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STATISTICAL STUDY OF EXCESS AND DEFICIENT RAINFALLS OVER JALPAIGURI

1. Jalpaiguri is a station situated at Latitude 26° 32' / Longitude 88° 43' and is a place in meteorological sub-division of Sub-Himalayan West Bengal and Sikkim. This station receives on an average (1901-2000) 3306.8 mm (2669.5 mm) annually (SW monsoon season) with normal (1951-1980) annual (seasonal) rainfall being 3249.7 mm (2540 mm). This station has not experienced any scanty (Percentage departure from normal greater than equal to –60 percent and less than or equal to –99 percent) and no rain (percentage departure from normal greater than or equal to -100 percent) during the period (1901-2000). Out of the hundred years (1901-2000), the station received excess rainfall (percentage departure from normal above +19 percent) on annual (seasonal) basis on 18(24) occasions, Normal rainfall (percentage departure from normal between –19 percent and +19 percent) on 73(64) occasions, Deficient rainfall (percentage departure from normal between –20 percent to –59 percent) on 09(12) occasions. In this paper, an attempt has been made to study the excess/deficient rainfalls over the stations by statistical methods utilized by Lund (1955) and Yao (1982). Initially, the annual (seasonal) rainfall series has been reduced to a graded series with 1 - representing excess rainfall, 2 - representing normal rainfall, 3 - representing deficient rainfall, 4 - representing scanty rainfall, 5 - representing no rain. The 5 - grade annual (seasonal) series is presented in Table 1. The annual (Seasonal) rainfall series for the period (1901-2000) over Jalpaiguri has been converted into a dichotomous variate x (0,1) for excess/deficient rainfalls. The series, so generated, is represented by ones and zeros where ones denote occurrence of excess/deficient rainfall and zeros denote non-occurrence of excess/deficient rainfall.

2. The standard sequential variability of the estimated separately for excess/deficient rainfall by making use of the relation $V_N = 100 \times \left[2\left(p' - p\right)\right]^{1/2}$ % where 'p' is the probability of occurrence of the excess/deficient rainfall and the 'p'' is the probability of occurrence of the excess/deficient rainfall in association with immediate occurrence of same excess/deficient rainfall and the probability of occurrence of excess/deficient rainfall is given as $p = N_e/N$ or $p = N_d/N$ where 'N_e' or 'N_d' represent the no. of times excess or deficient rainfall occurred and 'N' represents the sample size. The p' values are calculated out of number of excess rainfall years and number of deficient years in the respective cases. The calculated sequential variabilities are presented in Table 2. In any standard state of dichotomous series, ones and zeros occur alternatively and therefore, p = 0.5 and p' = 0.0 and V_N = 100 × [2(0.5-0.0)] = 100 % and $S_n = [2(p)(p\text{-}1)(1\text{-}r)]^{1/2}$ = 1 by taking 'r', the first order serial correlation coefficient as '-1' to represent interchangeability. From computations, it is seen that the value of p (p') is equal to 0.18(0.22)/0.09(0.0) for excess/deficient rainfall in annual series and p (p') is equal to 0.24(0.25)/0.12(0.0) for excess/deficient in seasonal series. The sequential variability of excess/deficient in annual (seasonal) series is 28%/42% (14%/49%).

3. Let 'p' be the probability of the occurrence of excess/deficient rainfall events, 'p'' be the probability of occurrence of excess/deficient rainfall events followed immediately by the occurrence of the same event, then Besson's coefficient of persistence is $R = (1\text{-}p/1\text{-}p') - 1$. If there is no persistence $p' = p$ and $R = 0$. If there is perfect persistence $p' = 1$ and R = infinite. If $p' < p$, then R

TABLE 1

Showing annual and seasonal excess, normal and deficient rainfall (1901-2000) in code

Year	Annual	Seasonal	Year	Annual	Seasonal
1901	2	2	1951	2	2
1902	1	1	1952	2	2
1903	2	2	1953	3	3
1904	2	3	1954	2	2
1905	2	2	1955	1	1
1906	2	2	1956	1	2
1907	2	2	1957	2	2
1908	3	3	1958	1	1
1909	2	2	1959	2	3
1910	2	1	1960	2	2
1911	2	2	1961	3	3
1912	2	2	1962	2	2
1913	2	2	1963	2	2
1914	3	2	1964	1	1
1915	2	3	1965	2	2
1916	1	1	1966	2	2
1917	2	2	1967	2	2
1918	2	2	1968	2	2
1919	3	2	1969	2	2
1920	2	2	1970	2	2
1921	2	2	1971	2	2
1922	2	2	1972	2	2
1923	1	1	1973	2	2
1924	1	1	1974	1	1
1925	2	2	1975	2	2
1926	2	2	1976	2	2
1927	1	1	1977	2	2
1928	2	2	1978	3	3
1929	2	2	1979	2	2
1930	2	3	1980	2	2
1931	2	1	1981	2	2
1932	2	2	1982	2	2
1933	2	2	1983	2	1
1934	2	1	1984	1	1
1935	2	2	1985	2	2
1936	2	2	1986	3	3
1937	2	3	1987	2	1
1938	1	1	1988	2	1
1939	2	2	1989	1	1
1940	2	2	1990	2	2
1941	2	2	1991	1	1
1942	2	2	1992	2	2
1943	2	2	1993	2	2
1944	2	2	1994	3	3
1945	2	2	1995	2	2
1946	2	2	1996	2	2
1947	3	3	1997	2	2
1948	1	1	1998	1	1
1949	2	2	1999	1	1
1950	2	1	2000	1	1

TABLE 2

Showing values of sequential variability, Besson's coefficient of persistence, persistence ratio, observed mean length, variance ratio, index of raininess, index of excess/deficient rainfall

S.No.	Parameter	Excess		Deficient	
		Annual	Seasonal	Annual	Seasonal
1.	First Order scc	0.05	-0.10	0.01	-0.14
2.	Variability	28%	14%	42%	49%
3.	Coeff.Persistence	-0.05	+0.01	- 0.09	-0.12
4.	Persistence ratio	+1.05	+0.809	+0.91	+0.88
5.	Obs. mean length	1.22	1.32	1.10	1.14
6.	Variance ratio	95%	99%	110%	114%
7.	Index of raininess	+0.33	+0.33		
8.	Index	+7.32	+7.04		

is negative representing a tendency for the alternation of occurrence and non-occurrence. If the value of '*R*' is positive, then $p' > p$, indicates some degree of persistence. The sign and magnitude of *R* is, therefore, a measure of predominance of persistence or interchangeability. The mean length of persistence will also give some indication of persistence in the series and is given by $1/(1-p)$. Another method to calculate persistence in the series is to use persistence ratio. The persistence ratio is defined as the ratio between observed and theoretical average length of a run of event, such as excess/deficient rainfall. The persistence ratio is given as $R_r = 1 + R$. The larger the value of 'R_r', the greater the predominance of persistence while the smaller value of 'R_r' indicative of predominance of interchangeability. It is also known that the first order auto-correlation coefficient can be a measure of persistence and the variability ratio $V_r = 100 \times (1- r)$ %. If the series is absolutely random, then the first order auto-correlation coefficient is equal to zero and variability ratio is equal to 100 percent. If the series has absolute persistence, then the first order auto-correlation coefficient is equal to one and the variability ratio is zero. If the series has absolute interchangeability, then the first order auto-correlation coefficient would be equal to -1 and variability ratio is 200 percent. Therefore, any value of 'V_r' not equal to 100 percent indicate non randomness and less than or equal to 100 percent indicate predominance of persistence and on the other hand, 'V_r' greater than 100 percent indicate interchangeability. The estimated first order serial correlation coefficient, variability in percentage, Besson's coefficient of persistence, persistence ratio, observed mean length and variance ratio for excess/deficient rainfalls both annual and seasonal are presented along with index of raininess and index for excess/deficient rainfalls in Table 2. The first order serial correlation coefficients excess/deficient for both seasonal and annual are tested for significance using *t*-test. The *t*-test showed that all the first order serial correlation coefficients are not at all significant at 95% confidence level. However, the

TABLE 3

Showing serial correlation coefficients of order 1 to 50, Chi-Square values for excess/deficient annual and seasonal rainfall (1901-2000)

	Annual				Seasonal			
	Excess		Deficient		Excess		Deficient	
S. No.	Accs	Chi-Square	Accs	Chi-Square	Accs	Chi-Square	Accs	Chi-Square
1.	0.05	97.42	-0.10	101.35	0.01	100.32	-0.14	95.04
2.	-0.01	97.42	-0.10	101.35	-0.01	100.32	-0.04	95.04
3.	-0.15	97.42	-0.10	101.35	-0.21	100.32	-0.14	95.04
4.	-0.15	97.42	-0.10	101.35	0.01	100.32	-0.04	95.04
5.	-0.15	97.42	0.02	101.35	-0.15	100.32	-0.14	95.04
6.	-0.15	97.42	0.15	101.35	-0.15	100.32	0.05	95.04
7.	0.05	97.42	-0.10	101.35	0.07	100.32	0.05	95.04
8.	0.05	97.42	0.27	101.35	0.01	100.32	0.15	95.04
9.	-0.08	97.42	-0.10	101.35	-0.10	100.32	-0.14	95.04
10.	0.12	97.42	-0.10	101.35	0.07	100.32	-0.04	95.04
11.	-0.01	97.42	0.02	101.35	0.01	100.32	-0.04	95.04
12.	-0.22	97.42	-0.10	101.35	-0.21	100.32	-0.04	95.04
13.	-0.22	97.42	-0.10	101.35	-0.15	100.32	-0.14	95.04
14.	-0.01	97.42	0.02	101.35	0.07	100.32	-0.04	95.04
15.	-0.01	97.42	-0.10	101.35	-0.04	100.32	-0.04	95.04
16.	-0.01	97.42	0.02	101.35	-0.04	100.32	0.05	95.04
17.	-0.15	97.42	0.02	101.35	-0.04	100.32	0.05	95.04
18.	-0.15	97.42	-0.10	101.35	-0.26	100.32	-0.14	95.04
19.	-0.15	97.42	-0.10	101.35	-0.15	100.32	-0.04	95.04
20.	-0.08	97.42	-0.10	101.35	-0.15	100.32	-0.14	95.04
21.	-0.08	97.42	-0.10	101.35	-0.10	100.32	0.14	95.04
22.	-0.08	97.42	-0.10	101.35	-0.21	100.32	0.05	95.04
23.	-0.22	97.42	-0.10	101.35	-0.21	100.32	-0.04	95.04
24.	-0.08	97.42	-0.10	101.35	0.07	100.32	-0.04	95.04
25.	0.05	97.42	0.15	101.35	-0.04	100.32	0.05	95.04
26.	0.05	97.42	-0.10	101.35	-0.04	100.32	-0.04	95.04
27.	-0.15	97.42	-0.10	101.35	-0.15	100.32	-0.04	95.04
28.	-0.08	97.42	0.02	101.35	-0.15	100.32	-0.14	95.04
29.	-0.08	97.42	-0.10	101.35	-0.15	100.32	0.05	95.04
30.	-0.22	97.42	-0.10	101.35	-0.21	100.32	-0.14	95.04
31.	-0.01	97.42	0.02	101.35	-0.15	100.32	0.05	95.04
32.	0.05	97.42	-0.10	101.35	-0.10	100.32	-0.04	95.04
33.	-0.01	97.42	0.27	101.35	-0.04	100.32	0.15	95.04
34.	-0.01	97.42	0.15	101.35	-0.10	100.32	-0.14	95.04
35.	-0.01	97.42	-0.10	101.35	-0.15	100.32	-0.04	95.04
36.	0.12	97.42	-0.10	101.35	0.01	100.32	-0.14	95.04
37.	-0.15	97.42	-0.10	101.35	-0.21	100.32	-0.14	95.04
38.	-0.22	97.42	-0.10	101.35	-0.26	100.32	-0.04	95.04
39.	-0.15	97.42	0.27	101.35	-0.21	100.32	0.05	95.04
40.	-0.0	97.42	-0.10	101.35	-0.04	100.32	-0.14	95.04
41.	-0.0	97.42	0.02	101.35	-0.15	100.32	0.05	95.04
42.	-0.01	97.42	0.02	101.35	-0.21	100.32	-0.14	95.04
43.	-0.01	97.42	-0.10	101.35	-0.15	100.32	-0.04	95.04
44.	-0.15	97.42	-0.10	101.35	-0.26	100.32	-0.04	95.04
45.	-0.15	97.42	0.02	101.35	-0.15	100.32	-0.04	95.04
46.	-0.08	97.42	-0.10	101.35	-0.21	100.32	-0.04	95.04
47.	-0.15	97.42	0.15	101.35	0.26	100.32	-0.04	95.04
48.	-0.15	97.42	-0.10	101.35	-0.15	100.32	-0.04	95.04
49.	-0.22	97.42	-0.10	101.35	-0.15	100.32	0.05	95.04
50.	-0.08	97.42	-0.10	101.35	-0.10	100.32	-0.14	95.04

first order serial correlation coefficients in case of excess rainfall on annual as well as seasonal time scales have positive sign. Therefore, it is imperative that there exists some persistence in the time series. It can be seen that Besson's coefficient of persistence in annual (seasonal) excess/deficient rainfall is +0.05/-0.09 (+0.01/-0.12). The computed values of coefficients in case of deficient rainfall for annual (seasonal) are all small negative values. The calculated persistence ratios for annual (seasonal) excess/deficient are +1.05/+0.91 (+1.01/+0.88) which all small positive values. The observed mean length in annual (seasonal) excess/deficient rainfall is 1.22/1.10 (1.32/1.14).

4. The index of raininess suggested by Yao (1982) has been utilized here to obtain an index of excess/deficient rainfall. This index gives information about the year to year fluctuations of raininess. The

temporal variability of excess/deficient rainfalls can be investigated by this index. The index is given as I = (E - D)/(E+D) where 'E' is the no. of times excess rainfall received and 'D' is the no. of times deficient rainfall received. Furthermore, an index of excess/deficient rainfall is utilized given by $I_f = 100 \times (V_{rd} - V_{re})/(V_{rd} + V_{re})$ where 'V_{rd}'or 'V_{re}' denote the variability ratio of deficient or excess rainfall respectively. If 'I_f' is equal to zero, then the climate is homogeneous with preference over excess or deficient rainfall. If 'I_f' is greater than zero, then excess rainfall dominated climate and if 'I_f' is less than zero, then deficient rainfall dominated climate. The calculated values of indices are presented in Table 2. From Table 2, it can be seen that the index of raininess in annual (seasonal) rainfall is 0.3333 (0.3333). The computed excess/deficient index annual (seasonal) has a value of +7.32(+7.04) which shows that the climate over Jalpaiguri is slightly 'excess' dominated one. That means, at Jalpaiguri, there is a slight tendency that a deficient year may alter with an excess year and a excess year have slight tendency to persist.

5. It is known that the sample sequential variability and population sequential variability are related by $n\ S^2/S_p^2$ where 'S' and 'S_p' are the standard deviations of sample and population respectively and it has got Chi-Square distribution with 'n' degrees of freedom where $n = N$-1. N being the sample size. For large values of 'n', the S^2 approaches normal. Similarly, for sample sequential variance of order 'l' is related to the populaltion sequential variance as n S_l^2/S_{pl}^2 and which has Chi-Square distribution with $n = N$ - l degrees of freedom. To search for periodicities in the excess/deficient rainfall series, the above technique is employed to the dichotomous variate x (0,1). The sample variance of dichotomous variate x (0,1) represents with $x = 1$ for excess/deficient rainfall and $x = 0$ for non-occurrence of excess/deficient rainfall. For the standard state, the sequential variance is $S_p^2 = p(1 - p)$ and sample sequential variance as $S_l^2 = 2 \times [p - p'(l)]$ and $S_{pl}^2 = 2 \times S_p^2 [1- r(l)]$. The computed r(l), l = 1,2,3..50 for annual (seasonal) excess/deficient are presented in Table 3. If there is a cyclic period in the excess/deficient rainfall series, 'S_l^2' would be a minimum for $(1+1)^{th}$ period. If there is a perfect cyclic period, then S_l^2 would be zero. For this purpose, S_l^2 has been calculated for 1= 1,2,3.....N/2. To decide any presence of cyclic periods, corresponding to the minimum value of S_l^2, a significant test has been applied to test the Null-hypothesis $H_0 : S_{pl}^2 = S_p^2$ against the alternative $H_1: S_{pl}^2 < S_p^2$. The critical region of size (α) χ^2 is less than or equal to $\chi^2(\alpha)$ and χ^2 is given as $n[p\text{-}p'(l)] / [p(1\text{-}p)]$. The computed χ^2 values annual (seasonal) excess/deficient rainfall are presented in Table 3. If the sample is random, then the r(l) = 0 and χ^2 is equal to n. The probability that χ^2 is equal to n is 0.5 according to tabulated values. That means, the probability of presence of cyclic period of length (1+1) is 0.5. If there is a strict cyclic period of length (l+1) then r(l) = 1 and $\chi^2 = 0$. If there is no strict cyclic period of length (1+1) then r(l) = -1 and $\chi^2 = 2n$. In this way, the annual (seasonal) excess/deficient rainfall series converted to dichotomous variate x(0,1) is searched for separate periodicities in both excess/deficient rainfall series. Making use of the above technique, which is similar to the technique of variance analysis, spectrum analysis, the cyclic period of length 2 to 50 have been tested. The estimated values indicate no presence of significant periodicities in the excess/deficient rainfall series at 95 percent confidence level. The Besson's coefficient of persistence indicated predominance of slight persistence in excess rainfall over annual time scale.

6. In this paper, to study excess/deficient rainfalls in both annual and seasonal scales, simple and easy to use non-parametric methods on classified nominal measurements are utilized. The non-parametric tests are used here to test statistical hypothesis. The study indicated that there is a tendency for alternation of occurrence and non-occurrence in excess/deficient rainfalls over annual/ seasonal time scales. However, predominance of slight persistence is seen in excess rainfall over annual and seasonal scales. The search of presence of any periodicities in the time series of annual/seasonal excess/ deficient rainfalls indicated no significant periodicities present at 95% confidence level.

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