HOMOGENEITY AND TREND ANALYSIS OF TEMPERATURE FOR URBAN AND RURAL AREAS

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ABSTRACT

The objective of this work is to study the temperature of urban and rural areas and compare between them. Four tests for Homogeneity - the standard normal homogeneity test (SNHT), the Buishand range test, the Pettitt test and the Von Neumann ratio test and three tests for trend analysis- Turning point test for randomness, Regression test for linear trend and Mann–Kendall test were applied to thirty years of temperature data of urban and rural stations. For Bangladesh, capital Dhaka and for Japan, capital Tokyo were selected as urban station. Rajshahi and Gifu were selected as rural stations for Bangladesh and Japan. For Bangladesh, urban station Dhaka was classified as ‘Class-I’ or ‘useful’ station. It means the data series of this station seems to be sufficiently homogeneous for trend analysis. The rural station Rajshahi was classified as ‘Class II’ or ‘doubtful’. It means the results of trend analysis of the data series of this station should be regarded very critically from the perspective of the existence of possible inhomogeneities. This classification was done based on homogeneity tests applied on mDTR (annual mean diurnal temperature range) and vDTR (annual mean of the absolute day-to-day differences of the diurnal temperature range). Three location specific homogeneity tests - SNHT, the Buishand range test and the Pettitt test were applied to find a significant break in the data series. A significant break was found in the annual minimum temperature series around the year 1993 for the rural station, Rajshahi. Annual maximum, minimum and average temperature series – all showed positive trends. Rising trend in annual maximum temperature series was found higher in urban station, Dhaka. For annual minimum temperature series rising trend was stronger in Rajshahi. For Japanese stations, the urban station, Tokyo and the rural station, Gifu, both were classified as ‘Class II’ or ‘doubtful’. A significant break was found around the year 1988 for annual maximum, minimum and average minimum temperature series for both Tokyo and Gifu stations. Annual maximum, minimum and average temperature series – all showed positive trends. Urban station Tokyo and rural station Gifu both showed almost similar rising trends in annual maximum and minimum temperature series. The station selected as rural at Gifu might be located in a relatively urbanized part of the area.

Keywords: *temperature series of urban and rural stations, test for homogeneity, test for trend*

INTRODUCTION

Study of temperature has always been a topic of interest for researchers. Temperature trends have substantial effects on environmental and human resources. One of the important aspects of climate change is the change in temperature. The findings of IPCC 2007 that the glaciers of Himalaya will melt within 2035 or sooner and its subsequent clarification/retraction have sparked intense debate and discussion across the world. In recent times, study of temperature has become a hot topic of discussion. Increase in anthropogenic greenhouse gas concentration raises global average temperature. Global increase in greenhouse gas is primarily due to fossil fuel use and also land-use change Urbanization and the conversion of the Earth’s surface to urban uses are among the most rapid and

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visible anthropogenic changes. The process of urbanization produces radical changes in the surface and atmospheric properties of a region This study examines the homogeneity and trend in temperature in urban and rural areas. The objective of the study is to check the homogeneity of temperature data of urban and rural areas, find a break in temperature series, analyze trend in temperature series and compare the test results between the urban and rural areas. Four absolute test for homogeneity - the standard normal homogeneity test (SNHT) (Alexandersson, 1986), the Buishand range test (Buishand, 1982), the Pettitt test (Pettitt, 1979) and the Von Neumann ratio test (Von Neumann, 1941) were be applied. For trend analysis, Turning point test for randomness, Regression test for linear trend and Mann–Kendall test (Mann, 1945, Kendall, 1975) were be used. Homogeneity of the data series, break in data series, intensity of rising or falling trend in data series between urban and rural areas and their comparison will be the outcome.

LITERATURE REVIEW

In statistical terms, homogeneity of a data series implies that the data belong to one population and therefore have a mean value which is time invariant (Jayawardena & Lau, 1990). A climate series (such as temperature) is defined as homogeneous if the variations in the series are caused by the variations in weather and climate (Aguilar et al, 2003). But long-term temperature data from individual climate stations almost always suffer from inhomogeneities, due to non-climatic factors. Wijngaard et al. (2003) conducted an extensive analysis of daily European station series (1901 to 1999) of surface air temperature and precipitation with respect to homogeneity. They followed a two step approach for temperature data. In the first step they applied the aforementioned four homogeneity tests to evaluate the daily series. From the daily data series, they developed two testing variables - mDTR (the annual mean of the diurnal temperature range) and vDTR (the annual mean of the absolute day-to-day differences of the diurnal temperature range). In the second step, depending on the number of tests rejecting the null hypothesis, the stations have been condensed into three classes: ‘useful’, ‘doubtful’ and ‘suspect’. Wijngaard et al., (2003) in their study used 1% level. In this study, 5% level has been used. Class 1: ‘useful’ — one or zero tests reject the null hypothesis at 5% level, Class 2: ‘doubtful’ — two tests reject the null hypothesis at 5% level, Class 3: ‘suspect’ — three or four tests reject the null hypothesis at 5% level. For temperature data, two variables - mDTR and vDTR have been tested and calculated to classify the station. If the results are different, then the highest of the two category values (hence the least favourable) has been assigned to the temperature series of the station.

Wijngaard et al., (2003) made qualitative interpretation of the categories as follows- Class 1: ‘useful’. No clear signal of an inhomogeneity in the series is apparent. The series seems to be sufficiently homogeneous for trend analysis. Class 2: ‘doubtful’. It implies there are indications of presence an inhomogeneity of a magnitude that exceeds the level expressed by the inter-annual standard deviation of the testing variable series. The results of trend analysis and variability analysis should be regarded very critically from the perspective of the existence of possible inhomogeneities. Class 3: ‘suspect’. It is likely that an inhomogeneity is present that exceeds the level expressed by the inter-annual standard deviation of the testing variable series. These series should not be used in the analysis of trend and variability.

Martínez et al. (2009**)** applied three location specific homogeneity tests - the standard normal homogeneity test (SNHT), the Buishand range test and the Pettitt test to detect break year in annual maximum temperature and annual maximum temperature series of Spain. When two out of three tests detect the same year at a certain confidence level, the year was assumed as the breaking year.

Tests for trends for climatic data are of great importance. There are a number of statistical tests for trend analysis. Mann-Kendall test, regression test for linear trend, turning point test, etc. have been widely used to analyze trends by climatologists and researchers.

STUDY AREA AND DATA

Temperature data from urban and rural areas of Bangladesh and Japan have been used in this study. The available information of station and data are given.

Table 1 Station and data information

Station name	Station number	Location	Data range	Data type
Bangladesh				
Dhaka	11111	At latitude 23°46' N and longitude 90°23' E.	1980 to 2009	Daily maximum, minimum & average temperature
Rajshahi	10320	At latitude 24°22' N and longitude 88°42' E.	1980 to 2009	Daily maximum, minimum & average temperature
Japan				
Tokyo	44131	At latitude 35°41' N and longitude 139°46' E.	1977 to 2006	Hourly temperature data
Gifu	52586	At latitude 35°24' N and longitude 136°45' E.	1977 to 2006	Hourly temperature data

TESTS FOR HOMOGENEITY

Standard Normal Homogeneity Test (SNHT) assumes a null hypothesis that the annual values of the testing variable are independent and identically distributed. Under the alternative hypothesis it assumes that a step-wise shift (a break) in the mean is present. It is more sensitive to breaks near the beginning and the end of a series. Buishand range test assumes the same null hypothesis and alternate hypothesis like the SNHT. It assumes that the values are normally distributed. This test is more sensitive to the breaks in the middle of a time series. The Pettitt test assumes the same null hypothesis and alternate hypothesis like the SNHT and the Buishand test. This test is based on the ranks of the elements of a series. It is more sensitive to breaks near the middle of a time series. The Von Neumann ratio test (VNRT) assumes the same null hypothesis as the previous three tests but for alternate hypothesis it assumes that the series is not randomly distributed. VNRT assesses the randomness of the series, but does not give information about the year of the break. For all these four tests, if the test statistic exceeds the critical value at certain confidence level, the null hypothesis will be rejected at that confidence level.

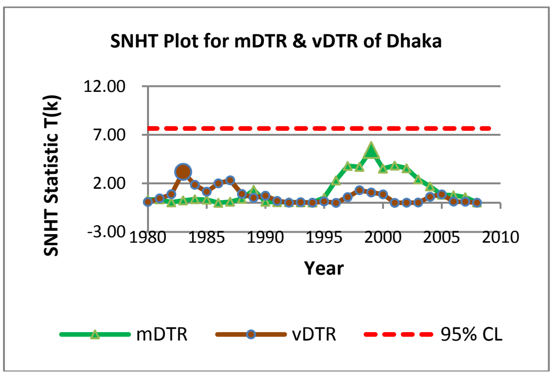

Figure 1 : SNHT plot of mDTR and vDTR of Dhaka

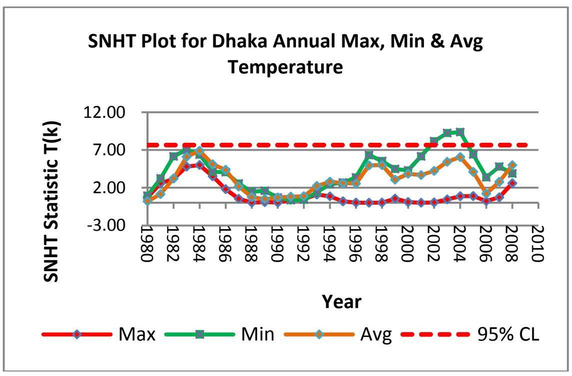

Figure 2 : SNHT plot of annual maximum, minimum & average temperature of Dhaka

Results of Homogeneity tests:

Table 1 Homogeneity test results of mDTR and vDTR of Dhaka station

Test Name	Maxima or minima of statistic value		Critical value at 95% CL (for n=30)	Corresponding year	
	mDTR	vDTR		mDTR	vDTR
SNHT	5.44	3.18	7.65	1999	1983
Buishand	3.23 $\frac{R}{\sqrt{n}} = 1.32$	0.35 $\frac{R}{\sqrt{n}} = 0.93$	1.50	1999	1987
Pettitt	**115**	64	±107	**1999**	1984
VNRT	1.21	**2.01**	1.42	-	-

(Statistically significant numbers are marked bold)

Test results of mDTR and vDTR have been used to classify the station. For mDTR, the test statistic values for Pettitt test is above the critical value and in case of vDTR, the test statistic for VNRT is above the critical value. As only one test rejects the null hypothesis at 95% confidence level, this station has been classified as 'Class I' or 'useful'. It means the data series of this station seems to be sufficiently homogeneous for trend analysis.

For Rajshahi station of Bangladesh and Tokyo and Gifu stations of Japan, two tests reject the null hypothesis at 95% CL. These stations have been classified as 'Class II' or 'doubtful'. It means the results of trend analysis of the data series of these stations should be regarded very critically from the perspective of the existence of possible inhomogeneities.

Table 2 Comparison of homogeneity test results of annual maximum, minimum and average temperature between Dhaka and Rajshahi station

Station	SNHT (Statistic value & *year*)		Buishand test (Statistic value & *year*)		Pettitt test (Statistic value & *year*)	
	Dhaka	Rajshahi	Dhaka	Rajshahi	Dhaka	Rajshahi
annual maximum temperature	5.00 *1984*	6.59 *1982*	2.49 $(\frac{R}{\sqrt{n}} = 1.18)$ *1984*	-2.12 $(\frac{R}{\sqrt{n}} = 0.97)$ *1984*	-84 *1984*	-79 *1984*
annual minimum temperature	**9.37** ***2004***	**15.42** ***1993***	-2.65 $(\frac{R}{\sqrt{n}} = 1.24)$ *1997*	-4.87 $(\frac{R}{\sqrt{n}} = \mathbf{2.23})$ ***1993***	**-115** ***1997***	**-193** ***1994***
annual average temperature	6.90 *1984*	4.26 *1997*	-1.84 $(\frac{R}{\sqrt{n}} = 1.08)$ *1997*	-1.38 $(\frac{R}{\sqrt{n}} = 1.19)$ *1997*	-104 *1984*	-105 *1997*

(Statistically significant numbers are marked bold)

Only for rural station, Rajshahi, there is a significant break around the year 1993 in annual minimum temperature series, because test statistics of SNHT and Buishand test exceed the critical value and indicate the same year, 1993.

For Tokyo and Gifu stations, on basis of test results, a significant break is found around the year 1988 in annual maximum, minimum and average data series.

TESTS FOR TREND ANALYSIS

In turning point test for randomness, the presence of high and low values are examined by determining the number of turning points in the series. Turning points occur in all except the first and the last. The variance of the expected number of turning points are obtained, a two tailed test of significance is carried out and standard normal deviate z is calculated. In Regression test for linear trend, regression coefficients are obtained by minimizing the squared error and The Student's t is calculated. The Mann-Kendall test is a rank-based non-parametric statistical procedure. The Mann-Kendall statistic (S) and the standard normal variate z are calculated. Positive values the Mann-Kendall statistic indicates an 'upward trend' and vice versa. For all three tests, at certain confidence level, if the calculated test statistic value exceeds the corresponding critical value z, then trend is significant at that confidence level.

Results of Trend Analysis

Table 3 Comparison of trend analysis test results of annual maximum, minimum and average temperature between Dhaka and Rajshahi station

Station	Turning point test for randomness	Regression test for linear trend	Mann–Kendall test
annual maximum temperature			
Dhaka	$E(p)\approx 19$ p=15 z = 1.79<1.96 Trend is **not** significant	T=0.817< 2.048 Trend is **not** significant	S =70; Trend is **positive** z = 1.23<1.96 Trend is **not** significant
Rajshahi	$E(p)\approx 19$ p=17 z = 0.89<1.96 Trend is **not** significant	T=0.762< 2.048 Trend is **not** significant	S =62; Trend is **positive** z = 1.09<1.96 Trend is **not** significant
annual maximum temperature			
Dhaka	$E(p)\approx 19$; p=13 z = **2.68**>1.96 Trend is **significant**	T=**2.857**> 2.048 Trend is **significant**	S =146; Trend is **positive** z = **2.59**>1.96 Trend is **significant**
Rajshahi	$E(p)\approx 19$, p=16 z = 1.34<1.96 Trend is **not** significant	T=**3.293**> 2.048 Trend is **significant**	S =161; Trend is **positive** z = **2.85**>1.96 Trend is **significant**
annual maximum temperature			
Dhaka	$E(p)\approx 19$; p=15 z = 1.79<1.96 Trend is **not** significant	T=**2.451**> 2.048 Trend is **significant**	S =106; Trend is **positive** z = 1.88<1.96 Trend is **not** significant
Rajshahi	$E(p)\approx 19$; p=17 z = 0.89<1.96 Trend is **not** significant	T=1.806< 2.048 Trend is **not** significant	S=112; Trend is **positive** z = **1.98**>1.96 Trend is **significant**

(Statistically significant numbers are marked bold)

Annual maximum, minimum and average temperature series – all showed positive trend. Rising trend in annual maximum temperature series has been found higher in urban station, Dhaka. But rising trend in annual minimum temperature series is stronger in rural station.

For Tokyo and Gifu stations, on basis of test results, it is found that annual maximum, minimum and average temperature series – all show positive trend. Urban station Tokyo and rural station Gifu both showed almost similar rising trend in annual maximum and minimum temperature series.

SUMMARY OF RESULTS

For Bangladesh, urban station Dhaka was classified as ‘Class-I’ or ‘useful’ station. The rural station Rajshahi and the urban station, Tokyo and the rural station, Gifu, were classified as ‘Class II’ or ‘doubtful’. Annual maximum, minimum and average temperature series – all showed positive trends in both countries. Rising trend in annual maximum temperature series was found higher in urban station, Dhaka. For annual minimum temperature series rising trend was stronger in Rajshahi. Urban station Tokyo and rural station Gifu both showed almost similar rising trends in annual maximum and minimum temperature series.

CONCLUSION

Generally long term temperature data from an area located in rural setting is very difficult to find. More and more rural areas are becoming urbanized day by day and losing their rural characteristics. That is why, selection of rural station can be crucial for analysis. In case of urban station, temperature should be correlated with rate of urbanization, increase of population, change in land use etc subject to the availability of data.

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