Impact of Pre-monsoon Thunderstorm on Environment in North East India

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Abstract: Pre-monsoon being the beginning of the wet period after a long dry spell (November to February) has great importance from various aspects, especially from agricultural, forestry and hydrological point of view. The environmental problems in the region related to pre-monsoon thunderstorm and rainfall are caused due to the scarcity of both surface and ground water. Hardening and cracking of agricultural fields because of prolonged drought, severe weather conditions like dust-storm, frequent thunderstorms, sometimes having very destructive mood causing heavy loss of property livestock and human life, heavy torrential rain etc are the common environmental problems during this season. These entire problems disturb the normal life of the people of the region during pre-monsoon season. Moreover besides being complex areal and temporal variation patterns of thunderstorm in the region due to its unique physiographic setting, various characteristics of rainfall and persistency of rain associated with thunderstorm vary significantly from place to place. Keeping all these point in mind a study on the characteristics of pre-monsoon thunderstorm of the region has been made. Investigation of the synoptic situations associated with the occurrences of pre-monsoon thunderstorm in the region has also been incorporated in the present study.

Key words: Pre-monsoon, Thunderstorm, Physiographic, North East India, Synoptic situation.

1. Introduction

Assam and its adjoining states are among the heavy rainfall regions of India. Because of the predominance of the southwest monsoon, rainfall in this region is highly seasonal (Kalita & Sarmah, 1986, Singh et al. 2011, Dash et al, 2012, Das 2015). Here rainfall occurs mainly during the period ranging from the month of April to September. Small amount of rainfall with occasional thunderstorms also occurs during the month of February and March. During the remaining part of the year rainfall is rather scanty leading to dry period. Based on the rainfall distribution throughout the year over the region the whole year may be divided into three periods namely, Pre-monsoon, Monsoon and Post-monsoon. The month of February, March, April and May form pre-monsoon period. During this period measurable amount of rainfall occurs due to cyclonic storm. Northeast India, on the average, receives an amount of rainfall of about 64 cm during this period (Ramdas, 1983). The month of June, July, August and September constitute the monsoon period. During this period sufficient amount of rainfall is received by the valley due to South West monsoon. The monsoon period is followed by post monsoon period, which includes the months from October to January; this is a dry and winter period. Besides this seasonal behaviour, it has been observed that the spatial rainfall distribution is also not uniform throughout the entire northeast India including Assam (Sarmah, 1969, Mahanta et al. 2012). In general, the rainfall at a place depends on many factors, such as regional wind circulation pattern, local physiographic pattern, distance from the sea, elevation etc. As far as Northeast India is concerned, areal distribution of rainfall seems to be governed to a large extent by the local physiographic of the region.

Thunderstorms are localized phenomena which have been defined as storms produced by a cumulonimbus cloud always accompanied by lightning and thunder (Lal, 1986). They are usually of short duration, seldom over two hours. Generally they are accompanied by wind gusts, heavy rain and sometimes hail.

Atmospheric instability, lifting of potentially unstable air and sufficient supply of warm moist air are the main factors favouring the formation of thunderstorm (Glode, 1977). There are marked seasonal and latitudinal anal variations in the height horizontal extent and duration of thunderstorms. Generally, they range from 4 km to 20 km in height above mean sea level, the maximum height is observed in tropical region during warm season. Thunderstorm may cause destruction of properties rendering thousands of people homeless, over rooting trees and damaging standing crops in the fields. Sometimes it may cause loss of cattle and human life also.

In India, interest in the study of thunderstorm has been evinced since long time back. In many parts of the country thunderstorms are seasonal and generally associated with rainfall. In northeast India, especially during pre monsoon season, they may be considered as blessings to the farmers to some extent, as farmers of the region are waiting for early rainfall to start their agricultural activities. Thunderstorms are weather hazards to aviation. A large percentage of air craft accidents occur due to it. So, the aviators dread thunderstorms and tried to keep away. Therefore, this severe weather phenomenon has always been considered as an important subject to be investigated by the weather scientist.

The period during which most of the thunderstorm occurred in India as a whole begins in the month of February and continues to the month of September. It is a very common phenomenon during the period February to May bin northeast India. The period of least thunderstorm activity includes the month of December and January the areal distribution of thunderstorm activity in India during the pre-monsoon months has already well explained by Rao, et al. 1983.

In northeast India, thunderstorm generally occurs during afternoon hours. During night and early morning hours also the region experiences considerable events of thunderstorms. Thunderstorms are sometimes accompanied with hail especially during the period February- May in Northeast India, mainly in near submontane regions.

The pre-monsoon thunderstorms of Bengal and Assam are sometimes associated with severe destructive northwesterly squalls of formidable violence called “Nor’westers” or “Kal Baisakhi” in Bengal and Bordoisilla” in Assam (IMD1944). Since the study region is considerably affected by these thunderstorms, therefore an attempt has been made to have a detail study on the thunderstorm activity over the region during pre-monsoon period.

Northeast India consists of seven states having hills and dales topography. The region belongs to the southeast Asiatic monsoon climate and more than about nine-tenth of its area lies into subtropical belt. Being influenced by the monsoon climate, rainfall in the region is highly seasonal having two distinct wet and dry periods. Pre-monsoon being the beginning of the wet period after a long dry spell (November to February) has great importance from various aspects, especially from agricultural, forestry and hydrological point of view. The environmental problems in the region related to pre-monsoon period are caused due to the scarcity of both surface and ground water. Hardening and cracking of agricultural fields because of prolonged drought, severe weather conditions like dust-storm, frequent thunderstorms, sometimes having very destructive mood causing heavy loss of property livestock and human life, heavy torrential rain etc are the common environmental problems during this season. These entire problems disturb the normal life of the people of the region during pre-monsoon season. Moreover besides being complex areal and temporal variation patterns of thunderstorm and rainfall in the region due to its unique physiographic setting, various characteristics of thunderstorm such as its temporal variation associated with rains, persistency of rains etc, vary significantly from place to place. Keeping all these point in mind a study on the characteristics of pre-monsoon thunderstorms and rainfall of the region has been made. Investigation of the synoptic situations associated with the occurrences of pre-monsoon thunderstorm in the region has also been incorporated in the present study.

2. Aims and Objectives of the study:

The present work on the pre-monsoon thunderstorm associated with rainfall in North Eastern region has been undertaken with the following objectives in view.

To investigate the synoptic variation associated with the occurrence of pre-monsoon thunderstorm in the region.

To study some aspect of temporal variations of thunderstorm activity during the pre-monsoon period.

3. Data collection and Methodology:

According to the classification of seasons on the basis of seasonal variation of rainfall and thunderstorm made by Indian Meteorological Department and most of the workers worked on rainfall climatology of India pre monsoon season consist of months of March, April and May. However the month of February is also incorporated in the present study, since very occasionally severe thunderstorm as well as rainfall occurs during this month in the studied region.

Daily data of thunderstorm activity have been collected from regional Centre, Guwahati, Airport for good number of stations well distributed in Northeast India. The database used for this study consists of daily thunderstorm data for the months of February, March, April and May. All these data for a period of thirty five years (1986 to 2020) have been collected for eleven stations well distributed all over Northeast India from the Regional Meteorological office, Guwahati is shown in Table 1.

Sl. No	Name of Station	Station code	Latitude	Longitude	Height from MSL (in meter)
1	Guwahati	GHT	26.11 N	91.45E	55
2	Mohanbagan (Dibrugargh)	MHB	27.29 N	94.58 E	106
3	Cherapunjee	CPJ	25.17 N	91.47 E	1313
4	Silchar	SLC	24.50 N	82.51 E	29
5	Rupshi (dhubri)	RUP	26.02 N	90.02 E	35
6	North Lakhimpur	NLP	27.14 N	94.07 E	102
7	Tezpur	TEZ	26.37 N	92.50 E	79
8	Shilong	SHL	25.34 N	91.56 E	1500
9	Imphal	IMP	24.44 N	93.58 E	798
10	Pasighat	PSG	28.04 N	95.22 E	274
11	Agartala	AGT	23.55 N	91.15 E	15

Table 1: List of rain gauge stations and their latitude, longitude and height from the mean sea level

Daily weather maps (Prepared by India Meteorological Department) connected with some Pre-monsoon spell have been used in this study. Only the cases where thunderstorms have been heard are considered as thunderstorm (Braham and Draginis 1961) and the time period from the starting of thunderstorm to the cessation of thunderstorm is considered as one event.

4. Results and Discussions:

Both graphical and statistical techniques are used to study the different characteristics of thunderstorm activity in northeast India during pre-monsoon period. Diurnal variation, pentad variation, month wise variation and year to year variation of the thunderstorm have been incorporated in this present study. Moreover, it has been assumed that a thunderstorm lasting for more than one hour is considered as having occurred during all the hours comprising the whole duration of thunderstorm.

4.1 Synoptic variation associated with the occurrence of pre-monsoon thunderstorm:

As per the conclusion made by Sen and Basu(1961) the principal favourable conditions for the occurrence of thunderstorm in the region the incursion of moist air in the lower levels to the valley and the

extension of the seasonal trough formed over northern India and existence of a discontinuity line of wind over upper Assam in lower levels. The orographic lifting of moist air acts as a triggering mechanism of the thunderstorm. The easterly katabatic wind that blows from the Tibetan plateau and from the foothills of eastern Himalaya during winter season is found to exist at the lower levels during pre-monsoon season also. This dry and somewhat cold air over the extreme north of Assam and warm moist south easterly or southerly air quite often results in an east west discontinuity of wind over Assam (Sen and Basu 1961). The two air currents of different origin remain totally separated up to a height of about 1.5 km because of the presence of Naga-Khasi-Jayantia-Garo Hills range between them (Mukherjhee and Ghosh 1965). Strong Southerly can however cross over the barrier at levels 1.5 km (a.s.l.) and above. These are expected to remain above the easterly over the Brahmaputra valley as theses are warmer and moist (with the progress of the summer season easterly are likely to weaken). During night and early morning hours the Katabatic wind from the Khasi and Jayantia Hills bring this warm and moist air mass to the Brahmaputra valley. This may results a front like structure in the valley during night and early morning hours. This is probably one of the reason why the pre-monsoon thunderstorm occurs over the Brahmaputra valley mostly during night and early morning hours (Mukherjee and Ghosh, 1965).

4.2 Diurnal variation of thunderstorm:

For the study of the diurnal variation of thunderstorm different workers divided a day into period of different duration. Raman and Raghavan(1960) divided a day into four periods each having duration of six hours. Mukherjee, Arunachalam and Rakshit(1964) divided a day into eight periods of three hours duration. However in the present study, hourly thunderstorm data have been used and a day is divided into twenty four periods of one hour duration for better understanding of diurnal variation pattern of thunderstorm. The average frequency of thunderstorm in each hour of the day during the pre-monsoon months February to May has been computed for all the stations under consideration. The results are presented in the table 2(a).

It can also be used to indicate the diurnal variation pattern of thunderstorm events of different stations in terms of the number of thunderstorm events in each hour of the day and can be expressed as the percentage of their respective daily total. The maximum and minimum numbers of thunderstorms with their time of occurrence at different stations are summarized in table 2(b). It also includes the hours of the day in which maximum and minimum number of thunderstorm events occurs. The average number of thunderstorm events per hour and its standard deviation is also incorporated in Table 2(b). It is clear from the result that the time of occurrence of the maximum and minimum number of thunderstorm events are different at different stations.From the above results it may also be concluded that the maximum number of thunderstorm occurs in between evening and early morning and the minimum number of thunderstorm takes place in between 1100-1500 hours (IST). This indicates that the katabatic flow from the hills may undercut the warm moist Southwesterly/Southerly air resulting in increase vertical ascent of the moist air, which may result thunderstorm.

4.3 Pentad variation of thunderstorm

Pentad variation of thunderstorm activity during the pre-monsoon period have been studied mainly in the light of the variation of (i) thunderstorm events (ii) thunderstorm days and (iii) thunderstorm days with precipitation. The yearly average pentad value of thunderstorm event, thunderstorm day and thunderstorm days with precipitation for each pentad starting from 1st February to 31st May have been calculated. Altogether there are twenty four pentads in each data series. The pentad values of all the three variables namely – thunderstorm events, thunderstorm days and thunderstorm days with precipitation are presented in table 3(a), 3(b), 3(b). These results indicate that there is a general tendency of increase in the thunderstorm activity from 2nd week of April to the 3rd week of May.

Hours	Stations										
	GHT	MHB	NLP	TEZ	IMP	AGT	CPJ	SLC	RUP	PSG	SHL
0---1	10.3	19.6	4.8	8.8	8.0	8.7	9.3	8.0	7.6	4.7	3.0
1---2	10.8	19.1	4.7	8.3	8.2	7.6	9.2	9.0	8.2	5.0	3.4
2---3	10.8	18.9	4.2	8.2	8.1	5.8	9.0	10.2	7.8	4.5	2.6
3---4	9.9	16.7	3.8	7.6	8.5	4.8	8.1	9.1	7.2	3.3	2.4
4---5	10.4	13.4	4.6	7.5	8.8	4.2	7.6	9.0	7.6	3.5	2.8
5---6	11.1	11.5	4.4	8.2	8.6	4.4	7.5	11.1	7.8	3.3	2.6
6---7	8.3	10.8	3.3	7.6	8.1	5.0	6.8	10.2	8.8	3.8	3.2
7--8	8.0	8.8	3.1	7.3	7.1	5.2	5.9	9.3	7.6	3.7	2.6
8---9	6.7	7.5	2.4	7.2	6.5	4.9	5.2	8.4	6.2	3.5	2.6
9---10	4.7	5.9	2.2	5.5	5.2	4.8	3.6	5.9	6.6	3.2	2.8
10--11	3.9	5.2	2.0	5.2	5.1	4.9	3.6	3.9	6.4	2.5	4.0
11--12	3.8	4.4	2.2	4.2	4.9	5.2	3.5	4.7	6.2	2.7	5.6
12--13	4.3	4.0	2.5	3.5	5.9	6.5	3.4	3.4	6.2	4.2	4.8
13--14	6.0	4.7	2.5	4.4	7.0	7.5	4.2	3.2	5.6	4.7	6.6
14--15	6.9	5.1	2.8	5.0	8.4	10.2	5.2	4.6	5.2	3.7	7.2
15--16	7.1	6.1	2.8	6.5	8.2	13.1	5.2	5.4	5.6	3.5	5.6
16--17	8.4	7.1	3.1	7.2	8.8	16.7	6.2	7.0	5.4	4.0	3.0
17--18	7.0	9.4	4.2	7.8	9.3	17.7	6.6	6.4	5.4	4.7	3.0
18--19	7.6	10.5	4.9	8.9	8.8	13.8	8.2	6.1	5.0	4.7	1.4
19--20	8.9	13.3	5.0	10.9	9.4	12.4	8.7	7.7	6.6	5.0	1.6
20--21	9.6	15.3	5.7	12.7	10.3	11.0	11.0	8.4	8.0	5.7	1.6
21--22	11.3	17.1	6.4	14.0	9.5	9.9	12.1	8.9	8.4	6.0	3.2
22--23	11.6	18.5	7.3	13.2	9.2	8.5	11.2	9.1	8.2	5.8	3.8
23--24	10.8	19.3	6.9	12.8	8.5	7.9	11.0	9.3	8.0	6.2	3.2

Table 2(a): Diurnal variation of thunderstorm events during pre-monsoon period for different stations of northeast India (in events per year).

Station code	Maximum(per season)		Minimum(Per season)		Mean events per day	Standard Deviation
	No of events	Time of occurrence (in Hrs.)	No of events	Time of occurrence (in Hrs.)		
GHT	11.6	22-23	3.8	11-12	8.3	2.43
MHB	19.6	00-01	4.0	12-13	11.3	2.44
CPJ	12.1	21-22	3.4	12-13	7.2	2.61
SLC	11.1	05-06	3.2	13-14	7.4	2.26
RUP	8.8	06-07	5.0	18-19	6.9	1.14
NLP	7.3	22-23	2.0	10-11	3.9	1.50
TEZ	14.0	21-22	3.5	10-11	8.0	2.84
SHL	7.2	14-15	1.4	18-19	3.4	1.50
IMP	10.3	20-21	4.9	11-12	7.9	1.44
PSG	6.2	23-24	2.5	10-11	4.2	1.01
AGT	17.7	17-18	4.2	04-05	8.3	3.89

Table 2(b): Time of occurrence of the maximum and minimum number of thunderstorm events at different stations during pre-monsoon period.

4.4 Monthly variation of thunderstorm:

For all the pre monsoon months and the season as a whole, the month wise variation pattern of thunderstorm activity has been studied mainly in the light of (i) the variation of monthly thunderstorm events, (ii) variation of thunderstorm days per month, (iii) month wise variation of thunderstorm days with rain and (iv) month wise variation of thunderstorm days without rain. The average month wise value of thunderstorm events, thunderstorm days, thunderstorm with rain and thunderstorm days without rain are presented in table 4(a), 4(b), 4(c) and 4(d) respectively. Visual presentation of these tabulated data have been incorporated in Figure 4(a), 4(b), 4(c) and 4(d) respectively.

PENTAD NO	PERIOD	NAME OF STATIONS------>											
		GHT	MHB	CPJ	SLC	RUP	NLP	TEZ	SHL	IMP	PSG	AGT	N.E India.
1	1Feb---5	0.4	1.4	0.1	0.2	0.2	0.3	0.4	0.2	0.5	0.2	0.7	0.4
2	6----10	0	0.2	0.2	0	0	0.1	0.3	0	0	0.2	0.2	0.1
3	11---15	0.1	0.6	0.4	0.6	0	0.2	0.5	0	0.3	0.2	0.4	0.3
4	16---20	0.7	1.9	0.8	0.7	0.4	0.6	0.8	0	0.7	1.5	1	0.8
5	21---25	0.8	1.4	0.6	0.9	1.4	0.8	1.4	0.6	0.6	0.7	1.1	0.9
6	26---2Mar	1	1.6	0.5	0.4	0.6	0.9	0.8	0.4	0.6	1.2	0.5	0.8
7	3----7	0.8	1.2	0.8	0.1	0.2	0.3	0.5	0.2	0.4	0.7	0.3	0.5
8	8----12	1	1.6	0.7	0.3	0.6	0.7	0.9	0	0.8	0.8	0.8	0.7
9	13---17	1	2.4	1.2	1.6	0.2	1.8	1.2	0.4	2	1	0.6	1.2
10	18---22	1.2	1.8	0.8	1.6	0.2	1	0.9	0	2.1	0.8	0.6	1.0
11	23---27	1	2.3	0.8	1.8	0.8	1.1	1.7	1	2.4	0.7	1.5	1.4
12	28---1 Apr	1.6	2	1.6	1.7	0.8	1	1	0.8	1.5	0.5	1.6	1.3
13	2----6	1.5	2.3	1.2	1.1	0.6	0.9	1.9	1.2	1.7	0.8	1.4	1.3
14	7----11	2.3	1.9	1.9	2.1	1.8	1.2	1.6	1.6	2.5	1	2.4	1.8
15	12---16	1.7	2.7	2.1	1.6	0.6	1.2	2.3	1.4	2.3	1.2	1.2	1.7
16	17---21	2.8	2.3	2.3	2.4	2.4	1.8	2.9	1.8	2.4	1.2	2.1	2.2
17	22---26	3.5	3.1	2.8	2.7	3	1.8	3.5	1.8	2.9	1	3.1	2.7
18	27---1 May	2.8	2.7	2.2	1.4	3	1.5	2.5	1.8	2.2	0.7	3.7	2.2
19	2-----6	3.3	2.2	2.4	2.7	2.6	1.7	3.2	2.4	2	0.5	2.6	2.3
20	7----11	2.7	2.3	1.9	2.6	1.6	1.8	2.4	2.6	2.1	0.3	2.7	2.1
21	12---16	2.7	2.2	1.8	1.9	1.4	2	2.3	1.2	2	0.8	2.8	1.9
22	17---21	2.6	1.3	1.1	1.6	1.2	0.7	2.1	2	1.5	0.3	3	1.6
23	22---26	2.3	1.6	1.5	1.4	1.8	0.8	1.9	1.2	1.8	0.2	2.5	1.5
24	27--31 May	2.2	1.5	1.8	2.2	2.4	0.9	2.6	1.2	1.6	0.3	2.7	1.8

Table 3(a): Pentad variation of thunderstorm days during pre-monsoon period for different stations of northeast India.

PENTAD NO	PERIOD OF PENTAD	NAME OF STATIONS------>											
		GHT	MHB	CPJ	SLC	RUP	NLP	TEZ	SHL	IMP	PSG	AGT	N.E. India
1	1Feb---5	0.2	1.3	0.1	0.1	0	0.3	0.3	0	0.4	0.2	0.4	0.3
2	6----10	0	0.2	0	0	0	0.1	0.3	0	0	0	0	0.1
3	11---15	0	0.2	0.2	0.3	0	0.1	0.2	0	0	0.2	0.1	0.1
4	16---20	0.3	1.5	0.5	0.6	0.2	0.5	0.3	0	0.5	1.3	0.4	0.6
5	21---25	0.6	1.2	0.4	0.8	0.8	0.7	0.5	0.4	0.5	0.5	0.8	0.7
6	26---2Mar	0.6	1.3	0.4	0.3	0.2	0.5	0.3	0.4	0.2	0.8	0.4	0.5
7	3----7	0.3	0.8	0.2	0	0	0.2	0.2	0.2	0.3	0.3	0	0.2
8	8----12	0.6	1.2	0.5	0.2	0.2	0.5	0.8	0	0.4	0.7	0.4	0.5
9	13---17	0.6	2	0.7	1.2	0	1.4	0.8	0	1.2	0.8	0.2	0.8
10	18---22	0.8	1.6	0.6	1	0	0.6	0.7	0	1.4	0.7	0	0.7
11	23---27	0.5	2.2	0.7	1.3	0.6	1	1.2	0.8	2	0.3	0.9	1.0
12	28--1 Apr	1	1.5	1.2	1.2	0.2	0.8	0.7	0.6	0.9	0.5	1.1	0.9
13	2----6	0.9	2	1.2	0.6	0.4	0.8	0.8	1	1.1	0.7	0.5	0.9
14	7----11	1.9	1.6	1.5	1.4	1	1	1.1	1.2	1.8	0.8	0.9	1.3
15	12---16	1.2	2.3	1.8	1.1	0.2	0.8	1.5	0.2	1.5	1	1	1.1
16	17---21	2.3	2.3	1.5	1.7	1.8	1.2	2.2	1.6	1.9	0.8	1.1	1.7
17	22---26	2.2	2.3	2.1	2	2.6	1.2	2.5	1.4	1.8	0.7	1.5	1.8
18	27---1 May	2.2	1.9	2	1.3	1.2	1.1	1.8	1.2	1.5	0.5	1.5	1.5
19	2-----6	2.3	1.5	2.2	2.3	1.6	1.2	2.1	2	1.6	0.5	1.6	1.7
20	7----11	1.9	2.2	2	2.2	1	1.5	1.8	1.8	1.9	0	2	1.7
21	12---16	2.2	2.1	1.6	1.9	1.2	1.8	1.8	0.8	1.3	0.5	2	1.6
22	17---21	1.5	0.9	1	1.2	0.6	0.4	1.4	1.2	1	0.2	2.3	1.1
23	22---26	1.5	1.2	1.2	1.2	1.8	0.5	1.5	0.8	1.1	0	1.8	1.1
24	27--31 May	2	0.9	1.8	2	2	0.7	1.7	1.2	1.2	0.2	2.5	1.5

Table 3(b): Pentad variation of thunderstorm days with rain during pre-monsoon period for different stations of northeast India.

PENTAD NO	PERIOD OF PENTAD	NAME OF STATIONS----->											
		GHT	MHB	CPJ	SLC	RUP	NLP	TEZ	SHL	IMP	PSG	AGT	N.E.India
1	1Feb---5	0.4	1.8	0.1	0.3	0.2	0.5	0	0.4	0.8	0.2	1	0.5
2	6----10	0	0.2	0.2	0	0	0.2	0	0	0	0.2	0.2	0.1
3	11---15	0.1	0.7	0.4	0.6	0	0.2	0	0	0.4	0.2	0.4	0.3
4	16---20	0.8	2.7	1.2	1	0.4	0.7	0.1	0	1.3	1.8	1.1	1.0
5	21---25	1.1	2	1.1	1.2	1.6	0.8	0.1	0.8	1.2	0.7	1.5	1.1
6	26---2Mar	1.3	2.7	1.7	0.6	0.6	1	0.1	0.8	1.2	1.8	0.6	1.1
7	3----7	1	2	0.8	0.1	0.4	0.5	0	0.2	1.2	0.8	0.3	0.7
8	8----12	1.3	2.4	1.1	0.3	1	0.9	0.1	0	1.6	0.8	1.3	1.0
9	13---17	2.1	4.6	1.6	2.7	0.2	2.1	0.2	0.8	4.2	1.2	0.6	1.8
10	18---22	1.3	2.5	1.2	2.6	0.2	1	0.1	0	3.5	1.3	0.7	1.3
11	23---27	1.7	4.3	1.1	3.3	1.2	1.6	0.1	3	5.1	1.3	1.9	2.2
12	28---1 Apr	3	2.4	2.2	2.9	1	1.2	0.1	1.8	2.6	0.5	2.3	1.8
13	2----6	2.1	3.7	2	1.4	0.8	1.1	0.1	2	3.8	1.2	1.5	1.8
14	7----11	5.3	3.6	3.1	2.8	2.4	1.7	0.1	2.4	4.4	1.3	3.3	2.8
15	12---16	3	5	3	2	0.6	1.8	0.1	2	4.1	1.8	1.5	2.3
16	17---21	4.5	4.4	3.3	4.1	4.4	2.2	0.2	3.2	5.5	1.5	3	3.3
17	22---26	6.9	4.8	3.8	4.1	4.2	2.2	0.2	2.8	5.2	1	3.9	3.6
18	27---1 May	4.5	4	3.5	2.4	3.8	2	0.2	2.4	3.3	1	4.2	2.8
19	2-----6	5.1	3.3	3.5	4.6	4.8	2.2	0.2	3.2	3.2	0.5	3.5	3.1
20	7----11	3.9	3.4	2.6	3.8	2.4	2.2	0.2	4	2.8	0.5	3.5	2.7
21	12---16	4.3	3.3	2.5	2.6	2.2	2.4	0.2	1.4	2.8	1.2	3.6	2.4
22	17---21	4	1.8	1.6	2.1	1.6	0.8	0.1	2.2	1.5	0.3	4.1	1.8
23	22---26	3.1	2.6	1.8	1.9	2.6	1.2	0.1	1.4	1.6	0.2	3.6	1.8
24	27--31 May	4.1	1.8	2	3	3	1.2	0.1	1.2	2.3	0.3	3.7	2.1

Table 3(c): Pentad variation of thunderstorm events during pre-monsoon period for different stations of northeast India.

Station Code	Months				
	FEB	MARCH	APR	MAY	Total
GHT	3	10	26.5	25.25	64.75
MHB	9	18.42	25.42	16.58	69.42
CPJ	3.23	7.62	18.85	15.54	45.24
SLC	3.67	11.11	16.67	18.89	50.34
RUP	2.6	3.8	16.2	17	39.6
NLP	2.85	7.38	11.15	10.38	31.76
TEZ	5.28	9.46	23.15	23.92	61.91
SHL	1.2	7.75	14.8	13.4	37.15
IMP	4.08	16.15	27.31	16.23	63.77
PSG	4.33	6.33	7.83	3.17	21.66
AGT	4.18	7	17.18	22.82	51.18
N.E. India	3.96	9.55	18.64	16.65	48.80

Table 4(a): Monthly distribution of average number of thunderstorm events during pre-monsoon period for different stations of northeast India.

Station Code	Months				
	FEB	MARCH	APR	MAY	Total
GHT	2.58	6.33	14.75	17.17	40.83
MHB	6.58	11.42	15.25	11.42	44.67
CPJ	2.23	5.85	12.54	10.92	31.54
SLC	2.78	6.56	11.33	12.78	33.45
RUP	2.4	2.8	11.2	11.4	27.82
NLP	2.38	6.23	8.38	8.23	25.22
TEZ	4.0	5.92	14.15	15.08	39.15
SHL	0.8	2.8	9.4	11.0	24.0
IMP	2.62	9.23	14.62	11.54	38.01
PSG	3.33	5.0	5.67	2.83	16.83
AGT	3.55	5.45	12.27	17.0	38.27
N.E. India	3.02	6.14	11.78	11.76	32.71

Table 4(b): Monthly distribution of average number of thunderstorm days during pre-monsoon period for different stations of northeast India.

Station Code	Months				
	FEB	MARCH	APR	MAY	Total
GHT	1.17	3.75	10.75	11.83	27.5
MHB	5.0	9.0	12.67	8.83	35.5
CPJ	1.31	3.69	9.85	9.85	24.7
SLC	2.11	4.67	8.22	11.11	26.11
RUP	1.2	0.8	7.2	8.4	17.6
NLP	2.0	4.62	6.23	6.23	19.08
TEZ	1.92	4.15	10.0	10.38	26.45
SHL	0.4	1.4	6.4	8.2	16.4
IMP	1.62	6.08	9.69	8.15	25.54
PSG	2.67	3.5	4.33	1.67	12.17
AGT	1.55	2.45	6.73	12.18	22.91
N.E. India	1.90	4.01	4.01	8.80	18.72

Table 4(c): Monthly distribution of average number of thunderstorm days with rain during pre-monsoon period for different stations of northeast India.

Station Code	Months				
	FEB	MARCH	APR	MAY	Total
GHT	1.4	2.7	3.9	5.3	13.3
MHB	1.6	2.4	2.6	2.6	9.2
CPJ	0.9	2.1	2.7	1.1	6.8
SLC	0.7	1.8	3.1	1.7	7.3
RUP	1.2	2.0	4.0	3.0	10.2
NLP	0.4	1.5	2.2	2.0	6.1
TEZ	2.1	1.8	4.2	4.7	12.7
SHL	0.4	1.4	3.0	2.8	7.6
IMP	1.0	3.2	4.9	3.4	12.5
PSG	0.6	1.5	1.3	1.2	4.6
AGT	2.0	3.0	5.5	4.8	15.4
N.E. India	1.1	2.1	3.4	3.0	9.6

Table 4(d): Monthly distribution of average number of thunderstorm days without rain during pre-monsoon period for different stations of northeast India.

Station Code	Total No of thunderstorm events	Total No of thunderstorm days	Thunderstorm days with rain		Thunderstorm days without rain	
			Actual days	% of Total	Actual days	% of Total
GHT	64.8	40.8	27.5	67.4	13.3	32.6
MHB	69.4	44.7	35.5	79.5	9.2	20.5
CPJ	45.2	31.5	24.7	78.3	6.8	21.7
SLC	50.3	33.4	26.1	78.1	7.3	21.9
RUP	39.6	27.8	17.6	63.3	10.2	36.7
NLP	31.8	25.2	19.1	75.6	6.1	24.4
TEZ	61.9	39.2	26.5	67.6	12.7	32.4
SHL	37.2	24.0	16.4	68.3	7.6	31.7
IMP	63.8	38.0	25.5	67.2	12.5	32.8
PSG	21.7	16.8	12.12	72.3	4.6	27.7
AGT	51.2	38.3	22.9	59.9	15.4	40.1
N.E. India	48.8	32.7	23.1	70.6	9.6	29.4

Table 4(e): Average number of thunderstorm days with and without rainfall observed during pre-monsoon period for different stations of northeast India.

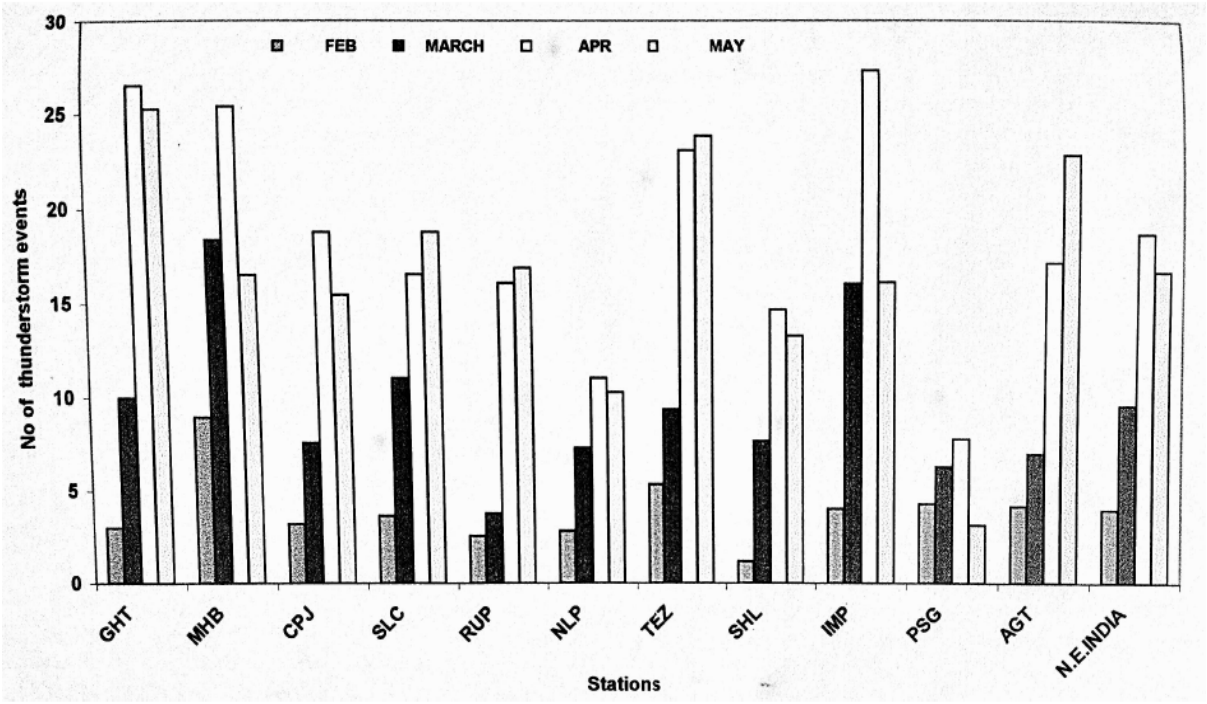

Figure 4(a): Average monthly variation of thunderstorm events during pre-monsoon period for different stations of northeast India.

Table 4(a) also indicated that the number of thunderstorm activity is the highest in the month of April which constitute about 38.20% of the total thunderstorm events those occurred during pre-soon period. Thus it is clear that the months of significant thunderstorm activity in northeast India are the month of April and May.

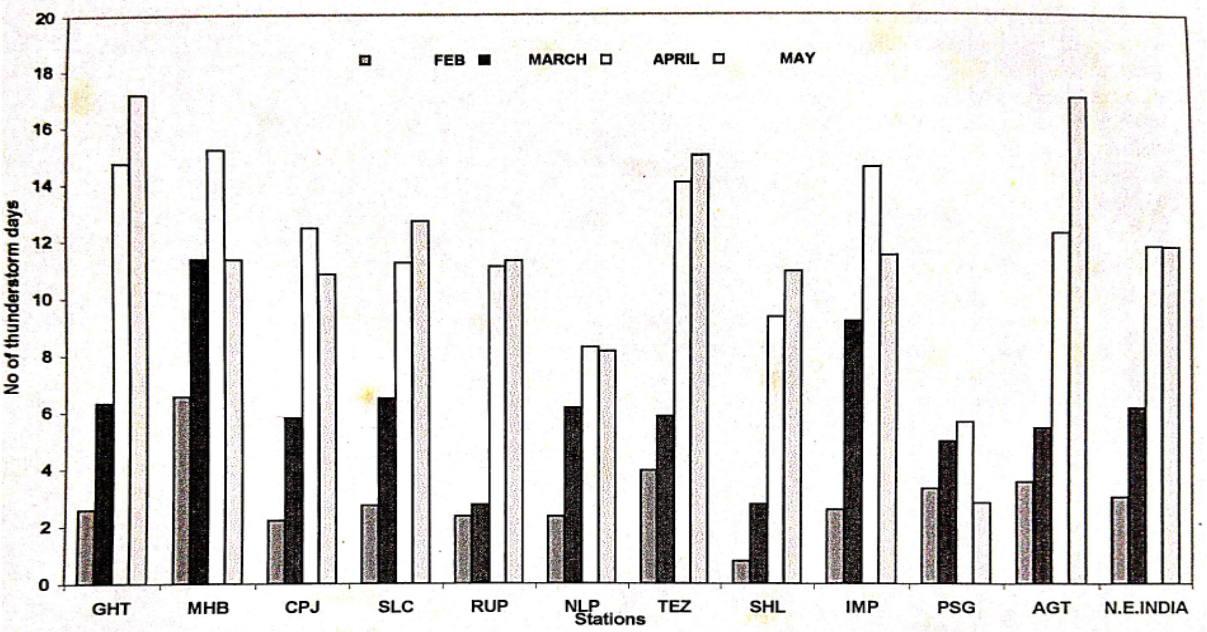

Figure 4(b): Average monthly variation of thunderstorm days during pre-monsoon period for different stations of northeast India.

It is also clear that on the average the region witness thunderstorm nearly twelve days during each month of April and May. These two months contribute about 73% of the total thunderstorm days of pre monsoon period. Thunderstorm days found to be lowest during February followed by March.

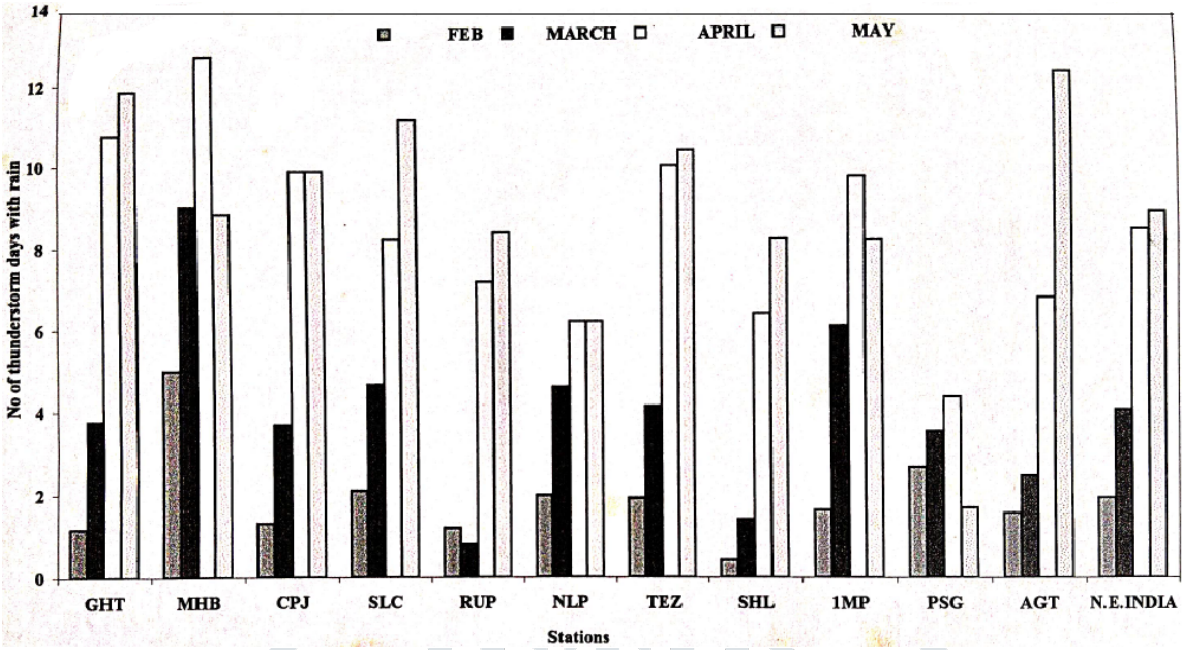

Figure 4(c): Average monthly variation of thunderstorm days with rain during pre-monsoon period for different stations of northeast India.

Table 4(c) gives the average month wise variation of thunderstorm days with precipitation at different stations during the pre monsoon period. It is clear from the table that about 19.3% of the total pre monsoon days (February to May) experience thunderstorms associated with rainfall. Moreover those days having thunderstorm with rainfall contribute about 70% of the total pre monsoon thunderstorm days. On the average the month of April and may witness significantly higher number of days of thunderstorm with rain while the month of February witness the least the least number of days experiencing thunderstorm with rain. For the region as a whole the number of thunderstorm days with precipitation during the months of February, March, April and May are found to be 5.81%, 12.26%, 25.59%, 26.9% of their respective number of thunderstorm days.

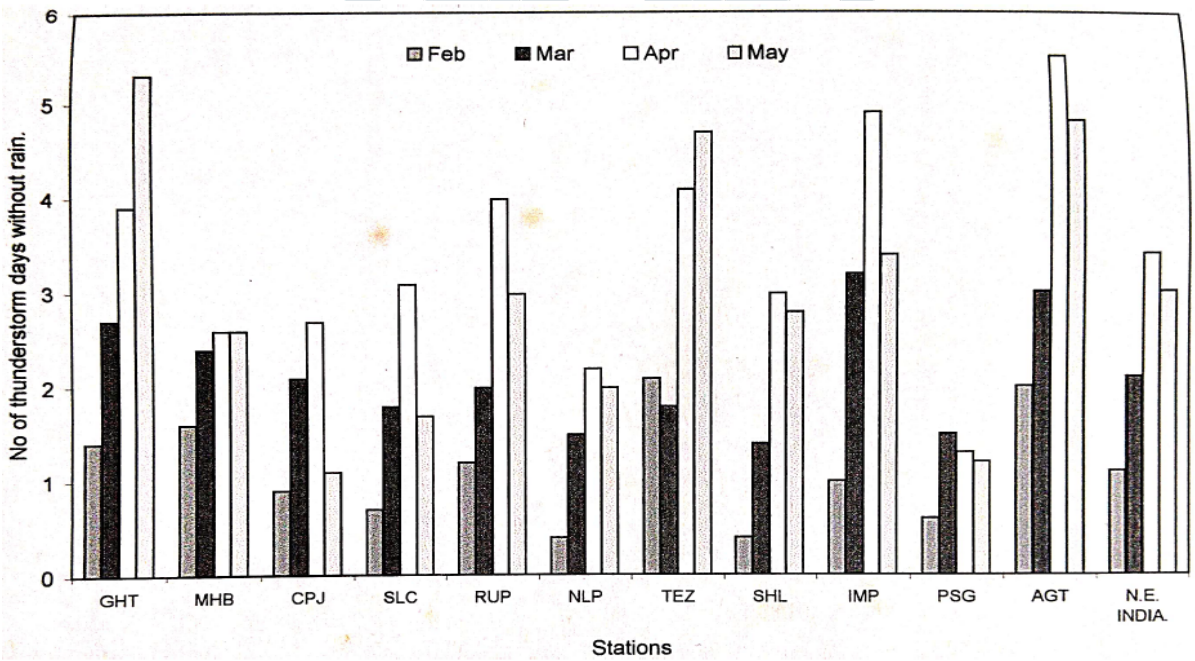

Figure 4(d): Average monthly variation of thunderstorm days without rain during pre-monsoon period for different stations of northeast India.

Comparing Table 4(c) and Table 4(d) the number of thunderstorm days without precipitation has been found out for all the stations and the results are presented in Table 4(e). It is a clear that about 8.1% of the total pre-monsoon days experiences thunderstorm without rainfall. Moreover those days having thunderstorm without rainfall contributes about 29.7% of the total thunderstorm days of pre monsoon period. On the average the months of April and May contain significantly higher number of days of thunderstorm without rain. For the northeast India as a whole the number of thunderstorm days without rain during the month of February, March April and May are found to be 11.3%, 21.6%, 35.1%, and 30.9% of their respective number of thunderstorm days without rain respectively.

From the Table 4(a), 4(b), 4(c) and 4(d), the mean values of thunderstorm events, thunderstorm days, thunderstorm days with rainfall and thunderstorm days without rainfall belonging to all the stations and the entire northeast India as a whole has been summarized in Table 4(e) . The average value of all the station which also represented the entire northeast India region indicates that about 48.8 thunderstorm events take place during pre monsoon period.

4.5 Year wise variation of thunderstorm activity:

An investigation of time series of thunderstorm events, thunderstorm days and thunderstorm days with and without precipitation occurred during the pre monsoon period has also been made for all the stations. As the time series are of short (35 years only) duration so the trend and periodicity analysis have not been tried. However some important statistics representing the fluctuation of the variables with time such as the minimum value and the maximum value, range of variation and standard deviation have been calculated for all the stations. The results have been incorporated in Table 5.

Name of station	Total thunderstorm days				Total thunderstorm days with rain				Total thunderstorm days without rain				Total thunderstorm events			
	max	min	ran	s.d.	max	min	ran	s.d.	max	min	ran	s.d	max	min	ran	s.d
GHT	53	21	32	8.4	35	15	20	5.0	19	6	13	4.4	91	26	65	16.2
MHB	52	39	13	5.0	45	28	17	4.5	18	6	9	2.9	91	54	37	10.4
CPJ	45	15	30	10.9	40	14	26	8.7	5	1	14	3.1	77	18	59	18.9
SLC	51	13	38	10.6	42	13	29	7.7	10	0	10	3.4	82	16	66	20.1
RUP	48	20	28	10.6	28	13	25	5.5	20	6	14	5.1	82	22	60	21.7
NLP	48	15	33	9.2	42	10	32	8.2	10	3	7	2.5	57	18	39	10.9
TEZ	50	21	29	8.5	39	14	25	7.2	19	7	12	3.3	53	23	60	16.8
SHL	30	13	17	6.1	24	9	15	4.9	10	4	6	2.1	50	16	34	11.5
IMP	54	28	26	7.9	39	15	24	6.4	16	8	8	2.8	103	42	61	18.8
PSG	36	8	28	10.9	29	5	24	8.7	10	1	9	2.9	52	9	43	17.3
AGT	61	26	45	9.4	42	9	33	8.3	19	10	9	2.4	88	32	56	14.5

max :- Maximum min :- Minimum ran :- Range (Maximum-Minimum). s.d. :- Standard Deviation

Table 5: Year wise variation of thunderstorm activity (thunderstorm days, thunderstorm days with and without thunderstorm events) during pre-monsoon period of Northeast India.

It is seen from the table that for high range of variation of thunderstorm events, thunderstorm days and thunderstorm days without rainfall and with rainfall the corresponding standard deviation are also high which reveals that the values of thunderstorm events, thunderstorm day and thunderstorm days with and without rainfall are highly fluctuating in nature. For low value of standard deviation it is seen that the range of variations of thunderstorm events thunderstorm days and thunderstorm days with and without rainfall are small. These values are different for different stations of northeast India.

5. Conclusion:

From this study it has been observed that pre-monsoon thunderstorm as well as rainfall has great environmental impact in the studied region. This type of study also helps in proper planning and management of thunderstorm related hazards during the pre-monsoon period. Diurnal variation of thunderstorm reveals that maximum number of events takes place within 2100-0300 hours (IST) i. e. at late night and early morning and minimum number of events takes place within 0800-1500 hours (IST). Pentad variation of thunderstorm indicates that there is general tendency of increase in the thunderstorm activity from 2nd week of April to 3rd week of May. It can also be concluded that highest number of thunderstorm occurs during the month of April. Maximum number of days of thunderstorm with rain occurs during month of May. During this month about 27% of the total number of thunderstorm days is associated with rain. About 27.3% of days during pre-monsoon season witness thunderstorm. The number of days of thunderstorm in the region is of the order of 11.07% days in April and 11.76 days in May, is so high in comparison to the average value of the Indian Subcontinent.

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