$
$$(2\pi\omega + \vartheta_0)$$

2.3 Shoreline Change Rate Model

We modified the general equation of the volume transport rate which introduced by Komar[3]. The modification was done based on the information of azimuth cut off along the fringe pattern as follows:

$$Q = 1.1\rho g^{3/2}[(\frac{V\lambda_{cut}}{2\pi R})^2]^{5/2}[2\omega G]^{-5/2} \qquad (6)$$
$$\sin\alpha_b \cos\alpha_b$$

where $\rho = 1020$ kg/m^3 for the sea water , g is 9.8 m/s^2 and α_b is the breaking wave angle and λ_{cut} is the azimuth cut-off. Following Vachon et al., [4], azmuith cut-off can be given by

$$\lambda_{cut} = 2\pi(\frac{R}{V})[\omega G]^{0.5}\int \zeta^{0.5}d\zeta \qquad (7)$$

where $G = \sqrt{\sin^2\phi + \cos^2\theta\cos^2\phi}$ and ζ is the variation of wave spectra amplitude along the fringe pattern. In many cases, where the short-term shoreline

changes are caused by cross-shore transport and they are small compared to the long-term changes [5]. The one-line model is considered as a means to identify the shoreline evolution. Following the assumption that the bottom profile moves in parallel to itself out of the depth of closure, the mass conservation of sand along an infinitely small length, ∂x, of the shoreline could be formulated as

$$\frac{\partial y}{\partial t} + D^{-1} \frac{\partial Q}{\partial x} = 0 \qquad (8)$$

where y is the shoreline position (m), x is the longshore coordinate (m), t is the time (day), D is the depth of closure (m), and Q is the longshore sand transport rate.

3. Results and Discussion

Fig. 1 shows the interferogram spectrum where the intensity peak appears to be truncated at azimuth wave number of about 0.015 rad/m. The spectrum intensity is between -8 to -10 dB. The maximum wave number is found a long the range direction with value is 0.4 rad/m. According to [1] Doppler shift is inducing smearing of the ocean spectra along the azimuth direction.
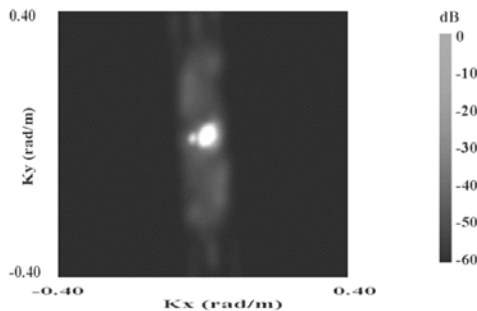

Fig. 1 Interferogram complex spectrum.

Figure 2 shows a holographic interfermetry 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 is 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.,[1].
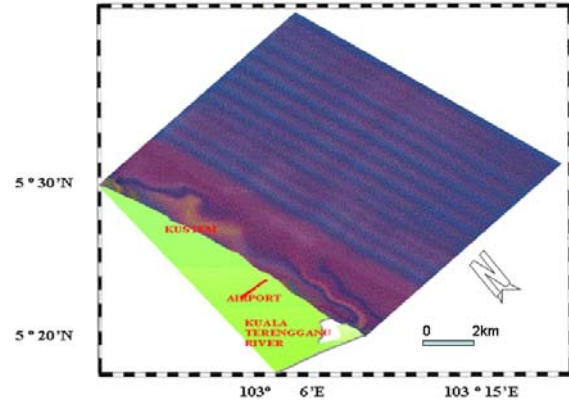

Fig.2. Holograhic fringes for wave refraction pattern.

It is clear that the wave convergence and divergence zones are indicated by curvature of holographic fringes (Fig. 2). This means that the holographic fringes are able to capture the ocean surface deformation due to wave refraction pattern. This result confirms the study of Maged [5]. Fig. 3 depicts shoreline change rate. The shoreline rate change of -0.5 m/day suggests the erosion event along Sultan Mahmud airport. It is interesting to notice that coastal erosion is coincided with convergence wave zone (Fig. 2). According to Komar [3] wave refraction convergence zone receives high input wave energy which can cause coastal erosion. This result confirms the study of Maged [5].
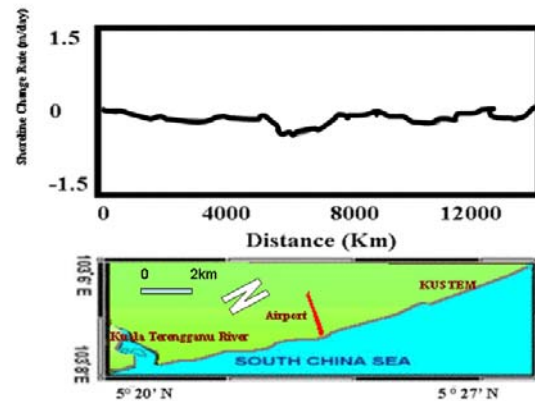

Fig. 3 Estimation of shoreline change rate from holographic model.

Table 1 shows the accuracy assessment of shoreline change rate. It is clear that holographic model can be provided information of shoreline change rate less than ± 0.05 m/day. The bias between estimated change rate and measured is 0.2 m/day which suggests that the

possibilities of mapping shoreline change rate from single AIRSAR image.

Table 1. Accuracy Assessment

Accuracy Assessment Parameters	Values m/day
Root mean square errors	± 0.042
Bias	0.2

4. Conclusions

This study was demonstrated method for estimating shoreline change rate from single AIRSAR data. Based on holographic model, it can be said that the ocean wave refraction pattern can be simulated to understand the mechanisms of shoreline change. In fact, the study has shown that the shoreline erosion is -0.5m/day and with high accuracy rate of less than ±0.05 m/day. It can be concluded that the integration between holographic model, azimuth cut-off, one dimensional sediment transport models is an excellent geomatica tool for modeling shoreline change rate.

References

[1] J., Duk, W. Moon ,D., Imail and D. Moller 2002. Remote sensing of Ocean waves and Currents Using AIRSAR Along-Track Interferometry (ATI). CD of Proceedings for the 2002 AIRSAR Earth Science applications Workshop March 4-6, 2002, Pasanda, California.

[2] L., Fabrizio, F. Bordoni, and F. Gini. Enhanced and New possible Functionalities of ATI-SAR through multibaseline Acquisition and Modern Spectral Estimation Techniques. CD of Proceedings for the 2002 AIRSAR Earth Science applications Workshop March 4-6, 2002, Pasanda, California.

[3] P. D., Komar,. *Beach Processes and Sedimentation*. Prentic-Hall, New Jersey. 1976

[4] W., Vcahon,. J.Camplell, A.L. gray and F.W. Dobsoon. Validation of along –track interferometric SAR measurements of ocean surface waves. IEEE Trans. Geoscience and Remote sensing, 37:150-162, 1999.

[5] Maged M., Along Track Interferometry Model for Shoreline Change. Journal of Physical Sciences. Vol. 15(1), 117-122, 2003.