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Interactive comment on "Spatial and temporal variability of rainfall and their effects on hydrological response in urban areas – a review" *by* E. Cristiano et al.

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RC = Reviewer comment AR = Authors reply

General Comment

RC: Spatial and temporal variability of rainfall and their effects on hydrological response in urban areas - a review by Elena Cristiano, Marie-Claire ten Veldhuis, and Nick van de Giesen

General comments: This manuscript is a scientific review on the variability of rainfall in urban hydrology. Several review papers have recently been published on urban hydrology in the main journals. An additional one could be interesting if it proposes an

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original point of view. As far as I know, it seems to be the case for this manuscript. Nevertheless, I consider that the manuscript requires a significant revision before its publication in HESS can be considered. - The manuscript covers a wide range of topics, sometimes from a very general point of view (for instance disaggregation, but not only), and paper sometimes already very well documented in text books (for instance hydrological processes). It is not consistent with a review paper which should present the state of the art of research on the addressed subject. The authors are recommended to focus on the most original part of the manuscript, for which a review presents an added value. - I have in mind several papers, which address the subject of the manuscript, and which have been omitted. I recommend that the authors provide a more comprehensive and exhaustive state of the art, representative of the recent studies. In addition, the references to studies of urban basins (instead of, or in addition to, natural ones) would be welcome in a manuscript covering urban areas.

AR: The authors would like to thank the reviewer for the time and effort spent reviewing our manuscript. We will make sure to check for additional references and to incorporate them in the revised version. The structure of the manuscript will be reconsidered, such that it focuses on the state of the art of research results in an urban hydrology context and addresses natural catchments only in reference to how processes in urban catchments are different. “Already well documented parts” will be removed and reconsidered with the aim of focusing only on recent progress.

Specific comments

RC: p1. 15-18: This sentence is questionable. Hydrologists have been working on rainfall radar measurement for a very long time, and have significantly contributed to this subject, including in urban hydrology (Einfalt et al., 2004 for a review). The cited references are recent and don’t reflect this long term research effort which has known a renewed interest with the emergence of polarimetric X-band radars which allow to solve some problems met with classic low-cost radars. p2. 1-3: I am not sure that it is more complicated, I would say different. p3.1-2 : I don’t well understand this

sentence p3. 3-21: Downscaling and upscaling in hydrology: This paragraph is a very brief and general introduction of downscaling methods. It is not very useful for the reader because the authors don't refer to the applications of these methods in urban hydrology, which is the subject of the manuscript. p3. 27-30: the paper by Julien and Moglen (1990) doesn't address the particular case of urban catchments. p4. 6-11: I have read the paper by Gericke and Smithers (2014). Their review of the existing methods doesn't address the urban basins. p4. 13-14: The production function is very different in natural areas and urban areas. Initial losses don't exceed 1 or 2 mm, and most of the impervious surfaces are directly connected to the hydrographic (or sewer) network. This statement is not valid for urban basins. p4. 24: The term response time is also often used; this term may be similar to the response time (Musy, 2011). p4. 32-33: To the best of my knowledge, the paper by Morin et al. (2001) doesn't address urban basins paragraph 2.3.2: "time scale characteristics". It is interesting to highlight these terms which characterize the basin dynamics are less used nowadays (see the topic called synthetic hydrology which addresses this subject). In my opinion, there are more or less equivalent, and too many words are used to name very close concepts, which can be confusing. It could be the opportunity to propose one or two terms. I think that most of the papers that are cited (not very recent) don't concern urban basins, which is a problem concerning the subject of this manuscript. I know that similar relations have been proposed (at the same period) in urban hydrology to relate the response (or lag) time of urban basins to the characteristics of basins: surface, imperviousness, slope, roughness . . . I recommend to add references on time scale characteristics that address urban basins.

AR: We agree that the focus of this section should be more on urban hydrology. Parts of this section will be reconsidered and rephrased. The focus will be only on urban areas, presenting results relative to natural catchments only when they are relevant to have a better understanding of the urban environment or if it is interesting to highlight the differences between the two areas. As for the time scales terminology, we have included a summary of terms used in the literature; we're not sure how to interpret the

reviewer's suggestion of proposing a particular term.

RC: p6. 15-20: I suggest to refer to Lanza and Stagi (2009) and or to Lanza and Vuerich (2009) for a recent evaluation lab. and field evaluation and comparison of rain gauges. p6. 18-19: the rain gauge data is punctual, but as rainfall field displays a spatial organization, this data is representative of rainfall in its neighborhood, in a surface area which depends on time step and decorrelation distance, itself related to the rainfall type. p6. 21: It exists in the scientific literature many papers, including review papers, dealing with the interpolation of rain gauges data for mapping rainfall fields by various methods, and I don't understand why the authors refer to Shaghaghian and Abedini (2013) not published in an international journal. p7. 10-14: The added value of polarimetric data is mainly: i) for ground clutter detection removal, and for X-band (and C-band also) radars for attenuation correction. X-band are strongly affected by attenuation of the signal by rainfall, and the correction of this problem is very unstable. Polarimetric data allow to efficiently correct this problem. p7. 15-25 : I don't agree with this paragraph for two reasons. The authors refer to a few studies dealing with the calibration of radar data by rain gauges, or the combination of radar and rain gauges data (which is a much more recent approach of this question). I think that these studies are not representative of the state of knowledge on that subject. In addition, based on a very limited number of studies, they conclude to the underestimation of rainfall by radar. I consider that this conclusion is erroneous and not justified p7. 28: Be more precise, please! The radar equation relates the backscattered power to the radar reflectivity factor, usually called reflectivity. This radar equation doesn't depend on the drop size distribution. p8-9. Paragraph 3.3. It seems that the weather is a very convenient device to analyze the spatial and temporal scales of rain fields for urban hydrology.

AR: Suggested references and others will be added in this section in order to have a better description of the state of the art of rainfall measurements and in particular on the importance of using weather radars combined with rain gauges to estimate rainfall. In particular we are going to refer to Thorndahl et al. 2016, (who offer a good review

on advances in weather radars and their application in urban hydrology), and to other references that will allow us to give a more precise description of radars, in terms of instrument, measurements and applications. See below for some of the references that will be added.

Thorndahl, S., Einfalt, T., Willems, P., Nielsen, J. E., ten Veldhuis, M.-C., Arnbjerg-Nielsen, K., Rasmussen, M. R., and Molnar, P.: Weather radar rainfall data in urban hydrology, Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-517, in review, 2016.

(on rainfall generator, suggested by reviewer#1)

Paschalis, A., Molnar, P., Fatichi, S., and Burlando, P.: A stochastic model for high resolution space-time precipitation simulation, Water Resources Research, 49, 8400– 8417, doi:10.1002/2013WR014437, http://dx.doi.org/10.1002/2013WR014437, 2013. Peleg, N. and Morin, E.: Stochastic convective rain-field simulation using a high-resolution synoptically conditioned weather generator (HiReS-WG),Water Resources Research, 50, 2124–2139, doi:10.1002/2013WR014836, http://dx.doi.org/10.1002/2013WR014836, 2014.

McRobie, F. H., Wang, L.-P., Onof, C., and Kenney, S.: A spatial-temporal rainfall generator for urban drainage design, Water Science and Technology, 68, 240–249, doi:10.2166/wst.2013.241, 2013.

Niemi, T. J., Guillaume, J. H. A., Kokkonen, T., 5 Hoang, T. M. T., and Seed, A. W.: Role of spatial anisotropy in design storm generation: Experiment and interpretation, Water Resources Research, 52, 69–89, doi:10.1002/2015WR017521, http://dx.doi.org/10.1002/2015WR017521, 2016.

(on rainfall uncertainty suggested by reviewer#1)

Ciach, G. J. and Krajewski, W. F.: On the estimation of radar rainfall error variance, Adv. Water Resour., 22, 585–595, doi:10.1016/s0309-1708(98)00043-8, 1999.

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Villarini, G., Mandapaka, P. V., Krajewski, W. F., and Moore, R. J.: Rainfall and sampling uncertainties: A rain gauge perspective, J. Geophys. Res.-Atmos., 113, D11102, doi:10.1029/2007jd009214, 2008.

Peleg, N., Ben-Asher, M., and Morin, E.: Radar subpixel-scale rainfall variability and uncertainty: lessons learned from observations of a dense rain-gauge network, Hydrology and Earth System Sciences, 17, 2195–2208, doi:10.5194/hess-17-2195-2013, 2013.

(on rainfall spatial distribution in 1 radar pixel, suggested by reviewer#1)

Peleg, N., Marra, F., Fatichi, S., Paschalis, A., Molnar, P., and Burlando, P.: Spatial variability of extreme rainfall at radar subpixel scale, Journal of Hydrology, doi:doi:10.1016/j.jhydrol.2016.05.033, 2016.

(other references)

Nielsen, J. E., Thorndahl, S. and Rasmussen, M. R.: Improving weather radar precipitation estimates by combining two types of radars, Atmospheric Research, 139, 36–45, doi:10.1016/j.atmosres.2013.12.013, 2014

Quirmbach, M. and Schultz, G. A.: Comparison of rain gauge and radar data as input to an urban rainfall-runoff model, in Water Science and Technology, vol. 45, pp. 27–33., 2002.

Sørup, H. J. D., Christensen, O. B., Arnbjerg-Nielsen, K. and Mikkelsen, P. S.: Downscaling future precipitation extremes to urban hydrology scales using a spatio-temporal Neyman–Scott weather generator, Hydrology and Earth System Sciences 15 Discussions, 12(2), 2561–2605, doi:10.5194/hessd-12-2561-2015, 2015.

Villarini, G., Seo, B. C., Serinaldi, F. and Krajewski, W. F.: Spatial and temporal modeling of radar rainfall uncertainties, Atmospheric Research, 135–136, 91–101, doi:10.1016/j.atmosres.2013.09.007, 2014.

RC: p8 : paragraph 3.2 “Influence of urban areas on rainfall”. This paragraph provides a brief, and general overview of this subject. What is its interaction with the subject of the manuscript ? Is this paragraph useful ? I am not convinced.

AC: The authors agree that the paragraph can be removed. Although it is an important topic, it is not relevant for the scope of the review.

RC: p9 to p14: section 4 Hydrological processes. This very long paragraph summarizes the main hydrological processes and the main approaches used to represent them, in natural and urban areas as well. It regroups the basic knowledge in hydrology, addressed in text books, and not suited to a review manuscript. This section must be removed.

AR: This section will be reconsidered, focusing only on the recent findings that are relevant in urban areas. The section will be largely reduced in order to highlight the main aspects that represent the most recent findings in urban hydrology.

RC: p15. 1-6: I don’t understand these sentences. Are stochastic models used in urban hydrology ? What type of models for what application? I don’t see its usefulness in this manuscript. It could be confusing for the reader. Please, remove it! p15. 11-14: As I understand this criterion, it concerns only the influence of the spatial variability of rainfall. There is many other factors involved in the choice of an hydrological model, depending on the applications of this model. p15. 24-31. The notion of physically-based or conceptual is valid at a given scale (in my opinion). The computational power is no more a problem, but I agree that the parameterization of a model, and the values to assign to these parameters remains a key issue. p16. 2-3 : it is an important element for all models at all scales p16. 5-13: I agree p16. 14-25: Meselhe et al. (2008): I have not found this article in WRR. This example is certainly interesting. Unfortunately, it doesn’t deal with urban hydrology. In a review manuscript addressing the hydrological response of urban basins, it is highly recommended to refer to papers which address the subject of the manuscript.

AR: The model section will be restructured focusing more on the models that are used in urban areas. A table that include a list of most common and used urban hydrodynamic models will be added.

RC: p17. 1-12: I would say that this subject is yet an open research subject, and the influence of spatial variability of rainfall on the basin response at its outlet is not yet well understood. A basin is a very powerful filter in time and space which smooths significantly an input impulse. Some studies, mostly dealing with flash floods, have been performed to determine the characteristics of rainfall which explain the variations of hydrographs at the basin outlet and reach different conclusions. p17. 13-16: It is interesting to keep in mind that a basin is a geographic system, not only characterized by its outlet. A distributed model allows to determine the flow at any location within the basin, if the rainfall is measured at corresponding scales.

AR: Thank you for the interesting comment. We agree that this is a good point to clarify, highlighting also the distinction between runoff area and runoff model grid.

RC: p17. 18.32 (paragraph 6.1.1): this reasoning applies to calculate the flow at the basin outlet, and it is no more valid if to get the flow at locations within the basin. p17. 25-26: I would suggest be very careful with these relations, which remain only indicative, and subject to a large mean error. For instance, it is very different from the equation 2. I would suggest to keep a critical and consistent approach along the manuscript. p17-18 (paragraph 6.1.2): I suggest to regroup it with 6.1.1. both deal the influence of rainfall variability according to the basin features : surface, length, response time . . .. p17-18. The subject of these two paragraphs (to be regrouped) - influence of spatial and temporal rainfall variability in relation with basin characteristics – is very important, and has been addressed by a large number of papers. The authors present in detail a limited number of studies (five or six). I suggest that they enrich their bibliography on that subject in order to provide a more comprehensive state of the art on that subject.

Lanza LG, Stagi L., 2009. High resolution performance of catching type rain gauges from the laboratory phase of the WMO Field Intercomparison of Rain Intensity Gauges. Atmos Res., 94, 555-563. Lanza L.G., Vuerich E., 2009. The WMO Field Intercomparison of Rain Intensity Gauges. Atmos. Res., 94,4, 534-543.

AR: The authors agree that the number of references is limited and some other references will be added (as for example Peleg et al., 2016). However, in urban areas, not too much has been done in this field, and most of the innovative and recent works are already included in the manuscript.

Peleg, N., Blumensaat, F., Molnar, P., Fatichi, S., and Burlando, P.: Partitioning spatial and temporal rainfall variability in urban drainage modelling, Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-530, in review, 2016.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-538, 2016.

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