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Interactive comment on "Improving the precipitation accumulation analysis using radar-, gauge- and lightning measurements" *by* E. Gregow et al.

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Anonymous Referee #1 Received and published: 17 April 2016

The aim of the paper is twofold: (i) present and assess a novel operational methodology to include lightning information in radar-gauge precipitation accumulations and (ii) analyze the impact of different integration time intervals in the radar-gauge correction method.

The topic of the paper is of interest for the readers of the journal and the manuscript is well written and concise. The idea of including lightning information in precipitation estimation for intense events is challenging and very interesting both from operational

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and research points of view.

Nevertheless, the methodology used for the assessment of the new method is not adequate to the purposes of the method and masks out any improvement provided by the method itself, that, as is currently presented, looks almost useless. For this reason I recommend that the study undergoes a major revision before publication. In the following my major concerns and a list of minor comments.

AUTHORS: The authors want to thank the reviewer for the professional and thorough revision of this paper. The new updated article version is attached as Supplement (see PDF-file)

Major comments:

1. The phenomenon of lightning is usually associated to convection, that is generally characterized by relatively small spatial scales. Such meteorological events are known to be difficult in terms of quantitative precipitation estimation (QPE) because: (i) owing to their small spatial scales are difficult to be adequately sampled by gauges and (ii) radar system may experience important problems due to attenuation of the signal, hail contamination and other issues. Therefore, the use of the LDA potentially represents an important source of information for improving the QPE for such situations. Despite this, results presented in this work show no significant improvement when LDA is used together with the already implemented system (Radar + RandB). If I understood correctly, the information provided by LDA is equivalent to a radar profile of reflectivity corresponding to locations and times in which a lightning occurred. This information is local in terms of space and time (as shown in Fig 6), therefore the potential effects of the use of LDA cannot be detected when large scales (the whole Finland) and long periods (seasonal) are used for the assessment, as they would be masked out. The authors partially recognize this problem and focus on a shorter period (the short, 4-days period) but keep on analyzing the country-scale picture. Furthermore, the use of only 7 independent gauges strongly limits the potential of the study, because of the small

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scales in which lightning information is available. In fact Tab. 2 confirms this: absolutely no information is available for the short study period (the more interesting one). I would recommend to revise the analysis as follows: (1) limit the analyses, both in space and time, to rainfall events characterized by lightning strikes; (2) select independent gauges in meaningful location for each event.

AUTHORS ANSWER: We fully agree to the concerns expressed by the reviewer in above comments. Though, at that time, setting up this system during 2014-2015, this was the best we could do due to many reasons (please see below comments). We did learn much during this study and will improve the methods in future developments, accordingly. Answer to 1): The focus is to improve the operationally running precipitation accumulation analyses, which use the spatial- and time resolution of 3 km and 1 hour, respectively. Gauge information is available as 1 hour accumulation from our real-time database. Therefore, the time resolution for analyzed accumulation is bound to be on hourly data. The verification within this article was performed during operational runs. Hence, rerunning longer periods would require resources not available due to all the extensive data input, which would have to be re-generate (including retrieval/extraction of data and format conversions). For the 4-days period (year 2014) we manually saved the input data, in order to rerun experiment where we exclude/include lighting from the data ingest and test different profile relationship generations. Answer to 2): Since the verification was performed during operational runs, the independent stations had to be set beforehand (i.e. excluded from the assimilation). Rerunning long periods with different independent stations, manually set for each event, would require extensive resources (see above explanation). By running the operational system for whole summer, we intended to retrieve a large statistical sample for verification. Unfortunately, summer 2015 was a period with very small amount of lightning cases. In the introduction we have added a short explanation of these limitations.

2. How are Fig 4 and Fig 8 obtained? Are they based on the dependent gauges? Do they show 1h estimates (I assume so since the figures show "mm/h" for the accumu-

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lations)? Using 1h estimates for the comparison with the dependent gauges (that are used on 1h scale for the RandB process) will have the Rad_LDA_RandB (1h product) necessarily being the best.

AUTHORS ANSWER: Note: After the revision of the paper, all figures and much of the text have been reorganized. Figure 4 was obtained from verification against dependent gauges and in Fig. 8 the independent gauges are used. This is now corrected and clarified in the new figure captions. Yes, they are both given as hourly accumulation values. We changed units to read “mm” and then, in text and figure captions, we mention that it is “hourly accumulation values”. Table 1 and 2 shows results for the dependent gauges, here one can see that Rad_LDA_RandB give same results as the Rad_RandB. The same result is achieved from the independent gauges (now also mentioned in the article text).

3. I suggest to choose one between r2 and Pareson’s correlation coefficient since the two statistics provide the same information. Moreover, basing results on RMSE can be tricky because errors are not weighted.

AUTHORS ANSWER: Yes, we agree. We have now removed the coefficient of determination (R2) from the verification. We would prefer to keep the RMSE, since it is widely used in literature and it is something that readers are used to interpret.

Minor comments:

1. The title should include more clearly the second objective of the study (impact of different integration time intervals in the radar-gauge correction method)

AUTHORS ANSWER: The title is now changed: “Improving the precipitation accumulation analysis using lightning measurements and different integration periods”

2. lines 1-5: the sentence is difficult to read. Moreover the second objective of the study should be better stressed. What about: "Two main objectives are addressed: (i) the assimilation of lightning observations in radar and gauge measurements and

(ii) the analysis of the impact of different integration time intervals in the radar-gauge correction method."

AUTHORS ANSWER: We agree and have now changed the first paragraph to read: “The focus of this article is to improve the precipitation accumulation analysis, with special focus on the intense precipitation events. Two main objectives are addressed: (i) the assimilation of lightning observations together with radar and gauge measurements and (ii) the analysis of the impact of different integration periods in the radar-gauge correction method.”

3. line 6: is the reference Gregow et al. (2013)?

AUTHORS ANSWER: Yes, thank you. This is now corrected (year 2011 → 2013).

4. The state of art section (lines 28-39) is rather short and can be organized in a clearer way

AUTHORS ANSWER: We have added text and references to the Introduction and organized it to become more clear. Added text include paragraphs: “The research of combining radar and surface observations, to perform corrections to precipitation accumulation, is well explored. Many have made developments in this field and much literature is available, for example Sideris et al. (2014), Schiemann et al. (2011) and Goudenhoofdt and Delobbe (2009). Recently, Jewell and Gaussiat (2015) compared performances of different merging schemas, and noted a large difference between convective and stratiform situations. In their study, the non-parametric kriging with external drift (KEDn) outperformed other methods in accumulation period of 60 minutes. Wang et al (2015) developed a sophisticated method for urban hydrology, which preserves the non-normal charactersitics of the precipitation field. They also noticed that common methods have a tendency to smooth out the important but spatially limited extremes of precipitation.” And: “Lightning is associated with convective precipitation, but in areas where a large portion of precipitation is stratiform, lightning data alone is not adequate for precipitation estimation. However, lightning has been used to complement

and improve other datasets. Morales and Agnastou (2003) combined lightning with satellite-based measurements to distinguish between convective and stratiform precipitation area and achieved a remarkable 31% bias reduction, compared to satellite-only techniques. Lightning has also been assimilated to numerical weather prediction models to improve the initialization process of the model. This can be done by blending them with other remote sensing data to create heating profiles (e.g. estimating the latent heat release when precipitation is condensed). Papadopulos et al. (2005) used lightning data to identify convective areas and then modified the model humidity profiles, allowing the model to produce convection and release latent heat using its own convective parameterization scheme. They combined lightning with 6-hourly gauge data, within a mesoscale model in the Mediterraiean area, and showed improvement in forecasts up to 12 hours lead time."

5. line 47: " usually with a higher quality than radar" a reference can be helpful

AUTHORS ANSWER: We have clarifed the sentence and added a reference in Sect. 2.1: "Rain gauges provide point observations of the accumulation. They are usually considered more accurate than radar, as point values, and are frequently used to correct the radar field (Wilson and Brandes, 1979)."

6. lines 54-55: "long" rather than "longer", "short" rather than "shorter"

AUTHORS ANSWER: This has now been changed.

7. line 62: more information about how "poor data quality" stations are identified is needed

AUTHORS ANSWER: Clarified in Sect. 2.1 by following sentence: "If measurements consistently indicate poor data quality, either manually identified from station error-logs or by inspecting the data, those stations are blacklisted within the LAPS process and do not contribute to the precipitation accumulation analysis."

8. line 70: Lat-Lon information are not shown in the figure

AUTHORS ANSWER: We have now rephrased the sentence to: “As Finland has no high mountains, the horizon of all the radars is near zero elevation with no major beam blockage, and, in general, the radar coverage is very good except in the most northern part of the country.”

9. lines 70-72: something is missing in the sentence

AUTHORS ANSWER: Changed to read: “During year 2014 and 2015 the utilization rate was > 99%.”

10. line 108: I couldn’t find the work by Pessi and Albers, 2014

AUTHORS ANSWER: We have now updated the reference with a web-link of the presentation: https://ams.confex.com/ams/94Annual/webprogram/Paper238715.html

11. lines 120-124: this is not useful for the purposes of the paper

AUTHORS ANSWER: We would like to keep these sentences about existing “default profiles”. Because, we believe it is relevant to point out that for experimental/operational usage, anywhere in the world, there is a direct possibilty to use and test the LDA method without collecting new, own statistical relationships.

12. line 121 and 127: I couldn’t find the work by Pessi, 2013

AUTHORS ANSWER: We have now updated the reference with a web-link of the presentation: https://ams.confex.com/ams/93Annual/webprogram/Paper215562.html

13. line 184: why 0.3? more details are needed

AUTHORS ANSWER: The threshold value for the hourly surface gauge measurements, retrieved from FMI real-time database, is 0.254 mm/h (i.e. everything below 0.254 mm/h is just 0). The sentence changed and moved to Sect. 3.4: “In this study we apply a filter to the verification datasets, where hourly accumulation data less than 0.3 mm are discarded (due to the lowest threshold value of surface gauge measurements from FMI real-time database).”

14. Fig 7: the colors of the regression lines are not explained in the caption

AUTHORS ANSWER: We have clarifeid and added the following to figure caption “The corresponding regression lines are represented with same color as the markers, for each method.”

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-113/hess-2016-113-AC1-supplement.pdf

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