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Increase of Heat Index over Bangladesh: Impact of Climate Change

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***Abstract*—**Heat Index describes the combined effect of temperature and humidity on human body. This combined effect is causing a serious threat to the health of people because of the changing climate. With climate change, climate variability and thus the occurrence of heat waves is likely to increase. Evidence is emerging from the analysis of long-term climate records of an increase in the frequency and duration of extreme temperature events in all over Bangladesh particularly during summer. Summer season has prolonged while winters have become short in Bangladesh. Summers have become hotter and thus affecting the lives of the people engaged in outdoor activities during scorching sun hours. In 2003 around 62 people died due to heat wave across the country. In this paper Bangladesh is divided in four regions and heat index has been calculated from 1960 to 2010 in these regions of the country. The aim of this paper is to identify the spots most vulnerable to heat strokes and heat waves due to high heat index. The results show upward trend of heat index in almost all the regions of Bangladesh. The highest increase in heat index value has been observed in areas of South-west region and North-west Region. The highest change in average heat index has been found in Jessore by almost 5.5^0C.

***Keywords*—**Anomaly**,** Heat index, Relative humidity, Temperature

I. Introduction

GEOGRAPHICALLY, Bangladesh extends from 20°340N to 26°380N latitude and from 88°010E to 92°410E longitude. Climatically, the country belongs to the sub-tropical region where monsoon weather prevails throughout the year in most parts of the country. The average temperature of the country ranges from 17 °C to 20.6 °C during winter and 26.9 °C to 31.1 °C during summer. The average relative humidity for the whole year ranges from 70.5% to 78.1%, with a maximum in September and a minimum in March [6].The climate is generally arid, characterized by hot summers and cool or cold winters and wide variations between extremes of temperature at given locations. Bangladesh has been aggravated by environmental degradation and cross- country anthropogenic interventions [2].

Heat index (HI) is a measurement of perceived temperature in human body indicating how hot it feels when relative temperature is added to the actual air temperature. Heat index is assessed to determine the stress that lay on humans by excessive levels of atmospheric temperature & moisture. As the relative humidity increases in the atmosphere the ability of human body to release heat through evaporation is restrained resulting in discomfort and stress. Humid regions of tropics and summer hemisphere extra tropics including southeastern United States, India, Southeast Asia and Northern Australia are the mostly affected regions of this consequence [4]. Periods of very high Heat Index have been associated with adverse human health consequences [9].

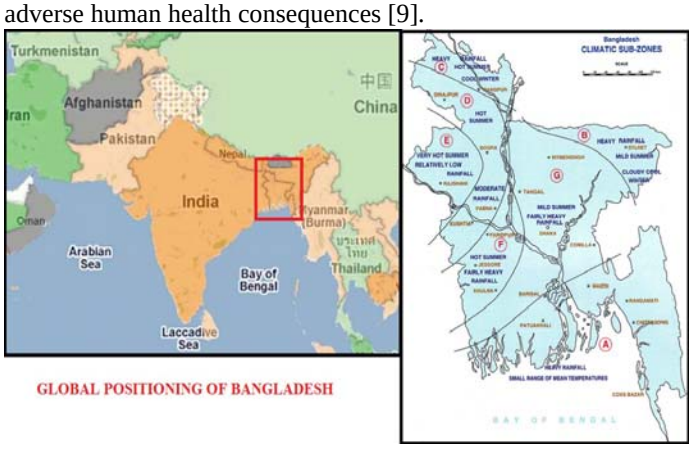

Fig. 1 Global Positioning of Bangladesh and Climatic Sub-zones of Bangladesh

Excessive heat acts on human health and individual performance causing discomfort, fatigue, heat cramps, heatstroke, heat exhaustion etc. The increase in heat index can even lead to collapse and death to humans and animals. Forecasts from the climate models imply that global surface air temperature will increase substantially in future due to radioactive effects of enhanced atmospheric concentrations of gases [4].

The infirmities and casualties derived from heat are likely to amplify with predicted incidence of global warming and increasing duration of heat waves. The thermoregulatory control of human skin blood flow is vital to maintain the body heat storage. Heat load exceeds heat dissipation capacity which alters the coetaneous vascular responses along with other body physiological variables [1].

II. Data And Methodology

The real time data of monthly dry bulb temperature and relative humidity for a period 1961-2010 was obtained from Bangladesh Meteorological Department (BMD), Dhaka in order to calculate heat index. Heat index was calculated for 20 stations out of 35 stations of BMD. For analysis Bangladesh is

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divided in four regions: i) North West Region (NWR) ii) South West Region (SWR) iii) Central Region (CR) iv) East Region (ER).

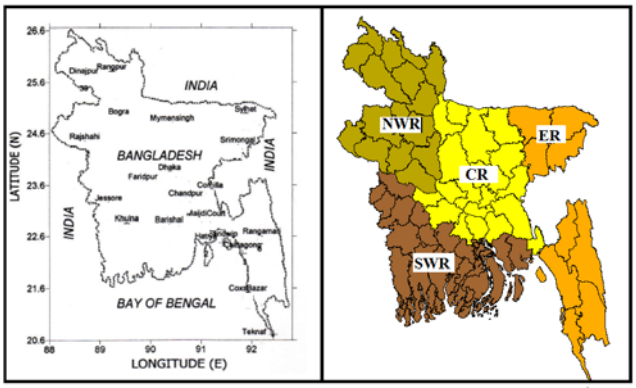

Fig. 2 BMD Station Map of Bangladesh (Study Area)

The Heat Index [7]-[8] is usually simplified as a relationship between ambient temperature and relative humidity versus skin (or apparent) temperature. There is a base relative humidity at which an apparent temperature ''feels'' like the same air temperature. Increasing (or decreasing) humidity and temperature result in increasing (or decreasing) apparent temperature.

In order to arrive at an equation which uses more conventional independent variables, a multiple regression analysis was performed on the data from Steadman's table. The resulting equation could be considered a Heat Index equation [5].

HI = -42.379 + 2.04901523T + 10.14333127R – 0.22475541TR – 6.83783 × 10-3T2 -5.481717×10-2R2 + 1.22874×10-3 T2R + 8.5282×10-4 TR2 – 1.99×10-6T2R2

Where, T = ambient dry bulb temperature R = relative humidity

Such a formula is applicable only when air temperature and humidity are higher than 26ºC and 39%, respectively. Because this equation is obtained by multiple regression analysis, the heat index value (HI) has an error of ±1.3°F (1.5ºC). The values of heat index were then further converted in Celsius scale.

III. Results And Discussion

A. Changes in Temperature and Humidity

Fig. 3 shows the summer (April-September) mean temperature, mean maximum temperature and humidity scenario of different parts of Bangladesh from 1961-2010. From the figure it is apparent that SWR is more vulnerable to heat index as both the temperature and humidity bars show high value.

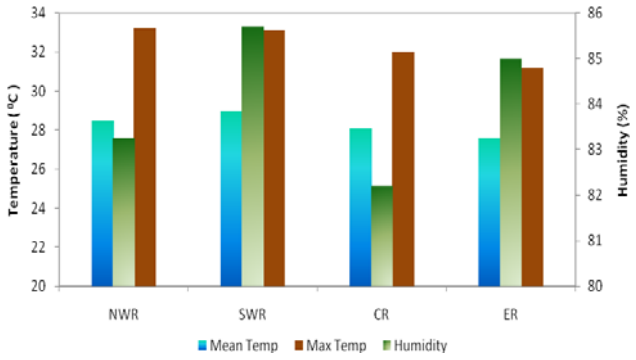

Fig. 3 Summer Temperature and Humidity Scenario in Different Parts of Bangladesh

TABLE I
Observed Change In Temperature And Humidity

Mean Maximum Temperature				
Years	**NWR**	**SWR**	**CR**	**ER**
1961-1990	32.97^{0}C	32.8^{0}C	31.76^{0}C	31.33^{0}C
1991-2010	33.47^{0}C	33.45^{0}C	32.28^{0}C	31.73^{0}C
Change	**+0.5^{0}C**	**+0.65^{0}C**	**+0.52^{0}C**	**+0.4^{0}C**
Mean Temperature				
1961-1990	28.37^{0}C	28.8^{0}C	27.9^{0}C	27.32^{0}C
1991-2010	28.52^{0}C	29.21^{0}C	28.24^{0}C	27.87^{0}C
Change	**+0.15^{0}C**	**+0.41^{0}C**	**+0.34^{0}C**	**+0.55^{0}C**
Humidity (%)				
1961-1990	81.5	85.78	80.4	84.97
1991-2010	85	85.64	83.8	85.1
Change	**+4.3%**	**-0.16%**	**+4.2%**	**+.15%**

Table I summarizes observed change in temperature over Bangladesh. Both the temperature and humidity are showing increasing trends in almost all the parts of Bangladesh except that the SWR is showing decrease of humidity. It is decreasing up to 0.16%. In the NWR the increase of maximum temperature in recent years is quite considerable. On the other hand comparatively small increase of temperature is observed in the very region in case of mean temperature. The changes of mean maximum temperature in SWR (+0.65^{0}C), mean temperature in ER (+0.55^{0}C) and humidity in NWR and CR (+4.3% and+4.2% respectively) between the period range of 1961-1990 and 1991-2010 are very significant.

B. Increase in Heat Index

Analysis of heat index shows that most of the country is under the effect of heat index and mean heat index value ranges from 42-50 ^{0}C in different parts of the country in summer which causes serious discomfort to the people of the

country. Bangladesh experiences highest value of heat index in the month of May when it crosses 60^0C in some parts of the country which causes many people to die due to heat stroke.

Heat index has increased in almost all part of the country. The trend drawn with the help of average (AMJJAS) heat index anomalies from 1961-2010 has shown tremendous rise in apparent temperature in SWR and NWR. The results are shown in Fig. 4 (a) and 4 (b). The total increase calculated is 5ºC and 4ºC in SWR and NWR respectively which is statistically significant at 95% confidence level. Fig. 5 shows the increase of heat index in different parts of the country. It is clear that the heat index increase governs in SWR and the increase becomes less gradually as it moves to the East.

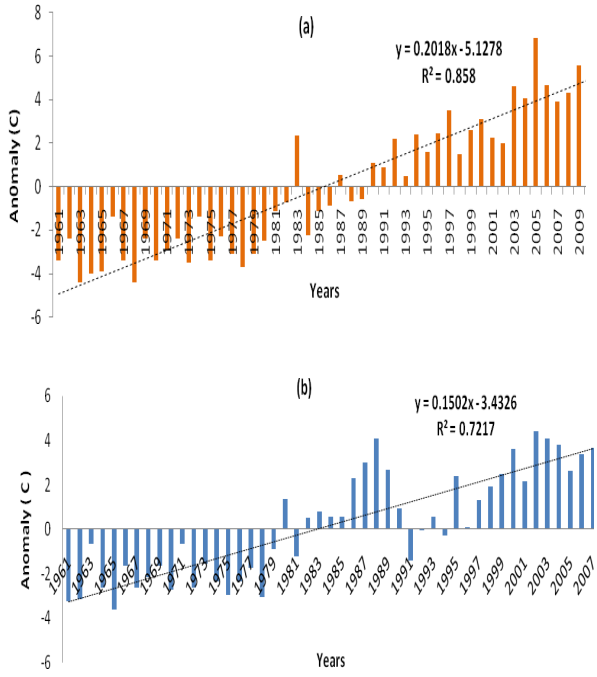

Fig. 4 (a) Heat index anomalies in SWR (Jessore station) 4 (b) Heat index anomalies in NWR (Rajshahi station)

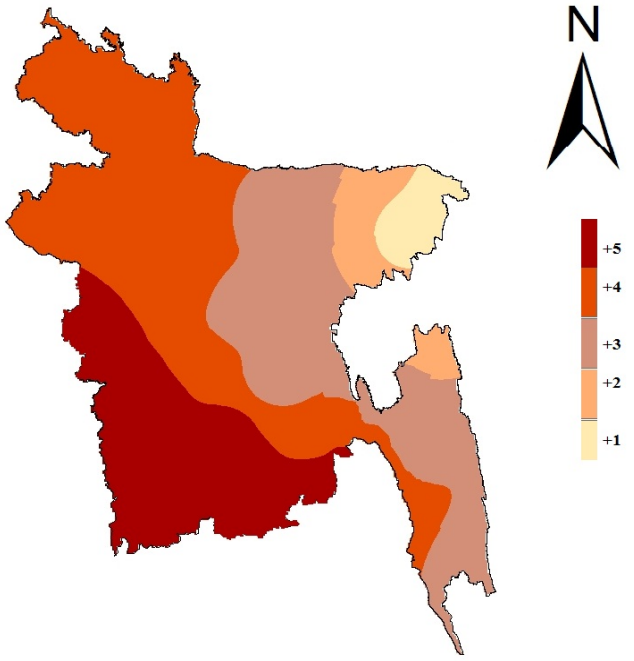

Fig. 5 Average heat index anomalies in different parts of Bangladesh during 1991-2010 with respect to 1961-1990

In Fig. 6 it is observed that in 2003, 2005 and 2007 many places over Bangladesh witnessed maximum extreme temperature to the tune of nearly 45^0C. The monthly mean temperature over the western part of the country was the highest in the last 48 years.

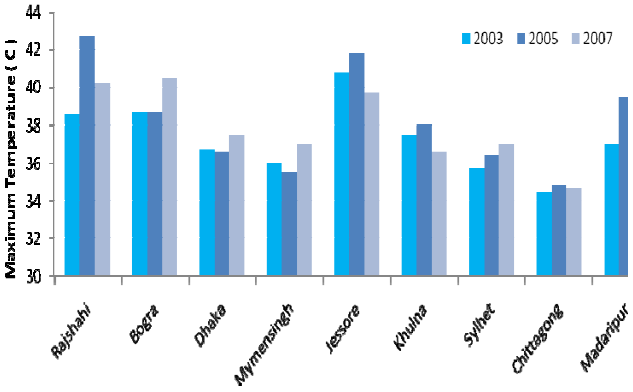

Fig. 6 Extreme maximum temperature in 2003, 2005 and 2007

In 2003 almost 62 people died due to extreme heat. In Fig. 7 heat index anomalies of 2003 and 2007 shows that it was severe in the western region of the country than the other parts.

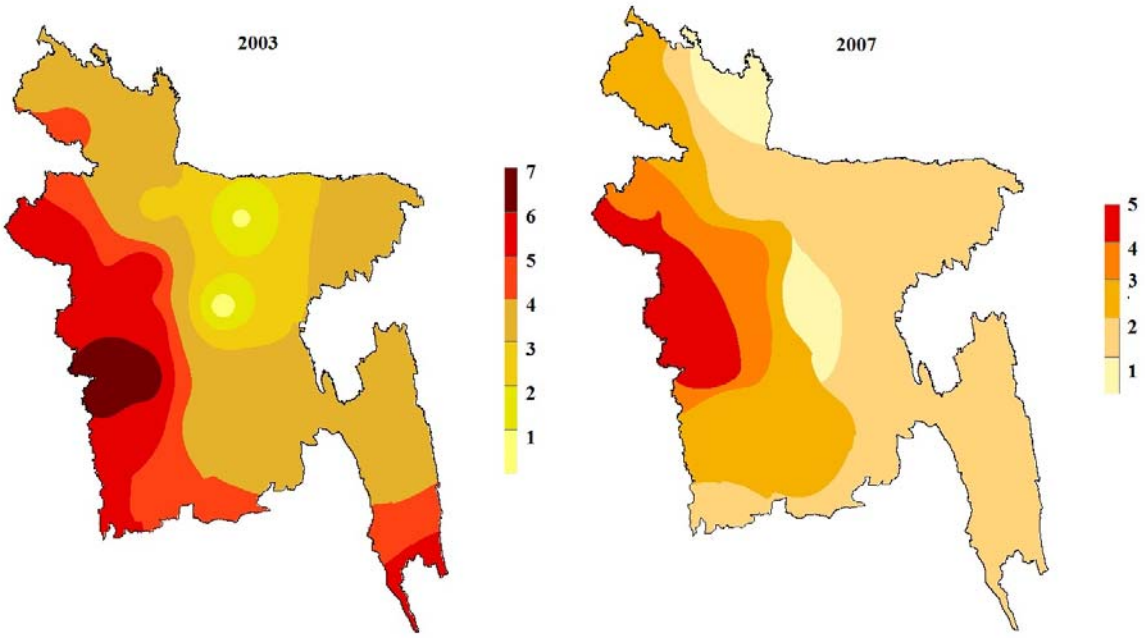

Fig. 7 Heat Index anomalies of 2003 and 2007 with respect to 1961-1990

IV. Conclusion

Heat index has become a matter of concern in the context of Bangladesh climatology along with most other countries. The heat index analysis from 1961-2010 in Bangladesh portrays the significant augment of both temperature and relative humidity in past 20 years. It is obvious that the global warming is responsible for the remarkable increase of maximum and mean temperature during summer. Besides adverse climatic condition, environmental pollution and the abatement and inconsistency of rainfall results in noticeably rising trend of humidity in north-west, central and eastern region. Evaluating the discomfort and health threat purpose it must be emphasized that both heat and moisture content play significant role in elevated heat index factor of Bangladesh. Mean heat index value ranges from 42-50 ^{0}C in different parts of the country in summer. Average (AMJJAS) heat index anomalies from 1961-2010 has shown tremendous rise in apparent temperature in SWR and NWR.

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