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MÔ HÌNH ĐỘNG LỰC HỌC TRONG RỪNG NGẬP MẶN

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Tóm tắt: Các bài toán động lực học trong vùng rừng ngập mặn là bài toán rất phức tạp và hiện nay vẫn đang tiếp tục nghiên cứu và phát triển. Trong báo cáo này, một số mô hình động lực trong rừng ngập mặn được giới thiệu như động lực học sóng, dao động mực nước triều và vận chuyển trầm tích. Mô hình lan truyền sóng trong rừng ngập mặn cho thấy năng lượng sóng giảm đáng kể do tương tác có xét đến tương tác của sóng tác động với các rễ và thân cây ngập mặn. Bài toán dao động mực nước triều trong rừng ngập mặn cho thấy sự tồn tại tính bất bất đối xứng của thủy triều và phụ thuộc vào hệ số ma sát trong rừng ngập mặn. Mô hình chuyển vận trầm tích trong rừng ngập mặn cho đến nay vẫn còn đang tiếp tục nghiên cứu do tính chất cố kết phức tạp và bài toán cản giữ vật chất vận chuyển của cây ngập mặn vẫn đang từng bước hòan thiện và phát triển. Một số kết quả tính toán được phân tích và đánh giá, áp dụng với số liệu thực đo tại vùng rừng ngập mặn Cần Giờ (thành phố Hồ Chí Minh).

Từ khóa: *Mô hình động lực học, Tiêu tán năng lượng sóng, Tính bất đối xứng thủy triều, Vận chuyển trầm tích, Rừng ngập mặn, Cần Giờ.*

HYDRODYNAMIC MODELINGS IN MANGROVE FORESTS

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Abstract: The problems of hydrodynamics in mangrove forests are very complicated and now continue studying. In this paper, some hydrodynamic modelings in mangrove forests are introduced such as wave dynamic, tidal oscillation, and sediment transport. Modeling of wave propagation in mangrove forest proves that wave energy is dissipated very quickly due to wave – mangrove trunk interactions. The tidal modeling in mangrove forest shows that tidal oscillations and velocities are asymmetry and depend on friction coefficients in mangrove trees. The modeling of sediment transport is developing due to the complicated cohesive sediment and the sediment retention of mangrove trunks and roots. The calculated results are analyzed and applied in the Can Gio Mangrove Biosphere Reserve (Ho Chi Minh City).

Key words: *Hydrodynamic modelings, Wave energy dissipation, Tidal asymmetry, Sediment transport, Mangrove forest, Can Gio*

I. INTRODUCTION

Mangrove forests are always considered as a friendly environment as well as effective barrier for people and living things in the coastal areas. Many research and experiments especially in hydrodynamics prove and emphasize the important role of mangroves in wave/ tsunami energy dissipation and soil retention. However, research in modelings in mangrove forests is spare and limited due to the complexities in mangrove forests. Characteristics of mangrove trunks and roots as well as the cohesion and porosity in mangrove soil are considered as some of main reasons in obstructing the developments of hydrodynamic modelings. The aim of this paper is to introduce some hydrodynamic modelings and preliminary studies in mangrove forests such as wave dynamic, tidal oscillation, and sediment transport. The calculated results are analyzed and applied in the Can Gio Mangrove Biosphere Reserve (Ho Chi Minh City).

II. MATERIALS AND METHODS

The scientific information in this paper were compiled from different projects in recent years which have been carried out by the Department of Oceanology, Meteology and Hydrology, University of Science, Hochiminh City. The main topics of study are on the hydro-litho-dynamical processes in mangrove forests such as wave dynamic, tidal oscillation, and sediment transport. Especially the National Project Code ĐT.NCCB-ĐHUD.2012-G/10: “Study on the impacts of hydro-litho-dynamical parameters to erosion/deposition processes in mangrove forest areas of Vietnam”.

III. RESULTS

1. Modeling of hydrodynamic waves in manfrove forests

Most of waves are dissipated quickly as propagating in mangrove forests. Many studies from field measurements in wave energy dissipation in mangrove forests have done since 1970s especially dissipation due to the characteristics of mangrove roots and trunks have studied and included such as Sato (1978), Mazda et al. (1997a, 1997b). Recently, the developing modelings have mentioned and developed such as Massel et al. (1999), Mazda el al. with SWAN adaption (2006) and then recently in 2011, Suzuki et al. developed SWAN model in which the dissipation due to trunk interaction and breaking waves was considered. In Vietnam, the studied of hydrodynamic waves started developing in year 2000s mainly based on filed measurements such as Vu Doan Phai (2005), Nguyen Danh Tinh (2007), Nguyen Xuan Ngoan (2007), Vuong Van Quynh (2010). Wave modelings in mangrove forests were adjusted and applied such as Nguyen Khac Nghia (2008) for SWAN model and Nguyen Duy Vinh et al. (2011) from a Delft3d model.

Our model WATRAMAN (Wave TRAnsformation in MANgrove forests) was developed from a predictive model of wave propagation through non-uniform forest in water of arbitrary depth (Hong Phuoc and Massel, 2008). The theoretical model solves a full boundary value problem for wave propagation with dissipation for non-uniform mangrove forest and arbitrary water depth. In particular, wave-trunk interaction and wave breaking were found to be the dominant dissipation mechanisms. A modified mild-slope equation including dissipation is applied for wave model over changing water depth within the mangrove forest. The non-linear governing equations for wave-trunk interactions are linearized using the concept of stochastic mineralisation. The more details for mathematical problems are presented in a separated paper. The results for wave height, wave spectrum and wave-induced velocities as well as for the coefficients of transmission and reflection suggest that most of the energy is dissipated within the mangrove forest even at relatively small distance. The effect of wave breaking plays a more important role on wave attenuation in sparse forest; however, it is smaller compared to the effect of wave–trunk interactions in the denser forest (Fig. 1). The numerical results of the model are verified and compared with the experimental wave data in Can Gio Mangrove Biosphere Reserve, Southern Vietnam (Fig 2.) (Hong Phuoc and Massel, 2006).

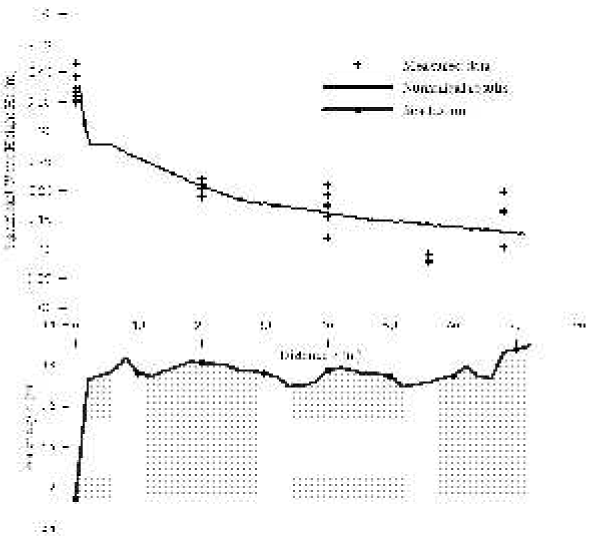
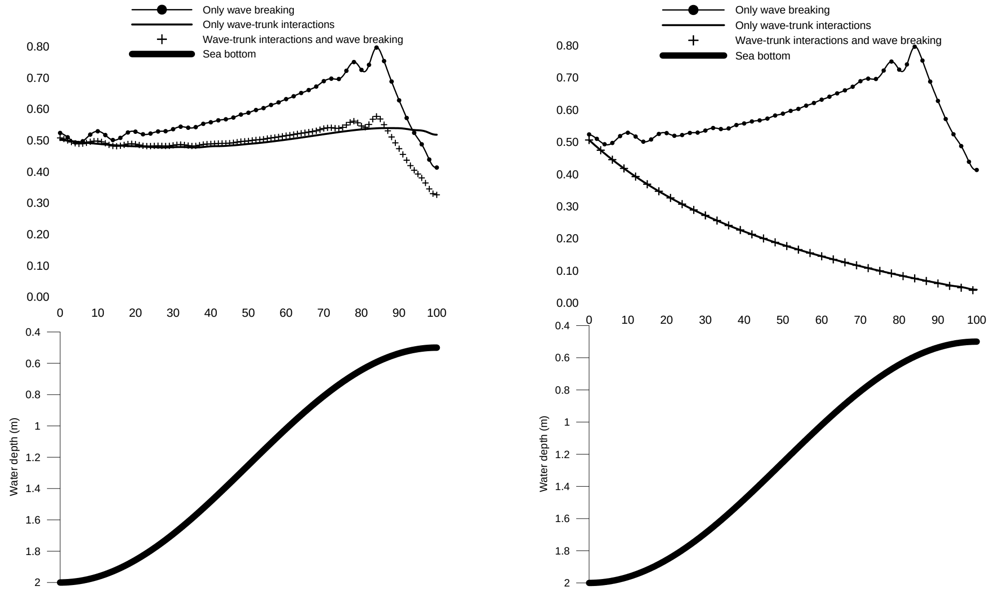


Figure 1. Comparison of numerical significant wave height with experimental data for water depths 2.1m



(a)

(b)

Figure 2. Influence of wave breaking and wave-trunk interaction on wave height attenuation in (a) less dense forest and (b) dense forest

2. Modeling of suspended sedimentation in mangrove forests

Mangroves grow in muddy flats – the marine and terrestrial boundary. Therefore, the erosion or accretion processes are very complicated because the sediments get cohesive and often move in suspension. The problems for sedimentation especially for suspended matters are always the difficult problems due to requirement of the large amount of parameters for calculations. The much more difficulties occur for the problems for suspended sedimentation in mangroves. It is required to capture the characteristics of chaos in cohesive sediment and to consider the interaction of mangrove trunks and roots in mud retention.

In general, the suspended sediment concentration (SSC) near the bottom is much higher than SSC at the surface due to higher turbulence at the bottom. Therefore, a 1-D model of vertical profile of sediment suspension is considered, in which the roles of tidal currents and waves are taken into account (Li and Parchure, 1998; Mehta, 2003). Within a water column of depth h, the vertical sediment transport is governed by upward mass diffusion due to turbulence and particulate settling. The change of concentration C with time at any elevation, z (measured positively upward from the mean water level), is determined by the magnitude and direction of the net sediment flux due to diffusion and settling. The vertical settling-diffusion equation can be expressed as a particular case of the general mass conservative equation:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z}\left(W_s C + K_z \frac{\partial C}{\partial z} \right). \qquad (1)$$

The equation (1) can be solved for some initial condition, C(z,0), and surface (z=0) and bottom boundary (z=-h) conditions, provided W_s and K_z are specified.

The boundary condition at the water surface is that the net flux of sediment at z=0 is nil, i.e.

$$W_s C\big|_{z=0} + K_z \frac{\partial C}{\partial z}\bigg|_{z=0} = 0\,, \qquad (2)$$

and at the water–fluid mud interface (z=-h) the net flux of sediment is determined by sediment entrainment, E, and deposition, S, i.e.

$$W_s C\big|_{z=-h} + K_z \frac{\partial C}{\partial z}\bigg|_{z=-h} = E - S\,. \qquad (3)$$

Specification of the fluxes, E and S, is crucial to an accurate simulation of the suspended sediment profile.

In the governing equation (1), the unknown concentration, C, is a function of the independent variable z and time t.

In mangrove forests, the sediment particles carried in suspension during tidal inundation are cohesive, mainly clay and fine silt, and form large flocs (Furukawa and Wolanski, 1996). The observed exponential decrease in sedimentation rate with distance from the creek enables the estimation of the settling velocity W_s of the suspended sediment in mangroves (Furukawa et al, 1997). Assuming zero re-suspension, the settling velocity W_s can be calculated from the equation for conservation of sediment mass as follows:

$$W_s = -\frac{hU}{C}\frac{\partial C}{\partial x}, \qquad (4)$$

where C is the suspended-sediment concentration, x is the distance across the mangroves, h is the water depth and U is the current velocity.

Various researchers have tried to model the suspension process by introducing an effective diffusion coefficient according to specific scenarios such as: suspended sediment induced by currents for steady flow or for non-steady (tidal) flow, suspended sediment induced by non-breaking waves, breaking waves or ripples, and suspended sediment induced by wave and current combination. Most expressions for the diffusion coefficient are empirical or semi-empirical. The corresponding expressions are presented in more detail in Van Rijn (1989, 2005).

When sediment concentration profiles are known, the mixing coefficient can be computed by a simple relationship (Van Rijn, 1989):

$$K_z = \frac{(1-C)^5 C W_s}{dC/dz} \qquad (5)$$

However, this equation cannot be applied when concentrations in the water layer are well mixed due to high turbulence, especially for strong wave action, in very shallow water in mangroves.

Based on the measurement data on 2012 on SSC in Nang Hai site (Can Gio), the mean setlling velocity was determined about $3.02\text{x}10^{-4}$ - $3.47\text{x}10^{-4}$ m/s and SSCs depend strongly to wave and current influence.

3. Modeling of tidal oscillation

Among the various types of water movement within mangrove areas, tidally driven currents are crucially important. The physical environment that supports mangrove ecosystems is basically formed by the tidal motion of seawater with a diurnal or semi-diurnal period, although the tide does deform significantly in mangrove swamps due to the high density of mangrove trees and roots (Mazda et al., 2007). Based on field observations and from the perspective of the preservation of mangrove ecosystems, Boto and Bunt (1981), Woodroffe (1985a, b) noted the importance of the material exchange between mangrove areas and the open sea that accompanies tidally reversing flows. Many studies in tides in mangroves such as Wolanski et al., 1992; Furukawa and Wolanski, 1996; Furukawa et al., 1997; Wu et al., 2001; Kobashi and Mazda, 2005; Mazda et al., 2005... Following the simple analytical model for flow in the creeks of Aucan and Ridd (2000):

- In the creek:

$$\frac{\partial u_1}{\partial t} = -g\frac{(h_1 - H)}{X} - r_1 u_1 \qquad (6)$$

$$u_1 B h_1 = \frac{\partial V_1}{\partial t} \quad \text{when swamp is not inundated} \qquad (7)$$

$$u_1 B h_1 = \frac{\partial V_1}{\partial t} + \frac{\partial V_2}{\partial t}$$ when swamp is inundated (8)

- In the swamp:

$$0 = -g\frac{[h_2 - (H - H_1)]}{X_s} - r_2 u_2$$ (9)

$$u_2 B_s h_2 = \frac{\partial V_2}{\partial t}$$ (10)

The model is formulated, built up and applied in the real conditions in Nang Hai creek, Can Gio mangrove Biosphere Reserve (Ho Chi Minh city). Observed data of current speed and water level in the creek in the year of 2005 were used to find the friction coefficients and in the swamp at the studied site and to apply in the model. Results from calculated modeling show obviously the tidal asymmetry in mangrove creek (Fig. 3). The peaks of current speed at flood and ebb tides are not equal as the swamp is inundated. The friction coefficients have influenced to the current speed in the creeks. the great influence in the tidal asymmetry. The friction coefficient in the creek can change remarkably the current speed in the creek, inducing the changes of the current speed peaks. The friction coefficient in the swamp is much smaller than in the creek.

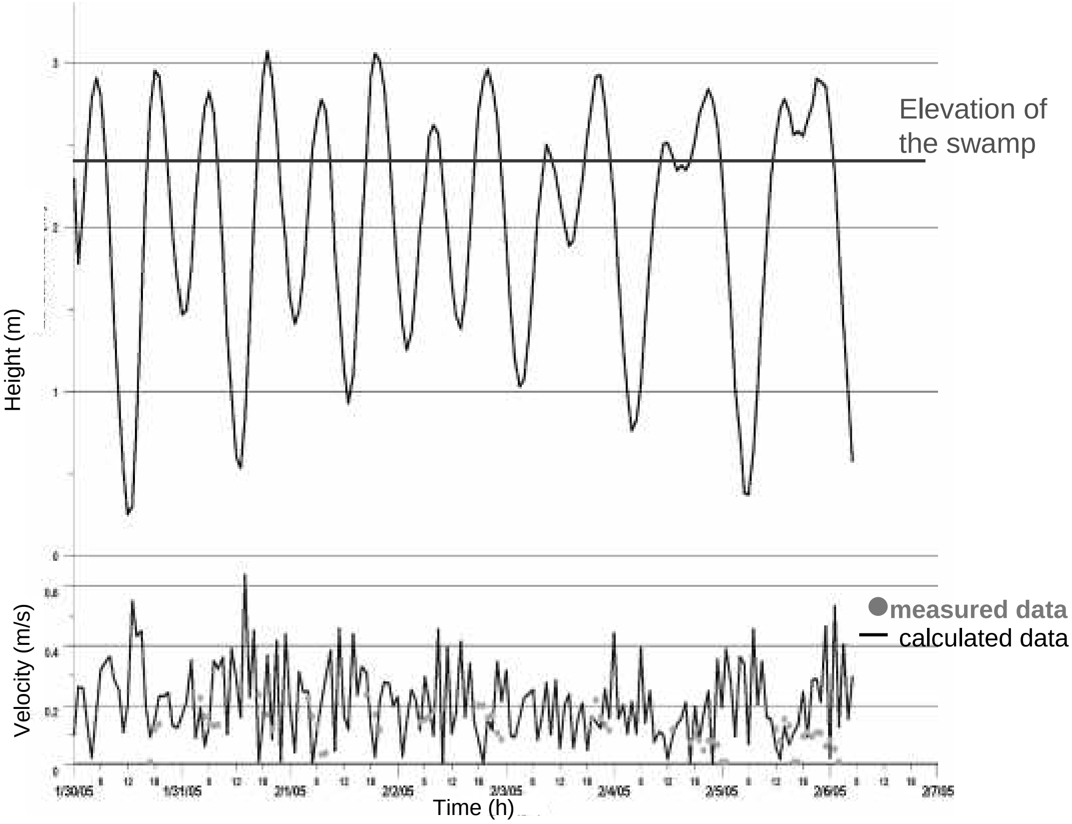


Figure 3. Current speed in the Nang Hai creek

IV. CONCLUSIONS

It is obviously that the problems of hydrodynamics in mangrove forests are very complicated and now continue studying. The hydrodynamic modelings in mangrove forests are introduced such as wave dynamic, tidal oscillation, and sediment transport and applied in Can Gio mangrove biosphere reserve. Although the modelings are not so complicated, they reflect the unique characteristics in mangrove forests. Developing modelings as well as collecting more measured data in mangroves are the main aims in our further research.

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