Anonymous Referee #2
nominated 08 Mar 2024, accepted 08 Mar 2024, report 28 Mar 2024

The paper is well-organized, well-written, and is an important contribution to the lightning detection community, especially in improving the lightning risk evaluation and related standards. Still, some aspects should be further discussed to emphasize the results.

Specific comments

The paper stresses that flash density (NG) is a crucial parameter to evaluate lightning risk (e.g. IEC 62305). However, there's no further mention of the norm neither in the discussion nor the conclusions. Results suggest the risk estimation of being struck by lightning should move to ground striking points (GSP) instead of NG. This point is relevant and should be discussed, as lightning risk has been introduced in the paper as one of the possible applications of the obtained results, but not further mentioned.

This remark is in line with the remark raised by reviewer 1. We propose to add following to the manuscript:

Within the domain of lightning protection and risk calculation, the selection of an appropriate multiplier for ground impact points per CG flash has long been a subject of discussion and was prompted at the time since LLSs only reported flash densities. Initially, Bouquegneau et al. (2012)[1] hinted at the necessity of applying a robust safety factor in risk component calculations, which could involve adjusting the value of Ng. Building upon this, Rousseau et al. (2019)[2] further reconfirmed doubling the Ng value in cases where Nsg is not obtained from a lightning detection system that meets the IEC 62858 standards, established by the International Electrotechnical Commission in 2019[3]. This approach aims to ensure a sufficient safety margin in risk assessments. On the other hand, the CIGRE TB 549 report[4] by the International Council on Large Electric Systems, released in 2013, suggests a more modest correction factor between 1.5 and 1.7, when only flash density data are accessible. One way or another, the optimal method involves directly calculating strike point density using a comprehensive lightning location network according to IEC 62858, made possible with present day state-of-the-art LLSs.
Recent research, such as the study by Vagasky et al. (2024)[5] along with the results of this study, suggests that doubling Ng may significantly overestimate actual needs. This is supported by our findings indicating that most regions within the EUCLID domain have a ratio of less than 1.6 ground strike points per CG flash (see Fig. 2b). Therefore, although using a factor of two to estimate Nsg offers a method to enhance lightning protection when only Ng data are accessible, it may also lead to unnecessary expense.

[1]Bouquegneau, C., A. Kern, and A. Rousseau, 2012: Flash density applied to lightning protection standards. Proc. GROUND 2012, Bonito, Brazil, Brazilian Society for Electrical Protection
[2]Rousseau, A. S., F. Cruz, S. Pedeboy, and S. Schmitt, 2019: Lightning risk: How to improve the calculation? Int. Colloquium on Lightning and POower Systems, Delft, Netherlands, CIGRE
[3]International Electrotechnical Commission, 2019: IEC 62858:2019: Lightning density based on lightning location systems – General principles
[4]International Council on Large Electric Systems, 2013: Lightning parameters for engineering applications. Working Group C4.407, CIGRE TB 549
[5]Vagasky, C., R. L. Holle, M. J. Murphy, J. A. Cramer, R. K. Said, M. Guthrie, and J. Hietanen, 2024: How Much Lightning Actually Strikes the United States? Bull. Amer. Meteor. Soc., 105, E749–E759, https://doi.org/10.1175/BAMS-D-22-0241.1.

Line 78. The method includes the CG stroke grouping (flash algorithm) as a first step before calculating the GSP. The flash algorithm parameters used are the classical ones introduced decades ago in the NLDN (Cummins et al., 1998). Since the stroke clustering has a bearing on the further GSP algorithm, I wonder if the EUCLID community has validated the Cummins criteria, since other studies (e.g. San Segundo et al., 2020) suggested that can be adjusted. Since the paper mentions the use of video and E-field records to estimate the EUCLID network detection efficiency, I think they should be used also to calibrate the flash algorithm, previous to the GSP calculation.

The feedback is appreciated. We were not previously familiar with the findings of San Segundo et al. (2020), which indicated that 5-10% of lightning flashes, as observed via LMA, could consist of multiple Ground Strike Points (GSPs) distanced over 10 km apart, and that flashes extending beyond 0.8 seconds are uncommon. By implementing a maximum duration of 0.7 seconds and a radius of 12 km for grouping, there would be a minor increase of 0.5% in the identified number of flashes. While we acknowledge the importance of utilizing the most advanced techniques and parameters in scientific research, it's important to note that our study encompasses various other uncertainties (such as in-cloud to cloud-to-ground misclassification (see also this reviewer's last remark), detection efficiency, etc.) that exert a greater impact than the 0.5% adjustment suggested in San Segundo et al. (2020). Furthermore, the current IEC 62858 standard employs the same algorithm as our study. Therefore, it was decided to maintain the existing flash algorithm in our research.

Regarding the distance between GSPs, note that Poelman et al. (2021)[6] investigated this as well in more detail and found that in Europe (based on ground-truth datasets taken in Austria, France and Spain) the 99th percentile of distance between GSP and the first stroke in the flash is below 10 km. However, the suggestion by the reviewer to use video and E-field records to (re)calibrate the flash algorithm is not straightforward. As stated in Poelman et al. (2021)[6] "*It is essential to highlight that the large maximum separation distances could well be the result of a location error by the LLS or a consequence of the manual grouping methodology based on the video information. From the perspective of cloud charge centers and the horizontal extent of downward leaders, it would make more sense to trace the lightning leader back to the location of the preliminary breakdown and only group strokes that emanate from a common charge region. However, this would require observations made by an LMA.*" Taken this comment into account, we believe the use of video and E-field measurements is not recommended.

[6]Poelman, D. R., Schulz, W., Pedeboy, S., Campos, L. Z. S., Matsui, M., Hill, D., Saba, M., Hunt, H.: Global ground strike point characteristics in negative downward lightning flashes – part 2: Algorithm validation, *Nat. Hazards Earth Syst. Sci.*, 21, 1921-1933, **2021**, https://doi.org/10.5194/nhess-21-1921-2021

Line 57 "the network's configuration has undergone changes in both the past and during the investigation period, i.e., 2013-2022. However, these changes are not substantial enough to significantly affect the results presented in the following sections" I think this statement needs a supporting reference.

The research by Schulz et al. (2016)[7], analyzed the LA from 2007 to 2014 based on measurements at the Gaisberg Tower. Although changes in the network occurred during this time frame, the LA improved steadily. In the same study, the Detection Efficiency (DE) was evaluated from data spanning different time periods (2008-2012, 2011, and 2012-2013) and regions within the EUCLID network. More recently, EUCLID network performance insights are complemented by the study of Schwalt et al. (2020)[8], which found stroke DE rates to be between 76% and 85.6%, based on ground-truth data from Austria across the years 2015, 2017, and 2018. The consistency between the DE findings of Schulz et al. (2016) and Schwalt et al. (2020) indicates that stroke DE have remained stable over the years, despite ongoing changes within the network. This stability suggests that network modifications during this period have not significantly affected the outcomes, underlining the reliability of the lightning detection capabilities over time.

[7]Schulz, W., Diendorfer, G., Pedeboy, S., and Poelman, D. R.: The European lightning location system EUCLID – Part 1: Performance analysis and validation, Nat. Hazards Earth Syst. Sci., 16, 595–605, https://doi.org/10.5194/nhess-16-595-2016, 2016.
[8]Schwalt, L., Pack, S., and Schulz, W.: Ground truth data of atmospheric discharges in correlation with LLS detections, Electric Power Systems Research, volume 180, 2020, https://doi.org/10.1016/j.epsr.2019.106065.

Line 122 to 126 It is mentioned that one of the aspects that leads to an overestimation of single-stroke flashes is the "misclassification of IC pulses as CG strokes." Can you develop this statement? What is the relative contribution of this factor? A supporting reference is needed here.

In their 2016 study, Zhu et al.[9] focused on evaluating the classification accuracy (CA) of cloud-to-ground (CG) and intra-cloud (IC) lightning activities, utilizing data from the U.S. National Lightning Detection Network (NLDN) and comparing it with optical and electrical field observations from the Lightning Observatory in Gainesville (LOG), Florida. It was found that the NLDN achieved a CG stroke CA of 92%. For the total of 153 IC events (including isolated IC events, IC events before first return stroke, and IC events after first return stroke), the CA was found to be 86%, while the CA for isolated IC events alone, i.e., complete IC flashes, was notably higher at 95%.
The evaluation of CA for the NLDN is relevant to EUCLID, as both networks employ comparable technology in terms of hardware and software.

[9]Zhu, Y., V. A. Rakov, M. D. Tran, and A. Nag (2016), A study of National Lightning Detection Network responses to natural lightning based on ground truth data acquired at LOG with emphasis on cloud discharge activity, J. Geophys. Res. Atmos., 121, 14,651-14,660, doi:10.1002/2016JD025574