2016 24th International Lightning Detection Conference &
6th International Lightning Meteorology Conference
18 - 21 April | San Diego, California, USA

Performance Characteristics of the Lightning Location System of Guangdong-Hongkong-Macau after the Upgrade in 2012

Yijun Zhang [1], Weitao Lu [1]
1. Chinese Academy of Meteorological Sciences
Beijing 100081, China

Luwen Chen [1,2] Qilin Wan[2]
2. Guangzhou Institute of Tropical and Marine Meteorology/Guangdong Provincial Key Laboratory of Regional Numerical Weather Prediction, CMA
Guangzhou 510080, China

***Abstract*—In this paper, the performance characteristics of the GHMLLS was re-evaluated based on observations of lightning flashes triggered during 2012-2014. The results showed that the flash detection efficiency and stroke detection efficiency was about 87% and 86%. The arithmetic mean and median value of location error was estimated to be about 402 m and 200 m. The arithmetic mean (median) value of the absolute percentage errors of peak current estimation was 39% (40%), being significantly smaller than their directly measured counterparts. Compared with the performance characteristics of GHMLLS before 2012, When the number of sensors of GHMLLS was significantly increased in 2012, the detection efficiency and location precision are found to be obviously improved, but the peak current were further underestimated.**

Keywords—GHMLLS; performance evaluation; triggered lightning; peak current estimation

I. INTRODUCTION

Lightning location systems (LLSs) have been widely applied in many countries and regions as pivotal equipment for lightning detection. Several LLSs have been set up in Guangdong Province, China. Among which. the Guangdong-Hongkong-Macau Lightning Location System (GHMLLS) was jointly established by the Guangdong Meteorological Bureau, the Hong Kong Observatory and the Macao Meteorological and Geophysical Bureau since 2005, when 5 IMPACT sensors were set, then, one more IMPACT sensor was added in 2007. In 2012, the GHMLLS was upgraded and 11 LS-7000 sensors were integrated into the lightning location network. In 2014, the performance characteristics of the GHMLLS was evaluated based on observations of lightning flashes triggered at the Guangzhou Field Experiment Site for Lightning Research and Testing during 2007-2013, and natural lightning flashes to tall structures in Guangzhou during 2009-2012 [Zhang et al, 2014]. However, for the evaluation of peak current estimation, the mean range-normalized signal strength (RNSS) in so-called LLP units from the Total Lightning Processor (TLP) software during 2012-2013, was mistaken for the peak current in kA units. In this paper, the RNSS reported by the GHMLLS was converted to the peak current in kA units following the empirical field-to-current conversion equation proposed by Cummins et al [2006], and the performance characteristics of the GHMLLS was re-evaluated based on observations of lightning flashes triggered during 2012-2014.

II. EXPERIMENT AND DATA

Fig 1 shows the distribution of sensors of GHMLLS, which has been unchanged since 2012. The combined MDF/TOA technology is used to detect CG lightning stroke information such as longitude and latitude, GPS time, peak current, polarity, reporting sensors, error ellipse, etc.

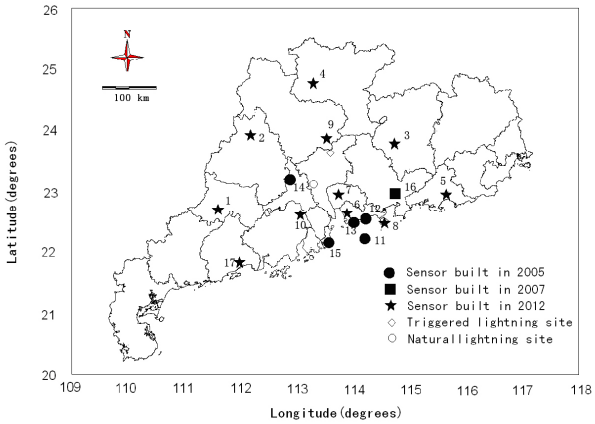

Fig.1 Distribution of sensors of GHMLLS (Zhang el al, 2014).

The rocket-triggered lightning experiment is conducted at Conghua, Guangzhou. A coaxial shunt with a resistance of 1 mΩ, measurement range of 0-100 kA, and bandwidth of 0-200 MHz, was used to measure the base current in the triggered-

lightning channel. During 2012-2014, a total of 15 lightning flashes containing at least one return stroke were successfully triggered. All the 15 lightning flashes are negative and triggered by classical method. The 15 lightning flashes contain a total of 81 return strokes. The peak current measurement of the single-stroke flash triggered on 19th May, 2013 is not available. The peak currents ranged from about -3.0 ~ -41.5 kA for the rest 80 return strokes. Fig 2 shows the distribution of the peak currents of the 80 return strokes. The GHMLLS database records were directly searched within ±2 ms before and after the GPS time stamp of each return stroke. As the result, the matched GHMLLS record was found to be within ±1 ms for the matching results.

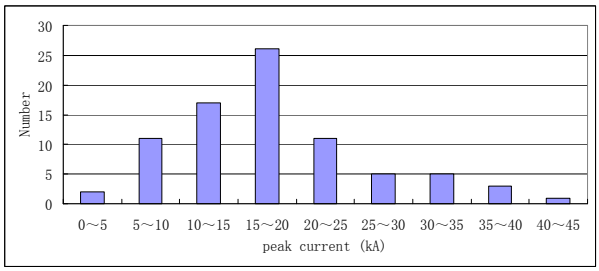

Fig.2 Distribution of peak currents

III. RESULTS

A. *Detection Efficiency*

During 2012-2014, the GHMLLS detected 13 flashes out of the 15 triggered flashes, and 70 strokes out of the all 81 strokes. Table 1 shows the detection of triggered lightning by GHMLLS.

Table 1. Summary of Flashes and Strokes Recorded in Triggered Lightning Experiment during 2012-2014, Along with Corresponding GHMLLS Detection Efficiency

Year	Number of Triggered flashes	Number of detected flashes	Flash DE	Number of confirmed strokes	Number of detected strokes	Stroke DE
2012	2	2	100%	8	7	87%
2013	5	4	80%	27	25	93%
2014	8	7	88%	46	38	83%
Total	15	13	87%	81	70	86%

Note that the 2 flashes missed by GHMLLS are both single-stroke flash, one peak current measurement of which is -5.9 kA while the other one is not available. The stroke detection efficiency of GHMLLS is found to be 100% when the peak current is greater than 25 kA, but drop to 58% when the peak current is smaller than 10 kA. Fig 3 show the stroke detection efficiency as a function of the peak current.

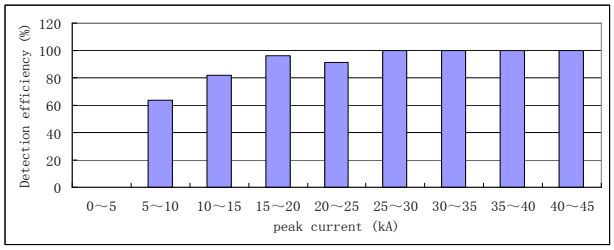

Fig.3 Stroke detection efficiency versus the peak current

B. *Location Accuracy*

The location errors were in the range of 60 - 3,530 m . The arithmetical mean location error was about 402 m, while the median location error was about 200 m. Figure 4 shows the spatial distribution of location errors for the 70 triggered lightning strokes detected by GHMLLS during 2012-2014. As a matter of convenience, the actual lightning stroke points are unified to the original point (0,0).

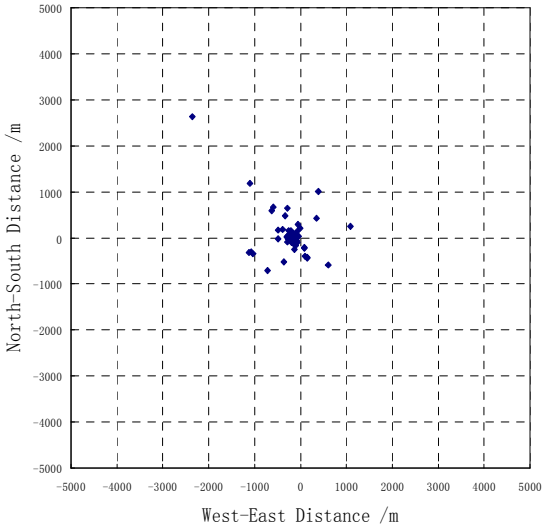

Fig 4. Plots of GHMLLS locations versus the corresponding actual strike point （0,0）

C. *Peak current estimates*

Just like the NLDN, the GHMLLS uses the following empirical field-to-current conversion equation (Nag et al., 2014):

$$i_p = 0.185 * \text{Mean(RNSS)} \qquad (1)$$

where i_p is the peak current in kA and mean range-normalized signal strength (RNSS) is the AM of range-normalized (to 100 km) magnetic field signal strengths, in so-called LLP units, from all sensors allowed by the TLP to participate in the peak current estimate. The following empirical formula is used to calculate the normalization of measured magnetic field signal strength, SS, to 100 km:

$$\text{RNSS} = \text{SS} * (r/100) * \exp((r-100)/1000) \qquad (2)$$

where r is in kilometers and SS is in LLP units.

Fig.5 shows the peak current estimated by GHMLLS versus peak current measured directly for the 70 return strokes triggered during 2012-2014. From this figure, it could be found that peak currents were under-estimated in a whole. The absolute percentage errors of peak current estimation were found to be within a range from about 4% to 76%, and the arithmetic mean and median value are calculated to be 39% and 40%.

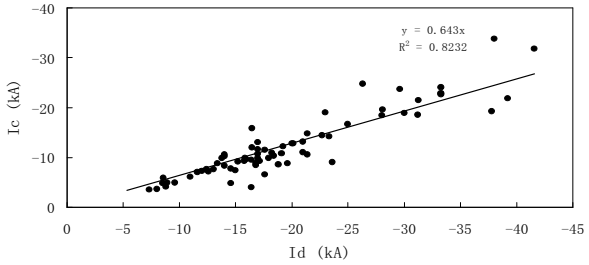

Fig 5. GHMLLS-reported peak current versus directly measured in the triggered lightning experiment.

Fig.6 shows the percentage errors of peak current estimation versus peak current measured directly. The AM value of the absolute percentage errors is found to be about 34% when the amplitude of peak currents are smaller than 20 kA (24 samples), while 42% when the amplitude of peak currents greater than 20 kA (46 samples). However, no obvious trend of percentage errors of peak current estimation is found to relate to the amplitude of peak current of return strokes.

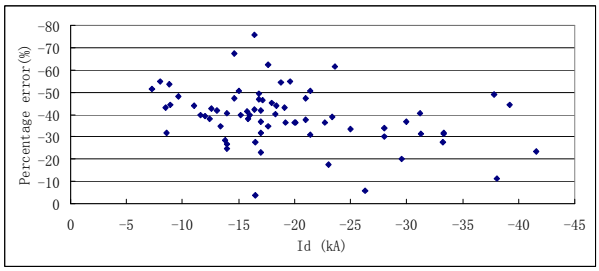

Fig 6. Percentage errors of peak current estimation versus directly measured in the triggered lightning experiment.

A total of 572 SS records, from 16 different sensors, participate in the peak current estimate for the 70 triggered strokes. The distance from the 16 sensors to the triggered lightning site range from 24.8 km to 259.9 km. The numbers of SS records from each sensor are within a range from 7 to 67. The peak current estimate is re-calculated following equation 1 and 2 for each sensor and compared with the ground truth. The AM values of percentage errors of peak current estimation for each sensor vary from -3% to -54%. Table 2 presents the distance from the triggered lightning site, the SS records number and the AM value of percentage error of peak current estimation for the 16 individual sensors. In a whole, no obvious relationship is found between the percentage errors of peak current estimation and the distance from the sensor to the triggered lightning site.

Table 2. SS records number and percentage error of peak current estimation for the 16 individual sensors

Sensor ID	Distance (km)	SS records number	AM of percentage error of i_p estimation	AM of absolute percentage error of i_p estimation
1	228.7	16	-39%	39%
2	147.7	45	-49%	49%
3	117.3	59	-38%	38%
4	223.4	38	-46%	46%
5	224.3	9	-36%	36%
7	76.3	65	-31%	31%
8	161.9	60	-38%	38%
9	27.4	40	-46%	46%
10	125	67	-27%	28%
11	169.6	20	-3%	18%
12	140.4	13	-31%	31%
13	137.8	7	-33%	33%
14	88.2	58	-39%	39%
15	164.4	38	-42%	42%
16	138.9	24	-29%	29%
17	259	13	-54%	55%

We checked the TLP configure files, and found that there were four gain modes for the sensors: "BField4_High"(9 sensors), "BField2_Med" (1 sensor), "BField1_Low"(3 sensors) and "BField6_Nldn" (1 sensor).

Note that in the top 4 sensors with relative small percentage errors, 3 sensors are of IMPACT type and the gain mode of which are set to be "BField1_Low" or "BField2_Med" in the TLP configure files. In the top 4 sensors with relative big percentage errors, all sensors are of LS 7000 type and the gain mode of which are set to be "BField1_High" or "BField6_Nldn".

IV. SUMMARY AND DISCUSSION

In this paper, the performance characteristics of the GHMLLS was re-evaluated based on observations of lightning flashes triggered during 2012-2014. The results showed that the flash detection efficiency and stroke detection efficiency was about 87% and 86%. The arithmetic mean and median value of location error was estimated to be about 402 m and 200 m. The arithmetic mean and median value of absolute percentage errors of peak current estimation was 39% and 40%.

It seems that the percentage errors of peak current estimation do not vary much with the amplitude of peak current of return strokes. For the 16 individual sensors, the AM values of percentage errors of peak current estimation ranged from 18% to 56%. No obvious relationship is found between the percentage errors of peak current estimation and the distance from the sensor to the triggered lightning site yet. In a whole, it seems that there is still much work remained for the improvement of peak current estimation of GHMLLS.

ACKNOWLEDGMENT

This work was supported in part by the National Natural Science Foundation of China (grant 41475003), the National Key Basic Research Program of China (grant 2014CB441405), and the Basic Research Fund of Chinese Academy of Meteorological Sciences.

REFERENCES

K. L. Cummins, M. J. Murphy, E. A. Bardo, W. L. Hiscox, R. B. Pyle, and A. E. Pifer (1998), A combined TOA/MDF technology upgrade of the U.S. National Lightning Detection Network, J. Geophys. Res., 103, 9035-9044.

K. L. Cummins, J. A. Cramer, C. Biagi, E. P. Krider, J. Jerauld,M. A. Uman, and V. A. Rakov (2006), The U.S. national lightning detection network: Post-upgrade status, Paper presented at the 2nd Conf. Meteorological Appl. Lightning Data, Amer. Meteorol. Soc., Atlanta, GA, USA.

A.Nag, S.Mallick, V.A.Rakov, J.S.Howard, C.J.Biagi, J.D.Hill, M.A.Uman, D.M.Jordan, K.J.Rambo, J.E.Jerauld, B.A.DeCarlo, K.L.Cummins, andJ.A.Cramer (2011), Evaluation of U.S. National Lightning Detection Network performance characteristics using rocket-triggered lightning data acquired in 2004-2009, J.Geophys.Res., 116,D02123, doi:10.1029/2010JD014929.

A.Nag, V. A. Rakov and K. L. Cummins (2014), Analysis of NLDN-estimated peak currents for positive cloud-to-ground lightning, IEEE Transactions on Electromagnetic Compatibility, 56(2), 404-412.

W. Schulz (2004), Lightning peak currents measured on tall towers and measured with lightning location systems. Paper presented at 18th International Lightning Detection Conference, Helsinki, Finland.

Yijun Zhang, Weitao Lu, Dong Zheng, Luwen Chen, Shaodong Chen and Xu Yan (2014), Evaluation for the Performance of the Guangdong-Hongkong-Macau, Lightning Location System, Paper presented at 23th International Lightning Detection Conference, Tucson, Arizona, USA