The time series of the Leeuwin Current transport from satellite altimeter measurements

X. Deng

School of Engineering and Centre for Climate Impact Management, The University of Newcastle, Newcastle, Australia

K.R. Ridgway

CSIRO Marine and Atmospheric Research, Hobart, Australia

R. Coleman

Centre for Marine Science, University of Tasmania, CSIRO Marine and Atmospheric Research, Antarctic Climate and Ecosystems CRC, Hobart, Australia

Abstract

The time series of the net baroclinic volume transport is estimated from TOPEX/Poseidon (T/P) and Jason-1 satellite altimeter data in the Leeuwin Current (LC) region (24°S to 33°S and 111°E to 115°E). The data used are altimeter-derived sea level anomalies (SLAs) along three ascending tracks offshore of Western Australia from 1993 to 2008, the ocean mean dynamic topography from CSIRO's Atlas of Regional Seas (CARS) climatology, and CSIRO's RV Franklin hydrographic measurements. We first infer the subsurface temperature and salinity structure from altimeter-derived SLAs using a model developed from historical in-situ observations of CARS, and then we compute the baroclinic transport along each altimeter track. The hydrographic sections from the RV Franklin cruise are used for validation. The time series of transport across each altimeter track, representing the flow of the LC, show a range of complex temporal signals during 1993-2008.

Introduction

Hydrographic and current observations suggest that the LC transports fresher and warmer tropical waters along the west Australian coast when its poleward flow is maximum during May–June (Cresswell and Golding, 1980; Smith *et al.*, 1991). Estimates of the volume transports of the LC have been published during the last two decades (e.g., Feng et al.,2003). However, previous transport estimates may only represent a local (e.g., Feng et al., 2003) or short period estimate (e.g., Smith et al., 1991; Fieux et al. 2005). Therefore, It is necessary to examine the long period of the volume transport and its seasonal, annual and interannual variations in the LC.

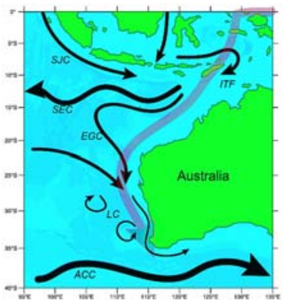


Fig.1. Schematic of the major surface currents in the east-southeast Indian Ocean (adapted from Feng et al., 2003). LC stands for the Leeuwin Current. A shaded, transparent arrow is used to highlight the waveguide along which the Pacific ENSO signals propagate.

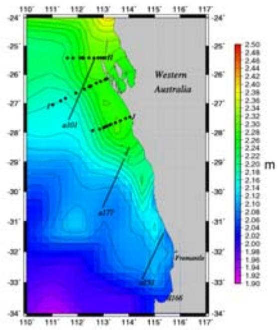


Fig.2. Distribution of selected T/P tracks and RV Franklin transects over the CARS in the LC region offshore of Western Australia.

Data

The contours show the steric height derived from CARS referenced to 2000m. Three T/P and Jason-1 tracks cross the LC and are overlaid with the CARS. Symbols of diamond indicate locations of transects H, I and J from CSIRO Franklin 10/2000, where the temperature and salinity data were measured between h 8/1000m.

The 'a' before the track numbers denotes an ascending track. The satellite orbits from south to north along the ascending track.

Altimeter track a101 crosses the RV Franklin transect I, which will be compared to each other below.

The CARS clearly captures our knowledge of the time-invariant component of the LC offshore of Western Australia (WA), where a narrow, strong LC moves poleward along the coastline west of WA.

Methods

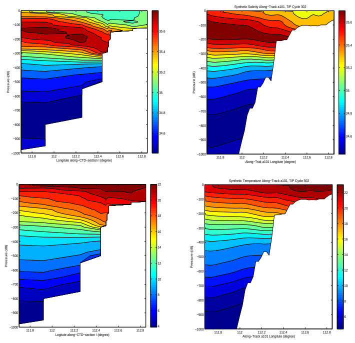
Instead of estimating the time series of the volume transport by an empirical relation between the transport obtained from oceanic in-situ data and altimetry SLAs (e.g, Zhu et al., 2004; Rintoul et al., 2002), our method directly infers the synthetic temperature and salinity from altimetry SLAs and historical ocean data using a multiple linear regression technique. The baroclinic transport is then estimated from the steric height inferred from the synthetic temperature and salinity.

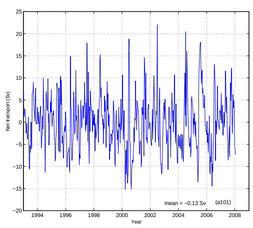
This method allows the influence of the variable topography with depth to be included in the estimate of volume transport. The baroclinic transport is referenced a 'level of no motion' (2000 m).

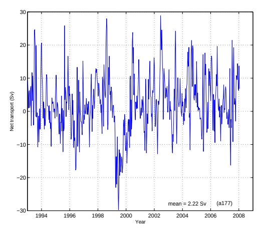
Comparison between RV Franklin and synthetic data

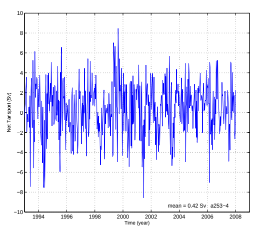
Figure 3 (right) shows the CTD salinity (PSU, top left) and temperature (°C, bottom left) from RV Franklin 2000 transect I. Synthetic salinity (PSU, top right) and temperature (°C, bottom right) from altimetry SLAs and CARS. The RV Franklin data along transect I were collected between 23-24 November 2000, while SLAs of track a101 were measured on 28 November 2000. Considering a 5-day difference between T/P and in-situ data, vertical profiles of synthetic temperature and salinity in Fig. 3 agree with observations along transect I.

In addition, we investigated the spatial pattern in layer 0-10 dB of the correlation between the surface synthetic salinity and temperature with observed surface salinity and temperature. The correlations are 0.98 and 0.72 respectively, suggesting that the synthetic temperature and salinity are compatible with the in-situ CTD observations.



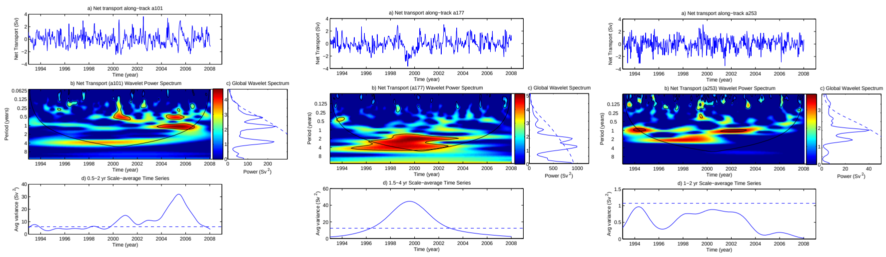






Time series of net transports (left top Figures)

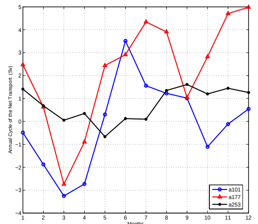
Figures 4, 5 and 6 (left) show the 15-year time series of net transport across the LC from January 1993 to January 2008 with a 10-day interval. The transport across a177 indicates a poleward flow with a mean of 2.22 Sv, while the mean net transports are -0.13 Sv (track a101) and 0.42 Sv (track a253), respectively. The estimated transports across the LC fluctuate widely and show a rich spectrum of frequencies from seasonal to interannual, and an annual cycle as well.



Figs.7, 8 and 9. (a) The normalised net transport time series for tracks a101, a177 and a253 are used for the wavelet analysis. (b) The local wavelet power spectrum of (a) using the Morlet wavelet. The shaded contours are at normalised variances shown in the colour bar. The thick contours enclose regions of greater than 95% confidence for a red-noise process with a lag-1 coefficient of 0.72. (c) The global wavelet spectrum. (d) Scale-averaged wavelet power over the 0.5-4 yr band for the net transport. The dashed line is the 95% level for net transport (red noise α=0.72).

Seasonal and interannual variability of net transports (left bottom Figures)

To isolate the different timescales, the net transports are analysed with the wavelet transform. The wavelet power spectra, global wavelet spectra and average transport variance are shown in left Figures 7, 8 and 9. The wavelet power is normalised and thus measures the deviations from the mean spectrum. In general, for the net transports across three tracks, the power is broadly distributed, with peaks in the 1-2-yr band in common. For track a101, the power appears high in bands of 0.5-2-yr and 4-yr during 2000-2007 and 1994–2002, respectively. The 5% significance level indicates that 2000-2007 contains intervals of higher transport variance, while 1993-1999 is a period of lower transport variance. The wavelet spectrum for transport across track 177 shows the highest power in a 2-4-yr band during 1995-2004.



Annual cycle

Figure 10 (left) shows the monthly net transport referenced to 2000 m across tracks a101, a177 and a253. During the summer months, the maximum net transports are 3.6 Sv, 4.4 Sv and 0.2 Sv for a101, a177 and a253 respectively. When crossing tracks a101 and a177, the LC has the minimum net transports of -3.3 Sv and -2.8 Sv in March, and the maximum transports of 3.6 Sv and 4.4 Sv in June and July (though track a177 has another maximum transport of 5 Sv in December). The LC flows across tracks a101 and a177 basically southward in summer and northward in winter, which agrees with previous results (e.g., Feng et al., 2003; Deng et al., 2008). It is also noted that the monthly mean of the LC appears a 0.5-yr cycle, which has not been reported before.

The LC across track a177 is dominated by southward flow in most months and only by northward flow during January and April. The LC across track a253 has smaller transport than both a101 and a177. However, the LC appears to flow poleward across a253 in most months. The seasonal cycle of the LC obviously appears to be very spatially dependent.

Discussions and conclusions

The time series of the LC flow across three altimeter tracks has been, for the first time to our knowledge, constructed using nearly 15-years of altimeter-derived sea level anomalies and CARS. The net LC flow across these tracks offshore of WA shows a range of temporal signals from seasonal to interannual.

Both the seasonal and interannual variations of the LC obviously appears to be very variable depending on the location. The LC flow across tracks a101 and a177 has a 0.5-yr cycle with basically southward in summer and northward in winter. It flows poleward across a253 in most months, but has smaller net transports than tracks a101 and a177. On the interannual time-scale, results from wavelet analysis suggest that the power is broadly distributed with peaks in the 1-2-yr band in common to three tracks. The wavelet spectrum for transport across track 177 also shows the high power in a 2-4-yr band during 1995-2004.

Further study is necessary to investigate the relationship between transport estimates and ENSO events, as well as comparison with more available oceanic in-situ data.

Contact:

xiaoli.deng@newcastle.edu.au

References

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