Seasonal Evolution of Barrier Layer and Temperature Inversions in the Bay of Bengal from Argo Observations

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1. Introduction

The Bay of Bengal (BoB) is well known for its unique features such as seasonally reversing monsoon winds, large amount of freshwater flux which independently or combinedly maintain and hold the seasonal variation of upper layer temperature and salinity. Barrier Layer (BL) is defined as the intermediate layer the separates the base of the mixed layer (ML) from the top of the thermocline. It acts as a "barrier" for the transfer of heat, momentum, mass, nutrient fluxes between the ML and the thermocline. Temperature inversions (TI) in the ocean is defined as a specific temperature structure in which the temperature at deeper depths is higher than that at shallower depths. Existence of BL with significant TI has a noteworthy influence on the sea surface temperature (SST) in the BoB (Shee et al., 2019).

2. Objectives

This study represents:

- Interannual and seasonal variation of BL thickness (BLT) and TI in the BoB.
- Signature of Indian Ocean Dipole (IOD) on BLT and TI during Summer in the BoB.
- Influence of BL with Strong TI on the ML heat budget and SST during Winter in the BoB.

3. Data

- *Argo float* (WMO ID: 5904302) – TS profiles during 09/12/2013 to 15/08/2017 with interval of 5 days. (Source: http://www.nodc.noaa.gov/)
- *AVISO* – Daily Sea Surface Height Anomaly (SSHA) with resolution of 25 km. (Source: http://marine.copernicus.eu/)
- *TropFlux* – Daily SST, heat & radiation fluxes *resolution 100 km. (Source: http://www.incois.gov.in/)*
- *TRMM* – Daily Precipitation with resolution 25 km. (Source: http://apdrc.soest.hawaii.edu/)

4. Methods

- *MLD:* the deepest depth "h" at which the density (Jana et al., 2015, Shee et al., 2019),

$$\sigma_{t(z=h)} = \sigma_{t(z=0)} + \alpha\Delta T,$$

where α is thermal expansion coefficient of seawater and $\Delta T = 1°C$.

- *Isothermal Layer Depth (ILD):* depth at which the temperature is decreased by amount ΔT from the SST.

- *BLT:* ILD – MLD

- *TI:* when temperature at subsurface is greater than the surface value by 0.1℃ or more (Girishkumar et al., 2013; Shee et al., 2019).

- *Mixed Layer Heat Budget* (MLHB) Equation (Rao and Sivakumar 2000, Shee et al., 2019)

$$\underbrace{\frac{\partial T}{\partial t}}_{(a)} = \underbrace{\frac{Q_{net}-Q_{pen}}{\rho C_p h}}_{(b)} - \underbrace{\vec{u}.\vec{\nabla}T}_{(c)} - \underbrace{\left[w_{-h}+\frac{dh}{dt}\right]\frac{T-T_{-h}}{h}}_{(d)} - \underbrace{\frac{K_T}{h}\left|\frac{\partial T}{\partial z}\right|_{z=-h}}_{(e)} + Residual$$

Where, (a) Temperature tendency (time change of heat content), (b) Net surface heat flux, (c) Horizontal advection, Vertical processes (= (d) Vertical entrainment + (e) Vertical diffusion term).

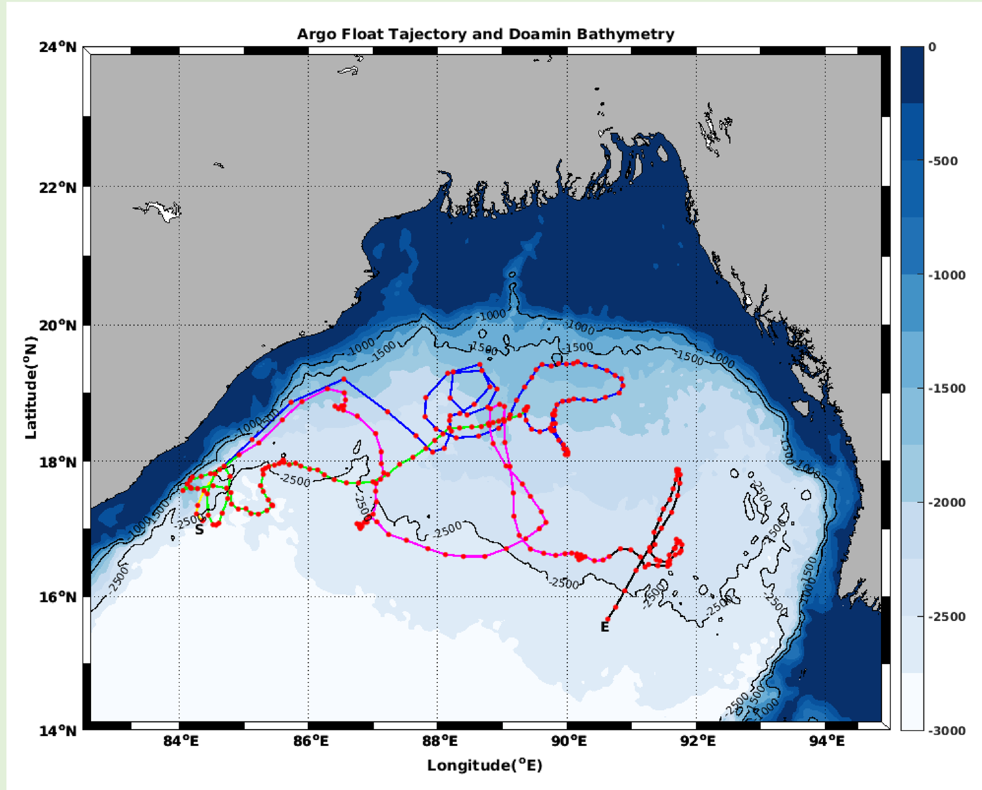

Figure1: Trajectory and positions of Argo float (red dots). Yellow, blue, green, magenta, and black lines represent the years from 2013 to 2017 respectively.

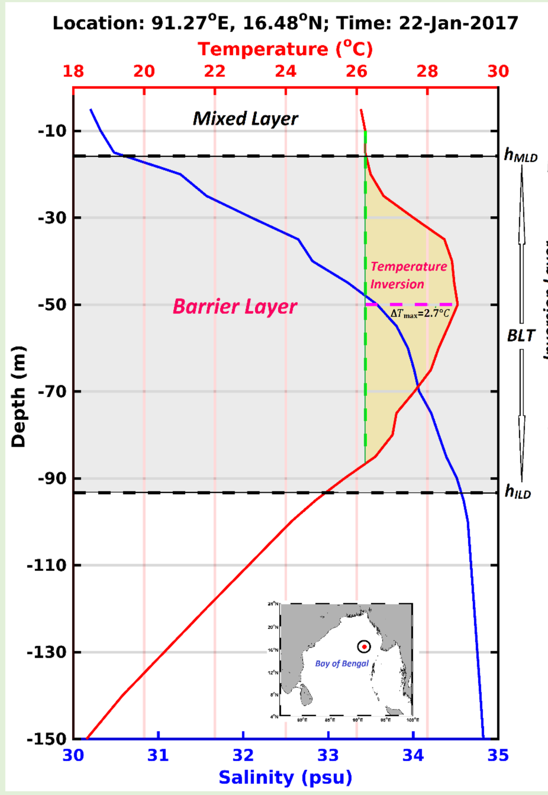

Figure2: Temperature and Salinity profiles of 22[nd] January, 2017 at 91.27°E, 16.48°N.

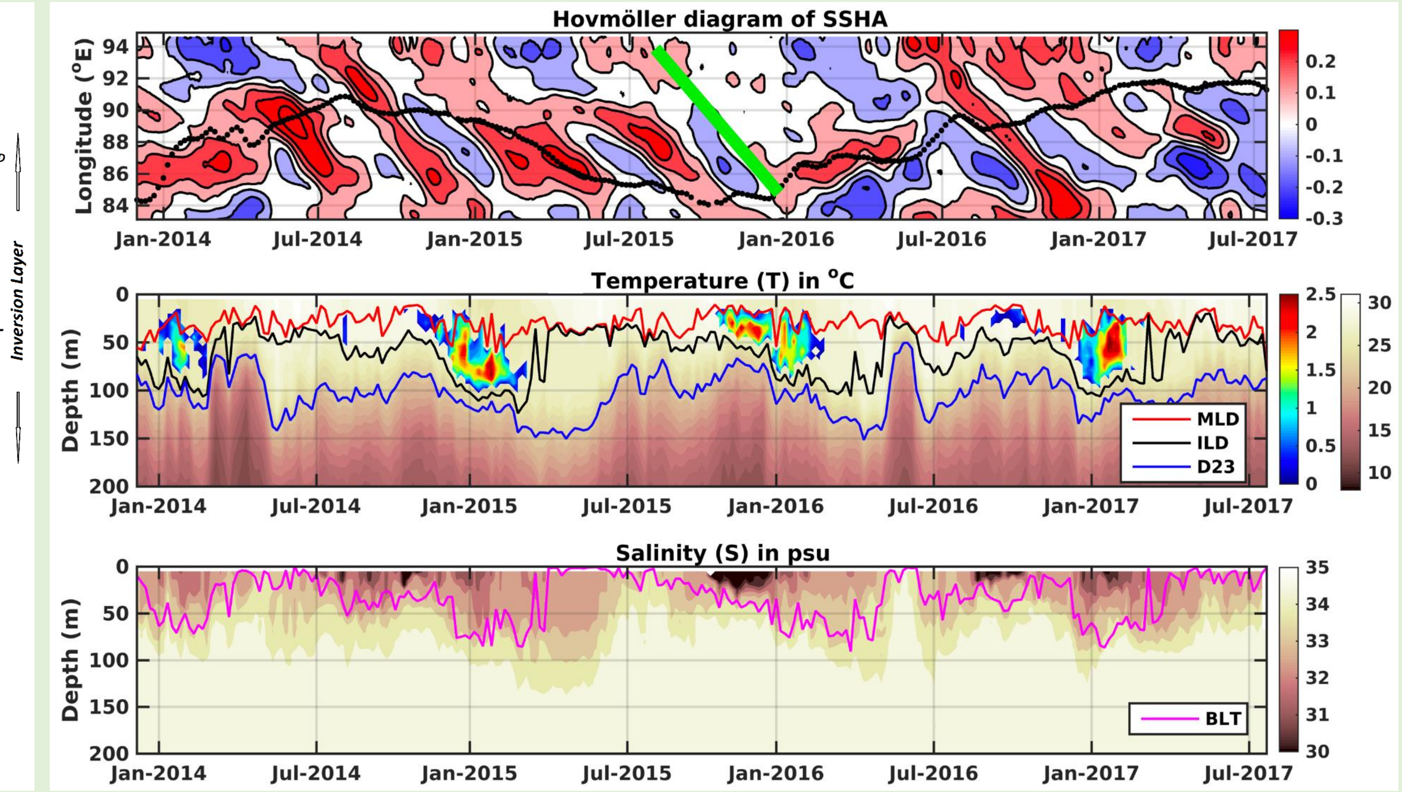

Figure3: Hovmöller diagram of latitudinal averaged SSHA between 17°N to 19°N (top). Black dots represent longitudinal positions of Argo. Time depth sections of temperature (middle) and salinity (bottom).

Table 1: Seasonal evolution of MLD, ILD, BLT, TI, and MLT.

	Summer (Jun - Aug)	Autumn (Sep - Nov)	Winter (Dec - Feb)	Spring (Mar - May)
MLD (m)	8-45	~5	10-55	5-40
ILD (m)	30-65	35-52	60-102	12-50
BLT (m)	20-50	12-48	≥70	0-25
Temperature inversion (TI)	Weak (~0.5°C) (August)	-	Strong (~2.7°C)	-
Mixed Layer Temperature (MLT)	~ 29°C	~30°C	~25-27°C	~31°C

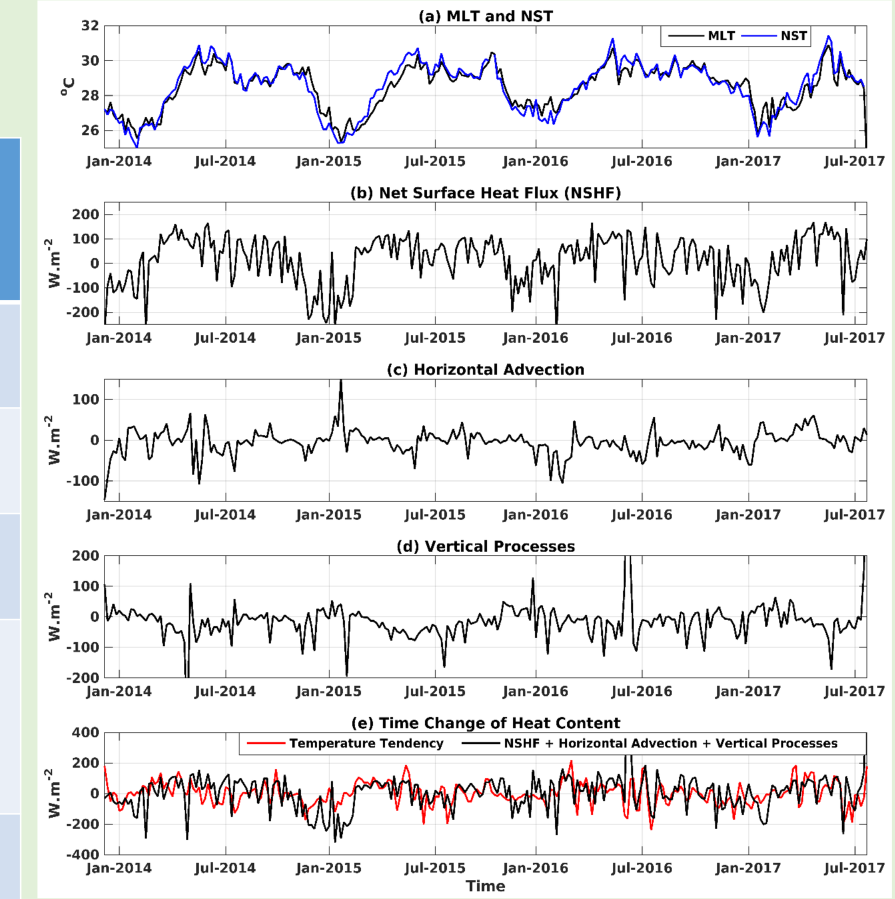

Figure4: Time series of different components of MLHB along the float.

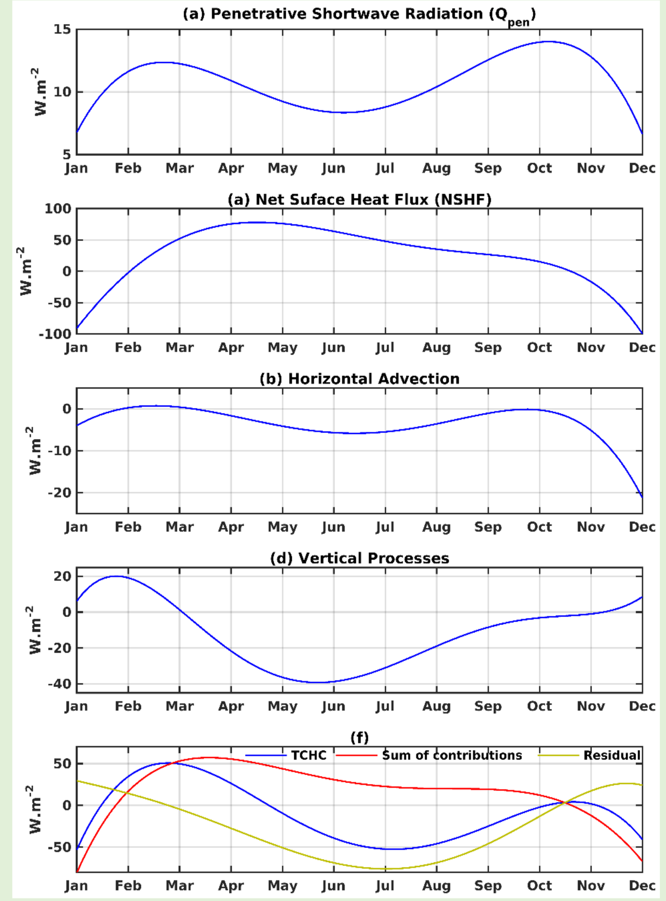

Figure5: Seasonality of different components of the MLHB.

5. Results

- Observed BLT shows a strong semiannual cycle with decreasing during spring (minimum) and fall seasons and increasing during winter (maximum) and summer (Fig. 3; Table 1). BLT is highly correlated with ILD (R=0.89).
- Temperature inversion is observed with strong intensity (~2.7°C) during winter season and with weak intensity (~0.5°C) during peak of summer season (Fig. 2, 3; Table 1).
- During positive IOD year equatorial remote forcing is generally weaker. Hence deepening of ILD during summer of positive IOD year (2015) is less compared to negative IOD year (2014 and 2016), which make BLT comparatively less and temperature inversion is absent (Fig. 2).
- During winter thick BL inhibits entrainment cooling of ML (Fig. 4d, 5d) by preventing exchange of the heat with cooler subsurface layers and the presence of strong temperature inversion layer (Fig. 3) prevents the drop of surface layer temperature. Thus both play a significant role in the evolution of winter SST (~26-27°C, Fig. 4a).

7. References

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