Author responses to the reviews

Response to RC1

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.

- It is correct that the manuscript follows on a previous publication where the lightning jump algorithm has been tuned for the GLM instrument. However, the objective and also results of the current manuscript have nothing in common with the previous paper. In this study 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. Consequently, the current manuscript is primarily concerned with thunderstorm characteristics rather than nowcasting.

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 changed the title into "Characterizing lightning jump and dive producing thunderstorms from geostationary observations" 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.

- We have reduced the number of characteristics in the manuscript (from 26 to 14) and excluded 5 thunderstorm categories from the discussion in order to focus on the most important results. We have also reorganized the results section to avoid duplication and allow for a clearer discussion.

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 satellite-based GLM LJs and LDs are found for storms with similar characteristics as severe thunderstorms. The latter have never been studied before and it is one main objectives 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.

- As previously mentioned, this study does not focus on the nowcasting potential. Instead, it aims to understand the implications for thunderstorm characteristics when a LJ or LD occurs.

- We would like to address your comment regarding the utility of GLM LJs in nowcasting. If LJs help detecting 1 in 2 severe thunderstorms in advance, then this is 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.

Obviously, 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.

The revised title is as follows: “Characterizing lightning jump and dive producing thunderstorms from geostationary observations”. 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 the following paragraph to introduce the concept of the LDs and potential meaning: “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.”

- 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.

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: “Characterizing lightning jump and dive producing thunderstorms from geostationary observations ”

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.

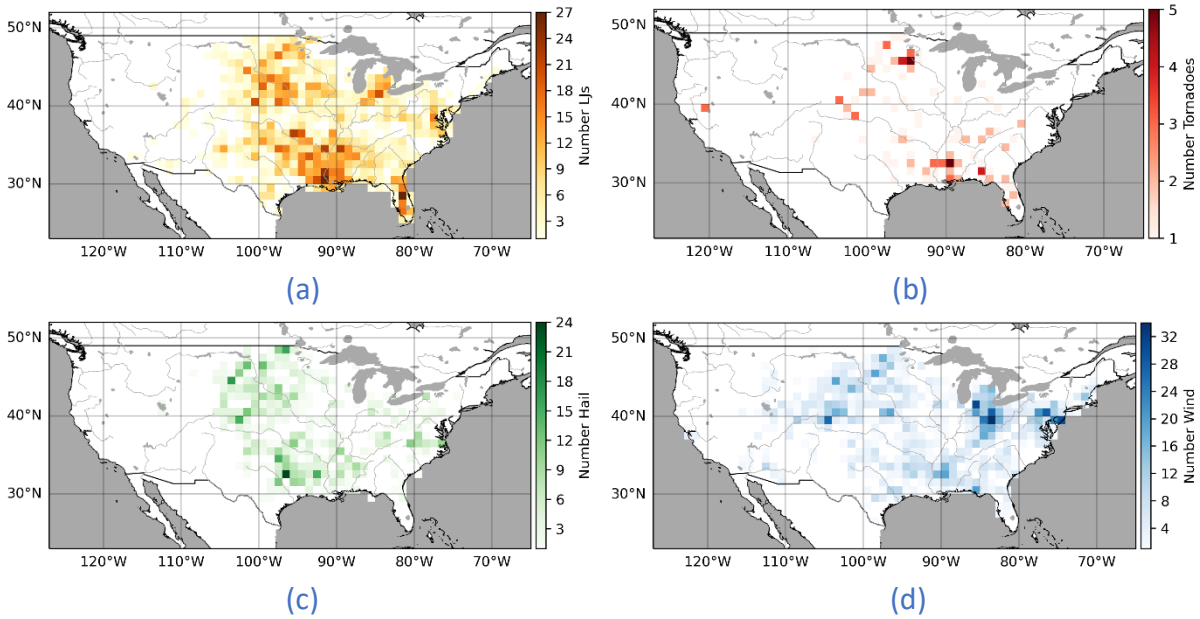

Figure R1: Number of (a) LJs, and the severe weather reports for (b) tornadoes, (c) hail, and (d) wind events as in the NCEI archive, per 1° x 1° pixel.

Response to RC2

We thank the anonymous referee #2 for his/her review and the positive feedback for our manuscript. We will address the referee comments in blue font below.

RC2: 'Comment on egusphere-2024-174', Anonymous Referee #2, 25 Mar 2024

Title: Thunderstorm characteristics with lightning jumps and dives in satellite-based nowcasting

Author(s): Felix Erdmann and Dieter Roel Poelman

MS No.: egusphere-2024-174

MS type: Research article

Thunderstorm characteristics with lightning jumps and dives in satellite-based nowcasting" by Felix Erdmann and Dieter R. Poelman presents an attempt of adapting the Lightning Jump to satellite imagery (Lightning Imager), as also introduces a new concept, such as the Lightning Dive.

We agree that the Lightning Dive (LD) is a new concept that has not been found in any publication (hence, no reference). The idea was first mentioned by US colleagues during the GLM science meeting 2022 (remotely), that found decreases in the lightning activity of a storm prior to or during tornadoes. The LDs are defined as negative LJs.

Since the objective of this paper is to investigate satellite-detected changes in the flash rate (i.e., GLM LJs and LDs), we included the LDs in our study. We added a paragraph in the introduction that introduces the idea behind the LDs:

“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.”

The results are interesting and promissing, having in mind the put in operation of the MTG in an early future. The main issue the lack of information regarding this last concept, because it is a novelty and it should be better introduced, with some examples that should help to make more understandeable to the reader.

Thank you for the positive feedback. We introduce the idea behind the LDs in the revised paper, but simultaneously focus more on the LJs.

Besides, there is some vaguety about the "severe weather" convept, which it must be better explained.

Severe weather is defined by the presence of a tornado, strong winds, and/or large hail. We use the NWS definition of a severe thunderstorm ("A thunderstorm that produces a tornado, winds of at least 58 mph (50 knots or ~93 km/h), and/or hail at least 1" in diameter.", https://www.weather.gov/bgm/severedefinitions). We added this reference to the introduction in manuscript.

Finally, the results are sometimes presented in a difuse way and I think the Authors could do an effort to improve the quality of presentation.

We re-structured our manuscript, with more focus on specific selected cloud characteristics.

You can find below the specific comments associated with the review.

L21: "The opposite behavior, a sudden decrease in the FR is termed a lightning dive (LD)" Referència?

We introduce the term here, based on an idea of colleagues from Georgia Tech. We introduce the concept in a short paragraph in revised manuscript, and we added the link to the presentation (https://goes-r.nsstc.nasa.gov/home/sites/default/files/2022-10/session_4/Losego_Megagraph.pptx, last accessed 19/04/2024) and the meeting (https://goes-r.nsstc.nasa.gov/home/index.php/meeting-agenda-2022)

Introduction: "Severe" or "Adverse" weather?

We added that we use the NWS definition of a severe thunderstorm.

Have you noticed if "However, most LJ algorithms were tuned based on ground-based lightning mapping array (LMA) data." are operational and running in real-time? (L44)

For example, the Meteorological Service of Catalonia runs a LJ algorithm operationally (Rigo and Farnell, 2022). A real-time use is possible since the algorithm is fast (less than 1 minute delay). Since the LJ algorithm are defined on the flash level, it should be considered that ground-based data must be clustered to flashes before the application of the algorithms, and there are effective algorithms to do that.

L80: "The object-oriented approach can effectively differentiate between convective and non-convective cloud cells, and track the convective cells through image recognition, identification of known patterns, and statistical models." Have you any feed-back comparing with weather radar database?

No, weather radar data were not analyzed and we do not know any comparison of the RDT cell tracking algorithm with a radar based cell tracking approach. Usually, the RDT cloud cells would be somewhat larger than radar based cells since the cloud shield covers a larger area than the convective cores and/or updrafts that can be detected with weather radars. You can compare Table 2 of Schultz et al. (2016) and Table 2 of Erdmann and Poelman (2023) for more details.

L104: why these thresholds?

We used the thresholds that were defined in previous studies (Schultz et al., 2009, 2011), also to be able to compare our results to the results of those studies.

Caption: "Figure 1. Relations between tools and data of this study." Is this a data flow? If yes, please change the caption.

No, the figure does not show a data flow. It simply introduces the different data types and software packages. We adapted the caption: “Data and product types of this study. The dependencies of products can be read from the top to the bottom, and they are also indicated by the arrows. On top, there is the input (grey), boxes with colored frames indicate the intermediate products, and the features in colored boxes are analyzed in the Results section.”

L 90: "During our selected study days (Table 1), there was one important GOES-16 downtime from 03 Jun 17:00UTC to 04 June 01:30UTC." change to "It is worth noting that there was one relevant GOES-16 downtime from 03 Jun 17:00UTC to 04 June 01:30UTC (Table 1)."

OK

L92: "It should be noted that only thunderstorms are analyzed that are defined as RDT cloud cells with GLM lightning activity." This sentence is difficult to understand.

We re-wrote the sentence: “An RDT cloud cell with matched GLM flashes defines a thunderstorm.”

L93: "This studies aims at understanding the meaning of LJs and LDs for thunderstorm characteristics." -> "This study aims to understand the meaning of LJs and LDs for thunderstorm characteristics."

OK

L95: "Such cells generally give rise to weaker weather phenomena compared to major thunderstorms." Partially disagree: warm rain clouds cause heavy rainfall and flash floods in many regions around the World.

Indeed, heavy rainfall or flooding can have other causes than a thunderstorm. We removed the sentence from the manuscript as it is not essential for this study.

Section 2.3: Have you considered the parallax effect? Besides, which is the general size of a RDT cell? Have you manually evaluated these thresholds in any case, to validate them?

Yes, the NWCSAF software corrects for parallax. The average size of an RDT cell is about 619.9 km2, and 2988.5 km2 for thunderstorm cells (Erdmann and Poelman, 2023). Please note that most of the time (>90% of NCEI reports matched to an RDT cloud cell) the report is located within the cloud cell contours. The 50 km threshold is applied to account for an uncertainty in the report location and/or the defined cloud contour. If a report is located within 50km of the cloud cell contour, then (i) the report is considered only if it isn't within the contour of another cloud cell, (ii) only the closest cloud cell is matched to the report. Hence, the 50 km are in practice very variable and state the maximum distance to match cell and report. We did not test longer distances.

We added to line 84: "RDT also corrects for satellite parallax effects."

L120: Have you evaluated the limitation of using standard scan instead of rapid scan? Which is the time running of the NWCSAF software?

No, we didn't. The processing times and data volume would increase significantly. This could be tested for a limited region. Since we tried to include many storms in the CONUS and GLM-16 field of view, we decided to use the 10-minute update cycle. NWCSAF can run with any satellite data that is given to the software as input. Our NWCSAF runs include the analysis and a 60-hour forecast. For one 24h period, NWCSAF runs about 20 hours on our institute server. However, a single 10-min slot with many active cells can need a processing time of up to 3 hours on our server. It should be possible to reduce the processing time through deactivation of some NWCSAF modules, but we did not test this.

L160: I think you should present an example of the LD, because is not an usual phenomenon as LJ and it needs to be assimilated by the reader.

We added a paragraph to explain the meaning of LDs in the introduction. LDs are really the opposite of the LJs where the flash rates decrease significantly (as of the LD detection algorithm) and rapidly from one minute to the other.

Section 3.1: the thunderstorm' categorization should be presented as part of the methodology. The analysis of the categories should be included in the Results section.

OK, we considered these suggestions for re-structuring the revised manuscript.

L172: Why do you think there are more LD than LJ?

This is based on the current algorithm configuration. LDs are often not only detected during the development of the storms, but also during their decay. A modified LD algorithm could exclude the dissipation phase of the storm when lightning activity always decreases and lightning dives can be triggered randomly. For example, require the flash rate to increases again after a sudden drop was detected.

L173: "A thunderstorm can produce more than one type of severe weather (the sum of withTornado, withHail, and withWind is greater than the number of severe TSs)." Please, write more clearly.

New: “The 3 categories withTornado, withHail, and withWind include the thunderstorms that produced tornadoes, hail, or wind, respectively. The sum of their counts (79+438+645=1162) exceeds the number of severe thunderstorms (970) meaning several thunderstorms produced more than one type of severe weather.”

L174: This sentence is reduntant and can be shortened

OK. We removed the explanation and just kept the first part: “All storms with a LJ also had a LD.”

L176: "There are storms with LJs and/or LDs that did not produce severe weather (59.9 % and 71.9 %, respectively)." Disagree. Severe storm can occurr but it has not been reported (or reported to the used database)

That’s a good point. We changed the sentence: “There are storms with LJs and/or LDs where no severe weather was reported (59.9 % and 71.9 %, respectively). However, these storms might have produced severe weather that was not reported.”

L319 Rigo and Farnell (2022) did not analyze LMA-based multi-LJ storms

Thank you for the comment. They used the XDDE LLS, not an LMA. We replaced “LMA-based” by “ground-based” in the manuscript.