1. INTRODUCTION

Lakshadweep Sea (Fig.1), off the southwest coast of India, exhibits strong seasonal variations in hydrography and circulation driven by seasonal reversal of winds, remote forcings and advections (Cutler and Swallow et al., 1984).

Present work addresses the formation of a cold pool (Fig.2) in the Lakshadweep Sea which we name as the Lakshadweep cold pool (LCP), during the summer monsoon period.

LCP develops due to upwelling of a poleward current under current, on an elevated bathymetry (mount) in the region. It is further intensified by wind-driven upwelling and strengthening of the poleward current. Chlorophyll-a concentration shows good correlation with the spatial spread and intensity of the cold pool. A method to enhance the existing upwelling in the region is proposed.

2. DATA SETS

3 day composite of TMI SST, 0.25° x 0.25° (1998-2005); GODAS pentad subsurface potential temperature and currents, 0.33° x 0.33° (1998-2005); SeaWiFS Chlorophyll-a concentration (Chla, 9 km x 9 km (1998-2005); ETOPO1 Bathymetry (1km); QuikSCAT winds (10m), 0.25° x 0.25° (2000-2005); AVISO merged gridded weekly sea surface height anomaly (SSH), 0.25° x 0.25° (1998-2005); Daily Netcdf (OIFlux), 1° x 1° (1998-2005).

3. EVOLUTION OF LCP

LCP forms during the fifth pentad of June as a small clouding in the grid 8.10°N/74.76°E (Fig.3a) with the southeastern trade current from the southern tip of India. Subsequently, it expands radially outward and, by July, forms a circular cloud with maximum spread and intensity (37°C). During August, it extends northward (Fig.3a) along the coast as a patch of cooler waters intensifying with positive wind stress curl. By September, the pool gets completely dissipated.

4. SOUTHWESTWARD SPREADING OF LCP

During July, LCP advances southwestward (marked by black arrow) (Fig.4a). Lakshadweep Low is present since June. South of 10°N, the surface flow is due north and it is due south north of 10°N (Fig.4b). These two currents meet near 9°N and propagate southwestward with the southwestward propagating LL droppng the LCP southwestward (marked by black arrow).

5. CHLOROPHYLL CONCENTRATION

During June, Chlorophyll-a concentration (Chla) is high along the southwest coast of India due to coastal upwelling (Fig.5a). (White patches show data void regions due to rainfall.) The formation of the LCP in July, Chla shows rapid increase (marked in Fig.5b). Its concentration and distribution exhibit good correlation with intensity and spread of SST in LCP (Fig.5c).

6. GOVERNING MECHANISMS

In order to find the mechanism of LCP, we have analyzed 4 parameters namely wind stress curl, net heat flux (Netflux), SSH, subsurface temperature profile and the bathymetry of the region in four Boxes 1-4 (Fig.6a).

24° isotherms show strong shoaling in Box 2 (where LCP forms) as adjacent regions (Fig.6b).

SST shows strong cooling in the Box 2 than the adjacent regions (Fig.6c). This suggests that some unique mechanism exist in this grid causing enhanced cooling of thermocline.

7. INFLUENCE OF SURFACE HEAT FLUX

SST tendency due to surface net heat flux is computed assuming that SST changes only due to surface heat flux. SST tendency (\(\Delta \text{SST} / \Delta t\)) is positive beyond mid-June. Hence, surface heat flux does not act as a factor responsible for the genesis and intensification of LCP (Fig.7).

8. INFLUENCE OF WIND FORCING

It has been well established that +ve wind stress curl induces upwelling/downwelling. During monsoon season, along the southwest coast of India, wind is northerly. Core of the Poleward windstress curl lies near the southern tip of India (Fig.8a, b) and extends northward along the coast from the southern tip of India towards the open ocean current is weak or negative. In order to analyze the influence of windstress curl on the formation and intensification of LCP, two locations are selected (1), at the core of LCP during its genesis (9.2°N/75°E) and (2), at the location of LCP during July (9.2°N/75°E) (Fig.8c).

9. INFLUENCE OF EDDY(II)INDUCED UPWELLING

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10. INFLUENCE OF BOTTOM TOPOGRAPHY

During the summers monsoon season, a narrow (40km wide) poleward undercurrent flows on the continental shelf along the southwest coast with its core between 010° to 200°m depth (Shetye et al., 1990) (Fig.12a). The current intensifies steadily since June and declines during late September (Fig.12b).

During all the years (1998-2005), LCP forms during the fifth pentad of June as a small circular surface cooling adjacent to the tip of the mount and gradually expands with the passage of time (Fig.13a). During July, the contours are well centered above the mountain (Fig.13b) marked by the arrow).

11. CONCLUSIONS

The following means of evidence suggest that interaction of undercurrent with the seamount accounts for the formation of LCP. (a) LCP originates as a small cloud just above the seamount and expands radially outwards. (b) A seamount in a flow can act as a barrier to upwelling through Taylor column. (c) The presence of a poleward undercurrent in the region. (d) The mount resides within the undercurrent. (e) Poleward undercurrent intensifies during the season (f) During the genesis of LCP, the core region of positive wind stress curl and LL resides away from the location. (g) The heat flux tendency is positive. (h) The contribution of lateral advection due to geostrophic and Ekman current are negligible during the genesis of LCP.

12. LCP AND MONSOON ONSET

The seasonal mean from the daily SST of LCP during June to September show alternate warming and cooling episodes during 29th June to 1st week of July (Fig.10). A similar anomaly (shown with ellipses) indicates an earlier onset in the forthcoming year and a warmer anomaly indicates a later onset of the southwest monsoon (Fig.15).

13. METHOD TO ENHANCE UPWELLING

Upwelling and biogeochemical activity connected with seamounts has been well established in many studies. The region 10°N/74°E is one of the biggest fish spawning grounds of southwest coast of India. Fig.17 shows the fish landings along the southwest coast of India. Among this, major amount of the fish catch is arriving from this region. Since all the factors are favorable for upwelling in this region, a small trigger through appropriate modification of the mouth or inserting conical structures on the wedge under the undercurrent can result in enhancement of the existing upwelling. This can provide nutrient-rich cooler waters in the surfaces layers. Consequently the spatial spread and intensity of the existing pool can be enhanced leading to increased productivity.

14. FUTURE WORK

Further studies to be carried out to quantify existing upwelling and to design modifications of the mount and dimensions of the conical structures to produce optimum upwelling volumes.

15. REFERENCES


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