Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 114 (2018) 256-264 EISSN 2392-2192

SHORT COMMUNICATION

Annual Variation Trend of Lightning Flash Activities over Sri Lanka

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ABSTRACT

The variation of the lightning activities over Sri Lanka and surrounded costal belt (5.75ºN-10.00ºN and 79.50ºE-89.00ºE) is studied using lightning flash data of Lightning Imaging Sensor (LIS) which was launched in November 1997 for NASA's Tropical Rainfall Measuring Mission (TRMM). The LIS data in the period of 1998 to 2014 are based on this study and there were 23838 lightning flashes over the landmass covered by Sri Lanka during considered period. The data show that average flash density has an increasing trend of 0.093 flashes km^{-2} $year^{-1}$. The linear trend is shown in annual flash count with the fitted straight line. Although there is a slight variation between years, there is a clearly increasing trend with 24 flashes per year. There is an incremental trend in distributing of lightning activities all over the country with time. Warming trends of surface temperature and atmosphere may have a correlation with increasing trend of the lightning activities over Sri Lanka and surrounded costal belt.

***Keywords*: LIS, Lightning protection, TRMM, Lightning flash density

(Received 12 November 2018; Accepted 26 November 2018; Date of Publication 27 November 2018)

1. INTRODUCTION

Lightning is a naturally occurring global phenomenon, started to appear significantly demystified after Franklin showed its electric nature with his famous electrical kite experiment in 1752 as well as previous studies has proved that a lightning flash occurs approximately 8 million times per day throughout the world [1]. These lightning flashes generate the powerful electric pluses which can be enough to kill people and animals, destroys trees and buildings, initiate forest fires during a thunderstorm stand as the causes of failures in the electric utility industry. Information on annual thunderstorm duration and rate of lightning flash are great interest to many different groups such as power generation companies, construction companies and local government agencies.

Therefore a comprehensive mechanism of lightning flash activities is required to provide an accurate weather information for all areas in the country. Today, lightning locating systems are used in many countries to study characteristic of lightning flashes [2]. These are more suitable for studies that investigating the average lightning parameters, distribution of lightning flashes, frequency and rate of the lightning. Furthermore, awareness of the community about lightning hazards and highly active time periods of lightning activities are significant factors to mitigate these types of unpredictable natural destructive hazards all over the country.

Moreover, lightning activities are not evenly distributed around the world, about 70% of lightning activities occur over the land in the tropics [3]. Furthermore the process of the thunderstorm formation in tropics is different to that of temporal regions in the world. But, generally previous studies in this field have presented that lightning activities vary with longitude, latitude, altitude, soil content, topography and vegetation of the region [4] and there is a noticeable lack of lightning activities in the surrounded costal belt of a country relative to landmass [5]. Furthermore, study about the variation trend of the lightning flash activities over Sri Lanka is important for local government agencies such as Metrological Department and Disaster Management Centre of the country to launch awareness programs to mitigate the damages to properties, deaths and conflagrations happening over the country.

On the other hand, most of the lightning detection systems such as National Lightning Detection Network (NLDN), Vaisala in US and satellites in NASA's Tropical Rainfall Measuring Mission (TRMM) collect the lightning data over the specific areas. TRMM satellites had collected detailed measurement of convective cloud system over the tropics. The Lightning Imaging Sensor (LIS) on TRMM had measured total lightning (intracloud and cloud to ground) using optical images.

The LIS identifies lightning activity by detecting changes in the brightness of clouds as they are illuminated by lightning electrical discharges [6]. This instrument records the time of occurrence of a lightning event, measures the radiant energy, and estimates the location etc... This is the most comprehensive global lightning data archive ever produced and is noteworthy for its high spatial resolution, detection efficiency and coverage [7].

This study includes only in Sri Lanka and surrounded costal belt and relevant data in the period from 1998 to 2014 was obtained from TRMM. It was analyzed to check whether lightning activities over Sri Lanka and surrounded costal belt have any variation trend by using the ArcGIS software (10.1 version).

2. DATA COLLECTION

LIS was launched in November 1997 on the TRMM satellite and operate until April 2015. Generally, the 35º inclination of TRMM orbit implies that locations near the equator are observed less frequently than the higher 35º latitude [8]. This low-earth-orbiting feature requires a minimum period of 49 days for LIS instrument to observe most locations on Earth at least once in each local solar hour of the diurnal cycle [9,10]. It could observe a 600 km ×600 km area of the earth with a spatial resolution of between 3 km and 6 km and it monitors individual storm for 80 seconds period and is passing over the Sri Lanka twice per day which means 160 s day^{-1}[11,12] as it passes overhead during both day and night. The LIS is useful for identifying spatial location of lightning, time of lightning events, and radiant energy from lightning activity with detection efficiency from 69% near noon to 88% at night [7]. For this study, total lightning data of period from 1998 to 2014 over the Sri Lanka and its surrounded coastal belt (5.75ºN - 10.00ºN and 79.50ºE - 89.00ºE) was obtained from [13].

3. DATA ANALYSIS

Maier [14] found that flash density may vary by an order of magnitude over distance of 20-30 km. Therefore, the data were organized into $0.2^0 \times 0.2^0$ latitude and longitude grids. Then, the mean lightning flash densities over selected area were calculated using ArcGIS software and obtain the comparison map to compare the lightning activities during three year moving average within 17 years.

R square value of variation pattern of the three year moving average of annual lightning flash density was calculated to check whether annual lightning activities have an increasing trend and moving average method is used to get an overall idea of the trend in the lightning flash count data from 1998 to 2014 since moving average method is extremely useful method to forecast long term trends. For this study, existing 25 administrative districts of Sri Lanka have been taken for the consideration to analyze the highly active lightning areas

4. RESULTS AND DISCUSSION

Variation of spatial distribution of the lightning activities over Sri Lanka and its surrounded coastal belt are analyzed using three year moving average method covering the period of 17 years from 1998 to 2014.

4. 1. Variation trend of the lightning flash density over Sri Lanka

Figure 1 presents the spatial variation of lightning flash density during three year moving avarege periods within 17 years over Sri Lanka and its surrounded coastal belt. According to comparison map, in the period of 1998-2005 highest amount of lightning has been concentrated in Gampaha (7.0873ºN /80.0144ºE), Kegalle (7.2513ºN/80.3464ºE) and Colombo (6.9271ºN /79.8612ºE) administrative districts. But, after end of the 2005, lightning activities have expanded all over the above three district and the districtboundariesof Ampara (7.2318ºN/80.6473ºE), Galle (6.0535ºN/80.2210ºE), Badulla (6.9934ºN/81.0550ºE) and

Kurunagala (7.4730ºN/80.3547ºN) can be identified as considerable lightning active areas in the country.

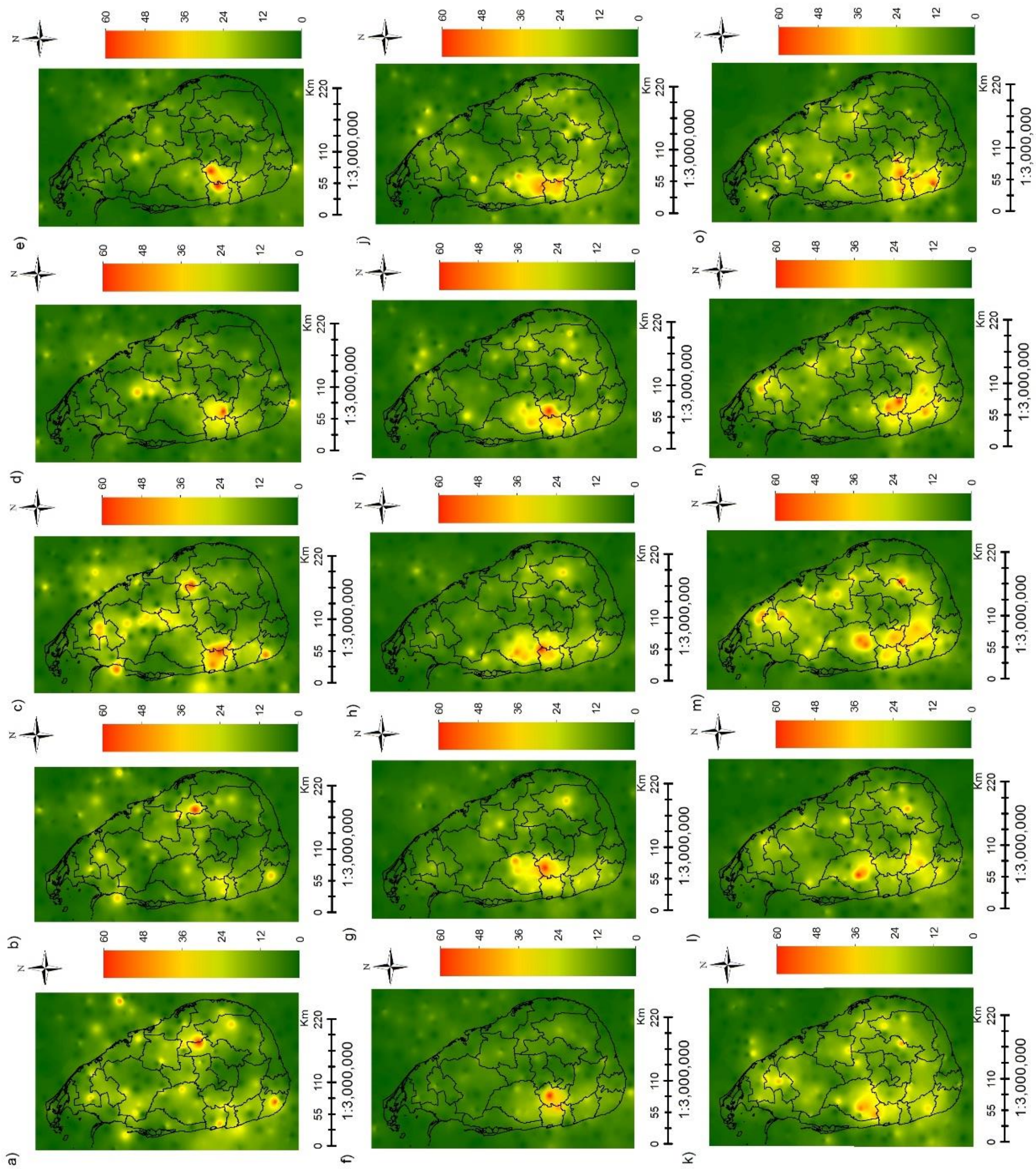

Figure 1. Spatial variation of lightning flash density during three year moving average time periods for17 years (1998-2014) over Sri Lanka. (a) 1998-2000; (b)1999-2001; (c) 2000-2002; (d) 2001-2003; (e) 2002-2004; (f) 2003-2005; (g) 2004-2006; (h) 2005-2007; (i) 2006-2008; (j) 2007-2009; (k) 2008-2010; (l) 2009-2011; (m) 2010-2012; (n) 2011-2013; (o) 2012-2014.

Figure 1 clearly show that, lightning activities over the country have been gradually increased after the 2005 and highest lightning activities have recorded in the Southern area comparing Northern area of the country. But, both lightning activities in Northern and Southern areas of the country show the graduall increasment trend over time. According to the lightning data from 1998 to 2014, it can be concluded that, there is an increasing trend in distributing of lightning activities all over the country with time.

Figure 2 shows the variation trend of thee year moving average lightning flash density over Sri Lanka and its surrounded coastal belt using selected data of 17 years (1998-2014). The linear trend is shown with the fitted straight line with R square value of about 0.38. Although there is a slight variation between years, there is a clearly increasing trend with 0.093 flashes km^{-2} $year^{-1}$.

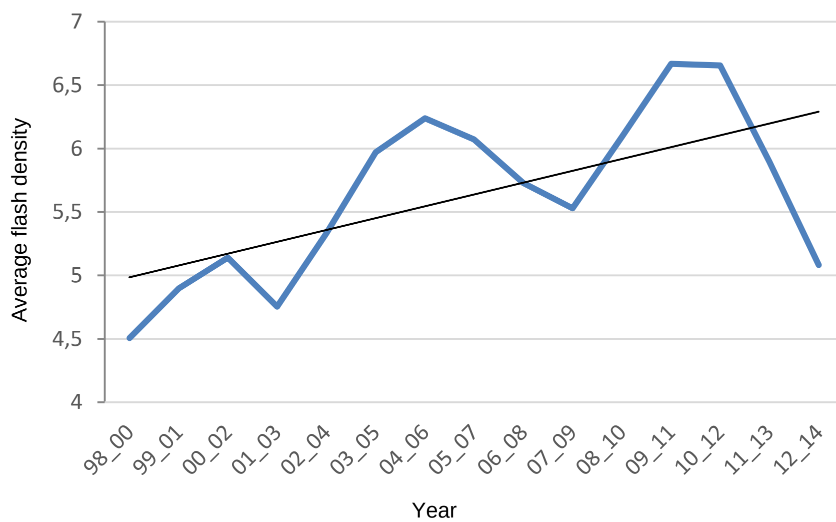

Figure 2. Three year moving average lightning flash density over Sri Lanka for 17 years (1998-2014) & $R^2 = 0.38$.

4. 2. Variation trend of the lightning flash count over Sri Lanka

Trend of the three year moving average of lightning flash count over Sri Lanka and its surrounded coastal belt is presented in the figure 3. The slightly incremental linear trend with the R square value 0.38 is shown with small variation during the selected period of years. As per the observed results, there is an increasing trend about 24 flashes per year. Furthermore, it is important to mention that according to the data maximum and minimum lightning flash counts over Sri Lanka were recorded in 2011 and 1998 years respectively. According to reported values in [11] using the same lightning data but only for the period from 1998 to 2012, the increasing trend is about 50 flashes per year.

Figure 4(a) depicts the variation trend of the lightning activities which occurred during the period from 1998 to 2014 over the existing 25 administrative districts of Sri Lanka. According to Figure 4 (a), although, irregular variation pattern of the lightning activities is shown over the all administrative districts, highest increment trending is showed in Nuwara Eliya (6.9497ºN, 80.7891ºE) and Kalurata (6.5854ºN/79.9607ºE) administrative districts with

$R^2 = 0.41$ and $R^2 = 0.39$ respectively. Figure 4(b) presents the trend lines of lightning variation patterns of 25 administrative districts during the period from 1998 to 2014. Furthermore, highly populated administrative districts such as Colombo (6.9271ºN /79.8612ºE) (R^2 = 0.10), Kurunegala (7.4730ºN/80.3547ºE) (R^2 = 0.16) and Rathapura (6.7056ºN, 80.3847ºE) (R^2 = 0.15) have a considerable increment trend of lightning activities from 1998 to 2014.

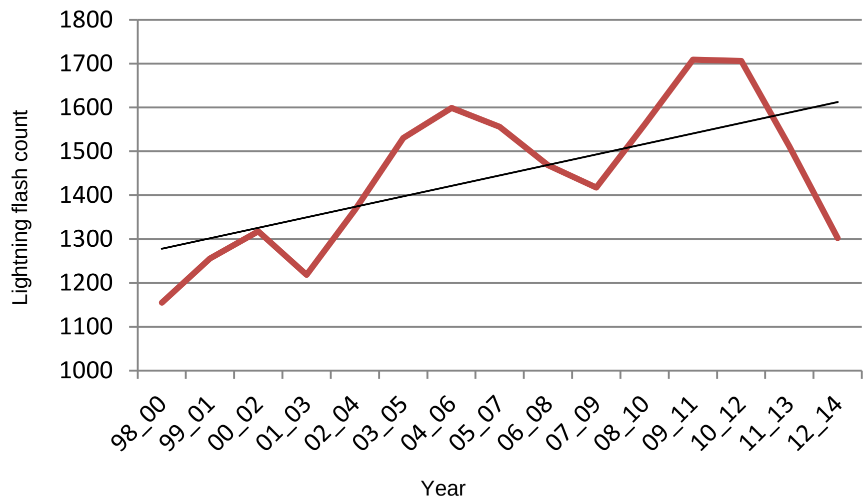

Figure 3. Three year moving average of lightning flash count over Sri Lanka for 17 years (1998-2014) & R^2 = 0.38.

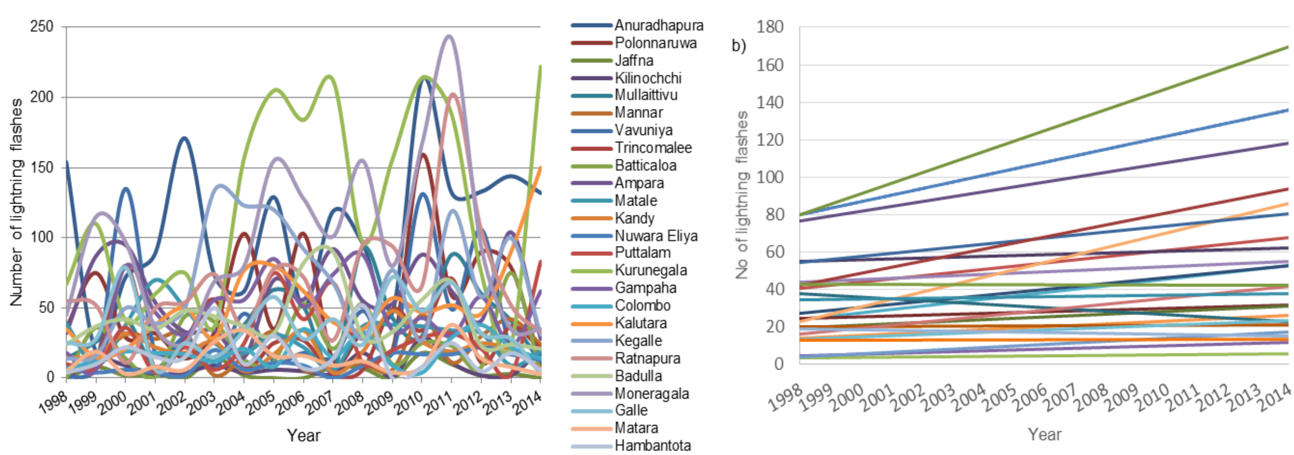

Figure 4. Variation of number of lightning activities over the administrative district of Sri Lanka in the period from 1998 to 2014 (a) Lighting variation of existing all administrative district in Sri Lanka; (b) Trend lines of lighting variation patterns over 25 administrative districts.

Furthermore, climate of Sri Lanka experienced during 12 months period, according to annual rainfall profile of Sri Lanka, there are two monsoon sessions and two inter monsoon seasons, namely Southwest Monsoon season (May to September), Northeast Monsoon season (December to January), First Inter Monsoon season (March to April), and Second Inter Monsoon season (October to November) respectively. Previously, Jayanthiran [5] presented that maximum lightning flash density over Sri Lanka was about 7.02 flashes km^{-2} $year^{-1}$ observed during the First inter monsoon season and months of April and October shows highest seasonal mean flash count. Furthermore, the diurnal variation of the lightning flash activities over Sri Lanka shows that maximum and minimum peak flash rate recorded at 11UTC (1630 Local hours) and 0UTC (0530Local hours) respectively [5]. Furthermore, maximum lightning flash density over Sri Lanka was reported as 19 flashes km^{-2} $year^{-1}$ in Jayawardana [11] for the period covering 1998 to 2012 and Maduranga [12] have presented it as 28.09 flashes km^{-2} $year^{-1}$ which covered the period from 1998 to 2014 and in both studies it was reported that maximum lightning activities took place in April. These seasonal lighting activities are agree with seasonal convective activities and temperature variation base on propagation of Intra-Tropical Convection Zone (ITCZ) over the studied particular area. Moreover, preceding behavior of lightning activities is important to understand the over research findings.

Dominant causes for the above described variation pattern of lightning activities can be described using atmospheric convection. Lightning discharges in thunderstorms are an indication of the intensity of atmospheric convection. Atmospheric convection occurs under unstable atmospheric condition, either due to the heating of the boundary layer by solar radiation during the day, or by the mixing of air masses of different densities. Lightning frequencies are related to the region of instability of the Earth's atmosphere. According to previous analysis, atmospheric instability do not occur randomly around the world, but have an organized pattern related to the climate of the Earth which is driven by the heating of the earth's surface by the sun. The distribution of global thunderstorm is directly linked with Earth's climate and general circulation of the atmosphere.

The maximum solar heating at the surface of the tropics result in rising thermals [15]. It is well known that global warming causes change in environment. Last decade is known to be the warmest period during the past decades. There are studies on the relationship between atmospheric parameters and thunderstorm activity [16]. Previous studies have proved that lightning activities over the past years have undergone change [17]. This study was proved the increment trend of the lightning activities over Sri Lanka. Fluctuation of lightning activities depends on the number of factors such as season, location and time [5]. Recent studies were suggested that lightning might change as the planet's temperature rises with the accumulation of greenhouse gases in the atmosphere. And the studies that have been done to date estimate the increase in lightning to be anywhere from 5 to 100 percent per degree Celsius rise a strikingly wide range.

5. CONCLUSIONS

Seventeen years of remotely sensed satellite mounted LIS data were used to determine the variation trend of lightning activities over Sri Lanka. According to special variation of lightning flash density, there is an increasing trend of lightning flash activities over Sri Lanka and its surrounded coastal belt from past decade and high populated administrative districts show highest lightning activities and high increasing trend. Average lightning flash density over country has been increased with time and it shows an increasing trend of 0.093 flashes km^{-2}

year^{-1}. Annual lightning flash count shows an incremental trend of 24 flashes per year. Maximum flash count had recorded in 2011. NuwaraEliya (6.9497ºN, 80.7891ºE) and Kalutara (6.5854ºN/79.9607ºE) administrative district show the higher incremental trend than the other high populated administrative districts.

Acknowledgement

The authors are thankful to the Global Hydrology Resource Centre (GHRC), Marshall Space Flight Centre (MSFC), Huntsville, USA for providing the LIS Science data.

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