FLOW CHARACTERISTIC IN OPPA BAY, JAPAN

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1. INTRODUCTION

Oppa Bay is a dynamic area to which discharge of the Kitakami River flows out. Connected to the bay is Nagatsura-ura lagoon, a semi-enclosed water body that is actively used for aquaculture of oyster. However, in summer of recent years, a huge amount of oyster was death caused by anoxic condition in bottom layer of the lagoon. Flow characteristic in the lagoon is greatly influenced by dynamics of the bay. Moreover, there is close relationship between the flow characteristic and its related water quality in the lagoon. Hence, understanding the dynamics in Oppa Bay is important for water quality improvement strategy in Nagatsura-ura lagoon.

2. STUDY AREA AND FIELD OBSERVATION

Oppa Bay is located in the Sanriku Coast faced to the Pacific Ocean in the northeast of Japan's main inland. It has a fan shape opened at 60 degrees of 7 km radius, with an almost constant bed slope of 1/120 along the bay axis. The Kitakami River flows into the bay at the eastern part. It acts as floodway for flood prevention of the Kitakami River Basin. In the southern part, Nagatsura-ura lagoon is located. It has an area of 1.41 km^2, a perimeter of 8 km, and connected to the sea by a narrow tidal inlet with a length of 1.7 km and a maximum depth of 2 m. The outline of geographical features is shown in Fig. 1.

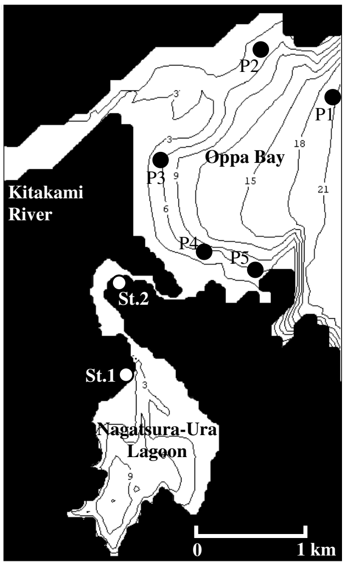
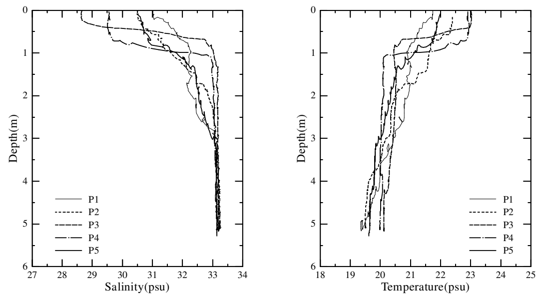


Fig.1 Lay out of the study area

In summer 2007, August 11th – October 12th, devices to measure Salinity and temperature was installed at P1 (see. Fig.1). Using five identical devices arranged vertically with 1 m interval at depths of 1-5 m below sea surface, time variation of vertical profile of temperature and salinity was measured. The same device has also been installed in the narrow tidal channel of St.2 since February 15th, 2006. To measure temperature and salinity spatial distribution in the bay, five point measurements, P1, P2, …, P5, were carried out at time of 14:00-15:00, August 11th, 2006 using AAQ 1183, a product made by ALEC Electronics Co., Ltd. In addition, automatic measurement devices have been installed in St.1 and St.2 to measure water level since the year of 2002.

3. RESULTS AND DISCUSSIONS

(1) Observation Result



(a) (b)

Fig.2 (a) Salinity and (b) temperature at points P1-P5

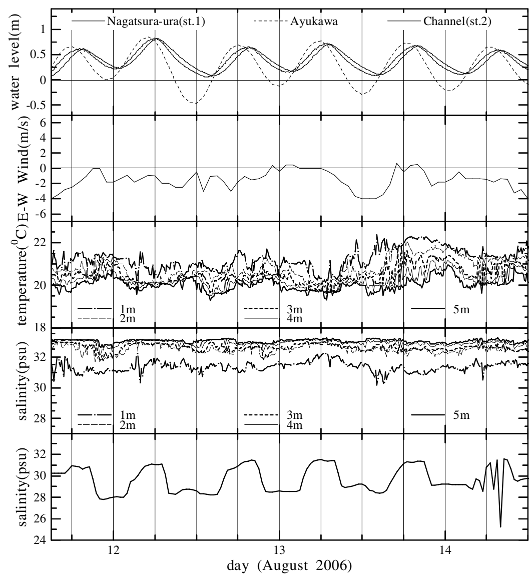


Fig.3 Time variation of water level, E-W wind, temperature and salinity at P1, and salinity at St.2

Fig.3 shows measured vertical profile of (a)salinity and (b)temperature at points P1-P5 on August 11th, 2006. Both measured profiles show that there was 1 m thin surface mixed layer that was also observed by Ishikawa et al. (2002). Salinity and temperature advected from Nagatsura-ura lagoon during ebb tide results in their respectively lower and higher values at points P3 and P4. Fig. 3 shows, from top to bottom of the figure respectively, water level at St.1, St.2, and Ayukawa Port, East-West wind, temperature at P1, salinity at P1, and salinity at St.2 during period of numerical simulation that will be explained later. Salinity in the channel gets higher during flood tide and oppositely during ebb tide indicating salinity difference between the lagoon and the open sea. The Kitakami River constant low water discharge of 3 m^3/s occurs in the period of simulation.

(2) Numerical Modeling and Calculation Condition

The hydrodynamic model adopted here is the one based on the hydrostatic pressure approximation and the boussinesq approximation, and fixed layer divisions in vertical discretization. This model basically follows the procedure introduced by Sato et al. (1993) with addition of baroclinic term to take into account the effect of density gradient. The turbulence closure modeling uses QETE (quasi-equilibrium turbulent energy) model of Galperin et al. (1988).

Calculation was done over 61 x-grids and 101 y-grids in which both directions have uniform mesh size of $\Delta x = \Delta y =$ 50 m. In vertical, the domain was divided into 40 layers. The first and the second layers were set to 0.675 m and 0.15 m of thickness, whereas layer thicknesses of 0.25 m, 1.0 m, and 2.0 m, were specified in layer ranges of 3-31st, 32-34th, and 35-40th respectively. The open sea boundary conditions were water level at Ayukawa Port, and the salinity and temperature at point P1. In the Kitakami River, based on low discharge observation of Kudo et al. (2002), salinity is set to 20 psu within 1 m of depth and 28 psu below it. Initial conditions for temperature and salinity in the bay area are specified from the observed profiles at P1-P5. In the lagoon, initials condition of salinity and temperature are obtained from St.2. Model was spin up for 24 hours, which correspond to 2 tidal cycles, to obtain field current before initial condition was specified. Bottom roughness coefficient of 0.001 was specified in the bay and the lagoon, while in the channel it was 0.04. Setting vertical grid size to vary within 0.1-2.0 m, they both correspond to manning coefficient of 0.019-0.031 and 0.036-0.15 respectively.

(3) Calculation result

Upper part of Fig. 4 shows measured and calculated water level in the tidal channel, along with water level at Ayukawa port. Good agreement between calculated and measured water level is achieved and it shows the water level characteristic, which cannot be lowered due to the existence of shallow tidal channel. Moreover, in the lower part, calculated salinity follows closely the observed value.

Fig.5 shows calculated current vector and salinity contour in surface layer at time (i) of Fig.4. Confirming Fig.2(a), which is plotted 24 hours before at similar tide condition, western region located between lagoon`s entrance and the Kitakami River is still affected by the salinity discharged from the lagoon during ebb tide.

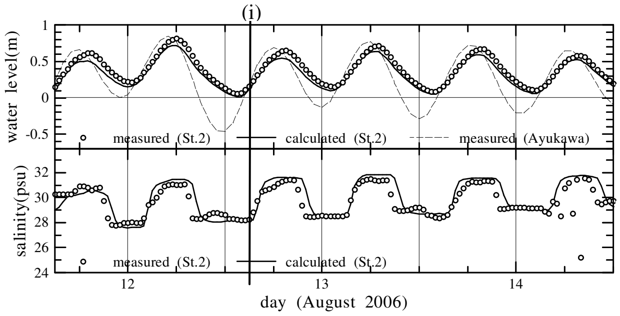


Fig.4 Measured and calculated water level and salinity

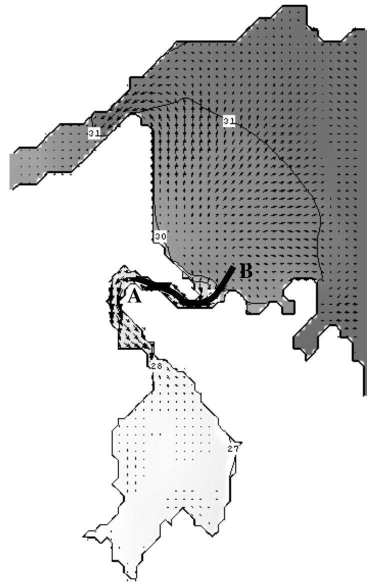


Fig.5 Calculated current vector and salinity contour in surface layer

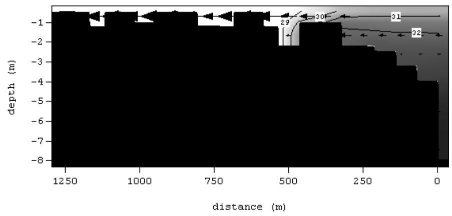


Fig.6 Calculated current vector and salinity contour at lagoon's entrance

Fig.6 plots calculated current vector and salinity contour at the lagoon's entrance along line A-B in Fig. 5. It shows that inflowing salinity experience strong mixture as it enters the narrow tidal channel. Furthermore, the turbulence model can reproduce 1 m thin surface mix layer at the ocean side.

4. SUMMARY

Some flow characteristics in Oppa Bay have been examined by field observation and numerical calculation. Numerical calculation can reproduce well the field observation result, which are water level and salinity in the tidal channel. Surface mixed layer of 1 m thickness nearby the Nagatsura-ura lagoon's entrance is also verified from the calculation.

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REFERENCES

1. Galperin, B., Kantha, L. H., Hassid, S., and Rosati, A. (1988), A quasi-equilibrium turbulent energy model for geophysical flows, J. Atmospheric Sci., 45, pp.55–62.
2. Ishikawa, T., Kudo, K., Hayasaka, H., Tanaka, S., and Takasaka, K., Behavior of Low Salinity Water in Oppa Bay, Japan, 5th Int. Conf. on Hydroscience and Engineering ICHE, Warsaw, Poland 2002
3. Kudo, K., Ishikawa, T., Hayasaka, H., Yamasaki, T., and Nomura, S., The Flow Rate for Conserving Estuarine Environment of New-Kitakami River, 5th Int. Conf. on Hydroscience and Engineering ICHE, Warsaw, Poland 2002
4. Sato,K. et al.: Efficient calculation method of 3-D tidal current, Proceedings of Coastal Eng. JSCE., Vol.40， pp.221-225. 1993. (in Japanese)