Studies of the Equatorial Currents in the Pacific

By N. G. JERLOV, Fishery Board of Sweden, Gothenburg

(Manuscript received May 15, 1953)

Abstract

Some dynamic results have been derived from oceanographic data collected in the equatorial currents in the Pacific Ocean during the Swedish Deep Sea Expedition. Horizontal current velocities geostrophically computed for three meridional sections bring out some characteristic features in the flow distribution within the Countercurrent. A survey of the mass transport of water from surface to 500 m depth reveals a slow eastward flow at 12°—15° N. The reality of this weak additional countercurrent is, however, not clearly established.

The Swedish ALBATROSS plan of action in the Pacific Ocean included the crossing of the system of equatorial currents by 4 sections with serial observations. The first section, which started in the beginning of September 1947, was laid out obliquely, nearly parallel to the American coast, from the Galapagos Islands to 18° N (fig. 4). The course was then changed for the Marquesas Islands and extended across the Equator to 3° S where the ship arrived on 9th of October. The third section, Tahiti-Hawaii, was run in November in a nearly meridional direction. The serial work in the fourth section was accomplished before the end of the year but the conditions were then rapidly approaching the northern winter situation when the system of equatorial currents is weakly developed.

In the sections the spacing of stations was about 2° and the time interval between them generally about 24 hours. The serial observations were usually limited to the uppermost 1,000 m but were at some selected stations —and always at the Equator—extended to the proximity of the bottom. Between the stations surface observations of temperature and salinity were made every hour, *i.e.*, about every 7th mile, and bathythermograms for the depth range 0—130 m were taken every 4th hour (about every 30th mile).

From the existing sections it is possible to construct by interpolation 3 equidistant meridional sections at long. 127° 30′, 149° 45′, and 172° 00′ W respectively. Thus, the experimental material is brought to a state which is suitable for the further interpretation of the currents. (Table 1.)

Table. 1. Oceanographic sections.

Section	Time	Latitude	Longitude
1	Sept.	2°44′S—17°46′N	92°45′ W—126°51′ W
2	Oct.	3°00′S—17°46′N	127°30′ W
3	Nov.	7°38′S—15°14′N	149°45′ W
4	Dec.	2°37′S—14°39′N	172°00′ W

The vertical distribution of density in the three meridional sections is shown in figs. 1—3. The typical structure of the water masses in the system of equatorial currents appears in

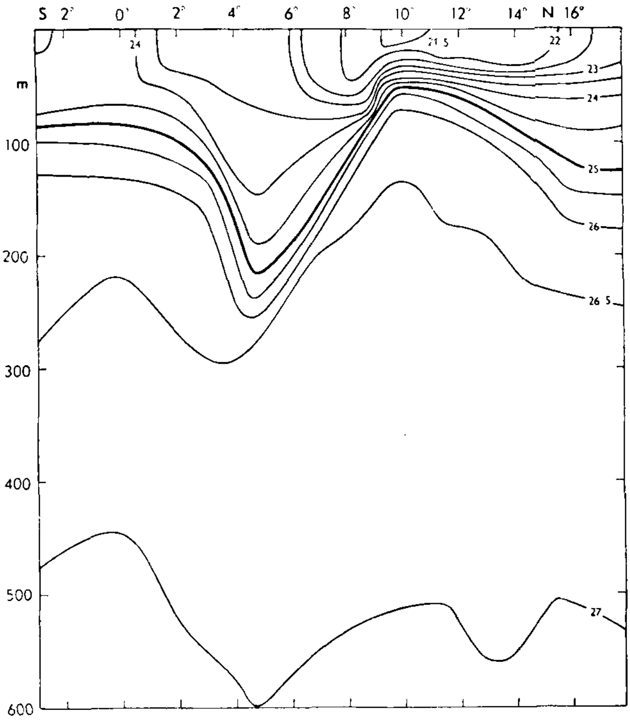

Fig. 1. Density (σ_t) distribution in a vertical section at long. 127°30′W in the Pacific Ocean.

the second section (fig. 1). The salient rise of the curves and their close packing at 10° N reveals the divergence at the northern boundary of the Countercurrent. The minimum in the trends at 5° N locates there the convergence at the southern boundary of the Countercurrent. The Equator Divergence claimed by theory (SVERDRUP, 1932; DEFANT, 1936) is also well developed.

In the third section the same characteristic features are found though somewhat less marked. The Northern Divergence is here apparently divided, two maxima existing, one at 9°.5, the other at 13°.5 N.

The fourth section reveals a displacement of the Countercurrent towards the south due to the seasonal change of its flow. The Northern Divergence is suggested at 8° N whereas the deepening of the isopleths at 3° indicates the convergence. The sharp drop of the curves between 5° and 3° gives evidence of a swift stream of the Countercurrent.

Computed anomalies of dynamic height at standard depths are listed in Reports of the Swedish Deep Sea Expedition, v. 3, Appendix, Table 2. DEFANT's (1941) procedure was employed for arriving at a representation of the absolute topography of the different isobaric surfaces. The depth of the reference layer or of the layer of no motion was found to lie between 500 and 900 m and nearest the surface at the Equator.

Derived values of dynamic heights for the sea surface are illustrated in fig. 4, the Equator station 111 being chosen as zero level. The sea surface south of the Galapagos Islands lies 30 cm below this level whereas just north of the Equator at long. 170° E it is 30 cm above. This slope near the Equator, which is due to the westward wind stress and associated with piling up of light surface water in the western Pacific, agrees well with previous estimates from DANA results (MONTGOMERY and PALMÉN, 1940).

The marked trough at the Equator gives evidence of the Equator Divergence and the ridge at 5° N, which towards the west gradually moves to the Equator, reflects the

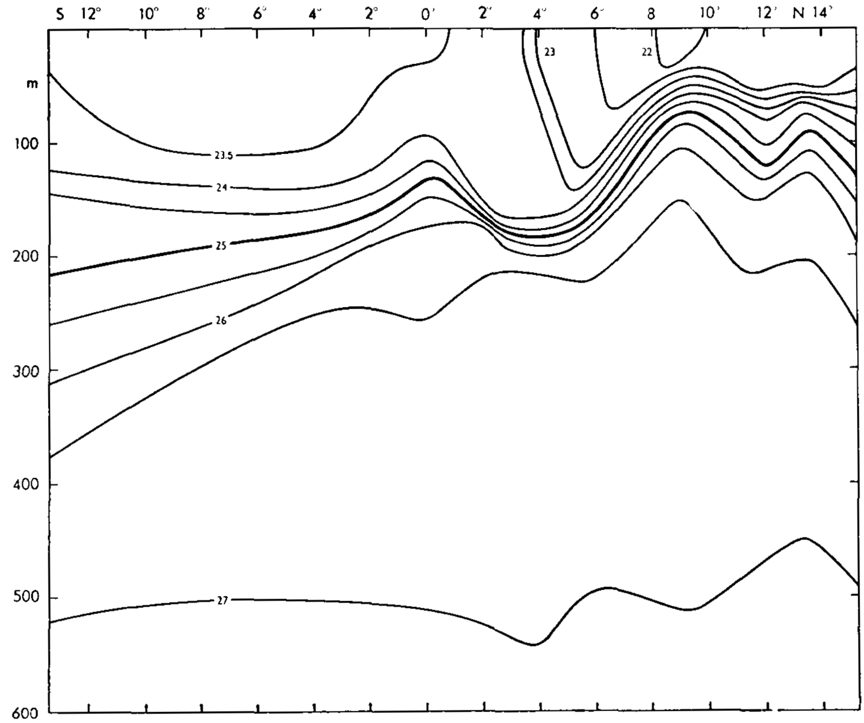

Fig. 2. Density (σ_t) distribution in a vertical section at long. 149°45′W in the Pacific Ocean.

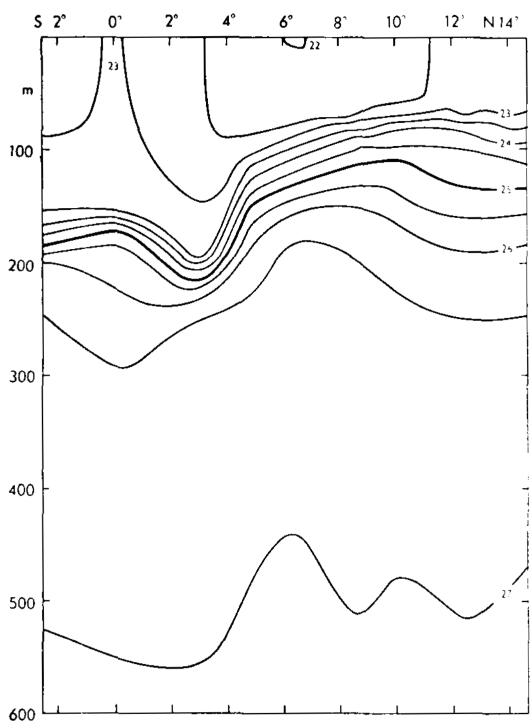

Fig. 3. Density (σ_t) distribution in a vertical section at long. 172°00′W in the Pacific Ocean.

convergence at the southern boundary of the Countercurrent. The figure also brings out two eddies in the Countercurrent in the first section.

The other trough at about 10° N connected with the Northern Divergence is divided in two branches in the first and in the third section. A slightly similar tendency in the second and in the fourth section is not distinguishable on the chart but appears at lower isobaric surfaces.

It has been stated that the equatorial currents in the Pacific are closely related to the slope of the discontinuity layer (SVERDRUP *et al.*, 1942). The density surface $\sigma_t = 24.5$ coincides with the maximum density gradient and roughly with the salinity maximum in the Pacific. A representation showing the depth of this density surface is remarkably consistent with that in fig. 4, troughs corresponding to ridges and *vice versa*.

As divergence regions are usually rich in phytoplankton whereas convergence regions are poor, the presence of these vertical water movements can be demonstrated by the

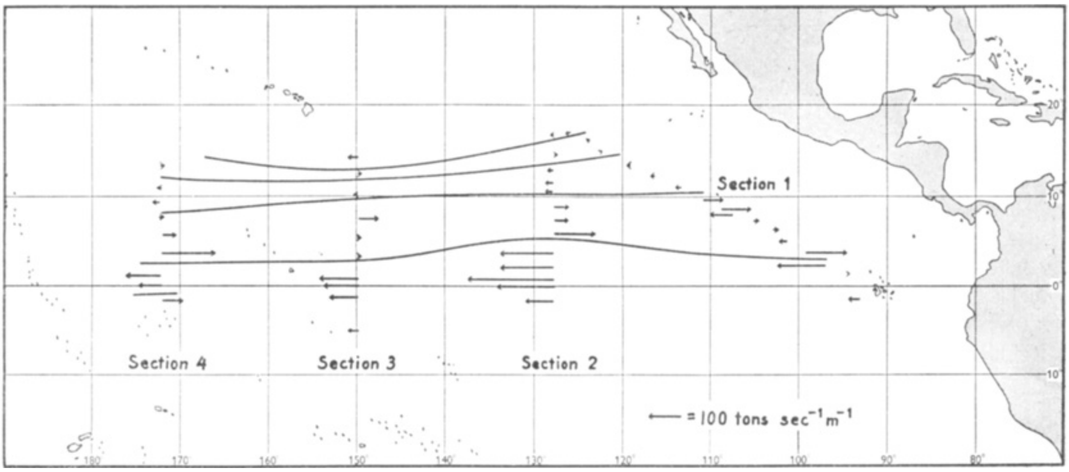

Fig. 4. Dynamic topography (cm) of the sea surface.

distribution of the particle content in the surface layer 0—50 m (JERLOV, 1953). On the chart in fig. 5 the divergence zones appear clearly and also some details associated with the dynamic features in fig. 4.

The horizontal velocities (cm/sec.) in the three meridional sections have been geostrophically computed and are shown in figs. 6—8. Near the Equator where the Coriolis' parameter is small the computation is uncertain. A more reliable value at the Equator is obtained by differentiating the equation with respect to the latitude and solving for the velocity at the latitude = 0°. However, surface current velocities can be derived from the drift of the vessel found from the ship's records and with due regard to the wind drift. A comparison between these and the values geostrophically computed—for what it is worth—reveals a considerable discrepancy in the vicinity of the Equator, the latter values being higher. Though this circumstance is taken into account the current velocities in the South Equatorial Current near the Equator are given with due reservation.

The Countercurrent flows with a maximum

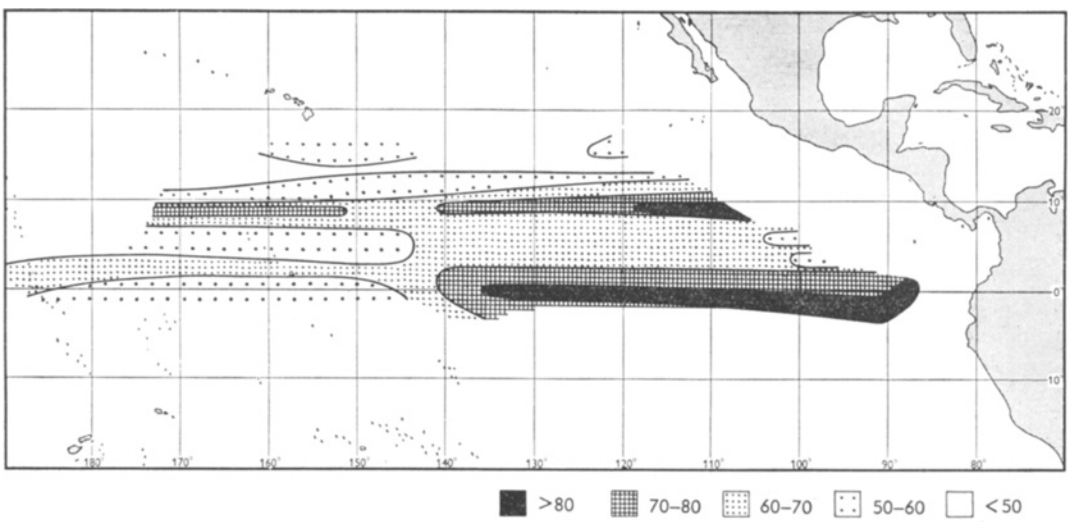

Fig. 5. Particle content in the uppermost 50 m.

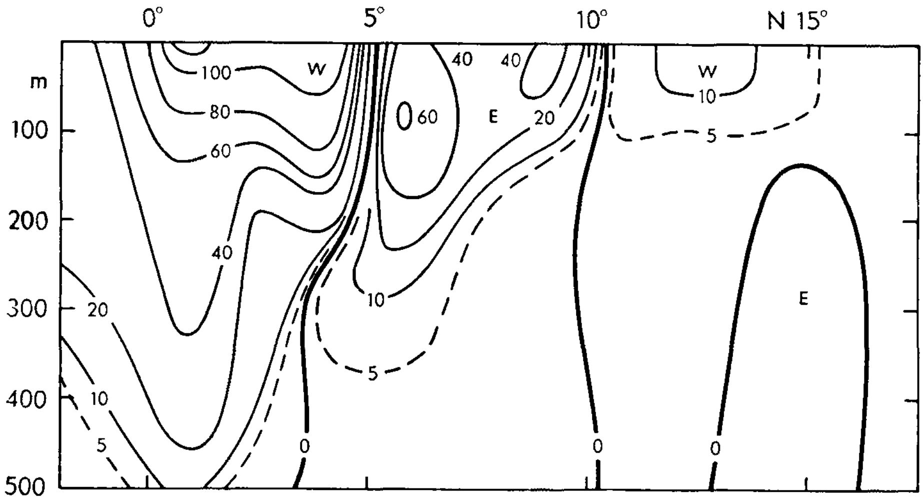

Fig. 6. Horizontal velocity (cm/sec.) in a vertical section at long. 127°30'W in the Pacific Ocean.

surface velocity of 60 cm/sec in the two easterly sections. In the westerly section a value of 100 cm/sec or 2 knots is attained which is due to the prevailing abnormal wind distribution which occasions a strong westward wind stress over the northern parts of the Countercurrent, so that its main flow is concentrated southwards where the stress practically vanishes. The appearence of the vertical structure of the Countercurrent in the second section (fig. 6) is in good agreement with that for the CARNEGIE section in the same region.

Two features in the flow of the Countercurrent are common to the three sections. The Countercurrent is deeper in its southern part and extends below the South Equatorial Current. Further it is observed that a weak eastward current occurs in the zone 12°—16° N. This phenomenon is present in the second section below 150 m only and might be ascribed to the effect of internal waves. But in the third section the current in view is stronger and penetrates the whole water column in conformity to the division of the Northern Divergence. In this case the South and the North Equatorial Currents are fairly shallow and the whole body of deep water from 5° S to 12° N moves eastwards. Finally the east-

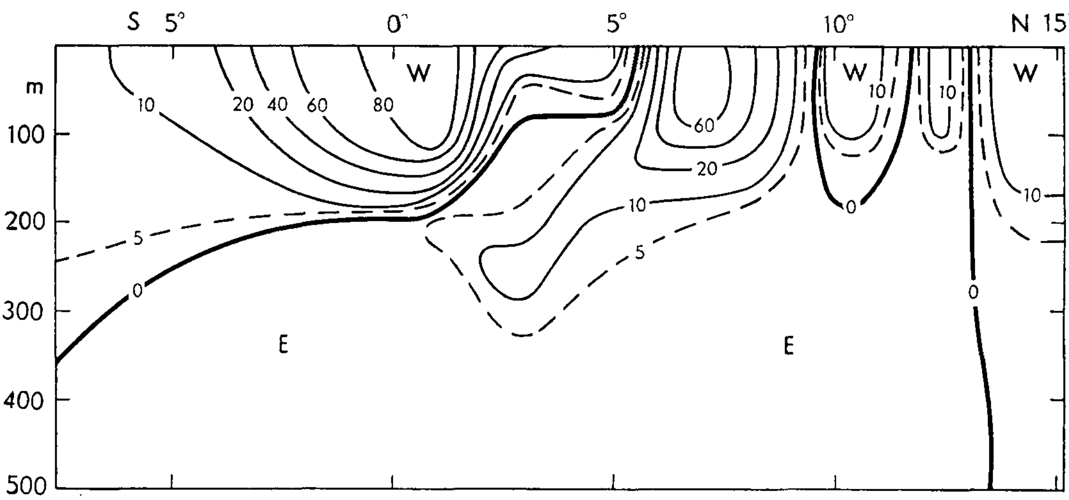

Fig. 7. Horizontal velocity (cm/sec.) in a vertical section at long. 149°45'W in the Pacific Ocean.

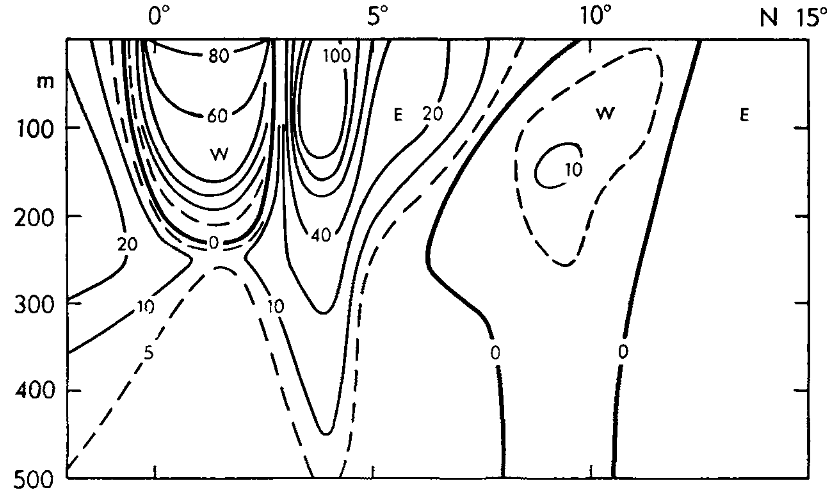

Fig. 8. Horizontal velocity (cm/sec.) in a vertical section at long. 172°00'W in the Pacific Ocean.

ward flow between 12° and 15° N in the fourth section is too weak to admit any definite conclusions about its reality.

We shall look at the problem of equatorial currents from another side and consider the horizontal distribution of the total mass transport of water. This can be obtained by integration from the vertical distributions of velocities in figs. 6—8. Another way is to use the integrated equations of horizontal motion which also takes the average wind stress into account (SVERDRUP, 1947; REID, 1948). The wind stress is small compared with the meridional pressure gradients, and therefore the two methods yield practically the same results. It is sufficient to extend the integration to 500 m only, as the contribution from deeper layers is negligible.

On the chart in fig. 9 the mass transport 0—500 m is represented as east-west vectors. Current conditions in the first section are incorporated in the figure. It is observed that the transport is not everywhere congruent with the surface current. For instance, in the southern part of the Countercurrent at 150° W the transport vector is directed against the surface current.

The total mass transport by the Counter-

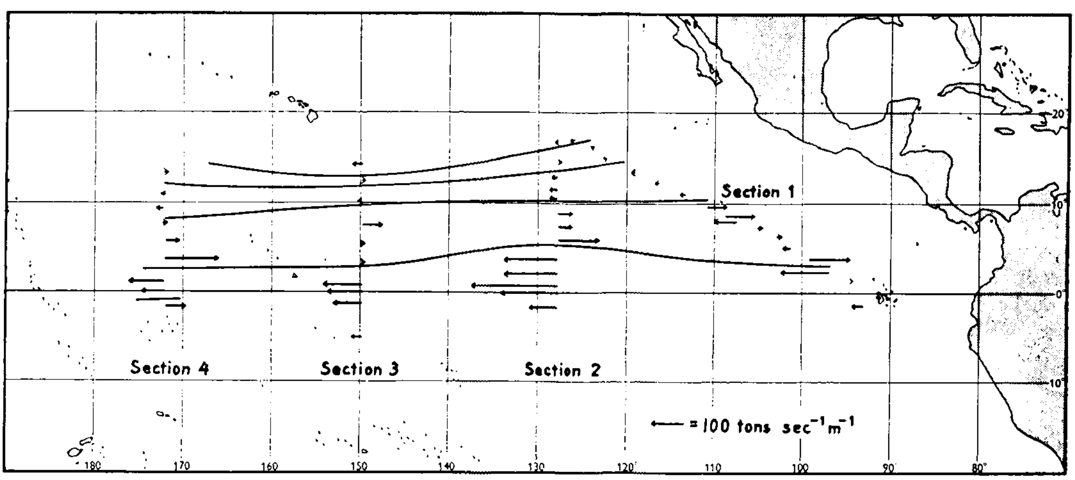

Fig. 9. Mass transport of water from surface to 500 m depth given as east-west vectors.

current within the boundaries given in fig. 9 was found to be:

at 127° 30′ W	36	million tons per sec.
149° 45′	25	
172° 00′	43	

These values compare well with that evaluated from CARNEGIE data which is representative for October and amounts to 25 million tons per sec. across the 140th meridian (SVERDRUP *et al.*, 1942). In fact, the total eastward flow within the system of equatorial currents should be taken into account. This would raise the second value only from 25 to 31 million tons per sec.

An interesting feature of the transport pattern is the narrow zone of water flowing eastwards at 12°—15° N. The consistent picture speaks in favour of the reality of this additional countercurrent. The horizontal particle distribution, which is little affected by tidal currents, also indicates its existence. It may appear that this phenomenon is related to the occurrence of multiple currents in the Gulf Stream (FUGLISTER, 1951). On the other hand, dynamic results must be interpreted with great caution, especially on account of the internal waves of tidal periods, and more observational evidence on this detail in the system of equatorial currents is needed.

The present paper is a preliminary report of the oceanographic work in the Pacific during the Swedish Deep Sea Expedition. The author is greatly indebted to Dr Hans Pettersson for his generous support and to the whole scientific staff on board the ALBATROSS for their unstinting co-operation. He wishes also to express his gratitude to Dr C.-G. Rossby for many helpful discussions and to thank Dr G. Koopman, who has carefully carried out the dynamic computations.

REFERENCES

DEFANT, A., 1936: Die Troposphäre. *Deutsche Atlantische Exped. Meteor*, 1925—1927, *Wiss. Erg.*, Bd. VI, Teil 1, 3. Lief., p. 289.

— 1941: Die absolute Topographie des physikalischen Meeresniveaus und der Druckflächen, sowie die Wasserbewegungen im Atlantischen Ozean. *Deutsche Atlantische Exped. Meteor* 1925—1927, *Wiss. Erg.*, Bd. VI, 2 Teil, 5. Lief., p. 191.

FUGLISTER, F. C., 1951: Multiple currents in the Gulf Stream system. *Tellus*, 4, p. 230.

JERLOV, N. G., 1953: Particle distribution in the ocean. *Reports of the Swedish Deep Sea Expedition*, **3**, No. 3.

MONTGOMERY, R. B., and PALMÉN, E., 1940: Contribution to the Question of the Equatorial Counter Current. *Jour. Marine Research*, **3**, p. 112.

REID, R. O., 1948: The Equatorial Currents of the eastern Pacific as maintained by the Stress of the Wind. *Journ. Marine Research*, **7**, No. 2, p. 74.

SCHOTT, G., 1943: Weltkarte. *Ann. d. Hydrogr. v. Mar. Meteorol.* Tafel 22.

SVERDRUP, H. U., 1932: Arbeider i luft- og havsforskning. [illegible] *Michelsens Institutt for Videnskap og Aandsfrihet, Beretninger*, **2**, No. 5.

— 1947: Wind-driven currents in a baroclinic ocean with application to the Equatorial Currents of the Eastern Pacific. *Proc. Nat. Accad. Sciences*, **33**, No. 11, p. 318.

SVERDRUP, H. U., JOHNSON, M. W., and FLEMING, K. H., 1942: *The Oceans, their Physics, Chemistry and general Biology*. New York.