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Atmospheric Measurement Techniques Discussions

Interactive comment on "SAETTA: high resolution 3D mapping of the total lightning activity in the Mediterranean basin over Corsica, with a focus on a MCS event" *by* Sylvain Coquillat et al.

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ATMOSPHERIC MEASUREMENT TECHNIQUES DISCUSSIONS

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Title: "SAETTA: high resolution 3D mapping of the total lightning activity in the Mediterranean basin over Corsica, with a focus on a MCS event"

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William Rison

Dear Associate Editor,

We are very grateful to Referee #1 for his criticisms and suggestions that we tried to take into account to improve the manuscript significantly. We also thank Referee #1 for the numerous corrections and references he proposes. You will find below our item-by-item response (indicated by *) to the comments and recommendations of Referee #1. The proposed modifications appear in blue font in the revised manuscript in order to readily identify them.

General comments:

This paper introduces the SAETTA 3D Lightning Mapping Array installed on the island of Corsica and discusses its general performance and climatology, and also illustrates the data by two case studies. It is found that in summer afternoons, a thunderstorm often forms at the particular location on the island, where the intersection of 3 wide valleys brings together the moist air by sea breeze circulation. One case study showcases the use of the rates of lightning flashes separated by size and finds surges of rates of tiny flashes confined to high altitudes during intense convective development. The other case study reveals a negative upper charge layer in the stratiform region of a Mesoscale Convective System (MCS) by activity of positive or recoil leaders detected by the LMA. In general, the paper is a good contribution. The selected case studies are interesting, but some earlier papers on the matter of small discharges as well as some with examples of negative charge layers in the stratiform region are missing. Also, the inclusion of radar images could give the case studies some more depth. The text also needs a number of technical corrections, suggested below. * We thank referee #1 for informing us about previous observation that are missing in the paper and for which he kindly gave the references. We carefully explored the literature and modified the manuscript accordingly. * We agree with Referee #1 about the interest of radar images but unfortunately Corsica did not have good radar coverage from the Météo France

radar network in 2015 (see Specific comment #3 below). We added a satellite image that provides a good idea of the 8 June 2015 event studied in present paper.

Specific comments:

1. Aircraft-related trails claimed in statistical results, but this has not been detailed with an example. * We deleted the sentences relative to the aircraft trajectories in order to avoid the addition of new figures since the paper is already long. In fact this point does not really matter in this article. It will matter later if we can get the flight data to evaluate the location efficiency of SAETTA. For information, the flight we were talking about produced an exceptionally huge amount of VHF sources (406210 sources, see figure at the end of present document).

2. Surges of tiny flashes. Other works have described them before, it is possible to add references and some discussion. * As suggested by Referee #1, whom we thank for the references they gave us, we added a paragraph with some discussion about previous observation available in the literature.

3. Stratiform high-altitude positive leaders. Other works have shown these before. Is it possible to investigate if they spawn off the first negative leader branch and then grow upward and sideward? This mechanism looks similar to the case of negative leader suddenly spawning (up or down) from a horizontal positive leader branch as in examples in van der Velde and Montanyà (2013). * We added references to previously observed flashes of the same type in a new paragraph of Section 4.2 and also added a comparison with figures by van der Velde and Montanyà (2013) in the following paragraph. * The analysis of these flashes certainly requires a further detailed study to precisely compare the processes that are involved in present flash and in the events reported by van der Velde and Montanyà (2013). For that, we would need more information about the examples mentioned by Referee #1. We have identified similarities with events reported in their Figures 2c and 2d and Figure 6 (event M). We suppose that Referee #1 focuses on the M (probably also N) event reported by van der Velde

and Montanyà (213). It would probably be interesting to compare the flashes by means of XLMA low speed animations for clearly identify each phase of those complex discharges. We think that this task deserves much more time and could be the subject of a new article in order to go further into the details of lightning physics, maybe through a collaboration with Oscar van der Velde and Joan Montanyà..

Radar analysis could help provide some context for topics 2 and 3, in terms of confirming cloud top altitude and evolution stage. Time-distance plots need the slopes indicated to have a proper reference. The text may be written a bit more concisely (remove some details or similar paragraphs). * In 2015, radar observation in Corsica was only available from the Aleria radar (located at low altitude on the eastern coast of Corsica) and Collobrières radar (located on the South-East coast of France at about 270 km from the center of Corsica). The former is close to the relief that acts as a mask and prevents from scrutinizing the depth of the events located on the West part of the island, the latter is very far from Corsica and does not bring good information. Only fragments of the cells were available from both radars so that we did not display those graphs. In order to bring a glimpse of the cloud formation during the 8 June 2015 MCS event, we displayed in Figure 10 the cloud cover observed around 12:35 UT during the 8 June 2015 storm event by the MODIS/AQUA polar orbiting satellite in the visible wavelength range. Unfortunately, only one passage could observe the event (the passage of MODIS/TERRA was too early). * As suggested by Referee #1 we modified the time-distance plot of Figure 14 right (distance between each VHF source and the first source versus time in function of altitude cloud charge polarity) in order to display reference slopes corresponding to speeds of 2$\times$104 m s-1, 105 m s-1, and 106 m s-1 (same slopes as in van der Velde and Montanyà, 2013).

Technical corrections:

Page 1

12: 80 us is the resolution per station, but after locating the sources, this is not the

resulting temporal resolution, which is decreased. 16: masking (also Page 5, line 10) * 12: The time resolution has been corrected. * 16: "Mask" has been replaced by "masking" in the abstract and in page 5.

18: integrated across the domain; reaches a first maximum 19: intersection of 21: lightning 22: and includes some high precipitation events * 18: We replaced "on the whole" by "across the". * 19: We replaced "crossroad" by "intersection". * 21: We replaced "lighting" by "lightning". * 22: We replaced "precipitating" by "precipitation".

Page 2

5: relaxation but perhaps a limiter? 14-15: thunderstorm cell; remove On another hand 22: high precipitation; climate change 24-25: network instead of instrument 27: which means 31: put comma after summits; meters altitude * 5: We added "and a limiter" after "relaxation". * 14: We replaced "thundercell" by "thunderstorm cell". * 14-15: We deleted "On another hand". * 22: We replaced "highly precipitating" by "high precipitation" and "climatic" by "climate". * 24-25: We replaced "instrument" by "network". * 27: We replaced "that" by "which". * 31: We inserted the coma and deleted "of".

Page 3

8: carrying humid air 14+18: original could be unique or unusual * 8: We replaced "humidity" by "humid air". * 14+18: We replaced "original" by "unusual".

Page 4

4: lightnings ! lightning processes * 4: We replaced "lightings" by "lightning". We don't think that the word "processes" is necessary here even though, indeed, each lightning comprises numerous processes that multiply the number of VHF sources emitted.

Page 6

Table 1: "Gap" ! vertical difference. But the table is not very interesting, the two

columns are almost identical. Is it necessary? * Table 1: We replaced "Gap" by "Vertical difference" in Table 1 and in its caption. We would have liked to readily have this kind of information about the other LMA networks... So yes, we think that it could be interesting for other researchers in case of future comparisons.

Page 7

13: average minimum altitudes * 13: We replaced "a minimum average altitude" by "average minimum altitudes".

Page 8

6: at best ! in the optimal situation 8: Koshak (also later on) 13: is therefore a suitable tool 18: north, south, east, west are not to be capitalized (also occurs later) 20: remove of before altitude * 6: We replaced "at best" by "in the optimal situation". * 8: We replaced "Koshack" by "Koshak" and also page 6 line 5 of the initial manuscript. * 13: We replaced "thus a good" by "therefore a suitable". * 18: We changed those capital letters to small letters in the whole manuscript. * 20: We deleted "of" before "altitude.

Page 10

Figure 4: maybe provide a figure with the difference between the two? At first sight they look almost identical. Also: Thomas et al. 2004 (also on Fig 3) 19: better goodness of fit, lower reduced chi-squared * Figure 4: Indeed both figures are very similar over and close to Corsica but the patterns corresponding to larger errors (> 400 m) a clearly different. We corrected the reference to Thomas et al. (2004). * 19: We corrected the sentence accordingly.

Page 11

4: From here on, 14: this seems to be the first sample. 15: Looking at the top frame * 4: We replaced "there" by "here on". * 14: This lightning was indeed detected by SAETTA during its first month of operation. Does Referee #1 think we should mention this information? Or do we correctly understand his comment? * 15: We deleted

"When".

Page 12

3: check if this is the continuation of the same leader as before using a time-distance plot (van der Velde and Montanya 2013) * 3: The considered graph (left graph in Figure 6) is not of importance in the paper. As a matter of fact this graph is only presented to show a typical CG flashes and is not a basis for a fine process analysis. Therefore we didn't add the plot proposed by Referee #1. However, the flash concerned is very similar to the event M reported by van der Velde and Montanya (2013) in their Figure 6. The time-distance plot should thus be similar to the one of the M event in their Figure 7, except that no subsequent CG occurs after the one at the beginning of the flash. We added this reference in the manuscript. To go further into details, one could mention that both present flash and the M event reported by van der Velde and Montanyà (2013) similarly exhibit a sudden multidirectional branching of a negative leader that rises the altitude of the upper positive charge layer in which it spreads. In the present case, the upward leader produces 3 branches, the first of them seems to be characterised by a very high ascent speed (probably faster than 105 m/s) and reaches the highest altitudes, probably subject to more intense electrical conditions. Its path is subsequently used in the end of the flash by a recoil leader. But so many details together with an additional plot may not be absolutely necessary and would lengthen the paper when this one is already very long.

Page 13

2: The sample size is not yet large enough to call this climatology 9: north, forming... 10: Need to show more detail and example of aircraft. It seems unlikely to result in more sources when a lightning flash produces far more. Could be interference from local noise that creates patterns? * 2: We replaced "It is far from representing a sufficient sample to call this climatology" by "The sample size is not yet large enough to call this climatology". * 9: We replaced "and" between "north" and "forming" by a comma.

* 10: As previously mentioned (specific comment 1 above), we deleted the sentences relative to the aircraft trajectories in order to shorten the paper and to avoid the addition of new figures since the paper is already long. But for answering to reviewer #1, the considered flight surprisingly produced an exceptionally huge amount of VHF sources (406210 sources, see figure at the end of present document). The aircraft probably encountered a large amount of ice crystals during its path through the trailing stratiform zone of the storm and underwent an intense collisional charging that could have produced numerous sparks from its wings. Maybe the detection threshold of SAETTA was also relatively low at that moment.

Page 14

10: stormy day... maybe better lightning day or thunderstorm day? * 10: We here replaced "stormy day" by "lightning day", and also in other 12 locations in the manuscript.

Page 16

2: southern France or in the south of France. 5-6: These ingredients are universally indicated in textbooks. The reference provided is not the real source. 7: begins * 2: We replaced "in South of" by "southern". * 5-6: We agree with Referee #1. This sentence - not clear enough - was just to mention that the storm events studied here are similar to those studied in southern France during the HyMeX program, for which the here listed ingredients are more or less of prime influence according to the atmospheric and orographic conditions. They have been identified so in Ducrocq et al. (2008), especially for the so-called "Cevenol events". We deleted the reference in order to avoid any mistake. * 7: We replaced "begin" by "begins".

Page 17

8-12: duration 3h50m 10: on top of a convective core 17: northerly wind 18: turns to northeasterly 19: is composed of general: it would help to have radar images and number the cores discussed in the text, then coordinates are not needed. How are

convective surges defined? Just from LMA data? 28: Marshall (also elsewhere) 29: thunderstorm structures (charge structures?) * 8-12: We modified the four durations according to the suggestion of Referee #1. * 10: We replaced "on top of convective core" by "on top of a convective core" 3 times in the same paragraph. * 17-18: Wind directions have been modified according to Referee #1 and Referee #2 suggestions. We chose potentially unambiguous formulations ("wind oriented toward the south"; "toward the south-west direction"). * 19: We replaced "constituted" by "composed". * General: As far as radar images are considered, we agree with Referee #1, see our response to the Specific comment #1 above. As suggested we labelled #1, #2, and #3 the three convective cores everywhere in the manuscript, it is very helpful for the reader. Without radar images, we think it's better to keep the information about the coordinates. The convective surges are now defined at the beginning of the 2nd paragraph in Section 4.1 (just from LMA data). * 28: We replaced "Marshal" by "Marshall" everywhere in the manuscript. * 29: The sentence has been modified according to a suggestion by Referee #2. OK with Referee #1, Stolzenburg and Marshall (2008) addressed the question of electrical structure in their paper.

Page 18

14: source density In this section or discussion, make references to small discharge surges, like Ushio et al 2003, Emersic et al 2011, MacGorman et al 2017 * 14: We replaced "sources" by "source". * In this section or discussion: We added a new paragraph inside which previous observation available in the literature are now discussed, as suggested by Refere #1.

Page 19

Fig 11 right, power: what do the diagonal lines mean here? * Fig 11 right: They must be references for the slope of the power distribution tail. We don't comment this kind of information. We can erase those lines if Referee #1 thinks it's necessary.

Page 20

m-1, min-1... make superscript 8: are in phase with convective surges... But how can we confirm this? Radar? * m-1, min-1...: We made superscripts and corrected the first one (m-1 -> min-1). * 8: We added a reference to Table 2 which provides the periods of occurrence of the surges. Those periods match the maxima of the red curve in the bottom graph of Figure 12.

Page 21

14: big flashes triggering dominates – hard to read, do the authors mean initiation of big flashes? 15-18: too much detail and everything looks similar. Needed? 20: convective surge positions * 14: We replaced "big flashes triggering dominates" by "initiation of big flashes dominates". * 15-18: Details on the maxima were given because it is precisely difficult to correctly identify them in Figure 12. We delete all values of maxima and kept only the information on their altitude in order to simplify the text. * 20: We replaced "convective surges positions" by "convective surge positions".

Page 22

1-2: over a vertical distance varying * 1-2: We replaced "on a height varying" by "over a vertical distance varying".

Page 23

6: in this case probably positive leaders themselves because of their very low power. 7: cloud-to-ground 9: intracloud 11: slightly tilted 12: does the positive leader really grow upward from the negative leader altitude? The graph suggests not (unclear). The vertical channel is mostly a later downward negative leader. On top of. 23: the slopes are missing in Fig 14 27: rather fast... This is still quite normal speed. See also van der Velde et al. 2014 27: 1.4x105 use superscript 28: Then, sources associated with the positive leader branch... 35: superscript * 6: Instead of deleting "(actually negative recoil leaders)", we prefer to develop further the possibility that observed positive leaders could in fact be the signature of retrograde negative breakdowns located close to

the tips of positive leaders. As analyzed by Edens et al. (2012) positive breakdowns do produce weak VHF emissions, however they may be masked by much stronger concurrent VHF emissions from negative breakdowns. But whatever positive leaders are directly or indirectly - via negative retrograde breakdowns at their tips – detected, this possibility does not question their presence and their location. * 7: We replaced "Cloud-to-Ground" by "cloud-to-ground". * 9: We replaced "intra-Cloud" by "intra-cloud". * 11: We replaced "slowly" by "slightly ". * 12: Yes it does, this is what we can observe with a low speed animation (XLMA). Only the upper end of this positive leader can be seen (indicated in green in the top panel of the bottom right graph in Figure 13). We mention that in the text. Yes later around the final phase of the flash the leader is a downward negative one (red lines in the upper panel of top left graph in Figure 13). Those negative leaders seem to start from the extreme southern tip of the upper positive charge layer. * We replace "on top the" by "on top of the". * 23: Figure 14 has been modified, the slopes are now present in right graph of Figure 14 (c.f. Specific comment #3 above). * 27: Yes, we now compare this value to that of van der Velde et al. (2014). * 27 and 35: Superscript has been correctly used. * 28: We corrected accordingly.

Page 24

4: descends along... and propagates... into 6: nice to see that! It could be interesting to select this point as the origin of an alternative time-distance plot. See also van der Velde et al (2014) * 4: We modified the sentence according to the suggestion. * 6: The paper is already very long so that adding a new figure that deserves much more comments is probably not adequate. However this is a very good idea that we'll try to carry out in forthcoming studies.

Page 25

2: needs rewriting, as one answer is also the question 7: van der Velde et al 2014, Lang et al 2010, Lu et al 2013, Soula et al 2015 could also fit 29: Could... not ? 33: one may wonder * 2: Yes, the question has been removed. * 7: We added these references,

except that of Lu et al. (2013) which is not available for us at the time we correct the manuscript. * 29: We corrected the interrogative sentence. * 33: We replaced "can" by "may".

Page 26

5: Similarly/Additionally... * 5: The correction is OK, it has been proposed by both Referees

Page 27

1: geometric performance 5: This performance 16: 2014-2016; a preliminary climatology * 1: We replaced "performances" by "geometric performance". * 5: We replaced "potential" by "geometric performance". * 16: The dates are corrected. We replaced "short of " by " preliminary".

Page 28

5: in van der Velde and Montanya 2013 a negative leader develops vertically from a positive leader, it seems here we have the positive equivalent. Interesting. 7-8: see provided references with similar discharges * 5: Indeed it's a very interesting remark from Referee #1. Collaboration could probably take place with Oscar van der Velde and Joan Montanyà in a close future. * 7-8: We thank Referee #1 for sharing his knowledge. We added the references in section 4.2 (as said above in response to the specific comment #3) and changed the sentence of line 7-8.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-192/amt-2019-192-AC1-supplement.pdf

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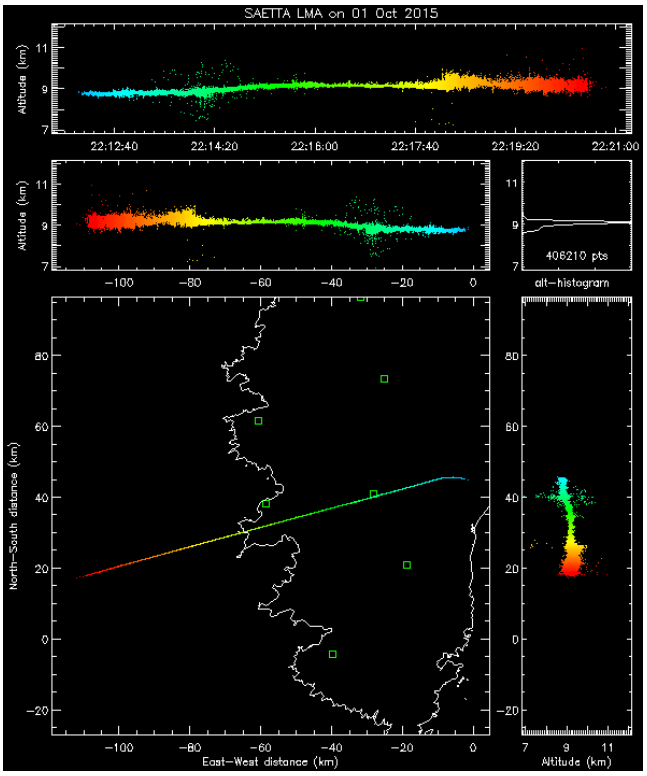

Fig. 1. Track of a commercial aircraft flying at about 9 km altitude that produced an exceptionally huge stream of sparks, which may be distinguished in the cumulative number of filtered VHF sources in the to