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Origin of the Surface Tropical Water in the Coral and Tasman Seas

J. R. Donguy and C. Henin

Centre ORSTOM de Nouméa, B.P. A5, Nouméa, New Caledonia.

Abstract

South of New Caledonia, a surface salinity maximum exists at about 30°S. At this latitude, the geostrophic flow is eastward and, consequently, it cannot originate in the Central Pacific Ocean. In the South Pacific, two kinds of surface salinity maximum are formed in two separated areas and they have different properties. These features are shown by several charts of surface salinity.

Introduction

A cargo vessel of the Sofrana Unilines sails each month from Noumea to New Zealand. Sometimes the liners of the Compagnie Generale Maritime also sail on this route, coming from or going to Europe. These ships have kindly taken at 4-h intervals a surface temperature measurement and a sampling of surface sea water; the salinity is measured later in the laboratory. The data obtained between November 1971 and November 1975 have been used to construct a space–time diagram showing the yearly variation of the mean salinity between 20 and 37°S. (Fig. 1).

Surface Salinity between New Caledonia and New Zealand

The surface salinity between New Caledonia and New Zealand is maximum at about 30°S. and minimum in the area close to New Caledonia. From 27 to 34°S. it is more than 35·70‰ between October and June, with an exception in January, and it has a maximum greater than 35·80‰ at about 31°S. between March and May. The origin of these high salinities poses a problem: are they coming from the tropical Central Pacific where the tropical salinity maximum is formed, or are they formed on the spot?

Dynamic Heights and Surface Circulation between New Caledonia and New Zealand

From 1958 to 1963, cruises between New Caledonia and New Zealand have been numerous, mainly in the austral summer from November to June (Fig. 2). Details are listed in the following tabulation.

Vessel	Cruise	Date	Reference
Vityaz	VI 27	Jan. 1958	Natl. Oceanogr. Data Center No. 900862
Tiare	Bounty	June 1958	ORSTOM, I.F.O. Rapp. Sci. No. 7
Orsom III	Choiseul	May 1959	ORSTOM, I.F.O. Rapp. Sci. No. 15
Gascoyne	G 1/60	Feb. 1960	CSIRO Oceanogr. Cruise Rep. No. 5
Gascoyne	G 2/60	Mar.–Apr. 1960	CSIRO Oceanogr. Cruise Rep. No. 6
La Dunkerquoise	France	Nov. 1961	ORSTOM, I.F.O. Rapp. Sci. No. 24
Gascoyne	G 1/62	Feb. 1962	CSIRO Oceanogr. Cruise Rep. No. 13
La Dunkerquoise	Hunter	Dec. 1963	*Cah. ORSTOM Sér. Océanogr.* 1966, **1**, 3–78

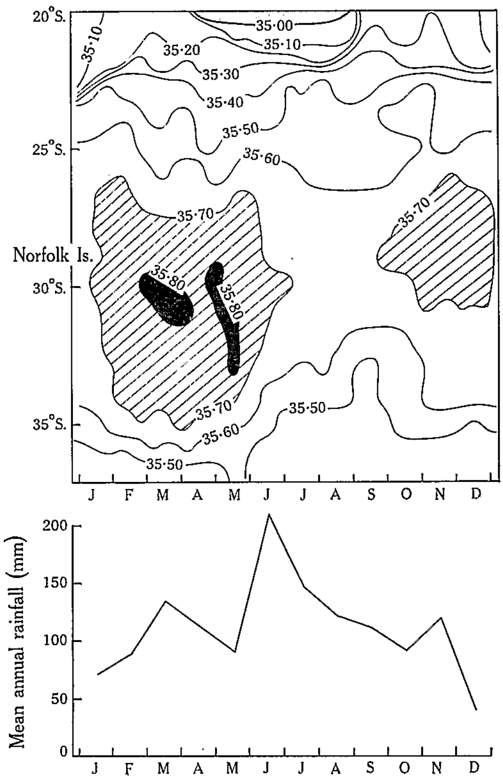

Fig. 1. Mean surface salinity (‰) along the track of the ships and mean rainfall for 1971–75 at Norfolk Island.

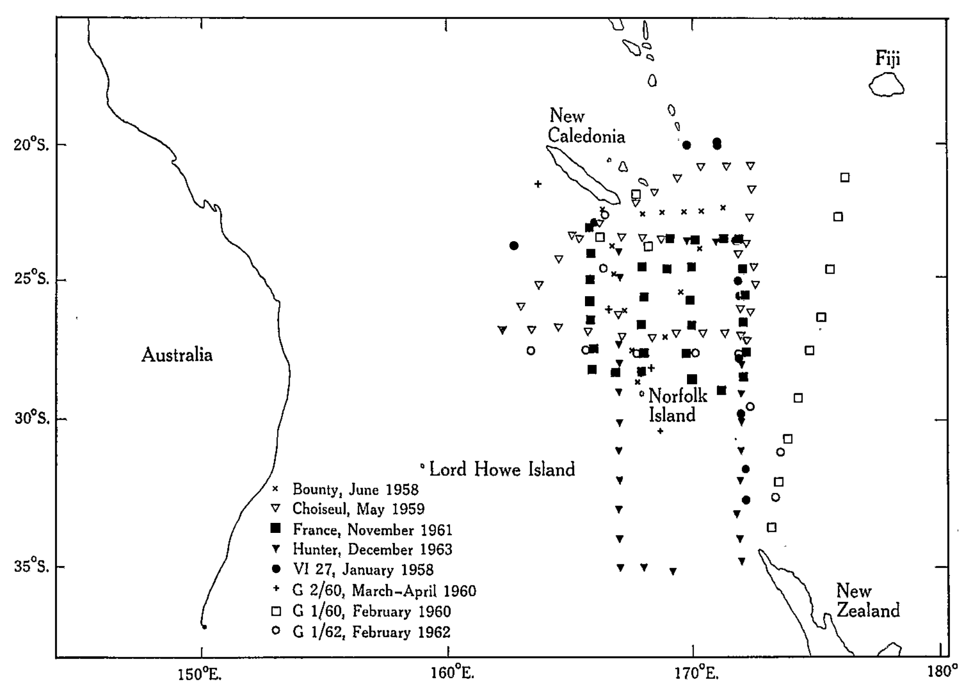

Fig. 2. Hydrographic stations occupied between New Caledonia and New Zealand from 1958 to 1963.

The hydrographic casts may be separated into two groups—one including the casts near the 166°E. meridian south of New Caledonia, and the other including the casts near the 172°E. meridian north of New Zealand. The dynamic heights computed by usual methods from hydrographic casts are relative to the 1000 decibars surface, with an accuracy of $\pm 0 \cdot 5$ dynamic cm. They are averaged from 20 to 30°S. at 166°E. (Fig. 3) and from 20 to 32°S. at 172°E. (Fig. 4). At 166°E. a dynamic maximum

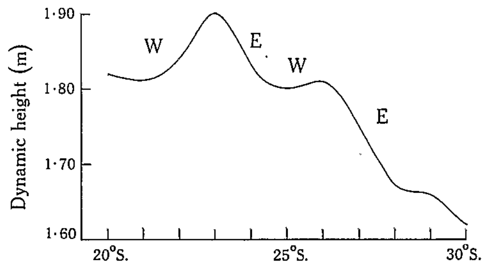

Fig. 3. Mean dynamic heights relative to 1000 decibars at 166°E. between New Caledonia and New Zealand.
W, westward flow.
E, eastward flow.

exists at 23°S., and from 23 to 30°S. the slope of dynamic heights is decreasing southward—consequently from 20 to 23°S. the flow is westward, and from 23 to 30°S. it is eastward. At 172°E., from 20 to 32°S., the slope of dynamic heights is decreasing southward and the flow is eastward. Assuming continuity of the mean dynamic heights calculated north of 20°S. at 170°E. (Donguy *et al.* 1976), and included in Fig. 4, with the ones south of 20°S. at 172°E., a dynamic maximum appears between 20 and 24°S. So, from New Caledonia to New Zealand the Tropical Convergence is located between 20 and 23°S., separating a westward flow in the north from an eastward flow in the south.

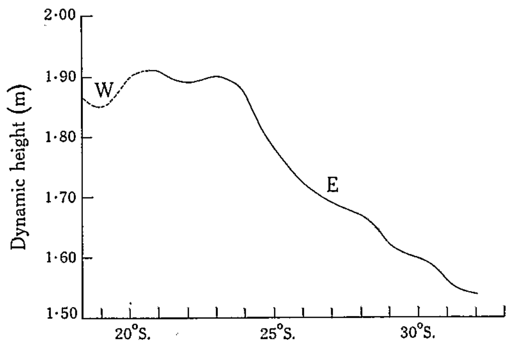

Fig. 4. Mean dynamic heights relative to 1000 decibars at 172°E. between New Caledonia and New Zealand. The dashed line is the mean dynamic height at 170°E. north of 20°S.
W, westward flow.
E, eastward flow.

This feature disagrees with the results of Wyrtki (1960) who showed a seasonal movement of the Tropical Convergence. At the time of the cruises used (November to June) the Tropical Convergence would be located at 30°S. instead of 20–23°S., but the westward flow south of 25°S. is weak. This discrepancy is probably due to the kind of data used from hydrographic casts and from ships' observations. In 1958 and 1959, Rotschi (1963) found the Tropical Convergence at 26 and 25°S.

Some features about the flow between New Caledonia and New Zealand may be deduced from examination of the difference between the mean sea level at Auckland (New Zealand) and that at Noumea (New Caledonia) from 1967 to 1974 (Fig. 5). The tide records from Auckland have been kindly provided by the New Zealand

Department of Lands and Survey, and the mean sea level at Noumea has been calculated by the Service Hydrographique (Brest) and by the Department of Oceanography, University of Hawaii. The data have been corrected for variations in atmospheric pressure. A small difference in mean sea level between Auckland and Noumea corresponds to only a weak westward flow or, on the contrary, a strong eastward flow (as in November 1967, September 1969, October 1970, October 1971, September 1972, and March and September 1973). Between New Caledonia and New Zealand the eastward flow is maximum from September to January. At this time the west wind prevails between 27 and 34°S. (Atkinson and Sadler 1970) and induces the acceleration of the eastward current. In 1973, the difference in mean sea level between Auckland and Noumea was small, inducing probably the strongest eastward flow during the 1967–74 period; it was an anomalous year (Donguy and Henin 1976*a*) with a strong westward flow from 20 to 10°S. This eastward flow between New Caledonia and New Zealand is probably a return current.

In conclusion, because the surface salinity maximum is associated with an eastward geostrophic flow, this water mass cannot originate in the Central Pacific.

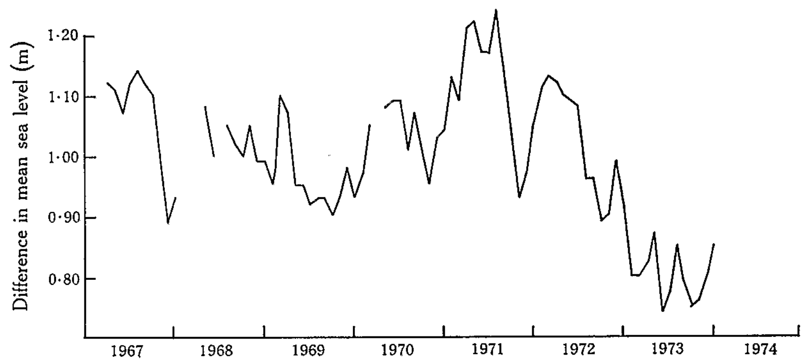

Fig. 5. Difference between the mean sea level at Auckland (New Zealand) and at Noumea (New Caledonia) from 1967 to 1974.

The Two Kinds of Surface Salinity Maximum in the South Pacific

All the surface data gathered by the Centre ORSTOM de Noumea have been used to establish charts of surface salinity between 160°E. and 140°W. from 10 to 40°S. at the following times: January–March 1958, January–February 1973, September–October 1974, February–March 1975, and November–December 1975. On each of these charts, in spite of the scarcity of the data, two independent surface salinity maxima occur, both defined by a salinity greater than 35·75‰.

Thus, in September–October 1974 (Fig. 6) and November–December 1975 (Fig. 7), the western salinity maximum reached eastward to 172°E. while the Central Pacific salinity maximum reached westward to 160°W. At this time, the latter is most widespread as a result of the settled dry season from 20°S. to the equator (Donguy and Henin 1976*b*); on the other hand, the western salinity maximum is weak (Fig. 1).

In February–March 1975 (Fig. 8), the western salinity maximum reached eastward to 173°E. while the Central Pacific one reached westward to 156°W. At this time, this latter is least widespread due to the wet season; on the other hand, the western

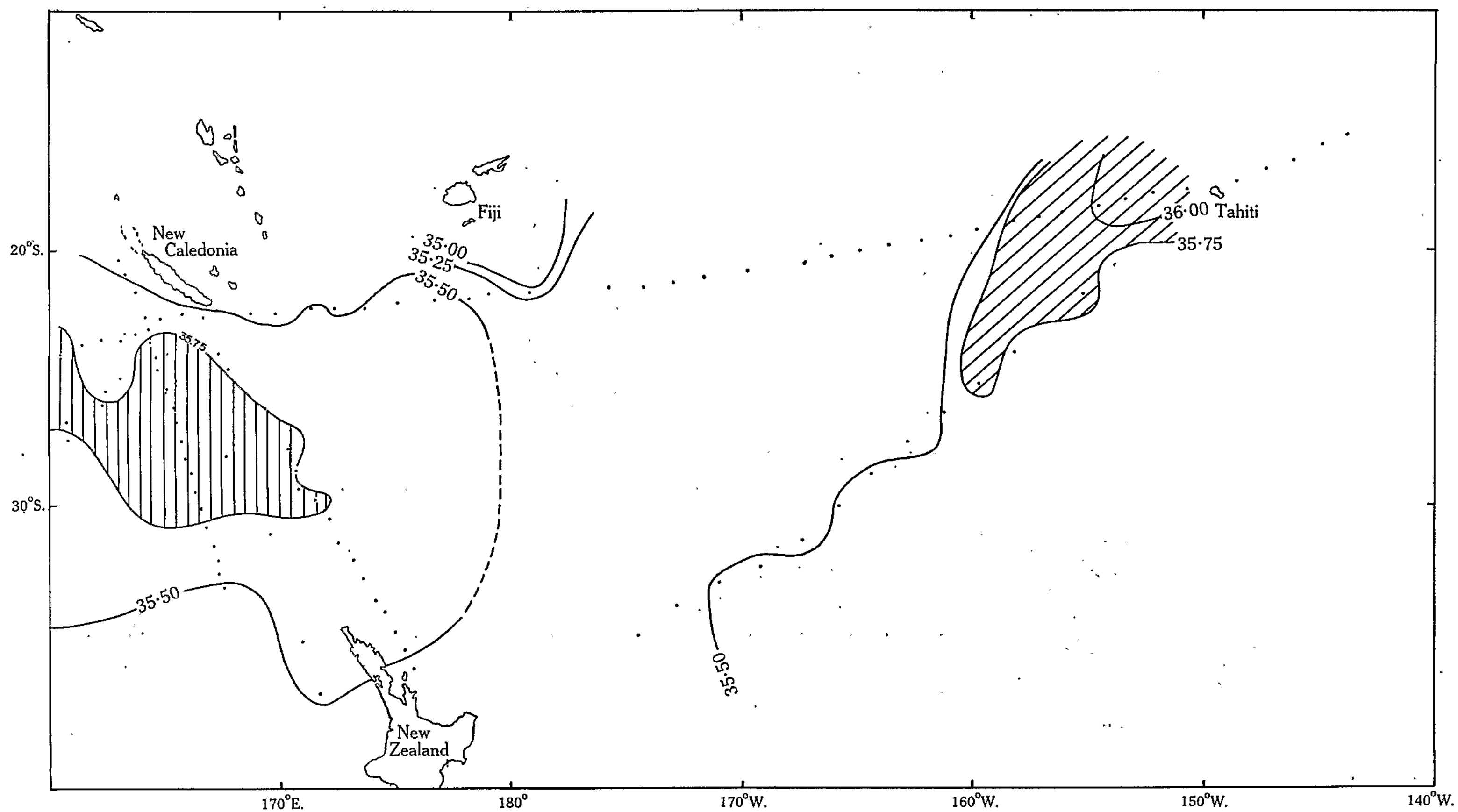

Fig. 6. Surface salinity chart in September–October 1974.

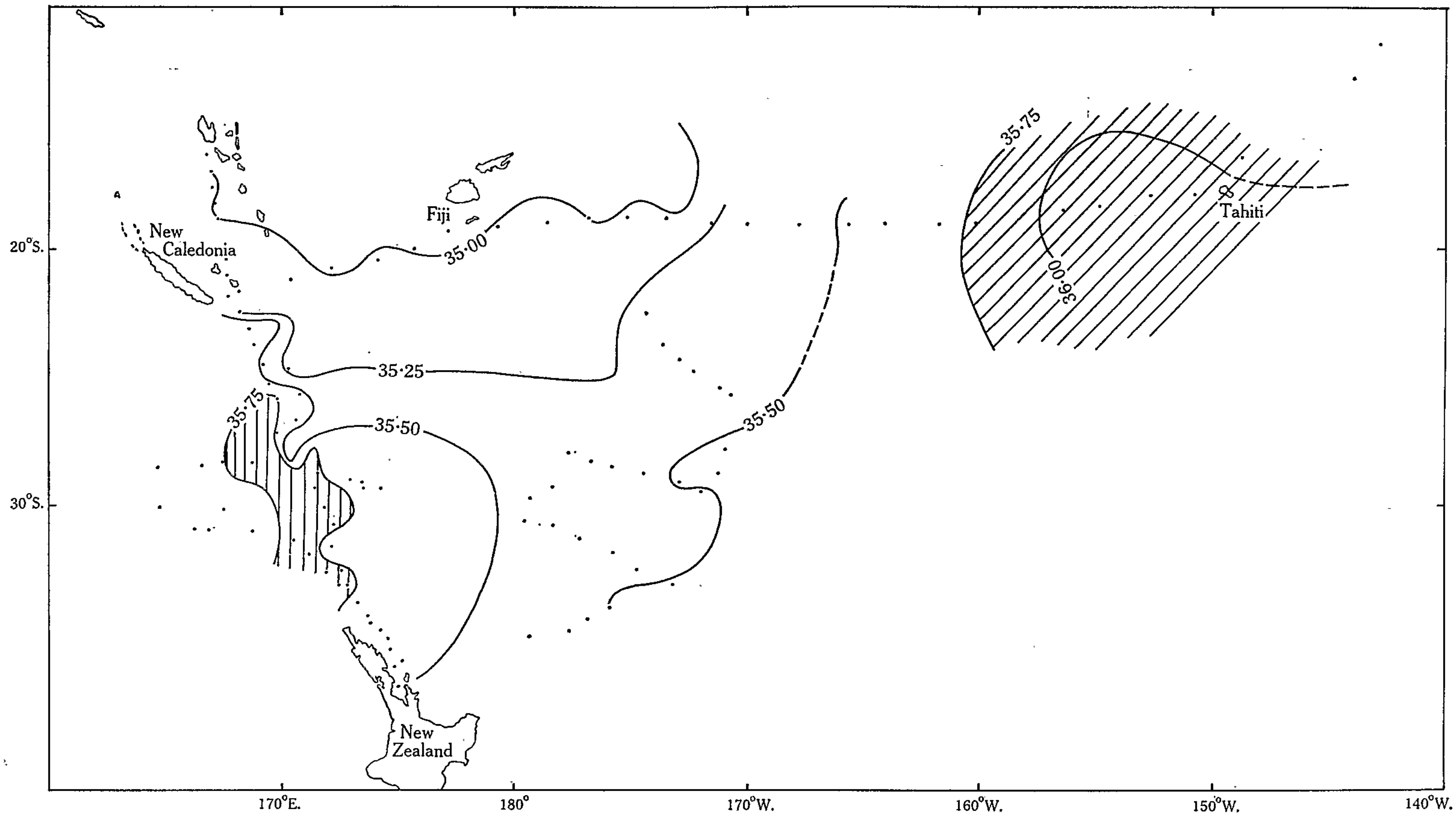

Fig. 7. Surface salinity chart in November–December 1975.

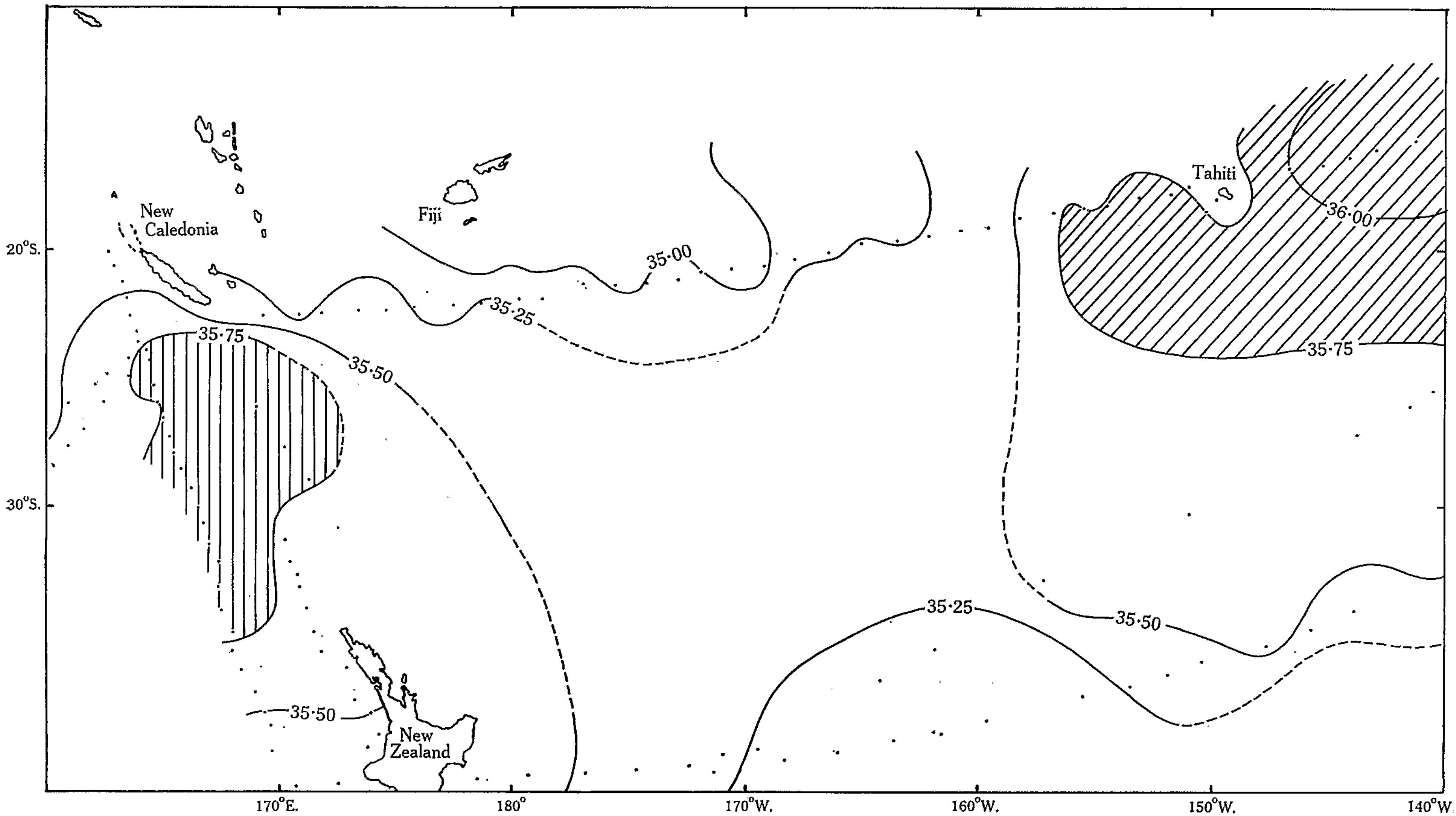

Fig. 8. Surface salinity chart in February–March 1975.

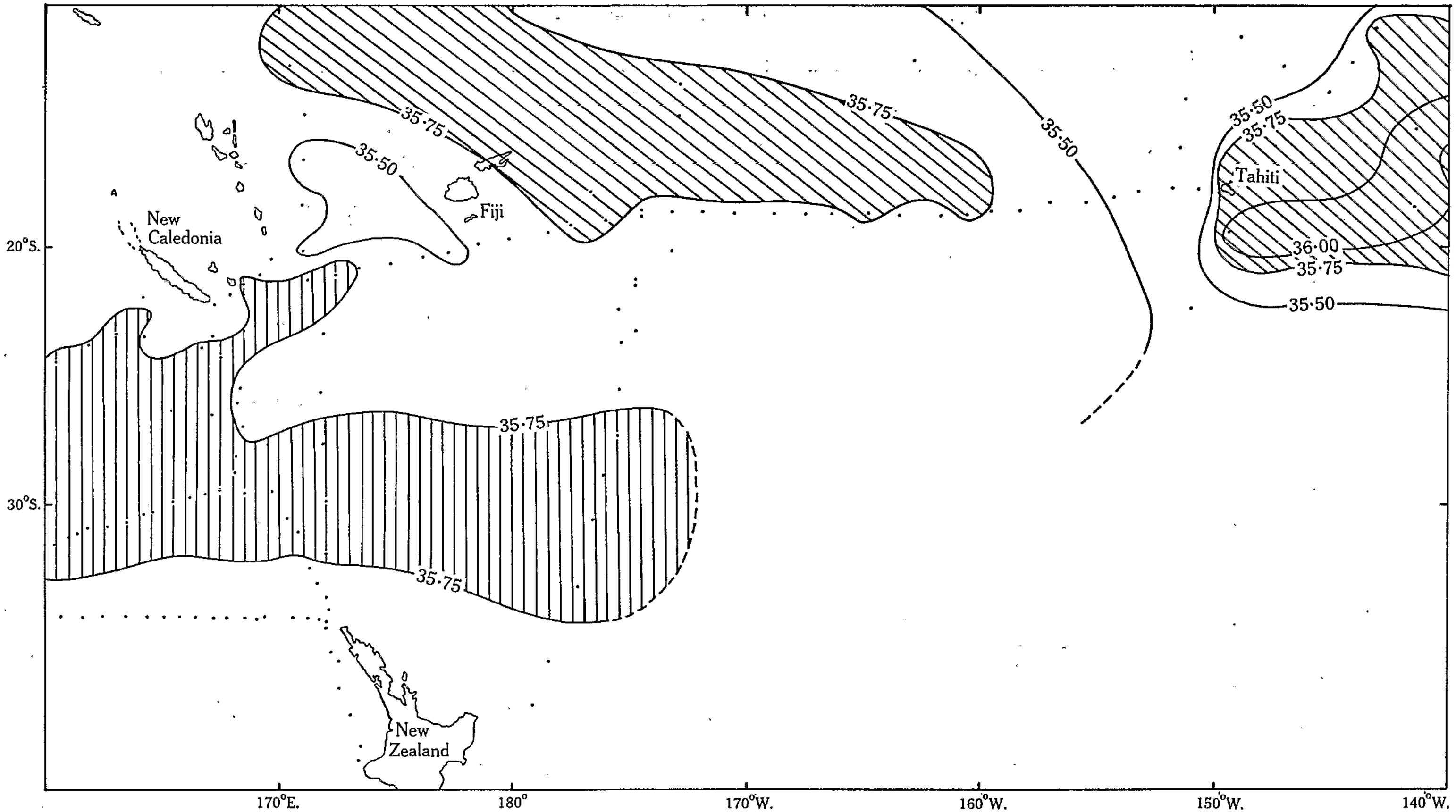

Fig. 9. Surface salinity chart in January–March 1958.

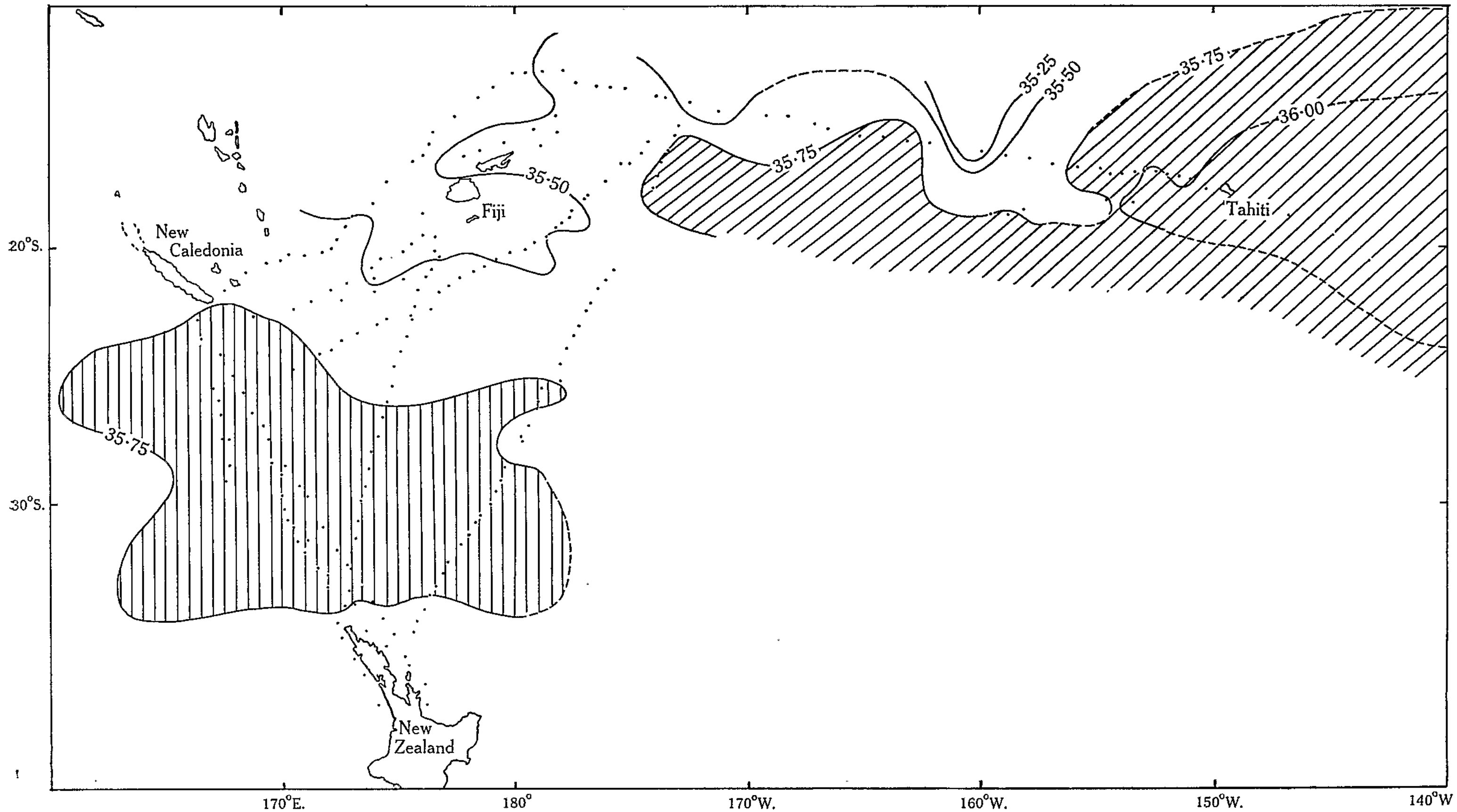

Fig. 10. Surface salinity chart in January–February 1973.

salinity maximum has high values (Fig. 1) but its geographic spreading is obstructed by the low salinity water coming southward south of 20°S.

The surface conditions observed during January–March 1958 (Fig. 9) and January–February 1973 (Fig. 10) have been established as anomalous north of 20°S. (Donguy and Henin 1976*a*). In the Central Pacific the surface salinity maximum has a small spreading; a secondary maximum induced by doming extended in 1958 from 10 to 20°S. and between 160°W. and 170°E., whilst in 1973 it extended from 15 to 20°S. and between 160 and 175°W. The extension of the western salinity maximum was large, reaching eastward to 175°W. in 1958 and to 178°W. in 1973, because it was not limited by the southward spreading of low salinity waters in these years which were anomalous.

Features of the Surface Salinity Maximum in the Coral and Tasman Seas

The separation of these two surface water masses is corroborated by the study of temperature–salinity diagrams (Fig. 11). Generally, the surface salinity maximum of the Central Pacific is characterized by a salinity greater than 35·75‰ and a temperature higher than 24°C, and has a Δst* value between 350 and 500 cl/t. The western surface salinity maximum is less than 35·90‰, has a temperature between 20 and 25°C, and has a Δst value between 300 and 400 cl/t. In early 1973, the western salinity maximum was not only more extended than in a normal year but was also stronger, reaching 36·00‰.

The data of the cruises Choiseul and G/60 carried out south of New Caledonia show that the surface salinity maximum is greater than 35·80‰ on a thickness of 100 m and has a Δst value of about 320 cl/t. This water mass, called by Wyrtki (1962) 'southern component of subtropical water', is independent of the one formed in the Central Pacific with a higher Δst value. Working with surface data from merchant ships, Rochford (1973) noticed the presence of a surface salinity maximum in the Tasman Sea with values reaching 35·80‰ in February 1969.

The occurrence of high surface salinity at about 30°S. coincides with the end of the dry season. Fig. 1 shows the monthly average rainfall for 1971–75 at Norfolk Island; it appears that the dry season ends in May and that the highest salinity also occurs in May, i.e. immediately after the time of minimum rainfall. On the other hand, the maximum rainfall occurs in June and the salinity minimum appears in July. Consequently, it seems possible that the surface water mass at 30°S. has been formed on the spot. Unfortunately, evaporation data are not available for the Tasman Sea and the evaporation–precipitation balance can not be calculated.

Conclusion

In the South Pacific Ocean two kinds of surface salinity maximum are formed—one in the Central Pacific, the other in the Western Pacific. The western salinity maximum is related to precipitations in the Tasman Sea but more data are required to indicate exactly how such a salinity maximum appears.

* Δst is connected to the σ_t term by the formula:

$$\Delta st = 0{\cdot}0273569-(10^{-3}\,\sigma_t)/(1+10^{-3}\,\sigma_t),$$

where Δst is expressed in centilitre/tonne. $\sigma_t = (\rho-1)\,10^3$, where ρ is the density of seawater.

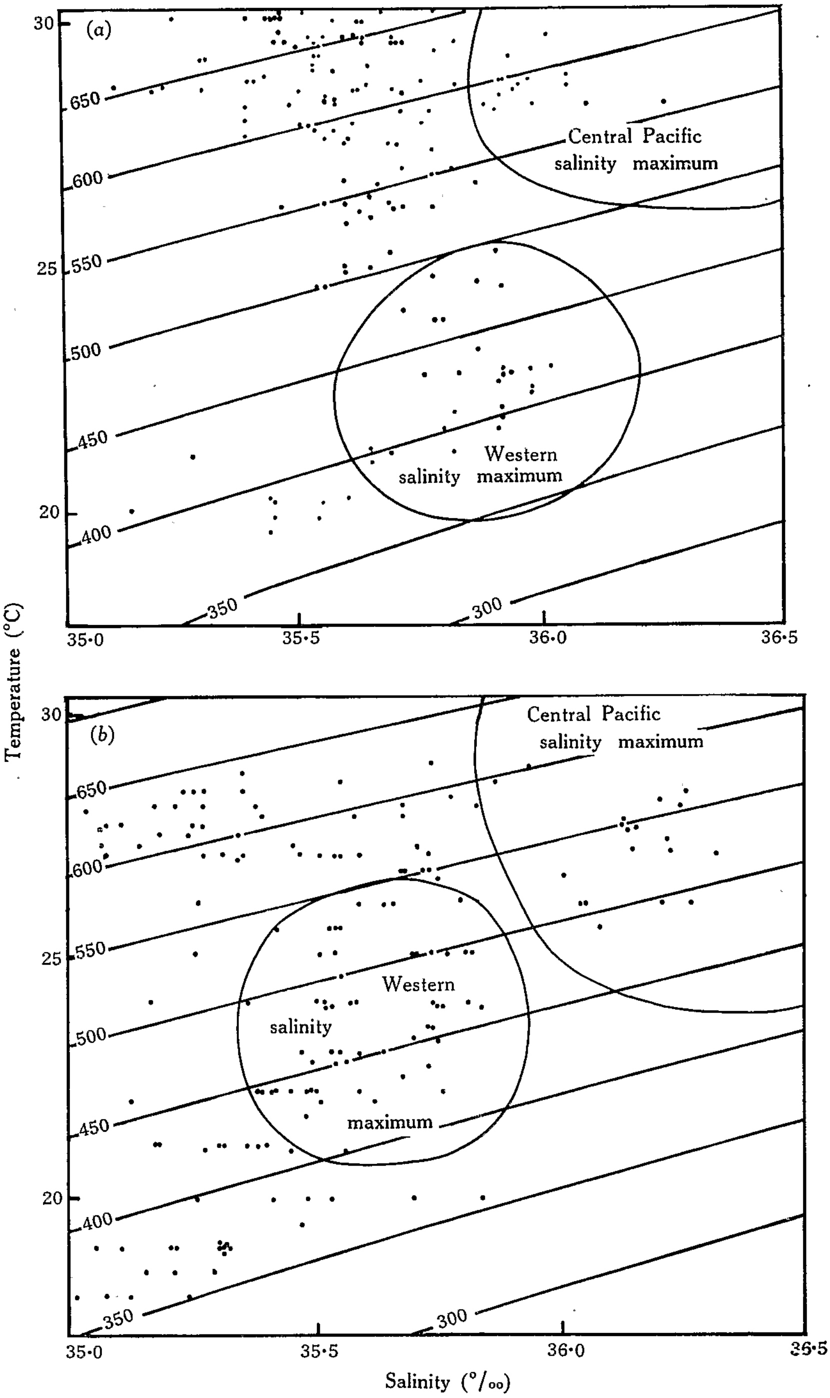

Fig. 11. Temperature–salinity diagram (*a*) in an abnormal year (January–March 1973), and (*b*) in a normal year (February–March 1975). The anomaly of specific volume is in centilitres/tonne.

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