

EQUATORWARD WESTERN BOUNDARY CURRENT IN THE BAY OF BENGAL DURING NOVEMBER-DECEMBER 1983

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ABSTRACT

Geostrophic circulation derived from the observed hydrographic data for the period November-December (1983) indicates the presence of a strong equatorward western boundary current (WBC) in the Bay of Bengal. The curl_z τ based on the climatological mean wind field for the same period broadly shows a negative field in the northern part which suggests a southward current away from the western boundary with an expected Munk layer flowing northward opposing the WBC. The WBC takes a turn and flows zonally eastward at about 12°N where curl_z τ is zero. Subsequently, a cold core gyre (CCG) is formed in the central Bay when the zonal flow merges with the northward current at 9°C. It is concluded that the WBC is mainly driven by the cross-shore density gradients caused by large quantity of river run-off.

INTRODUCTION

The western boundary currents (WBC) present in the other parts of the world ocean are permanent poleward currents associated with the general circulation driven by the large scale wind system and the Coriolis force (Stommel, 1965). However in the Bay of Bengal, as the wind stress and curl_z τ reverse biannually (Hantel, 1970), the WBCs also may be highly seasonally dependent. The biannual variation of the surface currents in the Bay of Bengal can very well be inferred from the recent atlas (Cutler and Swallow, 1984) where northward flow prevails along the western boundary of the Bay during February-June and southward flow during October-December with a variable flow in between. Some earlier studies also suggested the possibility of a southward current during northeast monsoon (NEM) along the western boundary of the Bay (Varadachari and Sarma, 1967). The density gradient generated by large amount of freshwater influx also would drive an equatorward baroclinic current during NEM.

In view of the above, the curl_z τ based on the climatological mean wind field is analysed and the geostrophic circulation of the Bay in the upper 1000 m during NEM has been examined to delineate the boundary current and its circulation characteristics.

DATA AND METHODS

The zonal and meridional wind stress components (τ_x , τ_y) in the western part of the Bay of Bengal (82°30'E) are computed from wind stress (τ) based on the climatological atlas of Hastenrath and Lamb (1979) using the aerodynamic relation:

$$\tau = \rho_a C_D |V|^2$$

where ρ_a is the density of air (1.175 Kg.m^{-3}); C_D , the drag coefficient (2.63×10^{-3}) and $|V|$ the magnitude of resultant wind velocity.

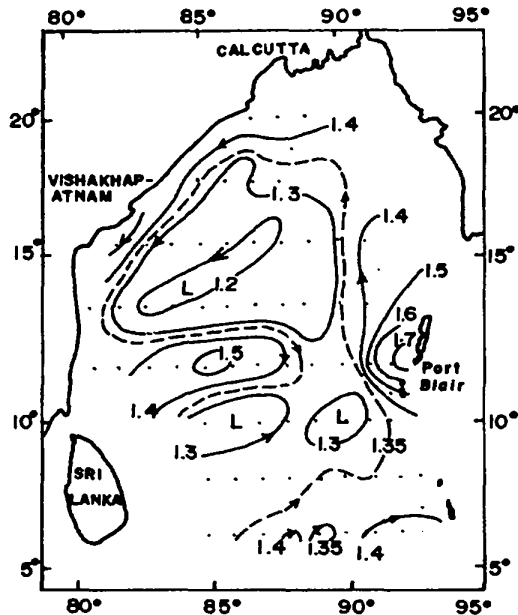


Fig. 1 Station locations and dynamic topography at 50 db with reference to 1000 db level.

The dynamic topography at 50 m, derived with reference to 1000 db level from the temperature salinity data collected using hydrocast on board RV *Gaveshani* during November-December 1983 is presented in Fig. 1.

RESULTS AND DISCUSSION

The $\text{curl}_z \tau$ has been considered as an independent forcing function acting over the ocean so that a steady state seasonal circulation could be evolved. In the tropical region the time required to reach a steady-state varies from one month (Lighthill, 1969) to two weeks (Düing, Molinari and Swallow, 1980; Leetmaa, Quadfasel and Wilson, 1982).

In the Bay of Bengal an analysis of the temporal variation of climatological wind stress components along the meridian $82^{\circ}30'E$ shows that during NEM the maximum wind stress occurs in December (Fig. 2). τ_x and τ_y show maximum of 0.8 Nm^{-2} in December centered around $12^{\circ}N$ lat. Accordingly the $\text{curl}_z \tau$ is computed for December to represent NEM period.

$$\text{Curl}_z \tau = \partial \tau_y / \partial x - \partial \tau_x / \partial y$$

In the central Bay, the zero line of $\text{curl}_z \tau$ ($\text{curl}_z \tau = 0$) separates the Bay of Bengal into two regions - a northern region with negative $\text{curl}_z \tau$ and the southern region with positive $\text{curl}_z \tau$ (Fig. 3). The magnitude of $\text{curl}_z \tau$ is considerably large in the northern parts ($4.26 \times 10^{-7} \text{Nm}^{-3}$) and it increases towards the coast. From the $\text{curl}_z \tau$ distribution, the transport near the western boundary driven by the negative curl is expected to be northward. In view of this the geostrophic circulation derived from observed temperature-salinity is analysed.

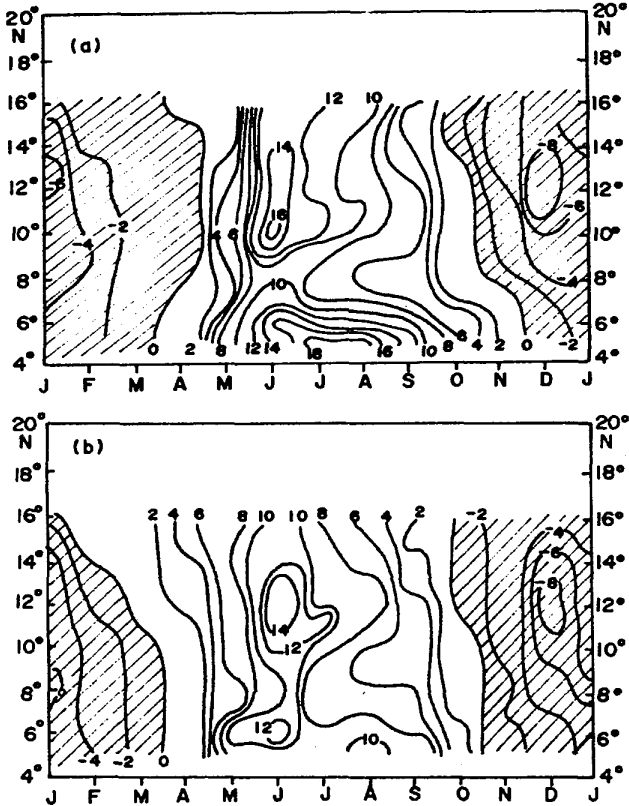


Fig. 2 Temporal variability of wind-stress components along 82°30' E, (a) τ_x (10^2Nm^{-2}) and (b) τ_y (10^2Nm^{-2})

The dynamic topography charts derived from the observed temperature-salinity fields, however, show southward current extending upto 12°N (Fig. 1). The WBC appears to originate from 19°N, flowing southward along the western boundary and turns offshore at 12°N off Madras. The shear in the isolines suggests a strong flow associated with the WBC. A typical cross-section of geostrophic velocity field along 14°N indicated that the WBC is a narrow current with velocity ranging upto

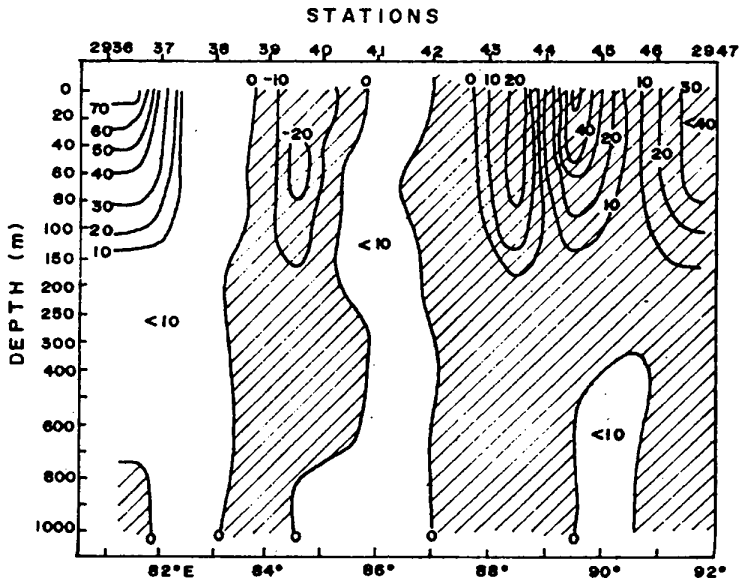


Fig. 3. $\text{Curl}_z \tau$ (10^{-7}Nm^{-3}) for December

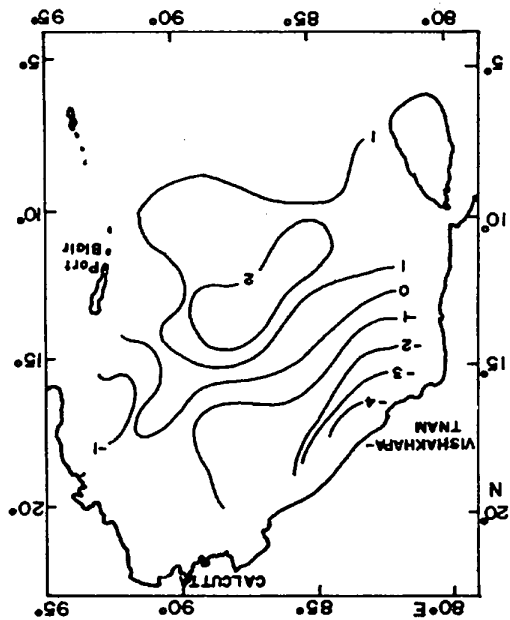


Fig. 4. Geostrophic velocity (cm.s^{-1}) across the WBC along 14°N (shaded region indicate northward flow)

70 cm.s^{-1} . The zonal flow along 12°N lat. encounters with the northward flowing current in the eastern part along 90°E, where it appears as a broad compensating current with velocity upto 50 cm.s^{-1} (Fig. 4). Thus, a large cyclonic gyre is formed in the central Bay of Bengal, north of 12N. The thermal structure across the gyre clearly shows that the WBC as well as the northward current at 90°E possess enough thermal gradients usually found to be associated with strong boundary currents (Fig. 5).

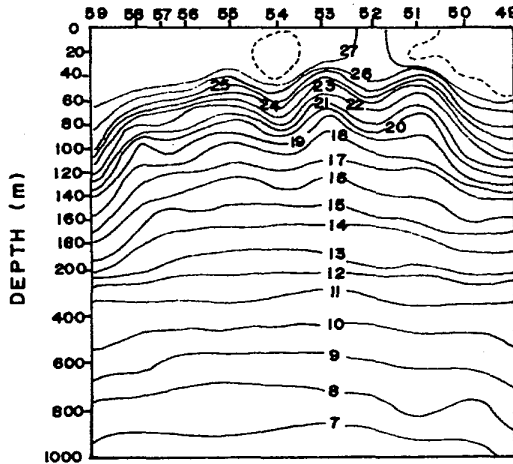


Fig. 5. Thermal structure across the WBC along 16°N

In general, the WBC observed in the Bay of Bengal during November-December is characteristically distinct in its equatorward nature compared to the WBCs observed in other parts where they are mostly driven by large scale wind system. In the Bay of Bengal the negative curl τ in the northern region should result in a northward flowing Munk layer near the western boundary. This would be opposite to the geostrophic flow present there. The circulation obtained from geostrophic method do support an equatorward baroclinic flow along the western boundary of the Bay of Bengal. It is concluded that the density gradient present in the northwestern region plays the major role in driving the WBC equatorward.

REFERENCES

- Cutler, A.N. and Swallow, J.C. (1984), Surface currents of the Indian Ocean (to 25S, 100E) compiled from Historical data archived by the Meteorological Office, Bracknell, U.K. Report No. 187. Inst. of Oceanogr. Sciences, Wormley, U.K., 8 pp. 36 charts.
- Duing, W., Molinari, R.L. and Swallow, J.C. (1980). Somali current: Evolution of surface current. *Science*, 209, pp. 588- 590.
- Hantel, M. (1970), Monthly charts of the surface wind stress curl over the Indian Ocean. *Mon. wea. rev.*, 98(10), pp. 765-773.

- Hastenrath, S. and Lamb, P.J. (1979), Climatic Atlas of the Indian Ocean: Part I. Surface climate and atmospheric circulation. The University of Wisconsin Press, Madison U.S.A.
- Lectma, A., Quadfasel, D.R. and Wilson, D. (1982), Development of the flow field during the onset of the Somali current. *J. phys. oceanogr.*, 12, pp. 1325-1342.
- Lighthill, M.J. (1969), Dynamic response of the Indian Ocean to onset of the southwest monsoon. *Phil. Trans. Royal. Soc., London, A* 265, pp. 45-92.
- Stommel, H. (1965), The Gulf stream, pp. 1-248, Univ. of California Press, Berkeley.
- Varadachari, V.V.R. and Sarma, C.S. (1967), Circulation of the surface waters in the North Indian Ocean. *J. Ind. Geophys. Union*, 4(2), pp. 61-73.