Ⅱ－28　A Three-dimensional Numerical Model of Flow and Salt Transport in the Hau River Estuary, Vietnam

Tohoku University　Graduate student　○ Nguyen Trung VIET
Tohoku University　Fellow Member　Hitoshi TANAKA

1. Introduction

The Mekong River starts at an elevation of about 5,000m in the Tanghla Shua (Mountain range) on the Tibetan Plateau. From its source, the river makes its way through six countries as China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam. Before flowing out the South China Sea, the Mekong River is divided into two main rivers: Tien River and Hau River.

During the dry season saline water from the South China Sea and the Gulf of Thailand move upstream along the rivers and canals of the Mekong Delta. The salinity intrusion into the Mekong Delta is very complicated. The highest salinity is usually observed in April. Currently, 1.77 million ha of delta lands are affected by saltwater intrusion, which not only affects irrigation development but also domestic water supply. Salinity worsens water quality and damages crop-lands. The most severe situations occur during the low flow reason when there is not enough flow to prevent seawater intrusion.

In the present study, a three-dimensional hydrodynamic model is used to simulate the process of flow and salt transport in the Hau River estuary, Vietnam.

2. Study area

The Hau River estuary (Latitude: $9^0$20'-$10^0$45'N, Longitude: 105°00'-$106^0$42'E) is a part of Mekong River Delta in Vietnam (see Fig.1). The total catchments area of the study site is about 490 km^2. Located in the monsoon tropical semi-equatorial climate zone, the climatic regime in the Hau River is dominated by the two monsoon seasons: the north-east (dry season, from December to April) and the south-west (rainy season, from May to November).

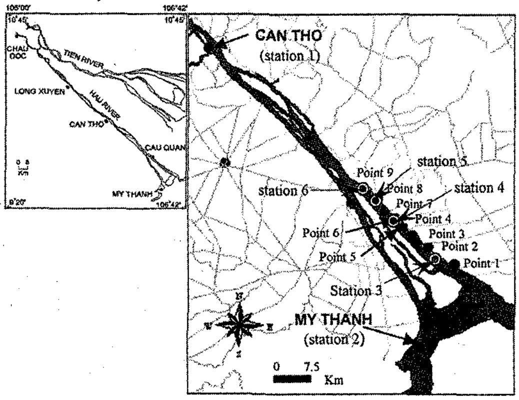

Fig. 1 Study area of the Hau River estuary, Vietnam

3. Governing equations

The hydrodynamic model used in the study is a three-dimensional (3D), finite difference, free surface numerical model utilizing the Boussinesq and the hydrostatistic approximations and mode split time step developed by Blumberg and Mellor, 1987. The mode split technique allows the 2D calculation of the free surface elevation and the velocity transport in barotropic approximation separately from the 3D calculation of velocity and thermodynamics (baroclinic mode) (Blumberg, 1977).

If (x*, y*, z, t*) are Cartesian coordinates, a transformation to the sigma system (x, y, σ, t) respectively, and governing equations are shown as follows (for more detailed information, see Blumberg and Mellor, 1987).

$$x^* = x,\ y^* = y,\ z = \frac{Z-\eta}{D},\ t^* = t \tag{1}$$

where D = H+η, is the ocean depth relative to the grid and η is the sea surface elevation.

Continuity equation

$$\frac{\partial DU}{\partial x} + \frac{\partial DV}{\partial y} + \frac{\partial \omega}{\partial \sigma} + \frac{\partial \eta}{\partial t} = 0 \tag{2}$$

Momentum Reynolds equations are

$$\frac{\partial UD}{\partial t} + \frac{\partial U^2 D}{\partial x} + \frac{\partial UVD}{\partial y} + \frac{\partial U\omega}{\partial \sigma} - fVD + gD\frac{\partial \eta}{\partial x} = \frac{\partial}{\partial \sigma}\left[\frac{K_M}{D}\frac{\partial U}{\partial \sigma}\right] - \frac{gD^2}{\rho_0}\frac{\partial}{\partial x}\int_\sigma^0 \rho d\sigma + \frac{gD}{\rho_0}\frac{\partial D}{\partial x}\int_\sigma^0 \sigma\frac{\partial \rho}{\partial \sigma}d\sigma + DF_x \tag{3}$$

$$\frac{\partial VD}{\partial t} + \frac{\partial UVD}{\partial x} + \frac{\partial V^2 D}{\partial y} + \frac{\partial V\omega}{\partial \sigma} + fUD + gD\frac{\partial \eta}{\partial y} = \frac{\partial}{\partial \sigma}\left[\frac{K_M}{D}\frac{\partial V}{\partial \sigma}\right] - \frac{gD^2}{\rho_0}\frac{\partial}{\partial y}\int_\sigma^0 \rho d\sigma + \frac{gD}{\rho_0}\frac{\partial D}{\partial y}\int_\sigma^0 \sigma\frac{\partial \rho}{\partial \sigma}d\sigma + DF_y \tag{4}$$

where ρ_o – the reference density, ρ - the in-situ density, g – the gravitational acceleration, P – the pressure, K_M – the vertical eddy diffusivity of turbulent momentum mixing. The Coriolis parameter (f) is introduced by using the β plane approximation.

The conservation equations for temperature and salinity

$$\frac{\partial TD}{\partial t} + \frac{\partial TUD}{\partial x} + \frac{\partial TVD}{\partial y} + \frac{\partial T\omega}{\partial \sigma} = \frac{\partial}{\partial \sigma}\left[\frac{K_H}{D}\frac{\partial T}{\partial \sigma}\right] + DF_T \tag{5}$$

$$\frac{\partial SD}{\partial t} + \frac{\partial SUD}{\partial x} + \frac{\partial SVD}{\partial y} + \frac{\partial S\omega}{\partial \sigma} = \frac{\partial}{\partial \sigma}\left[\frac{K_H}{D}\frac{\partial S}{\partial \sigma}\right] + DF_S \tag{6}$$

The model incorporates the turbulence closure developed by Mellor and Yamada, 1982 with level $2\frac{1}{2}$ model to provide for a realistic parameterization of vertical mixing

$$\frac{\partial q^2 D}{\partial t} + \frac{\partial Uq^2 D}{\partial x} + \frac{\partial Vq^2 D}{\partial y} + \frac{\partial \omega q^2}{\partial \sigma} = \frac{\partial}{\partial \sigma}\left[\frac{K_q}{D}\frac{\partial q^2}{\partial \sigma}\right] + \frac{2K_M}{D}\left[\left(\frac{\partial U}{\partial \sigma}\right)^2 + \left(\frac{\partial V}{\partial \sigma}\right)^2\right] + \frac{2g}{\rho_0}K_H\frac{\partial \rho}{\partial \sigma} - \frac{2Dq^3}{B_1 l} + DF_q \tag{7}$$

$$\frac{\partial q^2 lD}{\partial t} + \frac{\partial Uq^2 lD}{\partial x} + \frac{\partial Vq^2 lD}{\partial y} + \frac{\partial \omega q^2 l}{\partial \sigma} = \frac{\partial}{\partial \sigma}\left[\frac{K_q}{D}\frac{\partial q^2 l}{\partial \sigma}\right] + E_1 l\left(\frac{K_M}{D}\left[\left(\frac{\partial U}{\partial \sigma}\right)^2 + \left(\frac{\partial V}{\partial \sigma}\right)^2\right] + E_3\frac{q}{\rho_0}K_H\frac{\partial \rho}{\partial \sigma}\right) - \frac{Dq^3}{B_1}\tilde{W} + DF_l \tag{8}$$

In the model, the horizontal grid uses an orthogonal curvilinear system, while the vertical grid uses 10 sigma layers, in which σ varies from $\sigma=0$ at $z=\eta$ (at the water surface) to $\sigma=-1$ at $z=-H$ (at the river bottom).

4. Results and discussions

4.1 Time variation of salinity

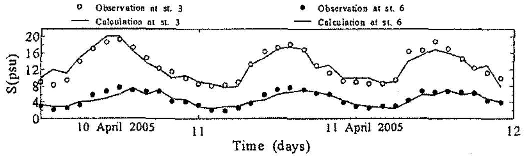

Fig. 2 Time variation of salinity at the station 3 and 6

Comparison of simulated salinity with measured data near the surface water level at the station 3 and station 6 within two days 10-11th April 2005 is shown in Fig. 2. It can be seen that there is a good agreement between observed and calculated result. In addition, the distinct different salinity concentration between station 3 and station 6 is shown.

4.2 Vertical profiles of salinity and temperature

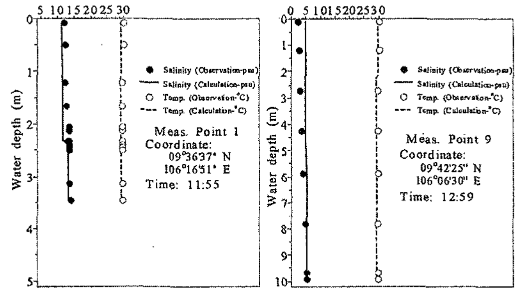

Fig. 3 Vertical profiles of salinity and temperature at point 1and 9

Figure 3 delineates the vertical profiles of salinity and temperature on 10th April 2005 at the measuring point 1 and 9, respectively. These figures illustrate the ability of the model to reproduce the entire vertical profile of the measured salinity and water temperature.

4.3 Longitudinal profile of salinity

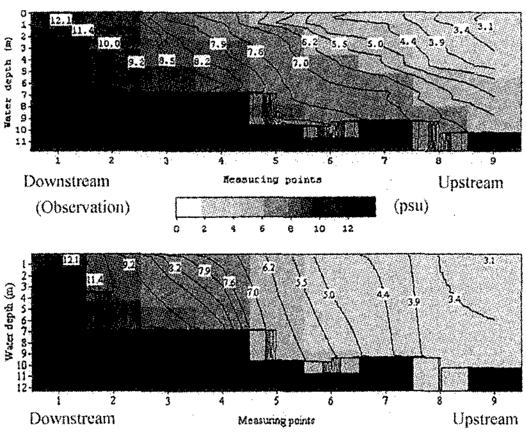

Fig. 4 Distribution of measured and computed salinity over depth

Figure 4 compares observed and calculated contours of the streamwise vertical salinity along the river. This figure clearly shows how the salinity concentration distributes along the Hau River from downstream to upstream. It is appeared that the salinity regime is well-mixed. Otherwise, the agreement between the model and measurement data is very good.

4.4 Water surface level

Figure 5 displays the water level at the station 6 on 10-11 April 2005. Prediction of water level is very necessary for water utilization management.

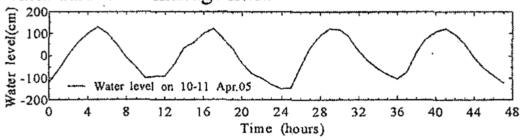

Fig. 5 Water level on 2 days: 10, 11 April 2005

4.5 Velocity at the transect

The cross-section's velocity contour of the station 3 at 0:00, 11th April 2005 is indicated in Fig. 6. It is shown that the velocity distribution is quite uniform over the whole transect. This is probably one of the reasons that the distribution of salinity concentration over cross-section is quite uniform.

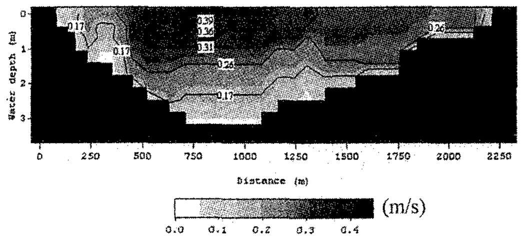

Fig. 6 Velocity contour at the transect of station 3

5. Summary

A 3D hydrodynamic model of the Hau River estuary, Vietnam has been used for tackling the problem of prediction of flow structures and salt transport. The study illustrates that reasonable success of estimation of salt transport improve the ability of the model to predict salinity regime.

Acknowledgements

Partial support of the RR2002 project from the Ministry of Education, Science and Culture, Japan is gratefully acknowledged.

References

Blumberg, A.F.: Numerical Tidal Model of Chesapeake Bay. Journal of Hydraulic Division, 103, pp1-10, 1977.

Blumberg, A.F. and Mellor, G.L.: A Description of a Three-Dimensional Coastal Ocean Circulation Model. Three Dimensional Coastal Ocean Models, by Norman S. Heaps (editor), American Geophysical Union, Washington, DC, pp1-16, 1987.

Mellor, G.L. and Yamada, T.: Development of a Turbulence Closure Model for Geophysical Fluid Problems. Reviews of Geophysics and Space Physics, Vol. 20, No. 4, pp 851-875, 1982.