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Spatial and Temporal Distributions of Malawi Lightning in January 2017

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Abstract—Detailed distributions of lightning over Africa have not been analyzed with data from ground-based lightning detection networks, except for South Africa. Of special interest is Malawi, where a very large lightning fatality rate was reported by Mulder et al. (2012). Data from the Global Lightning Dataset GLD360 have been analyzed. During January 2017, 363,204 strokes were detected, resulting in a stroke density of 3.1 strokes km⁻². As a result, this moderate lightning density is not consistent with the extremely large lightning fatality rate of Mulder et al. Spatially, the largest lightning frequency occurs in districts over Lake Malawi and on the adjacent western shore. Lowest stroke densities occur in the southern and western districts. In time, 10% of the January lightning strokes occurred on only one day. Details of the January stroke occurrence will be presented, but further examination with a larger dataset is indicated.

Keywords—Malawi, Africa, lightning density, lightning occurrence

I. INTRODUCTION

During the rainy season, particularly between December and February, newspapers often contain stories of lightning fatalities across Malawi. For example, in the past two rainfall seasons of 2015-2016 and 2016-2017, the media reported at least 15 lightning incidences, which led to at least 21 deaths. A

study of lightning mortalities indicated that Nkhata Bay, a district in Northern Malawi, has a remarkable annual lightning-caused mortality rate of 84 per million people [Mulder et al., 2012]. Published estimates for other African nations are 5.3 deaths per million people per year for South Africa, 15.5 for Swaziland, 0.9 for Uganda and 14 to 21 for Zimbabwe [references in Holle, 2016]. The annual lightning-caused mortality rates are estimated to be 6 per million for developing nations, and less than 0.5 for developed countries [Holle, 2016].

The government of Malawi is greatly concerned with fatalities that are caused by lightning. The government, through the Department of Climate Change and Meteorological Services (DCCMS), disseminates thunderstorm warnings and advisories to the public to minimize such losses. These messages are too general due to lack of information on the distribution of lightning across Malawi. In this study, lightning data are used to identify the times of lightning during January 2017, as well to map the spatial distribution of lightning over Malawi. Such maps may be used by governmental and non-governmental agencies for lightning related programs and services. For example, DCCMS may use such maps to develop lightning warnings and advisories that are specific for regions with large lightning densities.

Global maps of the distribution of lightning have been depicted with the Global Lightning Dataset GLD360 network [Holle, 2016] and with satellite observations [Albrecht et al., 2016]. National lightning climatologies have long been

published for the United States, as reviewed in Holle et al. [2016]. They have also been summarized in such publications as for Europe by Anderson and Klugmann [2014], for Japan by Sugita and Matsui [2014], as well as numerous other nations and regions. However, the only recent national-scale lightning density map over Africa was published for South Africa [Gijben, 2012]. Thus, details of the variations of lightning in Malawi are only implied from global maps, and temporal changes are not available at present. Note that one of the global maxima in lightning is located several hundred km to the north and west of Malawi over the eastern Democratic Republic of the Congo [Albrecht et al., 2016; Holle, 2016]. In this research, we will therefore look at the spatial and temporal distribution of lightning strokes within Malawi for the first time.

II. GEOGRAPHY, CLIMATE AND DEMOGRAPHY OF MALAWI

Malawi is located in the southeastern part of Africa between latitudes $9^{\circ}22'$ and $17^{\circ}08'S$ and longitudes $32^{\circ}40'$ and $35^{\circ}55'E$ (Fig. 1). The country is approximately 860 km in length from north to south and 250 km wide at its broadest point [Carter and Bennet, 1973]. It is well known for its fresh water lake (Lake Malawi), which is the third largest and second deepest in Africa and falls within the notable geological feature of the Great East African Rift Valley. Malawi has a total area of approximately 118,000 km². The land area is 94,000 km² and surface waters (principally Lakes Malawi, Chilwa, Chiuta and Malombe) account for the other 24,000 km². Malawi's population is approximately 17 million.

Malawi's relief ranges in altitude from 30 m above sea level in the lower Shire area (southernmost part of Malawi) to 3,000 m on Sapitwa peak (Mulanje Mountains) in southeast Malawi. The three major physiographic divisions are the Shire Valley and the Lake Malawi coastal areas which are below 500 m; medium plateau areas such as the Shire Highlands and plains of the Central Region and the Mzimba plain in the north of Malawi, which are between 1,200 and 1,400 m above sea level and highland areas which are above approximately 1,500 m [Pike and Rimmington, 1965].

The country experiences two seasons, a cold season (winter) and hot season (summer). The cold season starts in May and ends in August. During these months there is no or little precipitation so it is called a cold dry season. The hot season is subdivided into two seasons, the hot dry season that spans September to October and the hot wet season that spans November to April. Significant precipitation falls in the hot wet season that is caused by the interaction of the Intertropical Convergence Zone, Congo air sources, cyclones in the Mozambican channel (between Madagascar and the Mozambican coast), easterly waves, and convergence of easterlies from Mascarene high and south easterlies from a high-pressure area off the Durban coast. These rainfall-bearing systems are convective in nature such that rainfall is mostly associated with thunderstorms [Kumbuyo et al., 2014].

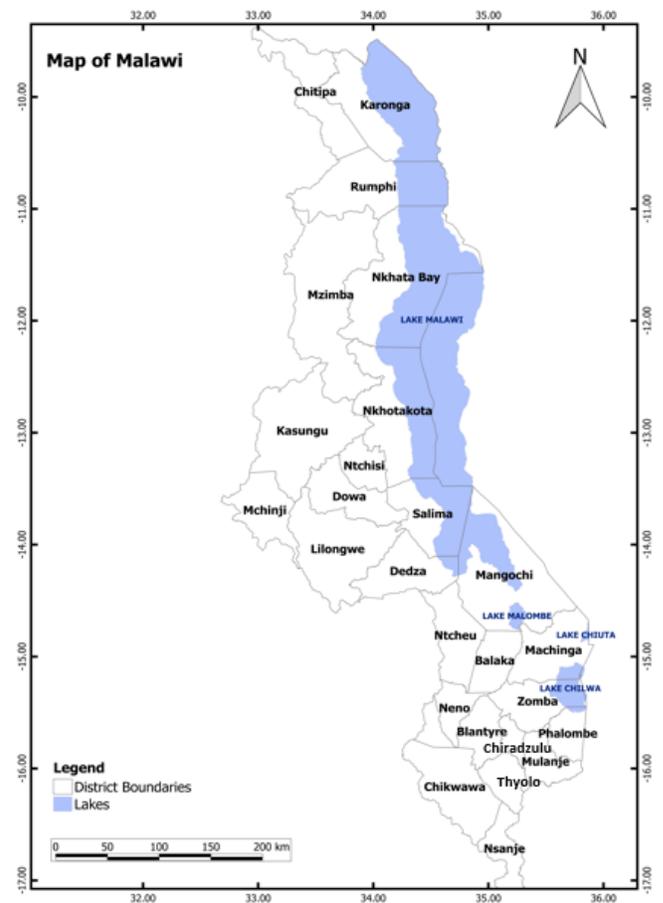


Fig. 1. Map of Malawi showing districts and major water bodies.

III. DATA AND METHOD

A. Data

In this study, lightning data were obtained by Vaisala's Global Lightning Dataset GLD360 network for the month of January 2017. This month was chosen as the most active in recent years of GLD360 data collection. GLD360 data are generated by a Vaisala owned and operated network of sensors distributed throughout the globe. Individual lightning discharges are located in near real-time by a central processor that aggregates sensor data from the entire network. Using electronics sensitive to the very low frequency (VLF) band, each sensor is capable of detecting lightning discharges over 6000 km away. This sensitivity, coupled with the wide distribution of sensors, enables the network to achieve relatively uniform performance over most areas of the globe. GLD360 provides an estimated 40 to 50% cloud-to-ground flash detection efficiency in this region. The dataset has not been corrected for detection efficiency. The median cloud-to-ground stroke location accuracy is estimated to be 5 km. Some in-cloud flashes are detected but individual strokes are not separately classified [Poelman et al., 2013; Pohjola and Mäkelä, 2013; Said et al., 2013; Mallick et al., 2014].

The GLD360 data were obtained in ASCII format and included date and time (UTC), latitude and longitude (in decimal degrees) and peak current [in kiloAmperes, with polarity of either positive (+) or negative (-)]. Signal strength and polarity variations are not examined in this study.

B. Method

GLD360 stroke data were processed with Microsoft Excel 2016, IBM SPSS Statistics 20 software and further analyzed and plotted with Quantum GIS Desktop 2.14.15 –ESSEN. Data from ASCII files were imported into IBM SPSS statistics software and Microsoft Excel. Databases for monthly, weekly and daily strokes were then created in Excel and the databases were converted into file formats that are readable by Quantum GIS. Shape files for monthly, weekly and daily strokes were created from database files and imported to QGIS software. More topographic datasets, for example, shape files for district boundaries and Lakes were obtained from the Department of Geological Surveys. All data that were plotted in QGIS were projected to the Arc 1950 coordinate reference system.

In order to understand lightning distribution patterns in January 2017, 22 km by 22 km grids were created by QGIS software. Then weekly lightning strokes database files for individual weeks were loaded to calculate the count of strokes per these square grids. Counts of lightning strokes were assigned to specific color using the BYG spectrum where blue = minimum counts and red = maximum counts. The resulting color-coded grids were overlain on district boundary shape files.

IV. RESULTS AND DISCUSSION

A. January 2017 stroke distribution

A total of 363,204 lightning strokes were recorded by GLD360 in Malawi during January 2017; peak currents ranged from -715.1 to +478.5 kiloAmperes. Fig. 2 summarizes the daily stroke counts for January while Table I gives basic statistical measures of lightning strokes during the course of this month

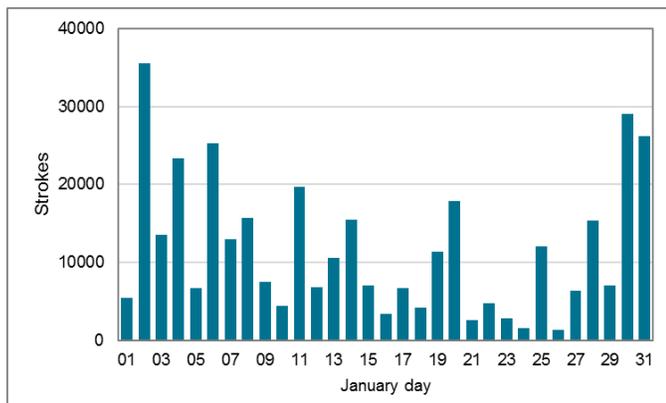


Fig. 2 Lightning strokes detected by GLD360 on each day of January 2017.

TABLE I. LIGHTNING STROKE STATISTICS FOR JANUARY 2017

Total strokes in January	363,204
Average strokes per day	11,716
Standard deviation	8,833
Minimum strokes per day	1,411
Maximum strokes per day	35,503

From Fig. 2 and Table I, note that in January, lightning is not evenly distributed by day. The highest number of strokes occurred on the 2nd with 35,503 strokes and the lowest on the 26th with 1,411. The average number of strokes per day in January was 11,716 with a standard deviation of 8,833. The spatial distribution of strokes for January in Fig. 3 shows that lightning occurred in all 28 districts of Malawi during the month.

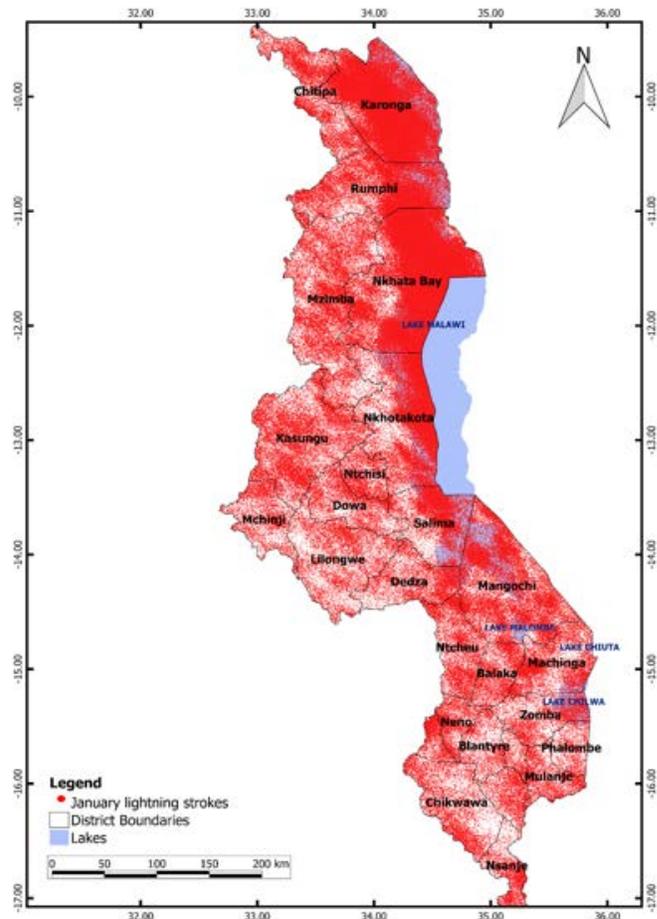


Fig. 3 Point plot of 363,204 strokes detected by GLD360 over Malawi in January 2017.

B. Weekly stroke distributions

A weekly analysis of lightning strokes is illustrated in Fig. 4. The largest number occurred in the first week of January when 122,843 strokes were recorded, and the smallest number was in the third week when 53,296 strokes were recorded.

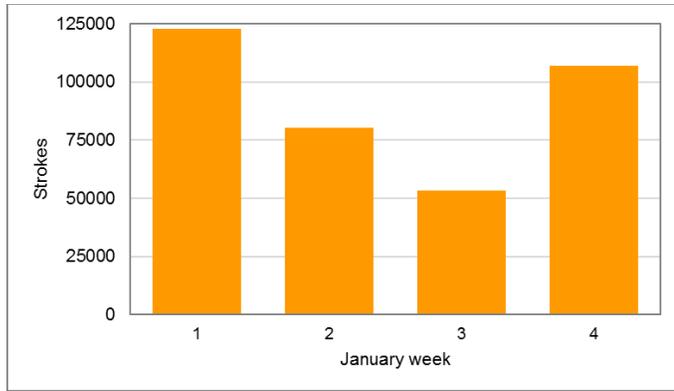


Fig. 4 Weekly distribution of of 363,204 strokes detected by GLD360 over Malawi in January 2017.

C. Week 1 from 01 to 07 January

A The distribution of lightning through week 1 is plotted in Figs. 5 and 6 using point and grid formats respectively. Lightning was recorded in all districts, especially over the lakeshore districts of Nkhata Bay, Karonga, Khotakota, and Salima and over Lake Malawi. Relatively large counts were recorded in Machinga, Mwanza, Neno, Phalombe, Ntchisi, Dowa, Kasungu and Mzimba. Small amounts occurred over Nsanje, Nkhotakota, Mangochi, and Chikwawa, and relatively small counts occurred over Ntheu, Deza, Chikwawa, Salima, Mzimba and the Nkhata Bay border.

The largest number of detected strokes on any day in January 2017 occurred on the 2nd (Fig. 7). Lightning was recorded in almost all districts except Nsanje. The lightning stroke count on this day was very high in Nkhata Bay and Machinga while Neno, Mchinji, Chitipa, Rumphi, Karonga and Lilongwe districts also recorded a relatively high stroke count.

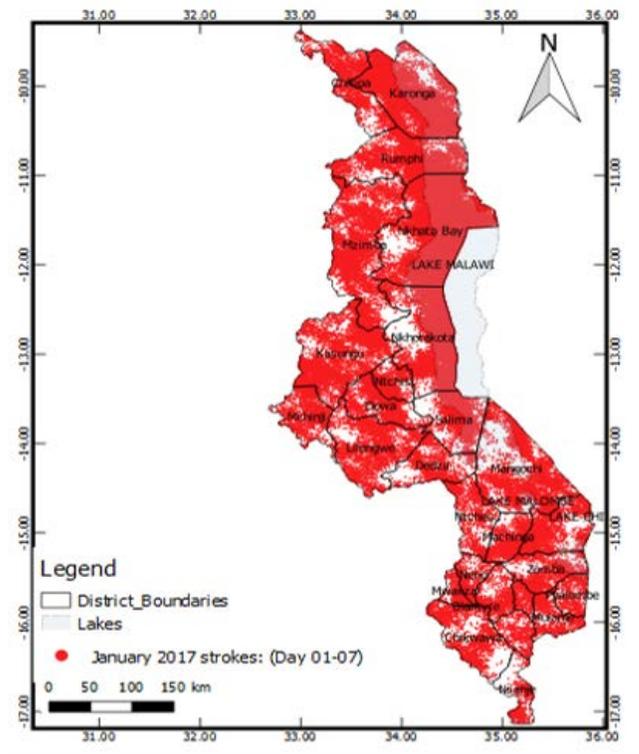


Fig. 5 Point plot of strokes over Malawi during the first week of January 2017.

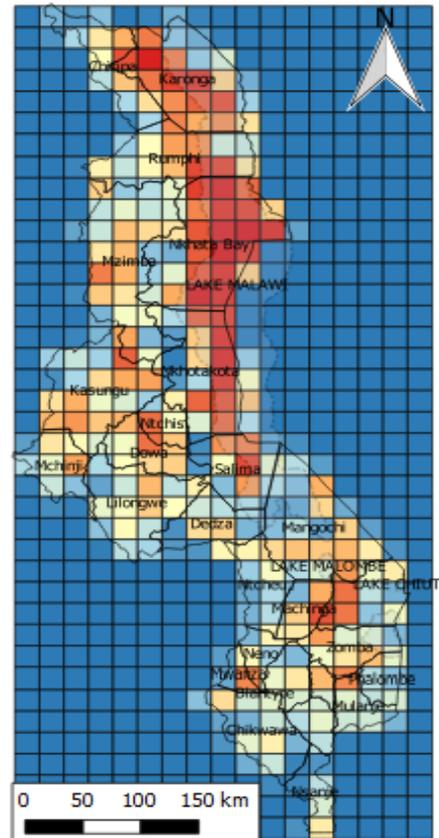


Fig. 6. Gridded distribution of strokes over Malawi during first week of January 2017.

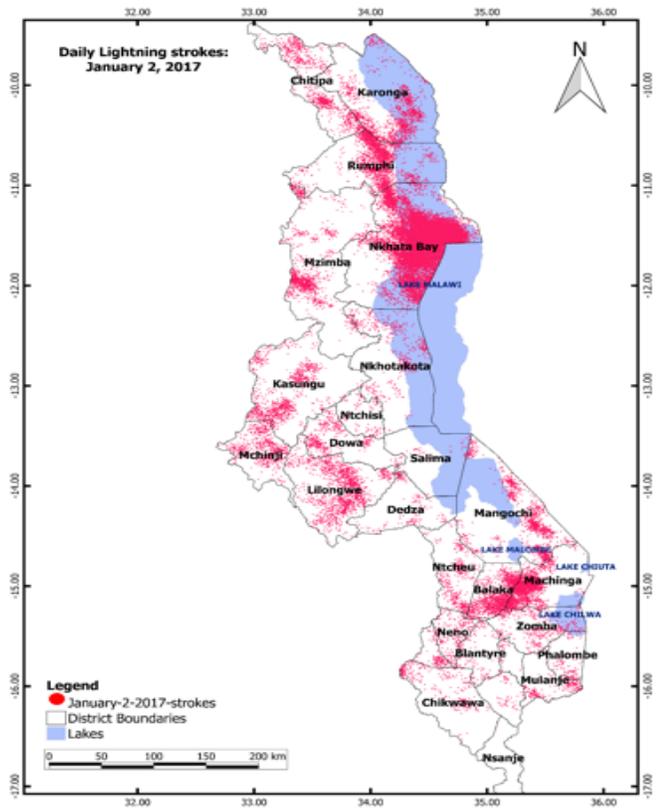


Fig. 7 Point plot of strokes over Malawi on 02 January 2017.

D. Week 2 from 08 to 14 January

The daily stroke counts during week 2 are highly variable (Fig. 2). The week 2 distribution of lightning using point and grid formats are shown in Figs. 8 and 9. Strokes occurred in all districts of Malawi (Fig. 8). According to the gridded map (Fig. 9), large counts were recorded over the Karonga, Rumpfi, Nkhata Bay, Salima, Neno, Nkhotakota and Mulanje districts. Relatively large stroke counts were recorded over Chitipa, Kasungu, Ntchisi, Mzimba, and Nsanje. Districts which had sparse occurrence include Mchinji, northwest of Lilongwe, Chikwawa, north of Nsanje, Phalombe, north of Ntcheu and Dedza West

Fig. 10 shows a sample on 11 January when the highest stroke count for the week occurred. The distribution of lightning strokes on 11th corresponds well with the weekly distribution of strokes. Lightning occurred mostly in the eastern part of the Northern Region (mostly within the Lake Malawi coast) in Karonga, Rumpfi and Nkhata Bay districts while in the Southern Region more strokes occurred in Mulanje, Neno, east of Zomba (within Lake Chilwa) and north of Balaka district.

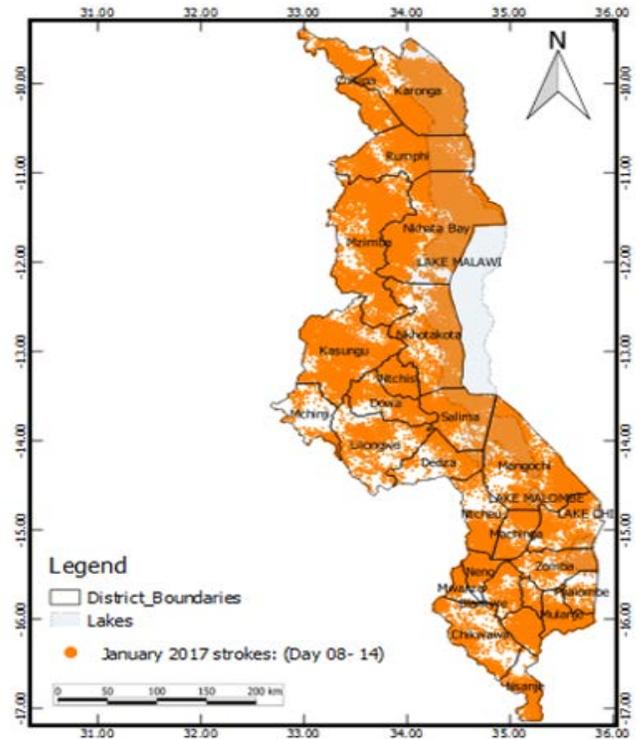


Fig. 8 Point plot of strokes over Malawi during second week of January 2017.

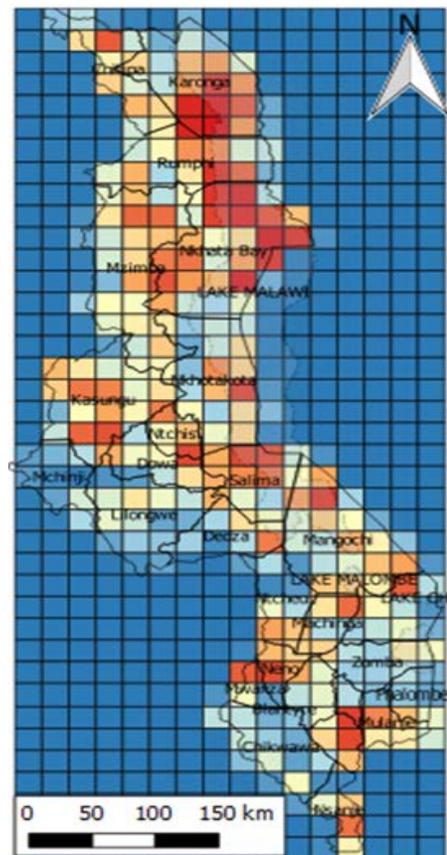


Fig. 9 Gridded distribution of strokes over Malawi during second week of January 2017.

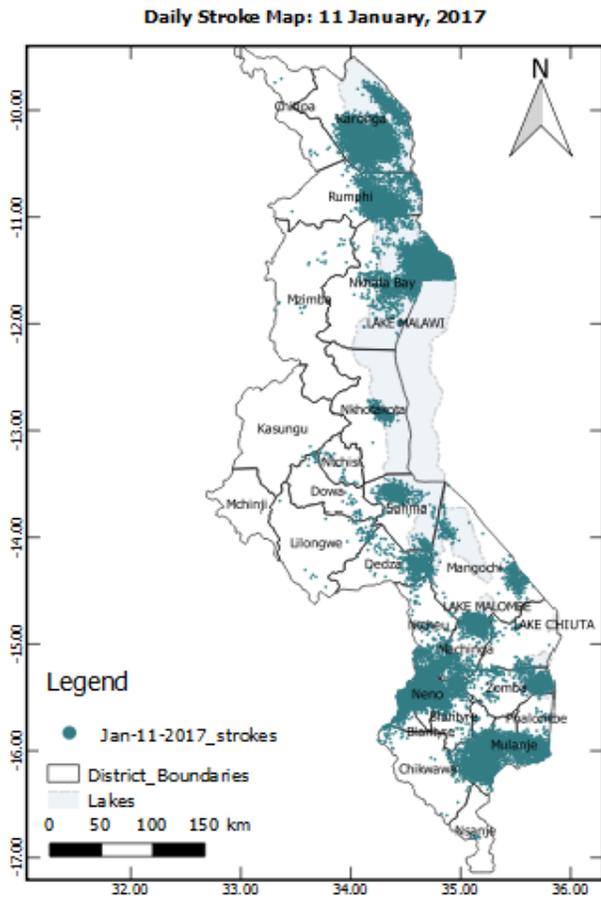


Fig. 10. Point plot of strokes over Malawi on 11 January 2017.

E. Week 3 from 15 to 21 January

The daily stroke counts during week 3 are variable but mainly lower than during other weeks (Fig. 2). The distribution of lightning through week 3 using point and grid formats is shown in Figs. 11 and 12. In the Northern Region, lightning was concentrated in the eastern part of Karonga (within the Lake Malawi locale), north and south of Chitipa, east of Rumphi (mostly within the Lake Malawi locale), Rumphi northwest, and the entire lake vicinity of Nkhata Bay to the east and west of Mzimba. Similar to the pattern in the north, strokes in the Central Region were more concentrated east of Nkhatakota (mostly the Lake Malawi coast), west of Kasungu, east of Salima, Dedza east and Ntcheu east. On the other hand, only a few districts had more lightning strokes in the Southern Region, for example, Mangochi, east of Zomba (within Lake Chilwa), Mwanza and western part of the Chikwawa district. Districts that had sparse occurrence include Nkhotakota, Ntchisi, Dowa, Lilongwe, Mchinji, Balaka, Mulanje, Phalombe, Chiradzulu, and Thyolo.

A sample daily map for the 20th, the day with the largest stroke count for the week, is in Fig. 13. Lightning only occurred in a few districts in the Northern Region (Chitipa, Karonga and Nkhata Bay); Central Region (Dedza, Nkhotakota and Salima) and only Mangochi in the Southern Region such that most strokes occurred within the Lake Malawi region.

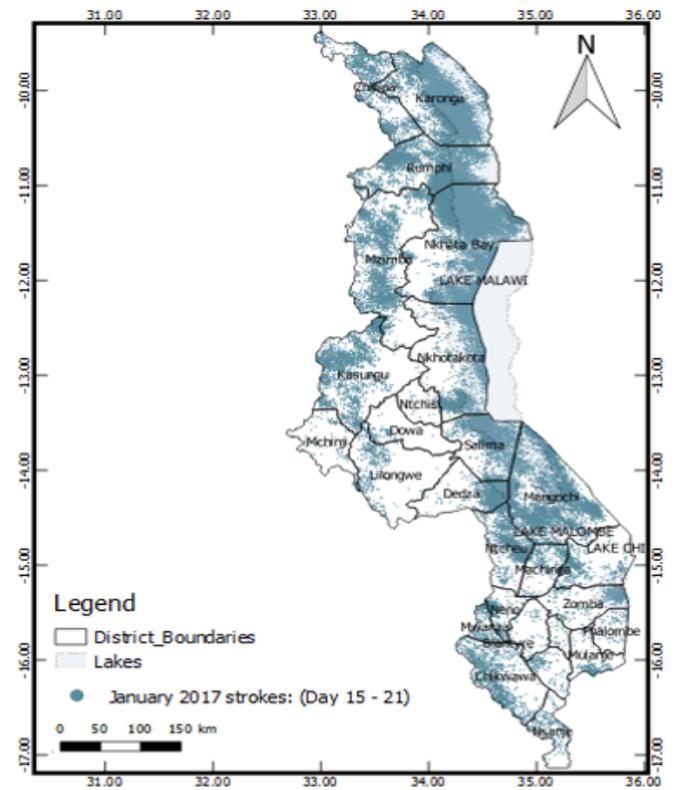


Fig. 11. Point plot of strokes during third week of January 2017.

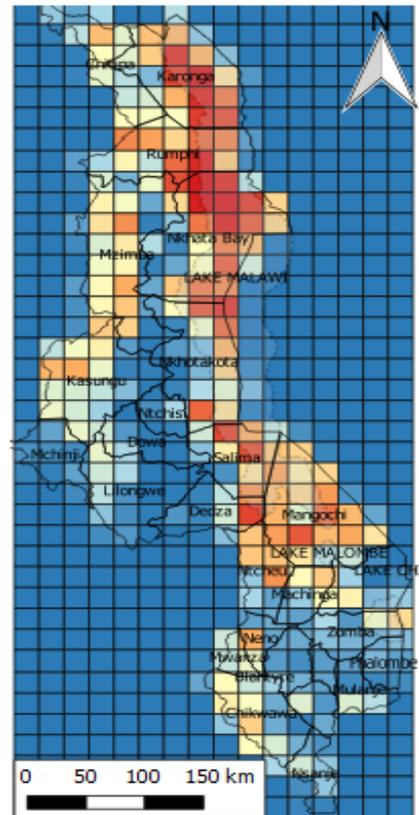


Fig. 12. Gridded distribution of strokes over Malawi during third week of January 2017.

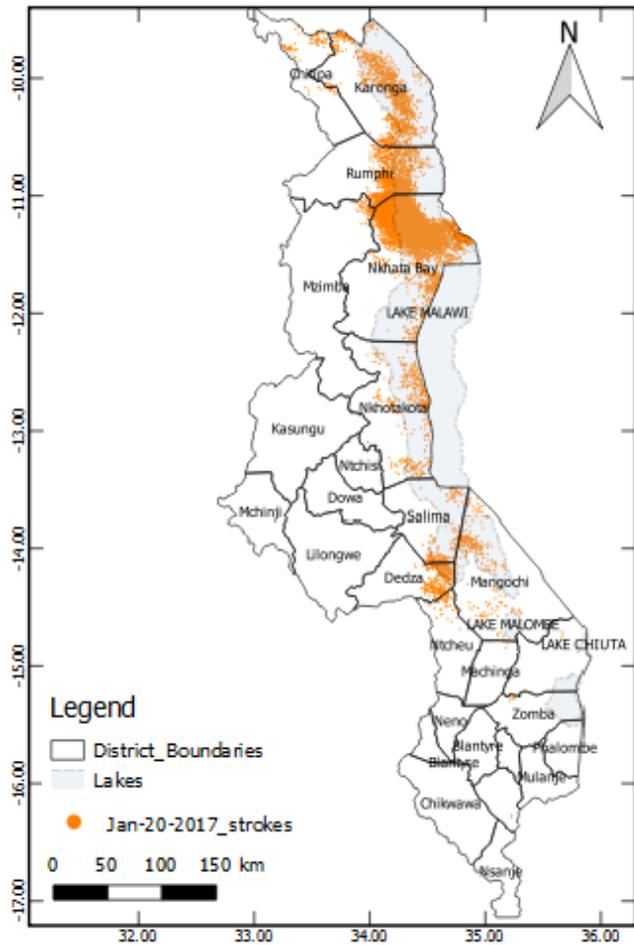


Fig. 13. Point plot of strokes over Malawi on 20 January 2017.

F. Week 4 from 22 to 31 January

Most of the lightning strokes in this final January week occurred on the last two days of the month. The distribution of lightning through the entire week is shown in Figs. 14 and 15. Many lightning strokes occurred in the Northern Region in northern Karonga (mostly on the lakeshore), eastern Rumpfi (mostly lakeshore areas), and northeastern Nkhata Bay (mostly the lakeshore areas). Few strokes were recorded over Salima and Lilongwe in the Central Region and Blantyre, Chiradzulu, Machinga and Thyolo in the Southern Region.

Lightning for the 30th, the day with the highest stroke count for the week, is in Fig. 16. On this day, strokes mostly occurred in the Northern Region (mostly along the lakeshore) in the following districts: north of Karonga, eastern Rumpfi and northeast Nkhata Bay. In addition, a few strokes were detected over the Central and Southern Regions north of Ntchisi, east of Lilongwe, Cape Maclear in Mangochi, the central areas of Ntcheu and Machinga, western Zomba, north of Blantyre, and most areas of Phalombe, Mulanje South and Nsanje.

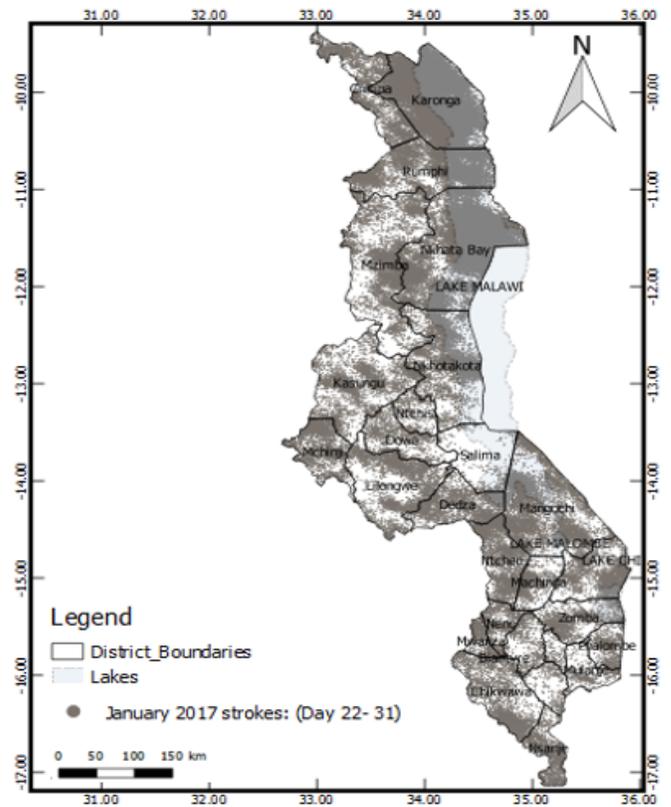


Fig. 14. Point plot of strokes during fourth week of January 2017.

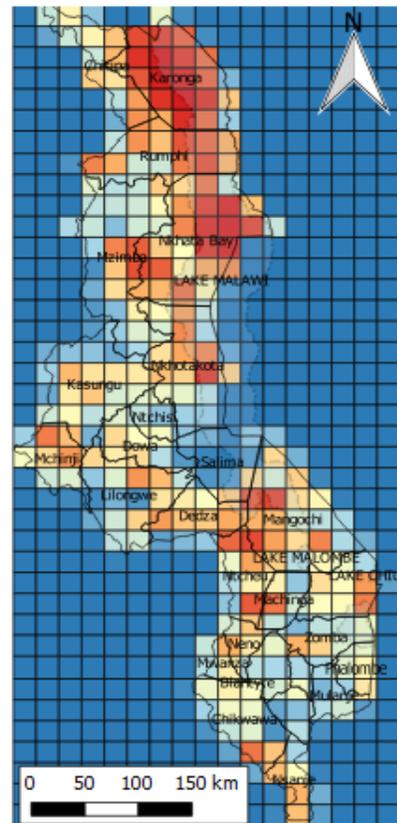


Fig. 15. Gridded distribution of strokes over Malawi during fourth week of January 2017.

V. CONCLUSIONS

A summary of lightning stroke counts by district is given in Table II for January 2017. A full-year dataset is indicated as desirable for a more complete description of lightning occurrence over Malawi. Table II divides the count into a scale of five categories based on the number of detected strokes. The distribution of lightning in Malawi for January 2017 shows that the largest concentration of lightning strokes occurs over Lake Malawi and on landmasses near Lake Malawi. Lakeshore districts near Lake Malawi experience frequent lightning. The number of lightning strokes decreases variably away from the coast of Lake Malawi. A rapid decrease in the number of strokes away from the lake is noted over the Nkhatakota and Mangochi districts. These districts show high counts on the lake interior of the districts and low counts over land adjacent to the lake and to the land that is further away. A moderate decrease in the number of lightning strokes away from the lake is noted over Salima while a minimal decrease is noted over the Karonga and Nkhata Bay districts. Using these premises, we can conclude that the Karonga and Nkhata Bay districts experience the highest numbers of strokes. Other districts with high stroke counts are Rumphi (mostly eastern part) and a part of Nkhatakota district that lies in the lake. Relatively high counts of lightning strokes occur over Salima, Neno, Rumphi (western part), and Mangochi (eastern part).

Furthermore, a number of districts experience a moderate stroke count, including Mzimba, Kasungu, Mulanje, Blantyre, Dowa, Ntchisi, Balaka, and Mwanza. Relatively low counts are experienced over Chitipa, Dedza, Machinga, Zomba, Thyolo, and Chiradzulu. Low counts were recorded over Chikwawa, Mchinji, Ntcheu, Lilongwe, Phalombe, and Likoma.

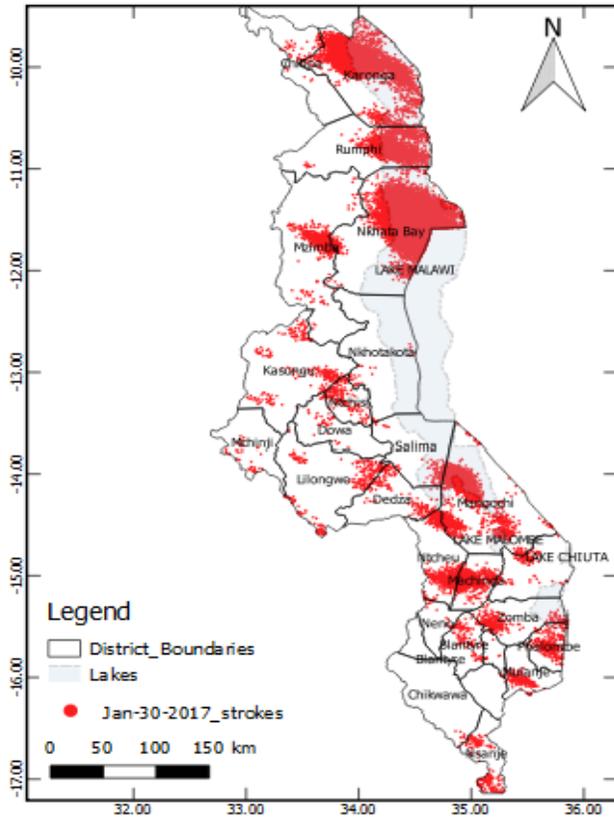


Fig. 16. Point plot of strokes over Malawi on 30 January 2017.

TABLE II. CATEGORIZATION OF JANUARY 2017 STROKE COUNTS OVER THE 28 DISTRICTS OF MALAWI

	Categories				
	High lightning stroke counts	Relatively high lightning stroke counts	Moderate lightning stroke counts	Relatively low lightning stroke counts	Low lightning stroke counts
Districts	Nkhata Bay Karonga Nkhatakota (over Lake Malawi)	Mangochi (eastern part) Rumphi (eastern part) Salima (eastern part) Neno	Mzimba Kasungu Mulanje Blantyre Dowa Ntchisi Balaka Mwanza	Chitipa Dedza Machinga Zomba Thyolo Chiradzulu	Chikwawa Mchinji Ntcheu Lilongwe Phalombe Likoma Nkhatakota (western part)

REFERENCES

- Albrecht, R. I., S. J. Goodman, D. E. Buechler, R. J. Blakeslee, and H. J. Christian (2016), Where are the lightning hotspots on Earth?, *Bull. Amer. Meteor. Soc.*, 97, 2051–2068.
- Anderson, G., and D. Klugmann (2014), A European lightning density analysis using 5 years of ATDnet data, *Nat. Hazards Earth System Sci.*, 14, 815–829.
- Carter, G. S., and J. D. Bennet (1973), *The geology and mineral resources of Malawi*, Government printer, Zomba.
- Gijben, M. (2012), The lightning climatology of South Africa, *S. African J. Sci.*, 108, Article 740, doi:10.4102/sajs.v108i3/4.740.
- Holle, R. L. (2016), A summary of recent national-scale lightning fatality studies, *Weather, Climate, and Society*, 8, 35–42.
- Holle, R. L., K. L. Cummins, and W. A. Brooks (2016), Seasonal, monthly, and weekly distributions of NLDN and GLD360 cloud-to-ground lightning, *Mon. Wea. Rev.*, 144, 2855–2870.
- Kumbuyo, C. P., H. Yatsuda, Y. Kitamura, and K. Shimizu (2014), Fluctuation of rainfall time series in Malawi: An analysis of selected areas, *Geofizika*, 31, 13–28.
- Mallick, S., V. A. Rakov, T. Ngin, W. R. Gamerota, J. T. Pilkey, J. D. Hill, M. A. Uman, D. M. Jordan, A. Nag, and R. K. Said (2014), Evaluation of the GLD360 performance characteristics using rocket-and-wire triggered lightning data, *Geophys. Res. Lett.*, 41, 3636–3642.
- Mulder, M. B., L. Msalu, T. Caro, and J. Salerno (2012), Remarkable rates of lightning strike mortality in Malawi, *PLoS One*, 7(1), 09 January, doi: [10.1371/journal.pone.0029281](https://doi.org/10.1371/journal.pone.0029281).
- Poelman, D. R., W. Schulz, and C. Vergeiner (2013), Performance characteristics of distinct lightning detection networks covering Belgium, *J. Atmos. Oceanic Technol.*, 30, 942–951.
- Pike, J. G., and G. T. Rimmington (1965), *Malawi: a geographical study*, Oxford University Press, London.
- Pohjola, H., and A. Mäkelä (2013), The comparison of GLD360 and EUCLID lightning location systems in Europe, *Atmos. Res.*, 123, 117–128.
- Said, R., M. B. Cohen, and U. S. Inan (2013), Highly intense lightning over the oceans: Estimated peak currents from global GLD360 observations, *J. Geophys. Res. Atmos.*, 118, 6905–6915.
- Sugita, A., and M. Matsui (2014), The frequency of lightning activity in Hokkaido as observed by the JLDN from 2000 to the present, paper presented at the 5th International Lightning Meteorology Conference, Vaisala, Tucson, 4 pp.