TRMM/LIS Observations of Lightning Activity over Indonesia

E.Y. Hamid, *Member, IEEE*, Z-I. Kawasaki, *Member, IEEE*, and R. Mardiana, *Member, IEEE*
Department of Electrical Engineering, Osaka University
Yamadaoka 2-1, Suita, Osaka 565-0871, JAPAN

Abstract: General statistical description of lightning activity on and around Indonesia is reported. Analysis on the collected data from a space-based lightning sensor, TRMM/LIS, during 18 months observation reveals that this region has high number of lightning flashes. Based on space-based measurement, we have made lightning frequency map over Indonesia and temporal variation of lightning activity over the five biggest island in Indonesia, which are useful for lightning protection design of power transmission system. The majority of the flashes are on the land and western part experiences higher lightning occurrence than eastern part. General patterns of the diurnal lightning activity are mainly characterized by the lightning activity in the afternoon.

Keywords: Lightning, Lightning Imaging Sensor, Lightning Location System.

I. INTRODUCTION

Lightning Imaging Sensor (LIS), an instrument which is equipped on Tropical rainfall Measuring Mission (TRMM) satellite, has been designed by a team of atmospheric scientists and engineers at Global Hydrology and Climate Center (GHCC) and NASA's Marshal Space Flight Center (Huntsville) to investigate the characteristic of lightning in tropical maritime continent region since November 1997. Figure 1 shows the Lightning Imaging Sensor integrated aboard the TRMM satellite.

The TRMM satellite travels a distance of 7 kilometers every second as it orbits the Earth, thus allowing the LIS to observe a point on the Earth or a cloud within a field of view of about 600 km x 600 km for almost 90 seconds as it passes overhead. LIS has an altitude of approximately 350 km and is used to detect the distribution and variability of total lightning (cloud and cloud-to-ground lightning flashes) that occur in the tropical regions of the globe within a band from 35°N to 35°S latitude. Figure 2 shows the example of orbital swaths from TRMM satellite during descending passes.

It is well recognized that the vast majority of global lightning flashes are found in the tropics as reported by *William and Heckman* [1]. They have investigated the longitudinal distribution of global lightning from polar orbiting ISS-b satellite and the Asia, especially Indonesia, experiences very high rate of lightning flashes. Lying in the Intertropical Convergent Zone (ITCZ), the weather is hot and humid almost all the years, these conditions are favorable for the development of lightning producing thunderstorm clouds. *Mackerras and Darveniza* [2] have made observation of variation of lightning occurrence over several cities in the world and their results show that the cities in the tropic regions always experience high lightning occurrence.

First comparison between LIS observation and ground-based measurement using Interferometer system in Japan has been reported by *Kawasaki and Yoshihasi* [3]. *Hidayat and Ishii* [4] have made lightning observations on Java Island, one of the Indonesia largest islands, employing four detection stations using combination of direction finding and time of arrival techniques. The comparison between LIS data and ground-based measurement around Java Island, one of the islands having high lightning occurrence has also been reported by *Hamid et al* [5] and it confirmed that both observation results generally were in a good agreement.

In this study, the general lightning activity recorded over Indonesia for 18 months observation from December 1997 to May 1999 is analyzed.

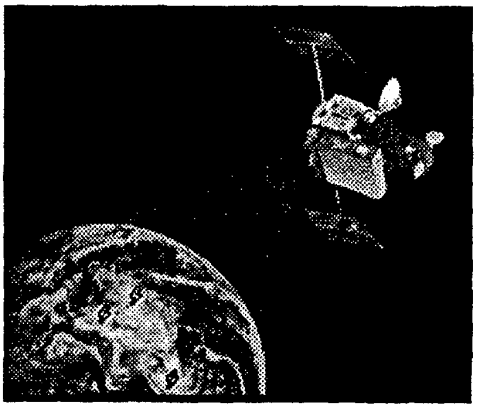

Fig. 1. The Lightning Imaging Sensor integrated aboard the TRMM satellite (from GHRC, NASA).

II. DATA COLLECTION

Data collection is provided by Global Hydrology Resource Center, NASA. LIS owns the 4 to 7 km spatial resolutions and 2 ms time resolution with 128 by 128 CCD matrix and telescope lens. Since LIS detects optical emissions during lightning discharges, LIS records both cloud and cloud-to-ground lightning flashes and does not discriminate between them, thus all lightning data provided in this paper correspond to all lightning flashes and do not specific to only cloud-to-ground flashes. LIS crosses over Indonesia approximately at least two times and maximum six

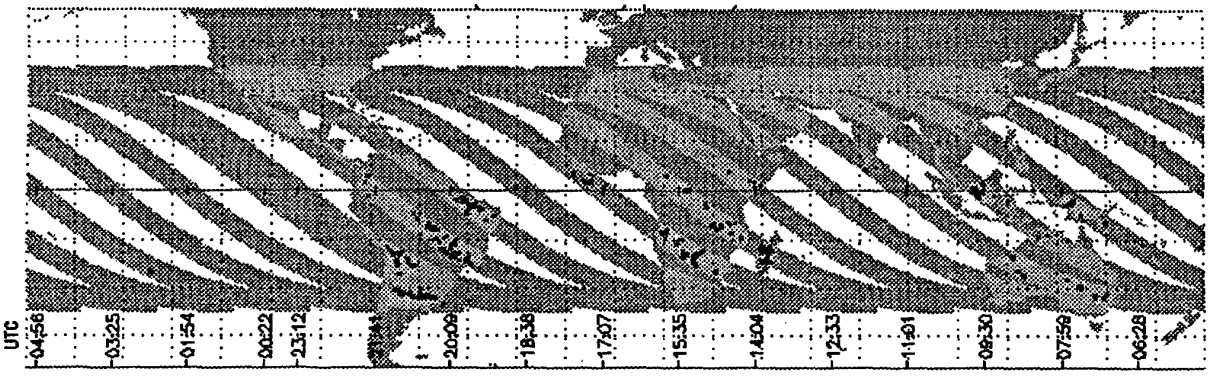

Fig.2. The LIS field of view and the orbital track of the TRMM satellite during descending passes in a 24 hour period (from GHRC, NASA).

times a day during ascending and descending passes, and the field of view is sufficient to observe a point on Earth or a cloud for about 90 seconds. Therefore the data presented here are not a full time lightning observation over Indonesia but are collected just during the LIS passes overhead Indonesia, thus the total number of lightning flashes will be much less than the number in the actual condition. The LIS data, which will be analyzed, is from December 1997 to May 1999.

III. LIGHTNING FREQUENCY MAP OVER INDONESIA

Indonesia lies between latitude 11°S to 6°N and between longitude 95°E to 141°E. A total of more than 63000 lightning were recorded during one a half-year observation. Figure 3 shows the contour of flash density over Indonesia averaged in the period of December 1997 to May 1999. Contour of flash density is calculated for each area 0.5 x 0.5 square degree, averaged in the square area 11°S to 6°N and 95°E to 141°E. As shown on this figure, most of the lightning activities took place on land and very little lightning activities on sea and on ocean. Sumatera, Java and Kalimantan, on the western part of Indonesia show higher flash density than that of Irian Jaya and Sulawesi in the eastern part. This explain that the islands close to the maritime continent should be considered to have higher level on lightning protection planning that those of the rest. Especially Java Island where most of population, industrialization, power transmission and power plant take place. On general the lightning activities concentrated on the western part both during dry season and during rainy season.

IV. TEMPORAL VARIATION OF LIGHTNING ACTIVITY OVER INDONESIA

To characterize the annual cycle, we analyze the monthly total number of flashes and diurnal variation for each five biggest island in Indonesia. The monthly variations are shown in Fig. 4 to 8. Since the weather in most parts of Indonesia is divided into two seasons, rainy season (November to April) and dry season (May to October), the different on monthly variation between both seasons is quite significant. The monthly variation of the lightning activity over Sumatera in Fig.4 is characterized by the low activity during August to September in dry season and high activity during March to April in the rainy season. The flash number reaches its maximum in March 1998 which total flashes were 5641. Monthly variation on Kalimantan in Fig.6 has similar characteristic with Sumatera, being maximum on March 1998 and then lower lightning activity in dry season. Similar characteristics are also showed over Java in Fig.6. During December 1997 to April 1998, the lightning activity increased to a maximum at about 700 flashes in April 1998 followed then by a sharp decrease to the minimum in May 1998. During September 1998 to March 1999 the lightning activity tended to increase, except on October 1998. Monthly variation on the eastern part of Indonesia, Sulawesi and Irian, are rather different from western Indonesia. Eastern part of Indonesia, Irian, shows highest total of lightning on December 1997 and November 1998 meanwhile Sulawesi have maximum on February 1999. It is noted that on the general the number of lightning flashes decrease significantly from December 1998 to May 1999 compared to the same moths in the previous observed year especially in the western part of Indonesia. This event may correspond to the occurrence of El-Nino period from mid of 1997 to mid of 1998. The investigation about the influence of El-Nino to the lightning occurrence is still on going.

Figures 9 to 13 show the diurnal variation for each biggest island in Indonesia. The peak times of the diurnal variation are rather similar from season to season, spreading from early afternoon to late afternoon. The figures show that the lightning activity start to increase from late morning and have a peak time in the afternoon and decrease just after midnight. The increasing in number of lightning flashes from late morning to the afternoon strongly correspond to the sunshine period on those regions.

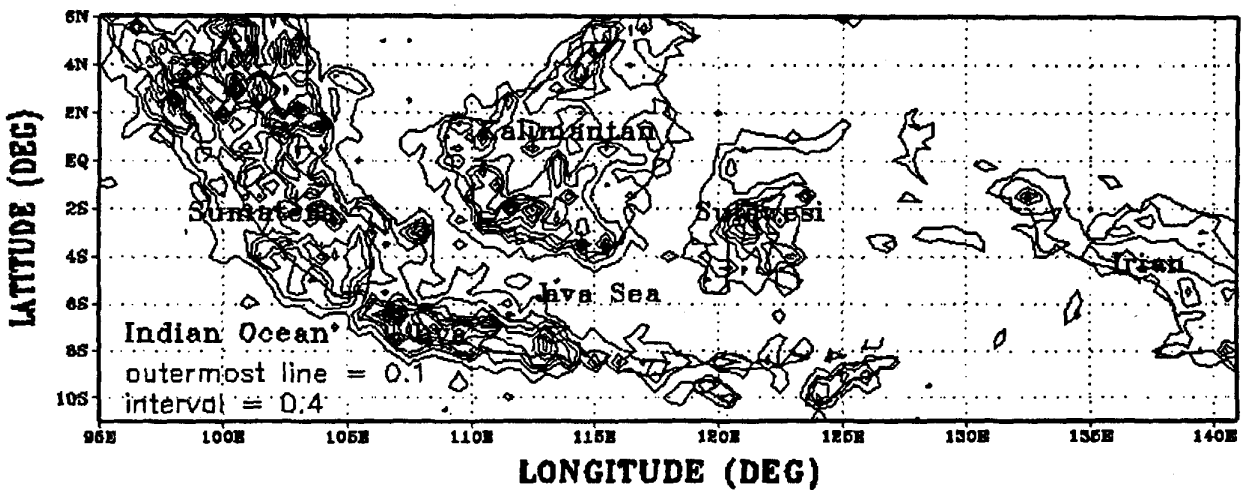

Fig.3. Contour of flash density (flashes/100 km^2/year) over Indonesia during 18 months averaged in the period of December 1997 to April 1999 as observed by LIS.

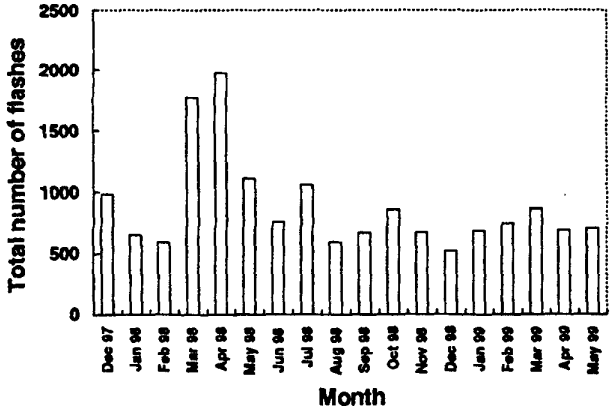

Fig. 4. Monthly variation on Sumatera Island

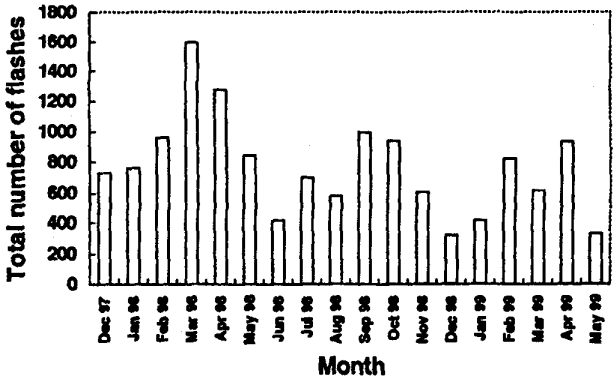

Fig. 5. Monthly variation on Kalimantan Island

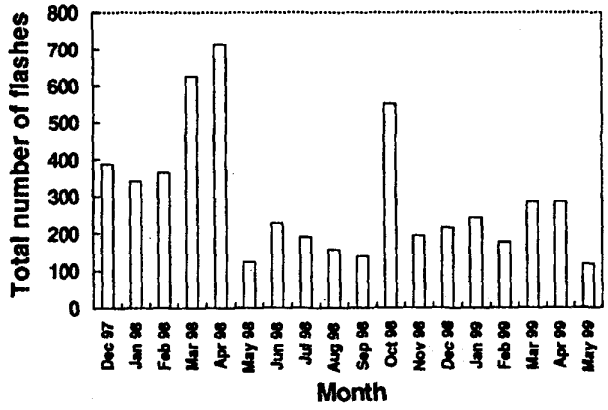

Fig.6. Monthly variation on Java Island

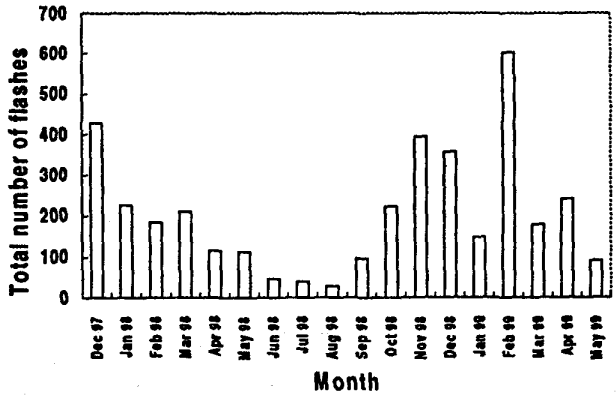

Fig. 7. Monthly variation on Sulawesi Island

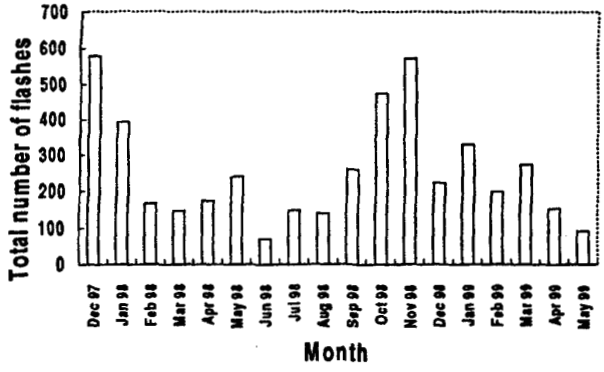

Fig. 8. Monthly variation on Irian Island

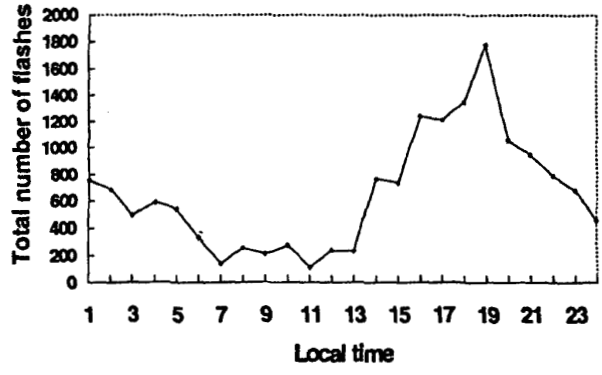

Fig.9. Diurnal variation on Sumatera island

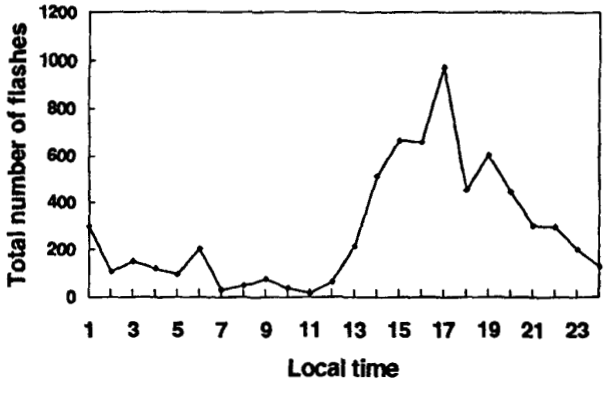

Fig.10. Diurnal variation on Java Island

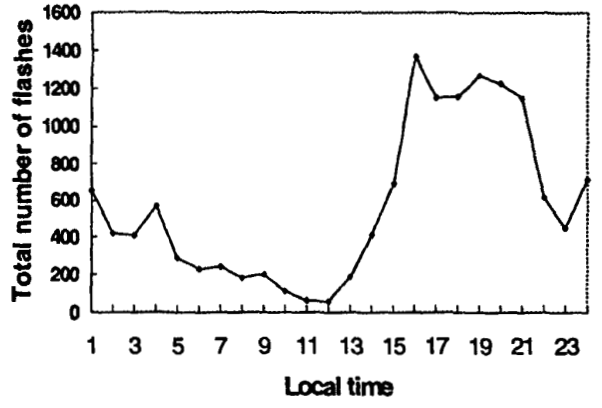

Fig.11. Diurnal variation on Kalimantan Island

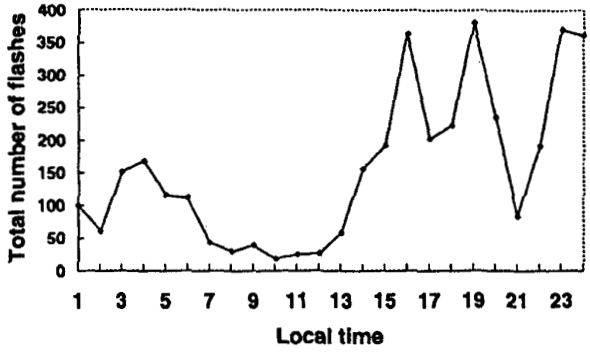

Fig.12. Diurnal variation on Sulawesi Island

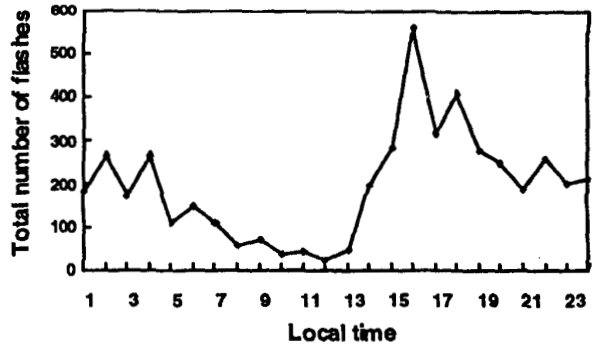

Fig.13. Diurnal variation on Irian Island

V. CONCLUSION

Indonesia has high frequency of lightning incident just like many other tropical countries. Sumatera, Java and Kalimantan islands, in the western part of Indonesia region, experience high lightning activity all the years compared with Sulawesi and Irian Jaya islands in the eastern part. The lightning activities concentrate on the western part both during dry rainy seasons. It is interesting to note that there is a big difference in the total number of lightning flashes during and after El-Nino periods, and this anomaly is still under investigation. Diurnal variation is apparently characterized by the lightning activity in the afternoon.

In term of power transmission planning, since the activity of lightning is concentrated in the western part close to maritime continent, those regions should be considered to have well protected from lightning flashes. Especially Java Island where most of population, industrialization, power transmission and power plant are located.

Finally since the number of lightning flashes may vary from year to year, it is necessary to collect statistical data measured over many years, not only to one and a half-year observation, to get a meaningful conclusion of lightning activity in tropical region generally and especially in Indonesia.

VI. ACKNOWLEDGEMENTS

We acknowledge with gratitude the contribution of Global Hydrology and Research Center (GHRC) for providing the LIS data. The data used in this study were acquired as part of the Tropical Rainfall Measuring Mission (TRMM), an international project jointly sponsored by the Japan National Space Development Agency (NASDA) and the US National Aeronautics and Space Administration (NASA) Office on Earth Sciences. The algorithms were developed by the TRMM Science Team and processed by the TRMM Science Data and Information System (TSDIS) and the TRMM office.

VII. REFERENCES

[1] Williams, E. R., and J Heckman. The Local diurnal Variation of Cloud Electrification and the Global Diurnal Variation of Negative Charge on the Earth. J. Geophys Res., 98. 5221-5234, 1998.

[2] Mackerras, D. and Darveniza, M., Latitudinal variation of lightning occurrence characteristics. J Geophys. Res , 99. 10,813-10,821, 1994.

[3] Kawasaki, Z-I., and S. Yoshihashi. TRMM/LIS observations of Lightning Activity, J. Remote Sensing of Japan, 18. 5, 86-93, 1998. (in Japanese)

[4] Hidayat, S., and M. Ishii. Spatial and temporal distribution of lightning activity around Java. J Geophys Res., 103. 14.001-14.009, 1998.

[5] Hamid, E.Y., Z-I. Kawasaki, R Mardiana, and K. Matsuura, TRMM/LIS Observations of Lightning Activity over Indonesia and Comparison with Ground-based Measurement around Java Island. J. Atmosp Elec., 19. 2. 153-164, 1999.

[6] Algorithm Theoretical Basis Document (ATBD) for the Lightning Imaging Sensor (LIS). George C. Marshall Space Flight Center, Earth System Science Division, Observing Systems Branch, NASA.

[7] Christian, H.J., R.J. Blakeslee, and S J. Goodman, The detection of lightning from geostationary orbit, J. Geophys Res., 94. 13,329-13,337. 1989.

[8] Christian, H J., R. J. Blakeslee, S. J. Goodman, D. A. Mach, M. F Stewart, D. E. Buechler, W. J. Koshak, J M Hall, W. L. Boeck, K. T. Driscoll, and D J Bocippio. The Lightning Imaging Sensor. Proc. 11th International Conference on Atmospheric Electricity, Guntersville, Alabama, June 7-11, 1999, pp 746-749.

[9] Christian, H J., Lightning likes land more than water. (http://thunder msfc nasa gov/bookshelf/news/lightning_likes_land htm l)

[10] Finke, U., and T Hauf. Characteristic of Lightning Distribution in Southern Germany. The 10th International Conference on Atmospheric Electricity, 380-383, Osaka, Japan, 1996.

[11] URL http://thunder.msfc nasa gov/lis.html

VIII. BIOGRAPHIES

Effrina Yanti Hamid was born in Medan, Indonesia in 1972. She received B.Eng. and M.Eng. degrees from Bandung Institute of Technology in 1995 and 1998, respectively Now, she is as a research student in Department of Electrical Engineering, Osaka University, Japan since early 1999. Her main interest is in Lightning and Image Processing

Zen-Ichiro Kawasaki. He received his B S., M.S. and Dr Eng degrees in Communicational Engineering from Osaka University in 1973,1975 and 1978, respectively. In 1989, he joined the Department of Electrical Engineering, Osaka University and is currently an associate professor. His researches mainly concern the observation of lightning, and the diagnosis techniques for power equipment Dr Kawasaki is also a member of the Society of atmospheric Electricity of Japan.

Redy Mardiana was born in Bandung, Indonesia in 1968. He received B.Eng. and M.Eng degrees from Bandung Institute of Technology in 1992 and 1997, respectively. In 1993/1994, he was in Forshungzentrum, Juelich, Germany. Now, he is as a Ph.D student in Department of Electrical Engineering, Osaka University, Japan. His main interest is in Lightning Detection.