MODELING TIDE AND STORM SURGE IN THE EAST COAST OF PENINSULAR MALAYSIA

LOY KAK CHOON

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by

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Symbols	*Descriptions*	*Units*
H	instantaneous water elevation	m
h	depth	m
h_{max}	maximum depth	m
η	water elevation above the MSL	m
g	acceleration due to gravitational force (given 9.81)	ms^{-2}
x	distance in –x direction	m
y	distance in –y direction	m
t	time	s
u	velocity of x component	ms^{-1}
v	velocity of y component	ms^{-1}
n	Manning Roughness co-efficient for friction	$m^{-1/3}s$
$\eta(t)$	function of elevation respect to the time	m
N_C	total number of harmonic components	unitless
i	index number of harmonic component	unitless
a_i	amplitude of i^{th} harmonic component	m
T_i	period of i^{th} harmonic component	s
α_i	phase angle of i^{th} harmonic component	radian
π	the ratio of the circumference to the diameter of a circle (given 3.14159)	unitless
V_n	normal velocity component	ms^{-1}
V_c	velocity component along the coastline	ms^{-1}
Q	injected water	m^3s^{-1}
ω	Earth's rate of rotation (given 7.2722×10^{-5})	s^{-1}
φ	Chézy bottom friction coefficient	$m^{1/2}s^{-1}$
ρ_a	density of air, kgm^{-3} (given 1.15)	kgm^{-3}
C_D	wind drag coefficient (given 0.0015)	
ρ	density of fluid (assumed 1150 for saline water)	kgm^{-3}
W_x	wind velocity in x-direction	ms^{-1}
W_y	wind velocity in y-direction	ms^{-1}
$\|W\|$	wind speed	ms^{-1}
u_0	velocity of injected water in x-direction	ms^{-1}
v_0	velocity of injected water in y-direction	ms^{-1}

k	wind shear stress parameter	unitless
f	Coriolis parameter	unitless
M	total flux in x-direction	m^2s^{-1}
N	total flux in y-direction	m^2s^{-1}
υ_x	dynamic eddy viscosity constant in x-direction	m^2s^{-1}
υ_y	dynamic eddy viscosity constant in y-direction	m^2s^{-1}
ϕ	latitude	degree
p	atmospheric pressure on MSL (10^2)	hPa
×	dimension of the area	unit square
M2	principle lunar (semi-diurnal tidal constituent)	
K1	luni-solar declinational (diurnal tidal constituent)	
°N	degree north from equator	
°E	degree east from Meridian Greenwich	
Δ	infinitesimal difference (delta)	
δ	partial derivative	
=	equal	
$<$	less and equal than	
$\geq$	more and equal than	
%	percentage	
$\lvert \cdot \rvert$	absolute value	
/	division	
m	meter	
s	second	
kg	kilogram	
hPa	hectoPascal	
rad	radian	

LIST OF ABBREVIATION

Abbreviation	*Full Description*
ASCII	American Standard Code for Information Interchange
B.C.	Before Christ
CDC	Climate Diagnostic Centre
CFL	Courant–Friedrichs–Lewy
COAL	Climate and Ocean Analysis Lab in Universiti Kebangsaan Malaysia
COAMPS	Coupled-Ocean Atmosphere Mesoscale Prediction System
DHI	Danish Hydraulic Institute
FDDA	Four-Dimensional Data-Assimilation
FORTRAN	Formula Translation
FTCS	Forward Time Central Space
FTFS	Forward Time Forward Space
GCM	General Circulation Model
GrADS	Grid Analysis Display System
GUI	Graphical User Interface
HHDDMMYY	HourDayMonthYear (e.g. 05020404 for 5.00am on 2 April 2004)
HHW	Higher High Water
HLW	Higher Low Water
INOS	Institut Oseanografi in Universiti Malaysia Terengganu
JTWC	Joint Typhoon Warning Centre
JUPEM	Jabatan Ukur dan Pemetaan Malaysia
LHW	Lower High Water
LLW	Lower Low Water
KUSTEM	Kolej Universiti Sains dan Teknologi Malaysia
MATLAB	*MATrixLABoratory*
MIKE SWMM	Modeling of Waste Water and Storm Water Systems
MMD	Malaysia Meteorological Department
MM5	Fifth Generation Mesoscale Model
MPI	Message Passage Interface
MSDOS	Microsoft Disk Operation System

MSL	Mean Sea Level
NCAR	National Center for Atmospheric Research
NCEP	National Center of Environment Prediction
NGDC	National Geophysical Data Center
NOAA	National Oceanic and Atmospheric Administration
NOGAPS	Navy Operational Global Atmosphere Prediction System
POM	Princeton Ocean Model
PSU	Pennsylvania State University
RAM	Random Access Memory
RBC	Radiation Boundary Condition
SCS	South China Sea
SLOSH	Sea, Lake, and Overland Surges from Hurricanes
SLP	Sea Level Pressure
SPLASH	Special Program To List Amplitudes of Surges From Hurricanes
SST	Sea Surface Temperature
SWE	Shallow Water Equations
TC	Tropical Cyclone
UKM	Universiti Kebangsaan Malaysia
USM	Universiti Sains Malaysia
UTC	Coordinated Universal Time
VCE	Vatnaskil Consulting Engineer

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ABSTRACT

The primary focus of this thesis involves the numerical simulations of the hydrodynamic flows in the coastal areas of Terengganu, which is subjected to tides and the two seasonal monsoons. For this purpose, we developed two numerical simulation models named TIDE-2D and TUNA-SU, based upon modification and enhancement of existing in-house models TIDE and TUNA-M2 respectively. Both models are governed by the two-dimensional depth-integrated shallow water equations (SWE), which are widely used to simulate similar hydrodynamic regimes. These equations are solved by means of the explicit finite difference method with a staggered grid system, which are restricted in the time step by the Courant-Friedrichs-Lewy (CLF) criterion to ensure numerical stability. The validation of TIDE-2D and TUNA-SU are performed by comparing the model simulation results with known analytical solutions and solutions derived from previously tested software AQUASEA. The tidal dynamics in the coastal areas of Terengganu is satisfactorily simulated by means of TIDE-2D. Similarly TUNA-SU performs satisfactorily to simulate interesting current patterns in South China Sea, which agree with observations during the northeast and southwest monsoons. Finally, two storm surge cases that occurred in Peninsular Malaysia's coastal areas are simulated by means of TUNA-SU. These two storm surges are induced by the Tropical Cyclone Vamei of 2001 and the Extreme Northeast Monsoons of 2004. Atmospheric inputs for these two storm events, which are required to model storm surges, are derived from simulations by the 5th Generation PSU/NCAR mesoscale model (MM5). Simulations reveal that the extreme northeast monsoon produced sea level rise of 50 to 60 cm while the observed sea level rise is 50 cm.