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A Shallow Zonal Jet South of Fiji

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ABSTRACT

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1. Introduction

In a recent paper, Webb (2000) presented evidence for shallow zonal jets in the South Equatorial Current in the Southwest Pacific. This was based on numerical model results from the high-resolution Ocean Circulation and Climate Advanced Modelling (OCCAM) model driven by ECMWF wind stress. Model resolution was sufficient to indicate that the current was broken up into a series of zonal jets by the extensive shallow topography associated with islands and reefs. These jets were prominent near the northern and southern extremities of the major island groups—Fiji, New Caledonia, and Vanuatu. The model defined the broad-scale structure of the jets and their effect on the temperature and salinity fields. Webb (2000) states that “Such features are relatively unknown and unstudied, so these results should provide a strong incentive for further detailed experimental and theoretical research in the region.” This statement reminded the present authors of oceanographic data collected south of Fiji in 1992, which appeared to show such a zonal jet, and these results are presented here.

2. Data

The World Ocean Circulation Experiment P14C hydrographic section between Auckland, New Zealand, and Fiji was occupied in September 1992, from the RV

Knorr (WOCE 1998). At the conclusion of the section an Acoustic Doppler Current Profiler (ADCP) and CTD survey was carried out in the Kandavu Passage between Viti Levu and Kandavu Island (Fig. 1). The P14C section concluded at station 52, and the four additional CTD/ADCP sections (Stations 53–68) plus a fifth ADCP-only section, were worked over the period 12–13 September 1992. The CTD casts were terminated at 1000 decibars to save time, although the channel depth in this region is around 2000 m. These supplementary data are not included in the WOCE database and are reported here for the first time. Data collection from the shipboard ADCP and the CTD casts continued the WOCE procedures used on the P14C line, and details of the methods and data accuracy are given in WOCE (1998).

3. Results

The ADCP showed clear evidence of a westward zonal jet in the Kandavu Passage. Maximum velocities in the core of the current were found at around 110-m depth (Fig. 2), and the current was strongest on the northern side of the channel. Maximum velocities were around 40 cm s^{-1}. Variations in core current strength in the sections probably reflect some tidal modulation of the flow, but all sections exhibited the westward zonal jet. There was evidence of a weak eastward counterflow (up to 10 cm s^{-1}) in places, on the southern side of the channel.

The CTD data was used to derive cross-track geostrophic velocity sections and salinity sections. The geostrophic velocities were calculated with a reference level at 1000 decibars, corresponding to the sampling limit for the supplementary CTD stations. However, it is interesting to note that the OCCAM model results (Webb 2000) found that flow at 1000 m was weak in the Fiji area. This would suggest that the use of a reference level at 1000 decibars was probably adequate for the present purposes. All the velocity sections showed a westward jet on the northern side of the channel, similar to that found with the ADCP. Consequently only three velocity and salinity sections are shown here (Fig. 3). Moving from east to west these are Section A (Stations 64–68), Section B (Stations 56–60), and Section C (the original P14C data) (see Fig. 1). On the northern end of each velocity the west-going jet is evident with core velocities greater than 30 cm s^{-1}. The depth of the core of the westward jet varied on the geostrophic sections. The core was found at 100 m on Section A, at the surface on Section B, and with a complex double core structure (surface and 400 m) on Section C. Similar but less marked core depth changes were seen in the ADCP sections with the core found at 110 m ± 60 m depth. The ADCP sections showed more fine-scale structure because of the inherent finer scale sampling compared with the CTD stations. Additional differences between the ADCP and geostrophic sections are to be expected from ageostrophic and topographic effects. The salinity sections show a subsurface salinity maximum at around 180-m depth and the highest values of salinity at the maximum generally lie under, or in, the westward jet. Salinity values in the maxima associated with the westward jet were highest on the eastern section (Section A, salinity greater than 35.8) and decreased slightly toward the west. On section C (Fig. 3), a second west-going jet can be seen between stations 47 and 48. Interpretation of this feature is problematic since it did not appear in the ADCP records and the salinity structure in this area showed weak double maxima.

4. Discussion

The present data suggests that a westward zonal jet does exist south of Fiji along the lines proposed by Webb (2000). He identified this jet on the WOCE P14C section (sometimes incorrectly referred to as P16 in his paper). The present additional data shows that this jet could be followed as a contiguous feature on other sections. Webb has proposed the name South Fiji Current for this feature. The key features of the jet from the OCCAM model were found in the ADCP and CTD data. First, the jet was a shallow subsurface feature. Webb found that the westward flow south of Fiji was stronger at the 200-m level than it was at the surface. He did not show flow at 100 m, but the present ADCP data suggests that the core of the jet is found at around this depth, while the CTD data did not clearly define a mean core depth but was consistent with a shallow subsurface feature. Second, Webb (2000) proposed that the characteristic subsurface salinity maximum associated with the westward jet was a key identification feature. The present data show salinity at the maximum that corresponds closely with that simulated in the OCCAM model. The model average salinity section through the South Fiji Current (Webb 2000, Fig. 13) shows a core layer with salinity greater than 35.7 psu at a depth of around 150 m. The data showed similar salinity values in the core depth of around 180 m.

In the ADCP and CTD data the width of the South Fiji Current was much narrower, with correspondingly higher velocities, than that found in the OCCAM model. Model current speeds were around 4 cm s^{-1}, whereas the data suggest current speeds of around 40 cm s^{-1}. However, this is not unexpected, as Webb (2000) notes that the model does not resolve very short scales and probably overestimates the width of the zonal jets and underestimates the strength. The resolution problem is not confined to the South Fiji Current but is seen over the whole New Zealand–Fiji section, where eddy-resolving expendable bathythermograph data (Roemmich and Cornuelle 1990) consistently show many short length scale features not resolved in numerical models. This is also illustrated clearly in the comparison between the OCCAM model and the WOCE P14C velocity section reproduced in Webb (2000, Fig. 14).

The OCCAM model results presented by Webb (2000) were the average conditions over a 5 year run after spinup. In contrast the present data were a snapshot from September 1992, and the question remains as to how representative of climatology these data are. Morris et al. (1996) studied the variability of the subtropical gyre in the South Pacific using the high-resolution XBT data along the New Zealand–Fiji–Hawaii track. They found that annual fluctuations were particularly prominent with gyre transport exhibiting a maximum in November and a minimum in May. The present data from September are approximately at the midpoint in this annual cycle. However, Morris et al. (1996) also examined interannual variability during the 1987–94 period and found that after 1991 gyre-scale transport was more intense with an increase in the number and intensity of small-scale circulation features. This was possibly related to the onset of the ENSO warm phase. The present data, being a snapshot, cannot prove the climatological permanence of the South Fiji Current but merely provide evidence that such a feature was seen at that time. However, the relationship of the current in the Kandavu Passage to the applied wind forcing is recognized in the *Pilot* (Hydrographic Office 1969), which reports that with strong easterly and southeasterly trade winds the current sets westward at rates of up to 1 knot (50 cm s^{-1}), but after westerly winds there is a decided eastward set.

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Figures

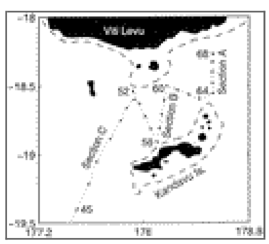

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FIG. 1. The survey area south of Fiji showing the ADCP transects and the CTD stations undertaken over the period 11–13 September 1992. Stations 43–52 are the northern end of the WOCE P14C line, while Stations 53–68 were supplementary CTD stations. The 500-m bathymetric contour is shown dashed

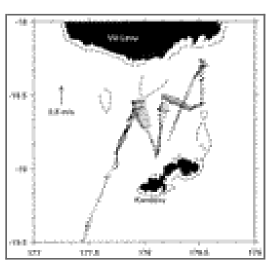

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FIG. 2. Current vectors at 110-m depth from the ADCP survey

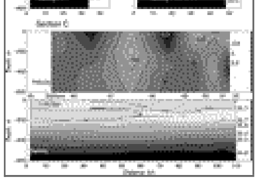

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FIG. 3. Cross sections of geostrophic velocity, relative to 1000 decibars, and salinity on Sections A, B, and C derived from the CTD data. Eastward velocity (m s^{-1}) is positive and the contour interval is 0.1 m s^{-1}. Salinity contour interval is 0.1 for salinity greater than 35.6 psu and 0.2 for lower salinity

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