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A STUDY OF DIFFERENT RAINFALL EPOCHS OVER MAJOR CITIES OF INDIA IN SUMMER MONSOON SEASON

1. It is well known that in big cities natural disasters, caused by weather phenomena, are mainly due to heavy to very heavy rainfall associated with storm, monsoon rain, depression etc. Also low to very low amount of rainfall for a number of days in a month might create scarcity of drinking water in some cities. The problems of temporary flooding and water scarcity are of vital concern to the governing agencies of major cities of India. In most of the developed and developing countries it has been possible to mitigate the damage caused by temporary floods and ameliorate water scarcity conditions through single or multipurpose hydrological projects. For implementing such schemes, data on seasonal rainfall amount at a station alone may not be a sufficient input as it only indicates the amount of average rainfall. The information on short duration epochal rainfall would be an additional input for flood control and water scarcity management. Sreenivasaiah and Yegna Narayanan (1958) studied the probabilities of occurrence of less than or more than 10", 20", 30", 40" and 50" rainfall during south west monsoon season in India. Rao (1958) studied the contribution of heavy falls to the annual and seasonal total and the frequency of very heavy falls (10" and above) in 24 hrs. Parthasarathi (1958) studied the maximum point rainfall of 10", 15" etc. in 24 hrs and the frequency of occurrence of 24 hrs. point rainfall of 10" and above in different parts of India. Short duration and maximum one day point rainfall analysis at a station for different return period have been studied by Dhar and Ramchandran (1970), Dhar and Kulkarni (1970). Maximum rainfall in relation to it's return periods have been studied by Harihara Ayyar and Tripathi (1971).

The earlier studies refer to above have not specifically addressed city flooding and water scarcity problems in urban areas and also the information about rainfall patterns in recent decades. These provide vital inputs to city planners and water management projects.

In this paper the contribution of different rainfall epochs, which has been defined as varying amount of rainfall reported at a station in 24 hrs, towards the total monthly rainfall in the south west monsoon months over twenty four major cities in India, have been studied.

2. For the present study daily rainfall data of 24 major cities in India during June to September for 30 years (1961-90) have been utilised. The data have been obtained from National data centre, office of ADGM(R), India Meteorological Department, Pune.

For the purpose of study the daily rainfall amount (mm) registered at a station, has been categorised into four epochs as under :

Category	*Nomenclature*	*Range of daily rainfall amount*
I	Light epoch	≥ 0.1mm but < 2.5mm
II	Medium epoch	≥ 2.5mm but < 65mm
III	Heavy epoch	≥ 65mm but < 125mm
IV	Very heavy epoch	≥ 125mm

The above categorisation is in accordance with that of India Meteorological department in classifying daily rainfall.

After categorisation, the rainfall contribution of each epoch towards monthly total rainfall in any month during south west monsoon season, averaged over 30 years, has been computed as per the following method.

If R^i_j be the rainfall (mm) contributed by i^{th} epoch towards total monthly rainfall in any month during monsoon season in the j^{th} year; where i = 1, 2, 3, 4 and j = 1, 2, 3, ... 30 for 30 years (1961-1990) and also if TR_j be the total monthly rainfall for that particular month in the j^{th} year, then $(R^i_j / TR_j) \times 100$ is the percentage contribution of the i^{th} epoch, in the j^{th} year, towards the monthly total rainfall for that particular month, hence $1/30 \sum^{30}_{j=1} (R^i_j / TR_j) \times 100$ is the average percentage contribution of the i^{th} epoch toward monthly total rainfall for that particular month, averaged over 30 years of study.

Now this average percentage contribution of each epoch towards monthly total rainfall for any south west monsoon month has been categorised in our paper as follows :

Category	*Nomenclature*	*Average (%) contribution*
I	Very low	≥ 0% but ≤ 5%
II	Low	> 5% but ≤ 15%
III	Moderate	> 15% but ≤ 30%
IV	Moderately high	> 30% but ≤ 40%
V	High	> 40% but ≤ 50%
VI	Very high	> 50%

TABLE 1

Average (%) contribution of various epochs in different months of south-west monsoon season

S No.	Station	Light epoch				Medium epoch				Heavy epoch				Very heavy epoch			
		Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
1	Agartala	01	02	03	03	69	70	77	73	14	21	16	16	16	07	04	08
2	Ahmedabad	02	02	03	02	68	62	64	64	21	25	20	23	09	11	13	11
3	Ambala	02	01	01	02	72	75	64	42	19	24	31	28	07	00	04	28
4	Bangalore C.O.	06	08	06	02	90	79	85	73	04	13	09	18	00	00	00	07
5	Bhopal	03	02	02	02	85	63	59	67	07	16	27	21	05	19	12	10
6	Bhubaneswar	02	02	02	02	73	74	73	81	14	20	20	11	11	04	05	06
7	Kolkata	02	02	02	02	73	75	74	69	17	20	19	14	08	03	05	15
8	Chennai	06	06	04	03	94	84	88	81	00	10	08	12	00	00	00	04
9	Delhi	04	02	02	02	82	73	67	63	04	22	15	21	10	03	16	14
10	Guwahati	02	02	02	04	86	77	86	84	11	13	12	12	01	08	00	00
11	Hyderabad	04	03	05	03	90	84	83	73	06	10	12	21	00	03	00	03
12	Jabalpur	03	02	01	02	68	84	62	73	17	14	22	25	12	00	15	00
13	Jaipur	03	02	02	04	78	73	82	92	13	11	11	04	05	14	06	00
14	Jammu	04	01	01	01	96	56	73	56	00	27	24	23	00	16	02	20
15	Jodhpur	04	02	03	02	82	83	86	74	14	15	11	15	00	00	00	09
16	Lucknow	02	02	02	02	60	72	72	59	22	24	19	25	16	02	07	14
17	Mumbai	01	01	02	02	44	47	66	65	30	32	21	19	25	20	13	14
18	Nagpur	03	02	03	03	77	74	73	74	20	17	20	17	00	07	04	06
19	Patna	03	01	03	02	74	72	71	70	23	16	23	14	00	11	03	14
20	Pune	04	06	11	05	81	81	82	77	11	13	03	18	04	00	04	00
21	Raipur	02	02	02	02	72	66	71	68	20	18	24	20	06	14	03	10
22	Rajkot	02	03	04	04	72	62	49	80	14	24	24	16	12	11	23	00
23	Thiruvananthapuram	02	03	04	03	78	95	91	69	17	02	05	26	03	00	00	02
24	Vishakhapatnam	04	04	04	04	81	89	82	85	15	07	11	09	00	00	03	02

3. The percentage contribution of different rainfall epochs in different months of southwest monsoon season are shown in Table 1.

The Table 1 shows that average percentage contribution of the light epoch (0.1 mm to 2.4 mm) towards monthly total rainfall is low to very low over all the major cities in India in the southwest monsoon months.

From the Table 1 it is seen that average percentage contribution of medium epoch (2.5 mm to 64.9 mm) is very high in most of the cities throughout the southwest monsoon season except for moderate contribution over Rajkot during August and over Chandigarh during September. It is also seen that the contribution of heavy epoch is in general moderate over Mumbai, Nagpur, Bhopal, Jabalpur, Patna, Kolkata, Agartala, Ahmedabad and Rajkot throughout the season. For cities in Gujarat and north India, the heavy epoch contributes in equal measures over the months.

During June-July the contribution of very heavy epoch ($\geq$ 125 mm) is 20 % or more over Mumbai. Besides this, Chandigarh in September and Rajkot in August also received 20 % or more contribution from very heavy epoch.

Orographic effect of western ghat and Khasi Jaintia hills influences the distribution of the contribution of heavy to very heavy epoch on the two sides of them. Due to forced orographic lifting of the moisture laiden air, generally windward side of the orographic barrier receives heavy to very heavy rainfall, and when the air comes to the lee side, then it carries less moisture. As a result of which lee side receive low to medium rainfall. This is clear from Table 1.

From Table 1 we see that, as one moves from west to east across Mumbai-Pune section of western ghat, then contribution of heavy to very heavy epoch reduced and also if one moves from south to north across Agartala-Guwahati section of Khasi Jaintia hills, then also same thing happens. So the cities on the foot hills in the windward side is fed from the higher epoch and those in the lee side are fed by lower epoches.

4. (*i*) Average percentage contribution of light epoch (0.1 mm to 2.4 mm) towards monthly rainfall was very low to low over all the major cities in India in all the southwest monsoon months.

(*ii*) Percentage contribution made by the two smaller epochs of daily rainfall towards monthly total rainfall, averaged over thirty years of study was high to very high in most of the cities under study.

(*iii*) The contribution of heavy epoch was in general moderate over Nagpur, Bhopal, Jabalpur, Patna, Kolkata, Agartala, Ahmedabad and Rajkot through out the season.

(*iv*) Mumbai lying on the wind ward side of Mumbai-Pune section of Western ghat and Agartala lying on the wind ward side of Khasi-Jaintia hills receive significant contribution from heavy to very heavy epoch.

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SOMENATH DUTTA
D. M. RASE

Meteorological Office, Pune – 411 005, India
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