Two types of hydroclimatic conditions in the South-Western Pacific

Hydroclimate
ITCZ
Surface salinity
Surface circulation
Heat content

Hydroclimat
Zone intertropicale de convergence des vents
Salinité de surface
Circulation de surface
Contenu thermique

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ABSTRACT

Two types of hydroclimatic conditions exist in the South-Western Pacific:
– one is characterized by the seasonal movement during the year from 10°S to 10°N of the Intertropical Convergence Zone of the winds, which induces the wet season and a surface salinity minimum. The surface circulation is made up of two current systems separated by the 160°W meridian. West of 180°, the maximum of heat content spreads from 10°S to 10°N.
– the other is characterized by the presence at the equator of the Intertropical Convergence Zone of the winds for several months. Due to heavy rainfall, the surface salinity minimum is found on the equator whereas, south of 10°S, a maximum is noticed. Only one current system exists from 160°E to 140°W. The heat content maximum moves from the Western Pacific to the Central Pacific. These conditions usually prevail 6 months after an El Niño phenomenon.

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RÉSUMÉ

Deux sortes de conditions hydroclimatiques dans le Pacifique tropical Sud-Ouest.

Il y a deux sortes de conditions hydroclimatiques dans le Pacifique tropical Sud-Ouest :
– l'une est caractérisée par l'oscillation saisonnière de la zone intertropicale de convergence des vents de 10°S à 10°N, qui amène la saison des pluies et provoque l'apparition d'un minimum de salinité de surface. La circulation de surface est constituée de deux systèmes de courants séparés par le méridien 160°W. A l'ouest de 180°, le maximum de contenu thermique s'étend de 10°S à 10°N.
– l'autre est caractérisée par la présence à l'équateur de la zone intertropicale de convergence des vents pendant plusieurs mois. Sur l'équateur, les pluies sont abondantes et un minimum de salinité apparaît, tandis qu'au sud de 10°S on remarque un maximum. La circulation de surface est caractérisée par la présence de 160°E à 140°W d'un seul système de courant. Le maximum de contenu thermique s'est déplacé du Pacifique Ouest au Pacifique Central. Ces conditions hydroclimatiques apparaissent habituellement 6 mois après El Niño.

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INTRODUCTION

All available surface data for the years 1956-1974 has been compiled for the South-Western Tropical Pacific Ocean, between 150°E and 130°W, and between 10°N and 25°S, to establish two surface salinity charts per year; in 1973-1974, four charts per year were drawn up (Donguy, Hénin, 1978 *a*). Since 1975, a number of ships of opportunity have provided enough data to draw up a monthly chart.

From these charts, the influence of the El Niño phenomenon in the South-Western Tropical Pacific has been pointed out by the occurrence of unusual surface features (Donguy, Hénin, 1976; Donguy, Hénin 1978 *b*). Now, with more accurate observations, two types of hydroclimatic conditions can be observed. One is characterized by the movement during the year, from 10°S to 10°N, of the Intertropical Convergence Zone of the winds (ITCZ), and the other by the presence at the equator of the ITCZ during several months.

HYDROCLIMATIC CONDITIONS WITH THE SEASONAL MOVEMENT OF THE ITCZ

According to Atkinson and Sadler (1970), the ITCZ has a seasonal oscillation from about 15°S in the South-Western Pacific (February-March) to 10°N in the North-Western Pacific (September-October) (Fig. 1). The wet season is mainly due to the presence in the Northern or in the Southern hemisphere of the ITCZ which brings rainfall. As a result, during March, in the South-Western Tropical Pacific, the ITCZ located about 15°S (Fig. 2) induces low salinity water by precipitations. In the Southern-Central Pacific, a maximum of salinity is due to the evaporation and, along the equator, the saline water is due to the equatorial upwelling induced by trade-winds.

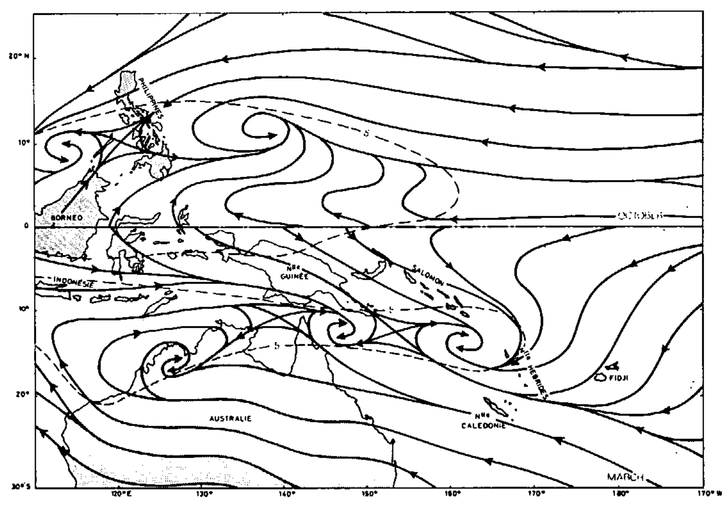

Figure 1

Wind field and seasonal positions of the ITCZ marked by a wind speed inferior to 5 knots in the Western Pacific: in the upper part, the position of the ITCZ in October: in the lower part, the position of the ITCZ in March (from Atkinson, Sadler, 1970).

Champ de vent et positions saisonnières de la zone intertropicale de convergence des vents, caractérisée par un vent inférieur à 5 nœuds dans le Pacifique Occidental : en haut, position de la zone de convergence en octobre; en bas, position en mars (d'après Atkinson, Sadler, 1970).

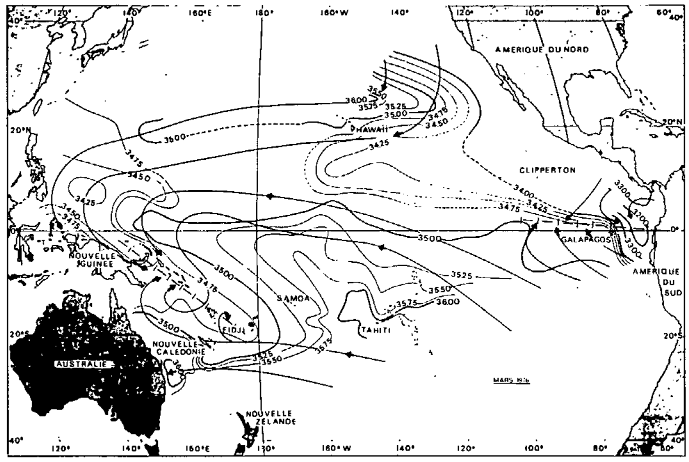

Figure 2

Surface salinity, per mil, March 1976. *Wind direction is marked by arrows, and the intertropical convergence zone of winds by a dotted line.*

Salinité de surface, mars 1976. La direction du vent est indiquée par des flèches, et la zone intertropicale de convergence des vents par une ligne discontinue.

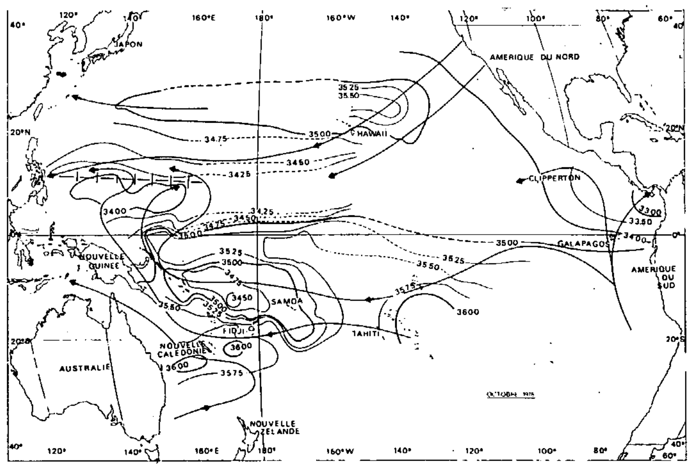

Figure 3

Surface salinity, per mil, October 1978. *Wind direction is marked by arrows, and the intertropical convergence zone of winds by a dotted line.*

Salinité de surface, octobre 1978. La direction du vent est indiquée par des flèches, et la zone intertropicale de convergence des vents par une ligne discontinue.

In October (Fig. 3), the ITCZ is located at 10°N where it induces low salinity water by precipitations. South of the equator, the zone of low salinity is still present, but smaller than in March. Due to the equatorial upwelling, we find high salinity along the equator.

Thus, when the ITCZ moves from 15°S to 10°N, an equatorial upwelling usually occurs. This feature involves a type of surface circulation resulting from the mean dynamic heights relative to 1000 dbar calculated from the hydrographic casts gathered between 1956 and 1970 (Fig. 4). The Equatorial Current occurs along the equator. South of 5°S, two current systems exist (Donguy *et al.*, 1976), and are separated by the 180° meridian: the eastward countercurrents have not the same origin each side of 180°, and the transported waters are different (Donguy, Rotschi, 1970).

A schematic picture of the main surface stream lines (Fig. 5), according to the mean dynamic topography, shows the importance of the eastward countercurrents in

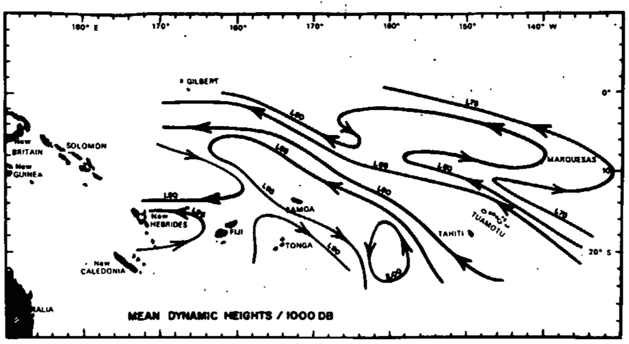

Figure 4
Mean surface dynamic heights in dynamic metres relative to 1 000 *dbar, in the South-Western Pacific.*
Moyenne des hauteurs dynamiques de surface en mètres dynamiques par rapport à 1000 dbar.

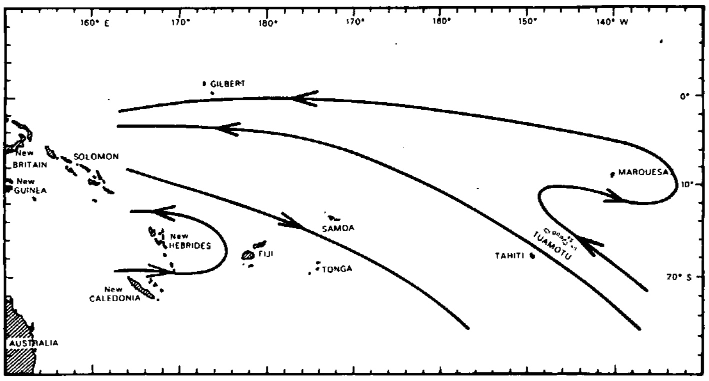

Figure 5
Schematic picture of the surface circulation in the South-Western Pacific in case of seasonal movement of the ITCZ.
Schéma de la circulation de surface dans le Pacifique Sud-Ouest en cas de mouvement saisonnier de la zone de convergence du vent.

the Western Tropical Pacific; in contrast, in the Central Tropical Pacific, the countercurrent seems to be only an oscillation of the Equatorial Current.

The distribution of the heat content into the first hundred metres is also an important feature of the hydroclimate. The unit used is the averaged temperature from the surface to a depth of 100 m. From NODC files, data was selected for a period just prior to the Austral summer and the Austral winter, when the movement of the ITCZ

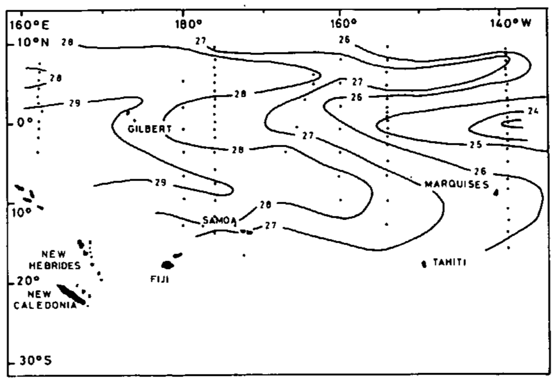

Figure 6
Heat content between the surface and 100 *m depth in October-December* 1961. *The unit used is the* 0-100 *m mean temperature.*
Contenu thermique entre la surface et 100 m de profondeur en octobre-décembre 1961. L'unité utilisée est la température moyenne de 0 à 100 m.

occurs. The data gathered between October and December 1961 (Fig. 6), before the Austral summer shows an equatorial minimum of heat content due to the equatorial upwelling; west of 177°E, the heat content is over 28 units, with a maximum over 29 units. Those of the Equapac Expedition (August-September 1956) give the same distribution of the heat content. So, with a seasonal movement of the ITCZ and the presence of an equatorial upwelling, a high heat content is stored west of 180° between 10°N and 15°S; this heat pool is divided by the western part of the equatorial upwelling into two branches spreading eastward.

HYDROCLIMATIC CONDITIONS WHEN THE ITCZ IS LOCATED ON THE EQUATOR

Instead of the seasonal movement of the ITCZ, the latter is sometimes located on the equator, west of 180°, for several months, mainly from September to April, as showed by Figure 7.

During March 1976 (Fig. 2), in the South-Western Pacific, the ITCZ was located at 15°S and the equatorial upwelling was active. In the Eastern Equatorial Pacific,

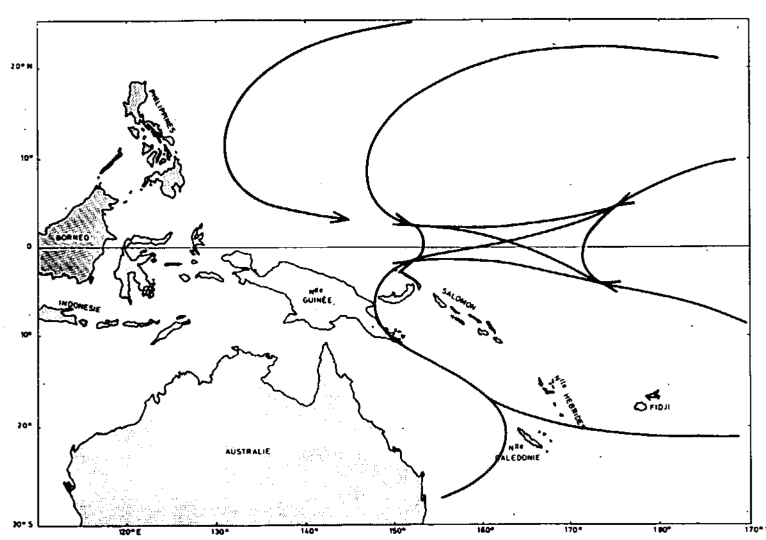

Figure 7
Wind field when the ITCZ is located on the equator during several months.
Champ de vent lorsque la zone intertropicale de convergence des vents est située sur l'équateur pendant plusieurs mois.

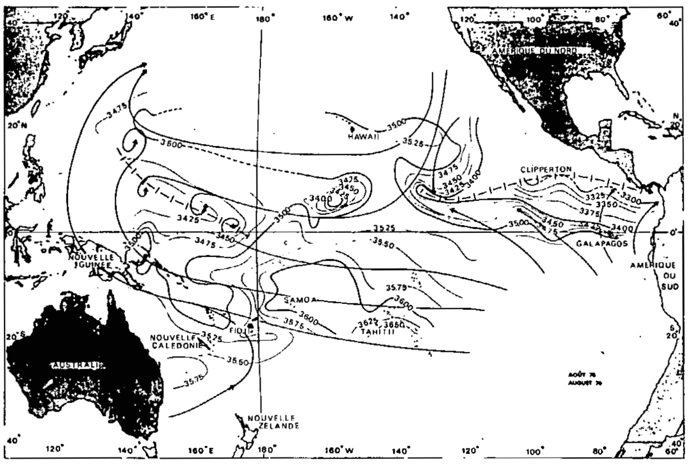

Figure 8

Surface salinity, per mil, August 1976. Wind direction is marked by arrows, and the intertropical convergence zone of winds by a dotted line.

Salinité de surface, août 1976. La direction du vent est indiquée par les flèches, et la zone intertropicale de convergence des vents par une ligne discontinue.

the 1976 El Niño was apparent: west of 90°W, a tongue of low salinity surface water disrupted the equatorial salinity front and moved southward. In August 1976 (Fig. 8), 6 months after El Niño, the hydroclimatic conditions were normal again in the Eastern Pacific. In the reverse, in the Western Pacific, the ITCZ was located partly on the equator, and consequently the equatorial upwelling does not exist west of 180°. This absence of the equatorial upwelling in the Western Pacific has been already described, notably by Bjerknes (1966).

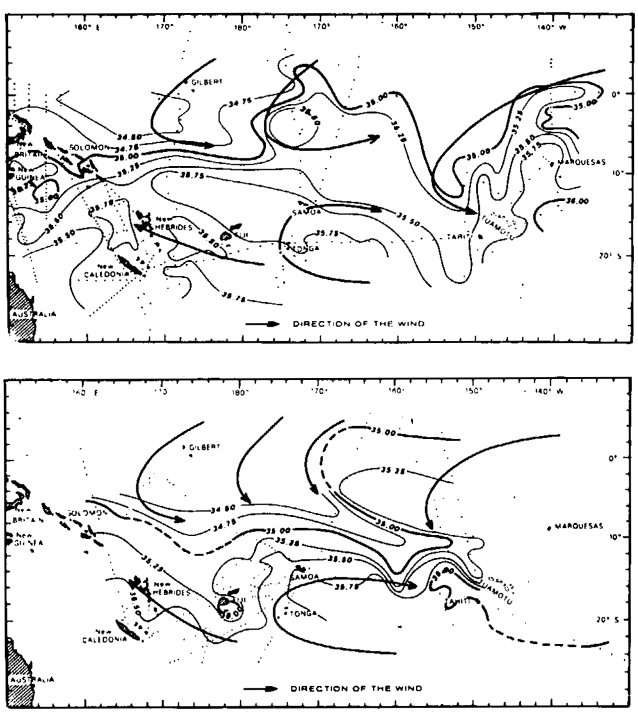

Figure 9

In the upper part surface salinity, per mil, January-May 1958. In the lower surface salinity, per mil, January-March 1973. Wind direction is marked by arrows.

En haut, salinité de surface, janvier-mai 1958. En bas, salinité de surface, janvier-mars 1973. La direction du vent est indiquée par des flèches.

The 1976 El Niño was moderate. In the case of a strong El Niño, as in 1957 and in 1972, the Western hydroclimatic anomalies also started late 1957 and late 1972, and continued into the beginning of the following year. The equatorial upwelling did not exist west of 140°W longitude in 1958 and 160°W in 1973 (Donguy, Hénin, 1976) (Fig. 9). The ITCZ staying on the equator instead of the equatorial upwelling induces heavy rainfall there. In the reverse, south of 10°S, the rainy season does not appear. This anomaly in the rainfall regime is clearly shown (Fig. 10) at the stations located approximately along the 180° meridian by the contrast between the mean precipitations and the precipitations observed from October 1957 to April 1958. During a year with a seasonal movement of the ITCZ, the rainfall maximum is observed at about 12°S, coinciding with the salinity minimum, and the rainfall minimum at about 2°S, coinciding with the equatorial salinity maximum and the equatorial upwelling. However, in 1957-1958, a double maximum occured, with peaks at 1°N and 6°S, the latter corresponding with the point of salinity minimum. South of 10°S, the rainfall was less than normal, causing a drought in the South-Western Pacific islands.

There are two examples of dynamic surface topography in the South-Western Tropical Pacific when the ITCZ is located on the equator: early 1958 during the International Geophysical Year, after the strong 1957 El Niño, and early 1977 (Fig. 11) after the moderate 1976 El Niño obtained during the cruise Danaïdes 2 carried out by the Centre ORSTOM of Nouméa. The schematic surface circulation deduced from the dynamic heights relative to 1 000 dbar, shows a very simple pattern (Fig. 12): from 5°S to the equator, the westward Equatorial Current; about 10°S, a weak eastward South-Equatorial Counter Current; between 15 and 20°S, the westward South-Equatorial Current and, south of 20°S, the eastward South-Tropical Counter Current, the two latter having a large extension.

Some of these features are corroborated by data gathered in early 1978 by W.C. Patzert during the Tahiti-Hawaii

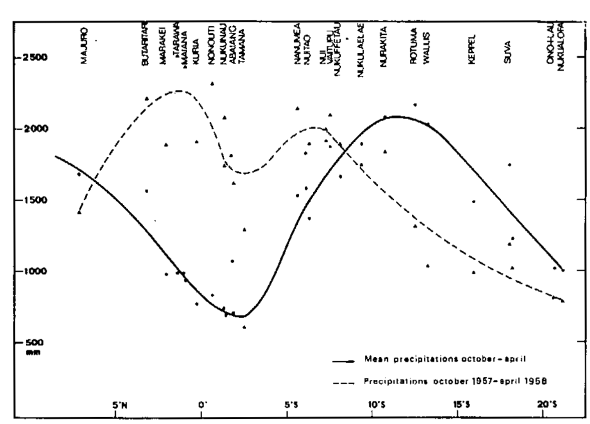

Figure 10

Rainfall in millimetres approximately along the 180° meridian. The solid curve shows the mean precipitation in October-April; the dashed curves shows the precipitation from October 1957 to April 1958. The names of the stations appear at the top.

Précipitations en millimètres approximativement le long du méridien 180°. La courbe en trait plein montre les précipitations moyennes d'octobre à avril. La courbe en trait discontinu montre les précipitations d'octobre 1957 à avril 1958. Le nom des stations apparaît en haut de la figure.

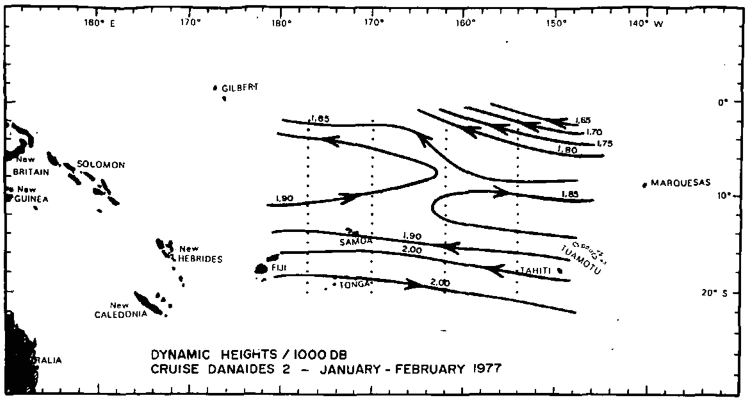

Figure 11
Surface dynamic heights in dynamic metres relative to 1 000 dbar, January-February 1977.
Hauteurs dynamiques de surface en mètres dynamiques par rapport à 1 000 dbar en janvier-février 1977.

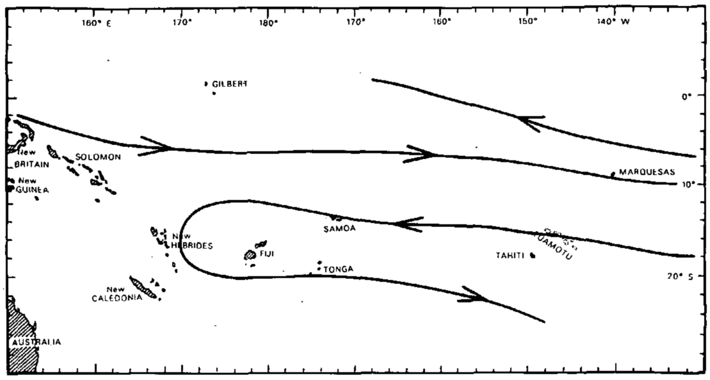

Figure 12
Schematic picture of the surface circulation in the South-Western Pacific with the ITCZ on the equator.
Schéma de la circulation de surface dans le Pacifique Sud-Ouest lorsque la zone de convergence des vents reste sur l'équateur.

shuttle experiment, as the surface salinity charts show for early 1978 the same hydroclimatic conditions than early 1977. Three drifting buoys show the presence of strong Equatorial Current, and one the presence at 10°S and 150°W of a weak South-Equatorial Counter Current (Fig. 13). To summarize on the area under study, there is, in this case, only one current system instead of two current systems when the ITCZ moves seasonally (Fig. 5). This feature is to be connected with the statements made by Wyrtki (1973), pointing out that, during the El Niño years, the countercurrents transport warm water from the Western to the Eastern Pacific.

The distribution of the heat content with the ITCZ located on the equator is also characteristic. After the strong 1957 El Niño, the heat distribution between the surface and 100 m depth from January 1958 to May 1958 (Fig. 14) shows a maximum (more than 29 units) in the Southern-Central Pacific from 170°E to 150°W (Hénin, Donguy, in press). After the moderate 1976 El Niño, the heat distribution from November 1976 to March 1977 shows also the same features, but not spreading as much eastward as during 1958. This distribution is very different to the case of the ITCZ seasonal movement (Fig. 6). Instead of a location west of 180° and on each side of the equator, the heat pool lies south of the equator and mostly east of 180°. The consequences of such a shift of the heat pool may be important: a preliminary study leads to a possible influence on cyclone formation (Donguy *et al.*, 1979). The heat asymetry between the north and the south hemisphere during the year following El Niño may also affect the climate.

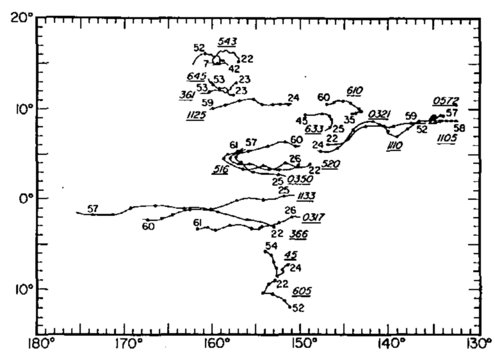

Figure 13
Trajectories of satellite tracked drifting buoy early 1978 in the South-Western Pacific, from W. C. Patzert. The number of the buoy is underlined, and the days are numbered from the 1st of January 1978.
Trajectoires de bouées dérivantes suivies par satellite début 1978, dans le Pacifique Sud-Ouest, d'après W. C. Patzert. Le numéro de la bouée est souligné, et les jours sont comptés depuis le 1er janvier 1978.

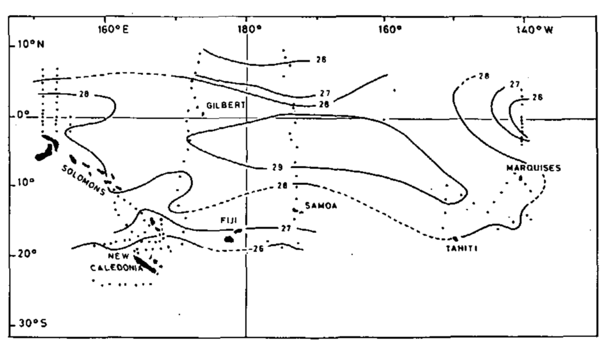

Figure 14
Heat content between the surface and 100 m depth, January-May 1958. The unit used is the 0-100 m mean temperature.
Contenu thermique entre la surface et 100 m de profondeur, janvier-mai 1958. L'unité utilisée est la température moyenne de 0 à 100 m.

CONCLUSION

These features recorded during 20 years of observations in the South-Western Tropical Pacific are consistent with the hypothesis of an equatorial Walker Cell existence, as already suggested by Bjerknes (1969).

When the ITCZ moves seasonally, a large Walker Cell spreads along the equator from America to Indonesia. This cell is at times broken, mostly after El Niño. Consequently in the Western Pacific, westerly winds prevail bringing rainfall and low salinity water. At the contact of the two cells, the ITCZ occurs and, due to the existence of the meridian Hadley cells, a drought appears in the tropical area. This hypothesis needs to be developed by theoretical work.

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