EOF ANALYSIS OF SHORELINE CHANGE AROUND THE NANAKITA RIVER MOUTH

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1. INTRODUCTION

The Nanakita river mouth is located at east side of Japan Coast, facing to the Pacific Ocean. The left side shoreline of river mouth stretch about 2 km until the breakwater of Sendai Port at north. The right side shoreline extends about 4 km until the breakwater of Arahama at south. The shoreline is relatively straight, only near the port breakwater has curve shape. All shoreline consist of sandy beach with average slope is about 0.11 (Kurosawa and Tanaka, 2001).

Starting December 1967, the construction of Sendai Port was begun. Large port basin had been excavated and almost 2 km long breakwater had been built. This huge structure had given a large impact on the surrounding coastal area (Tanaka and Srivihok, 2004). Since then the attention to the shoreline around the Nanakita River mouth has increased.

2. METHODOLOGY AND DATA COLLECTION

The Empirical Orthogonal Function (EOF) analysis was first developed in the early 1900's. The analysis is used for extracting the dominant pattern from random data sets. In the beginning the EOF analysis are widely used in meteorology, oceanography, and other study fields. The first application on coastal morphology was done by researchers at Scripps Institute of Oceanography. Winant et al. (1975) applied this method to the analysis of beach profile data sets collected at Torrey Pines, California. Since then, this application has continued become popular specially to focus upon cross-shore variability. One of recent application on long-shore variability is described in Miller and Dean (2007), where the EOF method was applied to shoreline data sets collected from some places at United States and Australia.

In EOF method, the shoreline data can be expressed as follows:

$$y(x,t) = \sum_{k=1}^{n} c_k(t) e_k(x) \qquad (1)$$

where $y(x,t)$ denotes the variability from mean shoreline ($y(x,t) = y_s(x,t) - \bar{y}(x)$, $y_s(x,t)$: the distance from baseline to shoreline, $\bar{y}(x)$: the mean shoreline), $c_k(t)$ is the temporal eigenfunction, $e_k(x)$ is the spatial eigenfunction, and n is the number of sections. The combination $c_k(t)e_k(x)$ denotes a mode of change and its variation through time. The first mode describes the most variance in the dataset and will reduce with the higher mode.

In this study, the EOF method is applied to the shoreline data around the Nanakita River mouth in order to analyze its behavior in long-shore direction. The shoreline data is collected by utilizing aerial photograph on this area.

The data collection was conducted by utilizing aerial photograph on this area. The aerial photograph has been taken every two months since 1990 until 2009. In order to utilize aerial photograph, firstly the image should be rectified, detect and delineate the shoreline. Then, the shoreline is measured from baseline and corrected with tide data for getting same datum level for all images.

In this study, the total shoreline length which is analyzed is 1,400 m. The left side is 900 m and the right side is 500 m from river mouth. Cross section or transect had been set up with 20 m interval. Every cross section is approximately perpendicular to the shoreline.

3. RESULTS AND DISCUSSIONS

Table 1 is shown the first five eigenfunctions which have majority in the shoreline variation at each side. The first five eigenfunctions account for over 95% of the total variability. The first mode of eigenfunction described by $e_1(x)$ dominate the variability on all side.

Table 1 Percentage of variability

Data Set	Percent Variance					
	$e_1(x)$	$e_2(x)$	$e_3(x)$	$e_4(x)$	$e_5(x)$	Remaining
Left Side	69.7%	14.3%	6.5%	2.6%	2.1%	4.8%
Right Side	87.9%	5.7%	2.9%	1.5%	0.9%	1.1%

3.1. First Mode Variability

Fig.1 shows the first mode spatial eigenfunction, $e_1(x)$, which is almost uniform along the shoreline and all have positive value on both sides. The associate temporal eigenfunction, $c_1(t)$, have high fluctuations due to annual season change. Moreover, there is also long term fluctuations which was showed from 1990 ~ 1999, 2000 ~ 2005 and 2006 ~ 2009.

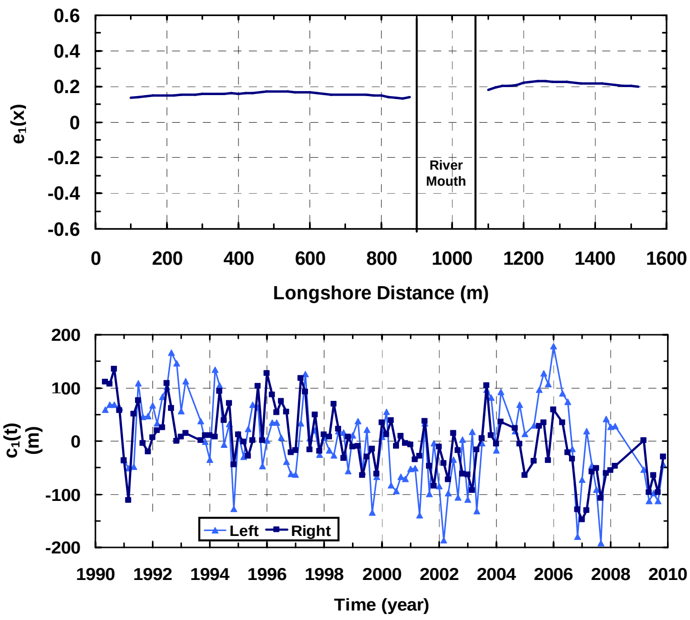

Fig.1 First mode $e_1(x)$ and $c_1(t)$.

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Associate with $c_1(t)$, the $e_1(x)$ will reflect the uniform shoreline advancement or recession depending on the sign of $c_1(t)$. Therefore, the $e_1(x)$ depict the cross-shore processes that dominate the variability in this area based on contribution value in **Table 1**. However, the left side (69.7%) has less influence than the right side (87.9%) due to the influence of port breakwater.

3.2. Second Mode Variability

The variability represented by $e_2(x)$ consist of one nodal point on both side. The positive values exist near the river mouth and negative value is in distant. The values of $c_2(t)$ also show the seasonal variation but no long term fluctuation exist as shown in **Fig.2**.

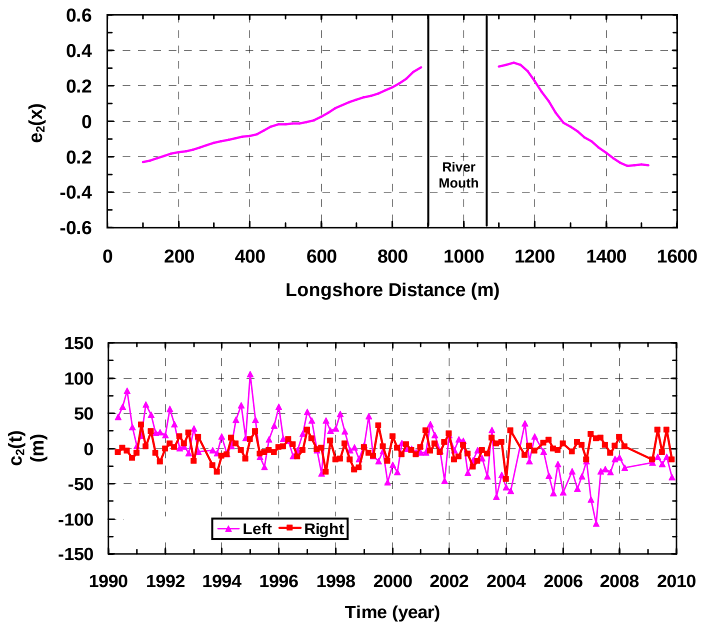

Fig.2 Second mode $e_2(x)$ and $c_2(t)$.

The combination of $e_2(x)$ and $c_2(t)$ reflect the different behavior between left and right side. For example in 1990, the $c_2(t)$ of left side is positive, so the combination value is positive near river mouth and negative on distant. In same time, the $c_2(t)$ of right side is negative, the combination value is negative near river mouth and positive on distant. This condition is almost same with beach which is influenced by jetty structure. River mouth acts such as jetty in this area. Hence, the second mode depicts the long-shore movement. The second mode also shows the effect limits of river mouth are 300 m and 200 m from river mouth on left side and right side respectively. The contributions of second mode are different with first mode. The value on left side is higher than right side. It strengthens the situation that the reflection waves from port breakwater influence the long-shore process on the left side of river mouth.

3.3. Third, Fourth and Fifth Mode

The 3rd, 4th, and 5th mode only contribute about 10% for left side and 5% for right side in total. **Fig.3**(a) shows the spatial eigenfunction of these three modes which all modes exist more than one nodal point specially on right side. The combined eigenfunctions ($\sum c_k(t)e_k(x)$) of these three modes is plotted in **Fig.3**(b) for giving clear illustration. These modes reflect the appearance of beach cusp or sand waves in this area.

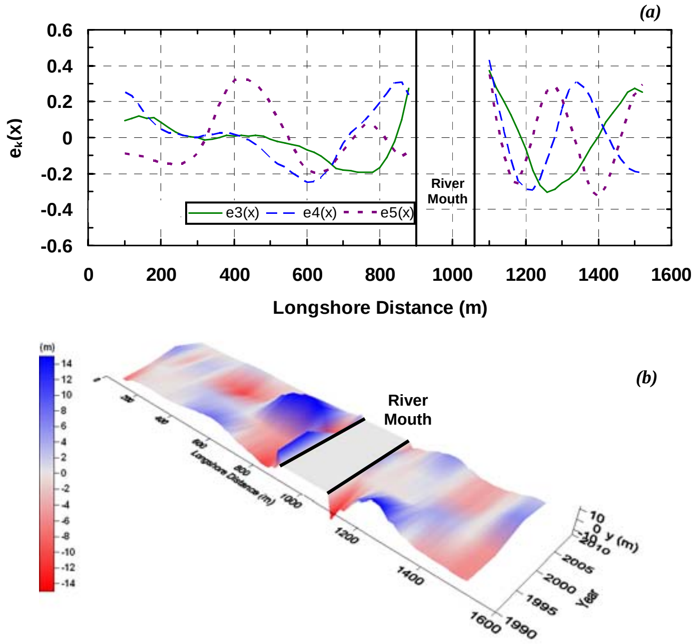

Fig.3 (a) Spatial eigenfunction of 3rd, 4th and 5th modes, (b) $\sum c_k(t)e_k(x)$.

4. CONCLUSION

The EOF analysis has identified the dominant mode of long-shore variability in the shoreline around the Nanakita River mouth. The results have revealed the cross-shore processes which dominate the variability in this area. It also exist the different behavior between left and right side due to effect of the port breakwater. The beach cusp or sand wave like feature is also identified from higher modes with minor contribution

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