Investigating the plausibility of a model based lightning risk indicator for South Africa

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ABSTRACT: South Africa is a lightning prone country. The South African Weather Service owns a cloud-to-ground lightning detection network which is measures lightning in real-time. This network is useful for lightning verification studies and the nowcasting of thunderstorms. Various products exist which can aid with the prediction of thunderstorms. None of these products directly attempts to forecast the potential of lightning occurrence in the very short range and short-range forecasts timescales. Frisbie et al. [2009] developed a Lightning Potential Index, which utilizes numerical model parameters to assess the possible lightning risk. This methodology was applied over South Africa to develop a lightning threat indicator, which was tested against the occurrence of lightning. Initial results of this product looks promising, and future adjustments of this index could make this product a valuable tool to assess the possible lightning risk.

INTRODUCTION

Lightning can cause death or injury among humans and animals [Blumenthal et al. 2012), damage to various infrastructures [Lynn and Yair 2010], and can be a hazard to various sectors like the aviation and forestry industry [Price 2013]. There is a need to forecast the areas where lightning can cause a threat [Lynn and Yair 2010] to ensure the protection of people and property.

The South African Weather Service owns a cloud-to-ground lightning detection network consisting of 24 sensors across the country and can detect lightning strokes with a predicted 90% detection efficiency over most of the country [Gijben 2012]. This network is useful for lightning verification studies and the nowcasting of thunderstorms, but fails to address the need for lightning prediction in the very short-range (2-12 hours) and short-range (12-72 hours) forecast scale.

Various thunderstorm indices are available in South Africa, which can aid with the prediction of thunderstorms [de Coning et al. 2011]. Since lightning is a product of most thunderstorms, these indices can indirectly forecast the possible lightning threat. No product currently exists in South Africa, which directly attempts to forecast the possible lightning threat for the next 48-hour period.

Frisbie et al. [2009] developed an index, called the Lightning Potential Index, which uses parameters from numerical weather prediction models as input to calculate the possible lightning threat that can be expected. In this index, Relative Humidity at -10^{o}C, Equivalent Potential Temperature Lapse Rate at 600mb, Lifted Index, most unstable CAPE (0-3km above ground level), Precipitable Water, and temperature at

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850mb combine into a single index to provide an outlook map of where the lightning threat is high.

This index was developed and tested over South Africa. The same methodology utilized by Frisbie et al. [2009] was also applied in South Africa. Observed lightning data was used for evaluating the index. Preliminary evaluation shows that that index is useful to forecast the lightning threat. Lightning was observed in most of the areas where lightning was forecasted. The index tends to over-forecast the lightning threat, but since this product supplies a warning, it is advisable to rather over-forecast the threat areas and not to under forecast these areas. This product is also experimental. Exactly the same methodology as was used in Colorado was applied to South Africa. Obviously environmental conditions differ in South Africa and future work will adjust this index for South African conditions.

DATA & METHODS

Model data from the local version of the Unified Model, operational at the South African Weather Service, was used to extract the numerical model parameters needed. The data was extracted on a 0.11 X 0.1112 degree resolution and for the region 22^{o}S to 36^{o}S and 15^{o}E to 34^{o}E. Data for every hour between 04Z and 21Z was obtained. Programs were written which calculated the maximum values from the model fields for an outlook map between 07:00-19:00UTC. 50 case days were considered.

The raw lightning data was extracted from the database at the South African Weather Service. Programs was used which reads in the raw lightning data and calculates the amount of lightning strokes falling inside all of the 0.11 X 0.1112 degree grid boxes correlating with the grid boxes for which model data was extracted. Summations of lightning strokes for the 12-hour forecast period was calculated.

Frisbie et al. [2009] developed his methodology for calculating the Lightning Potential Index (LPI) by combining the model parameters into a single index using the following equations:

$$A = (RH)^2 \times (\theta e \Gamma) \times (LI)^2 \times (-1) \qquad (1)$$

$$B = (muCAPE) \times (PW) \times (RH) \times 0.001 \qquad (2)$$

$$LPI = (A + B) \times (T_{850} - 272.15) \qquad (3)$$

In the above equations the variables used are:

RH:	Relative Humidity at -10^{o}C
ΘeΓ:	Equivalent Potential Temperature Lapse Rate at 600mb
LI:	Lifted Index
muCAPE:	Most Unstable CAPE in the 0-3 km above ground level range
PW:	Precipitable Water
T_{850}:	850mb Temperature in Kelvin

The LPI results are divided into four risk categories: Low Risk, Moderate Risk, Severe Risk and Extreme Risk. The same methodology of Frisbie et al. [2009] was used to develop and test the Lightning Threat Index over South Africa.

The lightning index was evaluated against observed lightning. This evaluation was done on a grid point by grid point basis. The percentage of all the lightning falling inside each risk category was calculated to determine if the correct amounts of lightning is predicted. To determine if the index is over forecasting the lightning threat, the percentage of the area covered by lightning for each risk category was also calculated. Various skill scores such as the probability of detection, probability of false detection, false alarm ratio and Hanssen-Kuipers discriminant was utilized (Wilks, 2005). These statistical score were calculated by using the standard contingency table approach of Hits (A), Misses (C), False Alarms (B) and Correct Negative (D). The statistical scores used are summarized in table 1.

Table 1 Definitions of statistical scores used. Source: http://www.cawcr.gov.au/projects/verification/

	Formula	Range	Perfect Score
POD	A/(A+C)	0 to 1	1
POFD	B/(D+B)	0 to 1	0
FAR	B/(A+B)	0 to 1	0
ACC	(A+D)/total	0 to 1	1
HK	POD-POFD	-1 to 1	1
BIAS	(A+B)/(A+C)	0 to ∞	1
TSCORE	A/(A+C+B)	0 to 1	1

RESULTS

Figure 1 shows the lightning index and detected lightning on 25 March 2012. This map provides a 12-hour outlook map of the lightning threat, which was calculated by plotting the maximum threat that was forecasted for the period between 0700 and 1900 UTC. The map with the detected lightning shows the total amount of lightning over the 12-hour period corresponding to the LTI map times. From Figure 1 it is clear that there was a good correspondence between the LTI and the observed lightning.

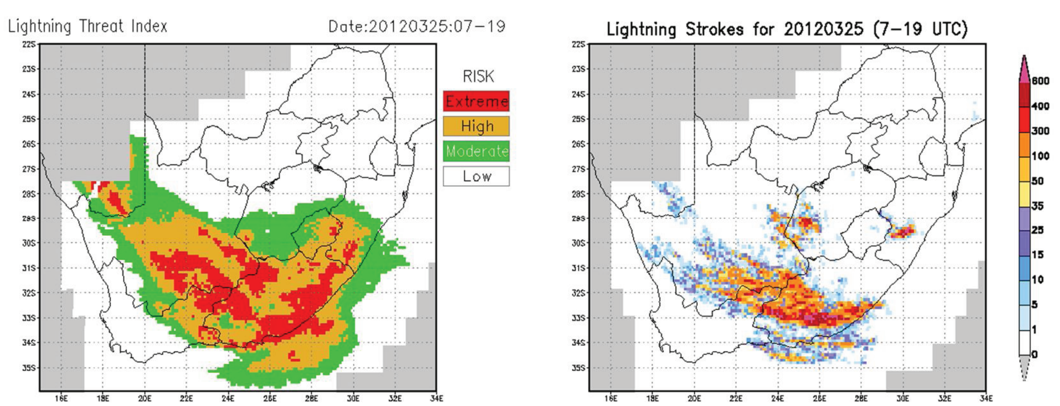

Figure 1: The lightning threat index (left) and the observed lightning (right) between 07:00-19:00UTC on 25 March 2012.

Figure 2 shows a graph with the percentage of the lightning that occurred in each risk category between 07:00-1900UTC on 25 March 2012. From this graph, one can see that most lightning occurred in the extreme risk category while almost no lightning was observed in the low risk category. This is the typical profile expected.

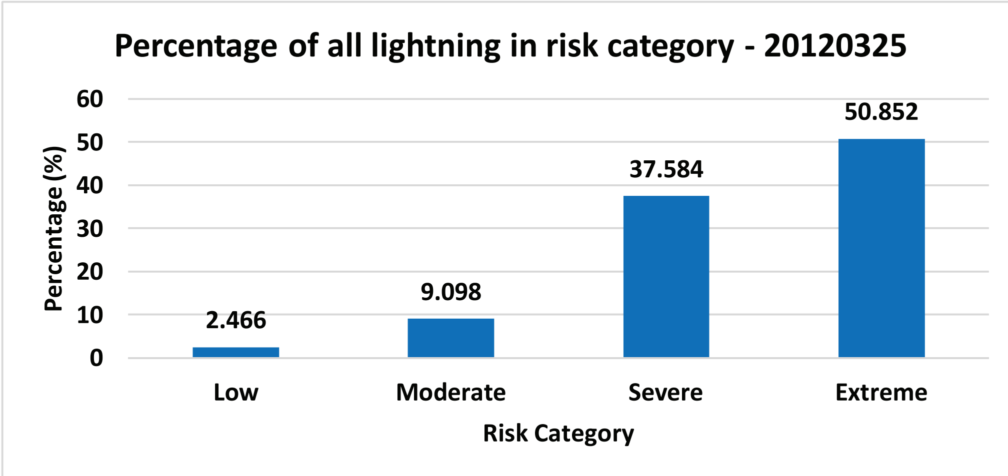

Figure 2: The percentage of the total lightning that occurred in each risk category between 07:00-19:00UTC on 25 March 2012.

Figure 3 displays a graph in which the percentage of the risk category, which was covered by lightning, is shown. The purpose of this graph is to show if the index is over forecasting the lightning threat. This graph was calculated between 07:00-19:00UTC on 25 March 2012. From the graph, it is clear that the index does over forecast the lightning threat, but for the low risk category, almost no lightning was observed, as one would expect.

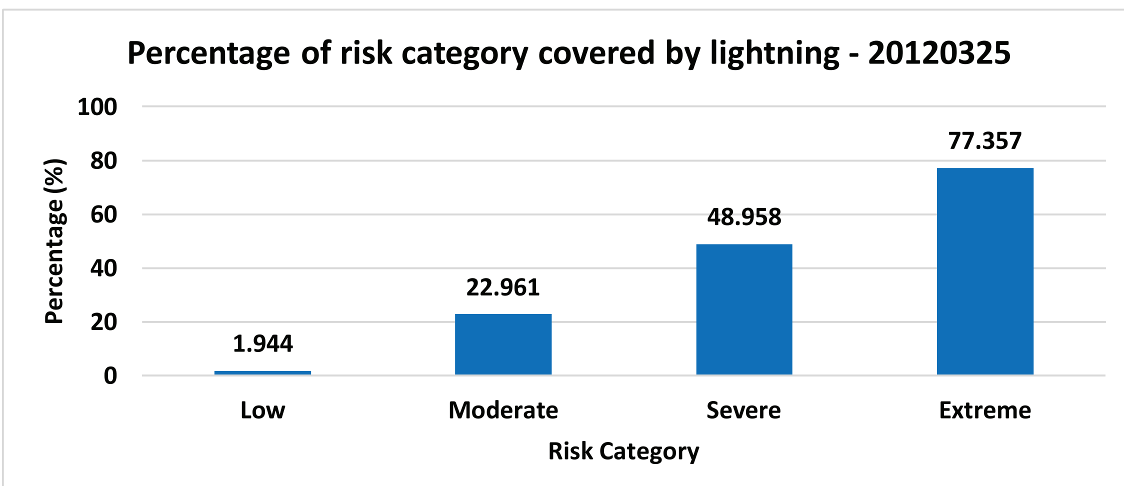

Figure 3: The percentage of the risk category covered by lightning between 07:00-19:00UTC on 25 March 2012.

Figure 4 shows various skill scores that was calculated between the index and observed lightning. This evaluation in the graph was for 25 March 2014 between 07:00-19:00UTC. One can see that the POD, POFD and HK scores are quite good. The FAR and Bias is high which indicates that the threat categories does over forecast the risk.

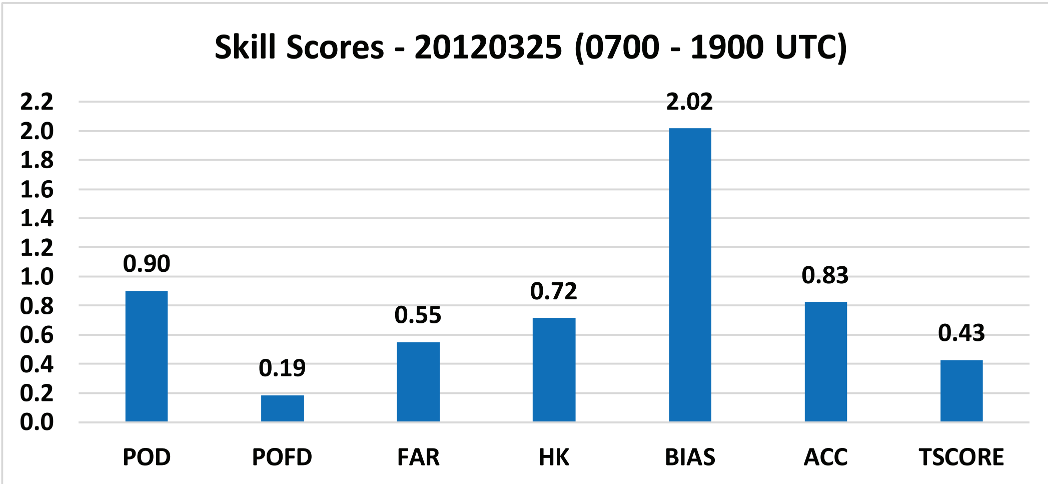

Figure 4: Statistical scores calculated between 07:00-19:00UTC on 25 March 2012.

CONCLUSIONS

The Lightning Threat Index was tested over South Africa using the same methodology as Frisbie et al. [2009]. Initial results of this model-based lightning threat index shows promising results. Lightning is predicted quite well, but the index does over forecast the lightning threat areas. Since this product produces a risk map, it is advisable to rather over-forecast the potential lightning risk. The environmental conditions in South Africa are quite different to that of Colorado. As a result, this product will be adapted to South African conditions in the near future.

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