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Seasonal Variation of Temperature in Dhaka Metropolitan City, Bangladesh

Md. Zakaria Hossain[1], Md. Nazrul Islam Mondal[2*], Sarose Kumar Sarkar[3] and Md. Abdul Haque[4]

[1] Institute of Environmental Science, University of Rajshahi, Rajshah-6205, Bangladesh
[2] Department of Population Science, and Human Resource Development, University of Rajshahi, Rajshahi-6205, Bangladesh
[3] Department of Statistics, University of Rajshahi, Rajshahi-6205, Bangladesh
[4] Department of Applied Mathematics, University of Rajshahi, Rajshah-6205, Bangladesh

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Abstract

The present study aims to analyze the impact of global climate change on the basis of seasonal variation of temperature in Dhaka city, Bangladesh. The daily data on temperature from the years 1953-2009 were used and collected from the Meteorological Department, Bangladesh. Pearson correlation analysis, least significant difference techniques and ratio to trend method were used to analyze the data. The results revealed that the temperature of pre-monsoon and winter seasons exhibited an insignificant positive correlation between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009'. However, the monsoonal and post-monsoonal temperature exhibited insignificant negative correlation between the periods '1953-1971 and 1991-2009', and positive correlation between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009'. The least significant difference technique identified the significant differences between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', '1953-1971 and 1991-2009' during monsoon and winter seasons. It also identified the significant difference in all the periods of four seasons except the periods 1953-1971 and 1972-1990 during pre-monsoon season and the periods 1972-1990 and 1991-2009 during post-monsoon season. Again, the ratio to trend method identified that the lowest average temperature in January, it gradually increased until June, fluctuated in July-October, and then decreased until December.

Keywords: Global warming; Temperature fluctuation; Climate change; Seasonal variation; Ratio to trend method

1. Introduction

The global warming has induced the changes in natural calamity as well as precipitation in different regions of the world. Bangladesh is recently experiencing climate change impact related to hazards like cyclone, rainfall, flood, draught etc. Season is the climatic type at any place associated with a particular time of the year (Das, 1995). The change of season is mainly due to the change in angle of the earth's axis in relation to the position of the sun at a particular place (Manabe et al., 2011). Weather is the term that denotes the state of the atmosphere at a given time and place that is constantly changing sometimes from hour to hour and at other times from day to day (Brohan et al., 2006). Climate is the average state of atmosphere near the earth's surface over a long span of time (Chapman and Walsh, 1993). It refers to many elements including temperature, precipitation, humidity, air pressure, and wind direction and movement. Geographical location (latitude, coastal or continental position) and physical setting influence the climate of any country (Dee and Uppala, 2009; Jones et al., 1999). Bangladesh extends from $20^0 34'$N to $26^0 38'$N latitude and from $88^0 01'$E to $92^0 41'$E longitude. It is bordered by the Himalayas to the north and by the Bay of Bengal to the south. As the Tropic of Cancer passes through the middle of the country a tropical climate prevails there. The influence of the monsoonal wind is so strong that as a whole, the climate of Bangladesh is known as a tropical monsoon climate.

Bangladesh is one of the top most nations vulnerable to climate change (Harmeling, 2008). The Intergovernmental Panel on Climate Change (IPCC) recognizes Bangladesh as one of the most vulnerable countries in the world to the negative impacts of climate change. Consequences of climate change like recurring floods, river bank erosion, drought in dry season, salinity increase as a result of back water effect in the coastal region, downing ground water level during the dry season, have been contributing to augment the vulnerability of many regions. Nevertheless, many regions of Bangladesh this country remain outside the ambit of climate change related actions (Titumir and Basak, 2012). Warrick et al. (1994) studied the variation of temperature over Bangladesh and identified that the mean-annual temperatures have been expressed as departures from the reference period 1951-1980. It is evident that, on this time scale, the entire region of Bangladesh is getting warmer. Since the later part of the last century, there has been an overall mean increase in temperature by 0.5^oC which was comparable in magnitude to the observed global warming. However, a good numbers of studies have been carried out on trends of change in climatic parameters in the context of Bangladesh. Warrick et al. (1994), Karmakar and Shrestha (2000) and Debsarma (2003) provided the assessment of changes in temperature over Bangladesh, while Chowdhury and Debsarma (1992), and Mia (2003) reported the changes in temperature based on analysis of historical data of some selected weather stations

* Corresponding author. e-mail: nazrulupm@gmail.com

in Bangladesh. Karmakar and Nessa (1997), and Karmakar (2003) provided the assessment of the effects of climate change on natural disasters.

In and around Bangladesh rainy season is divided into three periods: (i) pre-monsoon (March-May), (ii) monsoon (June-September), and (iii) post-monsoon (October-November) periods (Das, 1995; Islam and Uyeda, 2007). The Fourth Assessment Report of IPCC observed that the 100-year linear trend (1906-2005) of global average surface temperature exhibited a 0.74 (0.56 to 0.92) ^{o}C increase, which is larger than the global corresponding increase of 0.6 (0.4 to 0.8)^{o}C in the years (1901-2000) (IPCC, 2007). The area impacted by drought in Bangladesh might have increased since the 1970s (IPCC, 2007). Modeling studies by Haque et al. (1992) indicated that the average increase in temperature would be 1.3^{o}C and 2.6^{o}C for the projected years of 2030 and 2075, respectively. Therefore, the main aim of this study is to provide an assessment of seasonal variation due to climate change in Dhaka city, Bangladesh based on the analytical results of historical data of temperature.

2. Methodology

In this study the daily data on temperature from the years 1953-2009 were used. The data were collected from the Meteorological Department, Bangladesh. The data were divided into three climatological periods as first period (1953-1971) less industrialization period, second period (1972-1990) moderate industrialization period and third period (1991-2009) modern industrialization period. These data were analyzed using different analytical programs. The seasonal variation of climatic data is identified by correlation analysis and least significant difference techniques among three periods. Beside these, monthly variations of indices were checked by ratio to trend method. The three tests are employed to ensure the variation of three periods for four climatological seasons e.g., pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November) and winter (December to February). Seasonal mean values have been computed for these four seasons.

3. Results

3.1. Temperature

Attempts were made to identify the correlation in seasonal variation of temperature for four seasons into three segments of 19 years period in Dhaka city, Bangladesh for the total period of 1953-2009. The variation of yearly mean seasonal variation of temperature for four climatological seasons over Dhaka city are shown in Figs. 1-4, respectively.

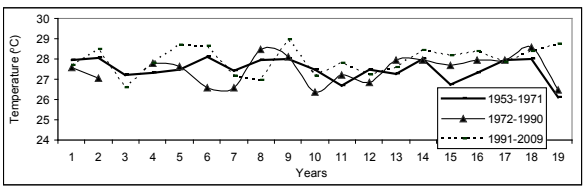

Figure 1: Variation of yearly seasonal mean temperature among three periods 1953-1971, 1972-1990, and 1991- 2009 during pre-monsoon season

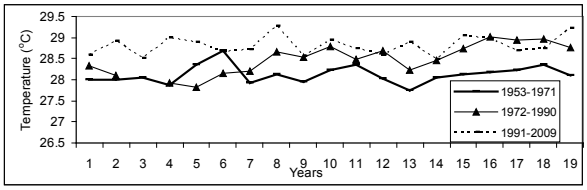

Figure 2: Variation of yearly seasonal mean temperature among three periods 1953-1971, 1972-1990, and 1991-2009 during monsoon season

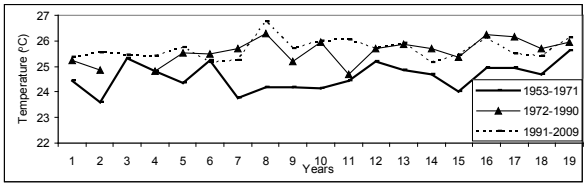

Figure 3: Variation of yearly seasonal mean temperature among three periods 1953-1971, 1972-1990, and 1991- 2009 during post-monsoon season

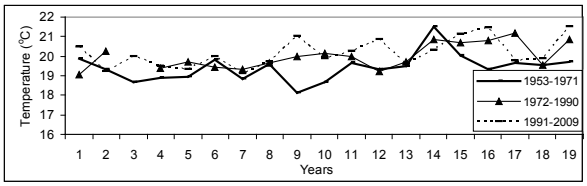

Figure 4: Variation of yearly seasonal mean temperature among three periods 1953-1971, 1972-1990, and 1991-2009 during winter season

The vertical axes of the figures of temperature represent temperature in ^{o}C and the horizontal axes represent year. Each of the data series of temperature exhibits period to period variation. From the figures, it is seen more seasonal variation in monsoon and post monsoon seasons and less seasonal variation occurred in pre-monsoon and winter seasons. The significant test of correlation in seasonal variation is shown below in Table 1.

Table 1: The correlation between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009' for temperature

Season	Period	Correlation coefficient (r)*	Degrees of freedom (df)
Pre-monsoon	1953-1971 and 1972-1990	0.34	11
	1972-1990 and 1991-2009	0.12	11
	1953-1971 and 1991-2009	0.06	11
Monsoon	1953-1971 and 1972-1990	0.16	11
	1972-1990 and 1991-2009	0.09	11
	1953-1971 and 1991-2009	-0.03	11
Post-monsoon	1953-1971 and 1972-1990	0.32	11
	1972-1990 and 1991-2009	0.39	11
	1953-1971 and 1991-2009	-0.01	11
Winter	1953-1971 and 1972-1990	0.34	11
	1972-1990 and 1991-2009	0.38	11
	1953-1971 and 1991-2009	0.18	11

***Note**: Significance of the correlation coefficients are carried out by t-test

From Table 1, it is seen that the correlation coefficients of temperature $r = 0.34$, $r = 0.12$, and $r = 0.06$ represent the insignificant positive correlation between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009', respectively, the during pre-monsoon season at 5% level of significance (Fig. 1). Again, the insignificant positive correlation coefficients $r = 0.16$ and $r = 0.09$ were found between the periods '1953-1971 and 1972-1990', and '1972-1990 and 1991-2009' respectively; the negative correlation coefficient $r = -0.03$ was found between the periods '1953-1971 and 1991-2009' during the monsoon season at the same level of significance (Fig. 2). Furthermore, the insignificant positive correlation coefficients $r = 0.32$ and $r = 0.39$ were found between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009' respectively; an insignificant negative correlation $r = -0.01$ was found between the periods '1953-1971 and 1972-1990' during the post monsoon season (Fig. 3). Likewise, the winter season also showed an insignificant positive correlation coefficients $r = 0.34$, $r = 0.38$, and $r = 0.18$ between the periods '1953-1971 and 1972-1990, '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009' respectively (Fig. 4). Thus, the findings suggest that temperature goes up over time during most of the periods though the correlation coefficients of temperature are not statistically significant.

3.2. Test of least significant difference

The mean difference of temperature between the periods '1953-1971 and 1972-1990' were not statistically significant, but the difference between the periods '1953-1971 and 1991-2009', '1972-1990 and 1991-2009' were statistically significant at 5% level of significance during pre-monsoon season. Monsoon season shows highly significant mean difference of temperature at 0.1% level of significance between periods '1953-1971 and 1972-1990', '1953-7191 and 1991-2009', '1953-1971 and 1991-2009', and '1972-1990 and 1991-2009'. On the other hand, the mean differences of temperature between periods '1953-1971 and 1972-1990', and '1953-1971 and 1991-2009' were statistically significant at 1% level of significance during the post-monsoon and the winter seasons. These results are summarized in Table 2.

Table 2: Results of least significant difference test showing the mean differences of temperature between the periods during four seasons

Season	Period	Mean Difference	Standard Error	p-values
Pre-monsoon	1953-1971 and 1972-1990	0.01042	0.21271	0.961
	1972-1990 and 1991-2009	-0.43762	0.21271	0.045
	1953-1971 and 1991-2009	-0.42720	0.20982	0.047
Monsoon	1953-1971 and 1972-1990	-0.36513	0.09097	0.000
	1972-1990 and 1991-2009	-0.32171	0.09097	0.001
	1953-1971 and 1991-2009	-0.68684	0.08973	0.000
Post-monsoon	1953-1971 and 1972-1990	-0.97792	0.15803	0.000
	1972-1990 and 1991-2009	-0.08787	0.15803	0.581
	1953-1971 and 1991-2009	-1.06579	0.15588	0.000
Winter	1953-1971 and 1972-1990	-0.57305	0.23101	0.016
	1972-1990 and 1991-2009	-0.17086	0.23101	0.463
	1953-1971 and 1991-2009	-0.74391	0.22787	0.002

3.3. Seasonal variation of temperature using ratio to trend method

The results of trend values obtained by using ordinary least square method are presented in Table 3. Again, the results of monthly seasonal indices used ratio to trend method are presented in Table 4.

Table 3: Results of trend value by ordinary least squares method

Year	1	2	3	4	5	6	7	8	9	10	11	12
1991	25.616	25.619	25.621	25.624	25.626	25.629	25.631	25.634	25.636	25.639	25.641	25.644
1992	25.646	25.649	25.651	25.654	25.656	25.659	25.661	25.664	25.666	25.669	25.671	25.674
1993	25.676	25.679	25.681	25.684	25.686	25.689	25.691	25.694	25.696	25.699	25.701	25.704
1994	25.706	25.709	25.711	25.714	25.716	25.719	25.721	25.724	25.726	25.729	25.731	25.734
1995	25.736	25.739	25.741	25.744	25.746	25.749	25.751	25.754	25.756	25.759	25.761	25.764
1996	25.766	25.769	25.771	25.774	25.776	25.779	25.781	25.784	25.786	25.789	25.791	25.794
1997	25.796	25.799	25.801	25.804	25.806	25.809	25.811	25.814	25.816	25.819	25.821	25.824
1998	25.826	25.829	25.831	25.834	25.836	25.839	25.841	25.844	25.846	25.849	25.851	25.854
1999	25.856	25.859	25.861	25.864	25.866	25.869	25.871	25.874	25.876	25.879	25.881	25.884
2000	25.886	25.889	25.891	25.894	25.896	25.899	25.901	25.904	25.906	25.909	25.911	25.914
2001	25.916	25.919	25.921	25.924	25.926	25.929	25.931	25.934	25.936	25.939	25.941	25.944
2002	25.946	25.949	25.951	25.954	25.956	25.959	25.961	25.964	25.966	25.969	25.971	25.974
2003	25.976	25.979	25.981	25.984	25.986	25.989	25.991	25.994	25.996	25.999	26.001	26.004
2004	26.006	26.009	26.011	26.014	26.016	26.019	26.021	26.024	26.026	26.029	26.031	26.034
2005	26.036	26.039	26.041	26.044	26.046	26.049	26.051	26.054	26.056	26.059	26.061	26.064
2006	26.066	26.069	26.071	26.074	26.076	26.079	26.081	26.084	26.086	26.089	26.091	26.094
2007	26.096	26.099	26.101	26.104	26.106	26.109	26.111	26.114	26.116	26.119	26.121	26.124
2008	26.126	26.129	26.131	26.134	26.136	26.139	26.141	26.144	26.146	26.149	26.151	26.154
2009	26.156	26.159	26.161	26.164	26.166	26.169	26.171	26.174	26.176	26.179	26.181	26.184

Table 4: Results of monthly seasonal indices by ratio to trend method

Year	1	2	3	4	5	6	7	8	9	10	11	12
1991	73.39	90.17	104.99	112.01	106.92	110.81	113.53	112.74	108.83	106.48	91.26	76.43
1992	72.14	80.32	105.65	116.16	111.08	114.97	111.06	112.61	112.21	106.74	92.32	72.06
1993	69.32	87.23	96.179	107.46	106.67	111.72	111.32	110.53	110.13	105.84	92.21	77.03
1994	74.3	78.96	102.29	108.5	113.16	112.76	113.52	112.74	111.95	106.11	91.33	73.83
1995	68.77	82.37	101.39	116.14	116.91	113.79	111.06	112.99	111.04	107.15	92.78	73.75
1996	71.02	85.37	106.32	112.13	114.83	109.78	112.1	109.76	112.85	104.31	90.73	76.38
1997	68.23	80.62	103.48	100.37	111.99	112.36	111.19	113.12	108.07	102.64	92.95	73.58
1998	66.21	84.01	94.459	106.06	112.63	118.81	111.45	111.83	111.04	110.26	96.71	78.91
1999	72.71	90.1	107.11	118.31	110.57	112.1	110.16	110.15	108.98	106.65	91.96	80.75
2000	72.24	80.34	98.489	107.75	108.12	112.36	111.96	112.34	110.4	106.14	94.55	77.56
2001	71	87.2	102.62	112.25	106.84	107.99	111.06	113.75	110.66	106.4	94.44	76.32
2002	75.93	87.09	100.96	106.34	107.1	109.02	109.78	110.15	111.3	105.51	92.41	78.16
2003	62.36	85.07	93.914	111.22	113.52	109.28	112.73	113.1	109.63	106.93	92.3	78.83
2004	69.98	83.82	104.19	106.87	116.85	109.54	109.91	111.82	106.43	103.35	89.89	80.66
2005	72.98	89.87	103.3	111.35	109.8	114.02	109.78	111.31	110.91	103.61	91.71	80.19
2006	72.51	95.52	105.1	109.69	111.6	111.59	111.96	111.56	109.25	106.94	93.13	78.95
2007	68.98	82.38	97.313	107.65	114.92	109.92	108	111.44	109.89	103.76	91.5	75.79
2008	72.72	77.69	101.79	111.73	112.1	109.8	109.02	110.16	110.53	103.64	90.63	78
2009	75.32	89.07	103.21	115.04	111.21	115.4	110.81	110.42	110.02	105.43	93.96	78.52
Total	1350.11	1617.21	1932.75	2097.1	2116.84	2126.03	2110.42	2122.5	2094.14	2007.89	1756.77	1465.69
Average	71.06	85.12	101.72	110.37	111.41	111.90	111.07	111.71	110.22	105.68	92.46	77.14
(Adjusted) seasonal index	71.07	85.13	101.73	110.38	111.43	111.91	111.09	111.72	110.23	105.69	92.47	77.15

Note: Monthly Seasonal Indices are obtained by ratio to trend method and adjusted indices are obtained by the formula of adjusting factor, k = 1200/ total of the average indices

From the monthly seasonal indices obtained by the ratio to trend method, it is found that the lowest average temperature in the month of January and then gradually increased until June and then fluctuated in the month of July- October and then decreased until December. These findings suggest that the lower temperature (compared to 100) in the month of January, February, November and December do not influence the sufficient rainfall. That is, about four months remained dry in the Dhaka city. On the other hand, it is seen that the temperature is moderately higher from April-October and the average temperature remained 10% higher than the standard (100). Since the indices are unit free, so it is compared lower and higher relative to 100. These findings can also be achieved in the graphical form which is shown in Fig. 5.

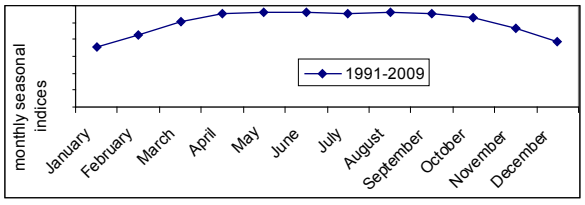

Figure 5: Changes in monthly seasonal indices of different month's temperature

4. Discussion

Though statistically insignificant positive correlations between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009' were found during the pre-monsoon season but trend of the temperature is upward. On the other hand, it was found an insignificant positive correlation between the periods '1953-1971 and 1972-1990', and '1972-1990 and 1991-2009', and negative correlation between the periods '1953-1971 and 1991-2009' during the monsoon season. Furthermore, it was seen that an insignificant positive correlation between the periods '1953-1971 and 1972-1990', and '1972-1990 and 1991-2009' but during the periods '1953-1971 and 1972-1990' exhibited an insignificant negative correlation during the post monsoon season. Likewise, the winter season also showed an insignificant positive correlation between the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009'. It was found the significant difference in all pairs of four seasons except the periods '1953-1971 and 1972-1990' during the pre-monsoon and the periods '1972-1990 and 1991-2009' during the post-monsoon season using least significant difference method. On the other hand, by ratio to trend method, it was found that

the lowest average temperature in the month of January and then gradually increased until June and then fluctuated in the month of July-October and then decreased until December. In this regard, a study of Zaman et al. (2013) about trend analysis of temperature in Bangladesh due to global warming and found increasing average mean temperature in May, and July-October during 1979-2008.

The yearly seasonal mean temperature increased gradually in the periods '1953-1971', '1972-1990', and '1991-2009' and the rates of change of temperature were 0.01°C, 0.02°C, 0.04°C per year during the pre-monsoon and were 0.04°C, 0.07°C, 0.08°C per year during the winter season respectively. On the other hand, the yearly seasonal mean temperature was found to be increasing at a rate of 0.004°C, 0.05°C, 0.008°C per year during the monsoon and of 0.03°C, 0.05°C, 0.02°C during the post-monsoon in the periods '1953-1971', '19972-1990', and '1991-2009' respectively. But, the temperature in the winter season (December-February) increased at much higher rate than the summer season (June-August). The findings of this research are consistent with the results obtained by the IPCC (2007) and Zaman et al. (2013). Moreover, Basak et al (2013) studied the climate change in Bangladesh using a historical analysis of temperature and rainfall data where the yearly average was maximum temperature increased at all regions in Bangladesh during the period of 1976-2008. The above results are very close to this study.

5. Conclusion

The pre-monsoon and the winter seasons exhibited an insignificant positive correlations among the periods '1953-1971 and 1972-1990', '1972-1990 and 1991-2009', and '1953-1971 and 1991-2009'. The monsoon and the post-monsoon seasons showed the insignificant negative correlation between the periods '1953-1971 and 1991-2009' and positive correlation between the other two periods. From the test of least significant difference, it is found the significant difference in all pairs of four seasons except pair 1953-1971 and 1972-1990 during the pre-monsoon and pair 1972-1990 and 1991-2009 during the post-monsoon seasons. On the other hand, by ratio to trend method it is found that the lowest average temperature in the month of January and then gradually increased until June and then fluctuated in the month of July-October and then decreased until December.

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