

## Role of cyclonic systems in excess and deficit monsoon years in India

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**सार** – इस शोध-पत्र में देश के अत्याधिक और कम मानसून वर्षा वाले वर्षों के दौरान चक्रवातीय तंत्रों (अवदाबों और चक्रवातीय तूफानों) से संबद्ध वर्षा के लक्षणों का अध्ययन करने का प्रयास किया गया है। आँकड़ों से यह पता चलता है कि अत्याधिक और कम मानसून वर्षा वाले वर्षों के दौरान बने तंत्रों की संख्या में कोई विशेष अंतर नहीं है। अत्याधिक मानसून वर्षा वाले वर्षों के दौरान ये तंत्र मई के महीने में उत्तर की ओर बढ़ते हैं जबकि कम मानसून वर्षा वाले वर्षों के दौरान ये तंत्र उत्तर – पश्चिम दिशा की ओर बढ़ते हैं। अत्याधिक और कम मानसून वर्षा वाले वर्षों के दौरान जून के महीने में इन तंत्रों के बनने की स्थितियों में इनके बनने के अक्षांतर के क्षेत्रों में कोई विशेष अंतर नहीं है। देशांतर के क्षेत्रों के मामले में, अत्याधिक मानसून वर्षा वाले वर्षों के दौरान ये तंत्र न केवल निचले देशांतरों के क्षेत्रों में बनते हैं बल्कि ये अत्याधिक मानसून वाले वर्षों की तुलना में कम मानसून वर्षा वाले वर्षों में तट के समीप भी बनते हैं। अत्याधिक मानसून वाले वर्षों की अपेक्षा कम मानसून वर्षा वाले वर्षों में सितंबर के महीने में इन तंत्रों के बनने की संख्या अधिक होती है। एल-निनो मानसून वर्षा के महीनों में वर्षा के वितरण को नियंत्रित करने वाला मुख्य कारक नहीं है।

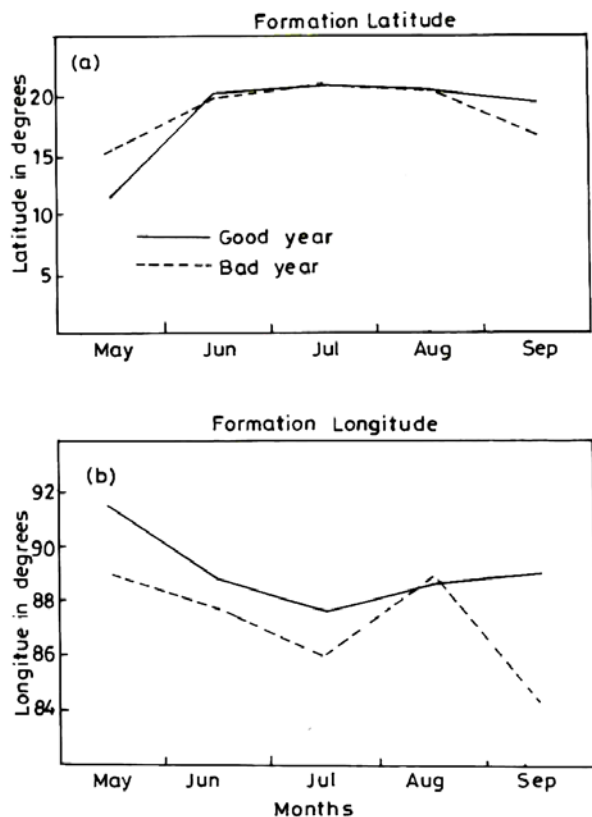
**ABSTRACT.** In this paper an attempt is made to study the rainfall features associated with cyclonic systems (Depressions and cyclonic storms) during excess and deficit monsoon years over the country. It is seen statistically that there is no significant difference in number of systems that formed during excess and deficit years. In the month of May systems travel mostly towards north in excess years whereas in deficit years they travel northwest ward. In June the formation positions during excess and deficit years have no significant difference in latitude of formation. In the case of longitude, the systems in excess monsoon years form slightly to the east compared to deficit years. In September the systems not only form at lower latitudes in deficit years but also they form close to coast in deficit years than in excess years. In September number of formation of systems in excess years is more than deficit years. El- Nino is not the major factor which controls the rainfall distribution in monsoon months.

**Key words** – Cyclonic systems, El-Nino, Deficit years, Excess years, OLR anomaly.

### 1. Introduction

Agricultural based Indian economy is highly dependent on monsoon rainfall. Monsoon is the part of general circulation of the atmosphere created by differential heating of the earth's surface such as that between summer and winter hemispheres. Monsoon depressions and low pressure areas are the major synoptic systems in the monsoon circulations. Saha *et al.*, (1998) concluded that the large diversity in the distribution and intensity of monsoon rains over different regions is due to land sea configuration, cold and warm oceans surfaces and high mountain ranges. Pai *et al.*, (1998) concluded that there is a significant difference in the 200 hPa circulation and higher anomaly pattern over Asia and Pacific region between excess and deficit monsoon years over India. Mooley and Shukla (1989) derived the monsoon trough activity index as the anomaly of the daily pressure

within the trough from the long period mean and found that the frequency of the normalized monsoon trough activity index is higher in years of excess monsoon than that in years of deficit Indian monsoon. Pandey *et al.* (1989) remarked that during strong monsoon situation the magnitude of the zonal available potential energy is greater than eddy available potential energy during initial and decaying stages. However during mature stage reverse is the case. Muthuchami (1990) found that the monsoon activity over India is inversely related to Southern Hemisphere Equatorial Trough (SHET). According to his study, the monsoon strength is directly proportional to the product of vortex strengths of cyclonic systems over Indian region and anticyclonic circulation over south Indian ocean. Muthuchami and Revikumar (1992) also found existence of inverse relation between monsoon circulation and SHET using satellite cloud imageries.



**Figs. 1(a&b).** Mean location of formation of cyclonic systems during excess and deficit rainfall years (a) Latitude and (b) Longitude

## 2. Data and methodology

The study is based on data for the period 1901-2002. The data on the storms and depressions for the period 1901 to 1990 were collected from the India Met. Deptt. Publication of storms and depressions over the Bay of Bengal and the Arabian Sea published in 1979 and 1996. For the remaining period upto 2002 the details were collected from annual cyclone review meeting report. The rainfall details were collected from the Weekly Weather Report published by India Met. Deptt., Pune. The rainfall years were categorized as excess, deficit and normal years based on the rainfall departure from normal. If the country's rainfall departure is more than 10 % of normal, that year is classified as excess year and if rainfall departure is less than -10 % that year is classified as deficit year. Initial positions and dissipation positions of storms in respect of excess and deficit years were computed from the tracks of the storms. The mean positions and standard deviations were computed to find out if there is any significant difference in formation position and final position of storms using *t*-distribution. Since El-Nino is found to have suppressed effect on

monsoon activity *t*-test was applied between mean position of storm deficit years and El-Nino/deficit years. The distance traveled by the storms (Component wise) is also computed during excess and deficit monsoon years to find out the existence of difference if any. In order to find out the effect of monsoon depressions on rainfall distributions over different sub-divisions the rainfall departure from normal in various sub-divisions were analysed during system weeks (A week is classified as system week if at least a cyclonic system is present in north Indian Ocean at least in a day of the week). Using two separate years [deficit (1987) and excess (1988)] with same number of depressions and storms rainfall features are discussed in detail. In order to illustrate the influence of El-Nino on rainfall, monsoon activity in 1997 and 2002 is discussed.

## 3. Results and discussion

During the study period there were 9 excess monsoon and 16 deficit monsoon years. The salient feature such as formation, dissipation and moment of cyclonic systems in excess and deficit monsoon years are discussed month wise.

### May

Figs. 1(a&b) show the mean position of formation of storms and depressions during May to September in respect of excess and deficit years. In the month of May systems formed at significantly lower latitudes in excess monsoon years compared to deficit years. Further in excess monsoon years the systems formed farther away from the coast than deficit years. (2.5 Deg apart). Figs. 2 (a&b) give mean dissipation positions of cyclonic systems in excess and deficit years. It can be seen that in excess years during the month of May the mean dissipation point is at about 90.5° E whereas in deficit years the mean dissipation point is around 86.5° E. In excess monsoon years the probability for the system to cross east of 85° E is less than deficit years. In both years the probability for the system to cross 80° E is very small. The intensification ratio (No. of cyclone/Total system & No. of severe cyclonic storm/Total system) have no significant difference in excess and deficit seasons.

### June

In June cyclonic systems formation positions during excess and deficit years have no significant difference in latitude of formation. In the case of longitude, the system in excess monsoon years form to the east compared to deficit years. In excess years they travel more northerly distance than in deficit years. However there is no significant difference between these two type of years in

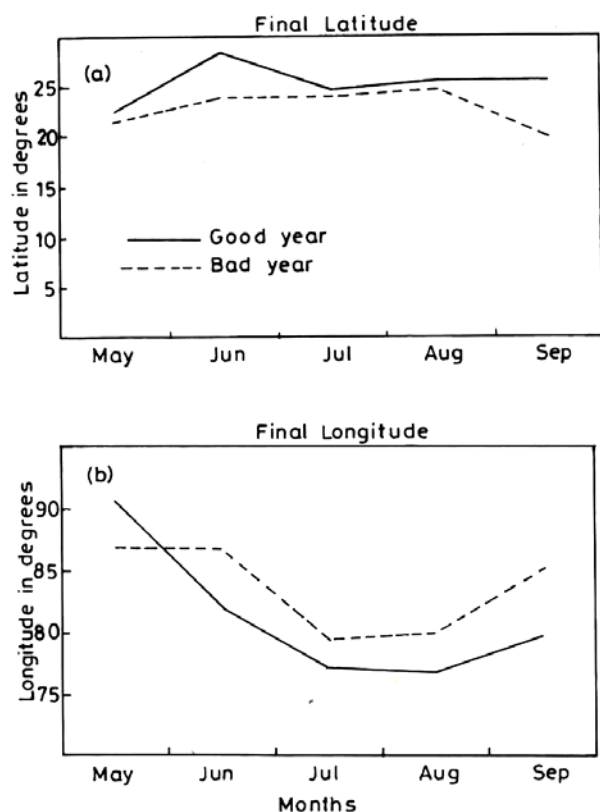


Fig. 2(a&b). Mean location of dissipation of cyclonic systems during excess and deficit rainfall years (a) Latitude and (b) Longitude

resultant distance traveled by the systems. The number of systems formed in excess years is greater than in deficit years. In excess years number of systems that crossed west of 80° E is more than that of deficit years.

#### July

During this month there is no significant difference in formation position between excess and deficit years in respect of latitude. However in longitude the difference exists. The traveling direction of storms during deficit and excess years are the same. The storms travel with more westerly component than northerly component in both kind of years. In this month in excess monsoon year the systems travel long distance towards west when compared to deficit years. From the *t*-test between the distance traveled in excess years and deficit years it is noticed that the difference in distances are not statistically significant. The number systems formed in excess and deficit years are the same. The probability for the systems to cross west of 85° E, 80° E and 75° E in excess years is greater than deficit years.

#### August

There is no significant difference in formation position of latitude and longitude between excess and deficit years. They travel more distance towards west in excess years. The probability for the systems to cross 85° E, 80° E and 75° E are more in excess years. There is no difference between excess and deficit years in number of systems. It is interesting to note that during this month intensification ratio is greater in deficit years than in excess years. This may be due to intrusion of trough in the upper air westerlies (divergent) which induce the systems to intensify and drag them to the north in deficit years.

#### September

In deficit years in September the formation position comes down to 16.5° N where as in excess years formation position does not shift southward and it remains at higher latitudes at 19.5° N. In this month the systems not only formed at lower latitudes in deficit years but also they form close to coast (84.0° E) than in excess years (89.0° E). As in the case of formation position final position of systems are also at lower latitude in deficit years. In excess years systems dissipate at western longitudes than in deficit years. There is no significant difference in distance traveled and the direction of movement of the systems between excess and deficit years. In excess years the final longitude position of the system is 80° E whereas in deficit years it is 85° E. Regarding number of systems, they are more in number in excess years than in deficit years.

In general during main monsoon months June, July and August there is no difference in number of formation or the distance traveled by the systems. But there is a marked difference in systems formation, dissipation and distance traveled during May. In September there is south eastward shift in systems formation during deficit years compared to excess years.

#### 4. El-Nino and deficit years

An attempt is made to determine the manner in which El-Nino affects the monsoon. On comparing deficit years with El-Nino years it is seen that in deficit years the rainfall quantity does not have any relation with El-Nino except in September. The *t*-test applied on rainfall distribution in El-Nino/deficit years and non El-Nino/deficit years reveals that there is no significant difference in rainfall amount in the monsoon season at 1% level even though there is a small suppressed activity of rainfall in El-Nino years. Fig. 3 gives the mean number of formation of the systems during deficit years and

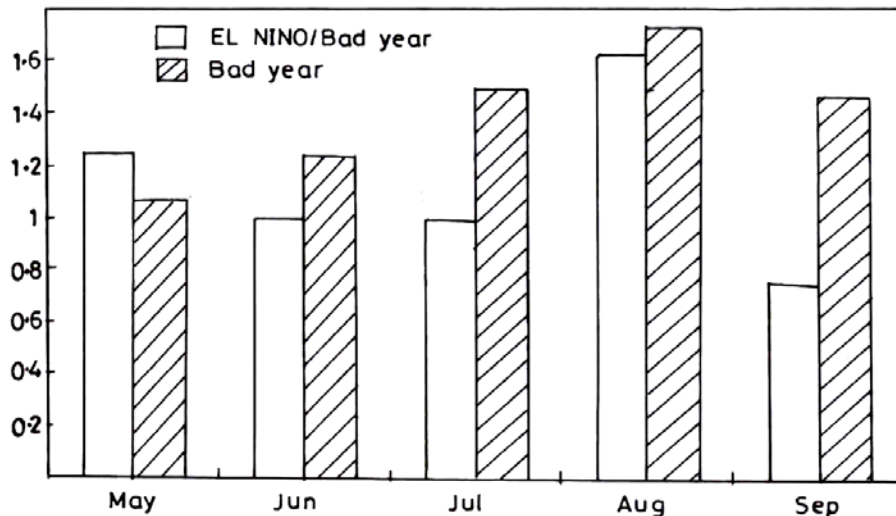


Fig. 3. Mean number of formation of cyclonic storms/depressions during May to September during El-Nino/deficit years and deficit years

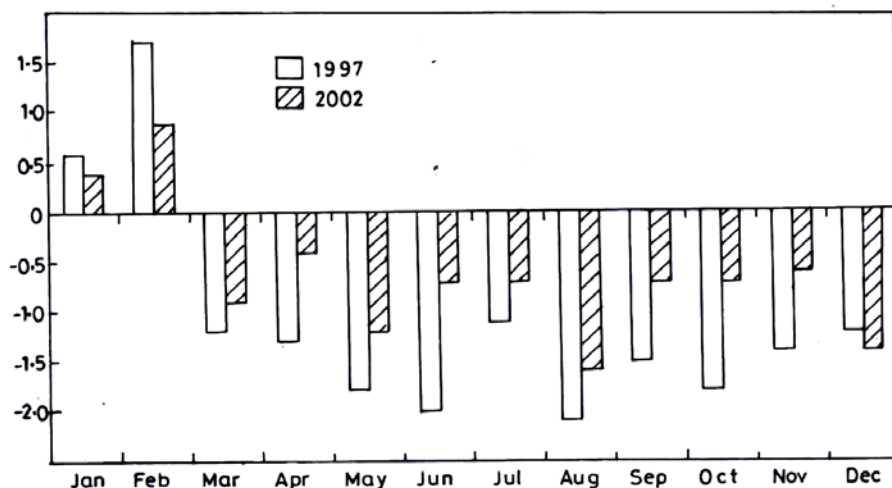


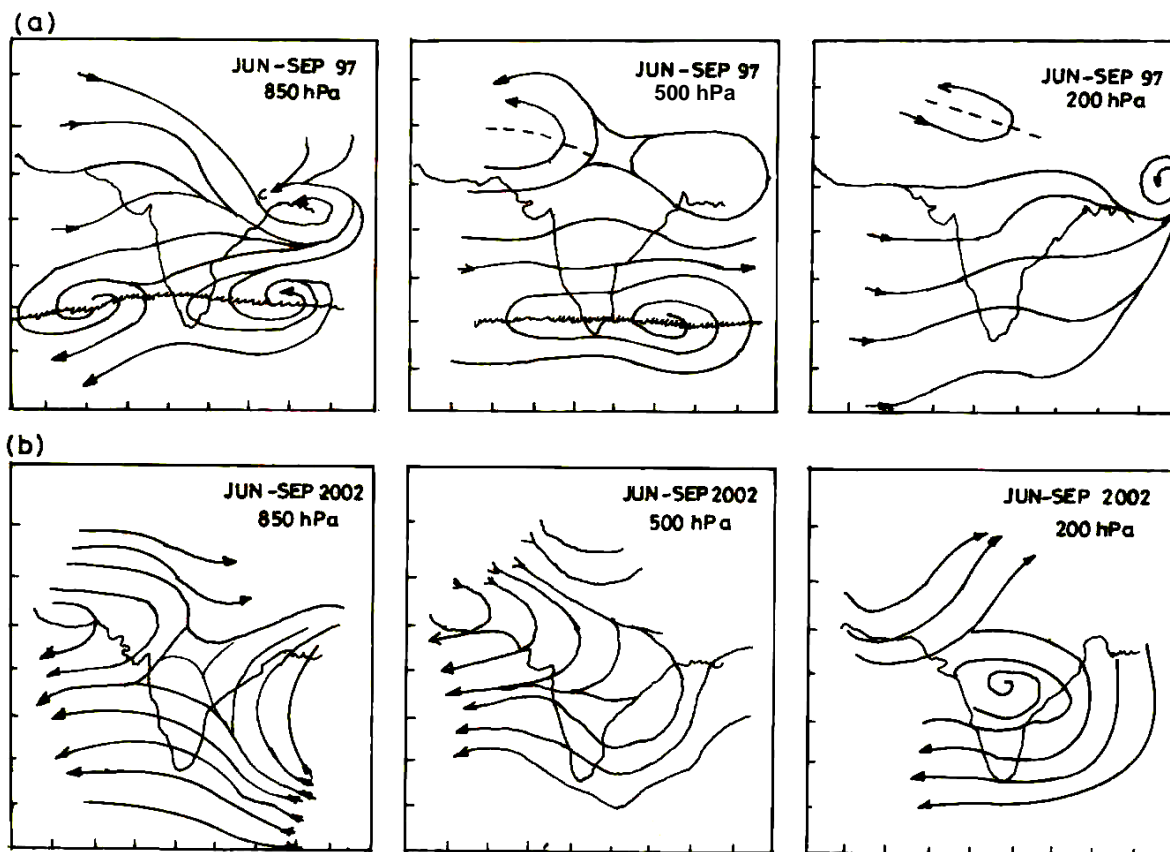
Fig. 4. Monthly SOI index during different months in 1997 and 2002

El-Nino/deficit years. It is noticed that there is no significant difference either in formation position or number of systems formation between El-Nino/deficit years and non El-Nino/deficit years except in September. In September the mean position of formation is at significantly lower latitude. It is also noticed that during September there is a significant decrease in system formation in El-Nino/deficit years as seen from Fig. 3.

Fig. 4 gives the Southern Oscillation Index (SOI) in different months during 1997 and 2002. It can be observed that though 1997 is a severe El Nino year it produced normal rainfall over the country (+ve 2%) but 2002 a moderate El-Nino year resulted in 19% deficit rainfall. It

is observed that in 1997 most of the sub-divisions received normal/excess rainfall though it is a severe El-Nino year but in 2002 many sub-divisions received deficit rainfall.

Though both 1997 and 2002 are El-Nino years there is lot of difference not only in rainfall pattern but also in flow pattern over the Indian sub-continent. Figs. 5 (a&b) give the mean wind anomaly at 850, 500 and 200 hPa level over India during June – September in 1997 and 2002. It is noticed that in 1997 anomalous cyclonic circulation is noticed in north India but on the contrary in 2002 the same area is replaced by anticyclone at 850 hPa level. It can be seen from 500 hPa and 200 hPa levels that intrusion of extra tropical westerlies took place much



Figs. 5(a&b). Wind anomaly pattern at 850, 500 and 200 hPa level over India during June – September in (a) 1997 and (b) 2002

to the lower latitudes in 2002. This intrusion not only did not allow the low intensity systems like low pressure area or cyclonic circulations to intensify but also dragged these low intensity systems toward north/northeastward. This is reflected in rainfall pattern in 2002 where the normal rainfall region is oriented southwest – northeast ward starting from Konkan & Goa to Assam region. But in both years surface pressure and temperature are above normal throughout the country. In 1997 six depression/cyclonic storms formed whereas in 2002 no such system developed. While studying the OLR anomaly during years 1997 and 2002 in July, it is seen that in 2002 high –ve OLR anomaly is extending towards northeast wards in central Pacific and over northwest Pacific the –ve anomaly is extending towards China. These anomalies are mainly due to the northwestward movement of storms in central Pacific during 2002. Over west Pacific the systems traveled more towards north rather than towards head Bay which is supposed to be the normal track of system from Pacific. This is one of the reasons the storms did not form over Bay in 2002. In 1997 the –ve anomaly is seen orienting east west and extends to head Bay and then towards the southwest along the monsoon current. This negative anomaly of OLR suggests the above normal clouding over north Indian Ocean.

Apart from the position of monsoon systems in determining excess and deficit years an attempt is made to study the relationship between rainfall distribution and number of cyclonic systems in respect of excess and deficit years. For this purpose sub-divisional rainfall distribution of two monsoons viz., 1987 (deficit year) and 1988 (excess year) have been considered. In both years the number of cyclonic storms and depressions are same but in 1987 monsoon failed (-11%) whereas in 1988 monsoon was excess (15%). In each of these years only four cyclonic systems formed during the monsoon season. The number of stations received rainfall in different rainfall intervals are noted in all the days of the disturbances. In 1988 in all the categories of rainfall intervals the mean number of stations are very much greater than that of 1987. Table 1 shows the distribution of rainfall in different sub-division during system weeks in the years 1987 and 1988. It is seen from the table that more rainfall occurred in 1988 system week period than in 1987. The mean rainfall departure from normal during system weeks is 7% in 1988 whereas in 1987 it is – 7%. Apart from this during the systems week less rainfall is noticed in central, west coastal and southern states in 1987 whereas in 1988 the rainfall is more in these areas and less in northeast region. It is seen that the mean total

TABLE 1

Sub divisional mean system week rainfall departure  
from normal in 1987 and 1988

Sub-divisions	1987	1988
Andaman & Nicobar Islands	-2.75	28.33
Arunachal Pradesh	-16.75	-27.67
Assam & Meghalaya	-14.50	-41.33
Naga., Mani., Mizo. & Sikkim	-10.00	-24.00
Sub. Himalayan West Bengal	9.75	-49.33
Gangetic West Bengal	16.75	52.00
Orissa	-25.25	8.67
Bihar plateau	20.75	13.67
Bihar plains	19.00	10.67
East Uttar Pradesh	-4.00	-20.00
Plains of West Uttar Pradesh	-13.00	-11.00
Hills of West Uttar Pradesh	-10.75	-28.00
Harayana Chandigarh & Delhi	0.75	2.00
Punjab	-4.75	2.00
Himachal Pradesh	0.25	-21.33
Jammu & Kashmir	12.00	38.33
West Rajasthan	-11.00	5.00
East Rajasthan	-4.00	1.00
West Madhya Pradesh	12.50	6.00
East Madhya Pradesh	5.50	-29.33
Gujarat Region	-28.25	-25.67
Saurstra & Kutch	-16.00	79.67
Konkan & Goa	-16.50	101.33
Madhya Maharastra	-17.25	22.33
Marathwada	-28.50	-1.33
Vidarba	-16.25	-8.33
Coastal Andhra Pradesh	-14.00	-3.00
Telangana	-27.00	30.67
Rayalseema	-13.25	21.33
Tamil Nadu & Pondicherry	-1.25	3.00
Coastal Karnataka	0.00	107.33
North interior Karnataka	-14.25	15.67
South interior Karnataka	1.25	45.00
Kerala	-26.25	-2.00
Lakshadweep	-4.00	-48.00
Mean	-6.89	7.25

rainfall of the country during the system days are more in excess years than in deficit years apart from change in spatial distribution of rainfall. From this it can be inferred that structure, point of landfall, track and speed of movement may be responsible for rainfall amount rather than just the number of systems or number of days the system surviving.

On examining the movement of monsoon systems it is noticed that in deficit years they travel significantly faster than that of excess years.

## 5. Conclusions

The study has indicated that statistically there is no difference in number of systems that formed during excess and deficit years. In excess years systems travel more distance than deficit years. In the month of May systems travel more meridional component in excess years whereas in deficit years they mostly travel northwest ward. In June the formation positions have no significant difference between excess and deficit years in latitude of formation. In the case of longitude the systems in excess monsoon years form slightly to the east compared to deficit years. In September the systems not only form at lower latitudes in deficit years but also they form close to coast in deficit years (84.0° E) than in excess years (89.0° E). In September number of systems formed in excess years is more than deficit years. El-Nino is not the major factor which controls the rainfall distribution in monsoon months.

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