Authors reply to reviewers' comments

Dear Anonymous Referees,

Thanks for your careful review of the manuscript. We read the reviewers' comments carefully, have considered and responded to all the reviewers' comments, and revised the manuscript accordingly. My detailed responses, including a point-by-point response to the review and a list of all relevant changes, are as follows:

Reviewer #1: The paper analyses lightning data from two Lightning Location Systems (LLS) in China recorded during one year (2020), in a first part, and the characteristics of the CG lightning flashes by using data from one LLS recorded during 6 years (2016-2021), in a second part. The link between the two parts is not obvious since the choice of the LLS for the second part was apparently due to the dataset availability. There is no clear conclusion in the first part which could guide the choice for a set of data from an LLS to achieve the second part of the study. This first part, if it is included, must be more justified and shown as more relevant. The second part is consistent enough to make interesting the study, but many ambiguities do not allow to understand and follow the thread of the analysis to make an evaluation. The main ambiguities are related to the difference between flash and strokes which is not clearly announced, to what is provided in the datasets (flashes or strokes), to the use of two terms for the same parameter (or not, we cannot know) rate and proportion of +CG, to the current and the discharge intensity
The paper must be deeply revised to clarify many questions of terminology and several missing information and justification.

Response: Through careful consideration, we also agree that the first part is somewhat irrelevant to the second part, so we decided to keep only the second part of the content. And following your valuable comments, the second part of the content has been extensively revised and enriched. The wording of the entire text has also been significantly modified. There are three main changes made:

a. The original system abbreviation, ADTD, has been changed to CNLDN (China National Lightning Detection Network) based on its latest official name, and a valuable site layout has been obtained, as shown in Fig. 1.

b. When analyzing the differences between +CG and -CG flashes, a more detailed statistical analysis was performed by dividing China inland into four regions according to the opinions of the second reviewer.

c. The analysis of the distribution of +CG and -CG discharge current was added.

1. The authors talk about detection efficiency (DE) in the abstract at line 22 (with values of 24.5% and 50.5%) but they do not indicate for which lightning entity it is applied: flashes or strokes? It is important to know at many steps in the study what is considered. Indeed, the DE is larger for flashes than for strokes, at least for -CG flashes. Very often in the paper, I was confronted to this problem (another example at line 26 in the abstract, another at line 103). A complete review (text, figures) is necessary for the authors to clear up any ambiguity. For the strategy of the study, it seems the DE for ATDT is only 24.5 %, it is very low for an LLS and for CG lightning (especially if it is applied to flashes). I think this point is not well commented for the following choice on LLS data and of course it should be interesting to well know if it was values for flashes or strokes, furthermore to make comparison by discussion with other LLS systems in the world.

   At line 132, I read "Time of occurrence, latitude, longitude, current peak value, number of located stations, (type of lightning) for each flash was obtained." Does it mean the strokes were not available? In figure 3 caption, it is indicated "strokes". Clarify the whole paper with that.

Response: Actually, the ambiguity of flashes or strokes did cause problems in the presentation of the text. In fact, as stated in lines 100-103, the lightning data used in this study are flashes grouped from strokes. So the detection efficiency was all of the flashes. The entire text has been checked and corrected. In fact, after removing the first part, the remaining contents have few descriptions of the detection efficiency.

The flash DE of 24.5% is indeed fairly low for a system working at the VLF band. But this percentage is likely to be underestimated because, in our last vision, only lightning detected by five or more stations was retained. However, in the new version, we did not perform such strict pre-screening of the data.

In addition, CNLDN (ADTD) is the only nationally deployed network in the China meteorological service and has not been evaluated on a national scale. Although the detection efficiency has relatively poor performance compared with other international developed networks, the analysis of the overall distribution trend of lightning and the comparison of +CG and -CG in China is still of scientific significance.

2. The problems of terminology can be grouped in a same comment, many times I noted fluctuant terms for an apparently same parameter:
   (i) for the +CG two words are used, ratio and proportion. The first example is at line 34 where "ratio" is used and a value is given in %. We can logically understand it is the ratio between +CG and -CG (but strokes or flashes we do not know). But, in the paper "proportion" is also used (first at line 372) and logically the proportion is calculated by +CG / CG and not +CG / -CG. It is necessary to use the same word (and the same parameter) everywhere to understand. They have to make a clear choice.

Response: Thanks kindly for your comments. The entire text and the labels on the figures have been corrected. We consistently use "ratio" to indicate the ratio between the two types of lightning flash (e.g., +CG / -CG) and "proportion" to indicate the proportion of a particular type of lightning flash in the total lightning flash (e.g., +CG / CG).

(ii) the second word to be corrected (and clarified) is for the current. The parameter provided by the LLS is the "peak current" for the strokes identified. Thus, the authors could use this word "peak current" (and to say for which stroke it is used). In a flash there are often several strokes and therefore several peak current values. Which one is used when the authors consider the flashes in the figures. Example at line 35: "The discharge intensity of +CG and -CG on the Tibetan Plateau is approximate, while the +CG always has a larger current than -CG on the plains" two words for the peak current and CG? which stroke is considered in the flash?

Response: Thanks kindly for your comments. The additional supplement has been added at line 103 "the first detected stroke representing the entire flash" .

3. About the first part of the paper, the comparison of two systems in China. It can be interesting for the community if general rules are pointed out. The first remark which challenged me is at line 95: "In reviewing the literature, comparative evaluation of these two networks is lacking and mainly aimed at localized areas." For who it is lacking? I am not sure these two specific networks (distribution and location of sensors, type of sensors, treatment of data) allow to generalize some results, and do the author reach information with a certain degree of universality in the study?

Response: Thank you for your comments, the first part of the content has been removed.

4. At line there is a sentence about the selection of data: "As 3D-LLS only retained lightning detected by five or more stations simultaneously this year, accordingly, this study did the same for ADTD data" Is it relevant? It means some flashes can be eliminated on one sensor and not on the other because the distribution of sensors is different for a system and for the other? I do not understand this criterion, it seems not relevant at all. Furthermore, is it applied for the second part of the paper when the characteristics of the CG lightning activity is analyzed for 2016-2020?

Response: In fact, the location results calculated by observations of five or more sites simultaneously would be more accurate but would miss many cases that were only detected by fewer sites, making the detection rate relatively low. However, we have removed the first part, which made data filtering just for the fairness of the two networks. In the second part of the analysis, the data were not filtered out by the site number. In fact, as mentioned in lines 98-99, CNLDN (ADTD) localized lightning using the TOA

method, which means that detections from three or more sensors are needed in the algorithm.

5. For the different maps represented in the figures, an information of distance scale could be given, longitude and latitude on the edges?

Response: Thanks for your suggestion. All maps in the article have been marked with latitude and longitude.

6. At line 173: “The DE difference between the two systems can be up to a hundred times." It is a huge difference! It would mean (for example) one is 5% and the other 50%! Is it significant? Is it calculated within an area large enough? For one pixel it is not significant. Does it mean the area is not covered? For which LLS is it a hundred larger?

Response: 3D-LLS has a blind detection area in the northwest of China and the Qinghai-Tibet Plateau, so the results are a hundred times smaller compared with the results under the coverage of CNLDN (ADTD). In fact, such a comparison is meaningless, so the part about the comparison of the two systems has been removed.

7. Figure 2 is the distribution of flashes versus peak current values. On the vertical axis it is ambiguous to note ratio. It is a proportion. There is no flash at low values of peak current (for both polarities) for ADTD. Is it already filtered and not for the 3D-LLS?

   At line 184 why to say the distribution is the same for both systems? The values are low but in proportion the difference seems large above 59 kA?

   At line 186, “of outliers in the 0-30 kA range” why between 0 and +30 kA and not between 0 and -20 kA?

   At line 190-191: “direction is much larger than that in the horizontal direction, so a significant number of misjudgment cases appeared” At which value of height a detected source is considered to belong to a CG flash?

Response: Thank you for your comments. The first part of the content has been removed.

8. Section 2.3. The references of studies given at lines 199-204 seem to use very different criterion values, probably because they do not consider the same matching, maybe strokes for some and flashes for other? It depends which systems are compared. This information is not discussed. The authors choose 1 s for the time criterion, it can be justified for flashes but it is not indicated.

It is not possible to understand the comment at lines 210 and 212 with the figure 3a. A proportion (clarify ratio in the figure) < 0.012 is not large. But the figure 3a displays the interval of time 0-50 μs, where are the other values? This distribution is difficult to analyze! Make another distribution and express the proportion in % it is easier to understand. Now in Figure 3 caption, I see "strokes"! Ratio is not clear in Fig. 3a,b

Finally, at line 227, we understand that the strokes are considered for matching. In these conditions, the Δt (delta t) cannot be as large as it is considered (0-1 s, line 210). If Fig. 3c include the common strokes from both systems, a time difference close to 1 s cannot be considered, such time intervals are not consistent with common strokes (not physically consistent). It can explain many dots largely out of the main cloud that follows a line.

Response: Thank you for your comments. Related content has been removed.

9. For the lines 245-248, it seems the negative CG flashes are also filtered according to the figure 2: no CG (flash or stroke) between -10 and 0 kA. It is not clear. Again, a lot of clarifications are necessary.

Response: Related content has been removed.

I do not see the utility of Figure 6; a ranking of the provinces is not scientific informative. The density distribution in Fig. 5 is much more informative.

Response: Fig. 6 in last vision has been removed.

10. Lines 374-375 and figure 7: the authors use ratio and proportion for +CG, it is not the same, ratio can be +CG/-CG or +CG/CG and proportion is +CG/CG. Clarify and use proportion (I think) in all figures and text.

Response: The entire text and the labels on the figures have been corrected. We consistently use "ratio" to indicate the ratio between the two types of lightning flash (e.g., +CG / -CG) and "proportion" to indicate the proportion of a particular type of lightning flash in the total lightning flash (e.g., +CG / CG).

The comment on "peak currents" at lines 382-383 is not relevant. The peak current values have to be explicit: average, median, others? And for -CG it also varies during the months between January and December.

Response: The boxes in Fig.4 and Fig.6 represent the distribution of the peak current of the flashes (the first stroke represents the flash). The white crosses and red lines in Fig.4 and Fig.6 represent the average peak current of each month. In the meanwhile, we also use "discharge intensity" to replace the current of the flash. The corresponding

text has also been revised.

11. For the hour-by-hour frequency and intensity variations, the time is not clear: define time CST. Normally CST is central time in US/Canada. The problem for China is the size, how many time zones and how to consider the same solar time or same conditions in solar influence for the figure 8? Figure 8: CST not defined, the curve is not defined. For panel a, the ratio values could be better clear with an interval between 0 and 0.16 to well show the variation amplitude.

Response: We apologize for the mistake of the time zone. In fact, the time zone used in this article is Beijing time, abbreviated as CNT (UTC+8). Fig.5, Fig.6 (Fig. 8 in the last vision), and all corresponding content have been corrected. As the whole China inland uses Beijing time consistently, so we only use one time zone for the analysis roughly, which will inevitably bring some bias to the analysis of the daily lightning variation. However, in the new version, when analyzing the features of +CG and -CG flashes, we conduct statistical analysis separately for four geographic regions, which can reduce the errors caused by using the same time zone.

In Figures 3, 4, 5, and 6, in order to make the comparison between regions more evident, we use the same y-scale range for each subplot.

At line 403, I do not see the same value for "lowest at 15:00, only 2%,": according to figure 8: the value seems to be between 0.09 and 0.1 (between 9 and 10 %). Again ratio is not clear.

Response: We apologize for the wrong ratio, and the real proportion is 9.6%. In the new vision, as we analyze the proportion of +CG separately in four regions, the related content has been replaced.

12. Section 3.2.2 is concerned by the ambiguity between ratio and proportion (line 411 "ratio" , line 416 "proportion"). What is plotted in Figure 9?

Response: We have consistently used "ratio" to indicate the ratio between the two types of lightning flash (e.g., +CG / -CG) and "proportion" to indicate the proportion of a particular type of lightning flash in the total lightning flash (e.g., +CG / CG).

The variable in Fig. 3, Fig. 5, Fig.7, and Fig.9 is proportion and has been corrected.

Lines 453-456: the sentence is not relevant. What is the idea there? LIS on TRMM could not estimate the discharge intensity (if you consider that as the peak current). LIS is an imager and the light from the flash that reaches the sensor is scattered by the cloud, the magnitude (optical) depends also on the location of the flash within the cloud. Anyway, LIS data does not provide discharge intensity, at least directly.

Response: Thanks for the reminder, the relevant content has been removed.

13. Conclusion. At line 476, it is indicated: “it is found that their detection time difference for the same return stroke is no more than 10 μs”, is it consistent with Figure 3a? When you look at the values of the vertical axis, you do not see that.

    At line 481: “the ratio of +CG flashes up to 21.4%, much higher than the ratio (8.5%) of ADTD". The values are averaged about the whole area and the whole year 2020 probably. Is the value 8.5 % consistent with Figures 7 and 8? In Figures 7 and 8, the minimum value of the ratio is between 0.09 and 0.1 (closer to 0.1). Is it the same parameter? What happens to have only 8.5 %? In both cases it is called ratio of CG+.

Response: The comparison of the two systems has been removed.

14. Minor comments:
- In the title “cloud” instead of “could”
- line 28: Thus,
- line 45: Therefore,
- line 144: “than for CG”

Response: Above errors have been corrected.

- line 157: To write “Fig. 1(a,b)” I think it is better “Fig. 1a,b”
- line 159: The colored scale (typical colors) is displayed in the figure, not useful to write that. Better to comment with maximum values reached in the figure.
- line 173: Is the sentence correctly written?
- line 179: “The peak current values of CG flashes detected by the two networks are compared (removing outliers above ±300 kA),"
- line 181: rewrite the sentence with a value. Most is vague and rephrase with lightning flash and peak current.
- line 250: “shows” It is present, the figure is in the paper.
- line 251: “Earth”

Response: Above contents have been removed.

- line 270: What is the resolution for the density calculation?

Response: All density maps have added a declare “The gird size is 0.25° ×0.25°”

- line 295: The shape of trumpet is not useful,

Response: The corresponding content has been deleted.

- line 345: It is a little strange to announce that now, the -CG and +CG have been already

discussed before in the paper.

Response: After removing the previous content, here is the first description of the difference between +CG and -CG flashes in lines 198-206. We think it makes sense to introduce the two types of CG flashes before discussing the difference between them.

- line 350: reference is not correct.

Response: The corresponding reference has been deleted.

- line 447: check the reference, the name must be written, not the first name for Qie I suppose.

Reponse: Thanks for your detailed suggestions. We have checked and corrected all the references.

- line 450: What does “that excites the positive charge region” mean? Why not the reverse? Which charge region excites the other? It is not really like that in the cloud physics. The maximum electric field region is generally between both regions (when they are extended).

Response: The corresponding content has been deleted. In new vision, we focused on the presentation of data results rather than the analysis of mechanisms.

Reviewer #2: ADTD and 3D-LLS are both nationwide Lightning Location Systems (LLSs) in China. However, up to now, the performance of the two LLSs in the whole country is not clear yet. This manuscript compared the records of the two LLSs during 2020 in the first part, and then analyzed the temporal and spatial CG distributions as well as the difference between +CG and -CG over China based on the ADTD dataset during 2016-2021 in the second part. It must be pointed out that the analysis and conclusions in the second part are meaningful only when the performance parameters of ADTD are available. However, the current analysis in the first part is definitely not enough to provide reliable performance evaluation of ADTD. It is suggested that the authors make a comparative analysis between ADTD dataset and contemporaneous data from other LLSs with known performance evaluation parameters (such as WWLLN), to get a general understanding of the overall performance of ADTD in China.

Response: Through careful consideration, we also agree that the first part is somewhat irrelevant to the second part, so we decided to keep only the second part of the content. And following your valuable comments, the second part of the content has been extensively revised and enriched. The wording of the entire text has also been significantly modified. There are three main changes made:

a. The original system abbreviation, ADTD, has been changed to CNLDN (China National Lightning Detection Network) based on its latest official name, and a valuable site layout has been obtained, as shown in Fig. 1.

b. When analyzing the differences between +CG and -CG flashes, a more detailed statistical analysis was performed by dividing China inland into four regions, in your valuable opinion.

c. The analysis of the distribution of +CG and -CG discharge current was added.

Major revisions are required before the acceptance of this manuscript. Major issues are listed in the following:

1. This manuscript is mainly divided into two parts, but the connection between the two parts is not tight. The support of the first part to the second part is weak. Some problems exist in the comparison between the two LLSs in the first part.

a) Lines 13, 139, and 470: The authors declared that the CG flash detection efficiency (DE) of 3D-LLS is twice that of ADTD, because the total CG records of 3D-LLS is about twice that of ADTD in 2020. However, the authors also stated that many +CG records of 3D-LLS were misclassified from IC events. Furthermore, the comparison is limited to those records detected by 5 or more sensors and the sensors distribution of 3D-LLS network is not uniform. Therefore, such a conclusion is debatable.

b) Line 147: The authors mentioned that the CG flash density in the vicinity of the Canton Tower was 20/km^2/year. Is this an average value for several years or just for

2020? Does the term “DE” at line 153 refer to “CG flash DE”? If so, a CG flash DE of 24.5% is quite poor for a modern LLS. Considering that the sensors of 3D-LLS have already been densely distributed in southern and eastern China (see Line 117), the CG flash DE of 3D-LLS (50.5%) is also far from good. In addition, though TOLOG data can provide very good ground truth, but the comparison with the ground truth from a certain station can only give the performance parameters of a LLS in a local region, not in the nationwide area. Hence, it is necessary to conduct an evaluation for a large range combining with other data.

c) Line 172: The authors mentioned that the DE difference between the two systems can be up to a hundred times. It could also be found in Figure 1 that the DE difference between the two systems exceeds at least 10 times in many areas in Sichuan, Neimeng, Jilin, Shandong and some other provinces. This indicated that the DE of ADTD in those areas is no more than 10%, even if the DE of 3D-LLS is speculated as good as 100%. Such low DE will seriously affect the reliability of the analysis results in the second part. In addition, If the sensors distribution of 3D-LLS network is very uneven and the ADTD network is relatively uniform, it will be meaningless to compare the two LLSs in the whole nationwide region, because such comparison can’t lead to a quantitative and reasonable performance evaluation results of ADTD in the nationwide area.

d) None of the sensor distribution map of the two LLSs was presented in this manuscript, which does pose a great obstacle to the understanding of the analysis results. It is suggested that the authors should not compare the two LLSs in the whole country, but to choose some certain areas where both LLSs have good sensors distribution to conduct the comparison and achieve a more reliable result. In addition, it is recommended that the authors further provide more information about the network distribution of the two LLSs as detailed as possible, such as the number of the sensors and the average baseline length in each province.

e) Line 198: The authors stated that “Comparing the detection results for the same radiation source is necessary for valuing the difference between the two networks”. It seemed that the authors used a time difference threshold of 1 s for matching common CG strokes detected by both LLSs in 2.3. It can be expected that such a rough standard will lead to a large number of mismatches.

f) Line 218: “The two networks have different criteria for grouping flashes, and if there was a missed stroke in a lightning flash and they did not use the same stroke to represent the flash, the same lightning flash could not be matched in this case, leading to the low matching ratio” is confusing. If so, why not match stroke, but flash?

Response: Thank you very much for your serious and meaningful comments above. The first part has been removed in the opinion of the first reviewer.

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2. In 3.1, the authors divided China into four major regions according to geographical

and climatic factors. Should these four regions be analyzed separately when analyzing the differences between +CG and -CG in 3.2?

Response: This suggestion helps us a lot. In the new vision of the text, we conduct statistical analysis separately for four geographic regions, which can also reduce the errors caused by using the same time zone. Also by the dividition, some interesting new findings are obtained.

3. In Figure 7b, the average peak current of +CG strokes (It is no doubt that the authors should recheck and clarify the words “flash” and “stroke” in this manuscript to avoid confusion) in summer is significantly lower than that in other seasons. Especially in August, it seemed that the median value of peak current of +CG strokes was even lower than that of the -CG strokes. Does this imply that the summer +CG dataset used in this manuscript was seriously contaminated by IC events?

Response: We have supplied in lines 100-103, the lightning data used in this study are flashes grouped from strokes, and the first detected stroke represents the entire flash.

In our study, +CG flashes with currents less than 10 kA are not removed to make sure the comparison between +CG and -CG fair. However, in order to prove the reliability of our conclusions, we have drawn a comparison after removing +CG flashes with peak current less than 10 kA. It can be seen from the below figures that even after removing the weak +CG flashes, the average current of +CG flashes is still lower than -CG flashes in August, which is an interesting finding of this study.

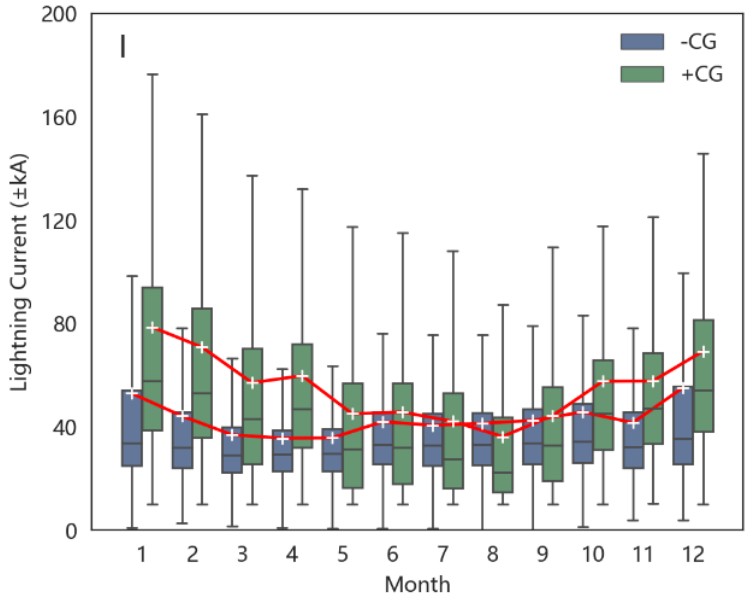

Figure a. Monthly variation of the peak current distribution of the +CG and -CG flash in Southern China. The +CG flashes with peak current lower than 10 kA have been removed.

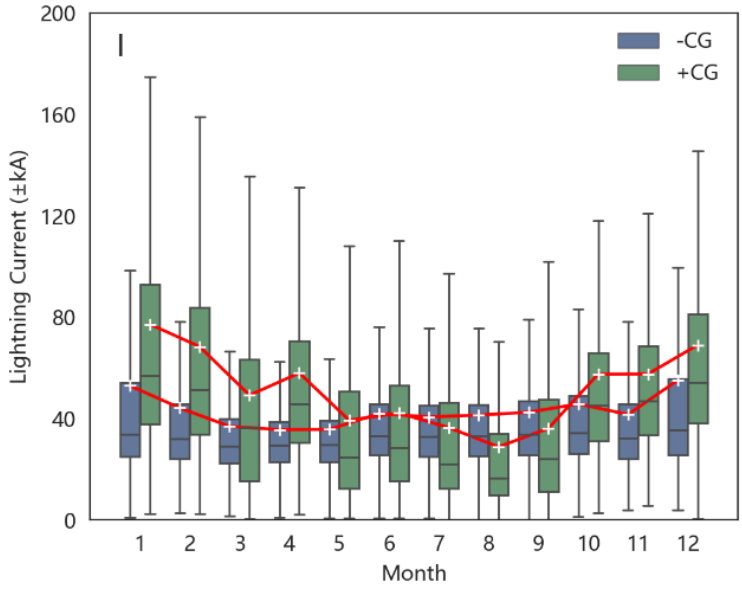

Figure b. Monthly variation of the peak current distribution of the +CG and -CG flash in Southern China. The +CG flashes with peak current lower than 10 kA are kept.