

HYDROGRAPHY OF THE NORTHERN BAY OF BENGAL DURING SOUTHWEST MONSOON

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ABSTRACT

Hydrography of the Bay of Bengal to the north of 19°N during southwest monsoon is discussed on the basis of temperature, salinity, oxygen and density distribution. The thermohaline features are analysed to understand the regional dynamics of the surface layer. The coastal upwelling was suppressed to the subsurface layer in the western side under warm diluted waters at the surface. The water column in the eastern side is mixed due to thermal convection. The hydrographic features show a strong narrow southerly current in the western side and a broad northerly flow in the eastern side of the area.

Key-words: Hydrography, temperature, salinity, dissolved oxygen, Bay of Bengal.

INTRODUCTION

Though a number of reports on hydrography of the Bay of Bengal are currently available, information pertaining to the area north of 19°N is meagre. Earlier, Ramasastry and Balaramamurty (1957) and Balaramamurty and Ramasastry (1957) reported on the circulation pattern of the surface layer of the western Bay of Bengal during premonsoon months based on temperature and density distribution. Rao and Sastry (1981) dealt with the hydrography and circulation pattern in the Bay of Bengal during late winter. Sastry, Rao, Murty, Sarma, Suryanarayana and Babu (1985) presented the watermass structure and hydrographic conditions of the Bay of Bengal along 88°E. Gopalakrishna and Sastry (1985) dealt with hydrography along the east coast of India during southwest monsoon. This paper presents some of the hydrographic conditions of the northern Bay of Bengal during southwest monsoon.

MATERIAL AND METHODS

Hydrographic data collected on board RV *Gaveshani* during 7th cruise from 26 August to 2 September, 1976 along 20°30'N and 19°N in the northern Bay of Bengal are utilised for the present study. Vertical and horizontal distribution of temperature, salinity, oxygen and density (σ_t) are presented and discussed.

RESULTS AND DISCUSSION

Temperature: The sea surface temperature (SST) was maximum (29.7°C) at 20°32'N, 88°54'E. SST values decreased from the northwestern corner to a minimum of 28.1°C at 19°N, 88°E (Fig.1a). At 50 m depth (Fig.1b), temperature was high (>28°C) in the eastern side of the area but low (<26°C) at 19°N, 86°E. Temperature distributions along 19°N and 20°30'N are presented

in Fig.1c and 1d. Mixed layer depth (MLD) was about 75 m in the coastal regions along 20°30'N and 40-50 m along 19°N. Temperature varied from 9 to 10°C at 500 m depth.

The stratification of water column in the northwestern sector was strong due to the presence of warm diluted water at the surface resulting from the large volume of river runoff from the Ganges during southwest monsoon. In the eastern side of the area, surface cooling developed convective mixing in the water column, which resulted in a weak stratification and enhanced MLD. The downward sloping of the isotherms and high MLD on the western side along 20°30'N (Fig.1c) indicate sinking of diluted waters along the coast. Similar depressions in the isotherms have been observed in the northwestern Bay of Bengal during southwest monsoon (La Fond, 1954, Colborn, 1975; Gopalakrishna and Sastry, 1985). In the western side of the 19°N section (Fig.1d), the upward sloping of isotherms associated with shallow MLD indicate offshore drifting of surface water. The ascending and descending features of isotherms indicate convergence and divergence of watermasses in the surface layer. Whereas, the wavy features in the thermocline indicate the presence of internal waves as reported earlier (La Fond and Rao, 1954; La Fond, 1957). The raised isotherms of the subsurface layer along 19°N (Fig.1d) associated with low temperature waters in the southwestern sector at 50 m level (Fig.1b) indicate upwelling along the coast. Upwelling along the east coast has been reported earlier during February to April (La Fond, 1954; Varadachari and Murty, 1968). Though supporting features of upwelling prevailed at the subsurface depths during southwest monsoon, their absence at the surface suggests suppression of upwelling due to large volume of freshwater discharge along the coast.

Salinity: Surface salinity was minimum (23.36×10^{-3}) in the northwestern region and maximum (32.63×10^{-3}) in the southeastern part of the area (Fig.2a). At 50 m depth (Fig.2b), horizontal gradient was strong in the northeastern part of the area. Along 20°30'N (Fig.2c), surface salinity was high (32×10^{-3}) at stn.8 and low at stns.1, 4 and 10 with values of 23.50×10^{-3} , 23.36×10^{-3} and 30.08×10^{-3} , respectively. Along 19°N (Fig.2d), low values were observed at stn.20 (27.86×10^{-3}) and stn.15 (28.89×10^{-3}) and high values at stn.17 (32.0×10^{-3}) and stn.13 (32.6×10^{-3}). Higher salinity values ($> 35 \times 10^{-3}$) were noticed below 75 m depth along 19°N (Fig.2c) and below 50 m along 20°30'N (Fig.2d). The values higher than 35.5×10^{-3} observed between 200 and 300 m depth along 19°N (Fig.2c) and below 100 m depth along 20°30'N (Fig.2d) are questionable, as no such high values are reported so far.

The halocline was stronger in the northwestern sector (Fig.2c) due to large volume of river discharge from the Ganges. The diluted waters of the southwestern region are due to the runoff from the Irrawady and the Salween rivers. Salinity distribution also indicates a strong stratification in the western side with a narrow southerly flow of diluted waters along the coast. Gopalakrishna and Sastry (1985) also observed a similar feature in consonance with the curl of wind stress. The raised isohalines in the central region show divergence of surface water and descending profiles in the subsurface layer indicate convergence of the water.

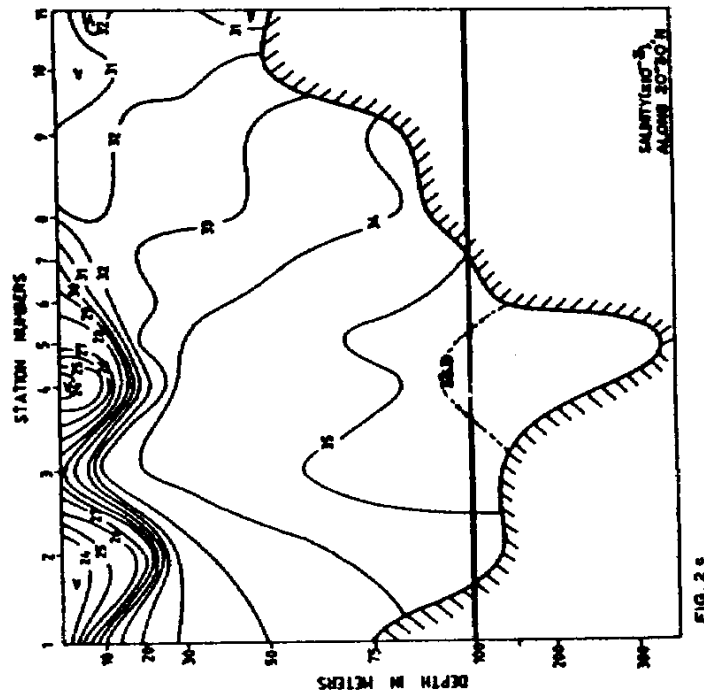
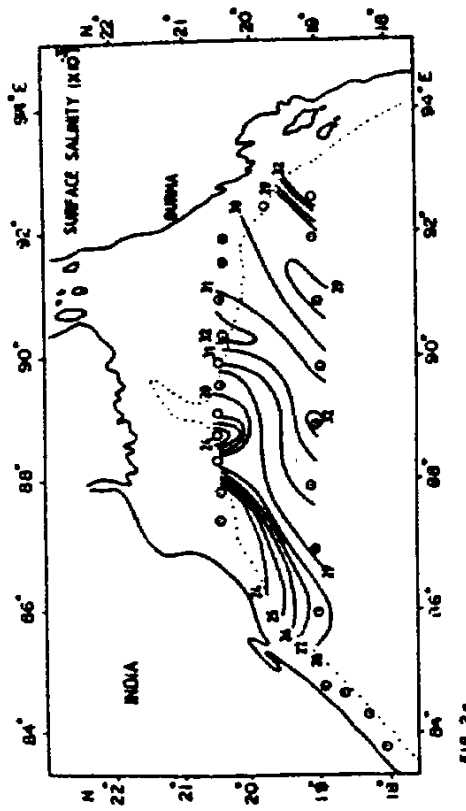
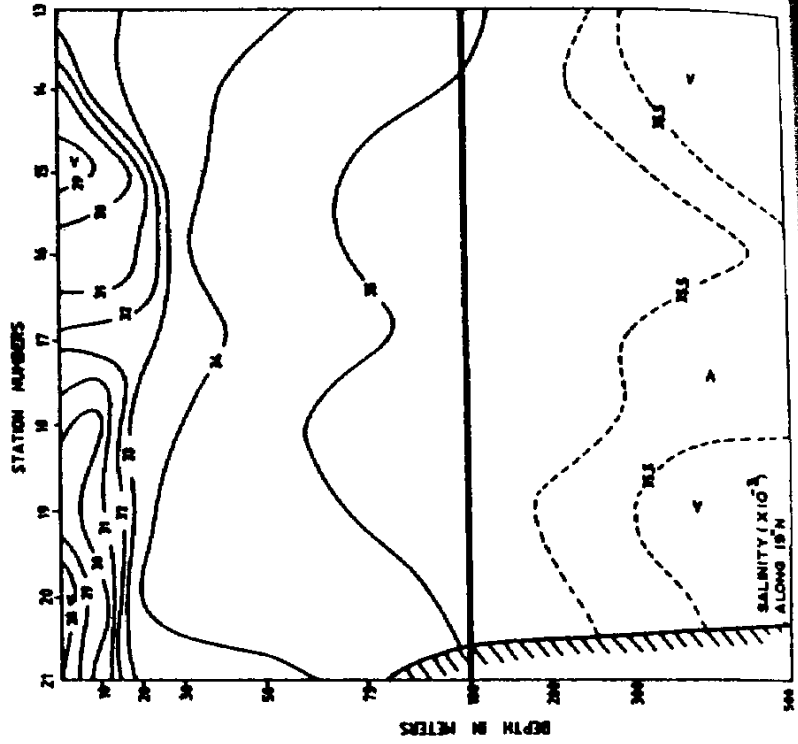
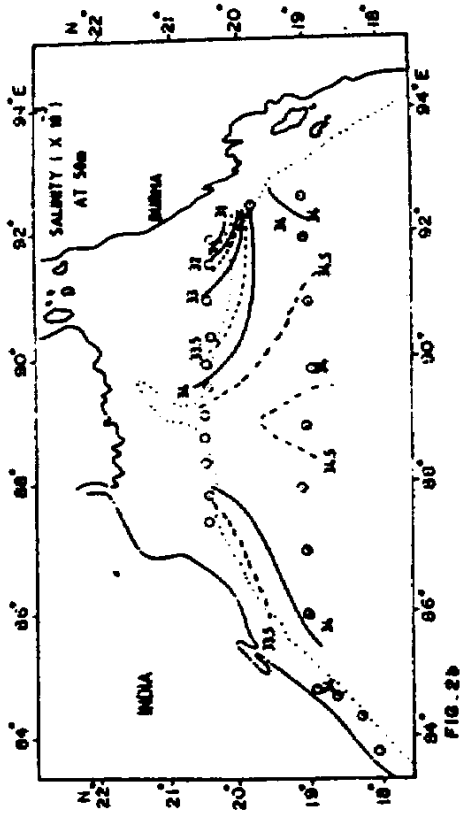


Fig.2. Distribution of salinity ($\times 10^{-3}$) at surface (a), 50 m depth (b) and vertical sections along $20^{\circ}30'N$ (c).

Dissolved Oxygen : The distribution of dissolved oxygen are similar to those of salinity field. The surface waters of coastal region are rich in oxygen due to increased dilution by river runoff. Surface values were high in the western part than those of the eastern part. Dissolved oxygen ranged from 6.01 ml/l in the surface layer of the northwestern sector to 4.4 ml/l in the eastern side (Fig.3a). At 50 m depth (Fig.3b), the values were high in the southern part of central region and low in the western part. Along 20°30'N (Fig.3c), oxygen around 0.39 ml/l was observed in the swatch of no ground. The values reduced further to 0.2 ml/l at 250 m depth along 19°N (Fig.3d). The 4 ml/l contour was located around 30 m depth in the west and around 75 m in the east along 19°N, which extended around 50m depth along 20°30'N. The upward trend of oxycline in the western side along 19°N section support the upwelling features as discussed earlier. The profiles were descending in the coastal region due to convergence of surface water. However, a depression in the subsurface profiles around str.6 along 20°30'N (Fig.3c) indicates convergence of watermasses in the central region. Comparatively low values of oxygen in the eastern side were due to convective mixing of oxygen rich surface water with oxygen depleted subsurface water. Similar observations have been reported in the Bay of Bengal (Anand, Murty, Jayaraman and Agarwal, 1967 and Naqvi, De Souza, Fondekar, Reddy, 1979).

Density : Density was low ($<14 \sigma_t$) in the northwestern sector (Fig.4a) with strong horizontal gradients in the surface layer. At 50 m depth (Fig.4b), the values were more than $21 \sigma_t$ with a low density water ($<19 \sigma_t$) in the northeastern sector. Along 20°30'N, the isopycnals sink along the coast with a dome-like feature in the central region (Fig.4c). Along 19°N, a high density water ($>20 \sigma_t$) at the centre was associated with ascending profiles around str.17 (Fig.4d). The pycnocline in the western side was stronger along 20°30'N than that of 19°N section. The trend of $22 \sigma_t$ and $23 \sigma_t$ isopycnals were similar to that of the isotherms in the subsurface layer.

Surface features of density distribution are similar to those of salinity and subsurface features resemble to those of temperature. The low values of density are associated with low salinity and high values of oxygen. The wavy profiles of surface layer are associated with convergence and divergence of surface water indicating the existence of multiple eddies. The raised isopycnals of subsurface layer with low densities in the surface along the east coast of India indicate the suppression of coastal upwelling as observed in the field of temperature and oxygen. The ascending isopycnals in the surface layer of central region along 19°N (Fig.4d) develop a cyclonic eddy, but the descending profiles in the subsurface represent an anticyclonic flow. Such features are developed due to change in climatic stresses of reversing monsoons in the area. Further, the hydrographic features during southwest monsoon are complicated due to the influence of alongshore stress of the wind opposing the stress from river discharges along the coast in the northern Bay of Bengal.

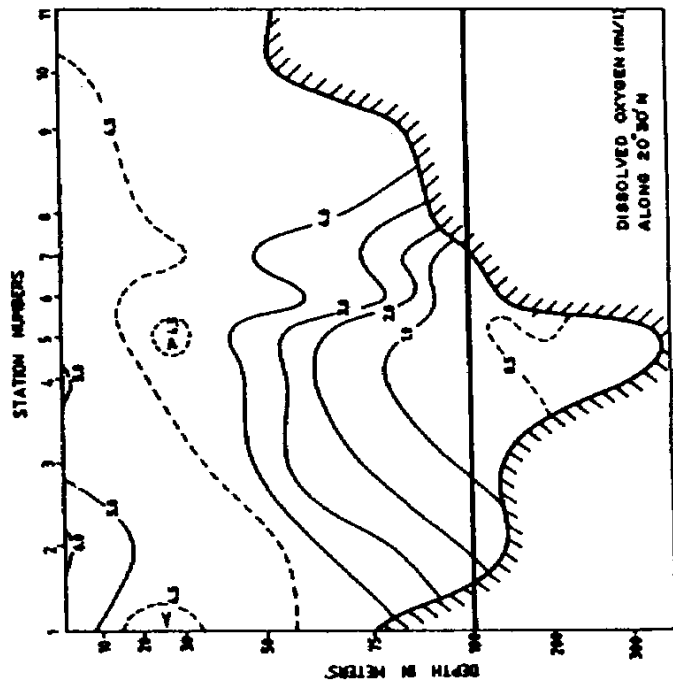
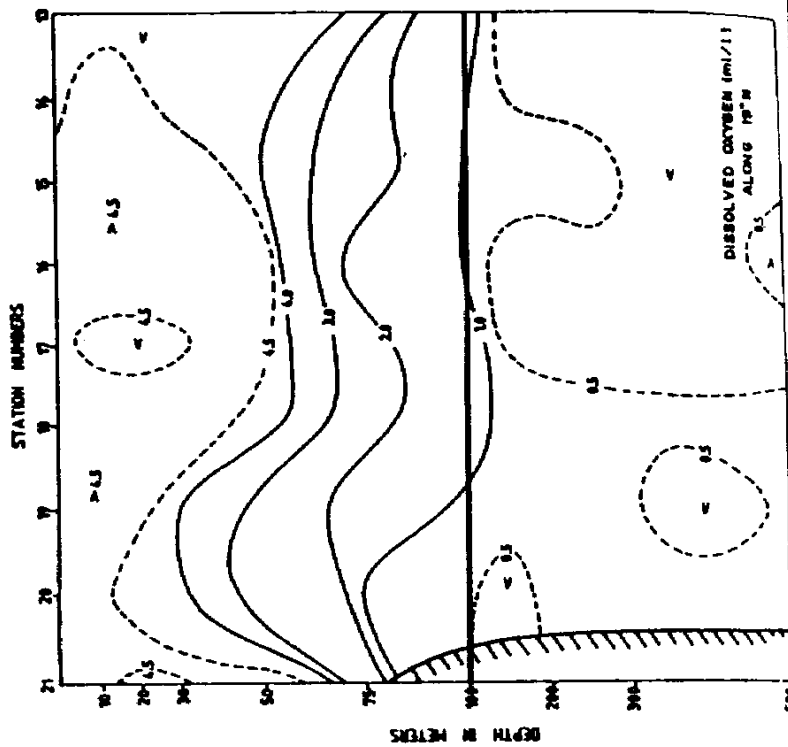
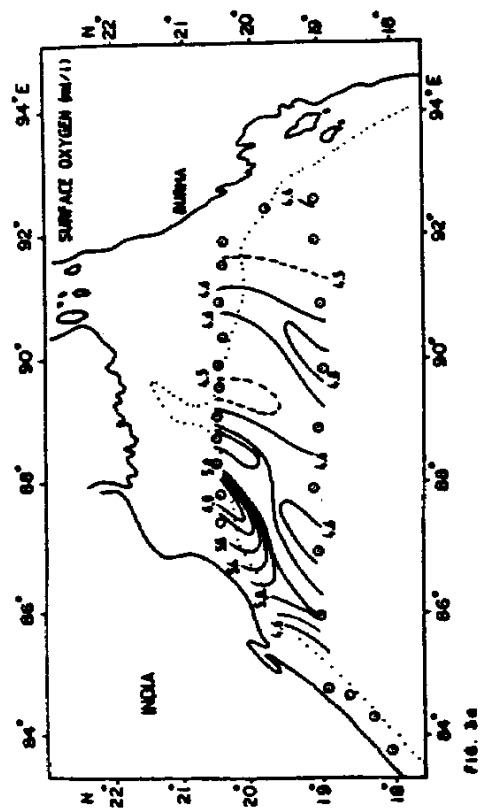
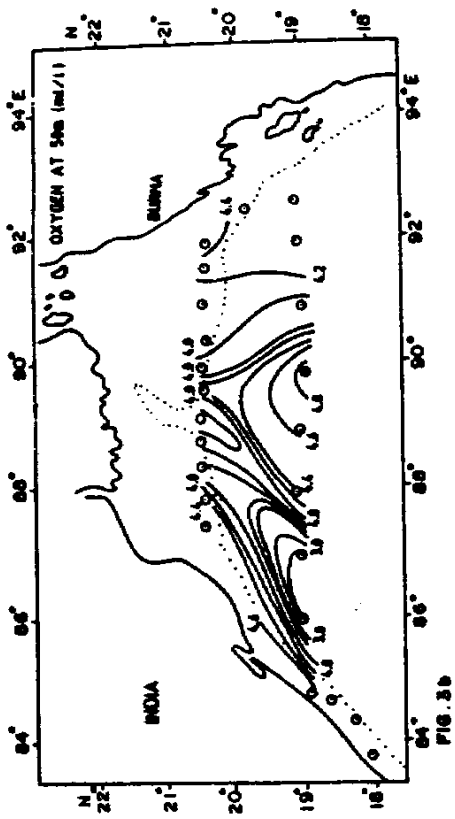


FIG. 3. Distribution of oxygen (ml/l) at surface (a), 50 m depth (b) and vertical sections along 20°30'N (c) and 19°30'N (c).

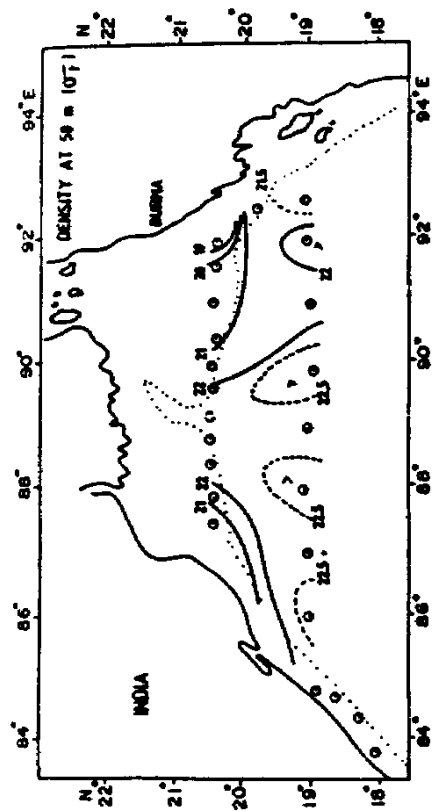


FIG. 4b

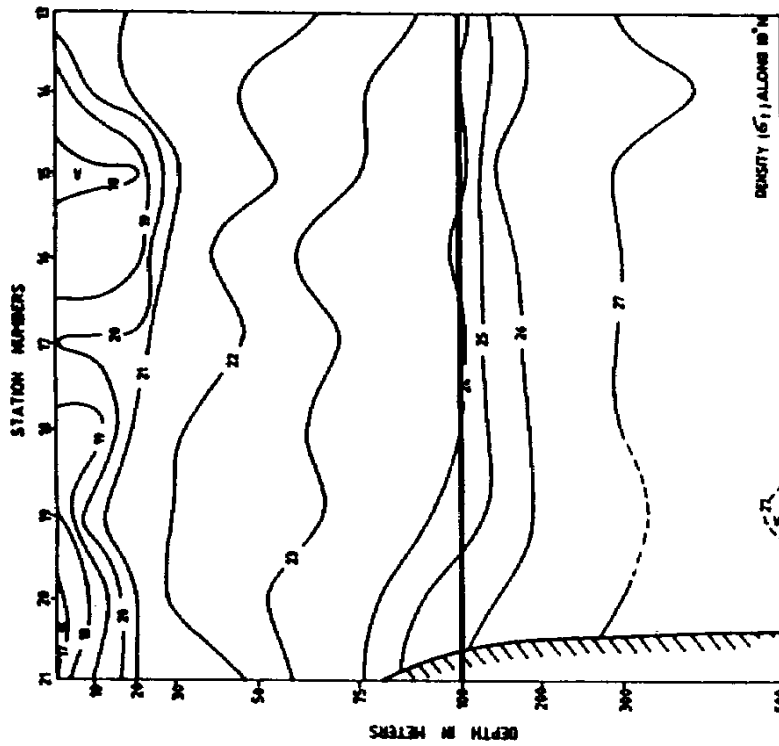


FIG. 4d

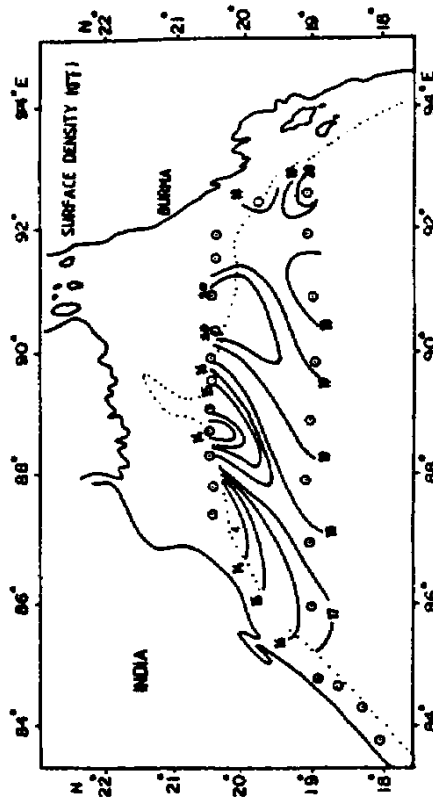


FIG. 4a

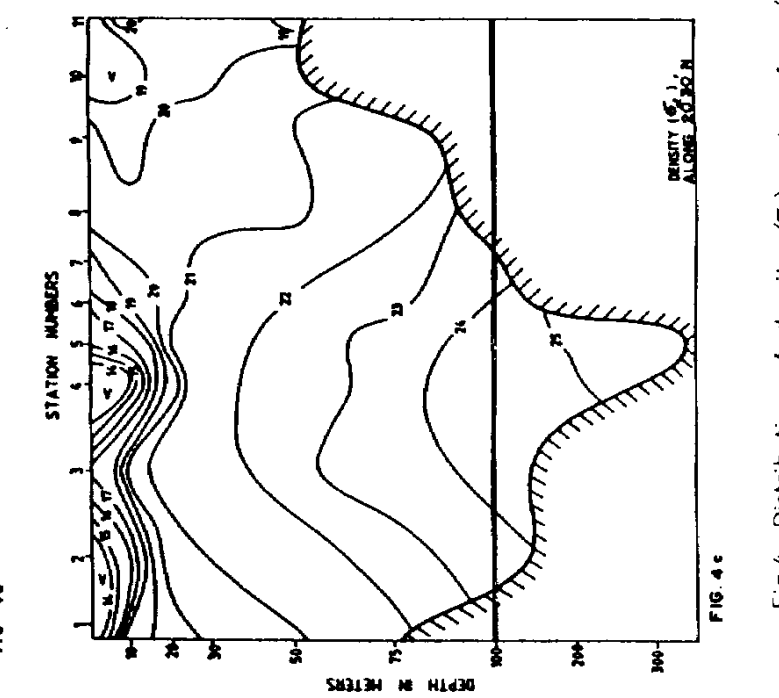


FIG. 4c

Fig.4. Distribution of density (σ_t) at surface (a), 50 m depth (b) and vertical sections along $20^{\circ}30'N$ (c) and $19^{\circ}N$ (d).

Fig.4. Distribution of density (σ_t) at surface (a), 50 m depth (b) and vertical sections along $20^{\circ}30'N$ (c) and $19^{\circ}N$ (d).

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REFERENCES

- Anand, S.P., C.B. Murty, R. Jayaraman and B.M. Agarwal, 1967. Distribution of temperature and oxygen in Arabian Sea and Bay of Bengal during the monsoon season. *Bulletin of the National Institute of Sciences, India*, **38** : 1-23.
- Balaramamurty, C. and A.A. Ramasastry, 1957. Distribution of density and the associated currents at the sea surface in the Bay of Bengal. *Indian Journal of Meteorology and Geophysics*, **8** : 88-92.
- Colborn, J.G., 1975. The thermal structure of the Indian Ocean. East-West Center Press, Honolulu, 173 pp.
- Gopalakrishna, V.V. and J.S. Sastry, 1985. Surface circulation over the shelf off the east coast of India during the southwest monsoon. *Indian Journal of Marine Sciences*, **14**: 62-65.
- La Fond, E.C., 1954. On upwelling and sinking off the east coast of India. *Andhra University Memoirs*, **1**: 117-121.
- La Fond, E.C., 1957. Oceanographic studies in the Bay of Bengal. *Proceedings of the Indian Academy of Sciences*, **XLVI(B)** : 1-46.
- La Fond, E.C. and C.B. Rao, 1954. Rotary currents of the Bay of Bengal. *Andhra University Memoirs*, **1**: 106-108.
- Murty, C.S. and V.V.R. Varadachari, 1968. Upwelling along the east coast of India. *Bulletin of the National Institute of Sciences of India*, **38**: 80-86.
- Naqvi, S.W.A., S.N. De Souza, S.P. Fondekar and C.V.G. Reddy, 1979. Distribution of dissolved oxygen during the south-west monsoon. *Mahasagar - Bulletin of the National Institute of Oceanography*, **12**: 25-34.
- Ramasastry, A.A. and C. Balaramamurty, 1957. Thermal field and the oceanic circulation along the east coast of India. *Proceedings of the Indian Academy of Sciences*, **46**: 1-47.
- Rao, D.P. and J.S. Sastry, 1981. Circulation and distribution of hydrographical properties during the late winter in the Bay of Bengal. *Mahasagar - Bulletin of the National Institute of Oceanography*, **14**: 1-15.
- Sastry, J.S., D.P. Rao, V.S.N. Murty, Y.B.V. Sarma, A. Suryanarayana and M.T. Babu, 1985. Watermass structure in the Bay of Bengal. *Mahasagar - Bulletin of the National Institute of Oceanography*, **18**: 153-162.
- Varadachari, V.V.R., C.S. Murty and C.V.G. Reddy, 1968. Salinity maxima associated with some subsurface watermasses in the upper layers of the Bay of Bengal. *Bulletin of the National Institute of Oceanography*, **38**: 338-343.