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LIGHTNING CLIMATOLOGY OF SOUTH AFRICA WITH A SPECIAL FOCUS ON LIGHTNING RISK MAPS

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1. INTRODUCTION

South Africa is a country prone to lightning. The summer (October to March) rainfall region is dominated by convective storms. A large portion of this region receives more than 60 thunderstorm days a year (Gill 2008), while areas over the Highveld and the eastern escarpment record on average between 10 and 15 lightning flashes per square kilometer per year. Lightning related deaths account for an average of between 1.5 and 8.8 per million of the population, (Jandrell *et al.* 2009), while insurance claims due to lightning amount to more than R500 million per year (Gill, 2008).

As a result, a lightning climatology of South Africa is vital to ensure the protection of people and their property against lightning. In 2005 the South African Weather Service installed a state of the art cloud-to-ground lightning detection network (LDN) from Vaisala consisting of 19 sensors across the country. This network was upgraded to a 23 sensor network in 2010. Figure 1 depicts the positions of the sensors distributed throughout the country.

FIGURE 1. The South African Weather Service lightning detection network sensor positions.

The data recorded by this network was used in the development of an initial lightning climatology for South Africa (Gill 2008). This initial climatology was however only updated in 2010 with the data from 2006 to 2010. More recently the data from 2011 was also included into the maps. Gill (2008) also proposed three risk maps in her initial climatology based on the climatology's of lightning flash density, median peak kiloampere, percentage positive maps, and average flash multiplicity. The first risk map, the lightning intensity risk, indicates areas prone to high intensity lightning, the second, the positive lightning risk, for areas at risk from lightning with a positive polarity, while the third risk map, the total lightning risk, gives the overall lightning risk. This paper presents the proposed risk maps based on lightning climatology maps for the 6 year period between 2006 and 2011. Figure 2 serves to orientate the reader in terms of the location of the provinces of South Africa.

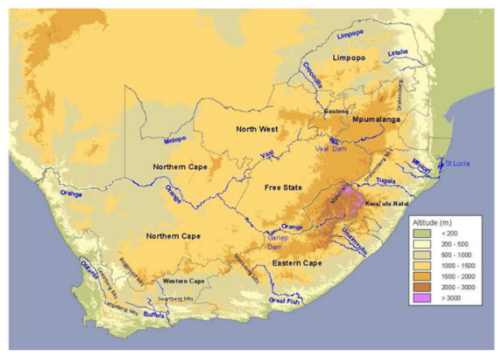

FIGURE 2. Map indicating the provinces of South Africa.

2. DATA AND METHODS

All the lightning fields were calculated and displayed on a 0.1° x 0.1° grid over the country. The lightning ground flash density, average flash multiplicity and median peak kiloampere maps were created for all lightning flashes, irrespective of the polarity of the flash. These maps were also created for only positive lightning flashes. The maps taking only the positive lightning into account are not discussed in this paper, but were used to create the positive lightning risk map. The maps of median peak kiloampere, average flash multiplicity and percentage positive will also not be discussed in the results of this paper.

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The ground flash density, displayed in Figure 3 was created by counting the number of lightning flashes over the 6-year period 2006–2011 for each individual grid box over the country. This summation was divided by the area of the grid box to give the number of lightning flashes per square kilometer and then finally divided by six to give the average annual number of flashes per square kilometer. All grid boxes over the country were considered, irrespective of the number of flashes.

Gill (2008) proposed a map called the lightning intensity risk map. The purpose of the lightning intensity risk map is to give an indication of areas at risk from high volumes of lightning. Three maps were utilised in the development of the lightning intensity risk map: the lightning ground flash density map, the median peak kiloampere map and the average flash multiplicity map. The lightning ground flash density map was selected for inclusion in this risk map because it identifies areas where lightning frequently occurs. Because higher currents found in a lightning flash may increase the risk associated with the flash, the median peak kiloampere map is also included in the calculations of the lightning intensity risk map. Finally, the average lightning flash multiplicity map is included in this risk map because a flash consisting of a number of strokes may transfer large amounts of energy to the ground (Gill 2008).

As this lightning intensity risk map is concerned with high volumes of lightning received, all lightning flashes, irrespective of polarity, were considered. Each of these input maps was reduced to an index varying between 0 and 1 by dividing the value from each grid box by the maximum number of the entire data set. The three maps, reduced to an index, were given equal importance in the development of the lightning intensity risk map and were simply added together. All the corresponding grid box values on each of the three input maps were added together. The sum of these three indices was in turn also reduced to an index varying between 0 and 1. The final map is displayed in Figure 4.

A second risk map proposed by Gill (2008) was the positive lightning risk map. This risk map identifies areas where lightning with positive polarity poses the highest risk. As input to this risk map, the positive lightning ground flash density map (Figure 3), the median peak kiloampere of positive polarity lightning map, the positive flash multiplicity and the percentage positive map were used.

Only lightning flashes with positive polarity were considered in the creation of this risk map. For the percentage positive map used as input in the risk map calculations, all lightning flashes irrespective of polarity were used to calculate the percentage of flashes with positive polarity. Each of the four input maps was given equal importance in the calculations. Each of these input maps was reduced to an index varying between 0 and 1 by dividing the value from each grid box by the maximum number of the entire data set. The four maps were simply added together. All the corresponding grid box values on each of the four input maps were added together. The sum of these four indices was in turn also reduced to an index varying between 0 and 1. The final map is shown in Figure 5.

Because high volumes of lightning are just as important as lower volumes of lightning with positive polarity when analysing lightning risk (Gill 2008) it is important to create a risk map that takes into account both of these different types of risk. Gill (2008) proposed combining the lightning intensity risk and positive lightning risk maps. The lightning intensity risk map addresses the risk associated with high volumes of lightning whilst the positive lightning risk map shows the areas at risk from positive lightning. This combination is called the total lightning risk map and serves the purpose of being a general purpose map that takes all the risks associated with lightning into account.

As input to the total lightning risk map, both the lightning intensity risk map and positive lightning risk map were considered. The results of these two maps were already reduced to an index between 0 and 1 as discussed earlier. Thus the two maps needed only to be added together by giving each map equal importance in the calculation. The value in each 0.1° x 0.1° grid box on the lightning intensity risk map was added to the value in the corresponding grid box on the positive lightning risk map. The sum was reduced to an index varying between 0 and 1 by dividing each grid box over the country by the maximum value of the entire data set. This result was then called the total lightning risk. The final map is shown in Figure 6.

3. RESULTS

3.1 *Lightning ground flash density*

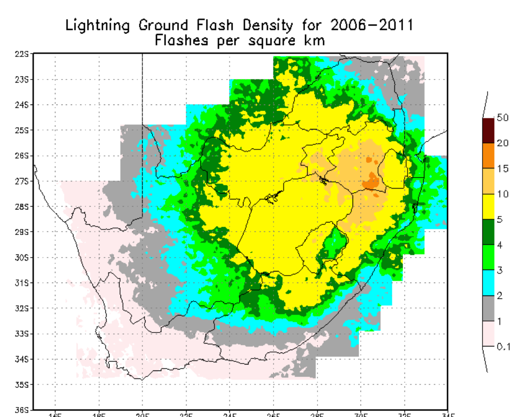

FIGURE 3. A map depicting lightning ground flash densities across South Africa for the 2006-2011 periods.

Highest flash densities are found along the Northern parts of the Eastern Escarpment, extending from the northern parts of KwaZulu-Natal into the province of Mpumalanga. Flash densities of between 10 and 15 flashes per square kilometer are seen from the western to north-western parts of Kwazulu-Natal extending into the province of Mpumalanga as well as the southern parts of Gauteng and the northern and north-eastern Free State. Small areas over the western parts of the North West Province and Lesotho also have flash densities of between 10 and 15 flashes per square kilometer. The central interior of the country receives between 5 and 10 flashes per square kilometer, and the flash densities decreases towards the west of the country. Flash densities also decrease towards the northern to north-eastern parts of the country, as well as towards the coast.

3.1 *Lightning intensity risk*

The lightning intensity risk map shows similarities to the lightning flash density map. Areas along the slopes of the Northern parts of the Eastern Escarpment are at extreme risk from lightning. The central parts of South Africa are at severe risk from high volumes of data. Towards the western parts of the country the lightning risk decreases. The Western Cape is the province with the lowest risk. The lightning risk decreases towards the northern parts of the Limpopo Province and the eastern and southern coastal regions.

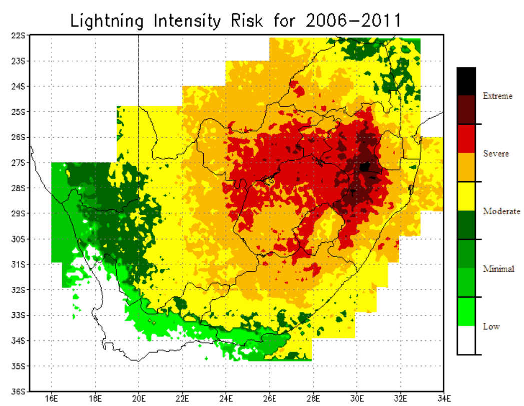

FIGURE 4. A risk map which identifies areas of South Africa that is at risk from high volumes of lightning for the 2006-2011 periods.

3.1 *Positive lightning risk*

Small isolated areas in the North West Province, Free State, Northern Cape, Eastern Cape, KwaZulu-Natal and Lesotho are at extreme risk from lightning with positive polarity Almost the entire country is at severe risk from positive lightning. Towards the west of the country the risk decreases. Low to moderate lightning risk is found along the Western Cape, western parts of the Northern Cape and a small area over the Eastern Cape.

3.1 *Total lightning risk*

From Figure 6 the central to northern interior of the country is at extreme risk from lightning. The highest risk from the extreme risk category is found along the windward slopes of the northern parts of the Eastern Escarpment. Most of the remaining parts of South Africa fall in the severe risk category. Low to moderate lightning risk is found along the Western Cape, western parts of the Northern Cape and a small area over the Eastern Cape. The Western Cape is the region in South Africa with the lowest risk, since most of this province falls inside the low risk category.

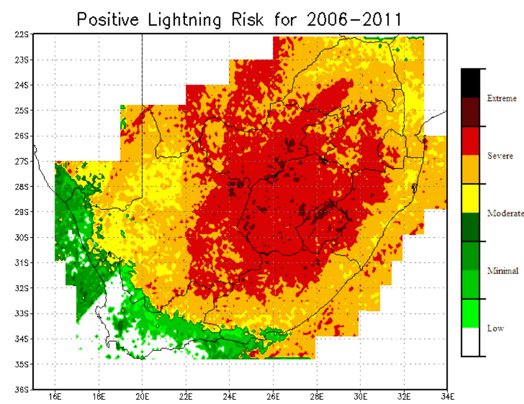

FIGURE 5. A map depicting the positive lightning risk across South Africa associated with positive lightning for the 2006-2011 periods.

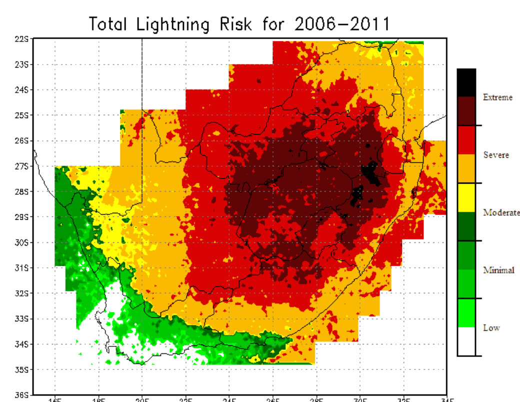

FIGURE 6. A risk map indicating the total lightning risk of South Africa for the 2005-2011 periods.

4.2 *Conclusions*

Before 2006, the South African Weather Service were unable to measure lightning activity over South Africa. This limited the SAWS in both its service delivery and public good. This inability changed with the installation of the state-of-the-art SALDN by the end of 2005. Gill (2008) was the first person to utilise this new technology in regard to developing an initial lightning climatology of South Africa with the data from 2006. Until 2010, this initial lightning climatology had never been updated, and this paper serves to update the climatology with the data for the 2006–2011 period. These data provide South Africa with the first lightning climatology, based on data for more than a year, measured by the new state-of-the-art SALDN.

Analysis of the maps shows that the highest concentrations of lightning are found over the central to northern interior of the country, with areas along the northern escarpment extending from the northern parts of KwaZulu-Natal into the Mpumalanga province topping the scale of lightning densities. The risk maps also confirm that these areas fall into the extreme risk category. Almost the entire country is at severe risk from both lightning with positive polarity as well lightning in general. Only towards the west of the country does the concentration of lightning, as well as the lightning risk, decrease.

This lightning climatology can now be used throughout South Africa for various disciplines. It will be especially useful for setting lightning safety standards. Priority areas can be identified to install lightning conductors in high risk areas like rural areas, as well as to focus attention on these areas for lightning safety tips to the public. Insurance companies can utilize these maps to identify high risk areas, Eskom can determine areas where lightning is most likely to interrupt power supply, areas at risk from lightning-induced fires can be identified and various other institutions may

4.4 *References*

Gill, T., 2008: Initial steps in the development of a comprehensive lightning climatology of South Africa. Unpublished thesis, South Africa, University of the Witwatersrand.

Jandrell *et al.,* 2009: Recent lightning research in South Africa with a special focus on Keraunopathology, Proceedings of the 16th International Symposium on High Voltage Engineering, Aug 24-28, Cape Town, South Africa

Note: This extended abstract is based on published work: Gijben M. The lightning climatology of South Africa. S Afr J Sci. 2012;108(3/4), Art. #740, 10 pages. http://dx.doi.org/10.4102/sajs.v108i3/4.740