Author's Response to Anonymous Referee #2

Anonymous Referee #2

This paper presents a statistical analysis of data from 16-years of TRMM precipitation radar and lightning imaging sensor for four regions with different terrain in subtropical East Asia. The results show different characteristics of the thunderstorms in the regions. They also suggest that the 30 dBZ echo top height is a good indicator for the occurrence of lightning in the regions. It is important to provide analysis of such long-term datasets in order to compare with models of thunderstorms. Ultimately the results will contribute to an understanding of the physical processes.

The authors are very grateful to the reviewer for their contributions to this manuscript, these constructive comments have allowed a substantial improvement of the manuscript. Our responses to comments and action taken are given below. Some other existing problems have also been revised.

Major comments.

1. There is no presentation of errors in e.g. the echo intensities, the altitude of the tops of echoes or the location and timing of the two signals (lightning and reflectivity).

Response: Yes, the errors and resolution information of data should be presented before it is used. However, due to the high-quality TRMM data has been widely recognized over the world already and there are numerous important papers have been published based on TRMM. Therefore, only the processing of the data and the methods used (limit the noise and exclude erroneous cases) are introduced while the description of data itself is relatively less than normal in the original manuscript. According to your comment, some related information about the TRMM data (the PR and LIS) has been added in the Data and method section in the revised manuscript.

2. Physical explanations should be presented for the results obtained. This is important because there are some differences between the current and previous results. There is little, or no discussion of these differences.

Response: Thank you, the necessary physical explanations have been supplemented in the revised manuscript based on your comment.

3. The results are discussed in the final section without reference to previous work, even when a different result is obtained. The discussion section should include such references.

Response: The discussion section has been re-organized based on your comment. Some too long and repeated statement have been cut as necessary.

4. There is very little new knowledge about thunderstorms and lightning in the paper. There are in fact several papers that present similar data, but with far more extensive analysis, albeit for different geographical regions.

Response: Sorry, please forgive the authors for not agreeing with this comment.

Firstly, the result shows that the 30 dBZ echo top height has a concise relationship with the occurrence probability of lightning in convective storms, which can be easily used in the lightning nowcasting and warning services.

Secondly, the result of this paper confirmed that combining the ratio of convective rainfall to total rainfall with the radar echo structure of convection is an effective and feasible method to distinguish the stage of different convection (instantaneous snapshot view of convection) observed by the TRMM. This can help us further explore and maximize the usage of the observation data from non-sun-synchronous satellites, e.g., the TRMM, the GPM.

On this basis, the coupling patterns of the radar echo structure feature and lightning activity with the evolution of the extreme thunderstorms are summarized and discussed according to the statistical analysis of 16-yr TRMM data. Furthermore, this study found that convection with stronger radar echo structure but less or no lightning, are considered as thunderstorms in

developing/cumulus stage. While those weak thunderstorms, with lightning but especially weak in radar echo core (maximum reflectivity less than 40 dBZ) are actually thunderstorms in the dissipating stage. It is believed that a more stable and reliable relationship between lightning and convective properties of thunderstorms will be obtained if considering these different situations in advance. This is benefit to improving the lightning data assimilation techniques and simulation results (Mansell et al., 2007; Fierro et al., 2013; Qie et al., 2014).

Specific Comments.

Attention should be paid to the English throughout the manuscript. Words are often used incorrectly.

Response: Thank you for your reminder, we have been carefully checked and revised the English edit of the manuscript.

Lines 11-14. The sentence is not clear. Useful method for what?

Response: It has been re-edited in the revised manuscript.

Lines 30-33. It is not true that thunderstorms usually occur randomly in space and time. The initiation of convection depends on several phenomena that are becoming better understood. Convection that forms over mountains for example can be quite predictable.

Response: Yes, the previous description was not accurate enough and which has been modified following your comments.

Lines 65-68. It is not clear why lightning is an excellent indicator for studying convective intensity. Do you mean that the lightning frequency is related to the intensity of the convection, for example?

Response: Yes, the lightning frequency is an indicator of convective intensity of thunderstorms. The description has been revised.

Lines 77-83. The results of these studies should be discussed.

Response: Revised.

Lines 86-91. The sentence should be more specific by stating what results have been

found and what understanding is still required. The word "formation" is not correct.

Response: Revised together with the previous comment and some incorrect description has been removed.

Lines 96-102. There are many physical reasons for the situations described, likely including errors in the reflectivity values. None of these are discussed and really should be.

Response: Yes, there are indeed many physical reasons as you mentioned, the revised manuscript has further supplemented. Actually, some efforts had been taken to avoid the adverse effects of the errors.

Lines 120-123. The advection of storms from one region to the other (e.g. from land to ocean) should be discussed somewhere.

Response: This paper is a statistical analysis of long-term and a large number of convective precipitation observed by the TRMM, therefore, the advection of storms has not been discussed in the manuscript.

Line 135. There should be a discussion of errors and their affect on the results associated with the values of the reflectivity, altitudes, locations and timing, as well as flash rates.

Response: Please refer to the response to the major comment 1.

Line 142. There should be as much description of the properties of the clouds in the four regions as possible. Typical soundings should be shown for the days when there is convection. Important information includes estimated cloud base temperature, altitude of the 0 and -20C levels, and typical depth of clouds for example.

Response: Yes, your comment is very important and useful in discussing convection. But, this paper aim to show the statistical results and the evolution characteristics of lightning and radar echo structure of thunderstorms, this section (2 Data and methods) mainly introduces the related data and method used in the study. However, we will consider your advise in the future discuss and study, thank you.

Line 143-144. The reader would be interested to know more about the results. Otherwise, I suggest deleting this sentence and ones like it.

Response: This sentence has been deleted in the revised manuscript.

Lines 144-146. Reference should be made to Byers and Braham.

Response: The reference has been added, thanks.

Lines 151 on ward. I think it's important to discuss the main result and physical explanations of the Bang and Zipser paper. There is no discussion of an MCS for example. The current discussion does not capture the development of convective systems.

Response: The main results and physical explanations of the Bang and Zipser (2015) is discussed in the Introduction section, this section is mainly the introduction of data and method rather than the result, thank you.

Line 189. It would be interesting to know results concerning convection over the Tibetan plateau from previous studies.

Response: The Tibetan plateau related result was discussed in the previous part of this paragraph, and some results of previous studies has been added there.

Table 1. The table should give the units for height and maximum reflectivity.

Response: The units of all the tables are checked and given in the revised manuscript.

Lines 193-196. It would be helpful to have a discussion in the Introduction of the relevance of the height of the 40 dBZ echo that other studies have found – i.e. with reference to the charging zone, and the size and concentration of graupel. The results here could then be put in context.

Response: Thank you, we have considered your suggestion during the revision.

Line 204. Is the last column of Table 1 Maxdbz6-11?

Response: Yes, it has been corrected in Table 1.

Lines 206-207. What is the relevance of the high terrain?

Response: Revised.

Line 206. It would be best to use the same terms consistently.

Response: OK, thanks.

Lines 218 - 224. The text should be replaced by an appropriate reference.

Response: The test has been re-edited by reference to the paper of Byers and Braham (1948).

Lines 231-234 and Figure 3. It is odd that the frequency of convective to total rainfall over the Tibetan Plateau increases to 7% for a value of zero. More information should be given about why there is a problem with identification of the rain type.

Response: The misidentification of tain type has beed supplemented in the revised manuscript. The explain of the misidentification from Fu and Liu (2007) is that the TRMM PR algorithm misidentifies weak convective rain events as stratiform rain events. The possible cause for this misidentification is believed to be that the freezing level is close to the surface over the plateau, so that the ground echo may be mistakenly identified as the melting level in the PR rain classification algorithm. This is believed to be the reason why there are about 7% of thunderstorm over the Tibetan plateau do not have convective rain according to the TRMM PR data.

Lines 275-276. It is implied here (I think) that if there is strong convection with e.g. a large trailing stratiform region, that it is a weak thunderstorm, which is not true.

Response: Sorry, this is a misunderstanding caused by the previous inaccuracy expression. It has been corrected in the revised manuscript.

Lines 316-317. This has been stated already.

Response: Removed.

Lines 317-324. A more in-depth discussion of the charging process should be given in the Introduction and this section deleted.

Response: Agree, the revised manuscript has reorganized the related content according to your comment. The necessary discussion and reference have been supplemented in the introduction. Thank you!

Line 325-331. Most of what is written here is well known and obvious. Echo top heights have been used before for this type of analysis.

Response: Yes, it is obvious, this section has been simplified, thanks for your comment.

Lines 338-340. This point should be mentioned earlier – see comment above.

Response: Sorry, it may be that the statement in original manuscript is not clear enough and cause the confusion. The previous part (comment above) is related to the ratio of convective rain to total rain in thunderstorm, which is about **thunderstorms**. The object discussed here is **strong convection,** precipitation events with maximum PR reflectivity exceeding 40 dBZ while regardless of lightning. Despite this, this part has been clarified accordingly.

Line 348. "Intuitive" is perhaps not the correct word.

Response: It has been corrected.

Lines 350-351. The result should be discussed relative to other studies.

Response: Here only introduces the result, the related discussion appears in in the following part together with the result of Table 4.

Line 360. I think it's better to delete "and confusing".

Response: Done.

Lines 360-363. Please refer to the appropriate figure.

Response: Done.

Lines 399-402. It doesn't seem necessary to make this statement.

Response: OK, this statement has been removed in the revised manuscript.

Table 5. Please explain the headings in columns 2-5.

Response: The table caption has been re-edited, thanks.

Lines 414-416. Is this not the definition of storm-type B?

Response: Not exactly the same. By definition, the lightning flash rate of storm-B and storm-C are both exceed 32 fl/min, and the 40 dBZ echo top height of storm-A and storm-B are both exceed 10.5 km. From the vertical characteristics of thunderstorms, a higher 40 dBZ echo top height does not mean the 20 and 30 dBZ echo top height are also higher, especially considering the different geographical features. Despite this, modifications have been made in the revised manuscript to avoid confusion.

Lines 423-425. Is that not obvious?

Response: Removed.

Lines 425-427. Again, obvious.

Response: Removed.

Lines 429-432. Why could the thunderstorms not simply be mature thunderstorms that are slightly weaker than Storm B type due to say less CAPE?

Response: Of course, your statement must be appear in nature if it is considered from the case study of thunderstorms. However, the purpose of this paper is try to use statistical methods to explain from the perspective of different stages of thunderstorm life cycle.

Lines 432-434. Likewise for C-type thunderstorms. Delete "fluffy cloud top structure".

Response: Done.

Lines 440-442. This has been stated previously.

Lines 451-481. This is all quite obvious and well documented; most of the text should be deleted.

Lines 490-512. There is nothing new in this discussion. Most of it should be deleted.

Response: According to these **3 comments,** this section (4 Lightning and echo structure patterns of thunderstorms) in the revised manuscript has been deleted and the related context of figure 6 has been briefly discussed in the end of section 3.4.

Section 5. There are three main points. 1. The current results should be discussed with reference to previous work. 2. Physical explanations should be given for the results using results from previous work. 3. The section is too long and should be cut by about half.

Response: Thank you very much for the suggestion, the Conclusions and discussion section has been reorganized in the revised manuscript according to your comment.