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Isahaya Bay, freshwater lake to an estuary again

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ABSTRACT

The inner 1/3 of Isahaya Bay which is a tributary of Ariake Sea in Japan was shut off from the sea by a dike for the reclamation and disaster prevention in 1997. On the other hand, several environmental and fisheries problems occurred in Ariake Sea after 1990s. Some fishermen insisted that the major reason for the decrease of fishing must be the influence of the dike construction and filed lawsuits. Now the court decision is fixed and Japanese government must open the gates to reintroduce sea water into the reservoir. We made numerical simulations of currents, hydrography and sediment transport to assess the influences of the gate opening. To choose the environmentally wise procedure of gate opening, it is needed to reduce the erosion and deposition of bottom sediments caused by the enhanced tidal current and to minimize the occurrence of hypoxia in the reservoir.

1. Introduction

Reclamations of estuary with double dikes system provide new land, fresh water supply and prevent disasters, however they generate great changes of ecosystem. Therefore, they often raise some social problems, e.g. Lake Grevelingen in the Netherlands (Bannink et al., 1984), Lake Shihwa (Hong et al., 1997) in Korea and Saemangeum in Korea (Hong et al., 2007). Isahaya Bay which is a tributary of Ariake Sea in western Japan is one of the typical cases.

Ariake Sea is a meso to macro-tidal estuary or ROFI (Region Of Freshwater Influence) located in Kyushu Island, western Japan. It has length of about 100 km, mean width of 18 km and mean depth of 20 m (Fig. 1). It has distinctive features in the semi-enclosed seas in Japan, e.g. the largest tidal amplitude in Japan up to 6 m, extensive mudflat which accounts for 40% of total tidal-flat areas in Japan and unique biota including 23 endemic species. Isahaya Bay is a tributary of the western Ariake Sea. A class A river Honmyo River flows into at the head of Isahaya Bay (Class A rivers are designated by the Minister of Land, Infrastructure, Transport and Tourism based on the important for the national economy and people's lives). The inner 1/3 of Isahaya Bay was shut off from the sea by a dike for the reclamation and disaster prevention in 1997. The mudflat and estuary in this area disappeared and reclaimed lands with an area of 8.2 km^2 and a fresh water reservoir with an area of 26 km^2 and mean depth of 1.1 m were constructed. The reservoir is connected to the sea by the north and south gates (Fig. 1). The gates are underflow type and the widths of the north and south gates are 200 m and 50 m respectively. The farming started in the reclaimed land in 2008 where the reservoir water is utilized for agriculture. On the other hand, several environmental and fisheries problems occurred after the end of 1990s in Ariake Sea, e.g. increase in red tide, occurrence of hypoxia, and decrease in bivalve catch. Some fishermen living in the coast of Ariake Sea insisted that the major reason for the decrease of fishing must be the influence of the Isahaya dike construction and filed lawsuits against the Japanese government to take off the dike or open the gates to reintroduce sea water into the reservoir and recover the tide. In December 2010, they won a lawsuit and the judgement was confirmed at the Fukuoka High Court. According to the court decision, Japanese government must open the gates until December 2013 and keep them open for 5 years thereafter to confirm the influence of the dike construction. But the gates are still closed and the government pays penalty to the plaintiffs now. It is because there is an intense opposition movement against the gate opening in the farmers and some fishermen who had been forced to change their fishing form under the influence of the dike construction. There are also problems from the scientific viewpoints. 1)The length of the dike is 7 km but the total width of the gates is 250 m. Therefore the gate opening will produce an environment that is different from now and before the construction of the dike. 2)How to distinguish the effect of gate opening and other natural variations? 3)The effect of gate opening is highly depending on the gate control procedure. How to decide it? Therefore, more information about the benefit and bad influence induced by the gate opening is needed. So we predicted the influence of the gate opening on the currents, hydrography and sediment transport in Ariake Sea with a 3-dimensional numerical model.

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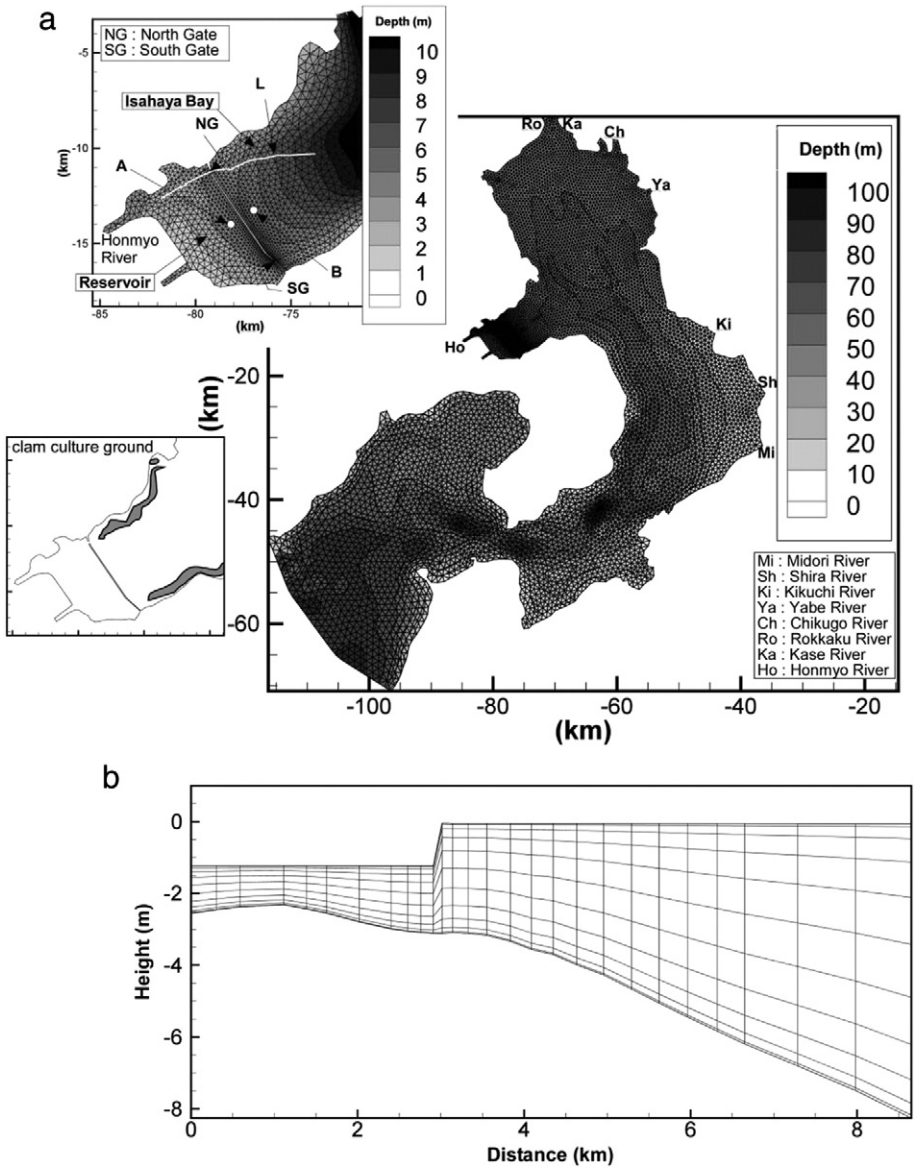

Fig. 1. Coordination of the model and bathymetry of Ariake Sea. Distribution of the clam culture ground in Isahaya Bay was also shown (a). Vertical coordination (σ layers) along the white line L in the map of Isahaya Bay (b).

2. Methods

We made numerical simulation of currents and hydrography of Ariake Sea with FVCOM (Finite Volume Coastal Ocean Model) (Chen et al., 2006). The model domain and grids are shown in Fig. 1a. The length of a side of a grid triangle at the Isahaya gates is 25 m. At the open boundary it is about 1200 m. The domain is separated vertically into 10 σ layers (Fig. 1b). The tidal elevation at the open boundary consisted of 6 major tidal constituents (M2, S2, N2, K1, O1, P1). For the vertical distribution of temperature and salinity at the open boundary, average data from 1967 to 2003 observed by Nagasaki Prefectural Institute of Fisheries at the station off Nomo-Saki was used. We constructed sediment transport model based on the FVCOM (Hamada et al., 2009). Erosion and deposition of the bottom sediments were calculated with the model.

In order to assess the influence of gate opening, we made numerical simulations with the climate and river discharge data of 2006 for 4 cases; 1) present state, 2) full-opening, 3) restricted-opening and 4) without dike. In the case of the restricted-opening, the reservoir water flows out in low tide and the sea water flows into the reservoir in high tide keeping the water level of the reservoir between −1.0 and −1.2 m. Calculation was conducted from 1 April to the end of December after the spin up time of 1 month. In the case of without dike, there is no reclamation and dikes constructed in 1990s. To represent the gate control in the model, upper bound of vertically averaged velocity V_{max} at the gate is set by the following formula:

$$V_{max} = G_N\sqrt{2g\Delta H}$$

where g is gravity acceleration, ΔH is the difference of water level in the reservoir and that in Isahaya Bay, $G_N = G / H$ is non-dimensional gate gap where G is the actual gate gap and H is the height of the water column at the gate. $G_N = 0$ and $G_N = 1$ means closed and full-opening condition, respectively. In the case of the full-opening, $G_N = 1$ continuously (Fig. 2). In the present and restricted-opening state, actual gate gap G is limited up to 0.9 m. This limitation is claimed by Kyushu Regional