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# Statistical study of surface temperature and rainfall over four stations in north Bengal

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**सार** – इस शोध पत्र में उत्तरी बंगाल के कुछ चुनिंदा स्टेशनों के विगत 30 वर्षों (1979-2008) के आँकड़ों के आधार पर सतह तापमान और वर्षा के हाल ही के रूख का अध्ययन प्रस्तुत किया गया है। इस अध्ययन से पता चला है कि बहुत तेजी से विकसित हो रहे दो नगर जलपाईगुड़ी और माल्दा में गर्मी बढ़ रही है जिसके लिए इन जिलों में हो रहे आधारभूत सुविधाओं का विकास और तेजी से हो रहे शहरीकरण उत्तरदायी हैं। माल्दा में रिकार्ड की गई गर्मी का मान जलपाईगुड़ी में रिकार्ड किए गए तापमान से कहीं अधिक है और बैलूरघाट में यह कम पाया गया है। बैलूरघाट में ऋतुनिष्ठ और वार्षिक कुल वर्षा की मात्रा में भी काफी बढ़ोतरी हुई है। यहाँ वर्षा की तीव्रता में वृद्धि मुख्य तौर पर मॉनसून पूर्व और मॉनसून ऋतुओं के दौरान पाई गई है। इस प्रकार की बढ़ोतरी की वजह कम विकसित नगर बैलूरघाट की पर्वतीय और भौगोलिक स्थिति है।

**ABSTRACT.** This article presents the study of recent trends of surface temperature and rainfall over some selected stations of North Bengal based on 30 years' data (1979-2008). The study revealed that the degree of warming are more pronounced over two most rapidly developing towns of Jalpaiguri and Malda which may be attributed to rapid urbanization and infrastructure development taking place in the districts; the degree of warming observed over Malda being more pronounced than that over Jalpaiguri and it is the least over Balurghat. Also, the intensity of seasonal as well as annual cumulative rainfall over Balurghat is increasing more significantly; the increase in intensity being most significant during the pre-monsoon and monsoon seasons; the geographical location and orography of Balurghat, the least developed town, may be attributed to such an increase.

**Key words** – Linear trends, Regression equations, Test of significance, Temperature and rainfall.

## 1. Introduction

North Bengal is the northern part of West Bengal in India. The area is strategically located with Nepal, Bhutan and Sikkim in the north, the Gangetic Bengal on the south, Bangladesh and Assam in the east and Bihar in the west. Thus, the plains of North Bengal start from the south of Terai region and continue up to the left bank of the Ganges. The southern parts of the district Jalpaiguri, North Dinajpur barring some extreme northern regions, South Dinajpur, Malda and southern part of Cooch Behar districts constitute this geographical region (Fig. 1. Map of West Bengal). Jalpaiguri town lies in the middle of the vast fertile plains known as Terai, south of the Himalayas; whereas Cooch Behar is situated in the foothills of Eastern Himalayas towards north-east of West Bengal close to Assam. Malda, also called the gateway of North Bengal, is situated on the western bank of the River Mahananda, whereas, Balurghat, the headquarters of the South Dinajpur district in West Bengal, is a small municipal town known for its pollution free environment.

Of late, due to ongoing rapid urbanization/ industrialization of towns and cities, Global Warming or Climate Change, which is primarily caused by carbon-dioxide and other green house gases that trap heat in the atmosphere, thereby leading to increase in the atmospheric and sea-surface temperatures, and subsequent increase in the water vapor content and clouding etc. in the atmosphere has remained a burning issue to the scientific communities and researchers. Pramanik and Jagannathan (1954) examined the trends of maximum and minimum


**Fig. 1.** Map of West Bengal

temperatures of 30 meteorological stations of India and concluded that there was no general tendency for a systematic increase or decrease in maximum and minimum temperatures. Hingane *et al.* (1985) have studied long term trends of surface air temperature over India; and Thapliyal *et al*. (1991) climate changes and trends over India. Recent findings by Mukhopadhyay *et al*. (1999) have however confirmed that there is a clear signal of urbanization in these warming, that there is a steeper rise in minimum temperature also in urban location (De, 2001). Krishnamurthy and Shukla (2000) reported that the major drought years were characterized by large-scale negative rainfall anomalies covering nearly all over India and persisting for the entire I.S.M.S. and intra-seasonal variability of rainfall during I.S.M.S. was characterized by the occurrence of active and break phases.The trend shown by the various meteorological parameters are not uniform for all Indian cities; percentage number of days of maximum/minimum temperatures with a threshold values of >35 ºC / <10 ºC are decreasing/increasing respectively over north India (Prakasa Rao *et al*., 2004). Late studies have shown that the frequency of heavy rains during the southwest monsoon show increasing trend over certain parts of the country. On the other hand, decreasing trend is seen during winter, pre-monsoon and post-monsoon months. Dynamical and anthropogenic causes have been attributed for this variation (De, 2001). Agashe & Padgalwar (2005) studied some characteristic features of I.S.M.S. rainfall over nine selected stations of Madhya Maharashtra. They found that monthly rainfall and number of rainy days decreased over most of the stations during the period 1991-2000. With this aspect in mind, an attempt has been made to study the recent trends, if any, in the time series of seasonal/annual maximum temperatures, minimum temperature, rainfall and number of rainy days over four developing towns in North Bengal, *viz*., Jalpaiguri, Cooch Behar, Malda and Balurghat.

## 2. Data and methodology

Due to non-availability of data set, a total four number of stations of North Bengal have been selected for the present study, *viz*., Jalpaiguri, Cooch Behar, Malda and Balurghat. Rainfall, frequency of rainy days, maximum and minimum temperatures of Jalpaiguri (latitude: 26°32′N; longitude: 88°43′ E; altitude: 83 m), Cooch Behar (latitude: 26°20′ N; longitude: 89°28′ E; altitude: 43 m), Malda (latitude: 25°02′ N; longitude: 88°08′ E; altitude: 31 m) and Balurghat (latitude: 25°13′ N; longitude: 88°47′ E; altitude: 26 m) observatories for the period 1979 to 2008 have been collected on monthly basis from National Data Centre (NDC), Pune and Regional Meteorological Centre, Kolkata. In the case of missing values, methods of interpolation have been used based on the empirical regression equation: $S_{m1}/S_{d1} = r.\ S_{m2}/S_{d2}$; where $S_{m1}$, $S_{m2}$ are the mean of the parameters (rainfall/temperature) of two stations; $S_{d1}$, $S_{d2}$ are their standard deviation; and r is the correlation coefficient between them. Several rainfall and temperature parameters have been computed and analyzed in this study, *viz*., mean, maxima, minima, range etc. Monthly data have been averaged to arrive at seasonal, namely winter (January-February), Pre-monsoon (March-May), Monsoon (June-September), Post-monsoon (October-December) and annual statistics.

Based on the above data, existence of trends, if any, in the time series of each of the above mentioned parameters, for each of the selected stations, have been examined. A linear regression equation ($Y = a + b\ t$) model has been tried for the study and significance in trends have been tested by powerful Mann Kendall Rank statistics. The result of the trend analysis of each of the aforesaid parameters for each of the selected stations and overall trends over North Bengal (by considering the mean of each of the seasonal and annual parameters over the four stations) are summarized in Table 1.

**TABLE 1**

**Results of trend analysis of meteorological parameters**

| Parameters | Winter | | | | | Pre-monsoon | | | | | Monsoon | | | | | Post-monsoon | | | | | Annual | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JPG | CHB | MLD | BLG | NB | JPG | CHB | MLD | BLG | NB | JPG | CHB | MLD | BLG | NB | JPG | CHB | MLD | BLG | NB | JPG | CHB | MLD | BLG | NB |
| Mean max. temp | N | N | N* | P | N | N | N | N** | P | N | N | P | N | P | N | P | P | N** | N | N | N | P | N** | P | N |
| Highest max. | P | P | N | N | N | N | N | N | N | N | N | P | P | P | N | P | P | N | P | N | N | N | N* | N | N* |
| Mean min. temp. | P** | P | P* | P | P** | P** | P* | P | P* | P** | P* | P | N | N** | P | P** | P | P | P | P** | P** | P* | P | P | P** |
| Lowest min. | P* | P | N | N | P | P** | P** | P | P** | P** | P | P* | P | P | P | P* | P | P | P | P | P* | P | N | N | P |
| Diurnal range | N** | N** | N** | N | N** | N** | N* | N** | N** | N** | N | N | N | P** | N | N* | N | N** | N | N** | N** | N** | N** | N** | N** |
| Total rainfall | P | P | P | N | P | P | P | N | N | P | P | N | N | N | N | P | P | P | N | N | P | P | N | N | N |
| Highest daily rainfall | P | P | P | N | P | N | P | N | N | N | P | P | P | N | N | P | P | P | N | N | P | N | P | N | N |
| Mean frequency of rainy days | N | P | N* | N* | N | P | P | N | N** | N | P | P | P | N** | N | P | P | N | N* | N | P* | P | N | N** | N |

P : Increasing Trend, N : Decreasing Trend, * : Statistically significant at 95% confidence level, ** : Statistically significant at 99% confidence level, JPG : Jalpaiguri, CHB : Cooch Behar, MLD : Malda, BLG : Balurghat and NB,: North-Bengal

## 3. Results and discussion

### 3.1. *Yearly trends in temperature*

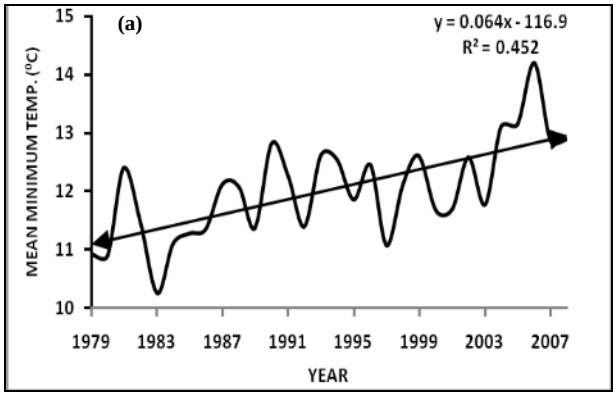
From the linear trend analysis depicted in Table 1, a decreasing trend in the mean maximum temperature has been observed over Malda during all the seasons and on the year as a whole; over Jalpaiguri (except in the post-monsoon season); over Cooch Behar in winter and pre-monsoon seasons; and over Balurghat during post-monsoon season only. The decreasing trend over Malda during pre-monsoon and post-monsoon seasons; and also on the year as a whole is found to be significant at 99% level of confidence.

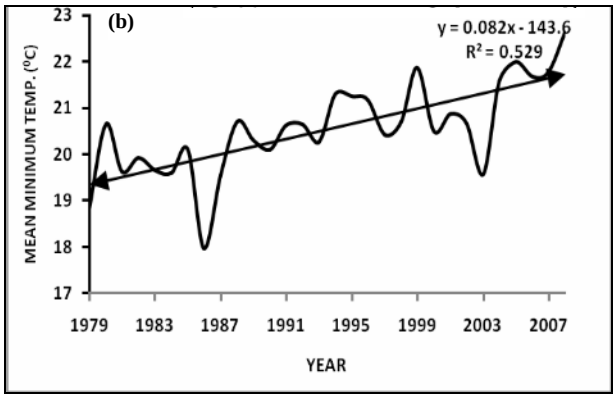
Also, a decreasing trend in the highest maximum temperature has been observed over Malda almost during all the seasons and on the year as a whole; over Jalpaiguri (except in winter and post-monsoon seasons); over Cooch Behar in pre-monsoon season only; and over Balurghat during pre-monsoon season and the year as a whole. The decreasing trend over Malda on the year as a whole is found to be significant at 95% level of confidence.

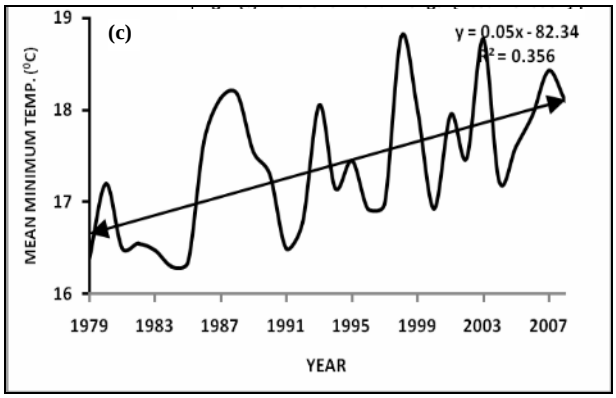
Further, an increasing trend in the mean minimum temperature has been observed over all the four stations under study almost during all the seasons and on the year as a whole. The increasing trend in the mean minimum temperature over Jalpaiguri during winter, pre-monsoon and post-monsoon seasons and also on the year as a whole is found to be significant at 99% level of confidence and during monsoon at 95% level. The increasing trend in the mean minimum temperature over Cooch Behar during pre-monsoon season and also on the year as a whole; and over Malda during winter season; and that over Balurghat during pre-monsoon season is found to be significant at 95% level of confidence. However, decreasing trend is observed over Balurghat during the monsoon season, which is found to be significant at 99% level of confidence.

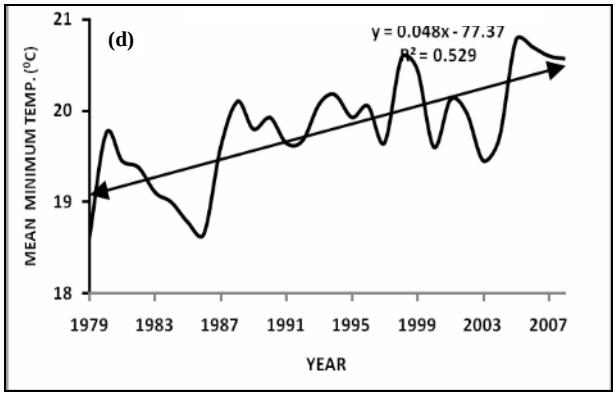
Also, an increasing trend in the lowest minimum temperature has been observed over Jalpaiguri and Cooch Behar during all the seasons and on the year as a whole; and over Malda and Balurghat during pre-monsoon, monsoon and post-monsoon seasons. The increasing trend in the lowest minimum temperature over Jalpaiguri during pre-monsoon season is found to be significant at 99% level of confidence; and that during winter and post monsoon seasons and also on the year as a whole is found to be significant at 95% level; and that over Cooch Behar during pre-monsoon season is found to be significant at 99% level of confidence and during monsoon at 95% level. The increasing trend over Balurghat during pre-monsoon season is also found to be significant at 99% level of confidence.

In order to ascertain the degree of warming over the four stations, linear trend analysis of diurnal range of temperature (mean monthly maximum minus mean monthly minimum) was also carried out. Accordingly, a decreasing trend in the diurnal range of temperature has

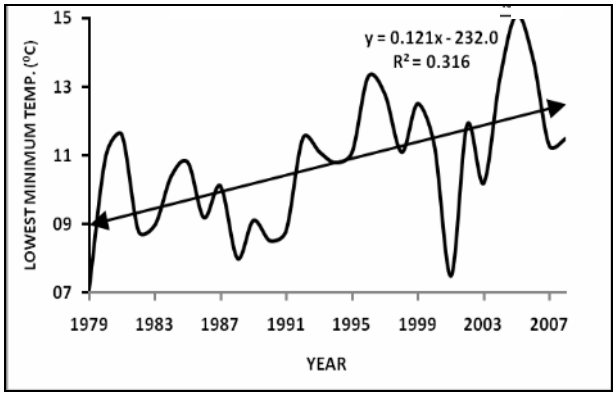



**Figs. 2(a-d).** Mean minimum temperature trends over North Bengal (a) winter (b) pre-monsoon (c) post-monsoon and (d) annual

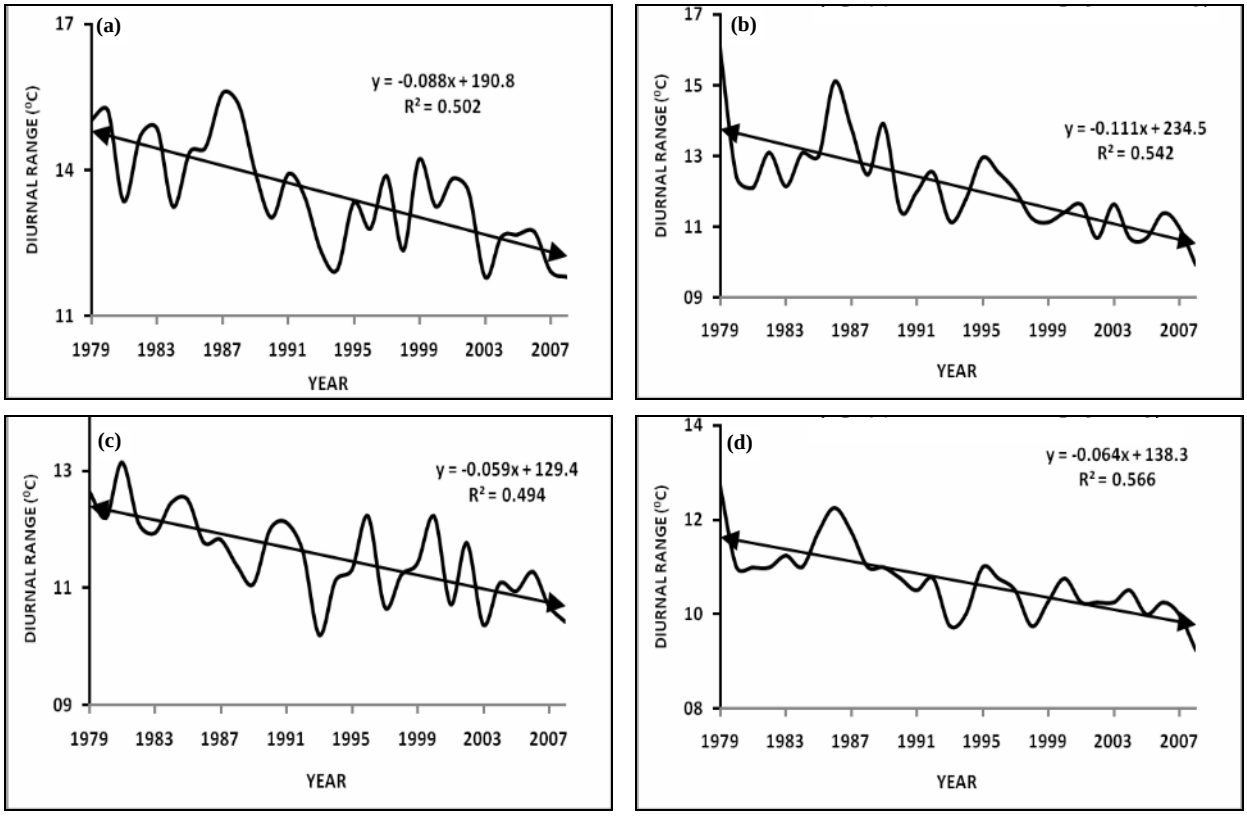



**Figs. 3.** Lowest minimum temperature trends over North Bengal (pre-monsoon)

been observed during all the seasons and on the year as a whole over Jalpaiguri, Cooch Behar, Malda and Balurghat (except monsoon season). The decreasing trend in diurnal range of temperature over Jalpaiguri during winter and pre-monsoon seasons and on the year as a whole; over Cooch Behar during winter season and also on the year as a whole; over Malda during winter, pre-monsoon and post-monsoon seasons and also on the year as a whole; and over Balurghat during pre-monsoon season and also on the year as a whole are found to be significant at 99% level of confidence. Evidently, the degree of warming is found to be more pronounced over two most rapidly developing towns of Jalpaiguri and Malda which may be attributed to rapid urbanization and infrastructure development taking place in the districts. The degree of warming observed over Malda is more pronounced than that over Jalpaiguri. Moreover, the degree of warming observed over Cooch Behar and Balurghat is less pronounced than that over Malda and Jalpaiguri; and it is the least over Balurghat, wherein an increasing trend in diurnal range of temperature during the monsoon is found to be significant at 99% level of confidence.

### 3.2. *Yearly trends in rainfall*

From Table 1, it has been found that the seasonal cumulative rainfall as well as annual cumulative rainfall show increasing trends over Jalpaiguri and Cooch Behar (except during the monsoon season); but show decreasing trends over Malda (except during winter and post-monsoon seasons) and Balurghat. Also, the highest daily rainfall show increasing trends during all the seasons over Cooch Behar; and that over Jalpaiguri and Malda (except during pre-monsoon season); but show decreasing trends over Balurghat. However, on the year as a whole, the highest daily rainfall show increasing trend over Jalpaiguri & Malda; and decreasing trends over Cooch Behar & Balurghat.




**Figs. 4(a-d).** Diurnal range trends over North Bengal (a) winter (b) pre-monsoon (c) post-monsoon and (d) annual

Further, the mean frequency of rainy days during all the seasons and the year as a whole show increasing trends over Jalpaiguri (except during winter) and Cooch Behar; but show decreasing trends over Malda (except during monsoon season) and Balurghat. The increasing trend in the mean frequency of rainy days over Jalpaiguri on the year as a whole is found to be significant at 95% level of confidence. The decreasing trend over Balurghat during pre-monsoon and monsoon seasons and the year as a whole are found to be significant at 99% level of confidence.

From the aforesaid trends, it is inferred that the intensity of annual cumulative rainfall over Jalpaiguri is decreasing significantly; whereas the intensity of seasonal as well as annual cumulative rainfall over Balurghat is increasing more significantly; the increase in intensity being most significant during the pre-monsoon and monsoon seasons. The geographical location and orography of Balurghat, the least developed town, may be attributed to such an increase in intensity of rainfall.

### 3.3. *Overall trends over North Bengal*

Overall trends over North Bengal have been arrived at by considering the average of each of the seasonal and annual parameters over the four selected stations which are depicted in Table 1. A decreasing trend is observed in the mean maximum temperature and the highest maximum temperature during all the seasons and on the year as a whole (highest maximum temperature being significant at 95% level of confidence). But increasing trend is observed in the mean minimum temperature during all the seasons and on the year as a whole, significant at 99% level of confidence (except during the monsoon season) [Figs. 2(a-d)]. Also, the lowest minimum temperature shows increasing trend during all the seasons and on the year as a whole; the trend being significant at 99% level during the pre-monsoon season (Fig. 3). Accordingly, the diurnal range of temperature shows decreasing trend during all the seasons and on the year as a whole, being significant at 99% level of confidence (except during the monsoon season) [Figs. 4(a-d)], implying a considerable degree of warming in the region during the last 30 years (1979-2008).

A decreasing trend is observed in the seasonal cumulative rainfall (except during winter and pre-monsoon seasons) as well as in annual cumulative rainfall, and a decreasing trend in mean frequency of rainy days during all the seasons (except during winter season) and on the year as a whole implying that the intensity of

rainfall is increasing although insignificantly. However, the highest daily rainfall shows decreasing trend during all the seasons and also on the year as a whole.

## 4. Conclusion

Following conclusions can be drawn from the present study.

(*i*) An increasing trend in mean minimum temperature over Jalpaiguri is found to be significant throughout the year (except during monsoon season) whereas a decreasing trend in mean maximum temperature over Malda is found to be significant throughout the year (except during monsoon season).

(*ii*) The decreasing trends in diurnal range of temperature are found to be significant throughout the year (except during monsoon season) over Jalpaiguri and Malda. Thus, the degree of warming are found to be more pronounced over two most rapidly developing towns of Jalpaiguri and Malda which may be attributed to rapid urbanization and infrastructure development taking place in the districts; the degree of warming observed over Malda being more pronounced than that over Jalpaiguri.

(*iii*) Also, a decreasing trend in the mean frequency of rainy days over Balurghat is found to be significant throughout the year (except during winter season). Thus, it may be inferred that the intensity of seasonal as well as annual cumulative rainfall over Balurghat is increasing more significantly; the increase in intensity being most significant during pre-monsoon and monsoon seasons. The geographical location and orography of Balurghat, the least developed town, may be attributed to such an increase.

(*iv*) Finally, a significant increasing trend is observed over North Bengal throughout the year (except during winter season) in the mean minimum temperature. Further, the lowest minimum temperature show increasing trend throughout the year whereas the diurnal range of temperature shows decreasing trend throughout the year (except during winter season), implying a considerable degree of warming in the region during the last 30 years (1979-2008). On the other hand, a decreasing trend in mean frequency of rainy days throughout the year (except during winter season) implies that the intensity of rainfall is increasing although insignificantly.

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