論文の内容の要旨

Satellite-based nearshore monitoring of suspended fine sediments discharged from multiple rivers
(沿岸域における複数河川から供給される浮遊細砂の衛星モニタリング)

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Under the significant load of human activity, such as constructions of dams and sand mining from riverbeds, coastal erosion has become one of worldwide problems. While the change of shoreline location can be directly observed by local residents or some other measures such as aerial photographs, it is difficult to monitor quantitative features of sediment discharge from rivers and nearshore movement of discharged sediment, which are primary causes of coastal erosions. Lack of such quantitative data makes it difficult to implement effective and appropriate measures for mitigations and protections of coastal erosion problems.

Satellite-based monitoring techniques can be one of powerful tools for understanding of the nearshore behavior of sediments discharged from the river and there are a number of existing studies which aim to use satellite data for monitoring of turbidity pattern in the nearshore area. Most of these studies, however, focus on the monitoring of specific region for a relatively short period of time and thus developed monitoring techniques may not provide us sufficient data to understand the characteristics of daily sediment movement which causes coastal erosions.

This study thus aims to develop a new satellite-based monitoring system, which enables us to capture the daily sediment behavior with relatively high temporal resolutions. Since the turbidity patterns are expected to change dynamically with tide, river flows, waves and some other factors, monitoring frequency and the number/duration of available data are some of primary features for selection of appropriate satellite for the present monitoring system. After the review and comparisons of several candidates of satellite data, this study selected the MODIS satellite, which records the data of each site twice a day and archives the data over the past sixteen years. All the archived data from the year of 2000 to December 2015 were utilized for the analysis. Data processing, such as downloading, reprojection, mosaicking and resampling, is automated in the Linux environment.

One of the unique and challenging features of this study is that we aim to use all the available MODIS data over the past sixteen years to understand the spatial and temporal behavior of the turbidity patterns. Some of MODIS data, however, are fully/partially covered by clouds and the present monitoring system needs to exclude the influence of the clouds in the analysis of the

turbidity patterns. While the red band has high reflectance from both cloud and high turbidity, the NIR band shows low reflectance from the turbid water but high reflectance from the cloud. Thus, this study utilizes these characteristics and newly determines the threshold value for detection of the cloud by the ratio of the difference of the red band and NIR band and the red band reflectance itself.

The present cloud masking algorithm is specially calibrated for clouds on the sea water and was improved in that the new system has less chance of misdetection of the cloud on the sea surface. Many of the obtained turbidity maps partially contain pixels with cloud. On the other hand, the observed horizontal length scale of the turbidity variation appears to be much larger than the pixels' size, 250m. Based on this fact, this study introduces a unique cell system to represent the spatial-temporal turbidity patterns. The developed cell system in the study area contains more than 16 pixels per cell and the average turbidity can be obtained even if the cell is partially covered by cloud. Alongshore boundaries of the cell were determined parallel to the shoreline so that selected cells are aligned at about the same distance from the shoreline. Several Matlab scripts were developed to automatically process daily images to estimate the turbidity in each pixel and to obtain average turbidity over each cell, in which the pixels covered by cloud were excluded. Besides such cell-based analysis, which increases the number of available data at each location, the original pixel-based turbidity data is also used for estimation of the area of higher turbidity around the river mouth. The developed monitoring system was then applied to Red and Ma river systems in northern part of Vietnam and to the Enshu-nada coast, Japan. In Vietnam, the Red River system shows decreasing trend of the turbidity of suspended fine sediment discharge while the Ma River tends to have increasing trend. Observed yearly variations of the turbidity at the Ma River mouth was then compared with the observed river discharge data and showed very clear correlation with each other. This feature validates the use of the present monitoring system for observations of turbidity patterns discharged from the river mouth.

Along the Enshu-nada coast, the cell-based daily turbidity product able to captures the direction and alongshore extent of suspended load discharged from the Tenryu River, and it shows a relationship with shape of the sandpit near the River mouth. Furthermore, the flood events of the Tenryu River were also closely correlated with estimated area of high turbid plume around the Tenryu River mouth.