Contrastive Analysis of Lightning Characteristics and Lightning Parameters in Hongya County

Jianxi HE*

Hongya Meteorology Bureau, Hongya 620360, China

Abstract Based on the data of cloud-to-ground lightning obtained by the lightning detection system in Hongya County during 2011 - 2015, the parameters of lightning current intensity and steepness in Hongya County were analyzed, and the lightning parameters and the annual average density of lightning stroke to earth were discussed in combination with the *Design Code for Protection of Structures against Lightning* (GB 50057 - 2010), so as to provide scientific guidance for lightning disaster prevention in Hongya County.

Key words Lightning characteristics; Lightning data; Lightning parameter

DOI 10.19547/j.issn2152 - 3940.2024.05.012

Lightning is the most spectacular and extremely important weather phenomenon in nature, and has characteristics of short discharge time (generally not more than 60 μs), large impact current (tens of thousands to hundreds of thousands ampere), high impact voltage (up to hundreds of millions of volts), large lightning current gradient (up to 10 kA/μs)[1]. The traditional lightning observation is manual observation[2], and can only be based on the statistical analysis of thunderstorm days, but the data recorded by the lightning positioning monitoring system is diversified to achieve comprehensive monitoring. Therefore, it is necessary to analyze the characteristics of local thunderstorms and lightning parameters based on lightning location data to provide theoretical basis for scientific prevention of lightning disaster[3].

1 Analysis of lightning monitoring data

1.1 Analysis of lightning intensity Table 1 shows the overall characteristics of lightning intensity data in Hongya County from 2011 to 2015. During the five years, the frequency of lightning in Hongya County was up to 45 751 times, among which the frequency of negative cloud-to-ground lightning was higher than that of positive cloud-to-ground lightning, and the ratio of positive and negative cloud-to-ground lightning was 1 ∶ 27. However, the intensity of positive cloud-to-ground lightning was greater than that of negative cloud-to-ground lightning.

Table 1 Overall characteristics of lightning intensity in Hongya County from 2009 to 2013

Cloud-to-ground lightning	Frequency // times	Percentage // %	Average intensity // kA	Maximum intensity // kA
Positive cloud-to-ground lightning	1 670	3.6	30.3	267.5
Negative cloud-to-ground lightning	44 081	96.4	11.2	194.5
Total	45 751	100.0	20.7	267.5

As shown in Fig. 1 and Fig. 3, the frequency distribution of current intensity of negative and total cloud-to-ground lightning in recent 5 years was relatively concentrated, and there was a single peak. The maximum was about 20 kA, and the frequency of lightning current intensity less than 50 kA was more than 98%, while that of lightning current intensity less than 100 kA was 99%. Seen from Fig. 2, although the curve of current intensity of positive cloud-to-ground lightning in recent five years also had a single peak, but it is much gentler than that of negative and total cloud-to-ground lightning, and the distribution range was larger than that of negative and total cloud-to-ground lightning. The central maximum was about 27 kA, and 98% of current intensity was less than 100 kA.

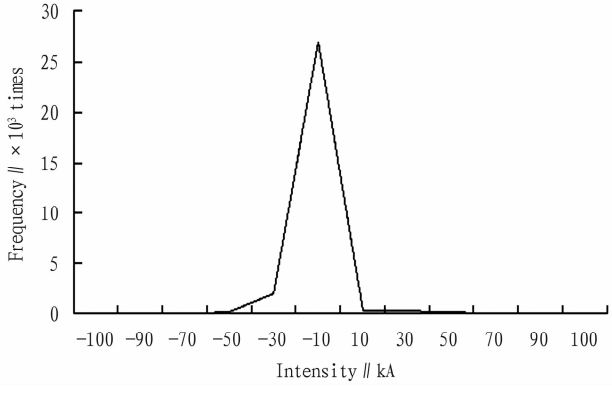

Fig. 1 Distribution of the frequency of total cloud-to-ground lightning intensity

Received: September 8, 2024 Accepted: October 11, 2024

* Corresponding author.

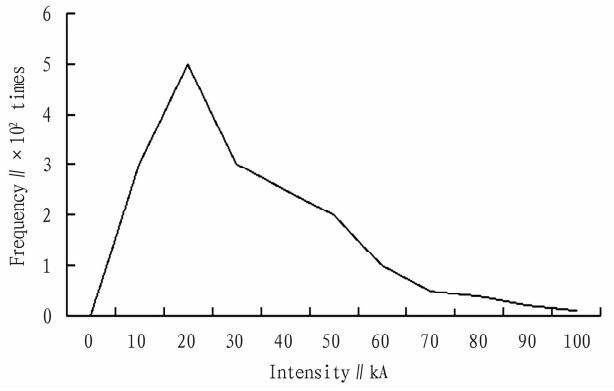

Fig. 2 Distribution of the frequency of positive cloud-to-ground lightning intensity

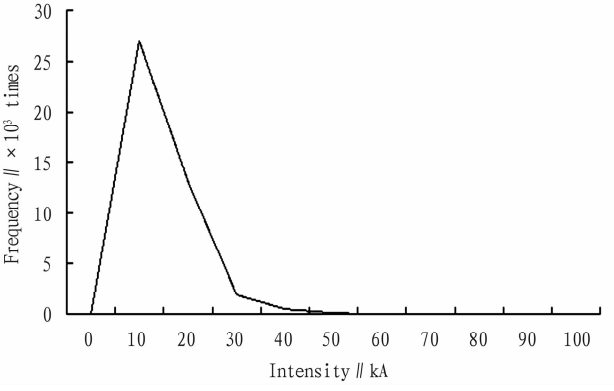

Fig. 3 Distribution of the frequency of negative cloud-to-ground lightning intensity

1.2 Analysis of lightning gradient From 2011 to 2015, the largest lightning gradient in Hongya County was −223.1 kA/μs, and the frequency of lightning gradient between −50 and 10 kA/μs was 43 979 times, accounting for 96% of the total frequency of lightning. The frequency of lightning gradient less than −50 kA/μs was 393 times, accounting for 0.8% of the total frequency of lightning. The frequency of lightning gradient less than −75 kA/μs was 45 times, accounting for 0.1% of the total frequency of lightning.

1.3 Analysis of daily variation of lightning The most important factors affecting the daily variation of lightning are the terrain and the local climate zone[4]. Hongya County is located at the southwest edge of Sichuan Basin, and the Qingyi River passes through the city. The temperature rise in the mountain area is greater than that along the river, and it is easy to form local circulation. The strong horizontal temperature gradient and uplift condensation are very conducive to the occurrence and development of strong convective weather[5-6], so lightning occurred more frequently in Hongya. According to the analysis of lightning data in the past five years, lightning was the most intense between 03:00 and 09:00, and then the frequency gradually decreased, and then increased from afternoon to evening. The daily variation of lightning generally had three peaks (Fig. 4).

2 Comparative analysis of lightning parameters

Tables F.0.1-1, Table F.0.1-2 and Table F.0.1-3 in Appendix F of the *Design Code for Protection of Structures against Lightning* (GB 50057-2010)[7] give the basic parameters of lightning current. In the standard, it is pointed out that the first positive lightning stroke current of class-I buildings is 200 kA, and the first negative lightning stroke current is 100 kA. In recent 5 years, there was only one time of positive lightning stroke current greater than 200 kA, and it was up to 267 kA. There were only ten times of negative lightning stroke current greater than 100 kA, and the maximum was 194 kA. The analysis shows that the distribution of lightning current parameters in Hongya County was basically consistent with those in the standard GB 50057-2010, but there were a few phenomena that were too large.

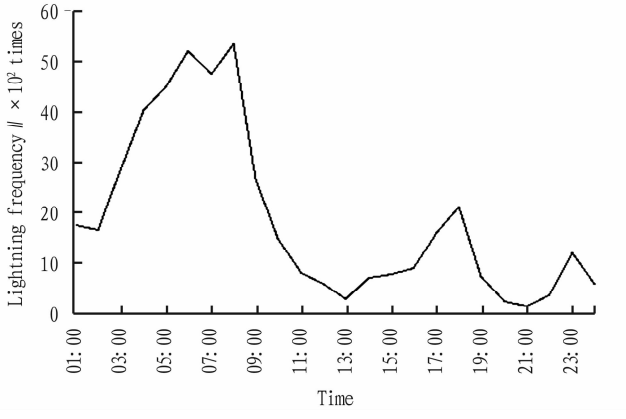

Fig. 4 Daily variation of lightning

The steepness of positive cloud-to-ground lightning in the standard GB 50057-2010 is $I/T = 200/10 = 20$ kA/μs, and the steepness of negative cloud-to-ground lightning after the first time is $I/T = 50/0.25 = 200$ kA/μs. The data show that the frequency of positive cloud-to-ground lightning steepness > 20 kA/μs in Hongya County was 224 times, accounting for 13% of the total frequency of positive cloud-to-ground lightning, and the maximum steepness of positive cloud-to-ground lightning was 188 kA/μs. There was only one time of negative cloud-to-ground lightning steepness >200 kA/μs, and the value was 223 kA/μs. The analysis indicates that the steepness of positive cloud-to-ground lightning in Hongya County was larger than that in the standard GB 50057-2010, and the distribution of negative cloud-to-ground lightning steepness was basically consistent with that in the standard GB 50057-2010.

3 Comparative analysis of thunderstorm days

3.1 Comparative analysis of the number of thunderstorm days and lightning days As shown in Table 2, the annual average number of lightning days detected by the lightning detection system in Hongya County during 2011-2015 was 46.8, and the annual average number of thunderstorm days observed was 24.8. That is, the latter was 22 d less than that the former (Table 2).

Table 2 The number of thunderstorm days observed manually and the number of lightning days detected by the lightning positioning system

Year	Thunderstorm days observed manually//d	Lightning days detected by the lightning positioning system//d
2011	21.0	41.0
2012	24.0	43.0
2013	29.0	54.0
2014	26.0	46.0
2015	24.0	50.0
Average	24.8	46.8

Because the division of day boundaries of the lightning positioning system and the manual observation was different, the recorded days of the same thunderstorm process were also different. It can be seen that the number of thunderstorm days recorded by the lightning positioning system and manual observation was not completely consistent, and the number of thunderstorm days recorded by manual observation can only roughly reflect the frequency of lightning activity within the diameter of 20 – 30 km of the observation station. The number of lightning days detected by the lightning detection system can represent the frequency of lightning activity in the whole county.

3.2 Comparative analysis of annual average density of lightning stroke to earth The annual average density of lightning stroke to earth is the main parameter to measure the frequency of lightning stroke, and is the basis for calculating the annual frequency of lightning stroke to buildings. In the standard GB 50057 – 2010, the annual average density of lightning stroke to earth Ng_1 is calculated as follows: $Ng_1 = 0.1 \times Td$ (Td is the local annual average number of thunderstorm days). The annual average density of lightning stroke to earth calculated based on the measured data of the lightning positioning system Ng_2 is calculated as follows: Ng_2 = the annual number of lightning stroke/land area. Table 3 shows that there was a great difference between Ng_1 and Ng_2, with an average correlation coefficient of 1.62.

Table 3 Comparative analysis of Ng_1 and Ng_2

Year	Ng_1 time/(km^2 · a)	Ng_2 time/(km^2 · a)	Correlation coefficient
2011	2.1	4.6	2.2
2012	2.4	3.2	1.3
2013	2.9	5.2	1.8
2014	2.6	1.7	0.7
2015	2.4	5.0	2.1
Average	2.5	3.9	1.6

4 Conclusions

(1) The analysis of the measured data of 45 751 times of lightning detected by the lightning detection system in Hongya County from 2011 to 2015 shows that the lightning in Hongya County was mainly negative cloud-to-ground lightning, accounting for 96.4% of the total number of cloud-to-ground lightning, and its average intensity was significantly lower than that of positive cloud-to-ground lightning.

(2) Lightning activity in Hongya County was the most intense from 03:00 to 09:00, and increased from afternoon to evening. The daily variation curve of lightning had three peaks.

(3) The average intensity of lightning current in Hongya County was about 20 kA, and the measured data of lightning current was basically consistent with the distribution of lightning current parameter in the standard GB 50057 – 2010, and only a few exceeded the lightning current parameter in the standard GB 50057 – 2010. Compared with the standard GB 50057 – 2010, the steepness of positive cloud-to-ground lightning was larger, and the distribution of negative cloud-to-ground lightning steepness was basically the same.

(4) The number of lightning days detected by the lightning detection system in Hongya County was significantly larger than the number of thunderstorm days obtained by artificial observation, which was related to the small coverage of thunderstorm days obtained by artificial observation in Hongya County.

(5) The average annual density of lightning stroke to earth calculated according to the standard GB 50057 – 2010 has certain limitations, and cannot truly reflect the annual average density of lightning stroke to earth. The average correlation coefficient of Hongya County was 1.62. This difference will affect the lightning protection classification level of buildings, and has a direct impact on lightning protection engineering and lightning disaster risk assessment. It is suggested that lightning observation data should be used as much as possible in practical application.

References

[1] CHEN WM. Principles of lightning[M]. Beijing: China Meteorological Press, 2006: 220, 375.

[2] China Meteorological Administration. Specification for surface meteorological observation[M]. Beijing: China Meteorological Press, 2003: 11.

[3] YU JH, ZOU JS, LI B, *et al.* Analysis of lightning data measured by Jiangxi Province lightning monitoring and positioning system[J]. Meteorological Science and Technology, 2009, 37(1): 102 – 105.

[4] MA M, LV WT, ZHANG YJ, *et al.* Analysis of lightning activity characteristics in China[J]. Meteorological Science and Technology, 2007, 35(S1): 1 – 7.

[5] ZHU QG, LIN JR, SHOU SW, *et al.* Principles and methods of weather science[M]. Beijing: China Meteorological Press, 2000: 425431.

[6] LUO X, CHEN WM, LI ZR, *et al.* Preliminary study on the relationship between electrical structure of thunderstorm clouds and lightning[J]. Journal of the Meteorological Sciences, 2007, 27(3): 280 – 286.

[7] Ministry of Machinery Industry of the People's Republic of China. Design code for protection of structures against lightning (2010 edition)[M]. Beijing: China Planning Press, 2010.