Lightning Safety Studies and Methodology of the African Centres for Lightning and Electromagnetics Network (ACLENet) for Improvement in Lightning Safety, Research, and Awareness

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***Abstract*— ACLENet (https://ACLENet.org), founded in 2014, is dedicated to decreasing deaths, injuries, and property damage from lightning across Africa. This paper details ACLENet's activities to carry out this mission which include research to gather lightning injury data into a publicly available database, investigation of mass casualty lightning events, addressing lightning protection (LP) challenges across Africa, public education, and working with the government of Uganda and lightning safety advocates worldwide. Multiple volunteers worldwide give their expertise, time, skills, and funds to support ACLENet. Citizen reporters from across Africa add to the injury database by reporting and translating injury news reports from tribal and local languages as well as doing primary reporting of incidents they can corroborate. ACLENet has been the model for two more multinational lightning safety advocacy programs, SALNet (South Asian Lightning Network) founded in 2020 and LALENet (Latin American Lightning Education Network) founded in 2022.**

Keywords*— *Lightning injury, lightning injury prevention, lightning risk assessment, lightning protection, school protection, property damage from lightning, education, lightning in Africa

I. Introduction and History of ACLENet

Daniel Esteban Villamil Sierra has said, 'Spreading the lightning safety message to all people must become the ethical duty among lightning researchers.'

In 2011, Richard Tushemereirwe, Chandima Gomes, and Mary Ann Cooper, met at a NAM S&T sponsored lightning protection meeting in Nepal, shortly after 18 children had been killed and 38 injured in a single lightning strike at Runyanya Primary School in Uganda on June 28, 2011, an event that catapulted the formation of the African Centres for Lightning and Electromagnetics Network (ACLENet) [1]. It was formally founded in 2014, incorporated in the USA and Uganda in 2016, and has been active in addressing lightning safety in Africa as a Community Based Organization (CBO) in Uganda and a 501c3 (nonprofit organization designation) in the USA.

ACLENet's mission is to decrease deaths, injuries, and property damage across Africa. How can we accomplish that in countries where lightning safe areas are not available, and people believe that demons cause lightning? We have formulated a three-pronged approach:

- Research, data collection, and publication.
- Education at all levels.
- Piloting practical lightning protection applications to solve challenges in Africa.

TABLE I. FACTORS THAT AFFECT THE RISK OF LIGHTNNG INJURY AND DEATH

Factors that INCREASE Risk	Factors that DECREASE Risk
Lightning Flash Density	
High lightning density	Low lightning density
Infrastructure	
Insubstantial housing resulting in lack of lightning safe areas for easy evacuation	Easy availability of lightning safe buildings and vehicles within easy reach
Lack of reliable and timely weather forecasts or forecasts that are only available to specific sectors (primarily aviation) of the economy	Weather forecasting system with high quality forecasts available to the public on a free and real time basis
No or little lightning detection data or non-availability to the public	High quality lightning detection data incorporated into forecasts
Delayed or nonexistent access to high quality medical care.	Easy access to high quality medical care
Population density / location	
Large rural population	Urbanization with high quality building construction
Social factors	
Labor intensive work such as farming, fishing and animal husbandry	Mechanized farming and stricter laws governing work conditions
Low literacy rate	High literacy rate
Little or no valid public education on lightning safety	An active media; news reports of injuries; enthusiastic public education with access to lightning safety information
Belief that lighting injuries are inevitable, regardless of personal behavior	Belief that personal action can make a difference in outcome
Strongly held cultural beliefs that lightning is called down by witches and reliance on myths such as what a person is wearing, is doing or their moral behavior affects risk	Knowledge that lightning is a natural phenomenon explainable by science

Adapted from [2]

II. Scope and Risk Factors of Lightning Injury across Africa

Table 1 illustrates four categories of factors related to lightning injury risk:

- Lightning flash density
- Infrastructure
- Population density and location
- Social factors

Africa contains many countries with very high flash density increasing their populations' exposure [Fig 1]. An estimated 90% of sub-Saharan Africa dwellings, often with mud brick walls and thatched roofs, are not lightning safe, leaving the population at risk 24/7/365. Rural populations tend to have few lightning safe structures and long distances people must travel to home, farm, market, or school while exposed to the weather. World Bank data for 2021 showed that 74% of Uganda's population, where ACLENet is based, are rural [3].

Lack of weather forecasts that include lightning information leave people unprepared. The lack of high quality, readily accessible medical care both at the pre-hospital and medical center levels along with no or minimal citizen training in first aid and cardiopulmonary resuscitation (CPR) leaves injured persons in peril.

Lack of public knowledge about lightning along with multiple cultural beliefs in mystical or demonic causes of lightning leave people unaware that their behavior can substantially affect their outcome when thunderstorms are in the area. Many African countries have low literacy rates and dozens of languages so education by print is seldom practical. Additionally, many countries, and particularly their rural areas, do not have reliable electricity and internet to provide electronic access to education or weather forecasts.

III. ACLENet Basic and Applied Research Activities

Good data is essential, not only as a tool for measurement of progress in programs, but also to convince governments and funders where interventions and funding are most needed. ACLENet activities include basic demographic research into injuries and deaths, as well as investigation of mass casualty incidents (MCI) as funding allows. Applied research in protecting schools, doing public education, and working with governments are also among ACLENet's activities.

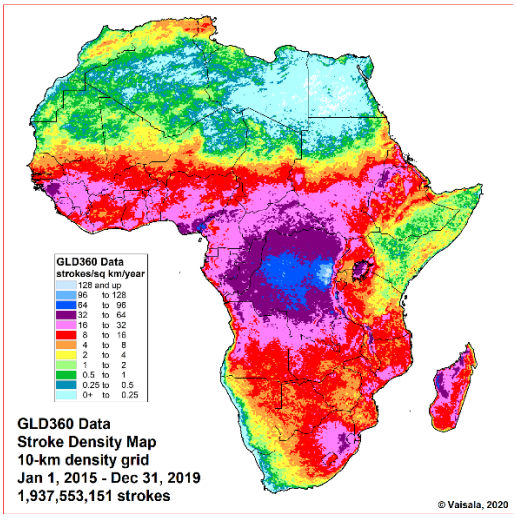

Fig 1. Lightning flash density across Africa, courtesy Vaisala.

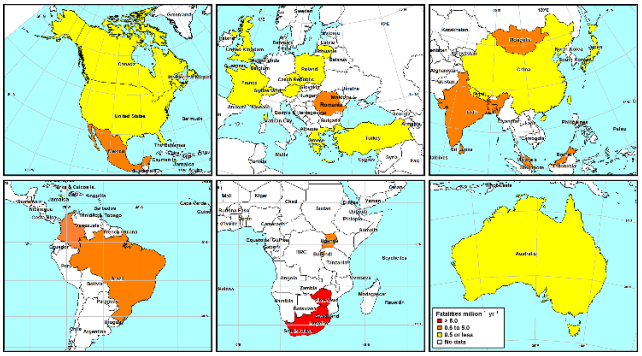

Fig 2. Lightning fatality rates per million people per year for 30 nations; updated from [4].

A. *Research into Lightning Casualties in Africa*

1) *Problem Statement and Background*

What is the incidence and setting of lightning injuries in each African country?

Little is known about the number of lightning injuries and deaths in Africa, because there have been few systematic studies (Fig 1). Exposure is high because of high lightning flash density and lack of 'lightning safe' (substantial building with plumbing and wiring) dwellings for shelter. Holle's continuing studies on global lightning death and injury numbers show that developing countries tend to have larger mortality rates than developed countries with Africa having the highest [4].

2) *Methodology*

Because few countries have mandated reporting of lightning casualties, researchers have learned to rely on media reports, which has become an accepted method for many decades in developed countries.

Data on injuries and deaths have been systematically collected since ACLENet's founding and often drives decisions on projects to pursue [5]. Earlier injury reports, as available, have also been incorporated in the online database. ACLENet volunteers monitor hourly Google searches in several languages of media reports on lightning. Additionally, 'citizen reporters' capture events in their countries, often translating reports from native languages or capturing social media and radio news, the most prevalent forms of communication in much of Africa.

3) *Results*

News reports are posted by country and year on the website and in the monthly newsletter, published since 2018 in 4 languages [6, 7]. This resource has become the largest publicly available database on lightning injuries with data on over 40 countries [5]. Because media reports are often taken off-line, the reports are kept in a uniform format and are freely available to the media and any interested researcher or government for download and study.

4) *Limitations*

The press in each country in Africa varies in quality and stability depending on government support, civil war and tribal strife, instability caused by health issues such as

HIV/AIDS, Coronavirus, Ebola, malaria and others, literacy, hundreds of languages, and other factors. These can limit the number of lightning incidents that are reported in countries facing challenges and in those picked up by Google searches.

Reports in African are also thwarted due to the reluctance of victims, families and communities to report lightning injuries because of the widespread beliefs such as lightning is a punishment for sins, it is caused by demons, it can be called down by hiring a witch, and that even talking about lightning can cause it to come down on a person or their family [7, 8]. The family of lightning victims may be shunned as cursed and forced to move away from their tribal lands to start over in new settings [9].

B. Investigation of Lightning Mass Casualty Incidents

1) Problem Statement

Can we learn things from multiple casualty incidents of lightning injuries that can be applied to their prevention?

2) Methodology

When funds allow, ACLENet sends trained, multidisciplinary teams to investigate and reconstruct the lightning mass casualty incidents in Uganda, examine the physical evidence, and interview witnesses, survivors, their families, and the community.

3) Results

Two investigations have been carried out to date, one of the Mongoyo Primary School disaster and another report of ten boys killed at a soccer game reported at this meeting as paper #1570874683 [10, 11].

4) Limitations

Multiple factors limit the number of investigations (funding, tribal conflicts, distance, rainy season making roads unpassable) and quality of results (language translation quality, time delays and memory after incidents, false witnesses seeking compensation, consistency between interviewers). The limitations encountered with each investigation help to improve skills, results, and reports for the next investigation.

C. School Lightning Protection (LP) Program

1) Problem Statements

a. What is the most vulnerable population in Africa?

A 2021 study of lightning casualties in Uganda using the database described above revealed that schools were the most frequently reported site of injuries and 10-19 the most often reported age group, which is not surprising considering that Uganda's median age is 15.9 against a global value of 30.3 years. making it one of the youngest nations in the world [12, 13]. ACLENet constructed a strategy to protect schools across Uganda that can serve as 'model schools' for lightning safety education, planned professional education in lightning protection that meets international standards, and work with government to adopt and implement international standards (Table II).

b. How can we develop a lightning protection plan for schools that can be scaled up to other countries (Table II)?

2) Methodology

Schools are selected based on criteria in Table II. An ACLENet team surveys the school using a tested report form, photographs each structure from all sides, takes measurements, notes ground makeup, typical occupant numbers and other human factors, and does soil resistance testing and other observations as indicated.

These data are submitted to the Lightning Protection Working Group (LPWG), a team of volunteer LP experts, ACLENet staff, installers, and occasionally donors. The LPWG addresses special problems such as satellite dishes, water towers, thatched roofs, rocky soil, and other factors in the design [14]. When possible, local materials which meet the criteria of IEC62305, parts 1,2,3,4, are utilized to decrease costs on materials which otherwise need to be imported with 35% customs and clearance fees attached.

3) Results

To date, LP systems have been installed at seven schools across Uganda, protecting over 5000 students and teachers

TABLE II. SCHOOL PROTECTION STRATEGY

Use 'model school' LP projects strategically distributed across Uganda Choose schools with prior lightning injuries when possible Easy to get to – located in areas with highways, electricity, internet, etc. Use as teaching centers for parents, teachers, students and local authorities/opinion leaders, engineers and installers Pre-record many of the teaching sessions for re-use with other audiences 'Train the Trainers' – work with secondary school math and science teachers to educate local teachers and students
Decrease cost of LP Source and use locally available, IEC62305-compliant materials as much as possible Encourage construction suppliers to stock or manufacture LP materials to avoid shipping, 30% import and storage fees, and other costs 'Template' common buildings designed for worst case soil conditions, etc.
Ensure high quality, IEC62305 compliant LP designs Recruit expert volunteer designers including those with experience in Africa University of Witwatersrand experts for more technical questions Review plans from NGO's and others wishing to donate designs / materials to assure compliance with IEC standards Design system of documents for each school installed including periodic visits to monitor and maintain LP system integrity Work with schools to take ownership of the system including learning to assess, repair, and maintain system integrity
Work with Uganda Government Adoption of IEC standards; inclusion in general building codes Work with builders to provide lightning protection systems consistent with IEC standards Train Uganda engineers / electrical installers in LP standards Work to assure compliance and enforcement of LP standards

Adapted from [15]

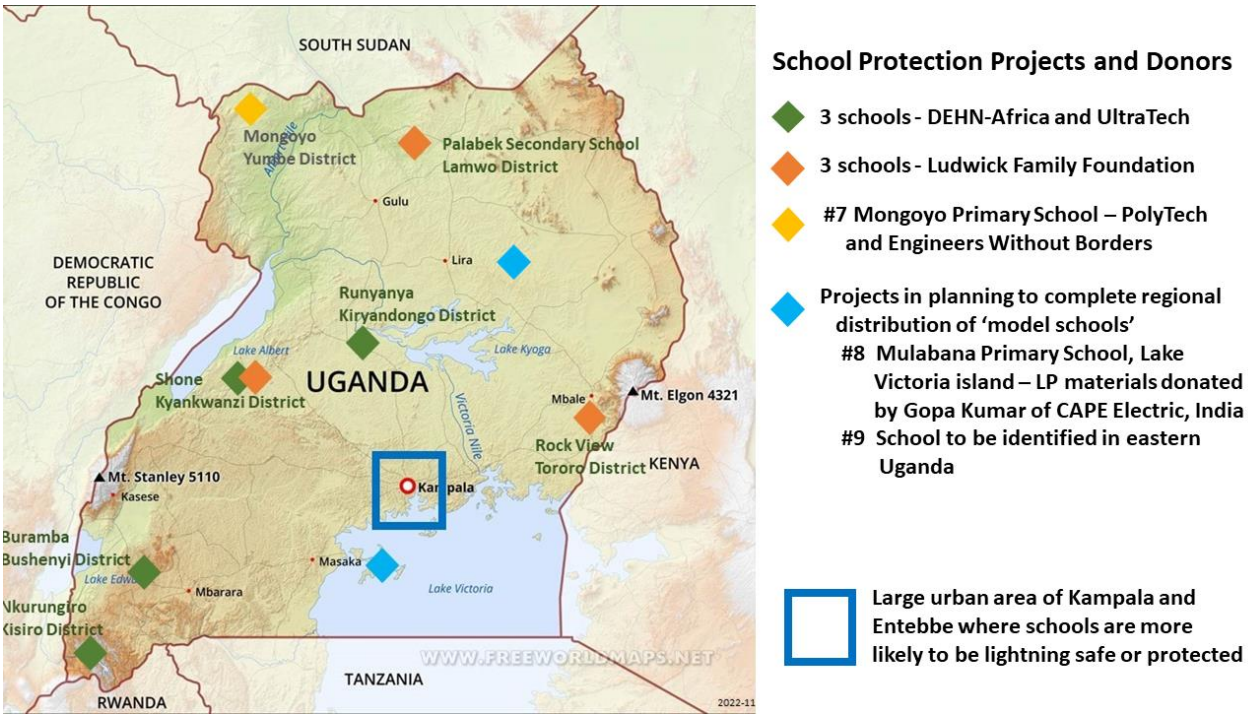

Figure 3. Map of ACLENet protected schools, strategically placed for future education projects.

(Fig 3). Maintenance visits are made to each school approximately every two years to assess system integrity, structural additions, and other factors.

Government action is very slow, but our influence has directly impacted the design of new secondary schools, now reportedly compliant with IEC standards.

In 2017, ACLENet received a thank you note from the Head Teacher (Principal) at Runyanya school who wrote saying, 'After the unfortunate incident in 2011 when lightning killed 18 students and seriously injured 38 others, enrollment at Runyanya School fell from about 600 students to under 400 as parents were afraid to send their children to school. After ACLENet installed the lightning protection system at our school, enrollment soared to over 800.' -- We have been told that enrollment had reached nearly 1200 in 2020 before Covid shut down Uganda schools. If more students feel safe continuing their school day, more will graduate and be able to help themselves, their families, and their country.

4) Limitations

Uganda is an extremely poor country with very poor infrastructure. Unlike developed countries where schools tend to be one large, organized building, most Ugandan schools are made up of multiple small buildings including teacher homes. LP systems compliant with IEC 62305 often exceed the cost of building the schools, but we have chosen to design for protection of lives, not replacement costs.

Funding, time, and personnel have limited the number of schools and especially the education program that has always been part of ACLENet's plan. We have trained designated people at each school to do visual inspections of their school, advise us of damage or vandalism, and do minor repairs. We are working with each school district to turn over ownership and responsibility for the systems, although we will continue as advisors, help facilitate repairs, and do biennial maintenance inspections.

D. Public Education

1) Problem Statement and Questions to be Investigated

How can we teach individuals behaviors that can help them avoid lightning injury?

How do we change cultural beliefs in demons, witches who can call down lightning, and many other misconceptions that are rife in Africa [5, 7-9].

How do we measure the effect of educational programs?

2) Methodology

In 2011, UNESCO said, 'Education has a central role to play in equipping people with lifesaving and environmentally sustainable knowledge and skills.'

ACLENet has always believed education and behavior change are key factors, but the reality is that there is no lightning safety without lightning safe areas. ACLENet is working to bring interntional lightning protection standards to Uganda and across Africa.

A few educational programs on lightning science, occurrence, and safe behaviors have been presented in the schools we have protected. ACLENet has also produced public service announcements broadcast during holiday seasons and newspaper inserts on lightning science and protection. Other strategies include working with primary and secondary teacher organizations in Uganda in a threefold effort to teach about lightning science and safety, dispel harmful myths, and report lightning casualty incidents that

have not been published in the media to build a more solid database for Uganda.

Since 2018, ACLENet has published a monthly newsletter for supporters, Ugandans, donors, and other interested parties [7]. It contains updates and photos of ACLENet activities, news reports and 'citizen reporter' reports of deaths and property damage from lightning for the prior month. It directly addresses lightning myths and folklore and often speaks out about areas of particular concern or those highlighted in news reports. It is now published in four languages.

3) Results

Educational programs at schools have been very well received with interested students and parents asking excellent questions. School districts have requested that we do considerably more education.

4) Limitations

The effectiveness of public education programs, if measured by behavioral change and decrease in the number of deaths, requires years of sustained effort [16]. In Africa, decreased deaths and injuries also depend on the availability of lightning safe areas for all people, a huge infrastructural as well as educational challenge.

Funding, time, training local teams in lightning science, and distance limit the educational programs ACLENet has been able to do.

IV. Other ACLENet Activities

Decreasing deaths, injuries, and property damage from lightning across Africa is a huge, multidimensional challenge. Not all ACLENet activities fit neatly into research algorithms. The first step is to believe that any effort can have a ripple effect to cause change not only in Africa but across the globe. The second is to recruit good hearted staff, volunteers, and donors to support the effort.

A. Encouraging Lightning Safety Advocacy Worldwide

ACLENet is not the first lightning safety advocacy program [16]. However, it is the first one conceived as multinational in scope. Founded as a pan-African organization, ACLENet has operated mostly in Uganda since its founding. However, many projects and individuals in other African countries have requested aid or consultations from ACLENet including those in Zambia, Rwanda, Tanzania, Kenya, Malawi, the Democratic Republic of the Congo, Mozambique, and others. Additionally, most of ACLENet's activities are translatable or scalable to other countries.

Organizations, sometimes using ACLENet's bylaws, have formed in Asia (South American Lightning Network, SALNet) and Latin America (Latin American Lighting Education Network, LALENet). These organizations and other safety advocates around the world annually commemorate International Lightning Safety Day, June 28, the day in 2011 when 18 children were killed and 28 injured by a single lightning strike at Runyanya Primary School, Kiryandongo district, Uganda.

B. Working with Governments

ACLENet has long sought productive relationships with government at all levels in Uganda. In February 2022, the Office of the Prime Minister of Uganda and ACLENet signed a Memo of Understanding to begin partnership in lightning injury prevention through education, standardized lightning protection, and warning systems. Both parties are working hard to make this agreement a reality.

We hope to increase standardized lightning protection and education activities in Uganda, working with the Ministry of Disaster Preparedness and Refugees in the Office of the Prime Minister as well as the Ministry of Education and Sports. Accompanying this partnership, ACLENet hopes to improve disaster response to lightning events and to scale up services to more schools, communities, and other nations across Africa.

C. Staff Development

ACLENet's staff serve many roles: administrator, photographer, writer, driver, installer, surveyor, public relations, accounts management, speaker, writer, educator, and others. We are working to provide a sustainable and firm foundation for future lightning safety work in Africa.

D. Disclosure: Fundraising

ACLENet is completely supported by donors, grants, and the work of our volunteers and receives no government funding. Thanks to generous grants from the Ludwick Family Foundation (LFF), ongoing Leuthold Family Foundation support, many individual donors, civic organizations, and an increasing number of corporate donors, ACLENet has been able to expand activities into many areas.

V. Conclusion

There is a huge amount of work to be done in Africa and around the world to prevent deaths, injuries, and property damage from lightning and to encourage building weather ready nations. This is not easy, but with the support from partners and friends across the world, it is the direction ACLENet is pursuing.

For nearly a decade, ACLENet has been working to accomplish many significant activities as outlined in this paper. The majority of ACLENet's work has been done by volunteers and supported by generous donors whose contributions maintain a small salaried team on the ground in Uganda to reach out to communities as well as to fund the real costs of school protection and ACLENet's other programs. The good news is that more individuals, foundations, and corporations are becoming aware of this problem and working with us to save and improve lives.

As ACLENet grows, there will necessarily be a transition to more paid staff in Africa, and, eventually, hopefully, an endowment to sustain ACLENet. Again, we cannot manage this transition without the support of donors and partners around the world and of governments in Africa.

ACLENet encourages research in this area and stands ready to support, mentor and encourage lightning safety advocates wherever they are located. It is a core member of the strong international lightning safety effort that has formed across the world, particularly in high-injury, lightning prone areas.

ACKNOWLEDGMENT

ACLENet wishes to thank our many donors and the Ludwick and Leuthold Family Foundations for their generous and ongoing funding, the members of the Lightning Protection Working Group who have donated hundreds of hours to protecting school children in Africa, DEHN-Africa, particularly Gerrit Meyer and Kirk Risch, PolyTech, Engineers Without Borders of Denmark, Gopa Kumar, and, most especially, ACLENet's faithful, creative, and hardworking staff, volunteers, citizen reporters, and Board of Directors.

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