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Studies on recent changes in premonsoon season climatic variables over Gangetic west Bengal and its surroundings, India

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RESUMEN

Se ha hecho un estudio comparativo, con el fin de tratar algunos temas científicos tales como los cambios de las configuraciones en la precipitación y en la temperatura para la estación previa al monzón, durante el periodo 1973-1992, en el Bengal oeste del Ganges y su área, aunque la precipitación de premonzón contribuye únicamente cerca de 12% de la lluvia anual, es la máxima cantidad fuera de la estación del monzón.

También ocurre después de una amplia interrupción de 8 meses. Mientras construíamos la serie de datos se identificó una área en particular, donde la máxima reducción en precipitación ocurre en el periodo reciente, 1983-1992. El análisis estadístico con las series de datos, revela que la disminución en precipitación y el aumento en la temperatura media, en el mes de marzo, son estadísticamente significativos.

Abril y mayo tienen la misma tendencia, aunque no son estadísticamente significativos. La curva de diferencias integradas muestra, invariablemente una relación inversa entre la temperatura media y la precipitación.

ABSTRACT

A comparative study has been made in order to address some scientific issues like changes in precipitation and temperature patterns for the premonsoon season during the period 1973-92 over Gangetic West Bengal and its neighbourhood, a region in the eastern part of India. Though premonsoon precipitation contributes only about 12% of the annual rainfall, it is the maximum amount outside the monsoon season.

It also occurs after a wide gap of eight months. While constructing the data series, a particular area has been identified where maximum reduction in precipitation occurs in the recent period 1983-92. Statistical analyses with the data series reveal that decrease in precipitation and increase in mean temperature in the month of March are statistically significant.

April and May follow the same trend though they are not statistically significant. Integrated Differences Curve shows invariably a reverse associateship between the mean temperature and precipitation.

Key words: Gangetic West Bengal, premonsoon, thunderstorms

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1. Introduction

Premonsoon season (March-May) is a transition period from the winter circulation to the monsoon circulation in India. Usually, monsoon starts in the early June every year over the eastern part of India and continues until September. Afterwards, postmonsoon season (October-November) is the most susceptible for the formation of tropical cyclone over the sea, the Bay of Bengal. Normally depressions form over the Bay of Bengal during the postmonsoon season. Some of them get intensified and become cyclone or severe cyclone while crossing the coastline anywhere along the east coast causing a heavy/very heavy rainfall over the affected region. However, the frequency of tropical storms passing through a particular region is low and rainfall in the postmonsoon season as a whole is insignificant except in the case of cyclonic storm activity. In the winter season (December-February), this part of the country gets affected with an induced low pressure system due to the passage of the western disturbances over the Himalayan region. As a result, a few mm of rainfall occurs. Once monsoonal circulation ceases over the area, insignificant amount of rainfall occurs until premonsoon season. During premonsoon season the winds in the lower levels are weak while in the upper levels strong westerlies of the winter circulation still exist (Ahmed and Karmakar, 1993). Lower level winds are then expected to be controlled by local circulations. The study area experiences a hot summer as the maximum temperature often exceeds 38°C. It is only modulated by premonsoon thunderstorms (Shea and Sontakke, 1995). Due to this strong insolation, a southerly flow continues in the lower level from the Bay of Bengal. This flow has been identified as sea breezes (Lohar *et al.*, 1994) which generates thunderstorm at the sea breeze front. Sea breezes also help in the formation of nor'westers, a different type of premonsoon thunderstorm, by supplying low level moisture in the inland. Depending on the triggering mechanisms such as dryline (Weston, 1972), low level jet (Lohar, 1996; Patra *et al.*, 1999) etc., thunderstorms form sporadically over the area and as a result significant amount of rainfall occurs. Tropical cyclone also forms during premonsoon season, the frequency of which is much lower than that of the postmonsoon season.

Based on a single station observations within Gangetic West Bengal (GWB), i.e., at Kharagpur (22°21' N, 87°19' E), Lohar and Pal (1995) showed that mean monthly premonsoon season precipitation has decreased in the period 1983-92 compared to the earlier ten years period (1973-82), particularly in the month of March. As a result, increase in mean monthly temperature is also shown (Lohar and Pal, 1999) in a further study. The result is also well supported through radar observation of convective activity in the study area (Sadhukhan and De, 1998). Such changes in mean temperature and precipitation are stressed to be linked with changes in local circulations as a result of changes in land use pattern. In the present study, this has been extended to cover a wider region (20°N-25°N and 85°E-89°E) which includes a large number of stations over GWB. Various statistical analyses have been performed to examine the changes in precipitation and mean temperature pattern within the study area.

2. Data and analysis

The following data sets have been used for the study

Daily and monthly rainfall data for the months March through May for 123 stations over GWB and adjoining areas in the states of Bihar and Orissa, India were collected from the National Centre for Atmospheric Research (NCAR), USA for the period 1901 through 1970. The same have been collected from India Meteorological Department (IMD) for about 52 stations during the period 1901-92, a few of which, however, are common with NCAR data sets. In order to make a denser network of meteorological stations, daily rainfall data were also collected from the Agriculture Department, Govt. of West Bengal, India, for the period of 1971-92, for each of the months March to May, adding about 61 more stations. The distribution of different observational stations (Fig. 1), fairly represents all geographical and climatological variations over the study area.

Mean monthly temperature data for the same months during 1901-92 have been acquired only from IMD. Though the number of stations are less compared with rainfall observation stations, they are well distributed all over the domain and may be taken as the representative of the whole region.

In the present study, since the interest lies on the recent changes in rainfall and mean temperature; rainfall and temperature data analyses have been carried out for a period of 20 years (1973-92). It is because, a short term fluctuations in the long term precipitation data series is noticed after 1973 (Sadhukhan *et al.*, 2000). The first 10 years (1973-82) has been considered as one period while the other from 1983-92.

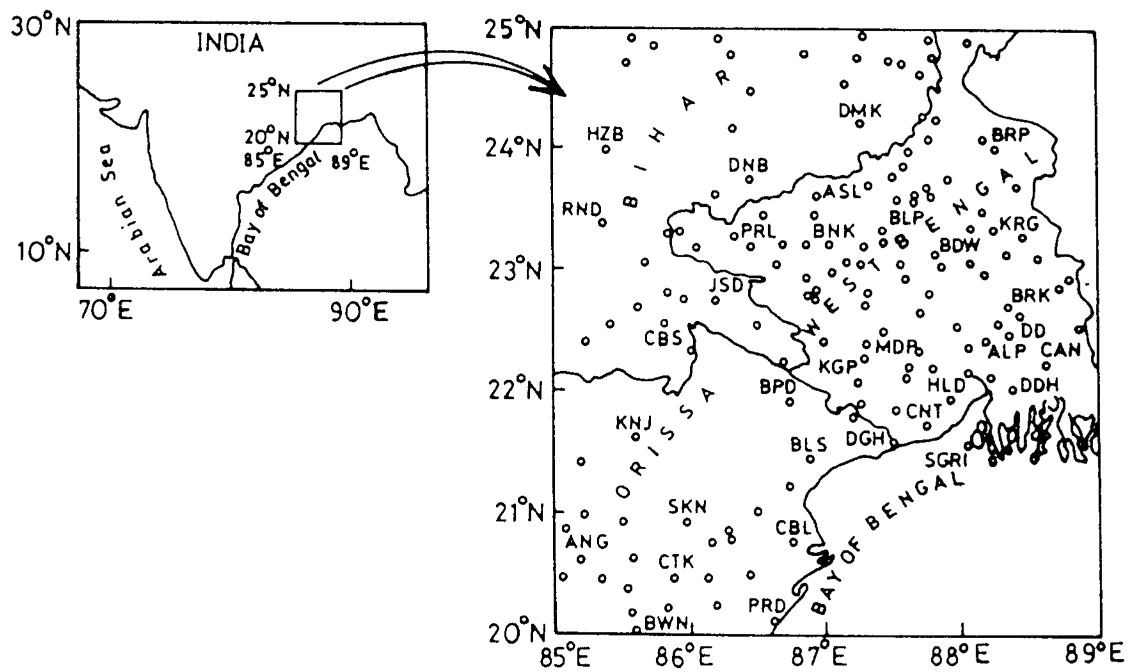

Fig. 1. Location of the study area showing the observation stations.

Examination of data for the twenty years period shows that in the premonsoon season only one tropical cyclone passed through the region during 25^{th} - 28^{th} May, 1989 (Mausam, 1990). As a result, a number of stations recorded heavy rainfall (Fig. 2). Since the premonsoon rainfall as a result of premonsoon thunderstorms is of great concern in this study, the amount of rainfall due to this cyclonic storm activity has been deducted while calculating the mean monthly rainfall for those stations. The difference in mean monthly rainfall (mm) in the two ten years periods has been calculated for all the stations for each of the premonsoon months (Fig. 3). The region near by Kharagpur, a station over the south eastern part of GWB, is well within the 30 mm contour showing significant decrease in mean monthly (March) rainfall in the later period (1983-92), which agrees with Lohar and Pal (1995).

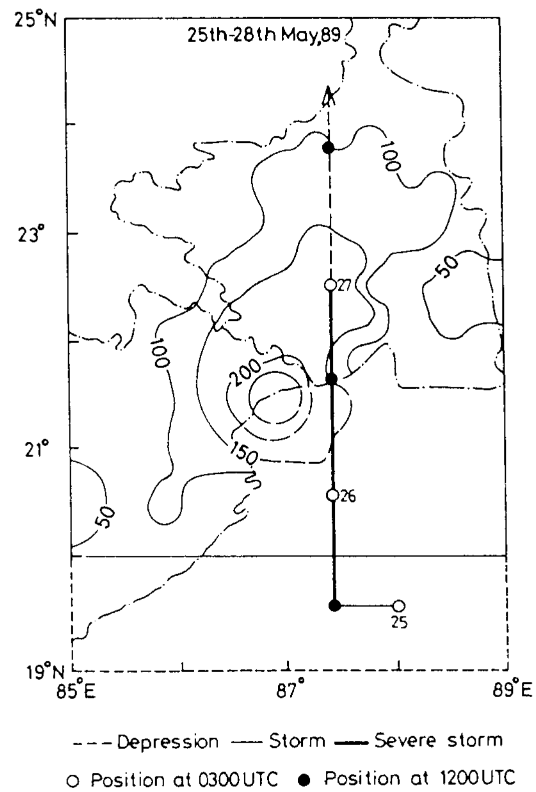

Fig. 2. Spatial rainfall pattern during the passage of tropical cyclone. Track of the cyclone has also been incorporated.

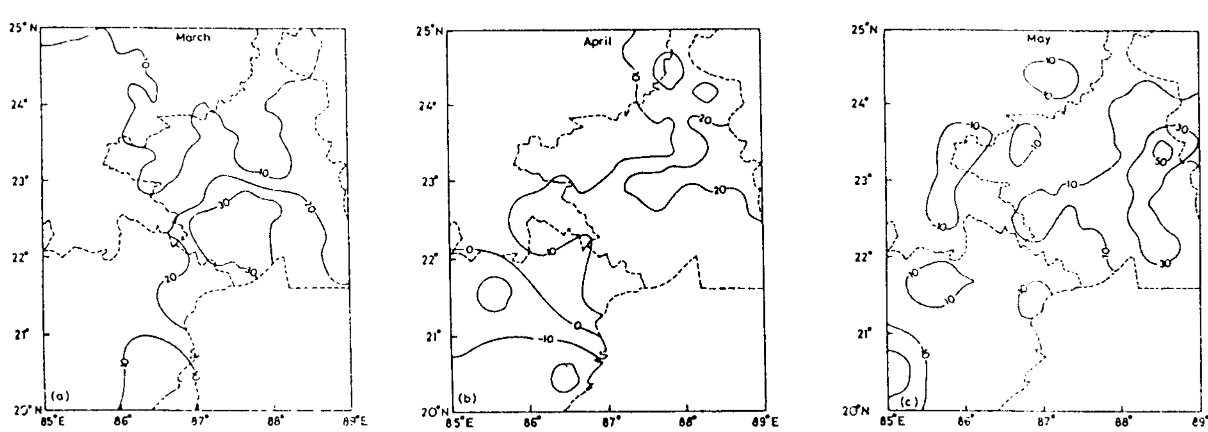

Fig. 3. Difference in rainfall (mm) in two periods 1973-82 and 1983-92.

A rainfall data series has been prepared for the month of March combining the stations lying within the 30 mm contour. Data series are also made with the same stations lying in this particular region for the month of April as well as for May. The temperature data series for each of the premonsoon months have also been prepared for the same region. With these data series statistical analyses have been made to find the changes in climatic variables during premonsoon season.

3. Results

Chi-square (Davis, 1973) and Kolmogorov-Smirnov (Press *et al.,* 1986) tests are applied to analyse the status of the rainfall series. Both the test statistics confirm that the data series for the months of March and May are non-Gaussian at 5% level of significance. However, the data series for the month of April is Gaussian.

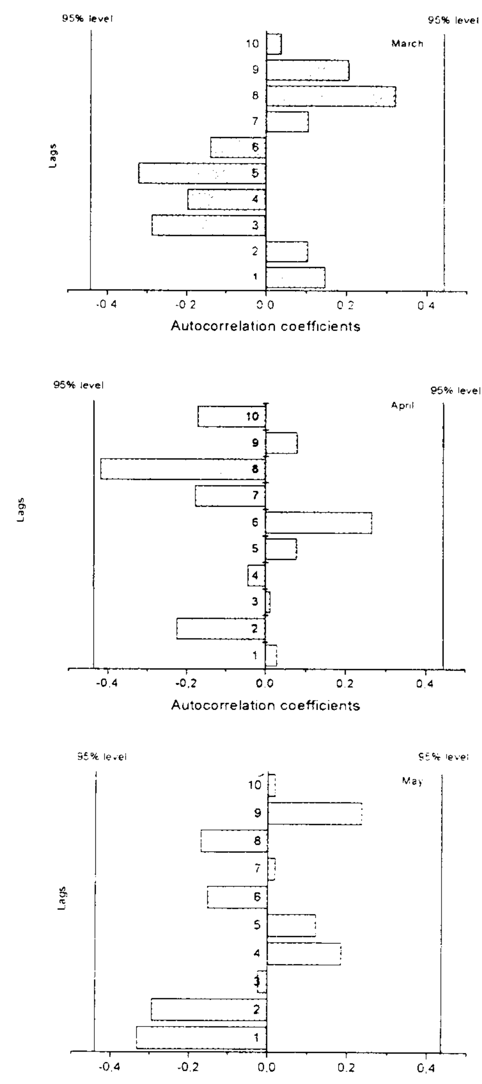

Fig. 4. Auto-correlation coefficients for March, April and May rainfall time series.

Wald-Wolfowitz test (WMO, 1966) for the non-Gaussian distribution (applied for March and May) and Anderson test (WMO, 1966) for the Gaussian distribution (applied to April) of the time series show the randomness of the series at 95% level of significance. The auto-correlation coefficients (Makridakis *et al.*, 1983) for the months March, April and May separately are given in the Figure 4. The three data series are also free from Markovian-type persistence (WMO, 1966) as the lag-one auto- correlation coefficient is insignificant at 95% level. The mean monthly rainfall along with standard deviation (SD) for the period 1973-82 and 1983-92 are given in Table 1.

Table 1. Mean monthly rainfall and their SD for the two periods 1973-82 and 1983-92.

Month	1973-82		1983-92	
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)
March	54.0	35.5	25.8	39.2
April	55.5	32.0	47.6	22.3
May (without cyclone)	115.7	68.9	108.4	36.2
May (with cyclone)	115.7	68.9	117.4	33.7

The Mann-Whitney test (Davis, 1973) is used as a non-parametric substitute for the student's t-test of the equality of the means of March and May data samples. The test suggests that the difference between the means in the case of March is significant at 5% level, and is insignificant in May. Student's t, on the other hand, a parametric test applied on the difference between the means for April gives the difference as insignificant.

Chi-square and Kolmogorov-Smirnov tests confirm the frequency distribution as Gaussian in case of temperature data series. The randomness of the time series for each of the premonsoon months, March through May, observed by Anderson test (WMO, 1966) and also through auto-correlation coefficient at 95% level of significance. The monthly mean and SD of the temperature in the two ten years period are shown in Table 2.

Table 2. Mean monthly temperature and their SD for the two periods 1973-82 and 1983-92.

Month	1973-82		1983-92	
	Mean (^{0}C)	SD (^{0}C)	Mean (^{0}C)	SD (^{0}C)
March	26.7	0.8	27.4	0.9
April	29.9	0.8	30.1	0.6
May	30.7	1.3	30.5	1.1

As in the case of rainfall, the difference between the mean temperatures in March is significant at 10% level according to t-test, while it is insignificant in April and May.

To inspect the association between the rainfall and mean temperature time series (1901-92), integrated differences curve (IDC) is used (Brito-Castillo *et. al.*, 1999). The IDC for each of the months separately (Fig. 5) well explains the reverse associationship between rainfall and temperature. During the hot summer days the mean temperature becomes high and comes down only when the thunderstorm occurs. In case of a thunderstorm event, the mean temperature remains low for at least a couple of days due to the shower and as a result, the mean monthly temperature decreases. So, the amount of precipitation whenever increases, the temperature decreases and viceversa.

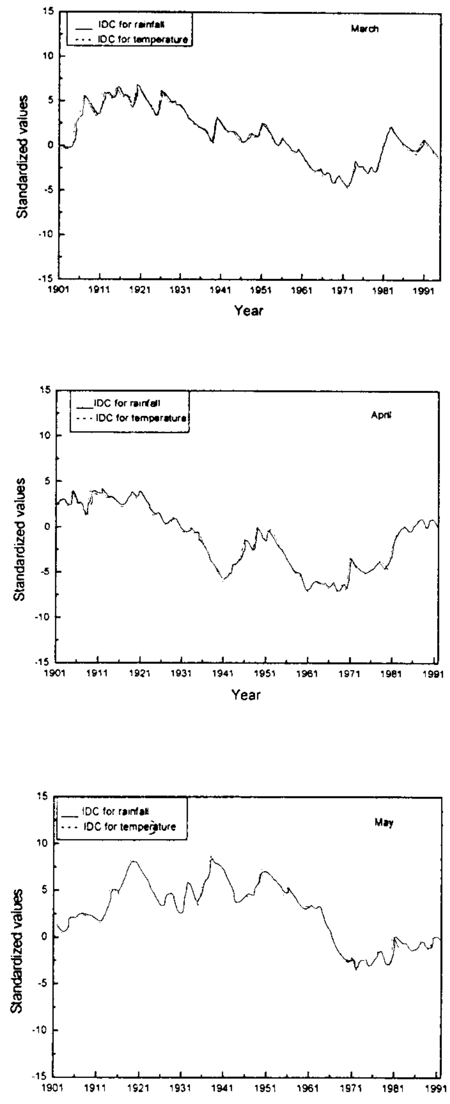

Fig. 5. Time series of precipitation and temperature as integrated differences curve.

4. Discussions and conclusions

Analysis of rainfall data over the area under study shows a decreasing tendency of rainfall in the second period (1983-92) compared to the first ten years period starting from 1973. It is noted that in the month of March, the rainfall decreases significantly (about 52%) in the later period over a large area which includes station like Kharagpur. Due to the decrease in rainfall, the mean temperature increases by 0.7°C, which is quite significant for a period of 10 years long. The same tendency in rainfall is also followed in the months of April and May. In April, about 14% decrease in rainfall with 0.2°C increase in mean temperature are noticed, though the difference is not statistically significant. A slight decrease in temperature (0.2°C) is noticed in the later period in May unlike March and April. This may be due to the passage of the tropical cyclone through the region. From the daily rainfall data the cyclone affected days were excluded while they are not excluded from the mean monthly temperature data due to the unavailability of daily temperature data. Moreover, it has been noticed that rainfall in the later period increases when the rainfall amount due to the cyclonic storm is considered (Table 1), showing again the inverse associationship between the mean temperature and rainfall.

A possible explanation behind such changes in rainfall is attributed to be a result of sharp change in land use pattern which took place over the area because of summer paddy (Boro) cultivation (Lohar and Pal, 1995). It has been started in the early Seventies and due to the increasing demand of food grains, the cultivation of summer paddy increased sharply in the Eighties and latter. Usually Boro crops are being cultivated during the winter season and harvested in the early April. As a result, during the month of March and to some extent in the month of April, soil moisture content over the land increases. This, in turn, decreases the temperature gradient between the land and sea surfaces. Hence, sea breeze activity over the area becomes less intense. So the moisture incursion from the sea towards inland decreases, causing lesser occurrence of convective activity over the area in the later period which agrees well with Sadhukhan and De (1998).

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