STUDY OF CONTOUR LINES CHANGE ON SENDAI COAST BY USING EOF ANALYSIS

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1. Introduction

Sendai coast has severe erosion after the construction of breakwater at Sendai Port. The longshore sediment transport move on northward direction according to the predominant wave from ESE and SE direction (Tanaka and Takahashi, 1995). As the matter of fact, shoreline should be retreated caused by sand obstruction in front of breakwater, unfortunately; it can be seen the remarkable change of topographic due to the wave reflection from breakwater (Tanaka, 1983).To overcome these aspect, it should be clarified the evolution of topographic in order for well understanding which would be useful for coastal management in this area. This study aim to detect the predominant modes of topographic change by using Empirical Orthogonal Function (EOF) to analyze contour lines data from 1967-1998. The time series of surveyed data were used as the input data in EOF analysis which produced the output describing the dominant spatial and temporal patterns of change in this area.

2. Study area and methodology

Study area located at the end of sandy beach in the north part of Sendai Coast, northeast of Japan, as can be seen from Fig.1.

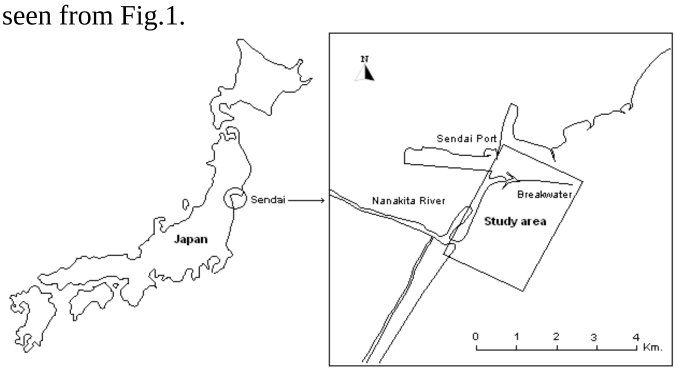

Fig.1 Study area

EOF technique was originally applied in coastal morphology to investigate variations in the beach profile shape and time in the middle of 1970s (Winant et al, 1975). The contour lines change can be expressed in terms of superposition of eigen function as follows:

$$H'(x,y,t) = \sum_{n=1}^{n_x} C_n(t) e_n(x,y) \quad (1)$$

where $H'(x,y,t) = H(x,y,t) - \overline{H}(x,y)$; $\overline{H}(x,y)$: average depth from 1967-1998; n_x denotes the number of survey data, and $C_n(t)$ and $e_n(x,y)$ are the temporal and spatial eigen functions, respectively.

3. Change of depth contours

The position of depth contours are the response to the forcing of waves, wind and current and depend on the supply of sediment to the beach. For well understanding, the behavior of temporal and spatial variation of contours had been conducted. Figure 2 shows the change of 0 to 15 m depth contours position at section x = 1500 m which were given by measurement their position from the reference line towards to the position of contour lines.

As can be seen from the figure, it can be inferred that when contour lines move forwards to the next deeper one that mean there is the steep slope of beach profile in that area. In case of positive slope of depth contours trend, there is some deposition results water depth get shallower; on the other hand, negative slope means water depth get deeper or erosion. Figure 2 illustrates the fluctuation during 1968-1973 due to breakwater construction. After severe erosion around Sendai coast, beach nourishment has been done by the Shiogama Port and Airport Office resulted position of near shore depth contour moved away from the beach as can be noticed during 1973-1974. In case of long term change, almost of depth contours position subjected to move seaward although there were some fluctuations owing to short term variations.

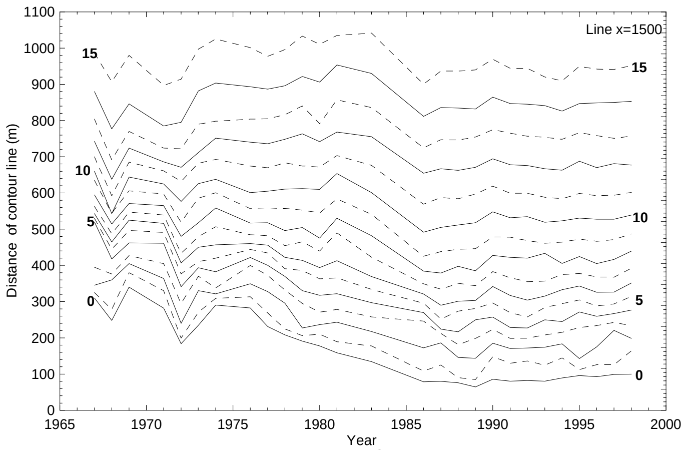

Fig.2 Change of depth contours

4. EOF analysis

The objective of the analysis is to separate the temporal and spatial dependence of the data so that it can be generated as a linear combination of corresponding function of time and space. These functions then objectively represent the variation of the beach configuration in terms of distance and in terms of temporal changes in topographic over the period of study. The analysis of contour lines has been done by using EOF technique which can be used to describe the variation in contour lines change to find characteristic temporal and spatial pattern in this data set.

Figures 3 and 4 show the 1st temporal eigen function and spatial function of shoreline and contour lines analysis at depth 5m, 7m, 11m and 13m respectively. The temporal and spatial components show positive and negative value denoting either erosion or deposition depending on the sign. In case of the same sign,

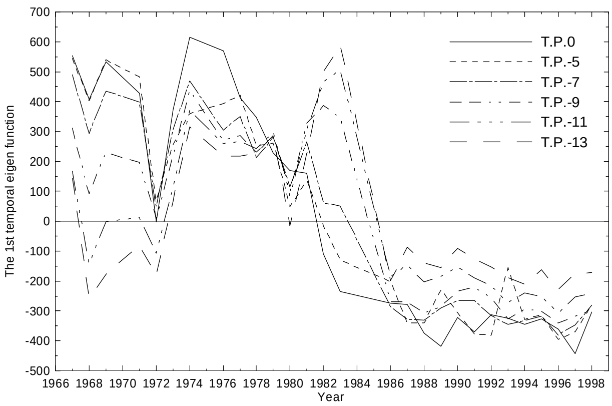

Fig.3 The 1st temporal eigen function

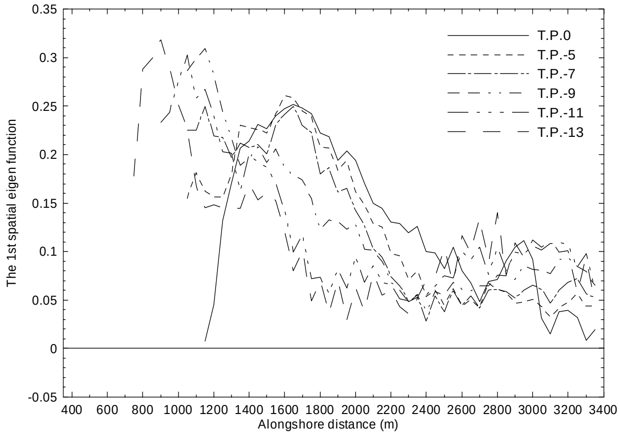

Fig.4 The 1st spatial eigen function

deposition would be occurred and erosion happened in vice versa.

Considering the 1st temporal eigen function in Fig.3, it can be noticed the fluctuation during the construction period of breakwater, 1968-1973. The remarkable change in 1972 occurred after the breakwater had 1450 m length especially for shallow contour lines. Thus sand dumping has been done twice during January 1972-May 1973 and 1974 in order to recover the beach after severe erosion. Due to that reason, contour lines shifted offshore that can be seen from Fig.2 easily. The corresponding change was found from Fig.3 when the 1st temporal eigen function moved upward during the beach nourishment.

It can be clearly noticed the delayed-change in Fig.3 from 1982-1985 when the 1st temporal eigen function started to change from positive to negative value. It was changed first in the shallower contour lines then following by the deeper ones. That means the erosion took place first in the shallow area then came next to the deep area.

For the 1st temporal eigen function, it can be well explained not only the natural contour lines change but also other man-made works such as the construction of breakwater and beach nourishment. It can be noted that the first component can explain a long term trend of contour lines change. In the contrary, it cannot be seen the corresponding changed from the 2nd temporal eigen function which have fluctuated trends as show in Fig.5 and Fig.6 ,thus the 2nd mode indicate the short term evolution. There were the similar trends in -11 and -13 depth contour lines that might be resulted from the differences behaviors between the shallow zones and the deeper zones.

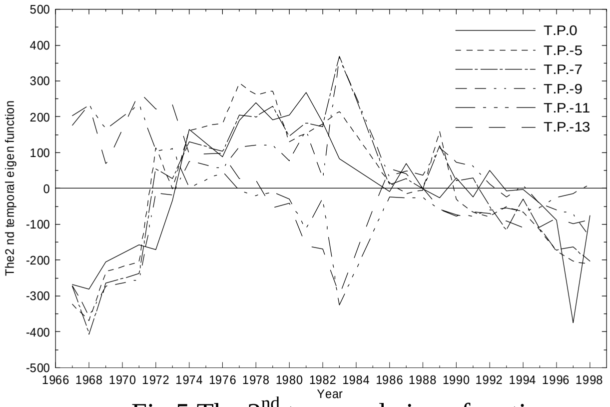

Fig.5 The 2nd temporal eigen function

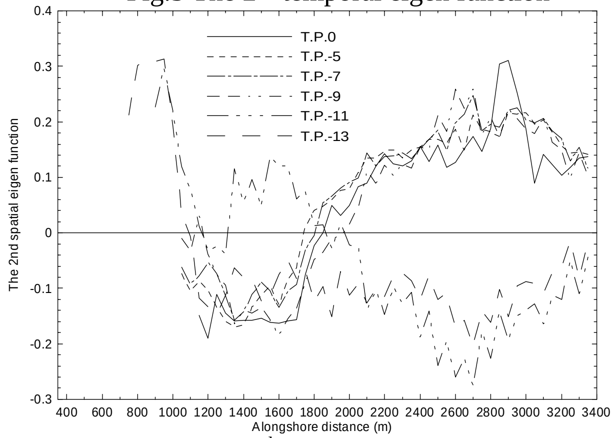

Fig.6 The 2nd spatial eigen function

5. Conclusions

The conclusions drawn from this study can be summarized as follows:

- The depth contour fluctuated during the construction of breakwater not only in shallow zone but also in deep area.
- For long term change, almost of depth contours position subjected to move seaward although there were some fluctuations owing to short term variations.
- It was found that the first mode can relate to physical mechanisms and other man-made works.
- It can be noticed the delayed-change from the shallow zones to the deeper ones.

Acknowledgements

The authors wish to express grateful thanks to Shiogama Port and Airport Office for providing topographic survey data of Sendai Coast.

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