We thank the anonymous referee #1 for his/her review of our manuscript. We will address the referee comments in blue font below.

RC1: 'Comment on egusphere-2024-174', Anonymous Referee #1, 13 Mar 2024

I have read this paper on lightning jumps and dives for the use in nowcasting, and while the topic is interesting, I think the paper needs major revisions before it can be considered for publications.

Major comments:

1) The paper is much too long. It appears to be a follow on of a previous paper by the authors that shows similar results.

We agree that the original manuscript is very long. We have revised the manuscript in a way we believe has improved the readability. Yes, the manuscript follows on the work of our previous publication where the lightning jump algorithm has been tuned for the GLM instrument. However, the objective and also results of this new manuscript have nothing in common with the previous paper. Here, we analyze cloud characteristics, while the previous paper correlated LJs and severe weather reports in order to optimize the LJ algorithm parameter for the GLM.

The paper appears to be a shopping list that brings basically all parameters possible to compare with lightning jumps and dives, without the focus needed and defined by the title of the paper. This is very distracting for the reader since there is too much information provided without a clear storyline. If you want to use lightning for nowcasting of severe weather or floods, you should focus on that.

We propose to slightly change the title into "Thunderstorm characteristics with satellite-based lightning jumps and dives" which better reflects the content of the manuscript. The main objective is not the nowcasting of severe weather (as in our previous paper) but to understand the LJs and LDs and what they reveal about the thunderstorms that produces them. To this end, we include a variety of thunderstorm characteristics and compare them for thunderstorms with and without LJs (and LDs).

It is clear to all (nothing new) that storms with LJs with be more developed with stronger updrafts, higher tops, colder tops, more overshooting turrets, etc. This is not new, and hence does not contribute to our scientific knowledge. Just presenting these results again does not make them novel or innovative.

This paper uses LJs and LDs that are detected from GLM observations. GLM observes lightning in the optical (oxygen band). Hence, the detection of lightning captures different processes of the lightning discharge that are different from those observed by VHF LMAs. Although the term LJ is used, the GLM LJs are often very different from the LJ that one would detect in LMA data, for example Murphy and Said (2020) showed that the GLM LJs are less correlated to radar variables than LMA LJs. The optical GLM LJs are apparently less correlated to cloud microphysics than the LMA LJs since GLM lightning detection is always influenced by additional aspects like viewing angle, cloud optical thickness, scattering of the light. That is exactly the point of this study. We want to find out if the optical GLM LJs and LDs correlate to cloud characteristics that are typical for severe storms although there are these additional aspects that affect the detection from space.

So I would focus ONLY on the use of LJ for severe events. Remove all the analysis not related to severe weather and LJs

That has been done in our previous publication and is not the objective of this work. Here, we investigate whether the LJs and LD are found for storms with similar characteristics as severe thunderstorms. This is done for the satellite-based GLM LJs and GLM LDs. The latter have never been studied before and it is one main objective to find out whether this concept provides meaningful information.

2) This brings me to the next point that as the authors point out in lines 176-177, 60% of storms with LJs do not produce severe weather, and there are severe weather events without LJs in 57% of cases. So this shows that lightning jumps from the GLM are NOT good for predicting and nowcasting of severe weather. So why continue with the paper then.

We do not agree with the referee here. If LJs help detecting 1 in 2 severe thunderstorms in advance, then this is a meaningful information for nowcasting severe weather. As referee #2 pointed out, the percentage is also affected by the fact that not all severe weather could be reported and the 59.9% is likely too high.

Note that there is no perfect nowcasting tool. Forecasters always combine different datasets (e.g., radar, satellite, and lightning) to identify the dangerous thunderstorms. In addition, the GLM LJs are based on total (CG+IC) lightning detection, and Erdmann and Poelman (2023) found that the leadtimes before the severe weather event can be longer than with other nowcasting tools (i.e., several tens of minutes). This is because the GLM detects the early high IC flashes well, and a GLM LJ can arise from that early lightning activity during the thunderstorm development.

Either the paper is not about nowcasting, and then you need to change the title and focus of the paper, or you need to prove that LJs are good in predicting severe weather.

Ok, we removed nowcasting from the title of the paper. The new title is "Thunderstorm characteristics with satellite-based lightning jumps and dives". Please note that lines 49-50, and lines 57-58 clearly state the objective of this paper mentioning optical LJs and LDs.

Here I would separate the analysis for tornadoes, wind damage, and hail. And if LJs are not good for detecting severe weather from GLM, then that too is a result, even if "negative". But no need to go on and on about cloud parameters linked to thunderstorms with LJs.

This would be a different study. We performed parts of the suggested tasks during the work on our previous paper (Erdmann and Poelman, 2023), and we did not see a specific behavior or correlation of the GLM LJs to a specific severe weather type.

3) I do not understand the interest in lightning dives (LDs). This is the first time I hear of their "importance" as a measure of thunderstorm activity. The physical meaning of LJs is the intensification of the storms, with stronger electrification, more rainfall, and maybe more severe weather. But why should we be interested in LDs which imply the decay of the updrafts in the storm, the drop in electrification, the drop in lightning, and hence the drop in probability of severe weather. Why should LDs be important for severe weather. Please explain the physical connection if you plan to keep talking about it. I would focus only on the LJs and remove the LDs analysis.

We added a paragraph to introduce the concept of the LDs and potential meaning. Based on previous preliminary results of US colleagues, the rear flank downdraft (RFD) can temporarily weaken the updraft and reduce the lightning activity shortly before or during a tornado. The RFD can also cause severe winds at the surface (reported events). Since LDs have never been studied, we included them in this work to investigate their meaning. We agree that overall the LJs are the more interesting features. We modified the conclusions to state this more clearly.

The following paragraph was added after line 27: "The LD exhibits behavior contrary to that of a LJ, leading to a rapid reduction in the FR as first mentioned by Losego et al. (2022). It is based on the idea that a decrease in lightning activity can precede events such as tornadoes or significant hail. That is the case since the rear flank downdraft (RFD) can be related to tornado development (e.g., Satrio et al., 2021; Mashiko, 2016; Markowski, 2002). Within the RFD, internal momentum surges can temporarily weaken the updraft or alter the hydrometeor content. Such a weakening of the updraft is correlated with reduced lightning activity, as noted by Deierling and Petersen (2008). Furthermore, downdrafts caused by intense rainfall or hail can interact with the storm's updraft and charging structure. These interactions can temporarily reduce lightning activity, as fewer ice particles collide, which is necessary to sustain strong electric fields through non-inductive charging."

Minor comments:

Title: The paper does not focus on nowcasting. Either it should, or the title should be changed.

We removed "nowcasting" from the title as it is not the objective of this paper. New title: "Thunderstorm characteristics with satellite-based lightning jumps and dives"

line 19: ...certain maxima and minima

OK

line 23: do you have a reference for "lightning dives" other than your own papers? Please add reference

No, we do not have a reference. We added a short paragraph to introduce the concept why it could be interesting to study it.

line 93: study aims

OK

line 124: Problem with text after 777.4nm

Thank you. We corrected the sentence. It was a formatting issue.

line 152: Both algorithm types use a FR

OK

line 172: do not produce

OK

line 174: It is obvious that what goes up must come down. Hence all LJs with be followed by a LD. Is this not a trivial conclusion

We understand the concern raised regarding the perceived triviality of the conclusion. However, we believe the conclusion is more nuanced than it may seem. The decrease of the flash rate can also happen slowly, and then one would not identify a LD there. We think that the LDs often occur during the dissipation phase of thunderstorms but further research is needed to confirm that idea. A modified LD detection algorithm could look at the development and mature phases of the storm only. For example, require the flash rate to increases again after a sudden drop was detected.

line 179: would still show

OK

line 196: Again, it is obvious that min pressure implies higher cloud tops and min BTs

We thought it is worth mentioning that the characteristics are consistent. However, the revised manuscript tries to reduce redundant information in order to be more concise.

Figure 2 appears to be a shopping list with no clear point. Are the overlapping blue boxes in 2a significantly different from each other?

We agree that Figures 2 to 4 are hard to read. The figures should introduce all thunderstorm categories and all cell characteristics that were studied. Since we have this information in Tables 2 and 3, we decided to simplify the figures. The revised manuscript discusses and shows selected thunderstorm categories and cell characteristics, and excludes/combines the ones that lead to similar conclusions.

If large parts of the IQRs (blue boxes) overlap in Figure 2, then these distributions for the categories are similar for the shown characteristic. If both the quantiles and mean values are higher in one category than in the other one, this can indicate that higher values are more likely in the first category than in the latter although the distributions are rather similar. The 6 (3 in the revised manuscript) categories with the lowest IQRs are statistically different (i.e., only upper outliers of their distributions match the lower distribution outliers of the other categories) from the remaining thunderstorm categories.

Line 217 and 236: Reference to Fig 2a should occur before Fig. 2b

OK. We modified Figure 2 to have the CT phase in a and the CRRs in b.

Line 330: Are these conclusions new? It appears a logical conclusion of more lightning in thunderstorms that has been studied for decades.

Yes, this is new as we are looking at optical LJs detected from GEO orbit. All previous studies used LJs that were identified from ground-based lightning locating systems (LLSs) that detect electromagnetic signals (LF or VHF) rather than optical pulses.

We state this explicitly in the Conclusions, and we added “GLM” to the bullet point heading to clarify that these conclusions mean the LJs/LDs detected in GEO GLM lightning time series.

line 334: "severe storms often feature".....quantify this. How often? This qualitative conclusion is not scientific

We did not analyze storm by storm, so we cannot quantify the statement. Hence, we modified the conclusion: “The means, medians, and IQRs of cell characteristic distributions for severe storms resemble those for the storms with LJs (and LDs).”

line 340: "might cause flash floods" is speculation. Do you not have information of floods at the surface? If not you cannot speculate so broadly.

We believe it is common understanding that heavy rainfall, in particular high rain rates (defined as large amounts of rain in a short time frame) are the key weather phenomenon causing flash floods. Of course, there are other aspects like the surface type, terrain, runoff that play a role, but it would be beyond the scope of this study to include a full hydrological analysis for each thunderstorm.

line 341: If the results here are similar to your previous publication, why do we need another publication saying the same thing? You need to provide new knowledge to advance the sciences and field of thunderstorm research and nowcasting.

Our previous paper did not look at cloud cell characteristics so this manuscript presents new results.

line 347: 2.1 +- what standard deviation? Same for 1.9. Are these values statistically different?

The ratios are calculated from fixed numbers, i.e., the number of LJs and LDs. There is no uncertainty assessment.

We cannot answer whether there is a significant difference between the warm and cold season. We simplified the sentence as follows, as it did not add value to the paper: “During all seasons, the number of LDs is about twice that of LJs.”

line 353: tropopause

Thank you, we corrected it.

Line 396: I would like to see more spatial plots in the paper like A1. Maybe a plot showing lightning jumps compared with severe weather reports of different kinds. I would add spatial plots to the main text

We agree that these plots are interesting for nowcasting aspects. However, as the focus of this manuscript is on the statistical analysis of the cloud cell characteristics, we would not add spatial plots to the main text.

Please see the spatial plots for the individual severe weather types in Fig. R1. We can see the locations of LJs best correlate with locations of tornadoes and hail reports, and not always with the locations of wind reports.

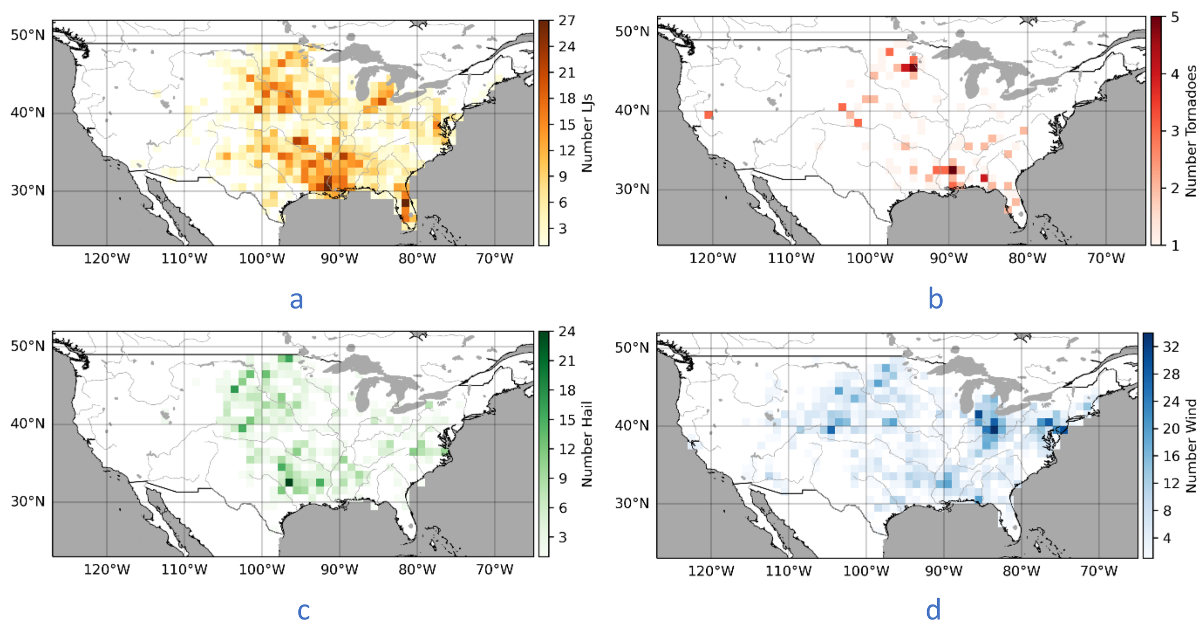

Figure R1: Number of (a) LJs, (b) tornadoes, (c), hail, and (d) wind events as reported in the NCEI archive per 1° x 1° pixel.