Formation of a sub-surface eddy in the South Eastern Arabian Sea

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Introduction

- The South Eastern Arabian Sea (SEAS) is of particular interest to the scientific community as it plays a crucial role in the onset of the Indian Summer Monsoon Rainfall.
- This region is also marked by the presence of the Arabian Sea mini warm pool, which attains the highest sea surface temperature (SST) during April-May over the global ocean.
- This region also manifested with the presence of oceanic eddies, named Lakshadweep, high and low.
- Previous studies have reported that salinity in the SEAS region can affect the monsoon onset and its strength.
- Marked by the presence of Laccadive Ridge and Maldivian Islands, SEAS is home to a number of eddies in the surface and the sub-surface arising due to bathymetry as well as strong density gradients because of different water masses.
- Understanding the dynamics in this region is essential for improving our ability to predict the monsoon onset.

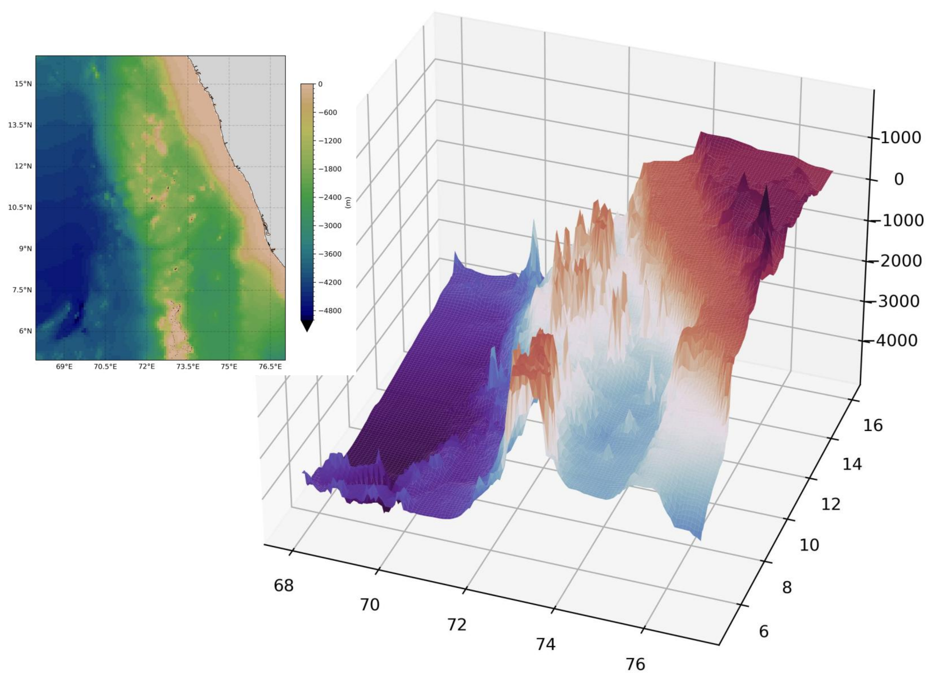


Fig 1. The bathymetry/relief of South Eastern Arabian Sea (SEA) from ETOPO5

Data and Method

Reanalysis	Model (Bathymetry)	Forcing	Assimilation	Citation
ORAS5	1° NEMO3	ERA-Interim, ECMWF NWP (2015-present)	3DVar-FGAT + ensemble-based a-priori bias correction scheme	Zuo et al 2017,2019
SODA	1/4°x1/4°MOM5	ERA-Interim	Optimal Interpolation	Carton et al., 2016
BLND	¼ MOM4p1 (Sindhu et al. (2007))	CORE-II inter-annual forcing	NIL	Rahaman et al., 2014
OM3	¼ MOM4p1 (Smith and Sandwell (1997))	CORE-II inter-annual forcing	NIL	Rahaman et. al., 2014

Table 1. Details of reanalysis/models used in this study

- The characteristics of the anti-cyclonic eddy are studied using simulations (1992-2005) from ocean models and reanalysis products.
- Sensitivity experiments were carried out to understand the effect of bathymetry in the formation of eddy

Results

Surface circulation at SEAS

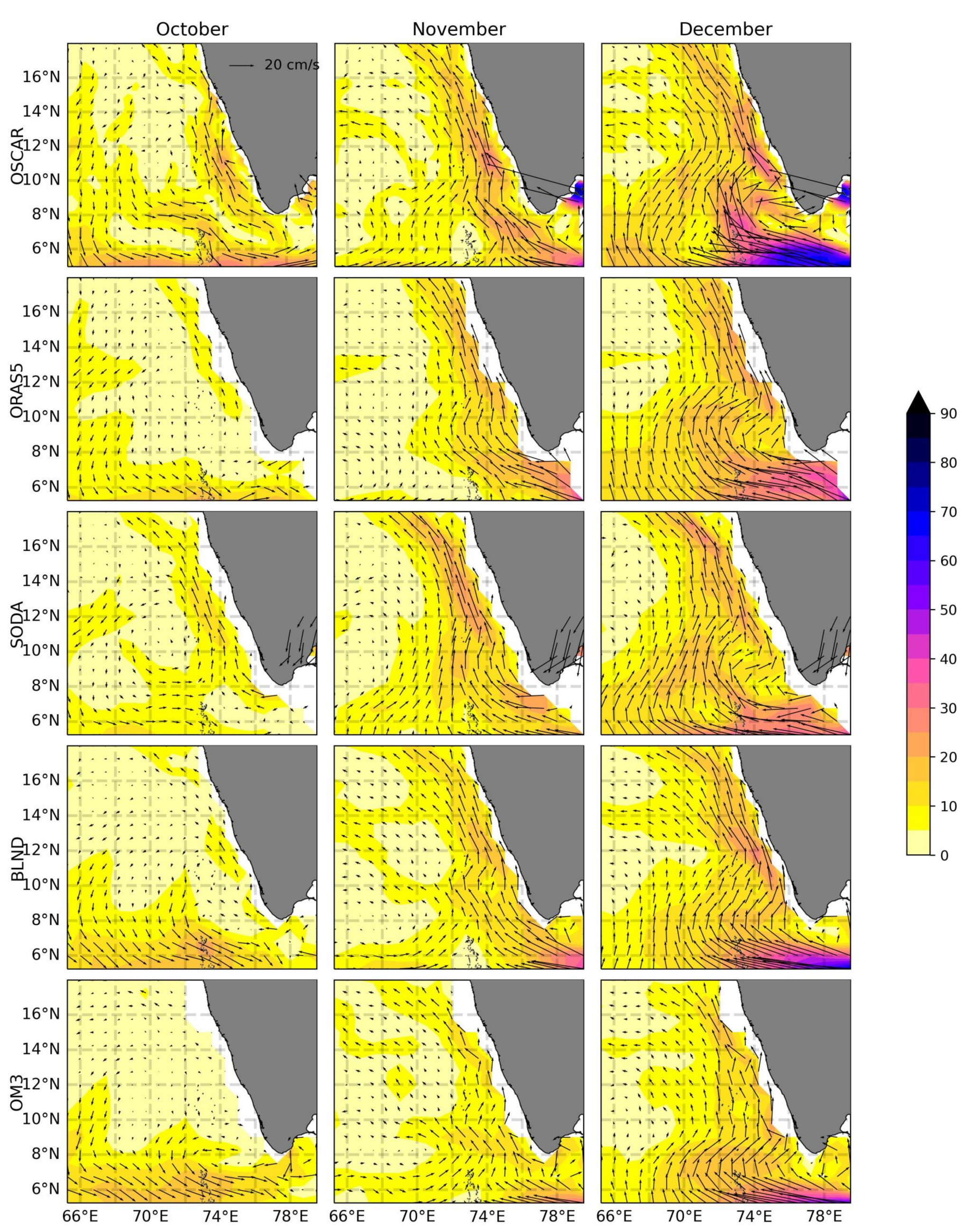
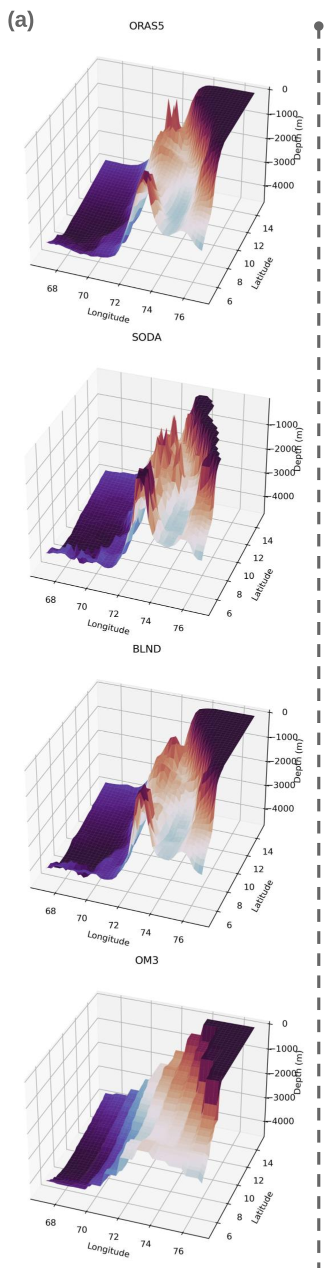


Fig 2. Surface circulation at South Eastern Arabian Sea (SEAS) from OSCAR and upper 30m averaged currents (1992-2005) from ORAS5, SODA,BLND and OM3. The background shows the current speed and vector shows the direction.

- Equatorward EICC on reaching the southern tip of Indian bend towards west because of the presence of Lakshadweep high.
- During fall, a poleward boundary current named West India Coastal Current flows along the west coast of India.

Climatological characteristics of eddy

- A subsurface cone shaped anti-cyclonic eddy is observed centered roughly at 10 °N during November and December.
- The formation of eddy begins to form in the upper thermocline region, where there is a strong halocline and becomes prominent in the lower thermocline region
- Most prominent in the inter-thermocline depth (200-400m) and extends up to 1000m depth
- The structure of this eddy is affected by the bottom topography between Laccadive and Maldives Islands.



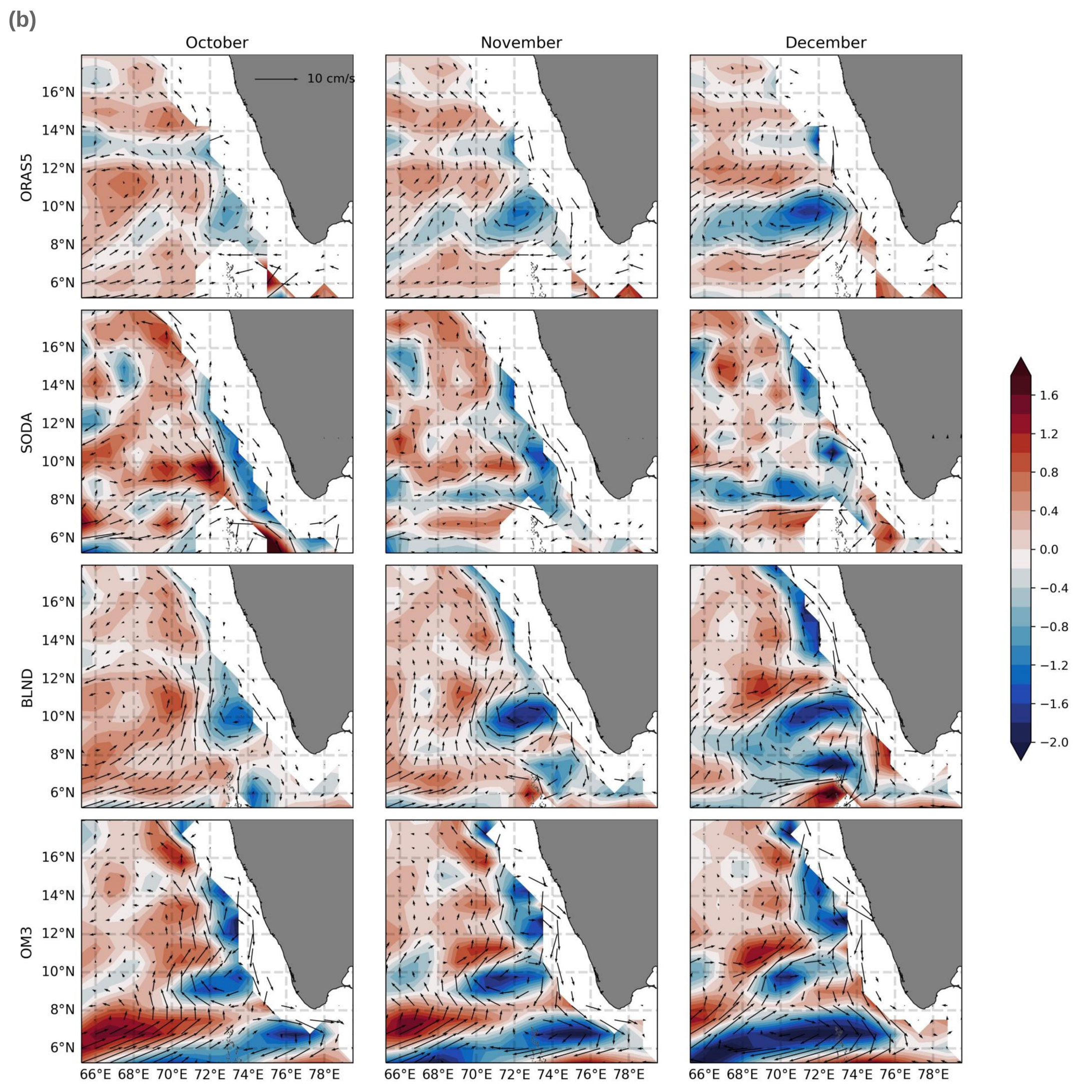


Fig 3. (a) Bathymetry used in the ocean model for ORAS5, SODA, BLND and OM3 at South Eastern Arabian Sea. (b) The relative vorticity averaged for 200-400m depth overlaid by current velocity vectors.

Characteristics and evolution of sub-surface eddy from daily simulation.

- To understand the evolution of the sub-surface anti cyclonic eddy at SEAS, daily outputs from the ocean model is analysed for the year 2003.
- The sub-surface eddy forms by the end of October and becomes more prominent in November.
- The eddy is cone shaped with wider bottom of the eddy reaching up to 1000m depth, and is skewed westward, because of the bathymetric slop in the region.
- The eddy propagates westward as the time progresses.
- SLA signature is absent and associated with the presence of eddy.

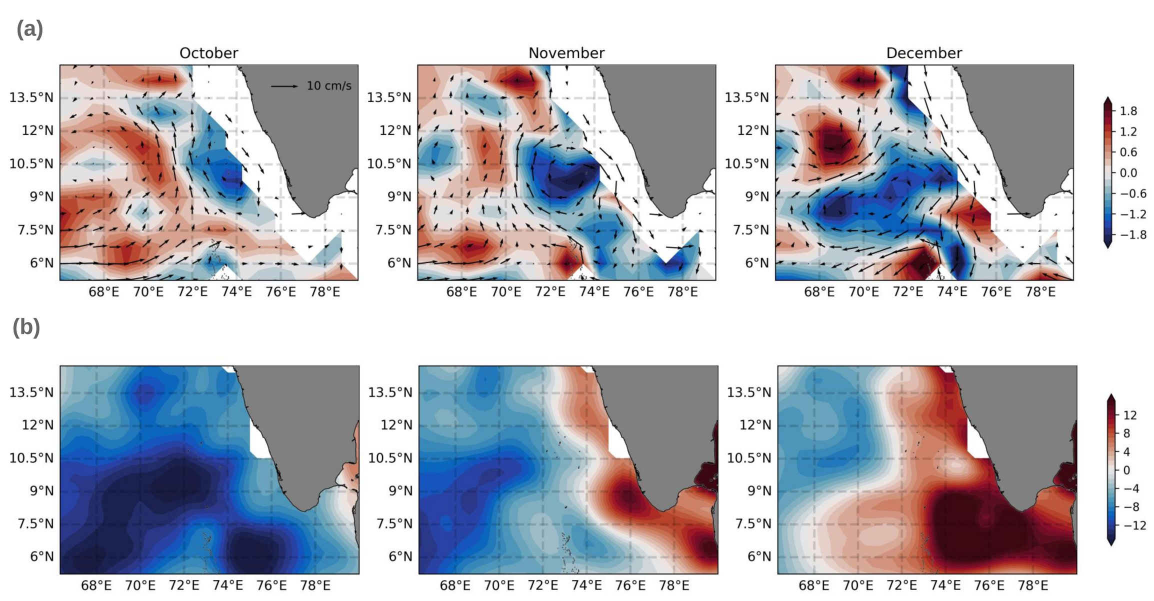


Fig 4. (a) The relative vorticity averaged for 200-400 m depth for the year 2003 from daily outputs of BLND overlaid by velocity vectors averaged for October, November and December months. (b) The lower panel shows the SLA from aviso during the same period.

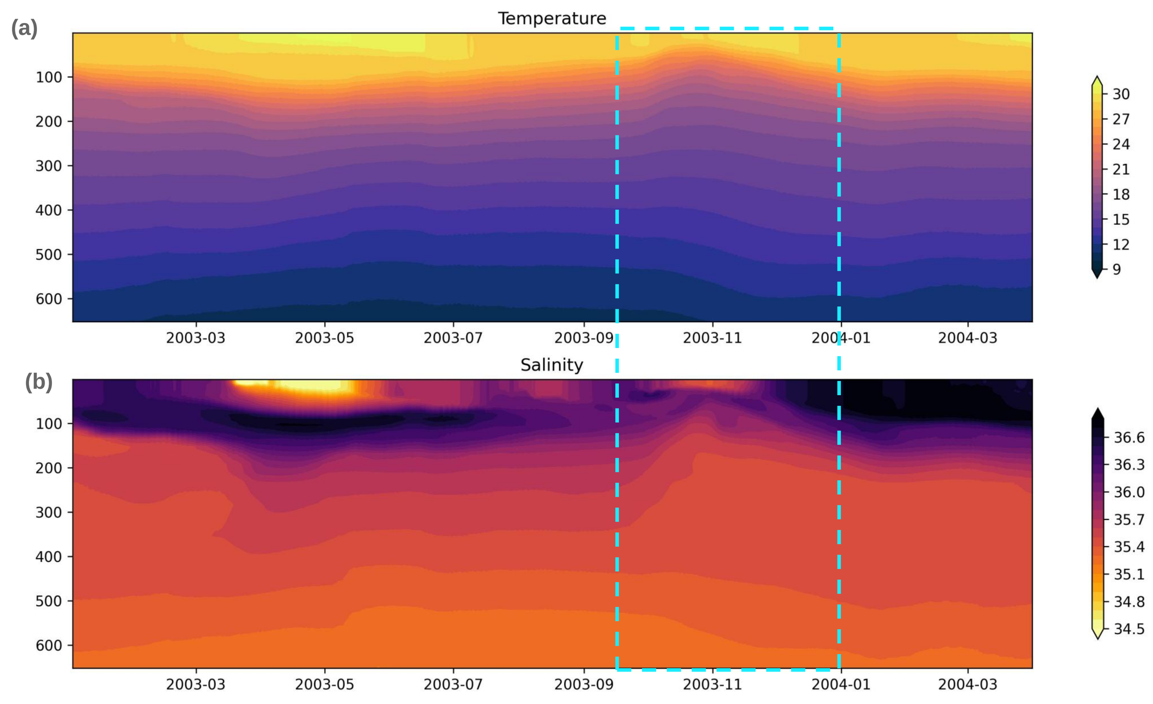


Fig 5. Depth vs Time of (a) temperature and (b) Salinity at 71E;10N, which corresponds to the core of the observed anti-cyclonic eddy during November.

- Double convex shape of isotherms are observed during the formation of eddy, which confirms the presence of eddy.
- Isohalines also show the presence of the observed anticyclonic subsurface eddy.

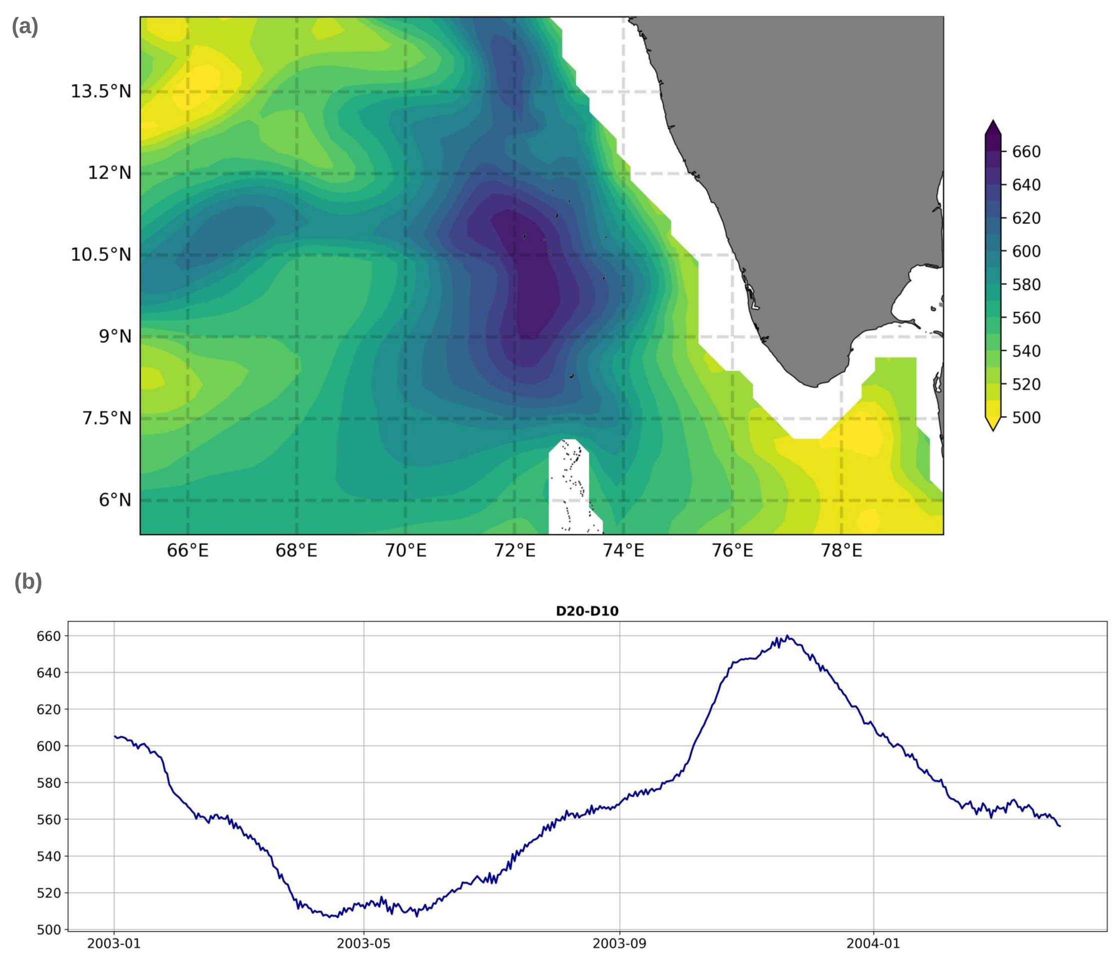


Fig 6. Difference between the depths of 20 degree and 10 degrees isotherms averaged for the month of November. b) The time series of the difference between D20 and D10 at 71E; 10N.

- During fall the EICC carries fresh water from N.BoB as a narrow stream to the southern tip of India, which then bends towards west.
- The high salinity water from the N.AS at the same time, creates a baroclinic instability that triggers the formation of an eddy.

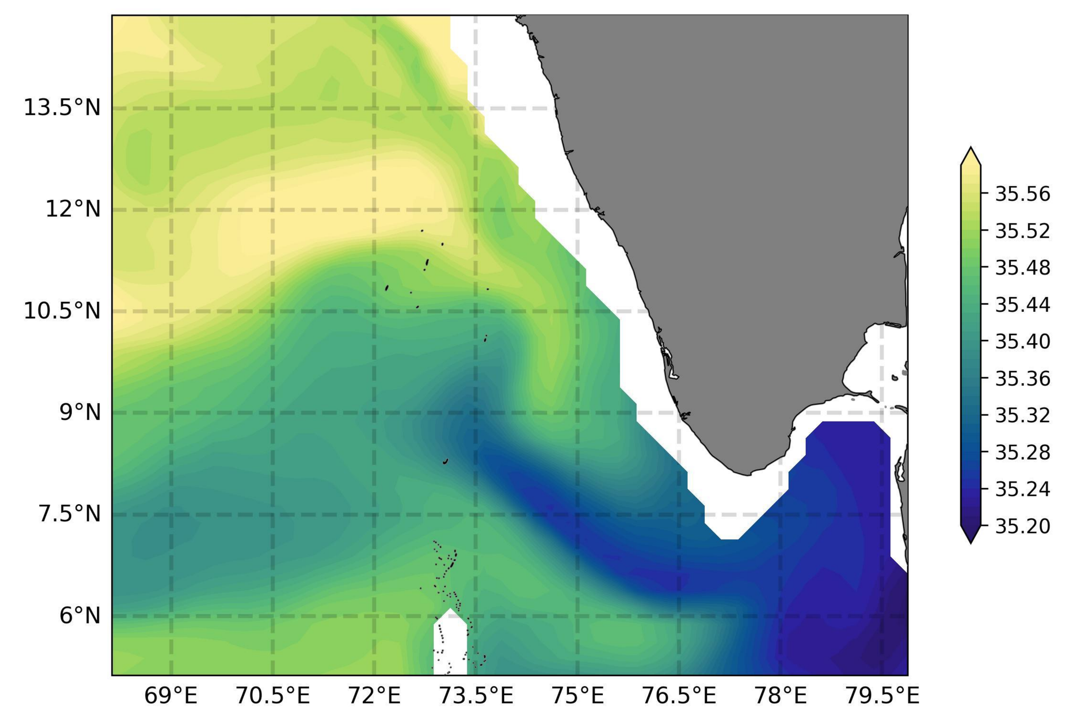


Fig 7. The salinity at SEAS region during November, at 300m depth. The low salinity water from BOB and high salinity water from northern Arabian Sea meets around 10N near Lakshadweep islands.

Conclusion

- A climatological (1992-2005) Sub-surface anti-cyclonic cone-shaped eddy is observed at the SEAS near Lakshadweep islands.
- The formation of eddy is triggered by the sharp gradient in salinity.
- The bathymetric feature affects the structure and evolution of the eddy.
- The presence of this kind of deep eddies helps in the mixing of deep ocean by increasing the velocity Chen et al. (2015)
- The accurate depiction of these eddies is crucial, as they can affect vertical mixing, heat transport, and circulation, which, in turn, can affect the monsoon onset.

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