Anonymous Referee #3
nominated 08 Mar 2024, accepted 12 Mar 2024, report 01 Apr 2024

The paper mainly discusses the ground strike points (GSP) spatial distribution over Europe based on cloud-to-ground (CG) stroke data from EUCLID network. It has a very short introduction that does not bring a clear motivation for the study. The description of the data and methods is fine, and the results are presented by nice figures and plots. However, the discussion is a little confusing, mixing different aspects of lightning detection that prevents from a good understanding.

1) My main concern is the actual motivation of the paper. Although the analyzes of the spatial distribution and the temporal characteristics of GSP are important for lightning protection, the paper does not discuss why we need of those results. In the Introduction (lines 26-32), it was said: "Among the various components that influence the risk estimation, the standard puts forward the flash density, NG, representing the number of lightning flashes per square kilometer per year, as one of the key parameters. However, by definition, the location of a flash is determined by the position of the first cloud-to-ground (CG) stroke within the flash. On the other hand, numerous studies, supported by high-speed camera observations (Rakov et al., 1994; Valine et al., 2002; Saraiva et al., 2010; Poelman et al., 2021a), have provided evidence that, on average, multiple ground strike points (GSPs) exist within multiple-stroke flashes. Hence, GSP densities should be given the pivotal role in lightning studies, particularly in the context of assessing lightning-related risks". The authors shall discuss more comprehensively how this study can effectively improve the lightning protection standards "in the context of assessing lightning-related risks". Remind that NHESS main scope is natural hazards, and the main topic of the paper must be connected to this subject.

This remark is in line with the remarks raised by reviewer 1 and reviewer 2. 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.

2) In lines 147-180 there is a long discussion regarding the lightning location limitations on measuring the CG strokes. I'm not sure if all those details are necessary. Chi2 and SMA are quality solution parameters that are used to select "good" solutions, which were used in the analyzes. In my opinion, these parameters might only be relevant for the study if the authors describe more comprehensively how EUCLID detects and geolocates lightning. Even in this case, I was wondering if this discussion can be suppressed.

Fig. 2 illustrates spatial plots across the entire EUCLID domain. While it is out the scope of this study to go in detail about the performance of the network on many different spatial sub-domains, the authors believe it is both relevant and informative to delve into a more detailed analysis within the specifically zoomed-in region presented in Figures 3 to 5. This examination aims in particular to shed light on the intricacies observed in relation to GSPF. Our goal is to illustrate that the EUCLID network exhibits robust calibration, especially when dealing with the challenging topography. However, it is important to note that, even with the effective calibration, the topography can still influence the spatial distribution of GSPF. This "exercise" highlights the network's precision while acknowledging the complex interplay between topography and performance metrics.

The authors propose to adapt what was already present in Sect. 2.1 in order to meet the request of the reviewer 'how EUCLID detects and geolocates lightning' as follows: "The network's primary function is to identify cloud-to-ground strokes (CG) and intracloud (IC) pulses within the very low frequency/low frequency spectrum. The location of the electromagnetic signals is accomplished employing time of arrival (TOA) and magnetic direction finding (MDF) techniques. For every lightning strike that EUCLID identifies, it meticulously logs a comprehensive dataset. This includes an accurate timestamp to the sub-microsecond, the strike's geographical coordinates, the nature of the event (distinguishing between cloud-to-ground (CG) and intracloud (IC) discharges), the discharge's polarity, an estimate of the peak current, and detailed waveshape metrics such as risetime and the duration from peak to zero. Additionally, EUCLID records both direct and inferred quality metrics, encompassing the semi-major and semi-minor axes of the 50% confidence ellipse for the event's location, the count of sensors that contributed to detecting the event, and the Chi^2 value, which assesses the agreement level among the participating sensors."

3) The paper also discusses the land-ocean peak-current contrast, which has already been described by several other publications cited by the authors: Cooray et al., 2014, Nag and Cummins, 2017 Poelman et al., 2016. I do not find any contribution of the GSP analysis to this topic. The same for the diurnal and seasonal variations (Figure 6). Is the intention of the authors only to present the GSP temporal behaviors? If yes, then you are please encouraged to discuss in more details how these characteristics impact on lightning protection and even on natural hazards.

The distinction between land and ocean peak currents has indeed been explored in previous research mentioned by the reviewer, with a focus on the flash and stroke level, rather than on GSP level as depicted in Figures 5a and 5b. The authors consider this to represent a subtle, yet significant, nuance when compared to the existing literature.

While presenting the spatial and temporal patterns is one aspect (Figures 5 and 6), our study goes further by attempting to establish a plausible connection observed between GSPF and GSP peak currents. Specifically, we argue that the observed temporal and spatial distributions of peak currents and GSPF may originate from a shared underlying cause. The authors recognize that the current data available from the EUCLID network limits our ability to delve deeper or provide further evidence for the relationship previously mentioned. Our inclination is towards utilizing this information to determine whether targeted laboratory experiments could provide additional insights into the hypothesis. For example, it could be interesting to explore whether an increase in leader tip potential could increase the tendency for branching-off, rather than following an already ionized path.

The scope of NHESS includes the detection, monitoring of natural phenomena […] and the spatial and temporal evolution of hazardous natural events […]. Therefore, the authors consider the temporal characteristics of GSPs highlighted in this study to be pertinent to the topic outlined by NHESS. Note that in the past, the authors have published a similar paper in NHESS, i.e., Poelman et al. (2016) describing the spatial and temporal observations of CG flashes in EUCLID.

4) Finally, the correlations of the GSP with multiplicity and peak current are discussed based on Figures 7 and 8. Again I do not find any relevance of these results in terms of GSP analysis, lightning protection, or natural hazards. I'd like to see a more comprehensive discussion on how these parameters affects the GSP results which will consequently impact on the lightning protection standards.

The authors are of the opinion that the analysis showcased in Figures 6 and 7 is indeed relevant to this study. While the peak current analysis depicted in these figures may not have a direct impact on the implementation of effective lightning protection measures, it offers scientific insights that align with findings reported in the existing literature concerning the peak current of cloud-to-ground (CG) strokes relative to their occurrence within a CG flash.