# Determination of Undocumented Change Point in Monthly Average Temperature Time Series (1941-2010) for Krishnanagar Weather Observation Station, West Bengal, India.

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**Abstract**

Analysis of lower atmospheric temperature variable can provide information on how the climate has evolved over the time scale. This can be accomplished through time series analysis. Trend and change point analysis in climatic variables is challenging due to their non-stationary nature. The principal objective of this study is to detect abrupt change and analyse trends in mean monthly surface air temperature time series obtained from krishnanagar weather observation station, West Bengal, India. The considered variables of temperature time series include mean maximum and mean minimum monthly temperature from 1941 to 2010. To accomplish this, we utilized the Sequential version of Mann-Kendall (Sq.M-K) trend test. The time series which was used was decomposed via average calculating of monthly mean temperature in order to separate their high-frequency and low-frequency components, prior to testing their statistical significance with the Sequential version of Mann-Kendall rank test. The reduced value of the $u\,(t_i\,)$ for forward and $u'(t_i\,)$ for backward statistic have been considered significant change points, above the considered probability (p=<0.05) value. Among all findings the more important and the statistically significant undocumented change points are present in 1981, 1983, 1987, 1968, 1970 and 1981 in the temperature time series for the month of July, October and November respectively. The mean monthly increasing trends in temperature may be attribute mostly by monsoon and post-monsoon warming.



**Keywords:** Sequential Mann-Kendall Test Statistic; Temperature Trend; Turning points

## Introduction

The average mean temperature of Global climate has changed day by day. Over the last hundred years, the Global Climate has changed significantly. The most recent assessment conducted by the Intergovernmental Panel on Climate Change (IPCC) reported an increase in the mean surface temperature of between 0.56° C and 0.92° C from 1906 to 2005 [1]. This increase is larger than the previous IPCC report, which mentioned that the global mean surface temperature has increased by approximately 0.3 ° C to 0.6 ° C from 1901-2000 [2]. Moreover, the regional climatic characters are most important factors which wholly operates the change of global climatic phenomenon. In this paper, we have selected one weather observational station, namely, Krishnanagar, West Bengal, India, and analysed its 70 years continuous temperature time series data-set to detect the undocumented change points, if any.

It is established that, the Change points are the times of discontinuities in a time series that can be induced from changes in observations, equipment, measurement techniques, environmental changes and so on [3]. Inferences drawn from climatic series frequently depends on "continuity of the measurement process," these are the lack of change points [4-8] establish that linear trends estimates are trustworthy only when the series are homogeneous in time. According to the systematic change of measuremental parameters and dynamic change of climatic condition, it is difficult to ensure that the climatic records are free from the change points. Moreover, many change points occur without documentation. So, these are the silent shaded factors of any temperature time series data-set. The World Meteorological Organization (WMO) Climate programme guidelines on climate metadata and homogenization (Lianso, 2003) list so many scientific homogenization assessment techniques, and many more method has been suggested. So many literatures have been produced in recent past, where, they mentioned, analysis of change points are the key factor to estimate the proper trend structure of any long-term temperature time series data-set. However, the detection of undocumented change points may refer the meaningful suggestions for climatic trend in future. More recent review attempts have been made by Peterson et al. [9], Ducré-Robitaille et al. [10], Rodionov [11], and DeGaetano [12]. The temperature regime features a high seasonal and annual variability in both temporal and spatial domains in tropical region providing the incentives for debating on temperature variability and by extension on climate change.



**Study Area**

Krishnanagar is located at 23.4°N 88.5°E. It has an average elevation of 14 metres (45 feet). Krishnagar is beside the Jalangi River. It is the municipal area and administrative headquarter of Nadia district in the Indian state of West Bengal. In response to the economic activities of this area, Krishnanagar is an agriculture depending zone except its municipal area. After the Koppen classification of Climate (1984), the area belongs to Tropical Savanna Climate (denoted as 'Aw') sub type. Mean annual temperature of Krishnanagar is slightly above 30 ° C. But in summer season the average temperature occasionally goes often beyond 35 ° C. The average temperature in winter has increased in recent past decade and the spell has become short as recorded by IMD (Alipur, Kolkata). The annual average rainfall has been recorded about 1500 mm. In order to the Monsoon climate distribution over Indian continent, June to July is the rainiest season, September to November is the Post Monsoon period, December to middle of February is the winter season and March to May is the hot humid summer season. From the recent past record obtained by IMD (Alipur,Kolkata), lower atmospheric temperature of Bethuadahari, Chapra, Bagula etc. are sensitive, where summer and winter temperature indicating more deviation value from the annual average temperature. These observations help to increase the research interest in temperature time series analysis of Krishnanagar weather observation station.

**Materials and method**

This analysis was based on atmospheric temperature data collected from Indian Meteorological Department (IMD) Kolkata (Alipur), recorded at Krishnanagar weather observation station for the period from 1941 to 2010. Mean monthly maximum and mean monthly minimum temperature for each of the months over the 70 years has been considered. Month-wise mean maximum and mean minimum temperatures have been averaged to get mean monthly temperature. Finally, the mean monthly average data-set were employed for statistical analysis. Sequential version of Mann-Kendall (Seq.M-K) test statistic is applied in order to identify the discontinuities and detection of thereby change points.

The sequential version of Mann-Kendall test [13] on time series $x$ detects approximate potential trend turning points in long time data series. The Sequential Mann-Kendall test is computed using ranked values, $y_i$ of the original values in analysis $x_j$, $x_j$, $x_j$ ......$x_n$. 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 [13]:

$$t_i = \sum_{1}^{i} n_i \qquad (1)$$

$$E(t_i) = \frac{i(i-1)}{4} \qquad (2)$$

$$var\ (t_i) = \frac{i(i-1)(2i+5)}{72} \qquad (3)$$

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

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



While $u\ (t_i)$ is estimated using the original time series $( x_{1,}\ x_2,\ldots x_n)$, the values of $u^{'}(t_i\ )$ are estimated in the same manner but starting from end of the series. In estimating $u^{'}(t_i\ )$ the time series is resorted so that last value of the original time series comes first $(x_{n,}\ x_{n-1,}\ldots,1)$.

The sequential version of Mann-Kendall test allows detecting of approximate beginning of a developing trend. When $u\ (t_i\ )$ and $u^{'}(t_i\ )$ curves are plotted. The intersection of the curves$u\ (t_i\ )$ and $u^{'}(t_i\ )$ locates in approximate potential trend turning point. If in intersection of $u\ (t_i\ )$ and $u^{'}(t_i\ )$ occur within $\pm$ 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.

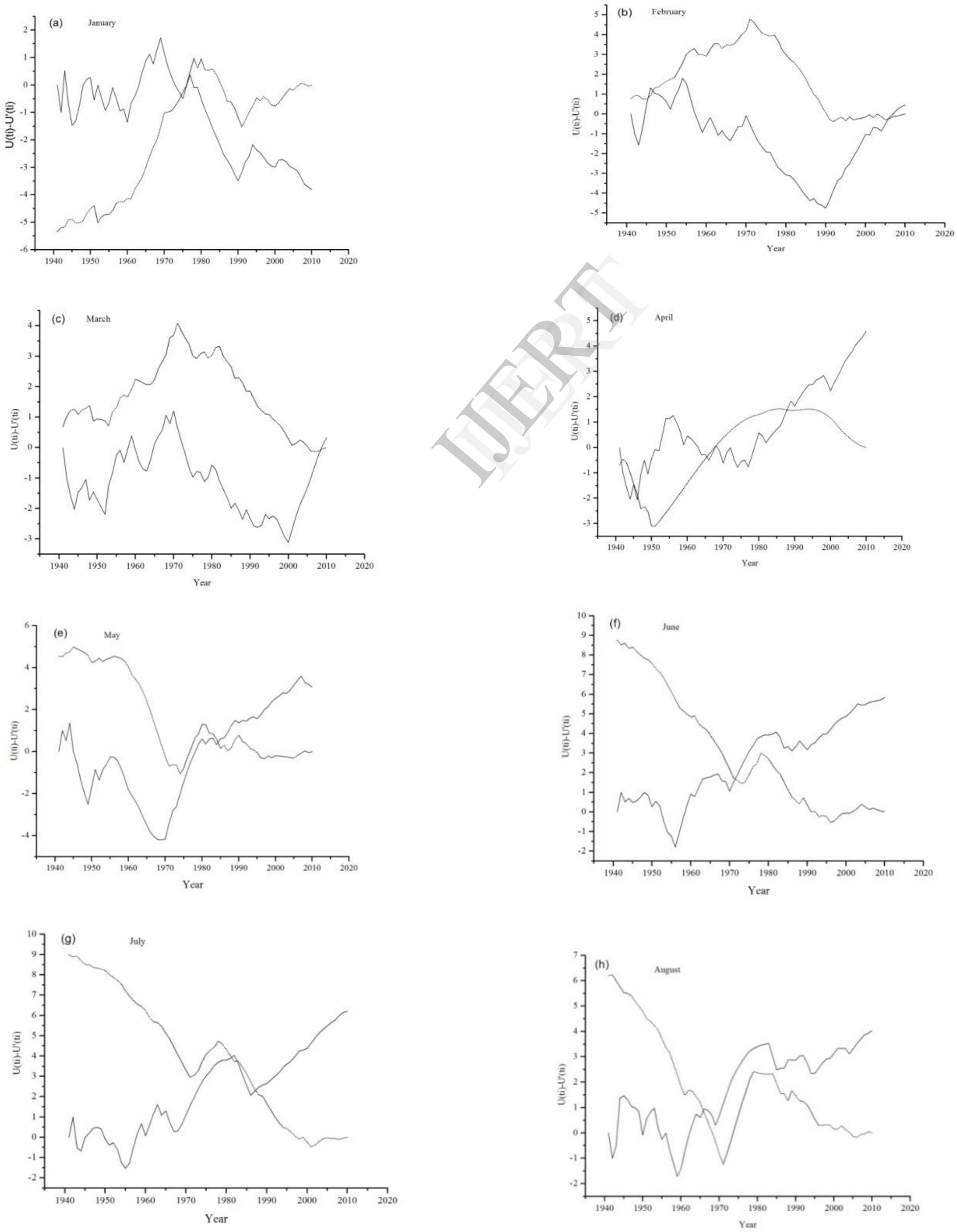
**Results and Discussion:**

The results of sequential version of Mann-Kendall test statistic for monthly average temperature data-set of Krishnanagar station have indicated some clear statistically significant undocumented change points in several month. The month-wise plots of $u\ (t_i\ )$

and $u'(t_i)$ values have been shown in Fig: 1, and the statistically significant and insignificant change points are also being shown in Table:1. For the month of January, (Fig: 1a) increasing trend from 1941 to 1978 is observed where the change point also detected in 1975. The forward $u(t_i)$ and backward $u'(t_i)$ sequential curves have been intersect in 1975, though this detected year of change is not statistically significant in respect of chosen level of significance (p=<0.05). After indicating the change point, the plots of $u(t_i)$ and $u'(t_i)$ have been made a divergent trend till 1991. After that, both the curves show significant decreasing trend till 2010. For the month of February, $u(t_i)$ plots (Fig:1b) show an increasing trend till 1941. The plots of $u'(t_i)$ values have indicated decreasing trend during 1952 to 1990 then the curve gradually rises upward to indicate an increasing trend till 2010. The forward and backward curves have indicated three undocumented change points over the considered period, which are in 1946, 1947 and 2006 respectively. Though these detected change points are not statistically significant. Sequential version of Mann-Kendall test statistic plots for March temperature has been given in (Fig: 1c). It shows that, $u(t_i)$ and $u'(t_i)$ curves have been through almost parallel way till 2000. After that the $u'(t_i)$ curve suddenly rises and intersect each other in 2008. Though at chosen level of significance, this detecting change point is not statistically significant. The plots of $u(t_i)$ and $u'(t_i)$ for the month of April has been shown in Fig: 1d. From the beginning to the end of the considering period, this month has indicated maximum change points, such as 1942,1946, 1966, 1968 and 1988 respectively. The increasing trends of $u'(t_i)$ plots have been indicating since 1951 to 1997. After that the temperature trend is in decreasing manner. All the detecting change points are less significant for this month. On the contrary, May and June temperature time series had an increasing trend after the abrupt change (Fig: 1e &1f). This two months also indicate single year of abrupt change in 1994 and 1971 respectively. Most significant undocumented change points in month wise temperature time series over the period from 1941 to 2010 for Krishnanagar station have been found for the month of July ( Fig: 1g). $u(t_i)$ plots for this month exhibit increasing trend in its average temperature. The plots of $u(t_i)$ and $u'(t_i)$ lines intersect each other in 1981, 1983 and 1987 respectively. All these detected change points are highly statistically significant at chosen level of significance (p=<0.05). Where, they have taken the value like 4.02, 3.75 and 2.37 respectively. On the other hand, the post monsoon months like October and November have been indicated statistically significant change points from their considered period. For the month of October, the significant change points are in 1968 and 1970 respectively (Fig: 1j).

In respect of the month of November (Fig: 1k), the total change points are in 1955, 1980, 1981 and 2002 respectively. Among them 1981 is the statistically significant change point over the considered data-set. The plots of $u\ (t_i\ )$ and $u^{'}(t_i\ )$ curves goes through spiral way and indicate a statistically significant change point in 1981.

**Figure 1: Abrupt change in Average monthly temperature as derived from Sequential version of Mann-Kendal test statistic, $u(t_i)$ forward sequential statistic and $u'(t_i)$ backward sequential statistic.**



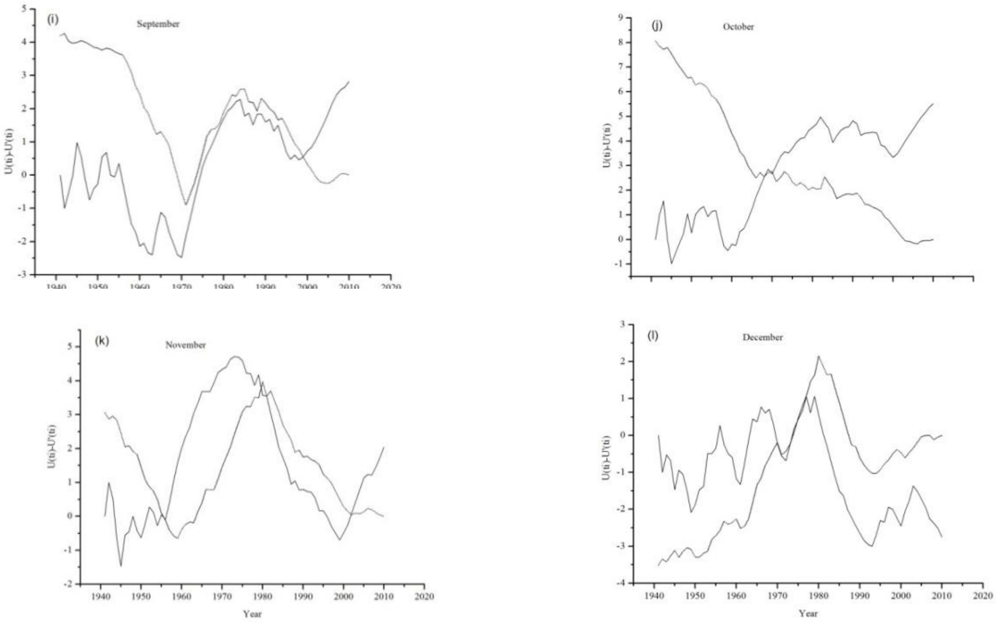



**Table: 1 Change points Detection by Sequential Mann-Kendall Test for Krishnanagar Observatory (values significant at p=<0.05*)**

| Months | Detected Change Points | | | | | Remarks |
|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | |
| January | 1975 | | | | | |
| February | 1946 | 1947 | 2006 | | | |
| March | 2008 | | | | | |
| April | 1942 | 1946 | 1966 | 1968 | 1988 | |
| May | 1994 | | | | | |
| June | 1971 | | | | | |
| July | 1981* | 1983* | 1987* | | | Significant |
| August | 1966 | | | | | |
| September | 1999 | | | | | |
| October | 1968* | 1970* | | | | Significant |
| November | 1955 | 1980 | 1981* | 2002 | | Significant |
| December | 1970 | 1975 | 1977 | | | |



## Conclusion

This paper has revealed results from the comparison of the mean monthly average temperature time series and their change points detected by the Sequential version of Mann-Kendall test statistic. The association of the results are very significant in respect of tabulated critical values. Sequential version of Mann-Kendall test analysis was consequently performed to identify the different change points as well as significant change points for different months of temperature time series data set. Sequential Mann-Kendall Test has proven to be an effective tool for gaining general possible outcome in to the undocumented change point detection in time series data set but in different months, it may indicate approximate potential changing year in the considered temperature time series. Furthermore, this analysis is indicating that the mean monthly temperature on monsoon and post monsoon season are going beyond the average level of temperature trend and the winter season has become short sequentially from recent past decade.

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