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Anomalous navifacial salinities in the tropical Pacific Ocean

by J. R. Donguy[1], C. Henin[1]

ABSTRACT

All available navifacial data from 1956 to 1974 have been compiled to produce two charts per year of surface salinity between 150°E and 130°W and between 10°N and 25°S. On each chart, the following main features are observed: south of 10°S and east of 160°W the tropical salinity maximum extending westward south of the equator; and a salinity minimum from 5°S to 20°S and west of 170°W. The oscillations of the position and intensity of these features are not all seasonal. This situation was inverted in 1957-1958 and in 1972-1973, when a salinity minimum on both sides of the equator reached south to 10°S and east to 150°W and was associated with westerly winds, which brought rainfall and induced eastward current; a salinity maximum extended westward to 180° between 10°S and 20°S and was associated with trade winds, drought, and westward current. The presence of low-salinity water in the central south Pacific displaced the tropical salinity maximum eastward. This contrasted situation induced a doming at 10°S. At the 1965-1966 transition, the beginning of the same anomalous process was observed, but the trade winds blowing at the equator early in 1966 reversed the hydrographic situation to normal again.

1. Introduction

For the southwest tropical Pacific Ocean, between Australia and 130°W, all navifacial data available for the years 1956-1974 have been compiled. These data have been kindly supplied by the U.S. National Oceanographic Data Center, the World Data Center, and the Japan Oceanographic Data Center. The navifacial observations from the C.S.I.R.O. (Cronulla, Australia), the Centre O.R.S.T.O.M. de Nouméa, the National French Navy, and the National Marine Fisheries Service (Honolulu) have been added. Hence, it has been possible to draw up for each year, from 1956 to 1973, two half-yearly charts of surface salinity (January-June and July-December) and four quarterly charts since 1973.

2. Variations of navifacial salinity

All the pooled data have been used to establish the chart of mean surface salinity (Fig. 1). On this chart, as also on those drawn for each year, the main

1. Centre O.R.S.T.O.M., B.P. A 5, Nouméa, New Caledonia.

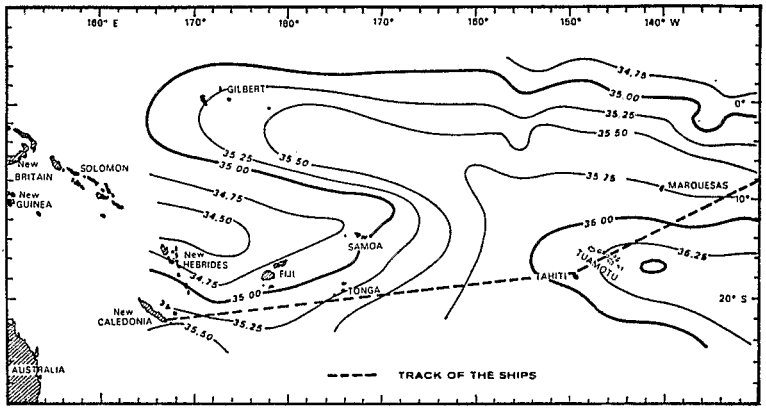


Figure 1. Mean surface salinity, per mil, 1956-1974. The dashed line shows the track of ships between Nouméa and Panama.

features appear as follows: south of 10°S and east of 160°W the tropical salinity maximum extending westward south of the equator; and, from 5°S to 20°S, west of 170°W, a minimum of salinity. These mean characteristics are close to those

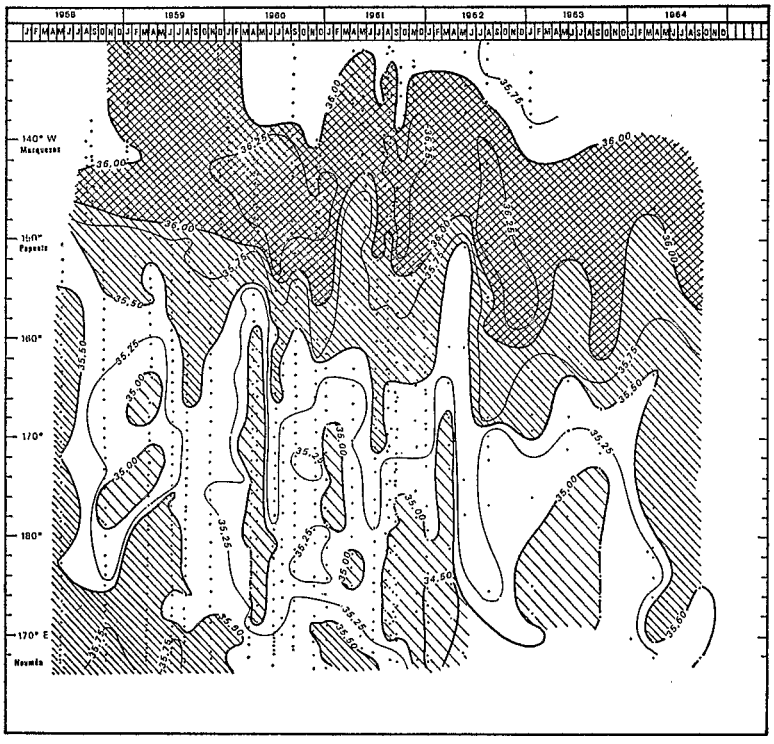


Figure 2. Salinity, per mil, along the track between Nouméa and Panama as far east as 130°W, 1958-1964.

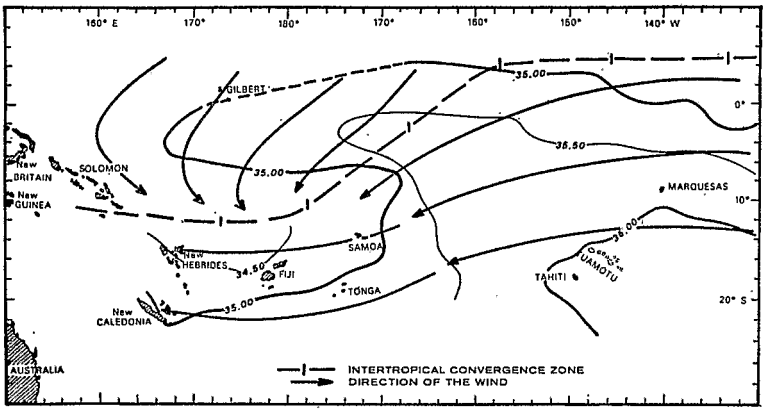


Figure 3. Mean surface salinity, per mil, January-March 1956-1974. The direction of the wind is marked by arrows, and the intertropical convergence zone of the winds is marked by the dashed line.

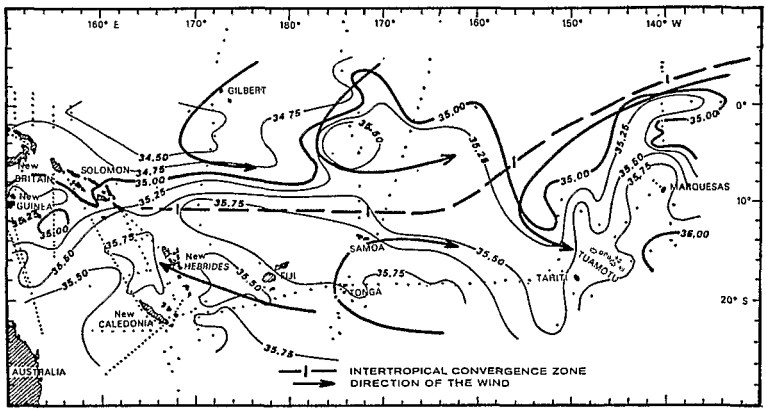
revealed by Reid (1969). However, as Hires and Montgomery (1972) have pointed out, there is a strong variability in the navifacial characteristics in the tropical south Pacific.

Indeed, navifacial observations made regularly from 1958 to 1964 along the track from New Caledonia via Tahiti to Panama (Fig. 1) as set out in a distance-time diagram (Fig. 2), show both seasonal variations and long-time variations: early in the year a salinity minimum appears regularly between 170°E and 160°W, and the tropical salinity maximum seems to be strengthened from August to December between 150°W and 140°W. However, a progressive westward spreading of this maximum is also pointed out, the isohaline 35.5 moving from 150°W in late 1958 to 170°E in late 1964. The oscillations of the position and the intensity of the extreme features do not seem only seasonal. Finally, in some years, completely anomalous hydrographic conditions may occur, as in 1958 and 1973.

3. Anomalies of navifacial salinities in 1958 and 1973

The mean surface salinity from January to March (Fig. 3), derived from all navifacial observations 1956-1974, is close to the annual mean (Fig. 1); in Fig. 3, the wind field prevailing normally at this time (Atkinson and Sadler, 1970) is also represented. The intertropical convergence zone of the winds lies at 12°S west of 180° and at 5°N east of 160°W. Accordingly, south of the convergence zone, the winds are northeast or east; north of the convergence zone, the winds are northeast on the equator and are deflected to northwest south of 5°S. The northeast winds sustain the equatorial upwelling and the northwest winds, which bring rainfall, explain the salinity minimum at about 12°S.

The hydrographic situation described by Fig. 3 has undergone the same disturb-



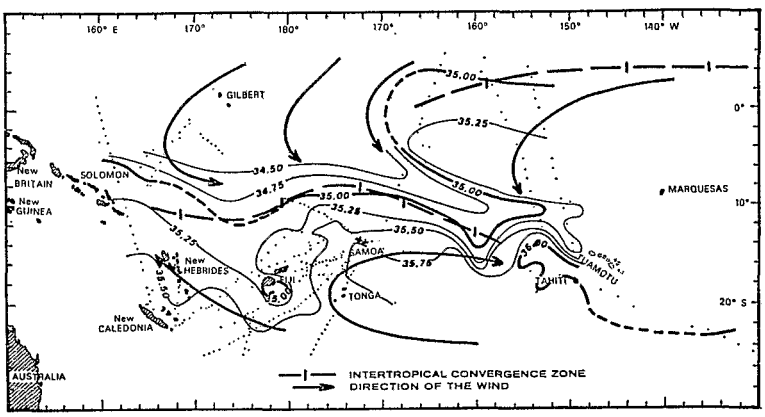


Figure 4. Surface salinity, per mil, January-June 1958. The direction of the wind is marked by arrows, and the intertropical convergence zone of the winds is marked by the dashed line.

Figure 5. Surface salinity, per mil, January-March 1973. The direction of the wind is marked by arrows, and the intertropical convergence zone of the winds is marked by the dashed line.

ance during at least three months in 1958 (January-March) (Fig. 4) and in 1973 (Fig. 5). Instead of the equatorial salinity maximum, an equatorial minimum is seen to extend eastward as far as 10°S 150°W. Between 10°S and 20°S and from 160°W to 180°, a maximum took the place of the salinity minimum. So, in the western tropical Pacific, the positions of surface salinity maximum and minimum were inverted. This exceptional situation coincided with exceptional meteorological conditions.

The meteorological conditions in early 1958 (Fig. 4) and early 1973 (Fig. 5) according to "I.G.Y. World Weather Map" (Hamburg, Germany) and "Tropical Strip Surface Charts" (Asheville, U.S.A.), were similar and remained almost sta-

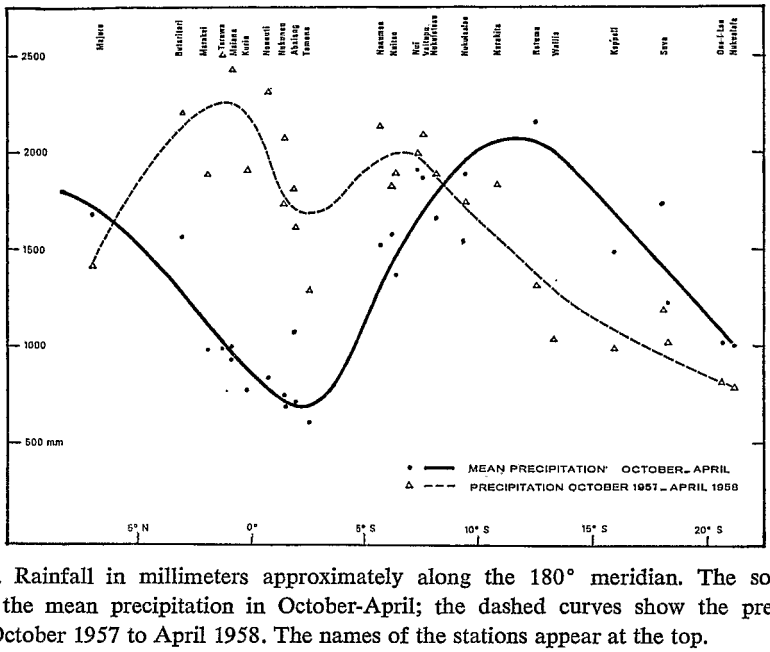


Figure 6. Rainfall in millimeters approximately along the 180° meridian. The solid curve shows the mean precipitation in October-April; the dashed curves show the precipitation from October 1957 to April 1958. The names of the stations appear at the top.

tionary at least from January to March. West of 160°W, the intertropical convergence zone was located at 10°S; east of 160°W, it was located north of the equator. An unusual low-pressure zone was established near 20°S 160°W. As a result the winds, which were northeast north of the equator, were deflected to west-northwest between 5°S and 10°S. These winds in 1958 were already noticed by Bjerknes (1966). They bring rainfall and may explain the presence of low-salinity water north of 10°S from New Guinea to 150°W. On the other hand, south of the convergence zone, the southeast trade winds sustained a drought in the southwest Pacific islands. This anomaly in the rainfall regime, already mentioned by Austin (1960) and Bjerknes (1969), is clearly shown (Fig. 6) at the stations located approximately along the 180° meridian by the contrast between the mean precipitation and the precipitation observed from October 1957 to April 1958. In a normal year 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. However, in 1957-1958 a double maximum occurred, with peaks at 1°N and 6°S, the latter corresponding with the point of salinity minimum; south of 10°S the precipitation was less than normal. This particular situation lasting such a long time seems to be induced by the south-Australian anticyclone, which, abnormally strong for the season, prevented the seasonal southward movement of the intertropical convergence zone. In 1958 and 1973 the meteorological and hydrological situations north of 10°S were opposite to those south

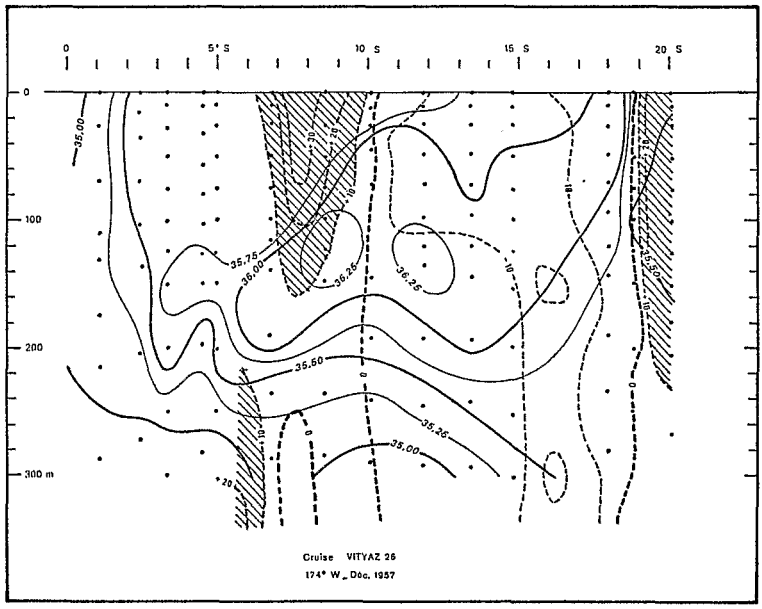


Figure 7. Meridional distributions of salinity, per mil, and eastward component of geostrophic velocity, relative to the 1000 db surface, cm/s, at 174°W during the cruise *Vityaz 26*, December 1957.

of 10°S. West of 160°W, north of the convergence zone the wind blew from the west and a tongue of low-salinity water (S < 35.0‰) reached eastward to 150°W. South of the convergence zone the wind blew from the east and a tongue of high-salinity water (S > 35.5‰) reached westward to 180°. The east component of geostrophic velocity has been superposed on the salinity distribution at 174°W (Fig. 7) by making use of the cruise *Vityaz 26* in December 1957 (N.O.D.C. n° 900862). North of 10°S there is an eastward surface current of 30 cm/s; south of 10°S, a westward current up to 15 cm/s. On the boundary, a doming of isohalines occurs. It is also possible to compare the salinity distribution at 174°W (Fig. 7) in December 1957 already considered with the distribution at 176°W (Fig. 8) in November 1961, as a result of the cruise *Vityaz 34* (N.O.D.C. n° 900065). In 1961, with normal meteorological conditions, the geostrophic currents were very weak and the salinity-maximum cell lay between 100 and 200 m deep. In 1957 the geostrophic currents exceeded 10 cm/s and the salinity-maximum cell almost reached the surface. The doming generated by the contact between the westward current and the eastward countercurrent thus caused the rising of the salinity-maximum cell into the upper waters. The same feature occurred at 170°E in July 1973 (Fig. 9) during cruise *Minepo 1* (N.O.D.C. n° 350078), where a doming occurred at 10°S on the vertical salinity distribution. But in July 1974, during cruise

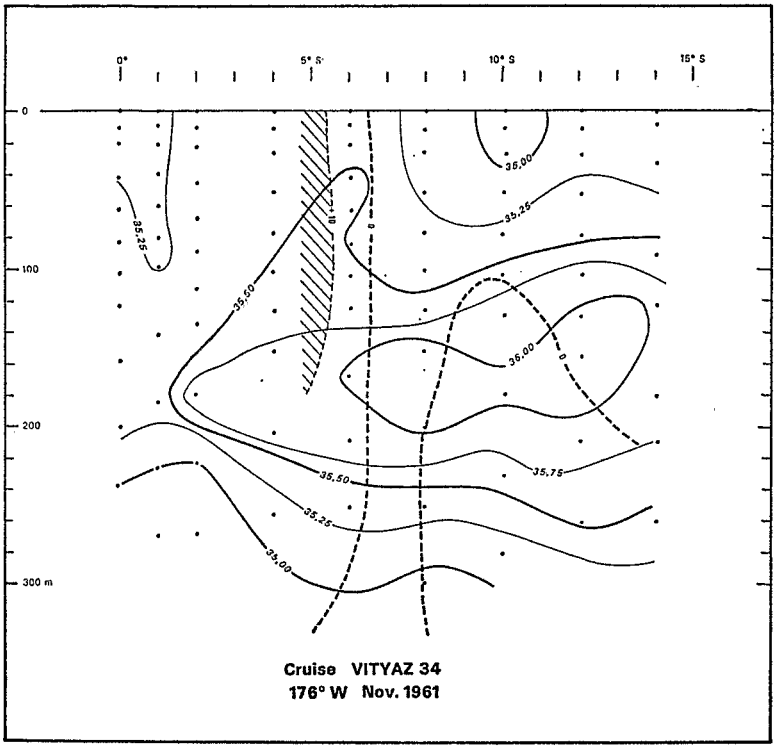


Figure 8. Meridional distributions of salinity, per mil, and eastward component of geostrophic velocity, relative to the 1000 db surface, cm/s, at 176°W during the cruise *Vityaz 34*, November 1961.

Minepo 2 (N.O.D.C. n° 350086), the meteorological conditions were normal again and no doming was observed.

4. Evolution of the navifacial salinity in 1965-1966

The hydrographic conditions in 1965-1966 also show, though less distinctly, an anomaly which may also be connected with unusual meteorological conditions. The chart of surface salinity in the southwest tropical Pacific (Fig. 10) for the second half of 1965 shows north of 10°S and west of 170°W a low-salinity zone ($S < 35.0‰$) instead of the equatorial salinity maximum. At the same time, south of 10°S, as in 1958 and 1973, a tongue of high-salinity water ($S > 35.5‰$) reached westward to 170°W. The hydrographic conditions of late 1965 were abnormal but less extreme than in 1958 and 1973. It seems that this sort of hydrographic situation is also generated by the meteorological conditions. According to the daily isobaric charts published by the Meteorological Service of New Zealand (Wellington, New Zealand), the meteorological situation during November 1965 and part

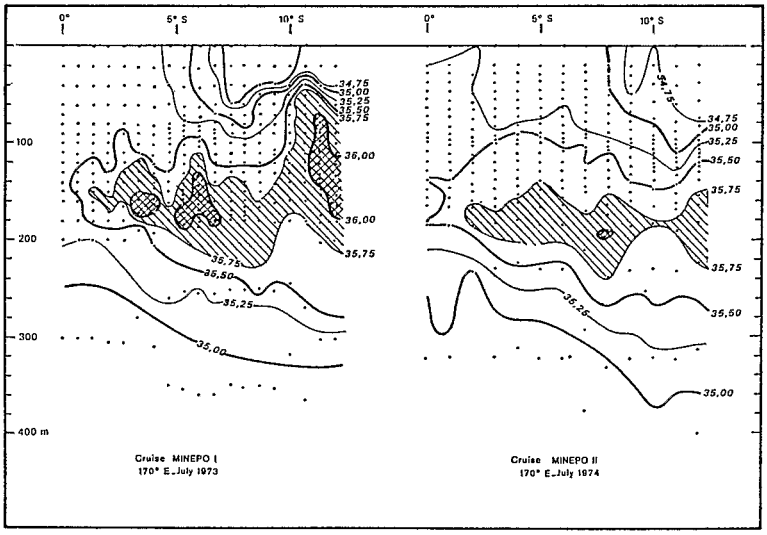


Figure 9. Meridional distributions of salinity, per mil, at 170°E during the cruise *Minepo 1* in July 1973 and during the cruise *Minepo 2* in July 1974.

of December remained almost stationary. The intertropical convergence zone of the winds lay at about 5°S, from 170°E to 150°W. Between this zone and the equator the wind blew from the west, resulting in the heavy rainfall on the equator (Bjerknes, 1969) and consequently the low salinities observed. South of the convergence zone the wind blew from the east, sustaining the westward movement of high-salinity water.

This abnormal hydrographic situation seems to have been briefer than in 1958 and 1973, and the navifacial data of early 1966 (Fig. 11) show normal equatorial upwelling. From 5°S to 10°S a tongue of low-salinity water reaches eastward to 165°W; south of 10°S a tongue of high-salinity water reaches westward to 170°W. In January-February 1966 the intertropical convergence zone lay at 10°S from 160°E to 150°W, and this situation brought about, on the equator, the presence of northeast winds strong enough to induce upwelling and, at about 10°S, west winds bringing rainfall. South of the convergence zone, east winds prevailed. The distribution of geostrophic currents at 170°E in March 1966 during the cruise *Bora 2* (Rotschi *et al.,* 1972) was consistent with this situation and a doming occurred at 10°S.

5. Conclusion

In 1957-58 and 1972-1973, abnormal meteorological and hydrographical features were observed: the direction of the wind was inverted as well as the respec-

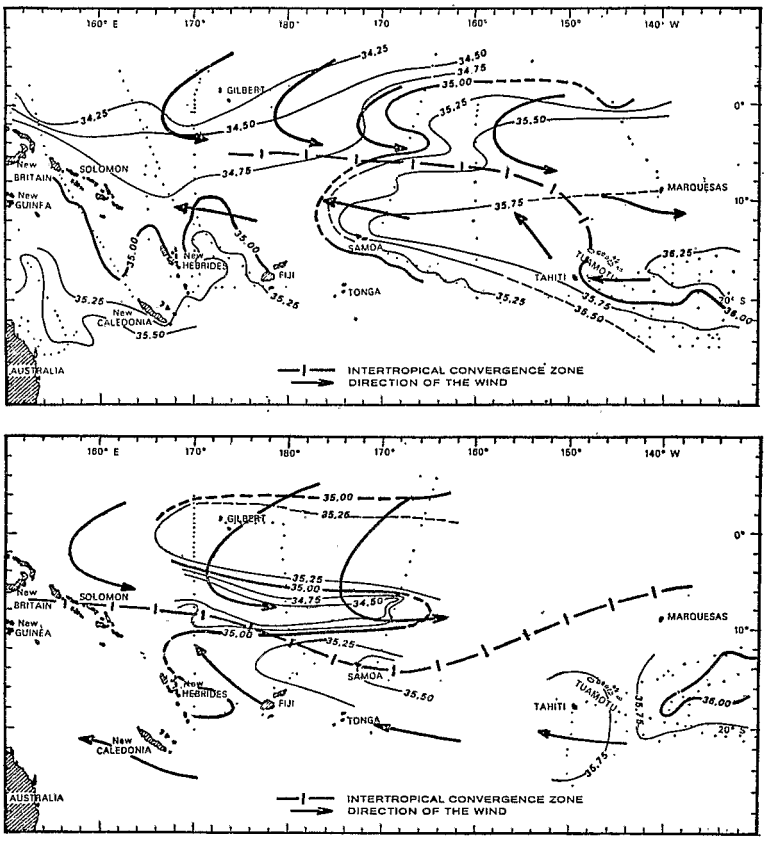


Figure 10. Surface salinity, per mil, July-December 1965. The direction of the wind is marked by arrows, and the intertropical convergence zone of the winds is marked by the dashed line.

Figure 11. Surface salinity, per mil, January-June 1966. The direction of the wind is marked by arrows, and the intertropical convergence zone of the winds is marked by the dashed line.

tive positions of salinity maxima and minima, the tropical salinity maxima moved eastward, and at 10°S a contrasted geostrophic situation induced a doming. In 1965, on the other hand, west wind, instead of the equatorial trade wind, did not prevail long enough and the abnormal conditions discontinued early in 1966.

During these same years, other drastic changes occurred in several areas of the Pacific, such as the appearance of the El Niño Countercurrent along the South American coast. The study of the hydroclimates of the tropical South Pacific may constitute a link in the chain permitting the explanation and then the forecasting of such phenomena.

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