Review of: **Quantitative rainfall analysis of the 2021 mid-July flood event in Belgium** by Michel Journée et al.

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Summary

The authors present an extensive analysis of the rainfall that has fallen over Belgium, and in particular the heavily hit Ardennes region, during the July 2021 flooding event. The authors introduce two rainfall products: one based on rain gauges, while the other product is the most recent radar QPE product of the Belgian RMI that has been improved with, among others, the information of this event. Both products are described in this paper, are analyzed and made openly available. I think and do agree with the authors that this rainfall dataset, including the analyses, is relevant for the extreme flooding event and potential follow-up studies that can make good use of such a validated rainfall dataset. However, I think that the manuscript in its current shape is not clear enough about what really is new in the processing and derivation of the rainfall datasets compared to what is available anyway. Hence, I would like to see somewhat more emphasis on the (new) methods used for these datasets, particularly for the radar QPE. In general, the methods can be described in more detail throughout the paper.

In addition, the structure of the paper was not always clear to me, as many methods are described in the results section. The paper would become clearer when all methods are placed in the methods section and when both the rainfall estimation and analysis methods are described in more detail. Finally, I think that the rainfall analysis for the (hydrological) application area(s) can be further emphasized and, where possible, extended. As this will be the application scale and field of the outcomes of this paper, I think this would increase the impact of the work. Summarizing, I think the paper needs some restructuring and more elaborate descriptions of the methods. The analyses themselves seem appropriate and supportive of the type of work and drawn conclusions.

In the sections below, I describe my suggestions in more detail in the general comments and line-by-line in the specific comments. Some minor suggestions for technical corrections are placed at the end under 'technical corrections'. I hope it helps in further improving this manuscript, which I hope to see in a published form in due course.

General comments

Rainfall product description

Besides the analyses of the quality of the rainfall products, I think a major component of this paper is the upgrade of the rainfall products and the fact that they are openly available for this event now. The descriptions of the rainfall product creation, especially for the radar QPE, is sometimes a little too brief and gives the impression that not much changed compared to the data that was already

present. I think that this does not give the work the rightful weight (and credit) on the improvements that have been made to come up with a decent radar QPE product, which is very challenging for a combination of an extreme event and (sometimes) orographically enhanced rainfall. Hence, I am fully supporting the enhancements that the authors have made to, in particular, the radar QPE product, but the description could be more extensive to make it clearer what processing steps have been taken and what has been changed compared to the operationally available product at that time. In the specific comments below, I have indicated where the authors can extend the descriptions.

Description of the methods

In line with my previous comment, I have noticed that the methodological description is sometimes too brief, which does not make it directly clear to the reader how certain analyses are performed and why certain choices were made. In the section with specific comments, I have mentioned where I think this is the case and what, in my opinion, can be added to the methods description to make it clearer.

In addition, the results section contains many methodological descriptions. It makes more sense to put the methodological descriptions that are present in the sub sections of the results in section two. This makes the paper better structured, which also helps in directly grasping the extend of the analyses that are present in this paper. When I started reading the paper, it seemed like it was only focusing on the creation of the rainfall products, but there turned out to be way more to it (so, a better structure helps there).

Application of areal averages (section 3.4)

This section does not get the weight it deserves, in my opinion. This is the application scale and, I think, one of the reasons the authors have made this dataset available and have put this analysis on paper. I think it would be good to extend this analysis a bit and show more hydrologically relevant information. The focus on the different catchment sizes is, by the way, very relevant and interesting.

The extension of the analyses could consist of emphasizing the cumulative rainfall sums (partially already present, but see my comments about figure 13 later on), as this directly shows both the difference in rainfall volume of the time period and when these differences occurred, increased or decreased. In addition, it would be even more interesting to see the effect of these differences on the simulated discharge for these catchments. I am aware that this may be slightly outside the scope of the current study, but by, for instance, applying the operationally used hydrological model with these two datasets as input, the authors could already present a very simple estimate of the effects of the different rainfall products on the simulated discharge. Do not see this as a must, but it would increase the impact of the work.

Specific comments

Lines 27 – 29: What does this exactly mean for hydrology and/or the flooding that took place?

Lines 70 – 74: What was the density (per km^2) of the gauging network and how does this density differ per region. I.e., how is the density in a heavily hit catchment such as the Vesdre, for instance? It's sometimes hard to estimate that from the figure.

Lines 81 – 82: How did this gap filling exactly work? Were gaps replaced with the data of the closest station, was some kind of spatial interpolation method used or something else?

Lines 82 - 84: How were the daily values adjusted? This, as well as my previous comment, is quite relevant information for the dataset you are providing.

Line 104 – “different kind of technology”: do you mean that the hardware of the radars is different?

Lines 104 – 105: This is indeed a major challenge. It would be interesting for the reader if the authors can briefly describe how RMI handles this to make their composite.

Lines 109 – 112: Could the authors describe in a little more detail what this basic radar estimation method is (just the Marshall-Palmer reflectivity to rain rate transformation, or more?) and how the comparison with the rain gauges took place. Regarding the latter, we often compare gauge location by corresponding grid cell, but it is also possible to take the rainfall advection into account (as the radar and rain gauges measure at different elevations), etc.

Lines 113 – 120: I think this is a major improvement of the radar rainfall estimation in hilly regions. Actually, this improvement makes the provided and described dataset unique and different from what was already available at the time. Although I am familiar with the method used, I do not think that the average reader is. Hence, can I ask the authors to put more emphasis on this procedure and describe it in more detail.

Lines 123 – 124: What was considered abnormal or unrealistic, i.e. was there a threshold or is this qualitative?

Lines 129 – 130: How is this identification of the precipitation type exactly done and what Z-R relationship is used? I know most of this is described in Goudenhoofdt and Delobbe (2016), but either refer explicitly to this paper or (/and) describe it here.

Lines 136 – 137 - “The rainfall accumulation over 5 minutes is obtained by computing the movement of precipitation using optical flow techniques”: What kind of optical flow techniques were used?

Lines 139 – 143: If any methods from other papers were used in the KED method and setup, then some referencing is necessary here.

Lines 160 – 161: Although I fully agree, what can be said about the quality of the radar here? I.e., is the radar missing any precipitation in space, or overestimating, in this region? As radar estimates in hilly and mountainous areas are challenging, this is to be expected. It would be very interesting to have an idea of this too. This could also point out why and where the combination of both data sources is going to be crucial for a good analysis of this event. The answer to this comes already partially back in Figure 4, so good to give some more details here.

Lines 164 – 168: This actually belongs in the methods section, which is right now missing for the analysis part of this paper.

Lines 175 – 176: Could the authors briefly describe the used method (and reason to use that method) from Van de Vyver (2012, 2013) in the methods section and then refer to the paper?

Lines 206 – 208 – “For longer accumulation durations (from 6 hours to 3 days), a clear trend towards extreme values can be noticed with, in parallel, an increase in the size of the severely affected areas.”: I think the authors can put some more emphasis on this finding. It would be interesting to relate this to literature findings (either here on in a discussion section) for similar extreme flooding events or similar rainfall patterns. I.e., is this what you expect or is this unique to this event?

Lines 221 – 243: This belongs in the methods section.

Section 3.3: I am not familiar with the NMF method, but can I ask the authors to explain a bit more elaborately what you are trying to reach with this method and why you focus in the results on a rank-3 NMF (and not more or less)? Why do we need the NMF method? Is it to be able to split the mesoscale rainfall field into more regional scale stratiform and convective rainfall, or is there another reason? See also my comment below related to figure 10a.

Figure 3: Here I would show the catchments that you are focusing on instead of the province of Liège.

Figure 10a: The sub panel is showing the difference between the rank-3 NMF and RADFLOOD21 data, right? This is not yet clear from the caption. In addition, from the figure and the corresponding text it is not directly clear to me if a difference is good or bad and how big of a difference is considered acceptable. As mentioned earlier, I am not familiar with the NMF method, so that definitely plays a role too. Is a small difference and indication that with (just) three ranks, and corresponding regions, you capture most of the rainfall in space and time, or should I interpret it differently?

Figure 12: Useful figure, but I think this figure fits better in the study area description. Hence, put it together with one of the first figures. I think it would fit well in figure 3.

Figure 13: It looks like the individual points in the graphs have relatively coarse steps (1, 2, 3, 6, 12, etc. hours), even though the data is based on hourly accumulations. Hence, I think the authors could put more data points in this graph, which more clearly identifies when differences between the two datasets occur. In fact, why not just go to 5-min steps and derive the cumulative sums on that time step?

Figure A1: Just to double check, we are looking at the maximum x-hour window accumulation that occurred, right? So, for e.g. the grids cells in the Vesdre, we are looking at the statistics of the maximum x-hr accumulation that occurred during the 3-day period and not the average? Besides, do you look at a rolling window in which for every 5-min steps a new x-hour window is assessed or have the authors assessed it differently? Good to briefly mention this in the methods and caption.

Technical corrections

Line 1 – “impacted severely Belgium”: impacted Belgium severely.

Line 20 – “total cost”: total economic damage (would suit better, I think).

Line 43 – “analysis”: analyses.

Line 44 - “event”: events.

Line 86 – “details”: detail.

Line 107: Although true, I think this needs some referencing.

Lines 130 – 131: Good to add a reference here.

Line 134 – “are here used”; are used here.

Line 157 – “is areas”: in areas.

Line 216 – “in a same area”: in the same area.

Line 225 – “technique”: techniques.

Lines 275 – 278: From a hydrologist’s perspective, it is more useful to provide these numbers in mm instead of in km^3. The same comment holds for the conclusion section.

Line 293 - “which makes very important”: which makes it important.

Line 313 – “should be also taken into account”: should also be taken into account.

Line 320 – “many field”: many fields.

Figure 2: The most important components of this figure, the radar locations and their 100-km range, are relative hard to distinguish from the rest of the map with the using colors. My suggestion would be to use different colors and somewhat larger font and icon size.

Figure 8: The figure has a title and a footnote, which are partially repeated in the caption. I would suggest to just keep the text in the caption and remove the title and footnote from the figure. In addition, this holds for some other figures, too.

Figure A2: What is the highest value in the sub panels? It seems that the maximum value of the color scale could be somewhat lower, e.g. 50 mm, that would give somewhat more contrast.

References

Goudenhoofdt, E. and Delobbe, L.: Generation and Verification of Rainfall Estimates from 10-Yr Volumetric Weather Radar Measurements, Journal of Hydrometeorology, 17, 1223–1242, https://doi.org/10.1175/jhm-d-15-0166.1, 2016.