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Detection of recognizing events in lower atmospheric temperature time series (1941-2010) of Midnapore Weather Observatory, West Bengal, India

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Abstract

In this study, trends of mean monthly surface temperature time series of each month were examined for Midnapore station, West Bengal, India for the period 1941-2010. The data-set has the observations of two variables: the mean monthly maximum and mean monthly minimum temperature. Major changes in the mean monthly temperature trends over the period considered, have been detected using the Sequential version of Mann-Kendall rank statistic. The plots of the values of sequential statistic $u(t_i)$ and backward sequential statistic $u'(t_i)$ intersect each other at points each of which indicates a change in the trend of considered data-set. The analyses of the mean monthly temperature signify warming of the winter temperature. Statistically significant ($p \leq 0.05$) abrupt changes has been detected in 1985, 1992 and 1995 in the temperature time series for February, October and November, respectively.

Keywords: sequential Mann-Kendall test statistic, change point detection, climate change.

1. Introduction

Significant rises in average surface temperature is a great threat for the Earth today, because the atmospheric temperature is the key factor to affect the other climatic parameters in local or regional scale. What kinds of climatic change are taking place or what are the different dimensions of the issue are the main questions in front of climate researchers. In the paper, we have considered lower tropospheric temperature as the selected parameter. Trend in temperature time series can be estimated by different statistical methods, each of such techniques has its advantages of disadvantages. The problem of detecting recognizeable event or an abrupt change in the temperature time series dataset over any period is widely known as the Change Point Detection in the field of statistics. Literatures suggest that use of this statistic is the most appropriate for detecting climatic change points as compared with other statistical tests in use. So, applying this test technique it has been tried to identify recognizing events or change points, which has estimated convincing qualitative change in the dynamic character of lower atmospheric temperature. Many researches are carried out to understand the climatic change or abnormality of temperature in different parts of the world. There are several recent studies on climatologic temperature time series trends and detection of change points, which conclude about temperature related complex functions of the climatic environment (Karpouzos et al.; 2010). In the past few years there has been increasing interest in using data mining techniques to extract interesting patterns from temporal sequences (Mannila et al.; 1997 and Padmanabham et al.; 1996). Over the past 40 years, many researchers have analyzed the temperature time series from various climate change perspectives spanning in wide range of temporal and spatial scales (Canyon and Douglas, 1984; Duchon, 1986; Karl et al.; 1988; Kadioglu, 1997; Jauregui, 1997; Tayanc and Toros, 1997; Bohm, 1998; Philandras et al.; 1999; Bohm et al.; 2001; Mihalakakou et al.; 2004). It is established that, the urban effect, anthropogenic causal connections are creating crucial effect on the atmosphere in short period of time. Indeed, atmospheric temperature becomes tranquil each after time scale. According to the Intergovernmental Panel on Climate Change (IPCC), the global mean surface-air temperature has increased by about 0.74˚C over the past century (1906 to 2005), with pronounced warming during the last 25 years. The air temperature time series for the Northern Hemisphere seems to have the same rate of change (Jones et al.; 2001). Observations made by the Indian Meteorological Department (IMD, Alipur), suggests that in the south eastern coastal part of the West Bengal, variations of the temperature for the last few decade appear to be similar to the variations of temperature that have been recorded globally.

2. Study area

This paper identifies and analysis the homogeneity in trend and recognizes change points in the monthly average temperature data set over 70 years. For this analysis, Midnapore weather observation Station has been selected, which has mostly a rural surroundings, but Midnapore is the district town located at the bank of river Kasai. Geographical location of this station is 22˚25'16.3" N and 87˚19'19.4" E and 90.8 km (56.4 miles) inland from

Digha coast. Being located in the coastal area of the state of West Bengal, the station experiences an equable climate throughout the years. The maximum average temperature in summer season is about 32-34°C recorded during July and average minimum temperature goes down even up to 15°C recorded in December. The summer season welcomes south-western return trade wind (SW Monsoon) with huge water vapour during May and June, which often creates local depression and small scale cyclonic effect, popularly known as "Kalbaishakhi". Considering the ancient literature of Hindu mythology and Bengali calendar, this area experiences six seasons in a year. Accordingly the prevailing temperature is transgressed in more sensitive patches over a year. Generally, dry winter season comes after hot humid summer at least 180 - 200 days apart. However, the fluctuations of monthly average temperature are more conspicuous in this region. Observations made by the Indian Meteorological Department have indicated that during last few decades, the coastal parts of the Midnapore and its adjacent area has experienced more frequent cyclonic effects in pre-monsoon and monsoon seasons. Moreover, the uncertainty of rainfall has increased over this area day by day. All these phenomena may be due to changes in long-term temperature trend. So, the present study is aimed at the examination long-term change of the atmospheric temperature in Midnapore weather station that involves temperature trend analysis and change point detection.

3. Materials and Method

This analysis is based on atmospheric temperature data collected from Indian Meteorological Department (IMD), Kolkata (Alipur) recorded at Midnapore 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 are averaged to get mean monthly temperature year-wise. The considered data set are continuous without any gap. Finally, the monthly average data-set has been employed for statistical analysis. In order to identify discontinuities and detection of change point thereby, sequential version of Mann-Kendall (Seq.MK) test statistic is applied. It is a well accepted and valid method suggested by many investigators.

3.1 Sequential Mann-Kendall Test Statistic

The Sequential version of Mann-Kendall test statistic (Sneyres et al.; 1990) on time series x_i detects recognized event or change points in long- term time series. The Sequential Mann-Kendall test is computed using ranked values, y_i of the original values in analysis ($x_1, x_2, x_3, \ldots, x_n$), The magnitudes of y_i $(i = 1, 2, 3, ..., n)$ are compared with y_j, $(j = 1, 2, 3, ..., i-1)$. 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 (Mohsin et al.; 2009):

$$t_i = \sum_{j=1}^{i} n_i \tag{1}$$

The distribution of test statistic t_i has a mean as

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

and variance as

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

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:

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

While the forward sequential statistic $u(t_i)$ is estimated using the original time series ($x_1, x_2, x_3, \ldots, x_n$),values of the backward sequential statistic, $u'(t_i)$ 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 ($x_1, x_2, x_3, \ldots, x_n$).

The sequential version of Mann-Kendall test statistic allows detection 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 approximate potential trend turning point. If intersection of $u(t_i)$ and $u'(t_i)$ occur beyond ±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 is greater than a chosen level of significance of Gaussian distribution the null hypothesis (H_0: Sample under investigation shows no beginning of a new trend) is rejected

4. Results and Discussion

Sequential version of Mann-Kendall test statistic calculated from monthly average temperature data set of Midnapore station clearly detects the statistically significant change points in yearly trend of monthly temperature. Plots of $u(t_i)$ and $u'(t_i)$ values for each of the months of a year have been shown in Fig. 1. In case of the month of January, an apparently decreasing trend is observed from 1950 to 1981 and after that the $u(t_i)$ curve further rises up to 2010. Though the curves intersect each other three times in 1944, 2004 and 2007, but they cannot be recognized as the significant change points as the associated probability values are much higher than the accepted level of significance ($p \leq 0.05$) (Table-1). The curve $u(t_i)$ and $u'(t_i)$ have maintained almost similar distance between each other on and from 1955 to 1987. For the month of February, $u(t_i)$ plot (Fig-1b) shows an increasing trend during 1964-1971 and 1992-2009 and the decreasing trends for 1951-1964 and 1972-1991. Overall trend of temperature for this month have also indicated gradually decreasing trend form start to end of the considered period. Several change points have been identified for this month. Among them the intersection point in 1992 is the only recognizable change point in respect of the considered confidence level. Though less significant change points in 1942, 1998 and 2008 can be identified in the temperature trend of February. $u(t_i)$ and $u'(t_i)$ plot for the month of March (Fig-1c) clearly intersects each other and indicates a change point in 1962. But this cannot be accepted as a recognizeable change point as the associated value is less than ±1.96 .After the change point in 1962, the $u(t_i)$ plot have gradually rises till 2003 and thereafter it descends till 2010. However, the $u(t_i)$ and $u'(t_i)$ curves for this month have started to diverge from each other since 1963 and attain a maximum difference in 2003. The overall trend for this month has indicates rising pattern.

Table 1. Statistically significant recognized event detection by Sequential Mann-Kendall Test of Midnapore Weather Observatory (Values significant at p<0.05 *).

Months.	Detected Change Points (Year)				Remarks
	1st	2nd	3rd	4th	
January	1944	2004	2007	-	
February	1942	1992*	1998	2008	Significant
March	1962	-	-	-	
April	1987	-	-	-	
May	1991	-	-	-	
June	2004	2007	-	-	
July	1943	1944	-	-	
August	1946	1949	1951	-	
September	1942	1958	1964	-	
October	1953	1986*	2001	2004	Significant
November	1950	1995*	2004	2006	Significant
December	1948	-	-	-	

Sequential version of Mann-Kendall test statistic results for the month of April, have been plotted as shown in Fig-1d. It shows that, the $u(t_i)$ and $u'(t_i)$ plots have made a divergent since 1987 where they have taken a reduced value of -1.836. In relation to the considered level of significance, associated probability value at the change point is very close to critical value. Yet, this change point cannot be taken as a recognizeable change point. But the $u(t_i)$ plot helps to understand that, the April temperature for Midnapore weather station increased since 1987. $u(t_i)$ and $u'(t_i)$ plots for the month of May (Fig-1e) indicate less significant change points. May temperature has an increasing trend prior to the abrupt change in 2004 and after that the $u'(t_i)$ value has a decreasing trend till 2010. The $u(t_i)$ and $u'(t_i)$ curves for the month of June (Fig-1f) have been almost parallel to each other till 1966. Henceforth, both the curves have made a convergent bend after 1967 and two less significant change points in 2004 and 2007, respectively have been identified. If we look at the temperature trend of July, August and September (Fig-1g, 1h & 1i), the $u'(t_i)$ plots exhibit an increasing trend. Graphical presentation of $u(t_i)$ and $u'(t_i)$ gives curves that could not find any recognized change point, even if they intersect each other for number of times. Apparently, the temperature trend of these three months exhibits uniformity over the period. $u(t_i)$ and $u'(t_i)$ plots for the month of October (Fig-1j) are very interesting and significant. Two curves intersect each other several times during the considered period 1941-2010. In 1986 a change point is detected which statistically significant. The associated value of this intersect point is higher than the considered confidence level ($p \leq 0.05$). The average temperature has continuously decreased since 1953. After the change point in 1986, the average temperature rises till 2010. So, the abrupt nature of change can be clearly established for October. Graphical presentation of $u(t_i)$ and $u'(t_i)$ values for the month of November also have indicated several change points. Two change points have been found to have occurred (Fig-1k). The change point in 1995 is the statistically significant and can be recognized as a significant change point while the other change point in 2004 is not significant for which the associated value of $u'(t_i)$ statistic is -1.952. The overall trend of the average temperature of this month has been found to be negative. In case of December a single change point in 1948 (Fig-1l) can be recognized statistically significant.

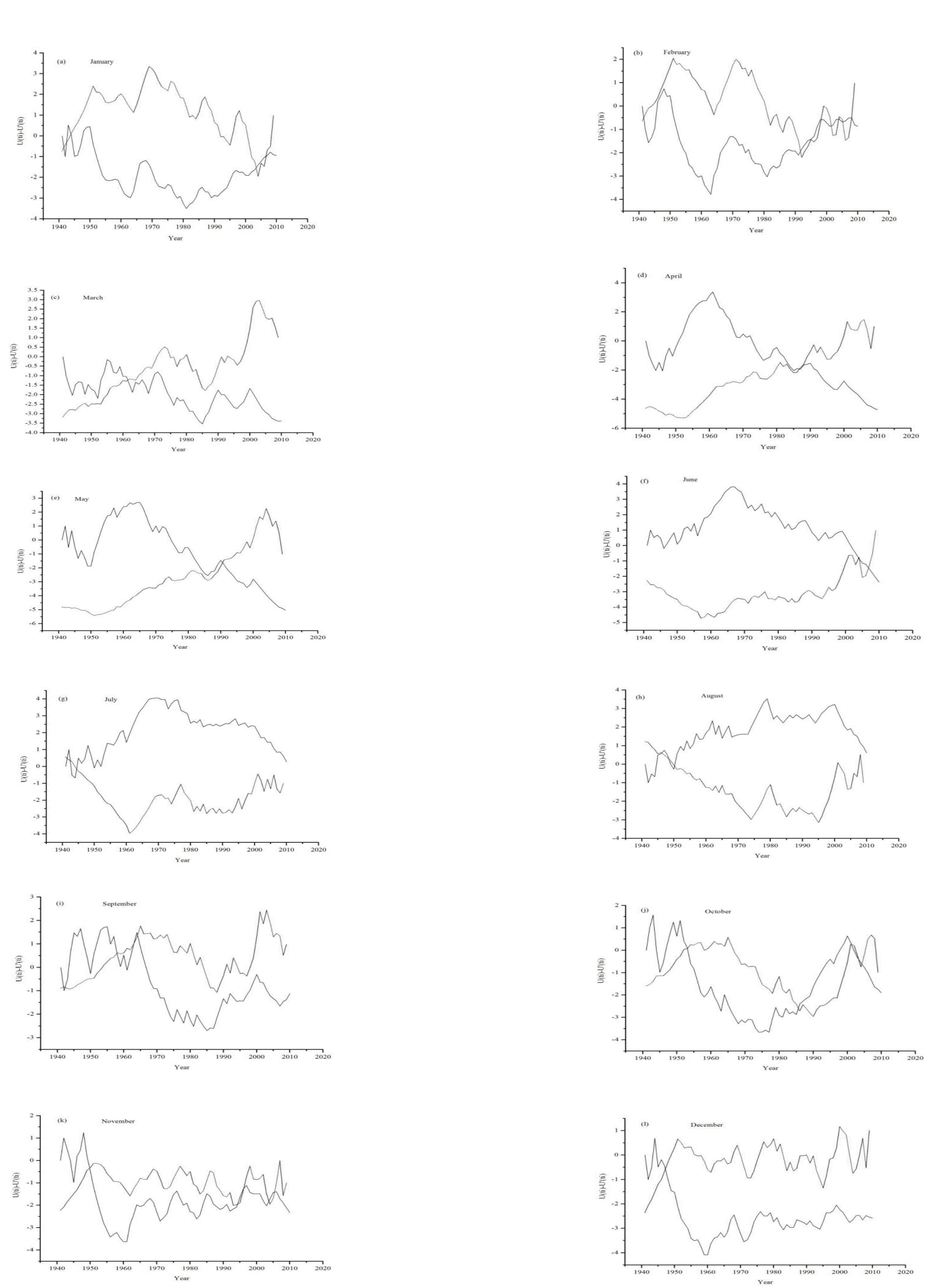

Figure 1. Abrupt changes in average monthly temperature as derived from Sequential Mann Kendall test rank statistic, $u(t_i)$ forward sequential statistic and $u'(t_i)$ backward sequential statistic with solid and dotted line respectively.

5. Conclusion

In this paper, sequential Mann-Kendal test statistic has been employed for detecting of significant changes in the monthly average surface temperature of Midnapore weather observation station during the period from 1941 to 2010.The dataset has passed an intensive homogeneity assessment. The results allows to suggest that average yearly temperature of Midnapore has significantly decreased over the 70 years in consideration, while average temperature of winter months has significantly increased since last 80s and early 90s of the last Century. Most significant ($p \leq 0.5$) rise in monthly average temperature has been found to have occurred in cases of October, November and February. This warming of winter appears to be similar to that has been found for the global temperature trend. This may be attributed to urbanization and deforestation the area has experienced by the area.

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