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Analysis of Temporal Trends of Rainfall Time Series (1901-2002) of Purulia Weather Observatory by Sequential Mann-Kendall Test, West Bengal, India.

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Abstract- Rainfall is the prime input in life. It is also an important Climatological component in our daily life. Different parts of the world experience with different climatological effect as well as different amount of rainfall throughout the year. The variation of the rainfall are also the important factors which lead the life system. This paper deals with the variability and trend analysis of the rainfall data set for Purulia weather observatory for the period from 1901 to 2002 (101 years). Sequential version of Mann-Kendal test statistic has been applied for the analysis of long term rainfall series. The chosen level of confidence is considered at 95% level of confidence followed by the Gaussian distribution. If reduce variable satisfy or be greater than the level of confidence then the null hypothesis would be rejected. Every rainfall series has been processed as their average monthly manner before they are employed for Sequential version of Mann-Kendall test. The monsoonal months of this area are more important because potential rainfall are being observed in this period. Though, some additional amount of rainfall has been received on the other seasons also. After the calculation through Sequential version of Mann-Kendall test statistic has been revealed that, monsoonal rainfall trend indicates decreasing trend just after 1945. Every series of data set detects several change points at different year. But the monsoonal months indicate at least three temporal spans over the considered time series and these are from 1908 to 1920, 1932 to 1958 and 1970 to 1980 respectively. The estimated change points are not statistically significant at considered level of significance but they are very important for the phase detection and variability identification.
Keywords –Rainfall analysis, Trend detection, Sequential version of Mann-Kendall Test.

I. INTRODUCTION

Rainfall trend analysis on different temporal scale has been a great challenge for the scientific community. In different angles, this community always tried to analyze the climatic behave as well as rainfall trend. All the scientific efforts focus on climate change, because all living and exogenetic forces have been controlled by the climatic effects over the world. Different climate investigation institution indicates a small positive global trend, even though large areas are instead characterized by negative trends [1]. Many research efforts reveal that the distribution of the global rainfall has some variability and it was established that, the nature of the change are significant in different parts of the world. The variability, extreme condition, flood, and drought etc are highly active over the tropical and subtropical area. Some European countries has also suffered by the rainfall variability over last century. With regard to the European context, negative trend areas are more pronounced in the central and southern regions, corresponding to the Mediterranean basins, whose most relevant characteristic is extreme rainfall variability, both in space and time [2-6]. Many of this variability over the European countries are significant and stressed by the combination of dry climate and an excessive water demand. India is the monsoon rain feed area which has common rainy season and all the water related activities starts their performance from this season. Agriculture, Industry, domestic consumption etc. gets their active phase from the rainy season. The yield of crops particularly in rain-fed areas of South Bengal depends on the rainfall pattern. Frequency or probability distribution of rainfall data from past series helps to relate the magnitude of the extreme events like floods, droughts and severe storms with their number of occurrences such that their chance of occurrence with time can be predicted easily. Most of the rainfall variability occurs in central India and over most dry region of the entire country. For that, the agricultural pattern are quite changeable than the other region of the Indian continent [7]. So trend analysis of the rainfall may carried out by the rainfall pattern over South Bengal area, which will help agricultural practice as well as any other hydrological planning.

II. STUDY AREA

This paper identifies and analyze the homogeneity in trend and recognizes change points in the monthly average rainfall data series over 101 years. For this analysis Purulia weather observatory has been selected, which has mostly plateau surroundings. Hot humid summer is the common dry season around this weather observatory. On-set of monsoonal rainfall always delay over this region. According to the past climatological records, station Purulia receives less amount of rainfall in many years. So that, the cultivation pattern and amount are not satisfactorily in respect of demand.

Materials and Method- This analysis is based on rainfall series collected from India meteorological Department (IMD) Kolkata (Alipur) recorded at Purulia weather observatory for the period from 1901 to 2002. Mean monthly rainfall of each of the months over 101 years has been considered for this analysis. The considered data set is continuous and consecutive in manner. Finally the mean monthly rainfall data set were employed for the statistical analysis. Apropos to identify the discontinuities and detection of change point hereby, sequential version of Mann-Kendall (Seq. MK Test) test statistic is applied. It is the accepted and robust statistical method that has been suggested by many researchers.

Sequential Mann-Kendall Test Statistic-The sequential version of Mann-Kendall test statistic [8] on rainfall time series x detects recognized event or change points in long time rainfall data series. The Sequential Mann-Kendall test is computed using ranked values, y_i of the original values in analysis $x_j, x_j, x_j \ldots x_n$. The magnitudes of y_i (i=2.......... n) are compared with y_j (j=1..... i -1). For each comparison, the cases where $y_i > y_j$ are counted and denoted by n_i . A statistic t_i can therefore be defined as [9]:

$$t_i = \sum_1^i n_i \tag{1}$$

The distribution of test statistic ti has a mean as

E(ti) =i(i-1)/4 (2)

And variance as var (ti)=i(i-1)(2i+5)/72 (3)

The Sequential values of a reduced or standardized variable, called statistic u (ti) is calculated for each of the test statistic variable ti as follows:

$$u(t_i) = \frac{t_i - E(t_i)}{\sqrt{var(t_i)}} \tag{4}$$

While the forward sequential statistic, u(ti) is estimated using the original time series (xi,x2,…..xn) values of backward sequential statistic, u'(ti) are estimated in the same manner but starting from end of the series. In estimating u'(ti) the time series is resorted so that last value of the original time series comes first (xn,xn-1,……., 1)

The sequential version of Mann-Kendall test allows identifying of recognizing event or change point beginning of a developing trend. When u(ti) and u'(ti) curves are plotted. The intersection of the curves u(ti) and u'(ti) locates in recognized event or change point. If in intersection of u(ti) and u'(ti) occur within 1.96 (5% level) of the standardized statistic, a detectable change at that point in the time series can be inferred. Moreover, if at least one value of the reduced variable in greater than a chosen level of significance of Gaussian distribution the null hypothesis (Ho: Sample under investigation shows in beginning of a new trend) is rejected.

III. RESULT AND DISCUSSION

The results after sequential Mann-Kendall test statistic are given in Table-1. The plots of monthly average rainfall associated to u(ti) and u'(ti) are shown in figure-1 month wise. The progressive u(ti) and retrograde u'(ti) both curves intersect four times on January rainfall series. The intersected years are 1913, 1926, 1952 and 1954 respectively. The calculated values statistic of these change points are not statistically significant. The progressive test statistic values for the January detects increasing trend after each intersect points. Moreover, the increasing trend of rainfall indicates at the beginning of the considered time series. All these intersected points cannot be recognized as a significant change point due to a probability value much higher than the accepted level of significance (5 % level of confidence). Rainfall in winter is the rear event over this region, but sometimes cyclone associated rainfall has been occurring in this region. In respect of the 101 years rainfall data, some amount of rainfall is very common for this region. Moreover, 101 years data series indicates after 1950, the amount of rainfall was quite more than the prior period. Rainfall trend for the three consecutive months like February, March, and April indicates negative nature. The below listed figure indicates that, the amount of rainfall dramatically changes its nature and indicating negative trend just after 1951. All these three months rainfall series indicates several change points but their calculated values are not satisfying for the chosen level of significance. Normal change points have been detected for the month of February at1908, 1945 and at 1950. March indicates several seven change points such as at 1904,

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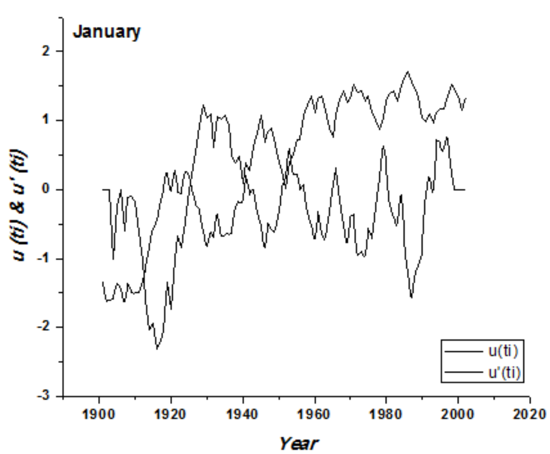
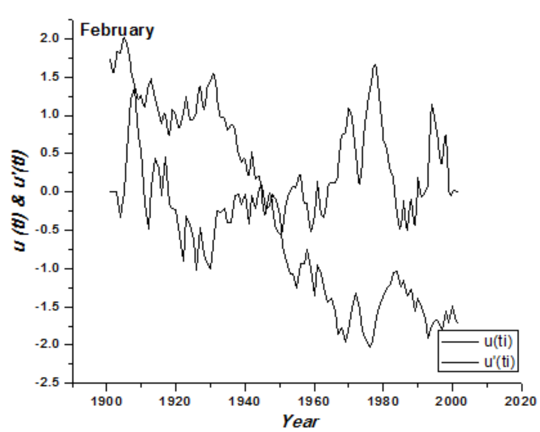
1908, 1917, 1921, 1951, 1984 and 1999. Generally monsoon comes after hot humid summer for this region. April, may, June and upto 15th of July commonly experienced hot humid summer. Each and every low pressure event drags huge water vapour from the Bay of Bengal coast and helps to develop few days' rain over this area. These types of atmospheric events initially regulate the lower atmospheric temperature become cool and finally on-set of monsoon starts after 15th July as usual. This phenomenon lasts maximum two and half months from the on-set of monsoon. So, July, August and September are the potential period for regular rainfall. After employed this method Sequential version of Mann-Kendall test statistic it has been revealed that, July, August and September have the same number of change points but there intersecting years are different. A minute observation of this analysis indicates three temporal spans for those months are there where u(ti) and u'(ti) (progressive and retrograde series) intersect each other. These noticeable temporal change points lies in between from 1908 to 1920, 1932 to 1958 and 1970 to 1980 respectively. It is also revealed that, the rainfall trend for these conjugate months are decreasing. All these time series data set starts their descend down trend just after 1948. The retrograde slope indicates positive trend for the month of July and the value statistic continuously increased since 1952. On the other hand, the trend slope for the month of August indicates decreasing trend since 1920. Moreover it was established that, the amount of rainfall decreased consistently through last 101 years. Winter months of this region receives little amount of rainfall and they also indicates decreasing trend.

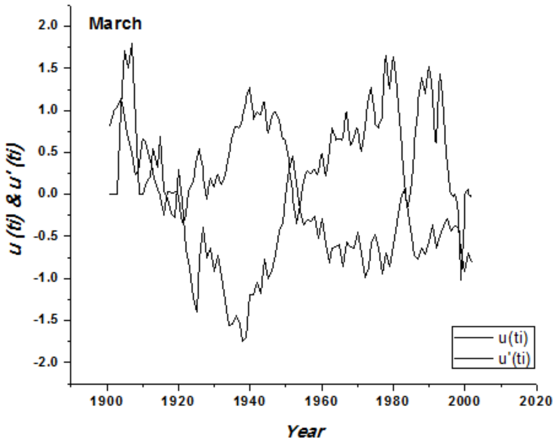
Table: 1. Statistically significant recognized change points by Sequential Mann-Kendall Test of Purulia Observatory (Values significant at $p<0.05$ *).

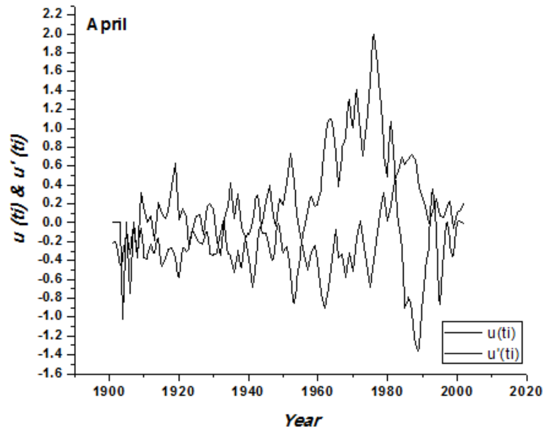
SL .No.	Months.	Detected Change Points (Year)									Re..
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	
1	January	1913	1926	1952	1954	-	-	-	-	-	
2	February	1908	1945	1950	-	-	-	-	-	-	
3	March	1904	1908	1917	1921	1951	1984	1999	-	-	
4	April	1903	1906	1908	1923	1933	1944	1955	1983	1994	
5	May	1908	1912	1924	1926	1961	1964	1966	1984	1995	
6	June	1910	1915	1926	1927	1929	1955	1958	1997	-	
7	July	1904	1910	1926	1952	1996	-	-	-	-	
8	August	1918	1932	1958	1972	1976					
9	September	1903	1908	1911	1948	1952	-	-	-	-	
10	October	1928	-	-	-	-	-	-	-	-	
11	November	1905	1907	1910	1961	1972	1987	1997	-	-	
12	December	1903	1911	1913	1931	1942	1990	1996	2000	-	

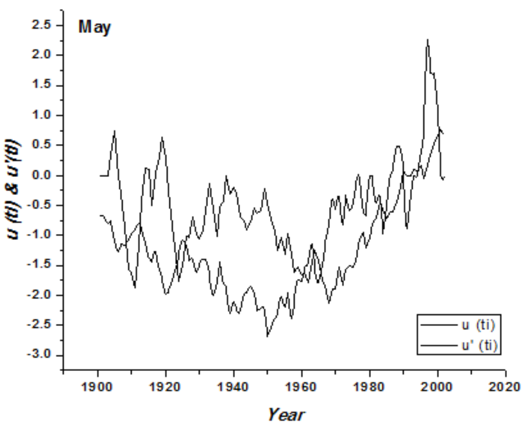
Figure 1: Abrupt changes in Average monthly temperature as derived from Sequential Mann Kendall test rank statistic, u (ti) forward sequential statistic and u'(ti) backward sequential statistic.

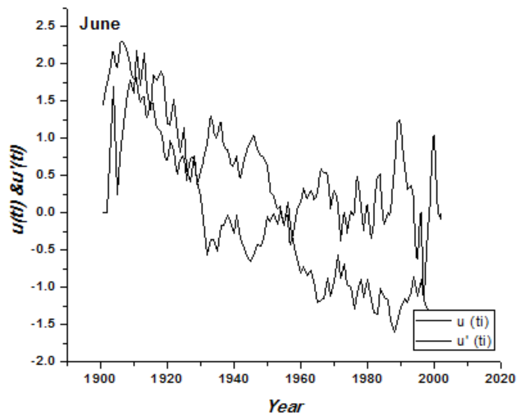


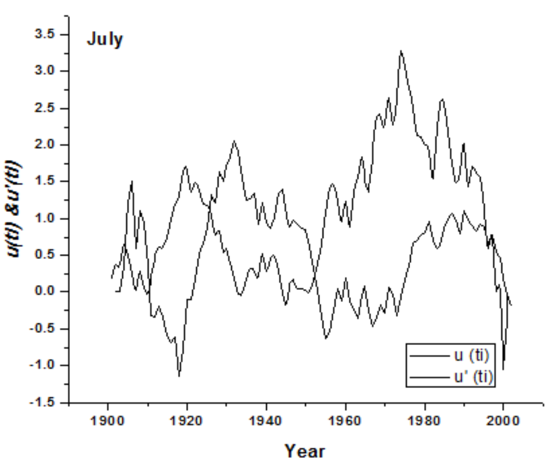


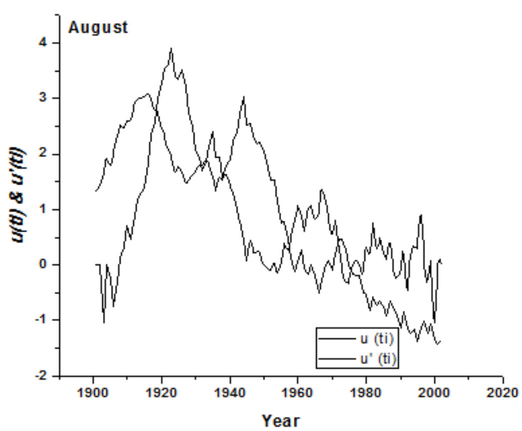

March
u (ti) & u' (ti)
Year
u(ti)
u'(ti)


April
u (ti) & u' (ti)
Year
u(ti)
u'(ti)


May
u (ti) & u'(ti)
Year
u (ti)
u' (ti)


June
u(ti) &u'(ti)
Year
u (ti)
u' (ti)


July
u(ti) &u'(ti)
Year
u (ti)
u' (ti)


August
u(ti) & u'(ti)
Year
u (ti)
u' (ti)

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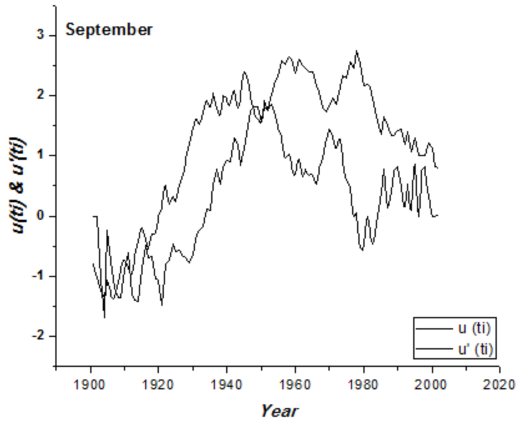

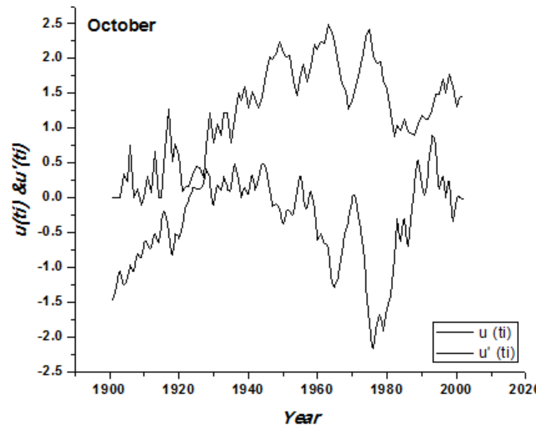

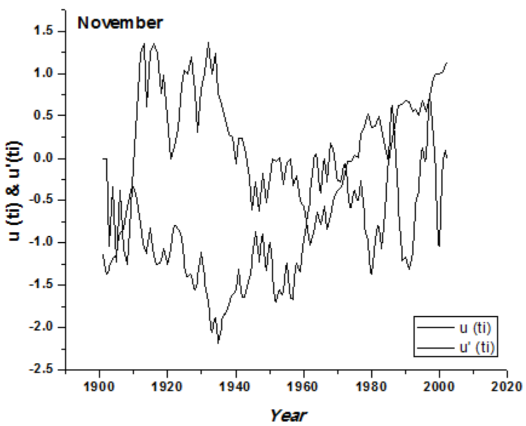

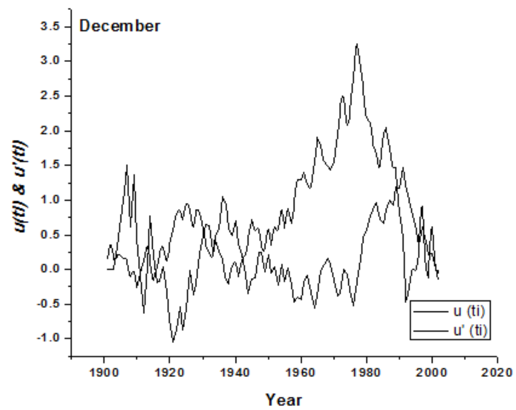

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