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# Diagnostic of the Zonal Displacement of the Warm Pool During El Niño and La Niña

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## Introduction

In the Pacific equatorial band, the eastern edge of the warm pool, subject to insignificant seasonal variations, is dominated by strong interannual displacements almost in phase with the Southern Oscillation Index (Figure 1). Over the 1971-73 El Niño-La Niña period, Gill (1983) suggested that such displacement was solely due to horizontal advection by zonal current anomaly. He also suggested that the anomalous advection results from local wind forcing and from its remote response through a succession of equatorial Kelvin and low-order meridional Rossby waves. McPhaden and Picaut (1990) reinforced this idea through direct velocity measurements at 165°E in 1986-88 and intuited the role of an equatorial Rossby wave. The purpose of the present study, based on observational findings and modeling analysis, is to assess Gill's suggestion on the specific 1986-89 El Niño-La Niña period covered by the GEOSAT satellite and to extend the results over the 1961-93 period.

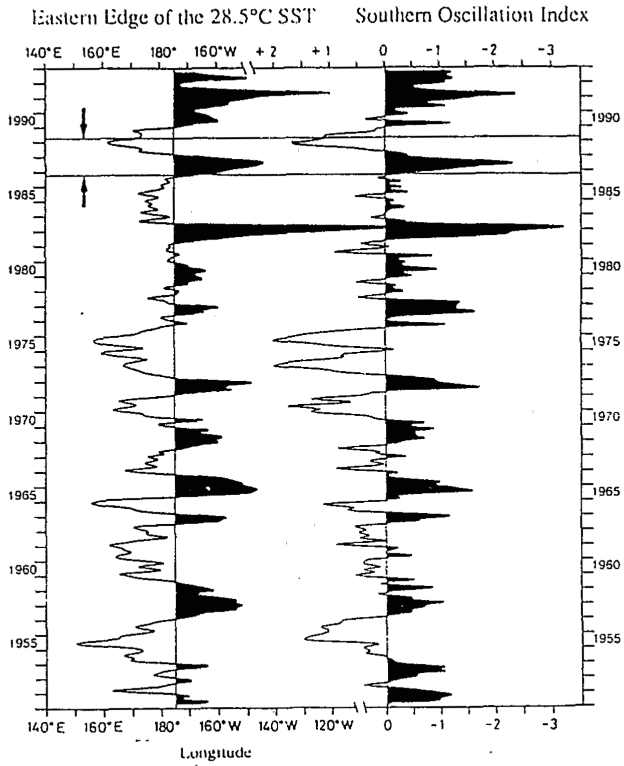


**Figure 1.** Zonal displacement of the 28.5°C SST averaged over 4°N-4°S and Southern Oscillation Index from 1950 to 1993. Monthly values are smoothed with a 1-2-1 filter, and the SOI axis is inverted. The November 1986-February 1989 period of GEOSAT study is outlined within the two arrows (from Picaut and Delcroix, 1995).

## Displacement of the Warm Pool During the 1986-89 El Niño-La Niña

Following the technique discussed by Picaut et al. (1990) and Delcroix et al. (1994), basin-wide zonal surface geostrophic current anomalies can be deduced from GEOSAT data, and they agree quite well with observed equatorial currents in the western and central Pacific. The displacements of water particles transported by the anomalous <4°N-4°S> GEOSAT-derived zonal surface currents is represented by the trajectories of two hypothetical drifters (Figure 2). The excellent agreement between the dashed and solid lines shows that the first baroclinic Kelvin and first meridional mode Rossby wave contributions are sufficient to account for the trajectories. These trajectories bracket the eastern edge of the warm pool (i.e., the 28.5°C isotherm), reflecting the dominance of zonal advection in changing SST in the central-western equatorial Pacific.

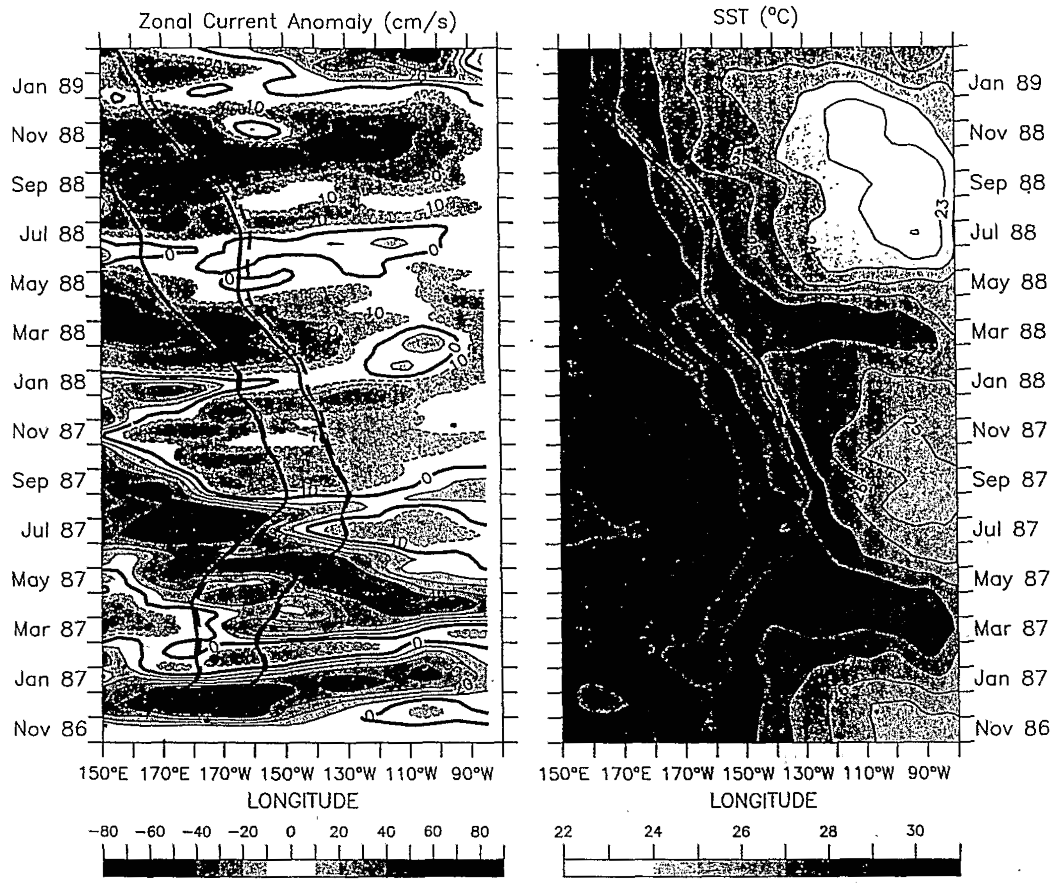


**Figure 2.** Left panel: longitude-time distribution of 4°N-4°S averaged zonal surface current anomaly derived from GEOSAT. Contour interval is 10 cm s$^{-1}$. Solid (dashed) lines denote eastward (westward) current anomalies. Right panel: longitude-time distribution of 4°N-4°S averaged SST. Contour interval is 1°C, except for the 28.5°C isotherm. Superimposed as heavy lines are the trajectories of two hypothetical drifters moved by the GEOSAT-derived currents; heavy-solid lines correspond to the total currents, heavy-dashed lines to the Kelvin and *m=1* Rossby mode contributions (from Picaut and Delcroix, 1995).

A more convincing test is to check the importance of zonal advection in the equation of heat within the two trajectories; in this domain the Lagrangian derivative of SST is close to zero since the trajectories bracket the 28.5°C isotherm. In Figure 3, the similar behavior between $\partial T/\partial t$ and $- u' \partial T/\partial x$ confirms that zonal advection by anomalous currents is a dominant mechanism for SST variations in the central-western equatorial Pacific, during the 1986-89 El Niño-La Niña period. The importance of zonal advection in changing SST in the central-western equatorial Pacific is also established through an analysis performed with the LODYC Pacific OGCM driven by the 1986-89 ECMWF wind stress. Meridional advection also contributes to SST changes, especially during La Niña. The relative importance of other terms such as vertical advection, surface forcing and mixing is presented in a more general study of heat budget of the warm pool (Maes et al., 1995, this volume).

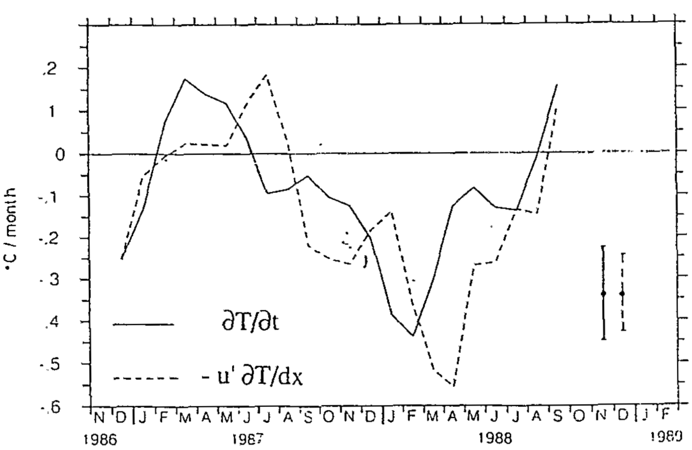


**Figure 3.** Comparison between SST tendency and zonal advection of temperature calculated in between the two trajectories of Figure 2. The 4°N-4°S averages are only computed up to August 1988, when one trajectory goes beyond the western limit of our current field. An estimation of the mean standard errors of $\partial T/\partial t$ and $-u' \partial T/\partial x$ is represented in the lower-right corner (from Picaut and Delcroix, 1995).

A detailed study on this subject (Picaut and Delcroix, 1995), indicates that the 1986-89 displacement of the warm pool appeared as a low-frequency movement resulting from high-frequency forcing, i.e., a succession of local wind forcing and its remote Kelvin and $m=1$ Rossby wave response in the equatorial wave guide. In the central-western Pacific, a $m=1$ downwelling Rossby wave, issued from the eastern Pacific, shifted the warm pool displacement from eastward to westward. With the return of the lending edge of the Warm Pool from the central to the western Pacific, a cold SST anomaly developed in the central-western equatorial Pacific in February-April 1988. This cold SST anomaly appears to be the very first manifestation of La Niña over the whole equatorial Pacific, and the downwelling $m=1$ Rossby wave, which shifted the displacement of the warm pool from eastward to westward, appears to be the pivot point of the 1986-89 ENSO cycle.

## DISPLACEMENT OF THE WARM POOL DURING THE 1961-93 PERIOD

This observational and modeling study of the 1986-89 El Niño-La Niña cycle was extended to the 1961-93 period, using a 10-vertical modes linear model forced by the FSU monthly wind stress. Model wind-stress projections onto vertical modes were calculated using a mean density profile representative of the climatology of the central-western equatorial Pacific. As expected from such simple model the comparison between modeled surface currents and near-surface currents observed from the TOGA-TAO array is not satisfactory, especially in the eastern equatorial Pacific where the correlation is close to zero and the ratio between modeled and observed amplitudes is 0.4. However, in the central and western Pacific the comparison improves with a correlation of 0.4 and a ratio of amplitude of 0.75. Despite these limitations, it appears that an hypothetical drifter, launched at 165°E and transported by the <4°N-4°S> modeled zonal surface current, remains in the central-western Pacific all over the 1961-93 period (Figure 4). In addition, its zonal displacement is mostly in phase with the displacement of the eastern edge of the warm pool, albeit of smaller amplitude. Another drifter, transported by modeled currents, limited to the first vertical mode, follows the same pattern with somewhat less amplitude. This last study suggests the importance of zonal advection and of the first vertical mode in the zonal migration of the eastern edge of the warm pool during most of ENSO events.

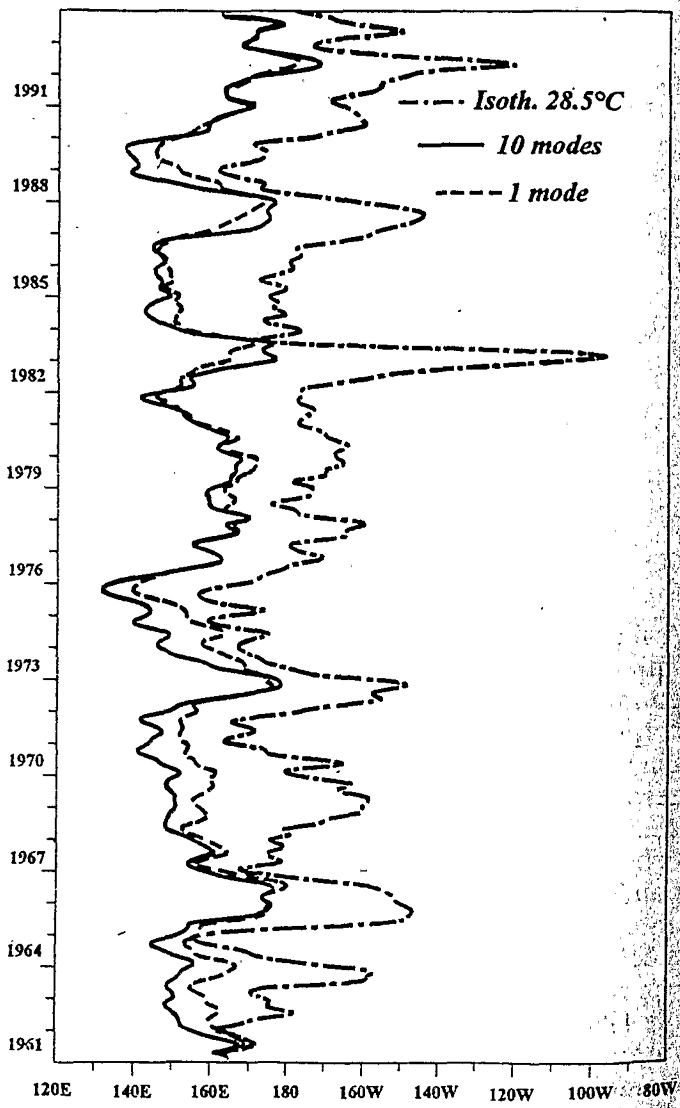


**Figure 4.** Zonal displacement of the 28.5°C SST averaged over 4°N-4°S and trajectory of an hypothetical drifter moved by the 4°N-4°S averaged surface currents derived from the linear model during the 1961-93 period (full line with 10 vertical modes, dashed line with the first vertical mode).

## CONCLUSION

Observational and modeling results indicate that interannual (El Niño-La Niña) displacements of the eastern edge of the warm pool is mainly due to zonal advection associated with local wind forcing and its Kelvin and $m=1$ Rossby waves response. For the specific 1986-89 El Niño-La Niña cycle covered by GEOSAT, a $m=1$ downwelling Rossby wave shifted the displacement from eastward to westward and therefore seems to have been the cause for El Niño to turn to La Niña. More observational and modeling studies are needed to quantify precisely the importance of zonal advection in the displacement of the warm pool and to explore this new way of transition from an El Niño phase to a La Niña phase.

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