CSIRO PUBLISHING
www.publish.csiro.au/journals/spjns The South Pacific Journal of Natural Science, 2007, 2, 10-15

The 1997-98 El Niño and 1999 La Niña evolution of current around the Fiji Islands

Savin Chand, Than Aung and Shivanesh Rao
The University of the South Pacific, Suva, Fiji

ABSTRACT
The current around Fiji Islands during different phases of 1997-98 El Niño and the subsequent 1999 La Niña was investigated. During its mature phase of the El Niño event, westward current of magnitude 20 cm s^{-1} developed in the region north of 15 ºS latitude and that the current of similar magnitude flowed in the reverse direction during 1999 La Niña event. Below 21 ºS latitude, the flow of magnitude 20 cm s^{-1} was eastward regardless of El Niño or La Niña conditions. The current between 15 ºS latitude and 21 ºS latitude was, however, not very clearly defined. At early stage of 1997-98 El Niño phase, the flow was eastward with an average speed of 5 – 10 cm s^{-1} and that at the later phase, the flow became westward at slightly greater speed of around 10 – 15 cm s^{-1}. However, contrary is observed during the La Niña period

1 INTRODUCTION

El Niño has made frequent appearances over the last century, with particularly severe occurrence in the 1997-98 event. Wang and Weisberg (2000) have sampled the evolution of this event over six different phases: antecedent (Aug 1996-Oct 1996); onset (Nov 1996-Jan 1997); development (Mar 1997-May 1997); transition (Jul 1997-Sep 1997); mature (Nov 1997-Jan 1998); and decay (Feb 1998-April 1998). Soon after this 1997-98 El Niño, a La Niña event had consequently occurred during 1999 period. The objective of this study is therefore to investigate the evolution of current, assuming geostrophy, during these different phases of El Niño period and the subsequent 1999 La Niña event around Fiji Islands in the spatial domain of 10 ˚S to 25 ˚S latitude and 170 ˚E to 190 ˚E longitudes.

This spatial domain is spanned by the Southwestern Tropical Pacific Ocean (SWTP) and it lies in the region of the South Pacific Convergence Zone (SPCZ). The SWTP encompasses the well-documented (e.g. Delcroix and Picaut 1998; Maes *et al.* 2002; Gouriou and Delcroix 2002; Delcroix and McPhaden 2002 and Folland *et al.* 2002) western equatorial pacific *warm pool* and the western equatorial Pacific sea surface *salinity front*. Studies have shown that during El Niño events and La Niña events, displacements of SWTP *warm pool* and *salinity front* and the associated migration of SPCZ about its mean location have strong influence on the density structure of the ocean and thus on the current through geostrophy.

During El Niño events, the SPCZ migrates further northeast in symmetric with the *warm pool* (Trenberth 1976), as shown in Figure 1b. As a result, there is a precipitation shortage over Samoa, Vanuatu, Solomon, New Caledonia and Fiji (Gouriou and Delcroix 2002), consequently accounting for higher than average SSS.

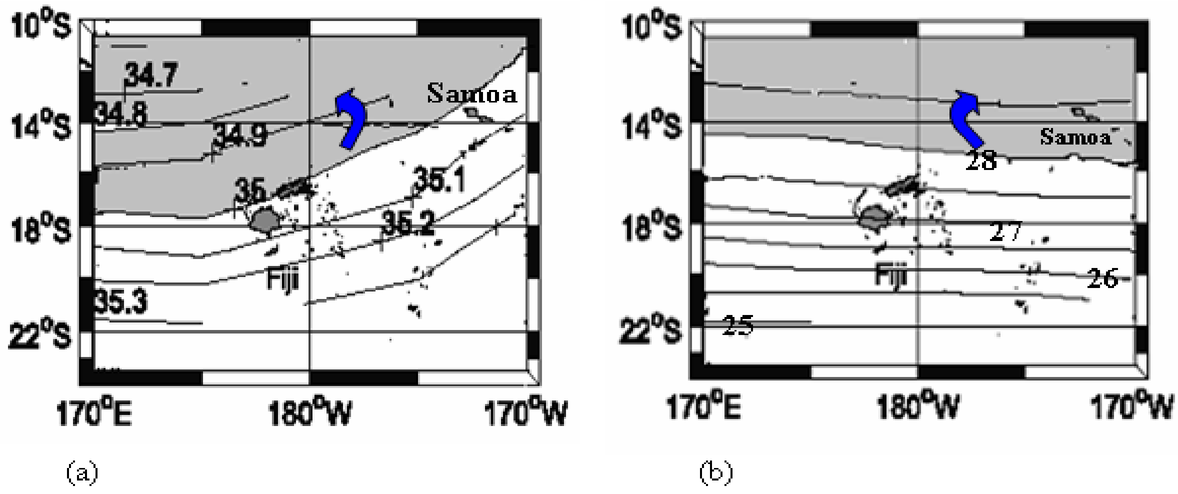


Figure 1. The mean location of Southwestern Tropical Pacific *salinity front* at 35 psu isoline (a) and 28 º C isotherms defining the arbitrary limit of the area of *warm pool* (b). Blue arrows represent northwest and northeast movement of the *salinity front* and the west Pacific *warm pool* respectively during El Niño periods. This figure is redrawn using information from Gouriou and Delcroix (2002) and Delcroix and Picaut (1998).

The higher SSS values in the Samoa, Fiji and Vanuatu regions during 1997-98 El Niño is also linked to the northwest displacement of the SWTP *salinity front* (35 psu isoline in Figure 1a) that separates saltier subtropical

10.1071/SP07002

waters (> 35 psu) from fresher western equatorial Pacific *fresh pool* waters. Gouriou and Delcroix (2002) have shown that the northwest movement of *salinity front* during El Niño event brings salty waters to the SWTP Ocean. This advection of salinity front also creates influx of cold water in the region (Alory and Delcroix 2002; Casey and Adamec 2002) through Rossby wave propagation.

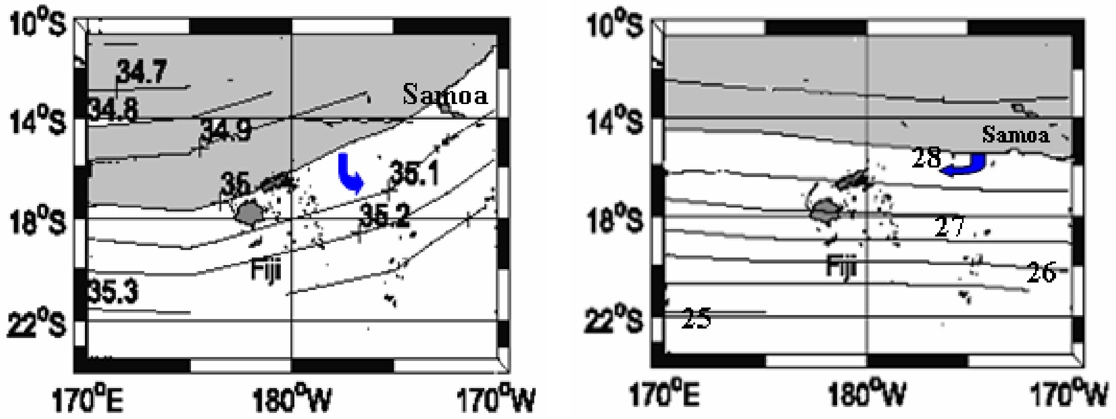
However, during the La Niña events, the southwest movement of SPCZ accounts for increased precipitation between Samoa-Fiji region, which lies on opposite sides of mean location of the SPCZ (Salinger *et al.* 1995). This excess precipitation leads to lower SSS (< 34.7 psu) as shown by Gouriou and Declroix (2002). There result is in agreement with Delcroix *et al.* (1996) who had indicated that the interannual variation of SSS in the SWTP Ocean is closely related to the rainfall regime linked to the displacements of the SPCZ. The southwest incursion of SPCZ is consistent with southeast movement of the SWTP *salinity front* (Figure 2a). This brings less saline water in the northern part of the study region.
Unlike the El Niño phenomenon, the northeast side of the study region undergoes increase in SST (warmer than 28 °C) during La Niña period. Figure 2b shows the mean location of 28 °C isotherm defining the arbitrary limit of the area of the *warm pool*. Its southwest movement during La Niña period brings warm water (> 28 °C) north of Fiji Islands. Gouriou and Delcroix (2002) have shown that the maximum variability of SST on interannual timescale has occurred between Vanuatu, Fiji and Samoa regions. This paper, thus, investigates the influence of the changes in these SST and SSS due to 1997-98 El Niño and 1999 La Niña events on the pattern of current around Fiji.

2 DATA

Series of datasets from two different sources have been used in this project; the climatological mean dataset compiled by Levitus *et al.* (2002) and the satellite altimetry dataset from the Topex-Poseidon space mission.

2.1 MEAN CLIMATOLOGICAL DATASET

The mean climatological data used in the study constitute mean monthly dynamic height fields of the sea surface relative to 1000 m depth level on global grid at a spatial resolution of 1° × 1° grid. These data were obtained from the National Oceanographic Data Center (NODC) archive, which is one of the national environmental data centers operated by the National Oceanic and Atmospheric Administration (NOAA) of the United States, via
ftp://ftp.nodc.noaa.gov/pub/WOD98/Data/website.



(a) (b)

Figure 2 The mean location of Southwestern Tropical Pacific *salinity front* at 35 psu isoline (a) and 28 ºC isotherm defining the arbitrary limit of the area of *warm pool* (b). Blue arrows represent southeast and southwest movement of the *salinity front* and the west Pacific *warm pool* respectively during La Niña periods. This figure is redrawn using information from Gouriou and Delcroix (2002) and Delcroix and Picaut (1998).

2.2 SATELLITE ALTIMETRY DATASET

The altimetry dataset used in the study consisted of 107 maps of sea surface height anomalies (SSHA) over the study area with a spatial resolution of 1˚ x 1˚ grid and a temporal resolution of every 7 days from August 1996 to August 1999. The series of files corresponding to these SSHA maps were obtained from a set of complete reprocessed Topex-Poseidon and ERS 1 and ERS 2 data.

These reprocessed data constitute the data corrected for all geophysical, media and instrument effects, produced by AVISO-CLS study as part of the Environmental and Climate EU ENACT project (EVK2-CT2001-00117) and with support from CNES, available on the AVISO ftp website: *ftp://ftp.cls.fr/pub/oceano/enact/msla/tpers/.* AVISO (Archiving, Validation and Interpretation of Satellites Oceanographic Data) is the French active archive data center responsible for reprocessing geophysical data and generating merged products with other available data records before distributing them to general public. (For more information on the methods of data processing, error estimation, gridding procedure and satellite calibration, user is referred to Chelton (1994), Le Traon *et al.* (1998) and Ducet *et al.* (2000).

3 METHOD

The map of mean dynamic height fields from Levitus climatology was added to each time-series map of SSHA to yield corresponding maps of total dynamic height fields. Then the currents were computed from these total dynamic height fields between the consecutive stations using the basic dynamical method highlighted in Pond and Pickard (1983). For convenience, these computations were programmed in the Matlab software and the resultant flow field in each map was described vectorially. The current velocities were validated with results from OSCAR that can be viewed on www.oscar.noaa.gov. [User is referred to Bonjean and Lagerloef (2002) and Lagerloef *et al.* (1999) for a more accurate method on surface current computations using satellite altimetry SSH, wind stress and SST].

Because the 1997-98 El Niño events constituted of six phases [antecedent (Aug 1996-Oct 1996); onset (Nov 1996-Jan 1997); development (Mar 1997-May 1997); transition (Jul 1997-Sep 1997); mature (Nov 1997-Jan 1998); and decay (Feb 1998-April 1998)], six respective maps of current were constructed. Each map corresponded to the mean of different El Niño phases. Similarly, the four maps of mean current spanning the 1999 La Niña event were constructed (i.e. November 1998; February 1999; May 1999; and August 1999) to identify the flow pattern during 1999 La Niña event.

4 RESULTS AND DISCUSSION

The flow patterns deduced from the combined sum of Topex-Poseidon SSHA and Levitus climatology during different phases of the major 1997-98 El Niño are shown in Figure 3. During the major 1997-98 El Niño event, westward current of magnitude 20 cm s^{-1} developed in the region north of 15 ºS latitude. The development of this westward current is linked to the depressed sea surface north of 15 ºS latitude as a result of northeast movement of SWTP *warm pool* (and SPCZ) and the associated northwest migration of the *salinity front*. This northeast movement of SWTP *warm pool* in association with northwest migration of the *salinity front* causes differences in the density structure of the ocean, resulting in the pressure gradient inclining north of 15 ºS latitude, which consequently generates westward current.

However, contrary is observed when 1999 La Niña period was at its peak during May 1999 (Figure 4). The current reverses direction and becomes eastward along the mean position of SPCZ as a result of higher and more elevated SSH north of 15 ºS latitude. However, this westward flow is not as dominant as the eastward flow during the 1997-98 El Niño because the 1999 La Niña was not as strong. Nevertheless, the pattern reversal is evident. The SWTP *warm pool* moves southwest in symmetric with the SPCZ and the *salinity fron*t moves in southeast direction, causing increase in the density field. This increases the SSH north of 15 ºS latitude and therefore reverses the pressure gradient compared to that observed during El Niño phase. As a result, the flow becomes eastward.

Below 21 ºS latitude, flow of magnitude 20 cm s^{-1} is eastward regardless of El Niño or La Niña conditions. This is the region where the lesser interannual variations of temperature and salinity occurred compared to that above 15 ºS latitude (Gouriou and Delcroix 2002). The broad eastward flow is thus the result of the South Pacific Current that originates partially from East Australian Current (EAC) and Antarctic Circumpolar Current (ACC).

The current between 15 ºS latitude and 21 ºS latitude is, however, not very clearly defined. At early stage of 1997-98 El Niño phase, the flow is eastward with an average speed of 5 – 10 cm s^{-1}. At the later phase, the it becomes westward at slightly greater speed of around 10 – 15 cm s^{-1}. The transition from west to east occurs during mature phase of El Niño where the flow is < 5 cm s^{-1}. This transition is however not very clearly defined. Opposite is observed in La Niña period. During its early phase, the current flows westward with an average speed of 10 cm s^{-1} and that during later stage the current of similar magnitude flows eastward. The transition from west to east, as with El Niño phase, is not clearly defined. This undefined movement of current in the transition phase could be attributed to the sporadically meandering of the weak flow (< 5 cm s^{-1}) as they move past the smaller islands dotting the region.

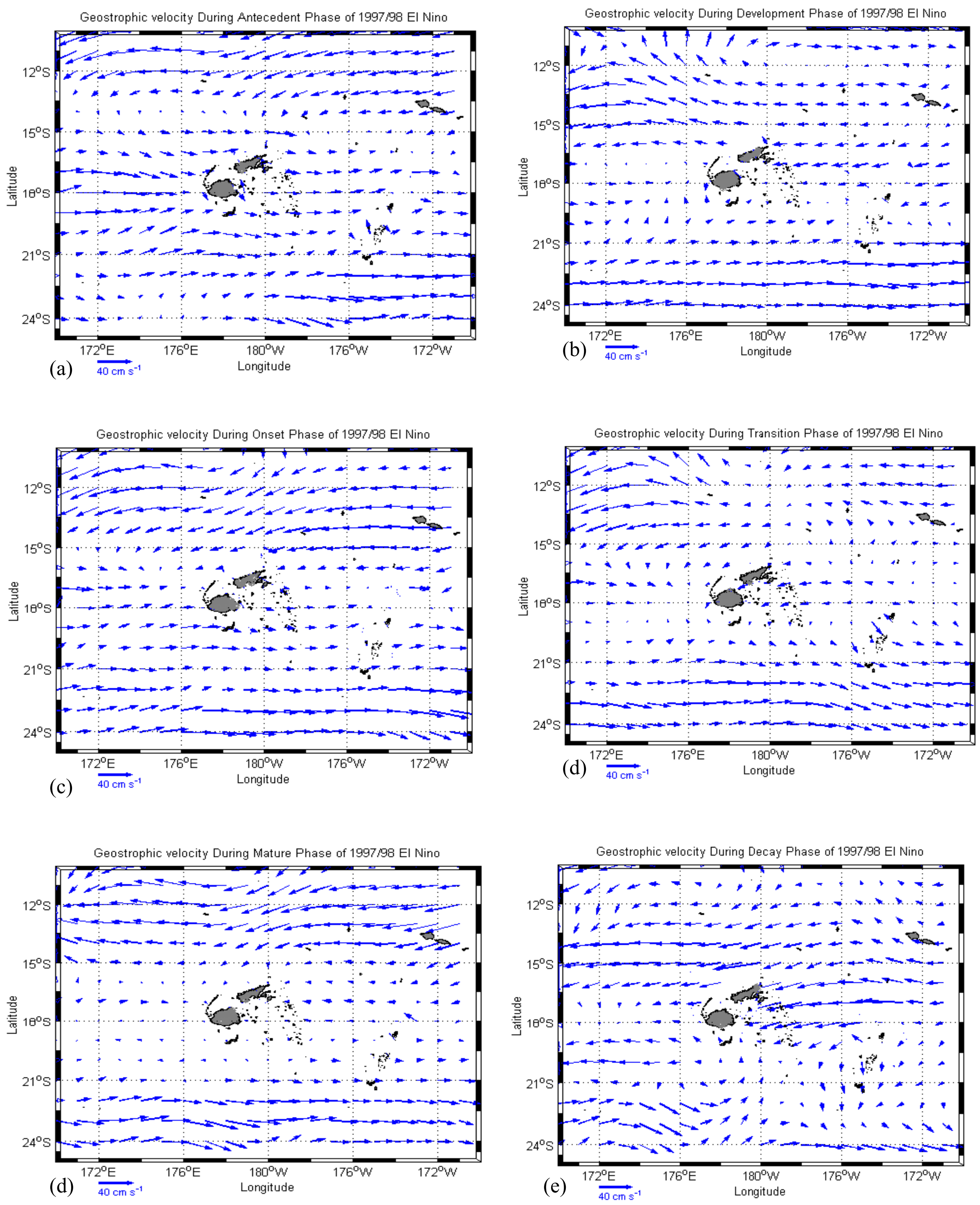


Figure 3. Current during the six phases of the major 1997-98 El Niño, assuming gestrophy.

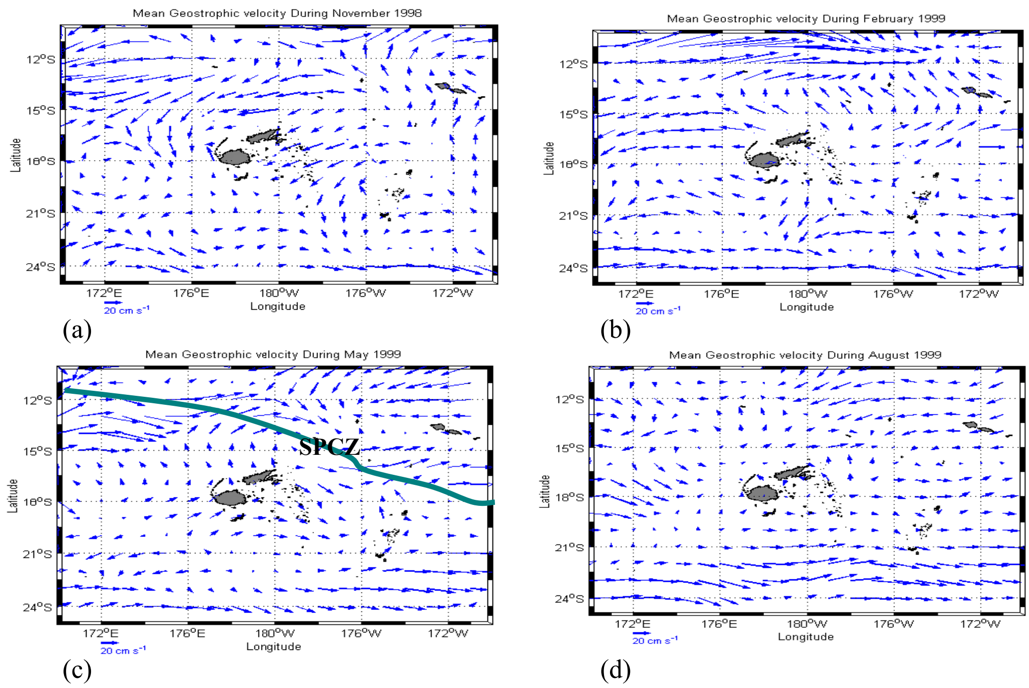


Figure 4. Flow pattern during 1999 La Niña period

5 CONCLUSIONS

The El Niño and La Niña evolution of surface currents have been identified in the study region. The characteristic flow north of 15 ºS latitude is 20 cm s^{-1} during El Niño period and that flow of similar magnitude is present eastward during the La Niña period. South of 21 ºS latitude, the flow is 20 cm s^{-1} eastward regardless of El Niño or La Niña conditions. Between 15 ºS latitude and 21 ºS latitude, the flow is weak (< 10 cm s^{-1}) and is not very clearly defined. The pattern of flow above 15 ºS latitude is linked to the respective movement of the sea surface *salinity front* and the west Pacific *warm pool* during El Niño and La Niña events and that flow pattern below 21 ºS latitude is linked to the major South Pacific Current which was not disturbed by the El Niño and La Niña events.

REFERENCES

Alory, G. and Delcroix, T. Interannual sea level changes and associated mass transports in the tropical Pacific from TOPEX/Poseidon data and linear model results (1964-1999). *J. Geophys. Res.* **107(C10),** 3153. doi: 10.1029/2001JC001067, 2002

Bonjean, F. and Lagerloef, G.S.E. 2002. Diagonistic model and analysis of the surface currents in the tropical Pacific Ocean. *Journal of Physical Oceanography* **32,** 2938,-2954.

Casey, K.S. and Adamec, 2002. D. Sea surface temperature and sea surface height variability in the North Pacific Ocean from 1993 to 1999. *J. Geophys. Res.* **107(C8),** 10.1029/ 2001JC001060

Chelton, D.B. 1994. The sea state bias in altimeter estimates of sea level from collinear analysis of Topex data. *J. Geophys. Res.* **99,** 24995-25008.

Cronin, M.F. and McPhaden, M.J. 1998. Upper ocean salinity balance in the western equatorial Pacific, *J. Geophys. Res.* **103(C12),** 27,567-27,587pp.

Delcroix, T., Hénin,C., Porte V. and Arkin, P. 1996. Precipitation and sea-surface salinity in the tropical Pacific Ocean. *Deep Sea Res.* **43,** 1123-1141,

Delcroix, T and Picaut, J. 1998. Zonal displacement of the western equatorial Pacific "fresh pool". *J. Geophys. Res.* **103(C1),** 1087-1098 pp.

Delcroix, T. and McPhaden, M. 2002. Interannual sea surface salinity and temperature changes in the western Pacific warm pool during 1992-2000. *J. Geophys. Res.***107(C12),** 8002. doi:10.1029/2001JC000862.

Ducet, N, Traon, Le P.Y. and Reverdin, G. 2000. Global high resolution mapping of ocean circulation from the combination of Topex/Poseidon and ERS-1/2. *J. Geophys. Res.* **105(C8),** 19477-19498.

Folland, C.K., Renwick, J.A., Salinger. M.J. and Mullan, A.B. 2002. Relative influences of the Interdecadal Pacific Oscillation and ENSO on the South Pacific Convergence Zone. *J. Geophys. Res.* **29,** 13. 10.1029/2001GL014201.

Gouriou, Y. and Delcroix, T. 2002. Seasonal and ENSO variations of sea surface salinity and temperature in the South Pacific Convergence Zone during 1976-2000. *J. Geophys. Res.* **107(C12),** 8011. doi:10.1029/2001JC000830.

Lagerloef, G.S.E., Mitchum, G., Lukas, R. and Niiler, P. 1999. Tropical Pacific near surface currents estimated fromaltimeter, wind and drifter data. *J. Geophys. Res.* **104,** 23,313-23,326,

Le Traon, P.Y., Nadal, F. and Ducet, N. 1998. An improved mapping method of multi-satellite altimeter data. *J. Atmos. Oceanic Technol.* **25,** 522-534, Levitus, S., Monterey, G. I. and Boyer, T. 2002. Seasonal Variability of Dynamic Height and its Fourier Analysis, *http://www.nodc.noaa.gov/OC5/dyndoc.html*

Maes, C., McPhaden, M.J. and Behringer, D. 2002. Signatures of salinity variability in the tropical Pacific Ocean dynamic height anomalies. *J. Geophys. Res.***107(C12),** 8012. doi: 10. 1029/2000JC000737.

Pond, S. and Pickard, G.L. 1983. Introductory Dynamical Oceanography. *2nd ed. Pergamon Press, Oxford*

Salinger, M.J., Basher, R.E., Fitzharris, B.B., Hay, J.E.; Jones, P.D., Macveigh, J.P. and Schmidely-Leleu, I. 1995. Climate trends in the south-west Pacific. *International Journal of Climatology* **15(3),** 285-302.

Trenberth, K.E. 1976. Spatial and temporal variations of the Southern Oscillation. *Quarterly Journal of the Royal Meteorological Society* **102,** 639-653

Wang, C. and Weisberg, R.H. 2000. The 1997-98 El-Nino Evolution relative to previous El Niño events. *J. Climate* **13,** 488-501.