

Thermal Structure & Flow Patterns around Seychelles Group of Islands (Indian Ocean) during Austral Autumn

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Properties of thermal structure in the upper 750 m around the Seychelles group of islands in the Indian Ocean, based on Expendable Bathythermograph (XBT) data collected in March 1984, are presented along with the inferred flow patterns. The topography of 20°C isotherm suggests a broad eastward flow in the northern and northeasterly flow in the southern regions of the islands. A divergence zone with shallow thermocline in the south is visualised as a result of shear flow between opposing zonal equatorial currents – equatorial counter current in the northern and south equatorial current in the southern parts of the islands. The presence of relatively low thermocline gradients in the north, resulted due to stronger mixing, indicates the probable existence of an equatorial undercurrent.

The Seychelles group of islands in the western Indian Ocean situated between 0° to 10°S and 50° to 60°E forms part of the Seychelles-Mauritius Ridge. The group is mainly dominated by a large bank extending over an area of approximately 54450 km², with its centre around Mahe island. Even though some detailed investigations^{1,2} have been made in the past on the current and thermal variability of waters at other near-equatorial island groups such as Maldives in the central Indian Ocean very few studies have been carried out in the vicinity of Seychelles group of islands. Studies of Leetmaa and Stommel³ based on the observations in the western Indian Ocean also indicate the existence of equatorial undercurrent and its response to strong transient events during February-June. However, these studies do not cover the southern part of Island group. In this paper, features of thermal structure in the upper 0-750 m water column around the entire Seychelles group of islands for austral autumn along with the inferred flow patterns are discussed.

Materials and Methods

During the 134 cruise of *R V Gaveshani* (7-25 March, 1984), XBT (Expendable Bathythermograph; make: Sippican; model: R-603G; temperature accuracy: $\pm 0.2^\circ\text{C}$; depth accuracy: $\pm 2\%$) was operated at 23 stations (Fig. 1) around the Seychelles group of islands to obtain depth-temperature profiles up to 750 m depth. Necessary temperature corrections were applied to the original XBT data using the bucket thermometer

readings which were simultaneously taken. Besides, depth corrections were also done in cases when the initial point of temperature trace deviated from the zero depth mark of the XBT record. Data were digitised at 10, 20 and 50 m intervals in 0-150, 150-450 and 450-750 m depth ranges

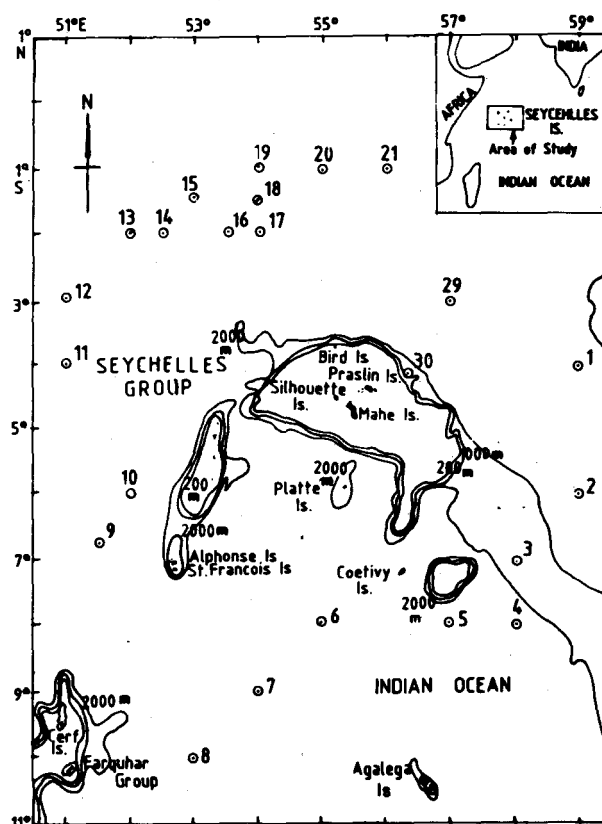


Fig. 1 – Station locations

respectively. For the purpose of the present study, the mixed layer and the thickness of thermocline were computed following Colborn⁴. The main oceanic thermocline was identified as a layer between the lower limit of permanent thermocline and the depth of the 7°C isotherm. Together with the spatial distribution charts of the thermal structure, vertical sections of temperature distribution in the western, eastern, northern and southern areas around the group of islands are also presented in order to understand the meridional and zonal variations in the thermal structure.

Results and Discussion

Spatial fields—Sea surface temperature (SST) increases towards the islands from both south and north (Fig. 2). The presence of warm waters in the vicinity of islands can be related to the effect of broad shallow nature. Cold surface waters (SST < 27.5°C) are conspicuously present around 9°30'S and 54°E. The mixed layer thickness (MLT) in general decreases from north to south (Fig. 3) with its minimum (< 20 m) around 8°S and 56°E which can be attributed to divergence. Similarly maximum value in MLT (> 90 m) in the north indicates convergence in the flow regimes. Since the topography of thermocline normally correlates with the field of geostrophic motions⁵, the knowledge of the former is obtained from the topography of 20°C isotherm for deriving flow patterns qualitatively.

The depth of 20°C isothermal surface (Fig. 4) in general increases from 40 m in the south to 110 m in the north together with low spatial gradients seen around the islands. The general downsloping of thermocline in the area towards northwest indicates a northeastward geostrophic flow near the islands, eastward flow in the north around 1°-2°S between 54° and 58°E and a northward flow around 9°S between 53° and 56°E since in the southern hemisphere the flow is organised in such a way that warmer waters exist to its left side. The depth of lower boundary of the permanent thermocline (Fig. 5) is in general low (< 200 m) around the main group of islands and it increases towards offshore in all directions from it. The thickness of thermocline (Fig. 6) is in consonant to the depth of lower boundary of the thermocline. Higher thermocline gradient values (> 0.08°C.m⁻¹) are seen in the vicinity of the islands whereas, they are low in the offshore regions (Fig. 7). The highest gradient (> 0.14°C.m⁻¹) is encountered in the southeastern region near Coetivy island. Relatively low values in the north (< 0.06°C.m⁻¹) indicate stronger

mixing probably under the influence of a vertical shear in the thermocline.

Vertical fields—Vertical thermal structures in the western (Fig. 8A) and eastern (Fig. 8B) regions of the study area show similar northward downsloping of isotherms below 50 m indicating a general eastward flow. At surface and near-surface levels, waters are more cold in the eastern region than in the western region. In the main thermocline region (below 300 m) also waters are relatively cold in the eastern region as seen from the uplifting of isotherms. Further, the steep northward downslope of thermocline in the upper 300 m of the eastern region in contrast to that of the western one (Fig. 8B) indicates a stronger eastward flow. When such strong zonal flow occurs in the leeward side of islands, upwelling is expected lifting up the isotherms under steady state conditions.

Vertical temperature structures in the northern and southern regions (Fig. 9) show different features in contrast to the similarity seen in the eastern and western regions. The thermocline is relatively shallow (< 20 m) in the south whereas in the north it is deep (≈ 90 m). In the south, the permanent thermocline slopes up eastward especially between 53° and 54°30'E (Fig. 9B) indicating a northerly flow. But in the north of the islands, there is not much east-west variation in the topography of permanent thermocline suggesting a weak meridional flow. It is further seen that thermocline is spread around 100 m in this northern part.

During austral autumn, the winds are moderate and they blow mainly from the east (Table 1). This wind field would cause a weak southerly drift in the surface layer. However, the effect of wind drift is not seen in the study area due to the presence of relatively strong density currents which are set in on account of the northwestward temperature increase. During March-April, the eastward current inferred from the topography of 20°C isotherm in the northern regions of the study area around 100 m depth is considered as a

Table 1 – Statistics of Observed Wind over the Study Area

Wind speed (knot)	% Frequency of Wind direction wind speed	% Frequency of wind direction
0 – 5	18	N 3
6 – 10	46	NE 27
11 – 15	32	E 37
16 – 20	4	SE 3
		W 15
		NW 15

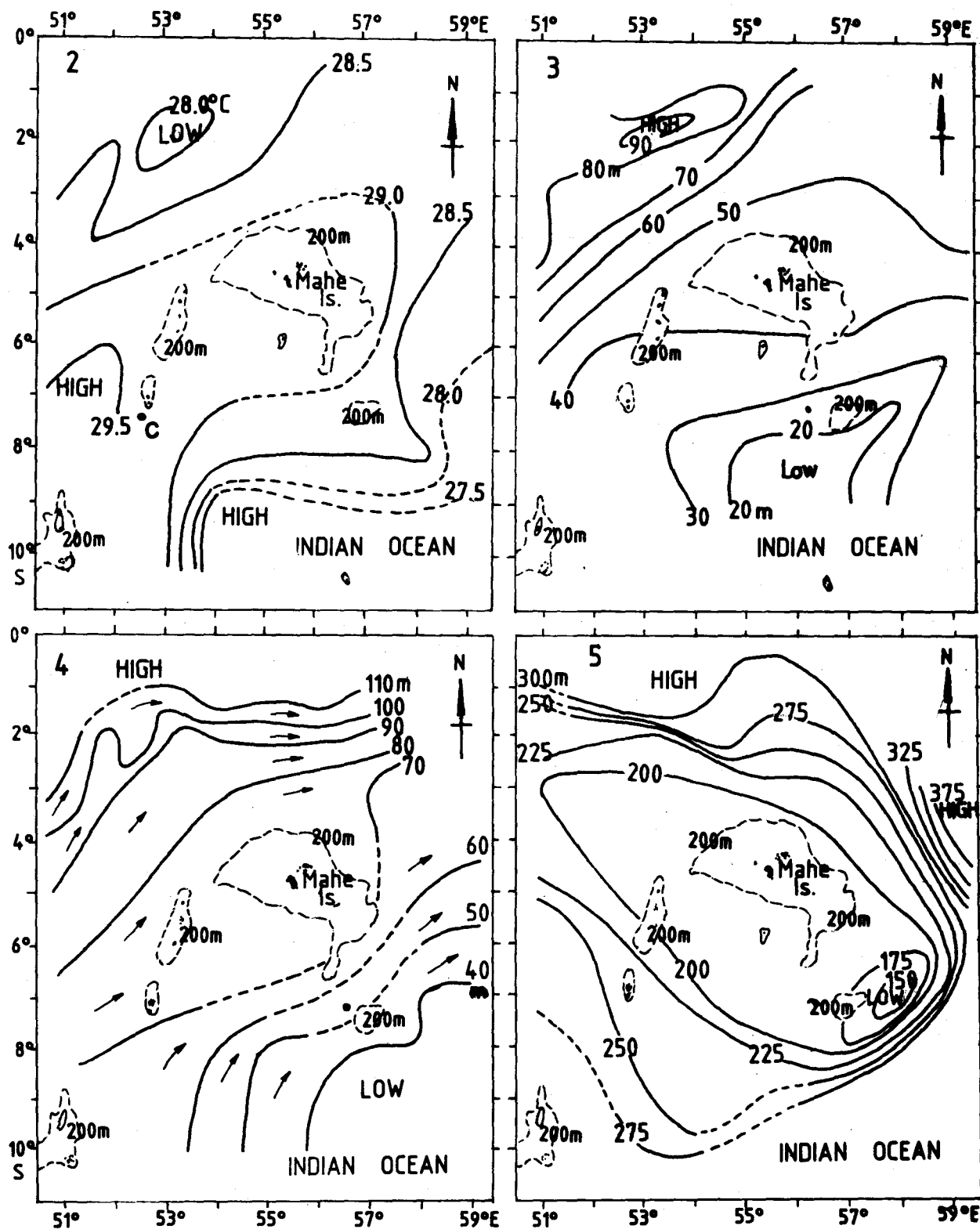


Fig. 2 – Sea surface temperature (°C). Fig. 3 – Mixed layer thickness (m). Fig. 4 – Depth of 20°C isotherm (m). Fig. 5 – Lower boundary depth of the thermocline (m)

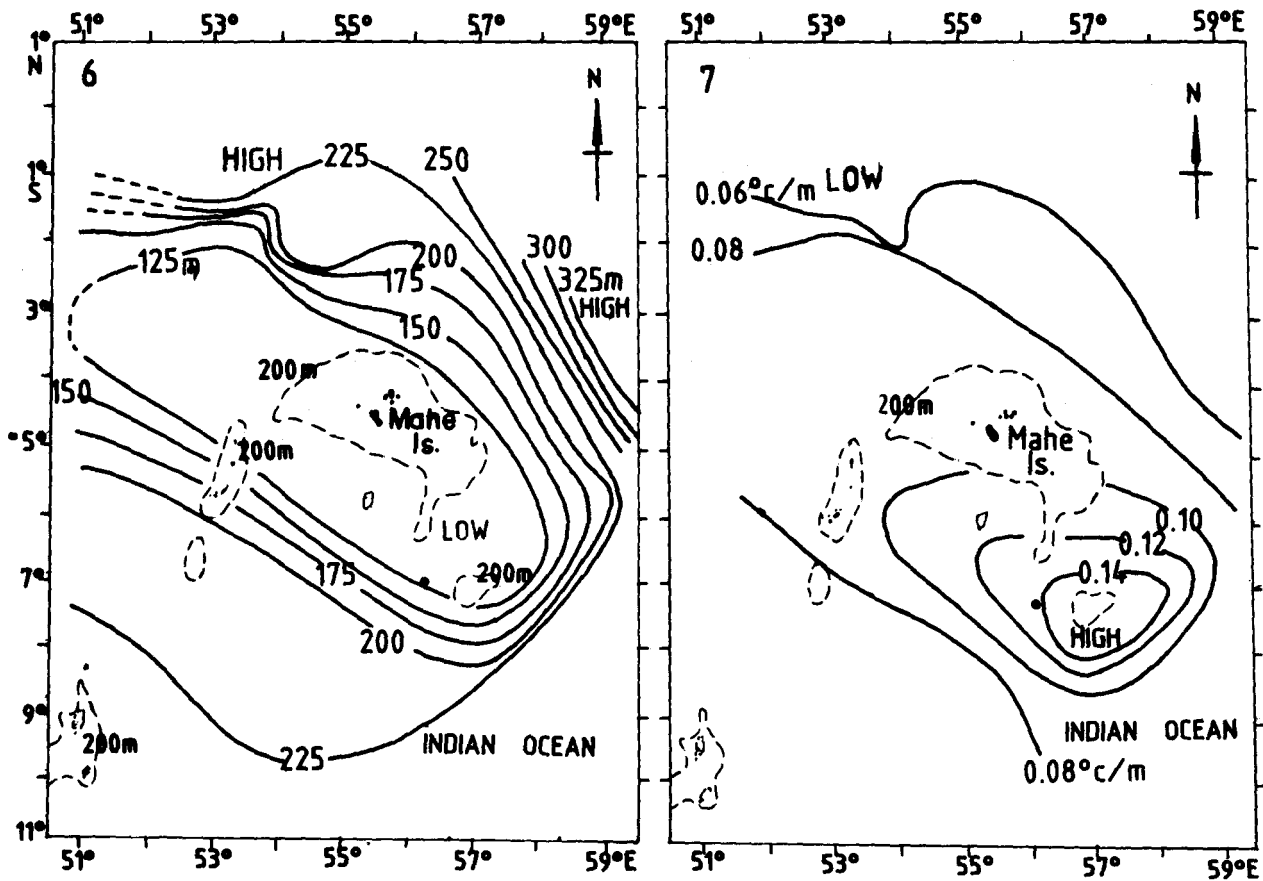


Fig. 6 – Thickness of the thermocline (m). Fig. 7 – Thermocline gradient ($^{\circ}\text{C}/\text{m}$)

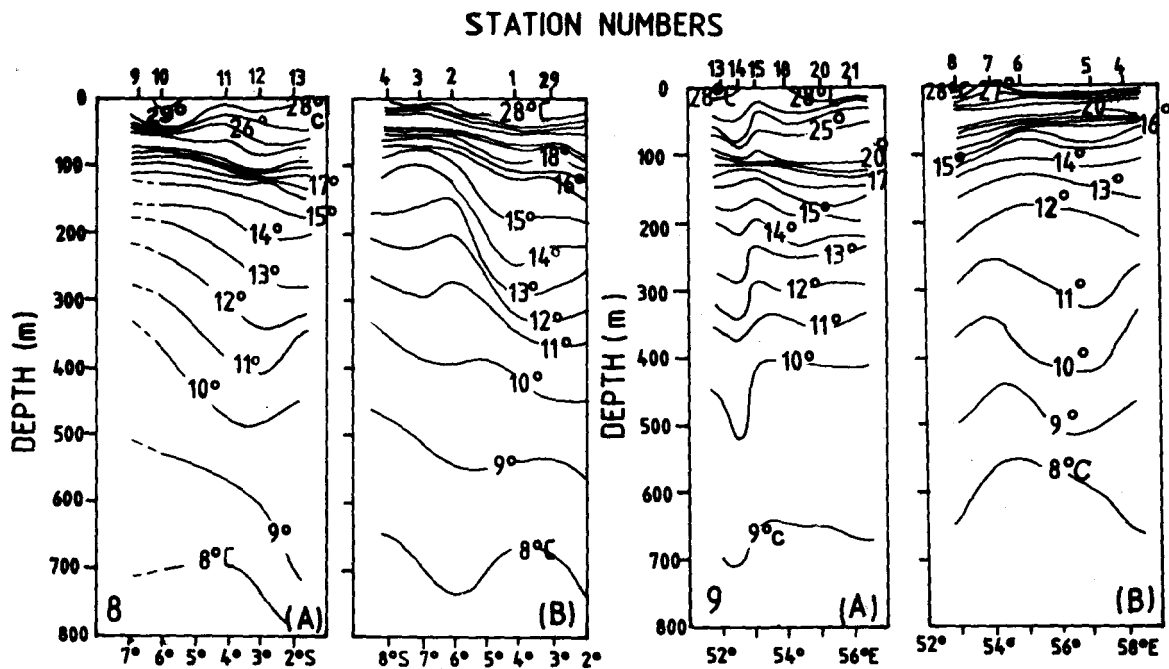


Fig. 8 – Vertical distribution of temperature ($^{\circ}\text{C}$) in the west (A) and east (B). Fig. 9 – Vertical distribution of temperature ($^{\circ}\text{C}$) in the north (A) and south (B)

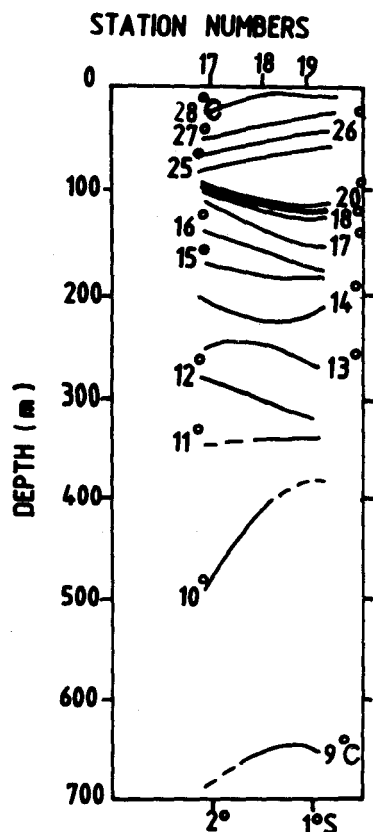


Fig. 10 – Vertical distribution of temperature (°C) along 54°E

part of equatorial undercurrent which normally flows along the equator³. Further, the presence of equatorial undercurrent is evident from the spreading of thermocline around 100 m depth along sts 17-19 (Fig. 10) towards equator. The strong vertical shear due to undercurrent gives rise to intensive mixing which in turn reduces thermocline gradients in the north. The equatorial undercurrent, a transient nature in the Indian Ocean, develops in response to the eastward pressure gradient force which is set up due to convergence of waters in the western boundary of the Indian Ocean. The accumulated water finds its way back in the depth range of 75-100 m. The earlier studies⁶⁻¹⁰ show a relationship between

seasonal wind stress and equatorial undercurrent and indicates that the latter disappears with the onset of summer monsoon over the northern Indian Ocean. In the south, a clockwise flow is developed as a result of horizontal shear between opposing zonal flows of equatorial countercurrent and south equatorial current. The very low values in the mixed layer as well as in the depth of 20°C isotherm are due to divergence in this clockwise flow. Düing¹¹ has also indicated the presence of a zone of surface divergence in the southwestern part of the present study area and its shift towards east with time from austral autumn to winter. The presence of divergence area, seen in the southern or southeastern part of the present study area, suggests an early shifting of this zone in 1984.

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