Answer to RC1 (Anonymous Referee), nhess-2021-12

General comments:

This paper presents a comprehensive study of negative downward lightning flashes based on high-speed video camera recordings of negative cloud-to-ground lightning in several regions around the globe. This study presents solid statistics that help improve the current lightning protection standard (change from flash density to ground-strike point density). The subject is suitable for this journal. Several comments follow. I recommend this paper be accepted after minor revisions.

Specific Comments:

1. Did the authors include upward lightning in South Africa dataset? If yes, I think those upward lightning contradicts your title (negative downward flashes). If not, please state so in the paper.

   => Upward lightning flashes are not taken into account in the South African data set. This will be highlighted in the next version of the manuscript.

2. “Note that in Austria two flashes are observed whereby a new GSP is created by the tenth stroke in the flash, while the channel belonging to the previous GSP was used four and seven times, respectively.” It would be interesting to know the interstroke interval preceding the 10^{th}

   => The interstroke interval preceding the 10^{th} stroke in the two flashes are 26.2 ms and 103.97 ms, respectively. This will be indicated in the next version of the manuscript.

3. Flash characteristic studies solely relying on high-speed cameras have limitations. I hope the authors could discuss those limitations and how those limitations could possibly influence the statistics presented. Two limitations that I can think of: (1) strokes creating a new termination could be missed by the camera (e.g., the stroke can occur at the back of cameras or simply out of view). (2) It is likely camera record length is not long enough to cover the entire flash. I see that length for SA dataset is only 1s with manual trigger setup (not sure what’s the pre-trigger and post-trigger during manual trigger setup), maybe this partially explains why most SA flashes are single-stroke flash. Simultaneous electric/magnetic field measurements/LLS data might help mitigate some of those limitations. They could be used to see if there are additional strokes in the vicinity but outside the field of view of camera or outside the duration of the camera records.

   => The introductory paragraph of Sect. 2 ‘Data acquisition and analysis’ will now include the limitations linked to high-speed camera observations of lightning as suggested by the reviewer:

   “Ground-truth campaigns are time consuming in order to gather enough data to be statistically relevant. To reach this objective, ground-truth datasets are collected from

different geographical regions and taken over various periods in time: Austria (AT) in 2012, 2015, 2017 and 2018, Brazil (BR) in 2008, South Africa (SA) in 2017-2019 and U.S.A. (US) in 2015.

It is of importance to recognize the limitations inherent to high-speed camera observations when used in flash characteristic studies. In particular, strokes creating a new termination could be missed by the camera when occurring out of the camera's field of view. In addition, the record length should be long enough in order to capture the entire flash, i.e., typically longer than one second. Aiming to minimize as much as possible the influence of the latter on flash statistics, high-speed camera observations should be checked against concurrent electric field measurements to ensure a stroke was not missed. In this, flashes with channels that are outside the field of view can be excluded from the data. For the measurements in all of the data sets presented in this study electric field measurements have been used, and therefore only flashes, where a clear visible channel to the ground is observed for all the associated strokes are included. However, it should be noted that even though such a selection of flashes is made, it does not undeniably resolve the true contact point all of the time. This is certainly true when the observations are made at ground level or even worse in the Alps. As such, the amount of ground strike points retrieved from the video fields as discussed later on in this study should be regarded as a lower limit. In the cases where the time interval between subsequent strokes is lower than 1 ms, the stroke is considered to be a forked stroke rather than a stroke creating a new GSP, which in turn reduces the multiplicity of the flash. All the data sets, except US, indicate the duration of the continuing current (CC) for each stroke if present in the recorded video fields.

In what follows, a description is given of the instrumentation set-up used at the different regions and the periods of investigation.*"*

=> Related to SA: The buffer time is not one second (as written in the original manuscript), but 1.8 second. We will adapt Sect. 2.3 as follows: "… The setup utilizes two high-speed cameras (a Phantom v7.1 and a Phantom v310) which are located North-West of the city. Frame rates used are in the range of 5000 to 15000 fps and all captured videos are GPS time-stamped. A 1.8 second buffer time is used and events are manually triggered. Typically, the pre-trigger and post-trigger were set approximately 60/40 of the 1.8 second buffer respectively. …."

4. "It follows that the channel creating a GSP is re-used by a factor of 2.3" I think the word "re-used" is ambiguous. Sounds like the termination created by a previous stroke will be re-struck by 2.3 subsequent return strokes on average. Your statement "A ground contact point is struck 2.35 times on average" in Line 166 is more accurate.

   => This particular sentence in the abstract will be simply rewritten as 'It follows that a ground contact point is struck 2.35 times on average.'

<u>Minor editorial suggestions:</u>

1. Line 65: “Hence, the role of high-speed camera observations.” This Is not a complete sentence.
2. Line 70, enable us to determine
3. L127, 150 m

=> Editorial suggestions will be taken into account