Thunderstorm warning systems in developing countries

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Abstract— **Numerous technological developments in recent years such as communication tools and the emergence of worldwide Lightning Locating Systems (LLS) make it possible to provide Thunderstorm Warning Systems (TWS) to protect people and property in developing countries. While there are still some issues to overcome, a first step consists in measuring the technical performance of TWS based on the GLD360 worldwide LLS for 6 places located on 2 continents and 6 countries. Finally, the results obtained exhibit performance levels relatively equivalent to similar studies conducted in Europe and the United States for example.**

Keywords—Thunderstorm warning systems (TWS), Lightning locating system (LLS), GLD360, Lightning protection, IEC 62793, Awareness.

I. Introduction

As it is estimated that 6,000 to 24,000 people are killed by lightning strikes each year worldwide [1], lightning injuries and deaths are a significant public health challenge, particularly in some developing countries [2] affected by a large number of thunderstorms and a lack of protected infrastructure to shelter. Being alerted to the imminent arrival of a thunderstorm can therefore contribute to effective protection, especially when people are in exposed areas, typically outdoors, and are warned with a sufficient lead time to find a lightning-safe-structure. The existence of shelter, itself protected against lightning or at least sufficiently protective, is essential and could raise question about the real interest of Thunderstorm Warning Systems (TWS) in certain areas where it is totally lacking. Nevertheless, when protection inside a brick, stone or cement-made refuge is possible, the risk is obviously lower to shelter inside than staying outdoor.

The aim of this study is to measure the effectiveness of TWS, based on Lightning Locating Systems (LLS) that currently covers all areas of the world, in order to determine whether this technical solution could effectively reduce the risk. In addition, some avenues are proposed for future consideration, with a view to implementing these solutions in developing countries.

II. Lightning detection and thunderstorm warning

We have chosen to study the implementation of a TWS in 6 randomly selected geographical locations in 6 different countries: Nepal, Bangladesh, India, Zambia, Uganda and Senegal. Located in developing countries, but not necessarily in the most urbanized areas, we have first checked on available satellite images, the presence of "solid" housing, necessarily required to shelter people. We then calculated the performance of an alert based on the Global Lightning Dataset GLD360 network owned and operated by Vaisala for each of these locations, in order to estimate the operational contribution of a TWS.

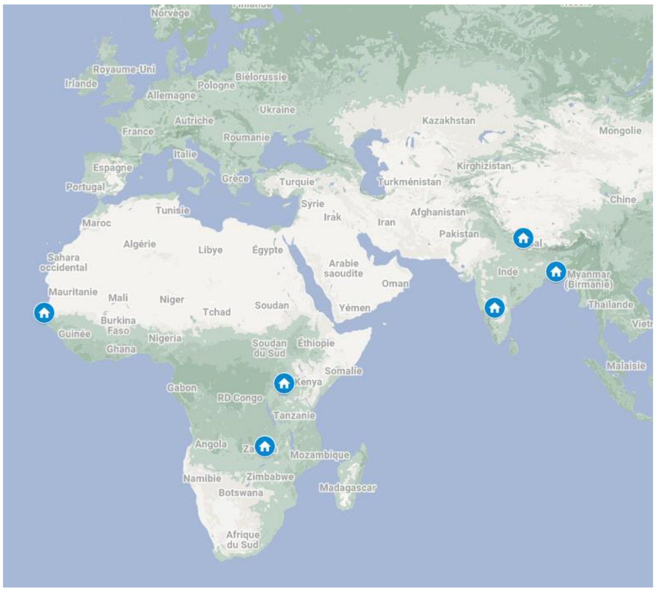

Fig. 1. Geographical location

A. *Lightning locating systems (LLS)*

Their principle is to detect the typical radio waves emitted in the atmosphere by the lightning discharges and to geo-locate them. As the wave propagates along the surface of the earth, very low frequency (VLF) ranges can be used with a lower efficiency than very high frequency (VHF) or low frequency (LF), but with significant improvements. Thus, the performance of GLD360 continue to increase and was around 80% in terms of detection efficiency (DE), for a median location accuracy around 2km in 2016 [3].

B. *Thunderstorm warning systems using LLS*

An existing and relevant method [4] consists in creating a monitoring area (MA) around a geolocated target to trigger an automatic alert message as soon as a 1st lightning discharge is detected within this zone. Given the possibility that the first lightning strike may occur on the site itself (overhead thunderstorm), this configuration must then be tested and optimized for each site to measure performance, considering local specificities in terms of lightning climatology. In our case, we have simply used a standard configuration that gives an initial idea of the performance of a TWS for each location, without seeking to optimize it. The configuration is based on a 25km radius circle MA, triggering on 1st discharge and a time to-clear (time between the occurrence of the last lightning discharge in the MA and the time when the alarm is released) of 60'.

An analysis of the scenario during a thunderstorm provides a concrete illustration of how this method works. Taking, for example, the case of a thunderstorm in the Dolpo region of Nepal on 07/27/2021 shown in Figs. 2-5.

During this situation, where a lightning related event (LRE) occurred at 13:47 in the target area, an alarm would have been sent at 11:39 or 12:19 depending on the type of discharge used. In general, intra-cloud (IC) are preferred to increase the lead time which is confirmed in the current case. At 16:30, one hour after the discharge occurred in the MA, the alarm would have been released.

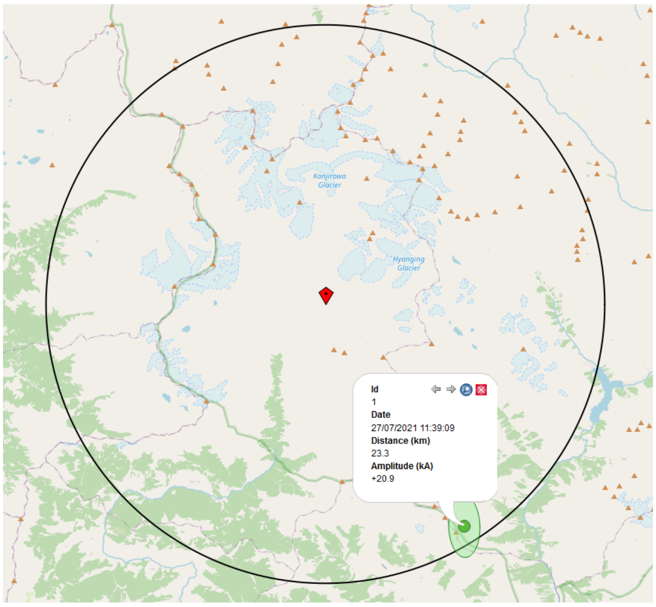

Fig. 2. Occurrence of the first intra-cloud (IC) discharge in the MA at 11:39

Fig. 3. Occurrence of the first cloud-to-ground (CG) discharge in the MA at 12:19.

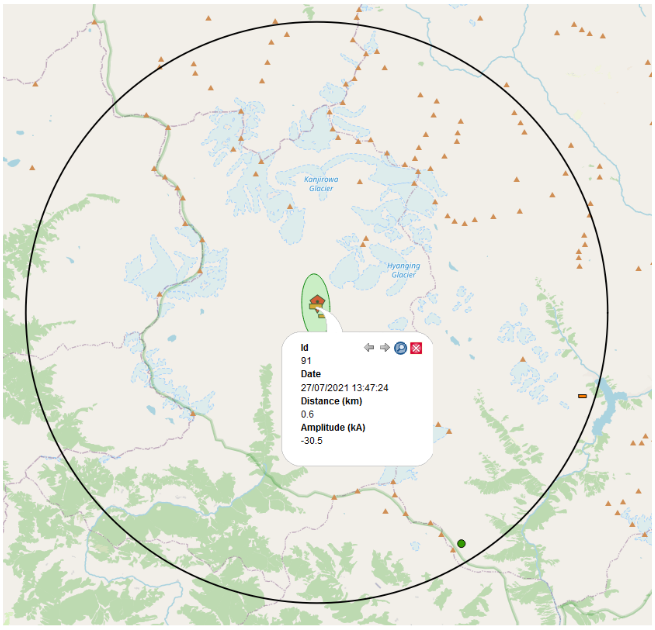

Fig. 4. Occurrence of the first lightning related event (LRE) at 13:47

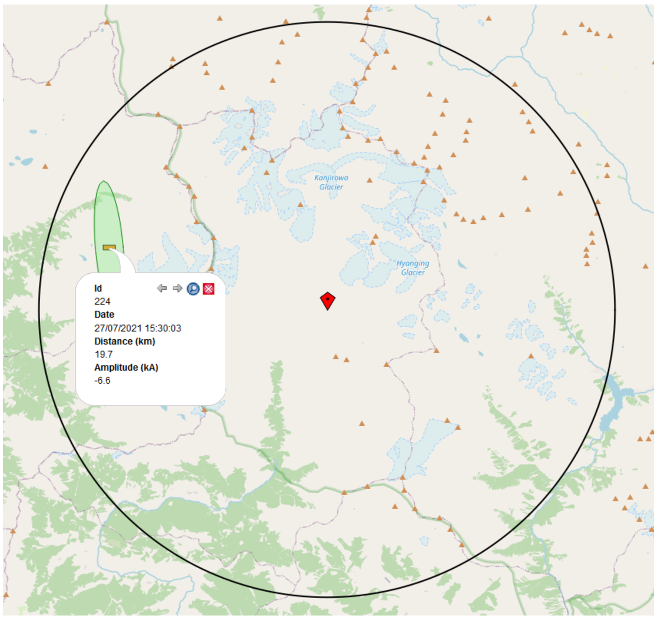

Fig. 5. Occurrence of the last discharge in the MA at 15:30

III. TWS PERFORMANCES FOR OUR 6 LOCATIONS

A. How to measure efficiency ? The method

The previous case illustrates a good efficiency of the method, as the alarm would have been sent more than one hour before the danger but must be confirmed on more thunderstorm events. We analysed all the thunderstorms that generated at least one LRE and calculated some performance indicators described in the IEC 62793 standard on TWS and defined as follow:

$$POD = \frac{EA}{EA+FTW} \quad (1)$$

$$FTWR = \frac{FTW}{EA+FTW} \quad (2)$$

$$PODx = \frac{EAx}{EAx+EA+FTW} \quad (3)$$

Where:
- POD means probability of detection.
- EA (effective alarm) is an alarm where a lightning related event (LRE) occurred.
- FTW (failure to warn) is the occurrence of LRE not preceded by an alarm.
- FTWR means failure to warn ratio
- “x” is the lead time (LT) in minutes necessary to apply procedures before the occurrence of LRE.

In addition, a LRE is defined as the occurrence of one or more cloud-to-ground (CG) events in the surrounding area, considered as a geographical area where a CG can cause a potential danger around the site. Four our study, we considered a 2 km radius area around the TWS location.

B. The results

- Thunderstorms and dangerous ones

The analysis covered 7 years of data over the period 2016-2022 with a total of 5490 thunderstorms, 682 of which with an LRE. Although this was not the aim of this study, these first results in Table I do provide some useful information. Finding out the proportion of thunderstorms that are actually dangerous can provide factual elements for awareness campaigns. While a little less than 1 in 6 thunderstorms heard or seen could, in reality, kill or injury people in Dakar, Ndola or Shapur, the risk is real that people would not take into account the dangerous one, as the others weren't so dangerous after all. In the extreme case of the Dolpo village, for example, less than 2% of thunderstorms seen or heard turned out to be dangerous as most of them strike to the west part as seen in figure 6. However, not all thunderstorms avoid Kaigaun, and it only takes one to kill you.

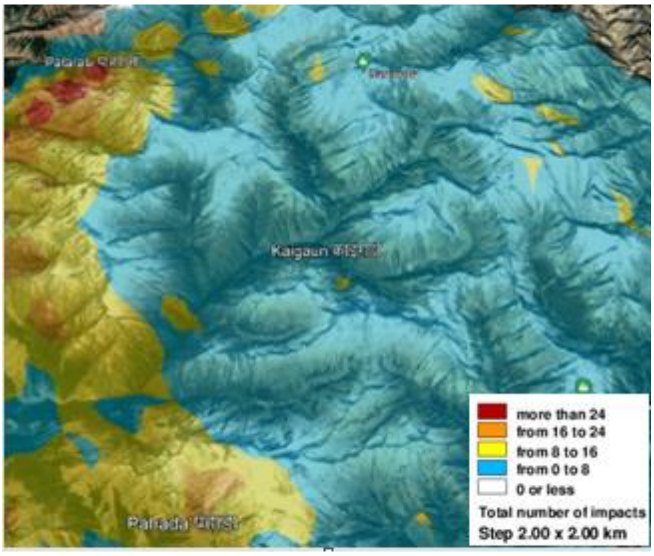

Fig. 6. Lightning density 2016-2022

TABLE I. NUMBER OF THUNDERSTORMS AND DANGEROUS ONES

Country	Type	Number of Thunder-storms	Number of Thunder-storms with LRE
Nepal	Small village in the Dolpo area	516	9
Senegal	Football ground (and school) near Dakar	253	44
Uganda	Fisherman Harbor on Victoria Lake	1772	156
Zambia	School near Ndola	1220	210
India	Isolated hamlet in Karnataka area	722	82
Bangladesh	High school in Shahpur	1007	181
Total		**5490**	**682**

- Warning performances

Despite the fact that the thunderstorms were located on different continents, the results were highly homogeneous, and an overall effectiveness can therefore be determined. In 98% of cases, on average, the LRE would have been preceded by an alert, the case of overhead thunderstorm with the 1st discharge occurring directly in the target being limited to 2%, confirming the relevancy of the method. Only the case of the village located in Dolpo area achieves slightly lower results, but this is due to the small number of events (9, compared with 210 for Zambia and 181 for Bangladesh, for example). It should also be noted that lead time exceeds 15' for 9 out of 10 dangerous thunderstorms, and 30' in 76% of cases in standard configuration, i.e. with room for improvement.

TABLE II. EFFECTIVE ALARMS AND FAILURE TO WARN

Country	Type	Effective alarms (EA)	Failure to warn (FTW)
Nepal	Small village in the Dolpo area	8	1
Senegal	Football ground (and school) near Dakar	44	0
Uganda	Fisherman Harbor on Victoria Lake	151	5
Zambia	School near Ndola	206	4
India	Isolated hamlet in Karnataka area	82	0
Bangladesh	High school in Shahpur	177	4
Total		**668**	**14**

TABLE III. POD AND POD WITH RESPECT TO 15’ LEAD TIME

Country	Type	POD	POD15’
Nepal	Small village in the Dolpo area	89%	78%
Senegal	Football ground (and school) near Dakar	100%	89%
Uganda	Fisherman Harbor on Victoria Lake	97%	88%
Zambia	School near Ndola	98%	88%
India	Isolated hamlet in Karnataka area	100%	90%
Bangladesh	High school in Shahpur	98%	88%
Total		**98%**	**87%**

IV. THE OTHER KEY SUCCESS FACTORS

Just as the existence of long-range networks represents an opportunity for developing countries, other technological developments can also encourage the implementation of TWS.

The dissemination of information is a crucial point that can prove particularly complex, and the development of social networks such as Whatsapp or Telegram opens interesting possibilities for mass dissemination of information to the public. We can also look at other alternatives such as "cell broadcast"[5], which enables the systematic dissemination of an alert around a given geographical point, or some other broadcasting protocols such as the common alerting protocol (CAP) promoted by the World Meteorological Organization (WMO) [6] which allow to disseminate alarms through TV, radio, social media or SMS.

Finally, educating the public through awareness campaigns, and sometimes also demystifying the risk posed by lightning, is a fundamental element of a TWS. In this respect, the role of NGOs such as ACLENet [7] can prove essential in supporting local structures with limited resources or expertise.

V. Conclusion and Discussion

Lightning is sometimes considered as a "natural disaster" [8], particularly in developing countries which are often located in areas where it strikes often, and where there is a lack of infrastructure to protect people and property. Alongside the installation of Lightning Protection Systems and awareness-raising campaigns, numerous technological developments can enable the implementation of TWSs to effectively protect people and property. As part of them, the opportunity offered by lightning detection networks covering the whole world for countries that cannot afford the luxury of investing in the installation and maintenance of lightning detection networks. A number of aspects need to be explored in greater depth, but as some TWS are already proving their effectiveness, this should not be a barrier to their emergence in the future.

Acknowledgment

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