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Water properties and transport of the Leeuwin Current and Eddies off Western Australia

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Abstract

Hydrological data from the western coast of Australia to 110°E are used together with direct velocity observations to investigate the water mass distribution and the associated circulation. High spatial variability reflects advective features related to the turbulent character of the Leeuwin region. The correlation between the sea surface temperature and the sea surface salinity distributions and the upper layer circulation depicts a southward warm and fresh Leeuwin Current along the coast with several branchings and three anticyclonic eddies offshore. The strongest eddy includes a thick surface mixed layer of 220 m and perturbs the hydrological structure down to more than 2000 m. The net transports through the four sections are northward in the upper layers with larger transports through the southern sections, which imply a westward transport just north of Abrolhos Islands. In the intermediate and deep-water layers, the net transport is southward across the southern section and divergent, implying an eastern inflow around 29°S. The data confirm that Subantarctic Mode Water is spreading north while the Antarctic Intermediate Water appears to recirculate to the south along the eastern rim of the Perth Basin.

Keywords: Indian Ocean; Leeuwin Current; Hydrology; Eddy; Transport

1. Introduction

Unlike the other subtropical eastern boundaries in the Atlantic and in the Pacific Oceans, where the currents are equatorward and associated with upwelling along the coast, close to the western Australian coast, the Leeuwin Current is the only eastern-boundary current in the world ocean that flows poleward, bringing warm low-salinity waters to the south (Wooster and Reid, 1963; Rochford, 1969; Cresswell and Golding, 1980; Legeckis and Cresswell, 1981; Godfrey and Golding, 1981; McCreary et al., 1986; Church et al., 1989; Godfrey and Weaver, 1991; Holloway, 1995). Off

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western Australia, the prevailing winds have a northward component throughout the year, stronger in December–March (low atmospheric pressure over Australia) and weaker in May–August (high pressure over Australia), which should drive an offshore surface Ekman transport. However, the poleward upper layer pressure gradient is quite large in the southeastern Indian Ocean, producing an onshore geostrophic transport, which overcomes the equatorward wind stress forcing (Thompson, 1984; Godfrey and Ridgway, 1985; Smith et al., 1991). Therefore, the coastal current flows against the northward winds. The eastern branch of the subtropical South Indian anticyclonic circulation is located at least 1000 km further offshore, although Andrews (1977) describes a northeastward flow of high salinity water which enters the eastern boundary region near 29°S, and names this flow the West Australian Current.

The southward eastern boundary current was named the Leeuwin Current by Cresswell and Golding (1980) after the Dutch ship *Leeuwin* which explored the south Australian coast eastward in 1622. The current runs parallel to the bottom topography and is strongest at the continental shelf edge (Church et al., 1989; Smith et al., 1991). Below the southward flow, extending down to around 250 m, an equatorward undercurrent brings high salinity high oxygen waters. The undercurrent is also detected through a reverse in the along shore pressure gradient (Godfrey and Ridgway, 1985).

The variability of the Leeuwin Current results from the different variability of its forcing mechanism components particularly the alongshore pressure gradient and the alongshore winds (which always act to weaken the current). The mean southward pressure gradient between the tropical warm-fresh Indonesian throughflow waters and the cool-salty waters off southwest Australia is a maximum in May–June (Godfrey and Ridgway, 1985) with a secondary maximum in November (Morrow and Birol, 1998). Direct year long observations give an annual-mean transport of about 4–5 Sv of warm low salinity waters which drives large heat exchanges from the ocean to the atmosphere comparable to the exchanges found in western boundary currents (Smith et al., 1991; Domingues et al., 1999; Josey et al., 1999; Morrow et al., 2003). Recent measurements give a mean volume transport of 3.4 Sv with a strong seasonal cycle and interannual variations (Feng et al., 2003).

It is a peculiar region where large instabilities, detected through drifting buoys trajectories, satellite infrared images and Topex-Poseidon satellite altimetry, appear along the coast and propagate mainly westward (Cresswell, 1977; Cresswell and Golding, 1980; Legeckis and Cresswell, 1981; Griffiths and Pearce, 1985; Church et al., 1989; Prata and Wells, 1990; Pearce and Griffiths, 1991; Morrow and Birol, 1998; Birol and Morrow, 2001).

One of the scientific objectives of the Transport Indian Pacific (TIP) cruise was to study the underlying structure of these sea level instabilities observed with Topex-Poseidon satellite altimetry in the Leeuwin Current region. This paper presents a description of the water properties and transports off western Australia during the TIP cruise which provides the background for the Leeuwin eddies study presented in two companion papers (Morrow et al., 2003; Fang and Morrow, 2003).

2. Data collection

Thirty-seven CTD-O_2 profiles (stations 39–75) were carried out along four sections positioned to sample the large sea level anomalies between the Australian coast and 110°E detected on the satellite altimetry maps received on board the French R.V. *Marion Dufresne*. The work was conducted from 24 September to 1 October, 2000, between Carnarvon and Fremantle using a Sea-Bird CTD fitted with an oxygen sensor and a fluorimeter associated with a 12 12-l-bottle rosette and an RDI LADCP (lowered acoustic doppler current profiler) fixed on the frame. The LADCP worked only from stations 39 to 47. Discrete samples were taken at each station to measure salinity, oxygen and nutrients. Oxygen titrations were made on board, following the modified Winkler method on a Tetler titrator, and salinity measurements were made with a Guildline Autosal