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Variability of convective activity over the Bay of Bengal and the Arabian sea

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सार — इस शोध में उत्तरी हिंद महासागर में संवहनी गतिविधि की मौसमी और अन्तः वार्षिक भिन्नता की जाँच करने का प्रयास किया गया है। इस शोध–पत्र में 26 वर्षों की अवधि के लिए (1979 से 2004 तक) राष्ट्रीय महासागरीय और वायुमंडलीय प्रशासन (एन. ओ ए. ए.) ध्रुवीय कक्षीय अंतरिक्षयान से प्राप्त किए गए मासिक माध्य बहिर्गामी दीर्घतरंग विकिरण (ओ. एल. आर.) का उपयोग किया गया है। इस अवधि को 13–13 वर्षों की अवधि के लिए, पहली अवधि 1979 से 1991 और दूसरी अवधि 1992 से 2004 तक के दो समूहों में बाँटा गया है। इस शोध पत्र में चार ऋतुओं [शीतकालीन, जनवरी–फरवरी (जे. एफ.), पूर्व मानसून मार्च– मई (एम. ए. एम.) , मानसून ऋतु, जून– सितम्बर (जे. जे. ए. एस.) और पश्च मानसून, अक्तूबर–दिसम्बर (ओ. एन. डी.)] के दौरान इनके रैखिक प्रवृत्तियों के विश्लेषण सहित संवहनी गतिविधि के मासिक और मौसम भिन्नता को प्रस्तुत किया गया है।

पहली अवधि और दूसरी अवधि के मध्य शीतकालीन ऋतु में मौसमी ओ. एल. आर. विसगतियों में पाई गई भिन्नता से यह पता चला है कि दक्षिणी अरब सागर और दक्षिणी बंगाल की खाड़ी में पहली अवधि की तुलना में हाल ही की अवधि (दूसरी अवधि) के दौरान संवहनी गतिविधि में वृद्धि हुई है तथा उत्तरी और मध्य अरब सागर (क्रमश : 99.9 प्रतिशत स्तर और 99 प्रतिशत स्तर) में संवहनी गतिविधि में उल्लेखनीय रूप से कम होती हुई प्रवृति से संबद्ध शेष क्षेत्रों में ठीक इसके विपरीत स्थिति का पता चला है। एम. ए. एम. के दौरान मध्य बंगाल की खाड़ी (99 प्रतिशत स्तर) और उत्तरी बंगाल की खाड़ी (95 प्रतिशत स्तर) में संवहनी गतिविधि में उल्लेखनीय रूप से वृद्धि की प्रवृति सहित पूर्व अवधि की तुलना में वर्तमान अवधि के दौरान बंगाल की खाड़ी और अरब सागर के पूर्वी भाग अपेक्षाकृत अधिक संवहनी पाए गए है मानसून ऋतु के दौरान पूर्व अवधि की अपेक्षा हाल की अवधि में मुख्य रूप से अरब सागर के दक्षिणी भागों (जुलाई के माह में प्रभावी) और दक्षिणी तथा पूर्वी बंगाल की खाड़ी के कुछ भागों में संवहनी गतिविधि बढी है और यह उत्तरी बंगाल की खाड़ी में संवहनी गतिविधि की उल्लेखनीय रूप से बढती हुई प्रवृति (95 प्रतिशत स्तर पर) के साथ संबंद्ध है। पश्च मानसून ऋतु से दक्षिणी अरब सागर में संवहनी गतिविधि में उल्लेखनीय रूप से (95 प्रतिशत स्तर पर) बढ़ती हुई प्रवृति का भी पता चला है।

ABSTRACT. The present study is an attempt to examine seasonal and interannual variability of convective activity over the north Indian Ocean. The monthly mean Outgoing Long-wave Radiation (OLR) data obtained from National Oceanic and Atmospheric Administration (NOAA) polar orbiting spacecraft are used in this study for a period of 26 year (1979 to 2004). The period has been divided into two groups of 13 years each with period (*i*) from 1979 to 1991 and period (*ii*) from 1992 to 2004. The monthly and seasonal variation of convective activity along with its linear trends analysis during four seasons [winter, Jan-Feb (JF); pre-monsoon, Mar-May (MAM); monsoon, Jun-Sep (JJAS); & post-monsoon, Oct-Dec (OND)] are performed.

The difference of seasonal OLR anomalies in winter season between period (*ii*) & period (*i*) indicate increase in convective activity during recent period [period (*ii*)] compared to that of period (*i*) over the south Arabian Sea & south Bay of Bengal and just the opposite occurred over the rest regions associated with a significant decreasing trend of convective activity over the north and central Arabian Sea (at 99.9% level and 99% level respectively). During MAM the Bay of Bengal and the eastern part of Arabian Sea are relatively more convective during the recent period compared to the former period with significant increasing trend of convective activity over central Bay of Bengal (99% level) and northern (95% level) Bay of Bengal. The convective activity increases mainly over the southern parts of the Arabian Sea (dominated in the month of July) and some parts of southern and eastern Bay of Bengal in recent period compared to that of former period during the monsoon season and is associated with significant increasing trend (at 95 % level) of convective activity over the north Bay of Bengal. The post monsoon season also shows significant (at 95% level) increasing trend in convective activity over south Arabian Sea.

Key words − Outgoing Long-wave Radiation (OLR), Convection, Bay of Bengal, Arabian sea, North Indian Ocean.

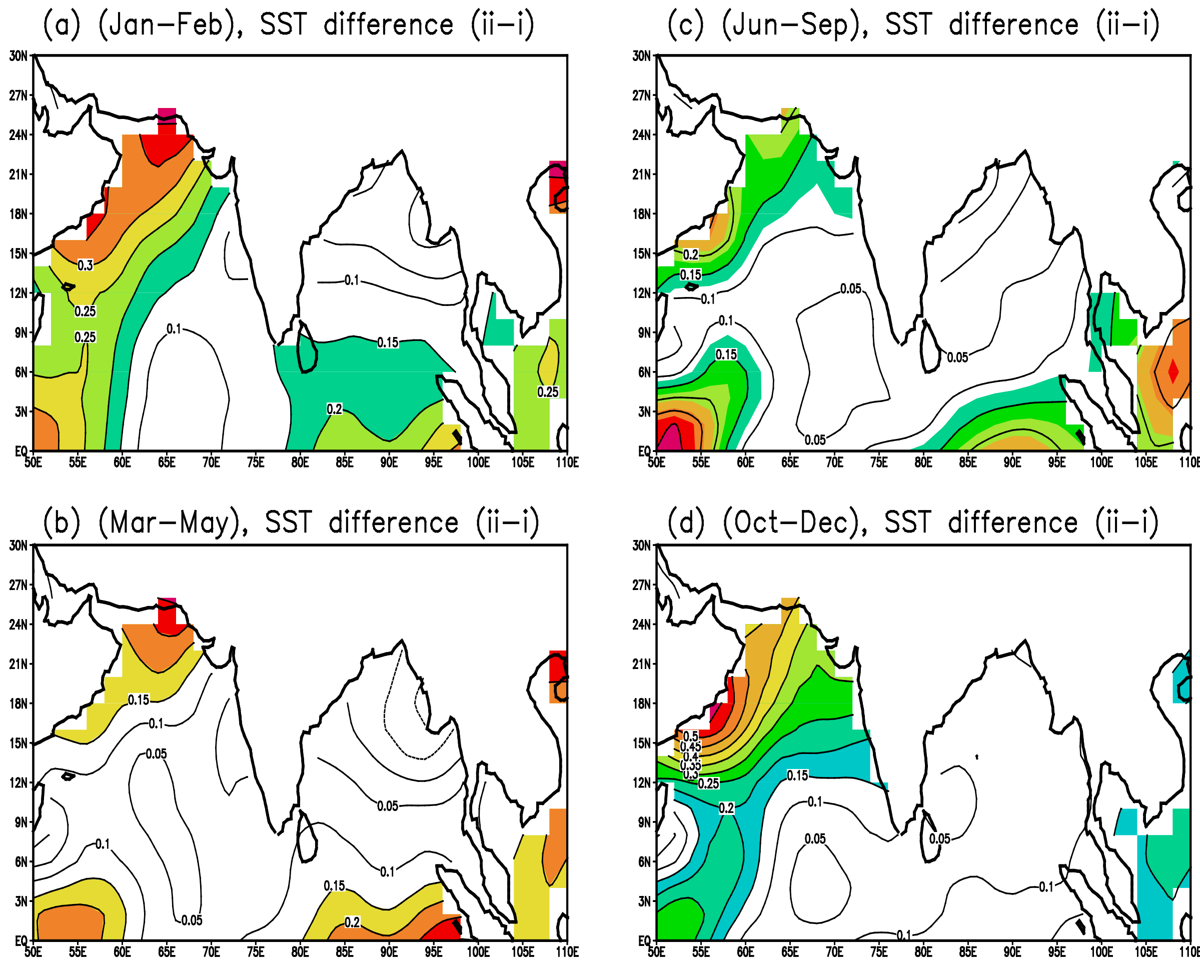
1. Introduction

The Indian monsoon variability on sub seasonal scales and on interannual scales is linked to variation of the convective systems over the ocean, where variability in turn depends on the Sea Surface Temperature (SST) through complex relationship. Several earlier studies (Sperber and Palmer 1996 and Webster *et al*., 1998) demonstrate the significance of the Indian Ocean SST and associated convective activity in influencing the monsoon. One of the most intense heat source regions in the global tropics is the Bay of Bengal located within the Indian Ocean. The convective precipitation and associated release of latent heat of condensation in this region drive a large portion of the global tropics and mid-latitudes (Krishnamurti & Surgi 1987; Lau & Chang 1987). The relationship between SST and Outgoing Long-wave radiation (OLR), an indicator of convection were discussed more than half a century ago by many researchers (Palmen, 1948; Bjerkness 1969). Palmen (1948) suggested that SST has to be above a threshold of 26.5° C for tropical disturbances to intensify to tropical cyclones or hurricanes. Bjerknes (1969) showed that the variation of convection over the tropical Pacific could be attributed to variations of SST. Studies on the variation of tropical convection over oceans with SST, based on different measures of organized deep convection such as cloudiness intensity, OLR and the frequency of Highly Reflective Clouds (HRC) has indicated a similar and highly non-linear relationship (Graham and Barnett, 1987; Zhang, 1993). Systematic investigation of variation of convection and its relationship with SST became possible only after the availability of satellite data.

On inter-decadal time scales, the tropical climate system experiences secular changes in recent time. One such climate shift occurred in 1976 and is characterized by significant changes in the structure and evolution of El Nino-Southern Oscillation (Trenberth 1990; Graham 1994; Wang 1995). The role of the Indian Ocean gradients of SST within the oceans are important in determining the location of precipitation over the Tropics, including the monsoon regions (Lindzen and Nigam 1987). It has been seen from the very recent study (Wang, 1995; Rajeevan *et al*., 2000; Pattanaik, 2005) that the SST over the Bay of Bengal region and equatorial Indian Ocean region is showing increasing tendency. Wang (1995) had shown a rapid transition from the cold to warm state of the Indian Ocean in the late 1970s. Rajeevan *et al.*, (2000) have also shown that over the equatorial Indian Ocean, till the early 1980s, SSTs have shown a sharp increase, which continued steadily thereafter. Nitta & Yamada (1989) used OLR as an index of tropical convective activity to investigate decadal variations of atmospheric circulations in the global tropical belt. Pattanaik *et al*., (2005a) has shown that the convective activity increases in the month of May over the Arabian Sea and the Bay of Bengal to the south of 25° N during the early onset year of 2004, whereas, during late onset year of 2003, the convective activity over the Arabian Sea is quite less compared to that of early onset year of 2004. With the important role of the Indian Ocean in the global climate system, it is desirable to know if there is any observable climate change during recent years. So in the scenario of increasing SST the question is how the convective activity varies over the Indian Ocean? Thus, the objective of the present study is to see how the convective activity varies interannually and also on longer time scale during different seasons over the north Indian Ocean (Bay of Bengal and Arabian Sea) particularly after the availability of satellite data (1979 onwards).

2. Data and methodology

The interpolated OLR data in 2.5° × 2.5° latitude-longitude grid measured from Advanced Very High Resolution Radiometers aboard National Oceanic and Atmospheric Administration (NOAA) polar orbiting spacecraft down loaded from the web site at http://www.cdc.noaa.gov/ for a period of 26 year are used in this study from January 1979 to December 2004. The SST data for the same period has been obtained from NOAA extended SST data set available from the NCEP. As pointed out by (Gruber and Krueger 1984) the local equatorial crossing time of the satellites have changed over the years. This in turn can cause some regional biases (Waliser & Zhou, 1997 and Lucas *et al*., 2001). The data are corrected by removing a statistically derived synthetic eigenvector that is associated with each of the equatorial crossing time bias modes. This synthetic eigenvector is used instead of the exact values of the satellite bias eigenvector to ensure that only the artificial variability is removed from the dataset (Lucas *et al*., 2001). There are also missing grids and missing values of OLR within grids basically due to satellite problems, archival problems or incomplete global coverage. A continuous data series is prepared by filling these gaps with temporal and spatial interpolation to minimize the



Figs. 1(a-d). Difference of seasonal SST anomalies during period (*ii*) (1992-2004) & period (*i*) (1979-1991) during (a) winter (JF), (b) pre-monsoon (MAM), (c) monsoon (JJAS) and (d) post monsoon season (OND). The difference more than 0.15° C is shaded

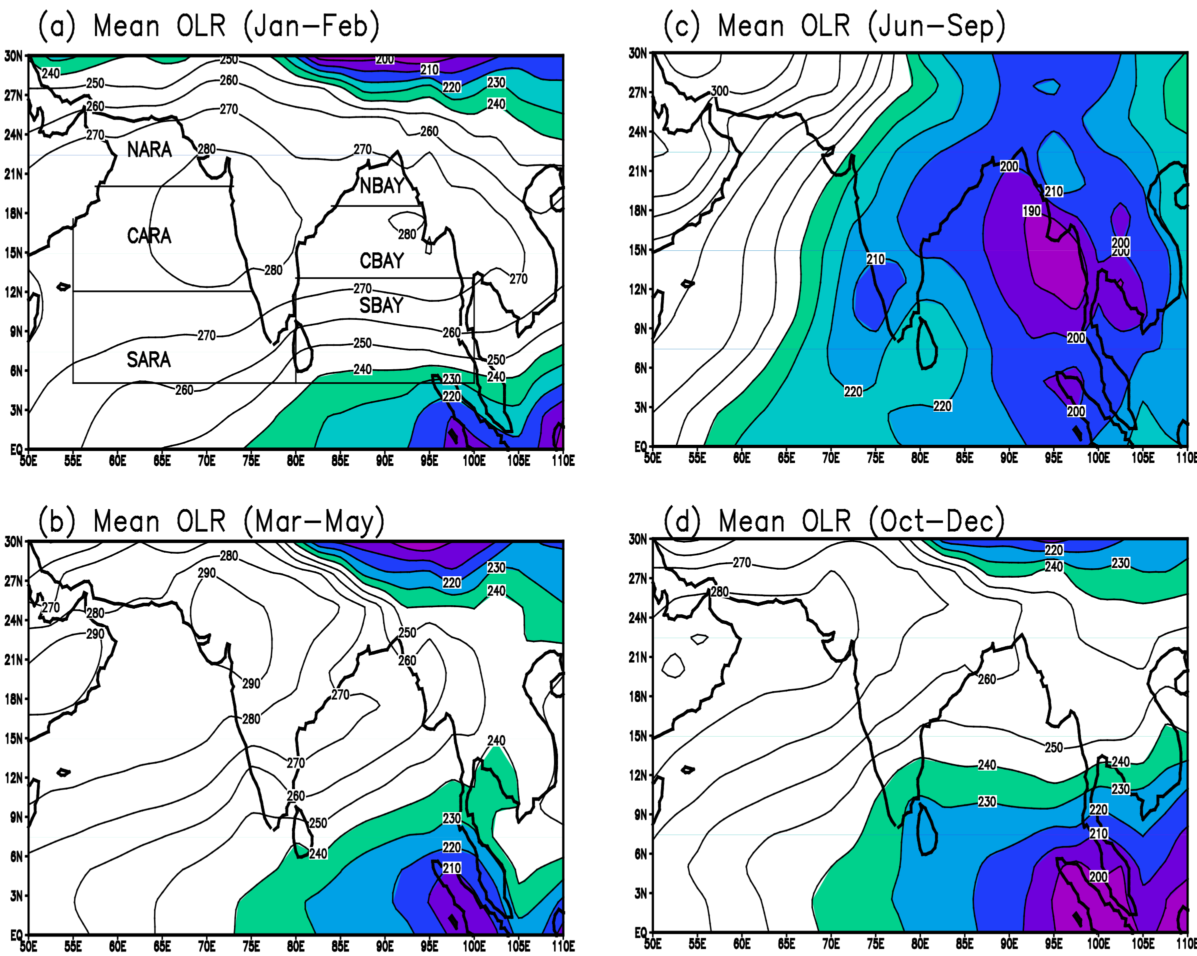
distance in space or time over which a value is interpolated. The details of the interpolation technique is available in Liebmann and Smith (1996).

In order to analyse the seasonal variation of convective activity, the seasons are identified as winter from Jan-Feb (JF), pre-monsoon from Mar-May (MAM), monsoon from Jun-Sep (JJAS) & post-monsoon from Oct-Dec (OND). In order to analyse the tendency of seasonal SST and OLR pattern over the north Indian Ocean the same 26 years period considered for the study of convective activity has been divided into two groups of 13 years each with period (*i*) (1979 to 1991) and period (*ii*) (1992 to 2004). A comparison of convective activity is performed by taking difference of OLR anomalies between these two periods.

3. Results and discussions

3.1. *Longer period change of SST over the north Indian Ocean*

Before the analysis of the seasonal variation of OLR anomalies over the north Indian Ocean is done, it is necessary to examine the tendency of SST patterns in recent time as the SST and convections are intermittently liked with each other. Many earlier studies in the recent past (Wang, 1995; Rajeevan *et al*., 2000; Pattanaik, 2005) have indicated increasing tendency of SST over the north and equatorial Indian Ocean in recent time. During the period of our present study the difference of SST anomalies is calculated between the recent period [period (*ii*); 1992 to 2004] to former period [period (*i*); 1979 to

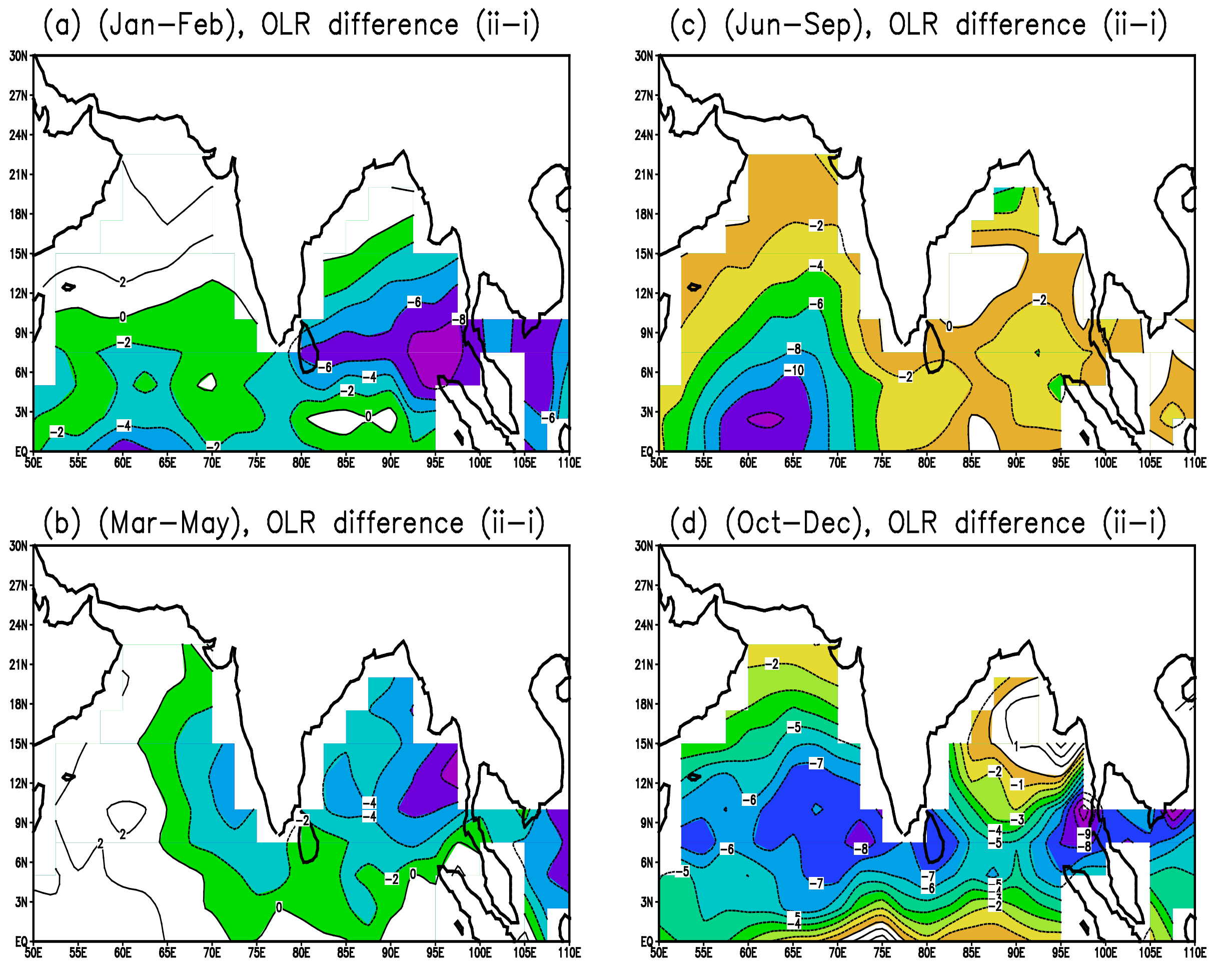


Figs. 2(a-d). Seasonal long-term mean (1979-2004) Outgoing Longwave Radiation (OLR) during (a) winter (Jan-Feb), (b) pre-monsoon (Mar-May), (c) monsoon (Jun-Sep) & (d) post monsoon season (Oct-Dec). The shaded regions are OLR with value less than 240 watts/m^2

1991] in all the four seasons [Figs. 1(a-d)]. The climatological mean considered was from 1971 to 2000. It is seen from Figs. 1 (a-d) that the SST over the north Indian Ocean is slightly higher during the recent period compared to the former period during all the four seasons, which is indicated by positive difference over all most the entire north Indian Ocean with maximum of the order of 0.5° C in western Arabian Sea during post monsoon season (OND). Though the difference of SST anomalies during these two periods is very small, the positive values over most parts of the north Indian Ocean shown in Fig. 1 indicate higher SST during recent period [period (*ii*)] compared to earlier period [period (*i*)] .

3.2. *Seasonal mean convective activity over the north Indian Ocean*

The OLR (a proxy for deep convection) is being used widely for the monsoon research (Webster, 1995; Krishnan *et al*., 2000; Gadgil *et al*., 2004; Pattanaik *et al*., 2005a & Pattanaik *et al*., 2005b). Gadgil *et al*., (2004) have suggested a possible link between the variation of deep convection over the equatorial Indian Ocean and monsoon rainfall by examining the OLR data over the Indian Ocean. The seasonal long-term (1979 to 2004) mean OLR during the four seasons mentioned above is shown in Figs. 2(a-d). The mean OLR pattern shows that the locus of OLR minima (say, OLR value less than 240 watts/m^2) lies mainly over the Andaman Sea and southeast Bay of Bengal during winter, pre-monsoon and post-monsoon seasons, whereas, during monsoon season (JJAS) it lies almost over the entire Bay of Bengal, Andaman Sea and parts of southeast Arabian Sea in the north Indian Ocean. Though it is very difficult to give a cut off value of OLR to delineate the areas of convection and no-convection the OLR value of 240 watts/m^2 is considered in the present study to distinguish more and less convective areas depending on whether the OLR

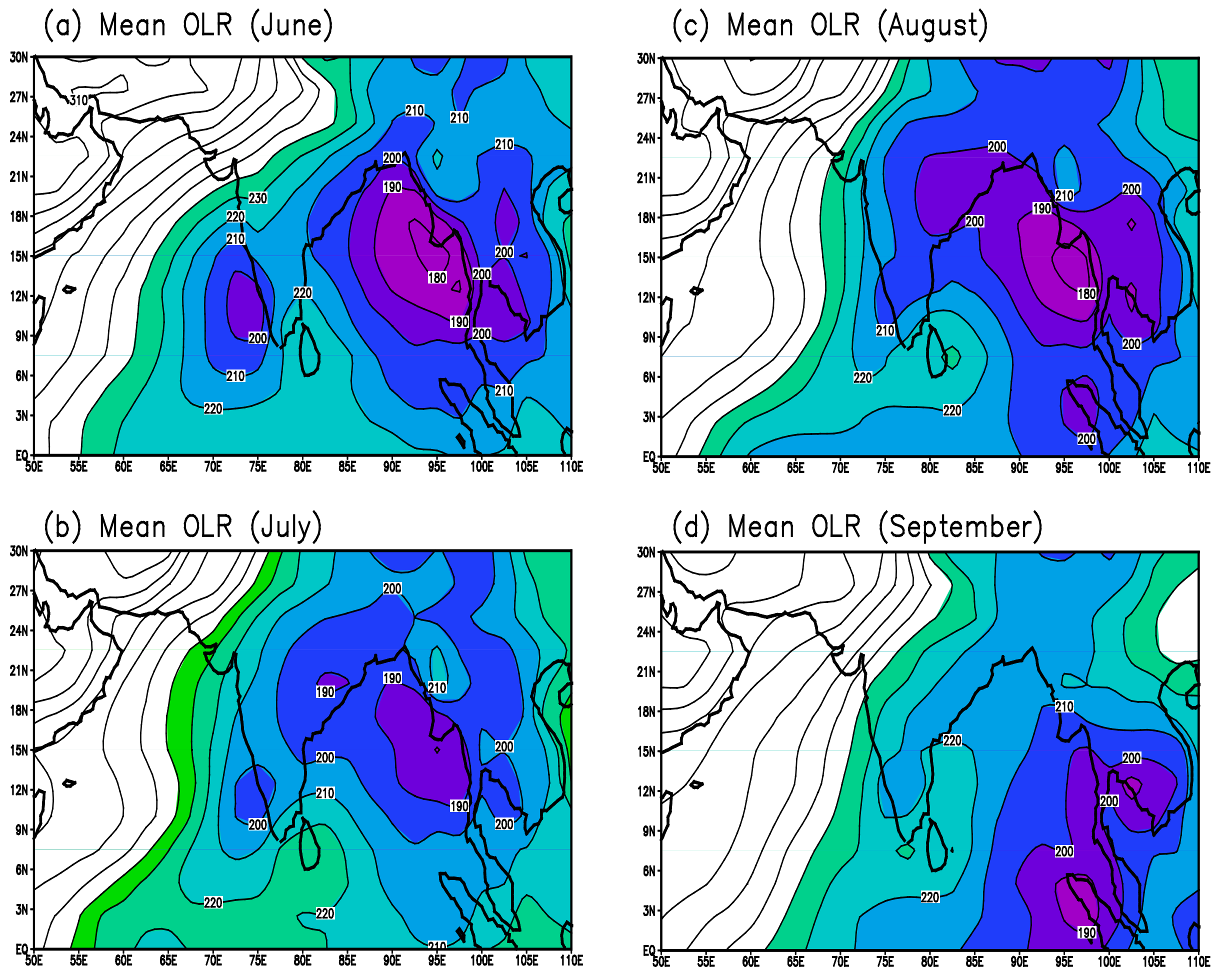


Figs. 3(a-d). Difference of seasonal OLR anomalies during (watt/m^2) period (*ii*) (1992-2004) & period (*i*) (1979-1991) during (a) winter (JF), (b) pre-monsoon (MAM), (c) monsoon (JJAS) & (d) post monsoon season (OND). The negative values are shaded

value is less or higher than 240 watts/m^2 respectively. It is also seen from Figs. 2(a-d) that the less convective areas with OLR more than 240 watts/m^2 are observed over almost the entire Arabian Sea and most parts of the Bay of Bengal during winter, pre-monsoon and post monsoon seasons and over the western Arabian Sea during the monsoon season.

3.3. *Longer period change of convective activity over the north Indian Ocean*

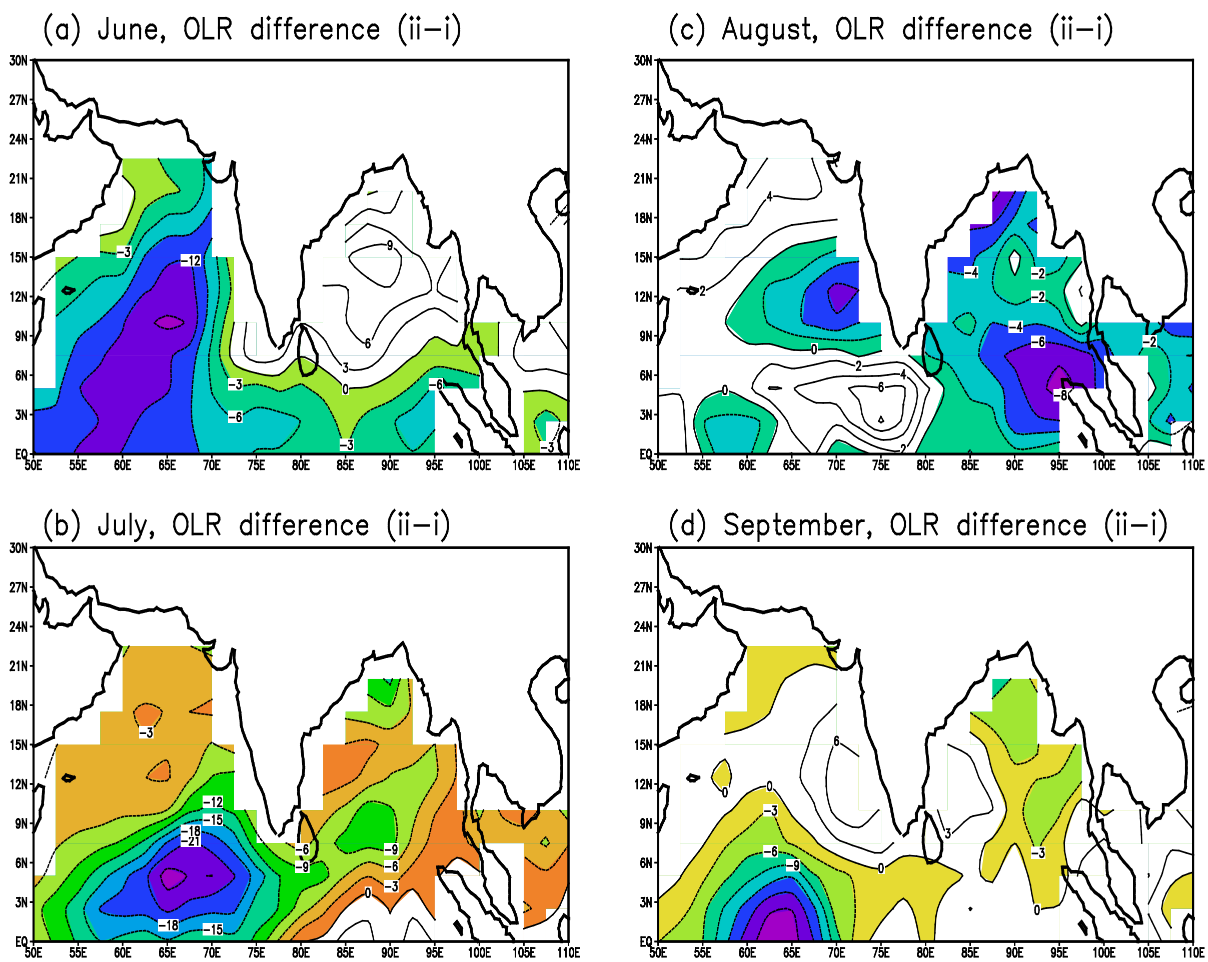
In order to analyse the longer period change of convective activity over the north Indian Ocean the difference in OLR anomalies during the 13 year periods between period (*ii*) and period (*i*) over the north Indian Ocean region (grid points over the oceanic region only) is shown in Figs. 3(a-d). Though the mean convective activity during the winter season (JF) is very less as indicated by higher mean OLR in Fig. 2(a) the negative difference of OLR over the southern part of Bay of Bengal and Arabian Sea [shown in Fig. 3(a)] indicates slight increase of convective activity during recent period compared to earlier period and just the opposite over the other regions. Similarly during pre-monsoon season (MAM) the Bay of Bengal and the eastern part of Arabian Sea are more convective during the recent period compared to the former period as indicated by the negative difference over the region [Fig. 3(b)] and just the reverse occurred in other regions. During the monsoon season [Fig. 3(c)] the difference is negative over most parts of the Arabian Sea and the Bay of Bengal except some parts of southeast Bay of Bengal off Andhra coast, where it is slightly positive. The magnitude of negative



Figs. 4(a-d). Mean seasonal OLR during (a) winter (Jan-Feb), (b) pre-monsoon (Mar-May), (c) monsoon (Jun-Sep) & (d) post-monsoon (Oct-Dec) season. The values <240 watts/m^2 are shaded

anomaly is very large over the Arabian Sea (of the order of –12 watts/m^2) compared to that over the Bay of Bengal during the monsoon season. Thus, the convective activity increases over many parts of the Arabian Sea and the Bay of Bengal in recent period compared to that of former period during the monsoon season with relatively stronger negative difference of OLR anomalies between the recent period and the earlier period over the Arabian Sea than that over the Bay of Bengal [Fig. 3(c)]. Increase of convective activity over the equatorial Indian Ocean was also indicated earlier by Chu and Wang (1997) during the monsoon season associated with decreasing trends of OLR. During the post monsoon season (OND) the convective activity increases during the recent period compared to that of former period over the Arabian Sea and the Bay of Bengal except some parts of east central Bay of Bengal [Fig. 3(d)].

As the convective activity during the southwest monsoon season over the Bay of Bengal and the Arabian Sea regions is linked with the monsoon activity over India, the variability of convective activity during the monsoon season (JJAS) on monthly scale has been analysed. The climatological mean OLR in monthly scale from June to September is shown in Figs. 4(a-d). With the arrival of southwest monsoon the convective activity increases over the Arabian Sea [Fig. 4(a)] and subsequently the convective area moves northward and cover the large parts of Indian sub-continent during the active monsoon months of July and August [Figs. 4(b &c)]. During September [Fig. 4(d)] the southward retreat of OLR minima begins with an increase in OLR value over the India region, indicating withdrawal of monsoon. On monthly scale during the monsoon season from June to September the difference of OLR anomalies between

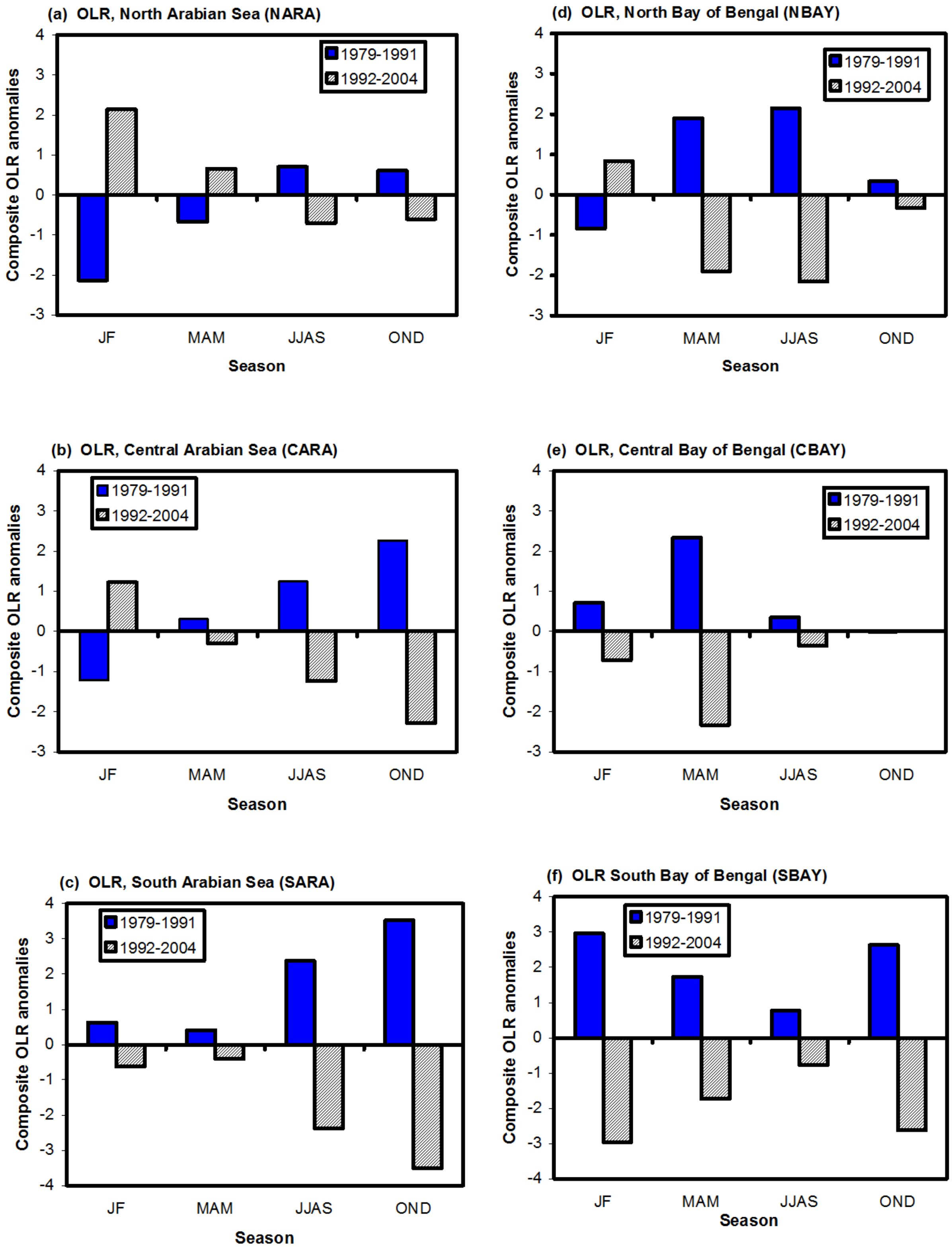


Figs. 5(a-d). Difference of monthly OLR anomalies (watts/m^2) during period (*ii*) (1992-2004) & period (*i*) (1979-1991) for (a) June, (b) July, (c) August & (d) September. The negative values are shaded

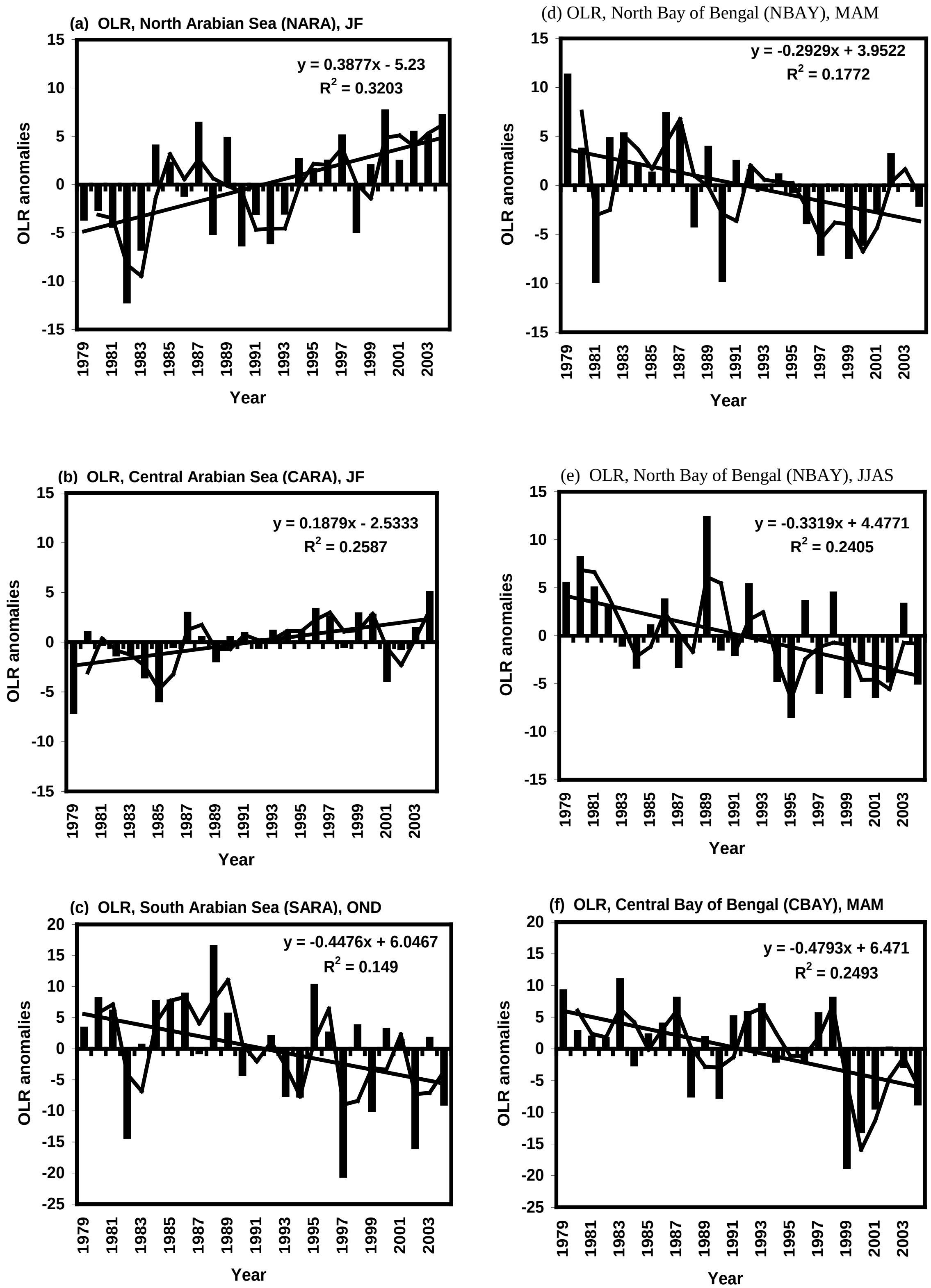
period – (*ii*) and period – (*i*) is shown in Figs. 5(a-d). The month of June (onset phase) shows very strong convection over the Arabian Sea during recent period compared to that of former period as indicated by the negative difference [Fig. 5(a)], whereas, over the Bay of Bengal (almost to the north of 5° N) the convective activity decreases during the onset phase of June in recent time compared to that of former period as indicated by the positive difference. During the month of July [Fig. 5(b)] the oceanic convection increases in recent times with comparatively stronger convective activity over the Arabian Sea compared to that of the Bay of Bengal. During August [Fig. 5(c)] the Bay of Bengal is more active compared to the Arabian Sea in recent period compared to the former period. During the withdrawal phase of September the convective activity increases over the southern Arabian Sea and eastern part of Bay of Bengal to the east of about 87° E in recent period compared to the former period as indicated by the negative difference, whereas, the reverse occurred over rest of the region with decrease in convective activity during recent period compared to the former period. It is also seen that the large increase in convective activity over the southern parts of the Arabian Sea during JJAS as shown in Fig. 3(c) is mainly dominated by the contribution from July as indicated by large negative difference of the order of –24 watts/m^2 [Fig. 5(b)].

3.4. *Longer period change of convective activity over the sectors of north Indian Ocean*

As it is seen from Figs. 3(a-d) & Figs. 5(a-d) the patterns of OLR difference between period-ii and period (*i*) shows asymmetry in convective activity over the



Figs. 6(a-f). The composite OLR anomalies during all four seasons for the two periods identified here. (a) north Arabian sea, (b) central Arabian sea, (c) south Arabian sea, (d) north Bay of Bengal, (e) central bay of Bengal and (f) south Bay of Bengal



Figs. 7(a-f). The interannual variability of OLR anomalies during JF, MAM, JJAS & OND seasons over the selected regions over north, central & south Bay of Bengal and Arabian sea. The region where the linear trend is significant is shown here

TABLE 1

Mean OLR over the different sectors of north Indian ocean during all the 4 seasons

Regions	Jan-Feb (JF)	Mar-May (MAM)	Jun-Sep (JJAS)	Oct-Dec (OND)
NARA	276	284	267	284
CARA	280	278	248	274
SARA	268	261	236	249
NBAY	277	267	199	260
CBAY	278	263	196	250
SBAY	256	240	206	227

southern and the northern parts of the Arabian Sea and the Bay of Bengal during different season. In order to quantify the OLR difference in both southern and northern parts separately, the north Indian Ocean has been divided into six blocks with three in the Arabian Sea and three in the Bay of Bengal as used by IMD for cyclone forecasting (IMD, 2003). The six blocks are as shown in Fig. 2(a), (*i*) north Arabian Sea (NARA); (*ii*) central Arabian Sea (CARA); (*iii*) south Arabian Sea (SARA); (*iv*) north Bay of Bengal (NBAY); (*v*) central Bay of Bengal (CBAY) and (*vi*) south Bay of Bengal (SBAY). While dividing these blocks the grid points over the oceanic region have been considered only. The climatological mean OLR over these sectors during all the four seasons are given in Table 1. Although convective clouds are formed over most parts of the north Indian Ocean Table 1 indicates large variation of mean convective activity over the different sectors of the Arabian Sea and the Bay of Bengal. As it is seen from Table 1 the deep convective areas with lower mean OLR is found over the north and central Bay of Bengal during the monsoon season, whereas, the OLR values are higher over other regions during the monsoon season and also during the rest of the seasons. The composite mean OLR anomalies during period (*i*) and period (*ii*) mentioned here over all the six regions are shown in Figs. 6 (a-c) for the Arabian Sea and Figs. 6 (d-f) for the Bay of Bengal. As indicated in Table 1 the mean OLR over these sectors during different seasons are different. The negative composite anomaly indicates increase in convective activity and positive composite anomaly indicates decrease in convective activity with respect to normal. It is seen from Figs. 6 (c&f) that over 'SARA' and 'SBAY' the anomalies during recent period and former period is just out of phase in nature with recent period showing strong negative anomalies compared to that of former period, which shows positive anomalies during all the seasons. These anomalies during both the periods are strong during the monsoon and post monsoon seasons compared to that of winter and pre-monsoon seasons over the 'SARA' [Fig. 6(c)]. On the other hand over the 'SBAY' the variability is least during monsoon season (JJAS) compared to other seasons [Fig. 6(f)]. Over the 'NBAY' [Fig. 6(d)] the convective activity is very strong during recent period compared to that of former period in pre-monsoon and monsoon season and it is slightly above normal during post monsoon season, whereas, during winter season it is just the opposite with more convective activity during former period compared to the recent period. Over the 'NARA' [Fig. 6(a)] it is slightly different with winter and pre-monsoon season showing more convective activity during former period compared to that of recent period as indicated by positive anomalies in recent period and negative during the former period. Fig. 6(a) also shows more convective activity during recent period compared to that of former period during monsoon & post monsoon season over the 'NARA'. Over the 'CARA' [Fig. 4(b)] the composite anomalies indicate increase in convective activity during recent period compared to former period from the pre-monsoon to post monsoon season, whereas, during winter season it is just the opposite like that of winter of 'NARA'. The 'CBAY' also shows large increase of convective activity during pre-monsoon season (MAM) in recent period compared to earlier period and the anomalies are very weak during both the periods in remaining seasons [Fig. 4(e)].

3.5. *Interannual variability of convective activity over the north Indian Ocean*

As it is seen in earlier sub-sections the difference of OLR anomalies during the two periods shows contrasting patterns of convective activity over southern, central and northern parts of the Arabian Sea and the Bay of Bengal during different seasons. In order to examine the interannual variability the linear trend of OLR anomalies have been analysed over the six regions, *viz*., 'NARA', 'CARA', 'SARA' & 'NBAY', 'CBAY' and 'SBAY' as identified in Fig. 2(a). The linear trend analysis is performed for all four seasons over these six oceanic regions. The case, which is significant atleast at 95% level is shown in Fig. 7(a-f). The convective activity significantly decreased over 'NARA' and 'CARA' [Figs. 7 (a&b)] during winter season as the OLR anomaly shows significant (at 99.9% level for NARA & 99% level for CARA) increasing trend, which is also reflected in Figs. 6 (a&b). During the pre-monsoon season (MAM) the 'NBAY' and 'CBAY' [Figs. 7 (d&f)] shows a tendency of increasing convective activity associated with decrease in OLR anomaly significant at 95% and 99% respectively. During the monsoon season [Fig. 7(e)] the significant decreasing trend (at 99% level) of OLR anomaly (thus, increase in convective activity) is noticed only over

'NBAY' region where the monsoon lows and monsoon disturbances mainly form during the southwest monsoon season. In spite of significant decreasing trend of monsoon disturbances over the Bay of Bengal region in recent time as reported earlier the significant increase in convective activity as seen over the north Bay of Bengal during the southwest monsoon season could be attributed to the increase in number of low-pressure systems indicated by earlier studies (Dash *et al*., 2004 & references therein). It is because the monsoon lows and monsoon disturbances during the southwest monsoon season mainly form in the region of the north Bay of Bengal (identified here as north Bay of Bengal in Fig. 2(a). Similarly, Fig. 7(c) also shows that during the post monsoon season the significant (at 95% level) increase in convective activity is reported over the southern Arabian Sea as indicated by decreasing trend of OLR anomalies.

4. Conclusions

Following conclusions may be drawn from the present study :

The difference of seasonal OLR anomalies between period (*ii*) (1992-2004) & period (*i*) (1979-1991) indicate increase of convective activity over many parts of the Arabian Sea and the Bay of Bengal in recent period [period (*ii*)] compared to that of former period [period (*i*)] during the monsoon season with relatively stronger negative difference of OLR anomalies over the Arabian Sea than that over the Bay of Bengal. Though the mean convective activity over the north Indian Ocean during winter, pre-monsoon and post-monsoon seasons is comparatively less than that during the monsoon season, the difference of seasonal OLR between period (*ii*) and period (*i*) indicate variability of convective activity between the period (*i*) & period (*ii*) during winter, pre-monsoon and post-monsoon season. The interannual variability of convective activity shows significant increasing trend over central Bay of Bengal (99% level) & north Bay of Bengal (95% level) during pre-monsoon season, north Bay of Bengal (95% level) during monsoon season and south Arabian Sea (at 95% level) during post monsoon season. It is also seen that the SST over the north Indian Ocean is slightly higher during recent period compared to earlier period during all the four seasons.

On monthly scale from June to September the convective activity increases in recent time [period (*ii*)] compared to former period [period (*i*)] over almost the entire Arabian Sea during June and July, central part of Arabian Sea in August and southern part of Arabian Sea in September, whereas, over the Bay of Bengal the convective activity increases in recent time during July and August and over the eastern part of Bay of Bengal in September. During June recent period shows decrease in convective activity over the Bay of Bengal.

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