



## CLOUD-TO-GROUND LIGHTNING FLASHES UNDER THE INFLUENCE OF POLLUTION IN MALAYSIA AND SOME COUNTRIES

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### ABSTRACT

The effect of air pollution produced from world war, industrial activities and transportation clearly can change the earth ecology system such as the atmospheric conditions. Base on few studies reported from by researcher in USA, Brazil, Spain and South Korea researcher have proven that the pollution effect can enhance the activity of lightning. Those information above motivate Advanced Multidisciplinary System Technology researcher in UTeM to report the cloud-to-ground lightning flashes in Malaysia the influence of pollution. Particulate Matter (PM<sub>10</sub>) and Sulfur Dioxide (SO<sub>2</sub>) concentration were used as gross indicator of Cloud Condensation Nuclei (CCN) and examined in relation to the urban increase in CG lightning activity. PM<sub>10</sub> concentration recorded in Subang, Ipoh and Bayan Lepas were 51, 50 and 49 μg/m<sup>3</sup> respectively. Meanwhile, SO<sub>2</sub> concentration recorded were 8, 7.9, 7.7 μg/m<sup>3</sup>. The three urban areas have average number of CG lightning flashes of 200, 197 and 184. An analysis related number of CG flashes against pollutants show positive correlation in Malaysia with reading of 0.94. This indicates PM<sub>10</sub> and SO<sub>2</sub> concentration have high influential factor in enhancement of CG lightning activity in Malaysia.

**Keywords:** urban areas, cloud-to-ground lightning.

### INTRODUCTION

The air pollution effect on the enhancement of lightning activity remains a controversial topic. The first indication of the pollution effect in Midwestern urban areas has begun with the first publication of reported by Westcott (1995). Then, followed others countries in Spain (Soriano *et al.*, 2002), Korea (Kar *et al.*, 2007), USA (Westcott 1995, Orville *et al.*, 2001, Steiger *et al.*, 2002) and Brazil (Naccarato *et al.*, 2003a, Naccarato *et al.*, 2003b, Pinto *et al.*, 2004, Farias *et al.*, 2009, Farias *et al.*, 2012). There are two factors used by them to explain about their findings; the increase of Cloud Condensation Nuclei (CCN) due to anthropogenic emission of 10 μm Particulate Matter (PM<sub>10</sub>) and Sulfur dioxide (SO<sub>2</sub>) and the enhancement of the convergence due to heat island effect. In general, most studies discuss on particular topic related to CCN interactions with cloud microphysics and the increase of temperature in urban areas or well known as Urban Heat Island (UHI). (Oke *et al.*, 1982) suggested that typically, UHI is related to many physical differences between urban and rural areas such as absorption of sunlight, increased heat storage of artificial surfaces, obstruction of re-radiation by buildings, absence of plant transpiration, and differences in air circulation. On the other hand, based on the finding of (Farias *et al.*, 2009) the UHI can be concluded that urban effect is the combination of an increased pollution concentration in the local air caused primarily by human activities and a thermodynamic effect due to differential heating of the city surface. Previous study related to urban effect in Houston reported by (Steiger *et al.*, 2002); found that, a

decrease of 12% in the percentage of positive flashes and no significant effect on the peak current of negative and positive CG flashes. The concentration of CCN over urban area can be uplifted by the pollution over the cities, thus it may change the cloud microphysical processes. Consequently, it also may change the charge separation processes in thunderclouds because of its close association with concentration, phase and the size of cloud particles. In addition, the increased of pollution is expected to be effective in suppressing the mean droplet size in the boundary layer, and more cloud water would therefore be operative in isolating the electric charge and finally leading to the production of enhanced CG lightning flashes (Orville *et al.*, 2001).

However, it should be stressed that study on enhancement of lightning activity under the influence of pollution in Malaysia is limited compared to the study that have been carried out in the United States, Brazil and others. This study will focus only on two types particulate matter (PM<sub>10</sub>) and sulfur dioxide (SO<sub>2</sub>). The purpose of this study is to analyze the pollution contribute to the enhancement of lightning activities only in Malaysia since there is no information regarding on this particular study that close to equatorial region. The information offered here excluding of population size and urban size.

Data Analysis In Malaysia were obtained from Malaysian Meteorological Department (MMD) which provides the data from 2004 to 2007. The methodology of the lightning observation by MMD has been described in Malaysian Meteorological Department (2015). The only



available data related to our analysis for comparison purposes only appeared in Spain (Soriano *et al.*, 2002). The CG lightning data in Spain were obtained from the lightning detection network deployed on the Iberian Peninsula that belongs to the Institute National de Meteorology. It uses ALDF model 141-T, manufactured by Lightning Location and Protection Inc. This lightning sensor has been described in depth by (Orville *et al.*, 1983) and (Lopez *et al.*, 1986). Note that all flashes, both negative and positive cloud-to-ground lightning, were included. A lightning flash may include several strokes, but the multiplicity was ignored in this study.

Air pollutant data in Malaysia were collected from Clean Air Initiative-Asia Secretariat comprising of data from 1996 – 2004. Malaysia's air quality monitoring network measures PM<sub>10</sub> and SO<sub>2</sub> by 51 Continuous Air Quality Monitoring (CAQM) stations that are linked via public telephone lines to National Environmental Data Center (EDC). In Spain, air pollutant data were obtained from the study of Luis Rivas Soriano and Fernando de Pablo from University of Salamanca, Spain (Soriano *et al.*, 2002).

The observation of PM<sub>10</sub> and SO<sub>2</sub> over urban areas in Subang, Selangor, Ipoh, Perak and Bayan Lepas, Penang were considered. All of these three urban areas are located in West Peninsular Malaysia. Overall, the CG lightning data and the result are based on three years observation period.

## RESULT AND DISCUSSIONS

Table-1 shows the average number of CG flashes recorded within the urban areas in Malaysia for the year 2004 to 2007. Number of CG flashes in urban areas of Subang, Ipoh and Bayan Lepas are 200, 197 and 184. Note that, the major industries in Subang, Ipoh and Bayan Lepas such as light manufacturing industry, heavy manufacturing industry, tin mining and smelting have contributed to a strong source of pollution (according to CAI-Asia, 2006). On the other hand, number of CG flashes recorded in Miranda de Ebro, Burgos and Leon are 203, 354 and 158, respectively. The main activities in those urban areas are clothes manufacturing, timber, and the production of metal and non-metal minerals product (Heleina *et al.*, 2008). Overall, those information from two countries mentioned above indicated that the industrial activities have contributed to the enhancement of air pollution thus indirectly enhanced the production of CG lightning.

**Table-1.** Average number of CG flashes (2004 -2007).

Urban Area/ state	Average number of CG flashes
Subang, Selangor	200
Ipoh, Perak	197
Bayan Lepas, Pulau Pinang	184

Table-2 shows the annual average concentration of PM<sub>10</sub> and SO<sub>2</sub> in Malaysia for the year of 2004. The annual average concentration of PM<sub>10</sub> and SO<sub>2</sub> recorded in Subang, Ipoh and Bayan Lepas are 51, 50, 49 µgm/m<sup>3</sup> and 8, 7.9, 7.7 µgm/m<sup>3</sup>. The annual average concentration of PM<sub>10</sub> in Miranda de Ebro, Burgos and Leon are 96.9, 90.9, 80.5. From the observation of this study, the annual average concentration of PM<sub>10</sub> in Malaysia and Spain are slightly different.

**Table-2.** Annual average concentration of PM<sub>10</sub> and SO<sub>2</sub> in Malaysia for the year of 2004.

Urban area/ state	Annual average concentration of pollutant	
	PM <sub>10</sub> (µgm/m <sup>3</sup> )	SO <sub>2</sub> (µgm/m <sup>3</sup> )
Subang, Selangor	51	8
Ipoh, Perak	50	7.9
Bayan Lepas, Pulau Pinang	49	7.7

Meanwhile, the annual concentration of SO<sub>2</sub> recorded in Malaysia is lower than annual average concentration of SO<sub>2</sub> recorded in Miranda de Ebro, Burgos and Leon (19.6, 19.7 and 57.0µgm/m<sup>3</sup> respectively) more than the factor of two. This is because since 1989, Malaysia was motivated to adhere to air quality guidelines called the Recommended Malaysian Air Quality Guideline (RMG) that was set by Department of Environment (DoE). For the urban areas considered in this study, it was expected that increased concentration of SO<sub>2</sub> contributes to the increase in CG flashes. Conversely, the PM<sub>10</sub> does not seem to be related to the increase of CG lightning. It is because an increased concentration of SO<sub>2</sub> at the surface would lead to increase in sulfate ion concentration in the boundary layer (Seinfeld, 1975). In addition, (Orville *et al.*, 2001) suggested that the increase in the cloud water reaching the mixed phase region of the cloud is paralleled by an increase in the separation of the electric charge therefore, it produces a greater CG lightning. Apparently, sulfate particles are generally more effective as CCN than PM<sub>10</sub>, thus it is reasonable to claim that the SO<sub>2</sub> concentration would be better related to enhancement of CG lightning than the PM<sub>10</sub>, although data from more years would be necessary to confirm this finding.

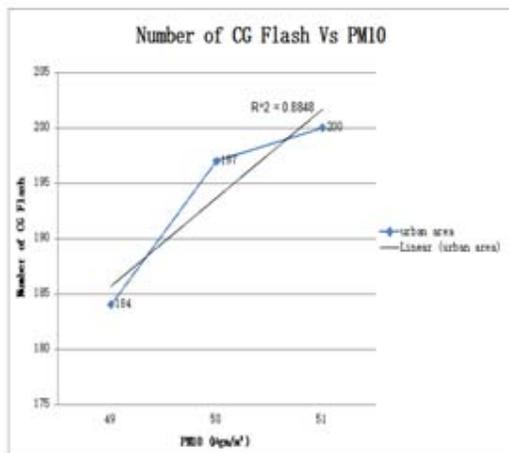


Figure-1. Number of CG flash Vs. PM<sub>10</sub>

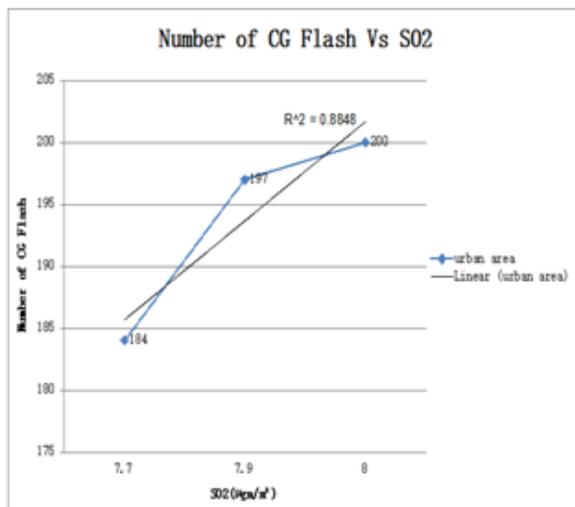


Figure-2. Number of CG flash Vs. SO<sub>2</sub>

Figure-1 and 2 shows the number of CG flashes in Malaysia versus PM<sub>10</sub> and SO<sub>2</sub> in µg/m<sup>3</sup> respectively. In this study, the positive correlation coefficient was found between PM<sub>10</sub> concentration and the number change in CG lightning flashes to the overall urban area with reading of 0.94. Besides, the positive correlation coefficient between SO<sub>2</sub> concentration and the number change in CG lightning flashes to the overall urban area was found to be 0.94. These results indicate a possible influence of pollution over urban areas against the number of CG lightning flashes. In this study, the positive correlation of both pollutants against number of CG flash lightning is same. In addition, this result deviates from result obtained by (Soriano *et al.*, 2002) who found that the correlation concentration of PM<sub>10</sub> and the concentration of SO<sub>2</sub> was - 0.15 and 0.55 respectively. The divergence of the comparison results may due to many factors such as wind speed, humidity, temperature and interaction between polluted gases. According to the observation result in Spain, it is difficult to generalize the conclusion that the

increases of SO<sub>2</sub> contributes in enhancing the CG flashes. Furthermore the increases of PM<sub>10</sub> does not influence the enhancement of CG flashes. Hence, data from different geographical locations and for more years are required to resolve this diversity in the findings. In future study, our team from Advanced Multi-Disciplinary in System Technology (AMDST) in UTeM will investigate the relationship of lightning profile under polluted environment with the lightning parameter as observed by Baharudin and co-authors (Azlinda Ahmad *et al.*, 2010, Baharudin *et al.*, 2012a, Baharudin *et al.*, 2012b and Baharudin *et al.*, 2014) which is primarily become an important information for lightning and protection coordination planning.

## CONCLUSIONS

An analysis of the number of CG flashes in urban areas in was performed. The results show that CG lightning activity is enhanced within of most of urban areas studied. PM<sub>10</sub> and SO<sub>2</sub> concentration were used as gross indicator of CCN and examined in relation to the urban increase in CG lightning activity. Overall, the results for Malaysia show positive correlation which may indicate that the existence of PM<sub>10</sub> and SO<sub>2</sub> concentration enhance the production of CG flashes in the proximity of equatorial region. As previously mentioned, enhancement of lightning activity under the influence of pollution in Malaysia is limited compared to other country, thus it may affect divergence of data. Besides that, factors such as wind speed, humidity, temperature and interaction between polluted gases also affect the result. The divergence of results can be resolved by performing more research and obtain more data from other geographical locations.

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