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Author(s)	Viet, Son Le; Watanabe, Yasunori; Tachibana, Harukuni; Mori, Akio
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PRELIMINARY NUMERICAL RESEARCH ON FLOW PATTERNS OF SEA - AND FRESH-WATER IN THE TAM GIANG, THUY TU AND CAU HAI LAGOONS IN A TIDAL SYSTEM

V.S. Le*, Y. Watanabe*, H. Tachibana*, A. Mori*

* Graduate School of Civil Engineering, Hokkaido University, Kita 13, Nishi 8, Kitaku, Sapporo, 060-8628, Japan

ABSTRACT

The Princeton Ocean Model was employed to study tide induced currents and salinity intrusion in the Tam Giang-Cau Hai lagoon complex. The model was forced by tides at two open boundaries named Thuan An and Tu Hien. The circulation pattern indicates the maximum velocities during ebb tide and flood tides are about 15 and 20cm/s, respectively occurring in the vicinity of Thuan An inlet. Residual current in Thuy Tu lagoon is higher in other regions, which indicates that salt water is transported into Cau Hai and then Thuy Tu lagoons through Tu Hien inlet. Residual current velocity in Tam Giang can be neglected. Thus, water exchange in this lagoon is weaker than in Cau Hai-Thuy Tu lagoons. The results of salinity intrusion simulation show that: well mixed regions are seen in Thanh Lam and Cau Hai lagoons. Partially mixed regions are in the northern parts of Tam Giang and Thuy Tu lagoons. During the simulation period, salinity intrusion through Tu Hien inlet is much stronger than that through Thuan An. A comparison between observed and computed results showed that the model can reproduce salinity concentration distribution in the lagoon system.

KEYWORDS

Princeton Ocean Model, Salinity intrusion, Tam Giang - Cau Hai, Tide induced currents

INTRODUCTION

The Tam Giang-Cau Hai lagoon complex is a typical marine protected area that comprises a series of coastal lagoons, situated to the north and east of Hue city (see Fig.1). The largest lagoon is Cau Hai, in the south-east of the site. This lagoon is connected to the sea via the Tu Hien mouth. To the north-west are three more lagoons, none of which is connected to the sea directly. The north-westernmost lagoons, Tam Giang and Thanh Lam, open into the Huong river, which flows into the sea via the Thuan An mouth. The third lagoon, Thuy Tu, connects Thanh Lam and Cau Hai lagoons. The width of Thuy Tu lagoon is very narrow with a minimum value of few hundred meters. The lagoons are separated from the sea by a large sand dune system. The shallow lagoon receives a mixture of fresh and salt water which causes regular, seasonal and spatial changes in salinity. The bottom is rather flat with an average depth of around two meters in most of the lagoon although some channels are 3-4 m deep, and near the Thuan An and Tu Hien inlets water depths are more than seven meters.

There were very few researches on hydrodynamic condition in the lagoon complex. *Nghiem et al. (2003)* showed the relationship between inlet openings and current velocity at inlets by one-dimensional hydrodynamic model. *Tran (2005)* applied a 2-D model to simulated current field in the complex but for very short time of simulation (12h). There was no report on the salinity intrusion in lagoons. In this paper, the current features and salinity intrusion in the Tam Giang-Cau Hai lagoon complex are numerically investigated by using the Princeton Ocean Model (POM).

MATERIALS AND METHODS

Present study is based on numerical approach. The Princeton Ocean Model (POM) (*Blumberg and Mellor, 1987*) is employed to compute current pattern and salinity concentration in the model domain. POM is a three-dimensional, fully nonlinear, primitive equation, ocean circulation model.

Model configuration and initialization

The POM was configured in a domain shown in Fig.1. It is noted that the original map of the study area has been rotated 52° clockwise to create the map shown in Fig.1. The model domain is about 16.5 x 67.0 km in x,

y direction, respectively. The both horizontal grid intervals were 100meters. Thus, the model consisted of 670x165 grid points in x and y direction, respectively. There were 6 levels in the vertical with finer resolution (log distribution) near the surface and bottom layers. A modification is made to the original topographic data: setting a minimum water depth at 1m in the model to prevent drying in shallow grid cells due to tide fluctuation.

The simulation period in this study was from June 4th to June 18th 2003. This period was chosen because tide levels at the two inlets are available. Fresh river discharge from surrounding rivers, especially Huong river, may play an important role to change current pattern and water quality in the lagoon complex. However, since no data about river discharges was available, they are assumed to be zero in this study as a first approximation. The averaged water temperature in summer 2003 obtained from the World Ocean Atlas 2001 (Conkright et al., 2002) was used as an initial condition, and the constant temperature was also given in the whole simulation period. There are two scenarios for initial value of salinity in the lagoons either zero or 35ppt. The later value is the same as the salinity concentration at open boundaries. All other variables are initialized from the rest.

Open boundary conditions

The lagoon complex is open to the South China Sea through two inlets named Thuan An and Tu Hien. Water levels at the two inlets are set equal to tide levels at Thuan An and Tu Hien, respectively. Salinity at two inlets is assumed constantly at 35ppt.

Model formulation

Difficulties arise during modeling process. Since there is no water level or current velocity data for calibration and verification, the results from this study may be rough descriptions of basic hydrodynamic mechanism in the study area while we still believe that the results give us information of overall features of water exchange in a tidal system. The following numerical experiments are made: the first experiment assumes that at initial the complex is completely mixed with sea water i.e. the model is run with initial value of salinity at 35ppt. To investigate how salinity is intruded into the lagoon, we perform a simulation with zero initial condition of salinity in study area in experiment 2.

RESULTS AND DISCUSSION

Since the lagoon is generally shallow and it is assumed to be well mixed in the first case. In each tide cycle, maximum current speeds occur at flood and ebb conditions. The current vector field at flood tide in the first case is presented in Fig. 2. In general, maximum speeds are found to occur in the regions around Thuan An inlet, Thanh Lam lagoon, the southern part of Tam Giang lagoon and the northern area of Thuy Tu lagoon while low velocities are seen in Cau Hai lagoon and the northern part of Tam Giang lagoon. The regions of large and small velocities at ebb tide are similar to that in flood tide condition (figure is not shown). During ebb tide, maximum current speed is about 15cm/s, while during flood tide it is about 20cm/s.

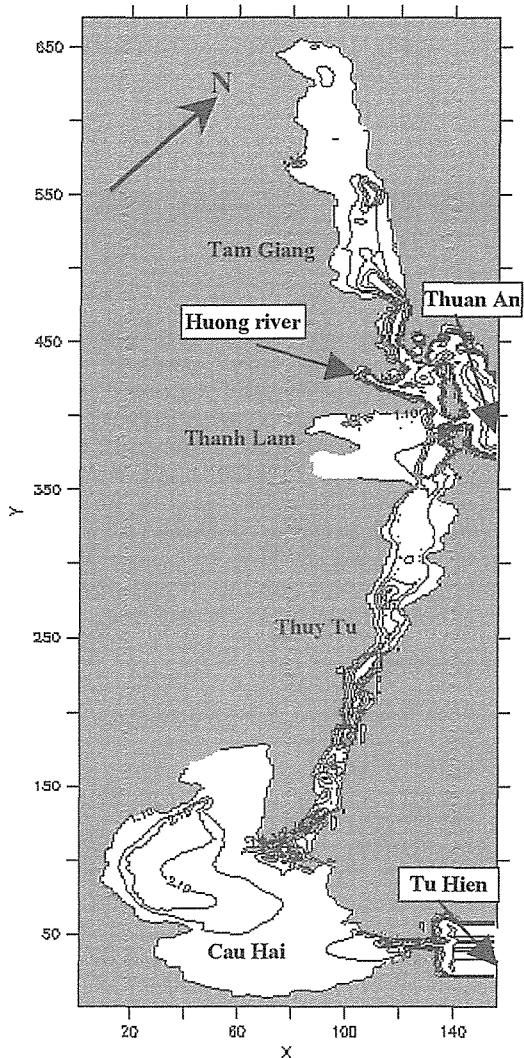


Fig. 1 Topographic data of the Tam Giang - Cau Hai lagoon complex. Contour label is in meter. Thuan An and Tu Hien mouths are also shown in the figure.

From the water quality point of view, the residual circulation is important because it associates with water exchange between salt water and fresh water. Fig. 3 presents time average of current velocity field in one tidal cycle. It can be seen that residual current in Thuy Tu lagoon is higher in other regions, indicating that salt water is transported into Cau Hai and then Thuy Tu lagoons through Tu Hien inlet. Residual current velocity in Tam Giang is very low to be neglected, and water exchange in this lagoon is weaker than in Cau Hai-Thuy Tu lagoons. Since the water tends to stagnate within Tam Giang, deterioration of waters is expected in terms of water exchange.

To investigate salinity intrusion mechanism from tide inlets to lagoon complex, the second experiment is implemented with a zero salinity concentration in the lagoons initially. Fig. 4 shows the salinity concentration in the model domain after 12 days of simulation. Although quasi-steady condition hasn't been reached, salinity concentration changes very slowly since this time. Well mixed regions are seen in Thanh Lam, Cau Hai and Thuy Tu lagoons. Salinity concentrations in these regions are in the range of 20-35ppt. Partial mixed regions are in the northern parts of Tam Giang lagoons where the salinity concentrations are less than 15ppt. During the simulation period, salinity intrusion through Tu Hien inlet is much stronger than that through Thuan An. Salt water from Tu Hien inlet is advected into Cau Hai, then Thuy Tu lagoons to mix with fresh water. This shows the important role of Tu Hien inlet to water exchange mechanism between the sea and lagoon complex.

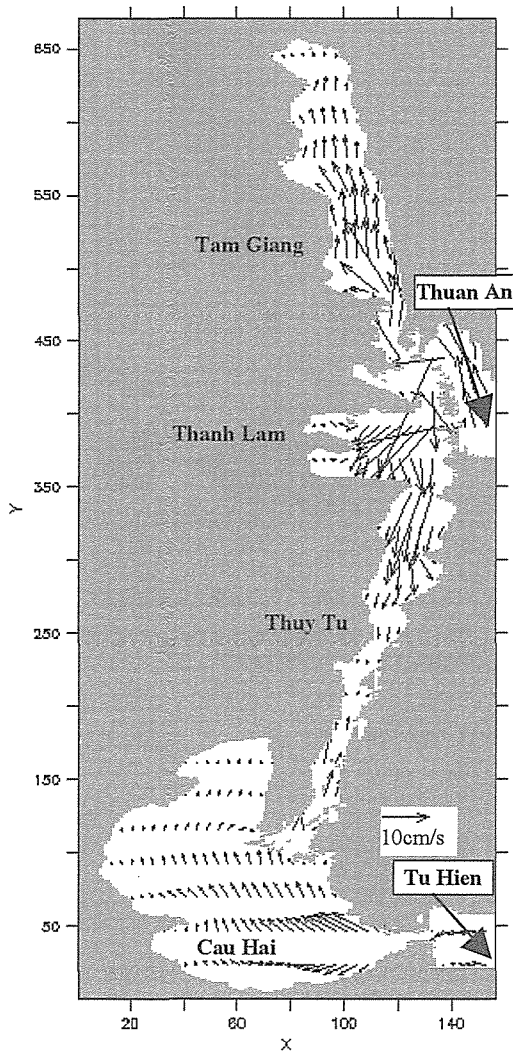


Fig. 2 Maximum current velocity during flood tide

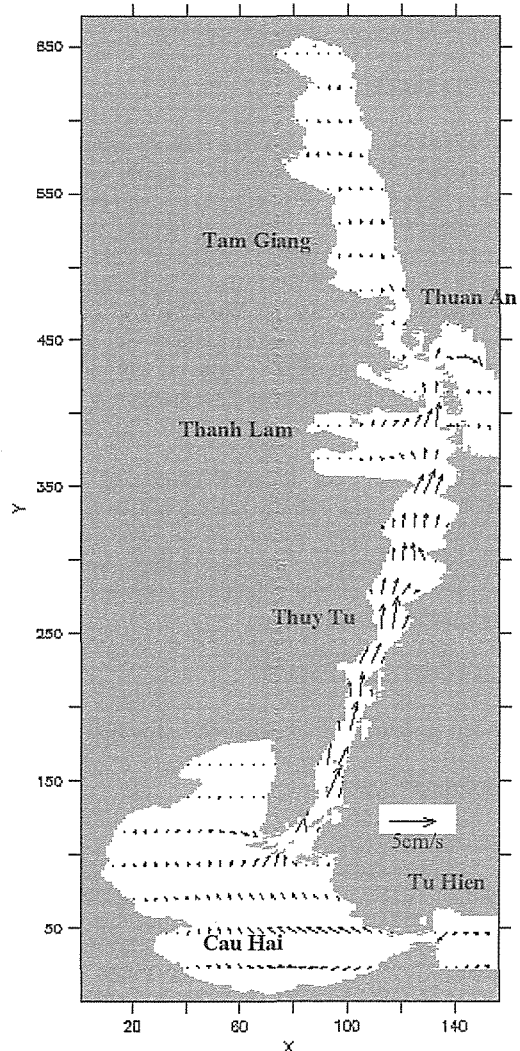


Fig. 3 Time average velocity in one tidal cycle

Field Observation

Our group conducted field surveys in the lagoon complex from 27 May to 5 June 2005. According to the investigation, there were many cultivation pods for shrimps in water areas of Thanh Lam and Tam Giang (see circles in Fig.4) and also cultivation pools on shore of Thuy Tu (see a rectangle in Fig.4). The lagoon water was pumped up to the pools to mix with freshwater to achieve most suitable salinity (1.6 to 1.8 %) for the shrimp cultivation. Our computational results of salinity in a range between 1.5 and 2.0 ‰ appear to cover the region where are many shrimp pods except the northern part of Tam Giang, which ensures our appropriate computations. It seems that the water of Thuy Tu needs to be diluted for the shrimp cultivation because of higher salinity.

CONCLUSIONS

The present paper studied tide induced current and salinity intrusion in a sea – fresh water area in Tam Giang – Cau Hai lagoon complex. A comparison between observed and computed results showed that the model can reproduce salinity concentration distribution in the lagoon system. Results from this study are useful indicators for management of the agricultural – aquaculture system and also controlling water quality in Tam Giang – Cau Hai lagoon.

In later phases, for a better estimation of current field and salinity concentration the following data are needed to be surveyed: fresh water discharges from surrounding rivers, water level and current velocity at least at one station inside model domain.

ACKNOWLEDGEMENT

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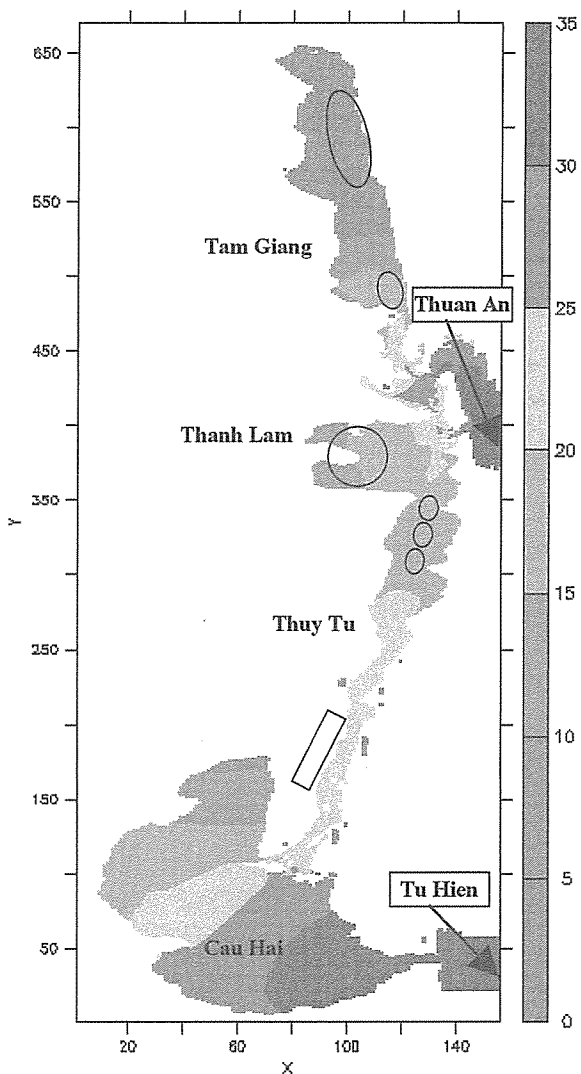


Fig. 4 Daily average salinity concentration at day 12th (ppt)

The ellipses and rectangle show the locations of cultivation pods and the pool, respectively.