Climatic Variability of Rainfall and Cyclonic Systems over Vidarbha: New Trends

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ABSTRACT

The present study has been carried out to identify variability and trends between cyclonic systems and annual rainfall in Part-I (1961-1990) & Part-II (1991-2020) of the meteorological data from Vidarbha, India. It has been found that a decreasing trend has been seen in the number of cyclonic systems formed over the Bay of Bengal and the Arabian Sea (-0.207 no. of CS /year and -0.118/year respectively) during Part I, whereas, it has been seen increasing in the number of cyclonic systems formed over the Bay of Bengal and the Arabian Sea (at the rate 0.042 no. of CS /year and 0.141/year respectively) in Part II. Consequently, it is also seen that rainfall trends have been increasing over east Vidarbha. It has been seen that there is a favourable influence of the formation of cyclonic systems on annual rainfall over Vidarbha and improvement in annual rainfall (at the rate of 1.27 mm/year) over East Vidarbha, but slightly decreasing trends (-0.033 mm/year) is seen over west Vidarbha. The impact of the increasing frequency of cyclonic systems over Arabian Sea has been seen over the rainfall of east Vidarbha during the year 1961-1990.

It is observed that trend of the frequency of the formation of cyclonic systems has been decreasing during 1982-2011 and increasing from 2012 onward. No definite trend in annual rainfall was seen during 1961-1983 and 1984 onward, it has been shown an increase over East Vidarbha and annual rainfall has been decreasing during 1988-2003 and 2003 onward no definite trend has been seen over West Vidarbha. There exists a high value of the coefficient of variance between Part-I and Part-II of annual rainfall and cyclonic systems, which indicates good variability for annual rainfall between Part I and Part II of annual rainfall and cyclonic systems. The outcomes of the study would be useful for good planning for agriculture, administration, forecasters and all concerned.

Keywords: *Coefficient of Variation, Cyclonic Systems, Standard Deviation, Trends.*

1. Introduction

The Earth's climate is never static. It varies at all timescales. The present environmental policy on climate change accepts climate change as a global issue. Climate is considered to be the greatest challenge faced by mankind in the present scenario. It is a long term atmospheric change and a global phenomenon. Climate variability describes short-term climate changes that take place over months, seasons and years and about of on to regional areas (Figure1). Therefore, it is equally important to find out climatic variability. Rainfall, relative humidity and temperatures are the main weather elements that directly influence the life of humans, animals and vegetation. They affect water resources, agriculture and other sectors of society. It is, therefore, needed to find out the climatic variability of small areas from time to time. In a changing scenario, it is vital to determine climatic variability to make excellent development and advancement in planning.

Most of the recent studies on the environmental and socio-economic effects of climate change are focused on the month, season and yearly averages to find out climatic change. Mooley and Shukla (1989) found that the frequency of Low Pressure Systems (LPS) has no relation with Indian Summer Monsoon Rainfall (ISMR); rather a positive correlation exists between the total number of days of LPS and ISMR. Kothyari and Singh (1996) showed that rainfall variables decreased and temperature variables increased trend. Singh and Mohapatra (2001) observed a decreasing trend in the depressions formed in the Bay of Bengal during the monsoon season. Das and Goswami, (2003) indicated a lack of significant increasing or decreasing rainfall trends over the entire northeast India. Dash et al. (2004) found that the number of

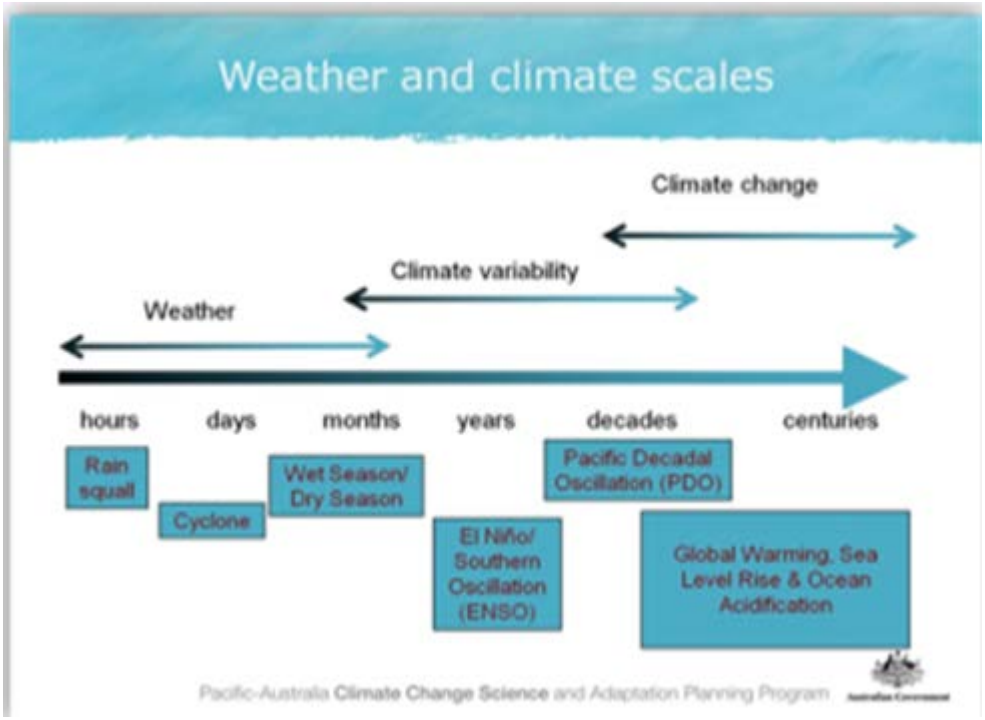

Figure 1: Weather and climate scales.

low pressure systems has been increasing during the last two decades but the unfavorable dynamic conditions do not permit their intensification into depressions and cyclones. Rase et al. (2009) found that seasonal monsoon rainfall over central India does not depend on the number of depressions forming in Bay of Bengal. Friedrich et.al (2009) pointed out in recent years; the Indian Ocean (IO) has been discovered to have a much larger impact on climate variability than previously thought. Kumar (2015) shows a higher variability in annual rainfall indicating that minimum temperature increased at a higher rate at Navsari and Bharuch these two stations as compared with maximum temperature. Kaur et al. (2021) found that the decrease in annual and monsoon rainfall is about 13 to 17 mm and 12 to 13 mm per year respectively at three locations in the lower Shivaliks of Punjab.

Vidarbha is a large land area that lies on the northern part of the Deccan plateau in India and agricultural production is the main job of the people in Vidarbha. Rainfall plays as one of the important contributing factors that determine the sustainability of the ecosystem and productivity of agriculture and it also has been considered one of the influencing factors in climatic variations. Therefore, the researcher aims to understand the long-term trends in climatic variability of the rainfall, and cyclonic systems (cyclonic disturbances, cyclones, and severe cyclonic storms) formed over the seas and land areas of Vidarbha.

Considering the above facts, the objectives of this study are set to (i) determine climatic variability of the rainfall between the period 1961-1990 and the years 1991-2020 of East & West (E&W) Vidarbha and of Vidarbha as a whole, (ii) find out trends of rainfall of E&W Vidarbha and cyclonic systems formed over the Bay of Bengal (BoB), Arabian Sea and the land, (iii) find out significant differences in rainfall between 1961-1990) and 1991-2020 of east & west Vidarbha and the whole of Vidarbha, and (iv) establish the relationship between rainfall of Vidarbha and cyclonic systems formed over BoB, Arabian Sea and the land.

2. Data and Methodology

In the present study, Vidarbha a meteorological sub-division has been considered to carry out research work. Geographically, it is divided into two subparts of east & west Vidarbha. Meteorological data of the departmental stations of Nagpur and Akola were considered representative of east & west Vidarbha respectively. The available meteorological data were obtained from NDC,

Table 1 Mean, Standard Deviation and Coefficient of Variance (CV) of Part-I & Part-II in respect of rainfall & cyclonic systems of various regions.

Region	Variable	Period	Mean	Standard Deviation	Coefficient of variance (%)
East Vidarbha	Rainfall	Part-I	1078.21	225.13	20.88
		Part-II	1126.16	252.31	22.41
West Vidarbha	Rainfall	Part-I	827.87	204.55	24.72
		Part-II	784.46	198.84	25.34
Vidarbha	Rainfall	Part-I	953.04	247.81	26.01
		Part-II	955.31	283.56	29.61
BoB, Arabian Sea & land	Cyclonic systems (cd, c, scs)	Part-I	22.66	6.27	27.66
		Part-II	15.91	4.45	27.96

CRS, Pune through Data Supply Portal (IMD), including frequency of cyclonic systems i.e. cyclonic disturbances (low pressure areas of cyclonic circulations, troughs etc), cyclone and severe cyclonic storms in the seasonal, annual and monthly rainfall and cyclonic systems for the period of 60 years (1961-2020). It has been divided into two parts Part I (1961-1990) & Part II (1991-2020). Mean, Coefficient of Variation (CV), Standard Deviation (SD) and trends & moving averages have been computed to examine interpretations and statistical inferences.

3. Results and Discussion

3.1 Statistical analysis

Table 1 reveals that the mean annual rainfall, SD and CV (1126.16 mm, 252.31 and 22.41 % respectively) of Part-II are greater than the respective values 1078.21 mm, 225.13 and 20.88 % of Part I over East Vidarbha. It indicates that the amount of the annual rainfall during Part II has been increasing as compared to Part I over East Vidarbha. CV of rainfall of Part II is slightly greater than Part-I, which indicates that the rainfall of Part-II has been more variable and less stable.

The annual mean rainfall, SD and CV (784.46 mm, 198.84 and 25.34 % respectively) of Part II are less (except CV) than the respective values of 827.87 mm, 204.55 and 24.72% of Part-I over West Vidarbha. It indicates that the amount of annual rainfall during Part II has been decreasing as compared to Part-I over West Vidarbha. Since CV of rainfall of Part II is slightly greater than that in Part-I, the rainfall of Part-II has been more variable and less stable.

In Vidarbha as a whole, the annual mean of rainfall, SD) and CV (955.31 mm, 283.56 and 29.61 % respectively) of Part-II are greater than the respective values of 953.04 mm, 247.81 and 26.01% of Part-I over Vidarbha. It indicates that the amount of annual rainfall during Part-II has been increasing as compared to Part-I over Vidarbha. CV of rainfall of Part-II is slightly greater than that in Part-I, which indicates that the rainfall of Part-II has been more variable and less stable.

In the case of the number of cyclonic systems (cyclonic disturbances, cyclones and severe cyclonic storms) formed during Part I and Part II over the BoB, the Arabian Sea and land, the annual mean, SD and CV (22.66, 6.27 and 27.66 % respectively) of Part I are greater than the respective values of 15.91, 4.45 and 27.96% of Part II. It indicates that the cyclonic systems formed during Part II were more than those formed during Part II. CV of cyclonic systems in Part II is slightly greater than in Part I. However, annual rainfall is more even though less number of cyclonic systems

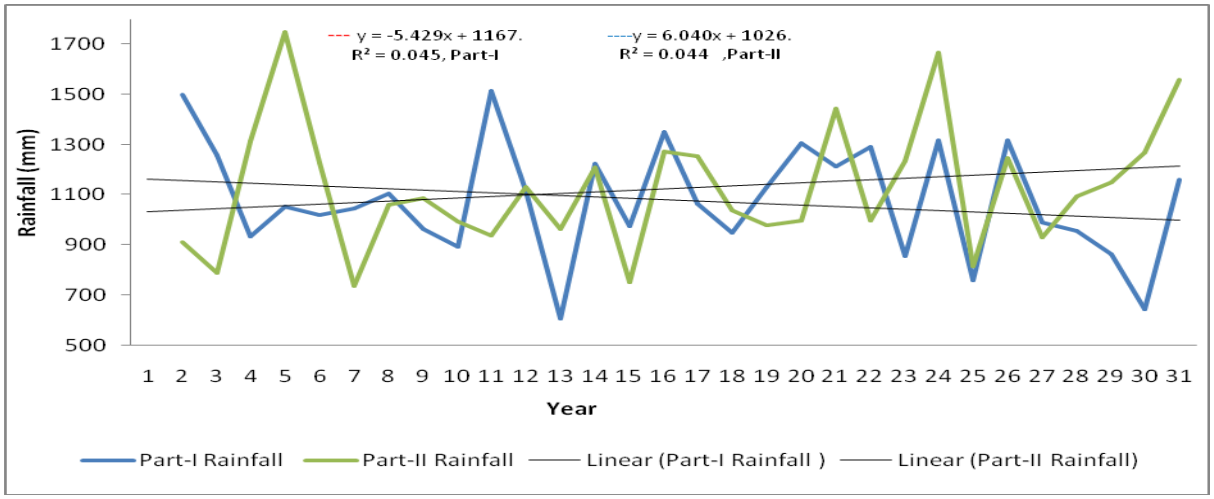

Figure 2: Rainfall (mm) of Part-I and Part-II of Nagpur.

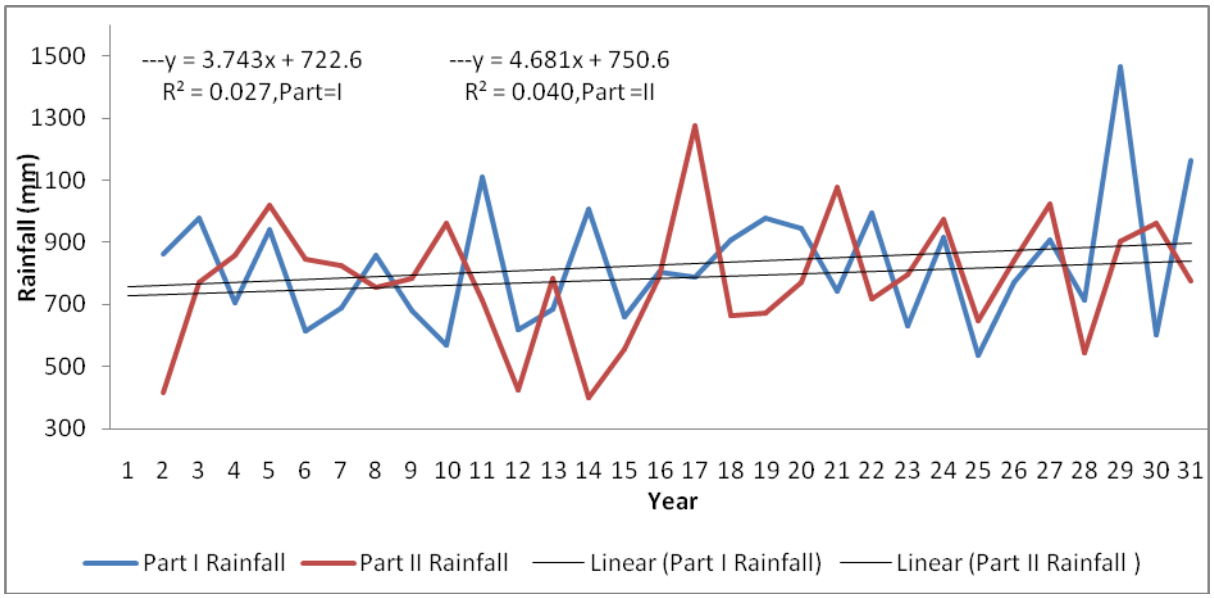

Figure 3: Rainfall (mm) of Part-I and Part-II of Akola.

formed during Part II. It indicates that there was no impact of the formation of cyclonic systems upon the rainfall of Vidarbha.

3.2 Analysis of moving averages and trends of rainfall and cyclonic systems

3.2.1 Moving averages and trends of annual rainfall

Figure 2 depicts the trends of the annual rainfall during Part I & Part II over Nagpur. It has seen a decreased trend at the rate of -5.429 mm / year with R^2 = 0.045, during 1961-1990. Whereas during Part II, it has seen an increasing trend at the rate of 6.040 mm/year with R^2 =0.044. It indicates that rainfall activities have increased over Nagpur during 1991-2020.

Figure 3 depicts the trends of the annual rainfall during Part I & Part II over Akola. It has seen an increasing trend at the rate of 3.742 mm/year with R^2 = 0.027 and during Part II, the trend has also seen increase at the rate of 4.681 mm/year with R^2 = 0.040. It indicates that rainfall activities have increased during both parts of 1961-1990 and 1991-2020, however, in Part II the value of the rate of increasing rainfall has seen more than in Part I over Akola.

Figure 4 depicts the trends of the annual rainfall during 1961-2020 over Nagpur and Akola. It has seen an increasing trend at the rate of 1.27 mm/year with R2 = 0.008 over Nagpur and for Akola, it has seen a decreasing trend at the rate of -0.033 mm/year with R2 =RE-06.

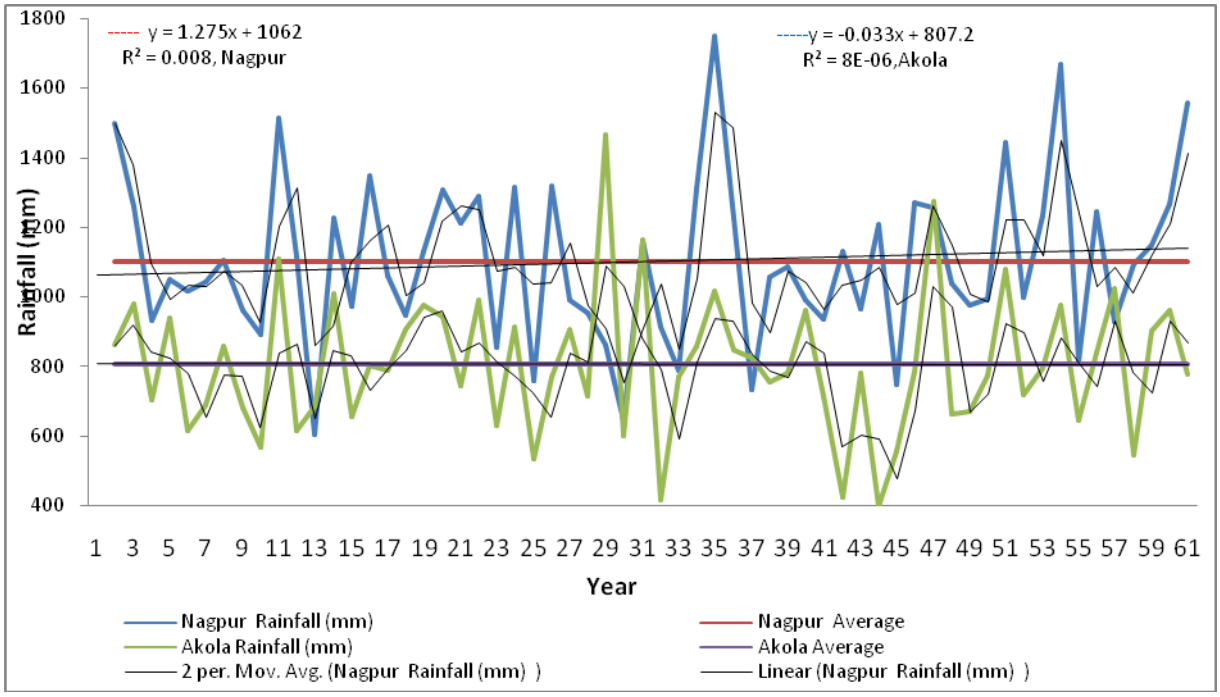

Figure 4: Moving averages and trends of rainfall (mm) for 1961-2020 at Nagpur and Akola.

The trend of the moving averages of the annual rainfall of Nagpur has shown that no definite trend of rainfall has been observed during 1961-1983 and from 1984 onwards, it has seen an increase. The trend of the moving averages of the annual rainfall of Akola has shown a decreasing trend during 1961-1971, an increase during 1972-1987, and again a decrease during 1988-2003 and 2003 onwards no definite trend has been seen of the annual rainfall over Akola.

Figures 2, 3 & 4 pointed out that during the period 1961-2020 rainfall activity has been increasing over Nagpur. However, it has slightly decreased over Akola, but during Part-II, rainfall activity has increased there.

3.2.2 Trends of frequency of cyclonic systems formed over BoB, Arabian Sea and land

Figure 5 depicts the trends of the frequency of Cyclonic Systems (CD, C, SCS) formed during Part I over BoB, Arabian Sea & Land. It has been seen a decreasing trend at the rate of -0.207 with R^2=0.110, of the frequency of cyclonic systems formed during Part-I over BoB, a decreasing trend at the rate of -0.118 with R^2=0.124,of the frequency of the cyclonic systems formed during Part-I over the Arabian Sea, whereas, an increasing trend at the rate of 0.012 with R^2=0.008, has been seen in the frequency of cyclonic systems formed during Part-I over land.

Figure 6 depicts the trend of the frequency of Cyclonic Systems (CD, C, SCS) formed during Part II over BoB, Arabian Sea & Land. It has been seen an increasing trend of the frequency of cyclonic systems at the rate of 0.042 with R^2=0.009 formed during Part II over BoB, an increasing trend at the rate of 0.141 with R^2=0.091 of frequency of the cyclonic systems formed during Part II over the Arabian Sea, and also an increasing trend at the rate of 0.032 with R^2=0.074 formed during Part-II over land.

Figures 5 & 6 show that the frequency of cyclonic systems decreased during Part-I (also pointed out by Singh and Mohapatra, 2001) and increased during Part-II over BoB and Arabian Sea whereas over land, it has increased during both Part-I & Part-II.

3.2.3 Moving averages and Trends of the frequency of Cyclonic Systems formed in total (over BoB, Arabian Sea and Land) during Part I and Part II

Figure 7 depicts the moving average and trend of the frequency of cyclonic systems formed over BoB, Arabian Sea & land during Part-I. There is a

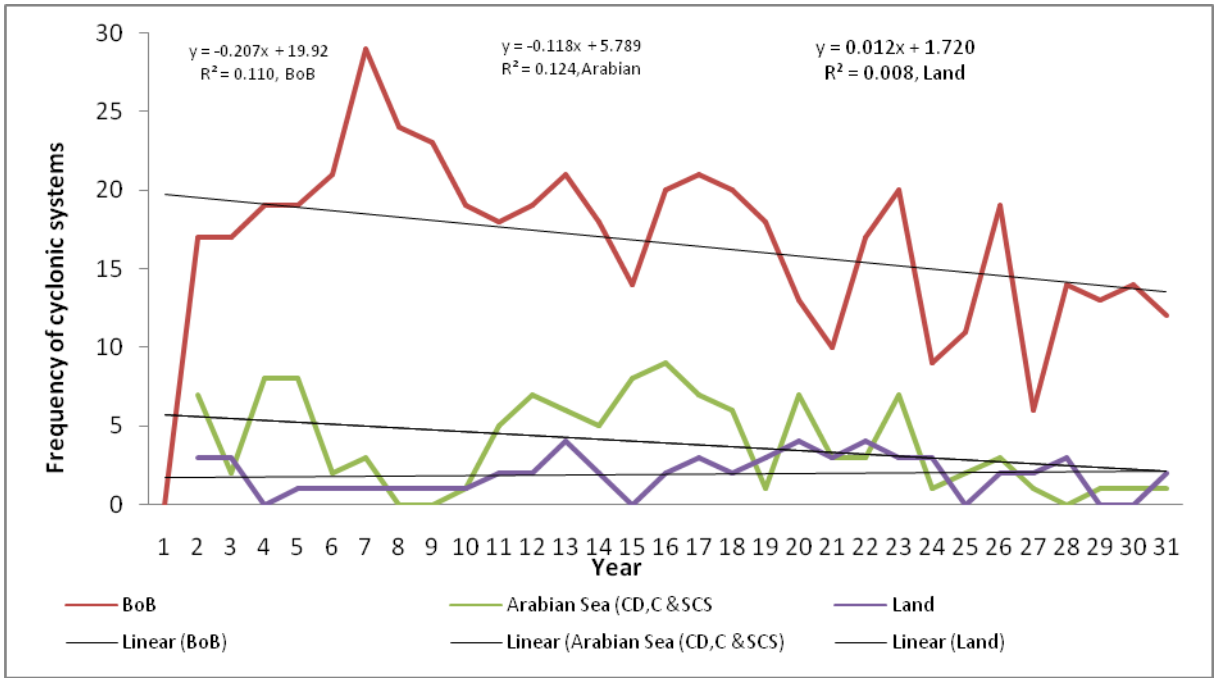

Figure 5: Frequency of Cyclonic Systems (CD, C, SCS) formed during Part-I over BoB, Arabian Sea & land.

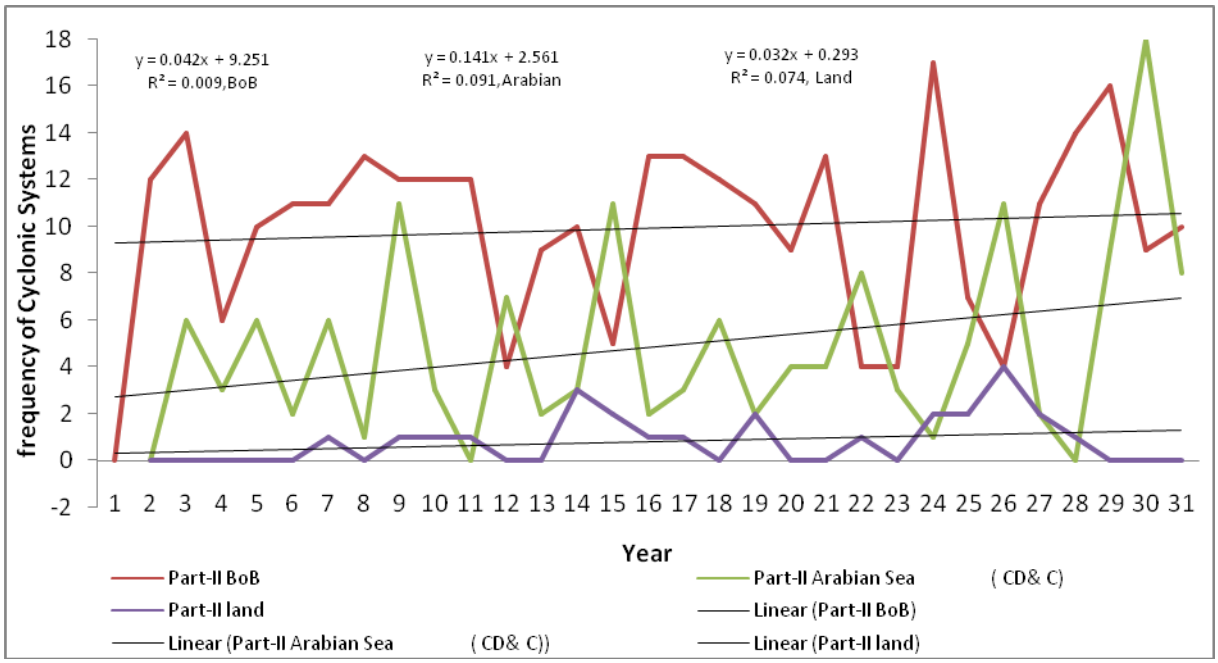

Figure 6: Frequency of Cyclonic Systems (CD, C, SCS) formed during Part-II over BoB, Arabian Sea & Land.

decreasing trend at the rate of -0.45 with R^2=0.399 during Part-I, and the moving average has sown no definite trends from 1961-1975. During 1976-1990, there is a decreasing trend.

Figure 8 depicts the moving average and trend of the frequency of cyclonic systems formed over BoB, Arabian Sea & land during Part-II. There is an increasing trend of frequency of cyclonic systems at the rate of 0.156 with R2=0.095 during Part-II and the moving average has no definite trend during 1990-2020.

Figure 9 depicts the moving average and trend of the cyclonic systems formed over BoB, Arabian Sea & land during 1961- 2020. There is a decreasing trend of frequency of cyclonic systems at the rate of - 0.205 with R2=0 during 1961-2020.

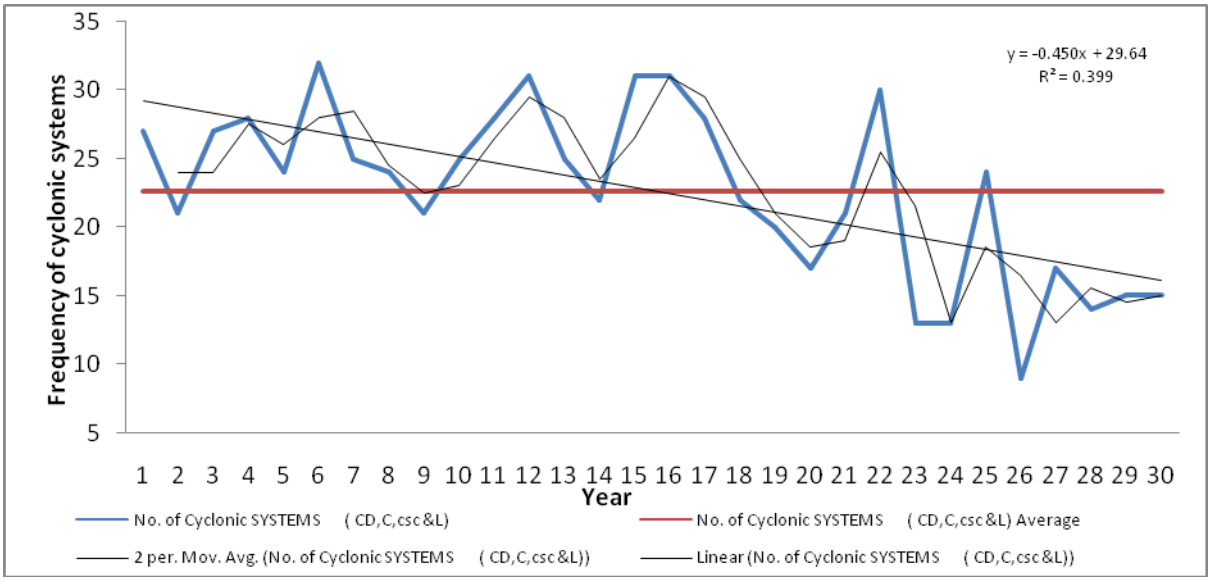

Figure 7: Moving average and trend of frequency of cyclonic systems formed in total (over BoB, Arabian Sea & Land) during Part I.

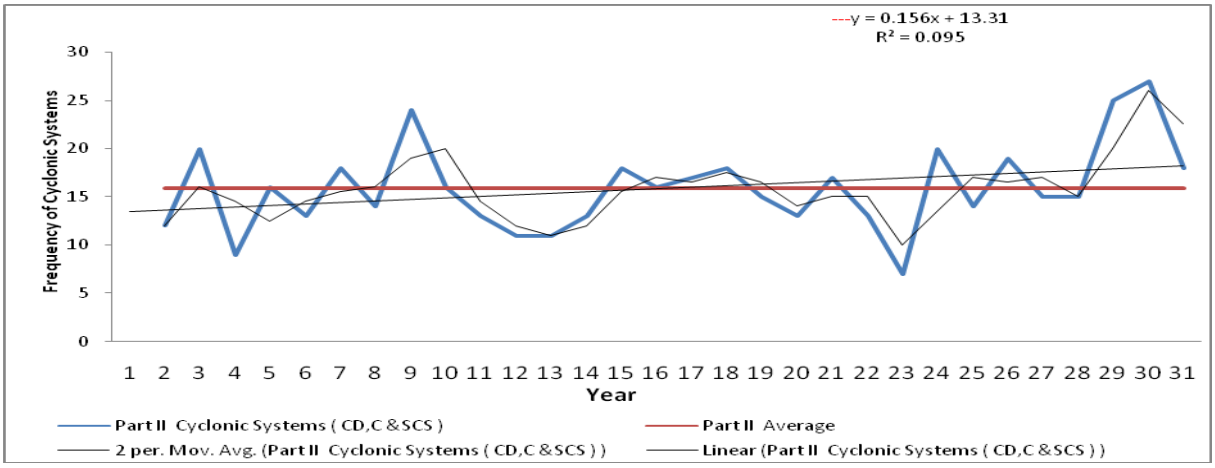

Figure 8: Frequency of Cyclonic Systems (CD,C, SCS) formed in total (over BoB, Arabian Sea & Land) during Part II.

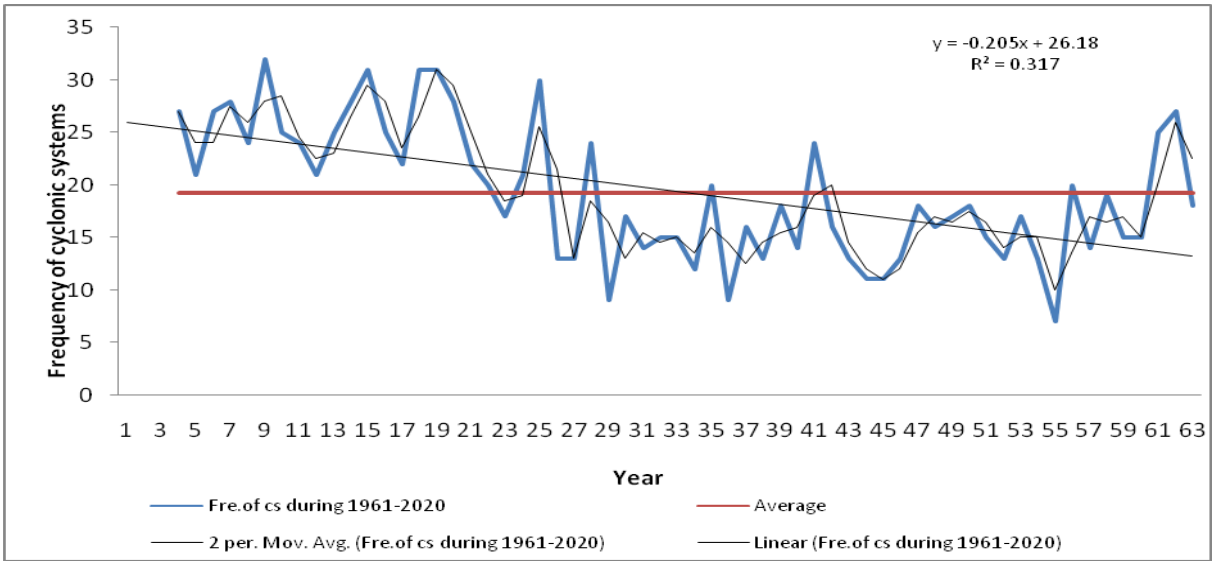

Figure 9: Trends and the moving average of the frequency of cyclonic systems formed in total (over BoB, Arabian Sea & Land) during 1961-2020.

The moving average has no definite trend during 1961-1988. There is an increasing trend observed during 1989-2003, and no definite trend onwards.

Figures 7, 8 & 9 show the decreasing trend of the frequency of cyclonic systems formed over BoB, Arabian Sea & land during 1961-1990 & 1961-2020, whereas the trend of the frequency of cyclonic systems has increased over BoB, Arabian Sea and land during 1990-2020.

Figures 2, 5 & 7 reveal the trend of rainfall over Nagpur and the trend of frequency of the cyclonic systems formed separately over BoB, Arabian Sea & Land and total (over BoB, Arabian Sea & Land) during Part-I. Figure 2 shows the trend of the rainfall has decreased over Nagpur during Part I, and Figure 5 shows the trend of cyclonic systems formed over BoB & Arabian Sea and Figure 7 shows the frequency of cyclonic systems formed in total (Over BoB, Arabian Sea & land) were also shown decreasing. It established a positive relationship between the rainfall and the formation of cyclonic systems formed separately over BoB & Arabian Sea and the cyclonic systems formed in total (Over BoB, Arabian Sea & land) during Part-I and the rainfall over Nagpur and the formation of cyclonic systems formed separately over land during Part-I established a negative relation.

Figures 2, 6 & 8 reveal the trend of rainfall over Nagpur and the trend of frequency of the cyclonic systems formed separately over BoB, Arabian Sea & land and total (over BoB, Arabian Sea & Land) during Part-II. Figure 1 shows the trend of the rainfall has increased over Nagpur during Part-II, and Figure 6 shows the trend of cyclonic systems formed over BoB, Arabian Sea & Land has shown increasing and Figure 7 shows the frequency of cyclonic systems formed in total (Over BoB, Arabian Sea & land) were also shown increased. It established a positive relationship between the rainfall and the formation of cyclonic systems formed separately over BoB, Arabian Sea & Land and the cyclonic systems formed in total (Over BoB, Arabian Sea & land) during Part-II over Nagpur.

Figures 3, 5 & 7 reveal the trend of rainfall over Akola and the trend of frequency of the cyclonic systems formed separately over BoB, Arabian Sea & Land and total (over BoB, Arabian Sea & land) during Part-I. Figure 3 shows the trend of the rainfall has increased over Akola during Part I, and figure 5 shows the trend of cyclonic systems formed over BoB & Arabian Sea has also seen the increasing trend and Figure 7 shows the frequency of cyclonic systems formed in total (Over BoB, Arabian Sea & land) were shown a decreasing trend. It established a positive relationship between the rainfall and the formation of cyclonic systems formed separately over BoB & Arabian Sea and the a negative relation has been seen between the rainfall & cyclonic systems formed in total (Over BoB, Arabian Sea & land) during Part-I. The rainfall over Akola and the formation of cyclonic systems formed during Part I over land established a negative relation.

Figures 3, 6 & 8 reveal the trend of rainfall over Akola and the trend of frequency of the cyclonic systems formed separately over BoB, Arabian Sea & Land and total (over BoB, Arabian Sea & Land) during Part-II. Figure 3 shows the trend of the rainfall has increased over Akola during Part-II, and Figure 6 shows the trend of cyclonic systems formed over BoB, Arabian Sea & land and Figure 8 shows the frequency of cyclonic systems formed in total (Over BoB, Arabian Sea & Land) were also shown increased. It established a positive relationship between the rainfall and the formation of cyclonic systems formed separately over BoB, Arabian Sea & land and the cyclonic systems formed in total (Over BoB, Arabian Sea & Land) during Part-II over Akola.

Figures 4 & 9 reveal the moving averages and trends of rainfall and cyclonic systems formed over BoB, Arabian Sea & Land during 1961-2020 over Nagpur & Akola. Figure 4 shows the trend of the rainfall has increased and figure 8 shows the trend of cyclonic systems has decreased over Nagpur, it established a negative relationship between the rainfall and cyclonic systems formed over BoB, Arabian sea & Land over Nagpur. For Akola, Figure 4 shows the trend of rainfall has slightly decreased and figures 9 shows the trend of cyclonic systems has also decreased over Akola, it established a positive relationship between the

rainfall and cyclonic systems formed over BoB, Arabian Sea & land over Akola. It has been pointed out that the moving averages of rainfall decreased during 1989-2003 and the formation of cyclonic systems increased during 1989-2003.

4. Conclusions

Based on the above analysis, the following conclusions are drawn in the given study:

(i) The rainfall during the years 1991-2020 has been more variable over east Vidarbha, west Vidarbha and the whole of Vidarbha. However, the formation of cyclonic systems formed during the years 1991-2020 over Bay of Bengal, Arabian Sea and Land are less variable.

(ii) The number of the formation of cyclonic systems formed during the years 1991-2020 over the Arabian Sea has been seen increasing; as a result, the amount of annual rainfall has increased over east Vidarbha during the same period. However, no significant relationship has been found between the number of cyclonic systems and annual rainfall over west Vidarbha.

(iii) Over East Vidarbha, no definite trend of the annual rainfall has been noticed during the years 1961-1983. However, from 1984 onwards there is an increasing trend over East Vidarbha. But, no definite trend of annual rainfall has been seen over West Vidarbha.

(iv) The annual mean rainfall has been increasing at the rate of 1.27 mm/year with R^2= 0.045 over East Vidarbha during the years 1961-2020. However, over west Vidarbha annual mean rainfall has a slightly decreasing trend at the rate of -0.033 with R^2=8E-06 during the period 1961-2020.

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