

PAPER • OPEN ACCESS

Consistency Analysis of two Lightning Systems in Hubei Province

To cite this article: Guoliang Li *et al* 2021 *J. Phys.: Conf. Ser.* **1732** 012093

View the [article online](#) for updates and enhancements.

You may also like

- [Evidence for solar wind modulation of lightning](#)
C J Scott, R G Harrison, M J Owens et al.
- [Thunderstorm neutrons](#)
L P Babich
- [The impacts of shipping emissions on lightning: roles of aerosol-radiation-interactions and aerosol-cloud-interactions](#)
Ruize Sun, Xiao Lu, Meng Gao et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Consistency Analysis of two Lightning Systems in Hubei Province

Guoliang Li^{1,*}, Jun Li², Xiang Li³ and Fang Yuan¹

¹Hubei Branch of Meteorological cadre training Institute of China Meteorological Administration, Wuhan, China

²Hubei Meteorological Information and Technology support Center, Wuhan, China

³Hubei Lightning Protection Center, Wuhan, China

*Corresponding author e-mail: guoliang_li@163.com

Abstract. In order to study the Hubei lightning locating system detection efficiency in 2015-2016, this paper adopts the method of mathematical statistics, compared and analyzed the distribution structure, detection efficiency, space-time distribution and lightning current characteristics between two lightning systems. The results show that the more sub-stations and the smaller the baseline distance are, the higher the detection efficiency is. The average number of cloud and ground lightning in 3D lightning locating system is 86.8% more than that in 2D system, and the proportion of positive ground lightning is slightly higher than that in 2D system. The positive and negative flashover of the 3D system are between 0-90kA, Positive current of 10-20kA and negative current of 20-30kA are the most. The positive and negative lightning in 2D system are between 10-100kA, the current has the highest percentage of 20-30kA and the lowest percentage of 10-20kA. The 3D system detection efficiency and lightning density distribution are better than 2D system. two sets are consistent in lightning time characteristics, geographical distribution and intensity distribution rules, which plays an important role in lightning disaster investigation, lightning monitoring and early warning and other business applications.

1. Introduction

Lightning location system is one of the main means of lightning monitoring. The ADTD time-difference direction-finding 2D lightning monitoring and positioning system (hereinafter referred to as the 2D system) established by Hubei provincial meteorological department in 2006 play an important role in lightning disaster investigation, lightning risk assessment, lightning protection, and thunderstorm weather process monitoring and warning, etc.[1]. The VLF/LF 3D all-lightning monitoring and positioning system (hereinafter referred to as the 3D system) established in 2014 added the function of cloud-to-cloud lightning monitoring and positioning. After analyzing the detection efficiency and spatial and temporal distribution characteristics of 2D and 3D system in Jiangsu province, Sun[2] believed that the detection results of the two systems were inconsistent due to their differences in model, detection technology and their own errors. Zhao[3] compared the ground lightning data of two sets of lightning positioning systems in Zhejiang province and obtained that the ground lightning density and annual average ground lightning frequency monitored by the electric power department were more stable than those monitored by the meteorological department. Feng[4] through the evaluation and analysis of ADTD data in Jiangsu province 2013, believed that the positioning accuracy and detection efficiency of 3D system is significantly improved than that of 2D



system. Compared to Jiangsu province, the 3D system added vertical direction of the detection channel in Hubei province. This paper makes a comparative analysis of the cloud-ground lightning data detected by the two systems in order to test the consistency, detection efficiency and coverage of the two systems in Hubei province, and to understand the differences between the lightning activity characteristics reflected by the two systems, so as to better play the role of lightning location data and further improve the accuracy of lightning warning and prediction.

2. Source of data

The data comes from the lightning database of Hubei province lightning location system. The 2D system is composed of 13 lightning locators, including Wuhan, Tianmen, Suizhou, Macheng, Shiyan, Xianning, Jingzhou, Jingmen, Xiangyang, Yichang, Enshi, Badong and Shennongjia. The 3D system is composed of 19 lightning locators, including Wuhan, Tianmen, Guangshui, Macheng, Yingshan, Huangshi, Shiyan, Zhuxi, Chongyang, Gongan, Jingmen, Xiangyang, Yichang, Badong, Xianfeng, Lichuan, Jianshi, Hefeng and Shennongjia. By using the 2015-2016 lightning monitoring data of two systems in Hubei province, this paper adopts mathematical statistics method to make a comparative analysis of the lightning day, time distribution, geographical distribution and current intensity distribution throughout the year. In order to achieve more accurate regional comparison in lightning statistics, when conducting regional lightning statistics, the statistical interval is no more than 10kA and the statistical regions are divided according to the current administrative regions.

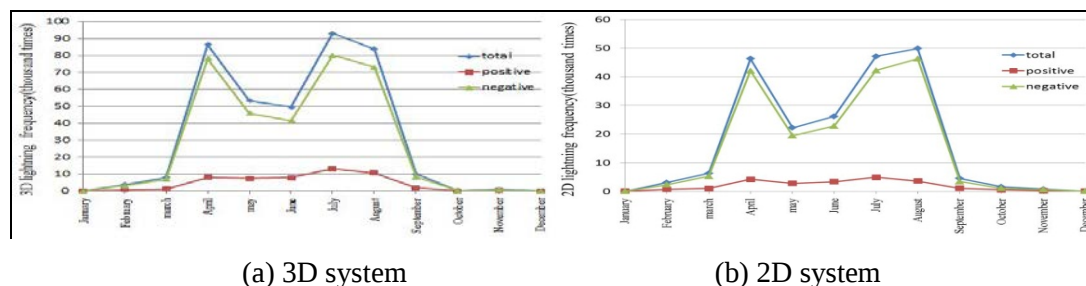
3. Comparative analysis of detection efficiency

If the lightning locator recorded more than two times of lightning (cloud lightning or ground lightning) in Hubei province, it is called the lightning day. 534 lightning days were detected by 2D system and 599 lightning days were detected by 3D system during 2015-2016, which was 65 days more than 2D system. In the lightning days monitored by 2D system, 2 days which had two lightning records were not detected by 3D system, accounting for 0.37%. In the lightning days monitored by 3D system, 42 days which had 2-37 lightning records were not detected by 2D system, accounting for 7.01%, which was caused by external influences [5]. In the 3D system, there are 9 stations in Suizhou, Jingzhou, Xianning and Enshi, but there are no stations in Guangshui, Gongan, Chongyang and Jianshi nearby. Meanwhile, there are 3 stations in southwest Hubei (Lichuan, Xianfeng and Hefeng), 2 stations in east Hubei (Huangshi and Yingshan), and 1 station in northwest Hubei (Zhuxi). There are 6 stations in total.

4. Comparative analysis of lightning time distribution characteristics

4.1 Analysis of annual lightning statistics

During 2015-2016, the annual average number of cloud and ground lightning detected by 3D system was 390,280.5, the average number of positive lightning was 51,603.5, accounting for 13.22%, and the average number of negative lightning was 338,677, accounting for 86.78%. The average number of lightning detected by 2D system was 208,886, among which the average number of positive lightning was 22,507, accounting for 10.77%, and the average number of negative lightning was 186,379, accounting for 89.23%. This indicates that the number of lightning detected by 3D system is more than that by 2D system, with an average increase of 86.84%. This may be due to multiple substations and new equipment of 3D system [6].



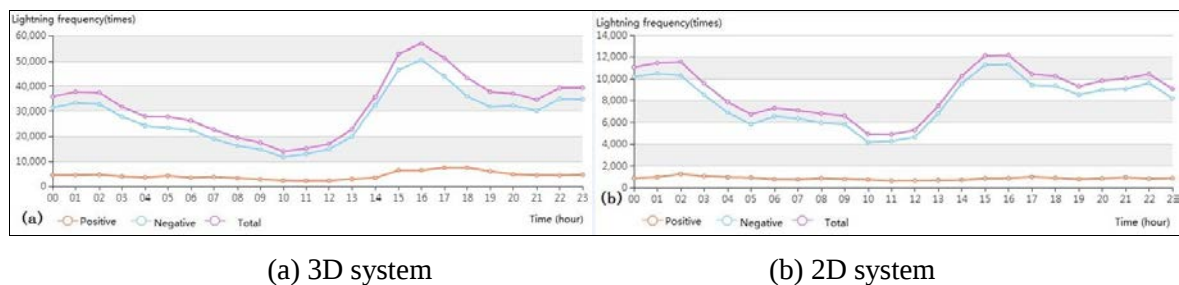
(a) 3D system (b) 2D system
Figure 1. Monthly lightning distribution characteristics in Hubei (2015-2016)

4.2 Analysis of monthly lightning distribution characteristics

From the monthly distribution of lightning in Hubei province during 2015-2016 (figure 1), it can be seen that the monthly distribution of lightning quantity in the two systems were basically the same, both in the form of double peaks. The monthly average amount of cloud-ground lightning in 3D system was more than that in 2D system. The highest peak was from July to August, and the second peak was in April. The largest difference in numbers occurred from April to September. It can be seen from the monthly positive and negative ground flash distribution of the two systems that the distribution characteristics were similar and the quantity difference was the same [7]. From the monthly lightning number, 3D system and 2D system have a good consistency.

4.3 Analysis of daily lightning distribution characteristics

The daily lightning distribution of two systems was basically the same from figure 2, the highest value is between 14 and 18, the lowest value is between 10 and 12, and the average number of cloud-ground lightning in 3D system at each time was more than that in 2D systems. From the daily lightning number, 3D system and 2D system have a good consistency [8].



(a) 3D system (b) 2D system
Figure 2. Monthly lightning distribution characteristics in Hubei (2015-2016)

5. Comparative analysis of lightning spatial distribution

5.1 Regional statistical analysis

Due to certain errors in the algorithm with only two stations [9]. For the accuracy of the data, only the lightning records with more than two stations involved in the calculation were used. Meanwhile, the administrative regions of Hubei province were divided into 45 regions according to the longitude and latitude for statistical analysis, and the lightning distribution detected by the two systems in each region was separately counted.

Table 1. The annual distribution table of 3D and 2D system in Hubei (2015-2016)

Latitude (N) and longitude (E)	29-30		30-31		31-32		32-33		33-34	
	3D	2D	3D	2D	3D	2D	3D	2D	3D	2D
108-109	10452	556	3518	834	0	0	0	0	0	0
109-110	12902	3266	15536	7257	1491	781	1748	771	803	190
110-111	3137	1224	23296	13805	14876	9701	15714	7365	2120	967
111-112	1712	996	15788	11975	23170	13057	7818	4675	259	129
112-113	5736	3658	17756	14276	13716	11903	2160	1522	0	0
113-114	20891	12016	25179	13240	9950	8051	2309	1508	0	0
114-115	21147	13354	39194	22825	13418	7178	0	0	0	0
115-116	6676	2630	46039	16140	10715	2723	0	0	0	0
116-117	525	151	511	151	12	1	0	0	0	0

It shows that, in each of the 45 regions, the number of 3D system was more than that of 2D system. The most lightning occurred in longitude (114-116E, 30-31N), and the lightning distribution of the two systems was basically the same. The major differences were (108-110E, 29-30N), (108-109E, 30-31N), (115-116E, 31-32N), and (109-110E, 33-34N). From substation layout system, the 2D system had substations in Suizhou and Jingzhou, the 3D system had substations in Guangshui and

Gongan nearby. As a result, the distance between the substations in the central region of Guangshui, Xiangyang, Jingmen, Gongan and Yichang increased by 30-50 km and the maximum distance between the stations reached 169 km compared with the distance between the substations in the central region of 2D system. The number of substations in southwest Hubei, east Hubei and northwest Hubei was more than that of 2D system, and the distance between substations was reduced. As can be seen from the table 1, the number of 3D system was more than that of 2D system, but the regional differences in the whole province were not very uniform. The regions with large differences were just located in southwest Hubei, southeast Hubei and northwest Hubei, while the differences in the central region were slightly smaller. This feature of lightning distribution was consistent with the layout of the two systems. This conclusion indicates that the substations had high density and high detection efficiency.

5.2 Comparative analysis of lightning density

It show that to the 2D system, the areas with high lightning density were mainly distributed in central, western and eastern Hubei, The areas with low lightning density were mainly distributed in the west of Shiyan in northwest Hubei, the north of Shennongjia, the north of Xiangyang and the west of southwest Hubei, which was consistent with the conclusion drawn by Wang [10] on the historical average lightning density in Hubei. 3D system of lightning density distribution is consistent with 2D system on the whole, but lightning density large area increased the southwest and the surrounding areas of Hubei province. Compared with 2D system, the number of lightning in 3D system was significantly increased, the lightning density was increased, and the regional density difference was more obvious, which was related to less 2D system and did not cover the edge areas.



2015-2016 3d cloud-ground average lightning density map in hubei province

(a) 3D system



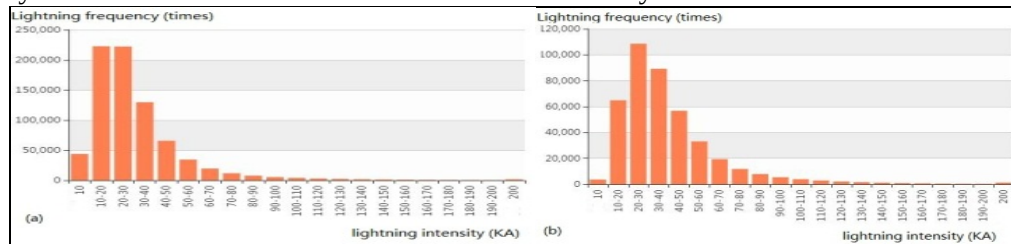
2d average lightning density map of hubei province in 2015-2016

(b) 2D system

Figure 3.Lightning density map of Hubei (2015-2016)

6. Comparative analysis of lightning current characteristics

Among the lightning detected in 2015-2016, 97.1 % of 3D system was between 0 and 90 kA, and 97.1 % of 2D system was between 0 and 110 kA. As can be seen from the figure, the intensity of lightning in 3D system was the highest at 10-30kA, followed by 30-40kA and less at 90 kA. The 2D system had the largest 20-30 kA intensity lightning, followed by 30-40 kA intensity lightning, and less lightning above 110 kA. The intensity distribution of the two systems presented a single-peak shape [11]. The maximum distribution position of 2D system was 10 kA larger than that of 3D system, which may be because the lightning current monitored by 2D system was too large or the lightning sensitivity monitored at 10-20 kA was lower than that of 3D system.

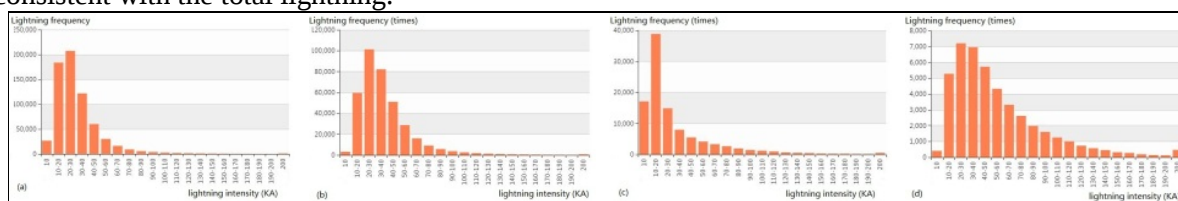


(a) 3D system

(b) 2D system

Figure 4. Lightning current intensity distribution (2015-2016)

According to the statistical analysis of positive lightning and negative lightning separately (figure 5), 93.4% of the positive lightning in the 3D system were mainly concentrated between 0-90 kA, with the maximum peak value between 10-20 kA, and the intensity of negative lightning between 0-90 kA account for 97.6% of the total negative lightning, with the maximum peak value between 20-30 kA. In the 2D system, 86.7% of the positive lightning was mainly concentrated in the range of 10-100 kA, and the maximum peak was between 20-30 kA, which gradually decreased after being greater than 100 kA. The intensity of negative lightning in the range of 10-100 kA account for 96.4% of the total negative lightning, and the maximum peak was in the range of 20-30 kA. It indicated that the two systems have basically the same distribution of positive and negative lightning intensity. The positive and negative lightning of 3D system was mainly concentrated in the range of 0-90 kA, and the positive lightning of 10-20 kA and the negative lightning of 20-30 kA were more frequent, while the positive and negative lightning of the 2D system was mainly concentrated in the range of 10-100kA. There were more positive and negative flashover 20-30 kA and less difference between 10-20 kA current than 3D system. The positive and negative lightning currents of the two systems are basically consistent with the total lightning.



(a) 3D system

(b) 2D system

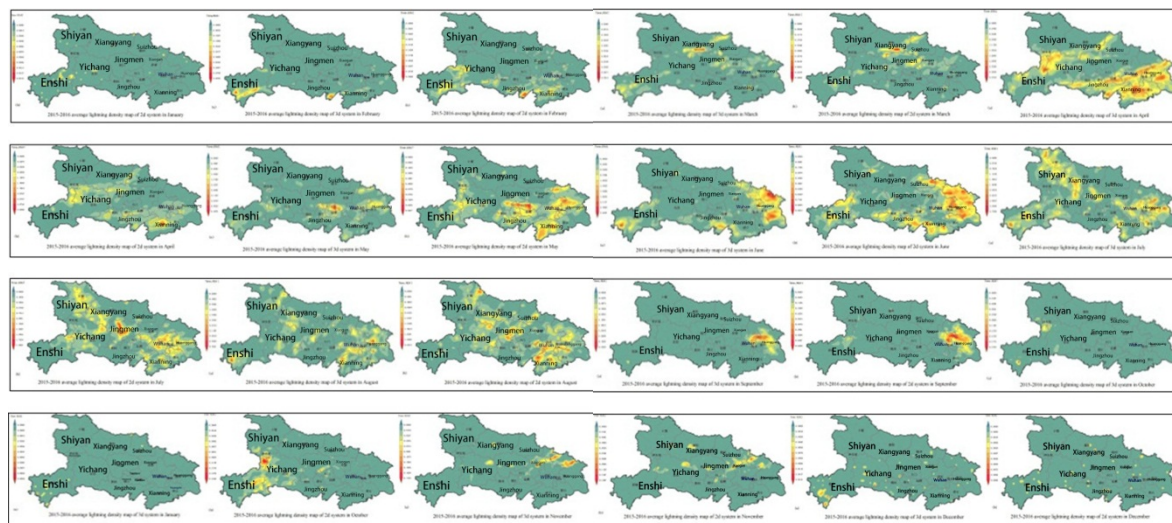
(c) 3D system

(d) 2D system

Figure 5. Lightning current intensity distribution (2015-2016)

7. Analysis of monthly lightning regional distribution

In the figure, it can be seen that the monthly mean lightning spatial distribution is different. The distribution of lightning density in each month of the two systems is basically the same, but the lightning density in 3D system is larger, especially the local lightning density from April to September is much larger, and southwest Hubei province is also more obvious. There is no significant difference between January to March and October to December, and the density distribution is similar. This show that the distribution of lightning density in each month in the 3D system was consistent with that in the 2D system, and the lightning density was larger and the level was clearer [12].



(a) 3D system (b) 2D system
Figure 6. Monthly lightning density map (2015-2016)

8. Conclusion and discussion

The detection efficiency, spatial and temporal distribution and strength characteristics of 2D system and 3D system are compared and analyzed, and the following conclusions are drawn:

(1) The lightning location efficiency is related to the number and distance of substations. The number of substations is large and the baseline distance is short, the detection efficiency is relatively high. Hubei 3D system has 6 more substations than 2D system, so the number of days of lightning detected by 3D system is more than that of 2D system. The number of days of lightning missed by 3D system is less than that of 2D system, and the detection efficiency is higher than that of 2D system.

(2) In 2015-2016, the average number of cloud-to-ground flashes in 3D system was larger than that in 2D system, the average increased by 86.8%, and the proportion of positive cloud and ground lightning in a 3D system is slightly higher than that in a 2D system. The monthly distribution characteristics of lightning quantity of the two systems are similar, and both of them show a double-peak pattern, with the highest peak in April, the second peak in July, and the lowest peak in January and February. 3D system months cloud flash number is more than 2D system, basically contains a number of 2D system lightning, have good consistency.

(3) The coverage of 3D system in Hubei province is much better than that of 2D system, especially in east, southwest, northwest and the border region of the province, the average number of lightning in each region is higher than that in 2D system. The two systems have a good consistency in the time distribution and geographical distribution of lightning, and the average lightning density distribution in each month is basically the same.

(4) It indicated that the two systems have basically the same distribution of positive and negative lightning intensity. The positive and negative lightning of 3D system was mainly concentrated in the range of 0-90 kA, and the positive lightning of 10-20 kA and the negative lightning of 20-30 kA were more frequent, while the positive and negative lightning of the 2D system was mainly concentrated in the range of 10-100kA. There were more positive and negative flashover 20-30 kA and less difference between 10-20 kA current than 3D system. The positive and negative lightning currents of the two systems are basically consistent with the total lightning.

Through two-year data comparison and analysis, the two systems have a good consistency, and 3D system is higher than 2D system in terms of detection efficiency and coverage, etc., but the data used is short, and it needs a long time to accumulate data for comparative analysis, in order to verify the consistency and reliability of data. The sensitivity of the 3D system to 10-20 kA lightning monitoring is high, which needs to be further confirmed.

Reference

- [1] Caixia Tian, Qiming Ma, Xiao Zhou, et al. Algorithm simulation of Jiangsu 3D lightning location system [J]. Journal of Wuhan university (science edition), 2014, 60(2): 115-120.
- [2] Min Sun, Zhongjiang Yang, Yingying Zhong, etc. Two kinds of lightning data contrast analysis [J]. Electric porcelain arrester, 2014 (6) : 109-114.
- [3] Wei Zhao, Yujun Jiang, Hangwei Tong, etc., Zhejiang province, two sets of lightning location system to flash data comparison [J]. Journal of applied meteorology, 2015, 26 (3) : 354-363.
- [4] Minxue Feng, Yu Zhou, Min Yu, et al. Evaluation and analysis of ADTD lightning positioning system data in Jiangsu province in 2013 [J]. Science, technology and engineering, 2015(7): 79-84.
- [5] Yunjun Zhou, Lei Huang, Juan Gu, et al. Lightning monitoring and early warning technology. Beijing: meteorological press, 2015, 192
- [6] Chuanlin Zhu, Guoliang Li, Chier Zhang, etc. 3 d lightning location system in Hubei province positioning error simulation analysis [J]. Journal of torrential rain disaster, 2017 4 (1) : 91-96.
- [7] Min Yang, Xiaoliang Yang. Lightning distribution characteristics in Beijing-Tianjin-Hebei region from 2007 to 2015 [J]. Journal of meteorology and environment, 2016, 32(4): 119-125.
- [8] Juan Wang, Yun Chen. Analysis of lightning distribution characteristics in China from 2009 to 2012 [J]. Meteorology, 2015(2): 160-170.
- [9] Xiubin Sun, Zhou Lu, Yang Liu, etc. Cloud flash localization algorithm research and its accuracy analysis [J]. Science, technology and engineering, 2014 (31) : 269-273.
- [10] Xueliang Wang, Kejie Zhang, Xiaoyan Huang, etc. The thunderstorm days in Hubei province and cloud lightning density relations research [J]. Journal of meteorological, 2012, 38 (6) : 728-732
- [11] Ji Yu, Zhongjiang Yang, Luwen Chen, etc. A lightning location system of Guangdong detection efficiency and accuracy evaluation [J]. Journal of plateau, 2015 (3) : 863-869.
- [12] Minmin Song, Yongguang Zheng. East China September 3 - clouds. Lightning density and intensity distribution [J]. Journal of tropical weather, 2016, 32 (3) : 322-333.