Seasonal and spatial variation of wind speed and the Thermocline Depth in the Indian Ocean

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Abstract

Water temperature profiles from ARGO drifters and wind data from the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) mooring from 2010 to 2012 within the selected Bay of Bengal (BoB), Equator (EQ) and South of Arabian Sea (SoA) area are used to assess the seasonal and spatial variability of wind speed and thermocline depth in the Indian Ocean and to assess whether there were any association between wind speed and thermocline depth within region and between regions. Maximum Temperature Gradient was used to measure the thermocline depth in the different regions.

BoB and EQ showed a distinct semi-annual variability with deep thermocline depth (104,124 m and 123,111 m) and maximum wind speed (5.8, 7.4 m s-1 and 3.5, 4.8 m s-1) during Northeast and Southwest Monsoons than that of SoA. Minimum wind speed (2.3,3.7 and 4.0, 4.8 m s-1) and shallow thermocline depth (77, 99 m and 71,72 m) observed during spring and autumn Inter-Monsoons of BoB and EQ. Inter-Monsoons is not clearly defined at SoA. Wind speed of a particular region had significant impact in changing its thermocline depth (Univariate Analysis of Covariance (ANCOVA): $F=18.89$, $df=2$, $p=0.001$, $p<0.05$).Wind speed of BoB showed significant positive correlation with its thermocline depth ($r=0.0499$, $p<0.05$). Wind speed of EQ showed significantly negative correlation with thermocline depth of SoA ($r=-0.66$, $p<0.05$) and wind speed of SoA showed significantly positive correlation with thermocline depth of BoB ($r=0.512$, $p=0.04$, $p<0.05$). However, no significant correlation is observed in the particular region and among the region with wind speed and thermocline depth. Thus, wind speed may influence the themocline depth considerably, the other oceanic process too may exert substantial influence on thermocline depth. This study provides baseline data regarding the wind speed and thermocline depth at the regions in the Indian Ocean that are useful for future studies.

Keywords: Indian Ocean, Wind Speed, Thermocline Depth, Air-sea interaction

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Introduction

Indian Ocean has highly dynamic air-sea interactions. Seasonal reversal of the monsoon winds and it effect on the ocean currents in the Northern hemisphere were the most outstanding differences in the Indian Ocean with other ocean (Tomczak et al., 2003). The monsoon circulation is mainly driven by the differential heating of the Indian Ocean and the adjacent land areas (Krishnamurti and Ramanathan, 1982). Wind forcing significant exchanges of heat across the air–sea interface (Riser et al., 2008). Vertical mixing processes in the upper ocean play a key role in determining the exchanges between the mixed layer and the underlying thermocline (Large et al., 1994). BoB, EQ, and SoA regions are highly affected by those facts. This study hypothesized that there was a relationship between thermocline depth (TD) and wind speed (WS) among and between the different regions of the Indian Ocean. If there is different WS between geographical region (BoB, EQ, and SoA) there would be variation in the TD between those regions between different seasons. Furthermore this study implicated to find the seasonal and spatial variation of WS and TD in selected regions of the Indian Ocean (BoB, EQ, and SoA) in consecutive three years since 2010 andto find association between wind speed and thermocline depth within region and between regions of the Indian Ocean.

Materials and Methods

The data have been extracted from multiple source bunkers for Indian Ocean .It consists of meteorology and hydrological data such as wind speed and water temperature profiles. Daily WS data were obtained by RAMA data center and monthly water temperature profiles were obtained by the Ocean ARGO database center. WS and water temperature data were collected from 1^{st} of January 2010 to 31^{st} of December 2012 period distributed on 55^{o}E-90^{o}E Longititude and 15^{o}N-15^{o}N Latitude selected different regions in the Indian Ocean. WS data were arranged annually (January to December) and averaged using MATLAB 7.7.0 version programming software and obtained the average wind velocity values of each month in the selected different regions and made graphs for each year. Maximum Annual average wind velocity is derived from the maximum average wind velocity of the three years from 2010 to 2012.Water temperature profile data were made for suitable text format and monthly arranged by the ocean data view 4.5.6 version software. Maximum angle method was marked to measure the TD in the different regions. Maximum temperature gradient = maximum angle of tan $\emptyset_{max}$ = thermocline depth.

Results

	BoB		EQ		SoA	
	WS	TD	WS	TD	WS	TD
NEM	5.8	104	3.5	123	8.3	92
1^{st}IM	2.3	77	3.8	99	-	-
SWM	6.8	124	4.4	111	6.8	60
2^{nd} IM	4.0	71	4.8	72	-	-
Pearson correlation and p value<0.05	r=0.0499, p=0.049 Significant Positive Correlation in 2011					
		R=0.51, p=0.044 Significant Positive Correlation in 2011				
			R=-0.66, p=0.02 Significant Negative Correlation in 2010			

Table 1:Summary of the thermocline depth (TD) and WS at Bay of Bengal, Equator and South of Arabian Sea from 2010 to 2012

The maximum WS and TD were observed during Northeast and Southwest monsoon at Bay of Bengal and SoA and minimum WS and TD was observed during the first and second inter- monsoon at BoB and EQ region. Inter monsoons are not clearly distinguishable at SoA.WS at BoB had positive correlation of WS and TD at BoB in 2010, 2012 and positive correlation between WS and TD at EQ in 2010 and 2011, but negative correlation in 2012. WS at SoA showed positive correlation with its TD in 2011 and 2012, but negative correlation in 2010.

Comparison showed that there were positive correlations between WS of particular region and TD of the other region in three consecutive years since 2010 except negative correlation between WS of BoB and TD of SoA in 2010 (table 1), between WS of BoB and TD of SoA in 2011, between WS of SoA and TD of EQ in 2011, between WS of BoB and TD of SoA in 2012, and between WS of SoA and TD of BoB and EQ in 2012. WS of a particular region had significant impact in changing its TD (Univariate Analysis of Covariance (ANCOVA): F=18.89, df=2, p=0.001, p<0.05).There was a significantly different WS between regions (ANOVA: F = 17.36, df=2, p=0.001, p<0.05) and significantly different TD between regions (ANOVA: F=16.75, df=2, p=0.001, p<0.05).

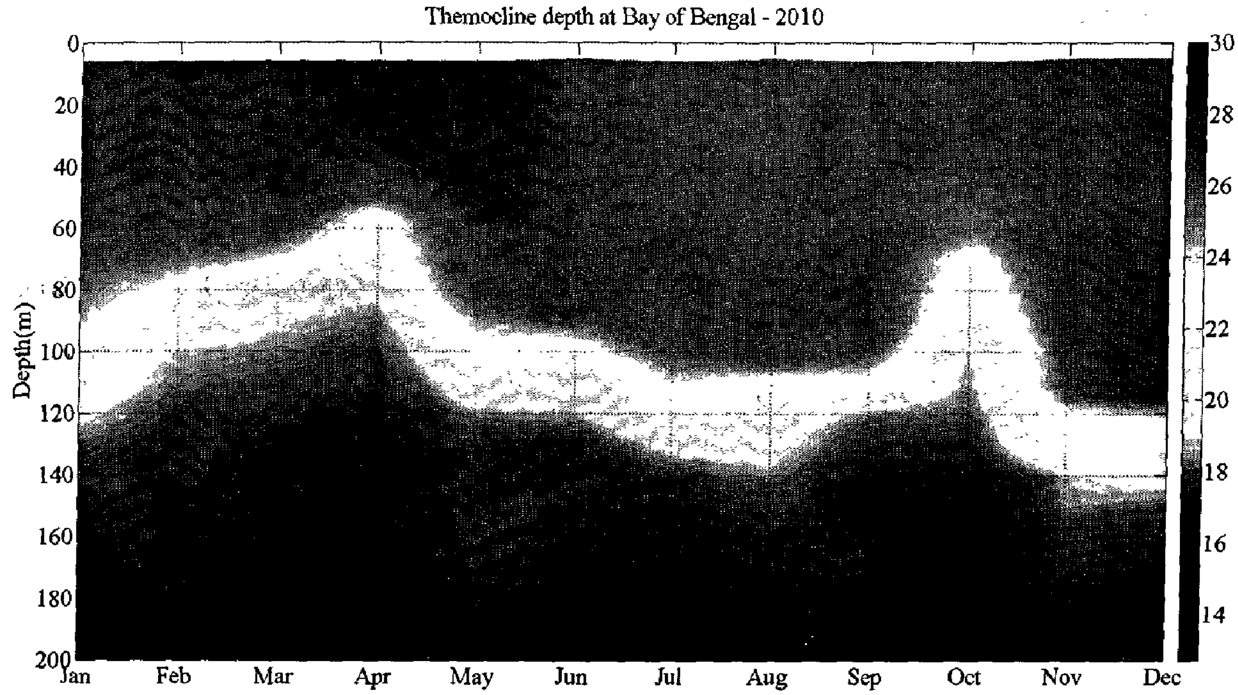

Figure2:Themocline depth variation with Temperature Profiles; at what location.

Discussion and Conclusion

BoB and EQ showing a distinct semi-annual variability with deep thermocline depth and maximum WS during Northeast and Southwest Monsoons than that of SoA.Minimum TD and WS observed at two inter-monsoon at BoB and EQ. Inter-monsoons are not clearly distinguised at SoA. The TD and WS at EQ and SoA did not exibit significant seasonal variation. Though the WS at SoA is strong, the TD is considerably low. It indicated that possibly excessive evaporation over the SoA served as stong stratification force. The study reveals that though the WS contributes to the seasonal fluctuation of TD, it is not the only parameter, which determines the TD. The evaporation and freshwater discharge by the rivers too exert significant influence on the TD. The outcome of this study was that various factors such as eddies, internal waves, water masses, upwellingand downwelling, underwater currents, suummer and winter cooling and monsoon effects influnce the structre of TD in the Indian Ocean, in the spatial and temporal scales and must be tested in long term periods for the future studies using sophisticated instrument and using a more advanced techniques..

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