Rainfall Trend and Variability for Some of the State's Capital of Indian Union during the 20th Century (1901-2000)

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ABSTRACT *Rainfall is an important parameter to study the climate change and variability of a place. A good number of studies regarding rainfall trend and variability during the 20th century on a global and regional level with yearly and seasonal scale were done but a combined and integrated study of rainfall trend and variability on smaller spatial area like a city, especially on a monthly scale, was rare for most of the major cities in India during the 20th century. The aim of the present study is to investigate the rainfall time series for thirty two (32) selected cities during the 20th century (1901- 2000) on a monthly scale which includes most of the capitals of the States in India. The rainfall trend during the past 100 years (1901 -2000) is found to be statistically significant at a confidence interval of 95 percent with a significance level of 0.05 for seven (07) cities namely; Aizawl, Agartala, Aurangabad, Chennai, Gangtok, Jorhat and Shillong for certain months among the thirty two (32) selected cities in India.*

Keywords: *Capital; City; Climate; India; Rainfall; Trend; Variability.*

Introduction

Climate change is a crucial issue that deserves urgent retrospection and research for mankind. Certain climatic behaviors and patterns occur naturally and are beyond the control of human intervention. But nature has been kind to mankind that most of the natural variations related with climate change were absorbed by the system of the earth. Unfortunately, the climatic conditions of the earth are now disturbed by the rampant activities of the humans.

Various studies on climate change across the world have concluded that rainfall and mean surface temperature of the earth are good indicators for assessing the climate change of the earth (Jhajharia and Singh, 2011).The rainfall trend and variability of some State's Capital of the Indian Union during the 20th century (1901 -2000) scattered across the length and breadth of India is considered for this study. This study is considered because rainfall is related to the availability of fresh water and agricultural production in a country like India. Most of the farmers in India are still dependent on rainfall for its farming activities. Moreover, fresh water scarcity is an important issue for a populous country like India. It is predicted that there will be more melting of glaciers and decrease in the availability of fresh water coupled with reduction in agricultural production due to climate change (IPCC, 2007). This will also affect the Indian sub-continent in the form of drying of many river basins leading to scarcity of fresh water (Gosain et al., 2006).The study on rainfall will give us an insight of the problem related with flood, drought and different natural calamities.

Studies on global rainfall trends have observed that precipitation within 10°N to 30°N has increased significantly from 1900 to 1950 while it has declined after 1970 (IPCC, 2007).Likewise, it has also declined across the Mediterranean, the Sahel, Southern Africa and parts of Southern Asia while it has increased in the eastern part of North and South America, Northern and Central Asia (IPCC, 2007). The studies on global average rainfall predicted that the earth may become wetter but there will be regional variation of rainfall across the earth (Dore, 2005).

The studies done on rainfall by various researchers like Mooley D. A. and Parthasarthy B (1984); Sarker R P and Thapliyal V (1988); Thapliyal V and Kulshreshtha S M (1991); Lal M (2001); Sinha Ray K C and De U S (2003) and Kumar V Jain S K and Singh Y (2010) have observed that there is no clear trend in the average annual rainfall of India. However, studies done by researchers like Koteswaram P and Alvi (1969); Jagannathan P and Parthasarathy B(1973); Raghavendra VK (1974); Chaudhary A and Abhyankar VP (1979); Kumar V, Singh P and Jain SK (2005); Dash et al.(2007) and Kumar V, Jain SK. (2010) observed that there is a significant trend for different region of India. It was predicted that there is a significant rainfall trend over small spatial scale in India (Srivastava et al., 1998). The frequency of heavy rainfall events have increased over many parts of India during the monsoon but have decreased during the other seasons (Sinha Ray et al., 1999).

Most of the studies regarding rainfall trend and variability during the 20th century were done in a global and national level. However, the investigation of rainfall trend and variability during the 20th century on a smaller spatial level like the state's capital city of the Indian union on a monthly scale seems to be very limited. Thus, the main aim of the present study is to evaluate the rainfall trend and variability of thirty two (32) selected cities including most of the capital city of the Indian states and union territory. Simple statistical techniques are initially employed to analyse the variability of the rainfall. The non – parametric like the Mann-Kendall test and the Sen's Slope Estimator are also used to study the rainfall trends. The parametric linear regression test was also done to show the trend for one of the city showing a high statistically significant trend.

Area of Study

India is the seventh largest country in the world in terms of area and the second most populous country in the world. It is bounded by the Indian Ocean on the south, the Arabian Sea on the south west and the Bay of Bengal on the south east. The great Himalayas span around 10 Indian States starting from the Northern part of India to the North Eastern part of India. This unique geographical distribution contributes to the formation of different climatic zones in India. In this study, most of the capital cities of the Indian states and union territories are considered depending on the availability of standard and quality data. Some additional cities have been included randomly for the states which could not qualify for the capital cities. One city, each from Haryana and Punjab, has also been included randomly with a contention that Chandigarh is a union territory and also the capital for both the states. The capital city of Arunachal Pradesh, Assam, Maharashtra, Orissa and Kerala are not included but a city from each of the state are also selected randomly. The cities that are not capital cities but included for this study are Aurangabad in Maharashtra, Bhiwani in Haryana, Cuttack in Orissa, Idukki in Kerala, Jorhat in Assam and Tamang in Arunachal Pradesh. Both the capital cities, Jammu and Srinagar, are included for the study from the state of Jammu and Kashmir. The cities from the state of Goa and the Union territory of Andaman & Nicobar Island, Daman & Diu and Lakshadweep are excluded due to non- availability of standard data. The longitude and latitude for the selected cities along with the respective state are shown in table1.

Sl. No.	Place	State	Latitude	Longitude	Sl. No.	Place	State	Latitude	Longitude
1	Agartala*	Tripura	23.8315° N	91.2868° E	17	Imphal*	Manipur	24.8170° N	93.9368° E
2	Aizawl*	Mizoram	23.7271° N	92.7176° E	18	Jaipur*	Rajasthan	26.9124° N	75.7873° E
3	Aurangabad	Maharashtra	19.8762° N	75.3433° E	19	Jalandhar	Punjab	31.3260° N	75.5762° E
4	Bangalore *	Karnataka	12.9716° N	77.5946° E	20	Jammu*	J &K ++	32.7266° N	74.8570° E
5	Bhiwani	Haryana	28.7752° N	75.9928° E	21	Jorhat	Assam	26.7465° N	94.2026° E
6	Bhopal*	MP^	23.2599° N	77.4126° E	22	Kohima*	Nagaland	25.6586° N	94.1053° E
7	Chandigarh *	H/P/C +	30.7333° N	76.7794° E	23	Kolkota*	West Bengal	22.5726° N	88.3639° E
8	Chennai *	Tamil Naidu	13.0827° N	80.2707° E	24	Lucknow*	Uttar Pradesh	26.8467° N	80.9462° E
9	Cuttack	Orissa	20.4625° N	85.8830° E	25	Patna*	Bihar	25.5941° N	85.1376° E
10	Dadra & N H*	Dadra & N H	20.1809° N	73.0169° E	26	Puducherry*	Puducherry	11.9416° N	79.8083° E
11	Dehradun*	Uttarkand	30.3165° N	78.0322° E	27	Raipur*	Chhattisgarh	21.2514° N	81.6296° E
12	Delhi*	Delhi	28.7041° N	77.1025° E	28	Ranchi*	Jharkand	23.3441° N	85.3096° E
13	Gandhi Nagar*	Gujarat	23.2156° N	72.6369° E	29	Shillong*	Meghalaya	25.5788° N	91.8933° E
14	Gangtok*	Sikkim	27.3389° N	88.6065° E	30	Shimla*	Himachal	31.1048° N	77.1734° E
15	Hyderabad*	AP^^/Telangana	17.3850° N	78.4867° E	31	Srinagar*	J & K ++	30.2247° N	78.7986° E
16	Idukki	Kerala	9.9189° N	77.1025° E	32	Tawang	AP +++	27.5781°N	91.8757 °E

MP^ = Madhya Pradesh; H/P/C + = Haryana/Punjab/ Chandigarh; J & K ++ = Jammu & Kashmir; AP+++ = Arunachal Pradesh

Table 1: Longitude and Latitude for the selected 32 cities (*Indicates that it is a state capital city; AP^^ = Andra pradesh)

Data and Methods

The rainfall data was analyzed for thirty two (32) selected cities in India during the 20th century (1901 -2000). A year was divided into four seasons as per the classification of Indian Meteorological Department namely, winter (January – February), pre monsoon (March – May), monsoon (June-September) and post monsoon (November –December). The data was obtained from Indian water portal and the trend and variability was studied by using parametric and non-parametric statistical methods. Initially, simple statistical analyses were employed to study the rainfall variability of the thirty two (32) Indian cities during the 20th Century. The statistical significance for the rainfall trend was analyzed by the non- parametric

Mann-Kendall test (Mann, 1945; Kendall, 1975) and the magnitude of the trend was determined by the Sen's slope estimator (Sen, 1968). The pre-whitening test of the given data set was not done due to the sample size larger than fifty (n≥50) with a comparatively high trend as explained by Bayazit and onoz (2007). The parametric linear regression test was also done to show the trend for one of the city showing a high significant trend. In Mann-Kendall test, the null hypothesis that all the observations of a time series are randomly ordered with no trend is tested against the alternative hypothesis that there is an increasing or decreasing monotonic trend. The Mann-Kendall test consists of comparing each value of the time series with the other remaining always in sequential order. If a data value is higher than the subsequent previous value, then the statistics (S) is incremented by +1.Likewise, a data value lower than the subsequent previous value is decremented by -1 for S. A zero value is assigned for S if the previous value is the same with the next subsequent value. The final value is obtained by the net summation of all the values of S.

The Mann-Kendall statistic (Salas, 1993) is given by

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \text{sign}(x_j - x_i) \qquad (1)$$

Where N is the length of the data set such X_i and X_j are the two generic sequential data values.
The function sign $(x_j - x_i)$ assumes the following values as

(a) +1, if sign $(x_j - x_i) > 0$ (2)
(b) 0, if sign $(x_j - x_i) = 0$ (3)
(c) -1, if sign $(x_j - x_i) < 0$ (4)

The standardized test statistic Z (Hirsch et al., 1993) is classified into three categories as:

(i) When S > 0, the value of Z is expressed as,

$$Z = \frac{S-1}{\sqrt{Var(S)}} \qquad (5)$$

(ii) when S = 0, the value of Z is equal to zero (Z = 0) (6)

(iii) When S < 0, the value of Z is expressed as,

$$Z = \frac{S+1}{\sqrt{Var(S)}} \qquad (7)$$

Such that the variance (Helsel DR and Hirsch RM, 1992) for a sample larger than ten (n>10) is expressed as

$$E(S) = 0 \qquad (8)$$

$$Var(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18} \qquad (9)$$

Such that n is the number of zero difference between the compared values (tied) groups and t_k is the number of data points in the k^{th} tied group. The presence of a statistically significant trend is evaluated by using the Z value. This statistic is used to test the null hypothesis that no trends exist. A positive Z indicates an increasing trend in the time series, while a negative Z indicates a decreasing trend.

The estimate for the magnitude of the slope of trend b is calculated using non-parametric Sen's method (Sen, 1968; Lettenmaier et al., 1994; Yue S and Hashino M, 2003; Partal T and Kahya E, 2006) as

$$b = median\left[\frac{(X_j - X_k)}{(j-k)}\right] \quad \text{for all } j > k \qquad (10)$$

Where b is the slope between data points $(X_j - X_k)$ measured at times j and k respectively.

Discussion and Result

The rainfall data for the thirty two (32) selected cities during the one hundred year duration (1901-2000) is analysed in terms of monthly mean scale. The maximum and minimum for the monthly mean rainfall of all the thirty two (32) selected cities is shown in table 2. The month and year representing the corresponding maximum or minimum monthly mean rainfall is also shown in the same table. The minimum monthly mean value of zero rainfall is repeating frequently for some of the cities. Therefore, the number of months on which there was no rainfall (Zero rainfall) during the 100 year duration (1901-2000) is presented on the table rather than the specific month and year.

Shillong is found to have the maximum monthly mean rainfall of 2059.14 mm during the month of July, 1974, among the thirty two (32) selected cities in India. The lowest value for the maxima of the monthly mean rainfall among the thirty two (32) selected cities is observed at Raipur (43.602mm). However, none of the months during the one hundred (100) year duration for Raipur qualified for zero rainfall. The minimum value of monthly mean rainfall for Raipur is observed as 24.83 mm which is very close to the maximum value of the monthly mean rainfall of Raipur. Twenty seven (27) cities out of thirty two (32) cities in India experienced at least one month duration of zero rainfall during the 20th century. Only five (5) cities namely: Aizawl in Mizoram; Idukki in Kerala; Jorhat in Assam; Raipur in Chhattisgarh and Srinagar in Jammu & Kashmir did not qualify for zero value of monthly mean rainfall. Shillong, Meghalaya, showed zero rainfall during the month of January, 1960, which experienced the highest value of monthly mean rainfall and normally remains wet during the whole year. The maximum of monthly mean rainfall for all the selected thirty two (32) cities in India during the 20th century are experienced during the monsoon season except Chennai and Puducherry. The maximum monthly mean rainfall for Chennai and Puducherry was observed in the month of November. The coefficient of variation for the annual average of the monthly mean rainfall is highest for Gandhinagar, Gujarat and lowest for Jorhat, Assam.

The rainfall trends show large variability for the thirty two (32) selected cities in India. The entire duration of one hundred years (1901- 2000) was analysed for the presence of trend at monthly scale. The magnitude of the change per annum was evaluated by using the non-parametric Sen's Slope estimator method and is shown in table 3. The significance of the trend was tested by using the Mann-Kendall method and the bold values indicate the statistical significance of 95% confidence interval at 0.05 significance level (α =0.05) . The evaluation of the one hundred years duration (1901-2000) in monthly scale for the selected thirty two (32) cities in India spread all over the country shows that the trend is positive for 200 months, negative for 130 months and zero for 54 months. The magnitude of Sen's slope estimator is statistically significant at 95% confidence interval of 0.05 level of significance for only twelve (12) months from a total of 384 months evaluated in this study. Six months out of the twelve months in a

Sl. no	Place	Max. (mm)	Month/Year	Min. (mm)	Month/year other than zero rainfall	No. of months with zero rainfalls	CV*
1	Agartala	1034.248	July of 1948	0	NA	17	0.16
2	Aizawl	1065.922	June 0f 1954	0.003	Jan of 1940 & 78	NA	0.14
3	Aurangabad	471.683	Sept of 1948	0	NA	121	0.22
4	Bangalore	360.945	Oct of 1943	0	NA	69	0.19
5	Bhiwani	356.271	Aug of 1908	0	NA	108	0.3
6	Bhopal	725.716	July of 1944	0	NA	131	0.22
7	Chandigarh	502.5	Aug of 1976	0	NA	50	0.24
8	Chennai	768.912	Nov of 1985	0	NA	95	0.23
9	Cuttack	506.192	July of 1956	0	NA	13	0.16
10	Dadra & NH**	1233.426	July of 1956	0	NA	412	0.23
11	Dehradun	602.829	Aug of 1956	0	NA	40	0.21
12	Delhi	511.537	Aug of 1908	0	NA	115	0.31
13	Gandhi Nagar	1133.676	July of 1955	0	NA	41	0.34
14	Gangtok	694.2	July of 1927	0	NA	476	0.13
15	Hyderabad	544.261	Aug of 2000	0	NA	159	0.22
16	Idukki	1009.215	June of 1957	0.157	Jan. of 1916,32,73,74,77,82,83	NA	0.15
17	Imphal East	997.439	June of 1954	0	NA	5	0.14
18	Jaipur	517.613	July of 1956	0	NA	118	0.31
19	Jalandhar	437.664	Aug of 1976	0	NA	47	0.29
20	Jammu	704.425	Aug of 1976	0	NA	13	0.29
21	Jorhat	677.056	June of 1910	0.19	Dec of 1906,17,27,42,68,70 &98	NA	0.12
22	Kohima	802.431	June of 1954	0	NA	4	0.13
23	Kolkota	892.145	Sept of 1978	0	NA	52	0.17
24	Lucknow	619.076	July of 1925	0	NA	61	0.23
25	Patna	534.685	July of 1943	0	NA	59	0.18
26	Puducherry	644.474	Nov of 1960	0	NA	32	0.22
27	Raipur	43.602	May of 1921	24.827	Dec of 1945	NA	0.15
28	Ranchi	639.029	July of 1990	0	NA	51	0.16
29	Shillong	2059.143	July of 1974	0	Jan of 1960	1	0.19
30	Shimla	587.354	July of 1936	0	NA	26	0.22
31	Srinagar	557.05	Aug of 1976	0.2	Nov. of 1901,06,08,10,15,17,20, 32 , 48, 55,69,70,73,76,87,88,93	NA	0.25
32	Tawang	935.487	June of 1962	0	NA	7	0.12

Cv* = Co-effecient of variation for the annual average of monthly mean Rainfall; NH** = Nagar Haveli

TABLE 2: Maximum & minimum of monthly mean rainfall during the 20th century for the 32 selected Cities in India

Sl.No	Place	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Agartala	0.003	-0.033	0.186	-0.166	-0.448	**-1.149**	0.821	0.060	0.355	-0.293	-0.053	0.000
2	Aizawl	-0.003	-0.074	**0.358**	-0.162	-0.424	**-1.340**	**0.945**	-0.080	0.116	-0.398	-0.066	0.000
3	Aurangabad	0.000	0.000	0.000	-0.005	0.034	-0.024	0.016	**0.431**	-0.328	0.206	0.000	0.000
4	Bangalore	-0.01	0	-0.012	0.015	0.061	0.177	-0.02	0.157	0.3	0.334	-0.119	0.024
5	Bhiwani	0.004	0.015	0.017	0	0.071	0.159	0.384	0.336	-0.059	0.011	0	0
6	Bhopal	0.012	0	0.004	0	0.016	0.079	-0.688	0.99	-0.728	0.037	0	0
7	Chandigarh	-0.029	0.06	0.077	0.004	0.07	0.08	0.477	0.261	0.13	0.015	0	-0.007
8	Chennai	**-0.118**	0.000	0.000	0.002	0.073	**0.211**	0.122	0.327	0.083	-0.295	0.143	0.201
9	Cuttack	0.002	-0.01	0.004	-0.018	-0.019	-0.15	0.521	0.11	-0.201	0.541	0.041	0
10	Dadra & NH**	0	0	0	0	0.005	0.415	0.073	0.647	0.14	0.035	0	0
11	Dehradun	-0.063	0.034	0.068	0.003	0.063	0.06	0.09	-0.053	-0.013	0.018	0	-0.009
12	Delhi	0	0.015	0.019	0.003	0.054	0.209	0.439	0.927	-0.004	0.012	0	0.003
13	Gandhi Nagar	0	0	0	0	0	-0.034	-0.286	0.336	-0.033	0	0	0
14	Gangtok	0.028	-0.027	-0.007	0.051	0.246	**-1.095**	-0.142	-0.225	0.486	**-0.385**	-0.001	0.000
15	Hyderabad	0	-0.004	0	0.011	0.014	0.15	0.081	0.877	-0.373	0.392	0	0
16	Idukki	-0.074	0.006	-0.103	0.04	0.081	-0.098	0.372	0.141	-0.218	-0.25	-0.183	-0.023
17	Imphal East	-0.008	-0.047	0.379	-0.287	-0.185	-1.413	0.628	-0.172	0.322	-0.407	-0.079	0.019
18	Jaipur	0	0.002	0.009	0.004	0.071	0.222	0.397	0.524	-0.046	0.019	0	0
19	Jalandhar	-0.015	0.072	0.08	0.004	0.06	0.062	0.608	0.39	0.192	0.018	0	-0.017
20	Jammu	0.017	0.227	0.23	0.036	0.109	0.082	0.719	0.439	0.085	0.042	0.01	-0.019
21	Jorhat	-0.02915	-0.011407	0.064911	-0.10478	0.044797	**-0.95677**	0.13817	-0.56836	0.198257	-0.21821	-0.056	0.0655
22	Kohima	-0.009	-0.004	0.256	-0.29	-0.108	-1.249	0.457	-0.293	0.333	-0.312	-0.039	0.043
23	Kolkota	0.007	-0.003	-0.047	0.017	-0.072	-0.105	0.43	0.086	0.656	0.486	0.014	0
24	Lucknow	0.07	-0.01	0.003	0.009	0.021	0.162	-0.469	-0.725	0.121	-0.004	0	0
25	Patna	0.106	-0.067	-0.019	0.002	0.044	-0.287	-0.616	-0.837	-0.03	0.037	0.001	0
26	Puducherry	-0.088	0	0	0.011	0.023	0.075	0.063	0.125	0.005	0.119	0.175	0.324
27	Raipur	0.015	-0.022	0.013	-0.006	0.03	-0.218	-0.296	-0.345	-0.481	0.067	0	0
28	Ranchi	0.079	-0.147	-0.032	0.005	0.064	-0.092	-0.053	-0.738	0.062	0.155	0.001	0
29	Shillong	0.019	-0.007	0.072	-0.208	0.077	**-2.211**	**1.711**	-0.699	0.268	-0.477	0.003	0.016
30	Shimla	-0.064	0.065	0.088	0.003	0.046	-0.013	0.001	-0.113	-0.076	0.023	0.000	-0.015
31	Srinagar	0.022	0.361	0.474	0.082	0.206	0.073	0.15	0.038	-0.088	0.041	0.034	-0.003
32	Tawang	0.007387	-0.024609	0.033014	-0.109849	-0.025691	-0.34058	0.66533	0.20882	0.307682	-0.03449	-0.034	-0.01479

TABLE 3: SEN 'S SLOPE ESTIMATOR FOR MONTHLY MEAN RAINFALL (in mm/year)

FIG 1:Temporal variation of monthly mean rainfall for the month of June (Shillong) during the 20th century (1901 - 2000) along with an eleven year moving average

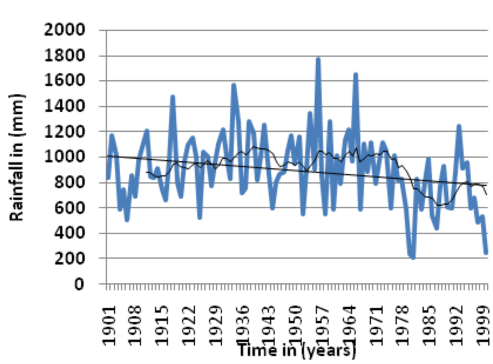
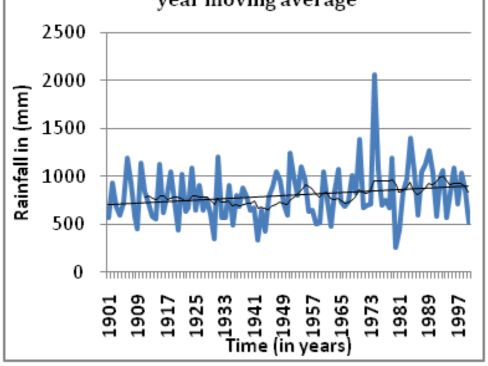


FIG 2: Temporal variation of monthly mean rainfall for the month of July(Shillong) during the 20th century (1901-2000) along with an eleven year moving average



year namely, February, April, May, September, November and December, did not show any statistically significant trend during the one hundred year duration (1901-2000) for all the selected thirty two (32) cities in India. Twenty five (25) cities from the total of thirty two (32) selected cities in India namely, Bangalore, Bhiwani, Bhopal, Chandigarh, Cuttack, Dadra & nagar haveli, Dehradun, Delhi, Gandhinagar, Hyderabad, Idukki, Imphal East, Jaipur, Jalandhar, Jammu, Kohima, Kolkata, Lucknow, Patna, Pondicherry, Raipur, Ranchi, Shimla, Srinagar and Tamang did not show any statistically significant trend during the one hundred year duration (1901-2000) in monthly scale. In other words, only 21.88 % of the total thirty two (32) selected cities (7 of total 32 cities) namely, Agartala, Aizawl, Aurangabad, Chennai, Gangtok, Jorhat and Shillong showed a statistically significant trend at 95% confidence interval of 0.05 significance level (α = 0.05) for the 100 year duration (1901-2000).

The statistical significant change in rainfall trend was more prominent during the monsoon season (for the month of June) as compared to the other seasons. The winter season namely, January and February, did not show any statistically significant trend for the selected thirty two (32) cities in India except a decreasing trend of 0.118mm/year for Chennai in the month of January. Similarly, the pre monsoon season (March – May) also did not show any statistically significant trend except an increasing trend of 0.358mm/year for Aizawl in the month of March. The monsoon season (June –September) of the year experienced the maximum number of change in rainfall trend during the one hundred year duration (1901-2000) for the thirty two (32) selected cities. Agartala experienced a decrease of 1.149mm/year for the month of June while Aizawl again experienced a decrease of 1.340mm/year during the month of June, an increase of 0.945mm/year during the month of July along with the increase in March that was discussed earlier. Chennai also showed an increasing trend of 0.211 mm/year for the month of June, apart from the decrease in trend shown in January. Jorhat also showed a decreasing trend of 0.9568 mm/year during the month of June. Shillong showed a decreasing trend of 2.211mm/year in the month of June but observed an increasing trend of 1.711mm/year in the month of July. Gangtok showed a decreasing trend of 1.095mm/year in the month of June along with a decrease of 0.385 mm/year in the month of October which is the only statistical significant trend shown during the post monsoon season (October – December). The temporal variation of the monthly mean rainfall for the month of June and July at Shillong is plotted in Fig 1 & 2 respectively. The Shillong station is selected because Shillong experienced the highest magnitude of increasing (July) and decreasing (June) trend among the thirty two (32) selected cities.

Conclusion

The study on the temporal variation of the rainfall time series is an important requirement for analyzing the climate change of a place. The statistical analysis along with the parametric and non-parametric statistical methods has been used to study the rainfall variability and trend. The rainfall trend of one hundred (100) years for the thirty two (32) cities shows a variation in the monthly mean. The maximum decreasing trend was found to be 2.211 mm/year for Shillong during the month of June while the maximum increasing trend was also found to be 1.711mm/year for Shillong during the month of July. Aizawl experienced a statistically significant increasing trend in the month of March and July and a statistically decreasing trend in the month of June. Agartala showed a statistically significant decreasing trend during the month of June. Aurangabad experienced a statistically significant increasing trend during the month of August. Chennai was observed to have a statistically significant increasing trend during the month of June and a statistically significant decreasing trend during the month of January. Gangtok experienced a statistically significant decreasing trend during the month of June and October. Jorhat experienced a statistically significant decreasing trend during the month of June. In short, seven cities namely; Aizawl, Agartala, Aurangabad, Chennai, Gangtok, Jorhat and Shillong experienced a statistically significant rainfall trend for a confidence interval of 95% at a significance level of 0.05 during the 20th century from the thirty two (32) selected cities. Further research is required to understand the rainfall trend and variability in smaller spatial scale which will be useful for planning and managing a specific place or area for developmental activities in the long run by taking into consideration the impact of climate change.

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