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Tropical cyclones over north Indian Ocean during concurrent occurrence of ENSO and IOD

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Abstract *There are two seasons for the formation of tropical cyclones over north Indian Ocean namely pre-monsoon (March – May) and post-monsoon (October- December). The frequency of of the cyclonic storms and severe cyclonic storms is found to be high during the post-monsoon season over north Indian Ocean (NIO) when the air sea interaction processes such as Indian Ocean Dipole (IOD) and El-Niño and La-Niña events would peak. It is observed that the IOD event occur simultaneously with the El-Niño and La-Niña events very often. The frequencies of cyclonic storms and severe cyclonic storms over NIO during the concurrent occurrence of IOD events with El-Niño and La-Niña have been analyzed. Results suggests that Ocean Atmospheric parameters such as mid tropospheric instability, mid tropospheric relative humidity and vertical wind shear are highly favorable for the formation and intensification of the cyclones over NIO during the concurrent occurrence of IOD events with El-Niño and La-Niña events.*

Key Words *Tropical cyclones, North Indian Ocean, El-Niño, La-Niña, Indian Ocean Dipole*

Introduction

Tropical cyclones form over warm ocean surfaces, having high sea surface temperature (SST) more than 26°C, low magnitudes of vertical wind shear and large magnitudes of low level relative vorticity, coriolis force and middle tropospheric relative humidity. Air-sea interaction processes like El-Niño, La-Niña (Philander 1983) and Indian Ocean Dipole (IOD) (Saji et al. 1999 and Webster et al. 1999) have significant impact on the cyclone activity over different ocean basins. Studies show that El-Niño event can occur simultaneously with the positive IOD events and the La-Niña can occur simultaneously with the negative IOD events. The frequency variations of the cyclonic storms and severe cyclonic storms during the concurrent occurrence of El-Niño and positive IOD and La-Niña and negative IOD over north Indian Ocean have been analyzed in the present study. It is observed that the El-Niño and positive IOD occurred simultaneously in 1982,1997 and 2006 and La-Niña and negative IOD occurred simultaneously in 2010.

Materials and Methods

The process of initiation of a cyclone is called cyclogenesis. There are six primary genesis parameters (Gray 1975) for tropical cyclone namely, 1. low level relative vorticity, 2. Coriolis parameter, 3. inverse of the vertical shear of the horizontal wind between lower and upper troposphere, 4. ocean thermal energy or

sea surface temperature above 26°C to a depth of 60m, 5. vertical gradient of equivalent potential temperature between surface and 500mb. 6. middle tropospheric relative humidity.

Zehr (1992) proposed a parameter known as Genesis Parameter (GP), which is the product of three dynamical parameters such as low level relative vorticity at 850 hPa, negative of low level divergence at 850 hPa (for low level convergence) and vertical wind shear co-efficient. GP is expressed in units of $10^{-12}s^{-2}$. This study also provides the threshold values for these parameters which are favorable for the formation of a cyclone, such as low level relative vorticity at 850 hPa is ($1.05x10^{-5}S^{-1}$), low level convergence at 850 hPa is ($0.33x10^{-5}S^{-1}$) and vertical wind shear co-efficient is ($10.3xms^{-1}$). Roy Bhowmic (2003) used this genesis parameter to study the developing and non-developing systems over NIO, and observed GP values around 20 $x10^{-12}$ sec $^{-2}$ against T-No:1.5 has the potential to develop into a severe cyclonic storm. Kotal et al. (2009) introduced a genesis parameter and termed it as the Genesis Potential Parameter (GPP) for the Indian Seas. The parameter is defined as the product of four variables namely vorticity at 850 hPa, middle tropospheric relative humidity, middle tropospheric instability and the inverse of vertical wind shear. Zehr's genesis parameter (GP) and two therm-dynamic parameters defined by Kotal et al. (2009) have been used in the present study to discuss the dynamic as well as thermo-dynamic features of the cyclones over NIO. The threshold of Mid Tropospheric Instability is 23ºC and the Threshold for Mid Tropospheric Relative Humidity is 40% or 0. The cyclogenesis parameters used for this study are

i) Low Level Relative Vorticity at 850 hPa LLRV

ii) Low Level Convergence at 850 hPa LLC (negative of low level divergence at 850hPa)

iii) Vertical Wind Shear Coefficient = [25.0 mS^{-1} -(200 – 850 SHEAR)]

20 ms^{-1}

iv) Middle Tropospheric Relative Humidity variable (M), M= [RH-40]

30

(where RH is the mean Relative Humidity between 700 and 500 hPa)

v) Middle Tropospheric Instability (I), I= T850 – T500.

(The temperature difference between 850 and 500 hPa)

The composite anomalies of all these parameters have been prepared using NCEP/NCAR Re-Analysis -II daily data. All the parameters are averaged with the cyclone days, and studied the variations of these parameters for the cyclones during the different types of IOD events. The genesis locations of all the cyclones during 1979 to 2010 are obtained from the cyclone e-Atlas prepared by India Meteorological Department (IMD). The study area includes Arabian Sea [50°E-78°E, 0°N – 30°N] and Bay of Bengal [78°E-100°E, 0°N – 30°N].

Tropical cyclones over NIO during concurrent occurrence of ENSO and IOD

Studies (Pradhan et al. (2011) and Sumesh and Ramesh (2013)) show that the concurrent occurrence of ENSO and IOD have got much influence on the formation and intensification of tropical cyclones over various basins. Tables (1)

gives the frequencies of tropical cyclones formed over NIO during the concurrent occurrence of El-Niño and positive IOD events and Table (2), gives the frequencies of tropical cyclones formed over NIO during the concurrent occurrence of La-Niña and negative IOD events. There have been 3 years in which the El-Niño co-occured with the positive IOD event. Out of this 3 years 2 cyclones have formed over the Arabian Sea and 9 cyclones have formed over the Bay of Bengal. The two cyclones over Arabian Sea have intensified into severe cyclones, and over Bay of Bengal 7 cyclones out of 9 have intensified into severe cyclones. This means there is a high possibility for the intensification of cyclones into severe cyclones during the concurrent occurrence of El-Niño and positive IOD events over the NIO. While during the concurrent occurrence of La-Niña and negative IOD events, the possibility of the intensification of cyclone to a severe cyclone is more than the other situation. There have been 1 cyclone and 1 severe cyclone over Arabian Sea and 3 severe cyclones over Bay of Bengal during this period. Over Bay of Bengal all the cyclones have intensified into severe cyclones, that means the possibility of getting a severe cyclone is more during the concurrent occurrence of La-Niña and negative IOD events.

Result and Discussion

From figure (1a), it is clear that both the cyclones have crossed the threshold for MTI, so it is clear that MTI is a conducive parameter for the intensification of these cyclones. From figure (1b), it is clear that both the cyclones have crossed the threshold for MTRH, hence MTRH is a conducive parameter for the intensification of cyclones over this basin during this period. From figure (1c), only one cyclone has crossed the threshold for LLRV, but for the other cyclones the magnitudes of LLRV were large so it is also a conducive parameter, for the intensification of these cyclones. From figure (1d), it is seen that no cyclones have crossed the threshold for LLC, so it is not a conducive parameter for the intensification of these cyclones. From figure (1e), it is clear that the magnitude of VWS is very less during this period, which helps the intensification of the cyclones over this basin during this period. It is concluded that all the parameters except LLC, are conducive for the intensification of cyclones over Arabian Sea during the concurrent occurrence of El-Niño and positive IOD events.

From figure (2a), it is clear that all the cyclones have crossed the threshold for MTI, so MTI is a conducive parameter for the intensification of these cyclones. From figure (2b), it is clear that all the cyclones have crossed the threshold for MTRH. The cyclones have formed at large magnitudes of MTRH, the magnitudes of MTRH is around (0.0 – 0.6) which is quite large. So MTRH is a conducive parameter for the intensification of these cyclones. From figure (2c), it is observed that only 4 cyclones have crossed the threshold for LLRV, and all the other cyclones have formed below $(0.5)x10^{-5}s^{-1}$. This means LLRV is not a conducive parameter for the intensification of these cyclones. From figure (2d), it is observed that no cyclones have crossed the threshold for LLC, all the cyclones have formed with magnitudes of LLC between [-2.0 to 0.0]$x10^{-5}s^{-1}$. This means that LLC is also not a conducive parameter for the intensification of these cyclones. From figure (2e), it is clear that, all the

cyclones have formed at very low magnitudes of VWS, this creates a favorable condition for the intensification of the cyclones, so VWS is a conducive parameter for the intensification of these cyclones.

From figure (3a), it is clear that both the cyclones have crossed the threshold for MTI, but from figure (3b), it is seen that only one cyclone has crossed the threshold for MTRH, and this cyclone has intensified into severe cyclone. From figure (3c), it is observed that one cyclone has formed at high magnitudes of LLRV, and the other cyclone has formed at low magnitudes of LLRV. The cyclone crossed the threshold for LLRV has intensified into severe cyclone. From figure (3d), it it is clear that both the cyclones have formed at low magnitudes of LLC, so LLC is not a conducive parameter. From figure (3e), it is observed that both the cyclones have formed at low magnitudes of VWS, so VWS is a conducive parameter. From this figure it is concluded that except LLC all the other parameters are conducive for the intensification of the cyclones over this basin during this period.

From figure (4a), it is clear that all the cyclones have crossed the threshold for MTI, so MTI is a conducive parameter for the intensification of these cyclones. From figure (4b), it is clear that all the cyclones have formed at very large magnitudes of MTRH, that means MTRH is a conducive parameter for the intensification of these cyclones. From figure (4c), it is seen that no cyclones have crossed the threshold for LLRV. All these cyclones have formed at an LLRV between [0.0 to 0.5]x$10^{-5}s^{-1}$. This means LLRV is not a conducive parameter for these cyclones. From figure (4d), it is seen that no cyclones have crossed the threshold for LLC. All the cyclones have formed at an LLC between [-2.0 to 0.0]x$10^{-5}s^{-1}$. This means that LLC is not a conducive parameter for the intensification of these cyclones. From figure (4e), it is clear that all the cyclones have formed at very low magnitudes of VWS, so this is a conducive parameter for the intensification of these cyclones. From this figure it is concluded that except LLRV and LLC, all the other parameters are conducive for the intensification of these cyclones over Bay of Bengal during the concurrent occurrence of La-Niña and negative IOD events.

Figure 1. Variations of Cyclogenesis parameters over AS during the co-occurence of El-Niño and Positive IOD events

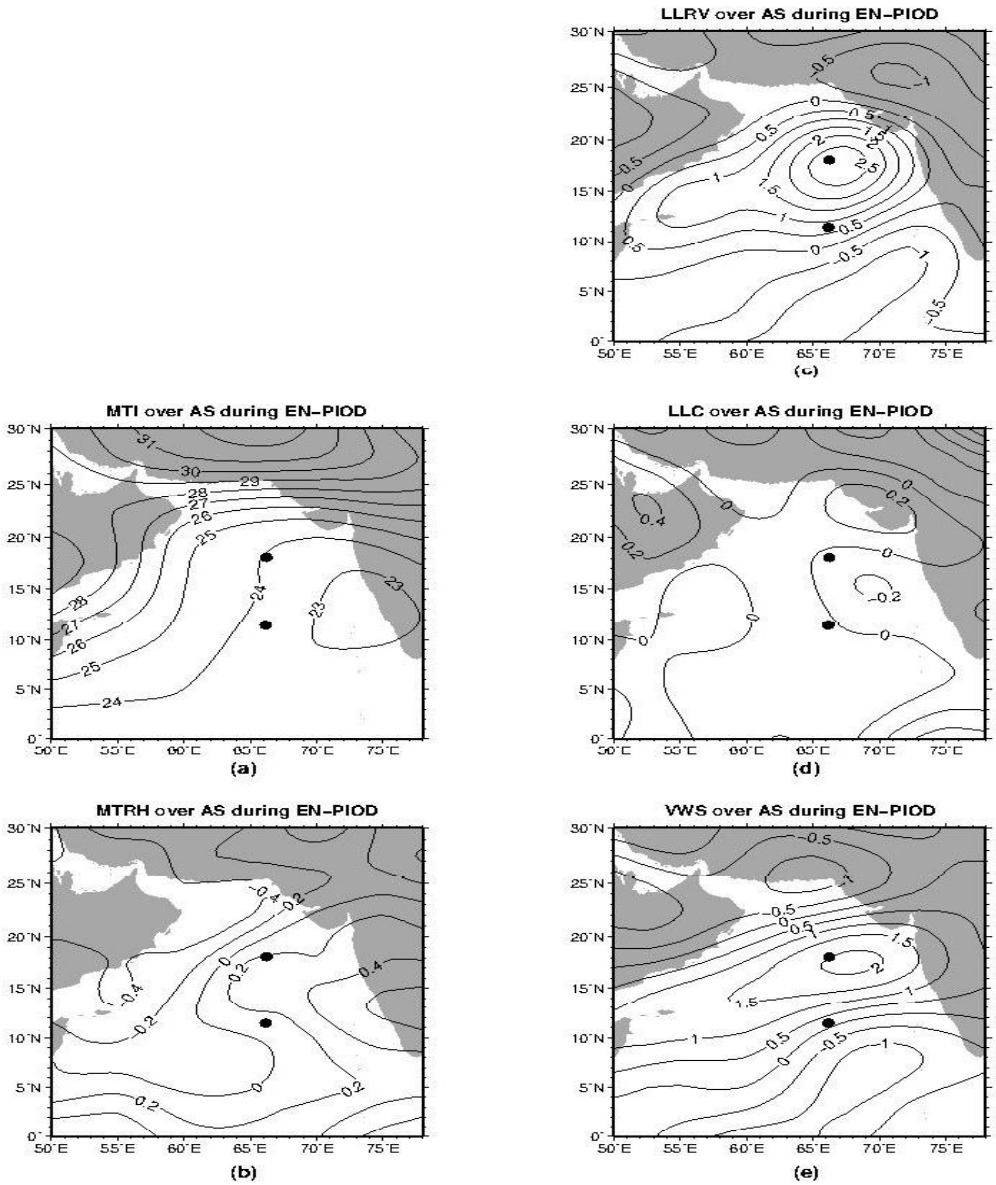


Figure 2. Variations of Cyclogenesis parameters over BB during the co-occurence of El-Niño and Positive IOD events

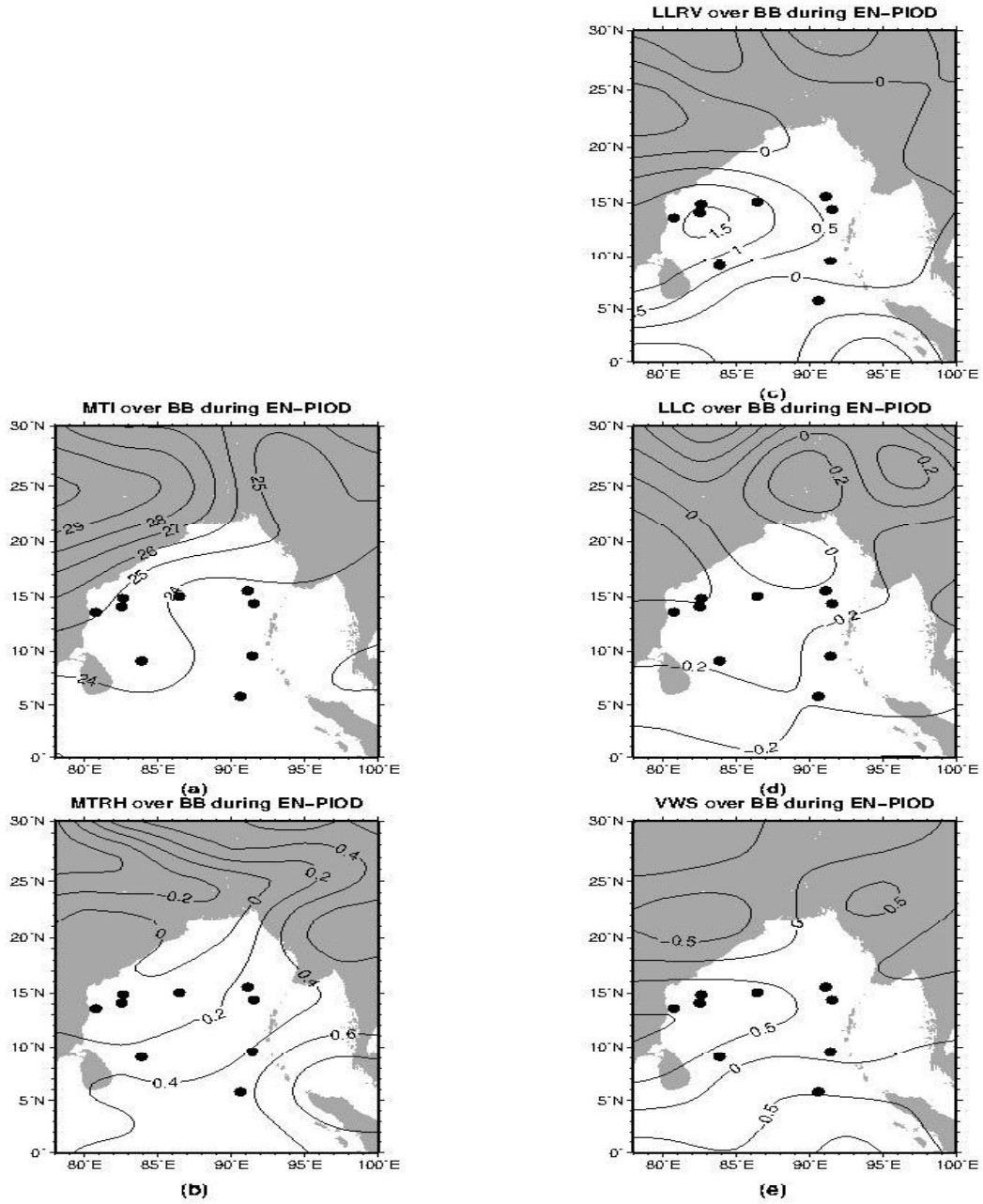


Figure 3. Variations of Cyclogenesis parameters over AS during the co-occurence of La-Niña and Negative IOD events

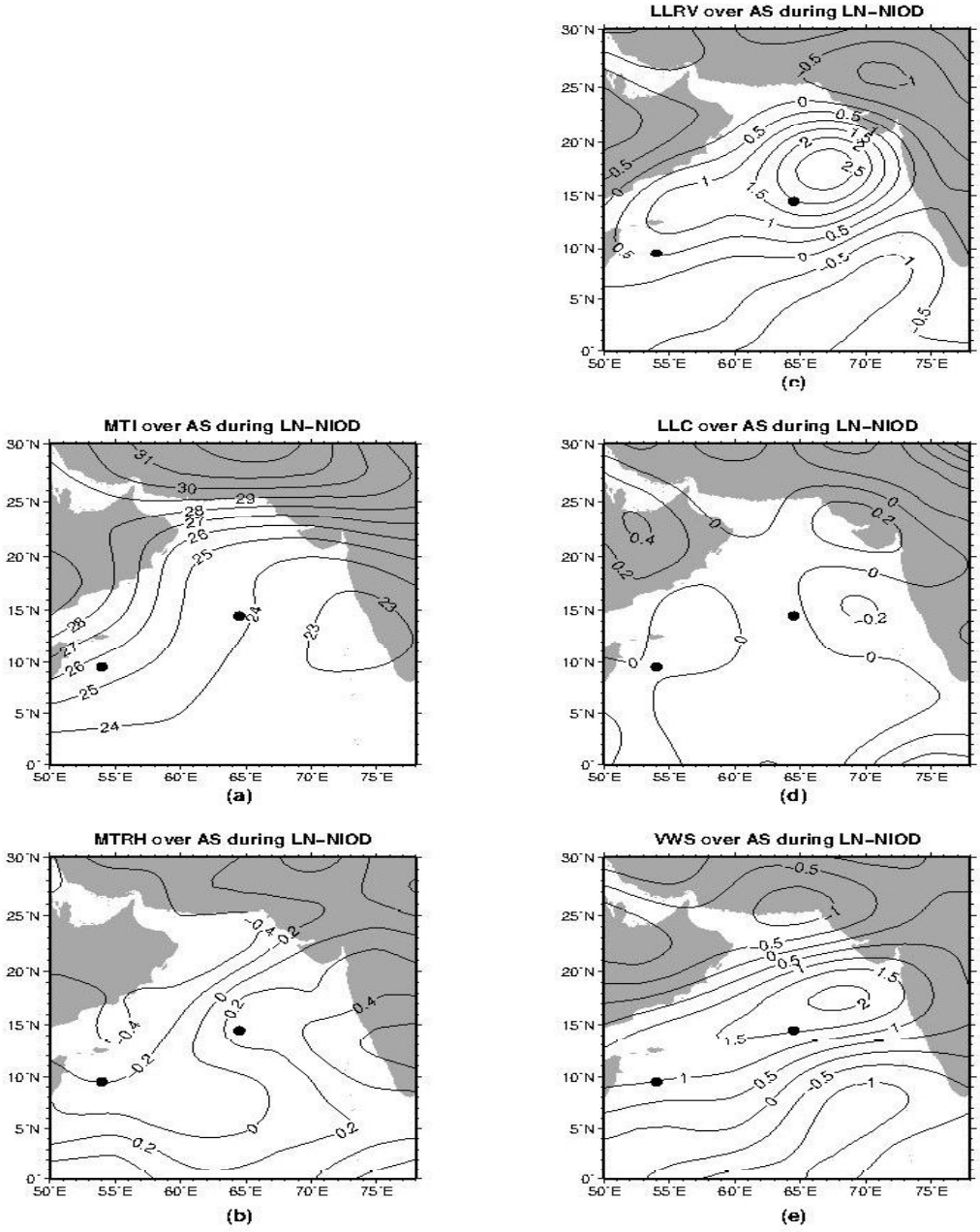
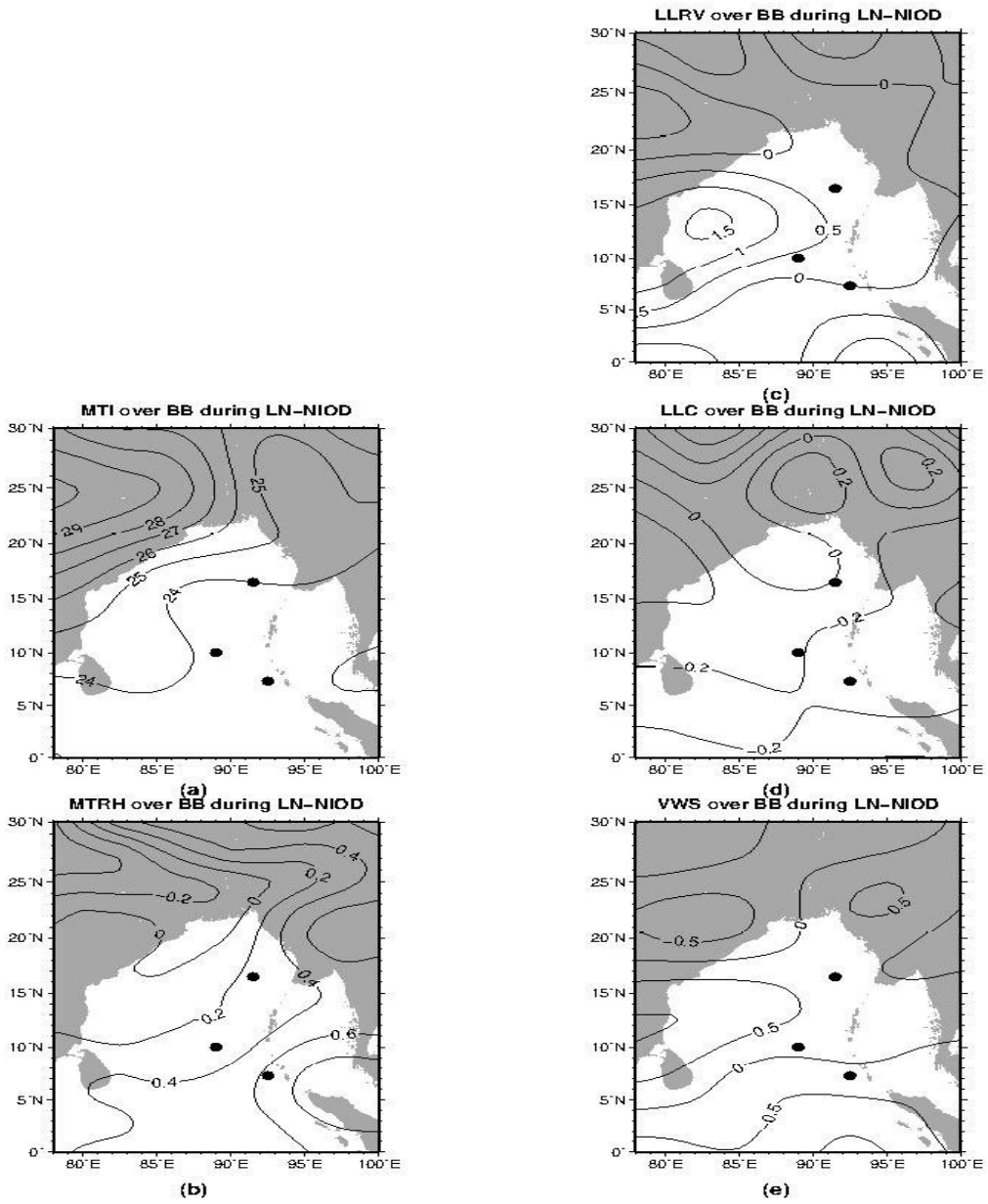


Figure 4. Variations of Cyclogenesis parameters over BB during the co-occurence of La-Niña and Negative IOD events



Summary

The combined influence of El-Niño and La-Niña events along with the IOD (both positive and negtive) events on the tropical cyclones over north Indian Ocean have been studied, the results show that the parameters such as MTI, MTRH and VWS are highly conducive for the formation and intensification of tropical cyclones over this basin. The magnitudes of MTI has crossed the threshold for all the combined events. The magnitudes of VWS were very low during all the events. It is observed that a very large magnitude of MTRH over Bay of Bengal during both the concurrent occurrence of El-Niño and positive IOD events and La-Niña and negative IOD events. But the magnitude of MTRH over Arabian Sea is found to be high during the concurrent occurrence of El-Niño and positive IOD events and, which is found to be low during the concurrent occurrence of La-Niña and negative IOD events. The other parameters such as LLRV and LLC are found to be not conducive for the intensification of the cyclones over these basins during these periods.

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