

Diurnal Rainfall Variation of Bangalore HAL Airport

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ABSTRACT: Diurnal rainfall variation of Bangalore HAL Airport station is analyzed here both temporally and seasonally. Three distinct seasons, Pre-Monsoon, Monsoon and Post Monsoon and two time periods (1969-1988 and 1989-2008) are considered in this study. The results indicates that in the recent years, frequency and amount of late afternoon and evening storms have increased and declines are noted in the rainfall between midnight and early afternoon. The increase in the late afternoon rain is mostly due to increase in convective rainfall which is most prominent in the summer or Pre-Monsoon season. The possible reason may be urbanization and change in circulation pattern which needs to be studied in detail to arrive at meaningful conclusion.

KEYWORDS: Urbanization, Rainfall, Diurnal Rainfall Distribution, Seasonal Rainfall.

I. INTRODUCTION

Variability of rainfall over short time scales, such as diurnal variations, is significant aspect of regional climate since precipitation occurring regularly during a specific time of the day is a result of complex interaction of regional and local dynamics and atmospheric circulation. Studying the diurnal variations and explaining its characteristics will deepen our knowledge of the rainfall generating mechanism and its influencing factors. The change in diurnal cycle of rainfall signifies a gradual change in climate patterns on the region. Urbanization can lead to adjustments in local precipitation pattern and mechanisms leading to changes in the diurnal cycle of rainfall (Balling and Brazel, 1987). Hence, the study of long term changes in diurnal cycle is necessary to find out any urban induced change in rainfall pattern.

Burian and Shepherd (2005) studied the impact of urbanization on diurnal rainfall pattern of the Houston metropolitan area by analysing data from 19 rain gauges located within and nearby Houston, USA. The diurnal patterns were compared within pre-urbanisation (1940–1958) and post-urbanization times (1984–99) for main urban area, upwind and downwind of the main urban area. It has been observed that the changes in diurnal pattern are most for urban areas (25% increases), whereas the majority of the increase is observed in the afternoon time, indicating an increase of convective rainfall in the summer time due to urban heat island effect. The rainfall in upwind area is found to be reduced in amount. For the period 1984 to 1999, the urban area along with downwind urban-impacted region registered greater rainfall amounts by 59% and 30% respectively, starting from noon to midnight as compared to upwind control region. They suggested that the changes in rainfall pattern due to urbanization should be factored into the urban drainage infrastructure design. Balling and Brazel (1987) analysed the summertime rainfall patterns for Phoenix, Arizona for the period 1954 through 1985. They found the diurnal pattern of rainfall to be changing during the period of urban growth, while the mean rainfall amount did not show any significant change. The late afternoon and evening storms have become more intense and frequent while there is a significant reduction in rainfall during the early hours of the day. Using the TRMM data, Kishtawal and Krishnamurti (2001) found that convective rainfall incremented during the late afternoon over Taiwan due to localized mass convergence caused resulted by the sea breeze. Hu (2003) studied multi-decadal fluctuation in summer season diurnal rainfall in central United States and concluded that in the decades when the southerly flow originated from the Gulf of Mexico dominated mechanism of rainfall, the diurnal pattern had large rainfall during late night/morning hours along with a sharp rainfall peak occurring in the midnight hour. During decades when the effect of southerly flow weakened, a dissimilar diurnal pattern emerged, having small late night/morning hour rainfall along with high rainfall occurring in the hours of late night/early morning. In an extensive study, Jung *et al.* (2001) studied 220 year precipitation series of Seoul, S. Korea, and divided the record into three periods – two wet period and one dry period. The two wet periods showed similar type of diurnal rainfall patterns of peak in early morning and minimum in the late night, but the dry period showed a different diurnal rainfall distribution. Yin *et al.* (2008) analysed

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the spatial distribution and seasonal alteration of diurnal variations of precipitation in the warm season (May to September) over China by use of hourly data obtained from 62 rain gauges during time period 1954–2001. Most of the studies on diurnal variation of precipitation over India were conducted long time ago (see in Basu, 2007). Recently, Basu (2007) studied the observed patterns of diurnal variation of rainfall over India during summer monsoon of 2004 using satellite derived hourly precipitation values. Hence, there is no study at all of long term changes in diurnal variations of rainfall, and that too for any urban area. In this study, this novel work was done for the Bangalore HAL airport.

II. DATA AND METHODS

The raw rainfall data base for this study consists of the hourly rainfall data collected from India Meteorological Department (IMD) Pune and IMD Bangalore for the 1969–2008 periods. From the raw data, several rainfall matrices were prepared in order to calculate the different parameters to quantify the changes diurnal rainfall patterns. The total data consists of 40 years. The total time period is divided into sub-period of 1969–1988 and 1989–2008 signifying the rate of urbanization assuming that the later sub-period will have more urbanization effect. The daily 24 hours is grouped into six parts following the recommendation of IMD, Pune. The seasons were divided as per the recommendation of IMD, Pune.

The statistical Wilcoxon Ranksum test was used to quantify the statistical significance of rainfall changes. The Wilcoxon Ranksum Test is one of the most powerful of the nonparametric tests for comparing two populations. It is used to test the null hypothesis that two populations have identical distribution functions against the alternative hypothesis that the two distribution functions differ only with respect to location (median), if at all. The Wilcoxon Ranksum Test does not require the assumption that the differences between the two samples are normally distributed. In many applications, the Wilcoxon Ranksum Test is used in place of the two sample t-test when the normality assumption is questionable. The methods are described briefly below: The data of the two samples x and y are combined and arranged in order of increasing size and given a rank number. In cases where equal results occur the mean of the available rank numbers is assigned. The rank sum R of the smaller sample is now found. Let N denote the size of the combined samples and n denote the size of the smaller sample. A second quantity

$$R_1 = n(N + 1) - R$$

is now calculated. The values R and R_1 are compared with critical values. If either R or R_1 is less than the critical value the null hypothesis of equal means would be rejected.

III. RESULTS AND DISCUSSION

In the urban area, due to urban heat island effect and precipitation forming mechanism, distinct diurnal cycle of rainfall can be observed. And changes in this diurnal cycle can be interpreted as a possible effect of urbanization on precipitation forming mechanism. Although, details cause of this changes are not studied in this paper but preliminary analysis have been undertaken to show that this type of changes is happening in Bangalore HAL airport area. Figure 1 and 2 indicted the general pattern of diurnal rainfall variations over Bangalore HAL airport area. The contribution of heavy rainfall starts to increase from late afternoon and in the evening time, there is tendencies of more occurrence of heavy rainfall. In the day time, drizzles dominate the rainfall amount and occurrences. This may be due to intensification of the rainfall causing mechanism due to higher convection due to UHI.

In order to investigate the changes in this diurnal pattern, the diurnal rainfall distribution of two time slice (1969–1988 and 1989–2008) have been compared and Wilcoxon Ranksum Test was done to quantify the statistical significance of these changes. The results (Figure 3, 4 and 5) indicates that late afternoon and evening storms have become more frequent and produce greater rainfall totals. Declines are noted in the frequency of rain events between early morning and noon; especially heavy rainfall occurs in the rainfall amounts between 16.00 and 20.00 IST. Statistical ranksum test results indicates that the changes in rainfall amount in 16–20 hours (Annual and Pre Monsoon season) and 12–16 hours in Monsoon season is statistically significant at 90% confidence level (Table 1 and Table2).

TABLE 1

RESULTS OF THE WILCOXON RANKSUM TEST BETWEEN TWO TIME PERIODS (1969–1988 AND 1989–2008) FOR BANGALORE HAL AIRPORT SEASONAL RAINFALL. THE VALUES INDICATE THE P-VALUES OF THE TEST. VALUES LESS THAN 0.05 MEANS STATISTICALLY SIGNIFICANT AT 5 % SIGNIFICANCE LEVEL (A)

Time of the day	Pre Monsoon	Monsoon	Post Monsoon	Annual
0–4	0.68	0.47	0.71	0.29
4–8	0.59	0.82	0.42	0.24
8–12	0.65	0.44	0.23	0.26
12–16	0.57	0.05	0.10	0.51
16–20	0.02	0.47	0.14	0.06
20–24	0.15	0.06	0.84	0.11

TABLE 2

RESULTS OF THE WILCOXON RANKSUM TEST BETWEEN TWO TIME PERIODS (1969–1988 AND 1989–2008) FOR BANGALORE HAL AIRPORT SEASONAL RAINFALL. THE VALUES INDICATE THE P-VALUES OF THE TEST. VALUES LESS THAN 0.05 MEANS STATISTICALLY SIGNIFICANT AT 5 % SIGNIFICANCE LEVEL (A)

Time of the day	Light Rainfall				Moderate Rainfall				Heavy Rainfall			
	PreM	Monsoon	PostM	Annual	PreM	Monsoon	PostM	Annual	PreM	Monsoon	PostM	Annual
0–4	0.84	0.18	0.58	0.12	0.32	0.84	0.58	0.97	0.93	0.22	0.69	0.49
4–8	0.45	0.85	0.46	0.22	0.98	1.00	0.31	0.69	1.00	0.86	0.61	0.92
8–12	0.65	0.39	0.20	0.30	0.16	0.69	0.73	0.46	0.34	0.40	0.34	0.61
12–16	0.59	0.05	0.68	0.32	0.20	0.04	0.07	0.13	0.97	0.93	0.42	0.99
16–20	0.28	0.95	0.34	0.76	0.03	0.47	0.79	0.09	0.12	0.73	0.03	0.08
20–24	0.11	0.69	0.90	0.46	0.34	0.31	0.18	0.60	0.42	0.15	0.58	0.13

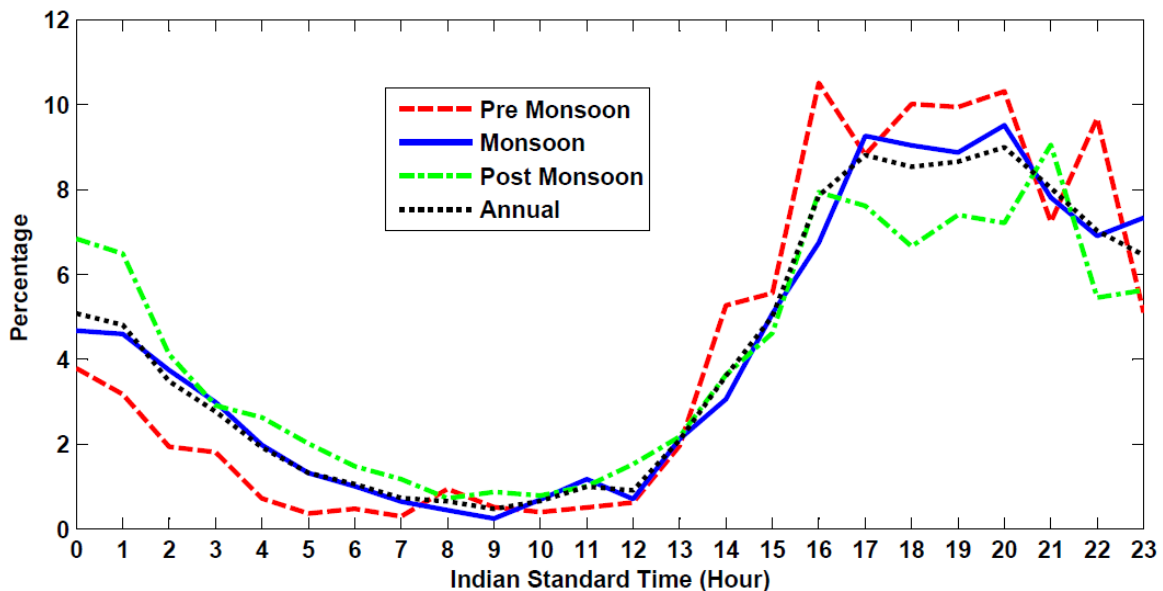


Fig. 1 Seasonal distribution of diurnal rainfall pattern

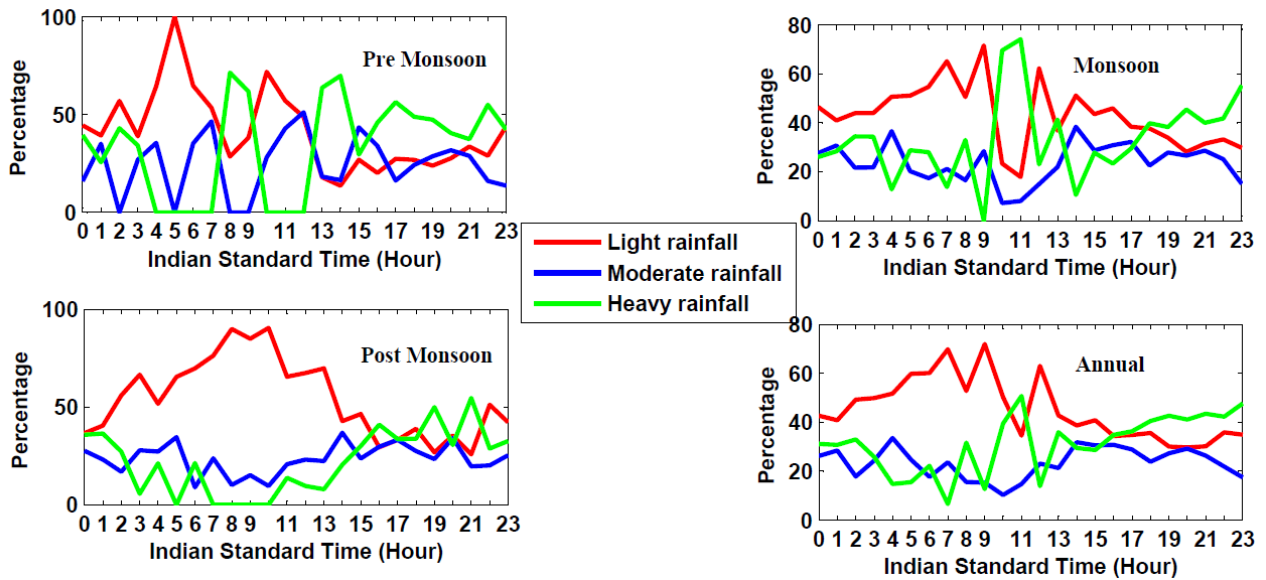


Fig. 2 Diurnal rainfall distribution of different intensities

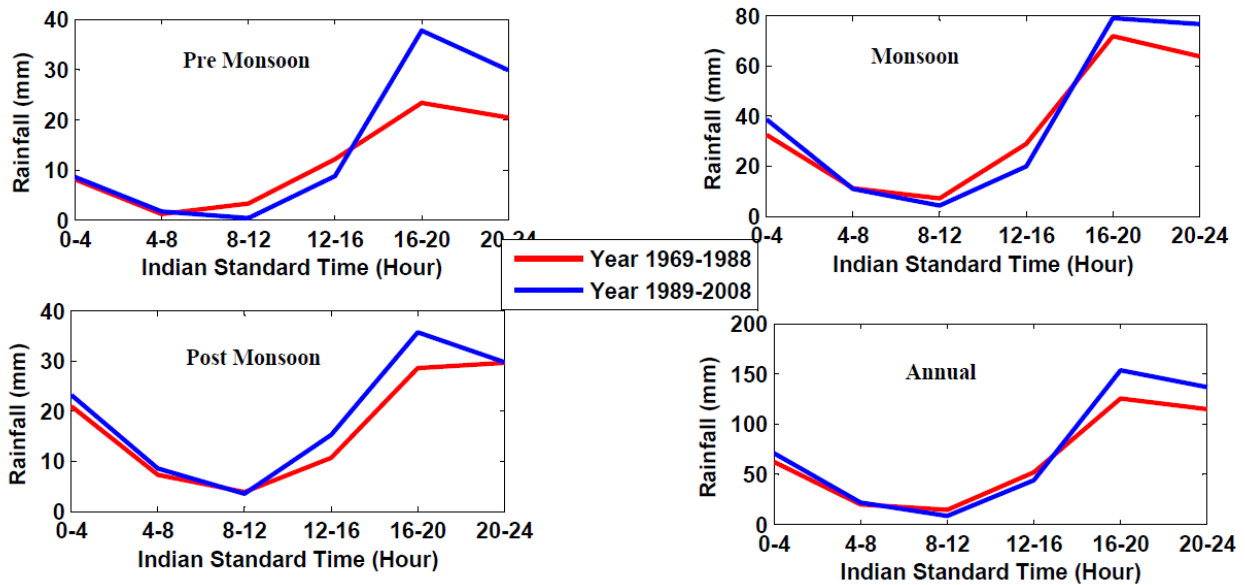


Fig. 3 Change in diurnal rainfall distribution

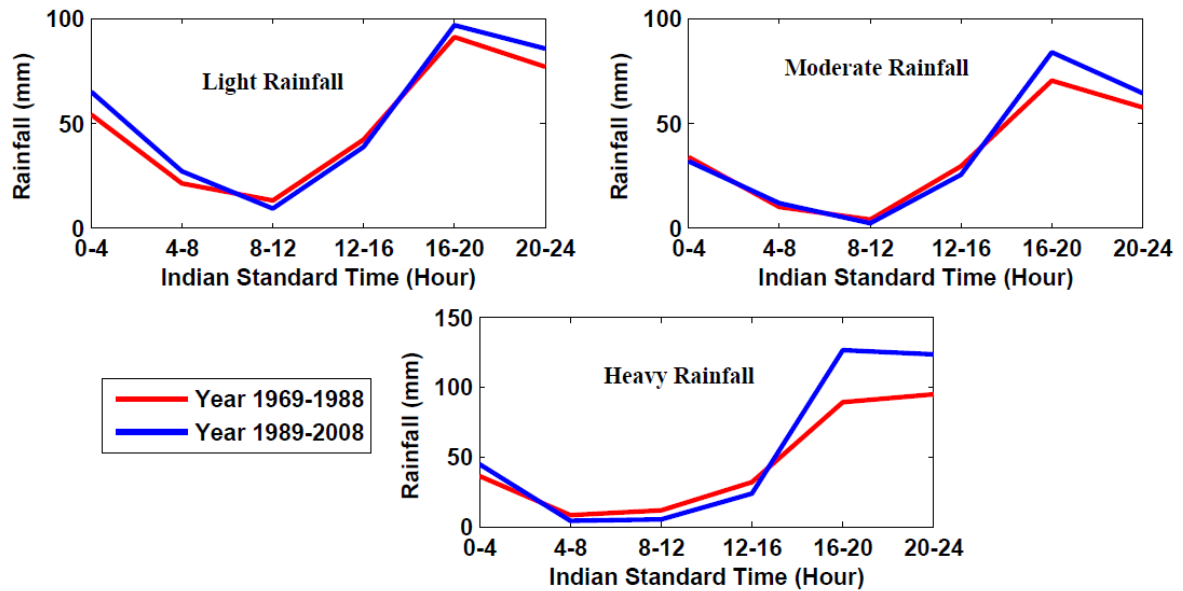


Fig. 4 Change in annual diurnal rainfall distribution of different Intensities

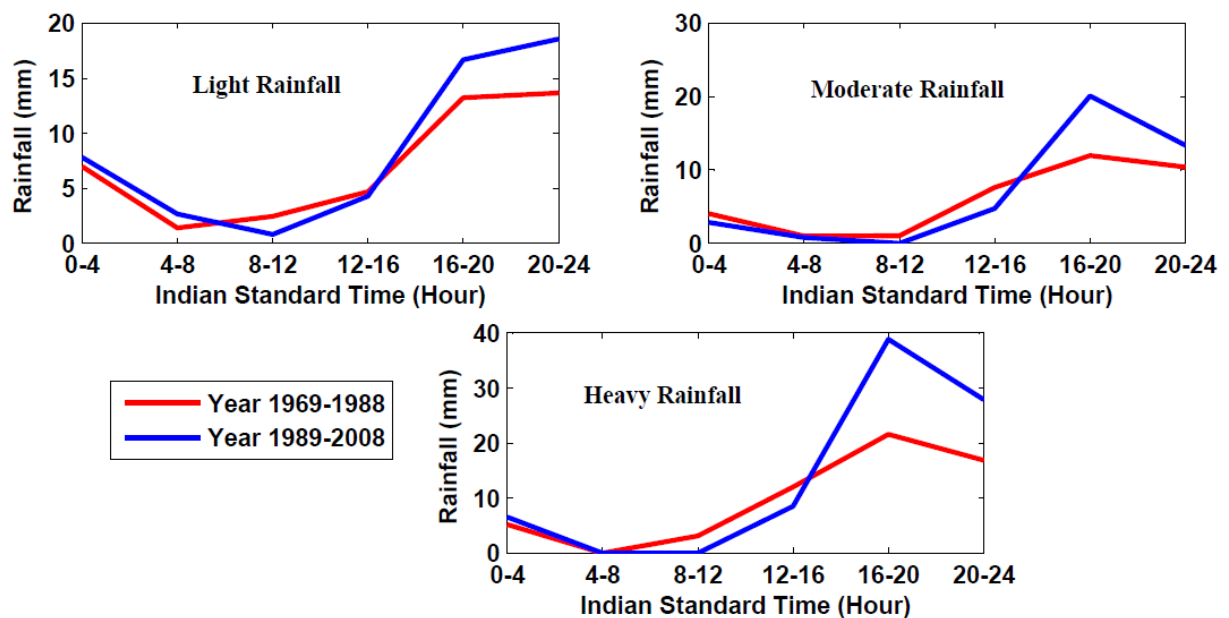


Fig. 5 Change in Pre Monsoon diurnal rainfall distribution of different Intensities

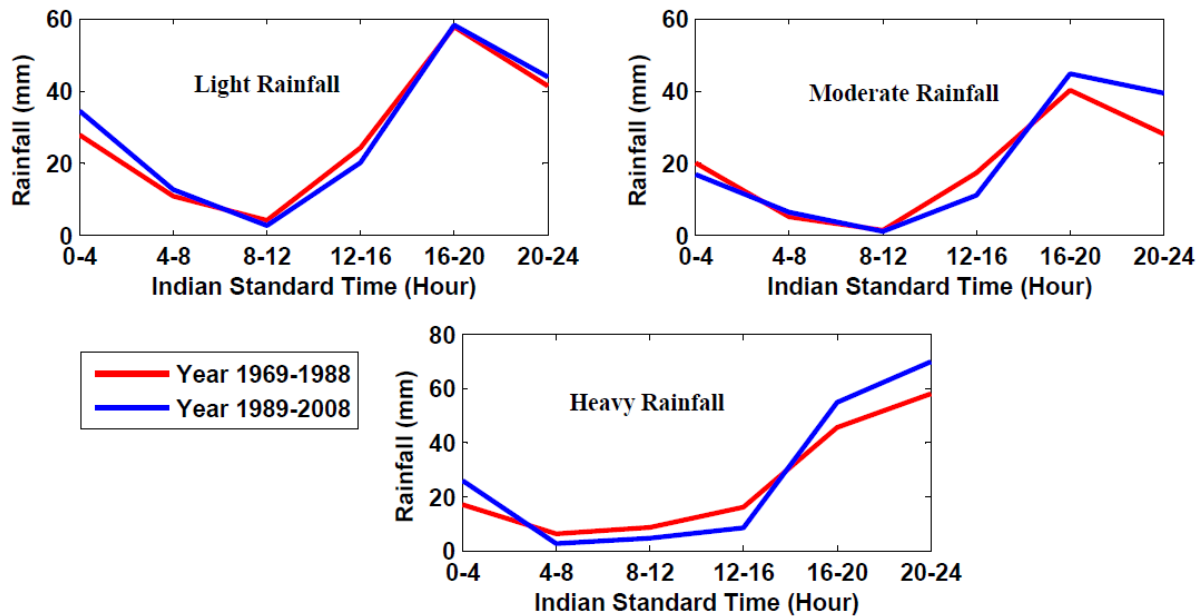


Fig. 6 Change in Monsoon diurnal rainfall distribution of different Intensities

IV. CONCLUSION

The results suggest that the diurnal rainfall pattern of Bangalore HAL Airport station is changing due to urbanization and other unidentified factors. The general trend is increase in heavy rainfall in late afternoon and evening. These needs to be investigated further and future planning should take into account these changes.

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