Reprinted from JOURNAL OF PHYSICAL OCEANOGRAPHY, Vol. 10, No. 12, December 1980
American Meteorological Society
Printed in U. S. A.

Climatic Teleconnections in the Western South Pacific with El Niño Phenomenon

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(Manuscript received 30 October 1979, in final form 9 September 1980)

ABSTRACT

In the western South Pacific, one year after a typical El Niño event, anomalous hydroclimatic conditions replace the usual ones. The abnormal meteorological conditions are characterized by the Intertropical Convergence Zone of the winds being arrested close to the equator. The equatorial area becomes rainy, and south of 10°S the wet season does not occur. The statistical comparison of the rainfall data with the intensity of El Niño events of the previous year shows a consistent correlation between both phenomena.

1. Introduction

Many authors have mentioned the equatorial climatic anomalies in the central and western Pacific Ocean, in the form of warm surface temperature and heavy rainfall inside a usual cool and dry area. Austin (1960) pointed out the example of 1957, then Bjerknes (1966, 1969) showed it was a more general phenomenon. Doberitz (1968), using cross-spectrum analysis between several equatorial stations, discovered sound coherencies of the anomalies from the western Pacific to the South American coast. Krueger and Gray (1969), based on satellite records of cloudiness, connected these events with the Walker circulation.

Most authors consider that the observed equatorial climatic anomalies are related to El Niño events occurring along the South American coast. Consequently, El Niño is no longer considered as a local event, but as a global phenomenon effective, particularly in the Pacific Ocean. However, although many authors have taken into account the equatorial anomalies, few of them have noticed the tropical ones (White and Walker, 1973). Donguy and Henin (1976) have shown that a drought occurred south of 10°S during a period of anomalous equatorial rainfall and that such hydroclimatic anomalies started in the western Pacific six months after an El Niño event (Donguy and Henin, 1978a).

2. Hydroclimatic conditions considered as normal in the western tropical Pacific Ocean

According to Atkinson and Sadler (1970), the Intertropical Convergence Zone (ITCZ) of the winds has a seasonal oscillation from about 15°S in the western South Pacific (February–March) to 10°N in the western North Pacific (September–October) (Fig. 1). In the tropical area, the rainy season is mainly due to the presence, in the Northern and in the Southern Hemisphere, of the ITCZ which usually induces rainfall. As a result, in the western tropical South Pacific, during March the ITCZ located at about 15°S induces low-salinity water by precipitation (Fig. 2). In October (Fig. 3), the ITCZ is located at 10°N where it also induces low-salinity water by precipitation. Saline water along the equator is due to the equatorial upwelling induced by trade winds and also to the low rainfall occurring in this area.

3. Anomalous hydroclimatic conditions in the western tropical Pacific

For some austral summers, the normal hydroclimatic conditions have been reversed (Donguy and Henin, 1976). West of 180°, instead of moving from 10°N to 10°S, the ITCZ remains close to the equator (Fig. 4). As a result, the equatorial upwelling disappears west of 180° and the equatorial area, which is usually dry, then becomes particularly rainy. The ITCZ does not reach the tropical area, the rainy season is not induced, and a drought results.

Such hydroclimatic anomalies have been pointed out after the 1976 El Niño, manifested in March by a low-salinity tongue moving southward along the South American coast (Fig. 2). Commencing in August 1976 (Fig. 5), in the western Pacific, the ITCZ was located partly on the equator instead of at 10°N as during 1978 (Fig. 3).

The occurrence of anomalous phenomena in the western and central Pacific Ocean and their intensity

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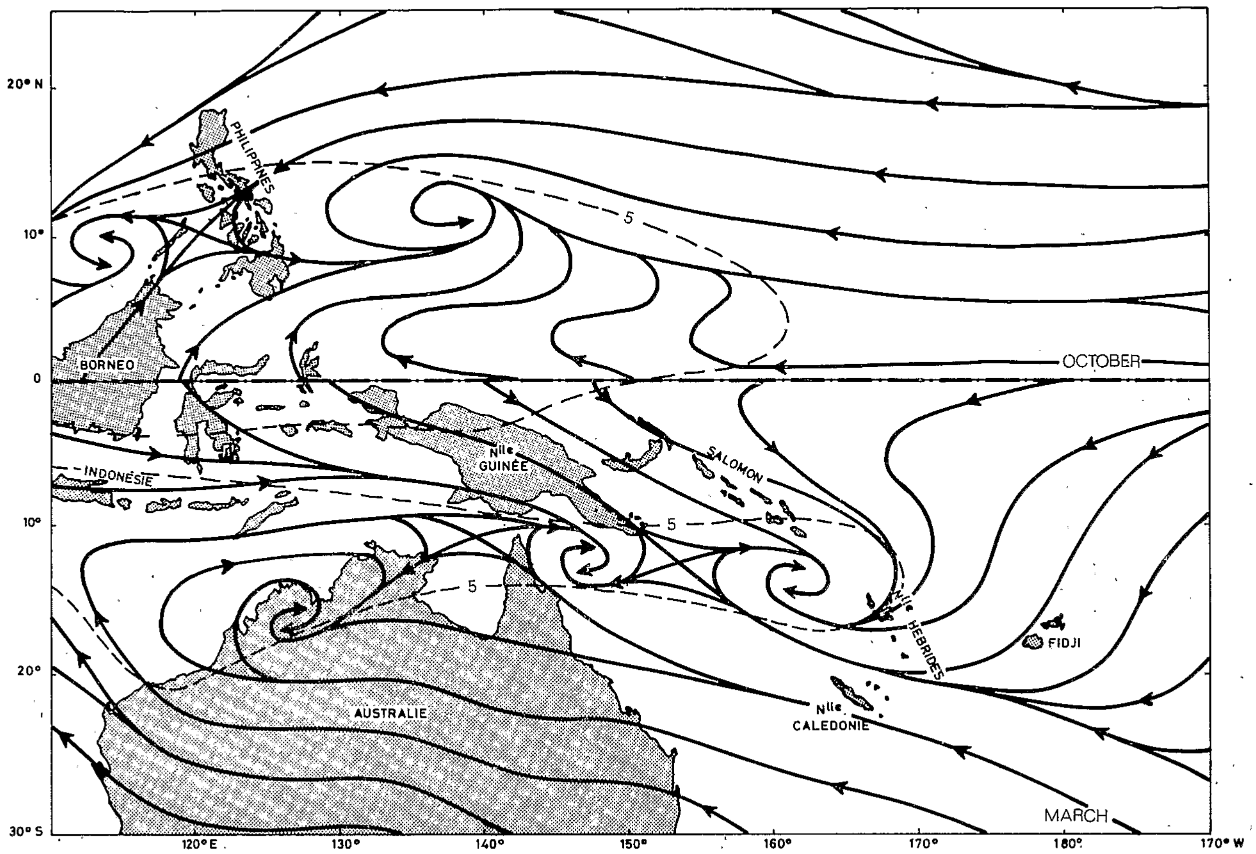

FIG. 1. Seasonal oscillation of the Intertropical Convergence Zone of the winds from 15°S (February–March) to 10°N (September–October). The wind speed minimum (<5 kt) is indicated by a dashed line.

are thus connected to the occurrence and to the intensity of the last El Niño event. It should be emphasized that such abnormal precipitation occurs only in the equatorial area of the western and central Pacific while a rainfall deficit occurs in the tropical zone.

Most of the rainfall data were obtained from Taylor (1973). These data recorded by a meteorological station are variable according to the elevation, location, structure and size of the base. However, if we take into consideration for a special period (rainy season or dry season) the observed rainfall and, for the same period, the mean rainfall calculated from the data recorded for many years, the ratio of the observed precipitation to the mean precipitation may be considered as independent of the characteristics of the station. For the considered period, it therefore gives information on excess or shortage of the rainfall.

Quinn *et al.* (1978) have established a classification index for the intensity of El Niño events from oceanographical, meteorological and economical considerations: 1, very weak; 2, weak; 3, moderate; 4, strong. We adopt this index as a measure of El Niño intensity here.

a. Equatorial area of the western Pacific

In the western Pacific, the equatorial area is usually dry with the occurrence of the equatorial upwelling, but strong rainfall periods are observed (Donguy and Henin, 1978b) due to the presence of the ITCZ. The rainfall data from the following stations have been considered (Table 1): Ponape, Ocean, Nauru, Fanning, Taiohae, Atuona and Papeari (Tahiti), all with more than 38 years of observation.

In order to establish a relation between the rainfall regime and El Niño events, the ratio of the observed and mean rainfalls between October and April for the year following El Niño is plotted against the El Niño intensity index (Fig. 6). Without El Niño (i.e., with an intensity equal to zero in abscissa), the ratio is usually less than 1. In case of El Niño, the ratio is usually more than 1 and increases with the intensity of the event (top panel of Fig. 6) but, as the data distribution is not normal, this feature is only an estimate. However, one can apply the Spearman rank correlation method to this data. The Spearman correlation coefficients are all positive (Table 1, middle entries). Good correlations

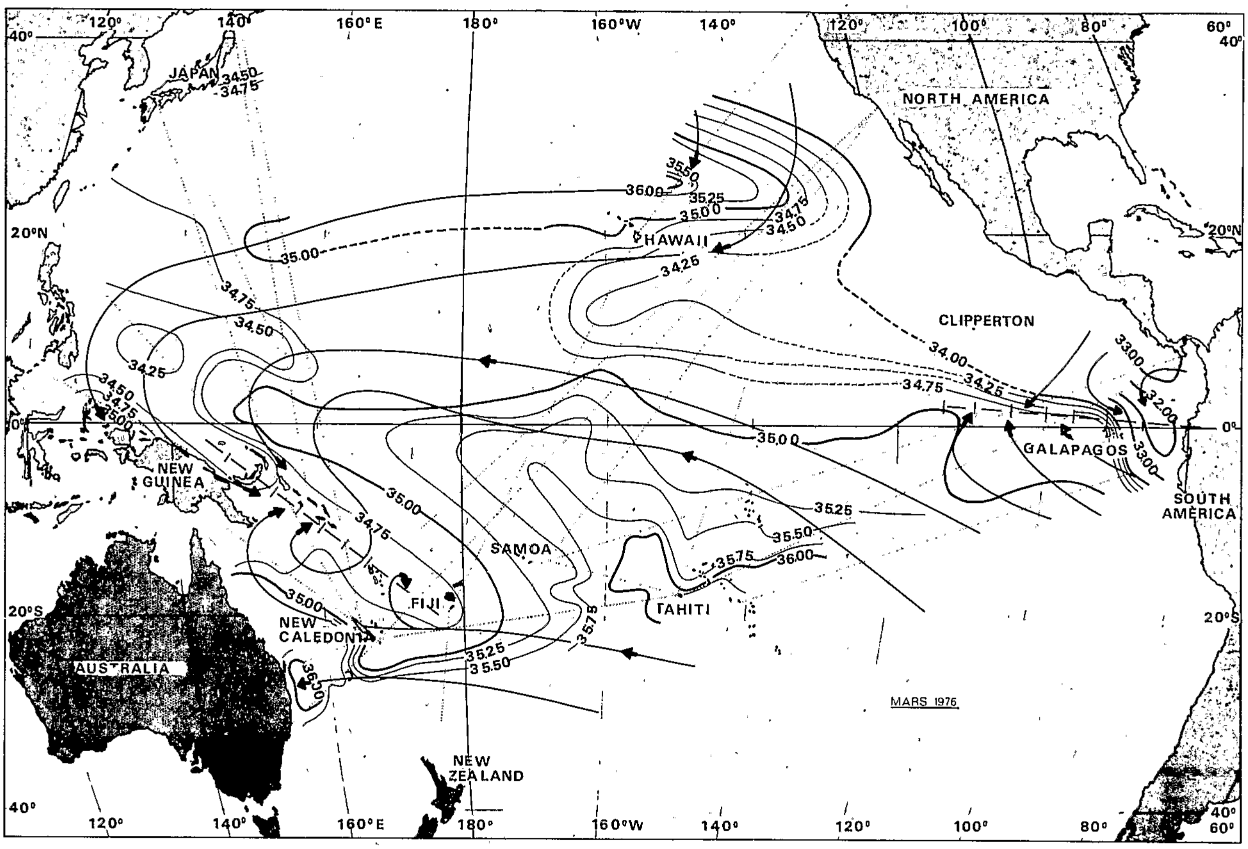

FIG. 2. Surface salinity (‰) in March 1976. Wind direction is indicated by arrows and the Intertropical Convergence Zone of the winds by a broken line.

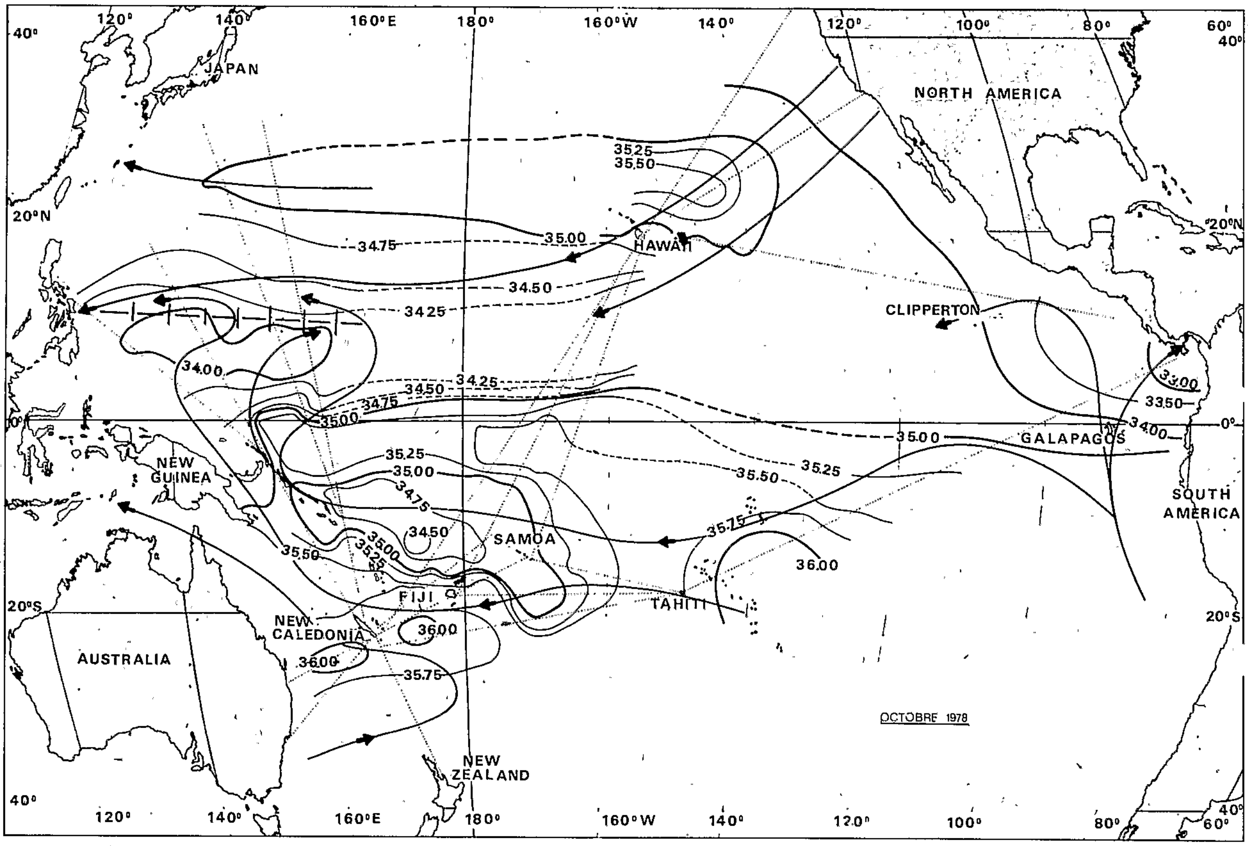

FIG. 3. As in Fig. 2 except for October 1978.

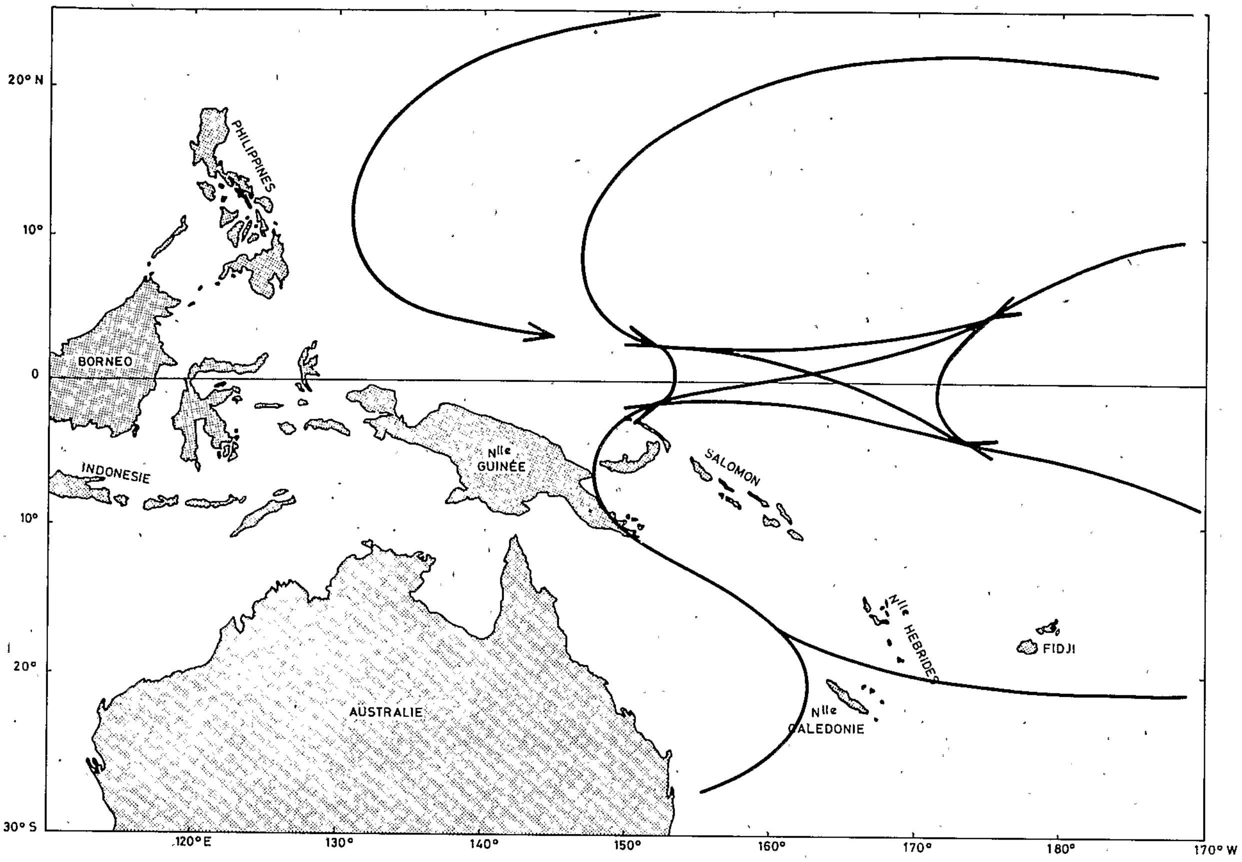

FIG. 4. Wind field when the ITCZ is located on the equator during several months.

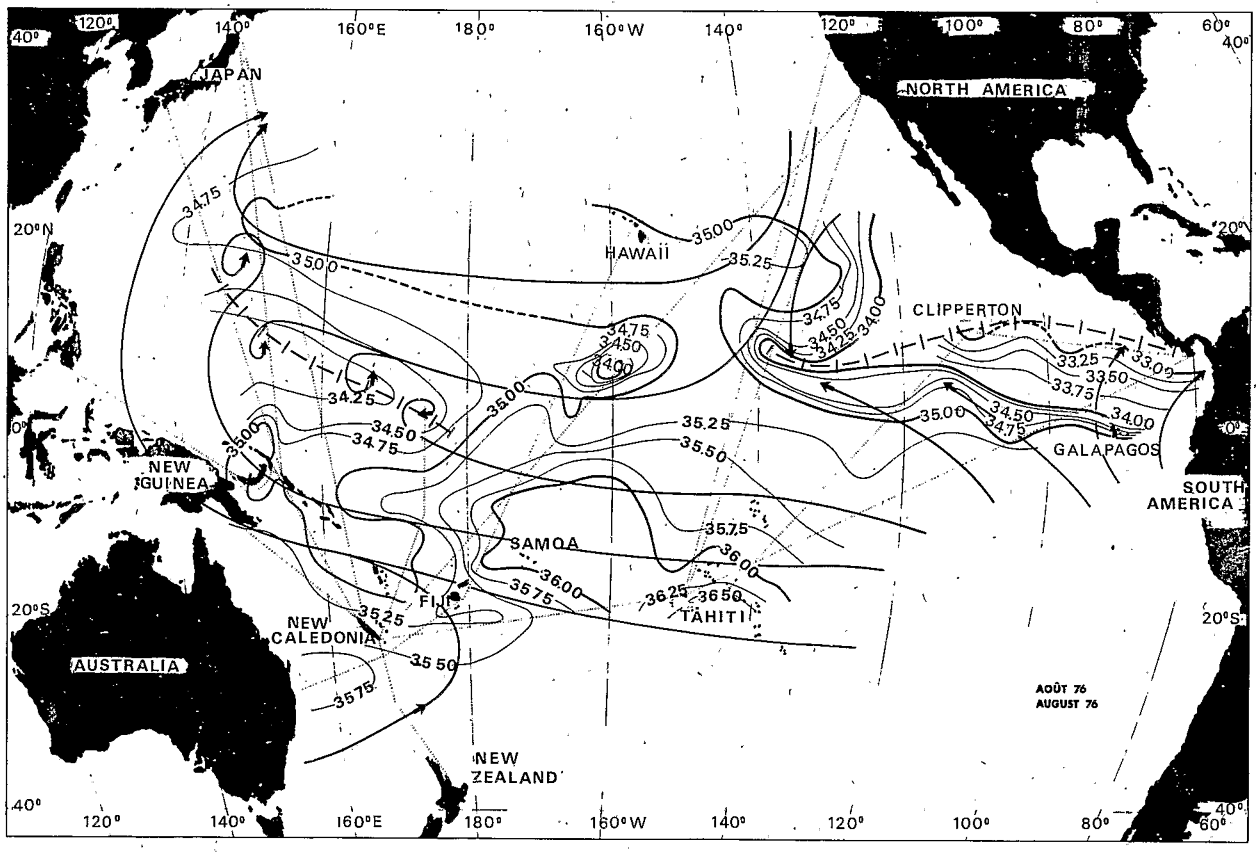

FIG. 5. As in Fig. 2 except for August 1976.

TABLE 1. Statistical comparison of rainfall data with intensity of El Niño events.

Station	Latitude	Longitude	Record length (years)	Spearman correlation	Significance level
Noumea	22°16′S	166°27′E	77	−0.49	0.0005
Suva	18°08′S	178°26′E	94	−0.32	0.005
Apia	13°48′S	171°47′W	89	−0.33	0.005
Nukualofa	21°08′S	175°12′W	38	−0.35	0.025
Rarotonga	21°12′S	159°46′W	80	−0.28	0.01
Norfolk	29°03′S	167°56′E	61	−0.26	0.025
Niue	19°02′S	169°55′W	51	−0.14	0.10
Cairns	16°53′S	145°44′E	75	−0.25	0.025
Ponape	6°58′N	158°13′W	45	+0.15	0.10
Fanning	3°55′N	159°23′W	57	+0.66	0.0005
Ocean	0°52′S	169°55′E	61	+0.57	0.0005
Nauru	0°30′S	167°00′E	60	+0.46	0.0005
Taiohae	8°56′S	140°05′W	38	+0.61	0.0005
Atuona	9°48′S	139°02′W	38	+0.63	0.0005
Papeari	17°45′S	149°20′W	54	+0.17	0.10
Truk	7°28′N	151°51′E	29	−0.47	0.005
Kwajalein	8°44′N	167°43′E	34	−0.22	0.10
Majuro	7°05′N	171°23′E	24	−0.31	0.10
Wake	19°17′N	166°39′E	38	−0.28	0.05

with high significance levels are noticed in the isolated equatorial islands Ocean, Nauru, Fanning, stations cross correlated by Doberitz (1968), and in the Marquesas islands Taiohae and Atuona; very poor correlations are noted at Ponape, north of the equator and at Papeari (Tahiti) south of the Marquesas Islands.

b. Tropical area of the western South Pacific

The observations of the events subsequent to the last El Niño phenomenon (Donguy and Henin, 1978a) show that they seem to precede a drought by one year in the tropical area of the western South Pacific, south of 10°S. This drought is due to the lack of the rainy season (October–April) caused by the absence of the ITCZ south of 10°S. As for the equatorial zone, we are only considering the stations with long series of rainfall measurements (over 38 years) (Table 1): Noumea (New Caledonia), Suva (Fiji), Apia (Samoa), Rarotonga (Cook Islands), Nukualofa (Tonga), Niue, Norfolk Island and Cairns (Australia). Fig. 6 is used as before. For all these stations, without El Niño (i.e., with an intensity equal to zero in abscissa) the ratio of the observed and mean rainfalls spread over each side of 1, the majority of the values being between 0.5 and 1.5. In case of El Niño, the ratio is usually <1, sometimes less than 0.5, and decreases with the intensity of the event. Since the data distribution is not normal, only the Spearman rank correlation can be used. The correlations for these stations are all negative. Although not as good as for the equatorial area, the best correlations are observed in Noumea, Suva, Apia and Nukualofa, with equally good significance levels. These areas are the most sensitive to the drought due to El Niño.

c. Tropical area of the western North Pacific

In the islands of the western North Pacific (Marshall, Caroline, Mariana), there is no report of drought after any El Niño event. These islands receive almost continuous rainfall all year round and the rainy season is not clearly defined. However, when the ITCZ stops on the equator and does not move to 10°N, it would be assumed that less rainfall than usual occurs. The ratio of the observed and mean rainfall is calculated between July and January but, unfortunately, the series of rainfall records for these islands is shorter than elsewhere (Table 1). Negative correlations exist between the rainfall and the intensity of El Niño at Truk (Caroline Islands) (Fig. 6), Majuro, Kwajalein (Marshall Islands) and Wake but, as the rainfall distribution is not normal, the Spearman rank correlation must be used. The best correlation then occurs in Truk with also a good significance and the poorest in Kwajalein. However, Ponape, in the same group of islands has a positive correlation.

4. Discussion

Correlation and significance may be influenced by groups structure of the El Niño time series. Sometimes a strong El Niño is repeated for two consecutive years. In the time series considered between 1883 and 1978, this feature occurred eight times, which is insufficient to change the degree of freedom significantly. Sometimes after the second year when El Niño occurs, the rainfall regime also changes drastically. In this case, in the tropical area, strong rainfall follows a year of low rainfall and, in the equatorial area, the situation is reversed. The second year of a strong El Niño does not always have the same effect as the first year.

The western Pacific may be divided into three zones (Fig. 7):

- A southern tropical zone from Australia to 160°W and from 10°S–25°S where the correlation between rainfall and El Niño index is negative. In this area the drought occurs due to El Niño, the most sensitive zone being located between New Caledonia and Samoa.
- An equatorial zone from 160°E to 130°W and from 10°S to 10°N, where the correlation between rainfall and El Niño index is positive. In this area strong rainfall occurs following El Niño, the most sensitive zone including Fanning and the Marquesas Islands.

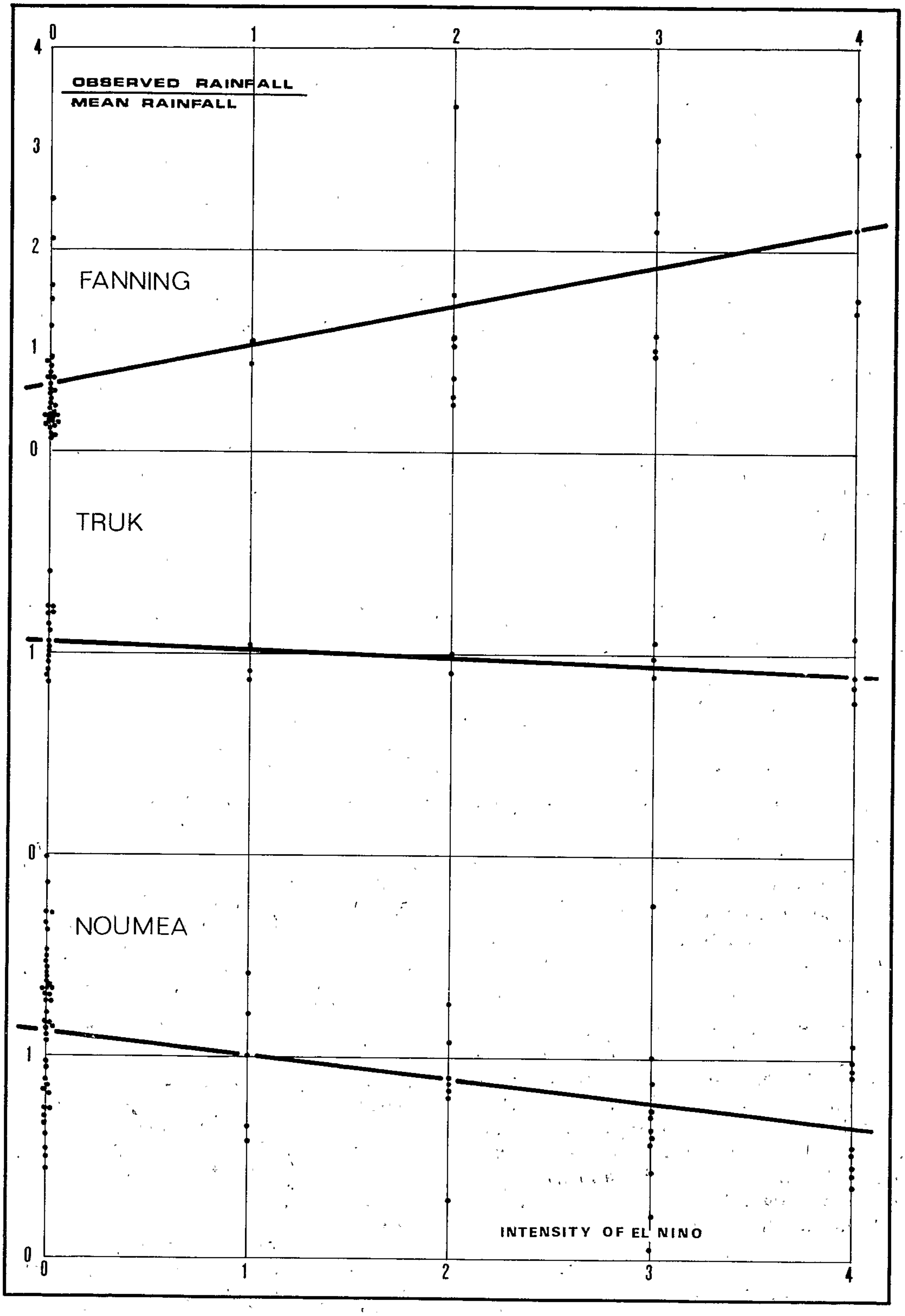

FIG. 6. Correlations between the intensity of El Niño and the ratio of the observed and mean rainfall at Fanning, Truk and Noumea.

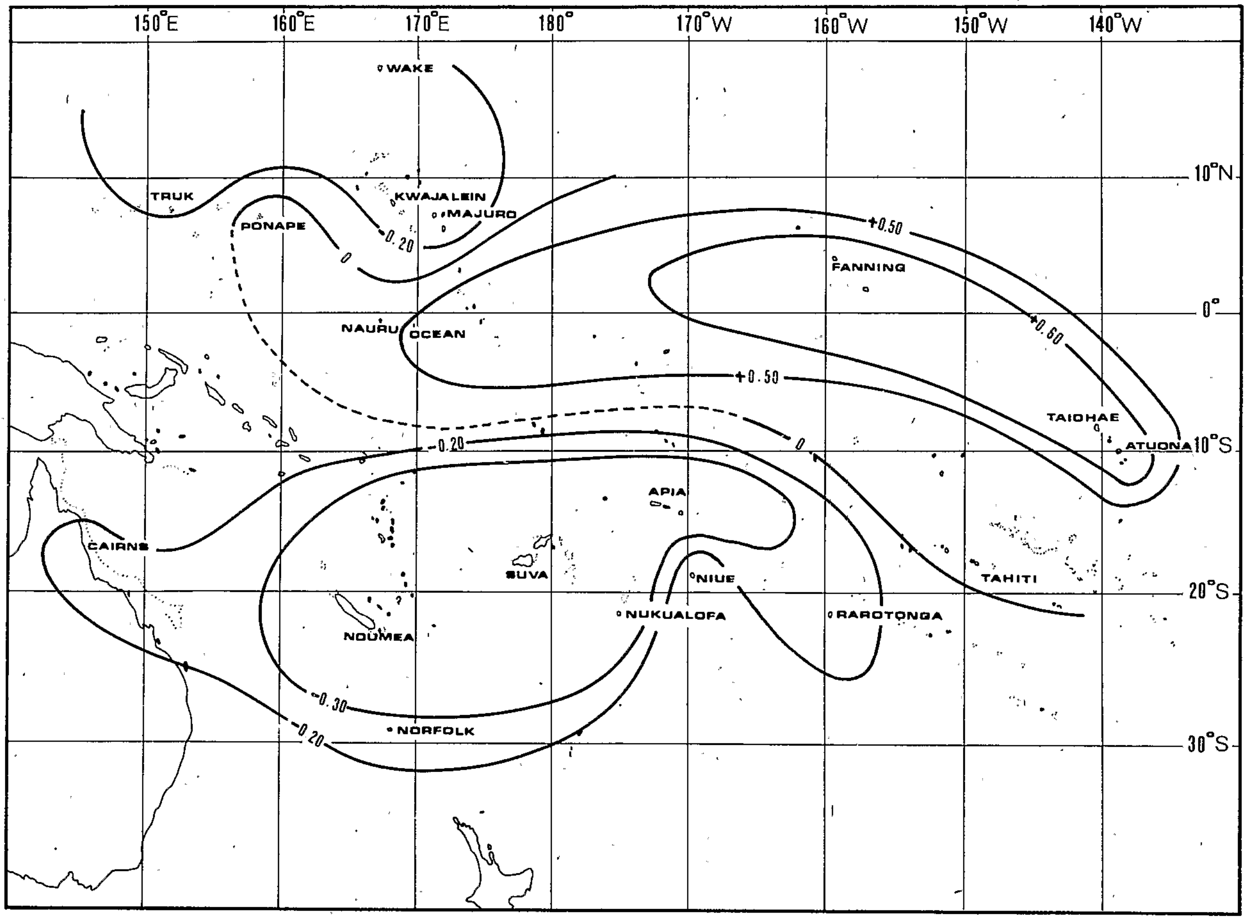

FIG. 7. Different zones of correlation between the intensity of El Niño and the ratio of the observed and mean rainfall.

- A northern tropical zone from 150°E to 180° and from 5–20°N, where the correlation between rainfall and El Niño index is negative. In this area the rainfall after El Niño is lower than usual.

5. Conclusion

In the western Pacific, two areas of good correlation between the rainfall and the intensity of El Niño have been determined, a positive one close to the equator and a negative one from 10–25°S. From 5–20°N, a negative correlation also occurs but must be only considered as a trend. At least for the western South Pacific, the appearance of El Niño is a significant indication for the occurrence of a drought during the following year.

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