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Comparison of the currents measured by electromagnetic current meter and bottom mounted ADCP in Otsuchi bay

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Abstract—Near-surface current data obtained by bottom-mounted Acoustic Doppler Current Profilers (ADCP) are compared with those by electromagnetic current meter (ACM) in Otsuchi bay, Sanriku ria coast in northern Japan during the two periods from October 2003 to March 2004 and from April to October 2004. Although near-surface data obtained by upward looking ADCP is affected by the acoustic beam reflected from the sea surface, the results show that those data have significant correlation with each other. This means that bottom-mounted ADCP is useful for estimating the transport from the sea-surface to bottom.

Key words: surface flow, Otsuchi bay, ADCP

Introduction

In the bays including the Otsuchi bay along whole Sanriku ria coast, various kinds of aquaculture business are performed briskly. Therefore, monitoring the water exchange of a bay is important when considering about material transport, environmental pollution and the aquaculture maximum permissible (e.g. Stickney and McVey 2002, Duarte et al. 2003).

Data obtained near surface by a bottom-mounted Acoustic Doppler Current Profiler (ADCP) is normally contaminated, because of the beam angle to vertical. In the case the beam angle is 20° (RD instruments Model WorkHorse Sentinel 600 kHz with accuracy ±0.5% of the water velocity, is used in this study), the thickness of surface layer in which the data is unavailable is only 6% (2.4 m) of the total depth (40 m). However, for a study of the total water exchange in a shallow bay, even thin surface layer current which is directly affected by surface wind can not be neglected.

There are few examples which compare the surface flow velocity measured with ADCP and that with the conventional current meter like an electromagnetic type or a rotor-type. These types need mooring system with a surface buoy which causes friction with fishing and ship traffic. Otobe et al. (1996) compared currents observed by ADCP with those observed by an electromagnetic current meter (Alec-Electronics Co., Ltd. Model ACM-8M, denoted by ACM here after) at the point depth of water of 12 m near to the shore in Otsuchi bay, with the result that they acquired the value of a good correlation coefficient (R=0.89) by comparison of 4.5 m depth data. Morishige et al. (2005) compared currents observed by several types of current meters in Tokyo and Sagami Bay. They pointed that surface currents observed by bottom mounted ADCP were more fluctuant than mooring type current meters.

Therefore, this report presents the results of the comparison between the surface currents of ADCP and ACM for the periods of research on the sea water exchange at the center of the Otsuchi bay (Otobe 2004).

Materials and Method

Observation

As shown in Fig. 1, three ADCPs were mounted on the sea bed along line crossing at right angle with thalweg (main axis) of the Otsuchi bay during the two periods from October 2003 to March 2004 and from April to October 2004. In this case, the station interval is selected to be approximately equal. The trawl resistant bottom mount (TRBM Model AL-200) manufactured by Flotation Technologies has a double axis gimbals which keep the ADCP vertical and a acoustic recoverable system (Benthos, Inc. Model M-867-A, Acoustic Releaser). In order to obtain the surface data, two ACMs were moored at 1 m depth by using a light buoy mooring rope of aquaculture about 50 m northward from station A and northward station C, respectively. The locations and water depth of each observation station and observation periods are summarized in the Table 1.

Data processing

The time series data of ADCP were obtained every 10 minutes at the interval of 1 m layer from the surface to bottom and ACM data were obtained every 30 minutes during the whole observation periods, respectively. We made the data used in this study by first processing as follows.

Over 80% Percent-good data indicating a threshold level obtained from 4 beams of ADCP were used. The lack data on the time series was made linearly temporal interpolation. The hourly mean data was calculated using 6 data obtained with ADCP and 2 data with ACM. The current direction obtained by magnetic compass in both ADCP and ACM were corrected using −7 degree geomagnetic anomaly. Original current data were decomposed into tidal component and residual component by using 48 hours tide-killer filter (Hanawa and Mitsudera 1985).

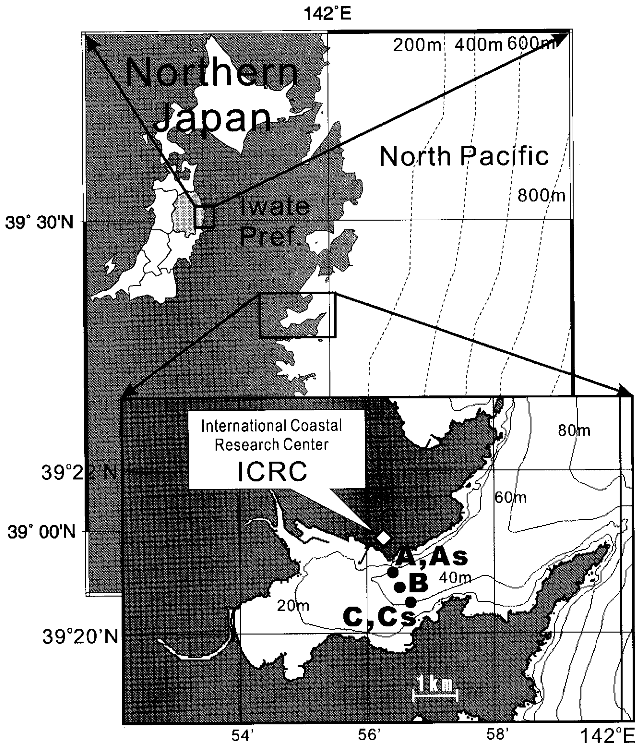

Fig. 1. Otsuchi Bay and the location of the stations. A, B and C indicate the stations of ADCP, As and Cs indicate the stations of ACM.

Table 1. A list of observation stations, depths and periods.

Instrument	Station	Position: Latitude	Position: Longitude	Depth (m)	Observation Periods
ADCP	A	39°20′42.2″N	141°56′22.4″E	40	8 Oct. 2003–3 Mar. 2004 21 Apr. 2004–28 Oct. 2004
	B	39°20′32.2″N	141°56′28.4″E	42	8 Oct. 2003–3 Mar. 2004 21 Apr. 2004–28 Oct. 2004
	C	39°20′23.2″N	141°56′39.4″E	41	8 Oct. 2003–3 Mar. 2004 21 Apr. 2004–28 Oct. 2004
ACM	As	39°20′43.8″N	141°56′22.1″E	39	15 Oct. 2003–27 Feb. 2004 14 Mar. 2004–29 Jul. 2004
	Cs	39°20′24.8″N	141°56′39.2″E	40	15 Oct. 2003–27 Feb. 2004 14 Mar. 2004–29 Jul. 2004

Results and Discussion

Daily averaged Residual Currents

Daily averaged residual currents in both periods are shown in Fig. 2. In the first period, stable south-eastward currents were observed at both stations and by both equipments. Some weak or reversal currents were infrequently recorded in middle November, in early December 2003, in middle January and in early February 2004. Even these infrequently events occurred simultaneously. Therefore, in this period, the currents at north side and south side of the Otsuchi bay are very coherent. On the other hand, in the second period, currents were unstable, especially in the ADCP data. Vectors of ADCP fluctuate and sometimes exceed over 30 cm sec^{-1}. This large fluctuation of ADCP vectors consists with the result of Morishige et al. (2005). Furthermore, it seems like that vectors of ADCP and ACM at each station appear not to co-vary.

Shikama (1986) pointed that the water exchange in a bay along Sanriku coast were mainly promoted by the vertical circulation (outflow in upper layer, inflow in lower layer) during the period of stable north-west wind in autumn and winter seasons. Otobe et al. (submitted) reported that in the first period of this study, very stable and continuous south-eastward winds observed at International Coastal Research Center (ICRC) located to the north of Otsuchi bay (see Fig. 1), but wind direction was quite variable in the second period. Because ACM current meters were mounted under the light buoy of aquacultural structures, the whirling of the light buoy acted to reduce the relative velocity of water to ACM for short periodic fluctuations by high frequent winds. Free and open surface above the ADCP is directly affected by surface wind and also 10 minutes time record interval of ADCP which is shorter than ACM (30 minutes) made large fluctuations and reduced average velocity.

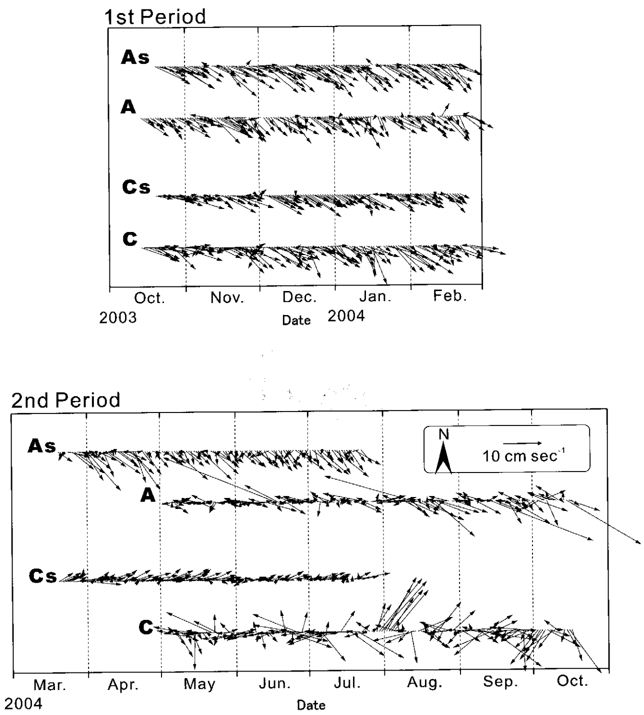

Fig. 2. Vector stick diagrams of current records after processing 48 hours tide-killer filter.

However, significant component of water exchange in Otsuchi bay is caused by the flow through on main axis of Otsuchi bay (60 degrees from North). These components obtained by both equipments were examined in the next section.

Comparison of velocity Components parallel to Main axis of Otsuchi Bay

Figure 3 shows the hourly time series of the components through the main axis at stations A (As) and C (Cs) for a period during which data obtained by the both equipments are available. In the first period, outward flow (the positive value) is relatively large (about 5 cm sec^{-1} in average) and shows lower variation in comparison with that in the second period at the both stations. In the second period, however, outward flow is relatively small (about 3–4 cm sec^{-1} in average) and shows larger variation with higher frequency at both stations. Although the current components obtained by ADCP show large fluctuation and are relatively small at the both stations and in both periods, the fluctuations pattern by ADCP is almost similar to that by ACM at the station A and C, respectively.

Scattering diagrams and regression line between hourly components obtained by ADCP (as X-axis) and ACM (as Y-axis) in each and total period are shown in Fig. 4. Correlation coefficients in all cases ($R=0.39$–0.61) are significant at 99% level. The intercepts on the Y-axis are positive (3.06–5.26 cm sec^{-1}) in all cases and the gradients are also positive but smaller than 1 (0.19–0.45). This means that the flow obtained by ACM was affected by less influence of local wind fluctuations than by ADCP in consideration of larger average outward components of ACM.

Considering the actual condition in Otsuchi Bay where

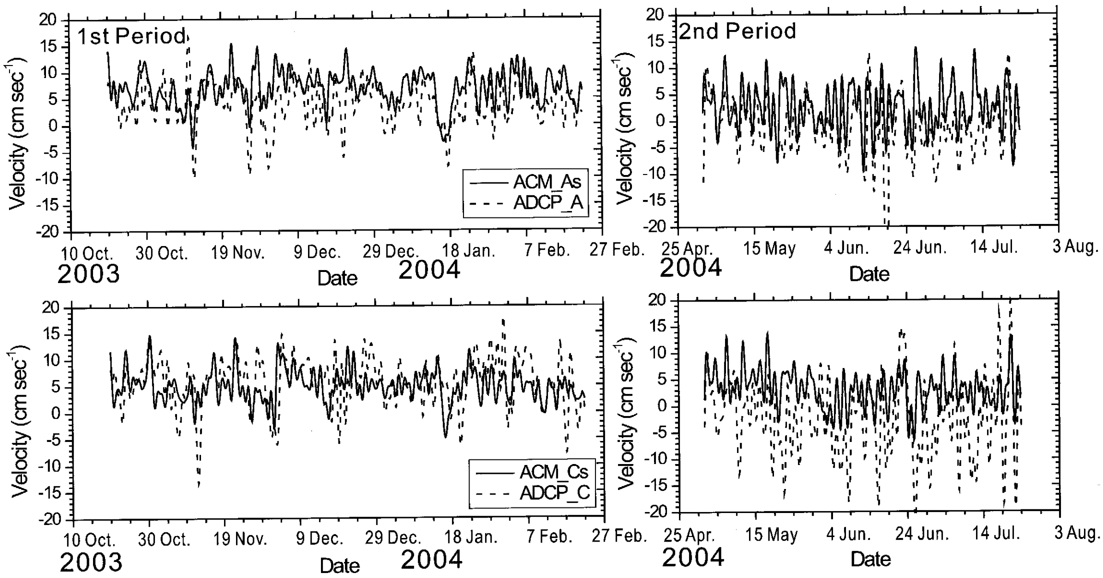

Fig. 3. Hourly time series of the components on the main axis (60°T) of Otsuchi Bay at each station for a period when flow data obtained by both equipments are available.

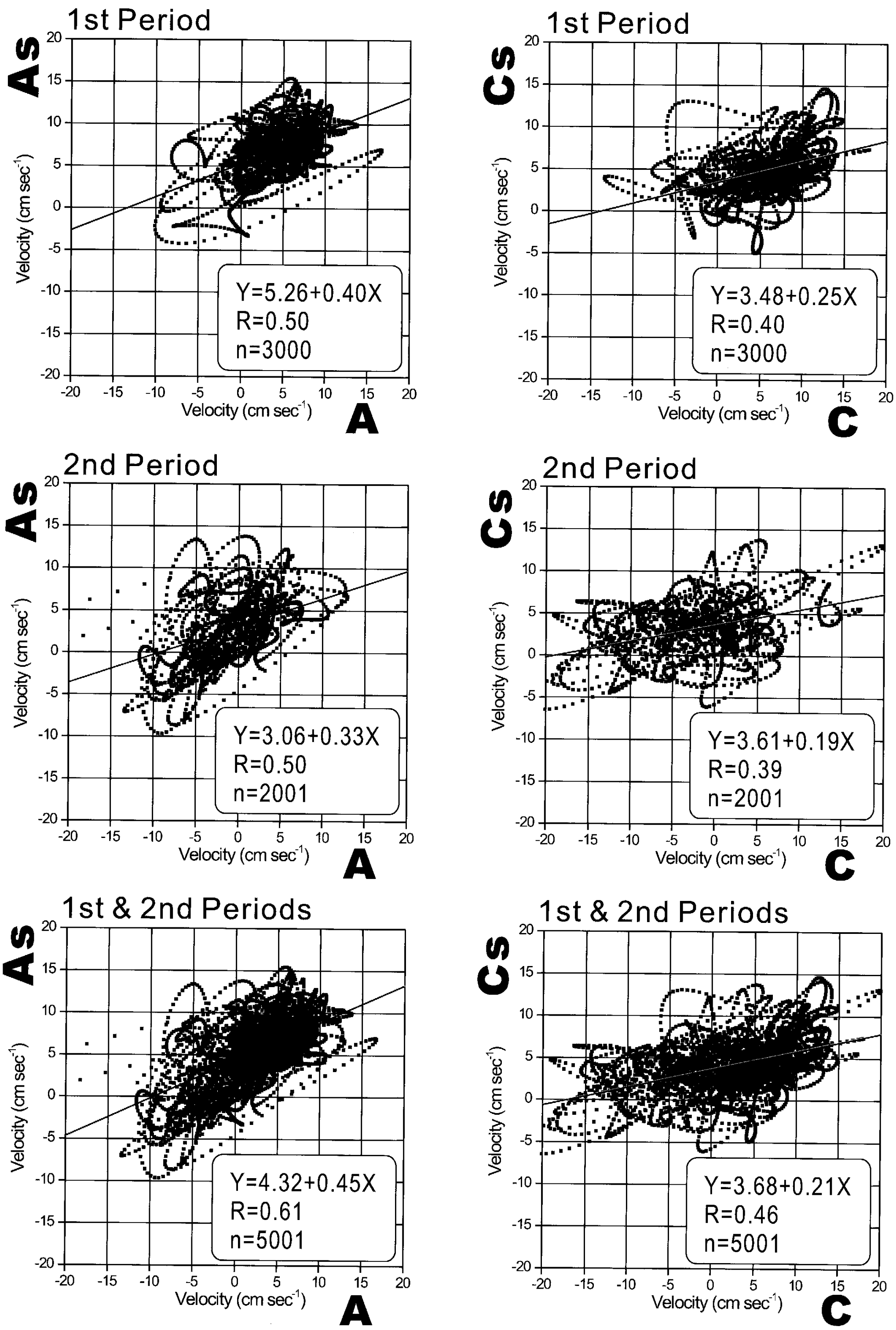

Fig. 4. Scattering diagrams and regression line between hourly components on the main axis of ADCP (as X-axis) and ACM (as Y-axis) in each and total period.

located a lot of aquacultural structures along both coastal side, stable outward components of ACM have much realities than by ADCP. However, at open surface condition like station B in the center area of the bay, surface flow is affected directly by wind. Then as the relation between the components of ACM and ADCP even in the wind unstable period (in Spring and Summer seasons) indicate significant positive correlations at both coastal stations, surface flow of ADCP could be used to estimate the water exchange on condition of a little reducing the effect of fluctuating wind as following more comparative data sets.

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