



# Lightning-caused Deaths and Injuries at Schools

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**Abstract**—Lightning casualties in developing countries often involve people inside unsafe structures and working outside during labor-intensive agriculture. A prominent scenario is the reporting of several events per year of multiple fatalities and injuries at schools in developing countries. To date, there has not been a collection of such cases. The present report summarizes 123 cases involving 218 fatalities and 710 non-fatal injuries related to schools outside the United States in the last 14 years. Nearly half of the events are from Uganda and India, often at primary or secondary schools.

**Keywords**—lightning casualties, school lightning events, school lightning fatalities, school lightning injuries, lightning injuries

## I. INTRODUCTION

The goal of this study is to examine lightning-caused casualties in and near schools outside the United States. News reports of multiple-fatality events at schools in Africa, in particular, has motivated the initiation of programs to address providing lightning protection at schools as an example for the general public in these areas.

A portion of the motivation for this paper is to provide information to two organizations:

1. ACLENet, the African Centres for Lightning and Electromagnetics Network ([www.ACLENet.org](http://www.ACLENet.org)) [1].
2. CELP, the Centre for Electromagnetic and Lightning Protection Research (<http://www.celp.upm.edu.my/index.php/en/>) [2,3,4,5].

The present report focuses on schools and uses some of the approaches used in previous studies of lightning casualties related to vehicles, dwellings, buildings, and bodies of water [6]. Lightning safety recommendations identify two reliable safe places. One is inside a large, substantially-built, enclosed building. The other safe location is inside a fully enclosed, metal-topped vehicle [6,7]. Neither of these is found as often in developing countries as in the United States.

There does not appear to be a prior study of lightning casualties inside or near schools outside the United States. This paper summarizes the demographics of school-related lightning casualty events outside the United States, mostly in developing countries. The terminology used is ‘fatalities’ to refer to deaths, non-fatal ‘injuries’ are also identified, and ‘casualties’ are the sum of fatalities and injuries.

## II. DATA

The cases were randomly collected, mainly through web reports and other publications and sources, although some are from published papers. The study period was limited to 2002 through 2015 in order to identify lightning impacts on contemporary structures. The reports may be biased by a number of issues including preconceived ideas of reporters, casualties, and witnesses about lightning and its effects [8]. In addition, multiple casualty incidents or those involving children may be considered more newsworthy. Cases involving deaths and non-fatal injuries in more remote areas may not reach journalists at all, particularly if they involve few people. The nature of the dataset precludes the conversion to an absolute rate for each scenario. Nevertheless, relative values generally indicate which types of events are more common than others.

## III. COUNTRIES

There are 123 events included in this summary that include 218 fatalities and 710 non-fatal injuries. Nearly half of the available reports are from Uganda and India (Fig. 1). The next most frequent sources of reports are Kenya and South Africa. It must be mentioned that not all countries in this compilation are considered to be developing, but for the sake of completeness, all data outside the United States are included. In addition, the dominance of Uganda does not represent a particularly dangerous threat in that county, but, instead, that special care has been taken to collect data there after ACLENet was founded in Uganda in 2013.

It is certain that many cases in other developing countries do not reach the web reporting system as often. In particular, countries that are unstable, not well covered by news media, or have other more newsworthy situations will not often be sources of lightning casualty reports. Additionally, non-English-language reports are less likely to reach the news collection sources available to the authors at this time. Another aspect is that events with multiple casualties are much more likely to be disseminated than those with one or a few casualties. As a result, we acknowledge that this is not a complete dataset that would support comparison among countries, nor is it representative of the annual total that occurs worldwide. It is only a compilation of those cases that are currently known.

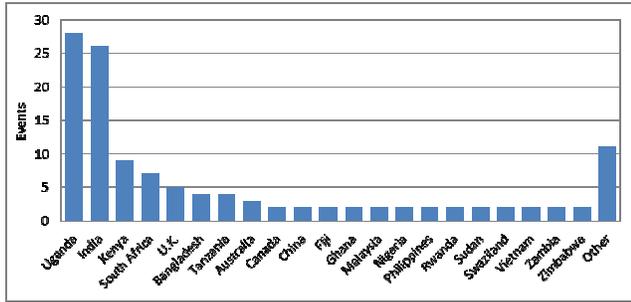


Figure 1. Country of school events in study (n=123 reports).

#### IV. DEATHS AND NON-FATAL INJURIES PER EVENT

The database consists of 218 fatalities and 710 non-fatal injuries in 123 reports. The number of deaths, non-fatal injuries, and total casualties per event are extraordinarily large compared to most other studies (Fig. 2). There are numerous cases with three or more deaths in one event and many events with 11 or more injured. The largest single case involved seven deaths and 67 non-fatal injuries at a South African kindergarten in 2010. The median number of fatalities per event is two, injured is nine, and total casualties is nine. Most events have more than one casualty

These numbers are in strong contrast to the United States situation where 90% of all lightning deaths and non-fatal injuries are to one person at a time [9]. It is likely, however, that the dataset is biased toward the tendency for events with multiple casualties to reach global media distribution more often than one-person events. Nevertheless, such numbers of people killed or injured per event is very different from any category that has been studied in the United States or other developed countries.

#### V. AGE AND GENDER

The age distribution of lightning casualties in this study is skewed toward younger years as would be expected for schools (Fig. 3). For these events, the ages were reported for only 156 individuals (17% of the total in the dataset) so that the distribution may be unrepresentative. The peak occurrence for those whose age was reported is in the range of 12 to 15 where 66% of the 156 reported ages occur. Older casualties were teachers, staff, and support personnel as well as parents at the school when lightning struck. This age distribution is specific to the category of schools. It differs from the age range of general casualty studies where the peak occurs in the late teens to middle twenties in the United States and other developed countries [9].

Given that this is a school population, the gender distribution of casualties is nearly equal (Fig. 4). The gender was reported for 311 individuals (33.5%). Once again, this is in full contrast with general studies in the United States and other developed countries where the gender has been about 75-80% male [9].

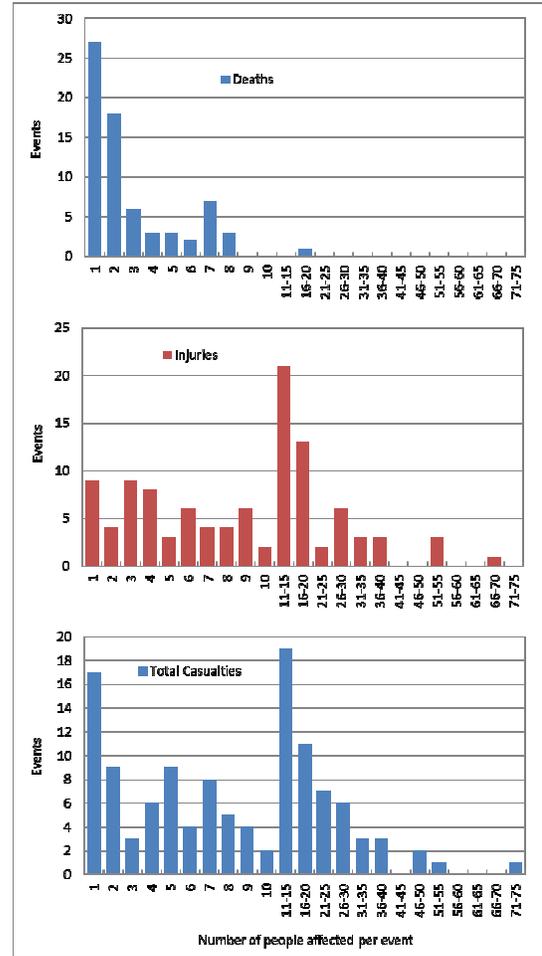


Figure 2. Deaths, non-fatal injuries, and total casualties per school event.

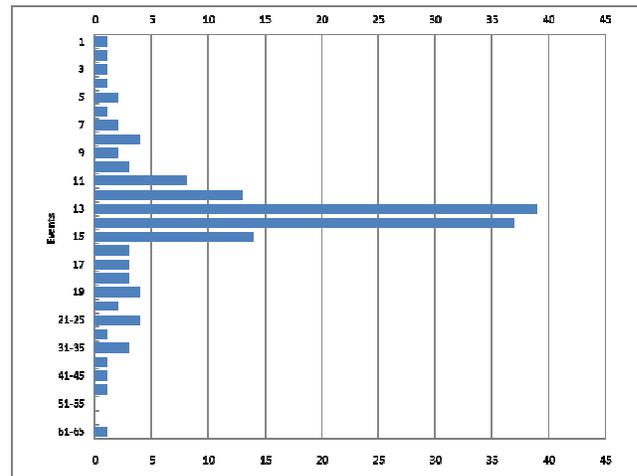


Figure 3. Ages of reported school lightning fatalities and non-fatal injuries (n=156 casualties)

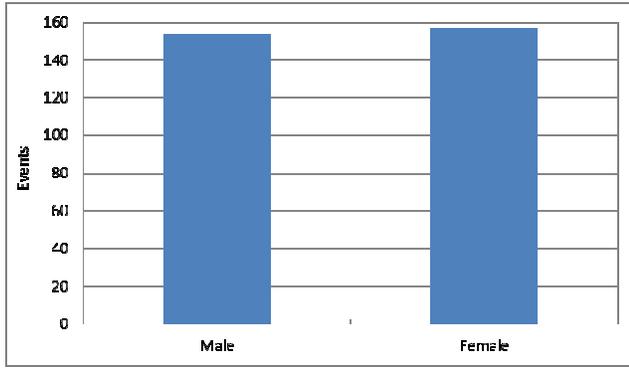


Figure 4. Gender of reported school lightning fatalities and non-fatal injuries (n=311 casualties).

## VI. LOCATION AND ACTIVITY

Unfortunately, only 84 (68%) of the newspaper reports gave specific information as to the location of the casualties when they were injured. The most common location and activity of the casualties was in the classroom (23/84, 27%) (Fig. 5). The next most common place (11 cases, 13%) was on the school campus or in the school yard but outside the classroom. Another 14 cases (17%) involved unstructured playing as well as soccer, cricket or physical education. A particular problem behavior was seeking shelter under a verandah (6 cases, 7%) or under a tree at the school (5 cases, 6%). Some cases involved students walking to and from school where appropriate shelter was probably unavailable, plus other situations common to students. It is clear that not only must the classroom block be made safe from lightning, but that procedures must be in place and in practice so that students are not on the playground or in other unsafe locations when a school has been properly protected from lightning.

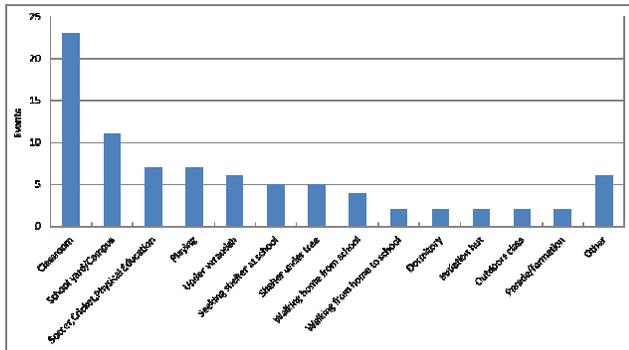


Figure 5. Location and activity of school lightning fatalities and non-fatal injuries (n=84 reports).

## VII. WEATHER

The type of weather at the time of the lightning incident stated in the news reports, provided in only 38 reports (31%), shows a wide variety of situations (Fig. 6). A downpour was most common; drizzle was next, followed by rain. Note that several events occurred after heavy rain, indicating that students and staff may have gone outside too soon. Others noted that it was not raining or was a clear sky. These are not unusual perceptions for lightning casualties since about 10 to 15% of cloud-to-ground flashes happen when no rain is falling at the ground at the time and place of the strike [10]. It also indicates a lack of awareness that, while part of the sky appears clear, another nearby area is producing a thunderstorm. These are common situations in tropical regions and during summertime in non-tropical areas so that vigilance for the lightning threat must be maintained. The situations in Fig.6 are similar to those found in the United States where lightning casualties occurred before, during, and after the maximum lightning rate at the time and location of the death or non-fatal injury [11,12].

## VIII. TIME OF YEAR, WEEK, AND DAY

The month of the year when these events occurred, between June and October, is consistent with the meteorological conditions of the main countries in the dataset, mainly Africa and India (Fig. 7).

Moving to the day of the week, the peak is during the school week of Monday through Friday, as expected (Fig. 8). Over the weekend, some students are in boarding schools, and some sports activities also occur.

Finally, the time of day is shown in two groupings. Most reports mention a broad time category, such as afternoon, instead of the exact times of the events. The result in both groupings is that most school lightning events took place during the afternoon hours (Fig. 9).

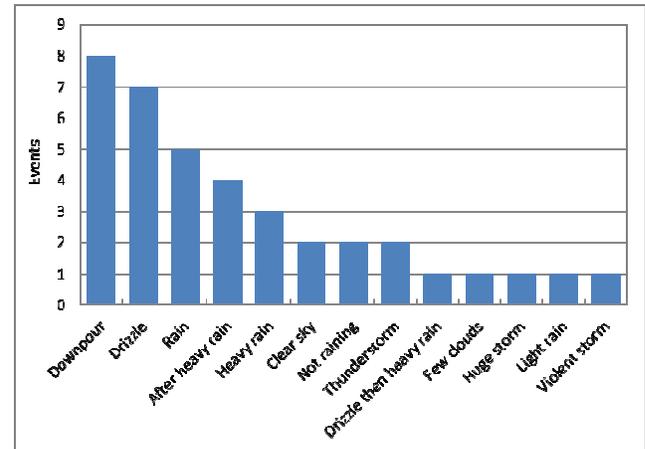


Figure 6. Weather at the time of school lightning fatalities and non-fatal injuries (n=38 reports).

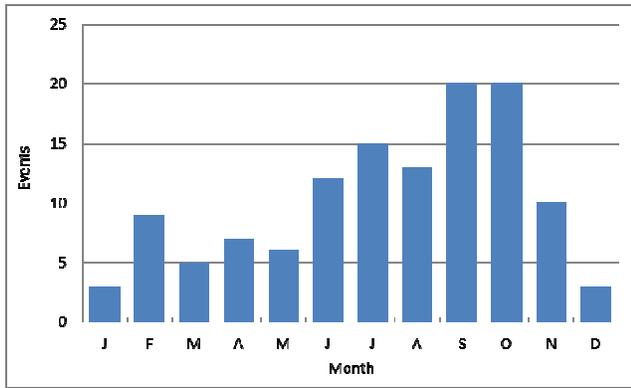


Figure 7. Month of school lightning fatalities and non-fatal injuries (n=123 reports).

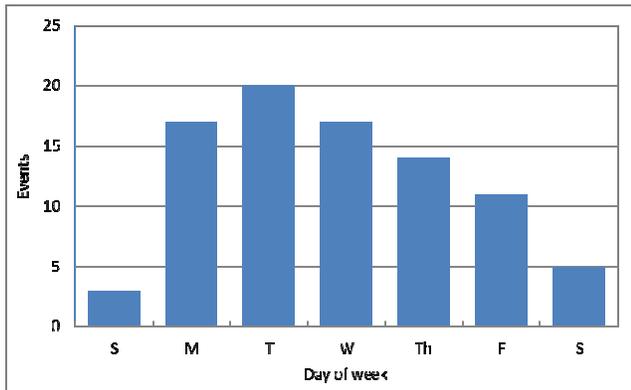


Figure 8. Day of week of school lightning fatalities and non-fatal injuries (n=87 reports).

### IX. DISCUSSION

A prior study was done of more general building-related lightning casualties in the United States [6] in which 44 events involved casualties at United States schools. Most events were outside school buildings, while only a few non-fatal injuries occurred inside schools. No fatal injuries occurred inside United States schools.

Many of the United States cases involved transportation, including those around buses and in parking lots. In addition, many events involved athletics. When the type of school in the United States was identified, seven universities, eight high schools, three middle schools, and 16 grade schools were involved.

For the current study of school events outside the United States, the most common school type was a primary school, followed by high school (Fig. 10). The dominance of primary schools may indicate that the peak age affected is even younger than the early teen years shown in Fig. 3. A portion of the cases occurred inside classrooms, which was rarely an issue in United States study, where no United States case resulted in fatalities.

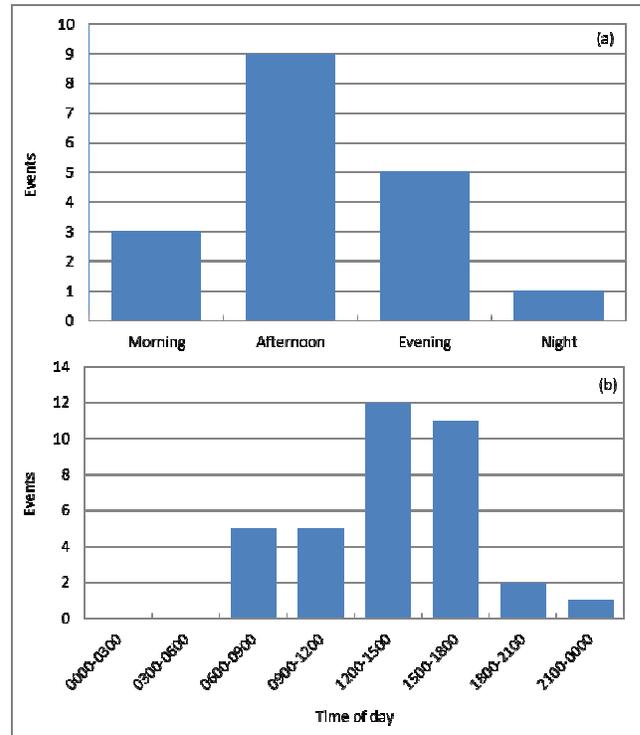


Figure 9. Time of day of school lightning fatalities and non-fatal injuries. The general time (a) was included in 18 reports, and the more specific time in Local Standard Time (b) was provided in 36 reports.

It is likely that the core issue involved in the number of fatalities occurring in developing country schools is the quality of the buildings. While United States schools are permanent, well-constructed structures designed to last decades with components following a building code, many schools in the developing world described in the current study are of mud brick or straw construction, often with tin or thatch roofs and often with no plumbing or electrical wiring for lightning to safely travel to the ground. Casualties from direct strike, side splash and ground current, all rare or nonexistent causes in United States schools, may be significant factors in developing countries where lightning protection systems are rare. In addition, lightning can cause keraunoparalysis, preventing students and teachers from evacuating the buildings and sometimes resulting in secondary injury as the burning thatch falls on them. Although some countries have endeavored to require lightning protection systems in schools, the majority of schools have no protection from lightning. This is particularly true for the large number of small primary schools in developing countries.

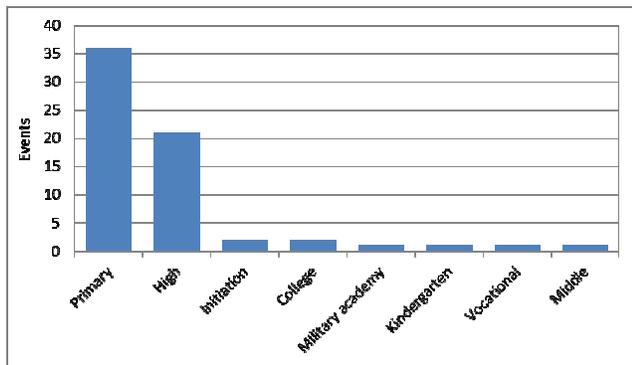


Figure 10. Types of reported educational institutions with school lightning fatalities and non-fatal injuries (n=65).

## X. CONCLUSIONS

This paper summarizes 123 reports of lightning casualties at schools outside the United States in the last 14 years that involved 218 fatalities and 710 injuries. There were surprisingly large numbers of people killed or injured per event, partially because they were clustered closely together in the school setting as well as because of the lack of lightning protection or flooring at most village schools. Although the age range peaked between 11 and 15 years old with almost exactly the same number of males as females, as might be expected at schools, only 17% of the cases reported ages so this may be an incomplete finding.

The most common school type was a primary school, followed by secondary school. Although the classroom was the most frequent single location of school lightning events, more total cases were related to outdoor activities in the school yard, playground, and under trees and verandahs than in the classroom. Since schools are often the most substantial buildings in villages, properly designed, installed and maintained lightning protection systems may be particularly effective. In addition, policies to bring students into lightning-safe locations when they are available are indicated.

Although it was often raining or raining hard, there were also cases with drizzle or no rain reported at the time and location so that monitored and reliable weather warnings are valuable. As expected for schools, events were most common from Monday through Friday, and most were in the afternoon.

A combination of teacher and student education about lightning risk, installation of lightning protection systems and reliable injury prevention policies may be lifesaving in these locations.

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