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BURANAPRATHEPRAT, Anukul
Department of Aquatic Science, Faculty of Science, Burapha University

YANAGI, Tetsuo
九州大学応用力学研究所

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Hydrodynamical Conditions of the Bangpakong Estuary in Wet and Dry Seasons

Anukul BURANAPRATHEPRAT [*1] and Tetsuo YANAGI [*2]
E-mail of corresponding author: anukul@bucc4.buu.ac.th

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Abstract

Hydrodynamical conditions of the Bangpakong Estuary in wet and dry seasons are studied by employing field observation data and diagnostic two-dimensional numerical experiment. Vertical distributions of salinity illustrate that this estuary can be categorized as the salt wedge estuarine type in wet season, and the slightly stratified (partially mixed) estuarine type in dry season. Results from model experiments show that stronger current can be found in wet season, and well mixing occurs near the river mouth in both seasons. The computed currents only represent the effect from density driving force, while the measured current data indicate the importance of three-dimensional structure of the circulation in this estuary.

Key words : *Bangpakong Estuary, Gulf of Thailand, diagnostic model*

1. Introduction

There are four main rivers namely the Maeklong, the Thachin, the Chopraya, and the Bangpakong flowing into the Upper Gulf of Thailand from the western to the eastern part, respectively. These rivers not only influence on lower salinity from fresh water, but also are important sources of sediment resulting from land erosion and the contaminants from area along the rivers.

The Bangpakong River is considered as a significant source of nutrient loading because it carries a great amount of contaminant from urban, rural area, pig farms, rice farms, and fish and shrimp ponds. Thus, plankton bloom can be occurred frequently in the eastern part of the Upper Gulf of Thailand (NRCT-JSPS, 1998).

The whole Upper Gulf of Thailand is located in an area influenced from the continental monsoon system, the northeast and the southwest monsoons. The dry northeast monsoon brings cool dry air from Siberia during November and March while the wet southwest monsoon brings warm moist air from Indian Ocean during May and October (Sojisuporn, 1998). These two monsoon conditions can affect directly to river runoff concerning to nutrients and suspended sediment loading. So the study of oceanographic variation between wet and dry seasons cannot be overlooked.

There was a cooperative research project between Thai and Japanese scientists namely National Research Council of Thailand and the Japan Society for the Promotion of Science (NRCT-JSPS) project to study the physical, chemical and biological characteristic of the Bangpakong Estuary during 1994 and 1997. That is the first step to investigate the causing of eutrophic condition and phytoplankton bloom in the Bangpakong Estuary. The results showed both temporal and spatial variations of oceanographic conditions of the Bangpakong Estuary, but the mechanism of them was not clearly understood.

The objective of this study is to investigate the hydrodynamical conditions of the Bangpakong Estuary between wet and dry seasons with the use of field observation data and diagnostic numerical model for more understanding of oceanographic conditions of this estuary.

2. Observation

Data from field observations of water temperature and salinity of the Bangpakong Estuary carried out by Harbor Department (Thailand) on 11-12 September 1995 and 19 April 1996 that were specified as wet and

*1 Department of Aquatic Science, Faculty of Science, Burapha University
*2 Research Institute for Applied Mechanics, Kyushu University

dry season periods respectively, are used in this study.

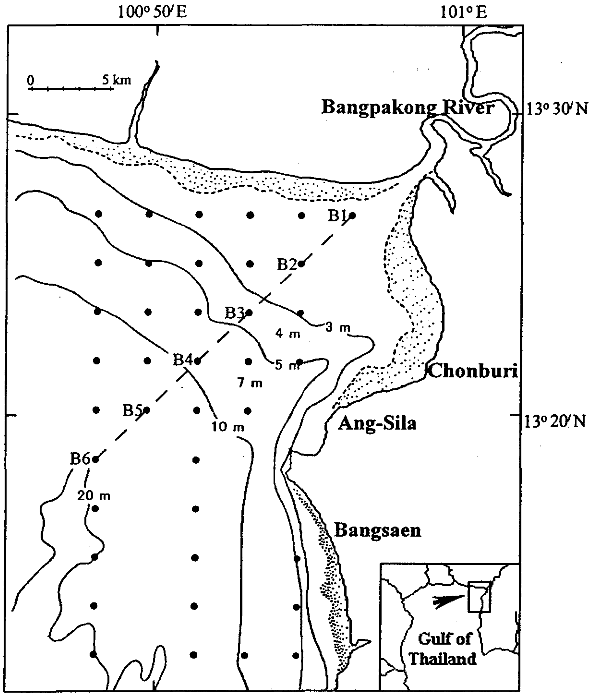


Fig.1 Observation stations in the Bangpakong Estuary. Broken line shows the stations for vertical section.

The studied area and observation stations are shown in Fig.1. Near surface (0.5-1 m) data at every station are employed to investigate the horizontal distributions, while 3 to 4 points of vertical measured data at each station along broken line (B-line) in Fig.1 are used to study the vertical distributions. Value of density in the form of sigma-t calculated by using observed temperature and salinity is presented as well. Both horizontal and vertical results used for distribution plotting are interpolated with the use of Gauss function from observed data to every grid point over studied area. The interpolation equations are shown as follow:

$$\zeta = \frac{\sum_{i=1}^{n} (y_i \cdot \zeta_{oi})}{\sum_{i=1}^{n} y_i}, \qquad (1)$$

$$y_i = e^{-d_i^2/r^2} \qquad (2)$$

Where ζ is calculated parameter such as temperature, salinity at any grid point. ζ_{oi} is observed data, n is the number of observed data, d_i is distance between the observed point and the calculated grid, and r is the influence distance (2 km and 2 m for horizontal and vertical, respectively) of the observed data.

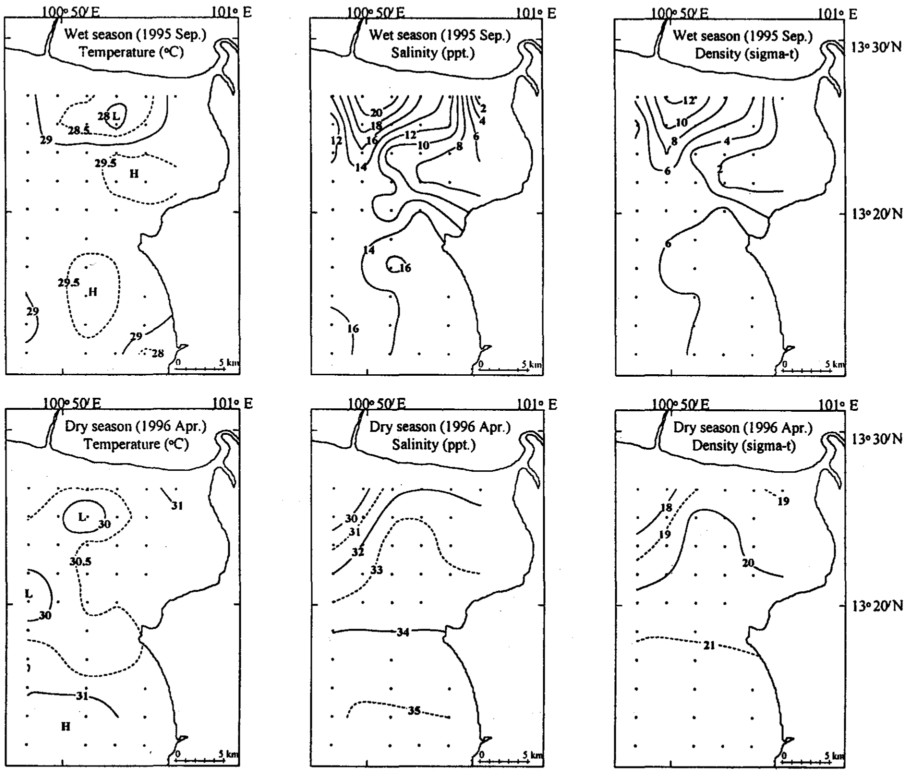


Fig.2 Horizontal distributions of water temperature, salinity and density (sigma-t) in wet (upper) and dry (lower) seasons. Dots show the observation stations.

Horizontal distributions of water temperature, salinity, and density are shown in Fig.2. Water temperature is around 28 °C to 29 °C in wet season and around 30 °C to 31 °C in dry season. Because dry season is during summertime, solar radiation is higher than that in wet season, therefore water temperature is also higher in dry season.

Interaction between fresh water from the Bangpakong River and seawater can be clearly seen from salinity and density distributions. In wet season, because of high river runoff, salinity and density in the entire area are much lower than those in dry season, but larger gradient appears.

The variation of oceanic condition in wet and dry seasons can be seen in the vertical distributions of temperature, salinity and density along the B-line shown in Fig.3 as well. The distribution in wet season illustrates that there is very low salinity water having no vertical density gradient in the area just from the river mouth boundary to station B2, while in most of the entire area, salinity and density tend to be stratified.

This is occurred from the high fresh water runoff from the Bangpakong River in wet season, which tells us that a huge of fresh water meets the seawater at nearly the river mouth and then floats on the seawater when it flows further to the sea. This characteristic doesn't appear in dry season, which has very small river runoff. The vertical salinity distribution in dry season shows no vertical salinity gradient near the river mouth as well, but a gradual salinity increase from the surface to bottom occurs.

3. Numerical experiments

In order to find out the vertical circulation of the Bangpakong Estuary in wet and dry seasons, the diagnostic numerical technique developed by Yanagi *et al.* (1996) is adopted. On the basis of the vertically two-dimensional flow assuming that there is no gradient of momentum and density in the normal direction to the B-line, the governing momentum and continuity

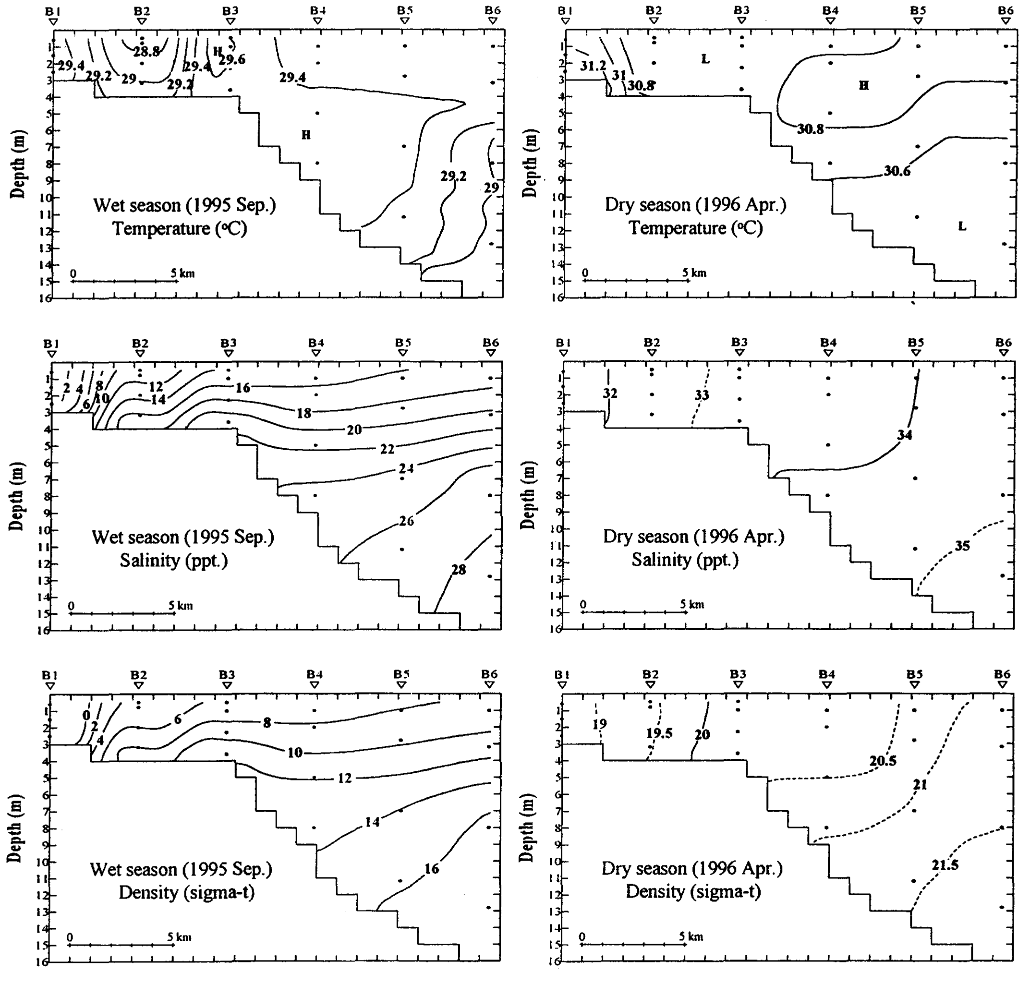


Fig.3 Vertical distributions of water temperature, salinity and density (sigma-t) along the B-line in wet (left) and dry (right) seasons. Dots show the observation points.

equations are as follows:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z} = -\frac{1}{\rho_0}\frac{\partial p}{\partial x}+A_h\frac{\partial^2 u}{\partial x^2}+A_v\frac{\partial^2 u}{\partial z^2}, \quad (3)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial z} = -\frac{1}{\rho_0}\frac{\partial p}{\partial z}-\frac{\rho g}{\rho_0}+A_h\frac{\partial^2 w}{\partial x^2}+A_v\frac{\partial^2 w}{\partial z^2}, \quad (4)$$

$$p = -\rho g z , \quad (5)$$

$$\frac{\partial u}{\partial x}+\frac{\partial w}{\partial z} = 0 , \quad (6)$$

$$\frac{\partial \rho}{\partial t}+u\frac{\partial \rho}{\partial x}+w\frac{\partial \rho}{\partial z} = K_h\frac{\partial^2 \rho}{\partial x^2}+K_v\frac{\partial^2 \rho}{\partial z^2}+\gamma(\rho^{*}-\rho). \quad (7)$$

Here x directs to B-line and z is positive upward with its origin at the sea surface. u and w are the velocity in x and z directions, respectively. f is Coriolis parameter ($2\Omega\sin\varphi$) where Ω is angular velocity of the Earth rotation and φ is latitude. g is the gravitational acceleration (980 cm s^{-2}), p is the pressure, ρ is the density of water, ρ_0 is the vertically average density of water, A_h is the horizontal eddy viscosity (10^5 cm^2s^{-1}), A_v is the vertical eddy viscosity (1 cm^2s^{-1}), K_h is the horizontal eddy diffusivity (10^5 cm^2s^{-1}), K_v is the vertical eddy diffusivity (1 cm^2s^{-1}), ρ^{*} is the observed density, and γ is the nudging constant (1/60 s^{-1}).

The observed density and no-motion of flow are specified for the initial condition. The radiation condition ($\partial/\partial x = 0$) is used at the offshore boundary, while river discharge (1,153 m^3 s^{-1} and 10 m^3 s^{-1} for wet and dry seasons, respectively) investigated by Boonphakdee *et al.*(1999) are conditions at the river mouth boundary. The wind stress in equation (8) given at the surface and the bottom stress in equation (9) given at the sea floor are employed for the surface and bottom boundary conditions, respectively. They are as follow:

$$\rho A_v\frac{\partial U}{\partial z} = \rho_a C_d\,|W|W \quad \text{at} \quad z=0 , \quad (8)$$

$$A_v\frac{\partial U}{\partial z} = r_b^2\,|U|U \quad \text{at} \quad z=-H , \quad (9)$$

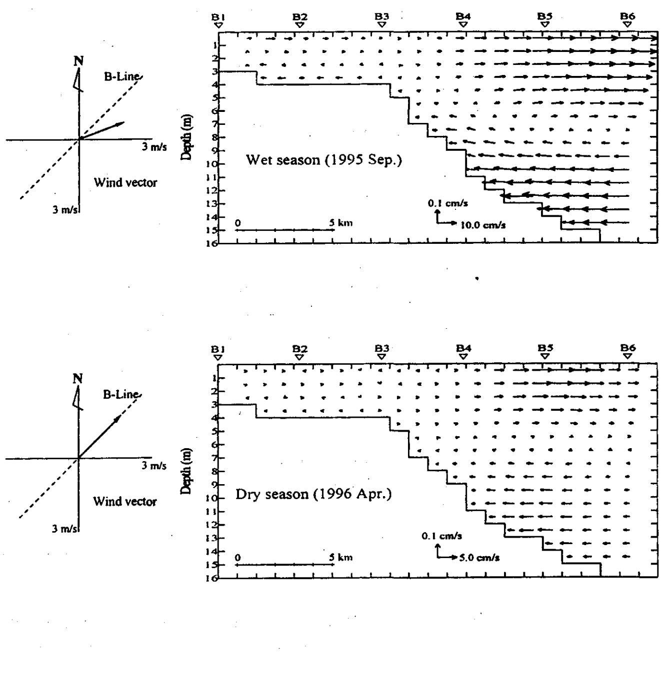
where U is the current vector, ρ_a is the air density (1.2×10^{-3} g cm^{-3}), C_d is drag coefficient at the sea surface (1.3×10^{3}), W is the wind vector from European Center of Medium Range Weather Forecast (ECMWF) shown in the study of Buranapratheprat and Bunpapong (1998), r_b^2 is the bottom drag coefficient (2.6×10^{-3}).

The numerical method used to solve all equations is from Yanagi and Isobe (1987). The horizontal and vertical mesh sizes are 1 km and 1 m, respectively. Time step is 100 s and running time is 5 days. The diagnostically calculated current along the B section in wet and dry seasons are shown in Fig.4.

The surface current flows from the river into the estuary while the near bottom current flows to the river mouth. Upwelling takes place along the slope between river mouth and offshore in both seasons, because the denser near bottom water intrudes into the estuary, and then upwells when it meets the sharp slope topography near station B4. However, well mixing occurs from the river mouth boundary to the area near station B4. A clockwise vertical circulation (seaward in the upper and landward in the lower layers) appears near station B5 in wet season. The maximum magnitude of current in wet season is 15 cm s^{-1}, while in dry season is 5 cm s^{-1}. The effect from wind is very small because its magnitude is very small; 2.5 m s^{-1} and 3 m s^{-1} in wet and dry season, respectively, and wind direction is opposite to surface current.

4. Discussion

The vertical distributions of salinity in Fig.3 show that the Bangpakong Estuary is categorized as the salt wedge estuarine type in wet season, and the slightly stratified (partially mixed) estuarine type in dry season from the classical definition of estuarine types by Pritchard (1955).



Averaged current data near the river mouth at station B2 measured by Harbor Department (Thailand) is employed for verification of computed current. Measured currents indicate the influence of river discharge generating seaward flows in all depth of water column in both seasons, and current magnitudes in wet season are 7 cm s^{-1}, 10 cm s^{-1} and 3 cm s^{-1}, and those in dry season are 0.5 cm s^{-1}, 2 cm s^{-1} and 3 cm s^{-1} at depth 0.5 m, 1.5 m and 3 m, respectively. Anyway computed currents near station B2 have the range of magnitudes from 1 to 3.5 cm s^{-1} in wet season, and those from 0.03 cm s^{-1} to 0.1 cm s^{-1} in dry season. Disagreement of computed results can be observed from weaker current magnitude and the current directions that don't point to seaward in entire water column (Fig.4).

The computed currents only represent for the effect from density driving force, while the observation tells that river discharge affects mostly to the circulation in this estuary. The discrepancy of result between model and observation is from the reason that this vertically 2-D diagnostic model cannot simulate the strongly horizontal circulation throughout the water column, which has 3-dimensional structure.

Diagnostically calculated current along B section in Fig.4 can be interpreted that besides nutrient loading from land by river runoff, eutrophic condition in the Bangpakong Estuary may be from upwelling that occurs in this area in both seasons as well. The study of the NRCT-JSPS (1998) has found the trend of increasing nutrient in the Bangpakong Estuary in wet season. The opportunity that nutrients are enriched into the water column in wet season comes from two reasons. First is the high river runoff and another is from the stronger upwelling. Anyway, high concentration of nutrient can be occurred in dry season as well, but not frequently. This is one of many questions that have to be solved in the future studies.

The concentrated studies have to be continued to understand the mechanism of eutrophic condition and occurrence of phytoplankton bloom in this complicated estuary. Because, besides of nutrient loading, the other physical and biological factors such as the circulation, light intensity, temperature, salinity and behavior of phytoplankton are significant factors interacting complicatedly to the phytoplankton bloom. So the future studies will have to include these relating factors in consideration.

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