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Satellite Observation of Lightning Activities Over Sri Lanka

W Jayawardena, M Fernando and DUJ Sonnadara[1*]
Department of Physics, University of Colombo, Colombo 3,Sri Lanka
upul.sonnadara@gmail.com*

ABSTRACT

Fifteen years of remotely sensed satellite mounted Lightning Imaging Sensor (LIS) data were used to determine the characteristics of lightning activities over Sri Lanka. The LIS is capable of detecting lightning flashes with 69% accuracy during day time and 88% accuracy during night time. In this study, a 5×5 km^2 grid was used for the analysis. From 1998 to 2012, there were 16,699 lightning flashes over the land mass covered by Sri Lanka. The data show that the highest occurrence of lighting activities is confined to the highly populated western part of the island while the south eastern and mountain areas have low occurrences. There is a clear spatial polarization of lightning activities during the south-west and north-east monsoon seasons. Lightning activities appear to be increasing by 50 flashes per year.It has a seasonal dependency with the south-west and first inter-monsoon seasons having the higher increase. The estimated maximum cloud toground lightning flash density was 19 flashes $yr^{-1}km^{-2}$observed during the south-west monsoon season.Inter-annual variation of occurrence of lightning flashes shows the expected bimodal distribution with the month of April having the highest occurrence of over 300 flashes.

1.0 INTRODUCTION

Characteristics of cloud-to-ground (CG) flashes over Sri Lanka have been studied in the past by number of researchers[1-4]. These studies were carried out remotely either by using lightning flash counters or by using a sensor system such as flat plate antenna to sense the electric field generated by distant lightning strikes and then digitizing the detected signals using transient recorders. Over the years, these studies have provided valuable insight into the understanding of the physics of the lightning process especially in the tropics.

Today, lightning locating systems are used in many countries to study long-term characteristics of CG lightning flashes. These systems have a typical range of 600 km, with many sensors interconnected to form lightning detection networks that span thousands of kilometres that can capture lightning in vast land masses[5-8]. These are more suitable for studies that involve in investigating average lightning parameters and lightning distributions since they are weak in extracting the details of individual waveforms but strong in detecting and processing data from many different thunderstorms.

In recent years, there have been several attempts to study the cloud to ground flash activities of Sri Lankan thunderstorms using the data provided by a lightning locating

system[9-13]. However, studies are not yet available in the literature that could provide an insight into the climatology of lightning characteristics over Sri Lanka.

The purpose of thepresent work was to present the CG lightning flash characteristics over Sri Lanka using satellite observations. The data were restricted to study the flash characteristics over Sri Lanka. The results are presented for the flash count in terms of spatial and temporal variations.

2.0 METHODOLOGY

National Aeronautics and Space Administration (NASA) records remotely sensed lighting data using satellite-based instruments. They measure lightning data using Lightning Imaging Sensor (LIS) which was launched on 28 November 1997 aboard the Tropical Rainfall Measuring Mission (TRMM) observatory. The TRMM satellite follows a circular orbit and flies at an altitude of 350 km, with an inclination of 35° to the equator[14]. The data are available for the past 15 years from December 1997 up to date (http://lightning.nsstc.nasa.gov/). The LIS detects and locates lightning with storm scale resolution (5-10 km) approximately over 35° S to 35° N. It can record the time occurrence of the lightning with 2 ms resolution, estimate the location and measure the radiant energy. LIS has 69-88% flash detection efficiency and detects cloud-to-cloud and cloud-to-ground discharges during day and night conditions. It monitors individual storms and storm systems for 80 seconds period while the storm is in the field of view of the sensor, which is sufficient to measure lightning flash rates in storms. It is passing Sri Lanka twice per day which means 160 s day^{-1}. Number of flashes is calculated on a 5×5 km^2 grid.

In this work, LIS lightning data from January 1998 to December 2012 period have been used to calculate cloud to ground lightning flash density (flashes/km^2/year) over Sri Lanka and the surrounding area. The flash density was calculated as;

$$FlashDensity(flashesyr^{-1}km^{-2}) = \frac{\sum Flashes}{5\times5\ km^2} \times \frac{24\times3600}{2\times80} \times \frac{1}{Years} \quad (1)$$

The fraction of cloud-to-ground flashes to the total flashes is uncertain. In the literature the fraction varies between around 25-55%. In this work 40% was chosen as the fraction. Therefore the density of cloud-to-ground flashes is taken as the 0.4 percent of the estimated density.

3.0 RESULTS AND DISCUSSION

3.1 Intra-annual variations

The monthly variation of the lightning flashes is shown in Fig. 1. A clear bimodal distribution is seen. The maximum lightning activity is seen over first inter-monsoon period (April). A less pronounced peak occurs during the second inter-monsoon period (October). The high percentage of lightning events in inter-monsoons is due to the fact that the ITCZ is positioned over Sri Lanka during these two periods. The ITCZ is a region of light winds near the equator, where winds from the southern hemisphere and

northern hemisphere converge and appear as a band of clouds that circle the globe near the equator. Over the Indian Ocean, during the northern hemisphere winter, the ITCZ cloud band is much broader than it is over either the Atlantic or Eastern Pacific oceans. The ITCZ zone induces semi-persistent low-pressure conditions causing heavy rain and lightning throughout the island and at many other places at the same latitude.

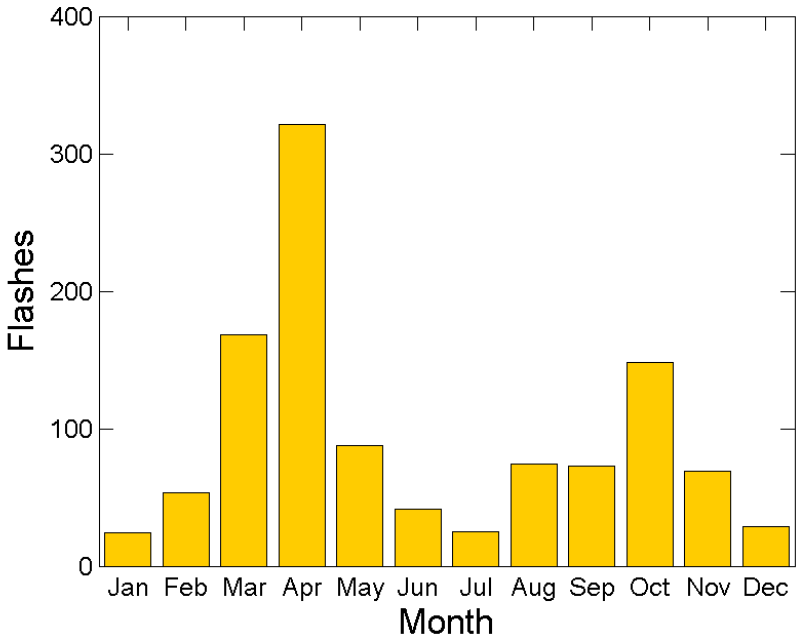

Fig.1: Variation of lightning flashes by month

In the first inter-monsoon period IM1, the ITCZ moves from south to north over Sri Lanka, with moisture laden air accumulated through the long track over Indian Ocean. Accordingly the energy released from latent heat can be high, which is favorable for vigorous thunderstorms. Therefore, strong thunderstorm activity with lightning is more frequent during this season compared to the second inter-monsoon period, IM2. On the other hand, the rainfall is highest in October-November period and less pronounced compared to April. This is due to the influence of depressions emerging over the Bay of Bengal, which gives heavy rain apart from local thunderstorms. The percentage of lightning per month is highest (46%) during the IM1 period and lowest (7%) during the Northeast monsoon season. Second highest percentage of lightning per month (25%) can be observed during the IM2 period followed by the Southwest monsoon (22%) period.

3.2 Spatial variations

The total observed flash density from NASA measurements is shown in Fig.2. The highest lightning density occurs in the western part of Sri Lanka. The maximum lightning density is around 19 fl km^{-2} yr^{-1} (7.7^o N, 80.2^o E). The lowest lightning density occurs in the south eastern coastal area. Also the mountain area has lower density than the rest of Sri Lanka. The density is low over sea compared to that over land area.

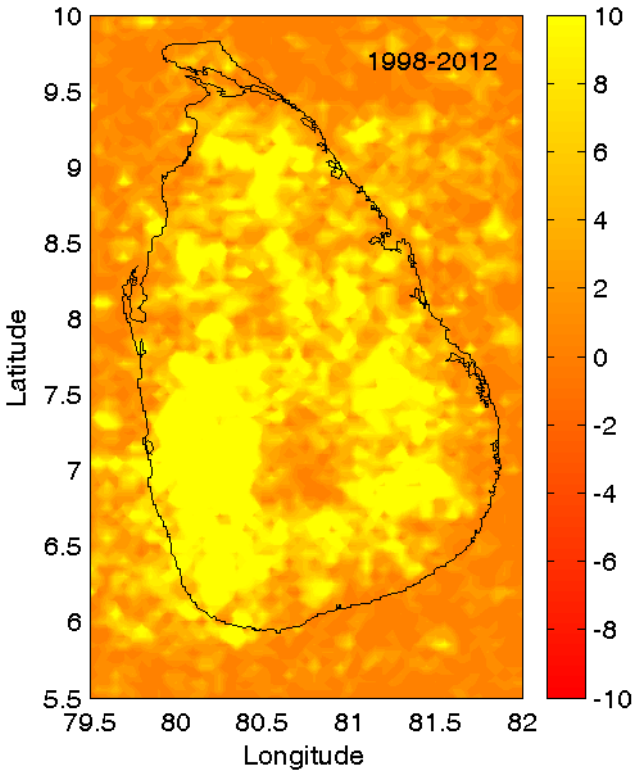

Fig.2: Total lightning density (fl km^{-2} yr^{-1}) according to LIS data

During Northeast monsoon season (NEM) which is from December through February,the lightning occurs in the lee side of the mountain area in southwest direction. The maximum density is around 7 fl km^{-2}yr^{-1}. During the Southwest monsoon season (SWM), which appears from May through September, the lightning density appears in the north-eastern part of Sri Lanka. This means that the lightning occurs in the lee side of the mountain area also during the SWM. The maximum density is around 12 fl km^{-2}yr^{-1} as during the SWM. The maximum flash density is around 12fl km^{-2}yr^{-1}during first inter-monsoon period which is similar to the SWM season. During this time period lightning activities are seen in many parts of the island except the eastern and south-eastern coastal area.Throughout the second inter-monsoon (October through November) season the lightning flashes are localized around the mountain region. The maximum density is around 8fl km^{-2} yr^{-1} for the second inter-monsoon season.

3.3 Temporal variations

Fig. 3 shows the trend of lightning activities over the last 15 years (1998-2012). The linear trend is shown with the fitted straight line. Although there is a variation between years, there is a clear increasing trend with 50 flashes per year. Data indicate that the increase is predominantly due to first inter-monsoon (March-April) and Southwest monsoon (May-September) seasons. Without having a longer duration of data set, it is difficult to study the periodicities in the observed variation.

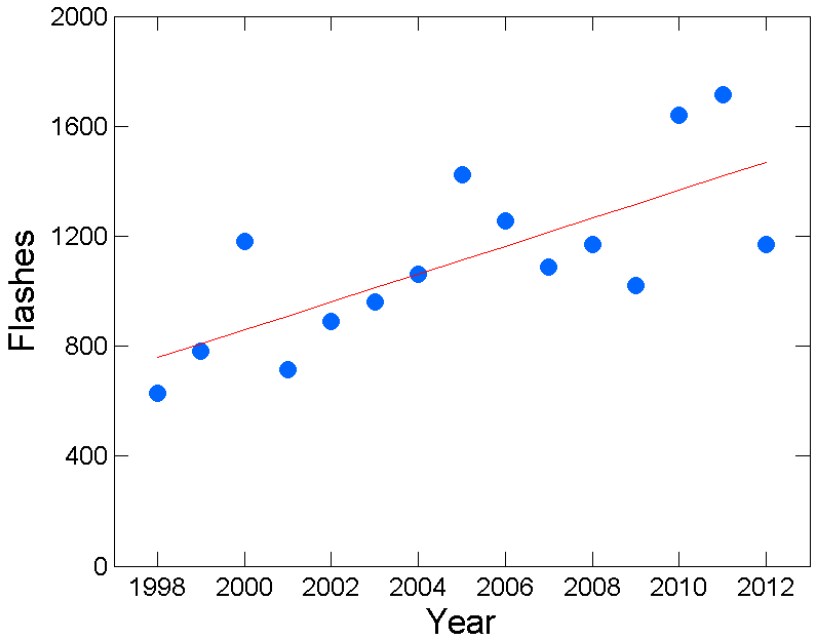

Fig. 3: Time trend of lightning density according to the LIS data

4.0 CONCLUSIONS

Fifteen years of remotely sensed satellite mounted Lightning Imaging Sensor (LIS) data were used to determine the characteristics of lightning activities over Sri Lanka. Months of April and October shows highest seasonal mean lightning flash count with310 and 160flashes respectively. Lightning activities show bimodal distribution with the month of April having the highest occurrence of over 300 flashes.

There is a clear spatial polarization of lightning activities during the Southwest and Northeast monsoon seasons. Lightning activities appear to be increasing by 50 flashes per year. The estimated maximum cloud to ground lightning flash density was 19 flashes yr^{-1} km^{-2} observed during the Southwest monsoon season.

ACKNOWLEDGMENT

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