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THE URBAN EFFECT ON THE CLOUD-TO-GROUND LIGHTNING ACTIVITY IN THE BUCHAREST AREA, ROMANIA

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Abstract. Previous studies have shown that there is an urban effect on cloud-to-ground (CG) lightning activity by examining the weekly variation of the number of days with CG lightning activity and the weekly variation of the PM_{10}. Data from Romanian National Lightning Detection Network and air pollution data from Bucharest Environmental Protection Agency were used study the effect of air pollution on CG lightning activity in the Bucharest metropolitan area. The study period covers three years from 2004 to 2007 (except 2006).The results indicated that there is no obvious effect of the PM_{10} on the NDCG. We speculate that an effect of air pollution (PM_{10}) on CG lightning activity cannot be inferred properly due to the fact that measurement of air pollution are done at 2 m above ground, and also due to the multiple interactions between thermodynamic effects and pollutants.

Key words: lightning activity, urban effect, aerosol.

1. INTRODUCTION

The first study that showed the influence on urban area on the cloud-to-ground lightning (CG) activity was published in 1995 by Westcott [11]. Westcott [11] revealed that for 16 cities from U.S. there is an enhancement of CG lightning frequency on the order of 40%–85% over and downwind of many of these cities. Recently, the urban effect influence on the cloud CG lightning activity was investigated in several studies carried out especially in the U.S. and Brazil (*e.g.*, [4–9]).

Farias *et al.* [4] investigated the importance of the air pollution using CG lightning data provided by the Brazilian Lightning Detection Network for a 6-year period (1999–2004). They observed a significant enhancement in the number of negative CG lightning flashes and a decrease in the percentage of positive CG flashes. The enhancement of the CG lightning activity during the week days over

São Paulo metropolitan region is related to the concentration of particulate matter smaller than 10 μm (PM_{10}) in suspension in the atmosphere.

Kar *et al.* [5] using data of CG lightning activity over five major cities in North Korea showed an enhancement of around 40–64% in the negative CG flash density and 26–49% in the positive CG flash density, observed over the urban areas compared to their surroundings. Also, the concentration of PM_{10} was positively correlated (0.795) with the number of CG flashes.

As was stated by Farias *et al.* [4] the urban effects on CG lightning activity are a combination of thermodynamic effects associated with differential heating of the city (urban heat island), and increases the local concentration of pollutants in the atmosphere, primarily associated with human activities.

Due to the multiple interactions between thermodynamic effects and pollutants, at the present the mechanism responsible for the urban effect on CG lightning is not well known. Several hypotheses have been proposed in order to explain this effect.

Breon *et al.* [3] analyzed the effects of aerosol concentration on cloud droplets size monitored by the satellite. Thus, an increase of the aerosols concentration reduces the size of the droplets, by reducing the coalescence process of rain. In this case a higher value of liquid water content is observed in the mixed phase region ($-10^{o}C$–$20^{o}C$) of the cloud. The mixed phase region of the cloud is also the region in which the most important cloud electrification mechanism, the ice-graupле mechanism, acts. Based on this mechanism the charges are generated in convective clouds by the rebounding collision between ice and grauple particles in the presence of supercooled liquid water. The increase of the liquid water content in cloud produce variations of the droplets distribution that can modify the microphysical processes of ice and cloud electrification.

Andreae *et al.* [1] have studied the smoking rain cloud over the Amazon, and suggested that the compositions of the aerosol particles in smoky and clean regions, and their concentration variations, can invigorate the convection.

In turn, Williams *et al.* [12] compared the electrification of convective cloud for polluted and clear conditions and pointed out that the aerosols effect on CG lightning activity is not clear.

Obviously there is no consensus on the effect of pollution the CG lightning activity. The reason is due to the complexity of the phenomena [4], but that to the lack of studies for different regions of the globe.

The goal of the present work is to analyze the effect of pollution on CG lightning activity in the region of Bucharest, based on the CG lightning data provided by Romanian National Lightning Detection Network (RNLDN, Antonescu and Burcea, 2010) and PM_{10} concentration measurements provided by Bucharest Environmental Protection Agency. We study the weekly variation the number of days with CG lightning in comparison with the variation of the PM_{10} concentration.

2. DATA AND METHODS

The CG lightning data provided by RNLDN were recorded for a period of 4 years from 2003 to 2007. The CG lightning data from 2006 were excluded from the analysis due to the fact, during this year, RNDDEA was partially functioning. For the analysis were selected all the days from the convective season (May – September) with more than two CG lightning flashes. For each of these days were analyzed the CG lightning flashes that occurred between 1100 UTC to 1900 UTC, representing the time interval in which the CG lightning activity associated with convective storm reaches his maximum [2].

The study area has 10 000 km^2 and is situated around Bucharest (238 km^2). This area was considered as representative of urban heat island of Bucharest. Pollution data (PM_{10}) for the region of Bucharest were provided by Bucharest Environmental Protection Agency (BEPA). The measurements network is has 8 stations (Fig. 1) divided in: regional background station – Balotesti, suburban background station – Magurele, urban background station – Crangasi stations, traffic stations – Mihai Bravu and National Military Circle and Industrial stations – Drumul Taberei, Titan and Berceni. In this study the data from the six stations situated in the metropolitan area of Bucharest, were used.

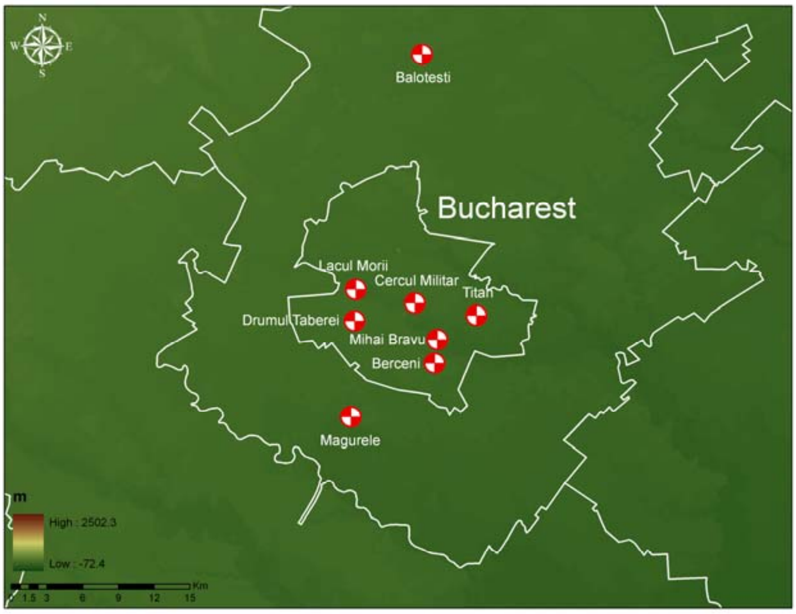


Fig. 1 – The topography of the Bucharest metropolitan region and air quality monitoring stations in Bucharest Environmental Protection Agency (BEPA). Stations are classified into four categories: regional background station (Balotesti), suburban background station (Magurele), urban background station (Lacul Morii) traffic station (Mihai Bravu and Cercul Militar) and industrial stations (Drumul Taberei, Titan and Berceni).

For Bucharest the air pollution sources are industrial stationary sources, usually focused on large industrial sites, but also densely populated residential areas (with development mainly vertical) and automotive vehicles traffic, particularly along major streets. Sources of air pollution in Bucharest region can be grouped into several main major categories as: 1) industrial – the substances discharged into the environment as a result of technological processes like: organic and inorganic powders that contains metals (Pb, Zn, Al, Fe, Cu, Cr, Ni, Cd), gases and vapors (SO_2, NO_x, NH_3, HCL, CO, CO_2, H_2S; 2) automotive vehicles traffic – that produce inorganic gases: nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and particulate matter (PM_{10}). Concentrations of air pollutants are higher in areas with traffic arteries surrounded by tall and compact buildings that prevent dispersion. 3) thermal power station – represent major sources of air pollution in urban areas, by way of operating with liquid fuels having a high sulfur content, spilling into the atmosphere significant amounts of SO2, NO_x, CO, CO_2, dust, smoke, fly ash.

When CG lightning data and are compared with the PM_{10} concentration the main problem is the high variability of the CG lightning that presents variations of several orders of magnitude depending on different meteorological conditions [4]. In order to overcome this limitation we use the procedure developed by Farias *et al.* [4]: the CG lightning data were converted in number of days with CG lightning (NDCG). For each day of the week was calculated the mean NDGC and the average concentration of PM_{10}. The analysis was done for entire study period and each year separately.

3. RESULTS

In Fig. 2 shows the weekly distribution of the mean concentration PM_{10} for all the 6 stations in site Bucharest metropolitan area. There is an increase from Monday (11.7%) to Friday and Saturday (15.5% and respectively 15.8 %) followed by a decrease on Sunday (13.3%).

The main source of particulate matter is (PM_{10}) in Bucharest region is associated with industrial activities and automotive vehicles traffic [10]. Due to the increase of thermal inversion and the decrease of pollutant dispersion by wet deposition, in autumn and winter the pollutant concentration tend to increase [4]. Due to the fact that CG lightning activity peaks during the summer months [2], we study CG lightning data from May–September interval.

In Fig. 3 are illustrated the weekly distributions of the NDCG for 2004–2007. The weekly variation of the NDCG for 2005 and 2007 has a minimum on Thursday, but the maximum values are reached at different moments: Sunday for 2004 and Tuesday for 2007 distributions (Fig. 3). For 2007, the weekly distribution presents a minimum for Tuesday and Wednesday, increasing toward the maximum values in Saturday (Fig. 3). The weekly distribution of the mean NDCG (Fig. 3) decrease from Tuesday toward the minimum values on Thursday, and then increases toward the maximum value on Sunday, followed a secondary maximum on Monday.

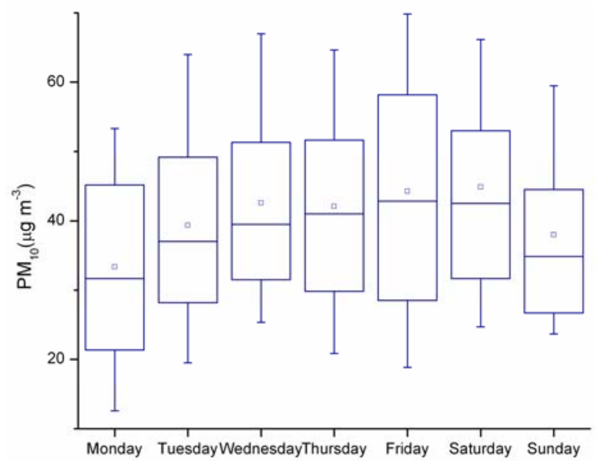


Fig. 2 – Weekly distribution of the PM_{10} concetration. Percentiles of order 0.10, 0.25, 0.50, 0.75 and 0.90 are represented.

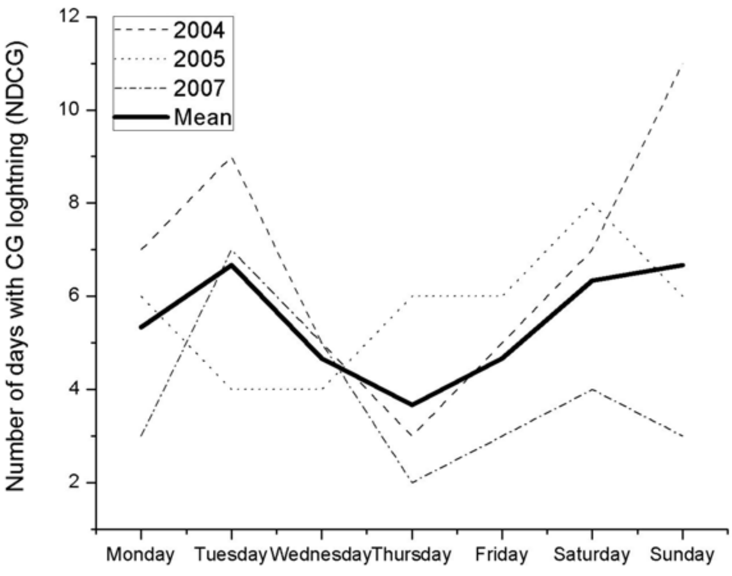


Fig. 3 – Weekly distribution of the number of days with CG lightning (NDCG) for 2003 – 2007 (except 2006) and the mean NDCG.

In order to highlight the effect of pollutants on CG lightning activity, in Fig. 4 is shown the weekly variation for mean NDCG and mean concentration of PM_{10}. The NDCG increase as the concentration of PM_{10} increase from Monday to Tuesday. For values greater than 40 μg m^{-3} the NDCG decrease toward minimum values on Thursday.

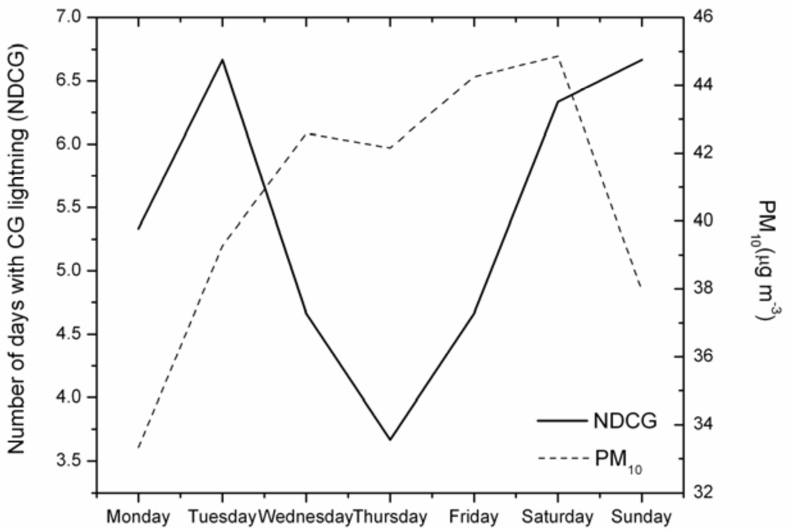
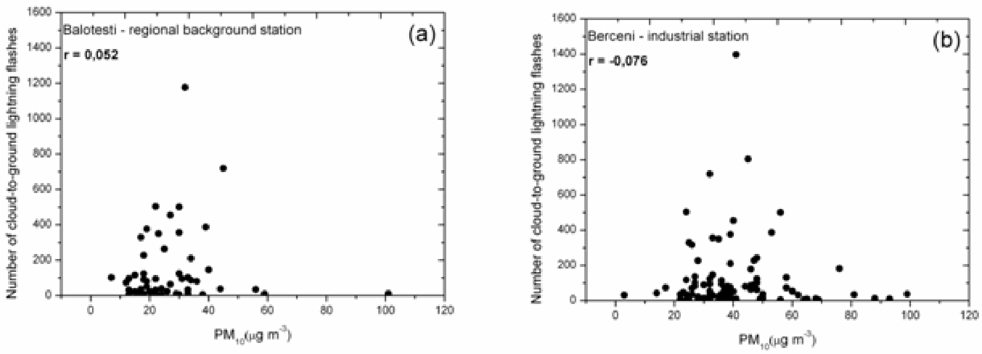


Fig. 4 – Weekly distribution of the mean number of days with CG lightning (NDCG) and mean concentration of PM_{10}.

The number of cloud-to-ground lightning as a function o PM_{10} concentration was also represented (Fig. 5). The analysis was done for each type air quality monitoring stations. The correlation analysis showed that there is no significant correlation between the number of CG flashes and PM_{10} concentration, the correlation coefficient ranging from from $r = 0.052$ (Fig. 5a) for Balotesti (regional background station) to $r = 0.222$ for Cercul Militar (traffic station).



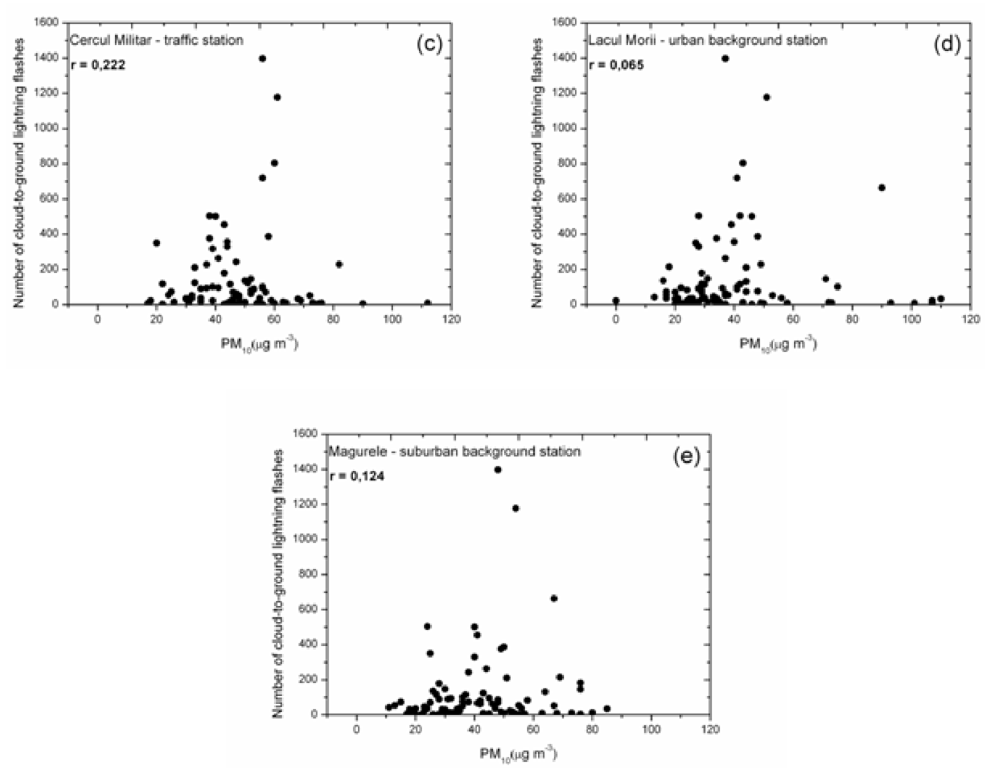


Fig. 5 – The number of cloud-to-ground lightning as a function o PM_{10} concentration, and the correlation coefficient (*r*) for: a) Balotesti – regional background station; b) Berceni – industrial station; c) Cercul Militar – traffic station; d) Lacul Morii – urban background station; e) Magurele – suburban background station.

4. SUMMARY AND CONCLUDING REMARKS

In order to highlight a possible effect of air pollution on the CG lightning activity we study the weekly variation of the number of days with CG lightning activity and the weekly variation of the PM_{10} in the metropolitan area of Bucharest city. The study was based on lightning data from RNLDN and air pollution data from. The study period covers three years from 2004 to 2007 (except 2006). The data from the convective season (May – September) and between 1100 and 1900 UTC, when the diurnal CG lightning activity peaks, were used. The results indicated that there is no effect of the PM_{10} on the NDCG.

We speculate that an effect of air pollution (PM_{10}) on CG lightning data it cannot be inferred properly due to the fact that measurement of air pollution are done at 2 m above ground, and also due to the multiple interactions between thermodynamic effects and pollutants.

Despite the fact that there is no consensus in issue of the urban effect on CG lightning activity, this subject is an important research topic necessary for understanding the role of humans on CG lightning activity

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