Numerical Study on the Influencing Factors of Salinity Distribution in the Natori Estuary

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1. Introduction

Effects of the Great East Japan Tsunami on fish populations and ecosystem recovery has been studied by Ito et al (2016), the distribution and abundance of bivalve can be affected by variations of salinity and depth of the water.

The Natori river mouth was severely eroded by the tsunami, and the water depth is now significantly deeper than before the tsunami (Tanaka et al. 2013). However, there are signs that many damaged areas of coastlines and river mouths are recovering and returning to their previously existing condition. Tanaka et al. (2014) proposed a methodology for understanding the morphological changes and recovery of river mouths due to tsunami propagation into rivers that uses water level measurements in rivers and the sea.

On the other hand, studies have been conducted to investigate the spatial and temporal variations of salt intrusion in the estuary. Previous research has yielded satisfactory methods based on remote sensing techniques, numerical models (MacCready and Geyer, 2001), and analytical solutions (Prandle, 2004). Numerical modeling has apparently become the prevailing method because of its convenience, and its results frequently provide high-resolution views of phenomena such as spatial and temporal variations.

The objective of this study is to investigate the salt transport mechanisms and the factors that have influence on salinity distribution in this area. Several observation datasets were collected, and a numerical modeling system was developed and used for this study. Once the validation showed good results in estimating salt intrusion, it is demonstrated that the modified model can be applied to an estuary system with complex geometry.

2. Study Area and Previous Result

The Natori River, located in central Miyagi prefecture, in the Tohoku region of northern Japan. It flows through the Sendai Plain and ends by draining into Sendai Bay.

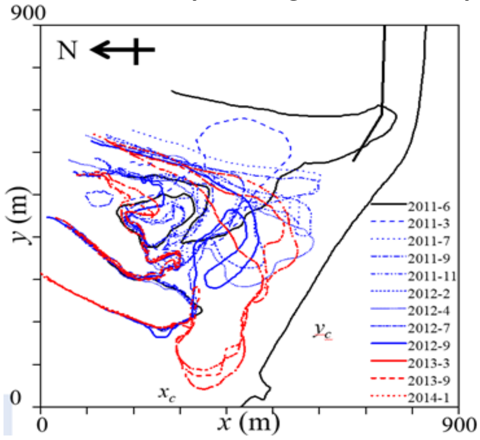

Figure 1. Shoreline position changes over time

The river's estuary is located on Japan's east coast, and faces the Pacific Ocean. Morphological change of the Natori estuary has been confirmed by tracking the shoreline (Figure.1)

In the first two years after the tsunami, the shoreline changes very frequently in estuary area, scouring and accumulation often occur. After two years of recovery, the shoreline gradually stabilized and obvious sediment deposition can be seen inside the river channel.

3. Methodology

3.1 Data Collection

The river discharge used in this study was derived from 2 stations (Hirose bridge, Natori bridge) located on two branches upstream of the Natori River respectively. The water level data used for the calibration is derived from two downstream stations (Hukurobara, Yuriagedaini); Data before and after the tsunami is obtained from the Japan Meteorological Agency website, which is recorded every hour. The tidal level is calculated by the Global Inverse tidal model and then compared with the measured data of Sendai Port before use to ensure the accuracy. Salinity data began to observe in 2003, Observation point around the Yuriage Bridge, The location and number of observation points vary depending on the year.

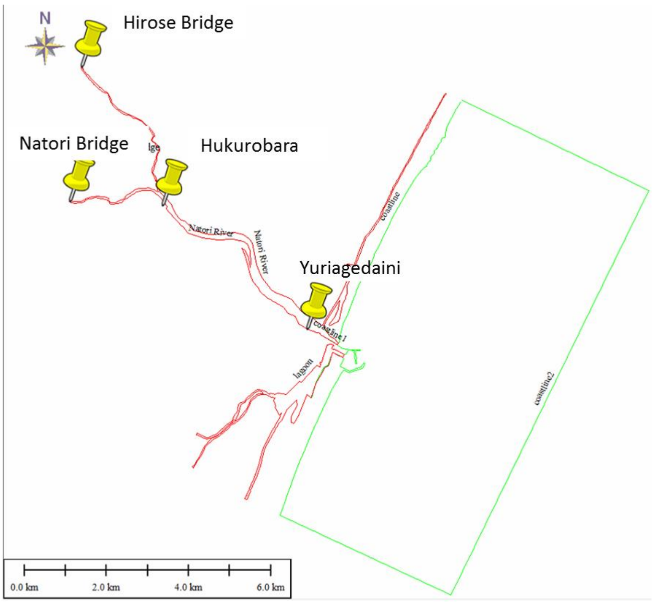

Figure 2. the Natori river and the location of stations

3.2 Numerical model setup

The EFDC model domain covers the Natori Estuary and upstream to the two branches. Curvilinear grids are used over the entire domain, a varying-size grid structure is used to better present estuary bathymetric. Use of 5 sigma layers was adopted in the vertical direction. At the two upstream boundaries, river discharges are specified with an inflowing

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salinity of zero, while the inflowing salinities at the coastal open boundaries are specified by 35 ppt.

4. Model Calibration

The hydrodynamic model is calibrated by comparing the modeled water elevations to measurements conducted during March and April 2009. The comparisons in the Yuriagedaini station are shown in Figure. 3. The model skill is evaluated by two index: RMS and Nash-Sutcliffe Efficiency Coefficient. In Yuriagedaini station RMS and Nash-Sutcliffe is 0.191 and 0.688 respectively. As the current comparison results are not ideal, by adjusting the parameters such as Roughness height, improve the model so that Nash-Sutcliffe Efficiency Coefficient higher than 0.85. Then On the basis of an accurate hydrodynamic model, the calibration of the salinity model is carried out.

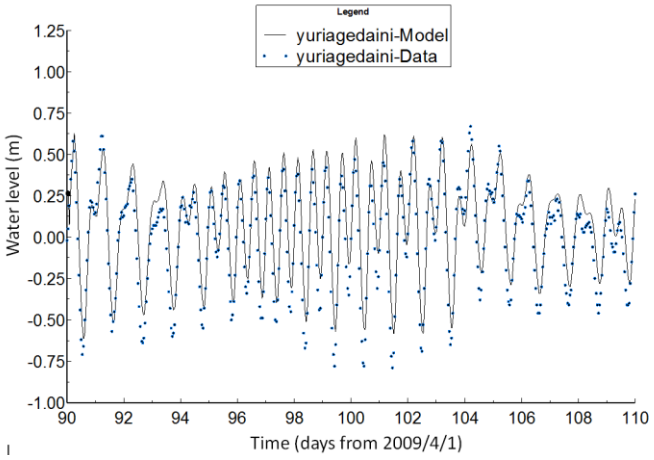
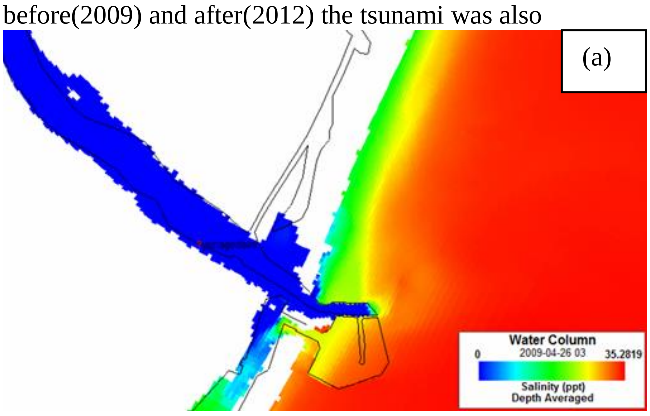
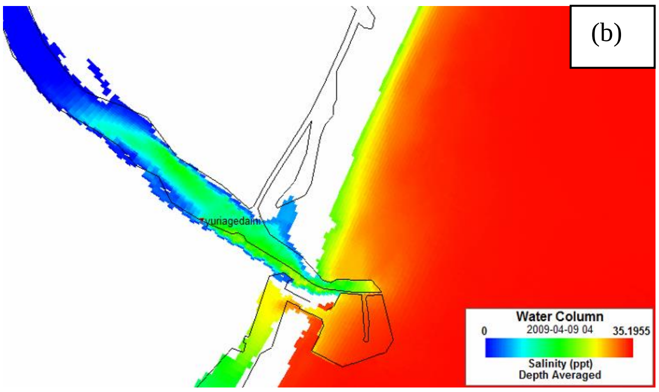


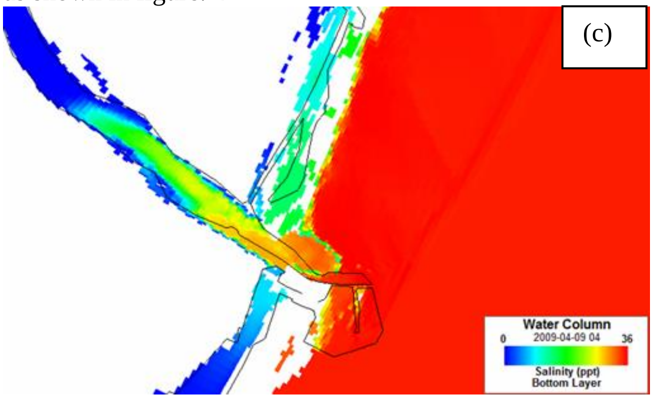
Figure 3. Calibration of water elevation in Yuriagedaini

5. The Response of Salt Intrusion to Changes in River Discharge and Morphology

From the salinity model results of 1 month, the analysis was carried out on April 12th with a small river discharge and April 26th with a large river discharge. The bathymetry data before(2009) and after(2012) the tsunami was also introduced in the model, to compare the influence of estuarine topographic changes on salt distribution. The result as shown in figure. 4







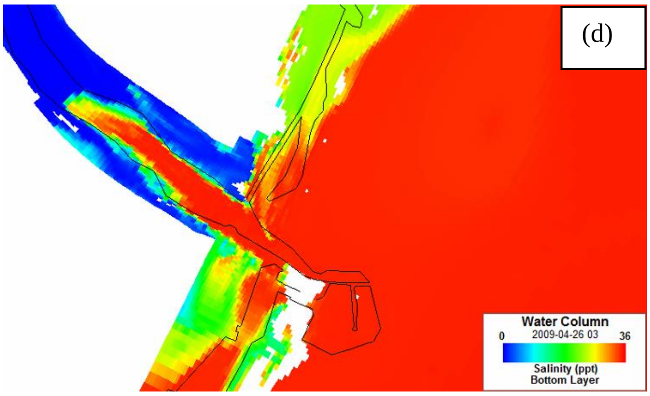


Figure 4. Model results of Horizontal salinity distribution in Estuary terrain before the tsunami with low (a) and high (b) river discharge, and terrain after the tsunami with low (c) and (d) high river discharge

6. Conclusions

Combined with the shoreline position in February 2012, The beach locating in front of Idoura lagoon was washed mostly by the tsunami, and river width also expanded greatly, which led to an increase in salt intrusion in the estuary.

For the different river flow at the upstream, salt intrusion recedes with higher river flow.

Acknowledgments

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