

# MITTEILUNGEN

## Watermass Structure and Current System in the Equatorial Western Indian Ocean during August, 1985

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### Summary

During the 17th cruise of RV "Sagar Kanya" (3rd to 21st August, 1985), two meridional sections were occupied between 4° N and 6° S in the equatorial Western Indian Ocean. The Dynamic Method was employed to derive geostrophic currents. At the equator, currents were computed using Montgomery's method [1962]. Westerly flows near Equator and easterly flows on either side of the equator are deduced. The presence of the Arabian Sea surface water, the Red Sea water, and the Pacific low salinity water is noticed along these two sections.

In this paper, our main objective is to study the watermass structure and geostrophic currents in the upper 500 m water column of the equatorial Western Indian Ocean during August, 1985.

### Wassermassenstruktur und Stromsystem im äquatorialen westlichen Indischen Ozean im August 1985 (Zusammenfassung)

Während der 17. Reise des FS "Sagar Kanya" vom 3. bis 21. August 1985 wurden zwei meridionale Schnitte zwischen 4° N und 6° S im äquatorialen Westteil des Indischen Ozeans gefahren. Die Dynamische Methode wurde benutzt, um geostrophische Strömungen festzustellen. Am Äquator wurden die Strömungen mit Hilfe der Montgomery-Methode [1962] berechnet. In Äquatornähe wurden westliche Strömungen und zu beiden Seiten des Äquators östliche Strömungen festgestellt. Das Vorhandensein des Oberflächenwassers der Arabischen See, des Wassers des Roten Meeres und des Pazifikwassers mit geringem Salzgehalt wurde anhand der beiden Schnitte beobachtet. Das Hauptanliegen dieser Arbeit ist es, die Wassermassenstruktur und die geostrophischen Strömungen innerhalb der oberen 500 m Wassertiefe im äquatorialen Westteil des Indischen Ozeans im August 1985 zu untersuchen.

### 1 The data

During the 17th cruise of RV "Sagar Kanya" (3rd to 21st August, 1985), two meridional sections were occupied across the equator in the Western Indian Ocean. The first section runs across the equator between 48° E and 53° E, parallel to the Somali Coast, the second along 60° E. The spacing between the stations varied from half a degree to one degree latitude. Hydrocasts for temperature and salinity were operated at seventeen and eighteen stations along the first and second section respectively, although a total of 21 stations were occupied along each section (Fig. 1). At most of the stations hydrocasts were operated up to 1000 m.

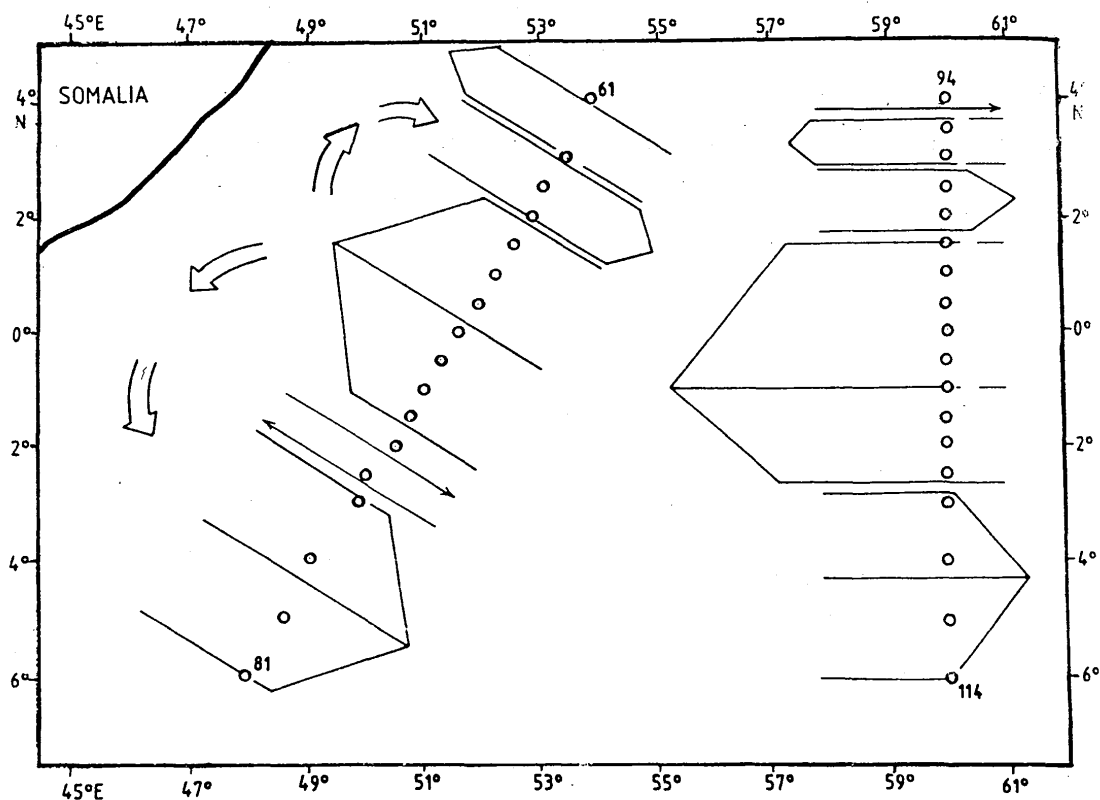


Fig. 1. Station location map and a schematic representation of possible surface currents

Temperature – Salinity (T–S) curves were drawn for each station. Depths of selected isotherms, isohalines, and isanosteres were read from these curves and the vertical sections of temperature, salinity, and thermocline anomaly were drawn for the above two sections (Fig. 2–7). The geostrophic current between the stations was computed with reference to 500 m and the results are shown in the Figures 8 and 9. Within one degree from the equator the geostrophic computations were carried out by differentiating the geostrophic equation with respect to the latitude following Montgomery and Stroup [1962].

$$v = -(2 \omega a)^{-1} (\Phi_{+\Delta\varphi} + \Phi_{-\Delta\varphi} - 2 \Phi_0) / (\Delta\varphi)^2$$

- here
- $v$  zonal component of geostrophic velocity
  - $\omega$  angular velocity of earth's rotation ( $0.729 \times 10^{-4}$  rad/s)
  - $a$  radius of the earth ( $6378 \times 10^3$  m)
  - $\Phi$  anomaly of geopotential
  - $\Phi_0$  anomaly of geopotential at the equator
  - $+\Delta\varphi$  latitude, North of equator
  - $-\Delta\varphi$  latitude, South of equator

## 2 Distribution of temperature

Figs. 2 and 3 show the vertical distribution of temperature along the two sections. The sea surface temperature increases from 25 °C in the west to about 28 °C in the east. This difference in sea surface temperature is clearly due to the proximity of the western section to the source region of the cold upwelled waters that is, from the Somali Coast. In the western section, the surface layer thickness is about 90 m around 2° N. On either side of the equator, its thickness decreases. Within the thermocline, considerable spreading of isotherms is seen around 3° S in the upper 200 m and this feature is not evident in the north. The spreading can be explained in terms of the principle of conservation of volume (Pickard and Emery [1982]) and is mainly due to the current shear that exist between the two opposing currents (Figs. 8 and 9).

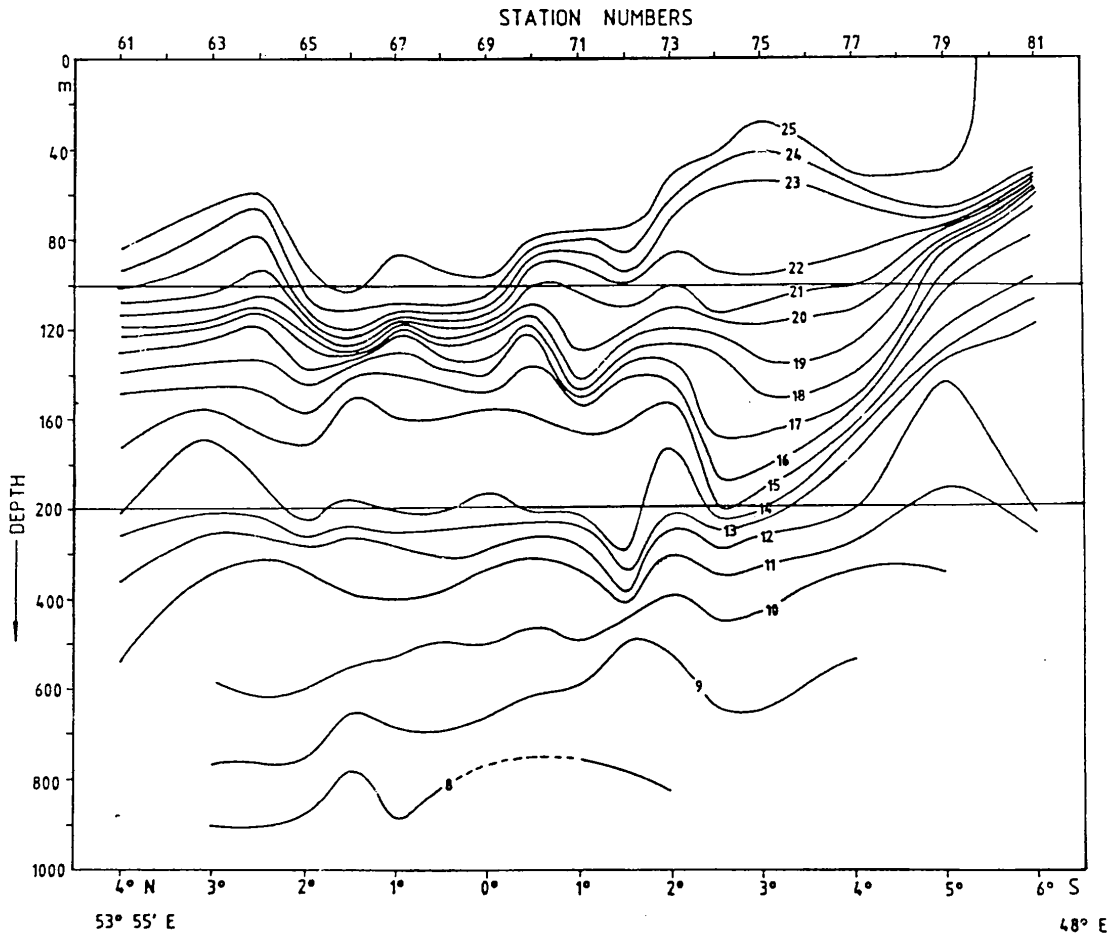


Fig. 2. Vertical structure of temperature in °C along 48 to 53° E

In the eastern section (Fig. 3) the mixed layer depth is relatively small at the equator (approximately 50 m). However, on either side its thickness increases to about 90 m. This is in contrast with the western section. The contrasting features of the thickness of the surface layer seem to result due to the dynamic processes of wind-induced divergence near the equator and the spreading of the upwelled water along the equator. In the western section, the influence of the colder (denser) water is such that the layer deepens. Further east, wind-induced divergence due to southeast trades raises the isotherms near the equator.

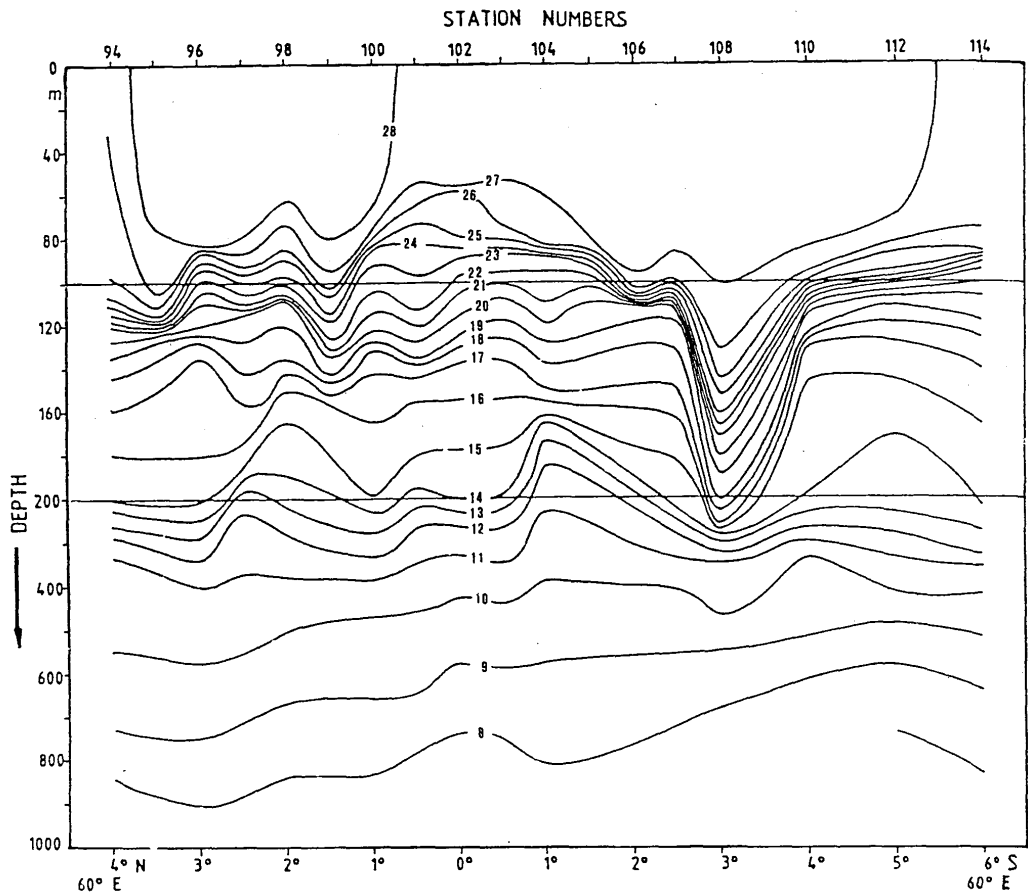


Fig. 3. Vertical structure of temperature in °C along 60° E

### 3 Distribution of Salinity

The vertical distribution of salinity along the two sections is shown in Figs. 4 and 5. In the west, salinity varies from 35.7 to 34.9. The high salinity is mostly confined to surface layers north of the equator and coincides with the 400 – 420 cl/t layer (Fig. 6). The high salinity water extends towards south in the form of a tongue like structure in the upper layers. This high salinity water forms over most of the Arabian Sea due to the excess of evaporation over precipitation and sinks to depth of 75 – 100 m. Below 500 m another high saline layer (35.1) coinciding with 80 – 100 cl/t in the depth range of 600 – 900 m extends toward south from 4° N. A low salinity (34.9) tongue extends toward north from 6° S on 100 – 120 cl/t.

The surface salinity along the eastern section (Fig. 5) shows a salinity minimum (34.7) at about 1° S. On either side of the minimum, the salinity increases to values exceeding 35.4. A high salinity core, again coinciding with 400 – 420 cl/t layer is present near the equator at 100 m (Fig. 5 and 7). South of 2° S an isohaline layer is seen in the upper 300 m. As in the west a subsurface salinity maximum (35.1) is present around 600 m depth north of equator and a low salinity layer (34.9) in the south.

The subsurface salinity maximum between 500 m and 900 m is clearly due to the penetration of Red Sea water. The subsurface salinity minimum is probably due to the incursion of low salinity Pacific water, Sharma et al. [1978].

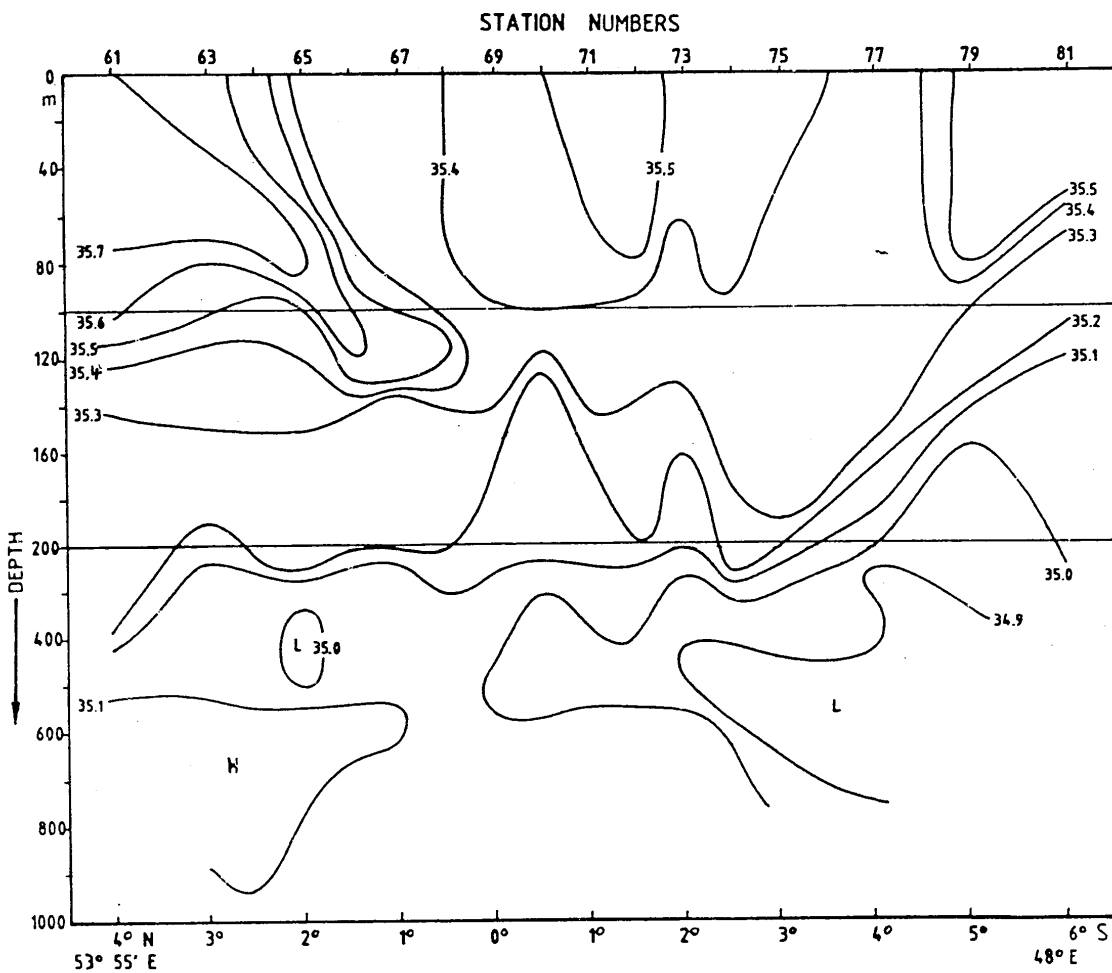


Fig. 4. Vertical structure of salinity along 48 to 53° E

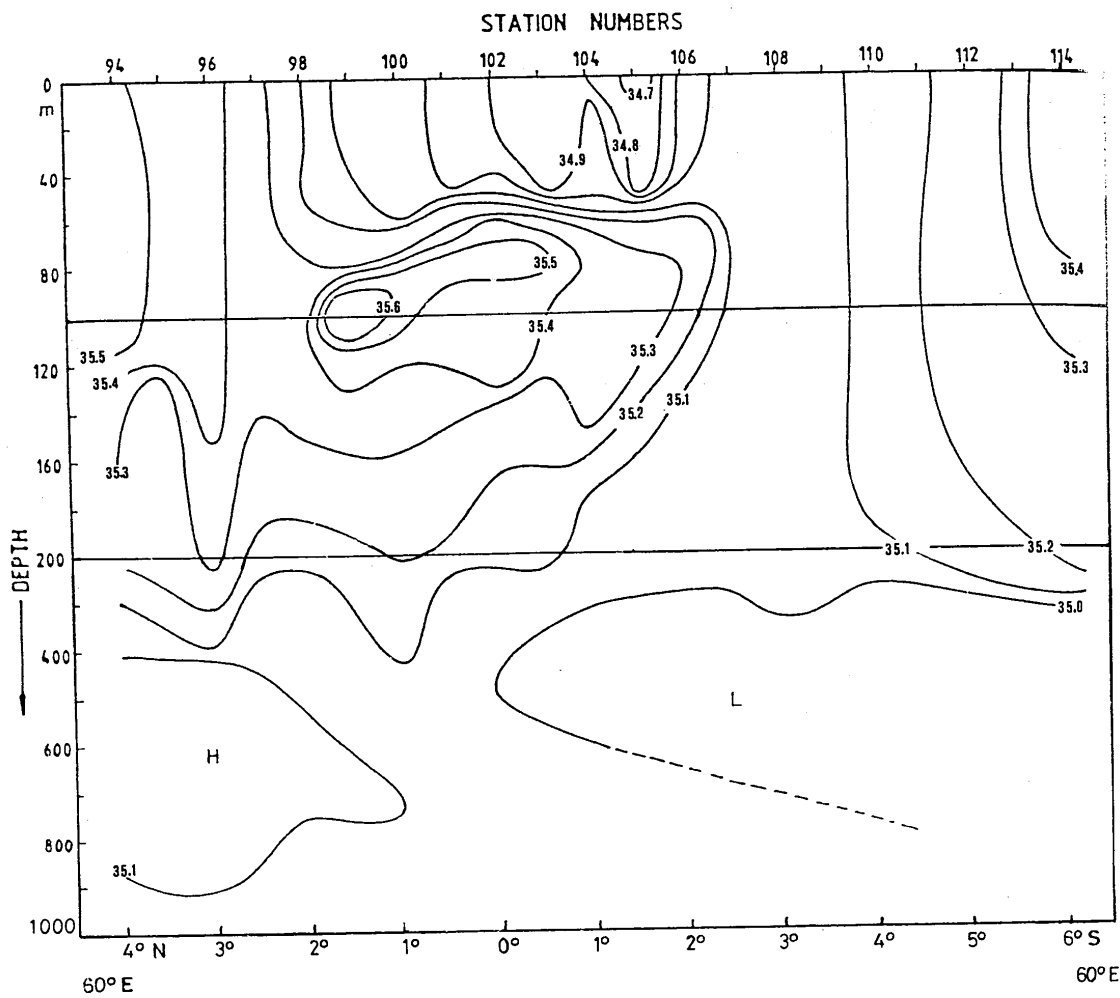


Fig. 5. Vertical structure of salinity along 60° E

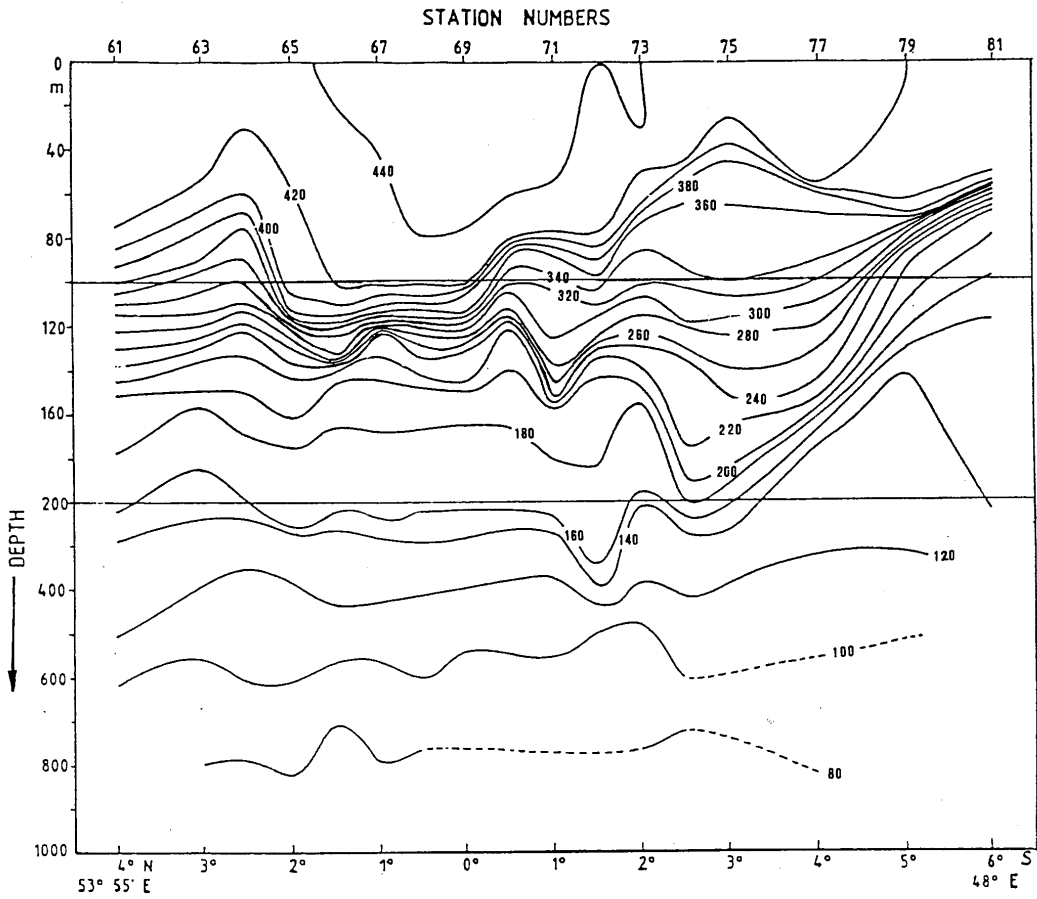


Fig. 6. Vertical structure of thermocline anomaly in ct/t along 48 to 53° E

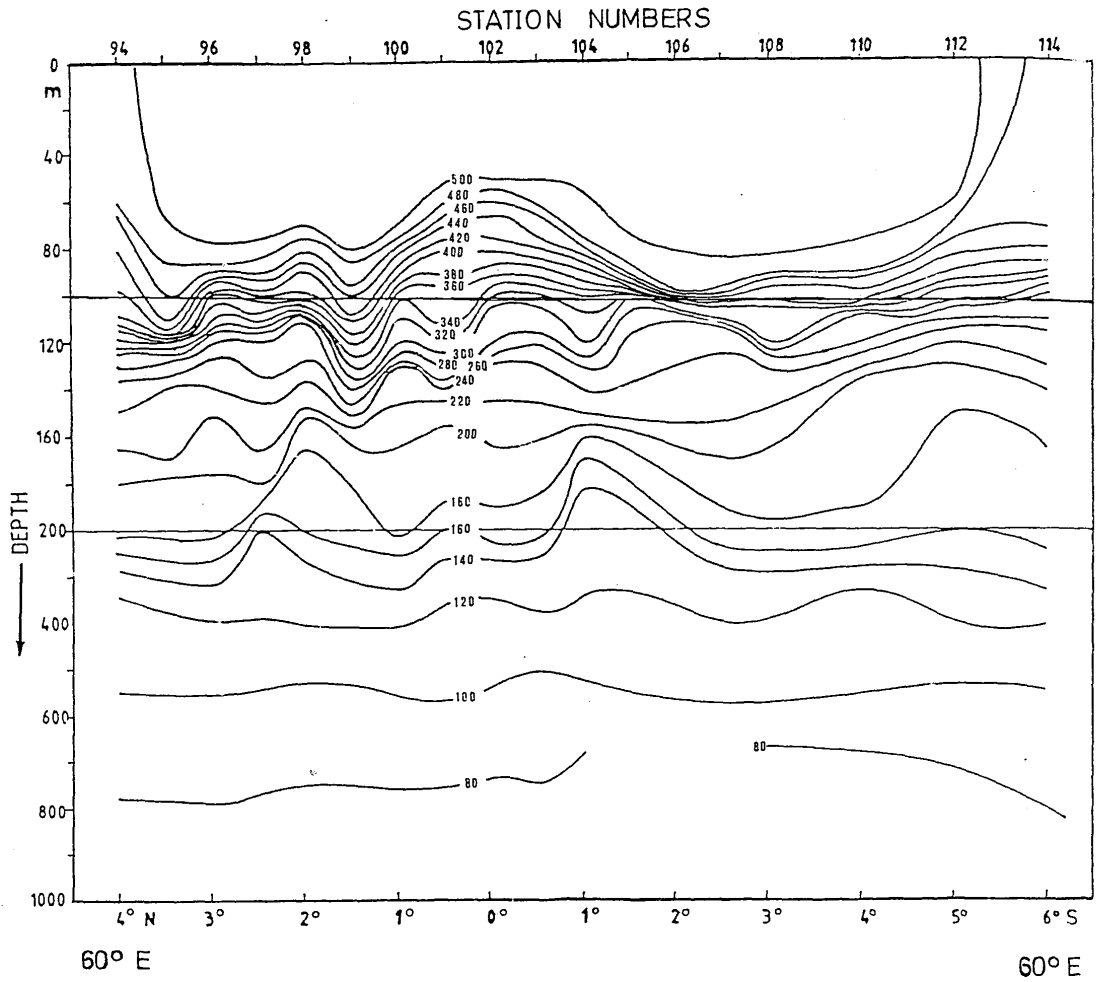


Fig. 7. Vertical structure of thermocline anomaly in ct/t along 60° E



#### 4 Relative currents

The geostrophic currents across the sections are shown in Figs. 8 and 9. Alternate bands of strong easterly and westerly flows are observed throughout the 500 m water column. At some locations the relative current speeds are as high as 3 m/s. In the west (Fig. 8), a broad northwestward flow extending down to 500 m is present between  $1^{\circ} 30' N$  and  $1^{\circ} 30' S$  during this season. This is in agreement with the earlier studies, D u i n g [1970] carried out for this region. In Fig. 1 the possible flow patterns in the western equatorial Indian Ocean during this season are schematically shown. A strong westerly flow along the equator divides into two branches close to Somalia, one turning northwest and the other southwest. These two branches turn east, one north of equator and the other south of it. The dominant westward flow between  $1^{\circ} 30' N$  to  $2^{\circ} 30' N$  is identified as the south equatorial current which has shifted its position towards north and is observed throughout the water column down to 500 m. The appearance of the vertical structure of the westward current centered near the equator in the region is in good agreement with that derived by D u i n g [1970] for late summer monsoon.

It may be remarked that the data are inadequate to explain the continuity of the westward flow from  $60^{\circ} E$  to  $53^{\circ} E$  but it is clear from the earlier studies Cutler and Swallow [1984] that the flow starts from  $80^{\circ} E$  and ends at  $53^{\circ} E$ .

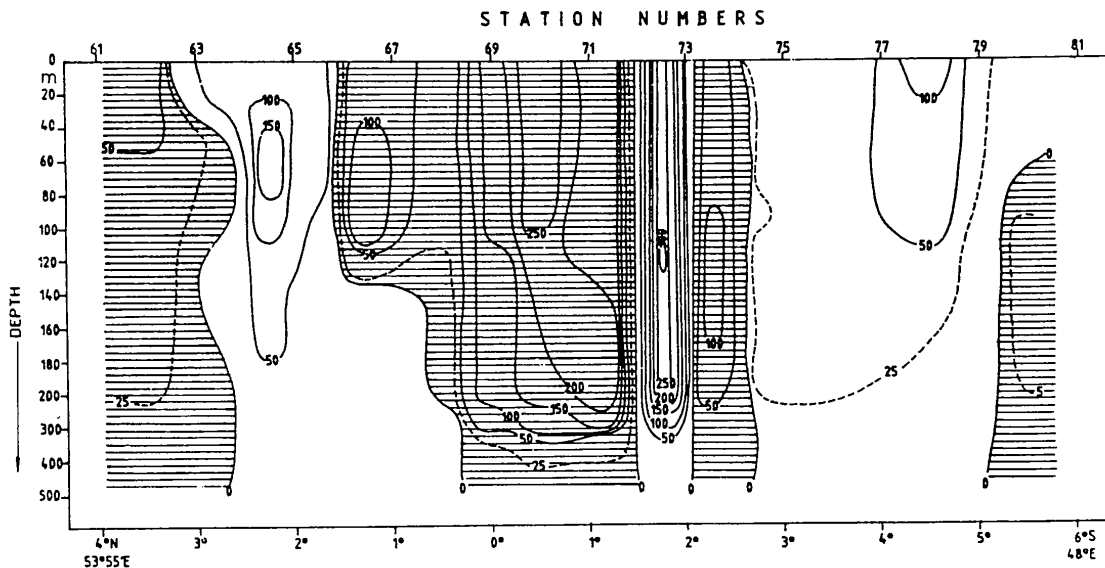


Fig. 8. Geostrophic currents in cm/sec relative to 500 m along  $48^{\circ}$  to  $53^{\circ} E$ .  
(HATCHED area indicates westerly flow)

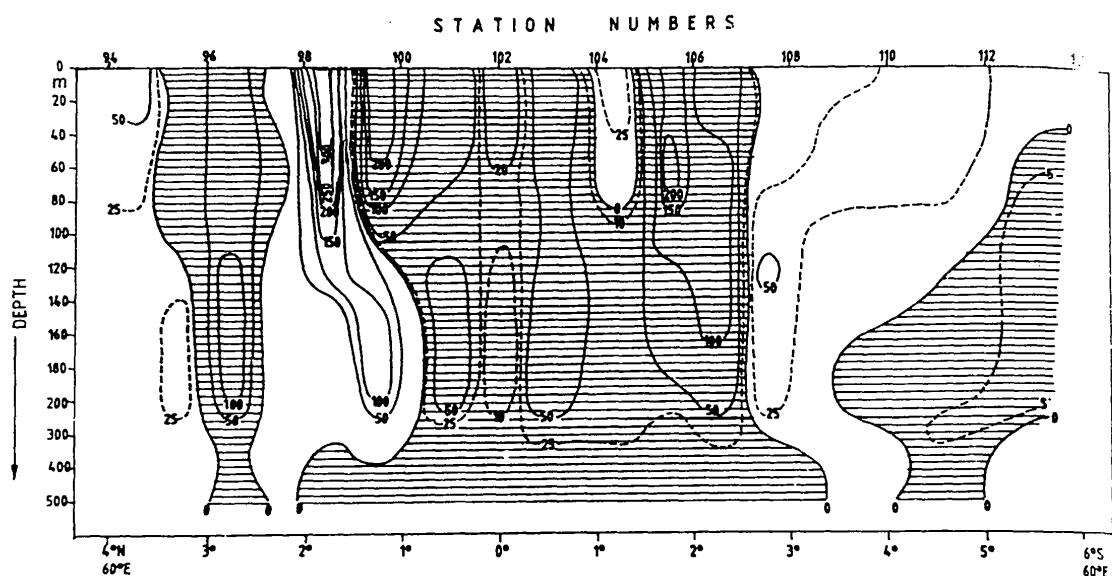


Fig. 9. Geostrophic currents in cm/sec relative to 500 m along 60° E.  
(HATCHED area indicates westerly flow)

### Acknowledgements

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