UNIVERSITI PUTRA MALAYSIA

WAVE SPECTRA AND SHORELINE CHANGE STUDIES BY REMOTE SENSING

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By

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Waves play an important role in shoreline configuration. The wave pattern can induce erosion and sedimentation. Wave pattern studies using radar imagery have a potential application for coastal areas. This study investigates if the shoreline change can be modeled by wave spectra information extracted from radar images. The study area is Kuala Terengganu, located on the East Coast of Peninsular Malaysia.

Mathematical modeling was carried out to extract wave spectra from radar (ERS-1 and AIRSAR/TOPSAR) data. The two-dimension Fast Fourier Transform (2-DFFT) was applied over selected windows on radar data. The results of the transform were wavelength and power spectra. The quasi-linear modulation model was used to map the radar wave spectra to ground-truth wave spectra to obtain the actual wave

spectra. The result showed that there was a significant difference between the quasi-linear model and the velocity bunching model. It suggests that the AIRSAR/TOPSAR data are better than ERS-1 data for wave spectra investigation. This is probably because the Doppler shift effects are smaller in AIRSAR/TOPSAR data than in ERS-1data.

The wave spectra information was then used to predict shoreline change based on wave refraction and sediment transport. Both the wave spectra pattern derived from radar data and the wave spectra change derived from ship observations, were used to model the shoreline sedimentation and erosion pattern. Actual shoreline change was estimated from remotely sensed data by using vectorization, overlaying techniques and field measurements. The estimated shoreline change gave a rate of erosion along Chendering of 3.5 m/year between 1959 and 1994. The rate of erosion was 1 m/year along the Sultan Mahmud Airport shoreline between 1970 and 1996. The areas of erosion are similar to observations made in the field. The predicted shoreline change, from wave modeling, gave a rate of erosion from Batu Burok to Batu Rakit of less than 2 m/year and a rate of erosion to the south of Chendering of 4 m/year. The predicted and estimated result showed that the shoreline south of Chendering was always dominated by erosion throughout the year. However, overall, the beach changes along the Terengganu shoreline studied was in a state of equilibrium. The periods of erosion were balanced by periods of accretion.

In conclusion, radar data (ERS-1 and AIRSAR/TOPSAR) can be used to extract wave spectra for shoreline change modeling. Verification can be done with the assistance of other sources of data such as ship observation, ground truth data, aerial photography, other remotely sensed data, beach profiling, and sediment sampling. The combination of classical techniques, predictive modeling methods, and remote sensing technology as used in this study allows for better understanding of the interaction between ocean wave and shoreline change over a larger spatial scale and in a shorter time frame.

Abstrak tesis yang di kemukakan kepada Senat Universiti Putra Malaysia sebagi memenuhi syarat untuk ijazah Doktor Falsafah

GELOMBANG-GELOMBANG DAN KESAN GELOMBANG OLEH KAWALAN JAUH

Oleh

MAGED MAHMOUD MARGHANY

Februari 2000

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Gelombang-gelombang mempunyai peranan penting di dalam penyusunan garis pantai. Bentuk gelombang dapat menyebabkan hakisan dan pemendapan. Bentuk gelombang dikaji mnggunakan gambaran-gambaran radar yang berpotensi kepada hal mengenakan kawasan pantai. Kajian ini menyelidiki perubahan garisan pantai dapat menjadi model melalui penerangan gelombang spektra diperoleh daripada gambar radar. Kawasa kajian ini ialah Kuala Trengganu, Pantai Timur Semenanjung Malaysia.

Model matematika didapati untuk memperoleh gelombang spektra daripada data radar (ERS-1 dan AIRSAR/TOPSAR). Dua dimensi mengubah bentuk data fourier (2-

DFFT) telah diguna seluruh jendela dipilih oleh data radar. Hasil daripada mengubah bentuk ialah panjang gelombang dan spektra gelombang. Garis quasi model perubah digunakan untuk memetakan radar spektra gelombang kepada tanah sebenar untuk memperoleh spektra gelombang sebenar. Keputusan menunjukkan bahawa terdapat perbezaan signifikan diantara model kecepatan gabungan. Ini mencadangkan bahawa data AIRSAR/TOPSAR adalah lebih baik daripada data penyelidikan gelombang spektra. Hal ini mungkin disebabkan oleh kesan pertukaran Doppler lebih kecil dalam data AIRSAR/TOPSAR berbanding dengan data ERS-1.

Maklumat panjang gelombang telah diguna untuk meramalkan perubahan asas garis pantai pada pembiasan gelombang dan pengangkutan endapan. Kedua pola spektra gelombang didapat daripada data radar dan perubahan spektra gelombang didapat daripada peninjauan kapal laut, model pemendapan garis pantai dan pola hakisan. Garis pantai sebenar berubah dianggar daripada data indera jauh dengan menggunakan vektor, teknik penutupan dan ukuran tapak. Anggaran perubahan garis pantai memberi purata hakisan sepanjang Chendering adalah 3.5 m/tahun diantara tahun 1959 dan 1994. Purata hakisan ialah 1 m/tahun sepanjang garis pantai lapangan terbang Sultan Mahmod diantara tahun 1970 dan 1996. Kawasan hakisan serupa kepada pengawasan dibuatdi tapak. Peramalan perubahan garis pantai, daripada model gelombang, memberi purata hakisan daripada Batu Burok kepada Batu Rakit lebih kecil daripada 2 m/tahun dan purata hakisan Chendering Selatan adalah 4 m/tahun. Keputusan peramalan dan anggaran menunjukkan bahawa garis pantai Chendering Selatan selalu mempengaruhi hakisan sepanjang tahun. Bagaimanapun, secara keseluruhan kajian, perubahan pantai sepanjang garis pantai Terengganu dikaji dalam bahagian keseimbangan. Masa hakisan adalah seimbang dengan masa permukaan baru.

Kesimpulan, data radar (ERS-1 dan AIRSAR/TOPSAR) dapat diguna untuk memperoleh spektra gelombang bagi perubahan model garis pantai. Vertikasi dapat dibuat dengan bantuan sumber data lain seperti peninjauan kapal laut, data sebenar bumi, fotograf udara, data indera jauhm tampang muka pantai, dan contoh endapan. Gabungan teknik terbaik, menganggar kaedah model, dan teknologi kapal angkasa (gambar radar) diguna dalam kajian ini dibenarkan bagi pemahaman lebih baik pada interaksi diantara gelombang samudera dan perubahan garis pantai seluruh skala angkasa lebih besar dan dalam bingkai masa lebih pendek.

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CHAPTER I

INTRODUCTION

Background

The study of the dynamics of ocean wave is always a challenging and intriguing process. Features of ocean waves are complex. It is not easy to understand ocean waves because there are many factors controlling them. Scientists study the factors separately but this will give them an imperfect answer. Scientists consider the waves as a most significant parameter of the coastal zone. Waves are normally the major energy input in the coastal zone. This energy is larger than the energy of water circulation and tide.

In the South China Sea, tide and tidal currents have small amplitude variations as compared to wave. For instance, the tidal height amplitude is less than 0.8 m (Taira et al., 1996) while the maximum wave height in the South China Sea is 3 m during the northeast monsoon (Maged and Ibrahim, 1996). Tidal current is also slower than wave motion. For instance, Taira et al., (1996) and Maged et al., (1998) found that tidal current speed in the coast of South China Sea is approximately 1 m/s. Maged et al., (1998) found that the maximum wavelength is 170 m. The estimated wave speed as function of this wavelength would be 10 m/s. This means that waves have more energy input in the coastal zone of the South China Sea. This is because of the fact that wave energy is a function of the second power of wave height and proportional directly to wavelength and wave velocity (Komar, 1976, and Robert, 1987).

Waves travel in many different directions as compared to tide and currents. Due to the incident angle of wave propagation, longshore currents occur. This can lead to sediment transport along the shoreline, which subsequently will cause erosion or sedimentation. Wave measurements and observations have been made from ships, as well as from onshore and offshore stations. These classical methods of measurements are unable to cover many factors of interest and are unable to investigate the wave interaction with the coastal area on a large scale. For instance, classical methods cannot be used to study a complicated coastal process such as the interaction between wave refraction, diffraction, reflection, and wave current interaction. Remote sensing techniques can cover large areas, and can image the complicated coastal process to provide information that includes wave and shoreline interaction, which cannot be observed by classical methods (buoy, ships, etc). This information is vital to the study of coastal erosion and sediment transport.

Microwave remote sensing has an advantage over the other types of remote sensing particularly in investigating wave spectra. The Synthetic Aperture Radar (SAR) has been proven accurate for recording wave spectra image over the ocean (Trevor, 1990). Hasselmann and Hasselman (1991) reviewed the potential and proven applications of radar satellite image in the coastal areas and over the ocean. Wave investigations by SAR image take place due to the interest of the scientists and researchers (Hasselmann and Hasselmann, 1991 and Vachon et al., 1994).

Wave information has a significant role for shoreline configuration. The classical method of visual observation of wave could contain errors, which could induce misunderstanding on the nature of the problem. The longshore currents