Analysis of the Statistical Behaviour of Daily Maximum and Monthly Rainfall Data at New Delhi During Monsoon Period

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ABSTRACT

A statistical analysis of monthly mean and daily maximum rainfall data at New Delhi during the monsoon (June–September) period 1940–1980 is presented. It has been observed that a good correlation exists between the monthly and daily maximum rainfall. A linear regression analysis of the data is found to be significant for all the four months. Some key statistical parameters like the mean values of Coefficient of Variability (CV), Relative Variability (RV) and Percentage Interannual Variability (PIV) have been studied and found to be at variance. However, their corresponding ratios between mean daily maximum and mean monthly rainfall are significantly lower.

Key words: Monsoon rainfall, Coefficient of variability, Relative variability, Percentage interannual variability

1. Introduction

Indian Summer Monsoon Variability is a much discussed and researched field, yet there is a considerable scope for further work and it is understanding. The south–west monsoon, which contributes more than 75% of the annual rainfall in a major portion of India, is the spring of the national economy. The rainfall has to sustain the increasing needs of agriculture irrigation, the increasing population and the rapid industrialisation. It is however noted that the monsoon rainfall over different parts of the country shows considerable interannual variability. The disparity in the rainfall distribution is so great that some parts suffer heavy droughts, while some parts suffer heavy floods. Thus the interannual variability of summer monsoon rainfall is a complex phenomenon and is known to depend upon the regional circulations as well the global features.

Year to year variations of the south–west monsoon and seasonal rainfall forecasting have been the major concern of the Indian meteorologists for more than a century (e.g. Normand 1953; Jagannathan 1960). The rainfall varies from year to year and even within a season over the country. Total rainfall data has been used in these studies to examine large scale fluctuations in rainfall (Klein 1965; Namias 1966; Harmack 1979; Rogers 1981). There are several studies that have been made on monthly anomaly maximum rainfall variance over a particular region (Mooley 1959; Agarwal 1961; Walsh and Mostek 1980; Diaz 1981; Singh et al. 1985).

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The studies on the analysis of frequency and intensity patterns of rainfall have also been conducted by a few workers in this field (Englehart and Douglas 1985; Chen et al. 1998). Wylby (1994) discussed the relationship between weather type and daily rainfall occurrence and amount in Southern England. Recently, Unkasevic and Radinovic (2000) have presented a statistical analysis of daily maximum and monthly precipitation for the climate of Belgrade, Yugoslavia and found a high correlation between the monthly and daily maximum precipitation. The rainfall studies conducted for India by previous workers have been primarily concentrated on the examination of rainfall series for south–west monsoon rainfall as a whole (e.g. Parthasarathy and Mooley 1978; Gadgil et al. 1993). Singh (1998) has studied the relationship between rainy days, Mean Daily Intensity (MDI) and seasonal rainfall in the normal, flood and drought years over India and concluded that linear relationship fits better than Logarithmic relationship. In the present study, a statistical analysis of monthly mean and daily maximum rainfall data at New Delhi during the period of 1940–1980 is presented. Different statistical parameters for the rainfall data at New Delhi have been calculated and discussed. It has been observed that a good correlation exists between the monthly and daily maximum rainfall.

2. Data sets used

This analysis used daily maximum and monthly rainfall at New Delhi (28°35′N, 77°12′E) during the period of 1940–1980. New Delhi is situated at a height of 235 m. above sea level and occupies an inland position in a monsoon region. Air of continental origin generally prevails over the station except during the rainy season. Only during the three monsoon months July, August and September, air of oceanic origin penetrates to this state and causes an increased humidity. The data has been taken from the India Meteorological Department (IMD), Pune. The data is for the complete period of 1940–1980 without any gap.

3. Data anlaysis and computing procedure

Monsoon rainfall over New Delhi during the months from June to September exhibits interesting oscillations. During this period, heavy showers are frequent on account of the strengthening of the monsoon over New Delhi area. The monsoon generally sets in the last week of June and withdraws towards the second week of September. The seasonal change in the frequency distribution of the maximum daily rainfall is presented in Fig. 1 for all the four months. In climatological studies, Rainfall Variability is expressed in both the absolute as well as relative terms. From amongst various absolute measures of variability, the Standard Deviation (SD), Absolute Mean Deviation (AMD) and Mean Absolute Interannual Variability (MAIV) are used in this study. These parameters can be defined as

$$\mathrm{SD}=\left[(N-1)^{-1}\sum_{i=1}^{N}(R_i-\overline{R})^2\right]^{\frac{1}{2}}, \tag{1}$$

$$\mathrm{AMD}=(N-1)^{-1}\sum_{i=1}^{N}\left|R_i-\overline{R}\right|, \tag{2}$$

$$\mathrm{MAIV}=(N-1)^{-1}\sum_{i=2}^{N}\left|R_i-R_{i-1}\right|, \tag{3}$$

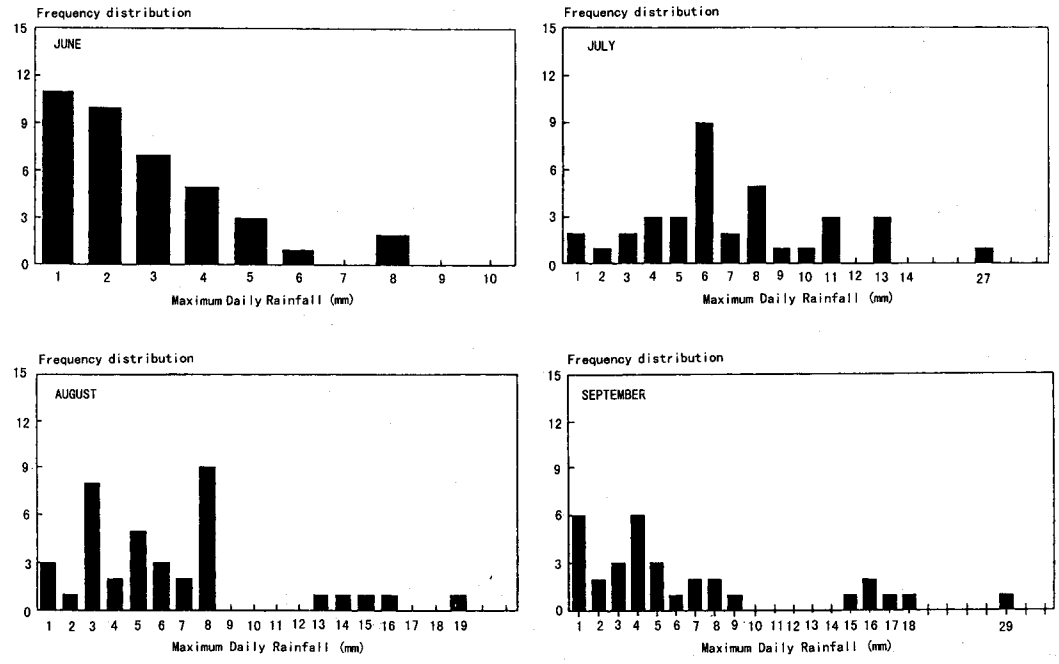

Fig. 1. Frequency distribution of the maximum daily rainfall at New Delhi during the period of 1940–1980. (June–September). Scale X axis: (1 = 0–10, 2 = 10–20, 3 = 20–30, •••, 29 = 280–290).

where R is the daily maximum rainfall or monthly rainfall or their ratio and $\overline{R}$ is the temporal mean for N years. When these three absolute measures of variability are divided by the mean and multiplied by 100, they give rise to three relative measures of variability. These are defined as Coefficient of Variability (CV), Relative Variability (RV) and Percentage Interannual Variability (PIV).

$$\mathrm{CV} = \frac{100 \times \mathrm{SD}}{\overline{R}}\,, \tag{4}$$

$$\mathrm{RV} = \frac{100 \times \mathrm{AMD}}{\overline{R}}\,, \tag{5}$$

$$\mathrm{PIV} = \frac{100 \times \mathrm{MAIV}}{\overline{R}}\,. \tag{6}$$

These are useful measures of variability and widely used in the climatological studies. To examine the correlation between daily maximum and monthly rainfall, the linear regression between these parameters have been carried out, using least square curve fitting method. The linear regression of type $R_M = a + bR_D$ are calculated for all the four months (June–September).

4. Results and discussions

4. 1 *Statistical analysis*

For the statistical analysis of the rainfall data, the six measurements of variability of

daily maximum rainfall, monthly rainfall and their ratio for all the months (June to September) have been calculated. The computing procedure for $\overline{R}_D$ and $\overline{R}_M$ have been described as follows: $\overline{R}_D$ is the average of daily maximum rainfall for each month (June–September) for all the 41 years (1940–1980). Also, $\overline{R}_M$ is the average of monthly rainfall for each month (June–September) for all the 41 years (1940–1980). Table 1 shows the mean daily maximum and mean monthly rainfall (June–September) during the period of 1940–1980.

Table 1. Mean daily maximum ($\overline{R}_D$) and mean monthly ($\overline{R}_M$) rainfall at New Delhi for the period of 1940–1980

Month	June	July	August	September	Yearly Average
$\overline{R}_D$ (mm)	23.0	62.70	59.20	61.50	206.70
$\overline{R}_M$ (mm)	49.6	232.09	229.6	140.26	651.55

The minimum rainfall occurs in the month of June, while the maximum rainfall occurs in the months of July, August and September respectively. The maximum mean monthly rainfall also occurs in the month of July and August respectively. The ratio of mean daily maximum and mean monthly rainfall has been shown in Table 2. The highest values of the ratio occur in the period of June and September, while the Coefficient of Variability (CV), Relative Variability (RV) and Percentage of Variability (PIV) increase for monthly rainfall in comparison to daily maximum rainfall for the months of June to September.

However for the daily maximum rainfall and their ratio between the daily maximum and monthly rainfall, the coefficient of variability is higher in comparison to relative variability and percentage interannual variability.

Table 2. The ratio between the mean daily maximum ($\overline{R}_D$) and mean monthly ($\overline{R}_M$) rainfall at New Delhi for the period of 1940–1980

Month	June	July	August	September	Yearly Average
$\overline{R}_D / \overline{R}_M$ (mm)	0.463	0.270	0.257	0.438	0.317

The six measurement of variability of daily maximum rainfall, monthly rainfall and their computed ratio at New Delhi for June to September are presented in Tables 3–5.

Table 3. Standard Deviation (SD), Absolute Mean Deviation (AMD), Mean Absolute Interannual Variability (MAIV), Coefficient of Variability (CV), Relative Variability (RV) and Percentage Interannual Variability (PIV) for the daily maximum rainfall at New Delhi during the period 1940–1980

Month	June	July	August	September	Mean
SD (mm)	2.62	8.77	8.93	9.32	7.41
AMD (mm)	0.41	1.38	1.41	1.47	1.17
MAIV (mm)	0.60	0.33	0.09	0.79	0.45
CV (%)	11.41	13.99	15.09	15.16	13.91
RV (%)	1.80	2.21	2.38	2.39	2.20
PIV (%)	2.64	0.53	0.16	1.29	1.15

Table 4. Same as Table 3 but for monthly rainfall

Month	June	July	August	September	Mean
SD (mm)	6.0	30.9	34.73	21.02	23.16
AMD (mm)	6.95	4.89	5.49	3.32	5.16
MAIV (mm)	2.12	1.99	1.14	1.06	1.57
CV (%)	12.09	13.31	15.12	14.98	13.87
RV (%)	19.30	21.08	23.92	23.71	22.00
PIV (%)	42.79	8.60	4.96	7.57	15.98

Table 5. Same as for Table 3, but for the ratio between daily maximum and monthly rainfall

Month	June	July	August	September	Mean
SD (mm)	0.018	0.022	0.003	0.008	0.013
AMD (mm)	0.0029	0.0036	0.0005	0.0014	0.0021
MAIV (mm)	0.0017	0.0005	0.0038	0.0055	0.0020
CV (%)	3.88	8.14	1.16	1.82	3.75
RV (%)	0.5	1.05	0.18	0.33	10.54
PIV (%)	0.34	0.14	1.30	1.33	0.78

4.2 *Linear regression*

Further the data is analysed to examine the correlation between the daily maximum (R_D)

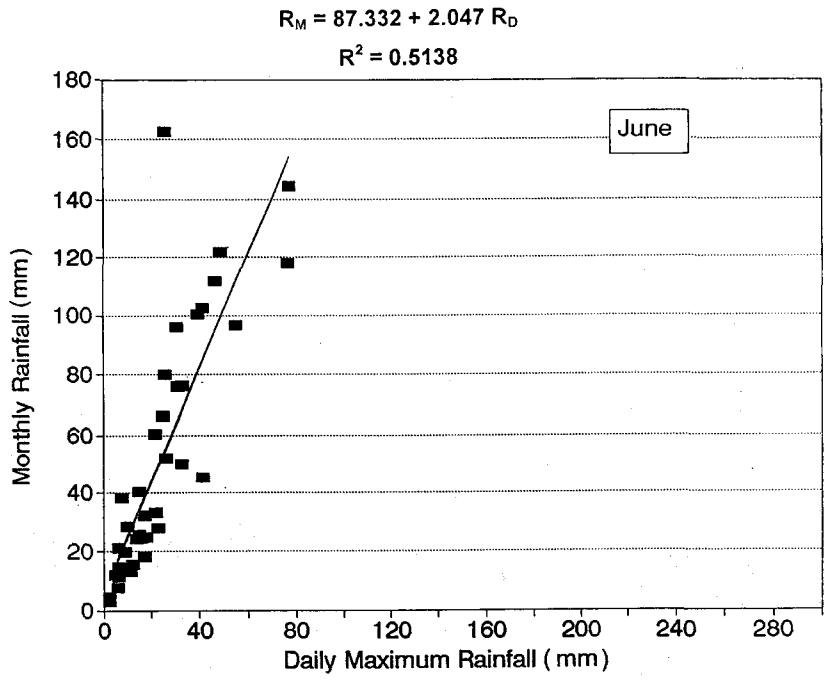

Fig. 2. Linear regression and correlation coefficient between the monthly (R_M) and daily maximum rainfall (R_D) at New Delhi during the period of 1940–1980 (June).

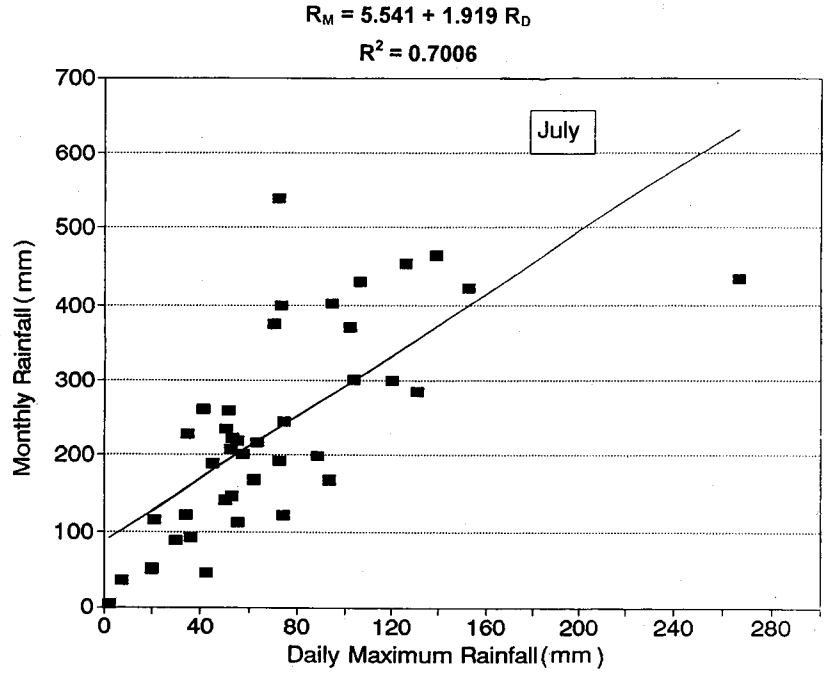

Fig. 3. Linear regression and correlation coefficient between the monthly (R_M) and daily maximum rainfall (R_D) at New Delhi during the period of 1940–1980 (July).

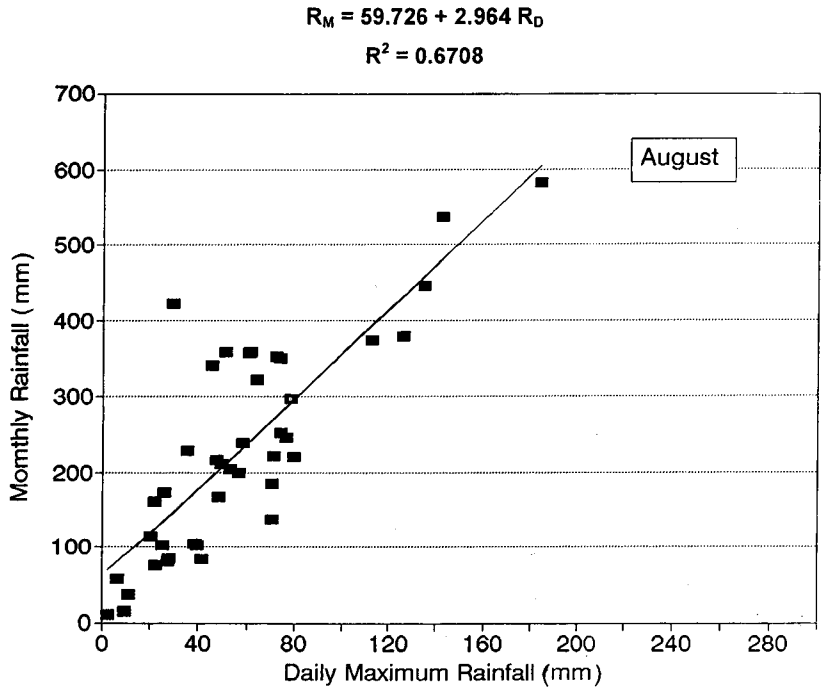

Fig. 4. Linear regression and correlation coefficient between the monthly (R_M) and daily maximum rainfall (R_D) at New Delhi during the period of 1940–1980 (August).

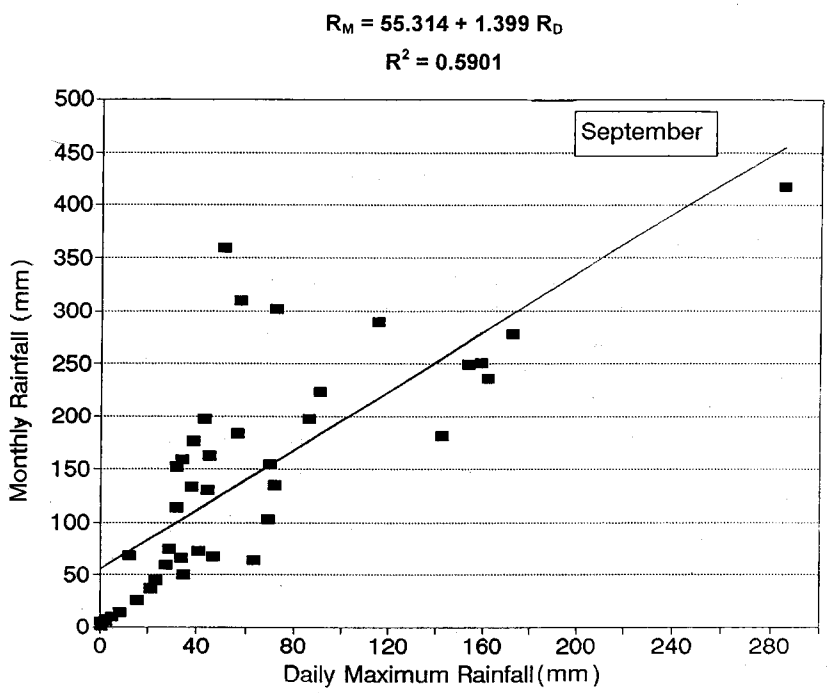

Fig. 5. Linear regression and correlation coefficient between the monthly (R_M) and daily maximum rainfall (R_D) at New Delhi during the period of 1940–1980 (September).

and monthly (R_M) rainfall. The linear regression between these parameters has been carried out using least square curve fitting method. The linear regression of type $R_M = a + b\ R_D$ is calculated for all the four months. Scatter diagrams of monthly and daily maximum rainfall at New Delhi for all the four months (June–September) have been presented in Figs. 2–5. The correlation coefficients have been found to be significant for all the cases. Table 6 shows some statistical data in relation to linear regression equation.

Table 6. Linear regression (statistics)

Month	June	July	August	September
Constant	5.54	87.32	59.72	55.31
R Squared (Correlation Coefficient)	0.70	0.51	0.67	0.59
Std Err of Coef.	0.20	0.31	0.33	0.18

5. Conclusions

The main conclusions of this study are as follows:

1) Monthly rainfall increases linearly with the daily maximum rainfall.

2) There is a significant correlation between daily maximum and monthly rainfall during these months (June–September).

3) The mean values of Coefficient of Variability (CV), Relative Variability (RV) and Percentage Interannual Variability (PIV) are different, but their ratio between mean daily maximum and mean monthly rainfall is significantly lower.

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