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Heavy rain at Chennai and its relation to cyclonic disturbances

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सार -- इस शोध पत्र में वर्ष 1964 से 1996 तक की अवधि के दौरान उत्तरपूर्वी मानसून से अक्तूबर, नवम्बर और दिसम्बर के महीनों में चेन्नैई में हुई भारी वर्षा और अत्याधिक भारी वर्षा की विशिष्टताओं का अध्ययन किया गया है। यह देखा गया कि वर्षा का भारी और अत्याधिक भारी होना मुख्यतः अवधि पर निर्भर करता है। बंगाल की खाड़ी में मानसून को प्रभावित करने वाले तंत्र को अवदाब अथवा चक्रवातीय तूफान अथवा प्रचंड चक्रवातीय तूफान के रूप में परिभाषित किया गया है। अक्तूबर और नवम्बर में तंत्र से अप्रभावित दिन की तुलना में तंत्र से प्रभावित दिन में औसत वर्षा 1.5 गुनी रही है। तंत्र प्रभावित दिनों और तंत्र अप्रभावित दिनों में वर्षा की तीव्रता और अवधि की विशिष्टताओं में कोई विशेष भिन्नता नहीं पाई गई है। अन्य बातों के सामान्य होते हुए भी यदि तंत्र प्रभावित भारी वर्षा नहीं होती है तो भी मौसम की कुल वर्षा आगे भी सामान्य रहेगी।

ABSTRACT. In this paper an attempt is made to study the characteristics of Heavy Rainfall (HR) and Very Heavy Rainfall (VHR) over Chennai in the North East Monsoon month of October, November and December and the period considered is 1964 to 1996. It is observed that it is mainly the duration which determines whether rainfall would be heavy or very heavy. Defining a system as Depression or Cyclonic Storm or Severe Cyclonic Storm in the Bay of Bengal, the mean rainfall in a System-affected day is 1.5 times that of Non-system-affected day in October and November. No striking differences could be found in intensity and duration characteristics of rainfall between system-affected days and non-system affected days. Even if system induced heavy rainfall does not occur other thing being normal, the total rainfall of the season can continue to be normal.

Key words - Heavy Rainfall –HR, Very Heavy Rainfall –(VHR) System-affected day, Non-System-affected day.

1. Introduction

Heavy rainfall (HR) constitutes one of the significant weather phenomena especially for urban conglomerates. A few studies on heavy rainfall in some cities of India have been done. Lal (1992) discussed the relationship between precipitation Index, which is a function of mixing ratio and pressure falls from a standard level to the saturation level and the occurrence of HR in Lucknow. Ganesan and Prasad (1985) discussed the various aspects of HR in Jaipur. Prasad *et al.*, (1994) discussed the synoptic situation responsible for the occurrence of Heavy rainfall and consequent landslides in Pauri Garhwal and Nainital districts during 9-10 July 1990. Ramesh Chand and Gupta (1991) studied the synoptic situation which caused HR over Northwest India during January 1989. Duggal *et al.* (1992) discussed the synoptic situations for HR activity in Yamuna catchment area for purposes of synoptic typing.

But no study appears to have been undertaken with regard to any one of the principal metropolitan cities of India. The present paper is an attempt in this direction and HR at Chennai (Nungambakkam) (13° 04′ N, 80° 13′ E, 16.0 m.a.s.l.) is being discussed in this paper. The occurrence as well as the quantum of HR at Chennai in relation to the cyclonic disturbances, namely, Depressions, Cyclonic storms and Severe Cyclonic storms in the Bay of Bengal is one of the aspects studied in this paper.

2. Data processing and procedures

The autographic charts of rainfall for the month of October, November and December during the years 1964-96 in respect of Chennai were examined and the following details were collected :-

(*i*) The number of heavy rainfall (HR) and very heavy rainfall (VHR) days.

(*ii*) The amount and duration of rainfall on each of the HR and VHR days.

(*iii*) The intensity characteristics.

TABLE 1

Mean value of rainfall in HR/VHR years and non HR/VHR years

Month	HR/VHR years		Non-HR/VHR years		HR/VHR years + Non HR/VHR years
	Mean amount (mm)	C. V.	Mean amount (mm)	C. V.	Mean amount (mm)
October	378.6	40.8	162.3	47.0	273.7
November	456.4	42.6	243.5	83.6	379.0
December	285.4	47.8	73.6	113.0	176.3

C. V. – Coefficient of Variation in %

TABLE 2

Contribution in percentage of rainfall due to HR/VHR rainfall

Month	HR/VHR contribution in percentage		Normal rainfall (mm)
	All the years	Only HR/VHR years	
October	24.2	45.5	273.7
November	35.0	53.3	379.0
December	26.1	55.7	176.3
Mean	29.0	51.5	276.3

TABLE 3

The mean duration (D) (minutes) and mean intensity (I) (mm/minutes) for 25%, 50%, 75% and 90% amount of HR/VHR rainfall in various months

Month	Mean amount (mm)	00-25		26-50		51-75		76-90	
		D	I	D	I	D	I	D	I
October	105.3	195	0.30	167	0.35	149	0.33	105	0.31
November	120.8	222	0.18	143	0.30	166	0.26	162	0.25
December	101.0	211	0.19	140	0.29	155	0.25	076	0.43

(*iv*) The various characteristics such as amount, duration and intensity of HR/VHR on the days of occurrence of cyclonic disturbances.

3. Methodology

From the data collected the following were computed.

(a) Percentage of HR/VHR days

(b) Defining a HR/VHR year as that year during which atleast one HR/VHR occurred for the concerned month, the percentage of HR/VHR years for different months were computed.

(c) Mean rainfall amount for HR/VHR days.

(d) Mean monthly rainfall amount for HR/VHR years and non-HR/VHR years, and their coefficients of variation were also obtained. C. V. (Coefficient of Variation) is computed as (Standard Deviation/Mean) x100.

(e) Percentage contribution of HR/VHR amounts to total rainfall in each month.

(f) Total duration of occurrence of HR/VHR on HR/VHR days in various months and their C. V.s

(g) Percentage frequency of total duration of different intensities.

(h) Percentage of system affected and non-system affected days. It is assumed that a system affects Chennai only when it is within 500 kms of Chennai. The HR/VHR days at Chennai on account of the systems affecting Chennai and bringing about HR/VHR days are called "System affected days" in this paper. The other HR/VHR days are called "Non-system-affected days".

(i) The percentage of simultaneous occurrence of HR/VHR in different coastal stations of Tamil Nadu on HR/VHR days at Chennai.

(j) In order to find out the difference in mean values of intensities, duration, etc t-test was applied using the formula

$$t = \frac{(X_1 - X_2)}{\sqrt{\frac{n_1 s_1^2 + n_2 s_2^2}{n_1 + n_2 - 2}}} \times \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

Where n_1, n_2 are the number of observations in each sample taken X_1, X_2 are their mean values and S_1, S_2 their standard deviations respectively.

4. Results and discussions

It is seen that the probability of occurrence of a HR day in the post monsoon season (October to December) is 2..3% and a VHR day is 0.9% and that of either a HR or VHR day is 3.2%. The highest probability is of course in November. In particular, the probability of occurrence of VHR in November is 3.4 times to that in October and December. HR/VHR is 66% for November and 50% for October and December.

The mean rainfall amount per HR or VHR day is maximum in November and is nearly 121 mm. For October and December, it is nearly 103 mm. As regards VHR only, the highest mean rainfall per VHR day occurs in October and its value is about 183 mm. As regards HR only, the highest mean amount occurs in November and is 92 mm.

It is seen that the mean monthly rainfall amount in a HR/VHR year is above normal and that in a non-HR/non-VHR year is below normal in each of the months of October, November and December (Table 1). It is below normal on 94%, 75% and 82% of the non-HR/non-VHR years and above normal on 71%, 67% and 81% of the HR/VHR years in October, November and December respectively. In the non-HR/non-VHR years, the mean amount is 0.6, 0.6 and 0.4 times the normal and in the HR/VHR years it is 1.4, 1.2 and 1.6 times the normal in October, November and December respectively. Therefore, without the occurrence of HR/VHR in a given month, that month is likely to register less than normal rainfall.

In a year about 3 days of HR/VHR occur at Chennai during the post-monsoon season. This contributes about 29% of rainfall (Table 2). That is each HR/VHR day can be taken, on an average, to contribute, about 10% of total rainfall. Therefore, other things being normal, even if only one HR/VHR day occurs, normal rainfall would be recorded for the season, taking the deficient rainfall to be 19% below normal.

The total duration of HR/VHR on a HR/VHR days is nearly 13 hours.

To study the nature of variation of intensities during the occurrence of rainfall, the durations taken to reach 25%, 50%, 75% and 90% of the total amount has been computed (Table 3). From these, the intensities of rainfall

TABLE 4

Percentage frequency of total duration in different intensity classes

Month	Intensity Class	Intensity : mm / 15 minutes																
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-20	20-25	25-30
October	Percentage frequency of total duration	56.3	14.1	8.8	4.3	2.5	3.1	2.1	1.1	3.0	0.7	0.5	0.1	0.2	0.7	1.6	1.0	--	--
November	-do-	56.5	15.1	8.1	5.4	3.0	2.5	2.3	1.3	0.6	2.2	0.6	0.3	0.4	0.3	0.2	0.9	0.2	0.1
December	-do-	53.9	13.4	10.0	5.2	2.5	3.1	2.3	1.9	1.4	3.3	0.2	0.6	0.2	0.4	0.3	1.3	--	--

TABLE 5

The amount and duration of rainfall on system affected days and non - system affected days

Month	System affected days				Non-system affected days			
	Amount (mm)		Duration (mts)		Amount (mm)		Duration (mts)	
	Mean	C.V. (%)	Mean	C.V. (%)	Mean	C.V. (%)	Mean	C.V. (%)
October	149.4	46.9	910.0	49.6	95.9	27.4	761.7	35.9
November	139.0	44.5	917.0	32.5	101.0	27.2	809.3	36.7
December	96.7	31.3	829.1	34.8	103.8	39.5	624.4	51.0

during the periods of 0 to 25%, 26% to 50%, 51% to 75% and 76% to 90% of total rainfall on a HR/VHR day were calculated.

On about 56% of the occasions of 15 minute – interval, the intensity does not exceed 1 mm / 15 minutes (Table 4). On about 1.3% of the occasions, it exceeds 15 mm / 15 minutes in November and December.

To study as to what mainly contributes to the total quantum of rainfall – whether it is the intensity or duration – "t - test" was applied to the mean values of intensities and durations of HR and VHR amounts of the concerned months. It is seen that the difference between total quantum of rainfall on HR occasions and VHR occasions arises essentially out of the differences in durations rather than those in intensities.

Out of the 38, 76 and 15 systems which affected Chennai during the period under consideration in October, November and December respectively, only 14%, 29% and 60% of such systems caused HR/VHR at Chennai. It is evident that in October, less than 1/6 of the affecting systems, in November less than 1/3rd of the affecting-systems and in December just more than 1/2 of the affecting-systems caused HR/VHR at Chennai.

The differences in HR/VHR characteristics between system-affected days and non-system-affected days have been studied. Table 5 gives the amounts of HR/VHR in system-affected days and non-system-affected days. They are significantly different in October and November but not in December. The mean rainfall on system-affected days is nearly 1.5 times that on non-system-affected days, in October and November.

From Table 6, it can be seen that, in October, about 4% of the total duration, 26% of total rainfall occurs in 15-25 mm / 15 minutes intensity range, on system-affected days. There is a significant difference between

TABLE 6

Percentage of duration and their contribution to total rainfall in various class of rainfall

	Intensity Class	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-20	20-25	25-30
											October								
System affected days	Percentage frequency of duration	38.1	22.1	11.4	8.0	2.5	4.9	2.0	1.0	0.4	2.0	0.4	2.2	0.4	0.5	0.3	2.5	1.8	
	Percentage contribution to total rainfall	5.9	10.4	8.9	8.9	3.5	8.4	4.1	2.4	1.0	6.0	1.4	7.9	1.6	1.9	1.1	13.7	12.8	
Non system affected days	Percentage frequency of duration	59.9	12.3	7.2	3.5	2.7	2.9	2.4	1.0	0.8	3.0	0.8	0.06	0.0	0.3	0.8	1.3	0.8	
	Percentage contribution to total rainfall	12.9.	7.9	7.8	5.3	5.2	6.8	6.6	3.2	3.0	12.0	3.4	0.3	0.0	1.9	5.2	9.9	7.7	
											November								
System affected days	Percentage frequency of duration	49.8	14.3	8.2	5.5	3.5	3.5	2.6	1.3	0.7	2.8	0.8	0.1	0.3	0.2	0.3	0.9	0.2	0.2
	Percentage contribution to total rainfall	11.0	9.4	9.0	8.6	6.9	8.5	7.4	4.5	2.5	11.6	3.8	0.6	1.7	1.2	2.2	6.6	1.8	2.5
Non system affected days	Percentage frequency of duration	58.0	14.5	7.4	5.1	3.2	2.3	2.6	1.4	0.7	2.0	0.7	0.5	0.5	0.3	0.2	0.7	0.2	0.9
	Percentage contribution to total rainfall	12.3	9.2	7.9	7.5	6.0	5.3	7.2	4.6	2.4	8.0	3.0	2.3	2.5	1.8	1.1	5.5	2.2	11.0
											December								
System affected days	Percentage frequency of duration	59.3	17.2	8.2	5.0	2.0	1.9	2.5	0.7	0.5	1.3	0.0	0.7	0.0	0.3	0.2	0.7		
	Percentage contribution to total rainfall	16.7	14.5	11.5	9.8	5.2	5.9	9.3	2.9	2.4	7.9	0.0	4.5	0.0	2.2	1.3	6.5		
Non system affected days	Percentage frequency of duration	50.5	11.0	11.3	5.4	2.8	3.9	2.2	2.6	1.9	4.6	0.3	0.5	0.2	0.3	0.4	1.5		
	Percentage contribution to total rainfall	9.5	6.2	10.6	7.2	4.7	8.0	5.4	7.4	6.1	16.6	1.2	2.3	1.1	1.8	2.2	9.8		

TABLE 7

Percentage of System – Affected days

Month	System induced HR days/HR days	System induced VHR/VHR days	System induced HR/VHR days/HR/VHR days
October	8.7	60.0	17.8
November	39.3	68.7	48.9
December	38.9	40.0	39.9
Mean	29.0	61.5	37.9

percentages of duration in intensity – ranges 0-1 mm, 1-2 mm, 2-3 mm and 3-4 mm / 15 minutes. The percentage frequency of duration is less on system-affected days in 0-1 mm / 15 minutes range but more in 1-2 mm, 2-3 mm, 3-4 mm and 11-12 mm / 15 minutes ranges.

In November, there is significant difference in the percentage of duration only in 0-1 mm / 15 minutes range.

In December, there is significant difference in 1-2 mm / 15 minutes range. It is more on system-affected days.

Since the system-affected HR/VHR days constitute 38% of the HR/VHR days which itself is only 3 days in a year (Table 7), even if system-affected days do not occur, only about one of the HR/VHR days would not occur. This would conceivably result in a reduction of total rainfall by 10%. This means that even if a system-affected (HR/VHR) day does not occur, still the seasonal total rainfall could be normal.

An analysis was made of the simultaneous occurrence of HR/VHR days in different coastal stations on the HR/VHR day in Chennai (Nungambakkam). The other stations are

Meenambakkam	(13°00′N, 80°11′E)
Covelong	(12°45′N, 80°15′E)
Cuddalore	(11°46′N, 79°46′E)
Nagapattinam	(10°46′N, 79°51′E)
Pamban	(09°16′N, 79°18′E)
Tuticorin	(08°48′N, 78°09′E) and
Kanyakumari	(08°05′N, 77°30′E)

The results are presented in Table 8.

Generally, the percentage of simultaneous occurrence decreases with distance for the coastal stations concerned.

On system-affected days, in stations closet to Chennai, the percentage of simultaneous occurrence of HR/VHR day is 47%, 95% and 75% in October, November and December. But slightly farther away, at Cuddalore for example, it is much less in October and November, than in December. In December, its value is close to what obtained nearest to Chennai namely 67%. In December only, on system-affected days, a HR/VHR day at Chennai is more likely to be a HR/VHR day at Cuddalore also. In October and November, the probability is 1/3rd of that in December.

On non-system-affected days at Chennai in December, the probability of Cuddalore being a HR/VHR day is nearly 1/2 of that on system-affected days. On non-system-affected days at Chennai, it is more likely to be a HR/VHR day in Meenambakkam and Covelong also (68% in October and 87% in November). In this regard, in October, it is more pronounced than on system-days. In November, it is almost the same both system-affected days and non-system-affected days. In October, non-system monsoonal activity causes much more widespread simultaneous occurrence of HR. In November, both system and non-systems are equally effective. In December, systems are more effective.

From the basic data available, it was seen that if a HR/VHR occurs on any day at Chennai, the conditional probability that the succeeding day would also be a HR/VHR day is 21%, 28% and 9% in October, November and December respectively. The conditional probability that the succeeding second day would also be a HR/VHR day is 4%, 9% and Nil in October, November and December respectively.

It is interesting to note that as regards the system-affected days, the conditional probability of one system

TABLE 8

Percentage of simultaneous occurrence of HR/VHR in different coastal stations of Tamil Nadu

Month		Stations						
		MNB	CLNG	CDL	NPT	PBN	TTC	KYK
October	HR/VHR days	70	55	33	15	11	11	11
	System days	60	33	20	00	00	00	00
	Non system days	73	63	36	18	14	14	14
November	HR/VHR days	89	95	30	20	00	07	07
	System days	91	100	27	09	00	05	05
	Non system days	86	92	32	32	00	09	09
December	HR/VHR days	56	45	47	30	13	04	04
	System days	78	71	67	38	13	11	00
	Non system days	43	00	36	27	13	00	07

MNB – Meenambakkam, CLNG-Covalong, CDL-Cuddalore, NPT-Nagapattinam, PBN-Pamban, TTC-Tuticurin, KYK-Kanyakumari

affected day being succeeded by another system-affected HR day is very high in November (35%) and about 10% in December. For October, it is nil.

5. Conclusions

(*i*) The mean rainfall amount on a HR/VHR day is 121 mm in November and 103 mm in October and December. Without the occurrence of atleast one HR/VHR day in a month, that month is likely to register less than normal rainfall.

(*ii*) The average total duration of rainfall on a HR/VHR day is about 13 hours. The mean intensity of rainfall on a HR/VHR day is about 0.16 mm/minute.

(*iii*) On about 56% of occasions, the intensities do not exceed 4mm / hour. On about 1% of the occasions, it exceeds 60 mm / hour.

(*iv*) It is the duration and not the intensity of rainfall which mainly causes VHR to be recorded.

(*v*) Only 14%, 29% and 60% of the systems that came within the 500 km range of Chennai caused HR/VHR in Chennai in October, November and December respectively. The mean rainfall on system-affected days is roughly 1.5 times that on non-system-affected days in October and November. It is practically the same in December. No striking difference could be found in Intensity/ Duration characteristics between system-affected days and non-system-affected days.

(*vi*) System-affected days constitute about 38% of HR/VHR days. Even if system induced HR/VHR does not occur, other things being normal, the total rainfall of the season would continue to be normal.

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