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Lightning monitoring and detection techniques: Progress and challenges in South Africa

Globally, lightning causes significant injury, death, and damage to infrastructure annually. In comparison to the rest of the world, South Africa has one of the highest incidences of lightning-related injuries and deaths. The latest available lightning detection techniques and technologies are reviewed and include current research in South Africa and South Africa's lightning detection challenges. Technological advances have contributed towards improving lightning detection and monitoring activities in many countries. South Africa has made considerably more progress in the field of lightning research than other African countries and possesses one of the three ground-based lightning detection networks in the southern hemisphere. However, despite these developments, rural communities in South Africa, and indeed in Africa, remain vulnerable to lightning, the occurrence of which is predicted to increase with climate change. A large proportion of the population of African countries resides in rural areas, where citizens participate in subsistence farming, and built infrastructure is not lightning safe. We recommend a call for the integration of indigenous and scientific knowledge as well as for the development of a participatory early warning system. Investigations into determining the most effective way to utilise existing monitoring networks – but with warning dissemination to rural communities – are also required. Lastly, future research on the development of lightning-safe rural dwellings or shelters, especially in lightning prone areas, is needed.

Significance:

- Climate change projections of increases in lightning incidence highlight an increased risk for vulnerable communities.

- There is a lack of literature focusing on lightning detection within rural communities.

- Technological advances now allow for better dissemination of lightning information and early warning within rural communities.

- The South African Lightning Detection Network is operational at a national level; however, there is no dissemination at a local level.

- There are currently no recommended design guidelines for informal dwellings and no safety protocols for rural communities.

Introduction

Lightning is one of the most frequently occurring geophysical phenomena.[1] Despite lightning being a familiar and researched phenomenon, it remains poorly understood, primarily due to the spontaneous spatial and temporal occurrence of lightning. There has been more than a century of research conducted on the physics and the phenomenology of lightning and yet some processes still require further in-depth research.[1,2] Lightning is complex and is usually accompanied by extreme weather such as hail, extreme wind gusts and heavy rainfall.[3,4] According to Blumenthal et al.[3], apart from incidental catastrophes and disasters, lightning strikes result in more deaths than any other natural event or phenomenon. In South Africa, the number of lightning deaths is about four times higher than the global average.[5] Although various studies report disparate lightning-related fatalities, the actual number may be higher as many injuries and deaths are often unreported.[6,7]

It is expected that extreme weather and the occurrence of lightning will also increase with climate change.[8] Africa has already experienced a warming trend, which is likely to continue in the future.[9] These climate change projections become an added concern for developing African countries that are already prone to lightning occurrences. Climate models support the positive correlation between lightning and global temperatures.[10] A study by Romps et al.[11] modelled the frequency of lightning strikes across the continental USA and predicted that lightning strike rates will increase significantly due to increases in global average air temperature. However, there is uncertainty regarding the expected changes in spatial distribution of lightning with climate change. Because climate change is intricately linked to almost all facets of society, developing countries are more likely to face the brunt of climate change due to their low adaptive capacity. Thus, monitoring and prediction of lightning incidences on a local scale for developing countries requires attention.

Lightning incidence itself may be a valuable variable that could be used to monitor climate change and severe weather changes.[7] There are now reliable ways for monitoring global and regional lightning activity in near real-time.[7] The ease of monitoring lightning across the globe using ground-based networks is frequently advocated. This ease makes lightning an attractive indicator for tracking changes in severe weather.[12] Climate models that include the impact of El Niño Southern Oscillation (ENSO) for South Africa predict increasing lightning activity as the climate becomes warmer and drier, despite the atmosphere becoming more stable.[10] These relationships indicate reduced rainfall, which may result in increased lightning incidence.[10]

Lightning has already been recognised as an important research topic on the African continent. Gijben[13] presents a review of the historical and current instrumentation used for the detection of lightning activity over South Africa. However, with an increase in the accessibility of detection methods and systems, it is important to re-evaluate their application in the South African context. Consequently, the objective of this review is to highlight the advances in lightning monitoring and detection, along with the major lightning detection challenges facing South Africa, including the relevance to rural communities.

Approach

In this review, we assess the latest lightning detection techniques and technologies used globally and include an update on the progress and challenges in lightning detection, with a focus on South Africa. A detailed summary of South Africa's current lightning research initiatives as well as future endeavours towards improving South Africa's lightning detection at a local/community level is highlighted. A mixed-methods approach was used, which included qualitative and quantitative inputs towards exploring existing lightning detection methods and investigating South Africa's current state of lightning detection. The focus was on the specific challenges facing South Africa, with respect to community-level lightning detection to provide feasible recommendations.

History of lightning detection

History internationally

Lightning was associated with God's anger up until the Middle Ages when the natural interpretation of attributing lightning to collisions between clouds by René Descartes began in the 17th century.[14] In 1746, Benjamin Franklin showed that lightning was electrical.[1] Franklin's well-known kite experiment in 1752 was a critical breakthrough in scientific research that showed that lightning was electrical.[1,2,6]

In the late 19th century, photography and spectroscopy became available as diagnostic techniques utilised for lightning research in England, Germany and the USA.[1,13] Investigations used time-resolved photographic techniques to identify individual 'strokes' consisting of a lightning discharge to the ground and the 'leader' that precedes the first strokes. In 1900, the double-lens streak camera was invented in England by Boys[15]. In the 1930s and after, Boys' double-lens camera was used in South Africa to study cloud-to-ground (CG) lightning.[16] Pockels[17-19] in Germany made the first lightning current measurements. Pockels analysed the residual magnetic field induced in basalt rock by nearby lightning currents and was able to estimate the values of those currents. Studies by Boys[15], Schonland[16], Pockels[17] and Uman[20] further elaborated on lightning photography and spectroscopy, while the early history of lightning photography and spectroscopy was comprehensively reviewed by Uman[21].

The modern era of lightning research dates back to work in England by Wilson[22], who investigated remote, ground-based electric field measurements. It was only about 20 years ago that transient luminous events and high-energy phenomena (runaway electrons, X-rays, and gamma rays including the terrestrial gamma ray flashes observed on orbiting satellites) were discovered and are still the subject of intensive present-day research.[1]

History in South Africa

In South Africa, lightning-related research can be traced back to the 1920s when Schonland and Malan, founding members of the Council for Scientific and Industrial Research (CSIR), pioneered the first electric field measurements in South Africa.[3] Much of the lightning research in South Africa was then continued and produced by Schonland and others during the 1930s.[23] The CSIR has continued to maintain its lightning research activities, and from the 1960s has actively participated in the development and testing of lightning detection equipment through the National Electrical Engineering Research Institute (NEERI) in Pretoria, and in cooperation with CIGRÉ (International Council on Large Electric Systems).[3]

In recent years, prominent South African institutions, including the South African Weather Service (SAWS), the University of the Witwatersrand and the University of KwaZulu-Natal have made significant contributions to the field of lightning research. The University of the Witwatersrand has led research on lightning medicine (keraunomedicine)[3] and lightning myths[24], whereas the nowcasting and forecasting of lightning threats[5] as well as the use of lightning to track the development of thunderstorms[25] in the country have been documented by the SAWS. Gijben et al.[5] recently developed a new lightning threat index for South Africa by using numerical weather prediction to enable forecasts of lightning threats. A study by Clulow et al.[26] conducted at the University of KwaZulu-Natal illustrated the use of ground-based lightning early warning systems for areas not covered by continent-wide lightning locating systems. These recent research studies and activities show the relevance of lightning through the ongoing advances in lightning research in South Africa.

Existing lightning detection techniques and systems

Existing lightning detection systems vary in terms of their spatio-temporal characteristics and identifying a suitable system for an application can therefore be complex (Figure 1; Table 1). Detection systems have different capabilities in terms of warning dissemination. Handheld detection systems for example have no dissemination capabilities and are spatially restricted, while national network systems have been integrated with global warning systems (i.e. the World-Wide Lightning Detection Network), and cover large areas (Figure 1).

Radiation that is emitted from lightning forms the basis of lightning detection and lightning location. During the lightning process, electro-magnetic and acoustic radiation is generated in various forms, which include radio emission (occurs in the form of short pulses), optical radiation (emitted by thermal radiation of the hot lightning channel) and acoustical radiation (mainly human based).[6,28]

During the last 50 years, various lightning mapping systems have been developed and operate at various frequency ranges and bandwidths. Ground-based detection systems using multiple antennas, space/satellite-based systems and mobile systems using a direction and a sense antenna in the same location are currently the three common types of lightning detection systems globally.[28] The most commonly used techniques remain the ground- and space-based lightning detection networks.[29] These networks are continuously improving, and their data are growing in importance for scientists and operational weather forecasters.

Satellite/space-based systems

Tracking thunderstorms and assessing cyclone intensification become important challenges in weather prediction for remote regions where surface observations and radar systems are not available. Significant advances in the understanding of global distribution and frequency of lightning have been made possible by the different types of satellite-borne lightning detectors.[30] Two primary satellite sensors that have been widely used include the National Aeronautics and Space Administration (NASA) Optical Transient Detector (OTD) and the Lightning Imaging Sensor (LIS) on board the Tropical Rainfall Measuring Mission (TRMM) satellite.[10,28,31] The OTD and the LIS are both low Earth orbit instruments, capable of detecting optical pulses from lightning flashes, during both day and night. However, they do not accurately separate CG and cloud lightning incidence. Additionally, the majority of these satellites, such as the LIS, are polar-orbiting satellites, with limited spatio-temporal coverage. They are also incapable of providing near real-time lightning monitoring, detection and warning.[30]

The OTD was operational from May 1995 until March 2000 with a spatial resolution of 8 km, while LIS, with a 4-km spatial resolution, was active from November 1997 to 2015.[32] The OTD and LIS systems were critically assessed, providing guidance on the applicability for research use and instruction for new instrument design.[31-35] A merged global lightning 0.5°-resolution data set composed of the individual LIS and OTD orbits is freely available online at http://lightning.nsstc.nasa.gov/data/data_lis-otd-climatology.html.[36] The LIS-OTD climatology is the most accurate depiction of total lightning across the planet to date and is named the High-Resolution Annual Climatology database.[37]
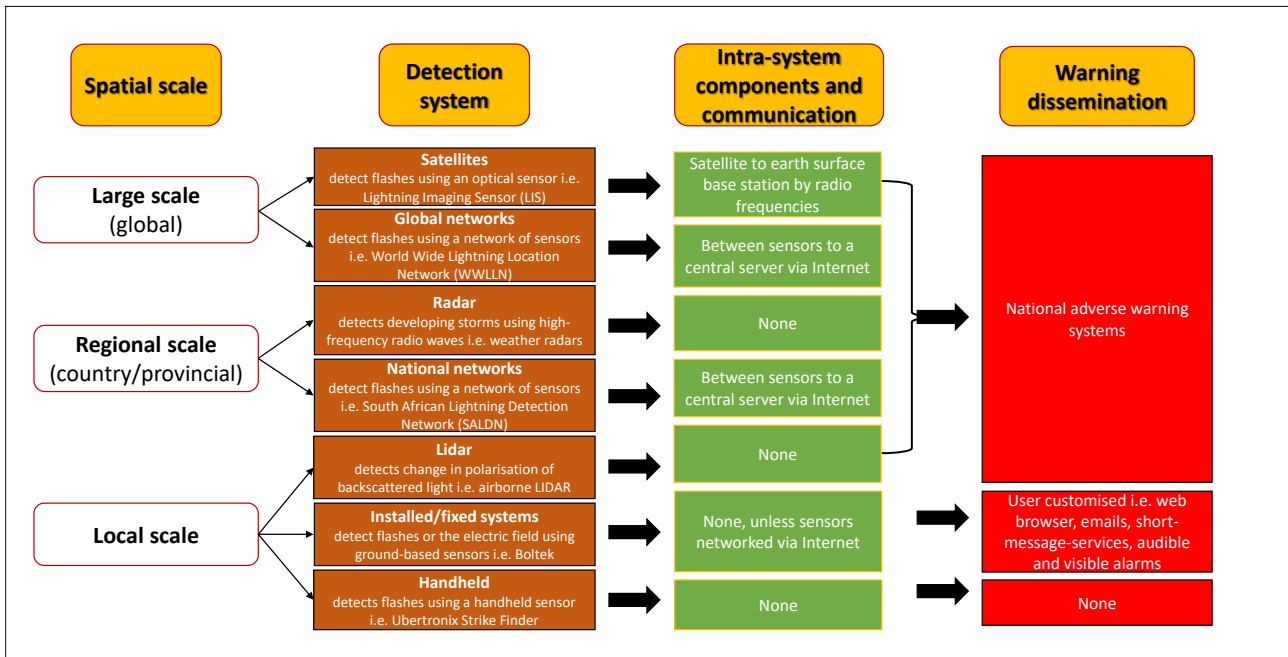
Figure 1: The spatial characteristics of existing lightning detection systems and their associated warning and alert dissemination capabilities.

Table 1: A list of present-day lightning detection options

Present-day lightning detectors	Generalised description
Radio frequency (RF) detectors	Measure past energy discharges from lightning and can determine the approximate distance and direction of the threat.
Inferometers	Multi-station devices, more costly than RF detectors, employed for research purposes and require a skilled operator.
Network systems	Multiple ground-based RF sensors are networked to determine location of lightning over large spatial scales (i.e. continent or country scale).
Electric field meters (EFM)	A pre-lightning sensor that measures the potential gradient (voltage) changes of the Earth's electric field (cloud voltages) and reports changes from predetermined thresholds to lightning breakdown values. They consist of a narrow reporting range and false alarms may occur from various sources such as dust storms.
Optical monitors	Detect light flashes from cloud-to-cloud lightning that typically precedes cloud-to-ground lightning.
Hybrid designs	Consists of a combination of the aforementioned technology designs such as RF and EFM sensors.
Meteorological information services	Includes meteorological subscription services usually sourced from a network system.

Source: Kithil[27]

The new generation series of GOES-R (Geostationary Operational Environmental Satellites) carrying a Geostationary Lightning Mapper (GLM) was launched in November 2016 and has been deployed in a geostationary orbit to continuously detect lightning activity over America and its adjacent ocean region in the western hemisphere.[38] The GLM is an optical sensor that detects total lightning (in-cloud, cloud-to-cloud and cloud-to-ground) activity over the western hemisphere.[39] The GLM delivers lightning measurements similar to those of LIS but provides continuous lightning detection.[38] This GLM will be able to provide high-quality data for forecasting severe storms and convective weather but only over the western hemisphere.[38]

EUMETSAT plan to launch the Meteosat Third Generation (MTG) operational meteorological satellite in 2021 with an onboard lightning imager operating on a continuous basis covering the entire MTG disk (including the entire African continent). It is expected to deliver near real-time information on total lightning for the purpose of supporting nowcasting of severe weather warnings and monitoring deep convection.[30] The development of such modern lightning detection instrumentation has been driven by a variety of practical needs and applications as well as research needs.[40]

Ground-based lightning detection networks

Ground-based global lightning observation networks are based on the Schumann resonance method.[10,41] As a result of the narrow time scale (sub-millisecond to millisecond) and the large spatial scales associated with the lightning current, the majority of the energy in the radiated spectrum is contained in the extremely low frequency (ELF 3–3000 Hz) and very low frequency (VLF 3–30 kHz) bands.[4] Further details on these different frequency ranges are given by Cummins et al.[42]

Electromagnetic waves disseminate at ELF and VLF frequencies, by being reflected from the ground and from the conducting layer of the atmosphere known as the ionosphere, and in this manner, they can travel large distances around the Earth.[4] The low loss propagation of sferics (typically 2–3 dB/1000 km) allow measurements to be conducted spatially from their source locations within the ionosphere waveguide. This makes networks of ELF/VLF sensors particularly useful in long-range severe weather monitoring applications, compared to weather radars. Weather radars use microwave-frequency radar beams that are blocked by mountainous regions when locating the presence of storms over several kilometres.[4]

According to Mayekar et al.[4], a low-frequency lightning receiver forms part of a node/sensor that captures electromagnetic radiation emitted by lightning. Several such nodes/sensors are distributed across a certain geographical area (to form a network), which rely on the use of either time-of-arrival[28,40,42] or magnetic direction-finding[28,40] techniques to detect lightning. The digitised data are sent to a central processing system, which processes these data to calculate the lightning signal characteristics such as peak current, polarity and source location. Finally, the central processing system sends this information to a user/display software.

Examples of regional LDNs include the South African Lightning Detection Network (SALDN) in South Africa[13], the European Cooperation for Lightning Detection (EUCLID)[28] and the National Lightning Detection Network (NLDN) in the USA[40,43]. Regional LDNs operate with sensors spaced relatively close to each other (e.g. the SALDN consists of 24 sensors spread across South Africa)[5], providing regional coverage of total lightning with high detection efficiency. These networks, however, do not provide information over oceanic regions or remote locations where no sensors are installed.[38] Over the years, long-range detection networks have also been developed to enable global coverage and real-time lightning detection, but with a lower detection efficiency than short-range detection networks and satellite detection systems.[38] Global LDNs consist of sensors separated by thousands of kilometres. Examples of global LDNs include the Global Lightning Dataset (GLD360)[44] and the World Wide Lightning Location Network (WWLN).[45] These sensors detect mainly CG with regional LDNs also detecting a small fraction of cloud-to-itself lightning.[5]

Recently, an innovative lightning location network, 'Blitzortung Lightning', has been established. This network is a worldwide, real-time, community collaborative network, and has been available since 2003. The network monitors magnetic field (H-field) and electrical field (E-field) emissions from lightning strikes and has a set of servers in Europe to correlate the time-of-arrival at detectors vs GPS-time to locate strikes.[46] A real-time, online map is available which displays strike information for North America. The web application notifies users via email, SMS (short message service) or URL-call when lightning is detected within their area. Strikes are colour coded to show how recent they are. Currently, coverage is biased towards the largest clusters of lightning detectors across Europe, USA and Australia, whilst Africa, Asia and South America remain devoid of detectors.

Handheld/mobile

Handheld lightning detectors allow users the opportunity to buy a detector easily from a retail store and set it up themselves instead of having to pay for a service or for lightning information. The cost of these devices varies according to the accuracy and design of the equipment. Such lightning detection instrumentation typically has limitations and the value of these portable devices requires consideration. They detect mostly the intensity of the electromagnetic pulse (EMP)[47] and are generally unable to detect cloud-to-cloud lightning (which usually precedes CG strikes), which is critical in recognising an approaching storm. Additional limitations include, but are not limited to, poor detection ranges, inability to determine direction or location of a lightning strike as well as interferences from other EMP-emitting devices (such as electrical equipment, fluorescent lights, appliances and even car engines), which may result in either missed strikes or false alarms. Examples of popular hand-held devices include the Ubertronix Strike Finder (Ubertronix, Inc. San Antonio, Texas, USA), designed to record lightning strikes during the day and night by using an infrared sensor and microcontroller-based technology,[48] while other options include the ThunderBolt Storm Detector (Storm Systems, Tampa, Florida, USA), SkyScan lightning detector (Extreme Research Corporation, Port Richey, Florida, USA) and the INO Weather Pro portable weather station (INO Technologies, Louisville, Colorado, USA).

Lightning detection in South Africa

Current lightning detection system

The SAWS had no role in measuring lightning activity prior to 2005.[49] Eskom, the major power utility of South Africa, operated a network of six Lightning Position and Tracking System lightning detection sensors.[50] Before this, the CSIR operated a lightning detection network of 400 lightning flash counters and was the first institution to produce a lightning flash density map for South Africa.[49]

Over recent years, the detection of lightning occurrences in South Africa has been undertaken by the SALDN, which is operated by the SAWS.[5] In 2005, the SAWS purchased a Vaisala, lightning detection network (LS 7000 and LS 7001, Helsinki, Finland), making South Africa one of only three countries in the southern hemisphere to operate such a network, with the others being in Brazil and Australia.[49] The network provided the SAWS with its first opportunity to explore lightning and also to provide lightning information to the public.[13] The network now consists of 24 sensors across the country.[5]

Lightning research initiatives

In recent years, the University of the Witwatersrand has participated in lightning research in South Africa and has been a key role player in the development of a multidisciplinary interest group called Lightning Interest Group for Health, Technology and Science (LIGHTS).[3] LIGHTS has been successfully running since 2015, contributing, disseminating and sharing vital information regarding lightning and lightning research in South Africa and within the broader African lightning community. The African Centres for Lightning and Electromagnetics Network (ACLENet) is a pan-African network of Centres that is dedicated to reducing infrastructure damage, injury and mortality resulting from lightning across Africa.[51] It operates as a not-for-profit and non-governmental organisation with national centres in Zambia, Malawi, Kenya and South Africa. The network consists of several research and technical advisors who are internationally recognised and serve voluntarily to advise ACLENet on education, research and grant proposals, mentor African researchers, supervise graduate studies and promote ACLENet worldwide. The ACLENet is designed to be user-friendly and can be translated online into Arabic, French, Portuguese, Spanish and Swahili. The network gathers and presents media articles about lightning injuries and deaths caused by lightning, which are listed by country. The Earthing and Lightning Protection Association (ELPA) is also a significant contributor towards the standard of safety in the South African lightning and protection industry. ELPA offers certification of qualified designers, installers and inspectors, with recognition by the University of the Witwatersrand, and the South African Institute of Electrical Engineers (SAIEE) amongst others.[52] LIGHTS, ACLENet and Eskom are among the collaborating institutions. ELPA has been established as a non-profit organisation of voluntary membership. The University of Zambia has also recently contributed towards the academic knowledge regarding lightning in Africa and has initiated an MSc and PhD programme in high voltage, electromagnetic compatibility, lightning studies and protection.[51]

In addition to the SALDN disseminating lightning warnings across South Africa via media broadcasts, a few other initiatives exist for alerting South Africans to possible threats from lightning. One such example is the WeatherBug application. WeatherBug is a mobile application brand owned by GroundTruth, a company based in New York City.[53] This mobile application provides near real-time lightning detection and provides alerts via the application. WeatherBug uses data from the Total Lightning Network (run by Earth Network) together with GPS location data from the users' mobile phones.[54] The Total Lightning Network dates to 2009, with initially most sensors existing in the USA. The network now covers areas of North and South America, Africa, Asia, Europe and Australia. AfricaWeather (Johannesburg, South Africa) is another example of a mobile application disseminating lightning warnings to South Africans. It is the only South African built application with lightning and storm detection capability.[55] The application provides basic free content (daily weather notices), while advanced features (including lightning proximity and lightning data) require a paid subscription. The online storm-tracking tool allows individuals to identify the location, intensity and time of recorded lightning strikes. AfricaWeather monitors the country's grounded lightning strikes using the Earth Network's (Germantown, Maryland, USA) Total Lightning Network.[55] Alerts are disseminated to numerous schools and golf courses across South Africa through a siren and spinning strobe light that is installed and maintained through a paying subscription, and to a list of specified contacts through SMSs.

Community-level lightning detection in South Africa: A new approach

Despite great strides being made in detecting lightning throughout the world, including South Africa, there remains a high number of lightning fatalities in many rural communities within developing countries such as South Africa. According to media articles and reports, several of these lightning fatalities occur whilst rural people are still present inside their homesteads. However, there is still a lack of literature that focuses on lightning detection within rural communities. Furthermore, no literature exists on determining effective approaches to communicate lightning data, threats and advance warnings in a manner appropriate for rural communities, as well as information on how to reduce lightning damage in rural dwellings. Such information is vital to assess risk knowledge as part of early warning systems, which is accounted for in the dissemination aspects to build response capabilities that will enable mitigation.

Based on the detection and warning systems reviewed, there are a number of community-level, automated possibilities available for South Africa that are appropriate for high-risk lightning areas. The first is that the national lightning detection network (SALDN) supplies areas with lightning warnings using the method employed by AfricaWeather. The second option includes a local measurement system, consisting of a single sensor/node. Numerous types of local measurement systems exist and continue to evolve. Examples of these stand-alone systems include the Boltek lightning detection systems (Port Colborne, Ontario, Canada) and the Campbell Scientific lightning warning systems (Logan, Utah, USA). These systems are not only capable of detecting lightning strikes, but are also capable of monitoring the electric field changes by using an electric field meter and providing warnings before the first lightning strike takes place. These systems are, however, expensive, but there are more cost-effective lightning flash sensors now included with some basic weather stations. The ATMOS41 by the METER Group (Pullman, Washington, USA) features a lightning strike counter with distance categories, as well as other meteorological sensors. A third approach includes identifying lightning prone communities using the SALDN and installing 'sacrificial towers' containing a lightning rod to divert the lightning pathway from dwellings.

Currently, in South Africa, the SALDN operates at a national level and has the capability of disseminating lightning data to a local level. However, this dissemination has not been implemented and rural communities continue to lack cognisance of the dangers of lightning. This remains a significant gap within lightning detection research in South Africa and a dire need exists to bridge the gap between the SALDN and rural communities.

Lightning detection challenges in South Africa

People residing in South Africa's rural areas are often outdoors due to work activities such as subsistence farming and livestock herding. Such individuals are the most prone to facing lightning-related risks.[24] The houses in rural communities are commonly not well earthed and provide little protection against lightning. Consequently, some lightning deaths occur whilst people are inside their homes. Many rural structures do not contain metal plumbing, electrical wiring or reinforcing steel that provide a pathway for a lightning current to be grounded.[24] Rural dwellings also do not have proper interior flooring, which increases the risk, as many deaths are due to ground currents from nearby lightning strikes, rather than direct strikes. Furthermore, rural housing often has thatched roofs or newspaper to insulate the roof, both of which are a fire risk.[24] Rural areas therefore lack lightning-safe shelters, and also have fewer fully enclosed metal-topped vehicles, leaving communities vulnerable to the threat of lightning. The economic implications and feasibility of building lightning-safe houses and structures as well as the installation of lightning detectors in high lightning risk areas requires further investigation. Investigation specifically into developing lightning-safe shelters is the key priority, and includes projects to fund and develop lightning safe shelters (such as schools, community halls, as well as lightning safe houses). This is urgently needed in South Africa where funders to support such initiatives are required. There also appears to be

no design criteria for establishing lightning-safe rural dwellings which is a critical need in South Africa.

Several cultural beliefs have been associated with lightning strikes (and thunder) in South Africa, which include mythical association. Indigenous South Africans have religious and traditional beliefs that lightning may be directed to strike someone, and that significant personality changes ensue after a lightning strike, and that it could be a sign of God's anger.[3,24,56] Such myths still exist and some hinder the necessity to take precautionary/mitigation measures, thereby increasing the risk of lightning injury.[56] This situation calls for the integration of selected relevant indigenous and scientific knowledge into educational packages that are relevant to rural community inhabitants.

The review of techniques shows that various lightning detection systems have evolved over recent years; however, the warnings are not disseminated well to rural communities. Various practical constraints such as poor network signals, a lack of knowledge and the cost of smartphones and data, are prohibitive to the success of such lightning detection systems. Consequently, rural communities continue to remain vulnerable to lightning threats.

Way forward and recommendations

Significant progress on South Africa's national lightning detection and monitoring has been achieved. Despite these advances, local level research and, more specifically, the vulnerability of rural communities to lightning incidence and threats require further attention as rural communities continue to live without any lightning warning. The proposed way forward for improving lightning detection on a local scale is through a system with monitoring and predictive capacity to improve the detection of lightning occurrences and assist rural communities in preparing for lightning through risk knowledge and near real-time/early warning systems is ultimately needed. This can be achieved through the communication and dissemination of alerts in a timeous and comprehensible manner in languages that are understood within specific communities. Building lightning-safe rural dwellings and shelters is also required as well as transformative adaptation. It has been shown that in rural areas using participatory research methodologies, as well as community-based adaptation planning, that adaptation can become an iterative co-learning process and facilitate transformative adaptation through the integration of indigenous knowledge with science-based systems. An opportunity therefore exists for bridging the gap between the existing SALDN and rural communities.

To raise awareness of lightning, a national lightning awareness week should be introduced to coincide with that run internationally to promote the magnitude of risks associated with lightning and how to minimise risks, especially in rural communities.

Conclusions

The current study provides a synthesis on the development and detection of lightning activity internationally and at a local level (South Africa). There are different lightning detection systems available, which vary in their spatial scale, detection and dissemination capability. The literature revealed significant and ongoing advances in detection methods, mainly using satellites, but the vulnerability of rural communities in countries like South Africa remains a challenge, mainly due to the insufficient dissemination of lightning warnings. The SALDN continues to accurately detect lightning activity at a national level but warnings are not disseminated to a local scale. Also, even if warnings are disseminated at a local scale, there are few lightning safe shelters/dwellings or fully enclosed metal-topped motor vehicles available in rural areas.

Myths and beliefs regarding lightning in rural areas also continue to remain a challenge in South Africa and hinder necessary precautionary measures. The national school education system needs to include lightning safety and the role of cultural beliefs associated with lightning. Education around lightning safety, the development of lightning safety protocols/guidelines and the involvement of multiple stakeholders – from community members and government extension officers to non-governmental organisations – is required.[56]

Acknowledgements

Competing interests

We declare that there are no competing interests.

Authors' contributions

M.M. was responsible for writing the initial draft. A.D.C. assisted with technical aspects, S.S. and M.J.S. with theoretical aspects and T.M. with community resilience aspects. A.D.C., S.S., M.J.S. and T.M. also provided supervision, assisted with reviewing and provided editorial contributions.

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