RF-074 **Development of Fine-Scale Substance Transport Measurement System for Assessing the Effect of Resuspension Event of Sea Bottom Sediment on Marine Environment（Abstract of the Final Report）**

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[Abstract]

Field measurement was carried out to elucidate fine sediment transport processes near the bed in Ariake Bay, Japan. Several acoustic velocimeters were deployed for the monitoring such as up-looking acoustic Doppler current profiler (ADCP), a downward-looking pulse coherent acoustic Doppler profiler (PC-ADP) and an acoustic Doppler velocimeter (ADV) for the bottom boundary layer study. Comparing the OBS data which are converted to suspended sediment concentration near the bed with the current field data, external force conditions for the resuspension event of bottom sediment was evaluated through the estimates of shear stress with measured velocity data. The critical force condition for resuspension of sediments was quantatively analyzed and the critical shear stress was estimated around 0.01 Pa. In addition to the measurement of physical parameters, as a preliminary study of examining how resuspension event affect on water quality change, eddy correlation method was applied in the field for *in situ* direct measurement of oxygen flux across the bed and our study successfully demonstrates a marked flux fluctuation (0.0–12.5 mmol O_2 m–2 h–1) within several hours and that the oxygen consumption fluxes increase with increasing horizontal velocity on flood tides.

In the present study, in order to establish experiment method for elucidating resuspension process of muddy sediment under wave dominant environment, some experiments were also carried out with muddy sediment sampled from a field with a laboratory flume. The experiment with the sediment transplanted into the flume from the field successfully reproduced resuspension process under extreme wave force condition.

1. Introduction

Measurement of current properties in the bottom boundary layer is crucial to understand sediment transport process and several acoustic velocimeters have been developed and applied in field measurement for bottom boundary studies (e.g. Sherwood et al. 2006, Precht et al. 2006). This study focuses on fine sediment transport processes in coastal and estuarine area and field monitoring was carried out in Ariake Bay, Japan with high resolution current measurement near the bed by using several acoustic velocimeters. In addition to the physical aspect in the bottom boundary layer including resuspension of sediments, we are also interested in how the resuspension event affects on water quality change. Since oxygen depression is prominent especially during summer season in the study area, eddy correlation method was applied in the field for *in situ* direct measurement of oxygen flux across the sea bed by use of microelectrode.

2. Research Objective

One of the scopes of this study is to elucidate the resuspension processes of bottom fine sediment by the forces induced by waves and currents with high resolution current measurement near the bed by using several acoustic velocimeters in the field. Another objective is to apply the eddy-correlation technique to *in situ* oxygen consumption flux measurements in order to overcome some disadvantages of conventional core incubation approaches determining solute exchange fluxes across the sediment–water interface, since they have limitations in terms of the reproducibility of hydrodynamic forcing and the representativeness of spatially-heterogeneous biological processes when applied to, in particular, shallow estuarine systems where wave- and tide-induced sediment resuspension regularly occurs. In estuarine and delta environment, it has been found that wave force plays a key role in sediment transport processes (e.g. Trakovski et al. 2007). There is less information on erosion or resuspension properties of muddy sediment under wave forces than that under the uniform current. In the present study, in order to establish experiment method for elucidating resuspension process of muddy sediment under wave dominant environment, some experiments were also carried out with muddy sediment sampled from a field with a laboratory flume.

3. Research Method

Field data presented in the study were collected in February 2008 with instruments mounted on bottom pods at a monitoring site in inner Ariake Bay (**Fig. 1**). The bay is a macro tidal estuarine system and the tidal range during spring tide varies from 4 m at the mouth and increases up to more than 6 m towards the inner bay. Sediments near shore in the bay compose of mud and their resuspension events were observed not only by wind waves but also by tidal currents (e.g., Nakagawa, 2007). The mean depth of the deployment site is 6 m and the bed is composed of silt (66%) and clay (33%). Instruments were deployed for the current and turbidity measurement from February 14 - 28, 2008.

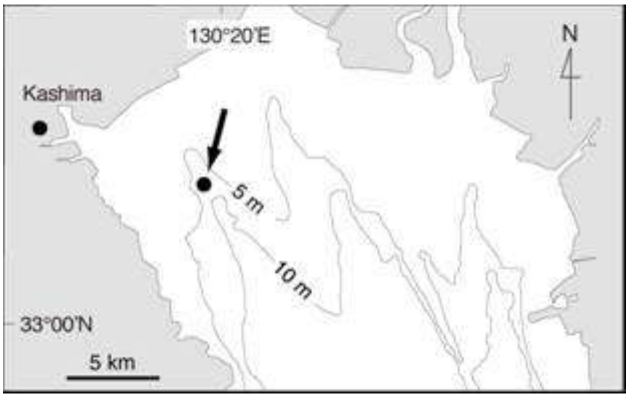

Fig.1 Study site

For the current measurement, the data were obtained with several acoustic velocimeters (**Fig.2**). A pulse coherent acoustic-Doppler profiler (Sontek, PC-ADP) was mounted at 1.2 m above the bed and measured the bottom boundary current profiles with the space resolution of 10cm bins. The sample rate was 10 minutes with 1Hz every one hour. ADVs (Nortek, Vector) were mounted for the measurement of turbulence near the bed and sampled three components of velocity at 20cm above the bottom for 4 minutes with 16 Hz every one hour. Five optical backscatter sensors (OBS) were mounted to provide suspended sediment concentration (SSC) profile at several elevations. The collected OBS data were converted to SSC in mg/l by applying calibrations with sediment samples from the site.

In order to estimate oxygen flux at the sediment-water interfaces, an oxygen microelectrode sensor (Unisense, OX10) were also applied during the field monitoring campaign. The sampling of oxygen concentration by the sensor was synchronized with a measurement of three components of velocity by an ADV and they were mounted on an instrument pod (**Fig. 3**) so that the target point is 20 cm above the bed. Due to the capacity of the data record system, they were deployed only for 24 hours on February 13-14 and 20-21 sampling continuously with the rate of 16 Hz. For the estimation of oxygen vertical flux, so called eddy correlation method (e.g. Berg et al. 2007) was applied here.

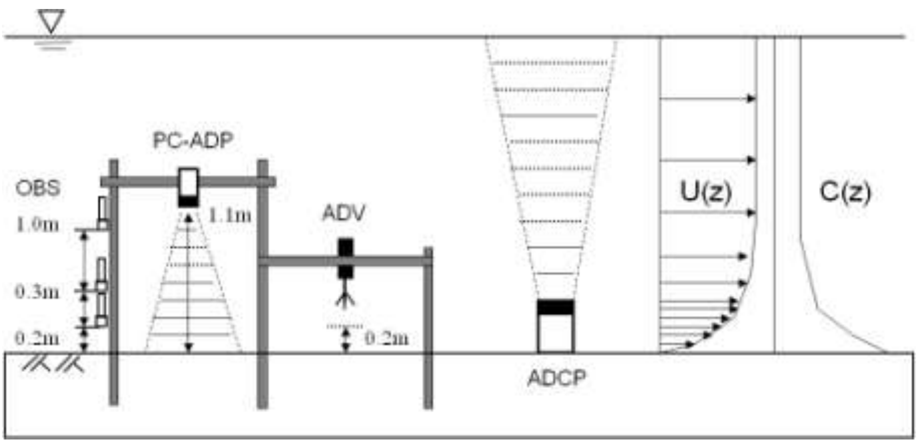

Fig.2 Instrumentation of current and turbidity measurement

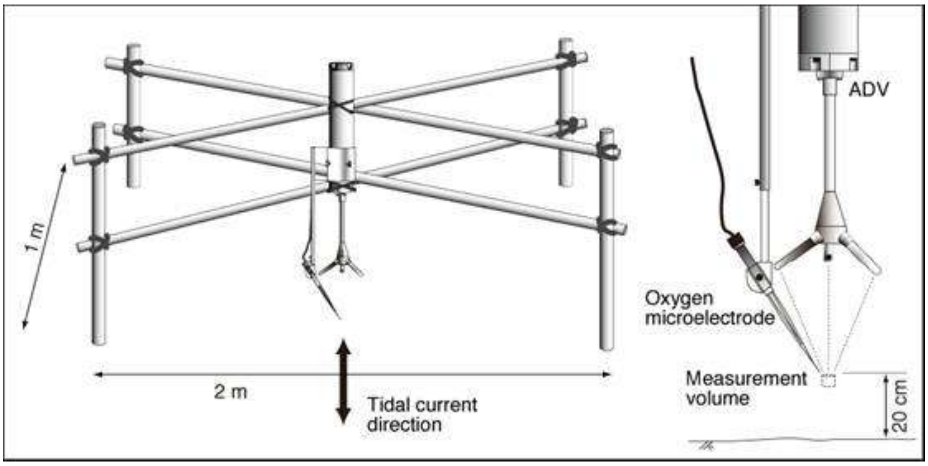

Fig.3 Measurement system for oxygen fluxes

In estuarine and delta environment, it has been found that wave force plays a key role in sediment transport processes (e.g. Sanford 1994, Chang et al. 2001, Trakovski et al. 2007). There is less information on erosion or resuspension properties of muddy sediment under wave forces than that under the uniform current. In the present study, in order to establish experiment method for elucidating resuspension process of muddy sediment under wave dominant environment, some experiments were also carried out with muddy sediment sampled from a field with a laboratory flume. The flume used here is the See Bed Experiment Flume at Port and Airport Research Institute (**Fig. 4**) and it can reproduce currents, oscillatory flows and surface waves by current generator and wave paddles. The sediment samples for the experiments were collected at the same location as where the field monitoring were deployed in Ariake Bay (**Fig.1**) using specially designed box core samplers with the size of 1.6 m (length), 0.4 m (width), 0.3 m (depth) so that the disturbance on the sediment structure makes minimum. For the measurement of current field and water quality changes, several acoustic velocimeters and optical back scatter sensors for suspended sediment concentration and dissolved oxygen sensors etc. were installed in the flume.

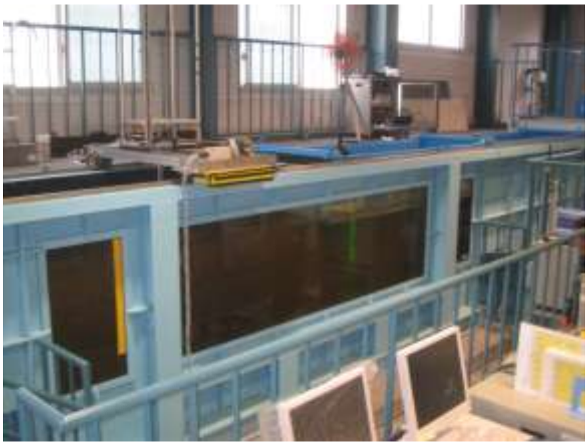

Fig.4 See Bed Experiment Flume (Port and Airport Research Institute)

4. Results

Measured time series data of tide, current speed and SSC at 20 cm above the bed are shown in **Fig. 5** during spring tide period. The current speed exceeds around 30 cm/s and higher SSC events are clearly shown in the data. The higher SSC event at the site is caused mainly by advection of turbid water from the shallower coast and intertidal mud flat area during the low tide of spring tide period with longer tidal excursion. Moreover, local resuspension of the bottom sediment at the site also affect on the SSC variation in ebbing and flooding tide phase with strong current speed. Critical force condition for resuspension of sediments can be analyzed through the estimation of bottom shear stress (e.g. Dyer 1986, Kim et al. 2000) with the current and the critical value was estimated around 0.01 Pa (**Fig.6**).

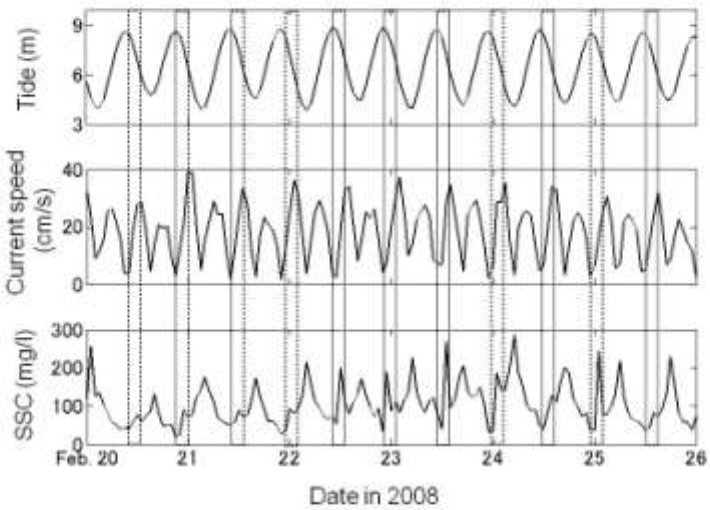

Fig.5 Observed data of tide, current speed and suspended sediment concentration at 20 cm above the bottom

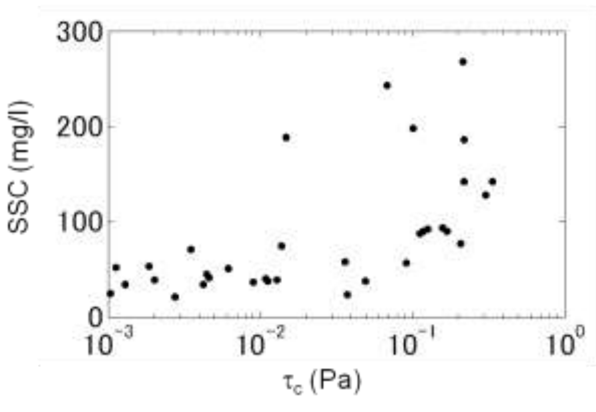

Fig. 6 Relationship between bottom shear stress and SSC

Time series data for the period of oxygen concentration sampling with microelectrode sensor are demonstrated in **Fig.7**. Oxygen concentration is highly correlated with SSC variation and they are high during low tide. It is conceivable that these higher concentrations might be caused by the advection of particles originate in algae since inner area of the site were utilized for cultivation of seaweed by fishery industry. Estimated oxygen flux with eddy correlation method is on the bottom of **Fig.7** and the values mean downward flux of oxygen or consumption rate at the bottom surface. Individual estimation of the flux was provided with oxygen concentration and velocity data for 20 minutes long. There is no estimated result in **Fig.7** when oxygen data are judged as error with extraordinary high values. The orders of the values are comparative to that of measured on intertidal flat in other Japanese bay (Kuwae et al. 2006). There is a tendency for the consumption rate to become higher under the stronger current condition especially during flooding tide as shown in **Fig.8**.

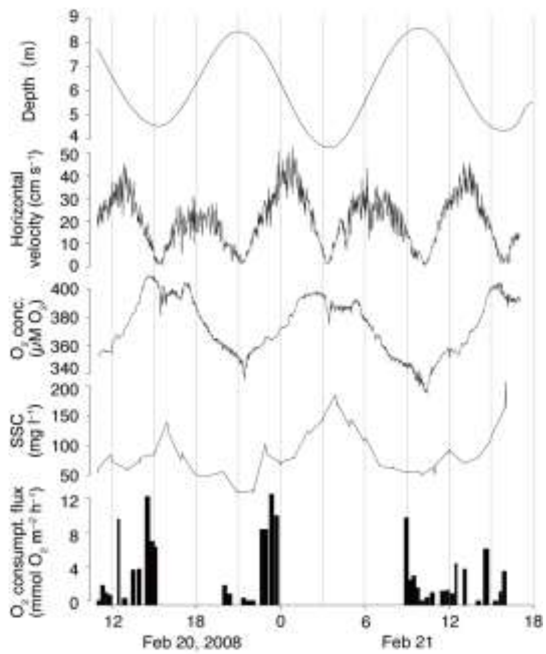

Fig.7 Observed oxygen concentration and fluxes

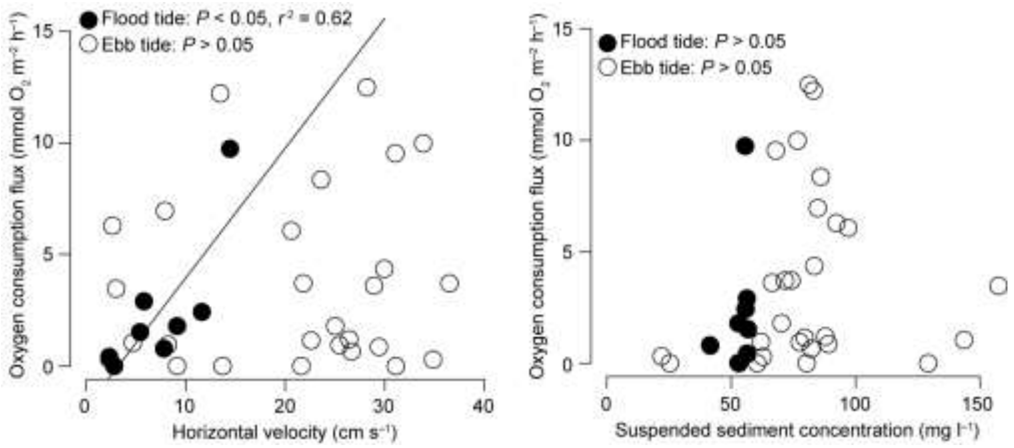

Fig.8 Correlations between oxygen flux and current speed and suspended sediment concentration

As an example of the experiment results, time series data of near bed concentrations of suspended sediment and dissolved oxygen under the oscillatory flow is shown in **Fig. 9** of a case for a period of 8 s and velocity amplitude of 40 cm/s. Suspended sediment concentration rapidly increases caused by resuspension of bed material right after the oscillatory flow starts. The suspended sediment concentration becomes, however, equilibrium state after the peak even under the continuous same flow condition. This means that erosion rate depends on the vertical structure or strength of sediment and the experiment with the sediment transplanted into the flume from the field successfully reproduced resuspension process under wave forces. As for the dissolved oxygen, it can be seen slight depression during the period of rapid increase in the suspended sediment concentration and it could be the process of consumption of dissolved oxygen by the suspended sediments.

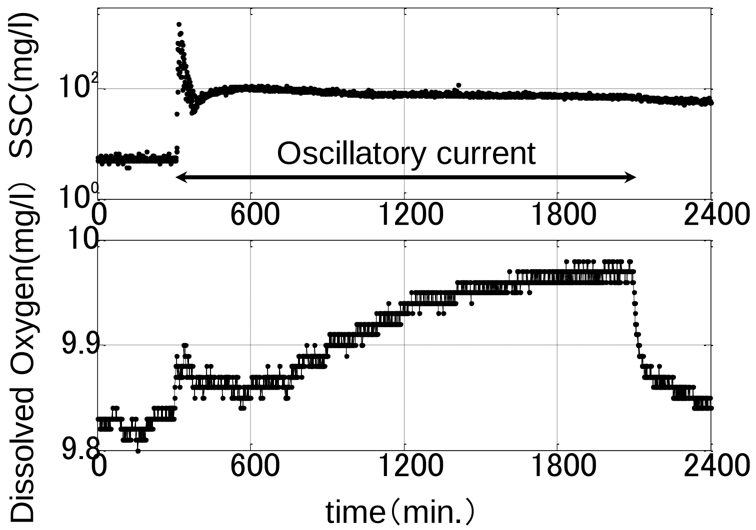

Fig.9 Flume experiment data for time series of suspended sediment concentration and dissolved oxygen under oscillatory flow

5.Disscussion

Based on a field measurement for bottom boundary processes, the critical force condition for resuspension of sediments under tidal current dominant case was quantatively analyzed and the critical shear stress was estimated around 0.01 Pa The result can be applied to the bottom boundary conditions for numerical modeling of sediment transport in the estuarine area. On the other hand, applying the eddy-correlation technique to *in situ* oxygen consumption flux measurements, our study successfully demonstrates a marked flux fluctuation (0.0–12.5 mmol O_2 m–2 h–1) within several hours and that the oxygen consumption fluxes increase with increasing horizontal velocity on flood tides.

In order to establish experiment method for elucidating resuspension process of muddy sediment under wave dominant environment, some experiments were also carried out in a laboratory flume with muddy sediment samples transplanted from field. The experiment results show successful reproduction of resuspension process under wave forces. The experiment technique established in the present study could be effectively applied for bottom boundary process near estuarine and coastal area, which is one of crucial factors for coastal and ocean environment.

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Major Publications

None