

Interactive comment on “Lightning flash multiplicity in Eastern Mediterranean thunderstorms” by Y. Yair et al.

Anonymous Referee #1

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The paper ‘Lightning flash multiplicity in Eastern Mediterranean thunderstorms’ presents data obtained from a lightning location system in Israel, and analyses the effects of changing the range and inter-stroke time criteria in an algorithm for converting stroke data into flash data. Although the topic of stroke-to-flash conversion techniques is relatively underdeveloped given the complex nature of lightning - and so additional discussion on the topic is to be welcomed - the way in which conclusions are drawn in this paper leave major concerns. The paper merits publication, if these points can be addressed.

- GENERAL COMMENTS

The key issue is that the authors suggest that the use of stroke-to-flash algorithm cri-

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teria of 10 km and 0.5 seconds between strokes are too relaxed, and so suggest an alternative approach of using criteria of double the location uncertainty of the network (in this case, using range criteria of 2.5 km) and an inter-stroke interval of 0.2 seconds. These conclusions are based on the evidence that the majority of strokes in a single flash occur within a couple of kilometres of the first stroke, and that the mean inter-stroke separation has generally been estimated to be around 60 - 90 milliseconds.

The authors’ own figures, however, show that the distributions of range and time interval between strokes are not narrowly distributed, but have extensive tails. The mean inter-stroke distance is given as 2.24 km, but Figure 2a) implies that somewhere between 20% and 25% of all inter-stroke distances were greater than 2.5 km. The authors reference a number of papers (page 3533, lines 10 -28) in which video evidence has been used to demonstrate that it not uncommon for the subsequent strokes in a flash occur greater than 2.5 km from the initial stroke.

Similarly, the majority of adjacent strokes occurred within 100 milliseconds of each other, but the tail in the histogram in Figure 2b) continues up to 500 milliseconds. Evidence exists of lightning flashes where the inter-stroke was greater even than 500 milliseconds within the same lightning event (Figure 1, Thomas, R. J., P. R. Krehbiel, W. Rison, S. J. Hunyady, W. P. Winn, T. Hamlin, and J. Harlin (2004), Accuracy of the Lightning Mapping Array, *J. Geophys. Res.*, 109, D14207, doi:10.1029/2004JD004549.)

In page 3533, lines 9-10, the authors cite ‘Rakov, Vladimir A., Gary R. Huffines, 2003: Return-Stroke Multiplicity of Negative Cloud-to-Ground Lightning Flashes. *J. Appl. Meteor.*, 42, 1455–1462. doi: [http://dx.doi.org/10.1175/1520-0450\(2003\)042<1455:RMONCL>2.0.CO;2](http://dx.doi.org/10.1175/1520-0450(2003)042<1455:RMONCL>2.0.CO;2)’. Referring to splitting strokes into separate flashes based on separate ground contact points, the authors state “In their view, this approach separates a single multi-grounded lightning discharge inappropriately into two or more flashes with one ground termination each.” The authors’ conclusions apparently take to opposite view, that strokes following the same channel partially but with well separated ground contact points are in fact separate flashes, without referring

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back to why they disagree with Rakov and Huffines.

The authors suggest the use of their own, stricter criteria, without discussing why these greater range and time interval strokes should be defined as individual flashes. They state that their approach will make the “flash data more reliable”, but have not apparently investigated the extent to which physically separate flashes are misclassified as single flashes by current stroke-to-flash algorithms. In fact, in page 3534, lines 1-3, referring to a video multiplicity study (Saba et al., 2010) they state that using time criteria of 500 milliseconds “provides higher reliability in the resulting flash data, but may have erroneously lowered the total number of flashes.”

Their assessment is based purely on lightning location system data, without the use of cameras, field mills, or lightning mapping systems to try and understand and characterise the lightning flashes. Their choice of using their own criteria seems to be based on preference, rather than being justified by a greater understanding of the phenomena of lightning flashes. Although suggestions of new approaches to grouping strokes into flashes should be welcomed, new suggestions should be based on well justified reasoning, backed up by data.

A number of other issues also need addressed:

The acronyms NLDN and NALDN are frequently used to refer to the same network (the US National Lightning Detection Network). NALDN also stands for North American Lightning Detection Network, which comprises of the NLDN and Canadian Lightning Detection Network (CLDN) combined. It appears that all references to the NALDN should in fact refer to the NLDN: if this is not the case, the NALDN should be specifically referred to, to prevent confusion to the reader. All such references are listed in the SPECIFIC COMMENTS section.

Section 3.2 starts by stating that multiplicity was calculated for time differences of 0.2 and 0.5 seconds, and distances of 2.5 km, 5 km and 10 km, and references Figure 3. Figure 3 itself shows data using 0.2, 0.5, 0.8, 1 and 2 seconds (although the first 3

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values are mislabelled in the legend as ‘ms’ rather than ‘s’), and distances of 2.5 km, 5 km, 7.5 km, 10 km, 100 km and 500 km. Why aren’t these additional data points mentioned in the main text? What was the purpose of testing the very relaxed time and distance values?

The precision with which the multiplicity is quoted varies from 1 to 2 decimal places. The degree of precision should remain consistent (preferably 2 decimal places).

Section 3.4 uses the NLDN inter-stroke interval and range criteria, but then uses new criteria of 0.2 seconds with ranges of 1 km and 10 km. This section is intended to demonstrate differences between individual events and the dataset as a whole, and so it would be much more useful to use consistent criteria (i.e. 0.2 seconds and 2.5 km) to make for easy comparison.

Greater uses of separate paragraphs would improve readability, e.g. Section 3.4 is one continuous paragraph.

- SPECIFIC COMMENTS

Page 3530, line 3: Change “The common method” to “A commonly-used method”.

Page 3530, line 5: Reference to NALDN (see GENERAL COMMENTS)

Page 3530, line 10: “Geographical distribution of single vs. multiple stroke flashes”. This is not what is provided. Change to “Geographical distribution of average multiplicity” or similar.

Page 3530, line 11: Reference to NALDN (see GENERAL COMMENTS)

Page 3530, line 26: “In the US,”: the way this sentence is structured implies that the NLDN is the only network in the United States, and that their approach to stroke-to-flash conversion is the standard. Other LLS exist in the US, which may use their own approach to creating flash data. This sentence should be reworded to clarify that it refers to an NLDN rather than a US-wide approach.

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Page 3531, lines 17-19: “The multiplicity determined according to the two different methods (before and after the upgrade) for two years after the upgrade were different.”: This sentence gives room for confusion, as it could be interpreted to mean the multiplicity determined before and after the upgrade. Change the phrasing in brackets to “(the pre- and post-upgrade algorithms)” or similar.

Page 3531, line 21: Reference to NALDN (see GENERAL COMMENTS)

Page 3532, lines 4-5: “found that the majority of negative flashes contain more than one stroke and that less than 20% are single-stroke flashes.” Surely saying that 20% of flashes are single-stroke flashes means that the majority (> 80%) of flashes contain more than one stroke? Remove the part about the majority of flashes, it is unnecessary.

Page 3532, line 7: Reference to NALDN (see GENERAL COMMENTS)

Page 3532, lines 15-19: The multiplicity of flashes using only flashes with 2 or more strokes is given (in this case, 2.7). The use of different techniques to derive values which are then both referred to as ‘multiplicity’ gives the potential of confusing the reader. Given that the percentage of single stroke flashes is mentioned (38.5%), it is simple to calculate the ‘standard’ multiplicity, i.e. the multiplicity including single-stroke flashes: $m = (1 - 0.385) * 2.7 + 0.385 = 2.05$. This value should be quoted as the multiplicity, giving mention to how it was derived from the number of strokes per flash in flashes with at least two strokes.

Page 3532, line 20-21: “Do multiple strokes of a single cloud-to-ground (CG) flash indeed hit the same physical location, in terms of geographical coordinates?” Asking this question implies that the answer is not known, when the following paragraph goes on to cite multiple papers where this has shown that strokes can hit different ground contact points during a single flash. Merging this question into the following sentence reduces the possibility of confusion, i.e. “If multiple strokes of a single cloud-to-ground (CG) flash indeed hit the same physical location, in terms of geographical coordinates, it would seem logical...”

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Page 3534, lines 21-25: Values of flash and stroke detection efficiency are stated as > 90% and > 80%, respectively, with no reference given as to where these values come from. Looking into a previous paper on lightning detection in Israel (Shalev, S., Saaroni, H., Izsak, T., Yair, Y., and Ziv, B.: The spatio-temporal distribution of lightning over Israel and the neighboring area and its relation to regional synoptic systems, Nat. Hazards Earth Syst. Sci., 11, 2125-2135, doi:10.5194/nhess-11-2125-2011, 2011.), the value seems to be an estimation based on similar configurations of networks. Evidence should be provided as why such figures are given, or different wording should be used to emphasise that this is only an estimate.

Page 3536, line 2: Reference to NALDN (see GENERAL COMMENTS)

Page 3536, line 11: Spurious precision when quoting the median as 2.00. The median will always be an integer, so the trailing decimal places are unnecessary.

Page 3536, line 14: Reference to NALDN (see GENERAL COMMENTS)

Page 3536, line 16: The symbol N is used for subsequent strokes here, but has already been used in line 1 on this page for total CG flashes, which may cause confusion. Use an alternative for one of these, if possible.

Page 3537, line 7: Reference to NALDN (see GENERAL COMMENTS)

Page 3537, line 12: “42 % to 71 % when using different range thresholds.” The spread is only 42 % to 67 % based on range thresholds, but is 42 % to 71 % based on different range and time thresholds. Amend accordingly.

Page 3537, line 19: Reference to NALDN (see GENERAL COMMENTS)

Page 3537, line 24: Reference to NALDN (see GENERAL COMMENTS)

Page 3537, line 25: “10 km².” It is assumed that this refers to 10 km by 10 km, in which case it would be 100 km², or equivalently (10 km)².

Page 3538 lines 3-5: The authors are surprised that the multiplicity is higher over the

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sea, but provide to reasoning into why they think this might be. It would be interesting for some hypotheses to be laid out here.

Page 3538, line 7: "It is a known fact that the number of contact points changes with the number of strokes." This needs to be made more general, as it is possible for a two stroke flash to have two separate ground contact points, but a much higher order flash to only have a single ground contact point. A statement along the lines of "increasing stroke order leads to an increasing likelihood of more ground contact points" would be more appropriate.

Page 3538, lines 21-22: "Similar to results reported by Fleenor et al. (2009, Fig. 5)." This sentence does not make sense on its own.

Page 3538, lines 23-25: The strokes in Figure 5 fall within very close range of each other (a maximum range of 3 km estimated between strokes 8 and 10 of event E1). The fact that the location uncertainty of the ILLS in this region is expected to be on the order of 1.3 km, and given the lack of ground truth data for these flashes, makes it difficult to determine if these were flashes with multiple ground contact points, as apparently implied by the authors, or merely flashes with the same contact point, where there is a location uncertainty associated with each stroke. To suppose that there is generally a very tight grouping of fixes in high multiplicity flashes based on only three flashes seems presumptuous. Providing error ellipses in the plot would provide more of an indication of the likelihood that these are in fact separate ground contact points, but could also make the plot extremely chaotic.

Page 3539, lines 7-8: "19 728 were negative cloud to ground flashes,": we are referring to strokes here, so should read along the lines of "were associated with cloud to ground flashes".

Page 3439, line 10: Clarify whether the coastal region is 10 km extending inland or extending offshore.

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Page 3539, line 13: "temporal distribution of flashes": Figure 6b) refers to strokes, not flashes.

Page 3539, line 14: "regular criteria": refer to as "NLDN criteria", for clarity.

Page 3539, line 16: Exclude references to multiplicity using only multiple stroke flashes, as it reduces clarity.

Page 3539, line 18: Exclude references to multiplicity using only multiple stroke flashes, as it reduces clarity.

Page 3539, line 20: Exclude references to multiplicity using only multiple stroke flashes, as it reduces clarity.

Page 3540, line 2: "general algorithm": replace with "NLDN algorithm".

Page 3540, line 20: Reference to NALDN (see GENERAL COMMENTS)

Figure 1: The caption says that this is the "multiplicity distribution in winter thunderstorms", but I see no reference in the text as to the period this subset of flashes was taken from. Please add more information as to the strokes that counted as being part of "winter thunderstorms".

Figure 3: The caption should probably read "Average multiplicity of negative cloud to ground flashes as a function of maximum stroke separation distance for a range of inter-stroke time intervals", or similar.

Figure 5: The caption should make it clear which sub-figure (a-c) refers to which event (E1-3).

Figure 6a): Over-precision in the axis labels (three decimal places is not necessary for the latitude/longitude values). The axes should be named.

Figure 6b): Column marked "More" in the time axis should be removed. The axes should be named.

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Figure 7: It is generally unclear what each line refers to. It is assumed that the line marked in the legend as 'single' is the peak current associated with single-stroke flashes. It is also assumed that other values (1st, 2nd, 3rd, etc.) refer to the peak current of strokes of that order in multiple stroke flashes, but it is not clear whether it might also be the peak current of the most powerful stroke in a higher order flash. Column marked "More" in the peak current axis should be removed. Legend value 'more' should be replaced with '> 10' or similar. Title "Histogram" is insufficiently descriptive. X-axis name "KAmp" is in fact the units: this should be replaced with "Stroke peak current (kA)".

- TECHNICAL CORRECTIONS

Page 3538, line 14: Figure 2b) is cited, when the author intends to refer to Figure 2a).

Page 3538, lines 16-19: The events in Figure 5 are referred to, but the numbers of strokes for events E1-3 referred to in the main text (17, 15 and 13, respectively) do not tie in with the number of strokes plotted in Figure 3 (13, 15, and 16, respectively).

Page 3540, line 7: 'Less than or equal to' symbol used when 'Greater than or equal to' symbol is required.

References: Typo in Cummins et al. (1998b), "Networkt" should be "Network".

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 1, 3529, 2013.