MAUSAM, **61**, 4 (October 2010), 547-552

551. 553.21 : 551.501 (541.2)

A statistical study of pre-monsoon weather over south Bengal using descriptive and inferential techniques

S. DASGUPTA and U.K. DE*

Department of Statistics, St. Xavier's College, 30 Park Street, Kolkata, India

**School of Environmental Studies, Jadavpur University, Kolkata, India*

(*Received 29 September 2008, Modified 15 June 2010*)

***e mail : deutpal2003@yahoo.com**

सार – भारतीय उपमहाद्वीप के पूर्वात्तर भाग में स्थित दक्षिण बंगाल में मानसून पूर्व स्थिति का सही–सही पता लगाने के लिए सांख्यिकीय आँकड़ों का संक्षेपण तकनीक, कर्व फिटिंग विधियों एवं आँकड़ा परीक्षण प्रचालानात्मक तथा अप्रचालानात्मक दोनों, को अपनाया गया है। यह शोध कार्य पश्चिमी पठार और ऊँची भूमि रढ़ तथा दक्षिण बंगाल के गांगेय क्षेत्र में फेले 15 प्रमुख वेधशालाओं में वर्ष 1969–2000 की अवधि के दौरान अभिलेखित आँकड़ों पर आधारित है। मानसून पूर्व वर्षा की समरूपता और भिन्न भिन्न स्टेशनों में इसकी भिन्नता का अध्ययन बार्टल्स और क्रस्कल वल्लीस परीक्षणों के उपयोग से किया गया है। इन स्टेशनों के लगातार 30 वर्षों की मौसम सूचनाओं का समय श्रेणियों के साथ विश्लेषण किया गया है। और इन क्षेत्रों में मानसून पूर्व वर्षा में हुए दीर्घावधि जलवायविक बदलाव, मौसमी और मौसम चक्र में हुए बदलाव का अध्ययन किया गया है। यह शोध पत्र क्षेत्रीय स्तर पर किए गए अध्ययन के बावजूद एक निश्चित प्रचालनात्मक और अप्रचालनात्मक परीक्षणें के उपयोग को दर्शाता है फिर भी जलवायु विज्ञान के संदर्भ में इसका अधिक उपयोग नही किया गया है।

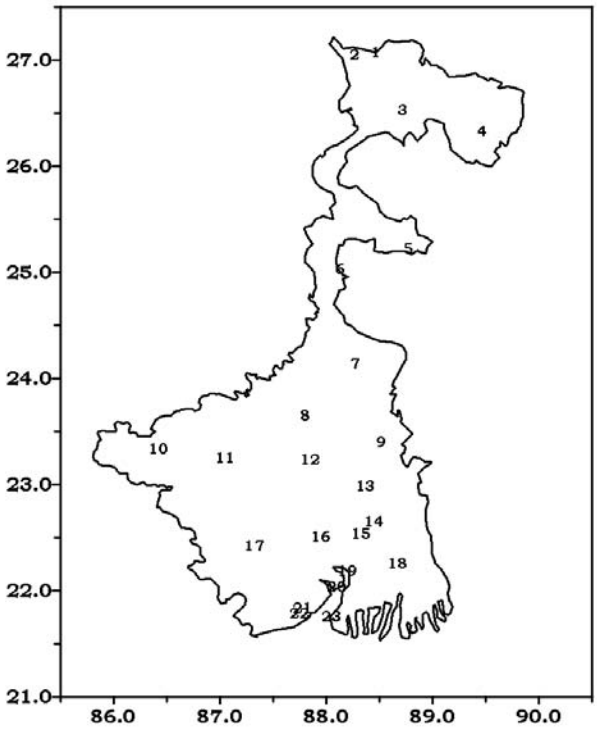
ABSTRACT. Statistical data summarization techniques, curve fitting methods and statistical tests, both parametric and non-parametric, have been applied to form a comprehensive idea about pre-monsoon weather over South Bengal situated in the northeastern part of the Indian sub-continent. The work is based on surface data recorded at 15 major observatories during the period 1969-2000, spread across the western plateau and highlands, Rarh and Gangetic region of South Bengal. The homogeneity of pre-monsoon rainfall and its variability over different stations has been studied using Bartlett`s and Kruskal Wallis tests. For stations with complete weather information for at least 30 consecutive years, time series analysis has been carried out on rainfall data for a climatological overview of long-term behaviour, seasonal and cyclical fluctuations of pre-monsoon rainfall in those areas. This paper, apart from being a regional study, highlights the use of certain parametric and non-parametric tests, not so widely used in the context of climatology.

Key words – Thundershower, Pre-monsoon season, Nor'wester, Bartlett's test for homogeneity, Kruskal Wallis test for homogeneity, Harmonic curve.

1. Introduction

West Bengal is geographically, culturally and ethnically the most diverse state in eastern India. With Bangladesh on its eastern border it forms the ethno-linguistic region of Bengal. To the northeast lie the states of Assam and Sikkim, to its southeast lies the state of Orissa. To the west it borders the state of Jharkhand and Bihar and to the northwest it borders Nepal. Stretching from the Himalayas in the north to the Bay of Bengal in the south, the state has a total area of 88,853 square kilometers. The state is bordered in the extreme north by the eastern Himalayas. After a brief Terai region bordering the Himalayan foothills belt starts the plains. The plains continue into the Ganges delta in the extreme south. The main river of West Bengal is the Ganga, which branches into the Hooghly and Padma on entering the state. The river Hooghly flows down South through West Bengal. The Padma enters the neighboring state of Bangladesh. Traditionally, the river Hooghly divides West Bengal into two regions (*i*) North Bengal and (*ii*) South Bengal.

Conventionally South Bengal comprises of all districts south of Maldah. Geographically South Bengal comprises of three conceivable regions. The Rarh region including the districts of Murshidabad, Birbhum, Bankura, Burdwan and parts of Midnapore intervenes between the



STATION NAME	INDEX	LAT	LON
KALIMPONG	1	27.07	88.47
DARJEELING	2	27.05	88.27
JALPAIGURI	3	26.53	88.72
KUCHBIHAR	4	26.33	89.47
BALURGHAT	5	25.22	88.78
MALDAH	6	25.03	88.13
BEHRAMPORE	7	24.13	88.27
SRINIKETAN	8	23.65	87.80
KRISHNANAGAR	9	23.40	88.52
PURULIA	10	23.33	86.42
BANKURA	11	23.25	87.05
BURDWAN	12	23.23	87.85
BAGATI	13	22.98	88.37
DUMDUM	14	22.65	88.45
ALIPORE	15	22.53	88.33
ULUBERIA	16	22.50	87.95
MIDNAPORE	17	22.42	87.32
CANNING	18	22.25	88.67
DIAMONDHARBOUR	19	22.18	88.20
HALDIA	20	22.03	88.10
DIGHA	21	21.83	87.78
CONTAI	22	21.78	87.75
SAGAR ISLAND	23	21.75	88.05
SANDHEADS	24	20.85	88.25

Fig. 1. Map of West Bengal with station locations

plateau and highlands of the extreme west (Purulia) and Gangetic West Bengal which includes the districts of Nadia, Hooghly, Howrah, North and South 24 Paraganas (Fig. 1).

The pre-monsoon season (March – May) in South Bengal is typically characterized by thundershowers popularly referred to as 'Norwester' or 'Kalbaisakhi'. These Norwesters which are usually predominant in hot tropical regions, are a result of the confluence of dry North–Westerly and hot, moist South – Easterly winds. Incidentally, all the thunderstorms in South Bengal in the pre-monsoon season are not norwesters, though around 50% of them are (Patra and De, 1997). The showers are a major source of rainfall over this region during this season. So, notwithstanding the damage they cause, these thundershowers are beneficial for agricultural activity, economy and human society at large. Consequently, they find an important place in meteorological research.

Basu (1982) has studied peak rainfall, expectation and trend of monsoon rainfall in Durgapur in South Bengal. Thunder squalls in Calcutta region were studied by Mukherjee *et al.* (1983). Chakraborty (1988) focused on the diurnal variation of relative humidity over Alipore in South Bengal and developed statistical approaches for forecasting of minimum relative humidity. Basu (1990) applied the method suggested by Eagleson (1970) to handle the problem of rainstorm depth and duration to study heavy rainfall spell over Calcutta. The density function of duration is taken to be Weibull-exponential and the density function for rainfall depth for each class interval of spell duration is fitted using the 2-parameter Gamma function. Biswas and Gupta (1993) studied the variability of southwest monsoon rainfall over entire West Bengal. Climatological studies and analyses of pre-monsoon thunderstorm frequency over Sriniketan, Alipore and Kalaikunda were undertaken by Kar and Bandyopadhyay (1996; 1998).

But as is apparent, there is hardly any reference on any comprehensive statistical study of pre-monsoon weather in general over South Bengal as a region or the homogeneity of the dominant weather characteristics over different areas of this region. The present work is an attempt to provide a comprehensive statistical overview of the dominant weather characteristics over entire South Bengal during the pre-monsoon months. The long-term behaviour of some of the weather patterns has also been studied. The homogeneity of the different weather

TABLE 1

Thunderstorm and rainfall statistics for major stations of South Bengal

Stations	Average no. of thunderstorms per season	Average duration of thunderstorms (in minutes)	Standard Deviation of duration of thunderstorms (in minutes)	Average monthly rainfall (in mm)			Average seasonal rainfall (in mm)	Maximum Daily Rainfall (in mm) during the period of study
				March	April	May		
Bankura	30	79.72	63.45	109.28	93.57	137.60	340.52	180.00
Behrampore	4	7.34	7.13	46.11	85.73	149.66	258.25	134.00
Purulia	20	10.09	12.22	33.40	36.66	71.48	140.25	124.00
Sriniketan	16	11.94	14.95	45.33	58.54	92.19	192.07	136.20
Krishnagar	3	12.85	10.46	44.57	61.65	150.25	256.51	804.00
Bagati	7	11.03	11.71	75.38	71.40	149.42	296.24	125.00
Midnapore	14	10.23	7.16	47.19	68.24	175.13	286.13	200.80
Uluberia	3	9.23	5.87	70.94	48.22	136.89	244.92	124.00
Alipore	21	19.00	18.67	38.40	63.37	147.76	240.44	123.00
DumDum	25	14.33	18.59	37.48	95.11	209.35	336.66	123.00
Diamond Harbour	10	12.47	10.19	43.50	60.70	139.32	243.58	290.70
Digha	14	15.80	12.80	32.69	45.01	151.53	234.97	260.80
Canning	14	16.12	10.51	44.42	77.35	130.46	239.76	615.00
Contai	15	10.26	7.80	43.31	37.06	98.89	179.26	99.80
Sagar Islands	11	14.47	13.37	61.77	68.72	101.13	231.60	134.40

characteristics within and between the different areas of the region has been studied using certain statistical tests; the use of which was hitherto unknown in the context of Indian climatology. Thus, apart from being a regional analysis, this paper focuses mainly on the use of data summarization and inferential techniques to draw meaningful information from meteorological data.

2. Data

The study over South Bengal is based on the pre-monsoon weather information recorded at 15 major surface observatories of the India Meteorological Department (IMD) located in this region at Behrampore, Purulia, Bankura, Sriniketan, Krishnagar, Bagati, Midnapore, Uluberia, Alipore, DumDum, Diamond Harbor, Digha, Canning, Contai and Sagar Islands. The data, which was acquired from the National Data Centre, IMD, Pune, has been recorded from 1969-2000 but in some stations data for some intermediate years are missing. However in no station is data recorded for less than 25 years.

3. Methodology

Frequency distributions were constructed for the time of commencement and duration of pre-monsoon thunderstorms and showers. The time of commencement was recorded in discrete time zones. The 24 hours of a day were divided into 8 time zones each comprising of 3 hours starting from mid-night. The mode of the frequency distribution of this discretized variable indicated the most frequent time of occurrence of a particular weather event. The average duration of a weather phenomenon together with its standard deviation was calculated using standard statistical formulae. Besides, the minimum, maximum, average and standard deviation of daily, monthly and accumulated seasonal rainfall were also computed for each station. The average number of rainy days per season was also calculated. While analyzing monthly rainfall, the accumulated rainfall for the available days for a particular month was extrapolated on a pro-rata basis to generate the rainfall figures for the entire month in case some data happened to be missing. However this was only applied in case data were available for at least 25 days of a month.

The total rainfall received in a particular month was recorded for the available years for a given station. The average of this set of rainfall figures gave the average rainfall of the month under consideration. The lowest of the rainfall figures for a particular month was taken as the minimum monthly rainfall for that particular month. Naturally therefore, the highest of the rainfall figures gave the monthly maximum.

Homogeneity of the different stations with respect to the average rainfall as well as variability in rainfall was studied using Bartlett`s (Goon *et al*., 1986a) and Kruskal Wallis test (Walpole and Myers, 1978). In addition, data for those stations with complete weather information for 30 consecutive years were subjected to harmonic analysis (Goon *et al*., 1986b) to model the observed oscillations in the data series.

4. Results and discussion

Unlike in North Bengal, in South Bengal there is a complete dominance of pre-monsoon thundershowers over other convective developments. In fact, isolated showers devoid of any thunderstorm development are completely absent in most parts of South Bengal during this season. It is also seen that thunderstorms strike most parts of South Bengal between 1500 hrs (IST) and 1800 hrs (IST) in the afternoon, with the exception of a few stations like Midnapore and Sagar Islands in the Gangetic belt, where these storms are most frequent between 1800 hrs (IST) and 2100 hrs (IST) in the evening.

The average number of thundershowers per season is seen to be highest in Bankura (30) and fairly high in Alipore (21), DumDum (25) and Purulia (20), but relatively low in Behrampore (4), Krishnagar (3), Bagati (7) and Uluberia (3). The average duration is seen to be highest at Bankura with unusually high average duration of 79.72 minutes and followed by Alipore meteorological station of Kolkata (19.0 minutes), Canning (16.1 minutes), Digha (15.8 minutes) and Sagar Islands (14.5 minutes). DumDum meteorological station in Kolkata, although in close proximity of Alipore records an average duration of about 14.3 minutes. Elsewhere the average duration varies between 9-12 minutes (Table 1).

The pattern of duration of thundershowers is seen to follow the exponential law almost everywhere in South Bengal. This is a statistical indication of the fact that thundershowers of lower duration are most frequent.

Maximum average rainfall in the month of March is recorded in Bankura (109.28 mm) and lowest in Purulia (33.40 mm). DumDum station of Kolkata records the highest rainfall on an average in April (95.11 mm), closely followed by Bankura (93.57 mm). Purulia records the lowest (36.66 mm). Although rainfall progressively increases from March to May over the entire region, DumDum and Purulia again record the highest (209.35 mm) and lowest (71.48 mm) average rainfall respectively in May. Bankura records the highest (340.32 mm) and Purulia the lowest (140.25 mm) rainfall on an average per season. The maximum daily rainfall during the period of observation is seen to be highest at Krishnanagar (804 mm) and lowest at Contai (99.80 mm) (Table 1). In case of the other stations the maximum daily rainfall lies within the range 100-300 mm.

TABLE 2

Periodicities (in years) in the rainfall series at major stations of South Bengal

Stations	March	April	May	Pre-monsoon season
Purulia	2.00	2.30	3.00	10.00
Midnapore	7.50	2.14	5.00	3.33
Alipore	2.00	3.33	2.70	3.33
DumDum	7.50	6.00	2.30	2.70

The Bartlett's test for variability of pre-monsoon rainfall over different stations stands rejected, indicating non-homogeneity in the variability of pre-monsoon rainfall. In general, variability is high in high rainfall areas and lower in low rainfall areas. As the different stations are not found to be homogeneous with respect to rainfall variance, therefore Kruskal Wallis test, which is the non-parametric analogue of the usual one-way analysis of variance technique, is applied. It is found that the average rainfall in the stations are more-or-less the same in the months of March, April and May.

Of the 15 meteorological centers, complete weather information for at least 30 consecutive years was available for Purulia, Midnapore, Alipore and DumDum. The series depicting rainfall received at these four stations during March, April May as well as the entire season of the different years is seen to exhibit insignificant trend. These series appear to be purely oscillatory in nature. Table 2 shows the estimated periodicities of the monthly and seasonal rainfall series for Purulia, Midnapore, Alipore and Dumdum as obtained from a Periodogram Analysis.

Harmonic curves are fitted to each of the above series using the periodicities obtained in Table 2 as

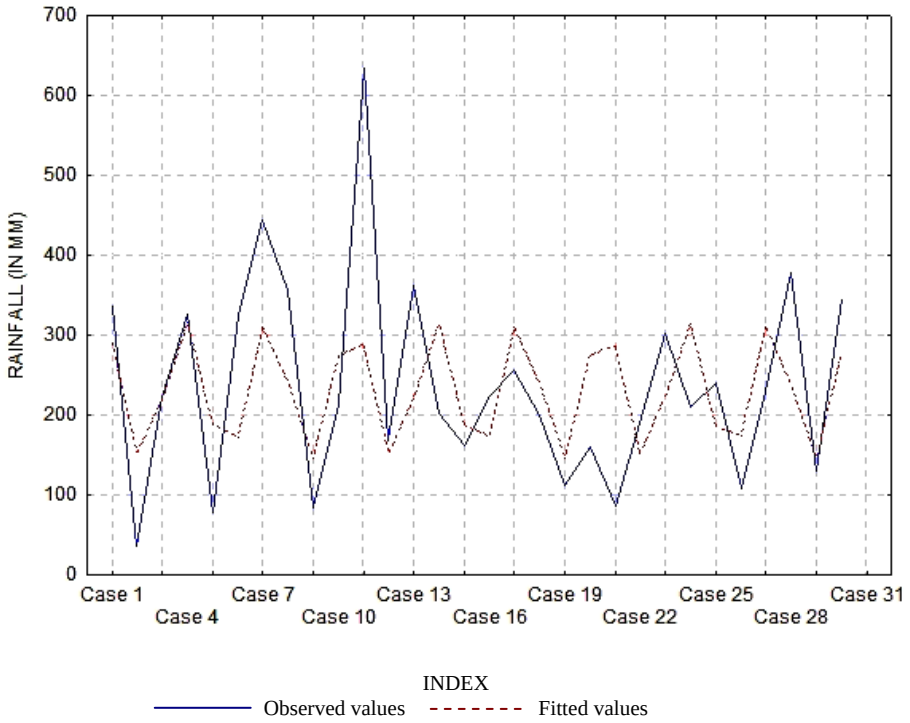


Fig. 2. Harmonic analysis of pre-monsoon rainfall at Alipore Station

estimates of the true periodicities. Fig. 2 shows the observed and predicted values (obtained from the fitted Harmonic curve) of seasonal rainfall at Alipore station of Kolkata. Case 1, 2,· · · etc. stand for the successive years. Similar figures for the remaining stations have been omitted to avoid repetition.

5. Conclusion

The pre-monsoon season over South Bengal is characterized by typical thundershowers popularly referred to as 'Norwesters'. These thundershowers are most frequent over the stations around late afternoon (3:00 pm – 6:00 pm) with a few exceptions. The average number of thundershowers per season over South Bengal varies from as low as 3-4 in some stations to as high as 20-25 to 30 in others. The average duration of thundershowers is seen to be highest in Bankura although in general, thunderstorms of shorter duration are more frequent over the entire region. Notwithstanding geographical diversities, the stations are found to be fairly homogeneous with respect to average pre-monsoon rainfall over different months as well as the entire season but not so with respect to rainfall variability. Variability is in general high in the high rainfall areas and lower in the low rainfall areas. Bankura records the highest number of thunderstorms in a season as well as the highest amount of seasonal rainfall on the average. DumDum station of Kolkata records the highest average rainfall in the months of April & May. Thunderstorms seem to be mainly dry over Purulia, which, despite a fairly high average number of thunderstorms per season, records an unusually low average daily, monthly and seasonal rainfall. The relative contribution of different months towards total seasonal rainfall is seen to be lowest in March and highest in May over the entire region.

The monthly and seasonal rainfall series for 30 consecutive years, wherever available, don't reveal any tendency to increase or decrease over time. Instead they are predominantly oscillatory in nature with varying periodicities. The propagation of these series can be modeled fairly well using standard sine-cosine curve.

Thus, apart from standard techniques of summarization of data, parametric and non-parametric tests have been successfully applied to form an idea of the homogeneity of a region with respect to a climatological

variable. Spectral analysis has also been carried out to form an idea of any recursive pattern in these climatological variables over years. The use of the approximate tests *viz*., Bartlett's and Kruskal Wallis is hitherto unknown in the context of regional climatology.

Acknowledgements

The authors are indebted to the National Data Centre, IMD, Pune for supplying valuable data from their archives and also to the Regional Meteorological Centre, IMD, Kolkata for helping us to fill in some of the gaps in the original data. The first author is personally indebted to Reverend Father P. C. Mathew, Principal, St. Xavier's College, Kolkata and the University Grants Commission, India for sanctioning leave under Faculty Improvement Program in order to pursue research activity in full earnest. The second author wishes to thank the Department of Science and Technology, Government of India, for sanctioning a research project of which this piece of work is a part.

References

Basu, G. C., 1982, "One day (24 hrs) peak rainfall expectation and trend of monsoon rainfall at Durgapur", *Vayu Mandal*, **3,** 105-108.

Basu, G. C., 1990, "Design of joint probability model of rainfall depth and duration during heavy rainfall over Calcutta", *Mausam*, **41,** 494-496.

Biswas, B. and Gupta, K., 1993, "Variability of southwest monsoon rainfall over West Bengal", *Mausam*, **44,** 353-358.

Chakraborty, K. K., 1988, "Diurnal variation of relative humidity over Calcutta (Alipore) and a statistical approach for forecasting minimum relative humidity", *Mausam*, **39,** 97-102.

Eagleson, P. S., 1970, "Dynamic Hydrology", McGraw Hill Book Company Inc., USA.

Goon, A. M., Gupta, M. K. and Dasgupta, B., 1986a, "Fundamentals of Statistics" Vol. I., World Press.

Goon, A. M., Gupta, M. K. and Dasgupta, B., 1986b, "Fundamentals of Statistics" Vol. II., World Press.

Kar, I. and Bandyopadhyaya, R., 1996, "Analysis of pre-monsoon thunderstorm frequency over Sriniketan and Kalaikunda- The possible association with solar activity", *Mausam*, **47**, 383-394.

Kar, I. and Bandyopadhyaya, R., 1998, "A climatological study of pre-monsoon thunderstorm frequency over Sriniketan, Alipore and Kalaikunda", *Mausam*, **49**, 262-264.

Mukherjee, A. K., Sen, P. N. and Chakraborty, K. K., 1983, "Dependence of diurnal variation of thunderstorms on physical features" *Vayu Mandal*, **3**, 105-108.

Patra, A. K. and De, U. K., 1997, "Role of a surface parameter on pre-monsoon thunderstorm days at DumDum (22.38° N, 88.28° E), Calcutta", *Indian Journal of Radio & Space Physics*, **26**,121-125.

Walpole, R. L. and Myers, R. H., 1978, "Probability and Statistics for Engineers and Scientists", Macmillan.