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Analysis of two nonfatal lightning accidents in Colombia

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ABSTRACT

Several lightning accidents involving human fatalities and injuries are reported every year in Colombia. This work presents and discusses two non-fatal lightning accidents, where the victims survived without evident permanent disabling traumas. In both cases, it was observed that metallic objects such as necklaces or buckle belts worn by the victims were intercepted by the lightning current. These metallic objects could possibly be a pathway to keep the lightning current on the victim's skin surface. To understand the interaction of these metallic objects and the indirect lightning currents, both the visual consequences of the indirect lightning current on the victim's skin and a comprehensive description of the cases scenarios are presented.

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1. Introduction

Some geographical areas in the world are particularly more prone to lightning activity than others. Local geographical and meteorological conditions play important roles in the lightning activity, such as topography, proximity to waterbodies, seasonality, seasonal variation, time of the year, mesoscale convective systems (MCS) or the interannual El Niño/Southern Oscillation (ENSO) among others [1–6].

Colombia, due to some of the mentioned factors, is one of the countries with critical zones of high flash density [2,4,7]. To this lightning activity contributes its complex Andean mountain ranges and its geographical position between the Pacific and Atlantic oceans in the northwestern of South America. Due its location in the middle of the equatorial zone that drives thunderstorms, Colombia is subjected to the ENSO phenomenon and MCS variations.

The large lightning activity linked to Colombia could explain many of the accidents with fatal and nonfatal consequences, as reported for 2012 and 2013 [8,2]. Sadly, between 2003 and 2012 almost one out of two lightning accidents reported by the Direction of Integrity Preservation and Security of the Colombian Army (DIPSE) left a dead soldier hit by lightning [8]. An analysis is required to determine the circumstances in which these events occur and to propose lightning protection measures to reduce accidents.

In this paper, two scenarios previously reported in Ref. [3], are described, in which two lightning accidents caused by indirect lightning currents occurred in backcountry areas of Colombia. Both cases, located in the maps shown in Fig. 1, relate scenarios where two soldiers were injured by lightning currents. These accidents did not produce evident disabling conditions but palpable burn marks in the victims' skins.

2. Geographical information

The accidents of the two soldiers that were struck by lightning during military activities were initially reported in Ref. [3] and are complemented here with more precise geographical and lightning data. These traumatic events occurred in mountainous zones of the northern part of Colombia, as it is explain as follows.

Case A occurred in a foothill extension of *Cordillera Central* (Colombian central mountain range) known as "*Serranía de San Lucas*" – on the Santa Rosa del Sur municipality, Department of Bolivar – placed at 1900 m above mean sea level, during a rainy night. The *Serranía de San Lucas* is an isolated long mountain range with forested mountain massif being thus the northernmost part of *Cordillera Central* in northern Colombia. It makes part of the Magdalena-Urabá forests moist ecoregion. As it is shown in Fig. 1(c), according to Köppen-Geiger climate classification, *Serranía San Lucas* corresponds to a transition area between the tropical monsoon climate to the tropical rainforest (equatorial climate). The

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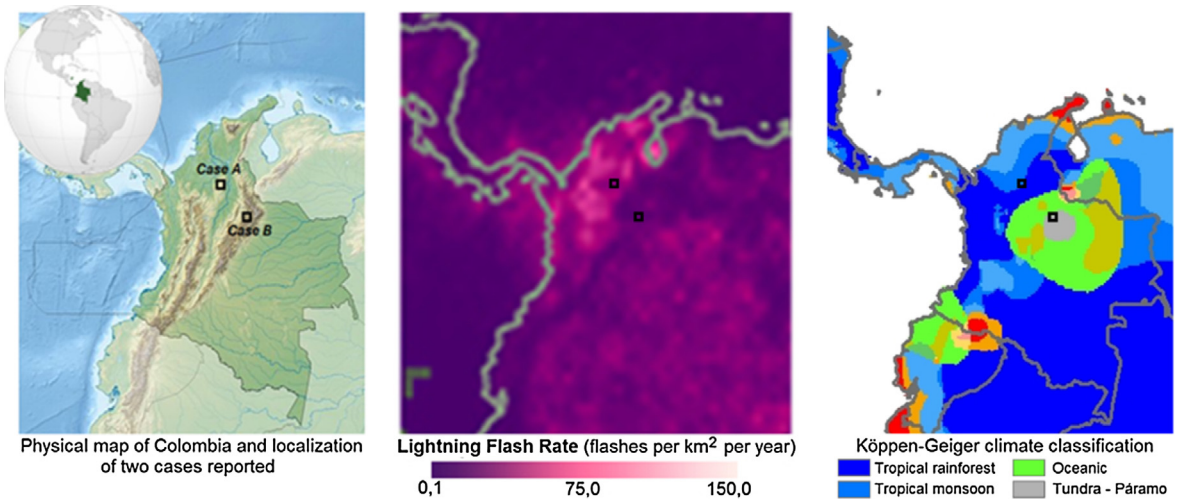

Fig. 1. Approximate location of the two nonfatal lightning accidents in a physical (a), lightning activity (b) and Köppen-Geiger climate classification (c) maps [3] (source: (a) adapted from wikimedia commons, (b) [9] and (c) [10]).

latter goes inside the Andean mountain range with local annual average temperatures driven by relief elevations.

Case B took place in the western side of the *Cordillera Oriental* (Colombian eastern mountain range) in the high altitude area known as "*Páramo de La Rusia*", on the border shared by Encino and Charalá municipalities, Department of Santander. Köppen-Geiger climate classification for this area corresponds to a transition between Tundra Climate and Oceanic Climate with strong altitude variations. The "*Guantiva-La Rusia*" Páramo complex has heights varying from 3100 m above sea level up to 4300 m above sea level. Due to the elevation, temperatures in the *páramo* can reach 0 °C and below, with low relative humidity.

According to lightning maps (Fig. 1(b)), it can be seen that the average atmospheric lightning activity is larger for the Case A than for the Case B. For the former case, the lightning flash rate is about 35 flashes per square kilometer per year while for the latter is around 15 flashes per square kilometer per year [9]. It is worth noting that the elevation in Case B is nearly 225% higher than in Case A.

3. Description of two accident scenarios

Lightning hazard increases during outdoor activities in open areas [2,11–14], such as leisure or recreational hiking, trekking, soccer, golf, farming, shepherding, but also military and security operations. In the case of Colombia, soldiers are continuously exposed to risk of lightning strikes in the accomplishment of their obligatory line of duty. The two case scenarios are presented below.

3.1. Case A: dug-out type shelter

For resting or protecting people from weather or from enemy attacks in military operations, trenches-like shelters are dug or semi-dug in the ground. Case A occurred at 19:15 h local time, placed on a top mountain of 1900 m above sea level with a temperate rainforest weather type, in a heavy rainy night. The victim was a 29-year-old sergeant of Colombian Army force resting in this type of excavated shelter. To isolate the shelter interior space from the ground moisture, the ground walls were covered with an outer layer of polyethylene film and terminated with wooden boards [3]. At the moment of the accident, the soldier was wearing an ornamental metallic necklace of gold alloy and had on his chest a portable communication unit. Fig. 2 presents the schematic of the scenario.

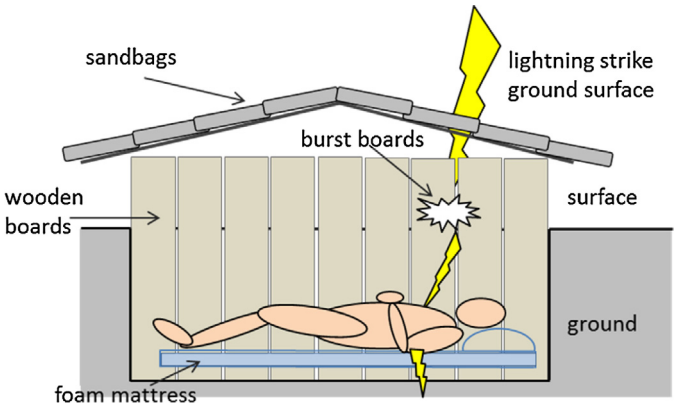

Fig. 2. Schematic representation of Case A, in which a soldier was resting inside of a semi-underground military shelter, which was struck by lightning.

According to GLD360 data of Vaisala, in the lapse of time between 19:00 h and 20:00 h on a radius of 20 km around the site, the area was struck at least by 27 strokes with currents between −57,8 kA and +88,9 kA as shown in Fig. 3 (Holle R., personal communication, October 20, 2016). According to the accident's local time reported and to the geographical uncertainties of the data set, the lightning flash current amplitude was identified as +88,9 kA.

Lightning struck directly on the ground surface circa 1 m from the shelter roof and the lightning current, instead of being dissipated on the surrounding ground, part of it flowed across the trench walls arrangement, breaking them and reaching the soldier's right side. The indirect lightning current left three diverted recognizable burn paths on the sergeant's skin, as shown in the photographs in Fig. 4. From these images, the indirect lightning current paths in the victim's body could be reconstructed. The lightning probably hits initially close to his right shoulder. Thereafter the current crossed superficially his right shoulder and was routed to the portable communication radio placed over the sergeant's torso and through the necklace he wore, ending at the elbow's area of his left arm. Fig. 4(a)–(f) shows the burns left by the lightning current on the soldier's body, on the necklace and on the sergeant's portable communication unit.

The necklace conducted a branch of the lightning current overheating it, burning around the soldier's neck, while it was melted and broken in small pieces, as it can be seen in Fig. 4(c). The overheated necklace left partial-thickness and full-thickness burns

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