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A study of Cyclonic Storms of the South Indian Ocean And Indian Summer Monsoon Rainfall

P. Chandrasekhara Rao*[1], Vishal. S. Thorat[2], Vrishali V. Kulkarni[1] and P.H. Raghavendra Rao[1]

[1]India Meteorological Department, Pune, India
[2]Junior Research Fellow, India Meteorological Department, Pune, India
*Corresponding Author: pcsraoimd@gmail.com

ABSTRACT

Coastal regions of the globe that have potential threat from the storms are studied well, but mid-oceanic storms which rarely approach the coast are not paid adequate attention. One such region is the South Indian Ocean (SIO) basin, where more than 15 storms form every year. Over 80% of these do not impact countries either in the West basin or those in the East basin but die out in the ocean itself. However they are likely to show considerable effect on the Indian summer monsoon rainfall. Hence, in this study an attempt is made to find the correlation of these storms with the Indian Summer Monsoon Rainfall (ISMR). Also, the effect of El-Nino Southern Oscillation (ENSO) on the genesis of storms is studied. During El-nino episodes, storms of the SIO get shifted to the Western part with the ultimate result of less rainfall over India. Storm activity gets significantly reduced in the Eastern part of SIO during El-nino. It is found that the correlation coefficient is -0.37 for the West SIO storms and all India rainfall during El-Nino years. Correlation coefficient of -0.15 is obtained for the West SIO storms and 0.26 for East SIO storms with the June all India summer monsoon rainfall.

Key words: South Indian Ocean, Indian Summer Monsoon Rainfall, El Nino, La Nina, Storms

INTRODUCTION

Tropical cyclones form in equatorial regions, where sea surface temperatures (SSTs) exceed 26-27°C, but rarely within less than 4°-5° from the Equator, some literatures have listed several other conditions favoring genesis, such as (i) large values of low level relative vorticity, (ii) weak vertical and horizontal wind shear, (iii) conditional instability through a deep atmospheric layer, (iv) large relative humidity in the lower and middle troposphere, all of which are fulfilled within the Inter-Tropical Convergence Zone (ITCZ), and (v) a deep oceanic mixed layer (Alberto et al., 2009). A rapidly rotating storm system with a low-pressure center, strong winds, and a spiral arrangement of thunderstorms and heavy rain is recognized as tropical cyclone (Kumar and Kumar, 2013). It is referred to by names such as hurricane in the Northeast Pacific or in North Atlantic, typhoon in North-Western Pacific, and tropical cyclone in the Indian ocean.

About one-third of world petroleum supplies and over half of sea-trade in crude oil pass through South-West Indian Ocean waters (Chang-Seng and Jury, 2010a). Sudden cyclogenesis and storm surges increase the risk of marine environmental hazards and coastline erosion, particularly for island nations such as Mauritius, Reunion and Madagascar (Chang-Seng and Jury, 2010a). More often, meridional pulses of the Indian Monsoon create periods of cyclonic vorticity and Tropical Cyclone development around 10^0S (Chang-Seng and Jury 2010b).

Each basin has different time periods of storm formation. Pacific and Atlantic basins have maximum storms during the northern hemisphere summer season. In the North Indian Ocean cyclones are in maximum number during pre- and post- monsoon seasons. In South Indian Ocean (SIO), tropical cyclone activity begins in late October and ends in May with its peak from late January to early March. Cyclones that form in the west of the SIO can affect Mauritius, Mozambique, Madagascar, Tanzania and Kenya, where as those in the east of SIO can affect Australia and Indonesia (Rao et al., 2012)

Cyclones are of different categories depending on the intensity, which is measured in terms of the prevailing wind speeds. There are seven categories of cyclones in the South Indian Ocean, tropical disturbance (< 27 kt), tropical depression (28 - 33 kt), moderate tropical storm (34 – 47kt), severe tropical storm (48 - 63 kt), tropical cyclone (64 - 89 kt), intense tropical cyclone (90 – 115 kt), very intense tropical cyclone (> 115 kt) (WMO/ESCAP Panel on Tropical Cyclones, 2015). For any region, storms that can affect the coasts are well monitored and studied but the storms that occur in the middle of the ocean are rarely considered in the study of rainfall over the land. Mid-oceanic storms can play an important role in the transfer of heat from one region to another. Since heat potential associated with the storm is considerably large, it can affect the weather patterns and the amount of rainfall. The effect of storms forming in the SIO on the Southwest Monsoon is discussed here.

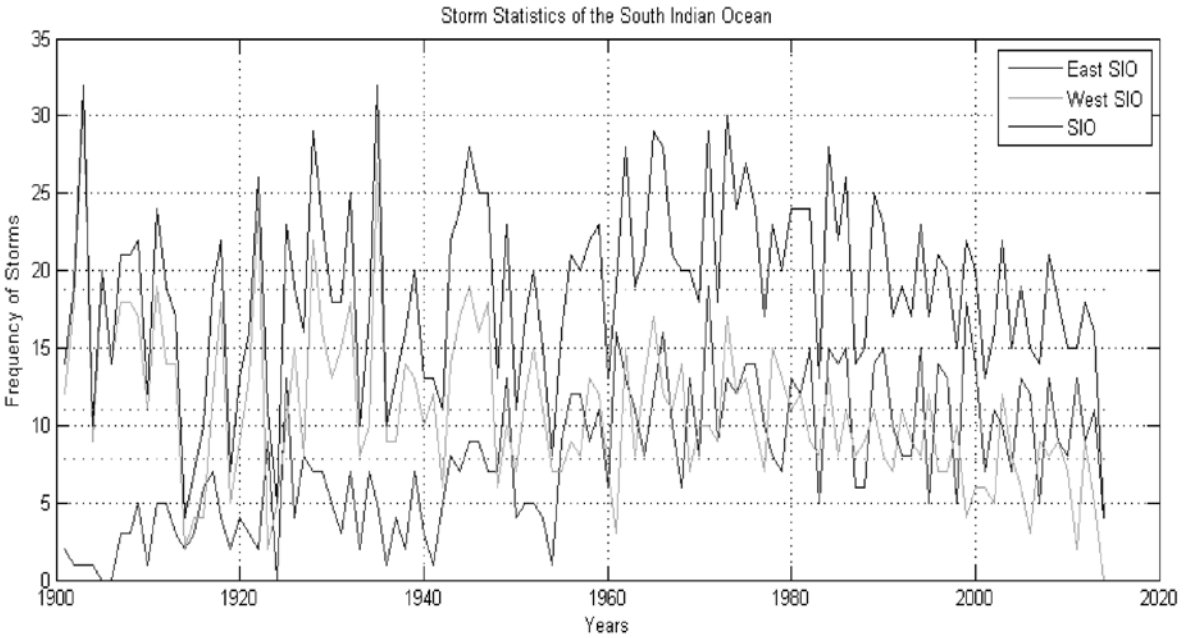

Figure 1. Frequency of Occurrences of Storms of the South Indian Ocean.

DATA AND METHODOLOGY

Yearly data of number of storms in South Indian Ocean is obtained from the NOAA's, National Climate Data Center (NCDC). International Best Track Archive for Climate Stewardship (IBTrACS) of NCDC has the centralised data of tropical cyclones worldwide to aid in understanding of the distribution, frequency and intensity of the storms (Knapp et al., 2010). Data are available for all the basins in the Network Common Data Form (NetCDF). Figure 1 shows the plot of all the tracks of storms formed in the South India Ocean for the period of 1901 to 2014. Storm statistics are shown for the separate east and west regions of the SIO in the following section.

After the storm statistics, analysis of storm activity with the Indian Summer Monsoon Rainfall (ISMR) is carried out. Data on the amount of rainfall in the respective monsoon seasons is acquired from the IMD data archive. And subsequently, it is shown how the El Nino and La Nina episodes have affected the storm activity. Data on the El Nino and La Nina is acquired from the NOAA's Climate Prediction Center (CPC) for the period of 1950-2015.

RESULT AND DISCUSSION

Storm Statistics

Annual frequency of the storms for the period from 1901 to 2014 is derived from the IBTrACS data set. Later, data are seperated for the east as well as west basins of the South Indian Ocean in order to understand the difference of occurences of storms between the two regions. In Figure 1, data are plotted for the east (bottom), west (faint line in the middle) and whole SIO (bold line on top of the figure) regions.

It is observed that the storms formed in the eastern SIO are less in number compared to western SIO. Total 2142 storms have been formed for the whole SIO region during 1901-2014. Among them 1250 and 892 storms have occurred in the western and eastern SIO respectively. On an average 19 storms have formed in a year in the SIO, 8 storms in the eastern and 11 storms in the western basin.

Storms in the east were well below average for the first half of the 20th century and increased only after the mid twentieth century and then remained almost constant there after. The storms in the west were at their peak during the first half of the 20th century. Later, in the late 20th century and at the beginning of the 21st century, frequency of storms has reduced drastically. (Overall the storm activity is showing decreasing trend from eighties, mainly attributed to the reduced number of storms in the west). Highest number of storms recorded in SIO is 32 in both 1903 and 1935, while those in the eastern basin are 19 in 1971 and 31 in western basin in 1903.

ENSO Correlation with the Storm Statistics

El Nino and La Nina are part of a larger cycle called ENSO. ENSO episodes from 1991 to 2010 and are captured and analysed with the corresponding storm activity of the South Indian Ocean. During the ENSO episodes, El-Nino or La-Nina, Storms gets shifted to the West SIO and

Table 1. El-Nino and La-Nina Years with ISMR (1901-2010).

EL-Nino, Storms and Rainfall					La-Nina, Storms and Rainfall				
El-Nino Years	No. of Storms in		Total no. of Storms	El-Nino Years R/F (mm)	La-Nina Years	No. of Storms in		Total no. of Storms	La-Nina Years R/F (mm)
	(WSIO)	(ESIO)				(WSIO)	(ESIO)		
1902	18	1	19	792.1	1903	9	1	10	891.9
1905	20	0	20	718.5	1909	17	5	22	927.9
1914	2	2	4	964.3	1910	11	1	12	940.2
1918	18	4	22	736.5	1916	4	6	10	1056.1
1930	13	5	18	876.4	1917	12	7	19	1124.2
1940	10	3	13	905.0	1922	24	2	26	957.5
1941	12	1	13	813.5	1924	5	0	5	972.8
1951	12	5	17	749.2	1933	8	2	10	1061.0
1953	11	4	15	983.4	1938	14	2	16	1005.0
1957	8	12	20	898.1	1942	6	5	11	1040.5
1958	13	9	22	1012.9	1950	7	4	11	923.2
1963	8	11	19	912.2	1954	7	1	8	914.4
1965	17	12	29	738.3	1955	7	9	16	962.0
1969	7	13	20	888.3	1964	13	8	21	1031.5
1972	9	9	18	697.4	1970	10	8	18	998.7
1977	7	10	17	911.3	1971	10	19	29	925.5
1982	9	15	24	767.4	1973	17	13	30	956.0
1986	11	15	26	769.8	1975	13	14	27	1011.5
1987	8	6	14	774.6	1988	9	6	15	1094
1991	7	10	17	828.3	1998	10	5	15	943.1
1994	8	15	23	1001.2	1999	4	18	22	863.2
1997	7	13	20	927.3	2007	9	5	14	942.9
2002	5	11	16	737.3	2010	7	8	15	911.1
2004	8	7	15	774.1					
2006	3	12	15	889.3					
2009	9	9	18	698.2					

cause less rainfall over India during the Indian Summer Monsoon Season. Table 1 shows the El-Nino and La-Nina years with corresponding SIO storms and Indian Summer Monsoon Rainfall (ISMR). It is found that the correlation coefficient is -0.37 for the West SIO storms and all India rainfall during El-Nino years. Correlation coefficients are -0.13 and -0.17 for the East and West SIO storms with ISMR during the La-Nina years.

Decadal Analysis of Storms:

Figure 2 depicts the decadal frequency graph of storms of East SIO (ESIO), West SIO (WSIO) and overall SIO. The graph shows alternate ups and downs in the frequency till 1970. There is an increase in frequency in the decade 1971-80 compared to previous decade, and the frequency has been decreasing since 1981. The ratio of storms of East SIO to West SIO remains between 0.3 and 0.4 for the decade, i.e., 1851-60, 1871-80 and 1911-20. The same remains between 0.4 to 0.6 for decades 1861-70, 1881-90, 1921-30 and 1941-50. The ratio drops to 0.1 for decades 1891-00 and 1901-10. The storms in the east have been on the rise since 1941. In fact, since 1961, there have been more storms in the East than in the West. The ratio has been more than 1 and increasing since 1961. The activity over the West was relatively higher till 1950, which was nearly double than that of East. Thereafter, the activity over East is gradually on the rise while it is decreasing over the West.

Storms in SIO and the ISMR

Maximum number of storms occurs in this SIO region during the four months of December, January, February and March and the Indian summer monsoon is from June to September. There seems to be little correlation between the storms and the immediate Indian summer monsoon rainfall season, especially in the southern peninsular India. Respective correlation coefficients are -0.106 and -0.187 for the monsoon seasonal and southern peninsular India (SPIN) rainfall. Rainfall of All India June (AI June), All

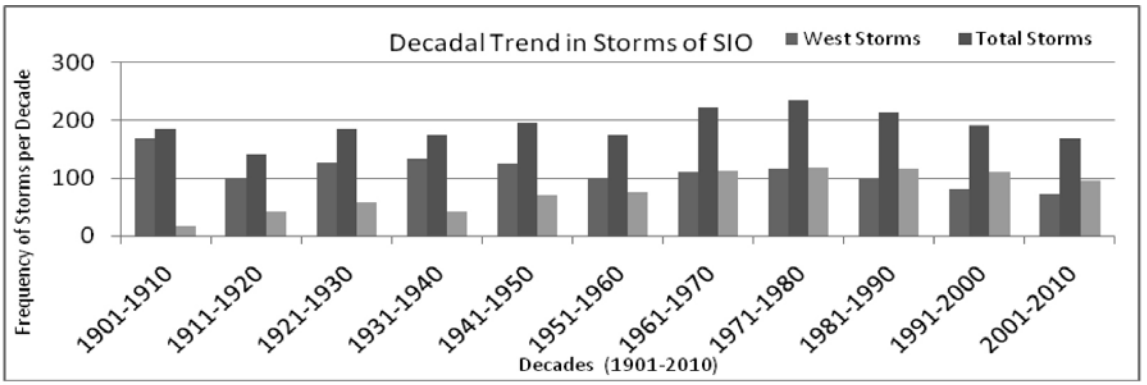

Figure 2. Decadal frequency of Storms of the South Indian Ocean.

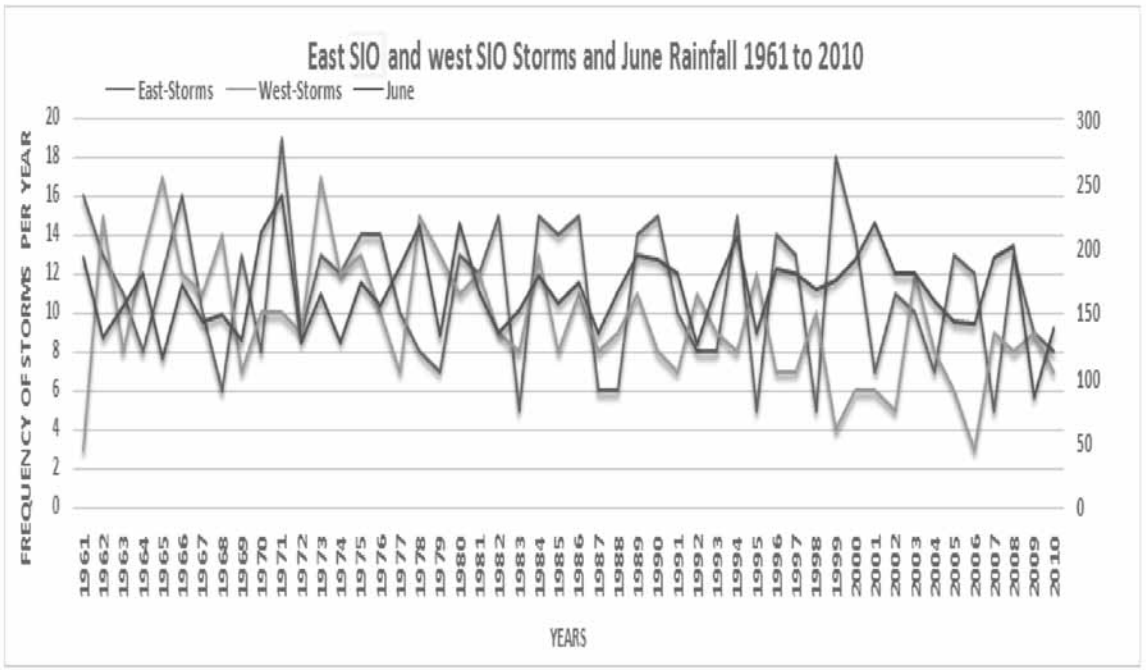

Figure 3. Rainfall in June, storms in East, West SIO (1961 -2010).

India (AI), Southern peninsular India (SPIN) and number of storms in East SIO (ESIO), West SIO (WSIO) for the period 1961-2010 are plotted in Figures (3, 4 & 5). The figures depict that storms in both West SIO and East SIO have been on the decline since last decade. The fluctuations in frequency of storms as well the number of storms is reducing.

At the same time, SPIN rainfall almost remains within the range of 922mm and 542mm. AI rainfall remains within the range of 1094 and 698mm. For the month of June, the rainfall range is from 85mm to 240mm; the SPIN and AI rainfall being a little on the higher side in the last 2 decades.

Figure 3 depicts storms in ESIO, WSIO and rainfall in June over India. For storms in WSIO and June rainfall, there is a negative correlation co-efficient (- 0.14619). For El Nino years 1965 and 2009, it is seen that Storms in WSIO increase in number and AI June rainfall decreases. For years 1963, 1977 and 1994, number of Storms in WSIO decreases and AI June rainfall increases. We can also see that for years 1969, 1972, 1982, 1986, 1987, 1991, 2002, 2004 and 2006, storms in WSIO and AI June rainfall both increase or both decrease together. For the year 1997, Storms in WSIO remain the same while AI June rainfall decreases.

For storms in ESIO and AI June rainfall, there is a positive correlation co-efficient of 0.26454. For El Nino years 1965, 1969, 1982 and 2002, it is seen that the number of storms in ESIO increases and AI June rainfall decreases. For years 1963 and 1977, storms in ESIO decrease and AI June rainfall increases. We can also see years 1972, 1986, 1987, 1991, 1994, 1997, 2004, 2006

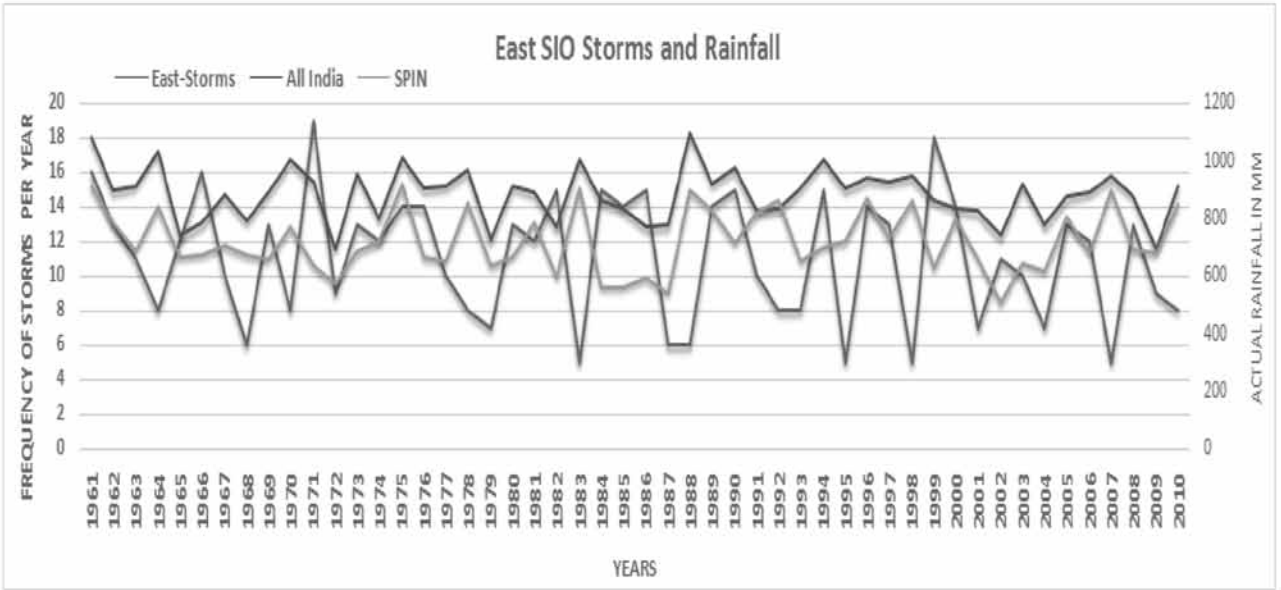

Figure 4. Rainfall AI, SPIN, storms in East SIO (1961 -2010).

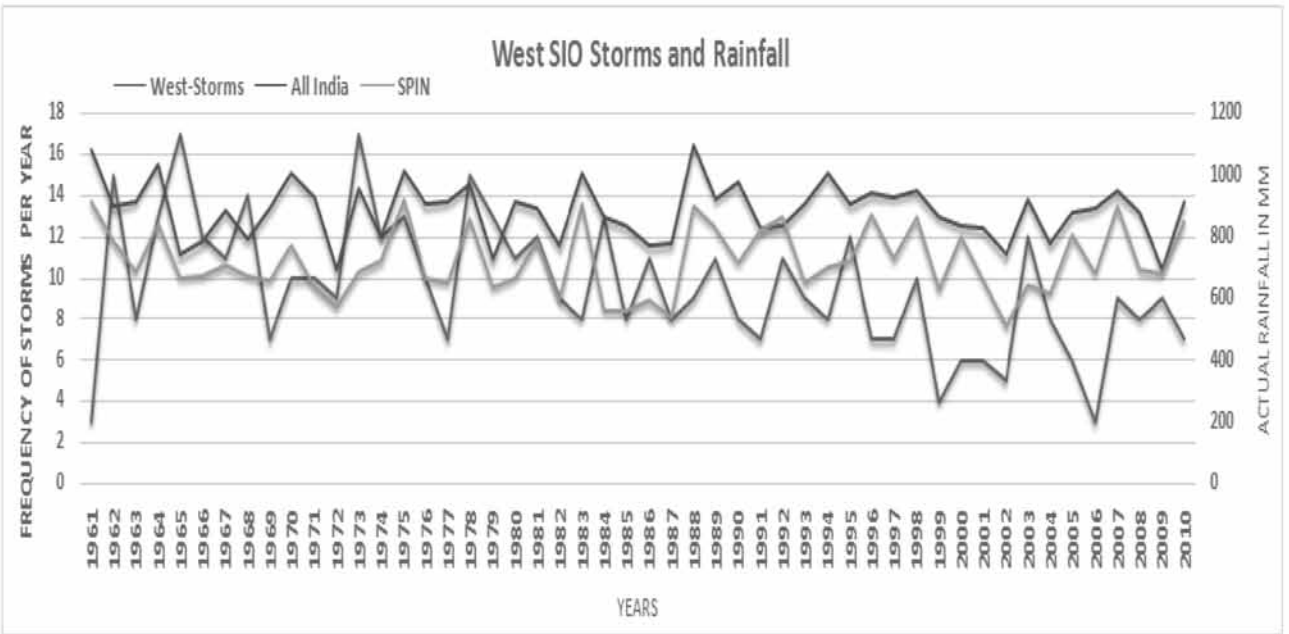

Figure 5. Rainfall AI, SPIN, Storms in West SIO (1961 -2010)

and 2009; where storms in ESIO and June rainfall both increase or both decrease together.

Figure 4 depicts rainfall of AI, SPIN rainfall and storms in ESIO. For the storms in ESIO and SPIN rainfall, there is a negative correlation co-efficient (- 0.21671). For El Nino years 1965, 1969, 1982 and 2002, it is seen that storms in ESIO increase and SPIN rainfall decreases. For year 1991, storms in ESIO decrease and SPIN rainfall increases. We can also see the years 1963, 1972, 1977, 1986, 1987, 1994, 1997, 2004, 2006 and 2009, when storms in ESIO and SPIN rainfall both increase or both decrease together.

For storms in ESIO and AI rainfall, no correlation is seen. For El Nino years 1965, 1982, 1986 and 2002, it is seen that storms in ESIO increase and AI rainfall decreases. For years 1963, 1977, 1987 and 2006, storms in ESIO decrease and AI rainfall increases. We can also see that for the years 1969, 1972, 1991, 1994, 1997, 2004 and 2009, storms in ESIO and AI rainfall both increase or both decrease together.

Figure 5 depicts graph of AI rainfall, SPIN rainfall and storms in WSIO. For the storms in WSIO and SPIN rainfall, no correlation is seen. For years 1965 and 2009, storms in WSIO increase and SPIN rainfall decreases. For years 1991 and 1994, storms in WSIO decrease and SPIN rainfall increases. We can also see that for the years 1963, 1969, 1972, 1977, 1982, 1986, 1987, 2002, 2004 and 2006, storms in WSIO and SPIN rainfall both increase or both decrease together. For year 1997, storms in WSIO remain the same while SPIN decreases.

For storms in WSIO and AI rainfall, no correlation is seen. For El Nino years 1965, 1986, 2009, it is seen that storms in WSIO increase and AI rainfall decreases. For years 1963, 1969, 1977, 1987, 1994 and 2006, storms in WSIO decrease and AI rainfall increases. We can also see years 1972, 1982, 1991, 2002 and 2004, where storms in WSIO and AI rainfall both increase or both decrease together. For year 1997, storms in WSIO remain the same while AI rainfall decreases.

CONCLUSIONS

1. Storms show decreasing trend towards end of the 19th century for whole SIO, although frequency of storms in the east SIO has increased. Decreasing trend is mainly attributed to the drastic reduction in number of storms in the west SIO.
2. The activity over the West SIO was relatively higher till 1950, which was nearly double than that of East SIO. Thereafter, the activity over East SIO is gradually on the rise and it is otherwise over the West.
3. AISMR is negatively correlated (-0.37) with storms in WSIO during the preceding months of the EL-Nino year.
4. All India June rainfall is negatively correlated (-0.14619) with the storms in WSIO and positively correlated (0.26454) with the storms in ESIO.

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Compliance with ethical Standards

The authors declare that they have no conflict of interest and adhere to copyright norms.

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