Fine structure variability

in the equatorial Western Pacific Ocean

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ABSTRACT

CTD and velocity measurements were carried out in the western equatorial Pacific ocean at 165°E in April 1988. Large-scale structures along this meridian are first described. Then, preliminary results of an 8-day long station at the equator are used to locate layers of high variability.

1. Presentation and data

The specific goals and scientific objectives of PROPPAC (PROduction Pélagique dans le PACifique) program are to study relations between physical processes and biological production. Main physical interest is to locate possible areas of vertical mixing. We will then establish how this local mixing interacts with large-scale hydrographic and velocity structures.

In the framework of this program, three cruises have been carried out along 165°E (20°S-6°N). Along the transect, every degree of latitude, a velocity profile is made down to 600 db and, at the same time, a CTD cast is done to 1000 db (Delcroix et al, 1987). Afterward, position for an eight-day long station is chosen in order to study variability of a specific situation.

We present here preliminary results of the cruise undertaken in April 1988:

1. Large-scale structures encountered from 5°S to 5°N along 165°E track (from April 3rd to 7th) are described using temperature, salinity, and velocity sections. Mean and standard deviation profiles are constructed from density data of the 8-day station (April 12th to 19th) in order to locate strong variability layers at the equator.
2. Then, a fine-scale variability study in the upper 400 m is initiated at the equator from the 8-day time series. Väisäla frequency, zonal vertical shear and zonal Richardson number are contour-plotted as functions of depth and time. The 29 profiles of zonal velocity, Väisäla frequency, zonal vertical shear, and zonal Richardson number measured during the 8-day long station have been averaged and are also presented. A mean "activity index" profile is compared to the averaged zonal Richardson number profile.

2. Large scale structures

As potential density section and temperature section look similar, only temperature section is presented here. However, salinity effect on the density field must be taken into account in areas where vertical temperature gradients are weak and vertical salinity gradients are strong (North Subsurface Countercurrent : 2°N-3°N).

A structure evidenced by the three sections shown in Figures 1a to 1c is an unusually strong equatorial upwelling. Delcroix et al (1987) only mentionned weak upwellings detected on temperature and salinity sections of the SURTROPAC cruises of January and August 1984.

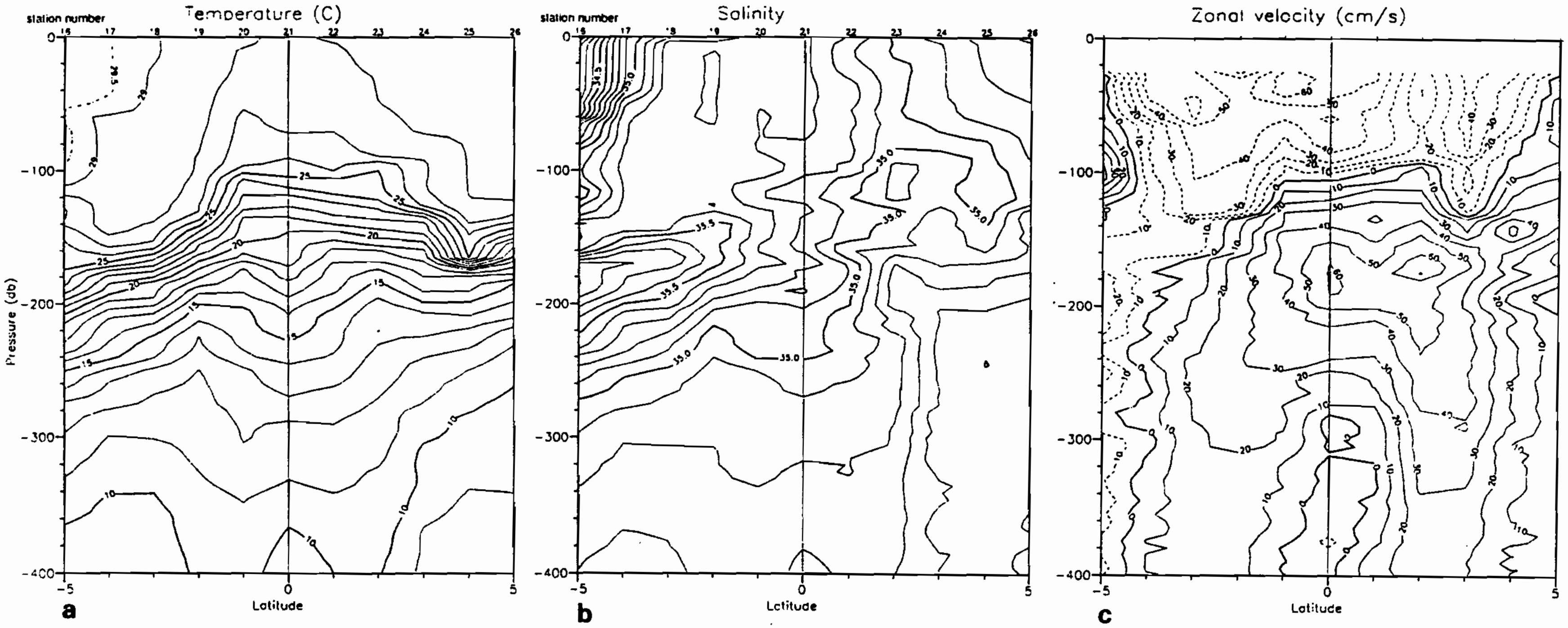

FIG.1. Large-scale stuctures of (a) temperature, (b) salinity, and (c) measured zonal current (ref. 600db) along 165°E.

In April 1988, we observe:

- a decrease in sea surface temperature (SST) from 28.6°C at 2°N and 2°N to 27.7°C at the equator;
- a strong meridional salinity gradient from the surface down to 100 m limiting the southern boundary of the upwelling at 4°S: | 0.5 (ppt) per degree of latitude;
- a strong South Equatorial Current (SEC) (Umax > 50 $cm.s^{-1}$) from 5°S to 5°N and down to 100 m. This strong westward flow has also been observed during the SURTROPAC cruise in January 1988 (Eldin, 1989) but it was not associated with an equatorial upwelling. SST between January and April cruises is measured by equatorial mooring (McPhaden and Freitag, 1988). It indicates a sharp fall in March 1988 and SST reaches value as low as 1°C below climatology at the end of the month.

Other main features have been observed during most cruises:

- isotherm spreading associated with Equatorial Undercurrent (EUC);
- vertical temperature gradient weakens under 300 m depth;
- EUC core is located in the area of maximum meridional salinity gradient (| 0.4 per degree of latitude at 170 m) situated at the northern edge of the high salinity tongue;
- under 300 m, westward Equatorial Intermediate Current (EIC) is hardly detected because of weak zonal velocity (5 to 10 $cm.s^{-1}$) and narrow meridional extension.

Layers of strong variations (in a statistical sense) are deduced from standard deviation profile of potential density (Fig. 2).

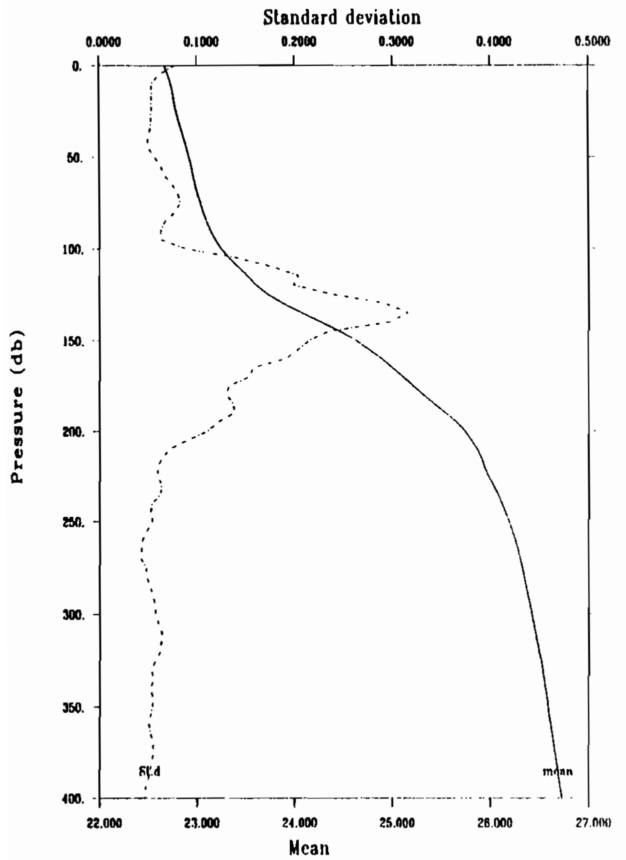

FIG.2. Mean and standard deviation profiles of potential density.

- The mixed layer down to 100 m is associated with small variations except a low maximum at 70 m.
- Strong variations are observed in the thermocline.
- Under the thermocline, there are small variations in the weakly stratified layer but a slight peak around 300 m.

This variability is not caused only by vertical displacements or shear instabilities.

Lateral advection of nearby water masses (which is not studied here) should be taken into account too.

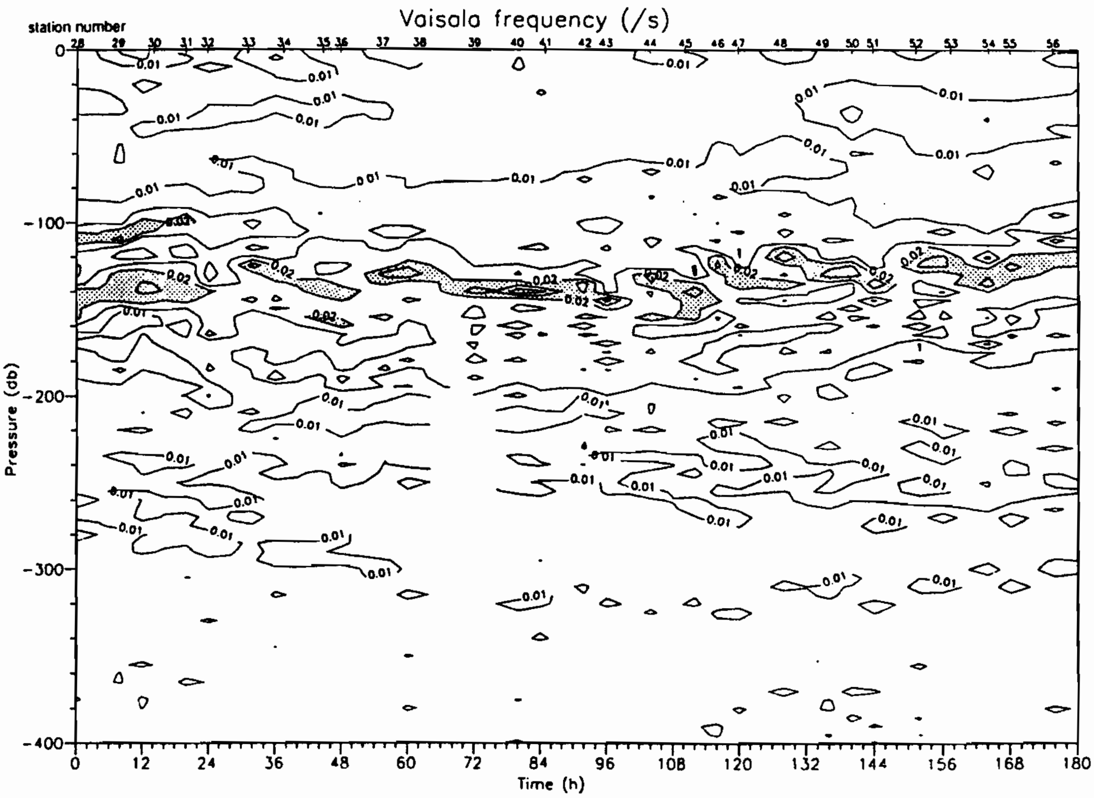

FIG.3a. Evolution of Väisäla frequency during the equatorial 8-day station.

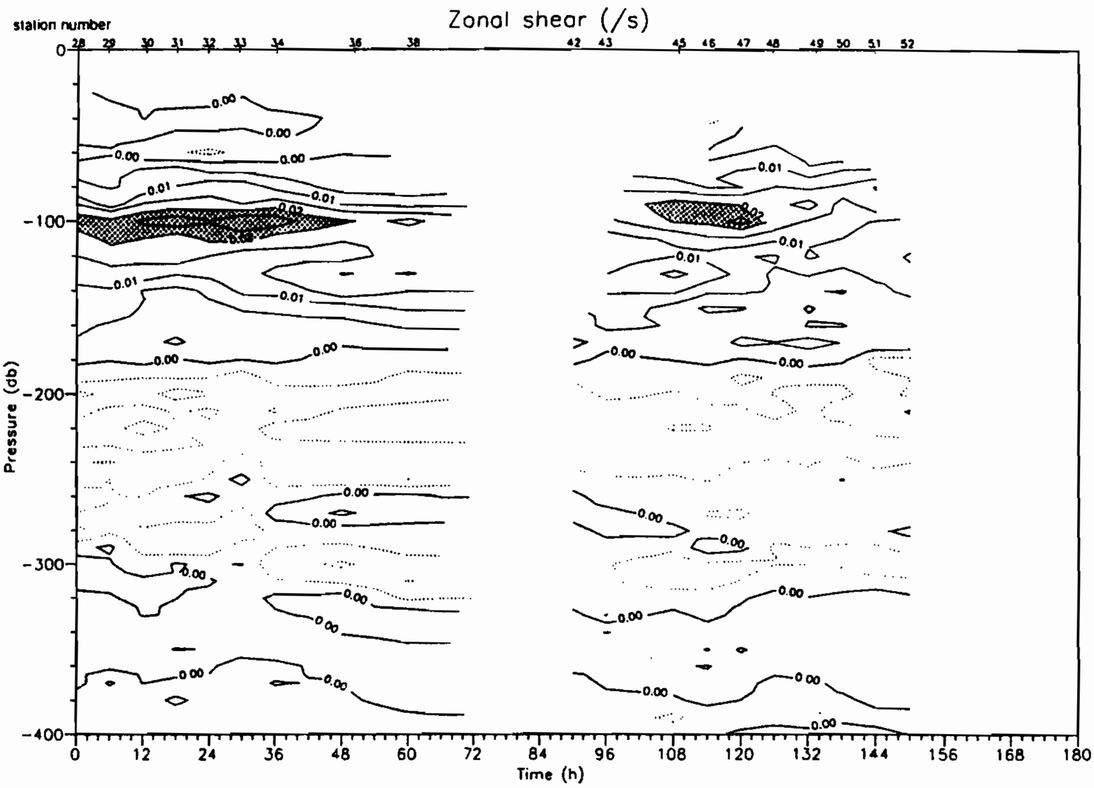

FIG.3b. Evolution of zonal vertical shear during the equatorial 8-day station.

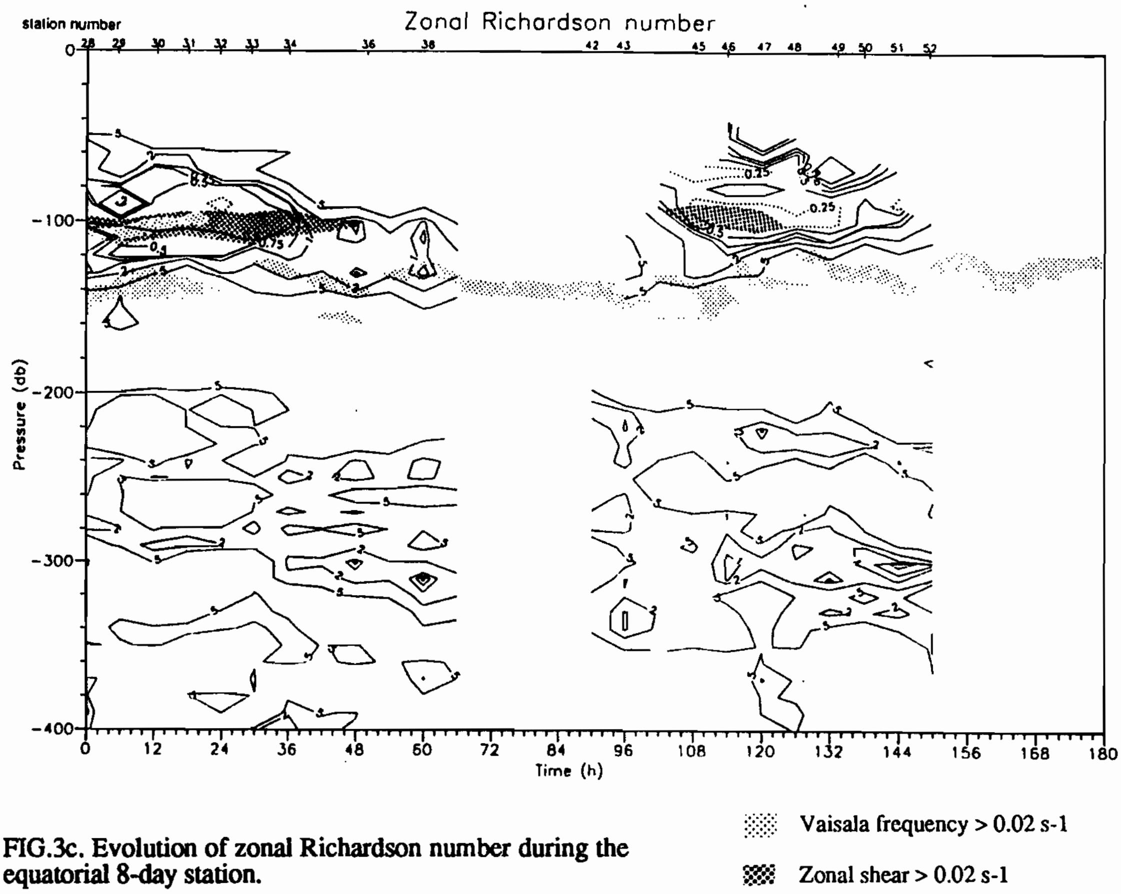

FIG.3c. Evolution of zonal Richardson number during the equatorial 8-day station.

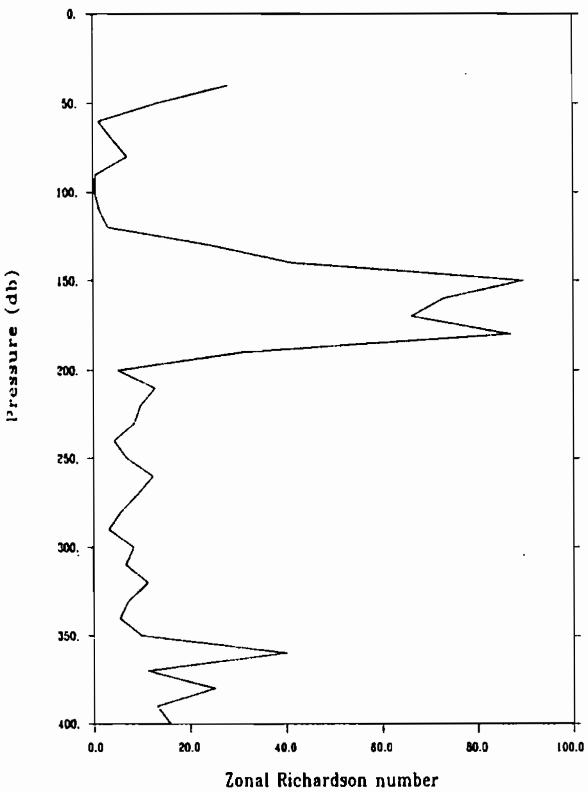

FIG.4a. Mean zonal Richardson number during the equatorial 8-day station.

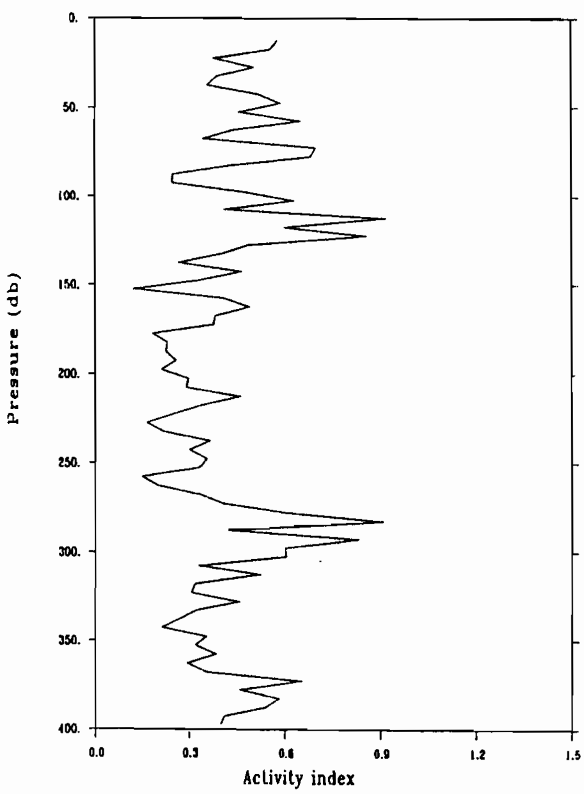

FIG.4b. Activity index computed from the potential density profiles of the equatorial 8-day station.

3. Fine scale variability

In this section, we identify layers of strong static stability and layers of large vertical shear of zonal current component and compare them to a statistical activity index. We also calculate Richardson numbers. Richardson numbers greater than 1. indicate a high stability regim in contrast to values smaller than 1. which represent destabilized system. If it is smaller than .25, the regim is considered as turbulent.

During all the 8-day station, the upper part of the thermocline constitutes the layer of strongest static stability (Fig. 3a).

The EUC core (evidenced in Figure 3b as the zero zonal shear value) is associated with a high Richardson number band (Fig. 3c).

Above the core, lowest Richardson numbers are confined in a layer closely linked to the highest shear region between 60 and 80 m. The critical value of 0.25 is reached during about 24 hours (it matches an intensive shear period) at the end of the station in a 15 m thick layer.

Around 300 m, between EUC and EIC, we find a layer where, although being bigger than 1., Richardson number is significantly lower than in the surrounding layers.

An activity index has been calculated from the potential density data of the 8-day station. It is defined as:

$$A = \mathrm{Var}\,(|\sigma/|z\,)\,/\,(\,<|\sigma/|z>\,)^2$$

where the sign < > indicates mean value. It is equal to the square of activity index used in McPhaden (1985).

Comparing the profile of averaged Richardson numbers (Fig. 4a) and the profile of activity index (Fig. 4b), two different regims are detected.

- Around 100 m, high activity index is associated with low Richardson number (< 1.). In this layer, part of the variability observed from the mean density profile may be caused by shear instabilities between SEC and EUC.
- At 300 m, there is also a high activity index peak (as well as a small standard deviation maximum in potential density) which lies in a layer where Richardson number remains high (> 1). It is not clear that this variability only results from vertical shear because of the weakness of the shear between EUC and EIC. We still have to remember that, even if it is weak, this layer lies in a discontinuity zone for temperature or salinity gradients, as well as for velocity. Mechanisms other than shear instabilities are probably related to this high activity. They may be associated with this weak discontinuity property.

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