Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2017-105-AC1, 2017

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Comparison of lightning activity in the two most active areas of the Congo Basin" *by* Jean K. Kigotsi et al.

Jean K. Kigotsi et al.

serge.soula@aero.obs-mip.fr

Received and published: 16 October 2017

Interactive comment on "Comparison of lightning activity in the two most active areas of the Congo Basin" by Jean K. Kigotsi et al.

Response to Anonymous Referee #1

Review for NHESS-2017-105

Title: Comparison of lightning activity in the two 1 most active areas of the Congo Basin Authors: Kigotsi et al.

General comments:

This manuscript presents an exploratory analysis of lightning activity over two distinct

areas of Congo Basin: 1) the area where the maximum annual lightning flash rate density (FRD) is observed (west of the mountains that delineate the Rift Valley), hereinafter called Area_max, and 2) the area just west of Area_max, where very high but less pronounced FRD is observed, hereinafter called Area_sec. The manuscript is of the interest to the audience of this journal but needs a few adjustments. I recommend its acceptance only after addressing the issues described below.

Response of the authors

The authors thank the reviewer for her/his careful work to evaluate the paper. We appreciate the comments and the remarks that help to improve the paper. The paper required a major revision and we hope to have made corrections enough to make the paper clearer and more relevant paper.

Substantial modifications are made, especially a figure is added to have a wider view of the data and justify some choices. The study is systematically extended to 2012 data, to have a more robust comparison between both areas, which is the goal of the paper. We delete a figure and add a new graph and a new figure to show one case of distribution of a strong daily lightning activity. We add information about the WWLLN data and network.

The interpretation is developed when possible. For example we now highlight an interpretation for the difference between both areas by using the paper by Jackson about MCS location over equatorial Africa: both areas (Area-max and Area_sec) are included in one of the four maximums described in Jackson et al.. They explain this large maximum is due to the AEJ-S, while two other maximums were explained by the orography and another by the Lake Victoria. We distinguish two maximums in this large maximum, from which Area_max combines the presence of AEJ-S with local orography and Lake Kivu.

We make most of the corrections suggested by the reviewers and we answer to the comments in the following.

Major remarks:

Data: a) Soula et al. (2016) did an excellent job in calculating WWLLN detection efficiency (DE) for each year (2005-2013). This work should leverage from Soula's work and correct 2012 (DE=4.44%) and 2013 (DE=5.90%) data before doing the analysis. The subtle differences from 2012 to 2012 shown here could be an artifact of the different DE.

Response of the authors:

First of all, we have to say the comparison is made between two areas with a large flash rate density (FRD) in Congo Basin and not from one year to the next.

These areas (Area_max and Area_sec) correspond to the maximums pointed out in Soula et al. (2016) and as the reviewer noted it in a comment, to the areas surrounding most hotspots in Africa noted by Albrecht et al. (2016). Area_max includes 6 out of the 10 hotspots (1,2,3,5,8 and 10) found in Albrecht et al., while Area_sec includes 2 out of the 10 hotspots (6 and 7).

The DE is considered in Soula et al. (2016) and it was calculated relatively to the LIS data that cumulate cloud-to-ground and intracloud flashes. Thus, the DE values found in Soula et al. are low for the whole study area, 5.9% and 4.4% for 2013 and 2012, respectively. However, the DE can depend on the region since the study area in Soula et al. was very large ($25° \times 25°$). Soula et al. (2016) have clearly highlighted the increase of DE between 2012 and 2013, the rate of which can be estimated at about 34%.

We noted also the DE was not constant in the whole study area considered in Soula et al. (2016). Thus, the values 4.44% and 5.90% are average values for the whole area. We consider now the specific values of DE for both areas Area_max and Area_sec. The new figure 1 is made to show different parameters for each area from 2005 to 2013:

- the lightning activity issued from LIS

- the lightning activity issued from WWLLN

- the DE estimation calculated according to the methodology presented in Soula et al.

We see DE was stronger in Area_sec from 2005 to 2009 and in Area_max from 2010 to 2013. The question to correct the data by applying DE can be asked. We choose to let the data without any corrections for several reasons:

- the correction can be applied only globally for a given area, it does not change the comparison of the parameters we compare between both areas when we use proportions (proportion of lightning versus month)

- the DE is calculated for one year and for a given area. To take into account an eventual correction we have to add flashes uniformly in each month, in each 1-hour time interval, in each day... It seems too artificial to correct all flash numbers at such small scales as 1-hour window, day, month...

- The correction could be made at the scale of the year for the number of flashes.

b) Also, why is it relevant to compare 2013 to 2012? Also, was there something different in terms of atmospheric conditions (such as significant droughts, rainier year, El Nino, La Nina, etc.)? My suggestion is to make it simple and combine the years, you may be inserting a lot of uncertainties in your analysis.

Response of the authors:

Figure 1 can be a response to the comment because it provides an overview of LIS and WWLLN data over the 9-year period. The two years 2012 and 2013 are selected because they correspond to the strongest detection efficiency (DE) from the years we have in our database.

In Soula et al. (2016) the LIS data were used to compare the activity from one year to the next. The difference for the whole region was low since the maximum was found in

2009 (195,316 flashes detected) and the minimum was found in 2012 (182,560 flashes detected), which provides a difference of 6.5%. Considering 2013, LIS data provides 192,443 flashes detected which represents an increase of about 5% from 2012. The interannual variability was found low by considering LIS data. Now we consider for this work of comparison the DE at the scale of each area (Area-max and Area_sec) and the LIS data at each area too. The new information allows better describing the WWLLN data used in this study.

Session 3.3: c) I really don't think that the analysis of number of days within classes of flash counts is considered an "Annual variability".

Response of the authors:

Done, we use now Day-to-day variability

d) Also, why use only 2013?

Response of the authors:

We use 2012 and 2013 for a study more robust.

e) L146-147: "The number of days without any flash (CL0) is much larger for Area_sec than for Area_max (7 and 0, respectively).". A difference of only 7 days is not representative of annual variability.

Response of the authors:

We change the first class because we now think it is not necessary to separate days without any flash and days with very low flash numbers (some cases have less than 10 flashes). Thus we consider now a first class corresponding to a very low flash rate (< 100 flashes per day in an area).

Session 3.4:

f) In essence, Fig.3 and Fig. 4 show the same results. Also, the results presented are

really confusing making me not to get the relevance of this session.

Response of the authors:

Section 3.4 is deleted.

Session 3.5:

g) Did your really expect a correlation between daily number of flashes in each area? This is a very weak way to show that thunderstorms are different within each area and you should rethink how to approach this issue.

Response of the authors:

We explain at the beginning the approach that consist in comparing the lightning activity day by day. It allows us to show the strong lightning activity is often local, even if the conditions favourable for storm developments are present in larger areas. Figure 7 shows an example of daily lightning flash rate density.

Session 3.6:

h) Very confusing: : : first of all, "monthly proportions" to what? To total number of lightning in each year? If the objective is to show "monthly activity", why not show flash counts by months? Or is it also the objective to show seasonal contrasts? Please explain better.

Response of the authors:

The section aims to present the annual distribution of the lightning activity, at the scale of the month. We call it now "Month-to-month variability". We add a figure to show the annual cycle at the scale of the season defined by DJF, MAM, JJA and SON, as in Christian et al. (2003).

i) Again, what is the relevance of comparing 2012 to 2013?

Response of the authors:

We do not compare 2012 to 2013, the reason for considering two years is to have a more robust comparison between two areas.

Minor remarks:

In general, review the significant figures (or digits) of all your numbers. E.g.: - L 99: ratios of 1.941 and 2.585, shoulb have only one significant digit –

Response of the authors:

We agree and correct. Two digits after dot are fine. 0.01 over 1 is about 1%.

L 106: 15.33 flashes km-2 <yr-1>, should have no significant digit after "point", while 8.22 and 8.62 should be 8.2 and 8.6 (considering that lightning strokes are a single unit)

Response of the authors:

For the values around 8 for the flash density, effectively one digit after dot seems enough because 0.02 over 8 is about 0.25%. Consequently, one digit for 15.33 seems also enough, it would be 15.3.

L 9-23: Avoid using abbreviations in the Abstract text, such as Area_max and Area_Sec, except if explicitly explained in the Abstract.

Response of the authors:

At the beginning of abstract (first sentence), Area_max and Area_sec are explained.

L 28-29: As a reference, Albrecht et al. (2016) show the impact of resolution (0.1o, 0.25o, 0.5o) while ranking the lightning hotspots. Please see Table ES4 of supplemental material: https://doi.org/10.1175/BAMS-D-14-00193.2.

Response of the authors:

Thank you for this comment about the very instructive table. The initial comment we made in the paper was essentially related to the shape of the maximum area in the

Congo basin. We note the reference to illustrate the effect of the spatial resolution on the maximum value of FRD and on its location and we develop the comments related to this aspect.

L 50-52: Table ES4 of supplemental material (https://doi.org/10.1175/BAMS-D-14-00193.2) also shows the persistence of DRC as the second Earth's lightning hotspot.

Response of the authors:

The response in the previous point includes the response to this comment.

L 69-88: Please, make it clear that WWLLN detects only cloud-to-ground (CG) lightning and that it does not detect intracloud (IC) lightning, which, in general, is the majority of lightning produced by a thunderstorm. This is also one of the reasons why your values in Fig. 1a differ from those of Albrecht et al. (2016).

Response of the authors:

We do not compare the values of the FRD in our paper with those in Albrecht et al. (2016) since they are not comparable. However, according to several references the WWLLN can detect IC flash strokes but with a lower detection efficiency. The system does not exclude the IC strokes, which could be made probably with a recognition of form.

For example, Rodgers et al. (2005) say :" The detection efficiency of the WWLL is also considered. In the selected region the WWLL detected _13% of the total lightning, suggesting a 26% CG detection efficiency and a 10% IC detection efficiency."

Abarca et al. (2011) says: "The network detects CG and intracloud (IC) flashes with the same efficiency as long as they have the same current magnitude and channel length (Lay et al. 2004; Rodger et al. 2005, 2006; Jacobson et al. 2006); however, CG DE is about twice the IC DE (Abarca et al. 2010) because CG flashes tend to have higher peak currents."

We note the WWLLN is less efficient for IC flash detection.

Abarca, S.F., Corbosiero, K.L., Vollaro D., 2011. The World Wide Lightning Location Network and convective activity in tropical cyclones. Mon. Weather Rev. 139, 175–191.

Rodger, C.J., Brundell, J.B., Dowden, R.L., 2005. Location accuracy of long distance VLF lightning location network: post algorithm upgrade. Ann. Geophys. 23, 277–290.

L 91, Figure 1: Although your analysis considers full years, the most adequate unit is “flash km-2 yr-1”, and it should be called “flash rate density”.

Response of the authors:

Done

L 93: “: : : days of year with thunderstorm activity: : :”. Since WWLLN detects CG lightning only, you should substitute “thunderstorm activity” by “lightning activity”.

Response of the authors:

The WWLLN detects also IC flashes, so thunderstorm activity can be used but lightning activity can be well adapted.

L 98-99: “On the contrary, the flash <rate> density <in an individual 0.05o resolution point> is very different : : :.” . Is that correct?

Response of the authors:

We compare the ratio between the maxima flash (rate) densities in both areas, calculated in 2012 and in 2013 (Table 1). The ratio for one year can be different in one year and in the other.

L 104-105: “By comparing with the values reported by Soula et al. (2016) for a resolution of 0.1_, : : :” which are???

Response of the authors:

The sentence that follows in the text gives these values. Maybe we are not clear, we try to improve it.

L 115-116: Please give scientific references for this affirmation, or you should state that this is a speculative affirmation.

Response of the authors:

It was noted in Soula et al. (2016). We note the number of flashes per stormy day is larger in the region of the main maximum. To have more flashes during a day of storm, there are three possible explanations: more storms, storms more active, storms more stationary. It can be also a combination of several of the three explanations.

L 127: “Both areas exhibit the same type of <diurnal lightning activity> evolution with a large: : :”

Response of the authors:

Done

L130: Please annotate that Local Standard Time (or Solar Time) is the same as UTC (i.e., LST = UTC -0)

Response of the authors:

We note this sentence at the beginning of the section: “The time is indicated in UTC, which is two hours late compared to Local Time (LT = UTC + 2).” Be careful, the local time is different in western DRC and eastern DRC and local time is different from solar time that needs a calculation. Local time is the time used in the eastern part of the country (DRC) including both areas (Area_sec and Area_max).

L 137-154: You should show only Figure 3 or Table 2, they are redundant. The same is valid for Figure 4 and Table 3.

Response of the authors:

Tables are rearranged. Table 3 is deleted and the new table 2 includes now 2012 and 2013 data. Figure 4 is deleted and the new figure 4 includes 2012 (a) and 2013 (b). The table provides the number of days for each class and the percentage of the total number of days. The figure has its usefulness for the tendency of the evolution in each area and their comparison.

L160-161: Please define the specific day (or months) regarding the 179 and 92 days span.

Response of the authors:

Deleted

L 189-190: "This observation is consistent with the fact that the lightning activity is more spread during the day in Area_sec as indicated in Figure 2.". This may be due to the contribution of nocturnal lightning by MCSs or isolated storms that develop later in the afternoon if compared to Area_max. If you take a closer look in Albrecht et al. (2016) Figure 3, you will see that there is more lightning during the night for the hotspots that are in Area_sec (i.e., 6th and 7th Africa's hotspots).

Response of the authors:

Good point. We add this comment: "This may be due to the contribution of nocturnal lightning by MCSs or isolated storms that develop later in the afternoon if compared to Area_max. Indeed, the work by Albrecht et al. (2016) shows in their Figure 3 that during the night, the hotspots located in Area_sec (i.e, 6th and 7th Africa's hotspots) exhibit a larger contribution to the daily lightning activity.

L 219: ": : : different locations of our areas". Not really. The daily cycles shown in Albrecht et al. (2016) consider a 1 degree box around the hotspots, and 6 out of 10 Africa's hotspots are within your Area_max and 2 hotspots (Africa's 6th and 7th positions) are within your Area_sec (vide Albrecht's Figs. 2 and 3).

Response of the authors:

We agree and the sentence did not express correctly what we wanted to say. We say now : "for several hotspots located in our areas"

L 219-220: "They found also a more pronounced daily cycle: : :". This is because they considered a smaller area (a 1 degree box around the hotspots).

Response of the authors:

We change the sentence to say our results are consistent with those from Albrecht et al.

Tables 2 and 3: "Number of days", plural in the first line of the tables.

Response of the authors:

Done

Table 3: explain what (%) means, i.e., proportion to what? The sum of % Is 100% in each column?

Response of the authors:

Deleted

Figure 4: Explain "proportaion of day"

Response of the authors:

Figure 4 is deleted but the proportion is still used. We now explain the proportion of days in the caption of the new figure 4 and in the caption of Table 2.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-105/nhess-2017-105-AC1-supplement.pdf

---

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-

2017-105, 2017.