Diurnal variation of lightning activity over the Indian region

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[1] Satellite (LIS) based lightning flash grid (0.5° × 0.5°) data for the Indian land mass region covering from 8°–33°N and 73°–86°E for a period of 4 years (1998–2001) were used to study the diurnal variation with one hour time resolution. The analysis revealed that there exists a strong diurnal cycle in the lightning activity with a prominent peak around 1000 UTC. An examination of seasonal diurnal variation suggests that the lightning activity was found highest in premonsoon and lowest in the postmonsoon season. *INDEX TERMS:* 3304 Meteorology and Atmospheric Dynamics: Atmospheric electricity; 3324 Meteorology and Atmospheric Dynamics: Lightning; 3399 Meteorology and Atmospheric Dynamics: General or miscellaneous; 4227 Oceanography: General: Diurnal, seasonal, and annual cycles; 6062 Planetology: Comets and Small Bodies: Satellites. **Citation:** Kandalgaonkar, S. S., M. I. R. Tinmaker, J. R. Kulkarni, and A. Nath, Diurnal variation of lightning activity over the Indian region, *Geophys. Res. Lett.*, *30*(20), 2022, doi:10.1029/2003GL018005, 2003.

1. Introduction

[2] For many years it has been a standard practice for a weather observer to record the starting and ending times of audible thunder as basic weather parameters. Today these records are used to describe the frequencies, diurnal variations and intensities of thunderstorms as well as lightning [*Brooks*, 1925; *Neumann*, 1968; *Rasmusson*, 1971; *Wallace*, 1975; *Changery*, 1981]. Thunder is produced by lightning and its distribution with time is an index of electrical activity of the storm. Knowledge of the lightning activity in the area of interest is an important tool to the meteorologists. A considerable literature is devoted to the discussions on diurnal variations of lightning activity for different regions [*Maier et al.*, 1984; *Reap*, 1986; *Lopez and Holle*, 1986; *Williams and Heckman*, 1993; *Westcott*, 1995; *Orville et al.*, 1997; *Jayaratne and Ramachandran*, 1998; *Pinto et al.*, 1999; *Williams et al.*, 2000; *Orville and Huffines*, 2001]. However, the studies pertaining to the diurnal variability of lightning occurrences over the Indian region are scanty, except a few studies by *Aiya* [1968] and *Boeck et al.* [1999]. Hence, in the present study, the diurnal variation of lightning activity over the Indian region is examined.

2. Data and Methodology

[3] The daily Lightning Imaging Sensor (LIS) data for 4 year period (1998–2001) at spatial resolution of 0.5° × 0.5° grid (∼55 km × 55 km) obtained from Global Hydrology and Climate Center Lightning Research Team at NASA's Marshall Space Flight Center have been used in the present study. The domain of the study covers the Indian region between 8°–33°N and 73°–86°E excluding the oceanic regions. The region is divided into 5-belts each of 5° latitude interval (8°–13°N, 13°–18°N, 18°–23°N, 23°–28°N and 28°–33°N). During the period of study the LIS satellite has made 1086 passes of 90 minutes each. Thus the total viewing time of the satellite over India is 97740 minutes which is about 67 days in 4 years or ∼16 days/year. The data set from LIS gives daily lightning flash count along with their starting and ending times in UTC, (for Indian region: LT = UTC + 5 1/2 hrs). From the available LIS time resolution of 90 minutes the data is interpolated to one hour resolution for convenience of the representations. Since the major goal of the present study is to examine the diurnal variation, the authors have given more importance to the starting and ending times of the flash counts. For this purpose, the lightning flashes occurred during the same time in all years are added together and are represented as percentage value against the respective hour. For example at 0000 UTC, during the period of study flash count is 67. This value is expressed as percentage with respect to total number of flash count (10219) which is equal to 0.70 and is shown against 0000 UTC. Similarly, the percentages were obtained for the remaining hours. The same method is used to obtain the diurnal variations for different seasons: premonsoon (March–May); monsoon (June–September) and post-monsoon (October–November).

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3. Results and Discussions

3.1. Diurnal Variation

[4] Figure 1a shows the diurnal variation of lightning activity in percentage with two peaks, first peak at 1000 UTC and second at 1600 UTC. The lightning activity is strong from 0600–1800 and weak during 0000–0400 UTC and then increases sharply with peak at 1000 UTC. This peak time is somewhat earlier than that reported elsewhere. For example, *Eriksson* [1976] found the peak activity at Pretoria, South Africa, ∼ at 1700 LT; while *Oladiran et al.* [1988] at 1800 LT in Ibaden, Nigeria. Times of maximum activity outside Africa include 1630 LT in Florida, USA [*Maier et al.*, 1984], 1700 LT in Darwin, Australia [*Williams and Heckman*, 1993] and 1600–1700 LT in Southern Germany [*Finke and Hauf*, 1996]. The probable cause of variation in peak time and distribution may be associated with the variations in the local mesoscale circulations. These mesoscale circulations are set up in response to the interplay between large-scale-circulations impacting on the diurnal cycle of insolation and underlying topographic features of the region [*Lopez and Holle*, 1986; *Pinto et al.*, 1999]. Studies made by *Price and Rind* [1994] at

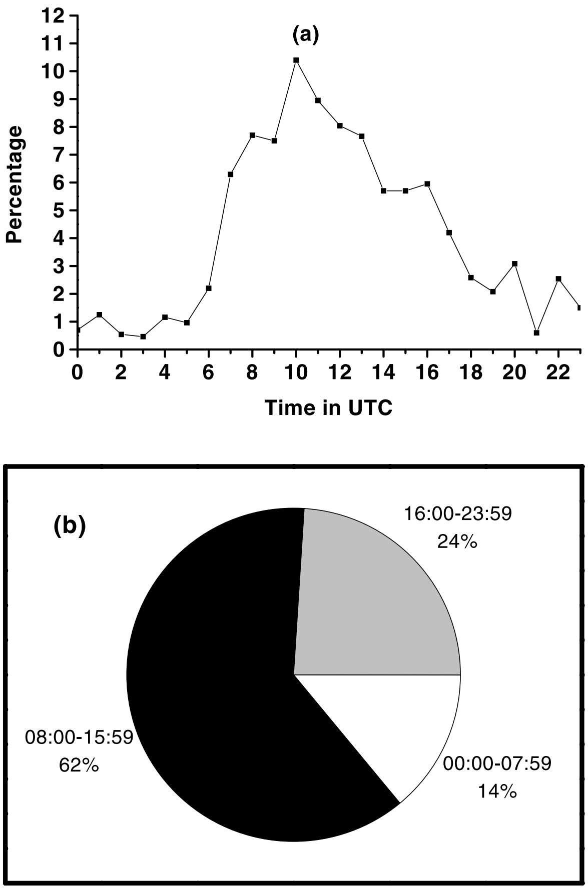

Figure 1. (a) Diurnal variation of lightning activity over the Indian region during 1998–2001, (b) Percentage distribution of lightning activity during 1998–2001.

tropical West Africa and Western United States showed that at both locations, the activity peaked in the mid-afternoon with minimum during the early morning hours. *Easterling and Robinson* [1985] made comprehensive analysis of the geographical distribution of the diurnal variation in thunderstorm activity and showed the time of peak activity varied significantly in space. Since lightning is physically related to the thunderstorm the present result of early occurrence of peak is in agreement with the studies by *Easterling and Robinson* [1985]. The percentage distribution of lightning activity during the total diurnal period is illustrated through a pie chart in Figure 1b. The total diurnal period is divided into three equal time intervals (0000–0759 UTC: early morning to afternoon, 0800–1559 UTC: afternoon to late evening, 1600–2359 UTC: late evening to early morning). It is seen that 62% of the activity is distributed between 0800–1559 UTC, 24% between 1600–2359 UTC and 14% between 0000–0759 UTC. This result is consistent with studies made by *Price and Rind* [1994] over tropical West Africa and Western United States.

3.2. Seasonal Diurnal Variation

[5] Since the majority of lightning occurs in the tropics and there is a significant difference between seasonal variations of lightning activity, authors have examined its diurnal variations during the pre-monsoon, monsoon and post-monsoon seasons. Figure 2a show diurnal variation of the percentage values of the activity in premonsoon season. It is seen that the curve exhibits typical diurnal variation with a prominent peak spread between 1000 to 1100 UTC. The small peaks at 0100, 0400 and 2200 UTC are not significant. The amplitude of the activity is highest in the afternoon (1000–1100 UTC). It remains strong till early hours of night (1730 UTC). The lower activity is from late evening to the early morning hours (1600–2359 UTC). The percentage distribution of the activity is shown in Figure 2b. It is seen that ~64% activity of higher magnitude is between 0800–1559, 24% between 1600–2359 and 12% between 0000–0759 UTC.

[6] Figure 3a displays the activity in monsoon season. This curve also exhibits diurnal variation with first prominent peak at 1000 UTC and two secondary peaks of nearly equal magnitude at 0800 and 1200 UTC. A careful examination of this curve suggests that from early morning till 0800 UTC the activity increases steadily, afterwards it shows frequent hourly fluctuations in its amplitude. The period of higher amplitude variation is between 0800–1800 UTC. The percentage distribution of the activity is shown in Figure 3b. It is seen that the distribution during the 0800–1559/0000–0759 UTC period is about 4% lower/higher than the pre-

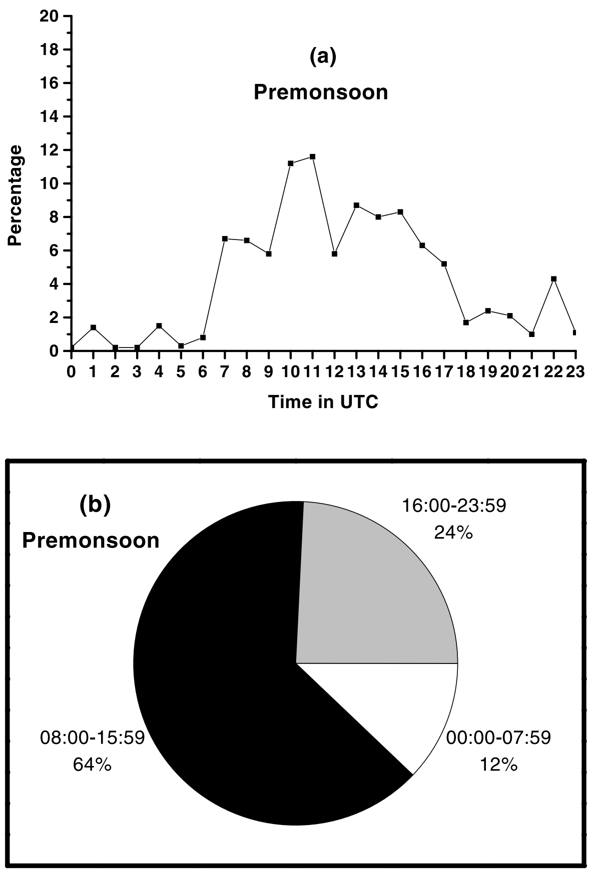

Figure 2. (a) Diurnal variation of lightning activity over the Indian region during premonsoon season for the period 1998–2001. (b) Percentage distribution of lightning activity during premonsoon season for the period 1998–2001.

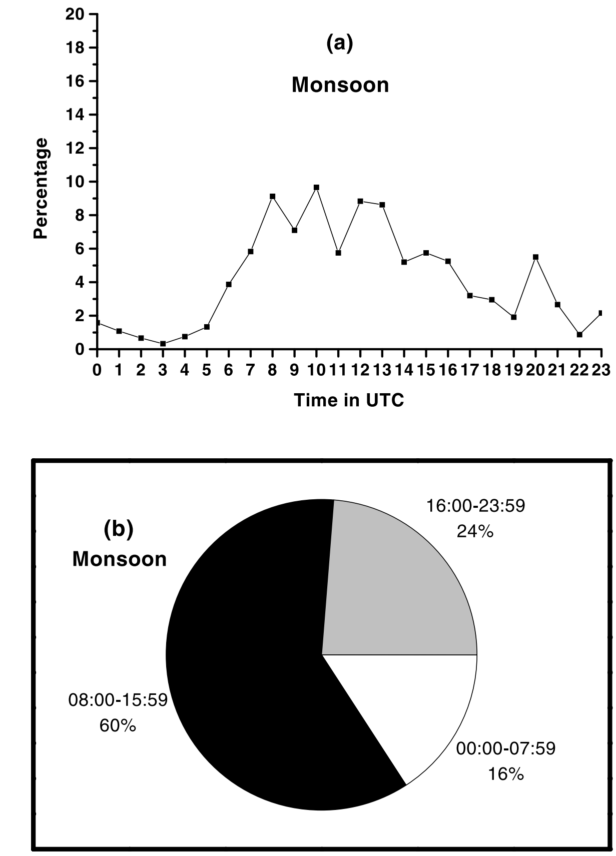

Figure 3. (a, b) same as Figure 2 (a, b), but for monsoon season.

monsoon season, while it is identical (~24%) between 1600–2359 UTC for both seasons.

[7] Figure 4a illustrates the postmonsoon season showing the variation similar to premonsoon and monsoon season with prominent peak at 0900 UTC and two lower peaks at 1200 and 1600 UTC. It also shows that the duration of the higher activity is reduced (~6 hrs as compared to premonsoon and monsoon seasons). Figure 4b shows the percentage distribution of the activity. It is seen that about 68% activity is distributed between 0800 to 1559 UTC and it is the highest among the other two seasons. The distribution between 0000–0759 and 1600–2359 UTC is nearly identical (16%).

[8] Inter-seasonal comparison of these figures suggests that in all three seasons the curve exhibits typical diurnal variation with the first peak between 0900–1100 UTC. The occurrence of the first peak is shifted earlier by an hour with the advancement of the season (premonsoon: 1100, monsoon: 1000 and post-monsoon 0900 UTC). This may be associated with shift in the maximum convective activity in each season in response to the diurnal cycle of insolation [*Williams*, 1994].

[9] The curve in each season shows variability in the pattern of the peaks. In the premonsoon season the peak is spread between 1000 to 1100 UTC, while in the monsoon season the peak shows large fluctuations in its amplitude for ~5 hours (0800–1300 UTC). In post monsoon season activity exhibits a single maximum at 0900 UTC.

[10] Thus, these observed different durations in the peak period of activity and maximum/minimum activity during afternoon-late evening/early morning hours are in agreement with *Oladipo and Mornu* [1985], *Reap* [1986], *Price and Rind* [1994]. Inter-seasonal comparison of the amplitude variation during afternoon hours suggests that in the premonsoon season the amplification is sharp and maximum, in the post monsoon season it is consistent and minimum, while in the monsoon season it is frequent but intermediate in magnitude than other two seasons. Thus, from the above figures [Figure 2a, 3a and 4a] it is seen that in the premonsoon season the activity is amplified by ~41% than the monsoon season, while in the monsoon/post monsoon season it is reduced by ~29/79% with respect to premonsoon season (flash counts for 3 seasons are 5232, 3701, 1086) which suggests that with the change of season, the phase and amplitude of the diurnal signal changes. The most likely reason for these phase and amplitude changes in different seasons is: in premonsoon/postmonsoon the cloud developed over the Indian region are mainly due to intense/moderate convective activity, while the clouds in the monsoon months are mostly characterized as maritime clouds having high cloud top heights but moderate updrafts [*Takahashi*, 1990] which leads to the minimum cloud electrification than that in the premonsoon season when the atmosphere is conditionally unstable and more electrically active [*Williams et al.*, 1992]. As compared to premonsoon, the postmonsoon season has weaker convection yielding a moderate to minimum growth of the

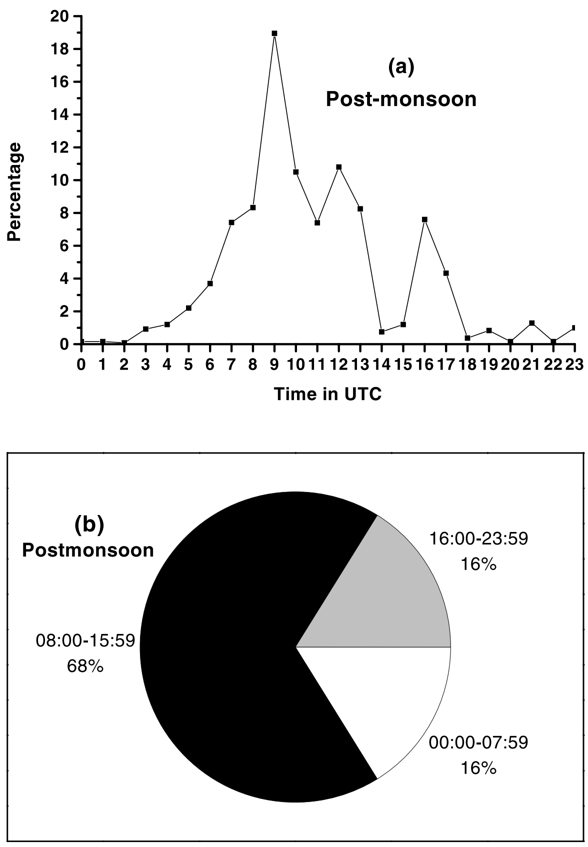

Figure 4. (a, b) same as Figure 2 (a, b), but for postmonsoon season.

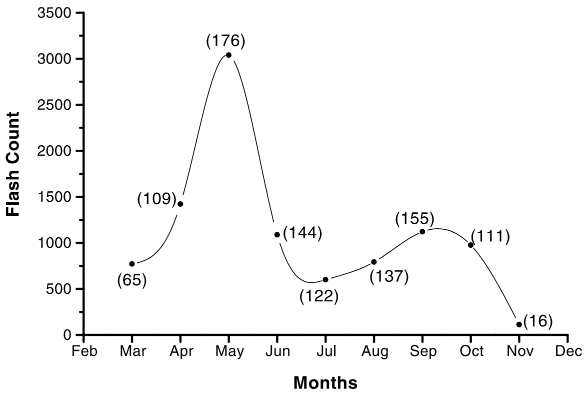

Figure 5. Monthly variation of the lightning activity during 1998–2001 over the Indian region.

cloud resulting to low electrification [*Kurz and Grewe*, 2002].

4. Seasonal Variation in the Electrical Conditions

[11] Though the results obtained in the above section, are comparable on a diurnal scale, it is essential here to confirm the same on annual scale. With this view, the authors have examined the monthly variation of flash count during the period of study. Figure 5 shows the monthly (March–November) variation of total flash count. The numbers in the bracket are the total number of passes on which flash count was recorded in respective months. It is observed that monthly flash count shows consistent increase from March and attains maximum in May and then the activity decreases till the end of July and again picks up from August and attains a secondary lower maximum in September. A careful examination of this curve suggests that the magnitude of the total flash count during premonsoon season is ~1.4/4.8 times higher than that of monsoon/postmonsoon seasons which clearly indicates the electrical vigor of the premonsoon season thunderstorm over the Indian region. The observed higher magnitude of flash count in the premonsoon seasons is an indication of the high electrically active state of thundercloud as intensity of thunder cloud is measured by the frequency of lightning [*Manohar et al.*, 1999]. The frequency of occurrence gradually decreases in June suggesting that with the advent of the monsoonal regime the electrical vigor is significantly diminished, whereas in the postmonsoon season, convection is weaker yielding a moderate to minimum growth of the cloud resulting to low electrification.

5. Conclusions

[12] The study brings out the following conclusions:

[13] (a) The diurnal variation of lightning activity over the Indian region shows a prominent peak at 1000 UTC and minimum in the early morning hours. (b) Seasonal diurnal variation shows that the activity is highest in the premonsoon season and lowest in the postmonsoon season. (c) Interseasonal comparison revealed that with the advancement of the season the peak occurrence time is shifted earlier by an hour. (d) Monthly variation of lightning activity suggests that the activity between March–May is 1.4/4.8 times higher than the June–September/October–November months.

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