2014 International Conference on Lightning Protection (ICLP), Shanghai, China

Lightning Occurrence Density in Guinea

Mamadou Lamine Bah
Department of Meteorology
Conakry, Guinea
lamine_bah@yahoo.fr

Mamadou Tounkara
Department of Meteorology
Conakry, Guinea
m_tkra@yahoo.fr

Chandima Gomes
Centre for Electromagnetics and Lightning Protection
Universiti Putra Malaysia
Serdang, Malaysia
chandima.gomes@gmail.com

Ari Davidov and Jim Anderson
Earth Networks-WeatherBug
Germantown, MD, USA
adavidov@earthnetworks.com

***Abstract*—This paper presents the preliminary results of the lightning detection system installed in Guinea, a coastal country in West Africa. This is the first time an automated lightning detection system has been installed in the region. The lightning hotspots and cold spots in the country have been identified and the pattern of lightning occurrence has been compared with the thunderstorm occurrence density data collected by ground based meteorological observations. A comprehensive discussion is made on the applications of information obtained from lightning detection system in Guinea and in the region.**

Keywords-lightning detection, isokeraunic level, ground flashes, density, Guinea, West Africa

I. INTRODUCTION

Guinea is a country in the western part of Africa, with geographic coordinates between 7°05 and 12°51 of northern latitude and 7°30 and 15°10 of western longitude. The country is bordered by Guinea-Bissau from North West, Senegal from North, Mali from North and North East, Côte d'Ivoire from East and South east, Liberia, from South, Sierra Leone from South West and Atlantic Ocean from West (Figure-1)

Guinea has a total land area of 245,857 km². The country has been divided into four main geographical sections. i.e.

> Lower Guinea: A lowland belt running north to south behind the coast which is part of the Guinean forest-savanna mosaic ecoregion;
>
> Middle Guinea: The pastoral Fouta Djallon highlands of the mid-country mountains
>
> Upper Guinea: The northern savanna landscapes
>
> Forest Guinea: Southeastern rain-forest region

Each of these regional segments corresponds to unique climate with characteristics of temperature, rainfall, soil, fauna, flora and relief. The hydrographic network unequally set out again between these four zones.

Apart from highlands in the mid-country, most parts of the country; the coastal region and the inland, has a tropical climate. The dry season, during which the north-easterly Harmattan winds prevail, lasts from November to April with October to December showing mixed nature (non-uniform dry and wet seasons based on the year concerned). The rainy season, which is governed by African western monsoon, lasts for 5 to 7 months (April-October) and characterised by season is relatively high and uniform temperatures, southwesterly winds, and high humidity. Thunderstorms very often appear during the rainy season (June and October). The distribution of this rainfall is non-uniform both in space and time. The precipitation depends on the latitude, topography and the continentality.

Figure-1: Map of Guinea and its neighbourhood. The blue pentagons show the locations of the 12 mobile communication tower sites where the EN lightning detection sensors have been installed.

The average annual rainfall in the country is 4,300 mm (169.3 in). Maxima rainfall are situated in Conakry (3700 mm) and Macenta (2700 mm); the minima are observed in the northern part (in Siguiri and Koundara with 1200 mm and 1100 mm respectively). Upper Guinea has a shorter rainy season and greater daily temperature variations.

The maxima temperature (superior to 30°C) is recorded in March-April in the north zone and the lowest temperature is observed in December-January in the Fouta-Djallon region (lower to 10°C in Labé). In Costal area and Forest area, average maximum moisture is high (more than 90%). The air is drier (less than 20% RH in January – March) on Mountainous slopes and Savana area, especially in dry season, when the Harmattan breathes.

Africa is known for lightning accidents over the last few decades as per both published and unpublished literature [1-10]. However due to the absence of a lightning detection system in the entire region prevented implementation of safety schemes and identification of lightning hot spots. In 2013 this drawback in the region was eased up to some extent as a countrywide lighting detection system, developed by Earth Networks has been installed. This study is the first attempt to provide lightning density maps of Guinea with detailed discussion on application of data.

II. Methodology

EarthNetworks has developed and operates a severe weather nowcasting system, the EarthNetworks Total Lightning System (ENTLS), that uses cloud-to-ground and in cloud lightning information to deliver localized and automated severe weather warnings as well as radar-like, national scale precipitation estimates to national and hydrological services and other government and industrial users.

The system is a total lightning detection network (detecting both cloud to ground and cloud flashes) from a single, compact sensor which is a wideband electrical field recorder operating at 1 Hz to 12 MHz frequency range. The system is designed to detect cloud flashes beyond the line of sight with high efficiency. It uses a dual digital signal processor, where lightning electric field waveforms are recorded and transfer red in real-time data transmission at nano-second GPS timing. In Guinea 12 sensors have been installed in strategic locations as it is depicted in Figure-1. The sensor locations are less-spaced closed to the coastal region due to the high lightning density and population density in that part of the country. The sensors have been installed in mobile communication towers operated by several communication service providers of the country.

The system can discriminate ground flashes and cloud flashes in addition to the locating of ground flashes at 100 m precision. The system can also differentiate positive ground flashes from negative ground flashes. For all types of lightning the peak current is also provided. In this study, the lightning density information observed for the 6 month period from July/2013 to December/2013 will be presented. Based on the results, we are in the process of analyzing the variation of ground flash density (negative, positive and total), cloud flash density and cloud flash to ground flash ration over the period. Furthermore, we also are in the process of analyzing the peak current of first return stroke and subsequent strokes. However, due to lack of preparation time these data will not be presented.

In addition to the data collected from the automated lightning detection system, we also present the meteorological observations made at 24 weather stations on number of storm days to compare the lightning density mapping done with automated detection system. The data presented on average thunderstorm days per year has been collected over 30 years by ground based observation stations spread over the country.

III. Results and Discussion

Figure-2 shows the variation of thunderstorm-days per year in the four regions of guinea throughout the year. The data shows that all four regions show somewhat similar variations where the storm density is coincided with April-December rainy season. During most of the wet months (May-September) Middle Guinea with mountainous landscapes show highest storm occurrence pattern, which is closely followed by Savannah regions of Upper Uganda. October is characterized by high thunderstorm density in all four regions. From October to May the Forest Uganda, the rainforests in the southern inland, tops the storm occurrence pattern.

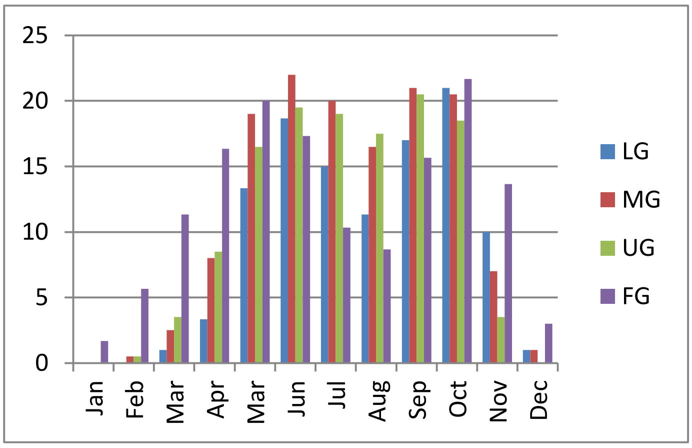

Figure-2: Average Storm occurrence pattern during the year. LG: Lower Guinea, MG: Middle Guinea, UG: Upper Guinea and FG: Forest Guinea

Figure-3 depicts cloud-to-ground flash (ground flash) maps in Guinea of the months from July to December 2013. Figure-4 and 5 depicts similar maps for cloud-to-cloud flashes (cloud flashes) and total flashes (cloud-to-ground + cloud-to-cloud).

It can be seen that the lightning density is in agreement with storm occurrence pattern that has been obtained by meteorological data. It is envisaged that March and July may have high lightning density in par with the storm occurrence pattern.

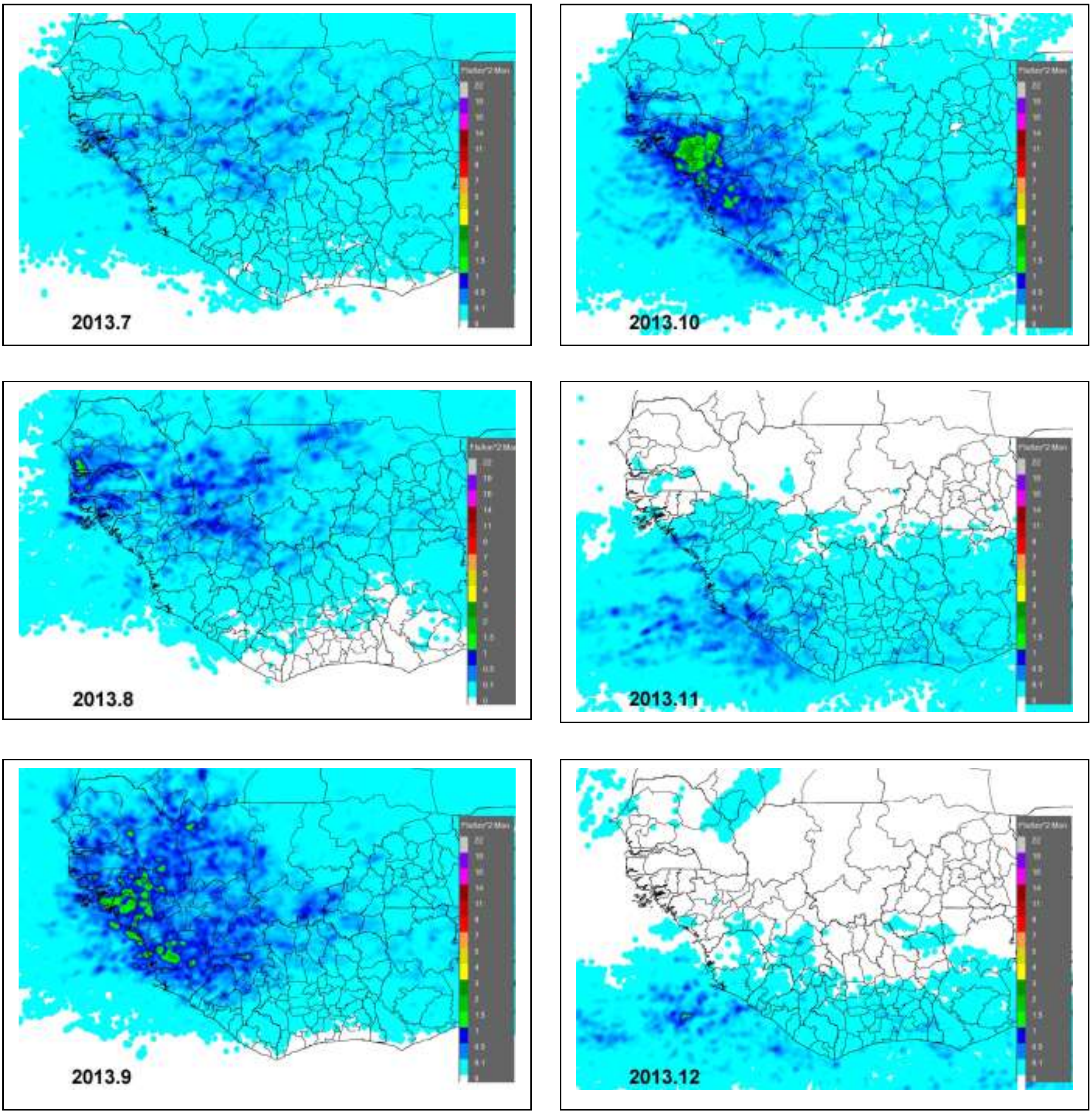

Figure-3: Lightning ground flash occurrence maps in Guinea from July to December 2013

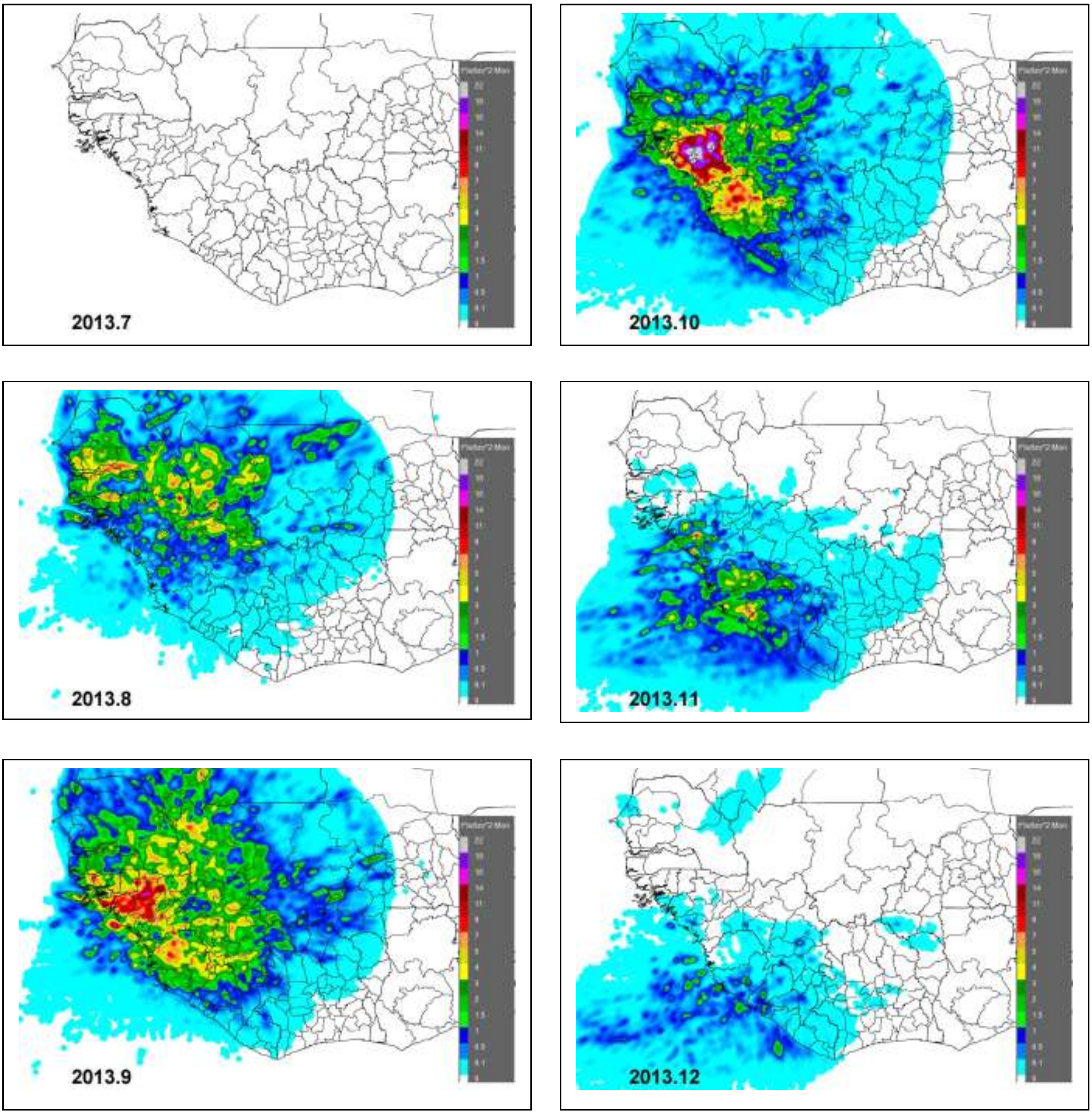

Figure-4: Lightning cloud flash occurrence maps in Guinea from July to December 2013

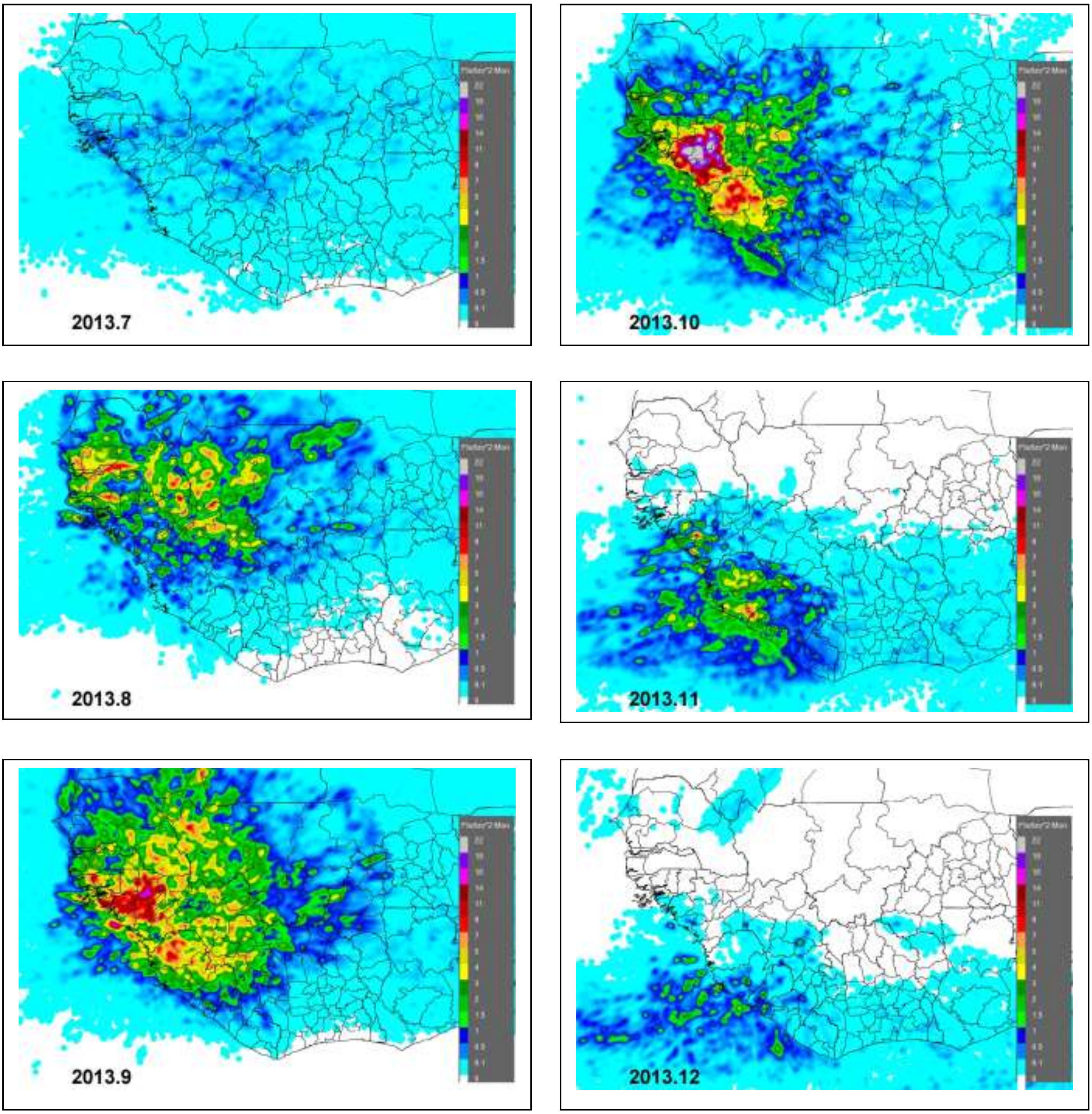

Figure-5: Total lightning flash (Ground flash + Cloud flash) occurrence maps in Guinea from July to December 2013

The maps in Figure 3-5 also shows that the lightning density in guinea is more prominent in the coastal land areas. Unfortunately these areas include the cities with highest population densities and industrial hubs of the country; Conakry, Fria, Kamsar. This fact further enhances the need for lightning mapping systems for the country in order to plan the development of industrial zones avoiding lightning hotspots. The country is undergoing rapid industrial development at the moment, thus lightning maps with accumulated data for at least 5 years is required for adequately conclude upon the hotspots. Hence, one can conclude that the present detection system is well-timely and it needs further enhancement in the region.

This pilot project in Guinea is a good example to show that how lightning detection could provide a quick and relatively cheap way for poor countries to acquire basic weather services. According to the data available from several other African countries, lightning takes a large number of human lives and livestock every year [1-10]. Unfortunately, none of the countries in the continent have lightning detection systems installed. Hence, the thunderstorm forecasting in the region is most often an unreliable estimation with high position and timing errors. However, the installation of the lightning detection system in Guinea has made it move from rough forecasts to real-time storm tracking within few months after the installation.

The biggest challenge in in implementing such systems in low-income countries such as Guinea is the cost factor. One solution adopted by the installers in this case is to use already erected mobile communication structures and their communication facilities for the installation of the lightning sensors. This choice reduced the installation and maintenance cost, however at the expense of the system continuity strongly depending on the infrastructure of a third party. The expenditure of the system developers, Earth Networks, in this project is around USD one million. Still the cost of that is much lower than that of even a simple Doppler radar system which would cost around $10 million.

Another obstacle at present is the lack of expertise in countries such as Guinea for routinely maintenance, trouble shooting in the event of system breakdown, and software/system development to suit the country. Such drawbacks make the maintenance and uninterrupted operation of lightning detection network an uphill task in the long run..

The most important part of the project is to make the system data and information available to the public. As in countries in Africa are fast moving ahead with mobile phone usage the best way of conveying the thunderstorm forecasting is sms alert. Now the Guinea project is making the ground work to start such mobile phone alerting system with the help of the telephone service providers.

It should also be noted that the traditional method of collecting information on thunder days to construct the isokeraunic level of a country has never been a reliable technique [11]. Apart from various human errors, recording deficiencies and data compilation errors the empirical formulae that are used to compute lightning ground flash density from thunder days per year data always have a large uncertainty [11]. Hence, the significance of a ground-based lightning detection system can never be compared with station based human observers that collect thunder day data.

IV. CONCLUSIONS

In this paper we have presented the initial results of the first lightning detection system installed in Africa. The system operates in Guinea a country in the West African coast. The network can nowcast lightning flashes, both cloud-to-ground and cloud-to-cloud. Although the detailed analysis are not presented in this paper, the system can discriminate negative ground flashes from positive and also depict the multiplicity and stroke currents.

There are many challenges in installing, operating and maintaining lightning detection system in a developing country such as Guinea. The high initial cost, fragile infrastructure, unreliable networking, lack of expertise for maintenance etc. are few such challenges. The dissemination of information among public, especially those in high lightning density areas, is treated as the most significant part of the project. Mobile phone alerting has been identified as the best mode of conveying the thunderstorm forecasting among such people.

ACKNOWLEDGMENT

Authors would like to thank the Earth Networks, the Department of Meteorology, Guinea and the Department of Electrical and Electronics Engineering, Universiti Putra Malaysia for their invaluable support in making this study a success.

REFERENCES

1. Mulder M. B., L. Msalu, T. Caro, and J. Salerno, Remarkable rates of lightning Strike mortality in Malawi, PLoS One, vol. 7:1, doi: 10.1371/journal.pone.0029281, January, 2012.
2. Akello R. J. and M O Ogada, Lightning activities in East Africa, 19th International Lightning Detection Conference, Tucson, Arizona, USA, 24-25 April 2006
3. Blumenthal R. Lightning fatalities on the South African Highveld – a retrospective descriptive study for the period 1997 - 2000. Am J Forensic Med Pathol, 26(1):66-69, 2005
4. Blumenthal R., E. Trengrove, I. R. Jandrell and G. Saayman, Lightning medicine in South Africa, S Afr Med J., 102(7):625-626, 2012
5. Dlamini W. M., Lightning fatalities in Swaziland: 2000 – 2007, Natural Hazards 50(1):171-191, 2009
6. Gijben M., lightning climatology of South Africa with a special focus on lightning risk maps, 22nd International Lightning Detection Conference, Broomfield, Colarado, USA, 2-3 April, 2012
7. Lubasi F. C., C. Gomes, M. Z. A. Ab Kadir and M. A. Cooper, Lightning Related Injuries and Property Damage in Zambia, 31st International Conference on Lightning Protection-2012, Vienna, Austria, September, 2012

8. Mary A. K. and C. Gomes, Lightning safety of under-privileged communities around Lake Victoria, Geomatics, Natural Hazards and Risk, June, 2014, http://dx.doi.org/ 10.1080/19475705.2014.922506

9. Mary A. K. and C. Gomes, Lightning Accidents in Uganda, 31st International Conference on Lightning Protection-2012, Vienna, Austria, September, 2012

10. Meel B. L., Lightning fatalities in the Transkei sub-region of South Africa. Medicine, Science and the Law 47(2):161-164, 2007

11. Gomes C. and M. Z. A. Ab. Kadir, A Theoretical Approach to Estimate the Annual Lightning Hazards on Human Beings, Atmospheric Research, 101, 719–725, 2011