WESTWARD PROPAGATION, INTENSIFICATION AND REFLECTION OF LAKSHADWEEP LOW AND ITS VARIABILITY IN PROPAGATION ALONG THE INDIAN EQUATORIAL WAVE GUDIE

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1. INTRODUCTION

Lakshadweep low (LL) is a cyclonic eddy which forms at the southern tip of India during June and propagates westward to the western coast of Arabian Sea during June to December. (Shankar and Shetye., 1997)

According to the reports the eddy propagates westward as it is from the southern tip of India. The analysis shows that the propagation does not takes places in a single stretch but took diversions in its track (Fig.1). Multiple eddy forms along 4-5°N as well as intensifies till to its annihilation at the southern Arabian Sea. The mechanisms for the intensification and diversions are addressed

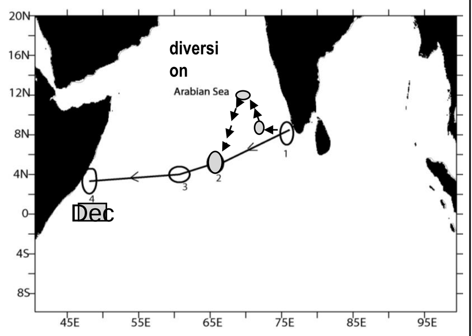


Fig.1 Schematic showing the westward propagation of LL (thick line); arrows shows the west ward shift, northward propagation and southwest-ward propagation.

The surface portion of the eddy dies out at the southern Arabian Sea but the subsurface portion of the eddy continues its propagation till to the western margin of the Arabian Sea and reflects back into the Indian Equatorial wave guide and propagates along the Indian equatorial wave guide as an equatorial upwelling upwelling Kelvin wave. Propagation speed shows variability with the potential density gradient.

2. DATA USED

1. The AVISO merged weekly SSH (Sea surface height) anomalies for the period 1996-2005 are utilized to map the LL. Geostrophic currents computed from the SSH, following Fu and Chelton (2001) are utilized to characterize the geostrophic surface circulation associated with the LL.

2. 5-day Mean Oscar current (1° x1°) (Ocean surface current analyses-Real time)(1996-2005) are used to map the surface currents in the southern Ocean. [http://www.oscar.noaa.gov/index.html].

3. NCEP GODAS (Global ocean data assimilation system) Subsurface potential temperature for the period 1996-2005. GODAS provides a resolution of 0.33° x 0.33° within 10° of the equator in the N-S direction. 1°x1° Vertical 40 levels, 10m resolution. in top 200m. GODAS assimilates temperature profiles from Triangle Trans-Ocean Buoy Network (TRITON and Pilot Research Moored Array in the Tropical Atlantic (PIRATA) moorings; and from Argo profiling floats [http://cfs.ncep.noaa.gov/cfs/godas].

3. WESTWARD SHIFT OF LL DURING THE MONSOON SEASON

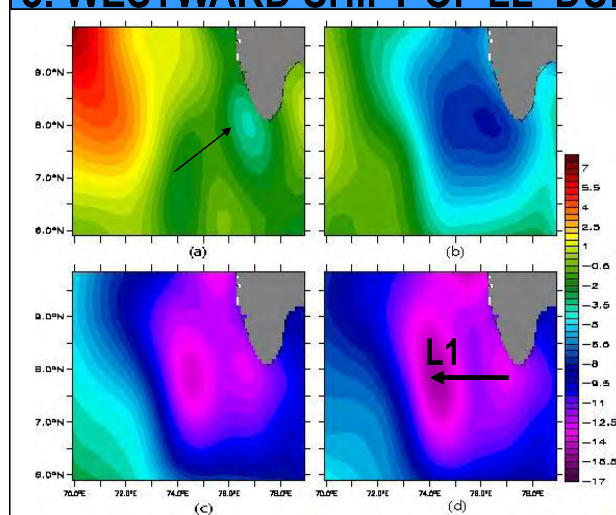


Fig.2 (a)-(d) Multiyear average(1996-2005) of SSH (cm). shows the location of LL during Jun-August.

(a). LL is located at 8°N/77°E during the end of May (Fig. 2a, shown with the arrow).

(b). Since June (Fig. 2b) LL expands spatially as well as intensifies (SSH~(-10.5cm on average)) and shows a westward shift.

(c). During July to August it is transferred to the location 8°N/74°E (marked with L1), (Fig. 2d), and forms as a circular low confined within the region 7-8°N74°E-75°E.

4. NORTHWARD PROPAGATION OF LL

1.During September LL propagates northward with an inclination due west along ~75°E up to 10°N from the location L1 (Fig.2, Fig.3)

2. Forms into a low in SSH at 10°N (L2, marked with circle) and intensifies with the progress of time(Fig.3). SSH decreases and subsurface temperature profiles shows an uplift (Fig.4& 5)

3. During the period LL gradually propagates southwest-ward. The southwest ward propagation accounts for the equator ward WICC in the region during the period.

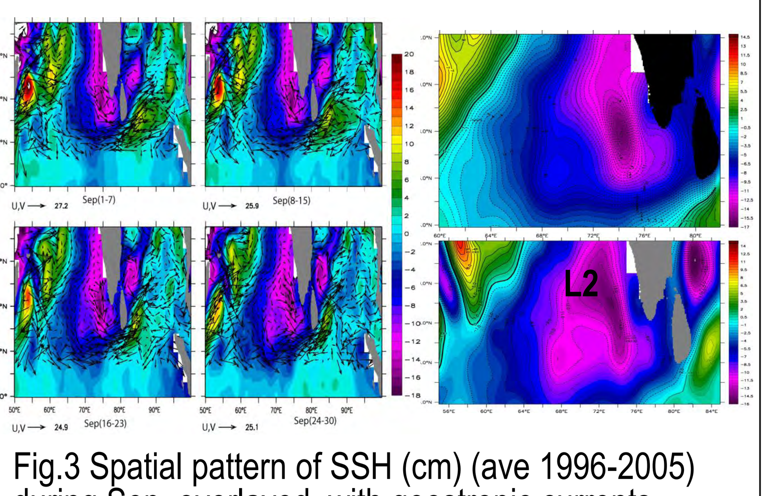


Fig.3 Spatial pattern of SSH (cm) (ave 1996-2005) during Sep, overlayed with geostropic currents.

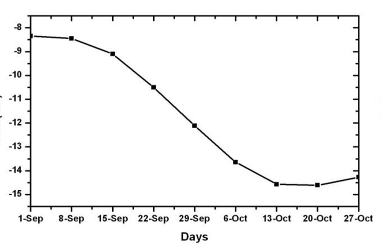


Fig.4 vertical temperature profiles for the grid 9-10°N/68°E-72°E

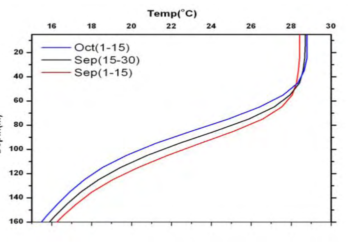


Fig.5 vertical temperature profiles for the grid 9-10°N/68°E-72°E

5. SOUTHWEST-WARD PROPAGATION OF LL

1.Southwest ward propagation continues till to November and forms into a circular low at the location 5-6°N/ 74°E-75°E (Fig.6 shown with circle)
2. This intensification is reflected in SSH and subsurface temperature profiles(Fig.8). This low intensifies with the southwest ward propagation from 10°N

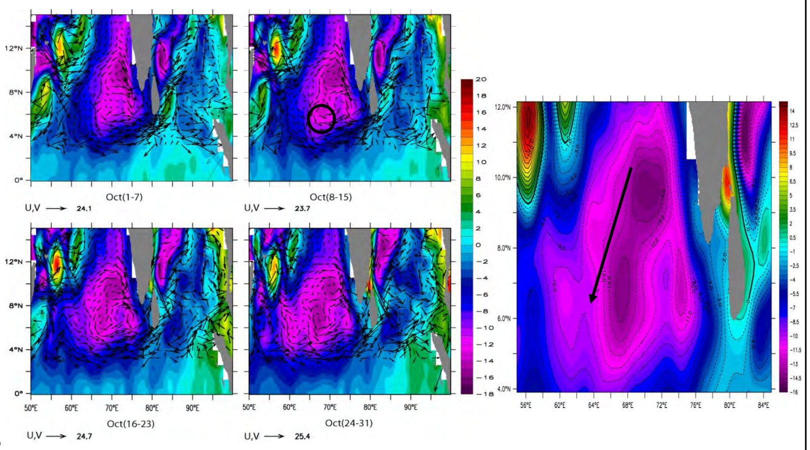


Fig.6 Spatial pattern of SSH (cm) (ave 1996-2005) during Oct, overlayed with geostropic currents.

3. The southwestward propagation intensifies during October and continues till to the first week of November when whole of the eddy formed at the location 'L2' gets completely shifted to the location 5°N/70°E

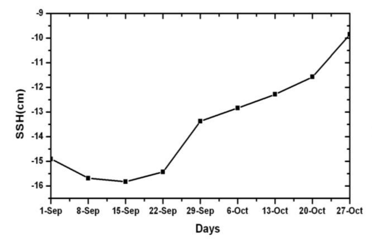


Fig.7 Spatial pattern of SSH (ave 1998-2005) during Sep, overlayed with geostropic currents.

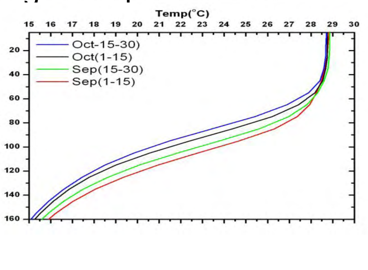


Fig.8 vertical temperature profiles for the grid 5-6°N/74°E-75°E

6. WESTWARD PROPAGATION

1. From the location (5°N/70°E) LL propagates westward along 4-5°N, simultaneously intensifying on its way. Multiple eddy forms along the track 4-5°N during this period

2 SSH (cm) increases from September to December till it get dies out (Fig.9)

3.The subsurface Potential temperature structure shows a continues uplift of thrmocline showing the downward intensification of LL (Fig.11)

4. The surface eddy weakens and die out at 5°N/50°E during the end of December (Fig.12)

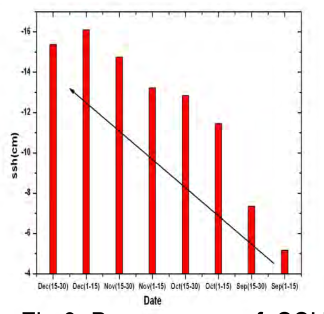


Fig.9 Box average of SSH (cm) on a 1°x1° grid within LL along 4-5°N during the westward propagation of LL

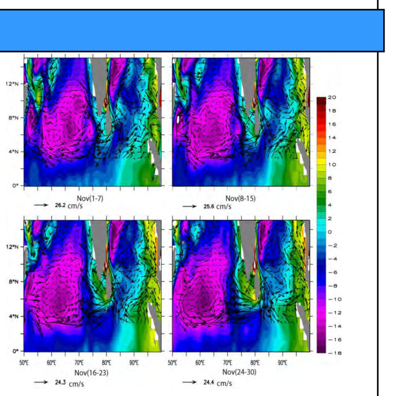


Fig.10

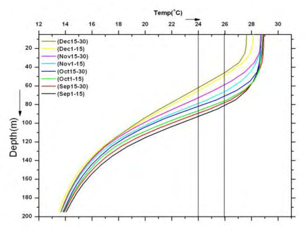


Fig.11 Box average of potential profiles on a 1°x1° grid within LL along 4-5°N during the westward propagation of LL

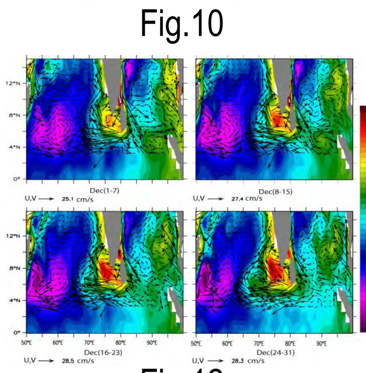
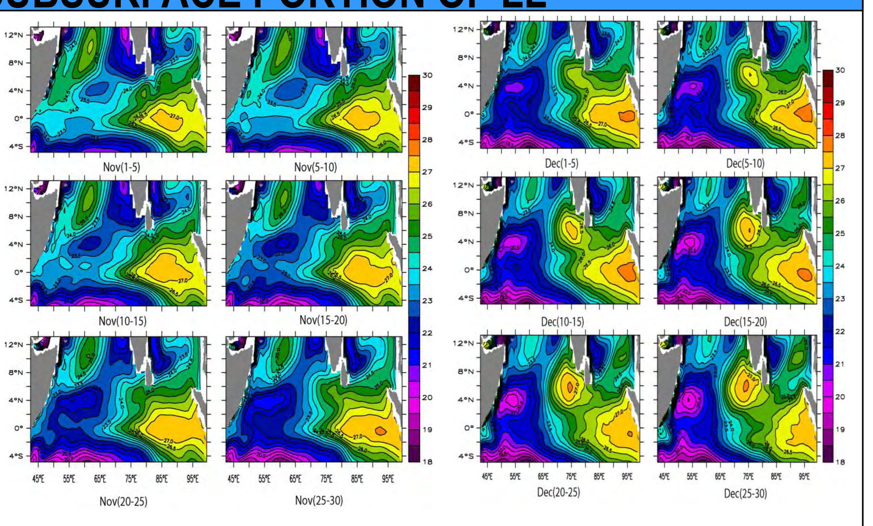


Fig.12

Fig.10&12 Spatial pattern of SSH (cm) (ave 1996-2005) during Nov and Dec overlayed with geostropic currents.

7. PROPAGATION OF THE SUBSURFACE PORTION OF LL

1. The sub surface portion of the LL also shows a similar propagation as the surface during June to Dec. The surface portion dies out at the location during late Dec. But the subsurface portion continues its propagation till to the western margin (Fig.13 a,b)



(a) (b)

Fig.13 subsurface potential temperature (°C) (climatology (1996-2005)) at 85m depth during (a), Nov; (b), Dec

8. MECHANISM FOR THE INTENSIFICATION OF LL

Associated with the inter-monsoonal westerlies a strong and narrow surface current (Wyrkti jet) develops in the central Indian Ocean during Oct-Dec and flows eastward, symmetric about the equator (Wyrtki, 1973). (Fig.14, core of the jet marked with boxes)

The southwest ward advection of SSH anomaly while reaching the zone (4-6°N) makes this region most conducive for the formation of cyclonic eddies during the period

The cyclonic shear (Fig.15) created due to the poleward variation in zonal velocity intensifies the LL. The core of the Jet shift westwards. Cyclonic shear also Shifts westward till to Dec (Fig.16). Correlation between the cyclonic shear and SSH anomaly increases from Sep-Dec (Fig.17).

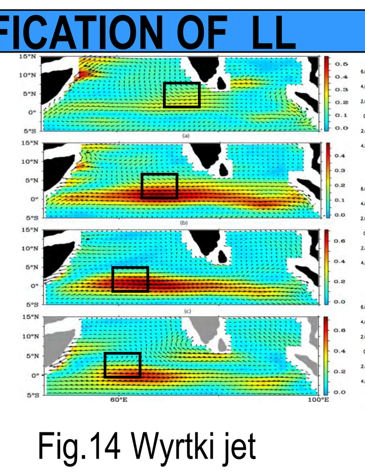


Fig.14 Wyrkti jet during Sep-Dec

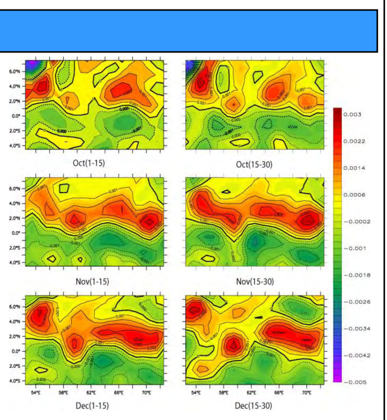


Fig.15 current shear computed from Oscar currents

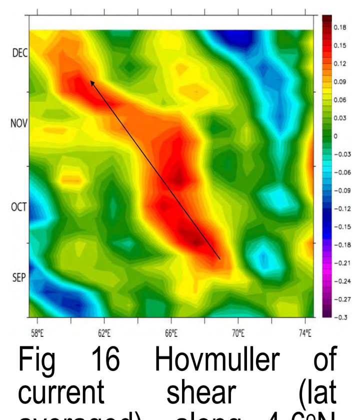


Fig 16 Hovmuller of current shear (lat averaged), along 4-6°N from September to December

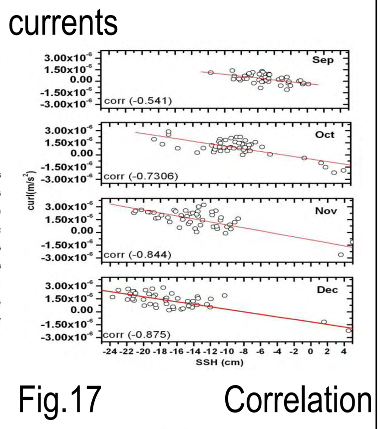


Fig.17 Correlation between SSH (cm) and shear(s^{-1}) along 4-6°N

9. REFLECTION OF LL FROM THE WESTERN ARABIAN SEA

Subsurface portion of LL after reaching the western coast of Arabian Sea reflects back into the Indian equatorial wave guide and propagates as an upwelling Kelvin wave during Jan-April (Fig.18). From the eastern margin it bifurcates and propagates northward along the periphery of Bay of Bengal as coastally trapped Kelvin wave and reaches the Lakshadweep Sea during early June. The reflection from the western margin shows 45° to the normal

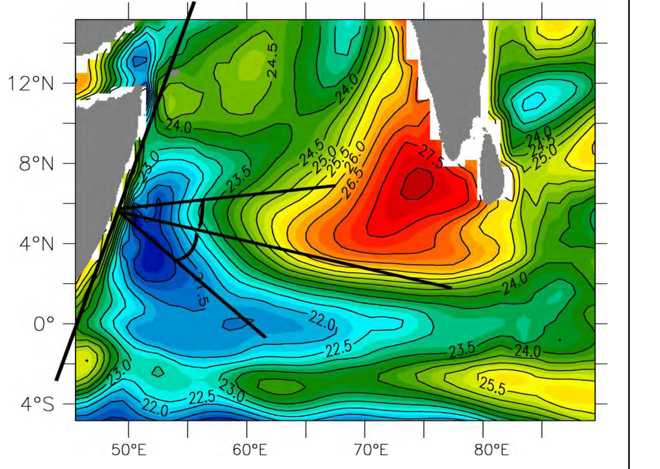
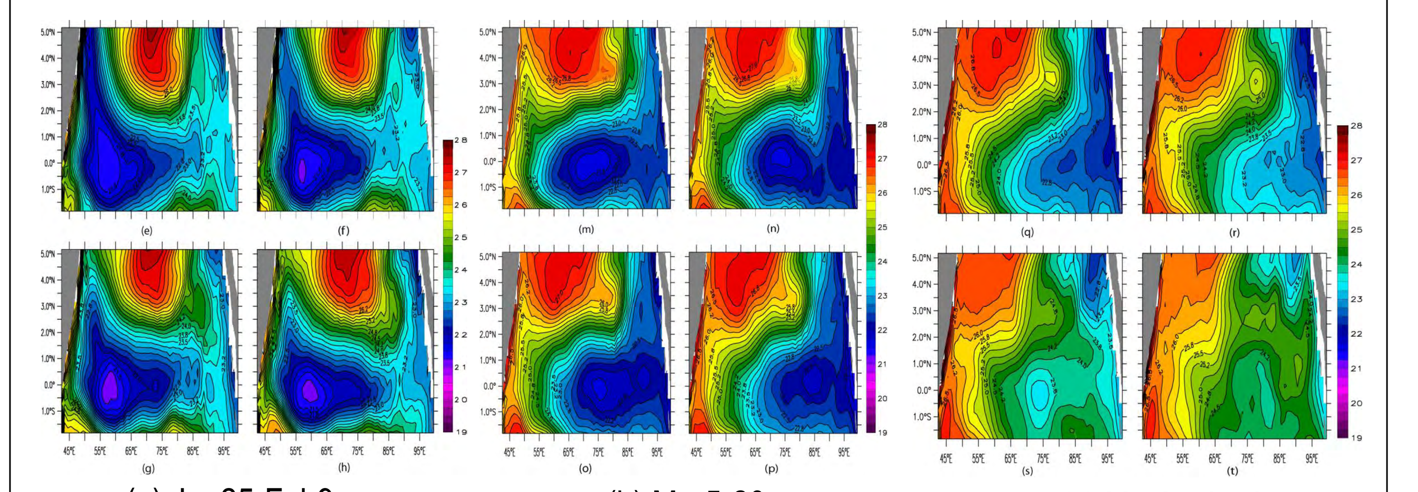


Fig.18 Reflection of the Subsurface portion of LL. GODAS(1996-2005) Pot-temp at 85m depth during Jan 25



(a) Jan25-Feb9 (b) Mar5-20 (c) Mar25-Apr9

Fig. 19 Shows the propagation of Kelvin wave along the equatorial wave guide. Average (1996-2005) of pot-temp at 85m depth. (a)-(c) represents Jan 25 to Apr 9

10. VARIABILITY IN PROPAGATION

Propagation of the Kelvin shows variability in speed after 65°E along the equatorial wave guide. After 65°E the speed increases to from 0.28m/s to1.25m/s. The Maximum propagation is seen near to 85 m depth.

Beyond 65°E towards east along 85m depth the density stratification increases due to the influx of cool low saline water from the bay of Bengal (Fig.22).

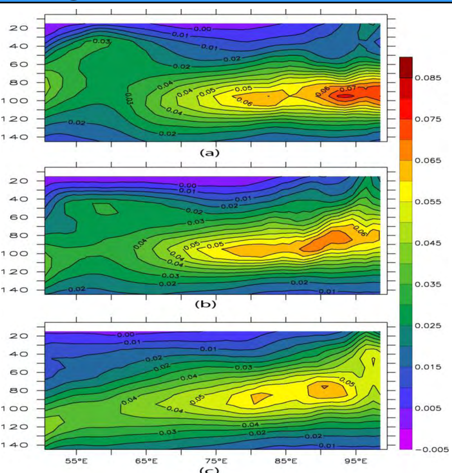


Fig.20 Vertical Potential density gradient computed from GODAS, ave for the region 0°-1°N during (a) Jan, (b) Feb, (c) Mar (1996-2005)

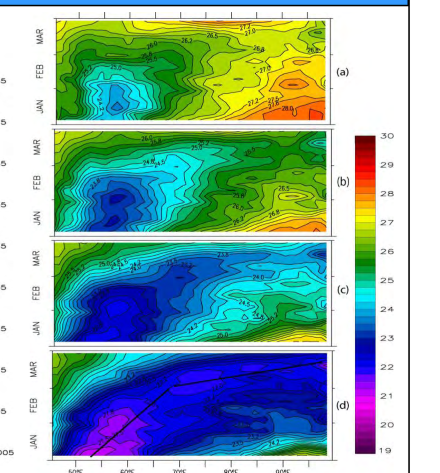


Fig.21 Hovmuller of Potential temperature (lat averaged,0-1°N) for (a) 55m,(b) 65m,(c) 75m and (d) 85m (1996-2005)

During the IOD year (1997) the wave is not seen to propagate across the wave guide(Fig.24)

During the year LL is leaked to the wave guide at 70°E during August before it reaches the western margin(Fig.23)

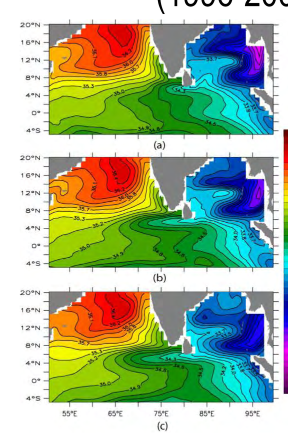


Fig 22 (a)-(c) Surface salinity pattern for Jan, Feb and MAR (ave 1996-2005) from GODAS

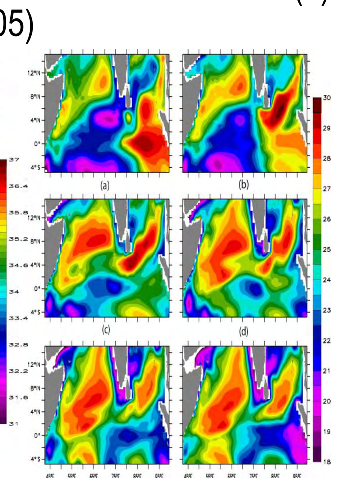


Fig.23 potential temp at 85m during Jun15-Aug 30 for the year 1997

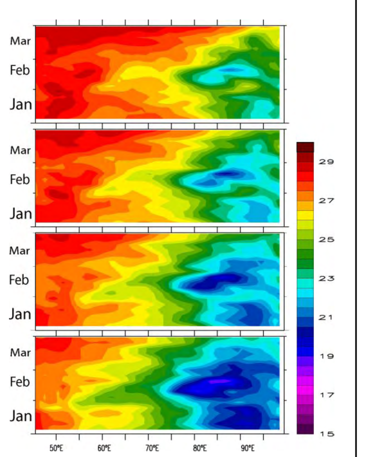


Fig.24 Hovmuller of Potential temperature (lat averaged,0-1°N) for (a) 55m,(b) 65m,(c) 75m and (d) 85m for the year 1998

11. CONCLUSIONS

1. LL shifts westward, northward and southwest-ward before it propagates westward along the southern Arabian Sea
2. During the westward propagation LL intensifies from surface to bottom
3. The intensification is due to the cyclonic shear created by the poleward variation in Zonal velocity of the Wyrtki jet stream
4. Surface portion of LL dies out near to the western margin, but subsurface portion of LL continuous to the western margin and reflects back into the Indian equatorial wave guide and propagates east ward along the guide as an upwelling Kelvin wave.
5. The maximum propagation is seem to be along 85m depth. The propagation speed increases after 65°E due to the vertical density stratification due to the influx of low saline water from the Bay of Bengal
6. During the IOD year 1997, wave is not propagated across the wave guide. Eddy gets leaked to the equatorial wave guide before reaching the western margin.

12. REFERENCES

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