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A study of decreasing storm frequency over Bay of Bengal

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ABSTRACT
Examination of Sea surface Temperature and frequency of storm over Bay of Bengal during monsoon season using long period data from 1901-1998 has revealed that the storm frequency has decreased on decadal scale since 1980s in-spite of increasing SSTs. Mean of storm frequency for epoch1 (1958-1980) is found to be significantly different than that for epoch2 (1981-1998). This prompted us to see if such a decrease in storm frequency is reflected in atmospheric circulation changes over Bay of Bengal on decadal scale. Hence decadal variation of anomalies of Sea Surface Temperature (SST), relative vorticity at 850hPa, horizontal and vertical shear of zonal wind averaged over Bay of Bengal during monsoon season, have been studied using monthly mean NCEP/NCAR reanalysis data for the period 1958-1998. The anomalies of these parameters are of opposite sign for periods prior to and after 1980. Results suggest that the changes in all the atmospheric parameters from epoch1 to epoch2 are related to decreasing storm frequency in-spite of favorable SSTs.

INTRODUCTION

Important role of tropical oceans in the variability of monsoon over India has been established with the availability of satellite data. Indian monsoon is maintained by propagation of convective systems organized due to synoptic scale disturbances within the planetary scale Tropical convergence Zone from warm tropical oceans to subcontinent. A good percentage of the rainfall over India during the summer monsoon season (June-September) is contributed by synoptic scale disturbances such as lows, monsoon depressions, cyclonic storms etc. India Meteorological Department classifies various systems as follows. A Low-pressure system with only one closed isobar and the surface winds in cyclonic circulation less than 17knots is referred to as low. A Low-pressure system with 2 or 3 closed isobars at 2 hPa interval and the surface winds in cyclonic circulation between 17 and 33 knots is referred to as depression. Depressions in which the wind speed exceeds 33 knots are termed as cyclonic storms.

The conditions favorable for the genesis of monsoon depressions according to Sikka (1977), are: Sea Surface Temperature is quite high (>29°C). The semi-permanent monsoon trough dips into the North Bay of Bengal indicating the presence of low-level cyclonic vorticity. Mid-level specific humidity is high. Weak vertical wind shear in the basic current. Rajeevan, De & Prasad (2000b) examined the relationship between Sea surface temperature (SST) and frequency of storm during monsoon season over Bay of Bengal using a long period data from 1901-1998. For this purpose, the disturbances of intensity of depression and higher, were considered as storms in their study. Their results showed that the storm frequency decreased at the rate of about 1 storm per decade since 1980's in spite of increasing SST. This result indicates that the warm SSTs alone are not sufficient for genesis and intensification of monsoon depressions. Subsequent studies (Patwardhan & Bhalme (2001), Singh (2001) and Rajendra Kumar & Dash(2001)) have also pointed out that there is a decreasing trend in the frequency of cyclonic disturbances over Bay of Bengal and Arabian Sea in monsoon season.

The objective of the present study is to examine the circulation parameters for the period 1958-1998 and study their changes since 1980, in relation to decreasing storm frequency over Bay of Bengal during monsoon. Details of the data and the methodology used are discussed.

DATA & METHODOLOGY

Storm frequency (SF) over Bay of Bengal for monsoon season from June to September (JJAS) is taken from, India Meteorological Department. Sea surface temperature (SST) data used is GISST1.1 (Global Sea-Ice and Sea surface Temperature) monthly mean data provided by Hadley Centre for climate prediction and research, U.K. GISST data available with us is up to 1994 on 3.75° long x 2.5° lat. From 1995 to 1998, Optimum Interpolated (OI) SST data from NCEP web site is used, which is on 1° long. x 1° lat. Monthly mean grid point data of zonal (u) and meridional (v) components of wind and relative vorticity (z) for the period 1958-1998 from NCEP/NCAR reanalysis has been used. Details of NCEP/NCAR reanalysis data are given in Kalnay et al. (1996).

The parameters u, v, z, horizontal shear of zonal wind at 850hPa (Hs), vertical shear of zonal wind (Vs) and SST have been averaged over Bay of Bengal region extending from 80°E-100°E, 10°N-25°N to obtain uA, vA, zA, HsA and VsA and SSTA. The 40-year period of study is divided into two epochs viz. epoch1 from 1958-1980 and epoch2 from 1981-1998, as the storm frequency and SST anomalies change sign around 1980. The Hs is calculated as difference of u between latitudes 25°N and 10°N averaged over 80°E-100°E. The Vs is calculated as the difference of u between 850hPa and 200hPa averaged over 80°E-100°E. Anomalies are prepared using NCEP climatology of the various parameters (uA, vA, zA, HsA and VsA) based on the period 1958-1998. The SST and storm frequency anomalies are standardized and 11-year running mean is plotted to study decadal variability. The temporal variations of u and v components of wind and their anomalies averaged over 80°E-100°E over Indian latitudes have also been studied. Time series of relative vorticity averaged over Bay of Bengal during monsoon season at 850hPa is prepared. Decadal variability of ZA, HsA and VsA over Bay of Bengal is studied by plotting 11-year running mean.

DISCUSSION

Decadal variation of SST and storm frequency anomalies over Bay of Bengal:

Fig.1 shows the 11-year running means of standardized anomaly of sea surface temperature (SST) and storm frequency (SF) for the monsoon season averaged over Bay of Bengal for the period 1958-1998. The figure shows that the storm frequency anomalies are small positive from 1963 till 1980. A decrease in storm frequency anomaly over Bay of Bengal is observed from 1980 onwards. In contrast, SST anomalies are found to be small negative from 1963 to 1980 and a change in their sign is observed thereafter. Thus the storm frequency is reduced since 1980 in spite of increasing SSTs and the storm frequency and SST variations are out of phase. It is also remarkable that the anomalies of SST (storm frequency) changed sign around 1980 and steadily increased (decreased) thereafter.

Decadal variation of tropospheric circulation features over Bay of Bengal:

Decadal variation of tropospheric circulation parameters such as wind, relative vorticity at 850hPa and horizontal and vertical shear of zonal wind over Bay of Bengal during monsoon season has been studied for the period 1958-1998 and the results are discussed below.

Latitude-time section of 11-year running mean of u and v at 850hPa averaged over 80°E-100°E during the monsoon season are shown in Figs 2a and 2b respectively. These figures

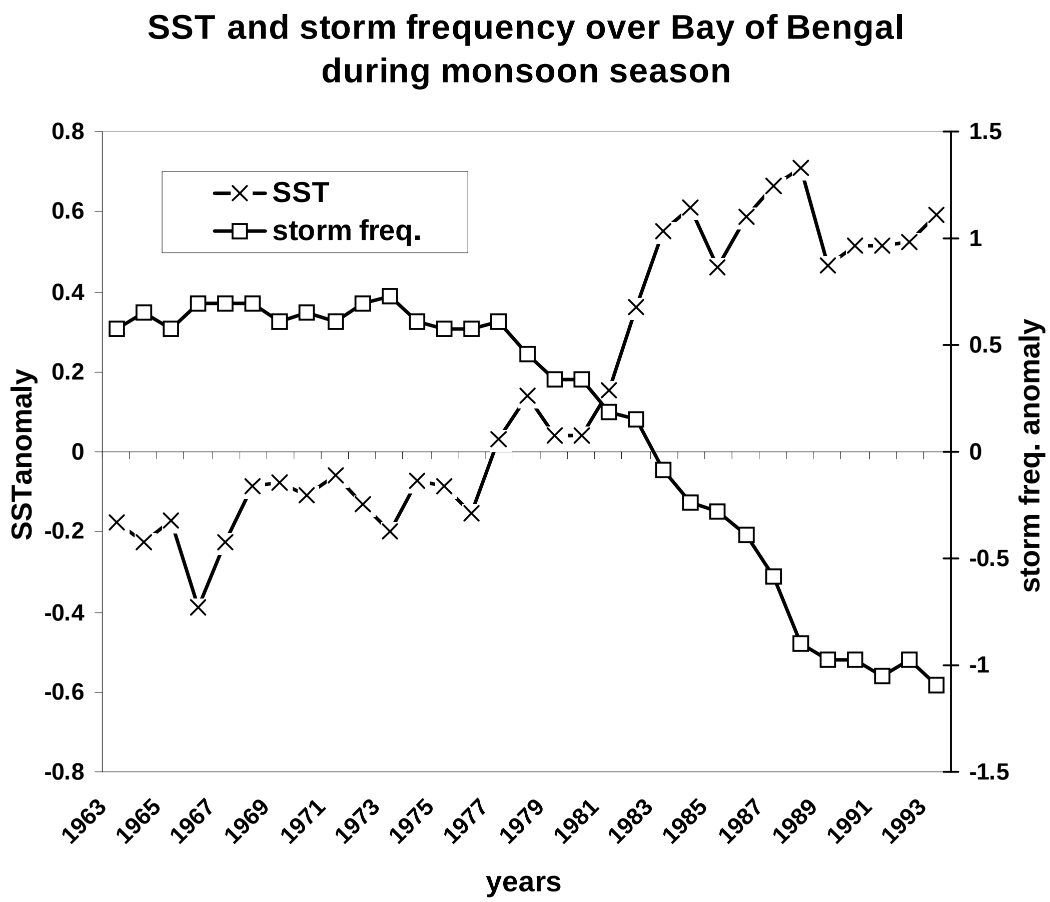

Figure 1. 11-year running mean of standardised anomalies

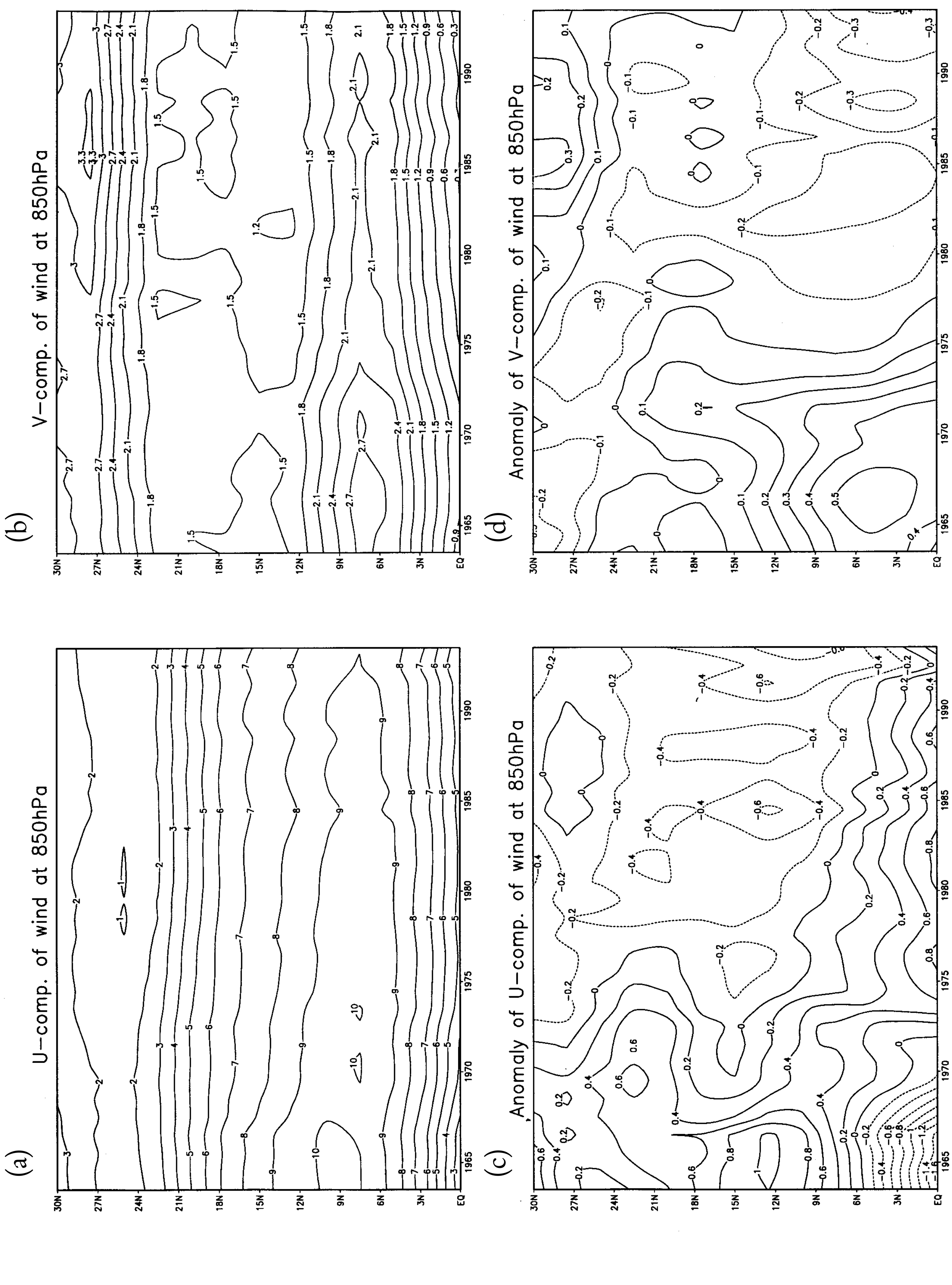

Figure 2. 11-year running mean.

show that the u and v at 850hPa in the monsoon season have decreased over latitudinal belt from 9°N to 30°N from 1980 onwards. This indicates that the strength of cross-equatorial flow is reduced since 1980. Such a zone of strong westerly winds in the lower troposphere is associated with active monsoon conditions over India. The same figure shows that the zone of strong winds also has become weaker since 1980. Time-latitude section for u and v components of wind at 500hPa (figure not shown) also shows similar decrease from 1980 though the wind speed at 500hPa is smaller than at 850hPa. Figs 2c and 2d show the temporal changes of anomalies of u and v components of wind at 850hPa. It is remarkable that the anomalies are positive during epoch1 while negative during epoch2 and reflect the decrease of u and v as is noticed in Figs 2a and 2b. This suggests that the monsoon circulation on decadal scale has become weak in the lower and middle troposphere.

11-year running mean of anomalies of z over Bay of Bengal during monsoon season for the period 1958-1998 at 850 hPa is shown in Fig.3a. Decadal variability of z is such that the anomaly is large positive around 1963 and then decreases rapidly till 1969. It is near normal (small positive) from 1969 to 1980. Anomalies of z changes sign to negative from early 1980 and decreases further till 1993. This change of sign around 1980 is consistent with the decadal variability of storm frequency (Fig.1). We have

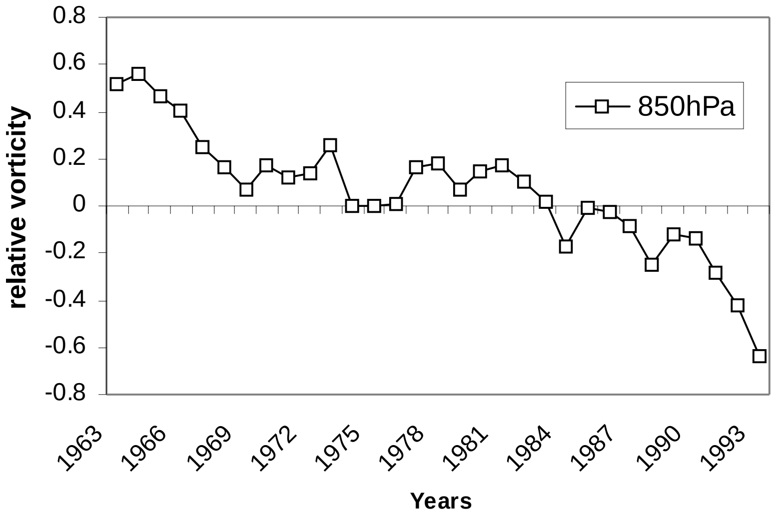

Figure 3(a). 11-year running mean of Relative vorticity anomalies over Bay of Bengal during monsoon season.

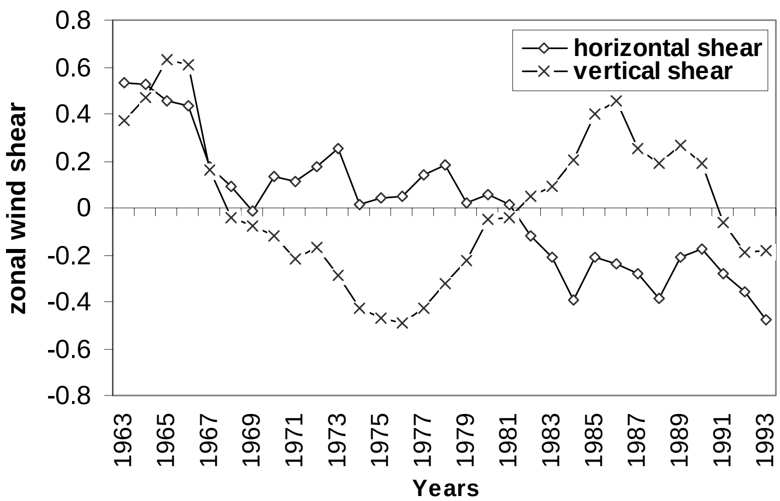

Figure 3(b). 11-year running mean of zonal wind shear anomalies over Bay of Bengal during monsoon season also studied trend of z at 850 hPa (figure not shown), which shows decreasing trend. This trend is tested using Man-Kendall rank statistic test for significance and found to be significant at 99% level of significance. The decreasing trend of relative vorticity is unfavorable for the formation of storms in epoch2. In contrast, near normal anomalies of low-level cyclonic vorticity prior to 1980's is consistent with the near normal storm frequency anomalies in epoch1.

Fig.3b shows 11-year running mean of standardized anomalies of south-north horizontal shear of u at 850hPa and vertical shear of u during monsoon season averaged over Bay of Bengal region. The horizontal and vertical shear anomalies are positive in the 1960s. From early 1970s to 1980, the horizontal shear anomaly is near normal (weak positive), while vertical shear anomaly is negative. A minimum in vertical shear anomaly is around 1975. It should be noted here that the storm frequency anomaly is weak positive from 1963 to 1980. Both horizontal and vertical shear anomalies change sign around 1980 such that the horizontal shear (vertical shear) anomaly becomes negative (positive) thereafter. The storm frequency anomaly has changed to negative around 1980 and decreased subsequently (Fig.1). The strong horizontal shear of zonal wind and weak vertical shear over Bay of Bengal during monsoon season have been noticed from 1969 to 1980, when decadal storm frequency was above normal and the change thereafter appears to be unfavorable. Rajeevan, De & Prasad (2000b) estimated horizontal and vertical shears for the years 1997 and 1998. The year 1997 has been marked with 6 systems while 1998 has 2 systems only. For these two years of contrasting storm activity they found that the 850hPa horizontal shear in 1997 (1998) was 6.6m/sec (2.0m/sec). However, vertical shear was 13.8m/sec (22.2m/sec) in 1997 (1998). We have calculated correlation between frequency of storms and horizontal shear and vertical shear of zonal wind during monsoon season over Bay of Bengal region based on the data for the period 1958-1998. The correlation coefficient (CC) between storm frequency and horizontal shear is 0.36, which is statistically significant at 95% confidence level. However, CC between storm frequency and vertical shear is small and statistically insignificant. It is noticed from Fig.3b that prior to 1969 (after 1990) vertical shear is unfavorable (favorable) for storm. In contrast, horizontal shear anomaly prior to 1969 (after 1990) is large positive (large negative), which is favorable (unfavorable) for storms. The storm frequency anomaly is small positive (large negative) prior to 1969 (after 1990) as seen in Fig.1. This result suggests that the role of horizontal shear is more significant in relation to storm frequency than that of vertical shear. However, this correlation should be analyzed with caution as it is based on data averaged over monsoon season. In reality actual number of days of storms are less than the season and varies from year to year. Also horizontal and vertical shears are averaged over full Bay of Bengal region, which might affect correlation. The relationship of storm frequency with vertical shear noticed in previous studies [Rajeevan, Medha Khole & De (2000a)], [Prince Xavier & Joseph (2000)] might be due to the selection of particular cases.

CONCLUSIONS

Decadal variability of various atmospheric circulation features over Bay of Bengal during the monsoon season for the period 1958-1998, have been studied in relation to decreasing storm frequency on decadal scale during monsoon season in the Bay of Bengal since early 1980s.

11-year running mean of time-latitude section of zonal and meridional components of wind at 850hPa and 500hPa averaged over Bay of Bengal shows decrease in circulation since late 1970s. 11-year running mean of anomalies of relative vorticity at 850hPa over Bay of Bengal indicates near normal anomalies in epoch1 and change in sign of anomaly is noticed in early 1980s. After 1980 anomalies of z remains on the negative side. Decadal variability of horizontal shear of zonal wind at 850hPa shows change in sign of anomaly around 1980 from positive to large negative. In contrast, anomaly of vertical shear of zonal wind between 850hPa and 200hPa changes from large negative to large positive around 1980. Results also indicate that the role of horizontal shear is significant in relation to storm frequency than the role of vertical shear. Decadal variability of all the atmospheric parameters discussed above consistently shows change in sign of anomaly around 1980 such that they are unfavorable for the genesis and intensification of storms after 1980. This suggests that the variability of the atmospheric parameters studied may be related to decreasing storm frequency since 1980 and its further decrease thereafter, in spite of increasing SST.

Limitation of the present study is that the features studied are averaged over monsoon season and not over the days when storm was present. Monsoon depressions form over central Bay of Bengal during June and September and over head Bay in July and August. However, the average is taken over full Bay of Bengal region. Decadal variability of atmospheric circulations features over Bay of Bengal have been studied in relation to decreasing storm frequency but there may be global factors which are responsible for decreasing storm frequency over Bay of Bengal. Thus the detail studies of more dynamical and physical parameters over atmosphere and also over oceans are necessary to understand the causes of decreasing storm frequency over Bay of Bengal. Further studies are also required to understand the causes of decadal variability of the circulation parameters studied. The space-time variation of rainfall occurs in association with the genesis and movement of synoptic scale systems such as lows, depressions, and storms. Hence the study of storm frequency is important for the variability of Indian Summer Monsoon.

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REFERENCES

Kalnay, E.M., Kanamitsu, R., Kistler, W., Collins, W., Deaven, L., Gandin, M., Iredell, S., Saha, G., White. J., Wollen, Y., Zhu, M., Chelliah, W., Ebisuzaki, W., Higgins, J., Janowiak, K.C., Mo, C., Ropelewski, J., Wang, A., Leetma, R., Reynolds, Roy Jenne & Dennis Joseph, 1996. The NCEP/NCAR 40-year Reanalysis Project, Bull. Amer. Meteor. Soc., 77, .437-471.

Patwardhan, S.K, &. Bhalme, H.N., 2001. A study of cyclonic disturbances over India and the adjacent oceans, Int. J. of climatology, 21, 527-534.

Prince K. Xavier & Joseph, P.V., 2000. Vertical wind shear in relation to frequency of monson depressions Tropical cyclones of Indian Seas, in Proc.of TROPMET-2000, Natl.Symp.on Ocean and Atmosphere, pp.232-245

Rajeevan, M., Medha Khole & De. U.S., 2000a. Variability of SST and tropical storms in the Indian Ocean in recent decades, in Proc. of TROPMET-2000, Natl.Symp.on Ocean and Atmosphere, pp.234-237.

Rajeevan, M., De, U.S. & Prasad, R.K,, 2000b. Decadal variability of Sea surface temperature, cloudiness and monsoon depressions in the north Indian Ocean, Curr.Sc.,79 (3), 283-285.

Rajendra Kumar, J. & Dash, S.K., 2001. Interdecadal variations of characteristics of monsoon disturbnances and their epochal relationships with rainfall and other tropical features, Int. J. of climatology, 21 (6), 759-771.

Sikka, D.R., 1977. Some aspects of life history, structure and Movement of Monsoon depressions, Pure and appl. Geophys., 115, 1501-1529.

Singh, O.P., 2001. Long term trends in the frequency of monsoonal cyclonic disturbances over the North Indian ocean, Mausam, 52 (4),.655-658.

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