Anonymous Referee #2

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

As already mentioned in the first review (and by the other reviewers) assessing the potential of CMLs for rain retrieval in a new region (here Brasil) could be a great addition to the work that has already been provided on this topic by several groups in Europe, Israel and Africa. Compared to other studies on the same subject and in the sub-tropics the data set available here is much richer (both in terms of available links and gauges ? with also a nearby disdrometer) and of great potential interest for demonstrating the advantages and limits of CMLs based rainfall measurement.

The present work is unfortunately far from delivering the full potential of the available data set.

Instead of the authors ?encouraging future work? on the data set and listing in their conclusion some of the many things that ?could be done?, one feels like encouraging the authors themselves to take the current analysis a step further in order to take better advantage of the data set and draw some convincing conclusions to ?shed some light on the suitability of CMLs? . This would be useful for the CML and hydrometeorology community.

R/. We thank the reviewer for recognizing the potential of our study, but we respectfully disagree with the reviewer's assessment of the first revised version of our manuscript. In our opinion, we performed extensive and quantitative analyses, which have been significantly expanded in our revised manuscript. In the Conclusions section, we 'encourage future work' "on sensitivity analyses focused on the optimization of RAINLINK parameters to improve the accuracy of rainfall estimates in subtropical regions". With this, we consider that future work should be focussed on the fine-tuning of RAINLINK parameters with the purpose of achieving a higher degree of accuracy in rainfall estimates (from RAINLINK) in other locations around the world. In our updated analyses, despite the specific issue of lacking CML data and metadata for the São Paulo metropolitan area, we managed to reveal a clear rain signal and provide an honest assessment of the quality of CML rainfall estimates.

The authors have added some additional work compared to their discussion paper but most of the reviewers? comments are far from being accounted for in this new version.

R/. We also regret that the reviewer thinks that we did not take into account most of the reviewers' suggestions. In the 17-page rebuttal we submitted, we implemented on average 80% of all the reviewers' suggestions, including the majority of the suggestions to perform additional analyses. We implemented these major changes in our first revised version, showing that we substantially revised our manuscript:

- We modified the RAINLINK algorithm in order to also retrieve rainfall depths from measurements of only minimum received power and we derived an optimal conversion factor to retrieve mean rain rates using disdrometer data from Brazil. Therefore, we were able to also systematically analyse 147 ER (Ericsson) CMLs.

- Although this was not specifically suggested, we added an independent gauge validation procedure in order to only select trustworthy gauges for the validation of CML rainfall estimates.

- Correlation with gauge records is not used anymore to remove or keep CMLs in the dataset.

- Scatter density plots of half-hourly CML rainfall depths vs. gauge rainfall depths over the entire 2.5-month period were added. Comparisons are not only presented for maximum CML-gauge distances of 1 km, but also 9 km.

- Although this was not suggested, we included cumulative time series of 30-min rainfall averaged over the city of São Paulo, Brazil, for CMLs and gauges over a 2.5-month period.

- Scatter plots of the performance of individual CMLs against gauges (coefficient of variation against coefficient of determination) for maximum CML-gauge distances of 1 and 9 km were included.

- Instead of a 50-km radius, a 9-km radius was used in the wet-dry classification. In contrast to the first version of our manuscript, all results in the first revised version have been processed employing the wet-dry classification.

- Comparisons are not limited anymore to CML-gauge pairs were both show a rainfall depth above 0 mm, but also include all rainfall pairs, i.e. zeros included.

- All the figures were updated.

The main problem is that the results of the CML-gauge comparison as presented (for instance Fig 6) are mostly showing that the method, as applied here, fails to reproduce the 30? rainfall time series satisfactorily. And because most of the links are in practice unusable and unreliable for Quantitative precipitation estimate, the use of a CML network to obtain high-resolution rainfields and quantify intense rainfall (for urban hydrology, landsliding risk detection etc.) as proposed in the introduction is a very bad idea!. The CML technique may be used to have a very rough (and quite biased) estimate of average rainfall over a city (cf Fig 3).

Some links (3?) behave well at least for a few events (Fig 4), however the ?well-functionning? links are detected a posteriori, thanks to the gauges, so not very usable in practice.

R/. We do recognize that mixed, not purely bad, results are obtained for the CMLs in São Paulo, but we strongly believe that papers with mixed results should also be published. We provide an honest piece of work clearly describing which CMLs have been filtered and why. Apparently, results are not always as good as found in other studies. We also notice that (part of the) metadata is erroneous, hence serving the community by pointing to specific problems which can be encountered in CML rainfall estimation. In our paper we do not claim that all these CMLs are useful to obtain high-resolution rainfields and quantify intense rainfall, but earlier studies do reveal this potential (e.g. Overeem et al., 2016). In our opinion, the dynamics of city-average rainfall in Figure 4 are reproduced fairly accurately. We have shown in (new) Figure 4 the cumulative average time series for all the 145/213 CMLs over the city of São Paulo (for 2.5 months of data). In that figure, one can see that for almost half of the studied period (i.e., 1.5 month continuously) the CML-series is in agreement with the global-/city-average obtained from gauge data. Even after a discrepancy for one intense rainfall event, the dynamics of the CML time series are remarkably similar to those of the gauge data. In addition, we also find a high correlation for a large minority of individual CMLs (Figure 7). Hence, we disagree that only 3 CMLs behave well. We also disagree with the reviewer's comment to question the validity and practicality of our method on the premise of an "a priori" rain gauge evaluation. Modern techniques of rainfall retrieval, such as radar and satellites, still use rain gauges for validation and calibration of their products, and thus their improvement is also "detected a posteriori".

The authors have dismissed the suggestions by several reviewers of the discussion paper, to understand better why so many links are in disagreement with the gauges and decompose and quantify the problem step by step (miss/false-detection ? why ?) .

R/. We have attempted to provide some explanations as to why the performance of several links is very bad (e.g., p.9, lines 6-14). Having said that, we think that more elaborate analyses of why several links do not seem to reproduce rainfall values is outside the scope of this paper. The uncertainty analysis was from the beginning not the aim of our current manuscript. Moreover, it will be very difficult to systematically explore these quality issues, because these are probably related to erronous metadata. Unfortunately, several attempts have not led to any help from people knowledgable on the CML datasets in São Paulo. Such involvement seems necessary to take this a step further. Finally, we developed a gauge validation procedure, which makes it more likely that disagreement between link and gauge estimates is due to the links.

One of Rainlink?s step is to compare the consistency of a link with its neighbors ? Couldn?t this feature be further exploited to detect the consistency among links and understand the problem - before comparison with gauges ?

Here the assessment is performed using the 30? time series, would results be better -in terms of detection at least- at the daily time step ?

R/. The use of the comparison of a link with its neighbors would yield information about the consistency of the occurrence of attenuation among links. If there is a lack of consistency this would mean that either the rain is highly variable or that there is a problem with a link. We disagree with the reviewer that this could provide much help for finding the causes of the bad link rainfall estimates, especially because we have an independent reference (gauges). A link wrongly identifying rainy periods can be caused by many different phenomena, e.g. dew formation on the antennas, and reflection or refraction of the beam. A link removed by the outlier filter points to a malfunctioning link, but does not provide a clear reason. Note that the wet-dry classification and the outlier filter are performed each 15-min time step, but already incorporate information from the previous 24 h. For instance, the outlier filter actually discards a time interval of a link for which the cumulative difference between its specific attenuation (based on uncorrected minimum received power) and that of the surrounding links (i.e. within a radius of 9 km) over the previous 24 h becomes lower than the outlier filter threshold. A comparison of CML and gauge rainfall estimates on a daily time step generally improves results and could be interesting. Note that we do already provide city-average rainfall accumulations, showing a clear rain signal over a 2.5-month period, i.e. over longer durations.

Other more minor point :

I also regret that the authors dismissed the suggestion made by more than one reviewers to provide not only global statistics but also statistics by rain classes, or at least quantifying if the links perform well in heavy or light precipitation. Once again, given that the authors put forward hydrology, floods, land-sliding as applications, and given the stress put in testing the method in sub-tropical climate with intense rainfall rather then in The Netherland, an analysis of the performance in heavy rainfall is very relevant.

R/. Although this could be an interesting analysis, we feel that this is outside of the scope of the present paper and a topic for future research. Note that Figure 6 provides scatter plots for the full range of rainfall depths over the entire 2.5-month period, hence already giving an indication of the performance as a function of rain classes.

Once AND IF a serions effort for improving the content is done , the english text will also need revising.

The presentation of the data, quality control, signal processing (outliers elimination etc.) and results still lack precision and clarity. (for instance still some confusion between R=ak^b and k=aR^b although already commented for in first review) ?

Some of the processing choices or data filtering appear quite arbitrary and should be better argued for and their impact quantified.

See detailed comments below.

R/. We note that anonymous referee #2 stated in the review of the first version of our manuscript that "This a major forthcoming of an otherwise very well written paper, which also provides a good review of the state of the art in CMLs based rainfall estimation.". Nevertheless, we have checked the paper for spelling and grammar errors, and corrected these where applicable. We thank the reviewer for noting that on one occassion the k-R instead of R-k relationship was used. We changed this into R-k relationship in Eq. 1. We reply to the other points in response to the detailed comments below.

DETAILED COMMENTS :

Section 1 Intro - Introduction

p2 l4

?backscattring (i.e. reflectivity) is not the only way to measure rainfall with radar, polarimetric radar may propagation parameters such as specific differential phase shift for accurate measurement of heavy rainfall. As a matter of fact the city of São Paulo is equipped with (at least) one polarimetric radar. ?

R/. The sentence "The accuracy of rainfall estimates from radar depends on how well the measurements of backscattered power from hydrometeors are transformed into rain rates." was rephrased as "The accuracy of rainfall estimates from radar depends on how well measurements of received signal power from hydrometeors or specific differential phase shift are transformed into rain rates."

p3 l24 : Sahel may be semi arid but rainfall in this region also falls as intense events (cf many recent articles on floods and rainfall intensification in Sahel) and is associated with deep convection ? the sentence is misleading. What may oppose the region is the terrain and oceanic influence in SP while flat/continental environment in Sahel.

R/. We agree with the reviewer and changed the text accordingly into: "Doumounia et al. (2014) focused on a semi-arid, tropical climate. Our evaluation is one of the first which focuses on a humid subtropical climate."

Section 2 DATA

P4 l14 : do you mean that for ER you have only received and not transmitted power ? Please clarify as this in an important point for attenuation processing.

R/. The sentence "The ER CMLs are assumed to have constant transmitted power levels." was rephrased as "As indicated by the metadata (i.e., lack of information for the transmitted power), the ER CMLs are assumed to have constant transmitted power levels.".

P4 l18-19 : doubt on the length of links - couldn?t this information been checked on site ? from your brasilian partners ?

Some free internet resources as for instance the site http://telecocare.teleco.cl9.com.br/telebrasil/erbs/

provides exact locations of RF antennas from all operators in Brasil ??.you may check some of the links displayed in Fig 1.

R/. We asked our Brazilian partner several times for more information on (meta)data, but this did, unfortunately, not yield additional information. We know the website the reviewer recommends. It will be hard to obtain additional information on the accuracy of link locations using this website. First of all, the website does not provide microwave link locations, but cell tower locations. I.e., it could only be verified whether a cell phone tower is present, but no information is provided on the connections between cell towers. In addition, our dataset is from 2014 and 2015, whereas the cellphone tower locations on the website probably provide the current locations. The TIM network seems very dense, and our dataset seems to contain only part of the data from their network. Hence, the usability of such a website is rather limited.

P4 l 28-29 : ?closest two gauges? ? Given the density of the network I assume it means very close (less than 1 km ?) in absolute term. But please provide an indication of the max range considered here.

R/. "closest two gauges" exactly means "closest two gauges" regardless the distance that separate them. It could be as short as, e.g., 200m or as long as 50km. In our previous rebuttal we presented a histogram of the pairing distribution of rain gauges. We showed in that figure that ~80% of paired-gauges lay within 6 km. The sentence "For every gauge (152 in total) the closest two gauges were selected for comparison;" was rephrased as "For every gauge (152 in total) the closest two gauges were selected for comparison (note that ~80% of paired gauges lay within 6 km);".

P5 l 1 : what is the rationale for these threshold values (bias and r2) ? they seem arbitrary unless you explain why they were chosen.

R/. Naturally, the choice of threshold values is somewhat arbitrary. We consider an r2 >= 0.6 and rB <= + 25% as adequate enough for the analyses we carried out. These values imply a reasonable agreement between nearby gauges, while still leaving some room for differences due to spatial rainfall variability.

P5 ? L17 : CML operating frequencies range from 7 to 80 Ghz (at least) depending on regions, regulations, length etc? b is not equal to 1 for the whole range. Please be more specific.

R/. We replaced "In the frequencies at which CML commonly operate, the exponent in Eq. (1) is ~ 1.0." with "For the majority of frequencies at which CML commonly operate (~13-40 GHz), the exponent in Eq. (1) is close to unity (i.e. between 0.8 and 1.2)".

P5 l28 : here you use R=ak^b and in (1) k=aR^b. Please be careful ? these inconsistencies in k-R vs R-k were already pointed out in the first review.

R/. This has been solved, since we changed this into R=ak^b in Eq. (1).

P6 1rst paragraph ? Figure 3

?it is clear from the figure that there certainly are differences ? ? - Please provide a more quantitative assessment of these diffrences between the curves and between frequency ? and add on figure or provide in text the values of the a,b coefficients for comparison.

R/. We consider that the difference between frequencies are clearly provided by the color scale. In the same way, we do not consider that crowding the Fig. 3 with 18 values of coefficients a and b (or even adding a table) will contribute further to the discussion we already presented in this paragraph.

P6 paragraph 2 ? Rainlink algo description :

1) at which time scale is done the comparison with nearby links to assess dry/wet ? 15 minutes ? please clarify

R/. The sentence "1) wet-dry classification - a link is considered for non-zero rainfall retrievals if the received power jointly decreases with that of nearby links (9-km radius for this study);" was rephrased as "1) wet-dry classification - for each 15-min interval (RAINLINK's default), a link is considered for non-zero rainfall retrievals if the received power jointly decreases with that of nearby links (9-km radius for this study);".

3)outlier removal : what do you mean exactly by ?deviates too much? ? how do you accumulate specific attenuation over 24 hours ?

R/. We replaced "exclusion of links for which the specific attenuation (accumulated over 24 h) deviates too much from that of nearby links" with "exclusion of a time interval of a link for which the cumulative difference between its specific attenuation (based on uncorrected minimum received power) and that of the surrounding links (i.e. within a radius of 9 km) over the previous 24 h becomes lower than the outlier filter threshold (-32.5 dB km^-1 h)".

4) what is the rationale for the value 2.3 dB ? is it applied what ever the frequency of the links ?

R/. This value is taken from the calibration by Overeem et al. (2013). A detailed sensitivity analysis has been carried out by Overeem et al. (2016) showing that this value is appropriate for a 2.5-year dataset from the Netherlands, also for different seasons. The majority of CMLs in that study have a microwave frequency of 37-40 GHz, but also CMLs with lower frequencies, down to 13 GHz, are used. They state that "the insensitivity of the parameter values (Aa and alpha) to season, and hence, to rainfall type, holds a promise for applying the optimal values to link data from other climates". Moreover, employing 12 days of data they report fairly similar values for Aa for frequency classes of 10-20, 20-30 and 30-40 GHz. Hence, we decided to use the value 2.3 dB for all CMLs in our study, irrespective of their microwave frequency.

p7

Section 3 ? results

P8 l1 ? ?Such a small difference (in 3 month accumulations) suggests that the gauge data set is reliable? ? As well know by the authors agreement in terms of bias over a 3 month period does not mean he series is reliable as a validation data set used at the 30? time step. Please be more serious in the assessment of the gauge data set.

R/. We agree that this small difference between validated and unvalidated gauges only reveals an agreement in terms of bias. In the gauge validation we excluded 56 gauges due to their relatively low correlation and/or high relative bias with respect to nearby gauges. The claim that all gauge data are reliable is therefore too strong. Hence, we decided to remove this sentence.

P8 l12 ? ?three best performing CMLs? - How exactly was that assessed ? are these the best performing CMLs over the whole period ? best performing in terms of which cretiria ?

R/. The sentence "1) time series from rainfall events for the three best performing CMLs;" was rephrased as "1) time series from rainfall events for the three best performing CMLs (i.e., CMLs for which r2>=0.6 and rB<= -+25% against their respective closest gauge);".

P8l17 ? the fig shows that the se three CMLs capture reasonably well tow of the rainiest events? ? NO it doesn because on 1 CML is shown for the 2 events !!

Fig 5 = why aren?t the 3 links shown for the 2 events ? this would be much informative.

The lines for the 2 ?upscaled series? should be made more visible ? as this is what we actually want to compare.

R/. No, this is not true. Figure 5 shows four panels, three CMLs (052, 041, 135, as indicated in the figure) and two events. Showing three CMLs for either of the two events is not possible due to availability issues in the CML data. Hence, we decided to keep the figure as it stands. Moreover, the figure is meant as an illustration, whereas other figures contain more global statistics on the whole CML dataset.

P8 L25 : I very much doubt that this is has any effect on the short links presented in Fig 4 and for 30? average.

I suggest using the dense available gauge network to check what the spatial decorrelation of the 30? average rainfall actually is for the SP.

R/. We thank the reviewer for noting this. As previously stated in reply to the reviewer's comment "P4 l 28-29", in our previous rebuttal we presented a histogram of the paired distribution of rain gauges. We also showed in that figure that the decorrelation distance for 30-min rainfall in São Paulo is ~8 km. Hence, the sentence "This is, on average, not the case here though as we found a decorrelation distance of ~9 km for 30-min rainfall in the city of São Paulo (not shown here)." was added at the end of the paragraph the reviewer refers to.

P8 l29 : the authors should make the effort to quantify this point (relative impact of wet antenna vs rain attenuation along the way) using the present or/and their other data sets?. Is there evidence that this bias in attenuation/rainfall is more present just after than just before the storm ?

R/. We remind the reviewer that the aim of this manuscript was not the quantification of such sources of uncertainty, and especially not in such a detail, and especially not with the quality of the available metadata. Our mainly aim for this work was a very first, relatively straightforward, but quantitative application of the RAINLINK algorithm to CML-data from São Paulo (despite all its issues of availability and metadata). Moreover, studying differences in attenuation before and after a storm will be hard in case of minimum and maximum powers over 15-min intervals. The quantification of wet antenna attenuation should ideally be done in an experimental setting with frequent logging. See our recent work on an experiment in the Netherlands over a 2-km link path (van Leth et al., 2017) and other studies on this topic (e.g. Leijnse et al., 2008; Schleiss et al., 2013).

CONCLUSION

The conclusion will have to re-written once the necessary additional analysis, which is suggested but not performed by the authors, has been done.

R/. The conclusions were indeed re-written in accordance with all the implemented changes that we carried out for the (previous) revised version of our manuscript. Please see our reply including the list of major changes at the beginning of this rebuttal.

/R. References

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