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Deep-circulation current through the Main Gap of the Emperor Seamounts Chain in the North Pacific

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ABSTRACT

The deep-circulation current in the North Pacific carries lower circumpolar deep water (LCDW), which is characterized by high dissolved oxygen and low echo intensity of reflected sound pulses. Using the characteristics of LCDW, we examined a branch current of the deep circulation passing through the Main Gap of the Emperor Seamounts Chain (ESC) by analyzing conductivity temperature depth profiler (CTD) data and data of velocity and echo intensity from a lowered acoustic Doppler current profiler (LADCP), which were obtained along 170°E immediately west of the ESC, along 180°W and 175°W over the northern slope of the Hess Rise, and along 165°W. The velocity and water characteristics showed that the eastern branch current of the deep circulation, which has penetrated into the Northwest Pacific Basin (NWPB) through Wake Island Passage, bifurcates around 30°N, 170°E in the NWPB into the westward main stream and a northward branch current, and that the latter current proceeds along the western side of the ESC and passes through the Main Gap of the ESC, flowing eastward. The current in the Main Gap at 170°E flows southeastward with eastward velocity cores around 4000 dbar and at depths greater than 4800 dbar centered at 5400 dbar. The current in the deeper core is stronger and reaches a maximum velocity of approximately 10 cm s^{-1}. The eastward current in the Main Gap enters the Northeast Pacific Basin (NEPB) and flows eastward along the northern slope of the Hess Rise. As the current flows downstream, the characteristics of LCDW carried by the current are diluted gradually. To the east of the Hess Rise, the branch current joins another branch current of the deep circulation from the south carrying less-modified LCDW. As a result, LCDW carried from the Main Gap is renewed by mixing with the less-modified LCDW coming from the south. Carrying the mixed LCDW, the confluence flows eastward south of 37°N at 165°W toward the northeastern region of the NEPB, where the LCDW overturns and changes to North Pacific Deep Water (NPDW). NPDW is probably carried by the westward current in the upper deep layer north of 37°N at 165°W.

1. Introduction

In the lower deep layer of the North Pacific (typically more than 3500 m depth), lower circumpolar deep water (LCDW) is carried by the deep-circulation current separating from the Antarctic Circumpolar Current, spreads into the Southwest Pacific Basin, the Central Pacific Basin, and the Northwest Pacific Basin (NWPB), and finally gathers into the Northeast Pacific Basin (NEPB; Mantyla, 1975; Mantyla and Reid, 1983).

Right after entering the Central Pacific Basin, the deep-circulation current separates into the eastern and western branches immediately north of the Samoan Passage (Fig. 1; Johnson and Toole, 1993; Kawabe, 1993; Kawabe

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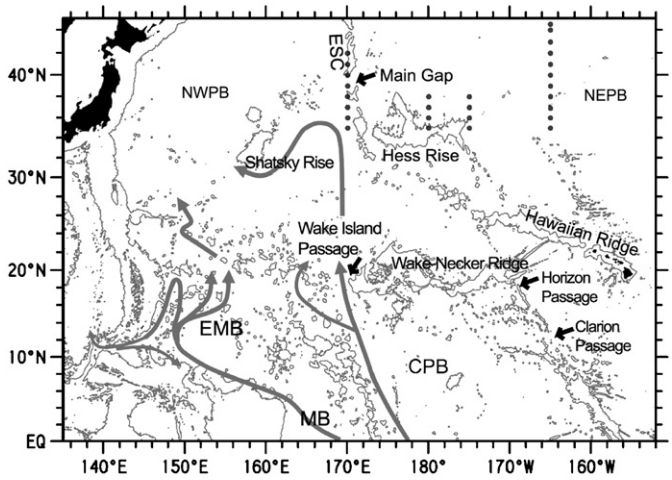

Fig. 1. LADCP stations on R.V. *Hakuho Maru* cruise KH-03-1 in the North Pacific (dots). MB, Melanesian Basin; EMB, East Mariana Basin; CPB, Central Pacific Basin; NWPB, Northwest Pacific Basin; NEPB, Northeast Pacific Basin; ESC, Emperor Seamounts Chain. Gray lines indicate 4000-m isobaths. Gray arrows show pathways of the deep circulation in the lower deep layer, which were concluded by Kawabe et al. (2003).

and Taira, 1995; Kawabe et al., 2003). The western branch current proceeds to the Melanesian and East Mariana Basins, and almost half of it enters the NWPB (Kawabe et al., 2003). The eastern branch current proceeds northward along the western boundary of the Central Pacific Basin; more than half of it proceeds farther north to enter the NWPB through Wake Island Passage having volume transport of a little more than 4 Sv (Kawabe et al., 2005), while the remaining little less than half separates from the eastern branch current, flows eastward south of the Wake–Necker Ridge, and enters the NEPB through Clarion and Horizon Passages (Edmond et al., 1971; Wong, 1972; Mantyla and Reid, 1983; Kato and Kawabe, 2008).

The eastern branch current turns cyclonic after passing Wake Island Passage and flows around 33°N, 165°E northwestward (Kawabe and Taira, 1995; Yanagimoto and Kawabe, 2007). Hamann and Taft (1987) suggested that part of the deep-circulation current passes through the Main Gap of the Emperor Seamounts Chain (ESC), showing that the northeastward current almost parallel to the isobaths flowed at a depth of 4000 m at the southern end of the Main Gap throughout the 9-month mooring of a current meter (Fig. 2).

In the present study, deep flow at the Main Gap of the ESC is examined in terms of vertical structure, upstream connection with the deep-circulation current, and downstream pathway in the NEPB. Current velocity and echo intensity measured with a lowered acoustic Doppler current profiler (LADCP) are analyzed using the characteristics of LCDW of low echo intensity; to be exact, the significant negative anomaly of echo intensity from the average at this latitude (Komaki, 2007).

2. Data

We performed full-depth conductivity temperature depth profiler (CTD)/LADCP casts at 27 stations at 170°E, 180°W, 175°W, and 165°W in the North Pacific during the period 19 May–15 June 2003 on the R.V. *Hakuho Maru* KH-03-1 cruise (Fig. 1). We used a 300-kHz LADCP manufactured by RD Instruments. Current velocity was estimated from LADCP data with the method of Komaki and Kawabe (2007). Barotropic tidal velocity, which was estimated using the tide model of Egbert et al. (1994), was removed from the current velocity data. Echo intensity data of LADCP, which were measured from sound pulses reflected from 12 m below the LADCP instrument (the third bin), were used in the water-mass analysis, because LCDW is characterized by low echo intensity (Komaki, 2007).

The stations are located at intervals of 1° latitude at 35–42°N, 170°E immediately west of the ESC (ES1–ES8), at 35–38°N, 180°W (A1–A4) and 35–38°N, 175°W (B1–B4) over the northern slope of the Hess Rise, and 35–44°30′N, 165°W (C1–C11; Fig. 2a). We originally planned to observe up to higher latitudes but gave up because of strong atmospheric lows that came to the observation area at 170°E, 180°W, and 175°W. At 165°W, we performed LADCP observations at 34°N and farther south, but did not use the data because echo intensity south of 34°N is too low to allow for velocity estimation (Komaki and Kawabe, 2007) and decreases too much toward 30°N to allow for LCDW detection (Komaki, 2007).

3. Deep current in the Main Gap of the ESC

The current in the bottom layer of the Main Gap of the ESC flows southeastward at ES5 at 170°E (Fig. 2b) and northeastward off the northern tip of the southern seamount (Hamann and Taft, 1987). The zonal component at ES5 in the Main Gap is eastward around 4000 dbar and at depths greater than 4800 dbar, carrying water of 1.15 °C and colder than 1.1 °C, respectively (Fig. 3). The shallower (around 4000 dbar) and deeper (below 4800 dbar) currents