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SOME CLIMATOLOGICAL ASPECTS OF THUNDERSTORM ACTIVITY OVER BANGALORE CITY

1. Thunderstorm is one of the most spectacular weather phenomenon in the atmosphere. While it has a number of beneficial effects on human society, it is dreaded for the hazardous weather elements associated with it. The hazardous weather elements associated with thunderstorms include (*i*) lightning (*ii*) hail (*iii*) strong horizontal winds with shear (*iv*) squall (*v*) strong vertical updrafts and (*vi*) heavy rain. Also, thunderstorm is hazardous to aviation by the way of (*i*) pressure perturbation leading to defective altimeter reading (*ii*) poor visibility due to heavy rain (*iii*) turbulence (*iv*) icing and (*v*) radiostastic and communication problem. A number of studies have been done on thunderstorm climatology of different stations and regions. Some of the studies dealing with climatological characteristics are Srinibasan (1954), Bhatt (1955), Krishna Rao (1961), Raman and Raghavan (1961), Rao and Raman (1961), Buwanathan and Faria (1962), Gupta (1970), Sankaran and Ramakrishnan (1973), Rao *et al.* (1978), Prasad and Puri (1985), Chatterjee (1990) and Kalita and Sarma (2000). The study by Deshpande (1975) dealt with characteristics of cumulonimbus clouds over Bay of Bengal and that by Chatterjee (1990) with some aspects of convective clouds over Delhi. Sankaran and Ramakrishnan (1973) have studied radar climatology of Bangalore and neighbourhood during pre-monsoon season. The present study deals with climatological characteristics of thunderstorm activity during pre-monsoon (March-May) and post-monsoon (October-November) months over Bangalore city. Though thunderstorms occur in monsoon season during weak monsoon activity, the frequency is very less. The rainfall during monsoon months is mostly due to stratiform clouds formed by the down slope flow of westerly/southwesterly wind from Western Ghat. The present study of thunderstorms is based on the observations over Bangalore city, representing the area within a radius of about 25 to 40 km.

TABLE 1

Frequency distribution of thunderstorm activity during 1985-1994

S No.	Weather phenomena	Month of occurrence				
		Mar	Apr	May	Oct	Nov
1.	TSRA/TSSH	06 (14)	57 (38)	92 (47)	64 (35)	07 (13)
2.	TS/TSRA/ TSSH	08 (18)	65 (44)	103 (53)	69 (38)	10 (19)
3.	↙ /TS/ TSRA/ TSSH	23 (52)	114 (77)	167 (86)	124 (68)	27 (50)
4.	Convective activity CB/↙/ TS/ TSRA	44	149	195	182	54
5.	RA/SH/TSRA/ TSSH	25	86	115	149	88

RA : Rain, SH: Shower, TS: Dry Thunder, TSRA: Thunder with rain, TSSH: Thunder with shower, ↙ Lightning, CB : Cumulonimbus cloud ( ) : Percentage frequency of weather phenomena out of total convective activity

2. The meteorological data of Bangalore city over a period of 10 years from 1985 to 1994 have been obtained from current weather registers of Bangalore city. The different parameters like day of occurrence, time of onset and duration of different activities like thunder rain/thundershower (TSRA/TSSH), dry thunder (TS), lightning and convective activity with at least development of cumulonimbus (CB) clouds have been analysed. Associated heavy rainfall and synoptic systems have also been analysed. The frequency distributions of thunderstorms and convective activities are given in Table 1. The frequencies of commencement and duration of only thunderstorm (TS/TSRA/TSSH), lightning/ thunderstorm (lightning/TS/TSRA/TSSH) and total convective activity (CB/lightning/TS/TSRA/TSSH) are shown in Fig. 1, Fig. 2 and Fig. 3 respectively. The daily probabilities of occurrence of lightning/ thunderstorm and total convective activity have been calculated and analysed to find out peak period of occurrence of these activities. The results are shown in Fig. 4(a) and Fig. 4(b) respectively for (a) lightning/thunderstorm activity and (b) convective activity with development of at least CB cloud.

3. The convective activity is seen to be maximum during the month of May followed by October, April, November and March (Table 1). The frequency of TS/TSRA/TSSH also shows the same pattern. The maximum convective activity and thunderstorm activity during the month of May may be attributed to the maximum heating in the lower tropospheric levels and most prominent north-south trough/line of wind discontinuity over south peninsula during the month. However the frequency of rain (RA)/shower (SH) with/

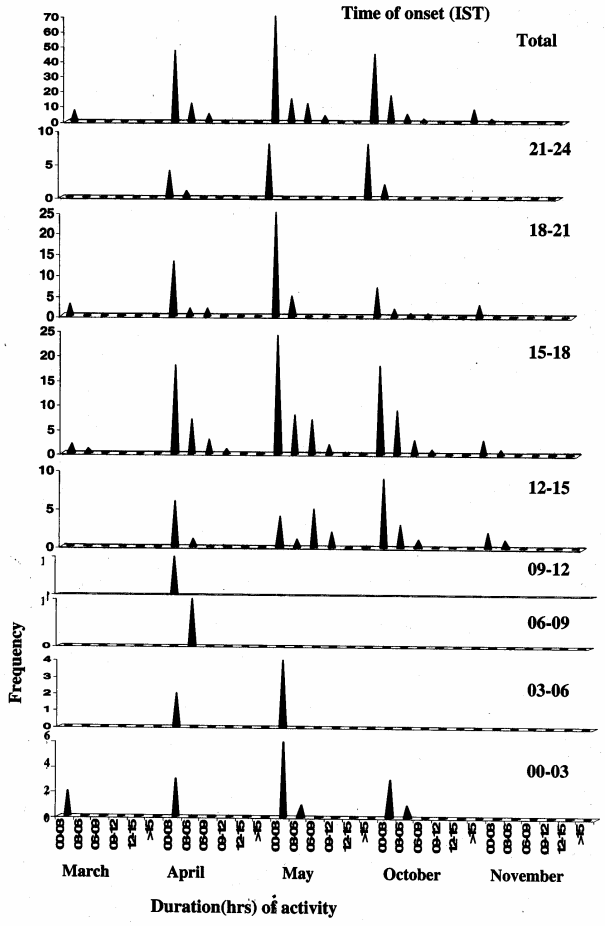


Fig. 1. Frequency distribution of onset and duration of TS/TSRA/TSSH

without thunderstorm is maximum in the month of October followed by May, November, April and March. The higher frequency of RA/SH with/without thunderstorm during October could be attributed to the northeast monsoon, which brings good rainfall over the region during October. The percentage frequencies of TSRA/TSSH, TS/TSRA/TSSH and lightning/TS/TSRA/ TSSH out of total convective activity are maximum during the month of May followed by April and October. Similarly the percentage frequency of TSRA/TSSH out of total RA/SH/TSRA/TSSH is also maximum during the month of May (80%) followed by April (66.3%) and October (43%). It indicates that the rainfall is more convective type during pre-monsoon than during post-monsoon season.

4. The frequencies of commencement of thunderstorm activity have been analysed for every three hours interval. The TSRA/TSSH starts more frequently between 1500 and 1800 hours IST followed by 1800 to 2100 hours IST for all the five months under consideration

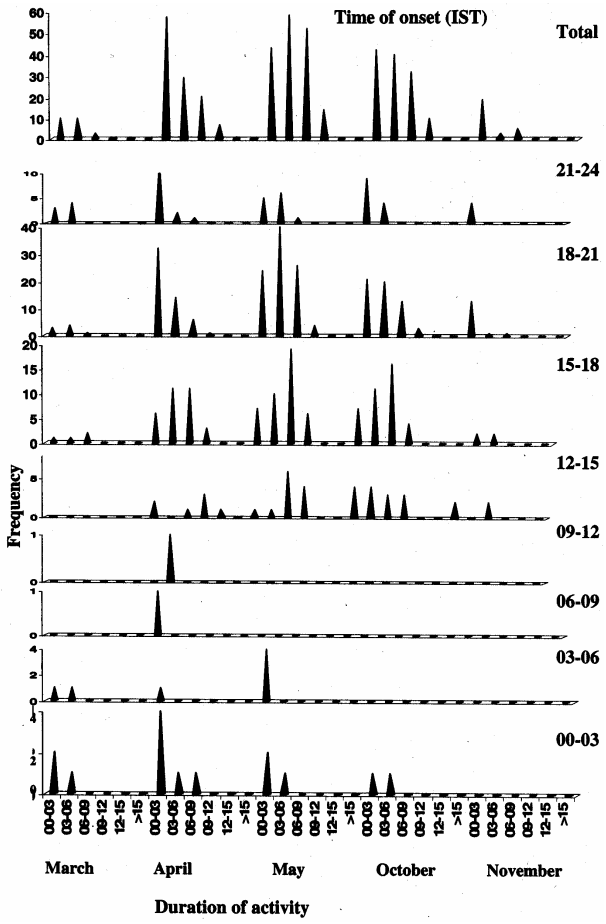


Fig. 2. Frequency distribution of onset and duration of lightning TS/TSRA/TSSH

(Fig. 1). The frequency of commencement of lightning/ TS/TSRA/TSSH is maximum between 1800 and 2100 hours IST for all the months also (Fig. 2).The frequency of commencement of convective activity is maximum between 1500 and 1800 hours IST for all the months (Fig. 3).

5. Most of the TS/TSRA/TSSH, lightning/ TS/TSRA/TSSH and convective activity have duration less than or equal to three hours for all the months except May. During the month of May, lightning/ TS/TSRA/TSSH are more frequent with duration between 3 and 6 hours whereas the convective activity is more frequent with duration between 6 and 9 hours. The daily probability of occurrence of lightning/ TS/TSRA/TSSH [Fig.4 (a)] shows negligible value in March and gradually increases in April to mid-May and then decreases towards end of May. There are three distinct peaks in occurrence during mid-April to mid-May. During post-monsoon season, the probability decreases from October to November with three peaks during mid-October to mid-November. The convective activity also shows similar occurrence [Fig. 4(b)].

6. Considering the duration of activity of TS/TSRA/TSSH with different times of onset, it is found that the activities commencing during 1500-1800 hours and 1800-2100 hours IST are most frequent with duration of $\leq$ 3 hours. Similarly, the activity of lightning/ TS/TSRA/TSSH commencing during 1500-1800 hours IST is most frequent with duration of 3-6 hours in April and 6-9 hours in May and October. The convective activity commencing during 1500-1800 hours IST is most frequent with duration $\leq$ 3 hours in April and October and 6-9 hours in May. The convective activity commencing during 1800-2100 hours IST is most frequent with duration $\leq$ 3 hours in April and October and 3-6 hours in May. Generally most of the convective activities originating during 1800-2100 hours IST were short lived compared to that originating during 1500-1800 hours IST. Comparing the activities in different months, the activities during May are more durable for different times of onset.

7. The analysis of synoptic systems at 0830 IST of day of the occurrence of convective activity indicates that the causative synoptic systems are mostly the north-south oriented trough/line of wind discontinuity in lower tropospheric level during pre-monsoon season, with the above systems being most significant during the month of May. Of course, this wind discontinuity shows some east-west oscillations during the season. The convective activity occurs as a result of interaction of this synoptic system and orography over the region in addition to the insolation and moisture availability over the region. Other synoptic systems associated with the convective activity over Bangalore are (*i*) embedded low level cyclonic circulation on the north-south oriented trough/wind discontinuity and (*ii*) the trough of low pressure/cyclonic circulation over Srilanka/Comorin/Lakshadweep region in association with the easterly waves. During the post-monsoon months of October and November, the convective activity is mostly associated with the northeast monsoon. The associated synoptic systems are (*i*) the low pressure systems like low, depression and cyclonic storm, developing over southwest Bay of Bengal and adjoining west central Bay and moving westwards across the south peninsula, (*ii*) the trough of low pressure developing over southwest Bay and adjoining west central Bay and moving westwards across the south peninsula and (*iii*) upper air trough in easterlies extending upto lower/middle tropospheric level over southwest Bay and adjoining west central Bay and moving westwards with/ without embedded cyclonic circulations. Considering the month-wise highest rainfall during the period under study, it is found that the highest rainfall of 25.3 mm has been recorded on 16 March 1987 for the month of March.

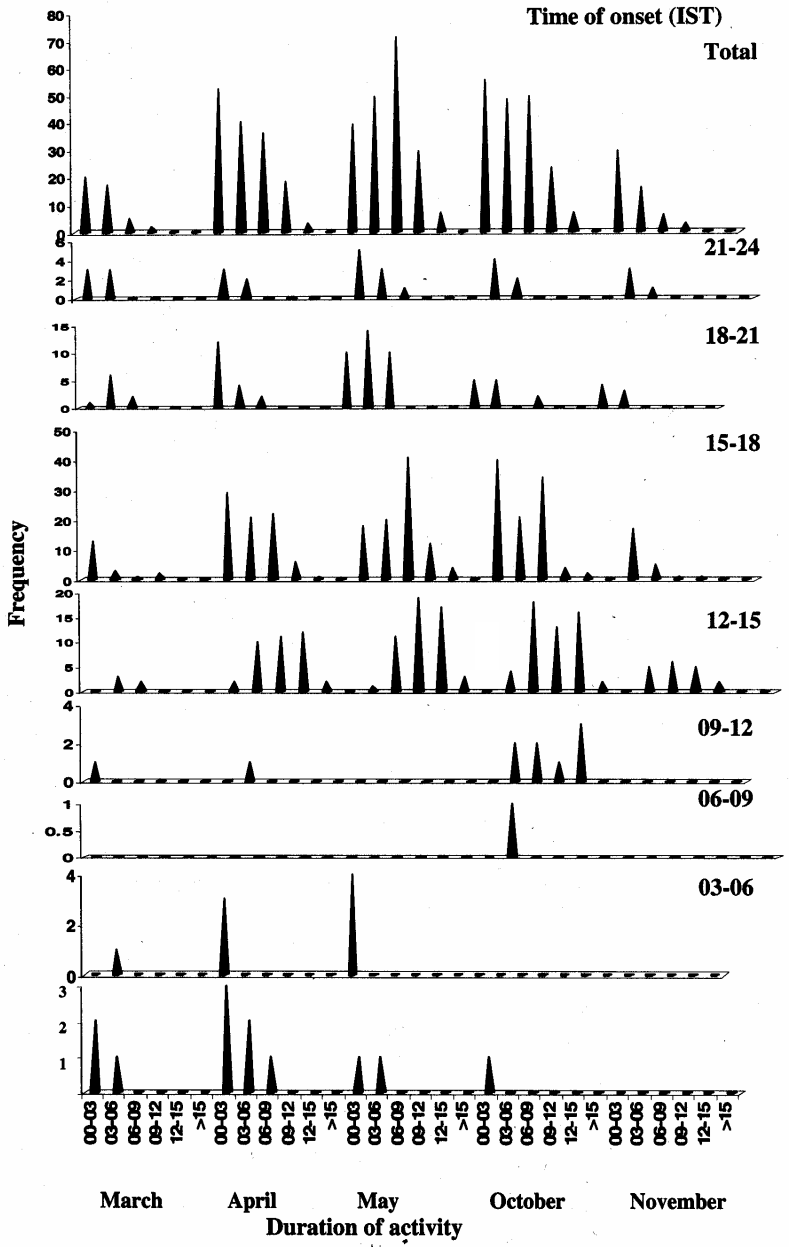
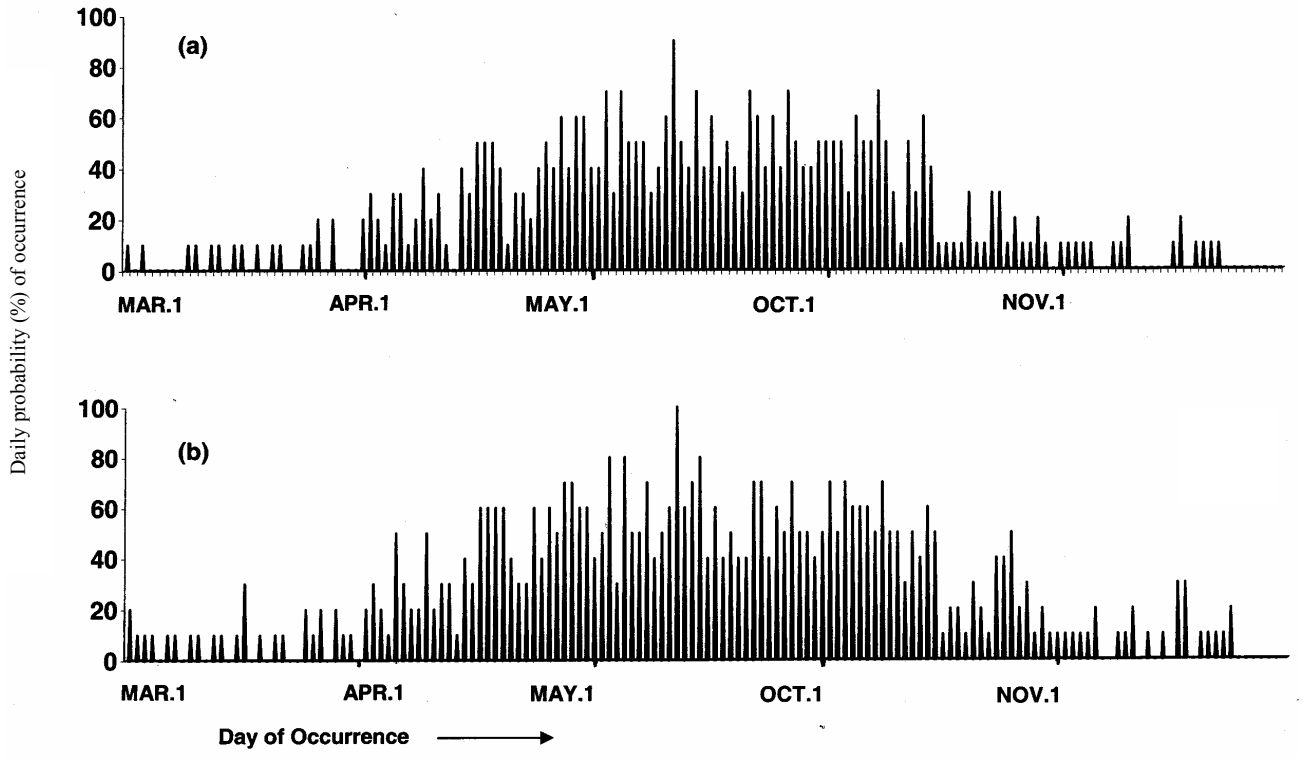


Fig. 3. Frequency distribution of onset and duration of convective activity (CB/Lightning/ TS/TSRA/TSSH)

For the month of April, the highest rainfall of 46.3 mm has been recorded on 27 April 1987. For the month of May, it has been 91.9 mm on 10 May 1991. For the month of October and November; the highest rainfall of 118.3 mm and 105.6 mm have been recorded on 30 October 1991 and 16 November 1991 respectively. During the year 1991; the highest rainfall recorded on 30 October and 16 November have been due to depressions located near Bangalore. It indicates that the thunderstorm activity without any large scale synoptic systems like low pressure area, depression, deep depression and cyclonic storm etc does not cause heavy rainfall (rainfall > 65 mm) in any of the pre-monsoon or post-monsoon months except the month of May. During the month of May, the thunderstorm activity without any large scale synoptic systems may cause heavy rainfall, even though the frequency of such heavy rainfall events are very rare.



Figs. 4(a&b). Daily probability of occurrence of (a) lightning/TS/TSRA/TSSH and (b) CB/lightning/TS/TSRA/TSSH

TABLE 2

Comparison of mean No. of days with thunder

Long term average	Mar	Apr	May	Oct	Nov
1931-60	1.2	7.0	12.0	7.0	1.3
1951-80	1.1	6.7	10.6	5.9	1.0
1985-94	0.8	6.5	10.3	6.9	1.0

8. The results have been compared with climatological tables for Bangalore city (India Meteorological Department, 1966, 1999) and the comparative figures are given in Table 2. It indicates that the mean frequency of thunder days is maximum during May for the period of 1931-60, 1951-80 and the period under study. The mean frequencies of thunder days, while comparing with those during 1931-60 period, show a decreasing trend over the years.

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