DIRECT VELOCITY MEASUREMENTS OF DEEP CIRCULATION SOUTHWEST OF THE SHATSKY RISE IN THE WESTERN NORTH PACIFIC

Daigo Yanagimoto (1), Masaki Kawabe (2), Shinzou Fujio (3)

(1) *Ocean Research Institute, The University of Tokyo, Minamidai 1-15-1, Nakano, Tokyo 164-8639, Japan, Email:daigo@ori.u-tokyo.ac.jp*
(2) *Ocean Research Institute, The University of Tokyo, Minamidai 1-15-1, Nakano, Tokyo 164-8639, Japan, Email:kawabe@ori.u-tokyo.ac.jp*
(3) *Ocean Research Institute, The University of Tokyo, Minamidai 1-15-1, Nakano, Tokyo 164-8639, Japan, Email:fujio@ori.u-tokyo.ac.jp*

1. INTRODUCTION

The Lower Circumpolar Deep Water (LCDW) transported by the global deep circulation from the Southern Ocean is known to spread to the basins in the North Pacific after passing the Central Pacific Basin (e.g., Mantyla and Reid [1]). Though the western North Pacific has so complex bottom topography that observational studies on the deep circulation has been made difficult, Johnson and Toole [2] and Kawabe et al. [3] found an eastern branch of the deep circulation flowing northward through Wake Island Passage and a western branch flowing through the East Mariana Basin at low latitudes (Fig. 1). Yanagimoto and Kawabe [4] indicated the both branches have northwestward flows between the Shatsky Rise and the Ogasawara Plateau, which is an eastward bulge of the Izu-Ogasawara Ridge.

We conducted hydrographic and mooring observations along a line located southwest of the Shatsky Rise. Kawabe et al. [5] analyzed the hydrographic data in 2004 and 2005, and found the deep homogeneous layer where LCDW exists has potential temperature (θ) lower than 1.2°C. They concluded that geostrophic volume transport of the eastern and western branches of the deep-circulation current transporting LCDW ($\theta < 1.2$°C) are slightly less than 4 Sv (1 Sv = 10^6 m^3 s^{-1}) and slightly more than 2 Sv, respectively. In their results, the location and volume transport of the branch currents are different between the observations undertaken in 2004 and 2005. This suggests marked temporal variability in the deep-circulation currents. We analyze the mooring data of current velocity, and document temporal variations in the volume transport of the deep-circulation currents southwest of the Shatsky Rise.

2. METHODS

We conducted direct current measurements for approximately 14 months at nine moorings (M1–M9) using 50 current meters along the line from M1 (25°42'N, 149°16'E) to M9 (31°13'N, 156°33E) (Fig. 1). The nine moorings were anchored during the period 15–23 September 2004 in the R/V Hakuho-maru KH-04-4 cruise and were recovered during the period 21 November to 1 December 2005 in the KH-05-4 cruise. Almost current meters were installed near the bottom and at depths of approximately 5500, 5000, 4500, 4000 and 3500 m.

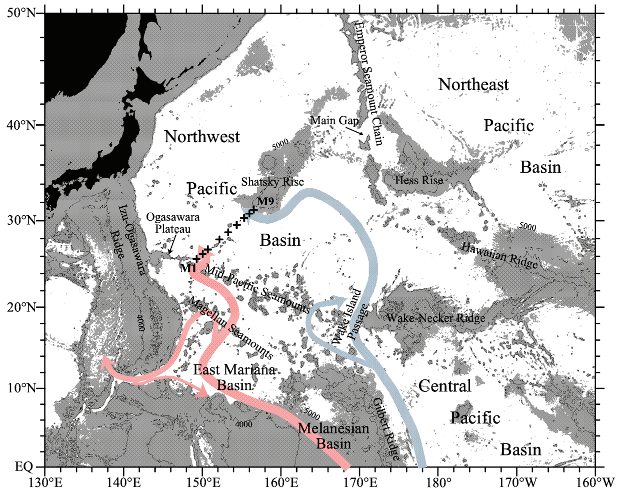

Figure 1. Location of nine mooring systems M1- M9 ("+"). Red arrows and blue ones show the pathways of the western and eastern branches of the deep circulation, respectively. Shading indicates water depths less than 5000 m and the 4000 m isobaths are shown.

Daily volume transport of the deep-circulation current was estimated by integrating objectively-mapped cross-sectional velocity components below the average isotherm of θ = 1.2°C for the two hydrographic sections obtained during the KH-04-4 and KH-05-4 cruises. On the base of the current properties of the deep-circulation current shown in the following section, we used velocities toward 270°–10°T between M1 and M3 for the total transport of the western branch and those toward 270°–360°T between M6 and M9 for the eastern branch.

3. RESULTS

3.2. Velocity field near the bottom

Velocities toward 270°–360°T shown by red arrows in stick diagrams of current velocities near the bottom are stable and dominant at M2, M4, and M7–M9 (Fig. 2). Periodic northwestward flow at M4 would be part of a clockwise eddy around a seamount located immediately

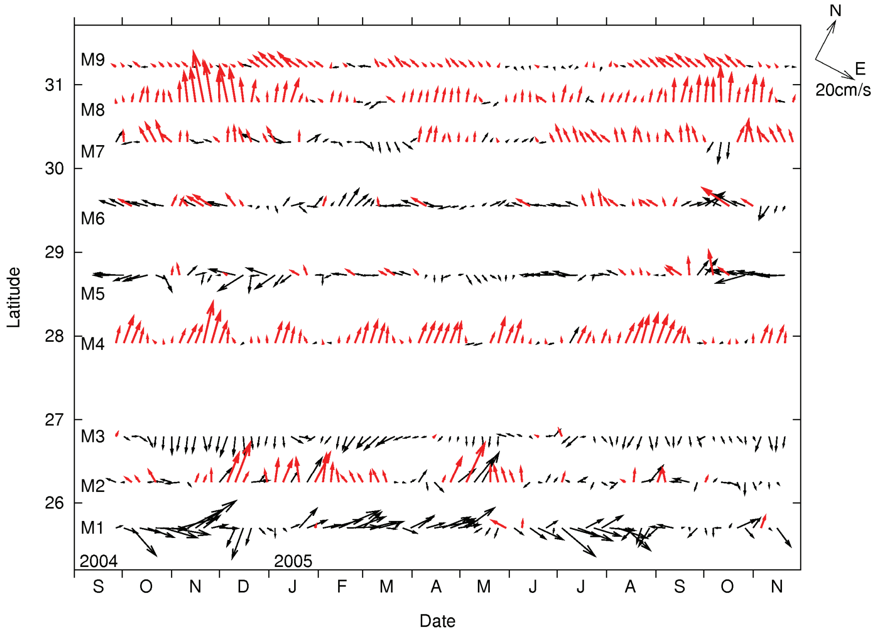

Figure 2. Stick diagrams of five-day-averaged current velocities near the bottom. Velocity components perpendicular to the observation line M1–M9 direct upward.

east of M4.

The western branch of the deep-circulation current flowing northwestward (besides 270°–360°T, high velocity toward 0°–10°T would also be the western branch) is detected almost exclusively at M2 (26°15'N), east of the Ogasawara Plateau, indicating a width less than the 190 km distance between M1 (25°42'N) and M3 (26°48'N). The mean current speed near the bottom at M2 is 3.6 ± 1.3 cm s^{-1}. The eastern branch of the deep-circulation current is located at the southwestern slope of the Shatsky Rise, flowing northwestward mainly at M8 (30°48'N) on the lower part of the slope of the Shatsky Rise with a mean near-bottom speed of 5.3 ± 1.4 cm s^{-1}. The eastern branch often expands to M7 (30°19'N) at the foot of the rise with a mean near-bottom speed of 2.8 ± 0.7 cm s^{-1} and to M9 (31°13'N) on the middle of the slope of the rise with a speed of 2.5 ± 0.7 cm s^{-1} (nearly 4000 m depth); it infrequently expands furthermore to M6 (29°33'N). The width of the eastern branch is 201 ± 70 km on average, exceeding that of the western branch.

3.3. Volume transport

Temporal variations of the volume transports of the western and eastern branches consist of dominant variations with periods of 3 months and 1 month, varying between almost zero and significant amount, and are correlated to each other with a phase lag of several months for the western branch. The almost zero volume transport occurs at intervals of 2–4 months. It is similar with variations of the current and volume transport at the Wake Island Passage (Kawabe et al. [6]). In the eastern branch, volume transport and current width are highly correlated, and, in other words, volume transport increases with current width.

Because the current meters were too widely spaced to enable accurate estimates of volume transport, mean volume transport is overestimated by a factor of nearly two, yielding values of 4.1 ±1.2 and 9.8 ± 1.8 Sv for the western and eastern branches, respectively. Sparsely distributed single-point measurements may yield large volume transports in wide basins in which current axes move over time, such as the strait in this study. In contrast, realistic volume transports are estimated in narrow straits such as the Samoan Passage (6.0 ± 1.5 Sv; Rudnick [7]) and the Wake Island Passage (3.6 ± 1.3 Sv; Kawabe et al. [6]).

4. REFERENCES

1. Mantyla, A. W., Reid, J. L., 1983. Abyssal characteristics of the World Ocean waters. Deep-Sea Research 30, 805-833.
2. Johnson, G. C., Toole, J. M., 1993. Flow of deep and bottom waters in the Pacific at 10°N. Deep-Sea Research I 40, 371-394.
3. Kawabe, M., Fujio, S., Yanagimoto, D., 2003. Deep-water circulation at low latitudes in the western North Pacific. Deep-Sea Research I 50, 631-656.
4. Yanagimoto, D., Kawabe, M., 2007. Deep-circulation flow at mid-latitude in the western North Pacific. Deep-Sea Research I 54, 2067-2081.
5. Kawabe, M., Fujio, S., Yanagimoto, D., Tanaka, K., 2009. Deep-circulation currents southwest of the Shatsky Rise in the western North Pacific. Deep-Sea Research I 56, 1675-1687.
6. Kawabe, M., Yanagimoto, D., Kitagawa, S., Kuroda, Y., 2005. Variations of the deep western boundary current in Wake Island Passage. Deep-Sea Research I 52, 1121-1137.
7. Rudnick, D., 1997. Direct velocity measurements in the Samoan Passage. Journal of Geophysical Research 102, 3293-3302.