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EQUATORIAL CURRENTS SYSTEM NORTH OF NEW-GUINEA

by

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Summary

Eight trans-equatorial cross sections giving zonal and meridional components of currents north of New-Guinea were carried out during the cruises Foc 1 and Foc 2 (January-February and June-July 1971) of the R/V CORIOLIS of the Centre ORSTOM of Noumea. The equatorial currents system is described during two contrasted wind regimes and comments are made on space-time variations of the main water drifts.

1. - Introduction

Following detailed studies at 170°E (MAGNIER et al., 1973) the equatorial zone located north of New-Guinea has been investigated in 1971 by the R/V CORIOLIS of the Centre ORSTOM of Noumea during two different seasonal cruises, Foc 1 and Foc 2. WYRTKI (1961) described the peculiar nature of this zone where equatorial currents end and where are formed two main currents : the north equatorial counter-current and the equatorial under-current (Cromwell current). Russian (KORT and al., 1966) and Japanese (MASUZAWA, 1967) studies have confirmed the hydrological complexity of the region and pointed out the importance of time-repeated investigations. The main aim of the Foc cruises was to specify mechanisms by which the Cromwell current gains some of its hydrological characteristics observed at 170°E (ROTSCHI et al., 1972) and to estimate the response of the superficial drift to the variations of the wind-regime.

The high density of the current measurements in the first 500 meters has permitted to precise the horizontal and vertical structures of the equatorial currents system between the north coast of New-Guinea and 5°N. In addition to these measurements, hydrological and physico-chemical parameters have been studied and results of these measurements have been used in others papers.

2. - Methodology

All current measurements were made with three self-recording Hydro-Products current meters, model 501 B; they were attached to the hydrological cable and lowered down from the ship; measurements were made every 20m from the surface to 500m and every 40m from 500m to 1500m; at each level, measurements of the speed and of the direction of the current were made every 8 seconds during 4 minutes. Only the average of those 4 minutes time series were considered.

Before lowering the current meters, 100m of cable were paid out and the ship manoeuvred to obtain the lowest cable angle with vertical. Once this equilibration was found, the course and speed of the ship were maintained troughout the current measurements.

The accuracy, at the surface, is $\pm$ 10° for direction and $\pm$ 10 cm/s for velocity. For deeper recordings, it is $\pm$ 5° for direction and the velocity accuracy remains unchanged because the great length of the cable dampens all short-terms movements like waves and swell. The depth of each current meter is assumed to be the length of the cable corrected for the wire angle and for the length paid out. The great number of hydrological stations carried out in the same zone and under similar conditions indicates that this method introduces into the depth evaluations an error of overestimation not exceeding 2%.

In fine, current measurement obtained at each level is evaluated relatively to a given reference (500m for the eight trans-equatorial cross sections presented in this paper) by vectorial difference.

3. - Meteorological features

Because its position at the west border of south-east Asia, New-Guinea is under a monsoon regime, specially in northern winter when high pressure are formed over the asiatic continent and low pressure over Australia. Between the high and the low, the monsoon develops; in full monsoon regime the pressure distribution is stationary and winds have a high constancy, specially over the sea. However the wind force is generally small, except in storms and typhoons observed north of Australia and over the Coral Sea.

In the course of december the monsoon crosses the equator as a north wind and south of it turns to the east, where it appears as the northwest monsoon, as observed during the Foc 1 cruise. From April the equatorial pressure trough moves quickly to the north and lies at the equator. The southeast trade again reach 5°S and grows stronger untill July. North of the equator the northeast wind system collapses in May and the south monsoon succeeds over the whole of southeast Asia and reaches its full development in July and August. During these months the low pressure is over Asia and the high over Australia. Over the open sea north of New-Guinea trade winds of force 4 are often exceeded as during the Foc 2 cruise. From October the equatorial trough begins to move rapidly southwards again and lies along a line from the center of the Bay of Bengal to the north coast of New-Guinea. Southeast trade winds weaken and begin to gradually collapse in November in a zone north of 5°S.

The diagram 1 summarizes the wind conditions observed from November 1970 to November 1971 at Manus island, located off the New-Guinea coast at 2°S and 147°E.

This variation of the atmospheric circulation finds its parallel in a corresponding variation of the oceanic surface drift, with however a delayed time response.

4. - Results

a) Currents :

The four trans-equatorial cross sections made during each Foc cruise present a structure chiefly characterized by the prevalence of zonal flows because the meridional components of the observed flows are generally weaker than the zonal components and their variability from a section to one another is more important.

During Foc 1 cruise (January-February 1971) there was, at the equator a superposition of opposed flows : near the surface, the water ran eastwards with an average speed of 20 cm/s; below, between 30m and 150m depth, there was an important core of westward flow, the speed of which was 50 cm/s. This current, named the equatorial current, reached the surface north of the equator. Its velocity core situated near 100m depth was spreading roughly of two degrees on both sides of the equator and had swifter observed speed at 146°E and 142°30E (fig. 1a and 1b); in fact that acceleration could be the result of the water stream narrowing between the coast and the south limit of the north equatorial counter current. Along the New-Guinea coast the New-Guinea current ran southeastwards with a maximum thickness not more than 200m. This coastal current can be linked with the equatorial superficial east flow like in figure 2a or be parted from it by a thin west flow like in figure 1a. Further east, the New-Guinea current moved off the equator towards the Coral sea, whereas at 154°E the equatorial superficial east flow kept close to the equator (fig. 1d). In the first 200m, the boundary between the equatorial current and the north equatorial counter current was well marked by an inversion along a vertical line located between 3 and 4°N of the meridional velocity gradient. North of this latitude the flow ran uniformly eastwards in the whole water column. At the equator and below 150m the flow ran also eastwards and was characterized, between 200m and 250m by a core where the speed exceedet 40 cm/s. This flow is the equatorial undercurrent extending across the Pacific ocean to the Galapagos islands. The lower boundary of this current was, at the very equator, close to 300m depth. Deeper there is a westward flow : the intermediate equatorial current (HISARD, RUAL, 1970). Both sides of the equator, the equatorial undercurrent was connected with two deep extensions going beyond 500m depth, characteristics of which have been summarized in table 1.

Longitude	142°30 E	146°E	150°E	154°E
Equatorial undercurrent lower limit (at the equator)	400m	320m	320m	300m
North extension	North of 3°N	poorly defined	North of 2°N	between 1°N 4°N
South extension	South of 0°30S	non existent	South of 2°S	between 2°30S and 3°30S

During Foc 2 cruise (June-July 1971), the circulation recorded in the superficial layers was somewhat different since the equatorial surface east flow had disapeared. In subsurface, the equatorial undercurrent had roughly the same features than in January, but its link with the north equatorial counter current seemed stronger. Below 300m, the deep extension of the equatorial undercurrent was badly defined, except at 154°E (fig. 2d).

b) Seasonal variations :

1) zonal components. From January to June, the main change in surface circulation is the quasi-disappearance of the New-Guinea current, only weakly remaining as a thin eastward flow close to the coast at 146°E (fig. 2b). In the other three cross sections of Foc 2, the surface is occupied by a westward flow spreading from the south of the zone to approximatively 2°N. This water is the upper part of the equatorial current, the velocity core of which always found south of the equator, is either close to the surface (fig. 2c and 2d) or in depth (fig. 2a and 2b). This current is existing downwards to 400m and is thus more developped than in January.

In June the southern limit of the north equatorial counter current is nearer to the equator than in January; its velocity core can exceed 60 cm/s as shown in figure 2a, 2b, 2c. Thus, in the south east trade winds season, it seems that the growth of the equatorial current has involved an equivalent strengthening of the north equatorial counter current. In January, the later, being poorly fed by the equatorial current, also weakens and has a minimal flow.

In subsurface, the equatorial undercurrent flow is scarcely altered by the reversing of the wind and its speed and depth features are roughly the same through the seasons. However its links with the north equatorial counter current are stronger in June : both currents are hardly separated and the equatorial undercurrent seems to be the underlying part of the north equatorial counter current. One can assume that farther west both flows are mingled (BURKOW and al., 1960), assumption in accordance with the main features of their waters. On the contrary of what was shown in January, it is difficult in June to precise the lower limit of the equatorial undercurrent and to describe its deep extensions; only in the figure 2d, one can see two deep east flows, north of 3°N and between the equator and 3°S.

2) meridional components. The equatorial circulation system being essentially zonal, north-south components have weak intensities and show important space-time variations; along the cross sections, the reversal of these components makes the sequential analysis difficult.

During Foc 1 cruise, superficial waters were roughly drifting northwards, that motion being canceled near the New-Guinea coast, except at 146°E (fig. 1b). At that season, there seemed to be no direct correlation between zonal and meridional components of the surface flows. At the level of its velocity core, near 100m depth, the equatorial current was preferentially drifting northwards with a meridional speed not exceeding 20 cm/s. In subsurface layers, motions were more complicated : at the equatorial undercurrent velocity core level, the meridional component was northwards at 142°30, southwards at 146°E, northwards at 150°E and non existent at 154°E. That alternation suggests that, in its eastwards movement, the equatorial undercurrent could follow a sinusoidal trajectory with an axis a little north of the equator. Below 300m, meridional components were quasi inexistent and only at 150°E (fig. 1c'), the intermediate equatorial current seemed to have a weak southward drift.

During Foc 2 cruise, the north-south components of the flows were stronger and less erratic than during Foc 1, and particularly north of the equator where the north equatorial counter current had a well pronounced northward drift at 149°E and 154°E (fig. 2c' and 2d'). South of the equator, surface waters belonging to the equatorial current had often, from one cross section to another, components of opposite direction, but deeper the drift was preferentially northwards.

In subsurface, the equatorial undercurrent velocity core, defined by the 40 cm/s isotach, was at 1°N. Its meridional drift was more homogeneous and was southward for the four cross sections and this can explain that its southern boundary had moved from 1°S to 3°S between 142°30E and 154°E. On the three western cross sections nothing can be said about meridional components below 300m; however at 154°E (fig. 1d') the two deep extensions of the equatorial undercurrent have a weak northward and southward component respectively north and south of the equator.

5. - Conclusion

In situ records made during the year 1971 north of New-Guinea allow to describe the currents system and the wind driven circulation fluctuations during two opposite wind situations. It appears in fact that the influence of the wind regime not only exerts on the coastal New-Guinea current, but also disturbs the great oceanic drifts like the equatorial current and the north equatorial counter current. However, the equatorial undercurrent variations do not seem to be directly linked to variations of the surface hydroclimatic regime.

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