Thermohaline Structure Variability along 165°E in the Western Tropical Pacific Ocean (January 1984 - January 1989)

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ABSTRACT

Distribution of temperature, salinity and dynamic topography, using data from eleven SURTROPAC, three PROPPAC and three US/PRC cruises between January 1984 and January 1989, is examined. Long term changes of dynamic topography give a new view of oceanic variability in the western equatorial Pacific ocean:

a) After the 1982-83 El Nino event a drastic change occurs between 1984 and 1985 with a sudden accumulation of warm waters,

b) A steady and continuous loss of heat appears since 1985 with a shallowing of the thermocline culminating in 1987 with the associated El Nino episode.

Continuous temperature data from Atlas moorings confirm the slow tendency between 1985 and 1987 giving a new insight of the El Nino scenario in the Western Pacific. These cruises also give a more realistic temperature/salinity relationship along 165°E and have therefore made it possible to determine the accuracy of dynamic topography obtained by the Atlas temperature data set and Levitus T/S climatology.

In addition, the meridional surface dynamic topography distribution suggests a global seasonal displacement of the equatorial surface current system composed of North Equatorial Counter-Current (NECC), South Equatorial Current (SEC) and South Equatorial Counter-Current (SECC). Individual cruises show that the SECC related to the South Pacific Convergence Zone of the wind (SPCZ) which was neglected until now might sometimes in the austral summer displays a very strong eastward flow, which is compararable to the NECC flow and should be carefully considered in the COARE project as a major current in the western South Pacific Ocean.

1. Introduction.

In the framework of TOGA the SURTROPAC Group based at the ORSTOM Center in Nouméa has initiated (since January 1984) meridional transects along 165°E from 20°S to 10°N (Fig 1).

Two cruises per year permit a good description of hydrographic and current structures in the western equatorial Pacific ocean (Eldin, 1989). Other programmes have also carried out transects along the same meridian. They are issued from:

a) a close cooperation between the United States of America and the People Republic of China studying air-sea interactions in the western Pacific since January 1986, and

b) another ORSTOM programme, PROPPAC ("Production Pélagique dans le Pacifique"), since October 1987.

We have therefore a relatively large number of cruises (17) along the 165°E meridian, covering five years, including 1987 when an El Nino event occurred.

In addition, along 165°E monitoring of the temperature distribution of the 0-500m upper layer on a daily average has also been initiated by Pacific Marine Environmental Laboratory (PMEL) between 5°N and 5°S, in close cooperation with SURTROPAC Group since July 1985 (Hayes et al, 1988). Continuous temperature observation of the 0-500m layer at the equator has also been made since January 1986 by a current meter mooring deployed by US/PRC.

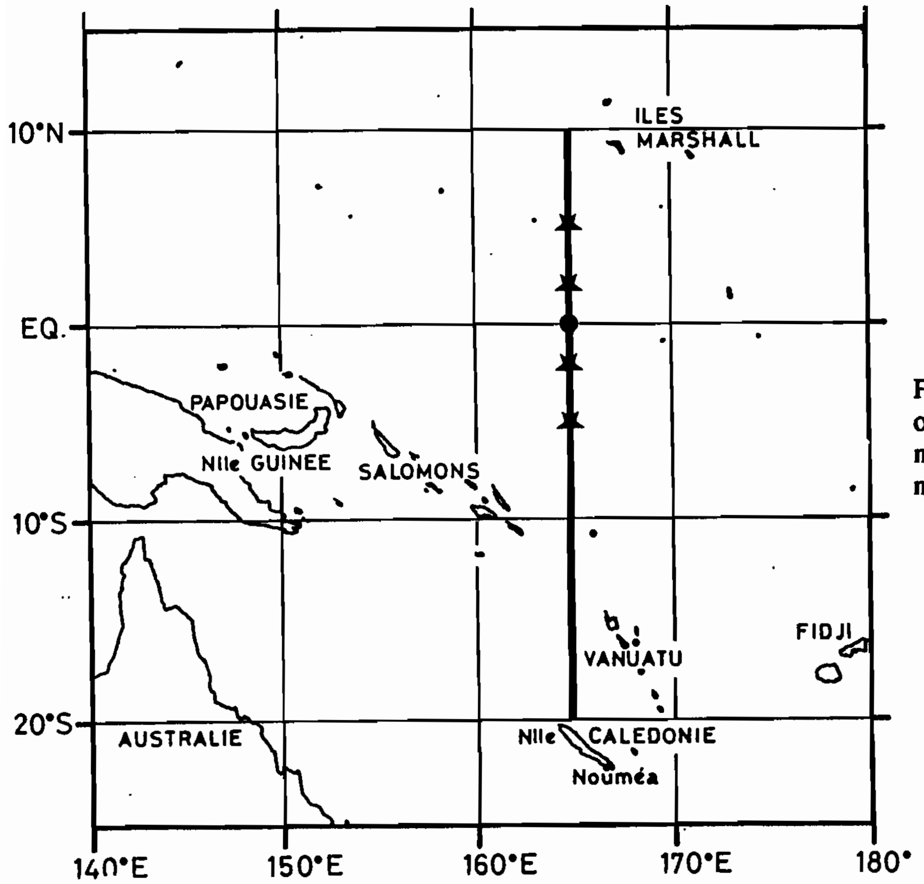

FIG.1. Location of oceanographic cruises and moorings along the 165°E meridian

This paper bring out the variability of dynamic topography, thermal and salinity structures using data sets from these cruises. Finally, a comparison of cruises and mooring data is made.

2. The 20°S-10°N transect.

The description of hydrologic stuctures using the first six Surtropac cruises between 1984 and 1986 has already been made in Delcroix et al. (1987), but the El Nino event in 1987 and the La Nina episode since 1988, bring out new elements of oceanic conditions in the western Pacific Ocean.

a. Thermal structure.

A typical temperature section made during Surtropac 11 cruise in January 1989 is presented Fig.2. An homogeneous upper layer is present on the equator from 5°S to 5°N. A well marked thermocline spreads on the equator at the location of the Equatorial Under-Current (EUC). The North and South Equatorial Counter-Currents (SECC and NECC) are characterised by a downward thermocline slope toward the equator. During this particular cruise the transport of SECC was of the same order of magnitude as the NECC (25 m^3s^{-1}). This suggests that this counter-current has to be considered in the volume budget of the western Equatorial Pacific.

The temperature distribution and in particular the thermocline depth governs its dynamic topography. Hence a large part of its variability came from the thermocline depth which varies in the range 50-200m near the equator during the period under consideration.

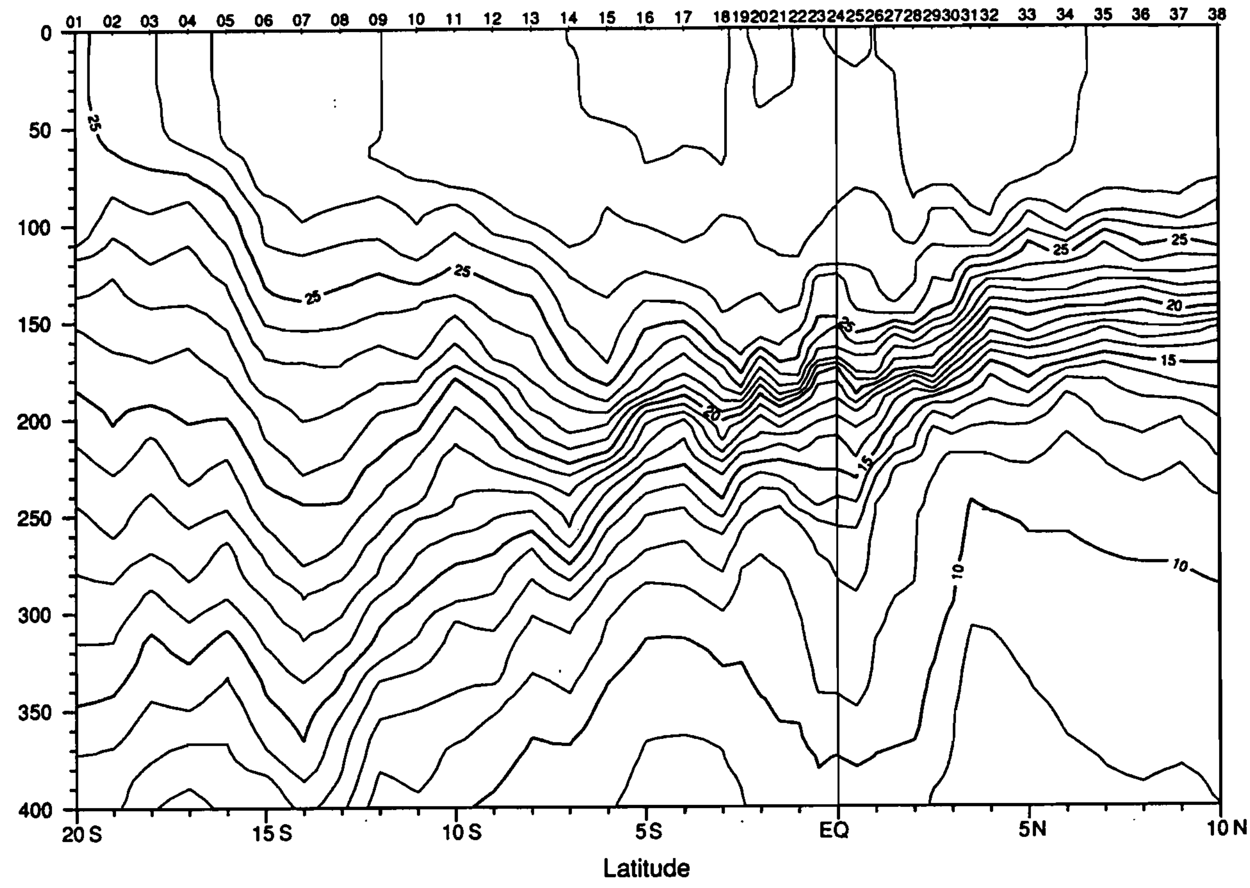

FIG.2. 0-400m temperature distribution along 165°E in January 1989.

b. Haline structure.

Salinity distribution along the transect (Fig.3) presents large gradients in both vertical and meridional directions:

a) vertical - Between surface low salinity waters in the NECC and SECC cores and the more salty water at the thermocline depth. The largest gradient lies between the waters of SECC with salinity smaller than 34.0, and the maximum of salinity greater than 36.0, which is the tropical water mass originating from French Polynesia in the southern hemisphere.

b) meridional - This tongue of high salinity waters reaches or crosses the equator and creates a meridional salinity gradient with low salinity northern hemisphere waters.

Although smaller than the effects of temperature on density, then on dynamic topography and on geostrophic circulation, the effect of salinity is quite marked particularly in the western equatorial Pacific, because of large variability of salinity values and haline gradients.

c. Dynamic topography.

To describe the dynamic topography variability in two contrasting seasons we have restricted Fig.4 to the SURTROPAC data set for January and June-July, since 1984.

The zonal equatorial current system is very well developed during January as indicated by upward dynamic height toward the equator in the two equatorial Counter-Currents (SECC between 10°S and 5°S and NECC between 9°N and 5°N). During austral summer, SECC is somewhat less pronounced while the two counter-currents seem to have shifted southward, the southern limit of NECC reaching 3°N.

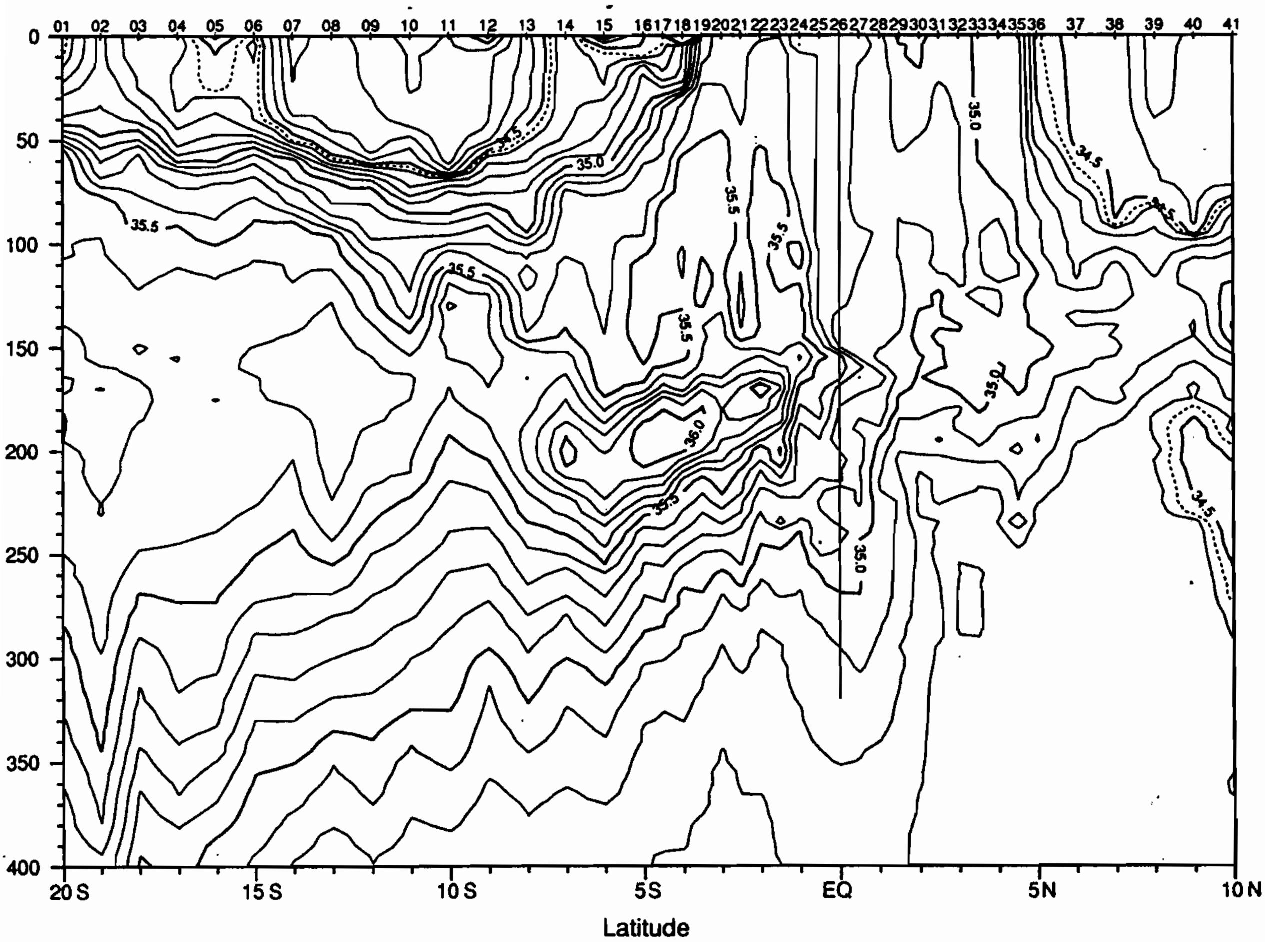

FIG.3. 0-400m salinity distribution along 165°E in January 1989.

The more striking feature is a very large interannual change (20-25 dyn.cm) between 1984 and 1987 occurring in the 5°N-5°S latitude band for January period and in the 0°-10°S latitude band for June-July. During 1984 surface dynamic height relative to 1000 db was low (185 dyn.cm), then a sudden change occurs in January 1985 with a maximum value of 205 dyn.cm, which was never noted before, then a slow decrease between 1985 and 1987. At this time the El Nino event was developing with low salinity waters and reduced upper layer.

d. Sea-Surface Salinity

Two typical distributions of surface salinity prevail during January and June-July (Fig 5):

a) In January the SECC usually carries low salinity waters with a minimum of 34.0. On the equator SSS is approximately 34.5 and the NECC is also characterized by low salinity surface waters (34.0 to 34.3).

b) In June-July the SECC is less pronounced and the SSS is somewhat saltier while the NECC being stronger carries lower salinity waters than in January (34.0). The change is much more developed in the equatorial band with a maximum of salinity of more than 35.0 related to upwelling associated with larger SEC.

Besides these typical distributions large anomalies occur such as the one observed during 1987 when the SECC disappeared in January eliminating the minimum observed generally near 10°S and in July when an eastward jet on the equator carried very low salinity waters

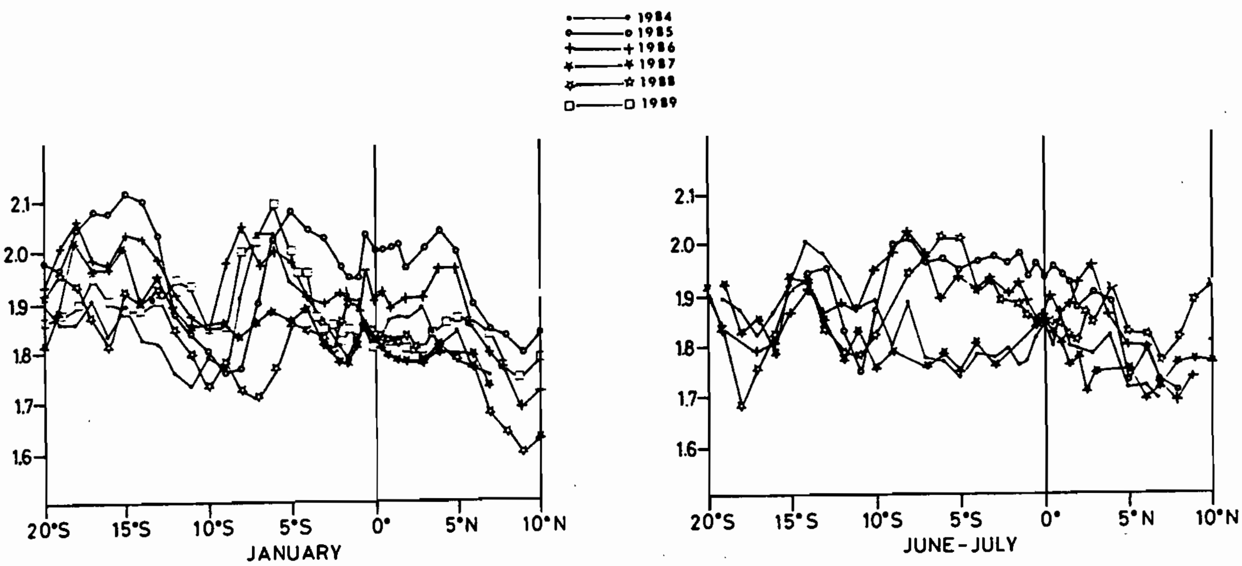

FIG.4. Surface dynamic height relative to 1000 db distribution along 165°E between January 1984 and January 1989. (left: January, right: June-July).

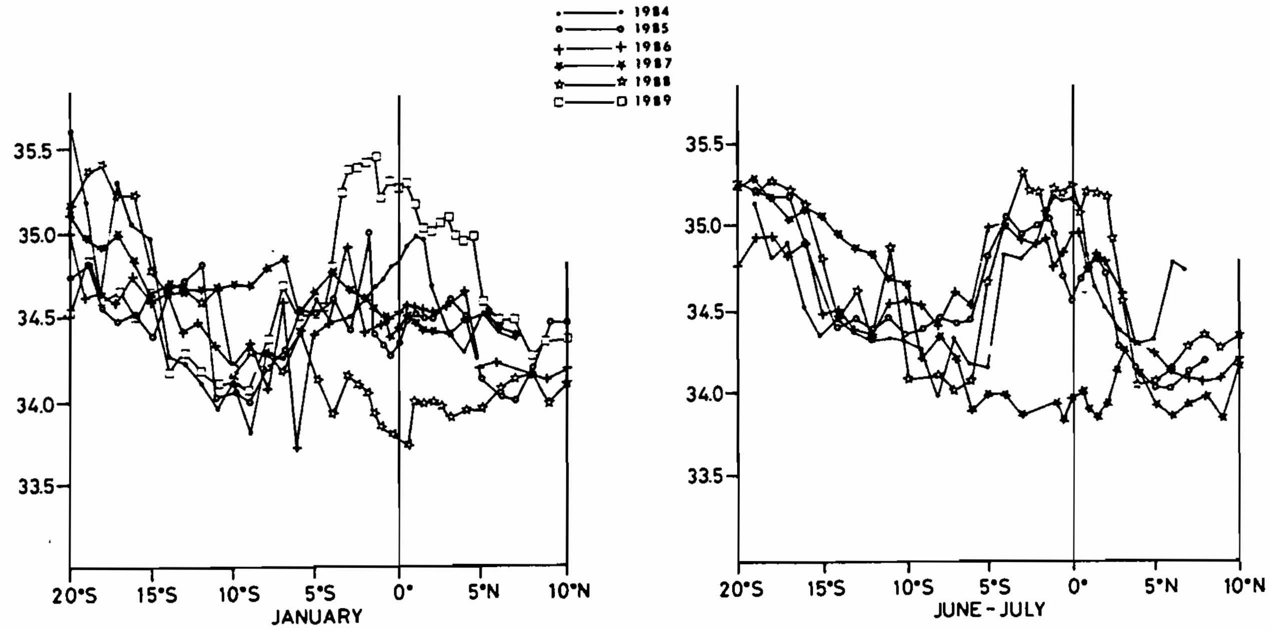

FIG.5. Sea surface salinity along 165°E between January 1984 and January 1989. (left: January, right: June-July).

(34.0 instead of 35.0). In January 1988 this low salinity remains on the equator before recovering normal values in July 1988. In fact, even in January 1989, the SSS was very high presenting a distribution generally observed in June-July. This may be explained by a very strong upwelling which started in April 1988 in the whole central and eastern Pacific reaching the 165°E meridian. At the same time, low rainfall contributed also to the presence of high salinity water on the equator for more than one year.

3. Equatorial band.

The equatorial band is of particular interest for the study of the variability of currents and thermal structure associated with waves which are developing in the equatorial wave guide (Moore and Philander, 1976).

At 165°E it is thermally monitored by Atlas thermistor chains at 5°S, 2°S, 2°N and 5°N by means of a joint PMEL-ORSTOM action and by US/PRC mooring on the equator (Fig 1). The SURTROPAC, PROPPAC and US/PRC cruises also gave information on the changes in time of SST, SSS and dynamic height on the equator.

a. Sea surface temperature (Fig 6).

The annual amplitude of the SST cycle is very small in the western Pacific where temperature is between 29.5 and 29.8°C for the 1984-87 period. January temperatures are generally higher than June-July temperatures by approximately 0.1-0.3°C. During the 1987 El Nino event SST was not different from that of previous years. However, a decrease of 1°C has been observed since April 1988 and remains till the last cruise in January 1989. As already mentioned the extension of La Nina toward the western Pacific has reached the 165°E meridian at that time.

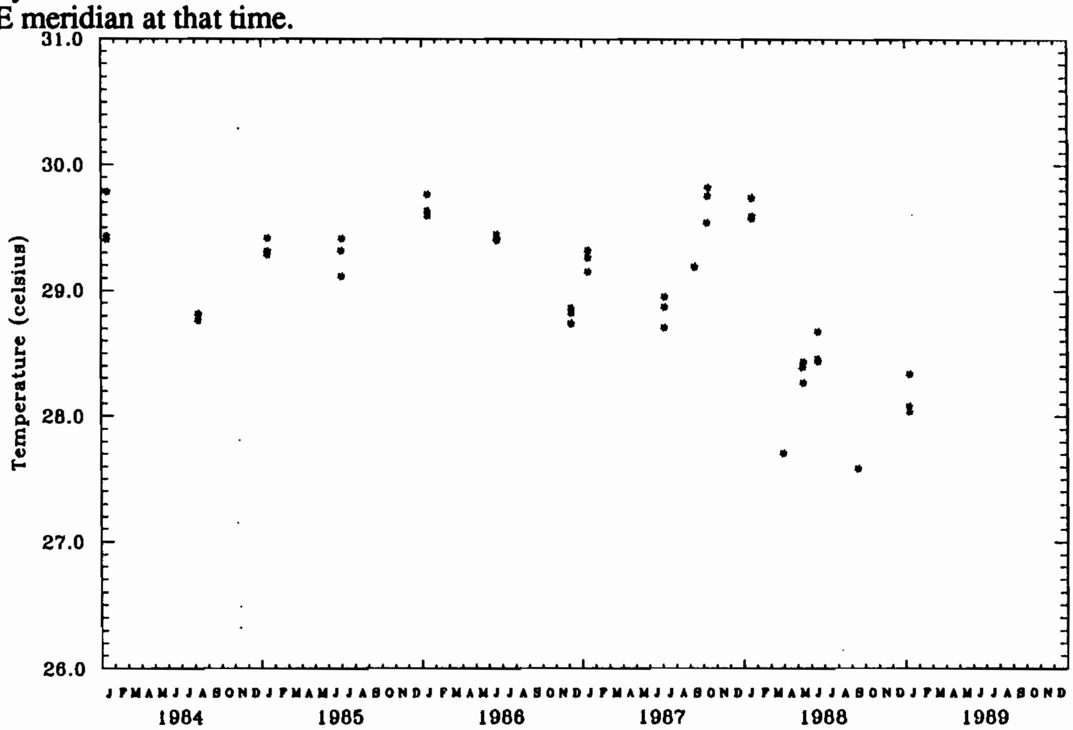

FIG.6. Sea surface temperature between 0°30 S and 0°30 N for the 1984-1989 period.

b. Sea surface salinity (Fig 7).

The annual amplitude of the SSS cycle is well marked during the first three years of observations (1984 to 1986). It will be noticed that SSS is larger in June-July than in January but the variation of SSS is confined to the 34.4-35.1 range. During the El Nino event, in 1987 SSS drops to a minimum of 33.6-34.0 due to low salinity waters from Western equatorial Pacific carried by eastward current. On the contrary, by April 1988, La Nina episode is marked by high SSS waters as already mentioned.

c. Dynamic height.

The surface dynamic height relative to 500 db versus time of the equatorial band 0.5°S-0.5°N from cruise data (Fig.8) shows a rapid increase between 1984 and 1985 and a

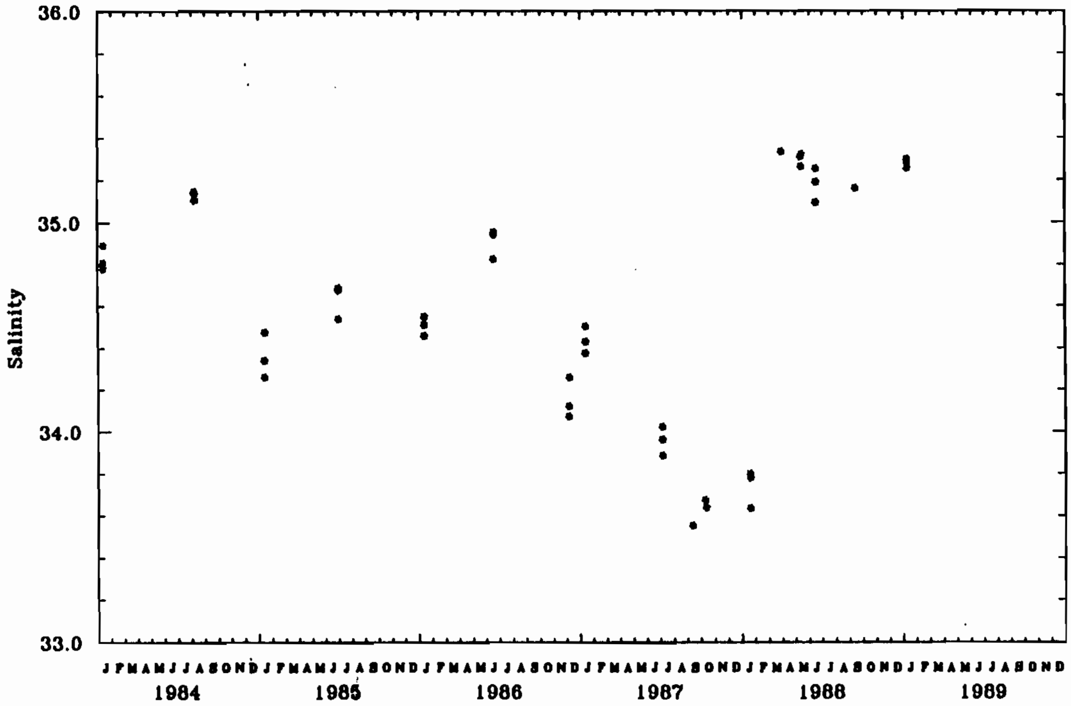

FIG.7. Sea surface salinity between 0°30 S and 0°30 N for the 1984-1989 period.

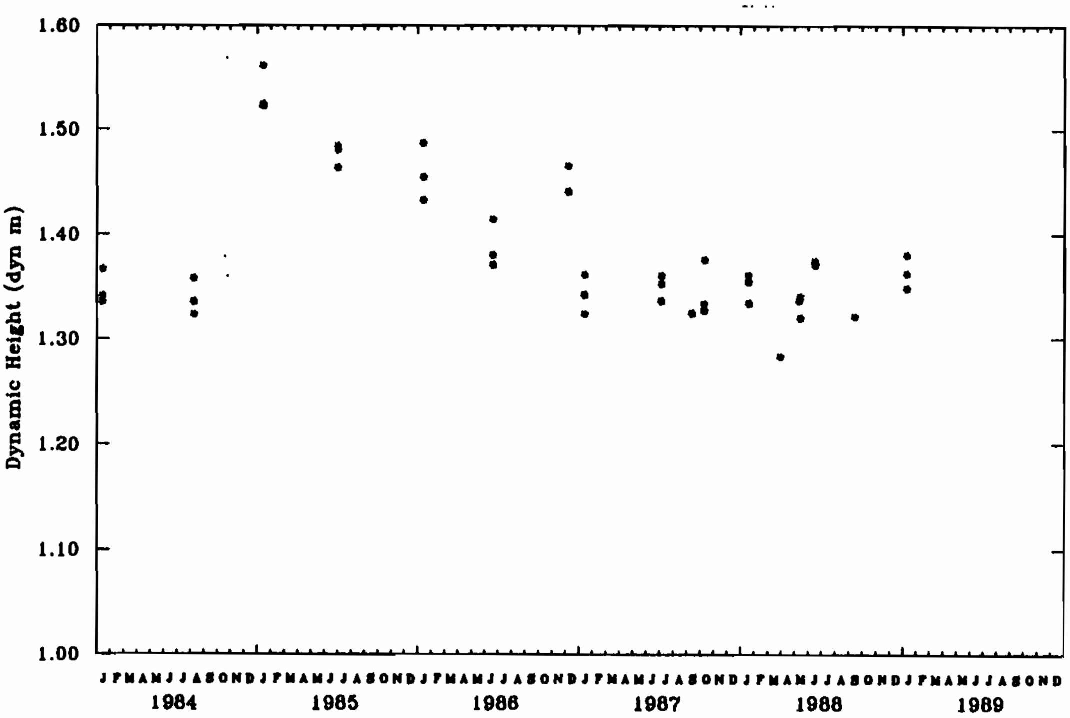

FIG.8. Surface dynamic height relative to 500 db between 0°30 S and 0°30 N for the 1984-1989 period.

slow decrease between 1985 and 1987. This diagram brings out the 20 dyn.cm variability and shows that no change appears in dynamic height between the 1987 El Nino and the 1988 La Nina episodes.

4. Comparison between cruises and moorings.

A comparison of cruises data and daily averaged data from thermistor chain was possible at 2°S-165°E where the Atlas system provided the longest time serie of 0-500m temperature.

Temperature and heat content from the two data sets were quite comparable while dynamic height from cruises and from temperature given by moorings using mean Levitus (1982)'s T/S relationship presents noticeable differences. Figure 9 shows that errors made using mooring and T/S relationship may be of +10 or -10 dyn.cm during the period of simultaneous data (from June 1985 to July 1988). It shows also that the range of dynamic height estimated by mean T/S and temperature data is twice the range of dynamic height from CTD cruise data (40 cm.dyn versus 20 dyn.cm).

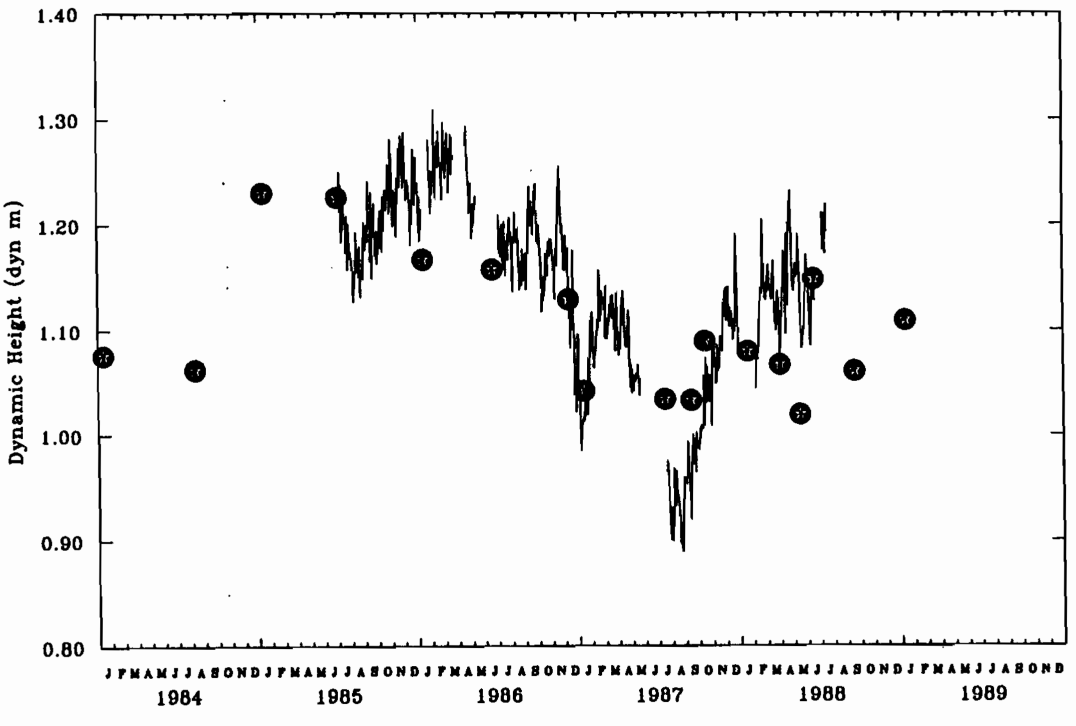

FIG.9. Surface dynamic height relative to 300 db at 2°S-165°E. Heavy lines : daily values from temperature distribution and mean Levitus T/S relationship; Dotted lines : dynamic height from individual cruises.

The reason for such differences lies in the T/S relationship change. Figure 10 reveals the very different T/S relationships at 2°S-165°E for each cruise. The dynamic height standard deviation has been estimated using the 17 available T/S relationships and the Atlas mooring temperature data set. It is of about 6 dyn.cm for the complete period of record. We may note also that the mean dynamic height using the cruise data set is very similar to the dynamic height obtained with mean Levitus T/S relationship.

5. Conclusion.

The results of the large monitoring effort in the western Pacific are encouraging. The need for monitoring is evident in this area of large changes in thermal and salinity distributions.

The effect of salinity on dynamic topography which was underestimated in the past has to be carefully examined in the western equatorial Pacific ocean.

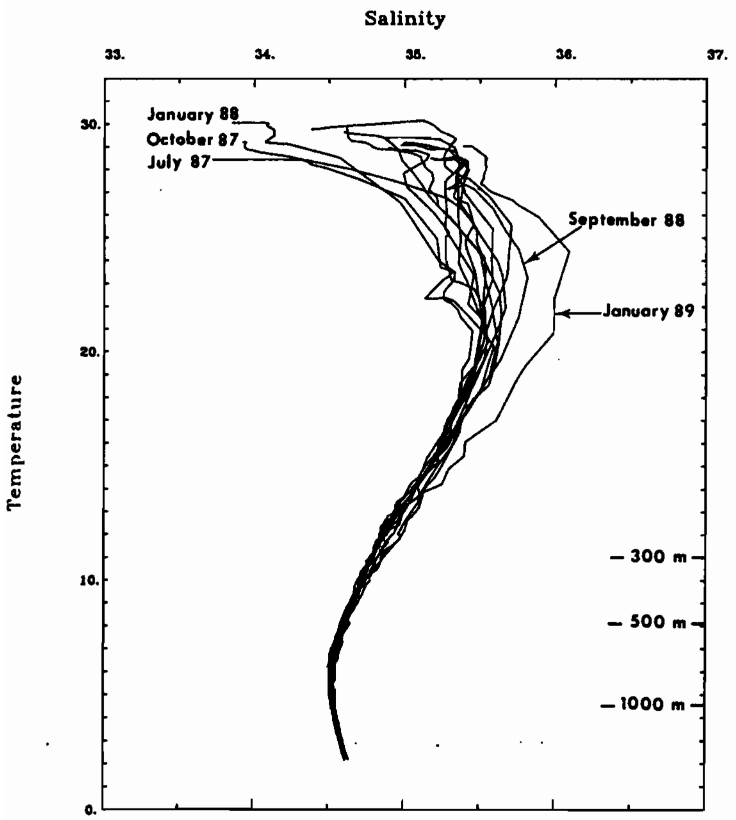

FIG.10. T/S curves for individual cruises at 2°S-165°E for the 1984/1989 period.

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