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TIDAL ASYMMETRY IN MANGROVE FOREST - CASE STUDY IN SOUTHERN VIETNAM

Tran Xuan Dung*, Vo Luong Hong Phuoc

University of Science, Vietnam National University - Ho Chi Minh city, Vietnam
*E-mail: txdung@hcmus.edu.vn

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Abstract. The study aims to analyse the tidal asymmetry in mangrove forest by using the numerical modelling and the measured data in two mangrove forest areas: Can Gio (Ho Chi Minh city) and Cu Lao Dung (Soc Trang province). The results of 2D model in the mangrove forest show that there is the asymmetry in current velocity: Two velocity peaks exist at flood tide and two at ebb tide. The current velocity is the sum of the tidal flows from the channel and from the tidal exchange between the creek and the swamp. The calculated velocity depends strongly on drag force, which is due to the mangrove vegetation. Furthermore, the results from analysing the measured data in February 2012 in Can Gio, Ho Chi Minh city and in Sept–October 2014 in Cu Lao Dung (Soc Trang) also prove the existence of the tidal asymmetry: The current velocity in the mangrove at flood tide is more dominant than velocity at ebb tide. The water level also has the asymmetry, changes in the tidal cycles but does not get so dominant as the velocity does.

Keyword: Tidal asymmetry, current velocity, mangrove forest, Can Gio, Cu Lao Dung.

INTRODUCTION

The mangrove forest is a diverse ecosystem and plays an important role in nature. In the mangrove forest, the physical processes are important in formation of the mangrove ecosystems. One key process is the asymmetry of the tidal currents in the creek. The dynamics behind this asymmetry had been alluded by Wolanski et al., (1980) [5]. In mangrove creeks, the peak current velocity is usually larger at ebb than at flood tide. This result is opposite to the situation in many estuaries without mangroves. The ebb dominance is believed to help to scour the channel. Friedrich et al., (1992) have studied the flow asymmetry in tidal embayments with inter - tidal flats and salt marshes. However, in such systems, the roughness is much smaller than in densely vegetated mangroves [2, 3].

DATA AND METHODS

Data sources. In present topic, the tidal asymmetry in the mangrove was analysed using numerical model and the measured data. Following the approach of the model suggested by Mazda et al., (1995), the numerical calculation was built and simulated for tidal evaluation. Moreover, the measured data of tides in February 2012 in Can Gio (Ho Chi Minh city) - in the framework of the project “Research on litho-hydrodynamics in erosion-deposition processes in mangrove forests in Vietnam” (code DT.NCCB-DHUD.2012-G/10), and in Sept–October 2014 in Cu Lao Dung (Soc Trang province) - in the framework of the project “Hydrodynamics and sediment flux in Song Hau river and Cu Lao Dung mangrove forests (Soc Trang)”, was analysed.

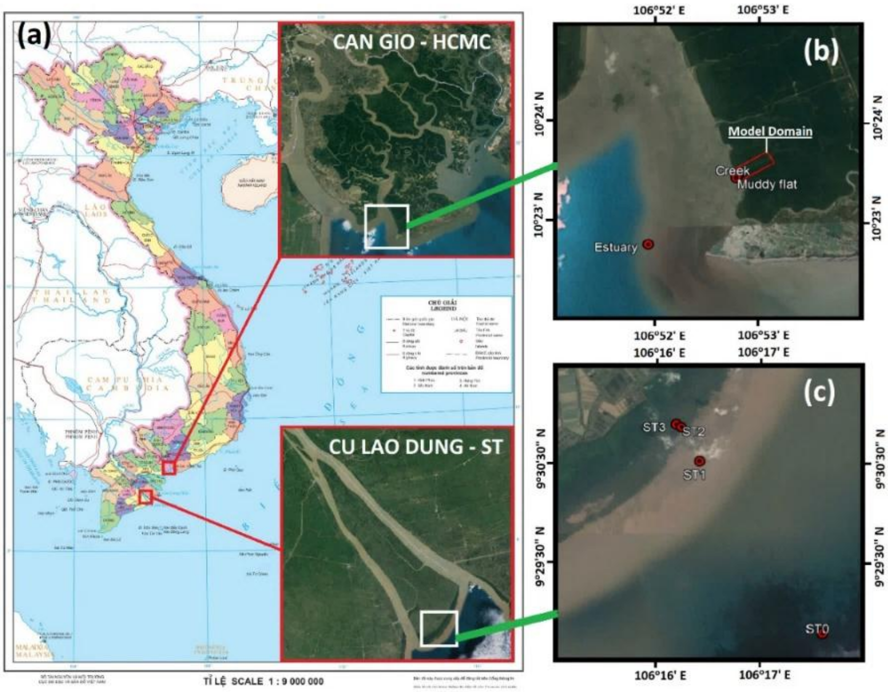

Fig. 1. The observation areas: a) The location of study areas, b) The location of the measuring stations in Can Gio (Ho Chi Minh city), c) The location of the measuring stations in Cu Lao Dung (Soc Trang)

Methods

Modeling of the tidal hydrodynamics in the mangrove forest

The governing equations. The governing equations with the depth - averaged momentum and continuity equations are suggested by Mazda et al., (1995) [2]:

$$\frac{\partial uh}{\partial t}+\frac{\partial uuh}{\partial x}+\frac{\partial uvh}{\partial y}=-gh\frac{\partial \zeta}{\partial x}-\gamma^2 u\sqrt{u^2+v^2} \quad (1)$$

$$\frac{\partial vh}{\partial t}+\frac{\partial uvh}{\partial x}+\frac{\partial vvh}{\partial y}=-gh\frac{\partial \zeta}{\partial y}-\gamma^2 v\sqrt{u^2+v^2} \quad (2)$$

$$\frac{\partial \zeta}{\partial t}+\frac{\partial uh}{\partial x}+\frac{\partial vh}{\partial y}=0 \quad (3)$$

Where: u, v - The vertically - averaged velocity in x and y directions; ζ - The elevation of water surface; *h* - the depth; γ^2 - the drag coefficient.

Model domain and parameter setup. The finite difference method ADI scheme suggested by Peaceman - Rachford [4] are used to solve the equations. The model domain is composed of a straight creek and fringing vegetated mangrove (length: 1800 m, width: 600 m) as shown in fig. 2.

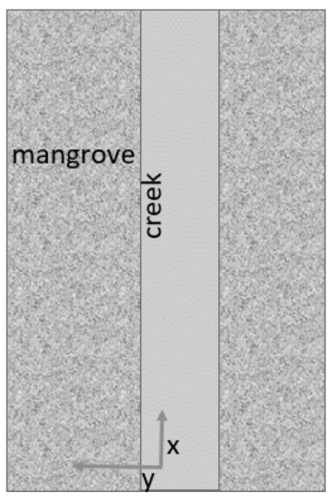

Fig. 2. Model domain

The model parameters are used as follows:

Space resolution: In x directions: Δx = 10 m, in y directions: Δy = 10 m; Time resolution: Δt = 10 s.

The drag coefficient - γ^2: Changes from 0.26 to 10 (in 5 cases) corresponding to the vegetation density from thin (at the edge of the mangrove) to thick and heavy vegetation (inside the mangrove) [2].

The depth of creek: 2.5 m.

Initial conditions: u = 0.5 m/s, v = 0 m/s, ζ = 1 m.

Boundary conditions: The model using the elevation of water surface in time for boundaries, without velocity. The elevation of water surface equation:

$$\zeta = Ae^{-\mu x}\cos\left(\sigma t - k_* x\right) \quad (4)$$

With A=1.2 m, σ = 1.42*10^{-4} corresponding to the semi-diurnal tide in the study area.

STUDY RESULTS

The calculation results. When propagating into the mangroves, the phase and amplitude of the water level change, especially from a distance of 100 m to 500 m, the water level decreases 0.3 m, with the phase lag of about 30 minutes (fig. 3).

The amplitude of velocity attenuates from 0.1 m/s to about 0.04 m/s after 500 m distances (fig. 3). When propagating into the mangroves, the second velocity peak trends to exist. The velocity formation mechanism could be explained in fig. 4, in which velocity is analysed into two components: the tidal current in the creek u_H and the current due to the swamp u_A:

$$u = \frac{L}{H}\frac{\partial H}{\partial t} + \frac{L}{HB}\frac{\partial A}{\partial t} \quad (5)$$

Where: $u_H = \frac{L}{H}\frac{\partial H}{\partial t}$ and $u_A = \frac{L}{HB}\frac{\partial A}{\partial t}$.

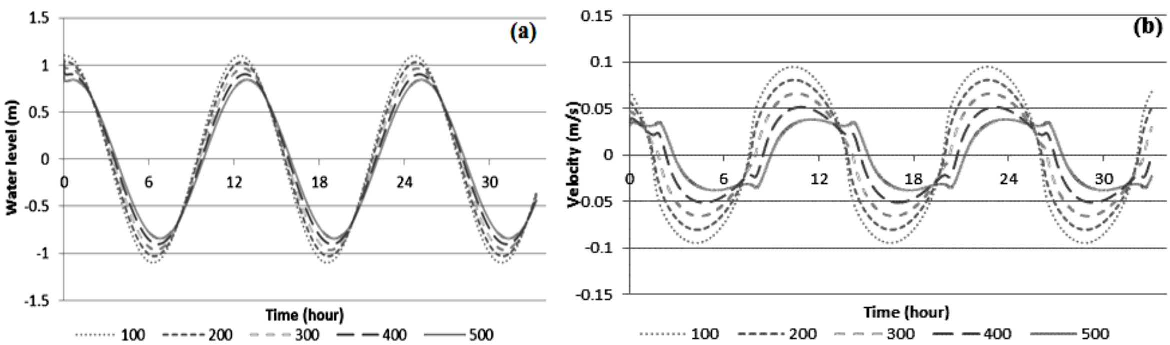

Fig. 3. Water level (a) and velocity (b) changing with time and distance from 100 m to 500 m at head of the domain

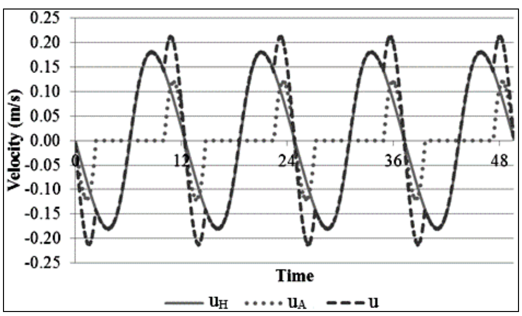

Fig. 4. Time series plot of u_A and u_H

Due to the impact of the water levels, the velocity u_H is maximum but u_A is equal to 0 because of no water entering the swamp. When the water flows into the swamp, the velocity u_A would exist and then get to maximum, therefore the second peak of velocity is formed.

The velocity depends obviously on drag force due to the mangrove vegetation γ^2. Fig. 5 shows that current velocity decreases with increasing values of γ^2. When γ^2 increases from 0.26 to 1, velocity decreases from 0.08 m/s to 0.04 m/s. When γ^2 keeps increasing up to 5, the velocity has decreased slowly and insignificantly. Therefore, the suitable drag force should be from 0.26 to 1.

The γ^2 coefficient also affects the velocity variation, especially at positions far away from the creek (fig. 5a). When γ^2 increases, the second velocity peak decreases rapidly and trends to be smaller than the first velocity peak. Unlike the velocity, the coefficient γ^2 almost has no significant impact on fluctuating water levels (fig. 5b).

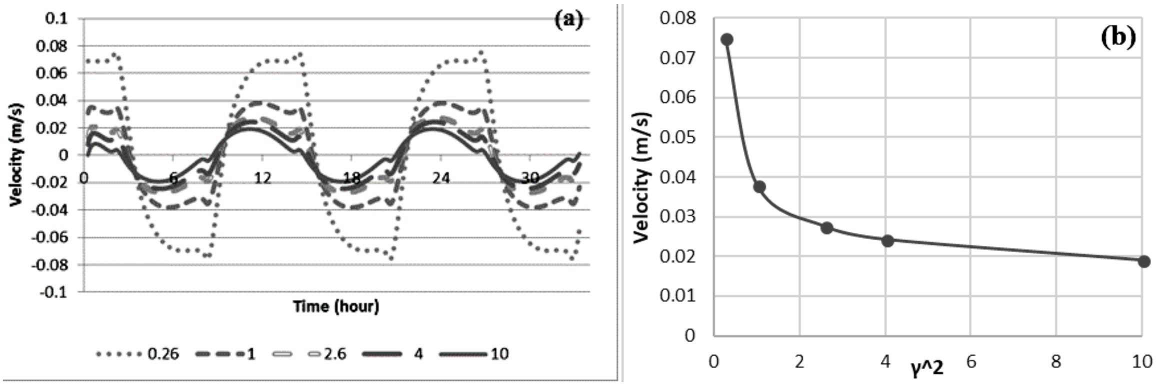

Fig. 5. a) Velocity for different values of γ^2, b) Dependence of the velocity on γ^2

The observation results. The two study sites are chosen: Can Gio mangrove forest - Ho Chi Minh City and Cu Lao Dung mangroves forest - Soc Trang Province. The data were measured in Can Gio: from 6th Feb to 13th Feb 2012, and in Cu Lao Dung from 21st Sept to 04th Oct 2014 (fig. 1), in which the water levels were conversed from the pressure values according to UNESCO technical papers in marine science [1].

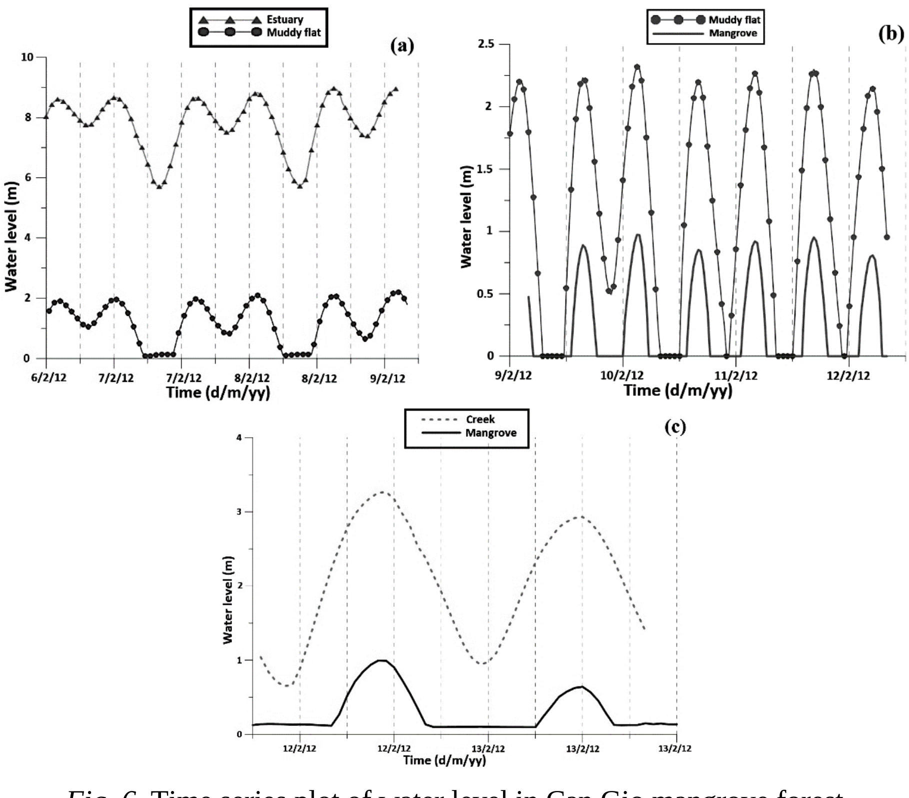

Fig. 6. Time series plot of water level in Can Gio mangrove forest

The observation results in Can Gio mangrove forest - Ho Chi Minh city: The measured data show that tide in the survey area is irregular semidiurnal tide and there is the tidal asymmetry in this area (fig. 6).

The velocity from the estuary into the mangrove is decreasing (fig. 7), especially in the mangrove the velocity magnitude is only about 22% of that in the estuary. Velocities in the mangroves and surrounding locations also express asymmetry: There is clear difference between the current velocity in flood tide and in ebb tide. In the mudflats and the mangrove, the velocity in flood tide is dominant, but in the creek that in ebb tide is dominant.

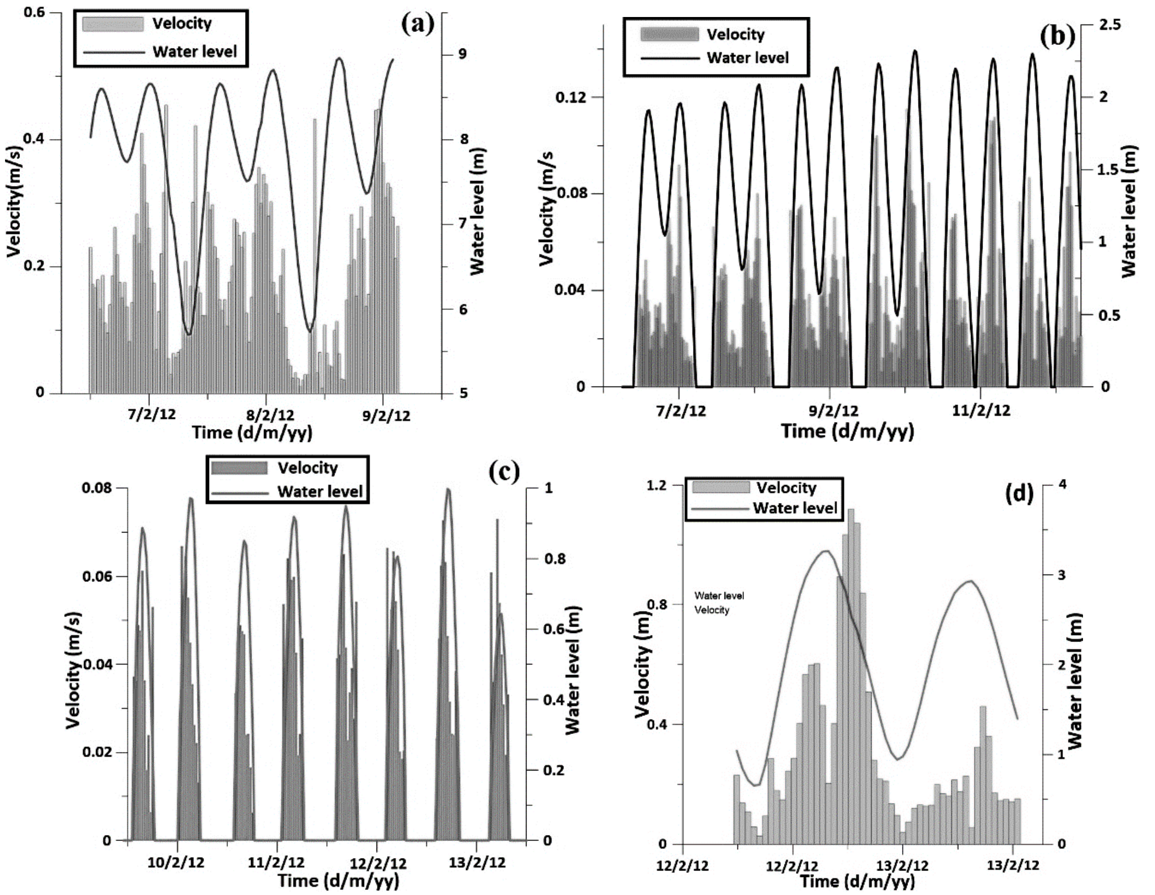

Fig. 7. Time series plot of velocity in Can Gio mangrove forest: a) In estuary, b) In muddy flat, c) In mangrove, d) In creek

The observation results in Cu Lao Dung mangrove forest - Soc Trang province: Similarly, tide in the Cu Lao Dung is irregular semidiurnal tide. The water levels in the mangrove express asymmetry, but this asymmetry is different in the time series (fig. 8). On 23rd Sept 2014, the flood tide was faster in the first tidal cycle, but in next tidal cycle, the ebb tide was faster. Similarly on 26th Sept 2014, the ebb tide was faster in both tidal cycles (fig. 9).

The maximum velocity is about 0.5 m/s in the outside station, and 0.2–0.3 m/s in the muddy flat (fig. 10). In the mangroves, the velocity is quite small, only about 0.1 m/s (fig. 10), and it also has asymmetry between flood tide and ebb tide. The SSC in the mangrove gets higher at flood tide and smaller at ebb tide. This partly reflects the dominance of the velocity at flood tide (fig. 11).

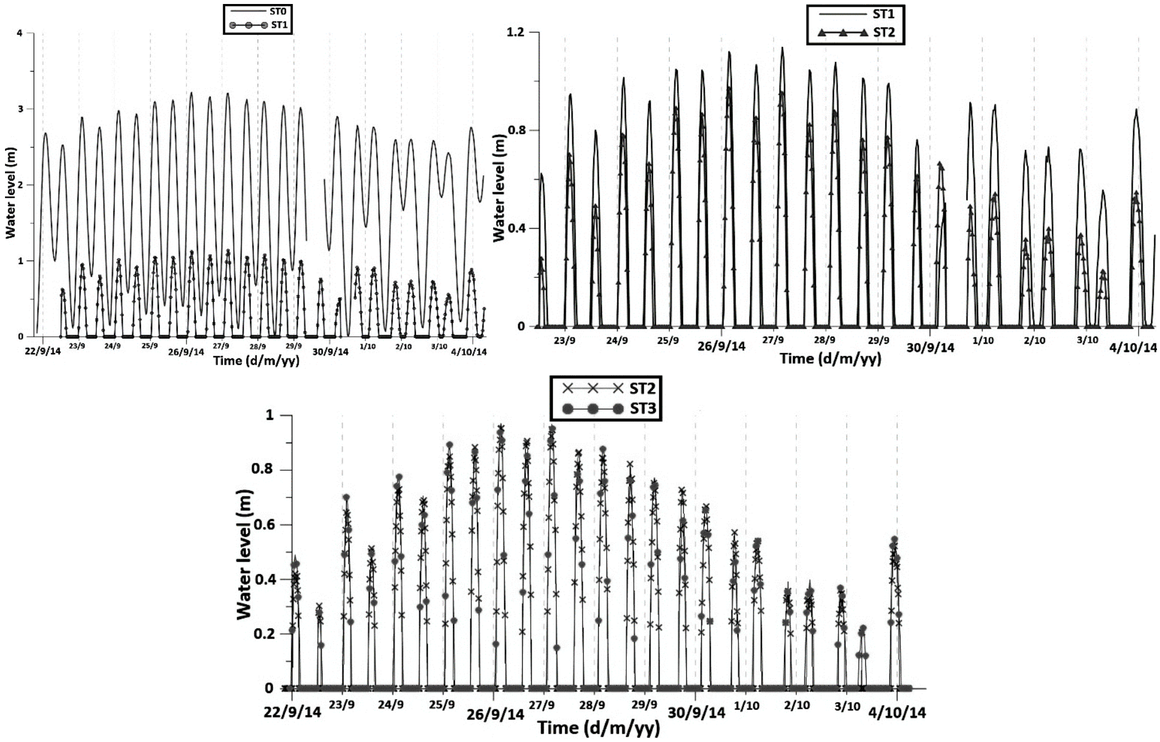

Fig. 8. Time series of water level in ST0 (outside), ST1 (muddy flat), ST2, ST3 (mangrove) in Cu Lao Dung mangrove forest

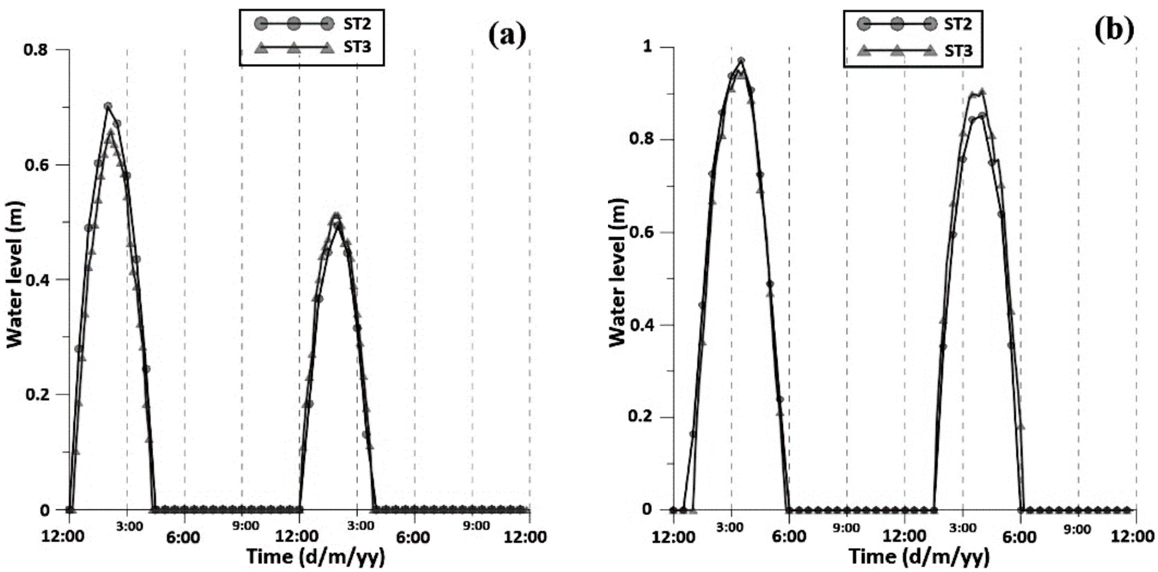

Fig. 9. Time series of water level on 23rd Sept 2014 (a) and 26th Sept 2014 (b) in Cu Lao Dung mangrove forest

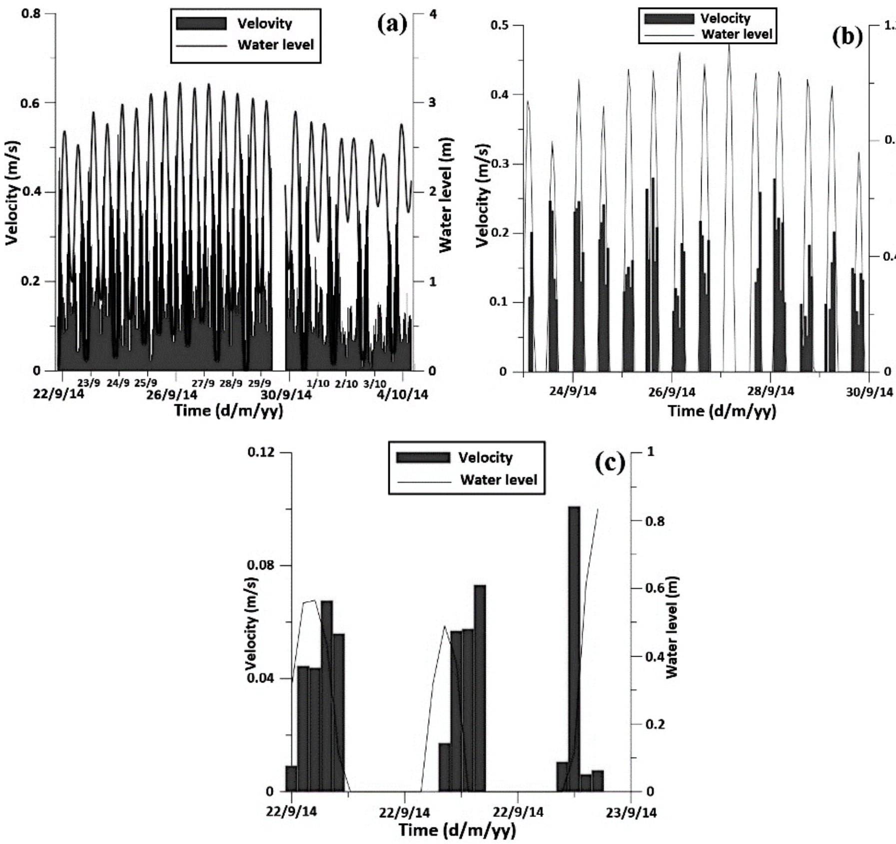

Fig. 10. Time series of velocity: a) In outside station, b) In muddy flat, c) In mangrove in Cu Lao Dung mangrove forest

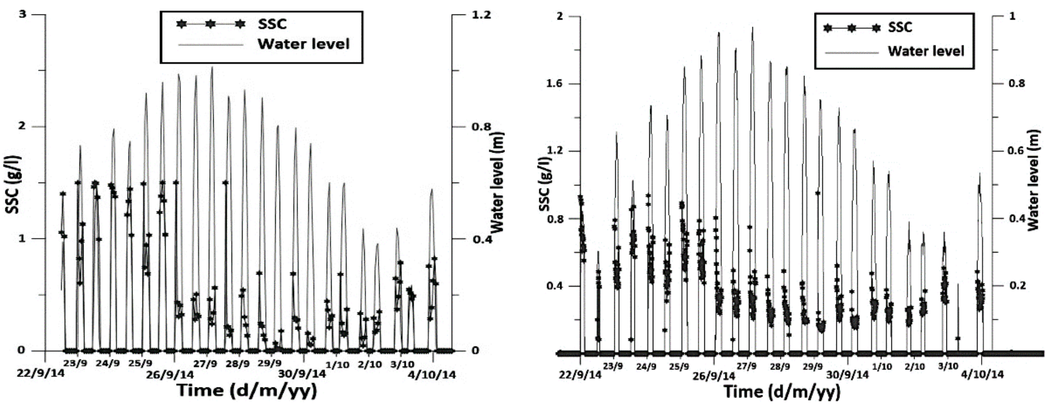

Fig. 11. Time series plot of SSC in the mangrove in Cu Lao Dung mangrove forest

CONCLUSIONS

The results of the model in the mangrove forest show that there is the asymmetry in current velocity: Two velocity peaks exist at flood tide and two at ebb tide. The velocity depends strongly on drag force due to the mangrove vegetation. The greater the friction is, the more decrease of flow velocity. However, when the friction coefficient increases to a certain value, its impact on the flow velocity is not significant.

The results from analysing the measured data in Can Gio (Ho Chi Minh city) and Cu Lao Dung (Soc Trang) show that the water levels in two sites change on phase and the fluctuation shape. The tidal asymmetry in both areas showed the similar characteristics. The water level and the velocity express asymmetry but the dominance is not clear in flood tide or ebb tide, except the velocity in the mangrove. The complexity of asymmetry in mangrove forest could be explained by the drag force effect.

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