A LIGHTNING CLIMATOLOGY OF NORTHEAST INDIA: 1998-2007

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Abstract: About 55,000 lightning flashes were recorded by the Lightning Imaging Sensor (LIS) during the 10-year period (1998-2007) in northeast India (NEI) and were analyzed to study their total climatology, seasonal, annual and inter-annual variations. The results suggest that the western region of the northeast India is prone to a maximum amount of lightning activity and the northeast and eastern part is minimal in activity. The activity shifts west and east as the season advances. It is stagnant in the western and southwestern region in the last season of the year. The highest percentage of activity is observed during the pre-monsoon season. During the annual course the activity exhibits bimodal variation giving an average value of 8.4 flashes/pass. The time series analysis of the parameter shows that the activity over NEI shows a consistent increase from 1998 to 2002 and then onwards it shows a consistent decrease. The activity in December is a characteristic feature for the region. The highest magnitude of activity is noticed in the year 2001 with 20 flashes/pass.

INTRODUCTION

Lightning is one of the most beautiful yet terrifying and little understood weather events on this planet. It is generated by the breakdown of electric fields in thunderstorm systems, through discharges that can be Cloud-Cloud (CC), Cloud-Air (CA) or Cloud-Ground (CG). It is estimated that around the world every second there are more than 2000 active thunderstorms producing roughly 100 lightning flashes (Brooks, 1925). Lightning is therefore, a far more common phenomenon than most people might think. Deaths and injuries to live stock and thousands of forest and bush fires and millions of pounds worth of damage to buildings, communication systems, powerlines and electrical systems also result from lightning, thus being a menace to people.

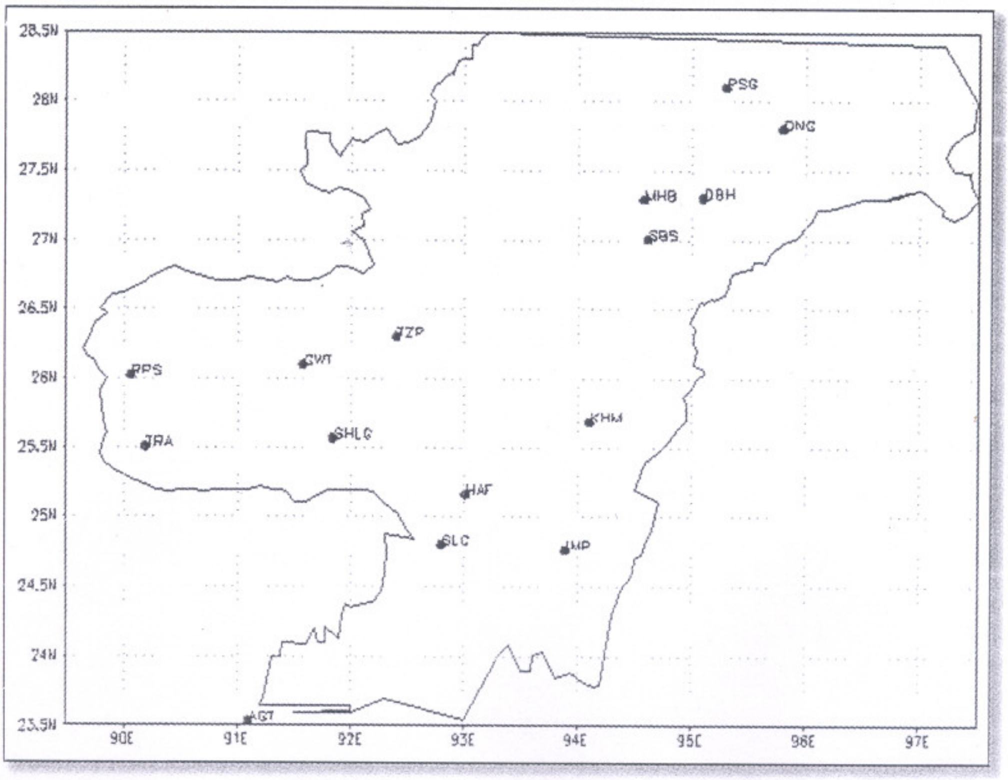


Figure 1. Topographic Map of North East India.

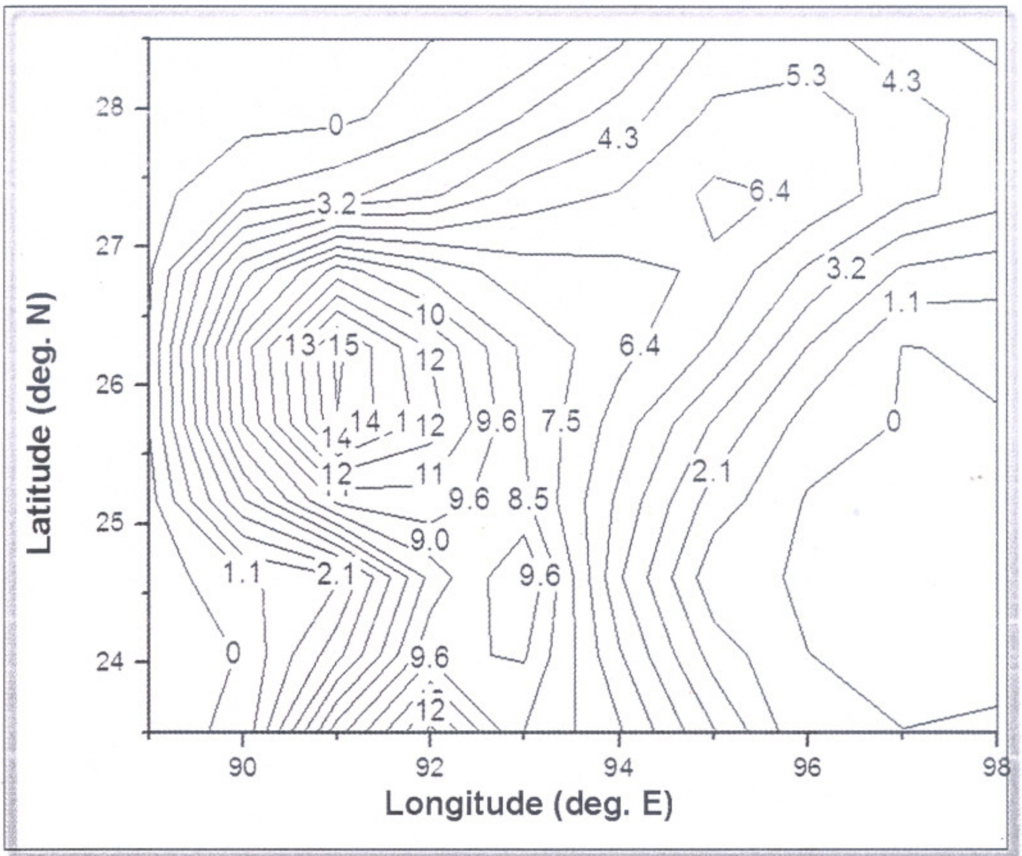


Figure 2. 10-year climatology of lightning activity (flashes/pass) over northeast India..

A review of the formal literature reveals that lightning events and their possible association with meteorological parameters have been examined by a number of researchers (Thotappallippi *et al.*, 1992; Price and Rind, 1994a,b; Mackerras and Darveniza, 1994; Orville, 1994; Orville *et al.*, 1997; Hodnaish *et al.*, 1997; Yair *et al.*, 1998; Pinto *et al.*, 1999; Boccippio *et al.*, 2000a,b,c; Nesbitt *et al.*, 2000; Williams *et al.*, 2000; Petersen and Rutledge, 2001; Toracinta *et al.*, 2002) in the tropics and extratropical region. Although the studies have provided a valuable look into the thermodynamic and meteorological parameter, the climatology of the parameter has not been discussed except in a few studies (Holt *et al.*, 2001; Orville and Huffines, 2001; Hodniash *et al.*, 1997). Similarly over the Indian region the parameter has been examined to study their diurnal and spatio temporal variability (Kandalgaonkar *et al.*, 2003, 2005, 2006). A survey of the available literature over the Indian region shows that minimum attention is given to the climatology of lightning. Studying the climatology of past lightning events provides additional information that can be used in some instances to increase the reliability of forecasts.

NEI is one of the most lightning prone regions in India (Rao and Raman, 1961; Krishna Rao, 1961; Rao *et al.*, 1978; Subramanian and Seghal, 1967). Every year the region receives quite a good number of thunderstorms during the pre-monsoon months (Chadhuri, 1961; Sen and Basu, 1961; Mukherjee *et al.*, 1964). The places of origin of these thunderstorms affect the foothill region of Chota Nagpur, of the hills flanking the northern and eastern boundaries of Bengal and Assam and the foot of the Khasi Hills (IMD, 1941). However, most of these thunderstorms belong to Type A and Type B of “Nor’westers” in Bengal. Type A usually starts in West Bengal and Chota Nagpur area in the afternoon hours and proceeds in the northwest and southeast direction to then eventually reach NEI. Type B thunderstorm originates in sub-montane districts of north Bengal during the night and in the early morning they move down to the mouth of Meghana and some of these thunderstorms affect NEI.

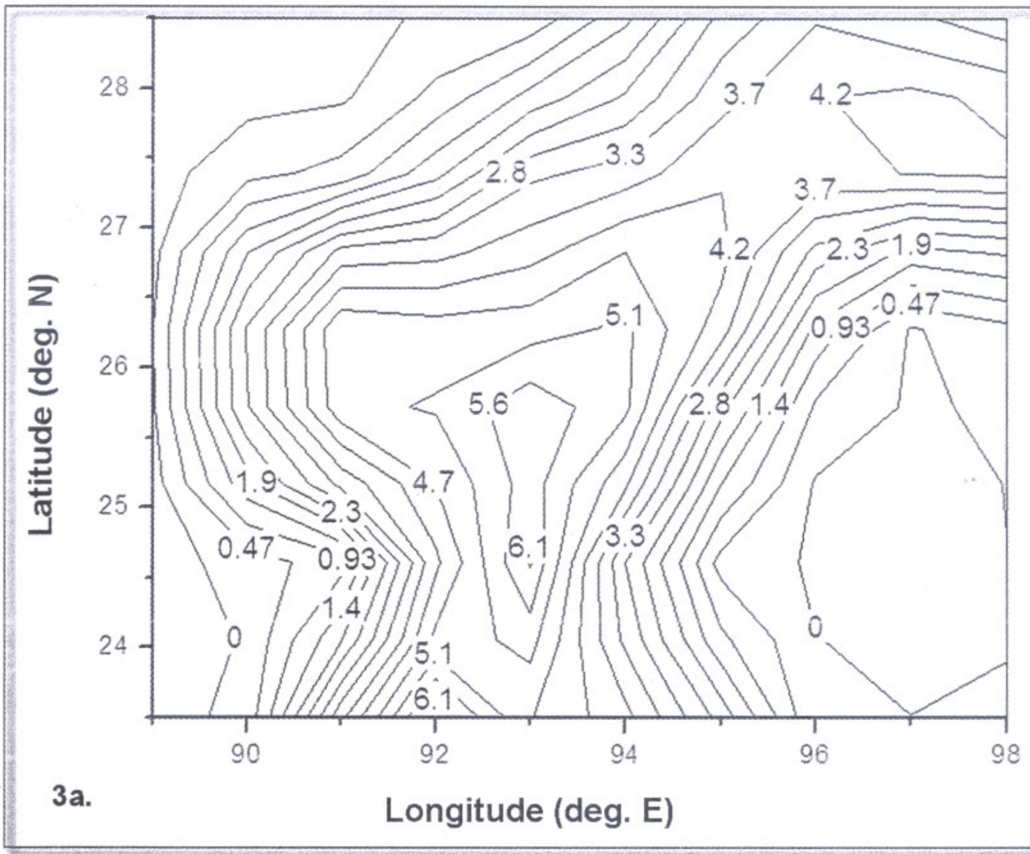
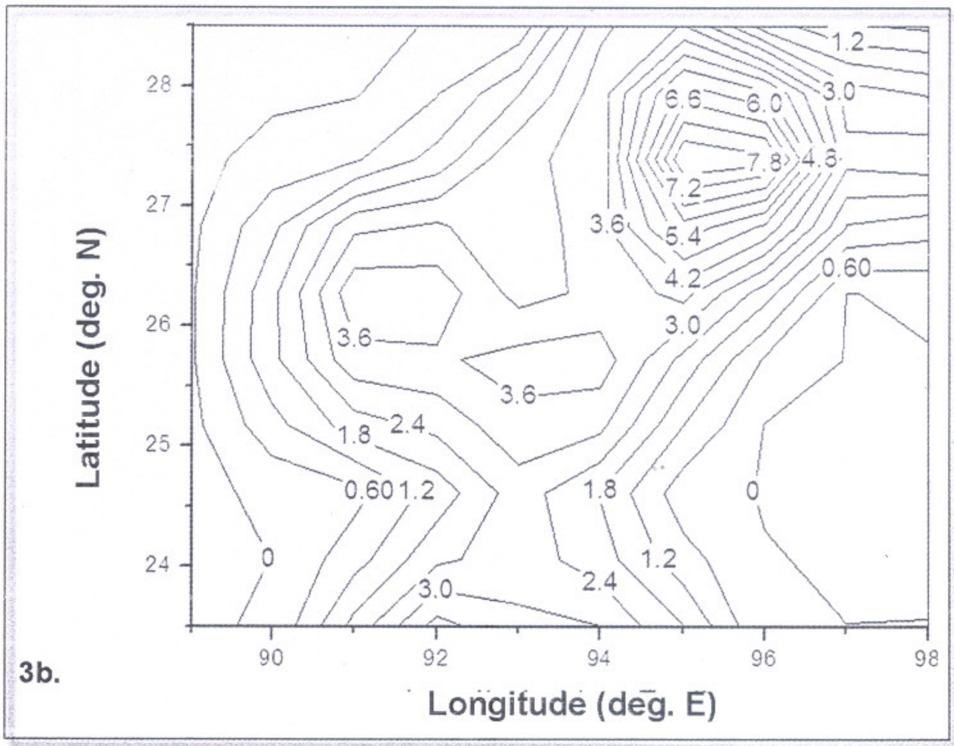


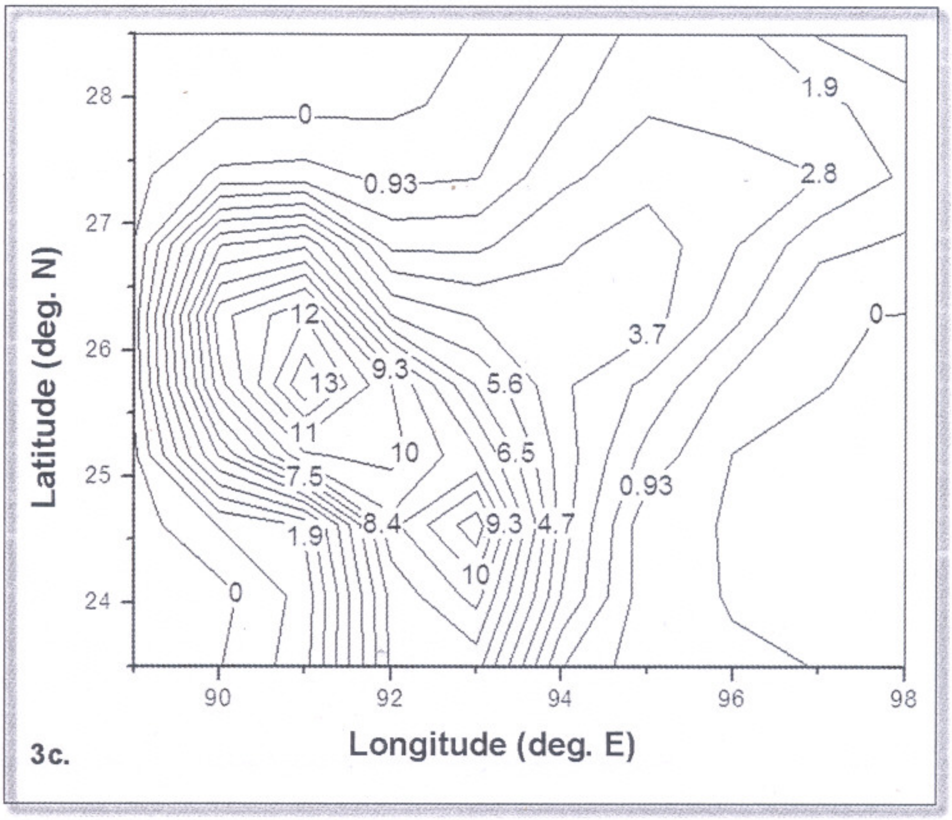
Figure 3(a-d). Seasonal variation of lightning activity (flashes/pass) over northeast India.

The mechanism of formation favourable for these synoptic situations and the movement of these thunderstorms have already been studied by several researchers (Desai, 1950; Mull *et al.*, 1955; Bose, 1957; Koteswaram and Srinivasan, 1958; Srinivasan *et al.*, 1973; Philip *et al.*, 1973; Kalita and Kalita, 1995). Although these thunderstorms are considered as blessings to the region providing much needed water in times of drought, some of them are devastating in nature and cause an enormous loss of property and life and they are a serious hazard to aviation. A number of studies describing the thunderstorm climatology, rainfall, convective clouds over NEI are available (Chowdhury and Banerjee, 1983; Kalita and Sarma, 2000), however the study pertaining to the thunderstorm relating to lightning over this region has not been noticed in the scientific community. Considering NEI is one of the major centres of electrical activity in the world, and it is influenced by synoptic, thermal and orographic factors, an examination of the spatio-temporal variability of the lightning may be considered as additional information. Therefore in this paper the authors assess for the first time, the climatology of the lightning over NEI during a 10-year period (1998-2007), which can be considered as the best available information to date.

DATA

The satellite-based LIS grid data (1° x 1°) for 10 year period (1998-2007) have been used in the present study. The details of the satellite are discussed elsewhere (Christian *et al.*, 1999; Boccippio *et al.*, 2000; Kandalgaonkar *et al.*, 2003, 2005). The present study's domain, NEI, stretches between 89° to 98°E longitude and 23° to 28°N latitude (Figure 1). For the analysis purpose the latitude belt is divided into six strips of a 1° interval each. The number of 1° x 1° boxes in the six latitude strips is 27 respectively. The lightning activity recorded by the LIS in each grid box during the 10-year period is utilized to study their spatial, temporal and seasonal variation.





RESULTS

Total climatology

Figure 2 shows the average number of flashes per pass contoured for the 10-year period (1998-2007) over NEI. From this figure it can be seen that the broad maximum (16 flashes/pass) of the activity exits along the west of NEI (26.25° N and 90.5°E) and it extends northwards, southwards and eastwards. Its extension towards northward is uniform while it is steep towards the east and south. A local minimum is evident in the northeast and eastern part of the region.

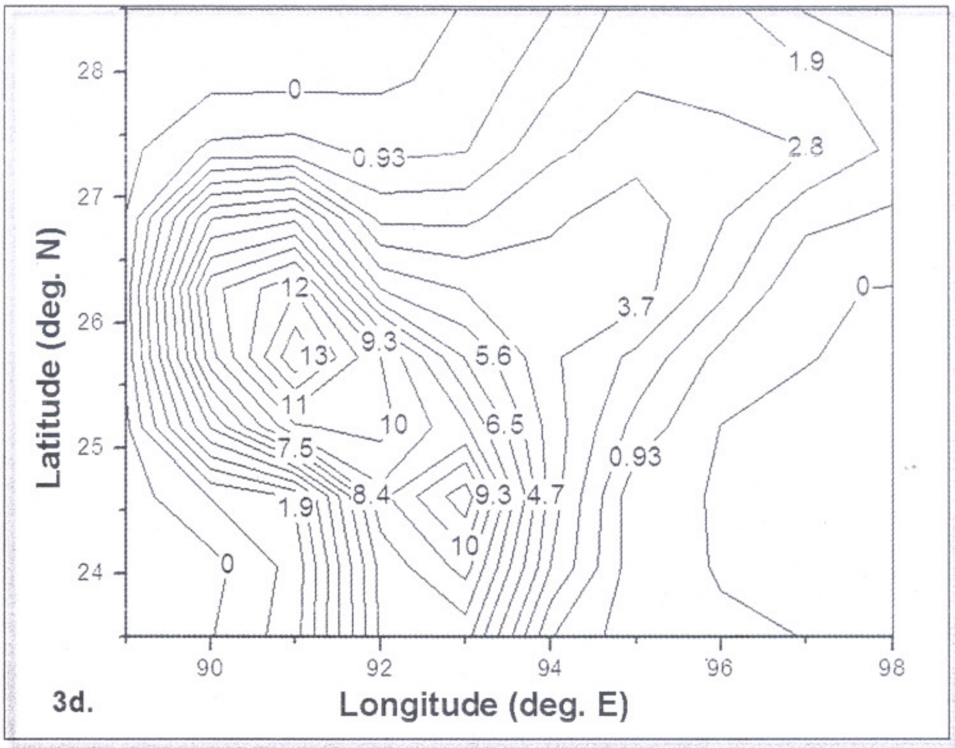


Table 1 gives the number of flashes/pass and the percentage of flashes and passes which occurred during the 10-year period for each latitude strip. From the table it can be seen that during the period of study the average number of flashes/pass observed over the entire NEI is 8.4. The highest number of flashes/pass is observed in the latitude strip 24°N-26°N. The percentage of occurrence in flashes and passes show that the number of these increases from 23°N to 26°N except 24°N and then starts decreasing from 27°N and becomes minimal at 28°N. The highest percentage of flash occurrences is 31 % and passes 28% respectively and these are between 25°N - 26°N. Chowdhury and Banerjee (1983) studied hailstorms over NEI for an 8-year period. Their studies revealed that the latitudinal strip between 24°N and 26°N and the longitudinal strip between 90°E to 92°E experienced a maximum number of hailstorms which is nearly 33 % of the total number of hailstorms occurring in this region. Since the formation of hail plays a part in electrical phenomenon during the thunderstorm event, any information about its formation may be useful for the identification that the storm may be intensifying.

Strip	Flashes / Pass	Percentage of flashes	Percentage of passes
23°N-24°N and 89°E-97°E	11.33	14.49	12.07
24°-25°N and 89°E-97°E	11.78	9.71	7.79
25°N-26°N and 89°E-97°E	11.23	30.61	25.74
26°N-2°°N and 89°E-97°E	10.30	30.33	27.79
27°N-28°N and 89°E-97°E	5.59	11.88	20.05
28°N-29°N and 89°E-97°E	4.27	2.96	6.54

Table 1. Percentage of flashes and passes and number of flashes/ passes in each latitude strip over NEI during 10-year period.

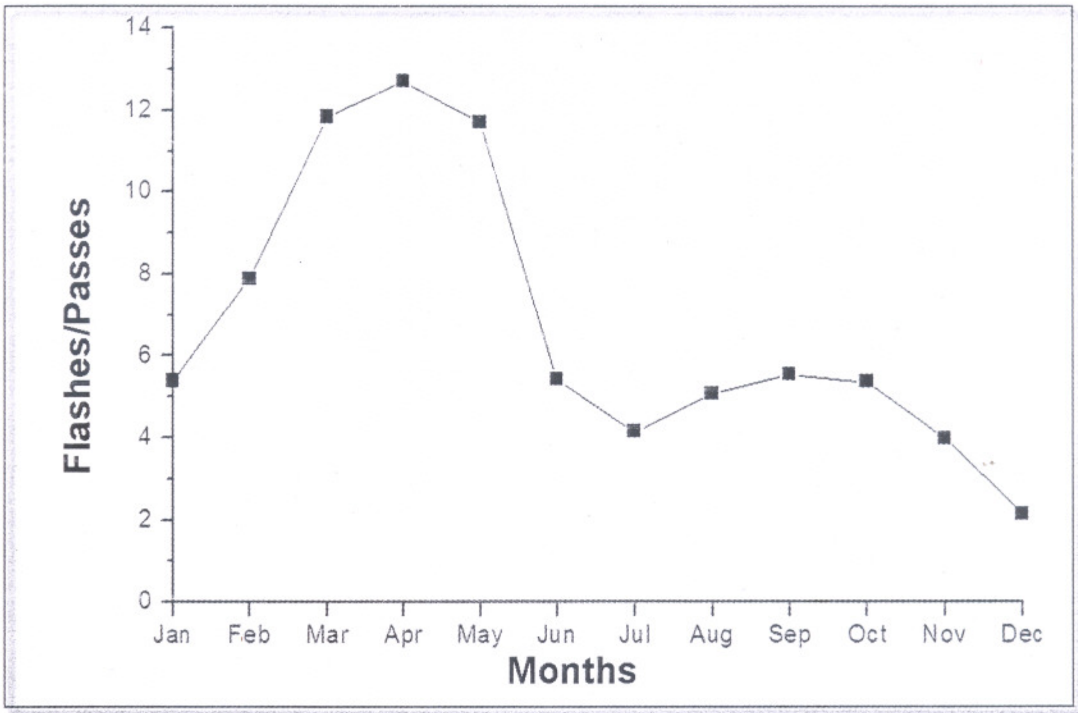
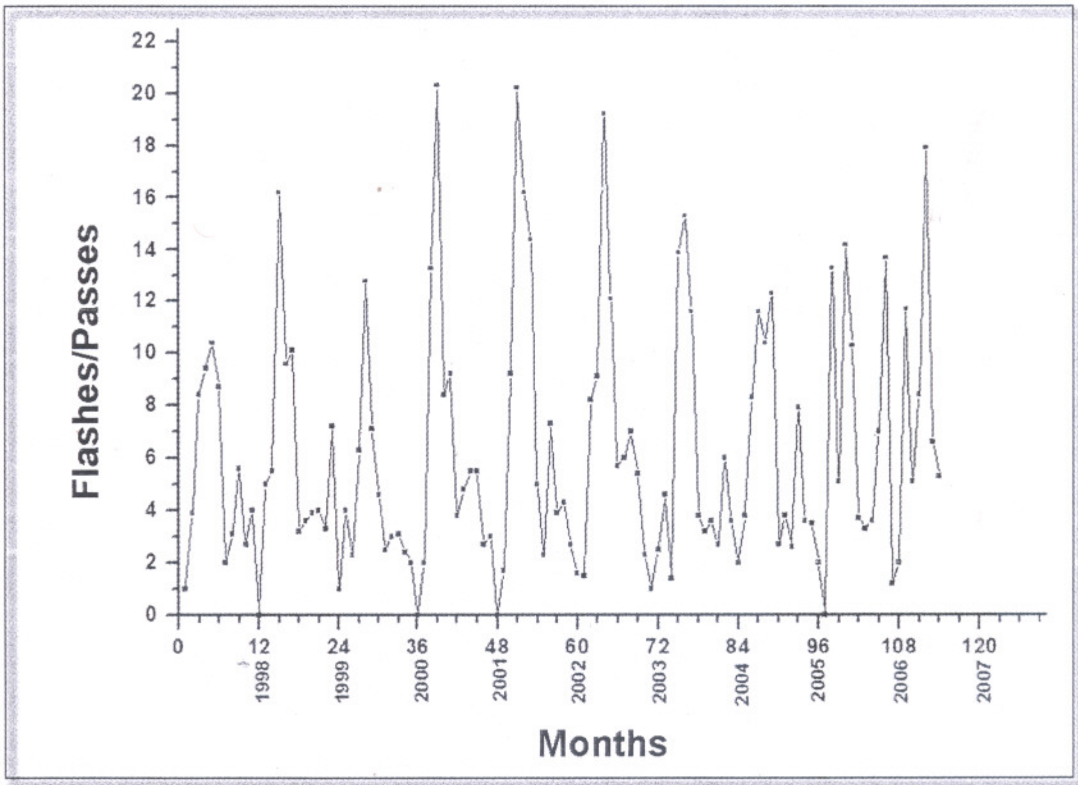


Figure 4a. Annual variation of lightning activity over northeast India.



4b Time series analysis of lightning activity over northeast India.

Many storm parameters such as temperature, electrical conductivity, hydrometeor type vary widely within thunderstorms and this variation may be important to electrification processes and lightning production (MacGorman and Rust, 1998). Thus the maxima in the lightning in the above mentioned strip is in agreement with the hailstorm studies made by Chowdhury and Banerjee (1983). The probable cause for the maximum lightning activity in the area between 24°N to 26°N could be due to the topography of NEI which includes the mountainous district of the Garo Hills and Khasi Jaintia Hills. Due to the hilly region, the convergence of the airmass of the contrasting thermal and humid characteristics is a potential reason for cyclogensis where marked instability frequently develops.

Roy (1939) showed that active thunderstorms often develop in this frontal zone, located mostly in the moist airmass. Within this frontal zone, convection develops when a warm and moist southerly airmass from the Bay of Bengal glides over the cold and denser current over the northwest. The buoyancy is enhanced by the effects of insolation (Zuidema, 2002). Williams (1994) suggested that the conditional instability is more fundamental for the development of thunderstorms and hence lightning. Thus the higher lightning activity over the region may be due to the consistent unstable condition of the atmosphere.

SEASONAL VARIATION OF LIGHTNING ACTIVITY OVER NORTHEAST INDIA

Figure 3a shows the contours of lightning activity during the pre-monsoon season. The highest activity of 28 flashes/pass was observed in the western part of NEI near Tura (TRA) and Roopsi (RPS). The next higher centre (8.4 flashes/pass) is located in the northeastern part of NEI between Dibrugarh and Darjeeling. The seasons lower the central activity (7 flashes/pass) and this is observed along the eastern part of NEI near Kohima (KHM). The above result of higher and lower activity centres is in agreement with the studies made by Kalita and Sarma (2000). Their results showed that thunderstorm days without rainfall is found to be highest at Agartala (40 %) followed by Rupsi, Imphal, Guwahati, Tezpur, Shiliong, Pasi Ghat, North Lakhimpur, Silicar, Cherrapunji and Mohanbari. The average number of flashes/pass in this season is 11.3.

Figure 3b gives the similar plot for monsoon season. In this season, entire NEI experiences the lightning activity but the magnitude of the activity is less compared to pre-monsoon season. The season's highest activity is 6.1 flashes/pass which is observed along the southwestern boundary of NEI. In this season the activity is shifted west. There are nearly six centres of higher activity ranging from 5.0 to 6.1 flashes/pass. The minimum activity of the season is seen north of NEI. From Figure 3b it can also be seen that in this season activity decreases from the west and southwest to the northeast and becomes minimal in the north. The average number of flashes/pass is 4.2.

Figure 3c gives the activity for post-monsoon season. From this figure it is seen that except northeast, northwest and southwest areas of NEI, the remaining areas experience minimum lightning activity (4.4 flashes/pass). The southwest part experiences the season's highest activity (18 flashes/pass). In this season the higher activity centres shift further west and crosses the entire northeast, western and southwestern boundary of NEI. The average number of flashes/pass is 4.3.

Figure 3d shows a similar contour for winter. From this figure it is seen that the higher activity centres are shifted eastwards concentrating again at the western, southwestern and southeastern part of NEI. The season's minimum activity is seen in the northeastern part of NEI. The average number of flashes/pass is 4.6.

The inter-seasonal comparison of the activity shows that in pre-monsoon season the magnitude of the activity is higher and is concentrated only in the western part of NEI and decreases towards the east initially with a uniform gradient, but later, with a higher gradient along the northeast. In monsoon season the activity shifted to the west. Thus the higher activity centres lie on the western and southwestern boundary of the region. Compare this to pre-monsoon season, and one finds that entire NEI experienced lightning activity of ~ 2-8 flashes/pass with a uniform gradient and the magnitude of the flash rate is also one third of the pre-monsoon season. Similar comparisons between the monsoon and post-monsoon seasons shows that, only the northeast, northwest and southwestern parst of NEI experiences higher activity in post-monsoon seasons and the rest of NEI shows minimal activity. Compare post-monsoon season in winter season, the activity is again shifted to the east and is concentrated along the western, southwestern, southern and southeastern parts of NEI.

The magnitude of the activity is also higher when compared to the post-monsoon season. Thus the inter-seasonal comparison of the activity shows that as the season advances the activity is shifted west and east and then becomes stagnant in the western and southwestern regions of NEI in the last season of the year. The percentage distribution of the activity during the different seasons is 68 % (pre-monsoon), 25 % (monsoon), 3 % (post-monsoon) and 3.4 % (winter).

ANNUAL AND INTER-ANNUAL VARIATION OF LIGHTNING ACTIVITY

Figure 4a shows the annual variation in mean monthly lightning activity over NEI. From this figure it is seen that during the annual course, lightning activity exhibits bimodal variation giving the first prominent peak (13 flashes/pass) in April and a second lower peak is spread between September and October months (5.5 flashes/pass) giving the average value as 8.4 flashes/pass. The minimum activity in monsoon season is apparent and varies between 4 to 6 flashes/pass.

Figure 4b shows the variation of monthly lightning activity over NEI as a time series from January 1998 to June 2007. From the figure it is seen that the activity over NEI shows a consistent increase from 1998 to 2002 and then onwards it shows a consistent decrease. The bimodal variation of activity is a characteristic feature of the region. A careful examination of time series shows that NEI experiences the activity in every month except during 1998, 2000, 2001 and 2005. The activity in December is a characteristic feature for the region. The highest magnitude of activity is noticed in the year 2001 with 20 flashes/ pass.

CONCLUSION

About 55,000 lightning flashes were analyzed in NEI in terms of their spatio-temporal distribution during the 10-year period studied (1998-2007). From this study, the authors conclude that the total climatology of lightning activity showed that the western region of NEI experiences higher activity and the minimum activity is located in the northeast and eastern parts of the region. Seasonal analysis of the activity shows that as the seasons advance, the activity is shifted to westward and eastward and becomes stagnant in the western, southern, southeastern and southwestern regions of NEI in the last season of the year. The percentage distribution of the activity during different seasons is 68 % (pre-monsoon), 25 % (monsoon), 3 % (post-monsoon) and 3.4 % (winter) respectively.

The lightning activity exhibits bimodal variation during the annual course and this is a characteristic feature for NEI. The average flash rate over NEI is 8.4 flashes/pass. The authors also conclude that the time series analysis of the parameter shows that the activity over NEI shows a consistent increase from 1998 to 2002 and then onwards it shows a consistent decrease. The activity in December month is characteristic for the region. The highest magnitude of activity is noticed in the year 2001 with 20 flashes/pass.

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