UNIVERSITI PUTRA MALAYSIA

DEVELOPING OF A MODEL FOR MEASURING AND EXTRACTING OCEAN SURFACE CURRENT PATTERNS FROM RADARSAT-1 SAR AND ALTIMETER DATA

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By

MOHAMED AHMED MAIYAS

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To the soul of my father

Who started dreaming of me to be a human rather than an educated person

and wished me to be a man of wisdom and positive thinking.

Today what I am is just because of his direction and affections

&

To the rest of my extended families

mother, brothers, sisters, wife and kids

your encouragement has seen me through this long journey

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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MOHAMED AHMED MAIYAS

May 2007

Chairman: **Professor Shattri bin Mansor, PhD**

Faculty: **Engineering**

Remote sensing technology can be used to collect large scale data on ocean areas and provide precise information on ocean surface dynamics and atmospheric interactions. Many other ocean surface features can be detected by utilizing this technology. In this study, a robust model was developed based on Doppler frequency that utilizes RADARSAT-1 SAR imageries in measuring and extracting ocean surface current patterns such as velocity and direction. The SAR data used in the study were acquired during the period 20-31 March 2005 and supported with altimeter data of GEOSAT-2 and TOPEX/POSEIDON also collected at the same period. The study area is located between the longitudes 102°50'00'' to 103°40'00'' East and latitudes 5°25'00'' to 5°40'00'' North, at the east coast of Kuala Terengganu. The area was divided into four main parts

comprising the onshore, fieldwork area, midshore, and offshore area witch is about 98 km. off the coast. The model was applied on the SAR image at three different modes (Wide- 3, High extended- 6 and Standard-2) with the objectives of 1) comparing between the modes and identifying the appropriate mode for coastal current modeling, 2) modeling the spectral intensity of the SAR data in the study area covering the onshore, midshore, offshore and the fieldwork area, 3) examining the impacts of tide and wind speed and direction on surface current movements on the coastal water of Kuala Terengganu, Malaysia and 4) investigating the impact of the Doppler frequency shift and incidence angle on the sea surface current detection. The results of the study were validated using TOPEX/POSEIDON satellite altimeter data for the same period and in situ data measurements taken with AWAC instrument during the fieldwork. The study did not only find that the incidence angle in SAR had an effect on the surface current patterns but also that, there is a strong relation between the image backscatter and Doppler frequency. It was again discovered that the velocity and direction of the current changed through the period of the study according to the changing of Doppler frequency shift used in the model to extract the sea surface current velocity and direction from the three SAR images. At the onshore area, the velocity of current extracted based on the Wide-3 mode varied between 0.22 m/s to 0.25 m/s with the average of 0.24 m/s, while based on the Standard-2 mode it varied between 0.52 m/s to 0.65 m/s with an

average velocity of 0.56 m/s. The analysis of the spectral intensity of the SAR data in different modes showed variation among the four areas. The spectral intensity values were low in the onshore as against the high values recorded in the offshore. Regression analysis was used to establish the coefficient of determination between the velocities extracted from SAR data and the AWAC in situ measurements. The analysis showed a fairly high correlation between them of R^2 of 0.753 with the highest velocity under 0.27 m/s, R^2 of 0.726 with the highest velocity under 0.32 m/s and R^2 of 0.863 with the highest velocity under 0.75 m/s. These results were obtained from the regression between the AWAC data and the RADARSAT-1 SAR in Wide-3, Extended High-6 and Standard-2 modes respectively. It can be said that the investigation between different radar systems should be used as geomantic tool to investigate water current movement.

Abstrak tesis yang dikemukakan kepada Senat Unversiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMODELAN CORAK ARUS PERMUKAAN LAUT DARI RADARSAT-1 SAR DAN ALTIMETER DATA

Oleh

MOHAMED AHMED MAIYAS

Mei 2007

Pengerusi: **Profesor Shattri bin Mansor, PhD**

Fakulti: **Kejuruteraan**

Teknologi Penderiaan Jarak Jauh boleh digunakan untuk mengumpul data berkenaan kawasan laut yang berskala besar dan dapat memberikan maklumat terperinci dinamik permukaan lautan dan interaksi atmosfera. Ciri-ciri lain permukaan laut juga boleh dikenalpasti dengan menggunakan teknologi ini. Untuk penyelidikan ini, satu model tahan lasak dibina yang menggunakan imej-imej RADARSAT-1 SAR dalam pengukuran dan pengasingan corak arus permukaan laut seperti kelajuan dan arah. Data SAR yang digunakan dalam penyelidikan ini diperolehi dalam tempoh 20-31 March 2005 dengan disokong oleh data altimeter GEOSAT-2 dan TOPEX/POSEIDON yang turut dikumpul dalam tempoh yang sama. Kawasan penyelidikan terletak di antara longitud

102°50′00″ hingga 103°40′00″ Timur dan latitud 52°5′00″ hingga 5°40′00″ Utara, di timur perairan Kuala Terengganu. Kawasan tersebut terbahagi kepada empat bahagian yang merangkumi persisiran dalam, kawasan lapangan kerja, persisiran tengah dan persisiran luar iaitu lebih kurang 98 km daripada persisiran pantai. Model tersebut digunakan ke atas imej SAR pada tiga mod yang berlainan (*Wide- 3*, *High extended- 6* dan *Standard- 2*) berdasarkan objektif berikut 1) membandingkan antara mod dan mengenal pasti mod yang bersesuaian untuk model arus perairan, 2) memodelkan intensiti spektral data SAR dalam kawasan penyelidikan yang merangkumi persisiran dalam, kawasan lapangan kerja, persisiran tengah dan persisiran luar, 3) mengkaji impak kelajuan ombak dan angin dan arah ke atas pergerakan arus permukaan perairan Kuala Terengganu, Malaysia dan 4) mengenalpasti impak anjakan frekuensi Doppler dan sudut insiden ke atas pengenalpastian arus permukaan lautan. Keputusan penyelidikan disahkan menggunakan data altimeter satelit TOPEX/POSEIDON untuk tempoh masa yang sama dan data pengukuran *in situ* diambil menggunakan alatan AWAC semasa kerja lapangan. Penyelidikan ini tidak hanya menemui sudut insiden dalam SAR mempunyai kesan ke atas corak arus permukaan tetapi juga terdapat kaitan yang kuat antara imej serakan-belakang anjakan frekuensi Doppler yang digunakan dalam model untuk mengasingkan kelajuan arus permukaan laut dan arah daripada tiga imej SAR tersebut. Di kawasan persisiran dalam, kelajuan arus yang didapati

berdasarkan kepada mod *Wide-3* berubah antara 0.22 m/s hingga 0.25 m/s dengan purata 0.24 m/s, manakala berdasarkan mod *Standard-2* ia berubah antara 0.52 m/s hingga 0.65 m/s dengan purata kelajuan 0.56 m/s. Analisis intensiti spektral data SAR dalam pelbagai mod menunjukkan variasi antara ke empat-empat kawasan. Nilai intensiti spektral adalah rendah di persisiran dalam berbanding nilai yang tinggi di kawasan persisiran luar. Analisis regresi digunakan untuk mendapatkan pekali penentuan antara kelajuan yang diperolehi daripada data SAR dan pengukuran *in situ* AWAC. Analisis menunjukkan korelasi yang agak tinggi antara data tersebut di mana $R^2 = 0.753$ dengan kelajuan tertinggi pada 0.27 m/s, $R^2 = 0.726$ dengan kelajuan tertinggi pada 0.32 m/s dan $R^2 = 0.863$ dengan kelajuan tertinggi pada 0.75 m/s. Keputusan yang diperolehi adalah daripada regresi antara data AWAC dengan mod-mod RADARSAT-1 SAR pada *Wide-3*, *Extended High-6* dan *Standard-2*.

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Department of Surveying and Mapping Malaysia (JUPEM)

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I certify that and Examination Committee has met on date of viva to conduct the final examination of Mohamed Ahmed Maiyas on his PhD thesis entitled "Modeling the Ocean Surface Current Patterns from RADARSAT-1 SAR and Altimeter Data" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MOHAMED AHMED MAIYAS

Date: 9 July 2007

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b	the chirp rate = $2kv^2 / R$
bT	Received signal azimuthal bandwidth
c	velocity of light = 3×10^8
f	frequency of an electromagnetic wave
$f_{\max}$	Doppler peak frequency shift
$f(x)$	spatial domain function
F_D	the change in the received frequency using AWAC
F_s	frequency of transmitted sound using AWAC
$F(u)$	frequency domain function
k	Radar wave number
M_1	First target direction
M_2	Second target direction
R	Radar slant range
t	Amplitude of the coherent in the image
T	Coherent integration time
T_s	Gaussian function with width
u	spatial frequency
V	satellite velocity = 6212 m/s
V_c	horizontal ocean current
v_r	Radial velocity of a target
x_0	location of a point target in the SAR image
τ	delay time
λ	Wavelength
θ	Incident angle
$\Delta\theta$	Local modification of the incident angle θ