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Post monsoon tropical cyclone activity in the north Indian Ocean in relation to the *El Nino*/southern oscillation phenomenon

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सार — उत्तरी हिन्द महासागर पर मानसूनोत्तर (अक्तूबर–दिसम्बर) उष्ण कटिबन्धीय चक्रवात सक्रियता तथा एलनिनों/दक्षिणी दोलन (ENSO) के मध्य सम्बन्धों की विवेचना इस शोधपत्र में की गई है। प्रारम्भिक विश्लेषण के लिये तूफानी दिवसों की संख्या की 83 वर्षों (1901–1983) की काल श्रेणी अध्ययन में प्रयुक्त की गई है। एलनिनों वर्ष की अवधि में तूफानी दिवसों की संख्या औसतन सामान्य से अपरिवर्तित रहती है। ऋतु के पूर्व, मध्य और बाद 48 वर्षों (1935–1982) की तूफानी दिवसों की काल श्रेणी को प्रयोग करके दक्षिण दोलन संकेतक के साथ (ताहिती तथा डार्विन के बीच माध्य समुद्र तल दाबान्तर) सहसम्बन्धों को आकलित किया गया है। जिसके फलस्वरूप ऋतु से पूर्व दक्षिणी दोलनांक (SOI) तथा तूफान सक्रियता के मध्य एक ऋणात्मक क्षीण सह सम्बन्ध प्राप्त हुआ। चार बारह वर्षीय सामग्री उप समुच्चयों के प्रयोग करने पर सह सम्बन्धों का परीक्षण सहसम्बन्धों की पुर्नगणना द्वारा किया गया है। उप समुच्चयों में सहसम्बन्धों का परिमाण विशिष्ट रूप से परिवर्तनशील पाया गया।

प्रति एलनिनो वर्ष की टकराव दर (तटपार करने वाले तूफानों की संख्या–तूफानों की कुल संख्या) तथा प्रति साधारण वर्ष की टकराव दर में कोई गुण–विवेचनात्मक अन्तर परिलक्षित नहीं होता है। एलनिनो वर्ष की अवधि में जलवायु विज्ञान के अनुकूल क्षेत्र से निर्मित तूफानों के क्षेत्र में कोई विशेष परिवर्तन नहीं पाया गया।

ABSTRACT. In this paper the relationship between post monsoon (Oct-Dec) tropical cyclone activity in the north Indian Ocean and *El Nino*/Southern Oscillation (ENSO) is discussed. The study uses a 83-year (1901-1983) time series of number of storm days for preliminary analysis. On an average the number of storm days during *El Nino* year is not departed from the normal. Using the 48-year (1935-1982) time series of number of storm days correlations were calculated with southern oscillation index (mean sea level pressure difference between Tahiti and Darwin) before, during and after the season. A weak negative correlation is seen between the storm activity and SOI before the season. Stability of correlations is examined by recalculating correlations using four 12-year data subsets. Magnitude of correlations is found to vary significantly in the subsets.

There is no appreciable difference between the strike rate (number of storm crossing the coast/total number of storms) per *El Nino* year and strike rate per non *El Nino* year. There is no marked shift in the area of formation of storms during *El Nino* years from the climatologically favourable area.

1. Introduction

The interannual variation of tropical cyclone activity within each ocean basin is of great interest. Past studies (Ding and Reiter 1981) related these variations to changes in the large scale atmospheric flow features. Recent studies have addressed to the causes for these changes in the general circulation which subsequently affect tropical cyclone activity.

Gray (1984 a) found out that *El Nino* event cause changes in the large scale atmospheric circulation which is associated with the variations in hurricane frequency in the Atlantic Ocean. He also found that the hurricane activity is altered during different phases of Quasi-Biennial Oscillation (QBO) in the zonal winds in the equatorial stratosphere. Gray (1984 b) used these inferences to develop a scheme to forecast hurricane activity in the Atlantic Ocean. Chan (1985) used cross spectrum analysis to find the interrelation between the Southern Oscillation Index (SOI) and tropical cyclone activity in the northwest Pacific Ocean.

Nicholls (1985) found a significant correlation between tropical cyclone activity in the Australian region and Darwin pressure prior to cyclone season.

The present study examines the relationship between post monsoon (October-December) tropical cyclone activity in the north Indian Ocean and *El Nino*/Southern Oscillation (ENSO). The frequency of cyclonic storms which cause considerable damage to the coastal areas is maximum in the post monsoon months.

2. Data

The number of cyclonic storms (system with maximum wind speed > 33 kt) days is taken mainly as a measure of storm activity of the season. A storm day is defined as a day when at 0300 GMT (0830 IST) a cyclonic storm was observed in the region. If two systems were observed at 0300 GMT on a particular day they count as two storm days. The number of storm days and number of cyclonic storms in each season, region of formation and number of storms striking the coast

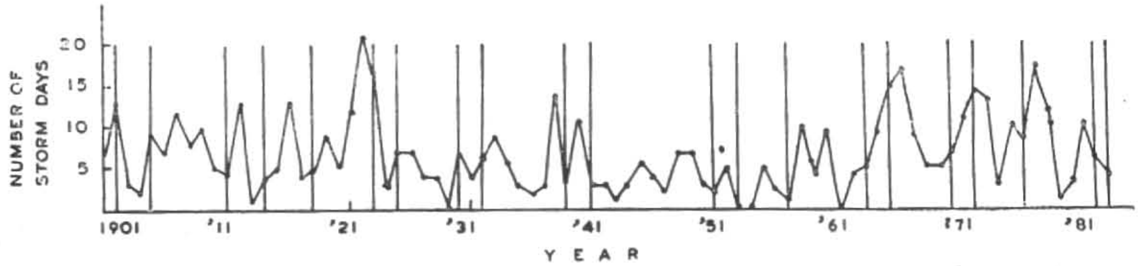

Fig. 1. Seasonal number of cyclonic storm days during the period 1909 to 1983. Moderate and strong *El Nino* years are shown by vertical lines

TABLE 1

Mean seasonal number of storm days for one year before (—), during (o) and one year after (+) a moderate or strong *El Nino* year

Period : 1901-1983, 21 events

	No. of storm days	No. of storm
EN (—1)	6.6	2.90
EN (O)	6.6	2.81
EN (+)	7.7	3.3
Average (1901-1983)	6.6	2.83

TABLE 2

Percentage of seasonal number of storms (top) originated in a 5°×5° square area and percentage of seasonal number of storms during *El Nino* years (bottom) originated in the 5°×5° square area, Period : 1901-1970

Lat.	55°-60°E	60°-65°	65°-70°	70°-75°	75°-80°	80°-85°	85°-90°	90°-95°	95°-100°E
15°-20°N				7.14		0.63	7.64	1.92	
				12.5		0	9.09	0	
10° 15°N	3.0	10.7	17.8	25.0	0.63	8.92	14.01	12.7	1.27
	0	0	12.5	25.0	0	0	6.06	15.2	3.03
5°-10°N		7.14	3.0	25	2.54	7.64	21.65	14.65	3.18
		25.0	12.5	12.5	3.03	12.12	30.3	15.2	3.03
0°-5°N						0.63	0.63	1.27	
						0	0	3.03	

for the period 1901-1970 were taken from the "*Atlas of Tracks of Storms and Depressions*" published by India Met. Dep. (1979). These details for the period 1971-1983 were taken from post monsoon weather summaries being published by India Met. Dep.

Fig. 1 shows the time series of number of cyclonic storm days in the season from 1901 to 1983. No trend is evident in Fig. 1. However, the Spearman rank statistic (WMO 1966) was used to test the randomness against trend in the time series. This statistic is preferred because several terms in the time series happened to be equal in value and the ranks of these terms are "tied". Spearman rank statistic r_s is computed and is 0.0539 and $t=0.4858$. The two tailed 95% probability points of "student's" t with 81 degrees of freedom is ± 1.992. Since the computed t lies within these limits, the presence of trend in the time series couldn't be substantiated.

Subbaramayya and Rama Mohana Rao (1984) found no significant trend in the time series of number of cyclonic storms also.

3. Preliminary analysis

The vertical lines from the abscissa in Fig. 1 indicate the moderate or strong *El Nino* years. *El Nino* years are those in which anomalous warm water develops off the South American tropical west coast and in the equatorial central Pacific.

Nine moderate or strong *El Nino* years were indentified by the author for the period 1950-1983 using the sea surface temperature index of southern oscillation (Wright 1983). This index is the mean monthly sea surface temperature anomaly over the area between 6° N-6° S and 180 °E -90° W. These *El Nino* years exhibited a maximum positive anomaly $\geqslant +1.0$°C and an anomaly change from the largest negative anomaly of the previous year to the largest positive anomaly of the warm episode year $\geqslant 1.5$°C, other moderate or strong *El Nino* years for the period 1901-1949 shown in Fig. 1 are those identified by Rasmusson and Carpenter (1982) and Quinn *et al.* (1978).

Average seasonal number of storm days for the period, 1901-1983 is 6.6 days. Among 21 warm event years, there had been 8 years in which activity was found above normal and in remaining 13 years activity was below normal.

Mean seasonal number of storm days and number of storms one year before (—1) during (O) and one year after (+1) a moderate or strong *El Nino* year were computed and are shown in Table 1.

From the table it can be seen that on an average during warm episode years neither number of cyclonic storm days nor number of storms is departed from normal. However, a small percentage increase in number of storm days and number of storms is seen after a warm event year.

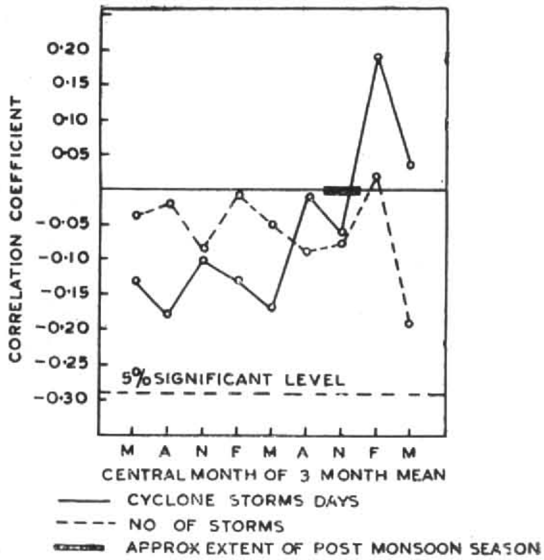

Fig. 2

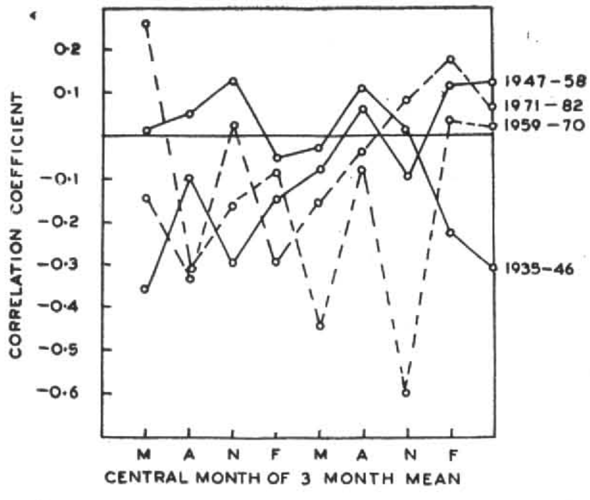

Fig. 3

Figs. 2 & 3. Correlations between anomalies of number of cyclonic storms days in north Indian Ocean with three month means of SO I : Fig. 2. correlation of anomalies of number of storms and in Fig. 3 correlations were calculated using 4 separate 12-year samples

Time dependent relationship between tropical cyclone activity and southern oscillation was further examined, since ENSO events do not occur at exactly fixed intervals. These events are aperiodic and does not coincide with the calendar year.

4. Time dependent relationship

To examine the time dependent relationship, monthly mean sea level pressure difference between Tahiti (18°S, 150°W) and Darwin (12°S, 131°E) is used as southern oscillation index (SOI). They were taken from Parker (1983). With this index large negative values correspond to warm events.

The anomalies in seasonal number of cyclonic storm days and number of cyclonic storms during the period 1935-1982 were correlated with the three month average SOI, before, during and after the season. The three month periods started with April-June, 18 months prior to the cyclone season and ended with April-June, 6 months after the season, thus covering 27 months, and there were nine time series of SOI. Correlation coefficients computed are shown in Fig. 2. The approximate extent of the period is shown by the thick horizontal line. The central month of the three-month average of SOI is indicated on the abscissa. The 5% significance level is shown by horizontal dashed line.

Correlation coefficients are negative prior to the season, attains a positive value just after the season and rapidly falls during the next three month period. In general, anomalies in cyclonic storm days have more correlation than that of number of storms. But none of the correlation coefficients is significant atleast at 5%.

The stability of the relationship between cyclone activity and SOI is further examined. For that correlations between anomaly in storm days and SOI were recalculated with four subsets of twelve years data and compared with correlations computed using the full data (1935-1982). Results are shown in Fig. 3. The general pattern is similar in each subset, *i.e.*, negative correlations before the cyclone season and positive correlations after the season except for the 1935-46 subset. But magnitudes of the correlations with SOI are not similar in all the subsets. For, *e.g.*, the correlation coefficient with SOI centred on month of May, five months prior to the cyclone season, using the full data is —0.17 but the correlations in the subsets vary from —0.07 to —0.44.

5. Strike rate and region of formation

The rate of storms striking the coast during *El Nino* years was computed and compared with the rate of storms striking the coast during Non *El Nino* years. The rate of storm strike per *El Nino* year is 0.53, while that per Non *El Nino* year is 0.48, not an appreciable difference. Gray (1984 a) found that the rate of hurricane strike in the Atlantic Ocean is 0.25, while that per Non *El Nino* year is 0.74, a three to one ratio.

It is further examined to see whether there is a marked shift in the area of formation of storms from the climatologically favourable areas of storm formation during *El Nino* years.

Table 2 shows the percentage of seasonal number of storms originated in a 5°×5° square area, shown at the top of 5°×5° square. The figures shown at bottom in the square are the percentage of seasonal number of storms originated in the $5^\circ \times 5^\circ$ square area during *El Nino* years. Period of study was 1901-1970. In this period there were 17 *El Nino* years. The percentage of number of storms was calculated for Bay of Bengal (east of 75°E) and Arabian Sea (west of 75°E) separately. In the Bay of Bengal more than sixty percent of storms were originated in the area between 85°E-95°E and 5°N-15°N. During *El Nino* years more than sixty per cent of storms were originated in the same area only. Thus, there is no marked shift in the region of formation of cyclonic storms from climatologically favourable area. This is the same case for Arabian Sea also.

6. Conclusions

(*i*) Among 21 *El Nino* years during the period 1901-1983, there had been 8 years in which tropical cyclonic activity as measured by the number of storm days was above normal. In remaining 13 years the activity was below normal. But average seasonal number of storm days and seasonal number of storms were not departed from normal.

(*ii*) Time dependent correlation analysis shows a statistically insignificant correlation between the storm activity and SOI before the season. Stability analysis shows that the pattern of correlations is same in all the subsets except in 1935-46 subset, but magnitude of correlations significantly varies.

(*iii*) There is no appreciable difference between strike rates of storms during *El Nino* years and non *El Nino* years.

(*iv*) There is no marked shift in the area of formation of storms during *El Nino* years from the climatologically favourable area of storm formation.

Thus, ENSO phenomenon does not have significant influence on the variability of cyclone activity in the north Indian Ocean,

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