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ARTICLE

Application of Regional Ocean Modeling System for Hydrodynamics in Binh Cang-Nha Trang Bay, Vietnam

Pham Xuan Duong[1*] **Phan Minh-Thu**[2,3] **Bui Hong Long**[1,3]

1.Dept. Marine Physics, Institute of Oceanography, Vietnam Academy of Science and Technology (VAST), Nha Trang, Vietnam
2.Dept. Marine Ecology, Institute of Oceanography, VAST, Nha Trang, Vietnam
3. Graduate University of Science and Technology, VAST, Vietnam

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ABSTRACT

Based on the data collected at the Cau Da station, the Regional Ocean Modeling System (ROMS) is applied for hydrodynamics (e.g. circulation and temperature-salinity) in Binh Cang - Nha Trang Bay, Vietnam. The results present the several cases of hydrodynamic regimes in the Bay during two mainly monsoon seasons (northeast and southwest monsoons). The clearly hydrodynamic regime occurs in the bay due to the impacts of rivers and monsoon conditions. These changes could be contributed to the hydrodynamic systems and water exchanges, that support basic scientific information for sustainable development of Binh Cang - Nha Trang bay.

1. Introduction

The rapid development of 2D and 3D hydrodynamic model have contributed to understanding the circulation systems of coastal and marine waters in recent years. These models could be applied for coastal water and river basin (such as NAM - Nedbor Afstrømnings Model [1],[2]; Mike11 [3],[4]) and ocean (for example, POM (Princeton Ocean Model) [5],[6], ROMS (Regional Ocean Modeling System) [7],[8], HAMSON (Hamburg Shelf Ocean Model) [9],[10], GHER (Geo-Hydrodynamics and Environmental Research) [11] and MIKE3 [12]). Each model was setup and run with different parameters. By the advantages of the models, therefore, numerical model is one of the optimal approaches to understand aquatic hydrodynamic systems both in the spatial and temporal scale. The specific variables of modelings as the key issues in modeling have simulated the coastal waters.

Binh Cang - Nha Trang Bay is located in the coastal region of the couth center of Vietnam. It takes an important role to help development of the tourism in the marine city, Nha Trang. Economics of Nha Trang City target to the tourism/marine tourism, aquaculture and navigation sectors. Thus, the feature of hydrodynamics in Binh Cang - Nha Trang Bay is contributed to these economic sectors. Because of the complexity of the natural system, as the understanding of the hydrodynamics in aquatic systems, we need to gather marine long-time observed dataset. Whereas the development of models helps to have the hydrodynamic information economically and effectively.

**Corresponding Author:*
Pham Xuan Duong,
Dept. Marine Physics, Institute of Oceanography, Vietnam Academy of Science and Technology (VAST), Nha Trang, 650000, Vietnam;
E-mail:duongpx63@yahoo.com

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However, the models, applied effectively into the model the effect of wind, density, shoreline, river water and the influence of the tide [13], have faced some problems. A number of computational models applying to the study area have ignored the bottom stress affecting the average of depth; and due to lack of water level fluctuation data in the liquid boundary and river flows, so several models just put on a four-wave model (M2, S2, K1, O1) and opening boundary (border river) are omitted.

2. Materials and Methods

2.1 The Regional Ocean Modeling System Origins of ROMS

The exited ROMS is a development of the S-coordinate Rutgers University Model (SCRUM) [14].. ROMS was rewritten to improve both in numerical and efficiency systems for the single and multi-threaded computer architectures. The ROMS also was expanded for the high-order advection schemes; accurate pressure gradient algorithms; several sub-grid-scale parameterizations; atmospheric, oceanic, and benthic boundary layers; biological modules; radiation boundary conditions; and data assimilation. Nowadays, ROMS has several open-coded versions developed by different institutions. More information on ROMS was found in ROMS developers or users (http://www.ocean-modeling.org and [15]).

2.2. Materials

The topography of the Binh Cang – Nha Trang area was taken in the scale 1:150,000 and has corrected by depth data measuring in recently years. The study area was made by 150×150 nodes of $\Delta x \approx 260 - 400\ m$, $\Delta y \approx 300 - 450\,m$ and $\Delta z \approx 0.4 \div 40m$ (Fig. 1).

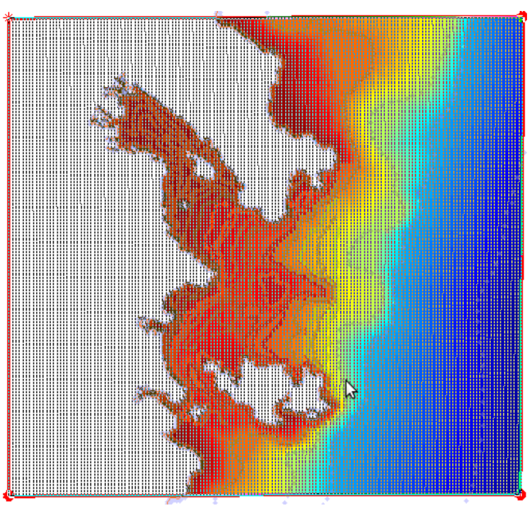

Figure 1. The calculation network diagram for in the Binh Cang – Nha Trang area

Due to the impact of the tropical monsoon the daily fluctuations of temperature are about 5°−7°C, the lowest temperature in the zone is about 14°C and the highest temperature is about 39°−40°C.

In the term of meteorology, beyond the regular tropical monsoon, the weather can be considered seasonally. Main wind directions during the dry season (northeast monsoon) are the southeast and southwest, whereas the rainy season (southwest monsoon) is the north and northeast with the main speed range from 2 to 5 m/s. In northeast monsoon, winds level can reach to the Beaufort number 11, and the calm wind is about 31.4%. In southwest monsoon, the wind is not strong with the calm winds frequency of 42%. Strong winds is rarely observed in Khanh Hoa. The moderate wind in Nha Trang is in the Beaufort number 3 (from 2 to 5 m/s, has not overcome the adverse biological limits). In the case of the most wind occurs, they are usually related to the hurricanes or tropical cyclones from the South China Sea.

The average river discharge in several years is used as the opening boundaries of the rivers.

2.3 Calibration

The process of calibration was set at two steps. The step 1 would find the time step, after running the model for the study area with different time steps, the time step $\Delta t = 30s$ (the Courant-Fredrichs-Lewy condition [16], [17]) is well adapted to the domain of space and grid selected. Step 2 would find the parameters for the study area. Used the method of trial - error and the method of determining direct some parameters, the coefficients of the model determinate based on observed measurement data (currents data to find the coefficient of exchange trouble horizontal, seawater density data were determined from the temperature, salinity and sea level). Calibration process parameters in the model used the test method - false sketched in diagram (Fig. 2):

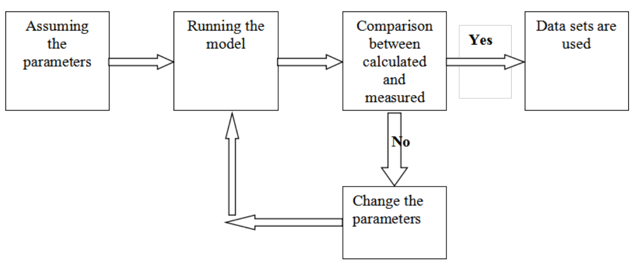

Figure 2. Calibration process diagram model parameters

Validation of the water level between the collected data and predicted results. Dataset to validate the ROMS model after adjusted was collected in August 2009. Data of sea level was collected at Cau Da station, whereas wind

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intensity, current, temperature, salinity were measured at 17 different surface stations. The results of qualitative evaluation show a good fit between simulated model results and observed data of sea level in Fig. 3. Standard error between predicted and observed data on sea level fluctuation in August 2009 was accepted as 10.2 (cm).

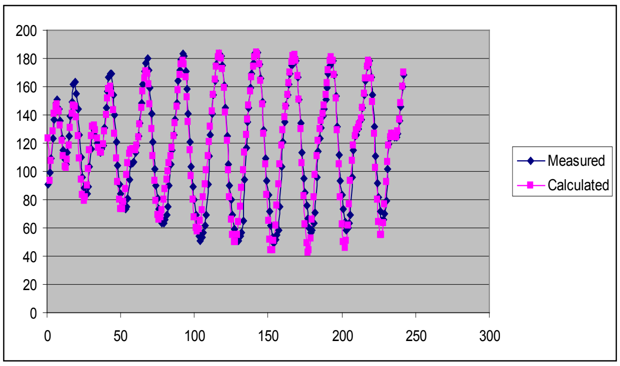

Figure 3. Validation of the model by sea level at Cau Da station

Validation of concurrency frequency between the calculated and measured values: The daily/nightly current frequency was unceasingly measured in many days at stations and compared to predicted current frequency at stations at southern open boundary (109.24°E, 12.18°N), Ke Ga (109.23°E, 12.28°N) and Hon Thi (109.24°E, 12.35°N) in the northeast monsoon (n =3240). Fig. 4 showed that very good fits between the predicted and observed data.

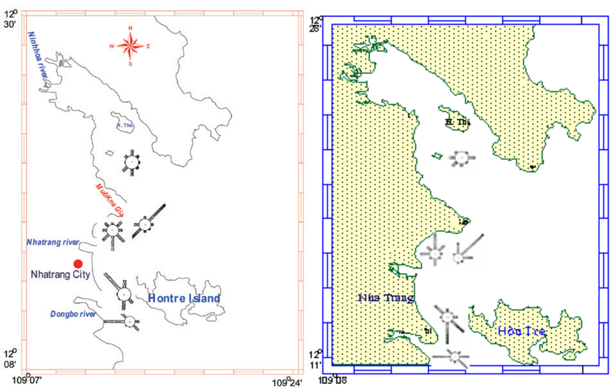

Figure 4. Compare the current frequency in the bottom layer between calculations (left) and measured (right) on the northeast monsoon

3. Results

Results of the calibration process and testing of this study allowed to apply of the ROMS model for current circulation systems in the Binh Cang – Nha Trang Bay. Current calculated in a long time was used to provide overall information in the tidal cycles in the studied area. During high tide and low tide (i.e. lowest, middle, highest tide) current regimes showed a different fluctuation (i.e. strong and weak current). Generally, based the current regimes, Binh Cang - Nha Trang Bay divided into three regions. The eastern offshore region the was dominated by the oceanic circulation of the Bien Dong due to the wind in both of northern and southern direction. The central region, where normally occurred the most complex dynamic process, could reveal to the dynamic interactive processes between seawater and discharge water, fluxed out in addition to the influence of the bottom topography of the bay, mainland shore, shore islands to the current here. Southern open sea region is normally a convergence of two currents (Fig. 5). The first current is from the north to the south, after crossing the strait of Hon Tre Island the curent divided into two different directions and forward to the south and met here.

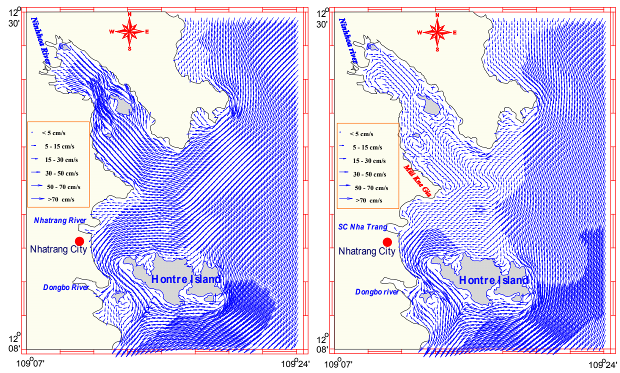

Figure 5. The current field in the surface (left) and bottom (right) on the northeast monsoon

Vertical current in the southwest monsoon: The results indicated that at the high tidal level, the vertical current speed at all levels fluctuated from -6 to 1×10^{-3} m/s (Fig. 6, 7).

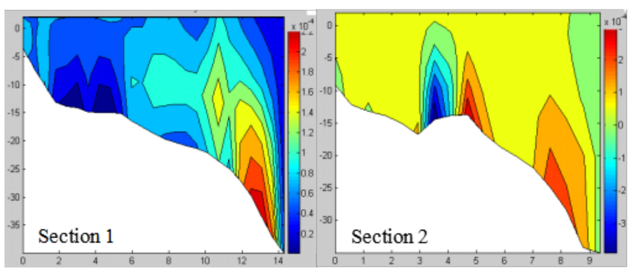

Figure 6. Vertical partition in m/s of sections 1 and 2 at high tidal phase

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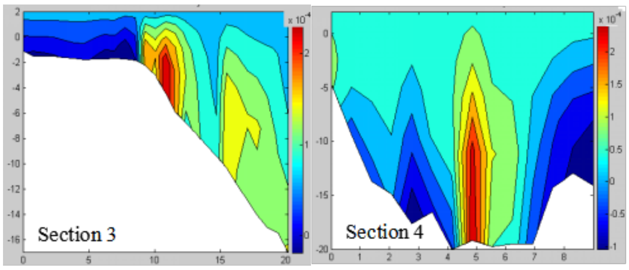

Figure 7. Vertical partition in m/s of sections 3 and 4 at high tidal phase

Vertical current in the northeast monsoon: The current partitions have the trends and partitions similar to of those of the southwest monsoon but with higher fluctuation amplitudes (Fig. 8, 9). In the southwest monsoon, vertical current in range of -10 to 4 10-4 m/s was less fluctuation amplitude than that in the northeast monsoon season in range of -20 to 4 10-4 m/s. Thus, disturbance of water layers was stronger and "sink" water at higher level comparing to 'float' water.

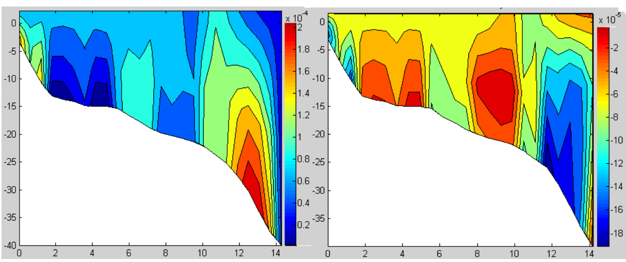

Figure 8. Vertical current in m/s of section 1, flood (left) and ebb (right)

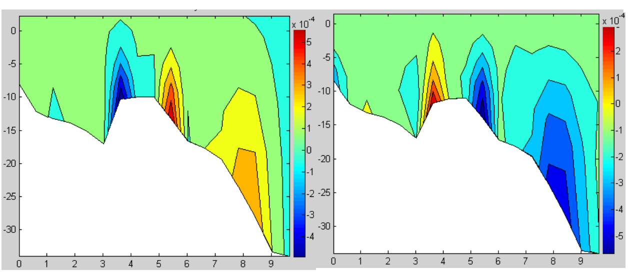

Figure 9. Vertical current in m/s of section 2, flood (left) and ebb (right)

Temperature-Salinity: the results have reflected the distribution trend of salinity and temperature regimes in the Binh Cang – Nha Trang Bay (Fig. 10). A general rule of the closer and shallower water areas was, the lower and lower salinity was. In addition, a significant change on temperature was found at different tidal cycles. At the lowest tidal level, the water level was lowest and vice versa. In regards depth, salinity pattern was quite complex. In some regions, salinity of the surface level was rarely changed. In some cases, salinity of bottom and surface layers was almost unchanged but strongly changed at middle layers.

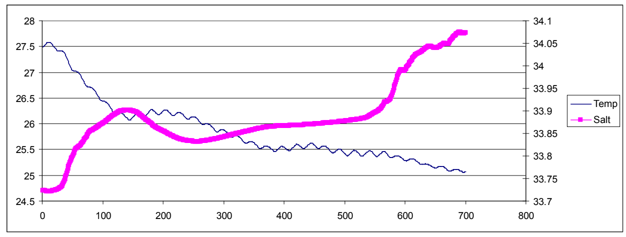

Figure 10. Temperature-salinity changes over time in the Dongbo river mouth

Morphological characteristics of the circulation: The vortex line was formed at the Nha Trang Bay (Fig. 11) and it only appears at high tidal phase. The vortex was found clearly at water level of from 1.9 to 2.4 m. Appearance event was highly dependent on seasonality. During the winter season, the vortex was often occurred at night and in the early morning, whereas in the summer season, it was normally appeared in the afternoon within two hours.

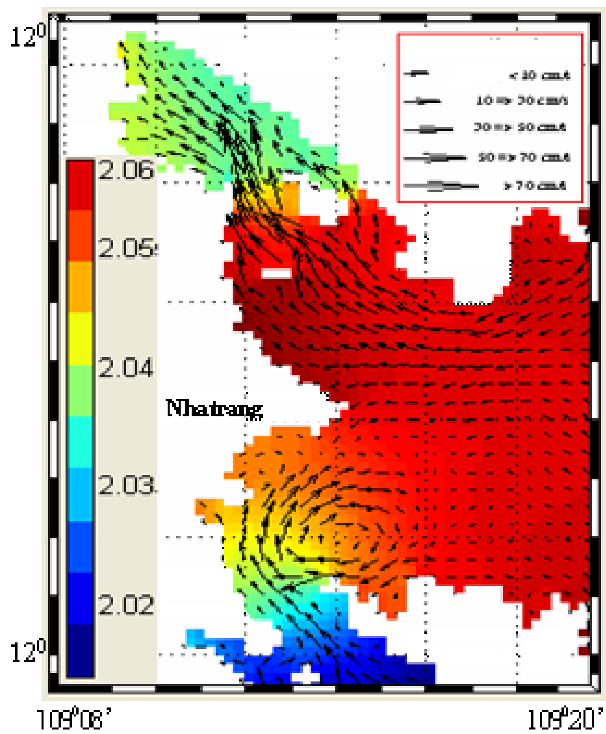

Figure 11. The vortex in the Binh Cang –Nha Ttrang bay area

The role of the major factors forming circulation in the Binh Cang-Nha Ttrang bay area: the ROMS model was run by following simulations (1) only density current, (2) the density current adding impact of river water flowed out (additional river), (3) the density current adding tidal effects (additional tide), and (4) the synthesis current (adding river and tidal effect). The results indicated that

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the differences of individual current component in the northeast and southwest monsoon (Fig. 12). The density current contributed approximately 13-16% of the synthetic current. The individual current of the density current and river water was contributed to 35 and 42% of the synthetic current in the northeast and southwest monsoon, respectively. The individual current of the density current and tidal effects figures at 58 and 71% in the northeast and southwest monsoon, respectively.

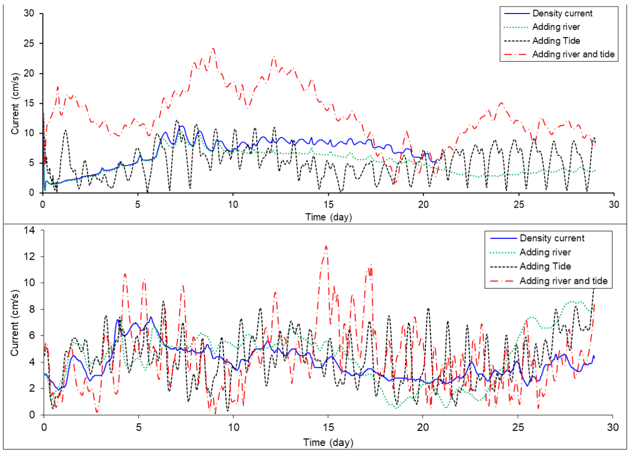

Figure 12. Current variation on the bay mouth in northeast (above) and southwest monsoon (below)

4. Conclusion

Application the ROMS model reconstructed relatively detail hydrodynamics in the Binh Cang – Nha Trang Bay, following in horizontally as well as vertically. In the term of vertical: in the flood tide, the trend was dominated sink water, whereas in ebb tide phase it was dominated the float water in the Binh Cang – Nha Trang Bay. At time of high tide, the water in the right-side bar rise with decreasing velocity values from the bottom to the surface and in the left-side bar sink water, at low tide, reverse the situation. In the term of horizontal: find and describe and explain the mechanism of formation and development of eddy currents in the Binh Cang – Nha Trang bay area which until now has not been mentioned. This study also was to quantify initial the role of each component which affects the circulation of the Binh Cang – Nha Trang Bay in the case of river and tidal effects to the synthetic current, the influence of these factors showed that on the rate of total very different.

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