Current Measurements with Surface and Subsurface Drifters*

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Abstract: An examination of behaviors of a subsurface drogue and a subsequent examination of current measurement with a drifter comprising the drogue as its important part are made in the channel between Oshima and Izu Peninsula. The drogue submerged to the anticipated depth of 300 m within 10 minutes after launching. Since then the drogue kept its depth and operated normally. From the comparison with the velocity measurement by the use of a currentmeter moored at a station in the vicinity of the drifter’s track, it is verified that the drifter’s motion well reflects the motion of a water parcel around the drogue.

1. Introduction

For exploring dynamical mechanisms of oceanic phenomena, a knowledge on the associated velocity field is requisite. Measurements of velocity field in the ocean have been a subject not easy to be settled satisfactorily. Recently, long-term measurements of velocity have been successfully made by the use of a moored array of currentmeters. But in a strong current region where the water velocity exceeds 2 knots, this means is not applicable mainly because of the lack of thin wire strong enough to be safe from a large tension produced for sustaining the array nearly vertically against a drag force of water.

The Lagrangian method of velocity measurement with drifters seems to provide one of practical means to approach this problem. For tracking a subsurface current by the use of a drifter, the drifter should be equipped with a subsurface drogue. Various kinds of drogue were examined by various investigators (Neumann, 1968). But, behaviors of these drogues were not treated well. Recent developments in positioning of drifters by the help of satellites enable a long-term tracking of drifters. Under such a circumstance, systematic studies of drogue technique have actively been made recently (Kinder et al., 1975; Molinari and Kirwan, 1975; Kirwan and McNally, 1975).

For the purpose of delineating current patterns in the shallow and intermediate layers of the meandering Kuroshio near the Izu Ridge, the tracking of drifters were tried by the authors from the R.V. Hakuo-maru in early autumn, 1975. Four drifters were used to follow currents at 0 m, 200 m, 500 m and 700 m layers. The drifters for 200 m, 500 m and 700 m layers could, however, only be tracked for 18, 4 and 15 hours, respectively, because of submergence of the drifters. Subsurface drogues used in the drifters were sea anchors of parachute type. Although behaviors of these subsurface drogues were not made clear, the submergence of the drifters is supposed to be brought about by the unanticipated descending motion of the drogues.

On following a suggestion by A. Bervus (Centre Oceanologique de Bretagne, C.N.E.X. O.) a canvas of rectangular window-shade type was adopted as a drogue instead of a sea anchor of parachute type. With an aim of examining behaviors of the new drogue, an experiment was made in a channel between Oshima and Izu Peninsula in May, 1976. The drogue was submerged to the depth of about 300 m and the tracking was carried out from the R.V. Tansei-maru. An Aanderaa currentmeter equipped with depth, temperature and salinity sensors was attached to the drogue. The main purpose was to obtain informations on the velocity of water relative to that of the drogue together with informations on the change
vertical motions delivered from the surface buoy which was under the direct influence of surface waves. For giving a help to tracking, a radar-transponder buoy and a light-beacon buoy were attached to the surface buoy as in the drifter for the surface layer. The subsurface drogue was a rectangular sheet 3 m broad, 15 m long and 0.65 mm thick. The sheet strength for stretching was 140 kg per 3 cm breadth. In order to keep the sheet unfolded, stainless steel pipes of 2.5 cm in outer diameter were sewn on along the upper and lower edges of the sheet, and to its lower edge a 100 kg weight was attached through a bridle.

The launching of these two drifters were made on 9th of May. Since then, the tracking of the two drifters was carried out by the help of a radar at the time interval of 20 minutes on referring to landmarks except for a period dedicated to the mooring of currentmeters and pressure gauges. The maximum distance at which the radar transponder is observable from the vessel is about 10 miles under the moderate sea condition. The distance between the two drifters increased with time and about one day after the distance reached 20 km. At 14h 45m on 10th of May the drifter for the surface layer was retrieved first and relaunched near the drifter for the subsurface layer. The latter drifter was then also retrieved on board for examining the working conditions of the subsurface drogue and for attaching an Aanderaa currentmeter just above the drogue. Through
the examination it was verified that the drogue worked well without being twisted or folded at the subsurface layer. It was seen that an expanding of the drogue at the sea surface prior to its descending to the subsurface layer resulted in the successful operation of the drogue at the subsurface layer (Photo 1). Throughout the period of experiment starting 13h 00m on 9th of May to 10h 00m on 11th of May, the wind speed was less than 2 in Beaufort scale.

3. Results

3.1. The analysis of drifter motions

By Kirwan et al. (1975), the motion of a drifter which consists essentially of two drag bodies $D_1$ and $D_2$ satisfies the following relation:

$$\rho_1 C_{D1} A_1 |V_1 - V| (V_1 - V) + \rho_2 C_{D2} A_2 |V_2 - V| (V_2 - V) = 0$$

where $V$ is the velocity of the drifter, $V_1$ and $V_2$ the velocities of fluids around $D_1$ and $D_2$, $A_1$ and $A_2$ the effective areas of $D_1$ and $D_2$ against the flows around them, $\rho_1$ and $\rho_2$ the densities of fluid around $D_1$ and $D_2$. $C_{D1}$ and $C_{D2}$ the drag coefficients of $D_1$ and $D_2$.

The motion of the drifter for the surface layer is governed by the air drag working on the surface floats and the water drag on the subsurface part of the drifter. At 00h 00m on May 11th, the wind speed $V_1 = 2$ m s$^{-1}$ in the southeast direction, namely on referring to a rectangular coordinate system with $x$-axis in the east-west direction and $y$-axis in the north-south direction, $V_1 = (-140$ cm s$^{-1}$, $140$ cm s$^{-1}$) approximately. From the tracking of the drogue, $V = (32$ cm s$^{-1}$, $50$ cm s$^{-1}$). On taking $A_1 = A_2 = 0.5$ m$^2$, $\rho_1 = 1.2 \times 10^3$ g cm$^{-3}$, $\rho_2 = 1$ g cm$^{-3}$ and $C_{D1} = C_{D2} = 1$ (for cylinder-type body such as $D_1$ and $D_2$), then we have $V_2 = (36.6$ cm s$^{-1}$, $45.6$ cm s$^{-1}$). Thus, the speed of water motion relative to this drifter is estimated to be 6.4 cm s$^{-1}$ which is of a comparable order of magnitude to the accuracy of 5 cm s$^{-1}$ in velocity estimation through the tracking of drifters with a radar.

The drifter for the subsurface layer is treated as a two drag-body system in the water, because both the wind drag on the surface buoy and the water drag on the drogue line can be neglected. For analysing the motion of this drifter the equation mentioned above can be used in this case, too. From measurements made at 00h 00m on May 11th, $V = (-15$ cm s$^{-1}$, $-3$ cm s$^{-1}$) and $V_1 = (36.6$ cm s$^{-1}$, $45.6$ cm s$^{-1}$). On taking $A_1 = 0.5$ m$^2$, $A_2 = 45$ m$^2$ and $C_{D1} = 1$, $C_{D2} = 2$ (for window-shade type drogue), then we have $V_2 = (-18.5$ cm s$^{-1}$, $-6.9$ cm s$^{-1}$) as the velocity of water around the subsurface drogue. Thus, the relative velocity of water around the subsurface drogue is estimated to be $(-3.5$ cm s$^{-1}$, $-3.9$ cm s$^{-1}$). The speed of this relative water velocity is 5.2 cm s$^{-1}$ and is comparable to the accuracy of velocity determination with drifters.

The record of Aanderaa current meter attached just above the subsurface drogue was analysed. It was shown that the current meter worked well only for the first one hour period, in which the recording was made at an interval of 10 minutes. For the remaining period the record was not meaningful due to a trouble in A-D converter. The current meter was a rental one and had not been regulated well. The measured water velocity was 11.5 cm s$^{-1}$ in the direction of 51° for the former half of the period and
6.5 cm s⁻¹ in the direction of 92° for the latter half. In this period the tracking of the subsurface drifter was unfortunately not made, because the sea-test of a newly made pressure gauge was carried out in reference to a newly obtained Aanderaa pressure gauge in the vicinity of Oshima. Thus, an estimation of the relative water velocity to be compared with the above-shown water velocity measured with the currentmeter cannot be made. It is seen that the measured relative water velocity is of the same order of magnitude as the estimated, although the measured and estimated velocities cannot be compared directly because these are for the different places at the difference times.

The Aanderaa current-meter record showed that the current-meter reached to the depth of about 277 m within 10 minutes after launching, and its depth was kept within 277±0.7 m throughout the period of recording. The change in depth of the subsurface drogue was thought to be similar in magnitude.

3.2. The examination of the current measurements with drifters

The trajectories of the surface and subsurface drifters are shown in Fig. 1. Both drifters moved almost in the same direction throughout the period of experiment except for the period of the clockwise circular motions. As is illustrated in the figure, the drifter for the surface layer moved at a speed much larger than that for the subsurface layer. About a day after the two drifters get separated each other and the parallel tracking of the two drifters became impossible. As been described before, the drifters were once retrieved on board and soon after relaunched. The tracking were thus divided into two stages. In the preceding stage starting 16h:00m on 9th to about 14h 00m on 10th of May, the drifter for the surface layer moved at the mean speed of 26.1 cm s⁻¹ in the direction of 34° from the north and the drifter for the subsurface layer at the mean speed of 7.6 cm s⁻¹ in the direction of 10°. In the following stage starting 16h 00m on 10th to about 08h 00m on 11th of May, the former drifter moved at the mean speed of 46.8 cm s⁻¹ in the direction of 33° and the subsurface drifter at the mean speed of 14.9 cm s⁻¹ in the direction of 4°. Both in the preceding and following stages, the mean speed of the drifter for the surface layer is about three times as large as that for the subsurface layer. And mean speeds of these drifters in the preceding stage are about halves of those in the following stage, respectively.

One more remarkable feature which is common to trajectories of both drifters is a loop formed counterclockwise during a period from about 21h 00m on 9th to 07h 00m on 10th of May (Fig. 1). In the corresponding period from 10th to 11th, such a feature cannot be found at all in the surface trajectory and a fragment of such feature is only found in the subsurface trajectory. For comparison, progress velocity-vector curves for the current records at 300 m at Stn. 2 and that at 150 m at Stn. 3 are drawn in the left and right parts of Fig. 3, respectively. The curve for Stn. 2 shows the characteristic feature similar to that of the trajectories of the drifters, that is, the curve is formed with an almost straight line in the northeast direction which is accompanied with a counterclockwise loop near the bottom of the curve. The other feature that the speed becomes about two times larger in the latter half period of measurement is also found in this curve. The progress vector curve for the Stn. 3, however, presents the quite different features from those described. The complicated meanderings are the characteristic feature of this curve. The mean velocity for this station in the latter half period is not doubled compared with that in the former half period. Stn. 3 was located very near to Oshima and the velocity field in the vicinity of the station is thought to be deformed greatly in association with a presence of complicated

![Fig. 3. Progress velocity vectors for the Stn. 2 (left) and Stn. 3 (right).](image-url)
From these results movements of our drifters for the surface and subsurface layers are concluded to well represent movements of nearby water parcels.

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