A Preliminary Assessment of Lightning Activity Around A South African Mining Town, eMalahleni

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Abstract—This paper presents the results of a preliminary study of lightning activity around eMalahleni, a South African town which is surrounded by an estimated 160 mines and 13 coal power plants. This area also falls within one of most polluted regions of South Africa with recorded particulate matter ($PM_{10}$) concentrations of about 80 $\mu g \ m^{-3}$ between 2009 and 2012. Cloud to ground (CG) lightning flash data from the South African Lightning Detection Network (SALDN) for 2013 was used to calculate the spatial distribution of overall flash density, positive flash density and average multiplicity in the region within a 250 km radius of eMalahleni. A total of 1127186 CG flashes were recorded in the area in 2013. The highest average flash densities in excess of 12 flashes/km$^2$/year were observed over the regions that are part of the Drakensberg escarpment. Flash densities ranging between 6 and 12 flashes/km$^2$/year were also observed near some of the mines that are not on the Drakensberg escarpment. Positive flash densities less than 1 flash/km$^2$/year were observed near mines and power stations compared to flash densities greater than 1 flash/km$^2$/year observed elsewhere. This might be an indicator that both elevation and mining activities are affecting CG lightning activity in this region. However, more data analysis needs to be conducted before conclusions can be drawn on the effects of mining and elevation on lightning activity in the region.

Keywords: cloud to ground lightning; elevation; eMalahleni; flash density; mining; SALDN.

I. INTRODUCTION

Several studies have been conducted in South Africa assessing the lightning climatology and pollution levels [1–4]. These studies showed that provinces such as Mpumalanga, North West and Gauteng have lightning flash densities in excess of 10 flashes/km$^2$/year [4, 5]. Some of these provinces also have the highest pollution levels in the country since that is where most coal power generation plants, metallurgical and petrochemical industries are located. Other studies conducted worldwide on effects of urbanisation have shown that the urban heat island and pollution can result in enhanced lightning activity over and downwind of urban areas [6–9]. This preliminary study focuses on areas around eMalahleni, a South African mining town that has high mining and power generation activities to assess their impact on lightning activity.

II. BACKGROUND

South Africa is one of the largest industrialised economies in Africa because of its vast mineral resources which are concentrated in its Mpumalanga, North West, Gauteng and Limpopo provinces [3]. Studies on South African lightning climatology show that areas in these provinces are in the severe lightning risk zones of the country with flash densities in excess of 10 flashes/km$^2$/year [5].

The mining and coal power generation activities in these provinces are major sources of atmospheric pollutants [3]. The high volume of road traffic due to these industries and incomplete combustion of fuel in informal settlements in the region for heating and cooking purposes also contribute to the increased atmospheric pollutants [3, 4]. An air quality study conducted in Mpumalanga province showed that the average daily winter particulate matter ($PM_{10}$) concentrations were around 80 $\mu g \ m^{-3}$ between 2009 and 2012 which is above the 75 $\mu g \ m^{-3}$ in the South African air quality act and 20 $\mu g \ m^{-3}$ World Health Organisation (WHO) guideline [4]. The study also showed that the pollution levels in this area have been increasing and are expected to continue because of the new coal power stations that are being constructed [4].

Studies conducted in other parts of the world assessing effects of human activities on lightning have shown increased cloud to ground (CG) lightning activity over and downwind of urban areas [6–8]. Most of the studies speculate that this is a result of the urban heat island (UHI) which enhances convergence and the high pollutant concentrations which act as cloud condensation nuclei (CCN) over the urban areas. One study showed a three times increase in lightning activity in regions near coal plants and highways [9]. The authors
attributed these enhancements to increased pollutant concentrations around coal plants and surrounding highways.

III. MINING ACTIVITY AROUND eMALAHLENI

This study focuses on areas within a 250 km radius of eMalahleni (formerly known as Witbank) a mining town in Mpumalanga province. Figure 1 shows the area highlighted in grey on the South African map. The area was chosen for this study because there are an estimated 160 active mines and 13 coal power stations within the area as shown in Figure 2 based on the data provided by Eskom (South Africa’s power generation utility).

The eastern part of the chosen area falls within the Drakensberg escarpment region of South Africa. Figure 3 shows the elevation variations in the study area in the red grid.

IV. LIGHTNING DATA ANALYSIS

CG flash data from the South African Lightning Detection Network (SALDN) for 2013 was used for this study. The SALDN network was installed in 2005 by the South African Weather Service (SAWS) [2]. This network is capable of detecting both intra-cloud and cloud-to-ground lightning discharges. The network was initially made up of 19 sensors and was later upgraded to 24 sensors in 2011 [2, 11]. The network has an approximated 90% flash detection efficiency and 0.5 km median location accuracy [2]. The ground-truth study of the SALDN conducted by Hunt et al showed a flash detection efficiency of 76% for upward lightning [11].

A. Preliminary Results

For the preliminary results, the study area was split into 0.125° longitude x 0.125° latitude (Approximately 173 km) blocks. The overall (positive and negative), positive and negative flash density were computed for each block.

A total of 1127186 lightning flashes were recorded in the study area in 2013 with 140404 of these being positive flashes. The average flash density for the study area was calculated to be 5.4 flashes/km²/year by dividing the total number of flashes in the study area by its area. Figure 4 to Figure 6 show the overall, negative and positive flash density (flashes/km²/year) results obtained for 2013 respectively. Figure 7 to Figure 10 show the overall flash counts per km for summer, autumn, winter and spring seasons for 2013 respectively. These values were calculated by dividing the total number of flashes recorded in a block by the block area.
Fig. 5. Negative flash density (flashes/km$^2$/year) for study area for 2013.

Fig. 6. Positive flash density (flashes/km$^2$/year) for study area for 2013.

Fig. 7. Overall flash count (flashes/km$^2$) for study area for 2013 Summer season (December - February).

Fig. 8. Overall flash count (flashes/km$^2$) for study area for 2013 Autumn season (March - May).

Fig. 9. Overall flash count (flashes/km$^2$) for study area for 2013 Winter season (June - August).

Fig. 10. Overall flash count (flashes/km$^2$) for study area for 2013 Spring season (September - November).
B. Preliminary Results Analysis

Figure 4 and 6 show high overall flash densities in excess of 12 flashes/km²/year and positive flash densities in excess of 2 flashes/km²/year respectively in areas that are part of the Drakensberg escarpment. These results are consistent with the other South African studies that showed a link between elevation and increased lightning activity [1]. However, average to high flash densities in the range between 6 to 12 flashes/km²/year were also observed near some mines that are not part of this escarpment. The seasonal results show that the highest number of flashes were observed in summer (Figure 7) while the least number of flashes were recorded in winter (Figure 9). In Figure 6 positive flash densities less than 1 flash/km²/year were observed near most of the mines and power stations compared to the positive flash densities greater than 1 flash/km²/year observed over the areas without mines. These results seem to indicate an increase in overall CG activity and reduced positive CG activity due to pollution in the region since other studies have shown that increases in aerosol concentrations can result in enhanced overall CG lightning activity and reduced positive CG activity [6, 8, 12].

C. Future Work

The preliminary results suggest that there might be a link between the high CG lightning activity in the study area with elevation and mining activity. However, more data analysis needs to be conducted before any conclusions can be drawn. This preliminary study will be used as part of a larger study of the effects of mining on CG activity in South Africa’s Mpumalanga province. The other analyses that will be conducted include the analysis of larger datasets for pollution, wind patterns, CG lightning.

V. Conclusion

Human activities have been linked to enhanced lightning activity from several studies that have been conducted worldwide. This paper presented the preliminary study of the effects of mining around eMalahleni that was conducted using 2013 CG lightning flash data from the SALDN. The area was chosen for the study because it has several mines, coal power plants and it falls within one of the most polluted regions of South Africa. The results shows high flash densities over regions that falls on the Drakensberg escarpment and over some of the mines that are not part of the Drakensberg escarpment. This is speculated to be a combination of pollution due to mining and elevation since these results are consistent with other studies that have shown the influence of terrain and pollution on lightning activity. However, a more detailed analysis needs to be conducted with more datasets before any solid conclusions can be drawn.

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