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Latent and Sensible heat flux variation in north Indian Ocean during ENSO and Indian Ocean dipole years

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Abstract

This study investigates air-sea flux variability associated with the ENSO and Indian Ocean dipole years in the Tropical and northern Indian Ocean. Objectively Analysed (OA) surface fluxes, and altimeter derived sea surface height anomaly datasets for a period of thirty years from 1986 to 2015 were utilised. First, the El-Nino and La-Nina years were separated and the difference between them was analyzed to understand the effect of ENSO. A similar approach was also followed for positive and negative Indian Ocean dipole years. It was found that the upwelling caused by planetary Rossby waves during El-Nino and positive Indian Ocean dipole years suppress the latent heat flux from ocean closer to the Somali coast. Ocean dynamics and thermodynamics both were observed to play significant roles in flux variation in this region.

1 Introduction

El-Nino Southern Oscillation (ENSO) is a regular variation of magnitude or position of sea surface temperature (SST) in the Pacific Ocean, which contributes to the global climate system, primarily through ocean-atmospheric interaction. The warming events associated with the Indian Ocean during these periods are a replica of the warming events in the Pacific [1]. So the teleconnection between ENSO and the Indian Ocean cannot be ignored. Further, the discovery of Indian Ocean Dipole (IOD) modes significantly improved the understanding of Indian Ocean dynamics. The anomalous cooling characterizes the IOD events in the southeastern equatorial Indian Ocean and anomalous warm SSTs in the western Indian Ocean [2, 3], even in the absence of El-Nino or La-Nina. Several theories have been put forward to explain the physical and dynamical mechanism associated with the eastern cooling and western warming events that appeared during IOD.

In this study, we focused on the variation of latent heat flux (LHF) and sensible heat flux (SHF) during El-Nino, La-Nina, and IOD events, as these fluxes contribute to the oceanic heat budget and control the SST by upper-ocean stratification and ocean currents [4]. The previous study by Chowdary and Gnanaseelan [5] suggested that during El-Nino only years, LHF and short wave radiation play a significant role in maintaining the basin-wide surface warming in the Indian Ocean. However, the main objective of this work is to understand the flux variation related to Indian Ocean dynamics during ENSO and IOD events.

2 Data and Methodology

To explain the variation of heat flux and ocean dynamics, objectively analyzed air-sea Flux (OA Flux), and sea level anomaly (SLA) data sets spanning a thirty years period from 1986 to 2015 were used. Both are daily gridded products with spatial resolutions of 0.25° X 0.25°. The OAFlux project improves the estimates of LHF and SHF through utilizing the best possible surface meteorological variables and the best possible bulk algorithm (COARE 3.0). Both satellite and numerical weather prediction model data (Reanalysis) was used as input [6] to COARE 3.0 algorithm. SLA data sets which were obtained from Archiving, Validation, and Interpretation of Satellite Oceanographic (AVISO) [7], and it is the merged satellite altimetry products from Ocean Topography Experiment (TOPEX)/ Poseidon, European Remote Sensing Satellites (ERS-1 and ERS-2), etc. Besides these, information on El-Nino and La-Nina were obtained from https://ggweather.com/enso/oni.htm, and positive and negative IOD years were obtained from http://www.bom.gov.au/climate/iod/.

3 Results and Discussion

The possible teleconnection of El-Nino and La-Nina on the Indian Ocean dynamics is modified after the idea of IOD came forward. So here, an attempt was made to investigate the variation of flux terms along with Bowen Ratio during the ENSO and IOD years separately.

3.1 Variation of heat flux during ENSO

The Oceanic Nino Index (ONI) has become the standard that the National Oceanic and Atmospheric Administration (NOAA) uses for identifying El-Nino (warm) and La-Nina (cool) events in the tropical Pacific. It is the running 3-month mean SST anomaly for the Nino 3.4 region (5^0 N - 5^0 S, 120^0-170^0 W). When the anomaly is greater than +0.5 °C for five consecutive, 3-months anomalies than it is called a warm phase (El-Nino) or else cold phase (La-Nina). Accordingly, the El-Nino and La-Nina years are listed from June to June basis for every year (Table-1).

Table-1: El-Nino and La-Nina years from 1986 to 2015

El-Nino				La-Nina		
Weak	Moderate	Strong	Very strong	Weak	Moderate	Strong
2004-05	1986-87	1987-88	1997-98	2000-01	1995-96	1988-89
2006-07	1994-95	1991-92	2015-16	2005-06	2011-12	1998-99
2014-15	2002-03			2008-09		1999-00
2018-19	2009-10					2007-08
						2010-11

*Table Courtesy (https://ggweather.com/enso/oni.htm)

Along with LHF and SHF, the Bowen ratio (ratio between SHF and LHF) is also taken into account as it is important for net energy budget calculation. Here it is observed that LHF is more in BoB during El-Nino years as compared to La-Nina years. Similarly, high LHF is also found near the Somali coast, and the southwest Indian Ocean near the equator. Low LHF is found in the south of the Indian Ocean situated near the equator and high LHF just below 5 °S (Figure-1). The high value always tends to be more during El-Nino years as compared to La-Nina years and vice versa for the case of low value. In the case of the SHF and Bowen ratio, high value is found near the Somali coast. Further, this high values of Bowen ratio extend towards the central Arabian Sea. This effect is possibly due to two reasons, firstly warming (cooling) in the western Indian Ocean (Eastern Indian Ocean) takes place during IOD, and secondly, during La-Nina years, the Indian Ocean experienced basin-wide cooling during the winter due to propagation of upwelling Rossby waves [8].

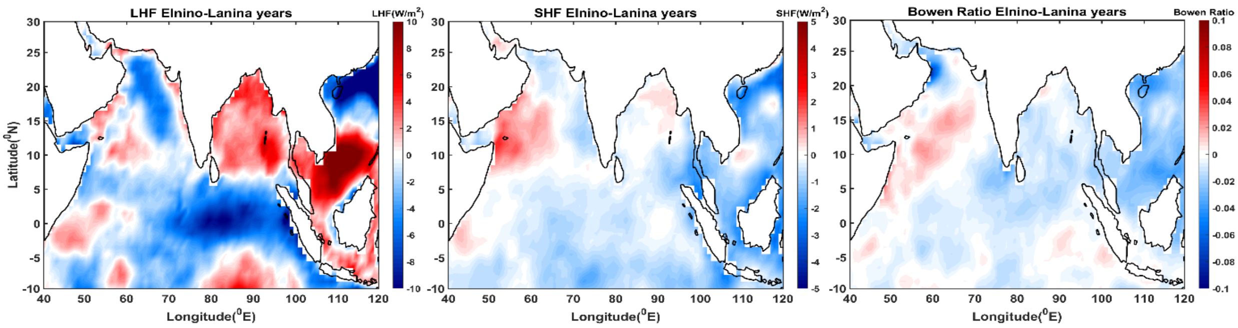

Figure 1. Spatial distribution of LHF, SHF and Bowen Ratio showing El-Nino & La-Nina years.

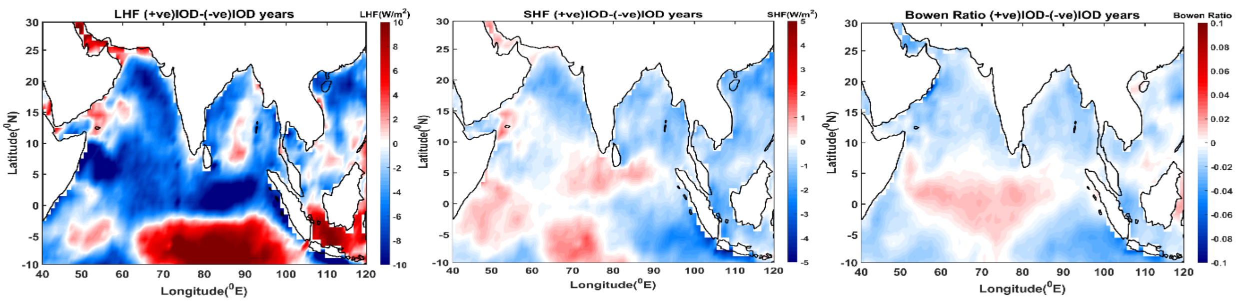

Figure 2. Spatial distribution of LHF, SHF and Bowen Ratio showing positive IOD-negative IOD years

3.2 Variation of heat flux during IOD

This analysis is limited to the period 1986 to 2015. During this period, the positive IOD years are 1994, 1997, 2006, 2012, and 2015; negative IOD years are 1989,1992, 1996, 1998, 2010, and 2014. Warmer than normal water in the western part of the tropical Indian Ocean is the signature of positive IOD and vice versa for negative IOD [2, 3]. Here the LHF during positive IOD is lesser than the negative IOD years (Figure-2) near the Somali coast because the easterly wind over the equatorial Indian Ocean during monsoon months causes upwelling in this region. This upwelling brings the cooler water to the surface, so the LHF becomes less. However, the SHF and Bowen ratio shows higher value during positive IOD as the air temperature becomes less compared to SST. The reverse phenomena occur in the eastern equatorial Indian Ocean; hence it shows higher LHF and lowers SHF (Bowen Ratio) during positive IOD years than negative IOD years. The time vs longitude plot of SLA along the latitude 5 °N shows the propagation of the Rossby wave (Figure-3) during positive IOD and El-Nino years.

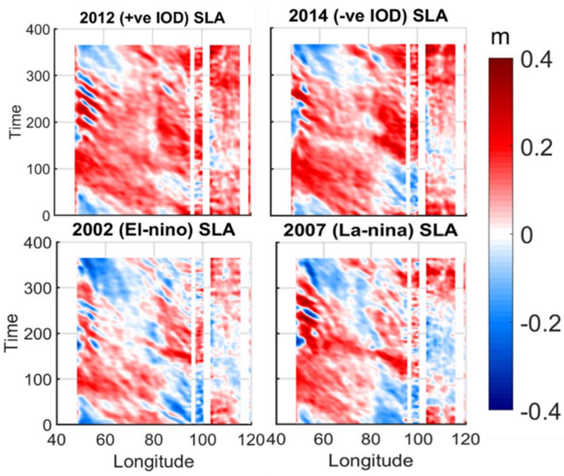

Figure 3. Time Longitude plot for +ve IOD, –ve IOD, El-nino and La-nina year along the latitudinal band at 5 °N

4 Conclusion

Positive IOD and El-Nino years show strong westward propagation of Rossby wave, which results in upwelling near the Somali coast during monsoon months. This results in cooler SST in this region, hence the LHF is less in this area during both positive IOD and El-Nino years. Although only one year each of four distinct cases has been shown here, all other years were also analyzed, and the results are consistent with it except for the co-occurrence of IOD and El-Nino year. This leads to the conclusion that both ocean dynamics and thermodynamics play an important role in regulating LHF and SHF variation during positive IOD and El-Nino years in the Indian Ocean. However, negative IOD and La-Nina years behave like the normal years in relation to heat flux variations.

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