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Behavior of high turbidity water outflow from Tokyo Bay in summer*

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Abstract: Intensive field observation on the behavior of high turbidity water outflow from Tokyo Bay was carried out in the summer of 1989. High turbidity water intermittently flowed out from the shelf of Tokyo Bay and it sank onto the shelf slope with a speed of about 40m/day. The sinking of high turbidity water onto the shelf slope may be due to the decrease of vertical turbulence above shelf slope. Such intermittent outflow of high turbidity water from Tokyo Bay plays very important role in the material transport from the costal sea to the open sea.

1. Introduction

It is well known that particles play very important role in the material transport in the coastal sea (e. g. SAKAMOTO, 1985; YANAGI, 1990). Particles in the coastal sea form the high turbidity water (which is reffered to as H. T. W. in this paper) being defined as the water with low beam-transmittancy. KAWANA and TANIMOTO (1984) revealed the characteristics of bottom H. T. W. in the Seto Inland Sea and MATSUIKE *et al.* (1986) observed that H. T. W. in Tokyo Bay flowed out through the upper layer near Futtsu Point in summer. On the other hand, YANAGI *et al.* (1989a) revealed that H. T. W in the surface layer of Tokyo Bay flowed out into the sub-surface layer of the slope water in winter due to the thermohaline front which is generated at the mouth of Tokyo Bay. YANAGI *et al.* (1989b) also revealed that H. T. W. in the surface layer and in the bottom layer of Tokyo Bay flowed out into the surface layer and the intermediate layer of slope water, respectively, when the Kuroshio front approaches to the coast in summer. However, the detailed behavior of H. T.W. after it flows out into the slope water is not clarified yet.

In this paper, we will reveal the detailed behavior of H. T. W. in the slope water at the mouth of Tokyo Bay in summer from the intensive field observation.

2. Field observation

Intensive field observation was carried out

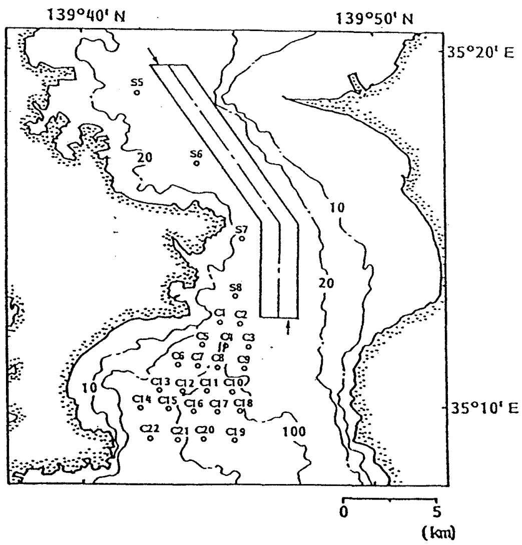

Fig. 1. Observation stations by R.V. Tansei-Maru in Tokyo Bay. Broken line represents the depth contour and numbers show the depth in meters. Arrows show the decided direction for steaming the sea route.

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at the mouth of Tokyo Bay (Fig. 1) by R. V. Tansei-Maru of the Ocean Research Institute, University of Tokyo, from 25 to 26 August 1989. The observation is limited to the western part of the bay mouth in Tokyo Bay because the eastern part is too shallow for the vessel to enter and the central part is occupied by a sea route and it is therefore prohibited to carry out a detailed observation by traffic regulation.

The vertical profiles of water temperature, salinity, dissolved oxygen, and beam-transmittance (light-pass of 1 m with the wave length of 486 nm) were observed as quickly as possible with the use of the OCTOPUS system (Ishimaru *et al.*, 1984). The OCTOPUS observations were carried out twice at all stations in the same manner on 25 and 26 August in 1989 (moon age is 23.5 and 24.5, respectively; neap tide) in order to detect the day-to-day variation in H. T. W. in the slope water. The observations were carried out from 6:30 in the morning till 17:30 in the evening on both days. The flood tidal current appears from the morning till about 16:00 and the ebb tidal current appears in the evening on both days.

3. Results

Figure 2 shows the day-to-day variations in vertical distributions of water temperature, salinity and density around the mouth of Tokyo Bay from 25 to 26 August in 1989. The moderate-mixed estuary type of density stratification was developed and there was no remarkable change in distributions of water temperature and density on both days. There was a little difference in the vertical distributions of salinity, i.e. the spreading of coastal (salinity is lower than 31) surface water with the thickness of about 20 m from the inner bay to Sta.S7 and the intrusion of salty (salinity is more than 34) bottom water with the thickness of about 10 m from the shelf slope to the inner bay on 26 August. Such change in the vertical distribution of salinity sug-

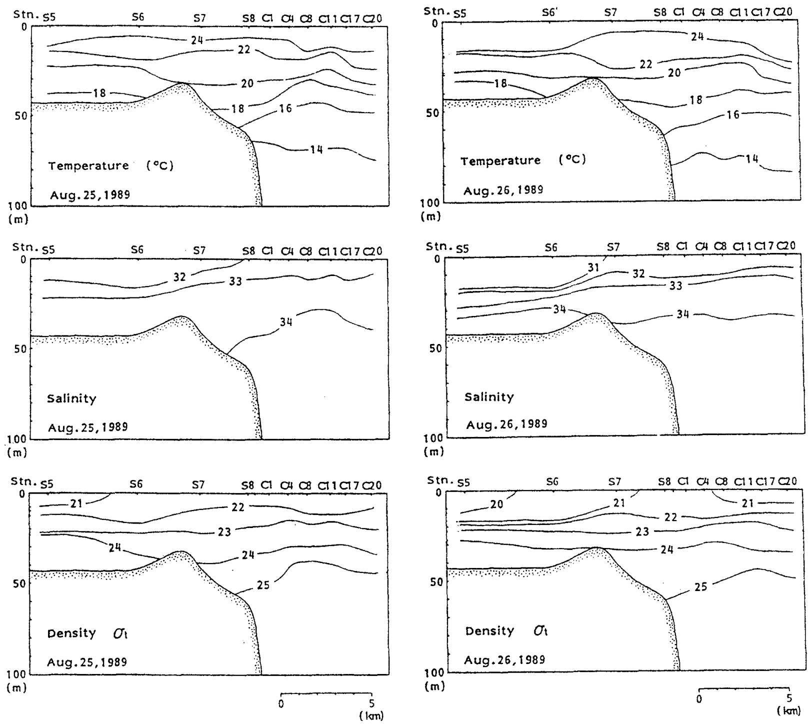


Fig. 2. Day-to-day variation in vertical distributions of water temperature, salinity and density at the mouth of Tokyo Bay from 25 to 26 August 1989.

gests that the vertical estuarine circulation developed from 25 to 26 August.

Figure 3 shows the day-to-day variation in vertical distribution of transmittancy around the mouth of Tokyo Bay from 25 to 26 August in 1989. The contour line of 20% in the surface layer spreads from Sta.S8 to all the observed area and that of 50% in the bottom layer from Sta.S7 to the middle point between Sta. S 5 and Sta. S 6 from 25 to 26 August. On the other hand, H. T. W. whose transmittancy is lower than 55% flows out into to subsurface layer (25m depth) above the shelf slope at Stas C4-C11 like a nose with the thickness of about 10m on 25 August. The local minimum transmittancy exists at 65m depth like a nose with the thickness of about 15m on 26 August. The dissolved and particulate materials are said to be easily spreading on the isopycnal surface. However, the isopycnal surface on 26 August does not change from that on 25 August from Fig. 2 while the vertical distributions of transmittancy drastically change on both days as shown in Fig. 3.

The spreading of 20% contour line in the serface layer and 50% one in the bottom layer of Tokyo Bay shown in Fig. 3 may be due to

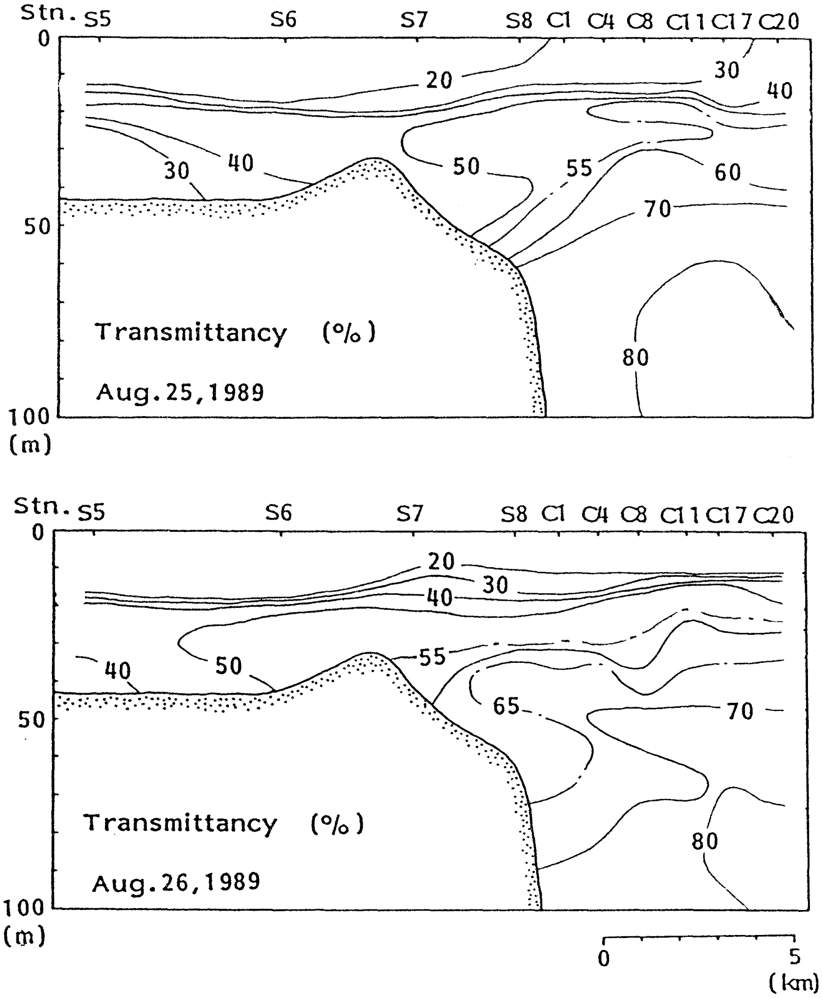
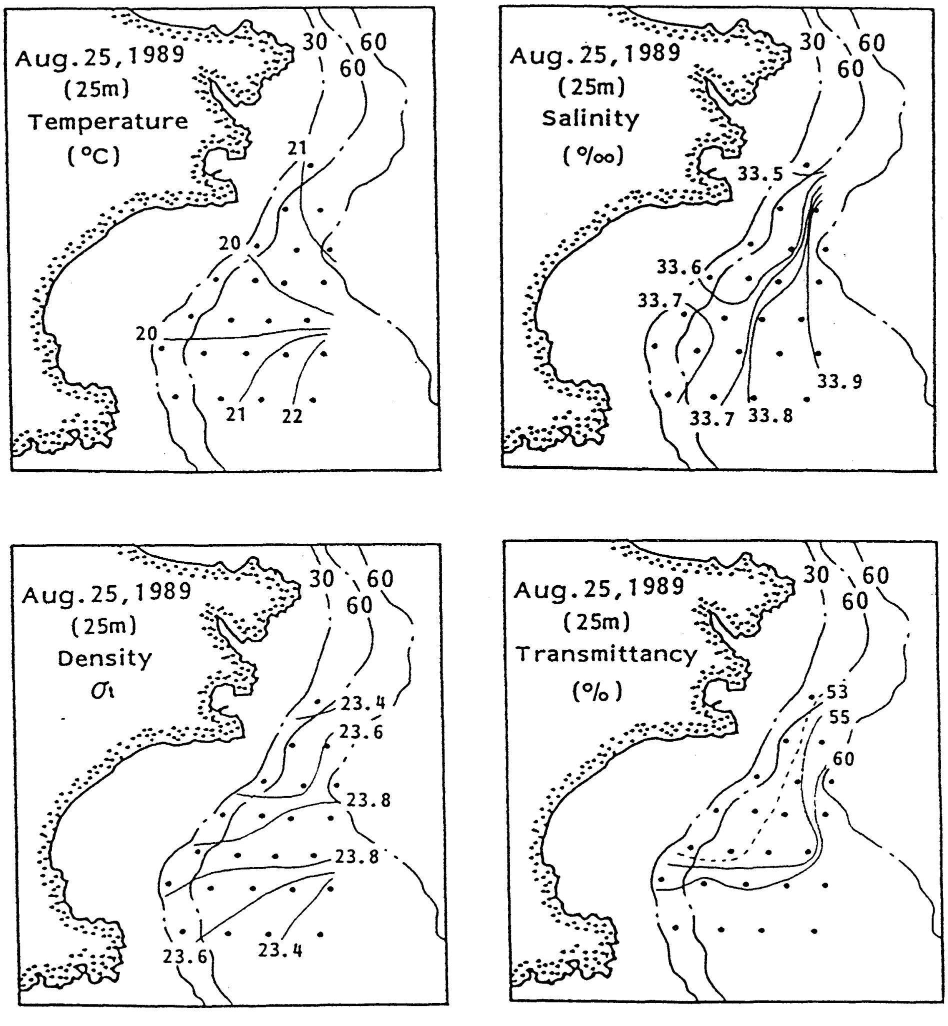
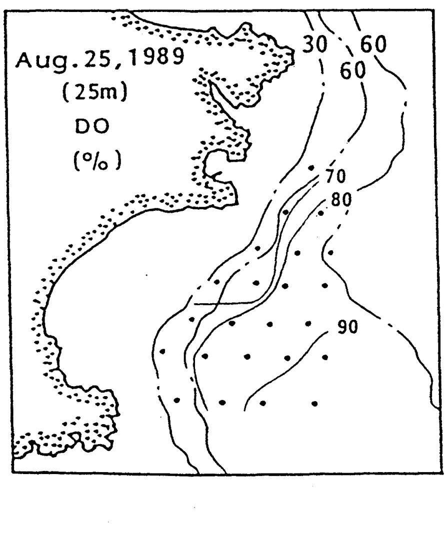
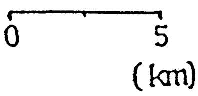


Fig. 3. Day-to-day variation in vertical distribution of beam-transmittancy at the mouth of Tokyo Bay from 25 to 26 August 1989.

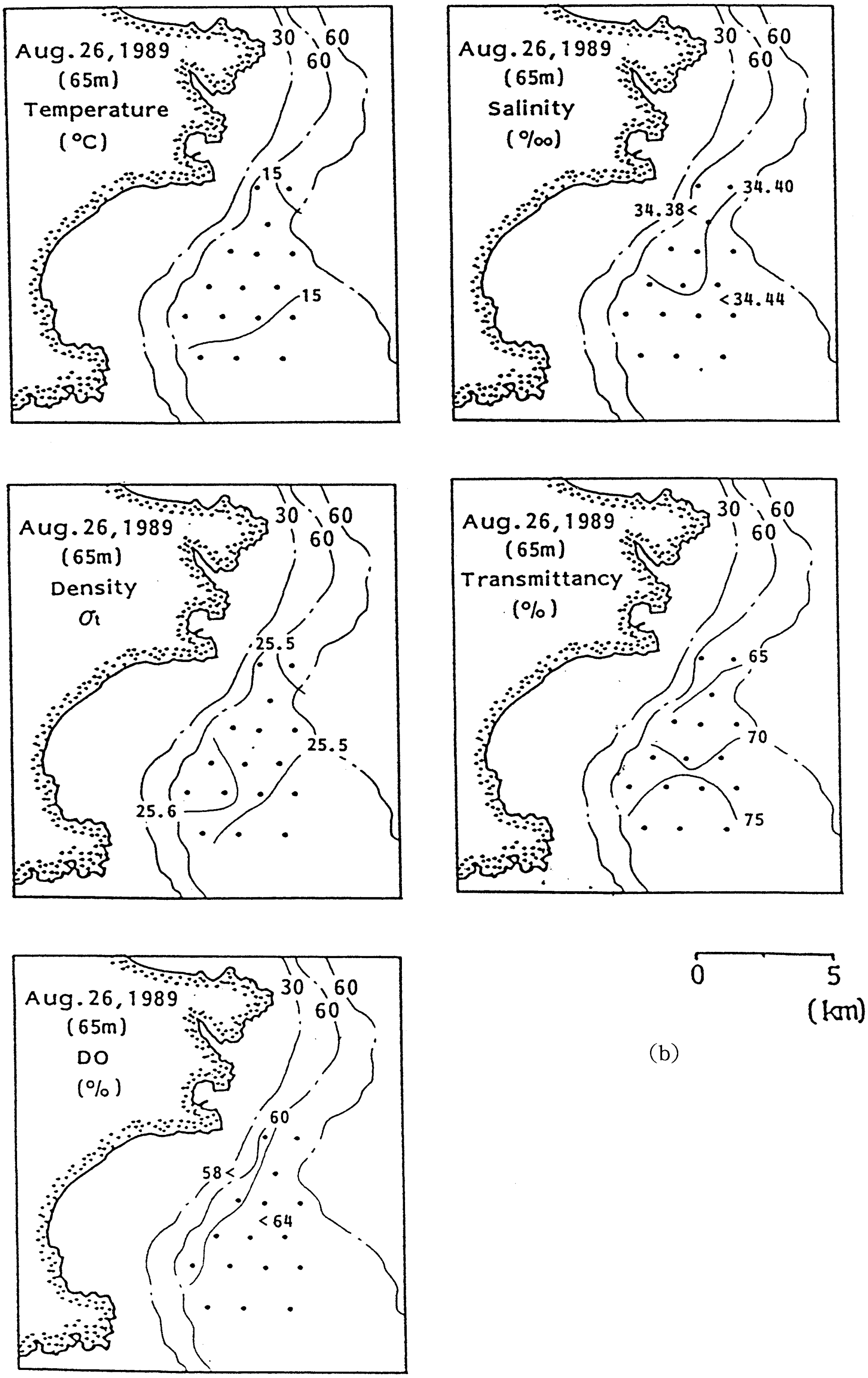






(a)

Fig. 4. Horizontal distributions of water temperature, salinity, density, beam-transmittancy and dissolved oxygen at 25 m depth on 25 August (a) and those at 65 m depth on 26 August (b) in 1989.


Aug.26,1989
(65m)
Temperature
(°C)
30
60
60
15
15
Aug.26,1989
(65m)
Salinity
(‰)
30
60
60
34.40
34.38<
<34.44
Aug.26,1989
(65m)
Density
σt
30
60
60
25.5
25.5
25.6
Aug.26,1989
(65m)
Transmittancy
(%)
30
60
60
65
70
75
Aug.26,1989
(65m)
DO
(%)
30
60
60
60
58<
<64
0
5
(km)

(b)

the development of vertical estuarine circulation. On the other hand, the nose-like spreading of 65 and 70% contour lines from 50 to 80m depth on 26 August shown in Fig. 3 may coincide with that of 55% one from 20 to 30m depth on 25 August. These results may suggest that the outflowed H. T. W. at 25m depth on 25 August sank downward at the speed of 40m/day (4.6×10^{-2}cm/sec) increasing its beam-transmittancy and thickness due to the mixing with the surrounding water from 25 to 26 August.

The horizontal distribution of outflowed H. T. W. at 25m depth on 25 August is shown in Fig. 4(a) with those of water temperature, salinity, density and dissolved oxygen. The water with lower transmittancy is observed along the north-western edge of the shelf slope and this means that H. T. W. outflows from Tokyo Bay with the coast to the right hand. The horizontal distribution of lower dissolved oxygen well coincides to that of lower transmittancy and this suggests that dissolved oxygen has been consumed to decompose the organic materials in H. T. W. In the same way, the horizontal distribution of sinking H. T. W. at 65m depth on 26 August is shown in Fig. 4(b) with those of water temperature, salinity, density and dissolved oxygen. The water with lower transmittancy is limited at the north-western edge of the shlf slope.

4. Discussions

The sinking speed of H. T. W. is decided by the sinking speed of each particle and the vertical turbulence. Figure 3 suggests that H. T. W., which does not sink on the shelf, sinks onto the shelf slope. This may be due to the decrease of vertical turbulence above the shelf slope because the sinking speed of each particle does not chage. The difference of vertical turbulence between the shelf and above the shelf slope may be due to the difference of the tidal current velocity, which is the primary origin of vertical turbulence at the mouth of Tokyo Bay. The tidal current and the vertical turbulence are large and the resulting sinking speed of H. T. W. is small above the shelf but those are small and the resulting sinking speed of H. T. W. is large above the shelf slope because the cross area of slope is smaller than that of the shelf slope.

We will carry out the sediment trap experiment to clarify quantitatively the behavior of H. T. W. at the mouth of Tokyo Bay in the near future.

Acknowledgments

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夏季東京湾から流出した高濁度水の挙動

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要旨：1989 年夏季，東京湾から流出した高濁度水の挙動を明らかにする精密観測を行った。東京湾から間欠的に流出した高濁度水は陸棚斜面上を 40m/day の速さで沈降した，これは陸棚上と陸棚斜面上での鉛直乱れの強さの違いに起因していると思われる。