

Energy and generating mechanism of a subsurface, cold core eddy in the Bay of Bengal

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Computation of available potential energy (APE) of a recently observed cold core, subsurface eddy (centered at 17°40'N and 85°19'E) in the Bay of Bengal revealed that the energy maxima associated with the eddy was of the order of $1.31 \times 10^2 \text{ J.m}^{-3}$. The estimated Rosby radius of internal deformation compared well with the diameter of the eddy ($\approx 200 \text{ km}$). The prevailing current system during the period of observation of the eddy was a southerly flow along the northwestern boundary forced by fresh water influx and a northerly flow along the southwestern boundary generated by wind forcing. The study showed that the energy density associated with the southward advective current ($2.5 \times 10^2 \text{ J.m}^{-3}$) was more than twice of that in the northward flow ($1.0 \times 10^2 \text{ J.m}^{-3}$). The study also indicated that the eddy obtained its energy from the APE produced mainly from the southward flowing boundary current.

It is becoming increasingly evident that ocean current is, almost everywhere, dominated by mesoscale/synoptic eddies which contain more energy than any other form of motion in the ocean. Though energetically active, eddies have been intensively studied only recently. The existence of eddies has important dynamical consequences/effects on fluxes and changes across the boundary. They transport, entrain and dispose chemicals, dissolved substances, particulate matter, nutrients, heat and small organisms¹. Eddies can induce upwelling and eddy momentum flux can contribute to the long-shore pressure gradient.

A cold core, subsurface eddy centered at 17°40'N and 85°19'E in the Bay of Bengal was observed² during early August 1984. The thermal structure indicate that it was confined below the mixed layer between 50 and 300 m and had a diameter of about 200 km. A temperature drop of 4°-5°C was observed at the centre of the eddy. In view of the implications of eddies in the general circulation and related processes, an attempt was made to understand the energetics and generating mechanism of the observed eddy.

As a part of the Bay of Bengal studies, 42 closely spaced (20 to 40 km apart) CTD stations were occupied during 21-29 July 1984 on board *ORV Sagar Kanya* near the western boundary of the Bay of Bengal (Fig. 1). Out of this a section normal to the coast across the eddy was chosen

to study the energy characteristics of the eddy. In addition, CTD data of 14 stations collected during early August 1984 along latitudes 16°N and 18°N were also utilized to compute the potential energy.

In this study, the interest is on that part of the potential energy manifested by the perturbation of the density surfaces relative to horizontal level surface, which is available for conversion into kinetic energy. It is referred to as the available potential energy (APE) and is computed using the relation³,

$$APE = \int_v \frac{1}{2} \rho_r N_r^2 \zeta^2 dV$$

where N_r is Brunt-Vaisala frequency; ρ_r , density of reference state, and ζ , pressure displacement between two surfaces viz. measurement point and

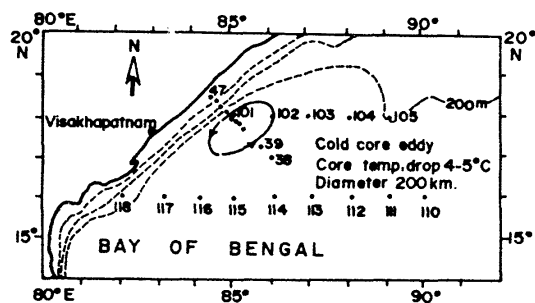


Fig. 1—Location of cold core eddy and CTD stations

reference point. In calculations, the reference sigma- θ profile computed from climatic mean data of Levitus⁴ have been used to calculate ζ . The distribution of APE density is presented only up to 500 db.

Distribution of APE density for the section normal to the coast across the eddy (Fig. 2) shows that energy maximum ($2.41 \times 10^2 \text{ J.m}^{-3}$) is confined to a region of about 125 km from the coast. At the centre of the eddy (i.e. 200 km from the coast) APE density is $1.31 \times 10^2 \text{ J.m}^{-3}$ and in the vertical plane the energy maximum is located between 50 and 300 m layer. Below 500 m, in general, APE values are $< 0.5 \times 10^2 \text{ J.m}^{-3}$.

In order to delineate the source of energy for eddy generation, APE is computed for 2 CTD sections along 16°N and 18°N (Fig. 3). There is a high energy zone in the western boundary as well as in eastern parts of the Bay (Fig. 3A). In general, though APE density along the western boundary and the eastern region are of the same magnitude, the horizontal area over which it is distributed varies. Along the western boundary, the high energy zone is spread over a distance of about 200 km from the coast whereas in the eastern parts it is over a distance of 500 km. Moving northward along 18°N , APE density shows a high energy zone with core value of $2.5 \times 10^2 \text{ J.m}^{-3}$ confined to the layer 50 to 150 m (Fig. 3B).

Having computed APE, it is essential to probe into the generating mechanisms of the eddy. In general, eddies are generated in the intense flow region as a result of large amplitude processes. In the open ocean, they could be identified as baroclinic instability of strong, horizontally sheared currents, topographic steering and direct atmospheric forcing⁵. Potential eddy generating areas are the regions of western boundary currents as well as other strong current environments including eastern boundaries and equatorial region.

As the observed eddy is well above the bottom where the average depth is 2500 m, the topographic effects are less significant. Hence the baroclinic instability of the boundary current and/or the wind forcing seem to be the predominant factors in the eddy generation. Such eddies tend to have a scale of the order of baroclinic Rossby radius (L_r) which is a natural scale in the ocean that is associated with the phenomena like boundary currents, fronts and eddies⁶. An estimation of the Rossby deformation radius [$L_r = (N/f).H$, where f is the Coriolis parameter; N , depth averaged Brunt-Vaisala frequency; and H , depth] in the ed-

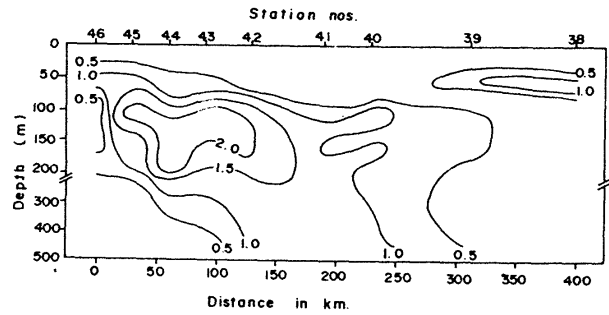


Fig. 2—APE density ($\times 10^2 \text{ J.m}^{-3}$) along the section across the eddy normal to the coast

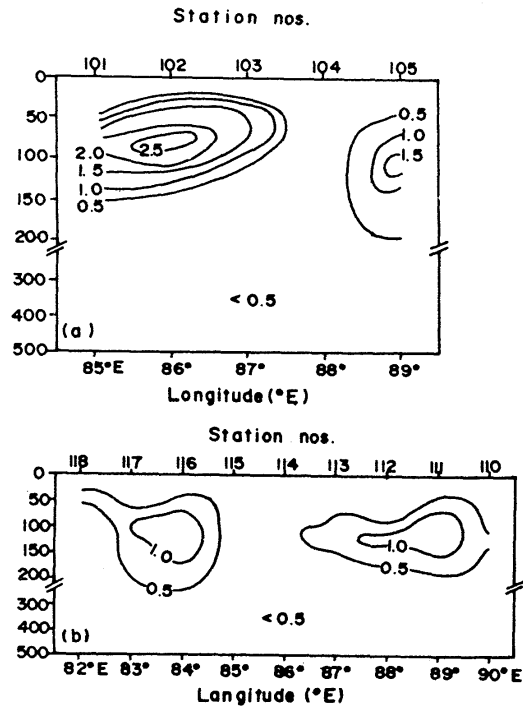


Fig. 3—APE density ($\times 10^2 \text{ J.m}^{-3}$) along (A) 18°N and (B) 16°N

dy region shows that L_r is 180 km. This is comparable with the diameter of the observed eddy.

In view of the above, the mechanism of eddy generation could be explained in the context of prevailing current system. During July-September, a seasonal boundary current flowing northward along the southwestern Bay (described earlier as monsoon drift^{7,8}) and a southward flow along the northwestern Bay form a part of the circulation in the Bay of Bengal (Fig. 4). The southward current along the shelf edge of the northern part of the western boundary is generated partly due to the cross-shore density gradient brought-in by the fresh water influx and to a large extent by the existing wind stress curl in the Bay of Bengal. Along the southern part of the western boundary,

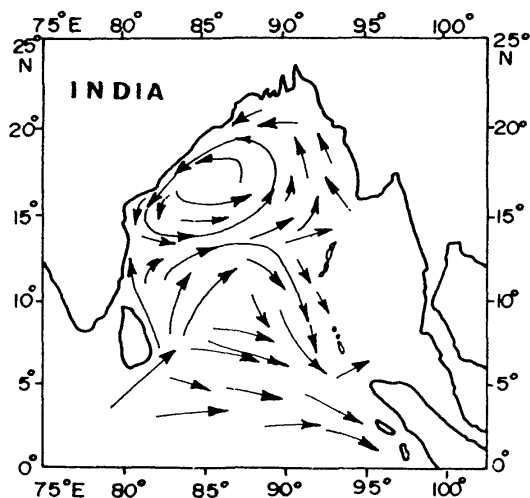


Fig. 4—Climatic mean circulation in the Bay of Bengal for southwest monsoon period (after Varkey⁸, 1986)

the northward current is caused by the predominant southwesterly wind forcing. At the interface of these opposing currents, a shear is developed where one would expect high APE. The APE associated with this shear zone is of the order of $2.5 \times 10^2 \text{ J.m}^{-3}$ which is comparable with average APE density associated with large scale currents ($4.0 \times 10^2 \text{ J.m}^{-3}$) reported elsewhere⁵. This high APE zone at the interface is congenial for the development of eddy.

It is worthwhile to note that APE density distribution showed a maximum along the western boundary. This, in conjunction with the current

system prevailing along the western boundary, indicated that the energy associated with the southward current ($2.5 \times 10^2 \text{ J.m}^{-3}$ along 18°N) is more than the APE found in the southern part along 16°N ($1.0 \times 10^2 \text{ J.m}^{-3}$) where the wind stress curl drives the northward flow. This suggests that the APE density caused by the fresh water forcing is more than twice that generated by the wind forcing. The baroclinic processes convert this energy stored in the mean flow (APE) into eddy energy. Hence it is concluded that the eddy obtained its energy from APE produced mainly from the southward flowing boundary current. ➤

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