LIGHTNING ATTRACTIVENESS INDEX FOR URBAN AREAS BASED ON DIGITAL SURFACE MODEL

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ABSTRACT

Lightning is a stochastic phenomenon and is responsible for several fatalities every year around the world. As an attempt to reduce its effects, different risk indices have been produced over the years and different strategies are used for people safety and property protection. This work presents a lightning attractiveness index based on a digital surface model (DSM) obtained using Google Earth 3D imagery and Structure from Motion (SfM) technology. A weighted kernel was then applied to the DSM using Google Earth Engine infrastructure. The results seem to consistently emphasize areas with higher and lower attractiveness and therefore, higher and lower risk. The index is expected to help in the development of improved lightning hazard models applied to urban areas.

Keywords — Climate, lightning, hazard, Google Earth, structure from motion.

1. INTRODUCTION

Different risk models for lightning incidence have already been proposed, considering several aspects, among those the terrain and earthen structures [1-4]. In the case of lightning hazard within urban areas, models use information mainly from the annual flash density, from the so-called collection area and considering specific location and protective factors [1, 2]. This idea is also part of the lightning attachment studies and lightning protection of electrical systems in general [4, 5].

The importance of these models for urban areas rely on its increasing importance with the development of modern lightning location systems. Many studies around the world found that lightning activity seem to occur more frequently at urban areas [6-8].

Despite studies regarding the lightning attachment and some of the risk indices have used digital elevation models [1, 5], they are applied as a regional factor and/or with reduced spatial resolution.

In this paper, an attractiveness index is proposed based a distance-weighted kernel which uses a Digital Surface Model (DSM) obtained by using Google Earth 3D tools and screenshots along with SfM technology.

2. MATERIAL AND METHODS

This study was held in the city of Santos, SP, Brazil (Figure 1). The city is interesting for this kind of study due the different existent features: mix of low and high-rise buildings, as well as flat areas combined with complex terrain. The whole area encompasses around 7800 hectares.

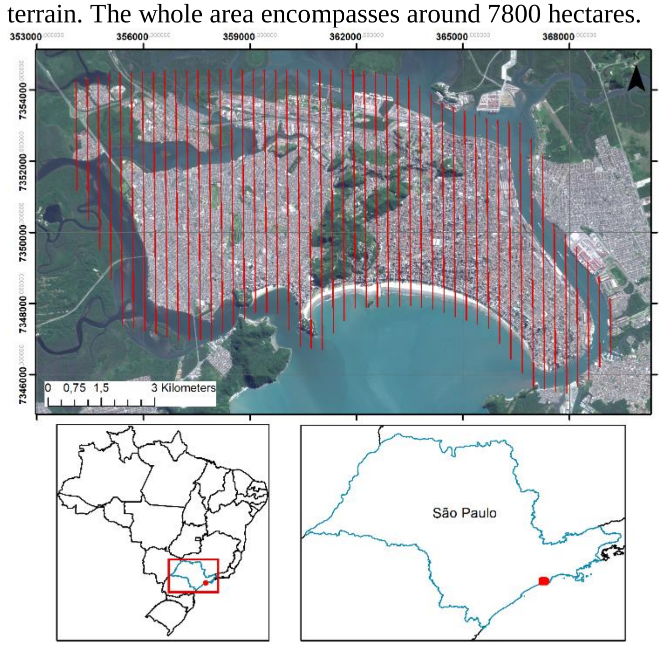

Figure 1. Santos area and lines used to fly with Google Earth ® 3Dtour tool. Background image is from Sentinel 2.

4.1. Digital Surface Model reconstruction

The DSM was obtained using Google Earth® (GE) tools and Agisoft Photoscan Structure from Motion (SfM) technology. With the three-dimensional view activated in GE, images were extracted using the tour (fly along path) and movie export tools. Flight mode was used along a defined trajectory using parallel lines (900 m from ground, camera tilt angle set to zero), which are expected to give around 65% of side overlap. Frontal overlap depends on the time between screenshots and was estimated to be around 90%. It is worth to mention that three-dimensional data in GE results from photogrammetry techniques applied to aerial images captured in September 2013 at the study region.

To get the model georeferenced, coordinates were assigned to each photo based on the number of photos and on the edge coordinates of each parallel line using a Python script. After that, the images (and estimated coordinates) were loaded into Agisoft Photoscan software and a high spatial resolution DSM was generated.

Elevation values were adjusted to an existent lower resolution elevation model (EMPLASA DSM with 5 m resolution) to give better results. This was done by aggregating both models by the minimum elevation in a 100 m raster and then taking their difference. After that, the resulting grid was resampled and added to the uncorrected DSM. The final DSM have 1 m spatial resolution.

4.1. Lightning attractiveness index

The attractiveness model presented here assumes that a lightning discharge is more likely to attach at elevated areas than its lower surroundings. Different works already used similar ideas, like the Electrogeometric Model (EGM) or rolling sphere theory [9, 10]. It assumes the existence of a protected area around a mast (or elevated sharp structure) based on the areas not affected by the 'rolling sphere', which radius, on the other hand, depends on the intensity of the discharge. The work of [5] is more specific on this point, suggesting the importance of high points in the attachment process.

With this in mind, the proposed index is based on the altitude difference between a given pixel of the elevation model and its surroundings. A weighted kernel as a function of distance was then used to determine the values at each pixel, as show in Figure 2. Thus, after a certain distance range, the altitude is not considered anymore. Due the computational demand for this procedure, the index was calculated using the Google Earth Engine infrastructure[11].

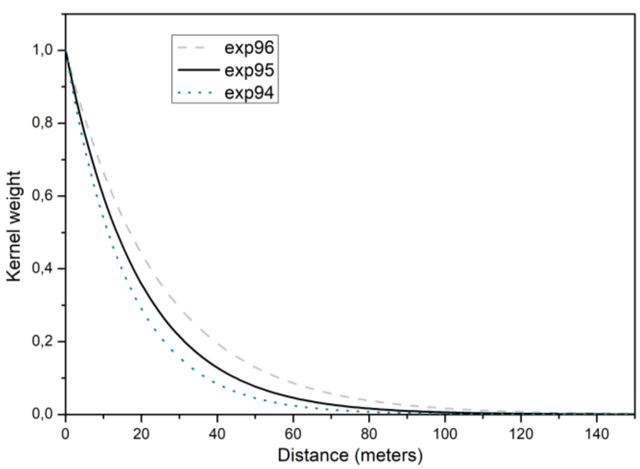

Figure 2. Kernel weighting used to produce the attractiveness index.

3. RESULTS AND DISCUSSION

The digital surface model (DSM) produced with the images extracted from Google Earth Pro is shown in Figure 3. Most of the lower areas are concentrated in the west side of the mountain ridge (in the center). Elevation varies from sea level up to around 273 meters. Since the new model was adjusted to an existent model, the altitude range is expected to be in the same range as the latter. From the highlighted area, it is possible to identify the different features inside the urban area, including higher buildings along the cost, as well as some isolated buildings surrounded by low-rise constructions. The region of the convention center is also visible (center-left).

The general observation is that the obtained model gives reasonable results and the applied procedure might be a simple way to obtain high resolution elevation data. We emphasize, however, that this data is not validated and should be applied only for general purpose research.

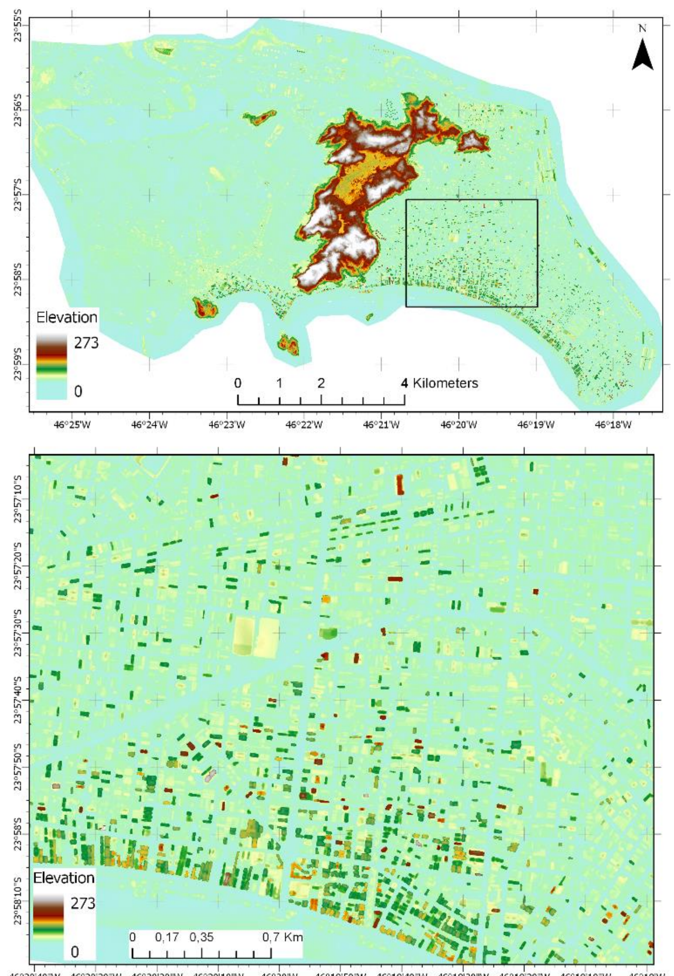

Figure 3. DSM obtained from the procedures using google Earth tools and SfM.

The attractiveness index resulting from the DSM is shown in Figure 4. It is possible to observe a clear difference at the region with higher altitudes in Figure 3, where the highest values are now concentrated in the areas with large altitude variations (scarps and mountain ridges). Considering the highlighted area, there is a clear variation from higher areas (buildings) and their surroundings, were lower values of the index are observed. This may be considered as an expected result, were the areas around tall structures are protected by those, as emphasized in the literature already discussed [2, 4]. Other interesting observation is that over flat areas the index retain an average value, which also make sense in terms of risk. Finally, considering the large edifications in the center-left, the values are higher at the edges, which may be reproducing the conditions of scarp edges increased electric fields suggested by [12].

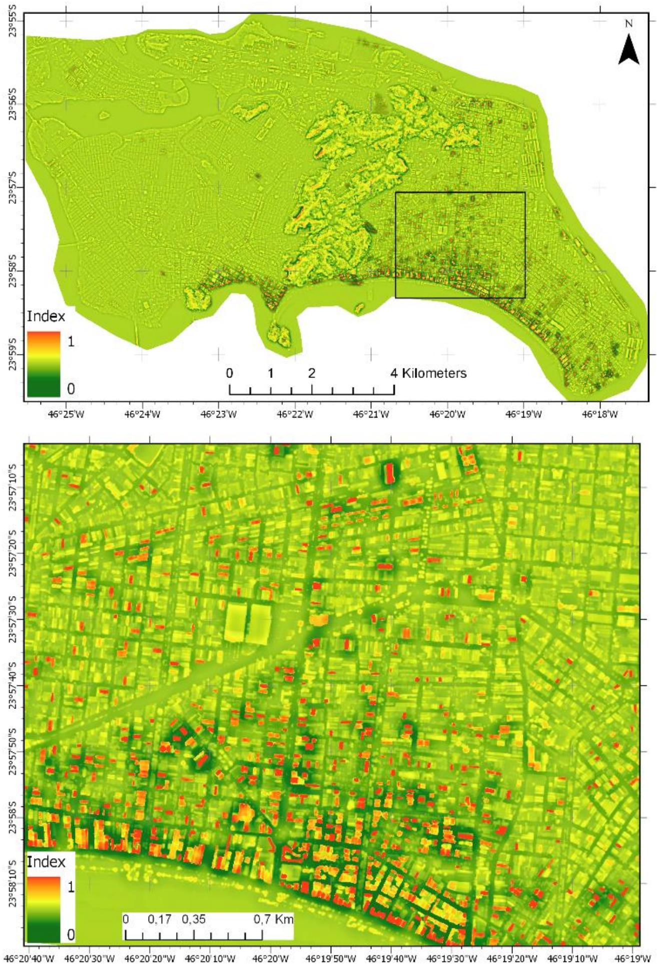

Figure 4. Attractiveness index resulting from the application of the distance-weighted kernel to the DSM.

5. CONCLUSIONS

The elevation model obtained from Google Earth provided reasonable results. Better results may be expected by using higher side overlap in the images acquisition. As already mentioned, there are limitations that indicate the model to be used only for general purposes research.

The attractiveness index seems to give satisfactory results, reproducing reasonably the areas expected to be more (and less) affected by lightning discharges. It is important to emphasize, however, that this method does not account for varying peak currents of lightning discharges. A specific factor or equation may be applied to include this information in the future.

6. ACKNOWLEDGMENTS

Our thanks to Google for giving access to Google Earth Engine and for developing the tools available in Google Earth Pro. Also, thanks to EMPLASA for giving access to the 5m DSM.

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