Effects of tides and upstream flow on inundation of Can Gio mangrove forest, Vietnam

Vu Thi Hoai Thu*, Tabata Toshinori**, Hiramatsu Kazuaki**, Trieu Anh Ngoc***, Harada Masayoshi**

1. Introduction

The Can Gio is a famous district for the mangrove swamps as mangrove biosphere reserve for Ho Chi Minh City (HCMC). Can Gio Bay is located in the downstream of HCMC, connecting the city's center to the sea. It has flat, low-lying topography that is affected by the tidal regime of the East Sea and by upstream flow of Dong Nai–Saigon river system. The historical flood event of 2000, which had a return period of 20 years, caused serious flooding in the downstream of HCMC, and the Can Gio was one of the most affected areas with approximately 90% of its area inundated. This research aims to investigate the inundation of the Can Gio Bay area in 2000, and the influence of the tide and upstream flow. A two-dimensional hydrodynamic model combined with a wetting and drying scheme was used to determine locations of inundated area.

2. Materials and methods

The two-dimensional hydrodynamic model with the wetting and drying scheme was constructed for this study. The governing equations of the model are as follows:

$$\frac{\partial U}{\partial t}+\frac{\partial}{\partial x}\{U(h+\eta)\}+\frac{\partial}{\partial y}\{V(h+\eta)\}=0\,, \tag{1}$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}=fV-g\frac{\partial \eta}{\partial x}+A_h\left(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right)-\frac{gn^2U\sqrt{U^2+V^2}}{(h+\eta)^{4/3}}\,, \tag{2}$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}=-fU-g\frac{\partial \eta}{\partial x}+A_h\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right)-\frac{gn^2V\sqrt{U^2+V^2}}{(h+\eta)^{4/3}}\,, \tag{3}$$

where η is the water level, t is time, h is the bottom level, $f = 2\Omega\sin\phi$ is the Coriolis parameter indicating the effect of Earth's rotation (Ω is the angular rate of revolution and ϕ is the geographic latitude), g is the acceleration due to gravity, n is the Manning coefficient, U and V are the x and y directions respectively of the horizontal velocity components in a Cartesian coordinate system, and A_h is the coefficient of eddy viscosity determined with the Smagorinsky model. A leapfrog finite difference method was used for numerical solutions.

Because the Can Gio area is flat and low-lying, the wetting and drying scheme with a land mask function (LMF) was applied to identify tidal flats (Uchiyama, 2004). In this model, the LMF used to identify and mask land in a mesh for simulations is characterized by two values: 1 for wet and 0 for dry. The water depth $D_{i,j}$ (= $h_{i,j} + \eta_{i,,j}$) of each grid cell (i, j) is compared with a threshold depth d_{cr} (= 0.2 m). If the water depth is greater than the threshold depth, the cell is determined to be wet. Otherwise, the grid cell is regarded as potentially dry. Then, the four cells adjacent to the potentially dry cell will be tested by following three conditions: 1) if the water levels of the four cells are less than $\eta_{i,j}$, 2) if the water depths of the four cells are less than d_{cr}, and 3) if the LMF results of all four cells are equal to 0. If at least one of these conditions is satisfied, the potentially dry cell is considered as land area. If none of these conditions are satisfied, the cell is wet.

GIS software was used to construct the 50-m-mesh depth dataset illustrated in **Figure 1**. Hourly inflows of the Thi Vai, Phu Xuan, Vam Co, Cua Dai, and Cua Tieu rivers were used to establish the boundary conditions. Observed tidal level at Vung Tau Station was used to calculate tidal variation at the entrance. The water levels

*Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University, **Faculty of Agriculture, Kyushu University, ***Thuyloi University
Keywords: Can Gio Bay, 2-dimensional hydrodynamic model, wetting and drying scheme, wetland, tidal regime

of the Soai Rap, Dong Tranh, Nga Bay, and Thi Vai rivers were used for validating the model.

Figure 2 shows the calculated and observed water level variation of the Thi Vai River station at one hour intervals from 00:00 (GMT+7) on August 7, 2009 to 00:00 on August 14, 2009. The results of this simulation show good correlation between the observed and simulated water levels with correlation coefficients *R* of 0.975, 0.969, 0.977 and 0.979 for the Soai Rap, Dong Tranh, Nga Bay and Thi Vai rivers, respectively. It can be said that the constructed model was accurate and satisfactory and this model was used for simulating and analyzing the flood event of 2000.

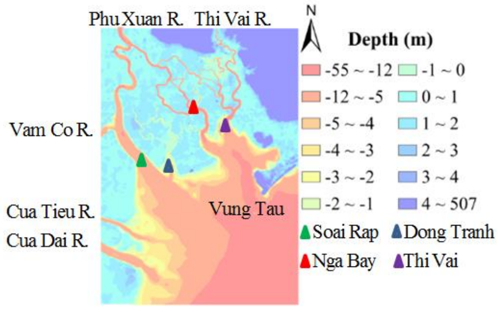

Figure 1. Bathymetry and model domain in the Can Gio Bay

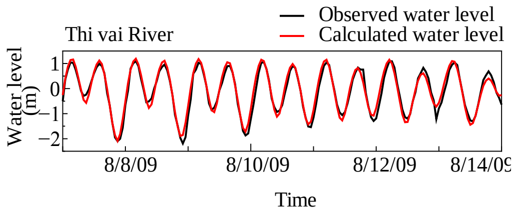

Figure 2. Observed and calculated water level of the Thivai River from 00:00 (GMT+7) August 7 to 00:00 (GMT+7) August 14, 2009

3. Results and discussion

Figure 3 and **Figure 4** show the results of inundated area and dryland area in the Can Gio Bay by simulated flood event of 2000. With the highest tide (+ 1.11 m) at 14:00 (GMT+7) on October 27, 2000, the water level reached the highest and came into the Can Gio bay, it caused substantial inundation of the Can Gio area. 75.59% of the area (53,213.50 ha) was inundated, and when the tide went out, the inundated area decreased dramatically by 28.64%, which highlights that the tidal range is an important factor causing of flooding in this area. When ebb tide reached to the lowest level (-1.09 m), the Can Gio area was still significantly flooded with 20,165.75 ha still inundated. It demonstrated that, when the tide withdrew, upstream flood maintained flow into the bay with significant discharge, and low-lying areas upstream were submerged. However, according to the 2006 official report by the Ministry of Agricultural and Rural Development, the inundation actually covered approximately 90% of the area. This discrepancy between the results of the proposed model and reported actual case is supposed that the proposed model used data input of DEM in 2006 for simulating the flood event of 2000. The areas incorrectly identified as non-flooded had undergone specific changes in land use such as land leveling and urbanization. These factors should be collected and analyzed in detail. This research is ongoing to develop and upgrade the proposed model in order to address urgent issues in the Can Gio Bay.

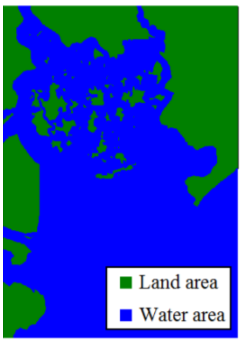

Figure 3. The highest flood tide at 14:00 (GMT+7) on October 27, 2000

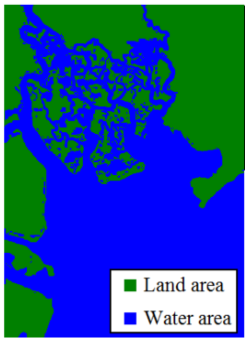

Figure 4. The lowest flood tide at 20:00 (GMT+7) on October 27, 2000

4. Conclusions

Tides and flood discharge from upstream are the key factors that influence inundation around Can Gio Bay. The inundated area changes depending on tidal trends. Moreover, flood discharge from upstream also impacts the upstream area of Can Gio and low-lying areas along rivers.

Reference: Uchiyama, Y. (2004): Modeling wetting and drying scheme based on an extended logarithmic law for a three-dimensional sigma-coordinate coastal ocean model, *Report of the Port and Airport Research Institute, Yokosuka, Japan*, **43**(4), 3-21