International Journal of Academic Research
ISSN: 2348-7666; Vol.5, Issue-6, June, 2018
Impact Factor: 6.023; Email: drtvramana@yahoo.co.in

Tropical cyclones over north Indian Ocean during normal and prolonged IOD years

K.G. Sumesh
Dept. of AgriculturalMeteorology
University of AgriculturalSciences, Dharwad,Karnataka-580005

Abstract *Positive Indian Ocean Dipole (IOD) events can exist in three different types over the tropical Indian Ocean, namely Normal IOD, Prolonged IOD and Unseasonal IOD. It can influence formation and intensification of tropical cyclones over north Indian Ocean (NIO). The strengthening of IOD activity is noticed during the post-monsoon (October-December) season. The influence of various air-sea interaction parameters on the formation and intensification of the cyclones and severe cyclones over this basin have been studied. Results show that the frequencies of severe cyclones are more over Bay of Bengal (BB) during the prolonged IOD and normal IOD years. The low magnitude of Low Level Convergence is observed over BB during all these periods and other cyclogenesis parameters like Low Level Relative Vorticity, Mid Tropospheric Instability, Mid Troposphric Relative Humidity and Vertical Wind Shear play significant role in the formation and the intensification of the cyclones over Bay of Bengal.*

Key words:- *Indian Ocean, Indian Ocean Dipole, air-sea interaction parameters*

Introduction

The Indian Ocean Dipole (IOD) event (Saji et al. 1999; Webster et al. 1999) is characterized by the anomalous warming and cooling of SST over the western and eastern equatorial Indian Ocean, this is a coupled ocean atmospheric process over tropical Indian Ocean and independent of the ENSO in the Pacific Ocean. There are two types of IOD events namely Positive IOD and Negative IOD. A positive IOD event is characterized as warmer than normal SSTs over the western tropical Indian Ocean and cooler than normal SSTs over eastern tropical Indian Ocean. A negative IOD event is characterized as cooler than normal SSTs over the western tropical Indian Ocean and warmer than normal SSTs over eastern tropical Indian Ocean. Both these IOD events have significant impacts on the formation and intensification of tropical cyclones over this basin.

Francis et.al (2009) shows that a Positive IOD event can be triggered by the occurrence of severe cyclones over Bay of Bengal. Sumesh and Ramesh (2013) states that the concurrent occurrence of El-Niño Modoki and positive IOD can produce more cyclones over NIO. Yan Du. et.al (2013) showed that there exists three different phases of positive IOD namely, the Unseasonal IOD (UNIOD), the Prolonged IOD (PRIOD) and the Normal IOD (NRIOD). This study further states that unlike the canonical IOD events, there will not be any ENSO activity in the Pacific Ocean immediately after the unseasonal IOD events, because of the IOD-favorable wind conditions. The frequency variations of the cyclonic storms and severe cyclonic storms during the prolonged IOD and normal IOD events have been studied.

Materials and Methods

The process of initiation of a cyclone is called cyclogenesis. Many authors have tried to quantify this cyclogenesis over various basins. Gray (1975) introduced six primary genesis parameters for tropical cyclone such as 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 $10^{-12}s^{-2}$. In this study Zehr has also found 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 ($1.05x10^{-}5S^{-1}$), low level convergence at 850 hPa is ($0.33x10^{-}5S^{-1}$) 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 threshold for Mid Tropospheric Instability is 23ºC and the threshold for the Mid Tropospheric Relative Humidity is 40% or 0. The cyclogenesis parameters used in this study are:

i) Low Level Relative Vorticity at 850 hPa LLRV = (∂v/∂x - ∂u/∂y)

ii) Low Level Convergence at 850 hPa LLC = - (∂u/∂x - ∂v/∂y)

(negative of low level divergence at 850hPa)

iii) $S = \text{Shear Coefficient} = \dfrac{[25.0\ mS^{-1} - (200 - 850\ SHEAR)]}{20\ ms^{-1}}$

iv) Middle Tropospheric Relative Humidity variable (M), $M = \dfrac{[RH-40]}{30}$

(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 variables 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 PRIOD and NRIOD 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 normal and prolonged IOD years

When we consider the frequencies of cyclones that formed over NIO we could see significant variations in the frequencies. Table (1 & 2) gives the variations in the frequencies of tropical cyclones formed over NIO during these periods. This shows that there are significant variations in the frequencies of tropical cyclones over this basin during the different types of IOD events. This means the frequencies of tropical cyclones over NIO are highly influenced by these various types IOD activities.

Table.1: Frequencies of tropical cyclones over over NIO during Normal IOD years

years	Arabian Sea		Bay of Bengal	
	Cyclonic storms	Severe cyclonic storms	Cyclonic storms	Severe cyclonic storms
1987	0	0	2	3
1997	0	0	1	2
2006	0	1	1	1
total	0 (0.0)	1 (0.33)	4 (1.33)	6 (2.0)

Table.2: Frequencies of tropical cyclones over over NIO during Prolonged IOD years

years	Arabian Sea		Bay of Bengal	
	Cyclonic storms	Severe cyclonic storms	Cyclonic storms	Severe cyclonic storms
1982	0	1	0	4
1994	0	2	0	2
total	0 (0.0)	3 (1.5)	0 (0.0)	6 (3.0)

From figure (1a), it is clear that the cyclone has formed above the threshold for MTI, it is influenced the cyclone in its intensification. So MTI is a conducive parameter for the cyclones over AS during the NRIOD years. From figure (1b), it is clear that the cyclone formed below the threshold for MTRH, it does not have any influence on its intensification, so MTRH is not a conducive parameter for the cyclones over AS during this period. From figure (1c), it is clear that the cyclone has crossed the threshold for LLRV, and it formed at a large magnitude of LLRV $(3.0)x10^{-5}S^{-1}$, this influenced the intensification of the cyclone, so LLRV is a conducive parameter for the cyclones over AS during this period. From figure (1d), it is observed that the cyclone did not crossthe threshold for LLC, it formed at LL between (0.0 to

0.2) x$10^{-5}S^{-1}$, this does not have any influence on this cyclone, so LLC is not a conducive parameter for the cyclones over AS during this period. From figure (1e), it is clear that the cyclone has formed at very low magnitudes of VWS, it influenced the intensification of the cyclone, so VWS is a conducive parameter fo0rf the cyclones over AS during the NRIOD years.

From figure (2a), it is observed that 6 cyclones have crossed the threshold for MTI, and 4 cyclones did not cross the threshold for MTI. Some cyclones which crossed the threshold remained as cyclonic storms and some cyclones which did not cross the threshold have intensified into severe cyclones. This means MTI is having no significant influence on the cyclones over BB for their intensification. So MTI is not a conducive parameter for the cyclonesover BB during this period.

From figure (2b), it is clear that all the cyclones have crossed the threshold for MTRH, and this influenced the intensification of these cyclones, hence MTRH is a conducive parameter for the cyclones over BB during this period. From figure (2c), it is observed that 5 cyclones have crossed the threshold for LLRV, and other cyclones did not cross the threshold for LLRV, there is no relationship between the magnitude of LLRV and the intensification of the cyclones over BB, so LLRV is not a conducive parameter for the cyclones over BB during this period. From figure (2d), it is observed that no cyclones have crossed the threshold for LLC, all the cyclones have formed at LLC between (-0.2 to 0.0) x$10^{-5}S^{-1}$. LLC does not have any influence on the intensification of the cyclones over BB, hence LLC is not a conducive parameter for the cyclones over BB during this period. From figure (2e), it is clear that all the cyclones have formed at very low magnitudes of VWS, which is very favorable situation for the formation and intensification of the cyclones, so VWS is a conducive parameter for the cyclones over BB during the NRIOD years.

From figure (3a), it is clear that all the cyclones have formed above the threshold of MTI, all of them have intensified into severe cyclones. So MTI is a conducive parameter for the cyclones over AS during the PRIOD years. From figure (3b), it is observed that no cyclones have crossed the threshold for MTRH, these cyclones have formed at MTRH between (-0.4 to 0.0). So MTRH is not a conducive parameter for the cyclones over AS during PRIOD years. Form figure (3c), it is observed that 2 cyclones out of 3 have crossed the threshold for LLRV, and the other cyclone formed at LLRV (0.5) x$10^{-5}S^{-1}$, it is also a large magnitude for LLRV. So LLRV is a conducive parameter for the cyclones over AS during PRIOD years. From figure (3d), it is observed that no cyclones have crossed the threshold for LLC, all the cyclones formed at LLC between (-0.2 to 0.0) x$10^{-5}S^{-1}$, so it is not a conducive parameter for the cyclones over AS during PRIOD years. From figure (3e), it is seen that all the cyclones have formed at very low magnitudes of VWS, it is a favorable condition for the cyclones over AS during these period.

From figure (4a), it is clear that all the cyclones have crossed the threshold for MTI, and all these cyclones have intensified into severe cyclones, so MTI is a conducive parameter for the cyclones over BB during the PRIOD years. From figure (4b), it is observed that out of 6 cyclones 4 have crossed the threshold for MTRH, but all the cyclones have intensified into severe cyclones, so MTRH is a conducive parameter for the cyclones over BB during this period. From figure (4c), it is observed that only two cyclones have crossed the threshold for LLRV, and other cyclones have formed at LLRV between (0.0 to 1.0) $x10^{-5}S^{-1}$, since all the cyclones have intensified into severe cyclones this is also a conducive parameter for the cyclones over BB during this period. From figure (4d), it is observed that no cyclones have crossed the threshold for LLC, all the cyclones have formed at LLC between (-0.2 to 0.0) $x10^{-5}S^{-1}$, since the magnitude is very less, there is no significant influence for LLC on the cyclones, so it is not a conducive parameter for cyclones over BB during this period. From figure (4e), it is clear that all the cyclones have formed at very low magnitudes of VWS, it is a favorable condition for the formation and intensification of cyclones, so VWS is a conducive parameter for the cyclones over BB during the PRIOD year.

Summary

The positive IOD events have significant impacts on the formation and intensification of tropical cyclones over NIO. This study states that the frequencies of tropical cyclones over NIO are highly variable during these NRIOD and PRIOD events. It further results that the frequencies of tropical cyclones are more in the PRIOD and NRIOD years. Even though these IOD events are in the positive phase a good number of tropical cyclones are formed over BB. A low magnitude of LLC is observed over BB, during all these periods and other cyclogenesis parameters like LLRV, MTI MTRH and VWS played significant role in the formation and the intensification of the cyclones over BB.

Acknowledgements

The author is grateful to the University of Agricultural Sciences, Dharwad and National Institute of Oceanography, Goa for providing all the facilities to carry out this research work. The author is thankful to India Meteorological Department, New Delhi for providing the cyclone e-Atlas. The author acknowledge the use of NCEP Re-Analysis -II daily data and free wares such as FERRET and GMT used in this research work.

References

Gray WM (1975) Tropical cyclone genesis. Dept of Atmos Sc Paper No. 232 Colorado State University Port Collins Co USA, p 121

Francis PA, Sulochana Gadgil, Vinayachandran PN (2007) Triggering of the positive Indian Ocean Dipole events by severe cyclones over the Bay of Bengal. Tellus 59A:461- 475

Kotal SD, Kundu PK, and Roy Bhowmik SK (2009) Analysis of cyclogenesis parameter for developing and non-developing low pressure systems over the Indian Sea. Nat Hazards (2009) 50:389–402. DOI 10.1007/s11069-009-9348-5

Roy Bhowmik SK (2003) An evaluation of cyclone genesis parameter over the Bay of Bengal using model analysis. Mausam (New Delhi) 54:pp. 351–358.

Saji NH, Goswami BN, Vinayachandran PN, Yamagata T (1999) A dipole mode in the tropical Indian Ocean. Nature 401:360-363

Sumesh KG and Ramesh Kumar MR (2013) Tropical cyclones over north Indian Ocean during El-Nino Modoki years, Nat Hazards, doi:10.1007/s11069-013-0679-x.

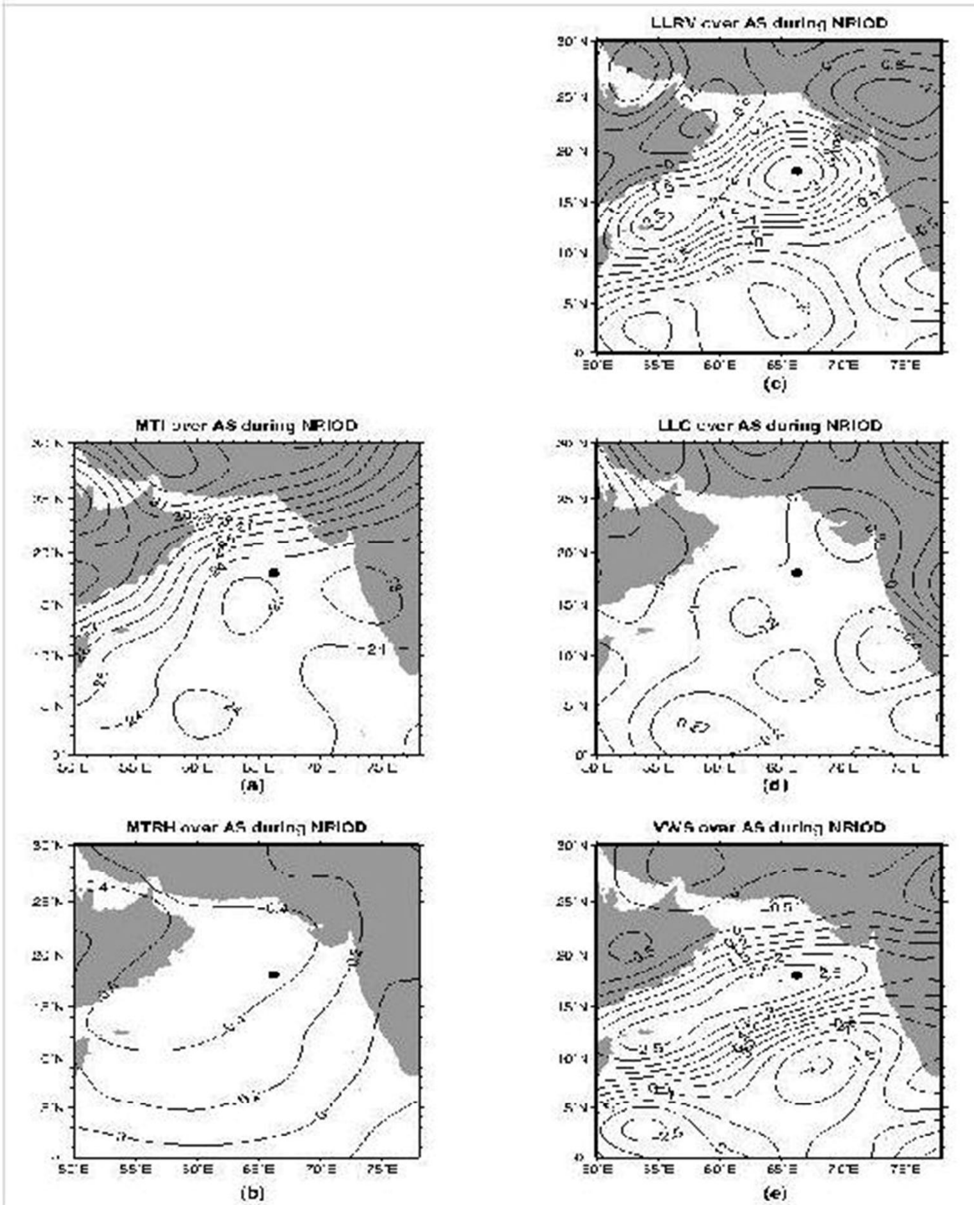
Webster PJ, Moore AM, Loschnigg JP, Leben RR (1999) Coupled Oceanic-Atmospheric dynamics in the Indian Ocean during 1997-98. Nature 401: 356-360

Yan Du, Wenju Cai, Yanling Wu (2013) A new type of the Indian Ocean Dipole since the mid-1970s. Journal of Climate, DOI: 10.1175/JCLI-D-12-00047.1, pp. 959-972

Zehr RM (1992) Tropical cyclogenesis in the western north Pacific. NOAA Tech. Rep. NESDIS 61, 181pp

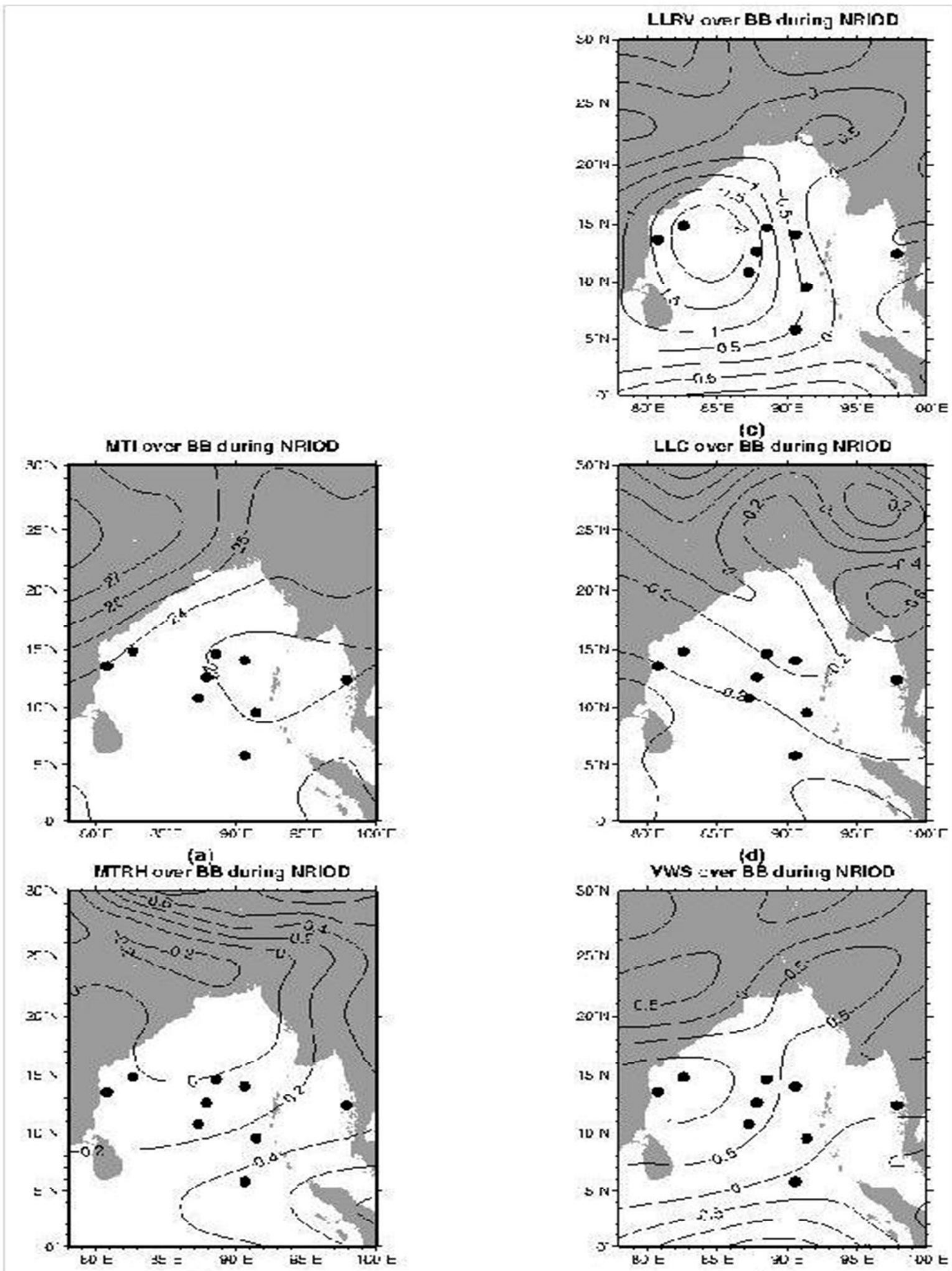
International Journal of Academic Research
ISSN: 2348-7666; Vol.5, Issue-6, June, 2018
Impact Factor: 6.023; Email: drtvramana@yahoo.co.in

igure 1. Variations of cyclogenesis parameters over AS during NRIOD years



International Journal of Academic Research
ISSN: 2348-7666; Vol.5, Issue-6, June, 2018
Impact Factor: 6.023; Email: drtvramana@yahoo.co.in

Figure 2. Variations of cyclogenesis parameters over BB during NRIOD years



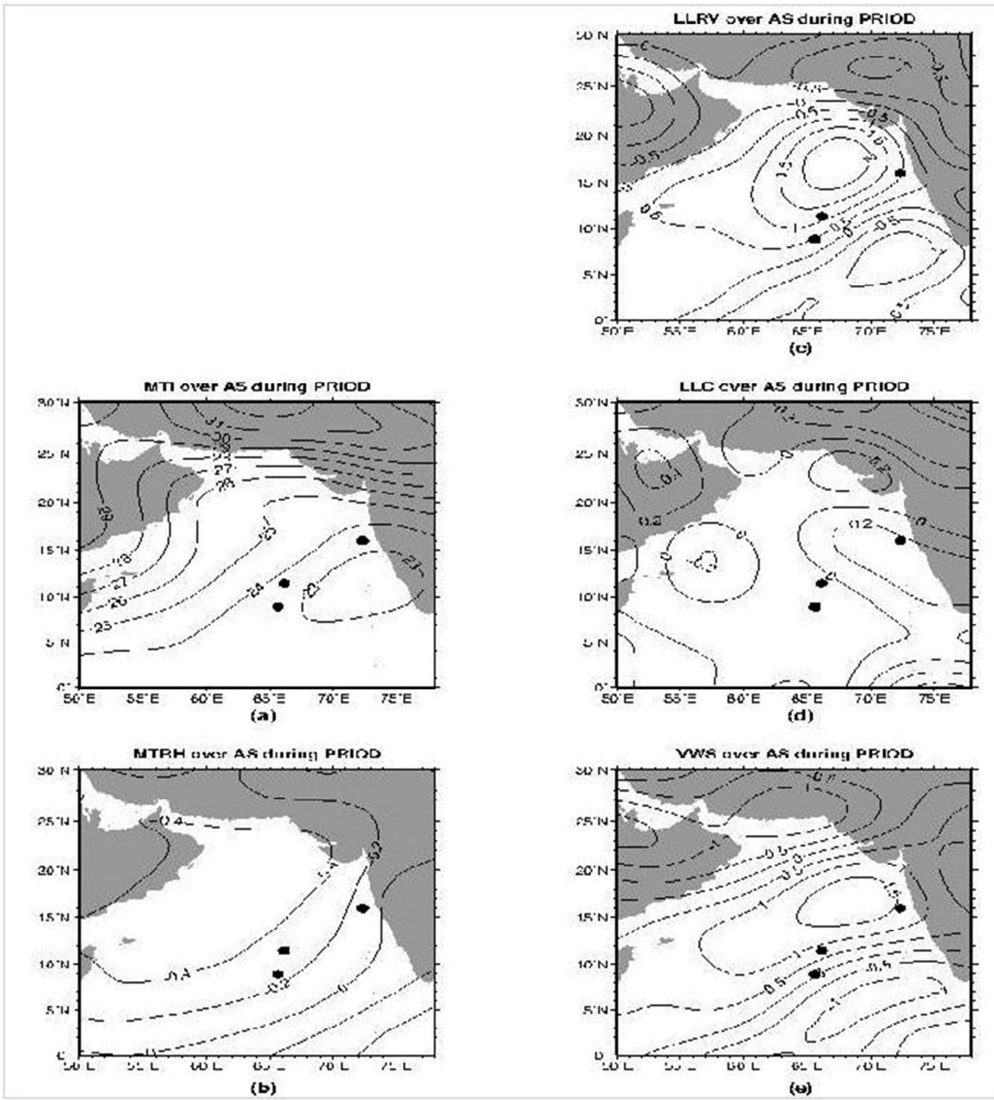


Figure 3. Variations of cyclogenesis parameters over AS during PRIOD years

Figure 4. Variations of cyclogenesis parameters over BB during PRIOD years