STABILITY AND MIXING IN THE NORTHERN BAY OF BENGAL DURING SOUTHWEST MONSOON

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ABSTRACT

Geostrophic flow, stability and mixing in the Bay of Bengal north of 19°N during the southwest monsoon is discussed. The flow pattern shows a narrow southerly jet in the western side and a broad northerly flow in the eastern side of the region resulting in a net mass transport to the south. Stability is stronger in the western side than that in the eastern side of the area. Mixing of the water column is explained in terms of static stability, Richardson number and density flux function.

Key-words: Watermasses, mixing, Bay of Bengal.

INTRODUCTION

Hydrography of the northern Bay of Bengal indicates a strong halocline with suppression of upwelling in the western side and convective mixing in the eastern side (Sasamal, 1989). Termohaline features also indicate a southerly flow of diluted waters in the eastern side and a broad northerly flow in the western side. The contrasting hydrographic features of surface layer to that of subsurface layer in the central region of southern section indicate reversal of flow pattern (Sasamal, 1989). Only a few reports (La Fond, 1968; Gopalakrishna and Sastry, 1985 and Sastry, Rao, Murty, Sarma, Suryanarayana and Babu, 1985) are available on the watermass and their dynamics in the western Bay. The present communication deals with dynamics and mixing of the Bay of Bengal on the north of 19°N.

DATA AND ANALYSIS

Hydrographic data along 19° and 20°30'N in the northern Bay of Bengal collected during the 7th cruise of R V Gaveshani were obtained from the Indian National Oceanographic Data Centre. For obtaining geostrophic flow, 500 m depth level has been chosen as the level of no motion for southern section along 19°N. The section along 20°30'N being shallow, 100 m depth has been considered as the level of no motion. For the stations shallower than the level of no motion, termohaline conditions of conjugate deep station has been considered for geostrophic computation. Static stability and Richardson number were computed to analyse the stratification of water column and mixing processes in the northern Bay.
RESULTS AND DISCUSSION

Fig. 1 representing watermass properties along 19°N shows variation in temperature from 23 to 29°C and salinity < 35.2x10^-3 in the upper 50 m layer. Salinity is low (< 34x 10^-3) in the surface layer (>400 cl/t) due to large volume of freshwater runoff from the northern rivers, the Ganges and the Mahanadi. Temperature varies from 11 to 23°C and salinity from 35.2 to 35.7x10^-3 within 400 to 150 cl/t (around 50 to 100 m depth), where the surface diluted water mixes with subsurface high salinity water. Beyond 150 cl/t, temperature values < 11°C and salinity between 35.0 and 35.6x10^-3 are noticed. Similar watermasses have been reported earlier in the western part of the central Bay of Bengal during the southwest monsoon (Poornachandra Rao, 1956; Balaramamurty and Ramasastry, 1957 and La Fond 1968).

Geostrophic Flow: Fig. 2 shows the flow field derived from dynamic topography (D in dyn.cm). Dynamic height at the surface (Fig.2a) shows comparatively high values of 80.4 dyn.cm and 78.3 dyn.cm in the northeast and northwest corner than
that of the central region. Distribution of dynamic height values indicate a broad northerly flow in the east and a narrow southerly jet to the west with eddy-like features in the central region. Surface features of dynamic height show an anticyclonic flow around 20°30′N, 88°54′E and 18°52′N, 89°57′E and a cyclonic flow around 19°0N, 87°E and 19°09′N, 91°56′E. At 50m level (Fig. 2b), the dynamic height values are comparatively lower around 91°56′E and 86°E and high at 89°E along 19°N. This supports the observations in the thermohaline field reported earlier (Sasamal, 1989).

Fig. 2a). Dynamic heights (dy. cm) at 0/100 db and (b) 50/100db.
Fig. 3. (a) Relative velocity (cm/s) along 20°E; (b) along 19°E.
Fig. 3 shows the distribution of relative velocity. Along 20°30'N (Fig. 3a), the surface flow in general is southerly with maximum velocity of 66.2 cm/s in the western side. The flow is towards north in the eastern side with a maximum velocity of 31.2 cm/s between 20 and 50 m depth. A shallow northward flow with a maximum velocity of 46.2 cm/s sandwiched within southerly flows is observed between 88° and 88°54'E of the northern section. Along 19°N (Fig. 3b), alternate bands of northward and southward flows are observed with maximum velocity of 53.4 cm/s between 20 and 30 m depth between 87° and 86°E and a northward flow of 15.7 cm/s at 150 m between 92°43' and 91°56'E. This indicates the presence of a number of eddies of varying strength and size at different levels of water column. Earlier, Rao, Antony, Murty and Reddy (1987) reported the presence of a cyclonic eddy in the northwestern Bay. The flow is mostly of estuarine type in the western side with a southerly flow of low salinity surface water and a northerly flow of sea water in the subsurface level. This agrees well with hydrographic observations in the northwestern Bay (Gopalakrishna and Sastry, 1985).

The mass transport along 20°30'N shows a northward transport of 3.14 x 10^6 m^3 in the eastern side and southward transport of 2.43 x 10^6 m^3 in the western side with a net transport towards north. Along 19°N, around 12.67 x 10^6 m^3 of water is transported to the south in the western part and 10.96 x 10^6 m^3 to the north between 87° and 89°E with a net transport of 9.04 x 10^6 m^3 to the south. This shows a diverging mass transport along these sections, which possibly brings up the subsurface water in the central region.

**Stability and mixing**: Fig. 4 shows distribution of static stability of the water column in the northern Bay. This indicates the effect of river runoff, wind stress, irregular bottom relief and tidal action. Dilution of surface water introduces buoyancy flux resulting in strong stratification in the water column. Thus the stability is enhanced and mass exchange is hindered across the level of stratification. The static stability (E x 10^{-5} m^{-1}) is found high in the surface layer and decreases with increasing depth. The values are high at around 15 m depth in the central region along 20°30'N (Fig. 4a) and at 35 m along the 19° section (Fig. 4b). This shows strong stratification in the surface layer, which is associated with the halocline. Relatively a weak stratification observed towards west is associated with high temperature and low salinity of the area. Low stability values in the eastern side are associated with spreading of isopleths as seen earlier in hydrography of the region (Sasamal, 1989), which is possibly developed due to surface cooling and thermal convection in the subsurface layer.

Fig. 5 shows distribution of logarithmic values of Richardson number (Ri). Ri is a non-dimensional number, which is given by the ratio of static stability of water column to its shear stress:

\[ Ri = N^2 / (dv / dz)^2, \]

where \( N^2 = -(g/p_0)(dp/dz) \) is the Brunt's Vaisala frequency. Low values of Ri
Fig. 4. (a) Static stability (E x 10^{-5} m^{-1}) along 20°30'N and (b) along 19°N.
Fig. 5. (a) Dynamic stability (in log R) along 20°30'N and (b) along 19°N.
Fig. 6. Superposition of density (broken lines) on density flux function along (a) 20°30'N and (b) 19°N.
(< 0.5) develop a dynamically unstable situation, which is observed in the surface layer and coastal region due to strong shear in momentum (Fig. 5a & 5b). This shows intense mixing in the surface layer, which decreases with increasing depth. The isopleths in the subsurface layer turn vertical with alternative bands of low and high values. This is due to relative change in geostrophic flow along the sections. Similarly, the density flux function (DFF) along with density profiles indicate the state of mixing in the water column (Fig. 6a). Intersection of density and DFF profiles indicate vertical mixing with mass exchange across the isopycnals, whereas mixing is lateral when the profiles are parallel to each other (Mamayev, 1975). Along 20° 30’N, isolated regions of cross isopycnal mixing is observed within 50 to 150 m and below 300 m depth (Fig. 6a).

In conclusion, it can be stated that the stability of the water column is higher in the western side than that in the eastern side of the area. The cross-isopycnal mixing is found dominant in the subsurface layer due to strong dynamic activity. Dynamics of the area is dominated by a cyclonic gyre with a strong and narrow southerly flow in the west and broad northward flow in the east with eddy-type flow in the central region.

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REFERENCES


