Reply to interactive comments on: Towards identification of critical rainfall thresholds for urban pluvial flooding prediction based on citizen flood observations, hess-2017-751

Reviewer #3

Comment 3.1

The paper brings new ideas to the understanding pluvial flooding from an urban hydrology perspective. They use crowd sourced data in a good way, where no other data is readily available. The paper is well-structured and well-written with a fluent and precise language. The figures are in general very good – clear and easy to interpret. In general, I am positive to the paper. I hope that the following comments can help to improve it. Especially there are a few things that could be better discussed (see specific comments). Most of the studies mentioned in the discussion section are written by the authors. It would be good if you could include references to others work as well and discuss the differences? Preferably studies about pluvial flooding from similar climatic zone, like the UK, Germany, Scandinavia, etc. There might also be relevant work from the U.S.

Response 3.1:

We thank you for reviewing our manuscript and making constructive comments. We agree with your point. In the new version of the manuscript, we will expand the discussion section including references to similar studies, in particular:

1. Mazzoleni, M., Arevalo, V. J. C., Wehn, U., Alfonso, L., Norbiato, D., Monego, M., ... & Solomatine, D. P. (2018). Exploring the influence of citizen involvement on the assimilation of crowdsourced observations: a modelling study based on the 2013 flood event in the Bacchiglione catchment (Italy). Hydrology and Earth System Sciences, 22(1), 391.
2. Paul JD, Buytaert W, Allen S, et al (2018) Citizen science for hydrological risk reduction and resilience building. Wiley Interdiscip Rev Water 5:e1262.
3. Sadler, J. M., Goodall, J. L., Morsy, M. M., & Spencer, K. (2018). Modeling urban coastal flood severity from crowd-sourced flood reports using Poisson regression and Random Forest. Journal of Hydrology, 559, 43-55.
4. Wang, C., Du, S., Wen, J., Zhang, M., Gu, H., Shi, Y., & Xu, H. (2017). Analyzing explanatory factors of urban pluvial floods in Shanghai using geographically weighted regression. Stochastic Environmental Research and Risk Assessment, 31(7), 1777-1790.
5. Cherqui, F., Belmeziti, A., Granger, D., Sourdril, A., & Le Gauffre, P. (2015). Assessing urban potential flooding risk and identifying effective risk-reduction measures. Science of the Total Environment, 514, 418-425.
6. Liu Y, Piyawongwisal P, Handa S, et al (2011) Going beyond citizen data collection with mapster: A mobile+cloud real-time citizen science experiment. Proc - 7th IEEE Int Conf e-Science Work eScienceW 2011 1–6 .
7. Buytaert W, Zulkafli Z, Grainger S, et al (2014) Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development. Front Earth Sci 2:1–21 . doi: 10.3389/feart.2014.00026
8. Muller CL, Chapman L, Johnston S, et al (2015) Crowdsourcing for climate and atmospheric sciences: Current status and future potential. Int J Climatol 35:3185–3203 .
9. Herman Assumpção T, Popescu I, Jonoski A, Solomatine DP (2017) Citizen observations contributing to flood modelling: opportunities and challenges. Hydrol Earth Syst Sci Discuss 1–26 .
10. Starkey E, Parkin G, Birkinshaw S, et al (2017) Demonstrating the value of community-based ("citizen science") observations for catchment modelling and characterisation. J Hydrol 548:801–817 .

11. Yang P, Ling Ng T (2017) Gauging through the Crowd: A Crowd-Sourcing Approach to Urban Rainfall Measurement and Stormwater Modeling Implications. 7:553–572 .

Comment 3.2
Abstract. Only rainfall mentioned. Imperviousness and distance to outflows are also investigated.

Response 3.2
We agree.
We will add findings with respect to the impact of imperviousness and the distance to outflow to the abstract text.

Comment 3.3
Sec2.1. There are only 7 years of data. Did you capture any extreme events? What are the return level of the most extreme rainfall in the study?

Response 3.3
The citizen call center system of Rotterdam started to record phone calls since 2010 so we only have collected data for seven years.

We will add specific information describing the rainfall intensity of different return periods, which are 9, 11, 18 and 21 mm for a return period of 1 year, 2 years, 10 years and 20 years respectively. More detailed information about the rainfall will be described in a new table in Section 2.

Comment 3.4
Fig1/Sec2.2. Why do the study areas not follow the sewer districts? Probably obvious if you know the system...

Response 3.4:
From a practical perspective, we focus on the city center of Rotterdam which is determined by the border of the administrative districts. The main reason is that each administrative district is managed by a individual water sector so data are also collected per administrative district. However, since the sub-catchments are relatively small-sized and flat, most of which are in a scale of 5 squared kilometers or less with multiple outflow points. The difference between an administrative district and a sewer district is not very dominating. We will clarify this point in Section 2.

Comment 3.5
Sec2.2. Three administrative districts are introduced, with a fourth district for comparison. These districts are not used in the analyses and neither mentioned in the discussion section (except for Kralingen once). I miss the comparison of the four districts. Why are the introduced and then not discussed?

Response 3.5

We agree with your comment.

In the new version of the manuscript, we will describe three districts just as the city center of Rotterdam without unnecessarily emphasizing any specific district names.

Comment 3.6

Sec2.2. The key concept of Rotterdam is introduced. OP and CSO are discussed, however not these solutions. Why do you mention them? Do they have any implications for the results in your study? Discuss or delete.

Response 3.6

We agree.

They will be removed.

Comment 3.7

Eq2. Not needed, enough to mention that it is a weighted average.

Response 3.7

We agree.

Equation 2 is not needed and will be removed.

Comment 3.8

Sec3.2&3.3. In the introduction, you argue for the importance to analyse varying temporal and spatial resolution. How did you choose resolution? Why 15 min, 1 h, and 24 hours? Why not 4, 8, 12 hours for instance? Did you analyse the drainage system in some way? Describe the process. Similar question for spatial resolution.

Response 3.8

We agree that different temporal or spatial resolutions may lead to different results. For the temporal resolution, we follow what was used in (Spekkers et al. 2017). For the spatial resolution, 1 km was adopted by the resolution of radar rainfall data while 250 m was used as a typical scale of a local street flooding (as explained in section 3.1).

Comment 3.9

Sec3.3. The assumptions for the flow path analysis are described and there are surprising results. I guess you made the analysis because you expected a relation. This result is barely discussed. Why where there no relation? Could the elevation be analysed better in a different way? What about distance to the main flow path or size of catchment area upstream instead of distance to downstream outlet? To me it seems strange to analyse the relation between a feature downstream of the flooded area, rather than the upstream area.

Response 3.9

This analysis was motivated by the study of (Gaitan et al. 2015), which was conducted based on a single, large flood event. This study aimed to check their findings based on a larger number of events. We will clarify this point in Introduction and Discussion.

Comment 3.10

Fig7. Confusing with the name "urban watershed". Why are not all the urban area a part of an urban watershed?

Response 3.10

We agree.

We will replace the name 'urban watershed' by '(separate) sub-catchment'. Between sub-catchments, there are almost no flows, since these are isolated polder areas. Only limited amounts of wastewater are sometimes pumped from one district to another, and then rounted to the wastewater treatment plant.

Comment 3.11

Sec3.1. A single National Rainfall Radar pixel is used for each study area. Where are these pixels used? In 4.1 temporal correlation analysis? There is no discussion about how representative one pixel are for the area. Any tests made to ensure this? Discuss shortly.

Response 3.11

We agree with your comment, which was also raised by other reviewers.

We will extract rainfall data per pixel from radar images and calculate an aerial mean value.

Comment 3.12

Sec3.4. It took long time to understand how you did the analyses on change point. This section could be written better. It says "The appropriate dataset were ranked by event number". Don't you mean that it was ranked by e.g. rainfall volume and then given an event number?

Response 3.12

Thanks for pointing this out. We agree.

We will revise this and make sure to explain the rationale behind change point analysis more clearly with mathematics formulations.

Comment 3.13

Sec4.1. The removal of outliers needs to be better discussed. How do define an outlier? The theory behind seems vague.

Response 3.13

The outliers were manually selected in the old version of the manuscript, which we also realized was arbitrary.

As explained in our reply to Reviewer #1 and Review #2, we will implement the robust regression to automatically identify outliers. Particularly, robust regression works by assigning a weight to each data point. Weighting is done automatically and iteratively using a process called *iteratively reweighted least squares*. In the first iteration, each point is assigned equal weight and model coefficients are estimated using ordinary least squares. At subsequent iterations, weights are re-computed so that points farther from model predictions in the previous iteration are given lower weight. Model coefficients are then recomputed using weighted least squares. The process continues until the values of the coefficient estimates converge within a specified tolerance.

Comment 3.14

Sec 4.1. How can you get flood reports on days with no rainfall (Zeros)? Explain the registration. 20 reports during a day with no rainfall seems strange. Are you sure that the radar worked?

Response 3.14

Reports on a day with no rainfall is mainly due to rainfall of the preceding days. We will clarify this point by giving details of the reports in the new manuscript.

Comment 3.15

Sec4.2. You study imperviousness in the same cell. What about the effect of imperviousness upstream the inundated area? Discuss.

Response 3.15:

We implemented an overland flowpath analysis, in which the effect of upstream-to-downstream flows were investigated. We will make sure to explain it more clearly.

Comment 3.16

Sec4.2. Impatient callers... How are the registration done? Are all calls registered? What are the reason for someone to call? Do they get compensation for damaged properties? Describe the registration process and discuss the implications for your analyses.

Response 3.16

We agree.

We will remove the discussion about impatient callers which does not fit here properly. Meanwhile we will add description of call registration in Section of methods.

Comment 3.17

Fig6. Did you use fine or coarse grid for these analyses?

Response 3.17

We used data per pixel (1 km x 1 km) for the analyses.

Comment 3.18

Sec5. Discuss limitations of the study. And as mentioned before, related it to others work from similar cities in the same climatic zone.

Response 3.18

As mentioned in our reply 3.1. We will expand the discussion and add comparison to similar studies.

Comment 3.19

Sec5. Spekkers 2015: You write that you found similar results before. Mention the differences between the two studies. Why did you get 7-8 mm/h in that study and 12.5 mm/h in this study? Mention the differences in data and methods used.

Response 3.19

We will add it in Discussion.

The study by Spekkers et al was based on insurance claims, instead of citizen reports. As they concluded, for rainfall events that exceed the 7–8 mm/h, failure processes in the public domain start to contribute substantially to the overall occurrence probability.

Comment 3.20

Fig1a. No need for all the details on the map, show a few city names instead. However, this is not crucial to change.

Response 3.20:

We agree.

Fig 1a will be replaced by a figure with cities names.

Comment 3.21

Fig1b&c. Scale not indicated.

Response 3.21

A scale will be added in the new version of the figure.

Comment 3.22

Fig1c. Hard to read the names.

Response 3.22

Fig 1c will be enlarged with larger fonts.

Comment 3.23

Fig2a & Fig3a. Hard to differ the marks in black and white print. For colour blind, the figure must be difficult to read at all.

Response 3.23

We agree.

To present the marks clearer, we will increase their sizes.

Comment 3.24

Fig2b & Fig3b. Difficult to see the two outliers on the left hand side.

Response 3.24

We will adjust the range of x-axis.

Comment 3.25

Spell out acronyms the first time (e.g. Dutch KNMI, German DWD and Belgium KMI).

Response 3.25

Thanks for this remark.

In the new version of the manuscript, the above-mentioned organizations will be described in full names as '*three European national meteorological services, names: the Royal Netherlands Meteorological Institute (KNMI) of the Netherlands, the German Weather Service (DWD) of Germany, and the Royal Meteorological Institute (KMI) of Belgium*'.

Comment 3.26

Sec5. paragraph 3. ", as higher rainfall amounts are more likely to cause damage to buildings." Compared to what?

Response 3.26

We agree that the statement is vague. In the new version of the manuscript, we will clarify that the rainfall depth higher than the proposed threshold may lead to a pluvial flood with higher likelihood.

References

Gaitan S, ten Veldhuis M claire, van de Giesen N (2015) Spatial Distribution of Flood Incidents Along Urban Overland Flow-Paths. Water Resour Manag 29:3387–3399. doi: 10.1007/s11269-015-1006-y

Spekkers M, Rözer V, Thieken A, et al (2017) A comparative survey of the impacts of extreme rainfall in two international case studies. Nat Hazards Earth Syst Sci Discuss 1–38. doi: 10.5194/nhess-2017-125