

FIELD MEASUREMENT OF SAND MOVEMENT ON RIVER-MOUTH TIDAL FLAT USING COLOR SAND TRACING

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The color sand tracing to investigate the characteristics of sand movement on the tidal flat (Rokujo-gata in Mikawa Bay, Japan) was conducted in the winter season. Field measurements of currents and water level were also conducted on the flat to grasp the driving factors of currents and sand movement. Currents on Rokujo-gata were affected by wind in alongshore direction which is the north-south direction, and by a tidal oscillation in cross-shore direction. In the winter season, the southward currents are dominant. However the strong northward currents are occasionally generated. It is supposed that these strong currents move sand actively on the tidal flat. The color sand was placed on Rokujo-gata. The sand tracing was conducted during 6 months by sand sampling at 18 locations in the tidal flat and color sand grain counting was also conducted. The color sand was scattered soon after the placement. However it was demonstrated that the color sand remained on the tidal flat even after 6 months.

Keywords: color sand tracing; sand sampling; field measurement; tidal flat; Rokujo-gata

INTRODUCTION

Tidal flats have rich environment for a coastal ecosystem. Rokujo-gata is a tidal flat placed in Mikawa Bay, Aichi prefecture, Japan and is extending at the river-mouth of Toyo River (Fig.1). This flat is a valuable place for a source of Japanese littleneck clam supply in Japan. The amount of the clam catch in Aichi prefecture, including Mikawa Bay, is usually more than 30 % of the total amount in Japan, and especially in 2011, the amount occupied around 60% (Fig.2). Most of their juvenile clams in Mikawa Bay are gathered at Rokujo-gata and are released into the other fishing places. Picture 1 shows bottom sand taken at Rokujo-gata. There are many juvenile clams. Clam fishing is important fisheries around Mikawa Bay. Therefore Rokujo-gata has an indispensable role for the clam supply not only in Mikawa Bay but also in Japan.

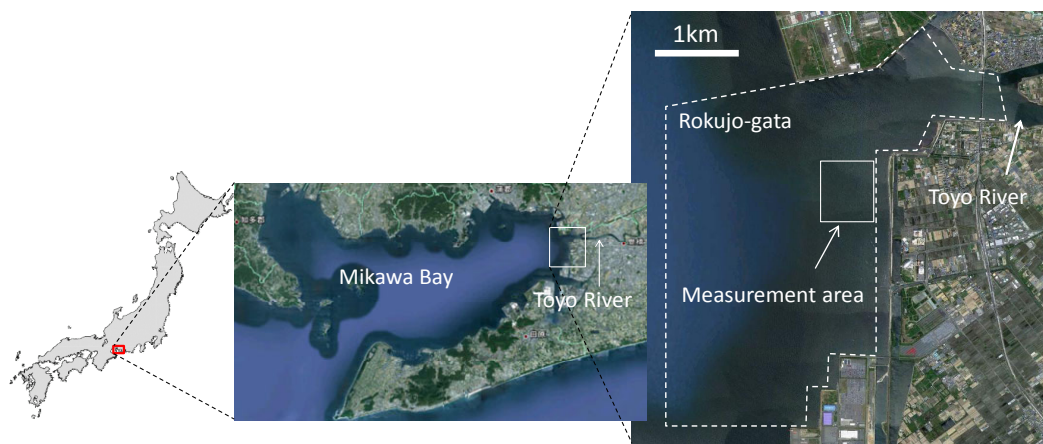


Figure 1. Place of Rokujo-gata and our measurement area in this research

It is conjectured that sand movement on a tidal flat has influence on transportation and settlement of juvenile clams. Ikushima et al. (2012) conducted field experiments about the hydrodynamic effects of scattering gravel and pole fences to enhance the settlement of juvenile clam in the flat. Their experiments demonstrated that juvenile clams sticking to gravel by a byssus move with bottom sand and reduction of bottom shear stress by pole fences improves the settlement and survival of juvenile clams. Sakurai and Seto (1999) investigated that the behavioral characteristics of juvenile clams in

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response to sand erosion and deposition using laboratory experiments. This research indicated juvenile clams can move downward and upward in the sand responding to the bottom sand movement such as erosion and deposition and juvenile clams are washed out of the sand and are transported with the sand when bottom current speeds above sandy bottom exceed some criteria. These researches show us that the settlement and survival of juvenile clams are closely related with the sand movement and it is necessary to elucidate hydrodynamics and sediment dynamics on the tidal flat.

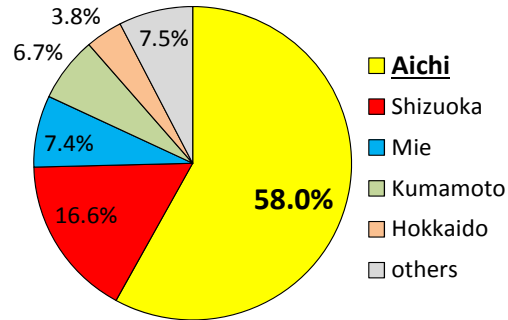


Figure 2. Market share of Japanese littleneck clam in Japan (2011)



Picture 1. Bottom sand with many juvenile clams at Rokujo-gata

The researches about sand movement on tidal flats were conducted by many researchers. They usually measured currents, waves, tidal oscillations, turbidities, associated ultrasonic backscatter and bathymetric changes to investigate the volume and direction of sand movement and its balance on the tidal flat (Uchiyama, 2007; Mariotti and Fagherazzi, 2012; Ralston and Stacey, 2007; Yamada et al., 2010). Field measurements of sand movement using fluorescent sand and colored sand were also carried out because these measurements can investigate the direction and speed of sand movement directly and quantitatively for a long time (Cabrera and Alonso, 2010; Hiramatsu et al., 2008; Kato et al., 1985). On the other hands, as many researchers know well, the experiment of direct sand tracing using fluorescent sand and color sand in a field, such as coastal area and river, is a laborious work and consumes a lot of time. Therefore their applications on a tidal flat are very limited. However it seems to be more useful to investigate sand movement on a tidal flat.

In this research, the color sand tracing was carried out on the tidal flat (Rokujo-gata in Fig.1) to investigate the characteristics of sand movement. Field measurements of currents and water level were also conducted on the flat to grasp the driving factor of currents and sand movement.

SETUP OF FIELD MEASUREMENTS ON THE RIVER-MOUTH TIDAL FLAT

Bottom Profiles

Cross-shore profiles of Rokujo-gata were measured at five lines, L1, L15, L2, L25 and L3 from the north, to grasp the bathymetric feature because the detailed bathymetric data was not stored (Fig.3). Water depth was measured by a leveling rod at every 5m from a shore to sea under the ebb tide. Figure 4 shows the time series of sea water level near Rokujo-gata. In the spring tide, the range of water level change around Rokujo-gata is about 2.5 m. Therefore, the water depth on Rokujo-gata becomes very

shallow in ebb tide and the depth measurement was conducted when the water level was going to low tide. The measured water depth at any time was corrected to the water depth from the mean water level by the water level measured with the interval of 10 minutes at nearest tidal station.

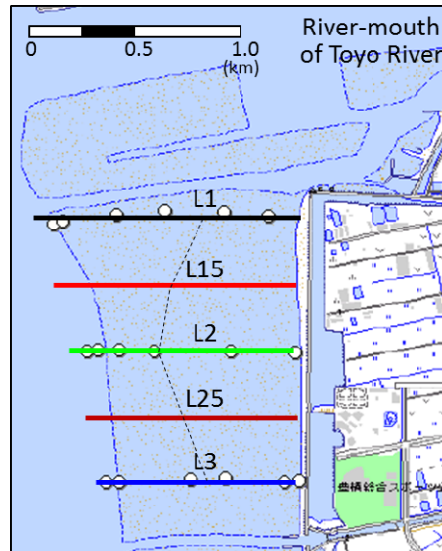


Figure 3. Bottom profile survey lines at Rokujo-gata

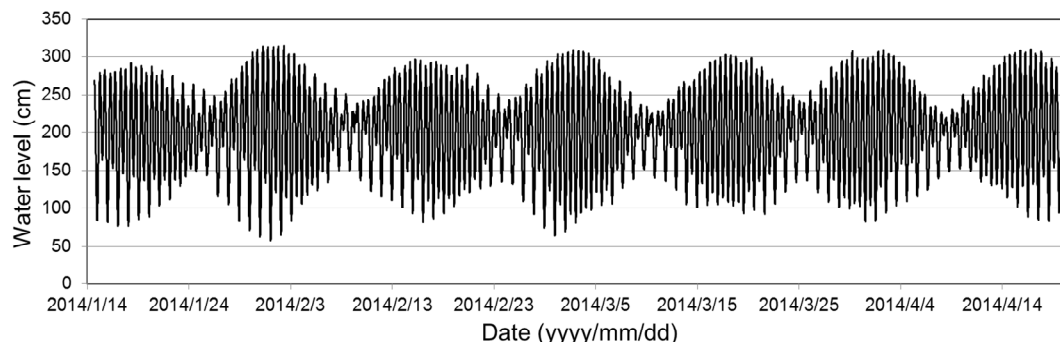


Figure 4. Water level record near Rokujo-gata from 2014-01-14 to 2014-04-20

Currents and Water Level

The field measurement of currents and water level was conducted twice in this research, a short-term measurement and a long-term measurement.

The short-term measurement was carried out at 1 location during only two daytime on September 14 and 15, 2012 to grasp the characteristics and generation mechanism of currents on this tidal flat. The setup location of instruments was close to the input location of color sand (red start in Fig.5). An electro-magnetic current meter for horizontal two directions and a pressure sensor to measure water surface changes were installed on the bottom. These instruments worked continuously with data sampling frequency of 10 Hz.

The long-term measurement was continued during 6 months, from November 2012 to March 2013, at 4 locations (Fig.5) to investigate the relationship between currents and sand movement. One electro-magnetic current meter and one pressure sensor were operated at each location. The data samplings were run every 1 hour by burst ping mode.

Wind data obtained at Toyohashi JMA (Japan Meteorological Agency) weather station, which is closest to the tidal flat although about 1.5km inland, were adopted in this research. Wind data are 10-minute average values.

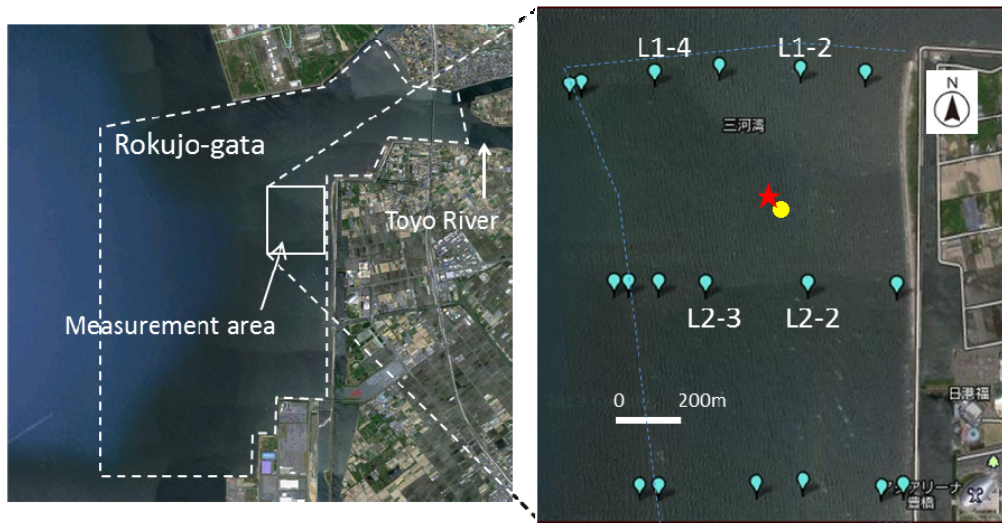


Figure 5. Locations of instruments for currents and water level, color sand input and sand samplings
 Red star : instruments for short-term measurement, L1-4, L1-2, L2-3 and L2-2 : instruments for long-term measurement, yellow circle : color sand input, light blue pins : sand samplings

Color Sand Tracing

Field experiment of color sand tracing was conducted on the tidal flat. Yellow color sand of 250kg was placed at the yellow circle in Fig.5 on September 14, 2012. Picture 2 shows the color sand placed on the tidal flat at low tide condition. The mean diameter (d_m) of color sand is approximately 0.3mm which is similar to the sea bottom materials on the tidal flat. After the placement of the sand, the bottom materials were taken at 18 locations until March 2013. Sand volume of 2L was sampled at each location. The sand volume was reduced to 500mL by the method of quartering. The number of color sand grain in sampled sand of 500mL was counted by visual inspection.



Picture 2. Color sand (500kg) placed on Rokujo-gata at low tide on September 14, 2012

RESULTS OF MEASUREMENTS AND COLOR SAND EXPERIMENT

Cross-shore Profiles of the tidal flat

Figure 6 indicates the cross-shore profiles obtained by the water depth survey. In the northern area from L1 to L2, the bathymetric profiles at these survey lines are relatively smooth and are almost constant depth up to 200m from a shore. The slope changes slightly in the vicinity of 200m from a shore.

On the contrary, in the southern area, the profiles repeat ups and downs. At L25, the profile indicates smoothly, such as the profiles in the northern area, up to 250m from a shore. But in the area farther than 250m, the profile repeats ups and down periodically. The slopes at L25 and L3 near the shore are steeper than those at L1, L15 and L2. Furthermore, the water depth along L3 is deeper than other survey lines on the whole. The characteristics of bottom profiles are much different between in the northern and in the southern areas. Moreover, waterways are formed in the cross-shore direction (Picture 3). It is inferred that these waterways also have influence on the wave and current conditions. The more bathymetric information, for example alongshore profiles and seasonal bathymetric features, has to be stored for discussion of sand movement on Rokujo-gata.

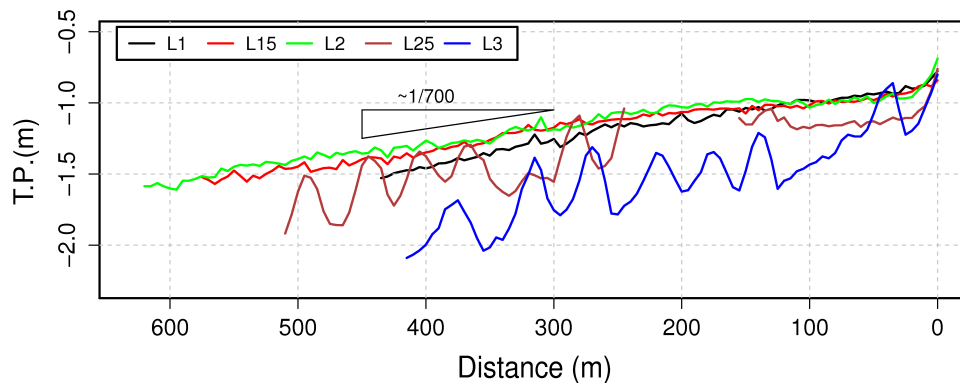


Figure 6. Results of cross-shore profile's survey at 5 lines



Picture 3. View of Rokujo-gata at low tide. There are many waterways in the cross-shore direction.

Characteristics of Currents and Water Level

Figure 7 shows the time series of water level, wind and currents measured during the short-term measurement (September 14 and 15, 2012). The eastward direction corresponds to the onshore-going and the northward or southward directions are alongshore. The current velocity in both directions gradually changed in both days. The relationship between wind and current velocities is indicated in Fig.8. Alongshore components (●, ■) of wind and current have evident correlation. On the contrary, cross-shore current velocity and gradient of water level in time illustrate positive correlation in Fig.9 (●, ■). The continuous data of water level and currents are averaged at every 10 minutes to compare with wind data in Fig.8 and 9. The gradient of water level is calculated using mean water level at every 10 minutes. These results indicate that alongshore currents, that is, north-south direction, on Rokujo-gata are induced by alongshore wind, whereas cross-shore currents are affected by temporal change of mean water level. It is supposed that the cross-shore currents are a part of tidal currents. The generating factors of currents on Rokujo-gata are clearly different in directions.

Figure 10 shows the results of current at L1-4 location and wind during 6 months. The measurements at 4 locations were tried in this research. Unfortunately, there are many data missing in these measurements. The L1-4 data are less missing in 4 data sets, and are used in this paper. The long-term measurement was conducted in winter season. The northerly wind is predominant around Rokujo-gata. Therefore, southward currents induced by wind are occurred frequently. However, strong northward currents are generated sometimes, and it seems to be periodic.

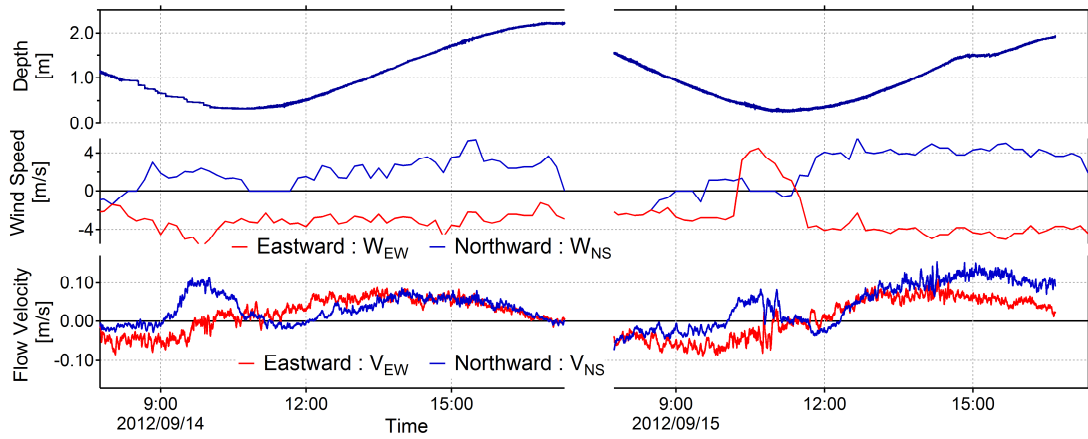


Figure 7. Time series of water level, wind and current on 2012/09/14 and 15 (short-term observation)

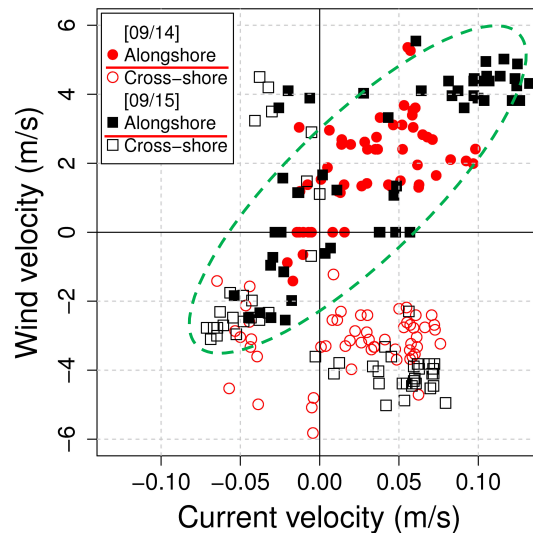


Figure 8. Relationship between current and wind in cross-shore and alongshore directions by 10 minutes averaged data.

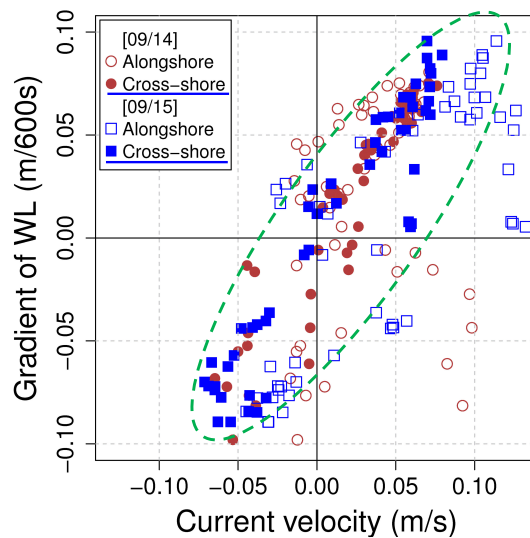


Figure 9. Relationship between current and water level (gradient of water surface) in cross-shore and alongshore directions by 10 minutes averaged data.

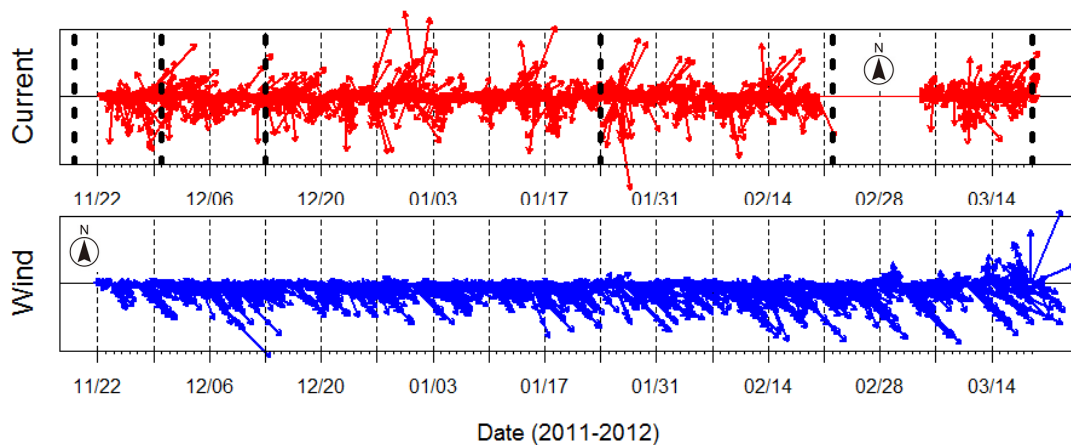


Figure 10. Current and wind conditions in winter season at Rokujo-gata (L1-4). Thick and dotted black lines indicate the sand sampling days which are corresponding to Figure 11 (a) ~ (f).

Sand movement on Rokujo-gata in winter season

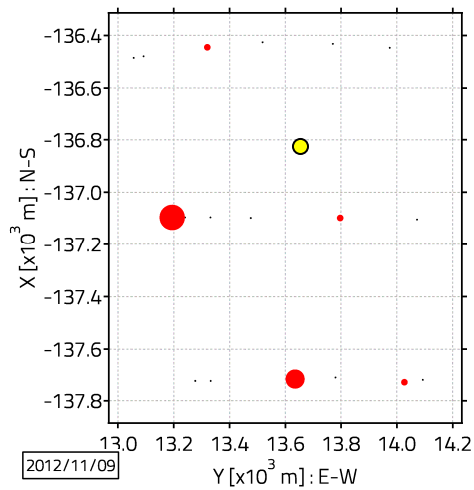
Figure 11 shows the results of color sand counting during 6 months. The size of circle indicates the number of detected color sand grain from 1 to 8. Within 2 months after the placement (November 19, 2012), color sand scattered widely on the tidal flat. Color sand grains were found at many locations, comparatively in the northern area. However it was confirmed that the grains were transported toward the southwestern direction from the input location. Half month later (November 30, 2012), the color sand grains were spread more to the southern. No color grain was found at the location where a lot of the color grains were detected most last time. The southward strong currents were occasionally occurred before November 30, 2012. It is supposed that these strong currents pushed the color sand to the outside of the color sand sampling area. On December 13, 2012, color sand grains were not detected in the southern area, and the total number of the detected color sand grain was reduced every sand sampling on January 24 and February 22, 2013. During this period, strong northward and southward currents were generated frequently. We guessed that a lot of color sand grains were moved actively by these intermittent strong currents, and as a consequence, they are transported to the outside, or moved among the sampling locations. However, on March 19, 2013, color sand grains were found at some locations again. Therefore, it was supposed that the color sand staying in the measurement area (on the tidal flat) exists in no small quantities. Whatever happens, it was demonstrated that the color sand placed in Rokujo-gata was remained there even after 6 months.

CONCLUSIONS

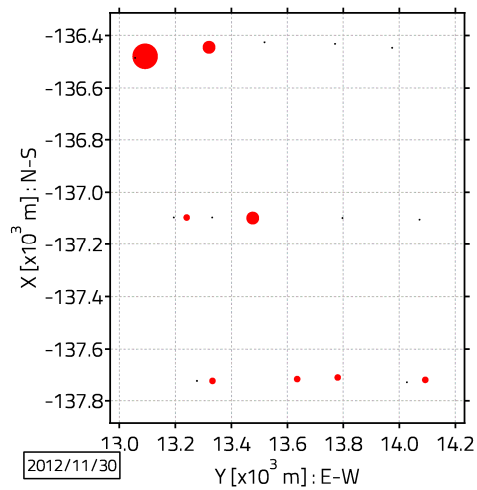
In this research, the following results were obtained.

- The currents on the tidal flat (Rokujo-gata) are strongly affected by wind in the alongshore direction and by tidal oscillation in the cross-shore direction, that is to say, wind-induced currents and tidal currents.
- The southward currents are dominant in winter season on the tidal flat. But the strong northward currents are generated occasionally.
- The color sand grains affected by currents are moved actively in the wide area on the tidal flat.
- However, it was very difficult to find the characteristic pattern of sand movement in this measurement.

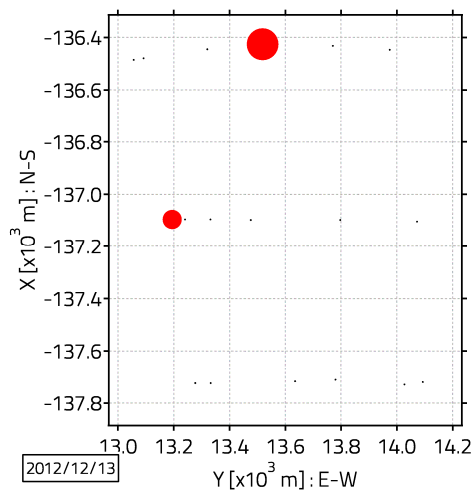
We will mention the problems of the measurement by sand sampling. Sand sampling is a kind of Eulerian investigation. Information which is obtained by the sampling and its analysis will be only at the sampling location. Therefore, it will be impossible to consider the additional information even though there are target traces, such as color sand grain, in the close vicinity of the sampling locations. Consequently, results and their interpretation are strongly depended on the spatial and temporal sampling conditions. Furthermore, it is difficult to estimate the direction of sand movement by this measurement. It will be essential to combine this kind of field survey and numerical simulation to ensure the continuous tracing and its accuracy.



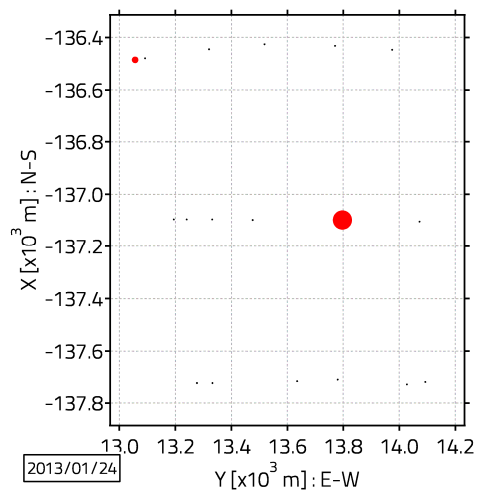
(a) November 19, 2012 (after 2 months)



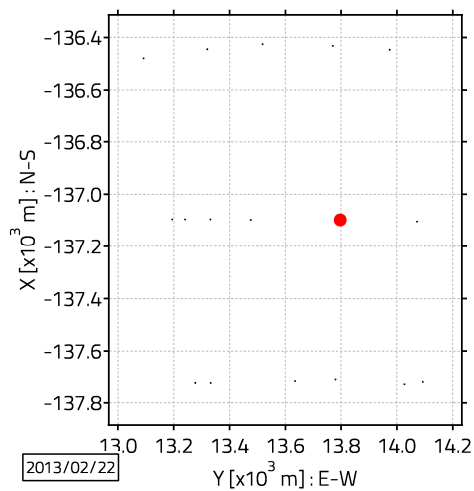
(b) November 30, 2012 (after 2.5 months)



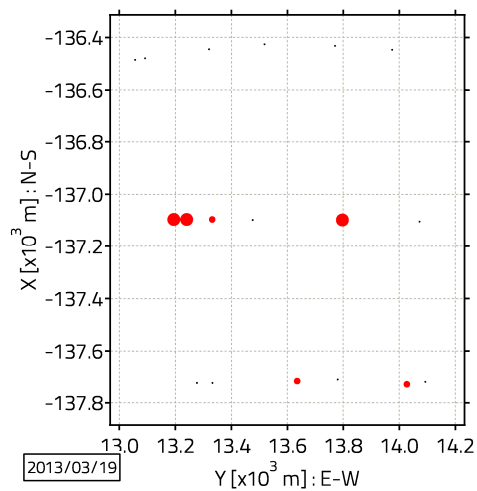
(c) December 13, 2012 (after 3 months)



(d) January 24, 2013 (after 4 months)



(e) February 22, 2013 (after 5 months)



(f) March 19, 2013 (after 6 months)

Figure 11 Results of color sand tracing during 6 months after placement of color sand. Yellow color sand was placed at yellow circle.

ACKNOWLEDGMENTS

This research was partly supported by a research grant from The Mitsui & Co., Ltd. Environment Fund.

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