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Relative role of individual variables on a revised Convective System Genesis Parameter over north Indian Ocean

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Abstract The present study is an attempt to evaluate the relative contribution of potential dynamical and thermo dynamical parameters in the formulation of the revised CSGP. The main objectives of the study are to quantify the composite variation of the revised CGSP over NIO. Tropical storms are intense low pressure systems that form over warm tropical ocean basins. Depending upon the intensity, they are classified as depressions, cyclones and severe cyclones. The results show that the revised CSGP is capable of distinguishing different categories of the storms. The CSGP exhibits large variability during distinct large scale background state. It is also found that the individual variables contribute in a different way during monsoon and non-monsoon seasons. The revised CSGP can be used to forecast all categories of convective systems over NIO during the monsoon as well as non-monsoon seasons.
Key words Tropical cyclones, Relative Vorticity, Convergence, Vertical wind shear, Convective Instability, Genesis Parameter.

Introduction

The process of initiation of a cyclone is called cyclogenesis. Gray (1975) introduced six primary genesis parameters for the formation of tropical cyclones namely (1) Low level relative vorticity, (2) Coriolis parameter, (3) The inverse of the vertical shear of the horizontal wind between the lower and upper tropsphere, (4) Ocean thermal energy or sea temperature above 26°C to a depth of 60m, (5) Vertical gradient of equivalent potential temperature between the surface and 500mb level and (6) Middle troposphere relative humidity. The product of these parameters is referred to as the Seasonal Genesis Parameter (SGP). Various authors have designed different cyclogenesis indices to estimate the cyclogenesis over various ocean basins (Royer et.al 1998, McBride and Zehr 1981, Zehr 1992, Roy Bhowmic 2003 and Kotal 2009). The present study is an attempt to evaluate the relative contribution of potential dynamical and thermo dynamical parameters in the formulation of the revised CSGP. The main objectives of the study are to quantify the composite variation of the revised CGSP over NIO.

Materials and Methods

The revised Convective System Genesis Parameter (CSGP)

The Convective System Genesis Parameter (CSGP) is a new modified index and it is different from the Genesis Parameter (GP) defined by Zehr (1992)

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and the Genesis Potential Parameter (GPP) defined by Kotal (2009). The dynamical parameters defined by Zehr (1992), the humidity parameter defined by Kotal (2009) and the Convective Instability parameter defined by Gray, (1975) have been used to construct this parameter. Hence the revised index is a product of five parameters and it is defined as

CSGP = (850VOR • 850LLC • S • HUM • CI)

Where

1) 850VOR= Low Level Relative Vorticity at 850 hPa (LLRV)
2) 850LLC= Low Level Convergence (negative of Divergence) at 850 hPa (LLC)
3) VWSC= Shear Co-efficient = 25.0ms-1 - (200-800 SHEAR) / 20.0ms-1 (SHR)
4) HUM = [RH – 40] / 30, Middle tropospheric relative humidity. (Where RH is the mean relative humidity between 700 and 500 hPa)
5) CI = (ThetaE_1000 – ThetaE_500), Vertical gradient of Equivalent potential temperature, between 1000hPa and 500hPa.

The magnitude of the VWSC parameter has been kept its maximum as $25ms^{-1}$, the magnitude greater $25ms^{-1}$ it will reduce CSGP to zero. The unit of this index is $10^{-10}s^{-2}$ degree K. All the convective systems that formed over NIO during the study period (1979-2008) have been considered for this study. Firstly these systems are classified in three categories as (1) depressions (which include both depressions and deep depressions), (2) cyclones (which include only cyclones) and (3) severe cyclones (which include severe cyclones, very severe cyclones and super cyclones). Further analysed the characteristics of this Index (CSGP) for all the categories in both monsoon (JJAS) and non-monsoon (JFMAM-OND) months of the said various climatic episodes.

Datasets used and selection of distinct background state

The NCEP/NCAR- Reanalysis 2 atmospheric data set (daily mean) have been used to calculate and analyse the dynamic as well as thermodynamic parameters. These cyclogenesis parameters are averaged over the period of the convective systems. The spatial resolution of this data is 2.5 x 2.5-degree grid. The study are extends the entire NIO basin covering the area bounded by 50^oE to 100^oE, and 0^o to 25^oN. In the present study, composite of all the individual parameters during the period of the each convective systems over NIO have been evaluated. Further divided the convective systems as they have formed in the monsoon and non-monsoon seasons. Spatial correlations have been computed between each of the individual parameters with the CSGP. The spatial correlations between each parameter with CSGP have been obtained to study the relative role of the individual parameters on CSGP and the influence of these parameters in the formation and intensification of the convective systems over NIO.

Results and Discussions

3.1 Grouping the storms into different categories of basic state

The characteristics of the Convective System Genesis Parameter (CSGP) have been analysed for all the cases of convective systems such as Depressions, Cyclones and Severe cyclones formed over NIO. Table 1 shows the total frequencies of the convective systems formed over NIO during the study period. In the case of depressions over AS, there have been 10 depressions during the monsoon seasons and 17 depressions during the non-monsoon seasons, and in the case of depressions over BB, there have been 63 depressions during the monsoon seasons and 44 depressions during the non-monsoon seasons of the study period.

Table 1. Total convective systems over NIO in the monsoon and non-monsoon seasons during the study period.

Category	Arabian Sea		Bay of Bengal	
	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon
Depressions	10	17	63	44
Cyclones	3	5	8	27
Severe Cyclones	5	11	3	42

In the case of cyclones over AS, there have been 3 cyclones during the monsoon seasons and 5 cyclones during the non-monsoon seasons, and in the case of cyclones over BB, there have been 8 cyclones during the monsoon seasons and 27 cyclones during the non-monsoon seasons of the study period. And in the case of severe cyclones over AS, there have been 5 severe cyclones during the monsoon seasons and 11 severe cyclones during the non-monsoon seasons, and in the case of severe cyclones over BB, there have been 3 severe cyclones during the monsoon seasons and 42 severe cyclones during the non-monsoon seasons of the study period.

3.2 Spatial variation of CSGP with respect different seasons

From figure 1(a) it is observed that the genesis points of the depressions over AS during the monsoon seasons are clustered around the region of 14°N – 20°N and 64°E – 72°E. But from figure 1(b), it is seen that the genesis points of the depressions are spread widely in the region of 5°N – 20°N and 58°E – 77°E, during the non-monsoon seasons. From figure 1(c), it is noticed that, the genesis locations of the depressions over BB during monsoon season are clustered in the area of 14°N – 22°N and 83°E – 93°E.

This region corresponds to the eastern end of monsoon trough and large values of CSGP found along the monsoon trough region. From figure 1(d) it is seen that the genesis locations spread over a large area of 5°N – 20°N and 78°E – 97°E, during the non-monsoon seasons. Most favourable genesis locations with higher values of CSGP is found around the region of 5-15°N and 83-90°E. It is found that lower values of CSGP favours the formation of DD over AS during both the seasons. On the other hand, higher values of CSGP is found over BB around the genesis locations of the DD during both the seasons.

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Figure 1. Variations of CSGP for the depressions over NIO during both the seasons of the study period

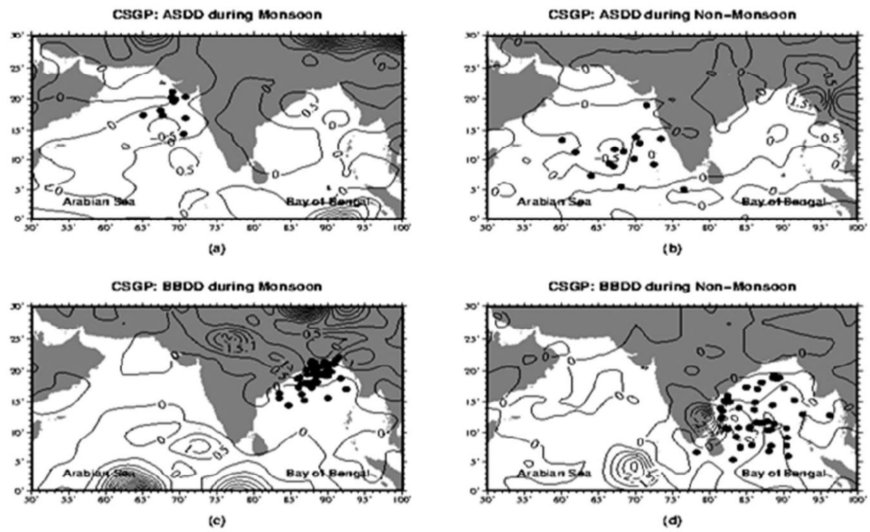
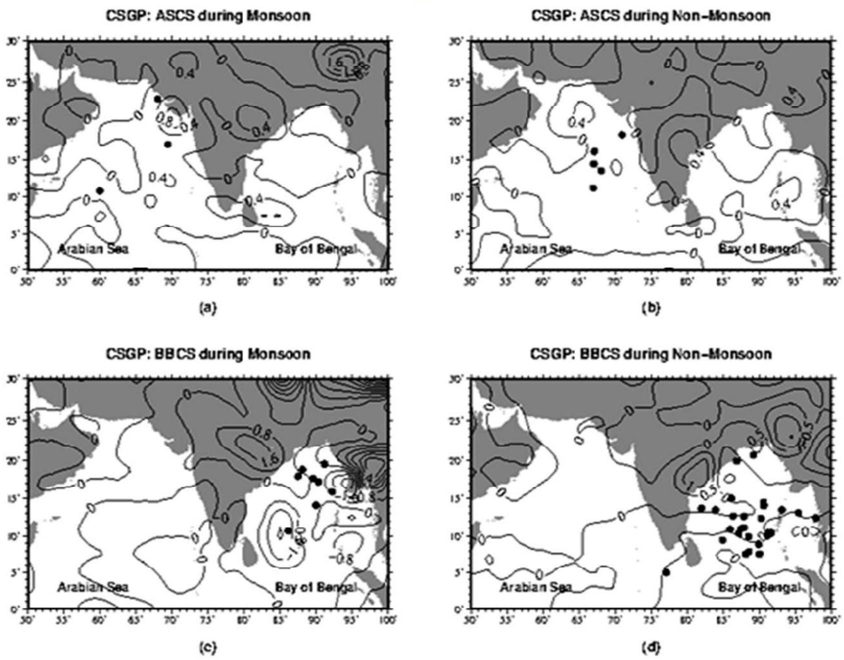
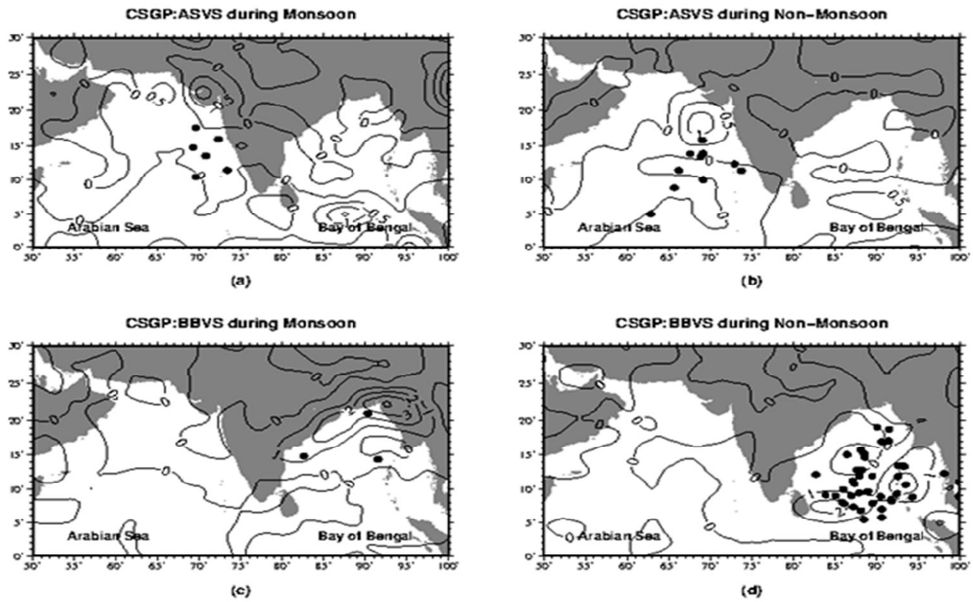


Figure 2. Variations of CSGP for the cyclones over NIO during both the seasons of the study period



From figure 2(a) it is observed that, the formation of cyclones is less over AS during the monsoon seasons and it is also noticed that these cyclones have formed against low values of CSGP. From figure 2(b), it is noticed that cyclones formed against low values of CSGP during this period. Only few cyclones have formed over AS during non-monsoon months and the genesis locations are mostly confined to a narrow region of 65-75°E and 10-20°N. During both the seasons, relatively lower values of CSGP is found over AS. From figure 2 (c), it is observed that very few cyclones have formed over BB during the monsoon seasons and most of them formed over the head BB with low values of CSGP. Figure 2 (d), shows the variations of CSGP for cyclones formed over BB during the non-monsoon seasons. Most favourable genesis locations of cyclones are found over south BB between 10-15°N and 83-95°E with low values of CSGP around the storm genesis locations.

Figure 3. Variations of CSGP for the severe cyclones over NIO during both the seasons of the study period



From figure 3 (a), it is noticed that the severe cyclones have formed against low values of CSGP. Most of the severe cyclones during monsoon season originated off the west coast around 70-75°E and 10-18°N. From figure 3 (b), it is seen that, most of the severe cyclone over AS during non-monsoon months has been formed around the region of 60-75°E and 5-15°N with slightly higher values of CSGP as compared to monsoon season. From figure 3 (c), it is seen that most of the severe cyclones during monsoon season have formed north of 10°N around the head BB with very high values of CSGP (0.0 to 3.0 $x10^{-10}s^{-2}$degreeK). From figure 3 (d), it is observed that most of the severe cyclones have formed south of 18°N between 85-95°E with high values of CSGP (0.0 to 2.0 $x10^{-10}s^{-2}$degreeK). And in the case of severe cyclones the large positive values of CSGP is concentrated around the genesis locations of the severe cyclones over both the basins. From this analysis it is found that, the depressions have formed at the low positive values of CSGP (~ 0.0 to 0.5 $x10^{-10}s^{-2}$degreeK), the cyclones have formed at the high positive values of CSGP (~ 0.5 to 1.0 $x10^{-10}s^{-2}$degreeK) and the severe cyclones have formed at a high positive values of CSGP (~ 1.0 to 3.0 $x10^{-10}s^{-2}$degreeK). From this study it is observed that the new modified CSGP is capable of distinguishing the intensity variations of the convective systems over NIO.

3.3 Relation between individual variables and CSGP over NIO during different season

Case 1. Depressions over NIO

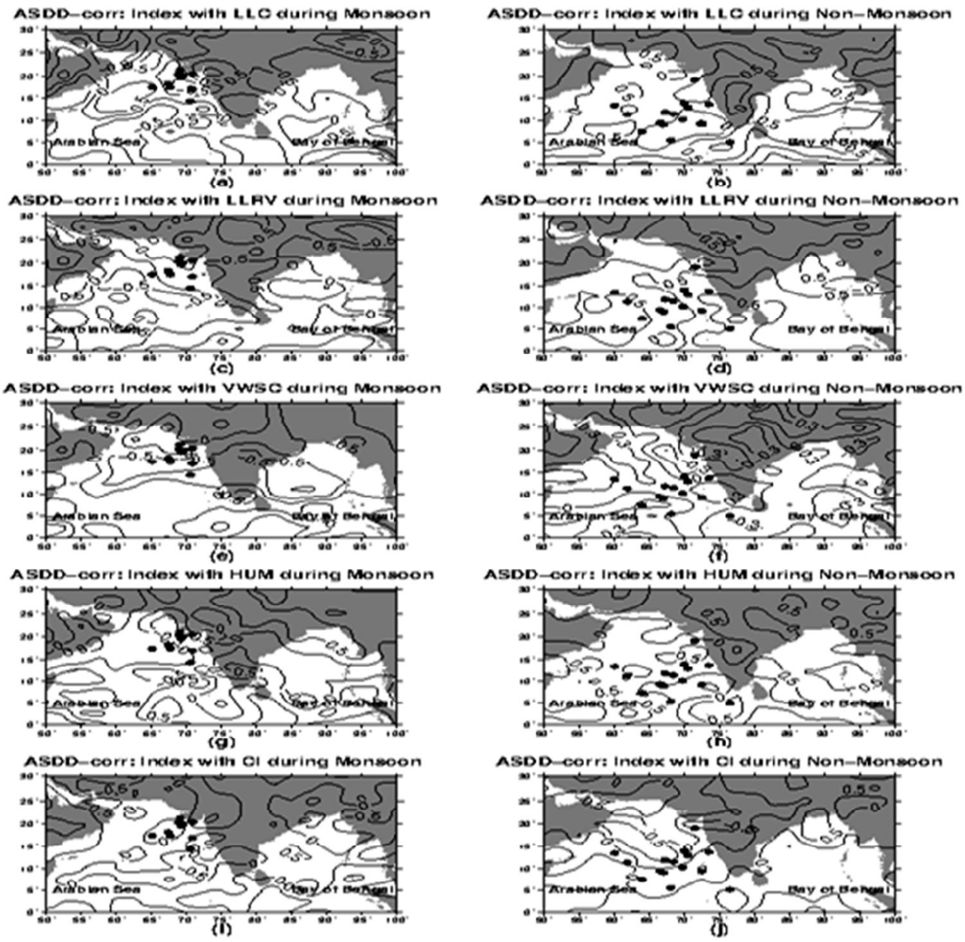
From figure 4 (a and b), it is observed that there exists a high positive correlation (~ 0.5) between LLC and CSGP for the depressions formed over AS during the monsoon as well as non-monsoon seasons. From figure 4 (c and d), it is observed that there exists a high positive correlation (~ 0.5) between LLRV and CSGP for the depressions formed over AS during the monsoon as well as non-monsoon seasons. From figure 4 (e and f) it is observed that there exists a negative correlation between VWSC and CSGP for the depressions formed over AS during the monsoon as well as non-monsoon seasons. From figure 4 (g and h), it is observed that there exists a high positive correlation (~ 0.5) between HUM and CSGP for the depressions formed over AS during the monsoon and non-monsoon seasons. From figure 4 (i and j), it is observed that there exists a high positive correlation (~ 0.5) between CI and CSGP for the depressions formed over AS during the monsoon and non-monsoon seasons.

From figure 5 (a and b), it is observed that there exists a high positive correlation (~ 0.6) between LLC and CSGP for the genesis of the depressions over BB during monsoon and non-monsoon seasons. From figure 5 (c and d), it is noticed that there exists a high positive correlation (~ 0.6) between LLRV and CSGP for the depressions formed over BB during the monsoon and non-monsoon seasons. From figure 5 (e and f), it is found that lower positive correlations exist between VWSC and CSGP for the genesis of the depressions over BB during monsoon and non-monsoon seasons. From figure 5 (g and h), positive correlations (~ 0.3 and 0.6) are obtained between HUM and CSGP for the depressions formed over BB during the monsoon and non-monsoon seasons. From figure 5 (i and j), it is observed that lower positive correlations (~ 0.2 and 0.4) exists for the genesis of the depressions during the monsoon and non-monsoon seasons.

Case 2. Cyclones over NIO

From figure 6 (a and b), it is observed that high positive correlations (~ 0.9 and 0.7) exist between LLC and CSGP for the cyclones formed over AS during the monsoon and non-monsoon seasons.

Figure 4. Spatial correlations of the composite of each parameter with CSGP for the depressions over AS during both the seasons of the study period



From figure 6 (c and d), it is observed that high positive correlations (~0.9 and 0.7) between LLRV and CSGP for the cyclones formed over AS during the monsoon and non-monsoon seasons. From figure 6 (e and f), it is observed that there high negative correlations exist between VWSC and CSGP for the cyclones formed over AS during the monsoon as well as non-monsoon seasons. From figure 6 (g and h), it is observed that high positive correlations (~ 0.9 and 0.7) exist between HUM and CSGP for the cyclones formed over AS during the monsoon as well as the non-monsoon seasons. From figure 6 (i and j), it is noticed that high positive correlations (~ 0.9 and 0.7) exist between CI and CSGP for the cyclones formed over AS during the monsoon and non-monsoon seasons.

From figure 7 (a and b), it is observed that high positive correlations (~ 0.5 and 0.6) exist between LLC and CSGP for the cyclones formed over BB during the monsoon as well as non-monsoon seasons. From figure 7 (c and d), it is noticed that high positive correlations (~ 0.5 and 0.6) exist for the genesis of the cyclones over BB during the monsoon as well as non-monsoon seasons. From figure 7 (e and f), it is observed that negative correlations (~ -0.5 and -0.3) exist between VWSC and CSGP for the cyclones formed over BB during the monsoon and non-monsoon seasons. From figure 7 (g and h), it is seen that high positive correlations (~ 0.5 and 0.6) exist between HUM and CSGP for the cyclones formed over BB during the monsoon as well as non-monsoon seasons. From figure 7 (i and j), it is observed that lower magnitudes of positive correlations exist between CI and CSGP for the cyclones formed over BB during the monsoon as well as non-monsoon seasons.

From figure 8 (a and b), it is observed that high positive correlations (~ 0.7 and 0.5) exist between LLC and CSGP for the severe cyclones formed over AS during the monsoon as well as non-monsoon seasons. From figure 8 (c and d), it is found that high positive correlations (~ 0.7 and 0.5) exist between LLRV and CSGP for the severe cyclones formed over AS during the monsoon as well as non-monsoon seasons. Figure 8 (e and f), it is noticed that high negative correlations exist between VWSC and CSGP for the severe cyclones formed over AS during the monsoon and non-monsoon seasons. From figure 8 (g and h), it is noticed that high positive correlation (~ 0.7 and 0.5) exist between HUM and CSGP for the severe cyclones formed over AS during the monsoon as well as non-monsoon seasons. From figure 8 (i and j), it is seen high positive correlation (~ 0.7 and 0.5) exist between CI and CSGP for the severe cyclones formed over AS during the monsoon as well as non-monsoon seasons.

From figure 9 (a and b), it is noticed that high positive correlations (~ 0.9 and 0.6) exist between LLC and CSGP for the severe cyclones formed over BB during the monsoon as well as noon-monsoon seasons. From figure 9 (c and d) it is seen that high positive correlations (~ 0.9 and 0.6) exist between LLRV and CSGP for the severe cyclones formed over BB during monsoon as well as non-monsoon seasons. Figure 9 (e and f), it is noticed that negative correlations exist between VWSC and CSGP for the severe cyclones formed over BB during the monsoon and non-monsoon seasons. From figure 9 (g and h), it is noticed that high positive correlations (~ 0.9 and 0.6) exist between HUM and CSGP for the severe cyclones formed over BB during the monsoon as well as non-monsoon seasons.
From figure 9 (i and j), it is seen that high positive correlations (~ 0.9 and 0.3) exist between CI and CSGP for the severe cyclones formed over BB during the monsoon as well as non-monsoon seasons.

Role of individual parameters on CSGP

From figure 10 (a) it is seen that there exist higher positive correlations for LLC, HUM and CI with CSGP. This means that these parameters are playing important role in the formation of the depressions over AS during the monsoon seasons. It is also observed that the SHR (shear component) is having negative correlations with the CSGP during the monsoon seasons. From figure 10 (b) it is seen that the parameters such as LLC, LLRV and HUM are having high positive correlations with CSGP. There are positive correlations for CI, but the magnitude is small, it means that its influence is less on the formation of the depressions over AS during the non-monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the non-monsoon seasons. From figure 10 (c) it is seen that the parameters such as LLC, LLRV and HUM are having high positive correlations with CSGP. This means that these parameters are playing important role in the formation of the depressions over BB during the monsoon seasons.

Figure 5. Spatial correlations of the composite of each parameters with CSGP for the depressions over BB during both the seasons of the study period

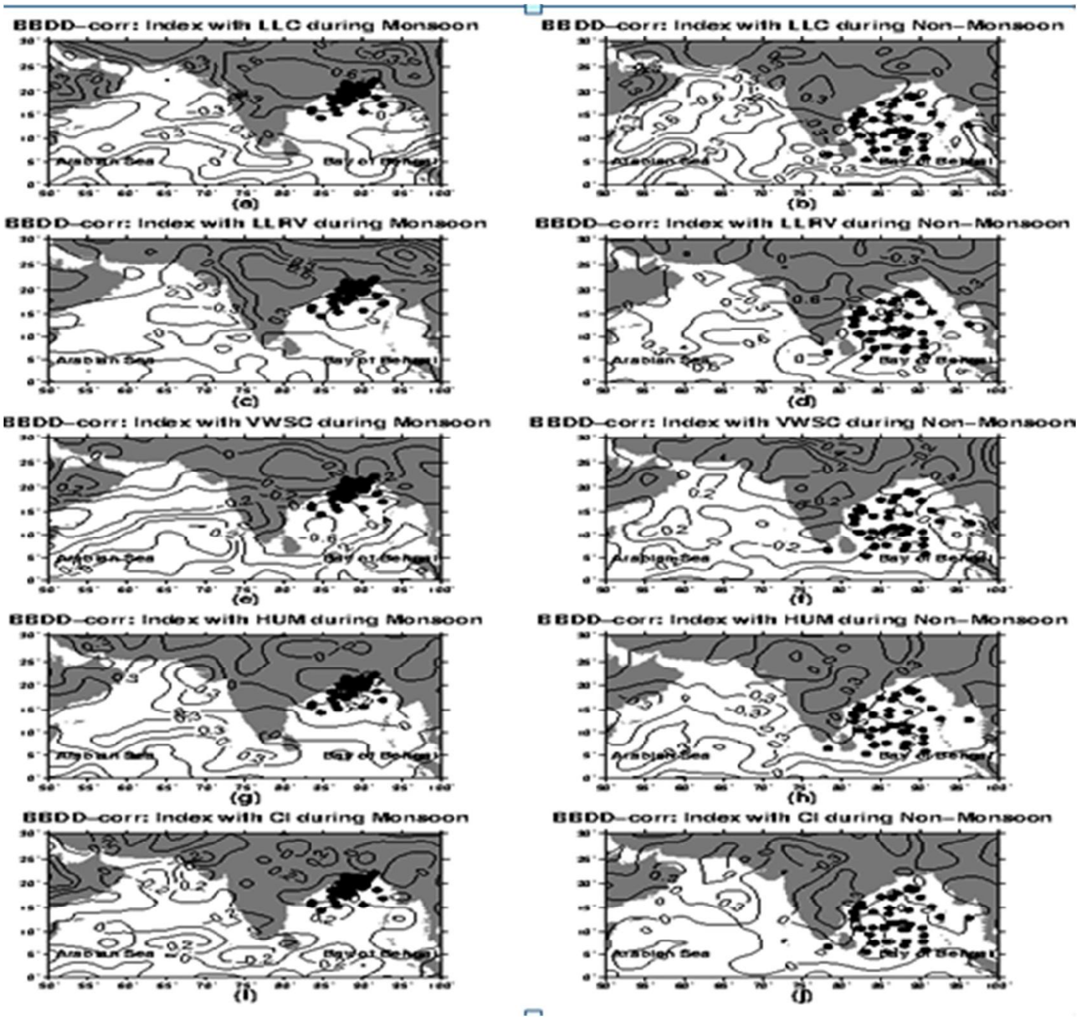
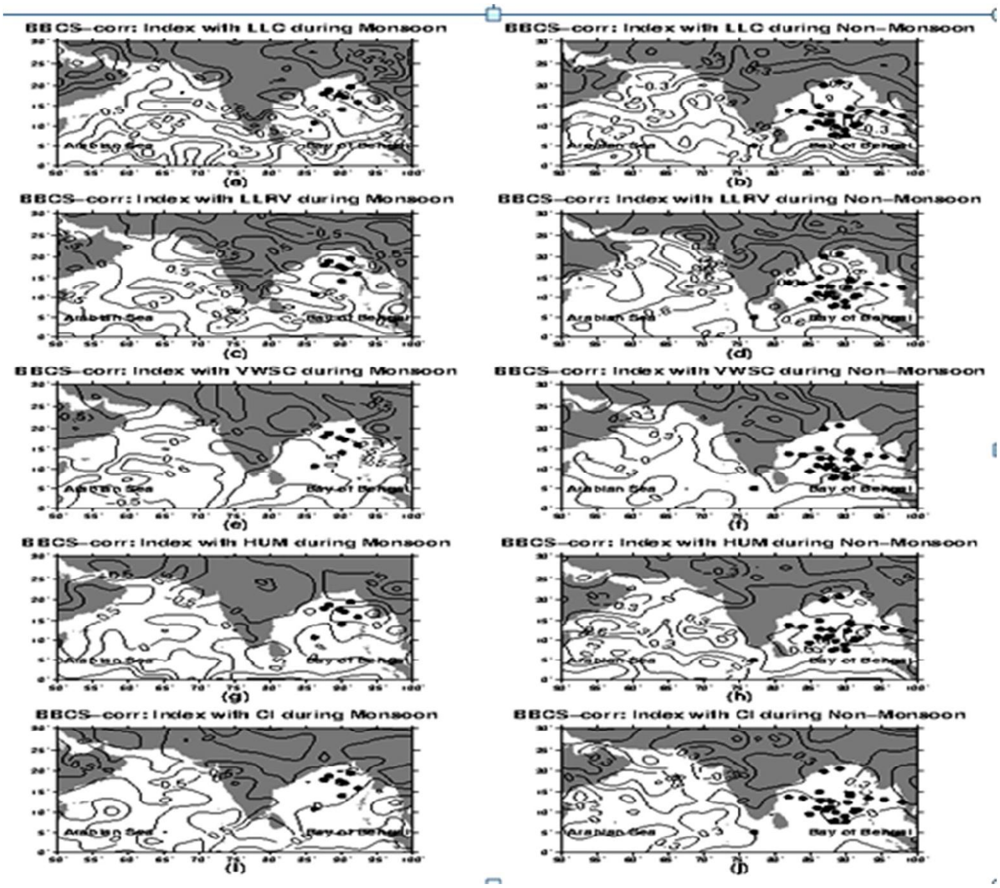


Figure 6. Spatial correlations of the composite of each parameters with CSGP for the cyclones over AS during both the seasons of the study period



There are positive correlations for CI, but the magnitude is small, it means that its influence is less on the formation of the depressions over BB during the monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the monsoon seasons. From figure 10 (d) it is seen that the parameters such as LLC, LLRV, HUM and CI is having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the depressions over BB during the non-monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the non-monsoon seasons. It is noted that for the formation of DD over BB during monsoon season, dynamical parameters such as LLC and LLRV is contributing significantly to CSGP as compared to HUM and CI parameters. However, during non-monsoon months, LLC, LLRV and HUM and CI are equally contributing to CSGP.

Figure 7. Spatial correlations of the composite of each parameters with CSGP for the cyclones over BB during both the seasons of the study period

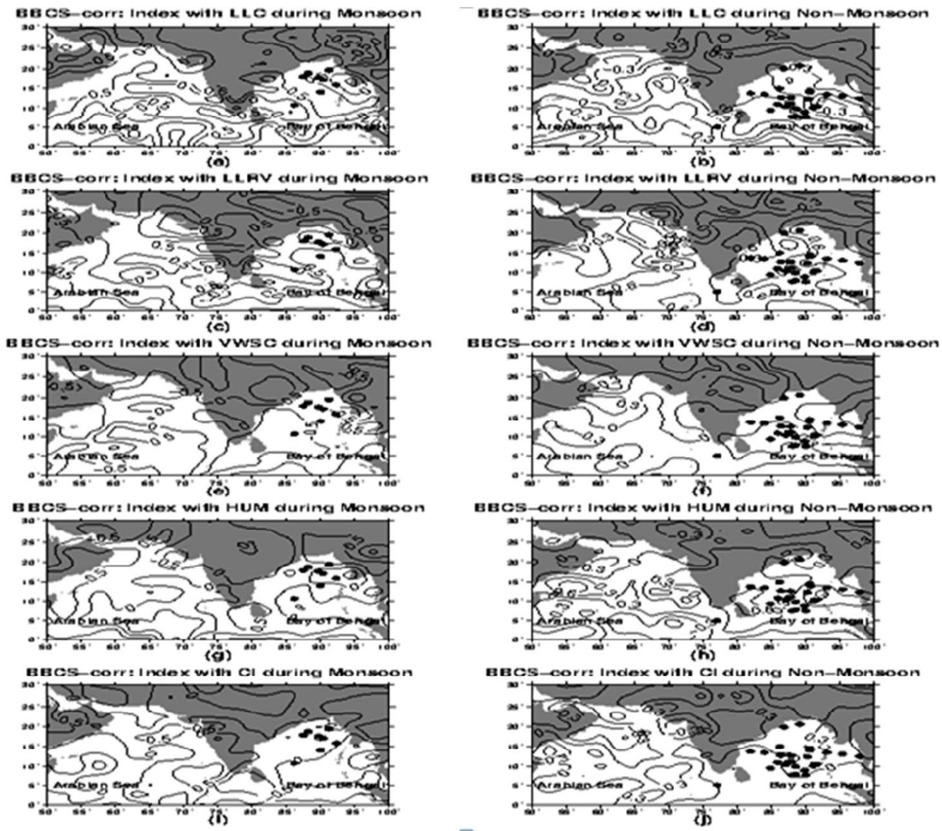


Figure 8. Spatial correlations of the composite of each parameters with CSGP for the severe cyclones over AS during both the seasons of the study period

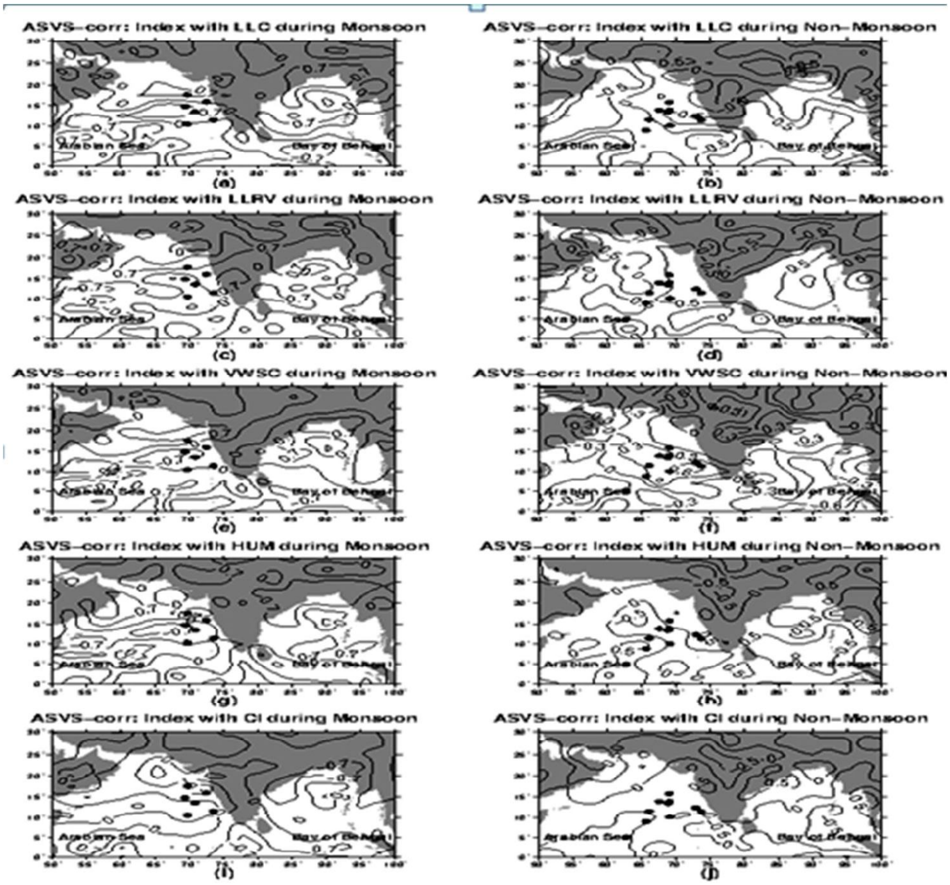
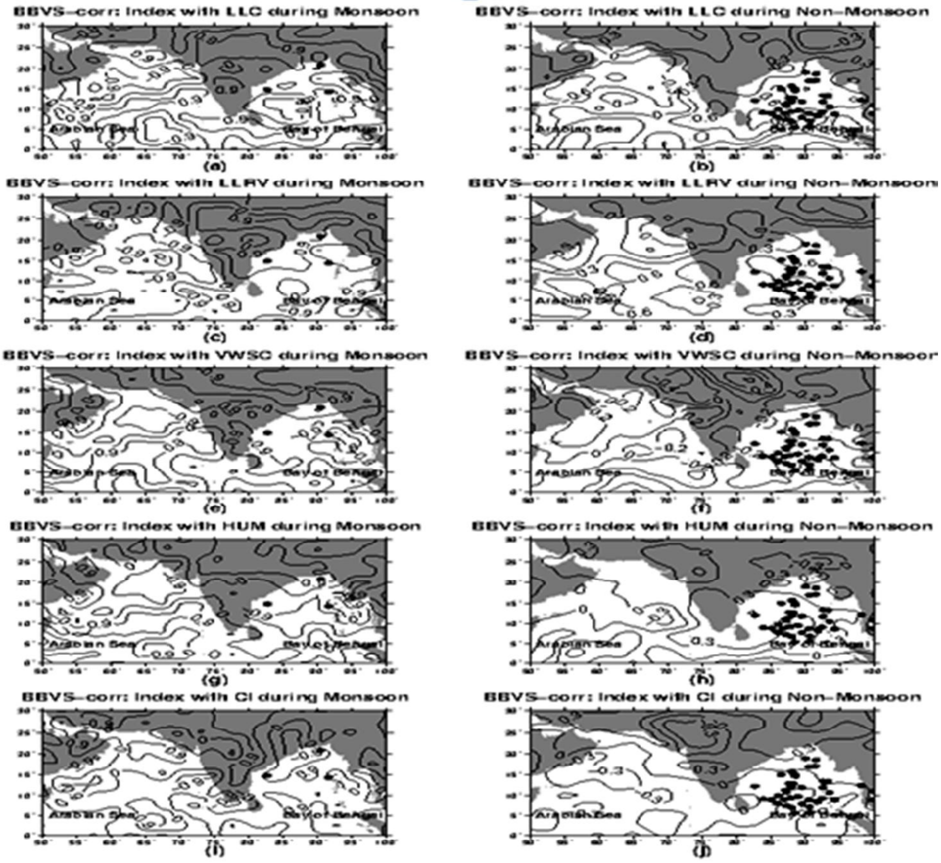


Figure 9. Spatial correlations of the composite of each parameter with CSGP for the severe cyclones over BB during both the seasons of the study period



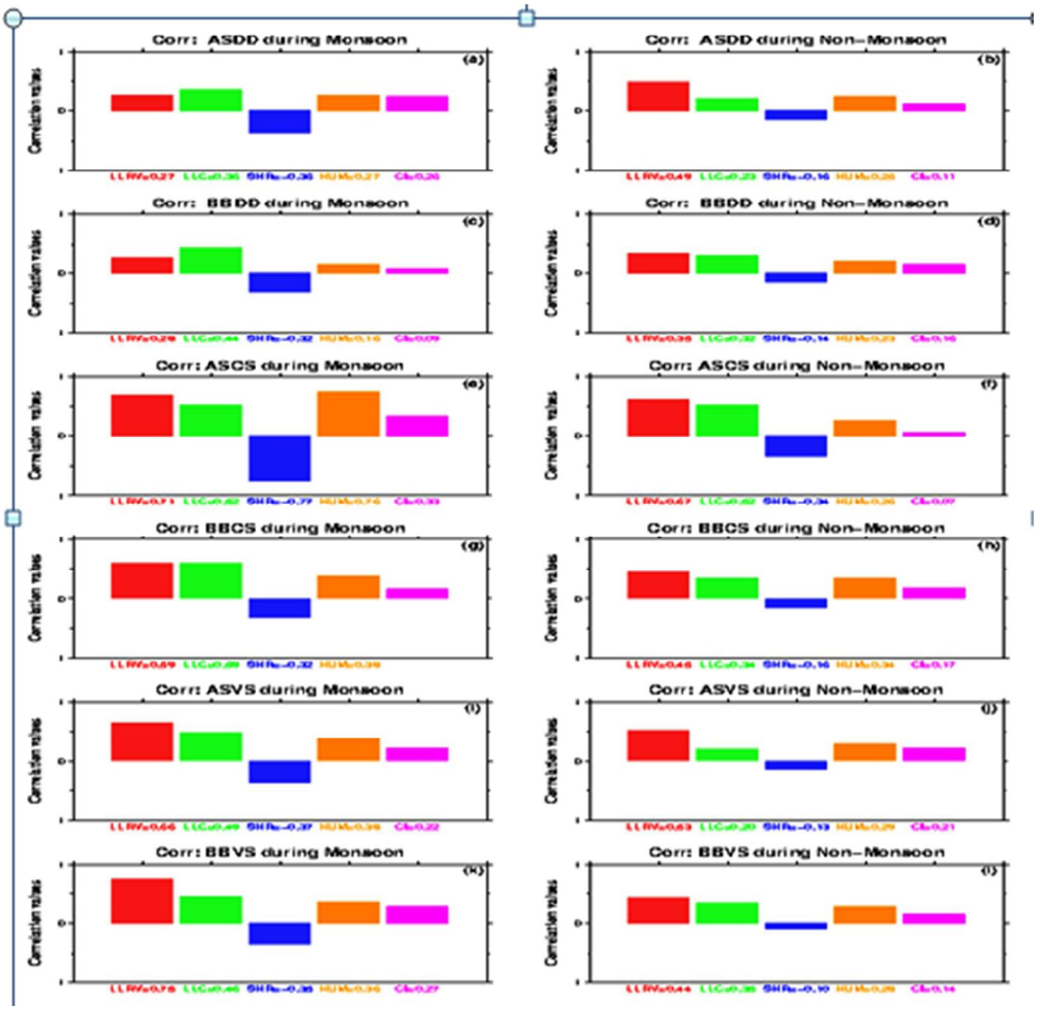
From figure 10 (e), it is seen that the parameters such as LLC, LLRV, HUM and CI are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the cyclones over AS during the monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the monsoon seasons. From figure 10 (f), it is seen that the parameters such as LLC, LLRV HUM and CI are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the cyclones over AS during the non-monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the non-monsoon seasons. Since SHR shows high negative correlation with CSGP during monsoon months, formation of cyclones are favoured with large contribution from LLRV, LLC, HUM and CI parameters as seen from the large positive correlation of these parameters with CSGP. During non-monsoon months, large LLRV, LLC and HUM is more important for the formation of cyclones over AS.

From figure 10 (g) it is seen that the parameters such as LLC, LLRV and HUM are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the cyclones over AS during the monsoon seasons. There are positive correlations for CI but its magnitude is very less, it means that it is not having much influence on the formation of cyclones over BB during the monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the monsoon seasons. From figure 10 (h) it is seen that the parameters such as LLC, LLRV and HUM are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the cyclones over AS during the non-monsoon seasons. There are positive correlations for CI but its magnitude is very less, it means that it is not having much influence on the formation of cyclones over BB during the non-monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the non-monsoon seasons. It is found that during monsoon season, formation of cyclones over BB is governed by the large dynamical contribution such as LLRV, LLC and thermo dynamical contribution from HUM. However, during non-monsoon months both dynamical and thermo dynamical parameters equally contributes to CSGP for the formation of cyclones.

From figure 10 (i) it is seen that the parameters such as LLC, LLRV, HUM and CI are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the severe cyclones over AS during the monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the monsoon seasons. From figure 10 (j) it is seen that the parameters such as LLC, LLRV, HUM and CI are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the severe cyclones over AS during the non-monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the monsoon seasons. Formation of severe cyclonic storms over AS during monsoon season is favoured by large contribution from LLRV, LLC, HUM and CI with dynamical parameters are contributing more to the CSGP value. During non-monsoon months, both dynamical and the dynamical parameters are equally contributing to the formation of severe cyclones over AS.

From figure 10 (k) it is seen that the parameters such as LLC, LLRV, HUM and CI are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the severe cyclones over BB during the monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the monsoon seasons. From figure 10 (l) it is seen that the parameters such as LLC, LLRV, HUM and CI are having positive correlations with CSGP. This means that these parameters are playing important role in the formation of the severe cyclones over BB during the non-monsoon seasons. It is also noticed that the SHR is having negative correlations with the CSGP during the non-monsoon seasons.

Figure 10. Correlation values of each parameter with CSGP for the depressions over NIO



Contribution of dynamical and thermo dynamical parameters to the CSGP over BB during monsoon and non-monsoon months exhibits almost similar relationship between each parameter and CSGP. More favourable contribution from both dynamical and thermo dynamical parameters are seen during monsoon season. However, LLRV, LLC and HUM are contributing more to CSGP value during non-monsoon months.

Conclusion

The characteristics of CSGP in the formation and intensification of the convective systems formed over NIO have been investigated. The spatial correlations of the individual parameters with the CSGP have been obtained to analyze the relative role of individual parameters on CSGP. It reveals that, the new modified index is capable of distinguishing the intensity variations of the convective systems and identifying the favourable cyclogenesis locations as well its further development and decay. It is found that the shear parameter is always have higher magnitude in the monsoon seasons and it is having a negative impact of CSGP. In order to compensate for large negative impact of the shear co-efficient on cyclogenesis, other contributing factors should be large enough to overcome the threshold value of CSGP required for the cyclones to form during monsoon season. However during non-monsoon months, due to lower values of the shear coefficient and its reduced negative impact on CSGP, moderate amount of LLRV and HUM along with positive contribution from LLC and CI favours the formation of severe and very severe cyclonic storms over NIO.

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