

Thermal Fluctuations in the Equatorial Pacific in Relation to the 1982-83 Warm Event

Since 1979, ships-of-opportunity in a joint France-U.S. program have been collecting XBT data along three trans-Pacific routes crossing the equator at roughly 160°E, 160°W, and 100°W. Consequently, temperature profiles are available from the surface to 450 m about every sixty miles. Beaufort wind speeds and wind directions have also been collected aboard the same ships and some others calling in Noumea.

Using these data, monthly mean temperature profiles were computed for three equatorial areas extending from 2°S to 2°N by averaging all the XBT data collected between 140°E and 160°E (western Pacific), 150°-170°W (central Pacific), and 110°-90°W (eastern Pacific) from 1979 to 1983. The number of XBT casts used to determine the mean profile varies from 2 to 10. Wind data are a little more numerous, from 5 to 30 observations per month. Zonal wind stress was computed using the wind data with the same grid and conversion factor used by Wyrki and Meyers (1975). The Southern Oscillation Index (SOI) was defined as the sea level atmospheric pressure difference between Darwin and the mean pressures at Tahiti, Rapa, and Easter Islands.

Figure 1 shows the 1979-83 evolution of

the zonal wind stress and the equatorial thermal structure at 160°E, 160°W, and 100°W. Isolated months without data (three months in the western and eastern Pacific, one month in the central Pacific) have been interpolated. When two or more consecutive months are missing, isotherms are not drawn; the largest gap appears in the western Pacific, extending from August to December 1981.

In the western Pacific, the thermal structure exhibits only very small changes from 1979 to 1982. As already noticed by Meyers and Donguy (1983), there was no build up before the 1982 event. In fact, although easterlies increased slightly in 1981, the isotherm depths were equivalent in August 1981 and January 1982. The first straight upward motion of the thermocline is noticed in August 1982, *i.e.*, one month after complete setup of westerly winds in the western Pacific and after a sharp decrease in mean sea level (Wyrki, 1983). The maximum isotherm shallowing was reached in January-February 1983. At this time, the upper part of the thermocline had risen about 50 m above its pre-1982 depth. The March 1983 values seem to indicate a slight withdrawal of the phenomenon, possibly connected to a strong increase in easter-

lies, an unusual feature at this time of the year.

In the central Pacific (160°W), the thermal fluctuations were coherent, with isotherms between 25°C and 14°C generally moving in phase. The alternate periods of spreading (1981) and constricting of the thermocline give evidence of strong variations of the vertical current shear between the surface and the Equatorial Undercurrent. In 1982 the thermocline deepened twice, dropping first in January-February and again in September, but they do not look very different from the seasonal variation. The most unexpected feature is the considerable rise of the thermocline at the end of 1982. For the first three months of 1983, the thermal structure in the central Pacific behaved approximately as in the western Pacific. Also noticeable was the strong spreading of the thermocline from February to April 1983.

The eastern Pacific best illustrates the thermal effect of the 1982 El Niño. Isotherm depth increased sharply from August to October, which is consistent with Hayes' (1983) sea level data. The maximum depth was reached in December 1982, when the upper part of the thermocline (21°C) was nearly 100 m lower than in December of the previous years. The isotherms began to rise in January

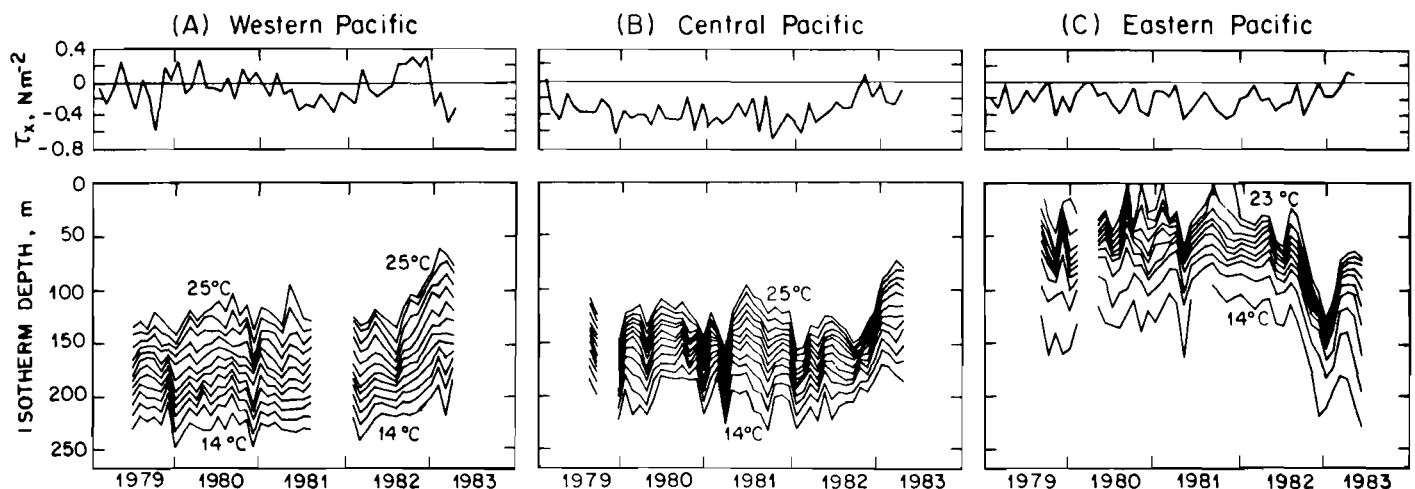


FIGURE 1 (Rebert *et al.*)

Monthly values of the zonal wind stress (τ_x , positive eastward) and depths of the 25°C to 14°C isotherms for the 2°N-2°S latitudinal band in (A) the western Pacific (140°-160°E), (B) the central Pacific (170°-150°W), and (C) the eastern Pacific (110°-90°W).

1983, but in May 1983 the isotherms in the lower thermocline again deepened and reached the January level.

Cross-correlations were computed (Table 1) between the different data files. For the isotherm depth correlations, the mean correlation coefficient was computed for the upper part of the thermocline. Because isotherms usually move approximately in phase, this coefficient was fairly constant from 23°C to 19°C, but below 17°C important changes sometimes occurred both in value and lag. In Table 1, the lag corresponds to the best observed coefficient; two numbers in this row indicate especially wide correlation peaks. The seasonal variations in the wind stress and isotherm depth were not removed, as these variations were very weak (Figure 1) compared to the total fluctuation: only in the central Pacific could seasonal variations be surmised. These correlations, which have no statistical significance because of the 1982 major event, represent only the best fit in the least square sense for the special case of the 1982 event. However, as the SOI seasonal variation is large and well-known, we present results for both rough data and deseasonalized data (*i.e.*, SOI anomalies).

In spite of the poor quality of the wind data, fair correlations appear between SOI anomalies and the wind stress in the central and western equatorial Pacific with a delay of one month, but no direct correlation was found between SOI anomalies and the wind stress in the eastern equatorial Pacific. Good inverse relationships occurred between the SOI and the isotherm depths in the western and eastern Pacific, with a five-month lag for the western Pacific and a two-month lag for the eastern Pacific, corresponding to the approximate delay between December 1982 (eastern) and February 1983 (western) peaks.

The best correlations between isotherm depths and wind stress were found for the zonal wind in the western Pacific. Negative correlation in the western and central Pacific indicates a convergence effect or baroclinic adjustment, *i.e.*, deepening of the thermocline when easterlies increase. No propagating phenomenon can be inferred from inspection of the lags. Notice that, for the central Pacific,

TABLE 1 (Rebert *et al.*)

The best cross-correlation coefficients (upper number) and lag in months (lower number), with column a leading row b between SOI, zonal wind stress (τ_z), and isotherm depths for three regions of the equatorial Pacific.

	SOI anomalies	τ_z central	τ_z eastern	τ_z western	isotherm western	isotherm central	isotherm eastern
SOI	1	0.2	0.4	0.6	0.6	0.5	0.4
SOI anomalies		2	1	5	5	1.4	3.3
τ_z central	0.5	1	0.4	0.4	0.4	0.6	0.7
τ_z eastern	0.4	1	4	5	7	7	7
τ_z western	0.6	0.4	0.3	1	0.7	0.7	0.5
isotherm western	0.6	2	3	1	1	2.5	2.5
isotherm central	0.5	1	0.4	0.4	0.4	1	0.6
isotherm eastern	0.4	1	4	5	7	7	7

the inverse relationship between local wind and thermocline depth was stronger than the direct relationship between low-frequency variations of wind stress and equatorial upwelling. In the eastern Pacific, a direct relationship appeared, but the decrease in the trade winds lagged the thermocline deepening by more than two months. This is in good agreement with the composite El Niño scenario described by Rasmusson and Carpenter (1981), showing that in the eastern Pacific the relaxation of easterlies lags the warming of surface waters.

Comparing isotherm depth variations, the largest inverse correlations appeared between western and eastern Pacific. Vertical motions in the eastern Pacific led motions in the western Pacific by two months. The central Pacific, which behaved much like the western Pacific, with a mean lag of one month, was negatively correlated with the eastern Pacific with a lag of two months. Thus, the lags between all these phenomena are coherent within one or two months.

Comparing this major 1982 event with similar features measured during previous El Niño Southern Oscillation events is rather difficult due to the lack of reliable thermal data sets. One must notice, however, that the lags observed between the upward and downward motions of the thermocline in the equatorial Pacific were really in poor agreement with models based on the propagation of equatorial waves and particularly with the correlations deduced from Busalacchi *et al.* (1983). For instance, if an eastward propagating wave was

responsible for the troughs observed in the central Pacific in 1982 and about three months later in the eastern Pacific, the speed of such a wave would have been only about half the Kelvin wave speed. Moreover, the peak observed in early 1983 also was not consistent with a westward reflected Rossby wave, since it appeared in the central Pacific before its occurrence in the eastern Pacific. It is therefore presently difficult to make any forecast of the evolution of the present event based on the observed thermal structure in spring 1983.

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