BAMS Article

Empowering Africa: Advancing Lightning Safety and Research Initiatives

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ABSTRACT: African countries experience some of the highest population-weighted lightning death rates globally. Most African countries lack recognized lightning protection standards, safety education, or other injury prevention strategies. This paper explores lightning hazards, safety challenges, and emerging research initiatives across the continent, highlighting the urgent need for expanded lightning risk awareness, research, and injury prevention strategies. Recent lightning mass casualty incidents in Uganda, including the 2024 Oweko Primary School in Uganda (79 injured) and the Palabek-Lamwo Refugee Camp (14 died, 34 hospitalized) incidents, as well as the 2011 Runyanya School tragedy (18 children killed, 38 hospitalized), underscore Africa's vulnerability to lightning strikes. The International Lightning Safety Day observed on 28th June commemorates the Runyanya disaster. The African Centres for Lightning Education Network has installed lightning protection systems at nine Ugandan schools and compiled the largest lightning casualty database with information on 45 countries. Other barriers to injury prevention include minimal or no funding, widespread cultural beliefs that link lightning to supernatural forces, and extreme linguistic diversity, all of which hinder education, data collection, and policymaking. The only exception is that South Africa has a long history of lightning research and outreach with university-based programs and public education. New tools, such as EUMETSAT's Lightning Imager, offering free, continuous satellite monitoring, create opportunities for progress, but addressing Africa's lightning hazard requires coordinated international partnerships and long-term commitment to scientific development, capacity building, technology transfer, inclusive safety strategies, and culturally grounded education programs.

SIGNIFICANCE STATEMENT: This paper addresses the underreported issue of lightning casualties in Africa, where lightning kills and injures more people per capita annually than most countries on other continents. Despite its devastating impact, lightning research is scarce across the continent, with only a few isolated efforts in place. This paper highlights the limited initiatives currently under way and emphasizes the urgent need to advance lightning research and injury prevention measures in Africa. Such efforts are crucial not only for mitigating the deadly effects of lightning but also for fostering global collaboration and improving resilience against natural hazards.

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1. Introduction

Lightning is an electrical discharge that originates primarily within deep convective clouds, where strong updrafts and microphysical processes generate and separate electric charge on a scale sufficient to overcome the dielectric strength of air (Rakov and Uman 2003). The predominant mechanism for this charge separation is the noninductive ice–graupel collision (NIC) process (Takahashi 1978; Saunders et al. 1991; Saunders 2008). In this process, supercooled liquid water droplets rime onto descending graupel particles, and charge is transferred during collisions between graupel and ice crystals in the presence of liquid water. Laboratory experiments (Takahashi 1978; Saunders et al. 1991) and in situ observations (Dye et al. 1986; Dye and Willett 2007) have revealed that the sign and magnitude of charge transfer during these collisions are highly sensitive to the local temperature and liquid water content (LWC). A typical reversal temperature exists from −10° to −15°C, where collisions at warmer temperatures transfer positive charge to the graupel, while collisions at colder temperatures transfer negative charge (Jayaratne et al. 1983). This temperature-dependent charge transfer, acted upon by gravity and updraft-driven particle sorting, leads to the development of the typical tripolar charge structure within a mature thunderstorm: a main midlevel negative charge region, a main upper-level positive charge region, and a pocket lower-level positive charge region (Williams 1989; Stolzenburg et al. 1998). The resulting electric field between these layers intensifies until it initiates dielectric breakdown, leading to the stepped leader, which is an ionized channel that propagates downward in discrete steps to establish a conductive path, as well as the subsequent lightning flash.

The meteorological environment that supports NIC processes and lightning production is characterized by deep, moist convection with sustained, robust updrafts (>10 m s^{-1}). Such updrafts are essential for maintaining the mixed-phase region (roughly from −5° to −40°C) where supercooled water, graupel, and ice crystals coexist (MacGorman and Rust 1998). Key environmental parameters that favor this regime include high convective available potential energy (CAPE), substantial midtropospheric moisture, and moderate vertical wind shear, which organizes convection and extends the lifetime of the mixed-phase region (Carey and Rutledge 1996; Liu et al. 2020). Consequently, the global distribution of lightning is heavily concentrated in continental tropics and midlatitudes during warm seasons, where these thermodynamic conditions are most frequently met (Christian et al. 2003; Albrecht et al. 2016). Africa, as a continent dominated by such convective regimes, experiences some of the highest lightning densities on Earth. A good example is the Lake Victoria basin, which has a unique mesoscale environment where lake–land breeze interactions and abundant moisture fuel persistent nocturnal convection (Anyah et al. 2006; Thiery et al. 2016; Nicholson et al. 2021a,b). This region experiences an average of two million lightning strikes annually as detected by the Global Lightning Dataset 360 (GLD360) network (R. Said 2024, personal communication) with the highest total lightning density about 450 flashes per square kilometer per year (Virts and Goodman 2020), making it one of the most electrically active regions (Zipser et al. 2006). The convergence of intense lightning activity with high population density and frequently limited access to reliable warnings and safe infrastructure creates a profound and ongoing societal hazard across the continent, where lightning-related casualties and damage are disproportionately high (Cooper and Holle 2019).

Fig. 1. The classroom block in Oweko Primary School where many of the children were sheltering from the rain when the incident occurred on 31 Jul 2024; the red marks indicate where each child was standing. Courtesy: ACLENet.

On 31 July 2024, lightning struck at Oweko Primary School in Nebbi District, Uganda, injuring 77 pupils, one teacher, and one support staff member during a football match involving multiple schools (Akantambira 2024). Pupils sought shelter from the rain both inside and on the verandas of the school buildings. Figure 1 shows a photo of one school building where many injuries occurred.

This was not the first lightning-related school mass casualty incident (MCI) in Uganda. On 28 June 2011, one lightning strike resulted in the deaths of 18 children and injuries to 38 others at Runyanya Primary School in Uganda (Fig. 2), the second highest recorded lightning death report (Cerveny et al. 2017). Such devastating events often lead to significant declines in school attendance, as parents are frightened for their children to attend; myths or rumors about the causes of the incident often spread. These widespread misunderstandings contribute to social unrest and hinder the implementation of effective safety measures. In response, 28 June was designated as the International Lightning Safety Day. Since its launch, the day has seen participation from over 25 countries on multiple continents.

Such lightning MCIs are rare in developed countries, where standardized lightning protection is often required for schools and public buildings and where lightning safety measures may be addressed with public education strategies. However, in rural Uganda and many developing African nations, these protective measures are often unknown or absent in schools, leaving children vulnerable to lightning strikes (Tumuhimbise et al. 2024). Unlike large block schools in developed countries, school buildings in Africa are often built on an as-needed basis, resulting in multiple small buildings. These are seldom adequately protected from lightning. In Uganda, lack of resources

Fig. 2. Injured pupils from Runyanya School at a local hospital. Courtesy: Mary Ann Cooper.

results in as many as 50–80 children in each classroom. When lightning strikes the metal roof, the electrical current either flashes onto the children below or flows into the ground causing ground currents and step potentials that may cause injuries to the crowded students. Additional danger arises from “upward leaders.” When lightning is about to strike, the strong electric field can cause upward discharges to jump from the ground or a pointy object in open courtyards and playgrounds to meet the descending strike. Children in these exposed areas are thus directly vulnerable to electrocution from these upward-streaming currents (Holle and Cooper 2016).

According to a couple unpublished interviews with the victims and locals (B. Akantambira 2024, personal communication), the incident at Oweko School led to widespread feelings of hopelessness and frustration within the community. The other schools that had gathered for the football tournament expressed anger toward Oweko School, believing that the school had “attracted” the lightning or hired witches to call lightning down to assure a football victory, even though most of the injured pupils were from Oweko School. Such beliefs, deeply rooted in African cultural interpretations of disasters (Trengove 2012), highlight the urgent need for public education on lightning safety (Akantambira 2024; Ndihokubwayo and Nkundabakura 2019).

Unfortunately, lightning-related fatalities in schools are not unique to Uganda; they represent a broader pattern of devastating events across the continent. Lightning hazards in Africa have long been underreported, underestimated, and overlooked. Africa experiences high population-weighted lightning death rate, with potential of more than five fatalities per million people annually (Holle 2016). This crisis is exacerbated by poor infrastructure, limited warning systems, and insufficient public education on lightning safety.

Additionally, lightning damage may also cause the loss of livestock, a critical asset for many African families, particularly in rural communities. Unlike other natural disasters like air pollution, which often go unnoticed, lightning strikes can have both immediate and long-term consequences on people’s lives and livelihoods (Tushemereirwe et al. 2021, 2024).

Despite its devastating impact, research on lightning hazards in Africa remains scarce, with only a few isolated efforts under way. This paper aims to highlight the limited safety measures and research currently being conducted, as well as stress the urgent need to expand lightning research and develop injury prevention measures across the continent. Such initiatives are essential for mitigating the deadly effects of lightning and for fostering global collaboration to improve resilience to natural hazards.

2. Lightning injury risk factors

Lightning injury risk is due to many factors, as shown in Table 1. Most of the factors that increase lightning injury risk are common in Africa and other developing countries. Large lightning densities are common in much of Africa, but especially critical is the lack of lightning-safe locations and involvement in labor-intensive outdoor agriculture. Medical care is often unavailable or poor quality. One of the worst issues is the belief that lightning is caused by spiritual factors such as witches, demons, or animistic factors so that there is nothing a person can really do to avoid injury (Elsom 2015; Trengove 2012; Trengove and Jandrell 2010; Ndihokubwayo and Nkundabakura 2019).

Of particular note is building construction. Many people in Africa, especially in rural areas, live in buildings that are not lightning safe. They may have no wiring, plumbing, or metal components in the walls and roof to act as a Faraday cage to safely divert a lightning surge around inhabitants. Instead, people inside mud brick and thatch homes and similar buildings are totally vulnerable to a lightning strike (Tumuhimbise et al. 2024). In developed nations, standard-compliant lightning protection is often mandated for public buildings and

Table 1. Factors that increase or decrease the risk of lightning injury. Adapted from Cooper et al. (2018).

Factors that increase risk	Factors that decrease risk
High lightning stroke density	Low lightning stroke density
Large rural population	Mostly urban population
Increasing population	Stable or decreasing population
Labor-intensive outdoor work	Mechanized farming and stricter work rules
Inadequate building construction	High-quality building construction
Lack of lightning-safe locations	Easily available lightning-safe buildings and vehicles
Lack of known behaviors to avoid lightning	Frequent advice on lightning injury prevention
Lack of reliable and timely weather forecasts	High-quality forecasts and weather apps readily available
No or little lightning detection available	High-quality lightning detection data widely accessible
Delayed or no access to quality medical care	Easy access to high-quality medical care
Low literacy rate	High literacy rate
High linguistic diversity (many local languages)	Effective multilingual communication or uniform language coverage
Minimal or no lightning safety education	Wide access to lightning safety information
Strongly held beliefs that injuries are inevitable and spiritually caused	Knowledge that lightning is a natural phenomenon that can be studied

those frequently inhabited by large numbers of people by building codes. In addition, buildings in Africa may have lightning protection materials that are not compliant with current international lightning protection codes and thus can fail.

3. Meteorological characteristics and lightning patterns in Africa

The distribution and intensity of lightning across Africa are governed by a variety of atmospheric processes, ranging from continental-scale monsoons to mesoscale storm complexes. The continent's unique geography includes the world's largest desert, major topographic barriers, and a vast tropical rainband, creating a dynamic environment where several key synoptic and mesoscale systems interact to produce some of Earth's most vigorous and electrically active convections. Understanding these drivers is essential for interpreting both high lightning frequency and the associated societal risks.

The primary seasonal driver of convective activity across much of western and central Africa is the West African monsoon (WAM). Developing during the boreal summer (June–September), the WAM is thermally forced by the intense heating of the Sahara Desert, which establishes a strong low-level pressure gradient between the hot continent and the cooler Gulf of Guinea (Cook 1999; Sultan and Janicot 2003; Nicholson 2013). This gradient drives a deep inflow of moisture-laden southwesterly monsoon flow inland. The northward migration of the intertropical convergence zone (ITCZ), which effectively marks the monsoon trough, defines the seasonal rain belt (Grist and Nicholson 2001; Hamilton et al. 2017). The WAM circulation is maintained by complex regional-scale processes, including interactions between the monsoon flow and topography, as well as organized water vapor transport pathways that sustain the moisture supply for deep convection (Thorncroft et al. 2011). The WAM thus establishes the large-scale environment of high moisture content and instability necessary for deep convection. The timing, intensity, and northward extent of the WAM directly control the seasonal migration of the region of maximum lightning activity, with peak lightning density closely following the monsoon rainband (Núñez Ocasio et al. 2021, 2024).

Embedded within the monsoonal flow are two interacting features critical for organizing isolated convection into larger, more electrically productive systems: the African easterly jet (AEJ) and African easterly waves (AEWs). AEJ is a midtropospheric (~600 hPa) easterly jet stream that flows from east to west across Africa, mainly during boreal summer

(June–September). It is a thermal wind response to the strong meridional temperature gradient at the southern edge of the Sahara. It exhibits maximum wind speeds just poleward of the monsoon rainband (Burpee 1972). The AEJ acts as a waveguide and a source of dynamical instability. Its vertical and horizontal shear provides energy for the growth of disturbances, which frequently organize into the mesoscale convective systems (MCSs) responsible for the majority of West African rainfall and severe weather (Thorncroft and Hoskins 1994; Knippertz et al. 2003).

AEWs are westward-propagating synoptic-scale disturbances embedded within the AEJ, with a wavelength approximately 2000–3000 km at periods of 3–5 days. They are generated through a combination of barotropic and baroclinic instability mechanisms associated with the AEJ's shear (Reed et al. 1977; Hopsch et al. 2010). The cyclonic vorticity and forced ascent in the trough phase of an AEW provide large-scale lifting that organizes and intensifies convection (Laing and Michael Fritsch 1997). AEWs are the predominant weather systems of the West African monsoon season and are high-impact lightning generators (Price et al. 2007; Chronis et al. 2007).

The MCSs are the dominant convective mode for severe weather and extreme lightning in Africa (Zipser et al. 2006). The life cycle of an MCS within an AEW trough creates a complex electrical structure capable of prolific lightning (Rutledge et al. 1992; Deierling and Petersen 2008). The sheer spatial extent and longevity of MCSs mean that a single system can produce tens of thousands of lightning flashes, posing a prolonged threat to life and property over a wide area (del Moral Méndez et al. 2023). Accurately representing MCS dynamics and electrification in models remains a central challenge for lightning prediction (McCaul et al. 2009; Finney et al. 2014).

In addition, Africa's varied topography acts as a critical mesoscale modulator of convection. Mountain ranges and highlands, such as the Cameroon Volcanic Line, the Ethiopian Highlands, and the East African Rift system, force orographic lift of moist monsoon or easterly flows. This lift enhances convective initiation, storm organization, and rainfall rates (Hamilton et al. 2017, 2020) and is associated with enhanced local lightning climatology, a pattern observed over major mountain ranges globally (Albrecht et al. 2016; Rasmussen and Houze 2016). Furthermore, modeling studies suggest that a warming climate may disproportionately increase rainfall intensity in these elevated regions (Núñez Ocasio and Dougherty 2024), implying a potential future amplification of lightning hazards in populated highland areas (Price and Asfur 2006; Price 2009).

Africa's lightning climatology is characterized by two extremes: a relative dearth of lightning over the hyperarid northeastern Sahara Desert and some of the highest flash densities on Earth, particularly in the Congo basin (Christian et al. 2003). This pattern, however, represents a simplification of the true complexity revealed by modern detection networks. Figure 3 illustrates the average annual lightning density (Fig. 3a) and average annual thunder hours (Fig. 3b) across Africa as detected by GLD360 (Said 2017; Said et al. 2023). These comprehensive data reveal intricate patterns that correspond closely with the continent's diverse climatic zones, topographic features, and the seasonal migration of convective systems.

4. International and regional frameworks for lightning safety

a. Global effort and contribution. While the meteorological drivers define Africa's lightning hazard, translating this scientific understanding into actionable public safety requires robust institutional frameworks and international cooperation. The World Meteorological Organization (WMO) plays a significant role in this effort by coordinating global and regional meteorological services, setting technical standards, and facilitating capacity building in developing nations in Africa.

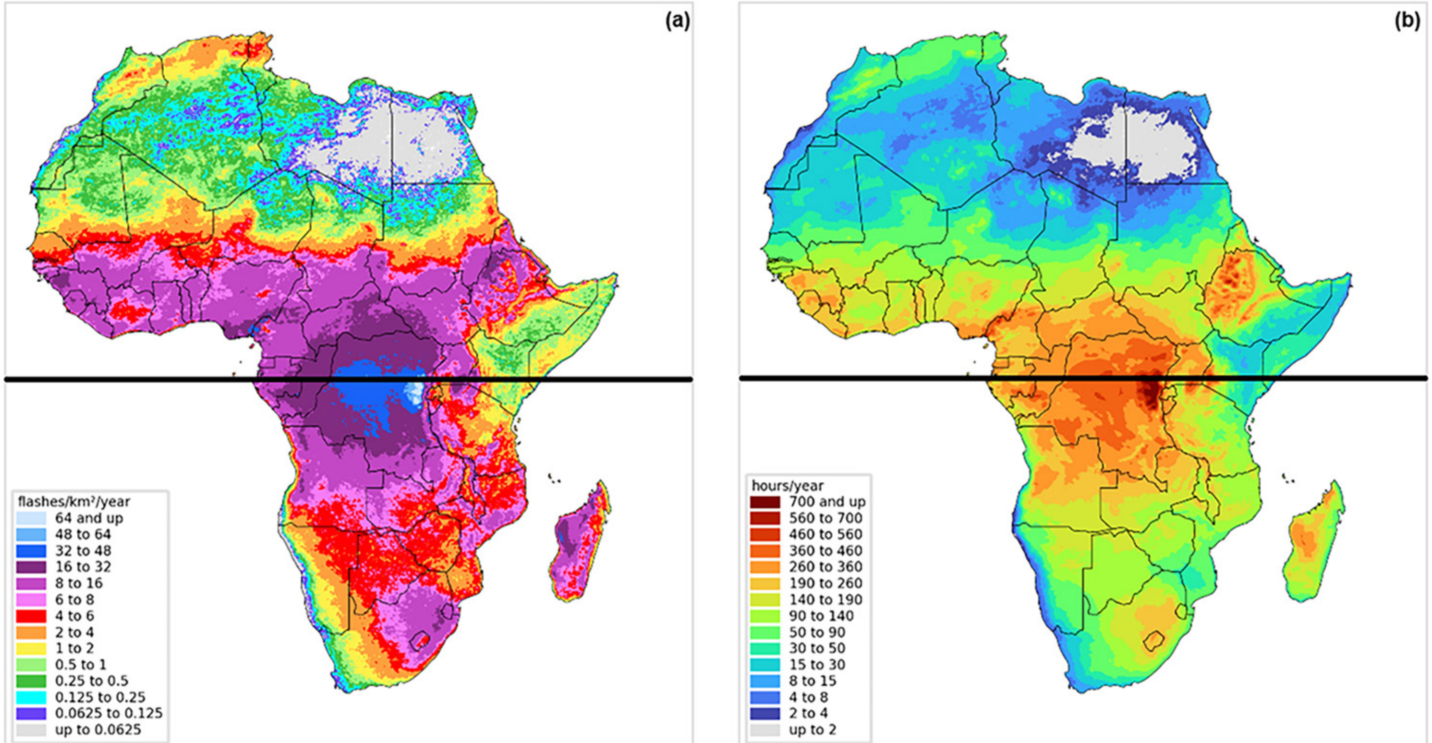

Fig. 3. (a) Average annual lightning density and (b) average annual thunder hours, as detected by the GLD360 between 2015 and 2024. The thick black line indicates the equator.

1) The "Early Warnings for All" initiative and MHEWS. Launched in 2022 and endorsed by the United Nations (UN) Secretary-General, the WMO-coordinated Early Warnings for All (EW4All) initiative is a cornerstone of the international disaster risk reduction, with the ambitious goal of ensuring universal protection from hazardous weather, water, and climate events by 2027 (WMO 2022). In Africa, this initiative directly targets the continent's high vulnerability to hydrometeorological hazards. The EW4All framework is built upon four interdependent pillars: 1) disaster risk knowledge; 2) detection, observation, monitoring, analysis, and forecasting; 3) warning dissemination and communication; and 4) preparedness and response capabilities (WMO 2022). For lightning safety, the EW4All mandate translates into strengthening National Meteorological and Hydrological Services (NMHSs) across Africa to develop and operate effective Multi-Hazard Early Warning Systems (MHEWS). This involves integrating real-time lightning data from global networks, such as GLD360, Earth Networks Global Lightning Network (ENGLN), or regional satellites into early warning and nowcasting systems (Salioet al. 2025).

2) Complementary international efforts and partnerships. The WMO's efforts are amplified through partnerships with other UN agencies, development banks, and scientific organizations. Key collaborators include UN Development Programme (UNDP) and UN Office for Disaster Risk Reduction (UNDRR). These agencies work with the WMO on the governance and community preparedness pillars of EW4All, helping to integrate weather warnings into national disaster management laws and local action plans (WMO 2025). World Bank and African Development Bank (AfDB), in collaboration with the Systematic Observations Financing Facility (SOFF), supports the strengthening of basic weather and climate observation data (e.g., Doppler radar networks, automatic weather stations) and implementing MHEWS projects across the continent (AfDB and SOFF 2024).

Complementing these operational and capacity-building initiatives are targeted research programs. A prime example is the hybrid forecasting of high-impact weather in Africa

(HIGHWAY) project, funded by the U.S. National Science Foundation (NSF) and led by the National Center for Atmospheric Research (NCAR) in partnership with African meteorological services. HIGHWAY is pioneering the integration of satellite lightning observations [primarily from the Meteosat Third Generation Lightning Imager (MTG-LI); Erdmann et al. 2023] with high-resolution ensemble forecasting models to specifically improve the prediction and nowcasting of severe convective storms and associated hazards across East Africa (Roberts et al. 2022). This aligns with the new University Corporation for Atmospheric Research (UCAR) Africa Initiative, a strategic framework to build equitable, coled research partnerships targeting critical Earth system challenges like weather, climate, and infrastructure in Africa (Tang et al. 2026). Organizations like the African Centre of Meteorological Applications for Development (ACMAD) and the Global Atmosphere Watch (GAW) programme facilitate research, training, and data sharing that underpin improved forecasting science (WMO 2024).

b. ACLENet: A model for grassroots action and community protection. The success of global initiatives like EW4All hinges on effective implementation at the national and local levels. In Africa, translating policy into life-saving action requires collaboration between meteorology agencies, disaster management agencies, and specialized nongovernmental organizations. One of the most prominent organizations dedicated specifically to mitigating lightning risk on the continent is the African Centres for Lightning Education Network (ACLENet), whose origins, strategies, and challenges offer a critical case study in bridging the gap between international frameworks and community-level protection (Lyons 2025).

1) Origins and development. The origin of ACLENet (formerly the African Centres for Lightning and Electromagnetics Network) can be traced to a 2011 international lightning protection meeting, organized by the Non-Aligned Movement Science and Technology (NAM S&T) Centre in Kathmandu, Nepal. This gathering brought together high-ranking professionals, scientists, and engineers from 17 countries. Uganda's representative, Richard Tushemereirwe, advocated for a follow-up meeting that was held in Africa in 2013. There, participants called for lightning injury prevention centers across the continent, leading to ACLENet's founding in Uganda in 2014.

From its early days, ACLENet prioritized protecting school children as research revealed that injuries to students in their classrooms were among the most frequently reported lightning incidents (Holle and Cooper 2016). The organization eventually brought together global experts, with donors giving materials, and specialists joining the Lightning Protection Working Group design team to address the unique challenges facing African schools. Over the past decade, ACLENet has grown from a small nongovernmental organization into a recognized sector across Africa, with countries including Kenya, Tanzania, the Democratic Republic of Congo, Zambia, Rwanda, Malawi, South Africa, and Mozambique requesting consultations on lightning protection and injury prevention.

A significant milestone came through the memorandum of understanding signed with Uganda's Office of the Prime Minister, now in renewal, which established a formal partnership framework (see Fig. 4). Under this agreement, ACLENet provides knowledge, design expertise, specialists, and educational materials for lightning injury prevention, while leaders from several ministries including Education, Labor, and Disaster Preparedness and Refugees support grant applications and participate in lightning mass casualty incident investigations. These ministries have requested ACLENet's reports as background documentation for their parliamentary presentations seeking increased funding for lightning protection, and the Ministry of Education has implemented requirements for standardized lightning protection on all new school construction projects.

Fig. 4. (left) The First Lady of Uganda and Minister of Education and Sports, Janet Museveni, meets with ACLENet's Cofounder and Managing Director, Mary Ann Cooper. (right) Group photo of the First Lady of Uganda and office with ACLENet's team.

2) School protection initiative. To date, nine schools across Uganda, most with documented histories of lightning deaths, have received standardized lightning protection systems. Figure 5 shows an example of teaching staff quarters at one of the most recently installed schools, and Fig. 6 shows the locations of schools protected to date. In addition to the criteria of past injuries, these schools were selected for ease of access so that they can be used as training centers for lightning safety education. These milestone achievements are regularly reported at international lightning meetings and featured in ACLENet's monthly newsletter (now distributed in five languages) to raise awareness, solicit additional donations, and encourage international standards committees to consider the specific challenges that developing world communities face when implementing lightning protection recommendations.

Fig. 5. (left) A lightning protection system after being fully installed on one of the staff quarter buildings at the Mulabana Primary School in Kalangala District. (right) ACLENet's chief installer, Isaac Tumuhimbise, installing a clipping conductor on a building roof at Bumangi Primary School in Kalangala District.

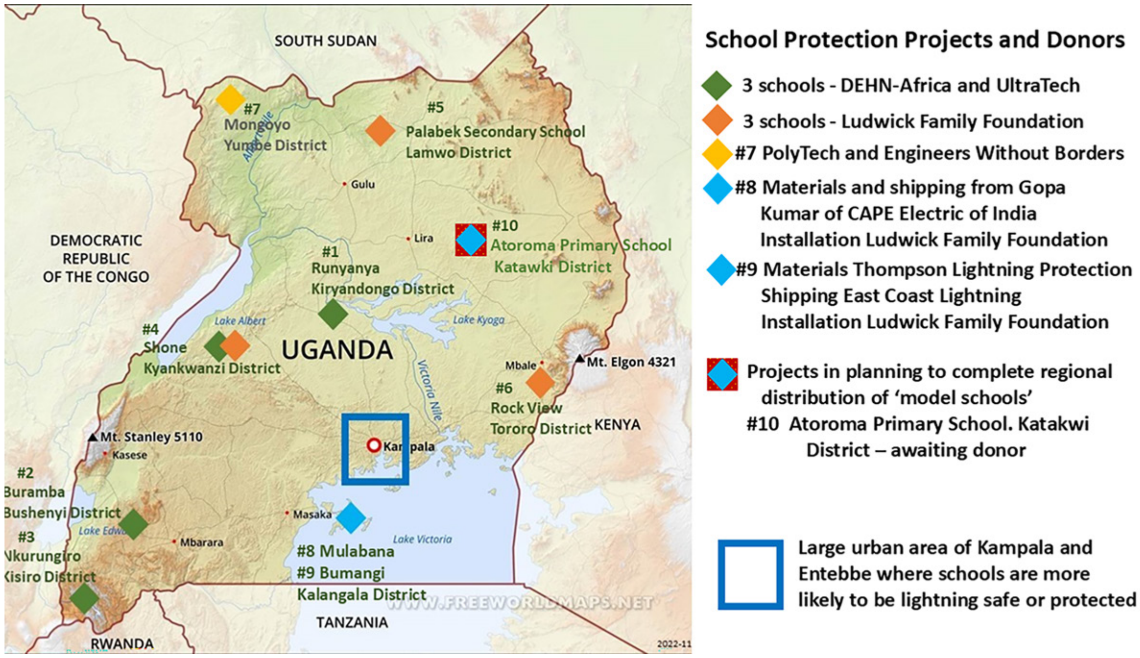

Fig. 6. Map of the nine schools protected from lightning by ACLENet as of February 2025.

3) Educational strategies and outreach. Over the years, ACLENet has experimented with various educational approaches to overcome the unique challenges of reaching diverse African populations. Traditional methods such as public service announcements and newspaper inserts proved expensive and limited in reach due to widespread illiteracy, lack of electricity for broadcasts, and the multiple languages spoken throughout Uganda. Recognizing the widespread adoption of mobile phones across the continent, ACLENet has developed an active social media campaign using multiple platforms to dispel lightning myths and educate audiences about lightning science and injury prevention methods. Educational webinars are made available through ACLENet's YouTube channel, and a grassroots national advocacy team has been formed to actively support major social media platforms in their languages and their communities.

4) Lightning injury database. One significant contribution to lightning safety efforts in Africa is ACLENet's publicly available lightning casualty database (Zhang et al. 2026, manuscript submitted to *Wea. Climate Soc.*). This database contains over 1100 entries to date and data from 45 of the 54 sovereign countries in Africa, which is the largest such dataset to our knowledge. News reports in several languages are gathered by volunteers around the world and staff as well as citizen reporters sending reports, often as translations from native language media or even local incidents they know of that have not been published. There is some indication that the African media is beginning to recognize lightning injury as a story worth publishing and occasionally even includes valid safety recommendations.

5) Future plans and partnerships. The 2013 NAM S&T call to establish lightning centers across Africa was ambitious, and progress has been slower than hoped. Interest exists in several countries, but funding gaps, limited personnel, and other challenges have hindered long-term success. Still, some individuals remain engaged with ACLENet as citizen reporters, social media advocates, translators, and in other supportive roles. For the next decade, ACLENet will focus its educational efforts on students, teachers, parents, and district officials to dispel myths and teach behaviors that can decrease lightning injury risk (Cooper et al. 2024). ACLENet hopes to improve upon the Uganda programs and successfully foster similar programs in other African countries, expanding the network's continental impact and creating a more comprehensive approach to lightning safety across Africa.

5. African lightning research and outreach infrastructure, challenges, and future perspectives

Although lightning poses a significant threat with more than a third of a billion to about 500 million strokes detected per year (Holle et al. 2018), the scientific infrastructure to study and mitigate these hazards remains severely limited. Most African countries lack dedicated lightning detection networks or systematic monitoring systems. Formal lightning science programs are virtually nonexistent in most nations, and educational initiatives focused on lightning safety are rare across the continent. This highlights a pronounced gap between the scale of the lightning threat and the scientific resources available to address it.

a. Research infrastructure and public outreach in South Africa. Against this continental backdrop, South Africa remains one of the few African nations with a well-established lightning research program and infrastructure. Its leadership in the field dates back to early camera observations by Sir Basil Schonland and the Bernard Price Institute (Schonland and Collens 1934; Schonland 1956), followed by groundbreaking lightning current and electric field measurements (Eriksson 1978, 1979; Anderson 1980). Today, this legacy continues through Ian Jandrell and the Lightning/Electromagnetic Compatibility (EMC) Research Group at the University of the Witwatersrand, which explores a wide range of topics including lightning physics, protection, detection networks, forensics, and injury mechanisms (Jandrell et al. 2009; Schumann et al. 2022; Guha et al. 2021; Smit et al. 2023; Gijben 2012; Fensham et al. 2023).

The Johannesburg Lightning Research Laboratory (JLRL) has made key advances, including Africa's first high-speed lightning video capture in 2017, improving understanding of lightning attachment and upward development (Schumann et al. 2022; Guha et al. 2021; Fig. 7). It also operates a current measurement system on the Sentech Tower, enabling synchronized high-speed imaging and current data collection (Smit et al. 2023; Fig. 7). The South African Lightning Detection Network supports regional research by supplying data on lightning stroke characteristics enhancing protection strategies (Gijben 2012; Mahomed et al. 2021; Fensham et al. 2023).

Lightning researchers from JLRL conduct comprehensive outreach programs in schools. These sessions employ hands-on demonstrations, interactive discussions, and real-world case studies to ensure information accessibility and retention while dispelling common myths about lightning. A notable success in public education from South African researchers is Professor Ryan Blumenthal from the University of Pretoria—the creator of the "Lightning Pathologist" television documentary series, consisting of eight episodes that aired on Digital Satellite Television (DStv, a television service providing direct broadcast satellite services across sub-Saharan Africa), in

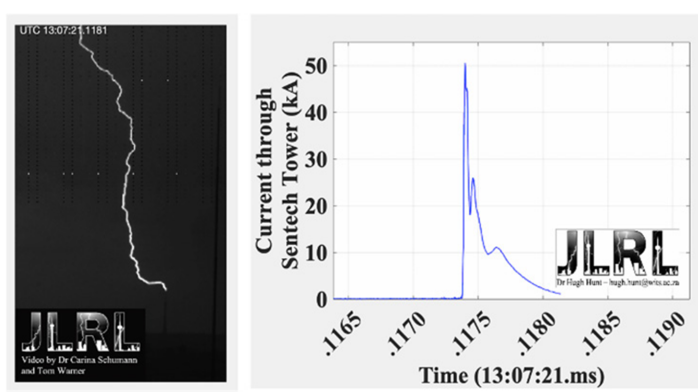

Fig. 7. (right) The first lightning current measurement and (left) optical image made at the Sentech tower at 1307:21 UTC October 2020. The event was a downward negative stroke and was part of a multiple ground strike point flash involving two other termination points.

2020 and reached over 2.2 million viewers (Hunt et al. 2020). This achievement demonstrates the potential for mass media to effectively communicate lightning safety information across diverse populations.

b. Current challenges. Despite South Africa's relatively strong research environment compared to other African countries, significant challenges persist. Research funding, while available, typically ranges from ZAR 100,000 to ZAR 1 million per project ($5,000–$50,000), which limits the scope and duration of research initiatives. While South African universities, like many across Africa, are experiencing increased enrollment (Altbach et al. 2019), with typical first-year engineering classes consisting of 300 or more students, graduation rates remain concerning with final classes often reduced to around 100 students.

Cultural and communication barriers pose additional significant challenges (Hunt et al. 2020). Many African cultures interpret lightning as supernatural events or a result of witchcraft (Trengove 2012; Trengove and Jandrell 2010; Ndihokubwayo and Nkundabakura 2019), leading communities to continue outdoor activities during thunderstorms because natural lightning events are perceived as less threatening than witchcraft-related phenomena. These challenges are further complicated by Africa's extraordinary linguistic diversity, with approximately 1000–2000 languages spoken across the continent. At least 75 African languages have more than one million speakers, while the remainder are spoken by populations ranging from a few hundred to several hundred thousand speakers. This linguistic complexity makes education and advocacy efforts exceptionally difficult across the continent, as scientific knowledge must be translated and culturally adapted for hundreds of distinct language communities. Remote communities predominantly communicate in their native languages, making scientific knowledge largely inaccessible to these populations who may be most vulnerable to lightning hazards (Essa et al. 2022; Gcaba and Hunt 2024).

c. Future perspectives. Addressing lightning-related challenges in Africa requires a multifaceted approach that builds on South Africa's research strengths while tackling barriers in funding, education, and communication (Guha et al. 2021; Mahomed et al. 2021). Future efforts should prioritize sustainable funding, culturally appropriate educational materials in local languages, and international partnerships that recognize Africa's unique contributions. Programs like the Lightning Pathologist series show how creative outreach can overcome traditional barriers to lightning safety education.

A major advancement comes with the launch of EUMETSAT's geostationary Lightning Imager (LI), which is the first of its kind over Africa, offering continuous, continentwide lightning monitoring (Enno et al. 2023). By providing free access to high-resolution data, the LI removes long-standing financial barriers. To fully leverage this tool, Africa needs targeted training programs for meteorologists, researchers, and educators. These must cover technical skills in data interpretation and real-world applications such as forecasting, public safety, and research tailored to local needs.

However, the broader African context demands even more ambitious and coordinated efforts. If South Africa, as the continent's lightning research leader, faces such significant challenges, the situation across other African nations is even more dire and requires urgent international attention and support. Future perspectives must include continentwide capacity building initiatives, technology transfer programs, and international partnerships specifically designed to establish basic lightning monitoring infrastructure in countries currently lacking these scientific capabilities. This could involve regional networks where South Africa's expertise serves as a foundation for training researchers from neighboring countries, developing low-cost monitoring solutions suitable for resource-limited environments and creating collaborative frameworks that enable knowledge sharing across national boundaries. Only through such comprehensive, continent-spanning approaches can Africa begin to address the disparity between its high lightning activity and its limited scientific resources for understanding and mitigating these hazards.

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