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Perturbation of regional ocean tides due to coastal dikes

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ABSTRACT

The tidal regime modeling system for ocean tides in the seas bordering the Korean Peninsula is designed to cover an area that is broad in scope and size, yet provide a high degree of resolution in coastal development areas, including the Saemangeum area in the eastern Yellow Sea and the Ariake Sea in Japan, where serious environmental problems have occurred after the completion of interior tidal dikes. With this simulation system, we have estimated the changes in tidal regime due to barriers at Saemangeum and Isahaya Bay in the Ariake Sea. Some results in terms of perturbations in tidal elevations due to the construction of coastal dikes are presented and discussed.

1. Introduction

The necessity of predicting changes in tidal regime caused by large coastal engineering developments has led to increased numerical modeling of tides on the continental shelf since the 1970s (Flather, 1976; Choi, 1978; Greenberg, 1979). In view of practical concerns related to pollutants, oil spill dispersal, search-and-rescue operations at sea, and navigation demands for accurate tidal predictions with respect to both time and space are increasing. The aim of this study is to predict how the construction of tidal barriers in the interior region of the Ariake Sea (the Isahaya dike) in Japan and another long dike on the west coast of Korea (the Saemangeum dike) would disturb and/or alter the system's natural tidal state. Because of the possible environmental consequences, it is important that correct evaluations are made. The only practical way of obtaining effective solutions is to construct a mathematical model that simulates the behavior of the tidal system, which plays a central role in the shelf sea, involving a set of equations of motion for the sea that are solved numerically to yield the tidal variation. The proposed changes in boundary configuration due to barrier schemes can then be inserted in the model and the resultant effects on the system can be estimated. The degree of confidence of these approximations is a function of accuracy with which the model reproduces the real system. During the past years, this approach has been widely used for the studies of barrier schemes in the Bristol Channel (Heaps, 1972; Miles, 1979; Owen and Heaps, 1979), the Bay of Fundy (Garrett, 1972; Greenberg, 1979; Duff, 1979), the west coast of Korea (Choi, 1978, 1981, 2001), and Isahaya Bay in the Ariake Sea (Kim and Yamashita, 2002; Kyozuka, 2002; Nadaoka, 2002; Takikawa and Tabuchi, 2002). One of the most difficult and important tasks in this approach is that a sufficiently large region should be considered in the mathematical modeling, since good results may only be expected by locating the open boundaries sufficiently far from the barrier sites, beyond the barrier's influence. Some previous studies (Heaps and Greenberg, 1974; Garrett and Greenberg, 1977; Garrett and Toulany, 1979) indicate that unreasonable results may be obtained if too small a sea area is considered in the computations. However, the open boundaries of the models reported for estimating tidal changes in the Ariake Sea and the Saemangeum area have been chosen arbitrarily in the previous studies. In this paper, a recently developed system for accurate modeling of the tides in the regional seas of the Korean Peninsula is introduced. We briefly describe the

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possible applications of this system for the simulation of barrier effects perturbing the tidal regime due to the construction of tidal dikes in the eastern Yellow Sea and Isahaya Bay in the Ariake Sea.

2. Tidal model for the Yellow and East China Seas

2.1. Geographical setting

The Mangyong–Geum (Mangeum) estuary is a relatively shallow macrotidal embayment (the average tidal range is 5.7 m on springs and 2.8 m on neaps) located at latitude 35°N on the western coast of the Korean Peninsula in the eastern Yellow Sea as shown in Fig. 1. Its maximum depth is 10 m (below Indian Spring Low) at the mouth of the Geum estuary; it also has a broad intertidal zone exposed during low tide. Similar to other estuaries on the western coast of Korea, tidal currents have a profound influence on sediment dynamics in the area. The severe winter storms arising from north-westerly winds also create strong currents. Therefore, tide and wave conditions of sufficient intensity categorize this area as a high-energy environment. The Saemangeum tidal barrier was constructed in this sea area in 1991, connecting offshore islands from the Bieung and Osic Islands in the southern Geum estuary to Daehangri in the southern Mangyong estuary, forming a 40,100 ha reclamation area and freshwater reservoir. As of June, 2003, 30.3 km of dike was constructed among total of 33 km leaving openings of 1.1 km at Sinsi Island gate construction area and 1.6 km at near Garyuck Island. About 1.8 km of openings between Yami and Bieung Islands which is for convenience, classified as number 4 dike have been closed in 2003. The final closure operation was then completed after completion of the sluice gates, in April 2006. Locally significant bed changes due to sand movement have been reported previously for the area along the dike alignment between Osik and Yami Islands (Choi, 2001). The sandbank-like deposition occurred at the originally-planned closure site at the number 4 dike between Yami and Bieung Islands; researchers recorded rapid sand deposition of 6-7 m over a period of 9 years along the dike alignment (spanning about 2 km). Choi (2001) reported that this bottom evolution with sand deposition is somewhat faster than the hydrodynamic interpretation of Huthnance (1982). Thus, the region exhibits not only remarkable features with regard to turbid suspended sediment movement as manifested in the satellite images, but also long-term bed morphological changes due to bedload (sand) transport that may play an important role in sediment dynamics in the region. In the northern portion of the Saemangeum dikes, extensive port development has involved the construction of parallel dike and quay walls at the Geum estuary. Although the project was started with the optimistic view that sediment supply from the upstream river would significantly decrease by damming the upstream river, a considerable amount of siltation has been observed in the channel. This siltation is possibly due to redistribution of sediment within the estuary from the continuous suspended sediment supply from the outer estuary along the coast, especially during winter monsoon.

The Ariake Sea includes a long inner bay, 90 km in length, 17 km average width, 1700 km^2 in area, and 20 m average depth, with a

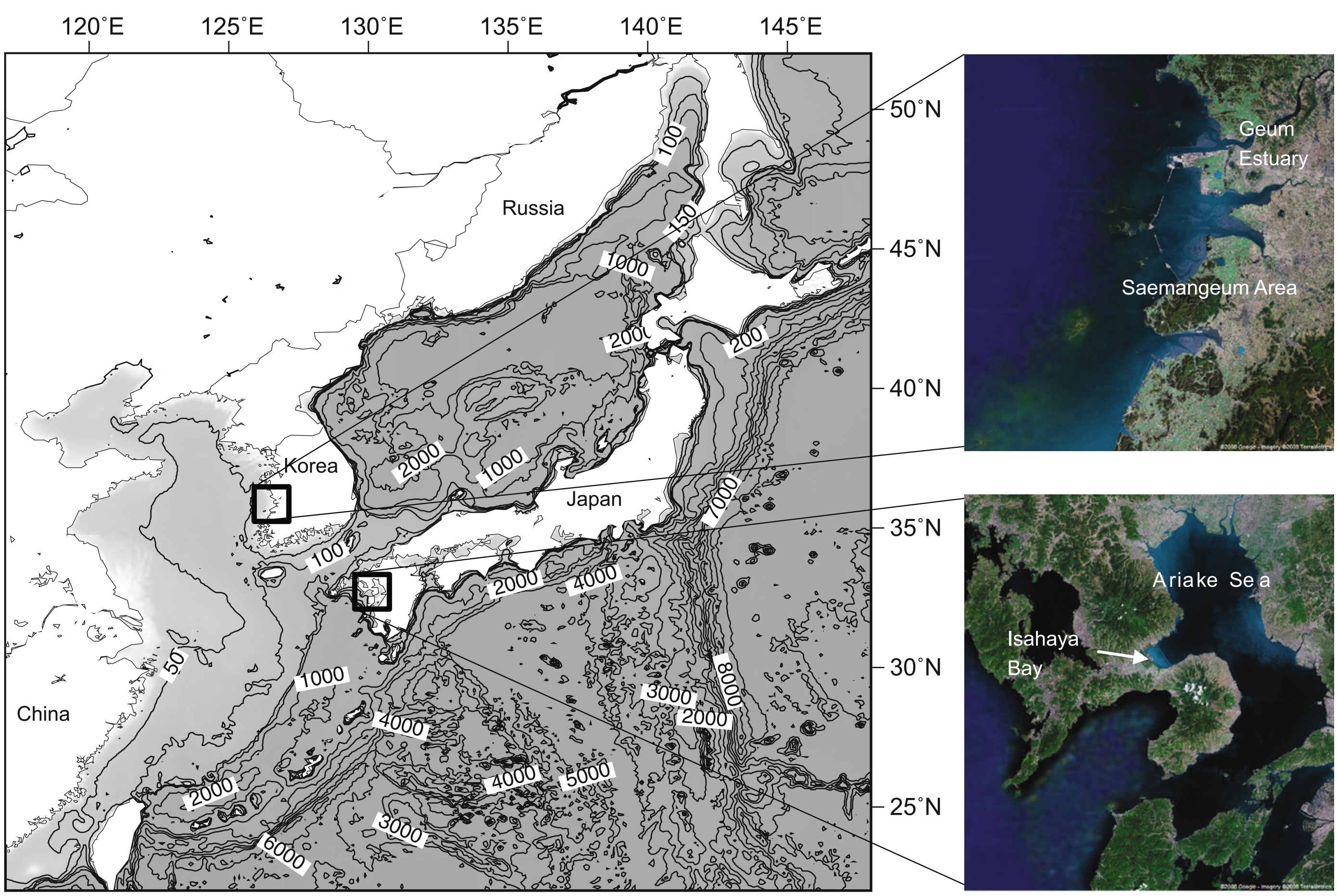

Fig. 1. Bathymetry and locations of the Saemangeum area and the Ariake Sea.