東シナ海における高濁度域

誌名	西海区水産研究所研究報告
ISSN	0582415X
著者	田中, 勝久 宇野, 史郎 坂本, 亘 代田, 昭彦
巻/号	64号
掲載ページ	p. 13-23
発行年月	1987年3月

Turbid Water Area in the East China Sea

Katsuhisa TANAKA*, Shiroh UNO*, Wataru SAKAMOTO**
and Akihiko SHIROTA***

Distribution of suspended matter and its chemical composition were investigated in the East China Sea, in three different seasons. Along the 31°30′N line, higher values of turbidity were consistently observed in the coastal area west of 123°E and in the central part of northern East China Sea (124°30′E-126°E). Turbid water was restricted below the seasonal thermocline in July, in which inorganic matter (mainly clay particles) was the major constituent. In November and April, suspended matter in the shallow part of the Continental Shelf was mixed vertically, and a front of turbidity was formed at 126°E-127°E. The turbid area in the northern East China Sea (south-west of Cheju Island) is located in an area of very fine bottom sediment. The suspended and bottom sediment in this area were supposed to be enclosed by a cyclonic eddy. A belt of low turbidity on the surface water of the Kuroshio Branch was observed in the Chinese coastal area.

Large rivers in China, such as the Yangtze River carry large quantities of suspended matter into the East China Sea[1], and then it makes a turbid water area along the Chinese coast[2]. Recently, distributions of suspended matter and its transportation were investigated in the offshore area of the Yangtze River[3] and on the relatively shallower part of the Continental Shelf[4]. However, the large-scale distribution of the suspended matter in the East China Sea and its seasonal change were not known well.

In the present study, we describe 1) spatial change of the turbidity or suspended matter distribution in the three different seasons 2) organic carbon content in the suspended matter in the East China Sea, especially on the 31°30′N line transection.

This work was partially financed by the Science and Technology Agency as a part of the Kuroshio Exploitation and Utilization Research (KER) programme.

昭和62年1月9日受理 (Recieved January 9, 1987)
西海区水産研究所業績第430号 (Contributions from the Seikai Regional Fisheries Research Laboratory, No. 430)
*Seikai Regional Fisheries Research Laboratory, Kokubu-machi, Nagasaki 850, Japan (田中勝久・宇野史郎，西海区水産研究所 〒850 長崎市国分町49)
**Faculty of Agriculture, Kyoto University, Kyoto 606, Japan (坂本亘，京都大学農学部 〒606 京都市左京区北白川追分町)
***Present address: Nansei Regional Fisheries Research Laboratory, Ōno-chō, Hiroshima-ken 739-04, Japan (代田昭彦，南西海区水産研究所 〒739-04 広島県佐伯郡大野町)

Method

The oceanographic observations of the East China Sea were done three times by R. V. Yoko Maru. The first cruise was in July 1980, and the second in November 1983. In these two cruises observation points were on the 31°30′N line from 123°E to 127°E. The third cruise was in April 1984 on the 31°30′N line and southern area of this line. The locations of the survey points discussed in this paper are shown in Fig. 1.

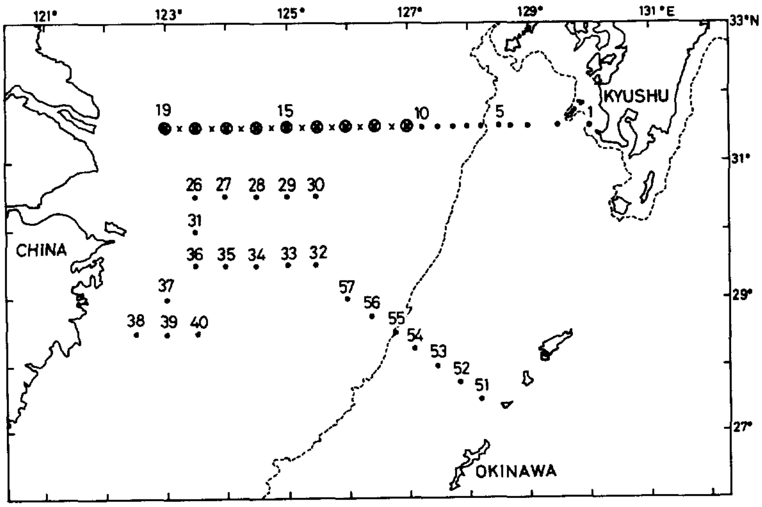

Fig. 1. Positions of observations and sampling stations in the East China Sea; Open circles in July 1980, crosses in November 1983 and small points in April 1984.

In the first cruise, water samples were taken by 10 *l* Niskin bottles and then passed through 265 μm mesh (GG54) net to remove large size zooplankton. 2-5 *l* of the water was passed through a pair of Wattman GF/C filters settled on a funnel to measure particulate organic carbon (POC), and through a preweighed single filter to determine dry weight of total suspended matter (TSM). GF/C filters described above were precombusted for 2 hours at 500℃. The samples were stored in a deep freezer at −20℃ in the dark prior to analyses.

In the laboratory, the filters for POC measurement were preliminarily dried at 60℃ for 12 hours. Then they were settled in a desiccator with concentrated hydrochloric acid to remove carbonate carbon. Each of the two layered filters was analyzed separately. The value of the second filter was substracted from the top filter value as a filter blank[5]. POC was measured by dry combustion method at 880℃ with a CHN analyzer (Yanagimoto CHN Corder MT-2). The presumed ac-

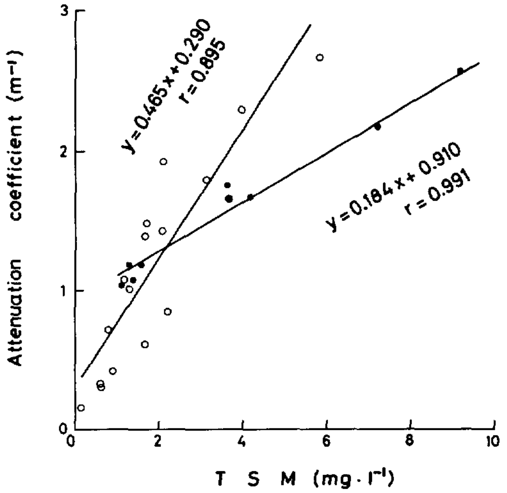

Fig. 2. Relations between beam attenuation coefficient α (m^{-1}) and dry weight of total suspended matter ($mg \cdot l^{-1}$) ; Open circles with XMS transmissometer and solid circles with NPL-2.

curacy of POC, determined by the maximum deviation among the triplicate samples of the study area, were $\pm 9.1 \mu g \cdot l^{-1}$ [6].

In the second and third cruise, the turbidity was measured by two kinds of beam attenuation meters. The first is by NPL-2 (NDK Co., Ltd.), which has 0.5 m pass length and centroidal wavelength at 677 nm. The other is by XMS transmissometer (Martek Instruments Inc.), which has 1 m path length and centroidal wavelength at 486 nm. On both apparatus, beam attenuation coefficient as α (m^{-1}) versus TSM ($mg \cdot l^{-1}$) was initially confirmed to be related in each straight line (Fig. 2).

Results and discussion

1. Cruise in July 1980

Vertical distribution of temperature, salinity, dry weight of total suspended matter (TSM), POC and the ratio of POC/TSM along the 31°30′N line in July 1980 are shown in Fig. 3. A seasonal thermocline is found at about 10 m depth and the water of higher salinity (S>32‰) lies below the thermocline. Above the thermocline west of 125°E, the POC/TSM values were higher than 0.3 suggesting the predominance of organic particles.

At 125°E and 123°E, higher values of TSM were observed below the thermocline where TSM exceed 5 $mg \cdot l^{-1}$ and the POC/TSM was lower than 0.03 at the bottom water. Such higher concentration of suspended matter in the bottom layer of the Continental Coastal Water was also observed by Asaoka[7] and Matsuike *et al.*[3]

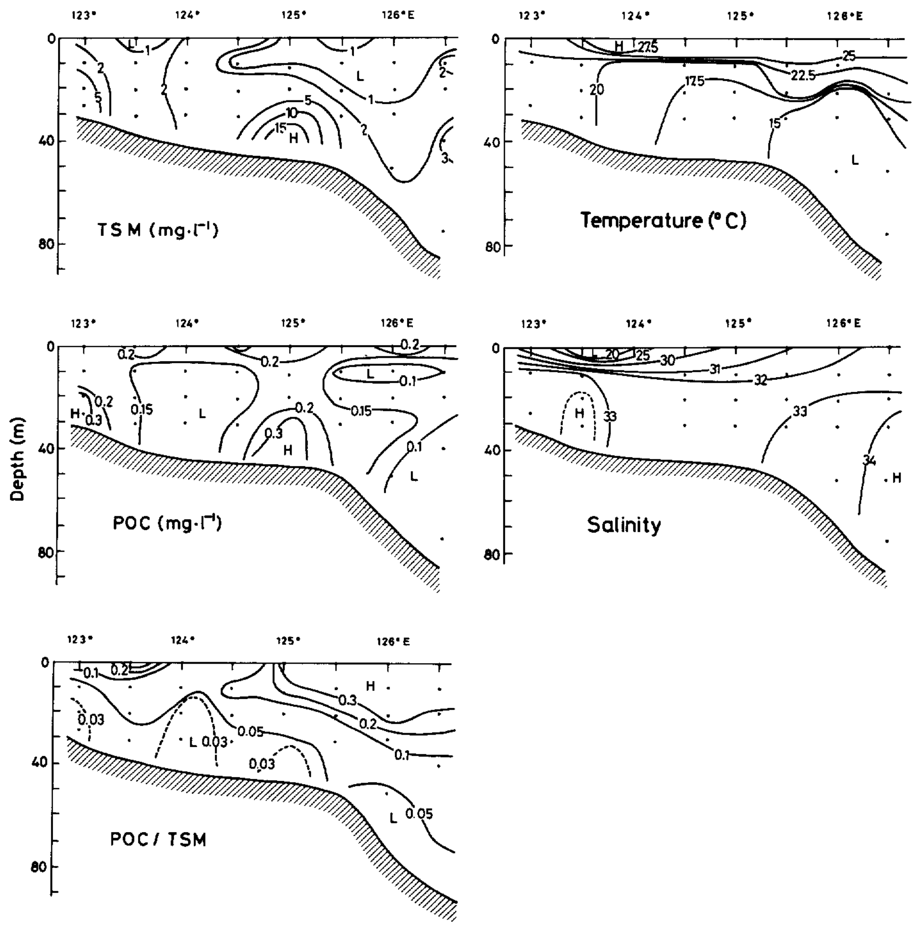

Fig. 3. Latitudinal sections of water parameters along 31°30′N line in July 1980.

The low POC/TSM ratio observed below the thermocline shows the predominance of inorganic particles, especially near the bottom of the Continental Shelf. In general, the mass of particulate organic matter (POM) is estimated by doubling the value of POC[8]. Then the fraction of inorganic materials would reach more than 90 % of total suspended matter near the bottom. These results suggest that the increase of TSM value below the thermocline was caused by that of the clay particles. The predominance of the clay particles below thermocline was already recognized by microscopic observations[6].

Surface water of the lowest salinity (S<20‰) and of the highest temperature (T>27.5°C) was observed on the surface water at 123°30′E. This fresh water discharge corresponds to the plume-like structure observed in June 1980 by BEARDSLEY *et al.*[9]. The higher value of POC/TSM and lower value of TSM at the surface water with considerably low salinity suggest that clay particles carried by the river are not probably transported with the water above the thermocline but are sedimented to the bottom water. However, below the thermocline, the values of TSM was low as compared to the other stations with slightly higher salinity (S>33.25‰). A large proportion of clay particles may be sedimented near the coast.

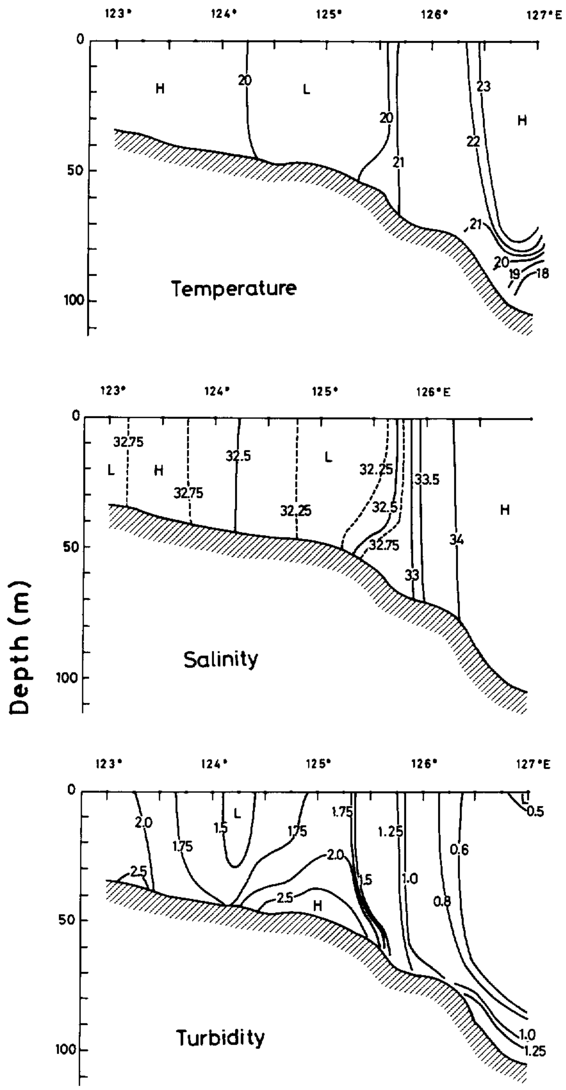

Fig. 4. Vertical distribution of temperature ℃ (upper), salinity ‰ (middle) and turbidity m^{-1} (lower) along 31°30′N line in November 1983.

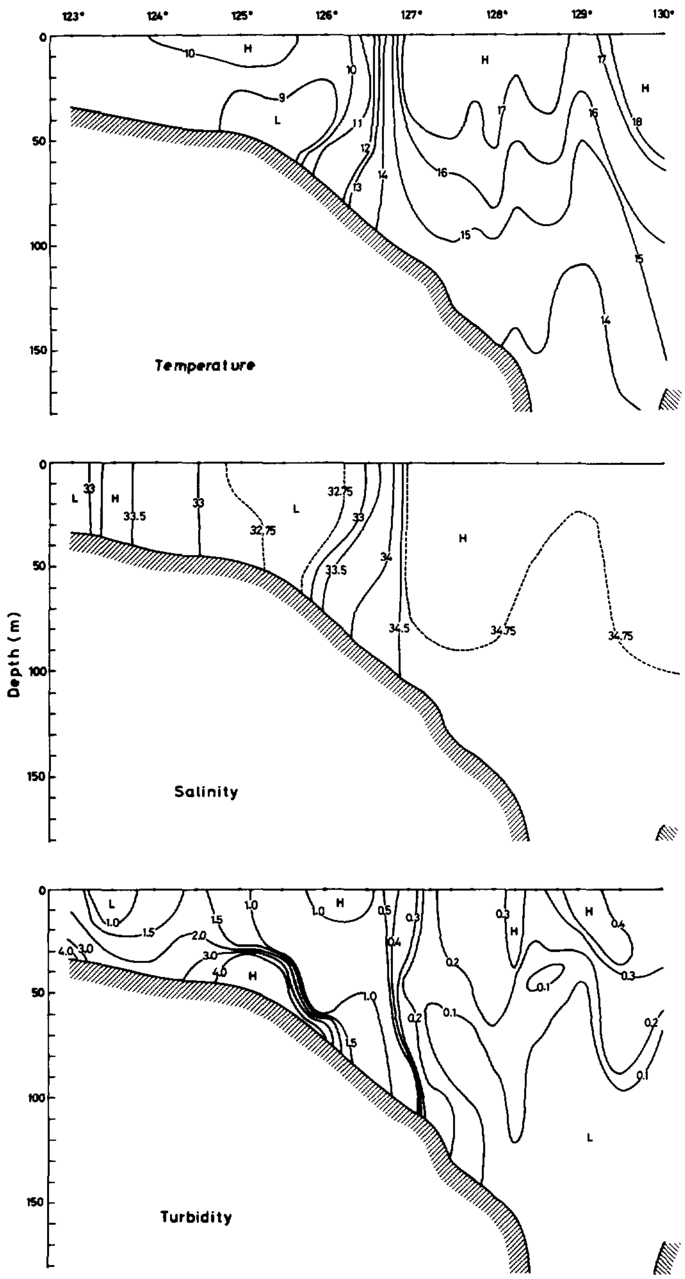

Fig. 5. Vertical distribution of temperature °C (upper), salinity ‰ (middle) and turbidity m^{-1} (lower) along 31°30′N line in April 1984.

2. Cruise in November 1983

Fig. 4, shows vertical distributions of temperature, salinity and turbidity in the line of 31°30′N in November 1983. Salinity and temperature stratification had almost disappeared by vertical mixing on the Continental Shelf, and a clear front between the Continental Coastal Water and the Tsushima Warm Current Water was observed between 125°30′E and 126°E judging from the vertical isohaloic lines. Across the front, the salinity in the surface water changed from 32.1‰ to 33.8‰.

Higher turbidity values in the bottom was found at two areas, and this tendency was similar to that of July 1980. However, the surface value at west of 126°E was rather higher than that in July 1980. The turbidity distribution on the surface also showed a front at about 126°E. Maximum salinity ($S>33.75$‰) associated with lower turbidity was again observed at 123°30′E.

3. Cruise in April 1984.

1) 31°30′N Section

Vertical distribution of water temperature and salinity in April 1984 show that the water is just in the transitional stage from vertical convection period to stable stratification period (Fig. 5). Stratification of water temperature was very weak and that of salinity was scarcely recognized on the Continental Coastal Water. This water formed a distinct front against the Tsushima Warm Current Water between 126°E and 127°E. Across the front, surface salinity, temperature and turbidity changed from 32.75‰ to 34.75‰, 10°C to 17°C, and $1.0\,m^{-1}$ to $0.3\,m^{-1}$, respectively (Fig. 5).

Turbid water in the bottom was found between 124°30′E and 126°E and at 123°E, resembling the results of July 1980 and Nov. 1983. Moreover, lower turbidity water with higher salinity at 123°30′E was observed again. Bottom turbid water centered at 125°E, 31°30′N was consistently observed in our investigations on three different seasons.

In the Chinese coastal area west of 124°30′E, the turbidity decreased gradually upwards from the bottom, while vertical distribution of σ_t showed little change (Fig. 6). These observations suggest that the suspended matter in this region is mainly supplied from the bottom water by convection, influencing up to the water surface. On the other hand, there was a sharp gradient of turbidity in the central part of the East China Sea (124°30′E-126°E), coinciding with that of σ_t (Fig. 6). Below this picnocline, turbidity increased drastically on approaching the bottom. This phenomenon indicates that the mixing of the bottom turbid water with surface water was restricted by the picnocline, which was already observed by Matsuike *et al.*[3] in the Chinese coastal region off the Yangtze River.

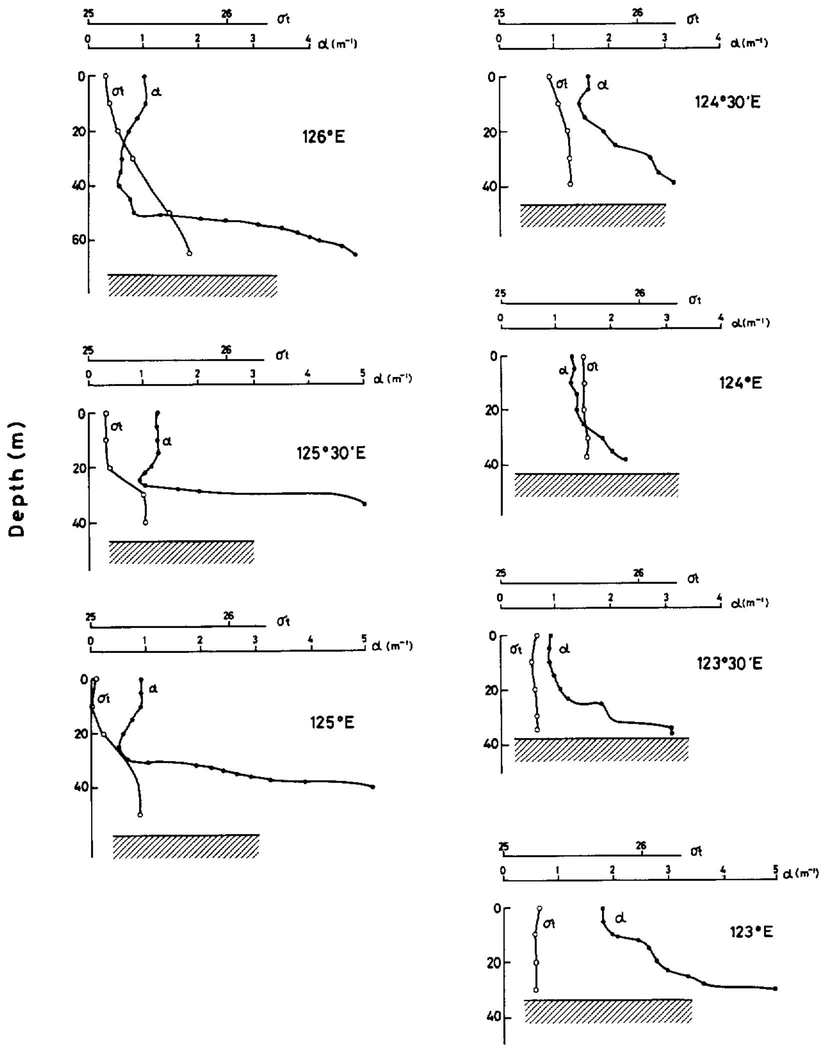

Fig. 6. Vertical distributon of turbidity (α) and σ_t at stations west of 126°E on 31°30'N line in April 1984.

2) Horizontal Distrinution

Horizontal distribution of salinity and turbidity on the surface and bottom water are shown in Fig. 7. In general, higher turbidity values were found in the bottom water and their distribution pattern was closely related to the current system and the features of bottom sediment.

There are three separate turbid water areas in the bottom water of lower salinity (S<33.5‰), namely south-west of Cheju Island (124°E-126°E, 30°30'N-31°30'N), off the south coast of China and off the Yangtze River mouth.

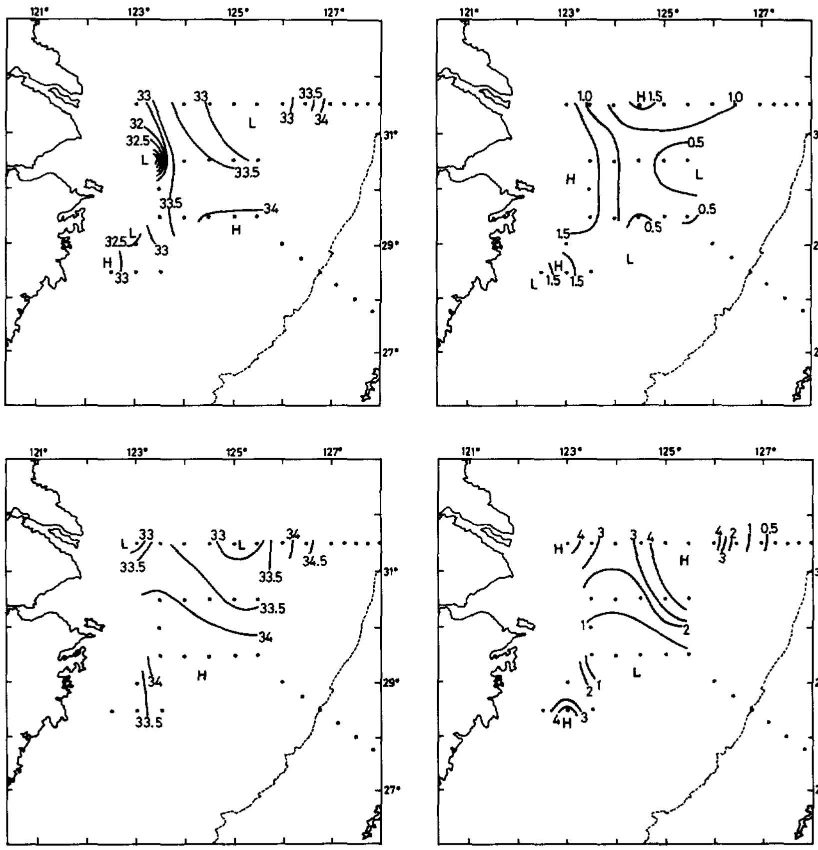

Fig. 7. Horizontal distribution of salinity ‰ (left) and turbidity m^{-1} (right) at the surface (upper) and bottom (lower) water in the East China Sea observed in April 1984.

In south-west of Cheju Island and off the south coast of China, the bottom sediments are mainly composed of fine mud or clay size particles[10,11]. In these regions, intense tidal current was measured near the bottom; up to 0.4 $m \cdot s^{-1}$ at 31°30′N, 125°40′E and up to 0.5 $m \cdot s^{-1}$ at 31°05′N, 123°50′E[12]. Further, a drastic change of turbidity was observed after vigorous wind at 31°30′N, 125°30′E (TANAKA *et al.* unpublished). The turbid water in these area can be postulated to be derived from the resuspension of the bottom sediments caused by strong wind or tidal current. On the other hand, the bottom sediment is covered by sand at the station off the Yangtze River mouth[10]. Suspended matter discharge from the Yangtze River may directly influence the turbidity in this region. INOUE[11] and ASAOKA and MORIYASU[13] suggested a counter-clockwise bottom current in the northern East China Sea. MAO *et al.*[14] pointed out the permanent existence of a cyclonic eddy centered at about 31°30′N, 125°30′E which correspond to the central position of the turbid water in south-west of Cheju Island and that of the isolated mud sediment[11]. The suspended and bottom sediment may circulate and be enclosed in this current system.

The Kuroshio Branch (Taiwan Warm Current) was recognized by its higher salinity in the Chinese coastal area which flows from the east of Taiwan towards the north[15]. The bottom salinity south west of the study area was higher than 33.5‰ stretching north to 31°30′N at 123°30′E. This corresponds to surface high salinity (S>33.5‰) and low turbidity (α<1.0 m^{-1}), which was observed on the line from 31°30′N, 123°30′E to 30°30′N, 124°E. This clean belt off the coast of China was also reported by the observations with some satellite visible images[2]. The consistent existence of maximum salinity assaciated with lower turbidity at 31°30′N, 123°30′E on the previous two cruises may have been caused by the intrusion of this body of clean water of Kuroshio Branch.

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東シナ海における高濁度域

田中　勝久・宇野　史郎・坂本　亘・代田　昭彦

抄　録

著者らは1980年7月，1983年11月，1984年4月の3回にわたり，東シナ海の北緯31°30′定線とその南方域において懸濁物の量的，質的な検討を行った．定線においては，東経123°以西の大陸沿岸寄りと，東経124°30′より126°までの東シナ海中央部の二ケ所に毎回高濁度域が認められた．後者は特に顕著であり，7月には水温躍層以下で，無機物粒子（粘土鉱物主体）によって構成される高濁度水が形成され，また4月と11月には鉛直混合により高濁度水の上層への輸送が認められ，清澄な水とのフロントが東経126°から127°において形成された．定線中央部の高濁度域は細かい底質域に当たり，この周辺域の懸濁物及び底泥は渦流によって滞留しているものと思われる．これらの高濁度域に対し，低濁度帯は大陸沿岸域の黒潮分派表層において認められた．