Reviewer #1

In this manuscript the authors introduce a scalable, data-driven framework for the analysis and the interpretation of CG lightning activity large datasets. This framework consists of Number Distribution Lightning Differential Space, and the Current Ratio Lightning Differential Space that combined can provide insights and information regarding the CG activity in storm regions. Overall, the manuscript is very interesting, well written and well presented. I suggest it should be published after some minor comments are addressed that could improve the readability of the presented work.

We sincerely thank Reviewer #1 for the thorough and positive evaluation of our manuscript. We are pleased that the reviewer finds our work interesting, well-written, and suitable for publication. We carefully addressed all comments, as detailed below. In addition, we made minor editorial revisions throughout the manuscript to improve clarity and grammar.

1) Figure 3 is not explained in the text, but it is discussed in combination with Figure 4. I suggest either a paragraph to be dedicated for the discussion of Figure 3, or Figures 3 and 4 to be combined into a multi panel figure and then the panels of this figure to be discussed in the manuscript.

Answer: We thank the reviewer for this helpful suggestion. In the revised manuscript, we enhanced the discussion of Fig. 3 by refining the opening paragraph of the Results and Discussion section. Specifically, we added an introductory sentence that frames the purpose of the number-distribution LDS and a concluding sentence that explicitly links Fig. 3 to the cluster analysis presented in the following paragraphs. This provides a clearer, standalone explanation of Fig. 3 while maintaining the existing structure of the manuscript and ensuring that it is now discussed directly within the text.

The changes in the text:

The opening of the Results and Discussion section: *"We first examine the Number Distribution LDS, which provides a statistical view of how stroke intervals populate the 2D dR–dT space. As shown in Fig. 3a–c, stroke intervals...."*

The concluding sentence of the Results and Discussion section:

"This 2D representation serves as the reference Number Distribution LDS, outlining the cluster structure that is examined in detail in the following paragraphs."

2) Is the caption of Figure 4 correct? Does it really refer to Fig. 1 or does it refer to Fig. 3?

Answer: Thank you for this comment. We corrected the figure caption to refer to Fig. 3.

The corrected Figure caption:

"*Figure 4: Projections of the Number Distribution LDS in Fig. 3 onto ...*"

3) Wouldn't a projection of Fig. 5 onto dR and dT (similarly to Fig. 4) be useful in presenting and discussing the results?

Answer: We thank the reviewer for this suggestion. We added one-dimensional summaries of the Current Ratio LDS into the revised manuscript, shown as a new figure (Fig. 6). Because the current ratio is not an additive quantity, these summaries cannot be presented as true projections. Instead, we compute the median current ratio along each axis, providing a meaningful and statistically robust representation analogous to the way Fig. 4 summarizes the Number Distribution LDS in Fig. 3. To explain the new figure, we added a paragraph to the Results and Discussion section.

The newly added Figure 6:

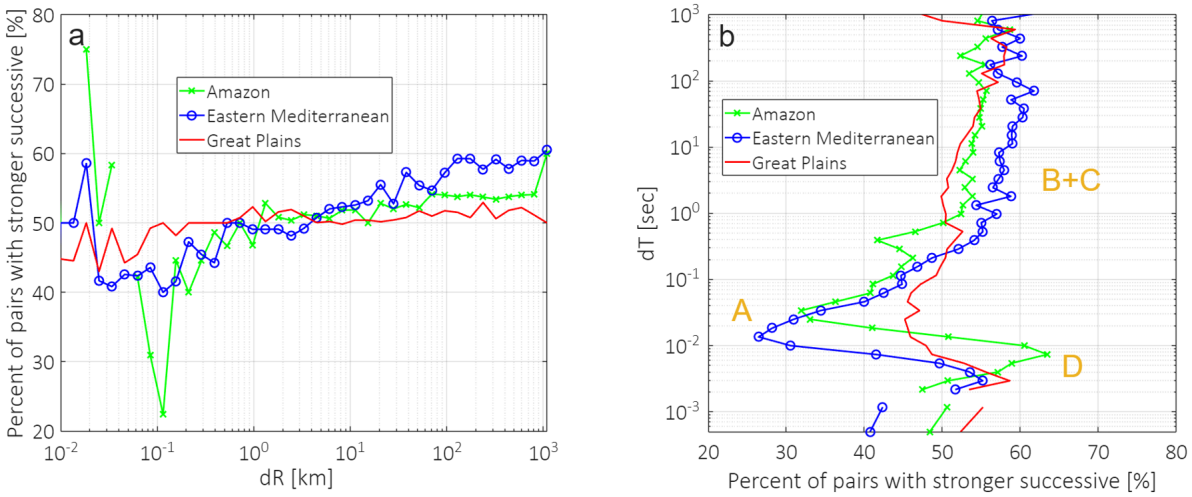

Figure 6: Median Current Ratio LDS projected onto the dR (a) and dT (b) axes, respectively, corresponding to the two-dimensional distributions shown in Fig. 5a–c. The position of cluster A–D is indicated in panel b.

The added paragraph:

"*Analogous to how Fig. 4 summarizes the Number Distribution LDS in Fig. 3,* ***Fig. 6*** *provides one-dimensional summaries that clarify the patterns seen in the two-dimensional current-ratio LDS in Fig. 5. Because the current-ratio is not additive, these summaries are computed as the median value along each axis rather than as projections. They highlight how the likelihood of a stronger/weaker subsequent stroke varies systematically with distance (****Fig. 6a****) and time interval (****Fig. 6b****) and demonstrate the contrasting behavior of cluster A versus clusters B and C more clearly."*

4) The authors state that the presented framework is suitable for comparing storm regions, validating lightning models and enhancing early warning systems. The whole discussion is dedicated in presenting a comparison between different storm regions, and thus it clear the contribution of the presented framework. There is no discussion how can the presented framework be used for the validation of lightning models and how can it enhance early warning systems. How can someone use the presented framework into achieving these goals?

Answer: We thank the reviewer for this comment. In the revised manuscript, we expanded the concluding section to clearly explain how the LDS framework can be used for the

evaluation of lightning models and the development of early-warning applications. In addition, we expanded the Summary section accordingly. These additions clarify the broader relevance of the LDS beyond regional comparison.

The extended Abstract part:

"This approach strengthens the ability to characterize multiscale lightning behavior, offers a framework for evaluating model representations of stroke and flash processes, and provides a basis for developing diagnostics relevant to operational monitoring and forecasting of lightning activity."

Added paragraph in the Summary:

"These capabilities support scientific and operational applications, such as comparison with cloud-resolving model outputs and lightning-parameterization schemes, and the provision of a diagnostic approach that may support probabilistic flash nowcasting or early-warning tools."

5) Can this analysis be also used for the investigation of Intra Cloud (IC) lightning activity? After all, the IC lightning activity dominates over the CG lightning activity in terms of occurrence. Why is this analysis focused only to CG flashes?

Answer: The LDS framework can also be applied to IC or mixed IC–CG datasets; however, because IC flashes exhibit very high breakdown rates and extremely short inter-stroke intervals, the inter-flash structure associated with clusters B and C does not emerge clearly in the 2D LDS. As the present work extends Ben Ami et al. (2022), our goal here is to demonstrate the full multiscale cluster structure, including clusters B and C, while also introducing the Current Ratio LDS across three climatic regions. For this reason, we focus on CG lightning in this study. We added a clarification to the revised manuscript to explicitly state it and to note that extending the analysis to IC lightning is a subject for future work.

The revised text in the Summary:

"In the present study, we focus on CG lightning strokes because the characteristic times of IC lightning differ, and hence the application of the LDS framework to this type of data requires further investigation in future work."

References

1. Ben Ami, Y., Altaratz, O., Koren, I., and Yair, Y.: Allowed and forbidden zones in a Lightning-strokes spatio-temporal differential space, Environmental Research Communications, 4(3), p.031003, DOI 10.1088/2515-7620/ac5ec2, 2022.