General

The manuscript entitled “Spatial and temporal variability of rainfall and their effects on hydrological response in urban areas - a review” by Cristiano et al. provides a literature review of the current understanding of hydrological processes in urban environments with a focus on spatial and temporal variability and scales. It is well written and understandable and would fit well into the scope of HESS special issue on rainfall and urban hydrology. I found no major issues or concerns to be addressed while reading the manuscript, but I have some suggestions of expending the content discussed in part of the sections. Please find my comments, corrections and suggestions below.

Specific comments [Page; Lines]

[1; 19-20] For that you can also add the relatively new use of high-quality imagery from unmanned aerial vehicles (UAVs). See the paper by Tokarczyk et al. (2015).

Tokarczyk, P., Leitao, J. P., Rieckermann, J., Schindler, K., and Blumensaat, F.: High-quality observation of surface imperviousness for urban runoff modelling using UAV imagery, Hydrol. Earth Syst. Sci., 19, 4215-4228, doi:10.5194/hess-19-4215-2015, 2015.

[1; 22] Typo: double bracket.

[1; 24-25] This is more or less a repetition of the last sentence of the previous paragraph.

[2; 5] “many aspects” – such as?

[2; 13-14] “Section 7, main knowledge gaps are identified for the with respect to accurate prediction” – please revise.

[2; 23] The colon is not needed.

[3; 3] The title is not completely accurate as you specifically refer to downscaling and upscaling of climate variable to be used as input into hydrological models.

[3; 9] “meteohydrology” – I believe that the term “hydrometeorology” is more common.

[3; 13] “Muthusamy et al., 2016” – this paper discuss upscaling rather than downscaling. I suggested changing the beginning of the sentence to “Statistical downscaling and upscaling approaches … ”.

[3; 14] In addition to the paper by Wilby and Wigley (1997) I would also suggest the authors to add the review paper of Wilks and Wilby from 1999 and the (relatively newer) paper by Fowler et al (2007). After all, this is a review paper that should cover the benchmarked papers in the field.

Fowler, H. J., Blenkinsop, S., and Tebaldi, C.: Linking climate change modelling to impacts studies: recent advances in downscaling techniques for hydrological modelling, International Journal of Climatology, 27, 1547–1578, doi:10.1002/joc.1556, 2007.

Wilks, D. S. and Wilby, R. L.: The weather generation game: a review of stochastic weather models, Progress in Physical Geography, 23, 329–357, 1999.

[3; 18-19] I believe that some progress has been made in the AR methods that are being used to generate distributed rainfall since the papers of Ferraris (2003) and Schertzer and Lovejoy (2011). I would suggest the authors to modify the sentence in lines 18-19 to account for some of the relatively new publications in the field. Maybe something like: “Autoregressive methods, also refer to nowadays as “rainfall generator models”, are used to generate multidimensional random fields while preserving the rainfall spatial autocorrelation (e.g. Paschalis et al., 2013; Peleg and Morin, 2014; Niemi et al., 2016)”.

The three references represent the state of the art high resolution rainfall generator that are now available: STREAP (Paschalis), HiReS-WG (Peleg) and STEPS (Niemi). To that you can probably add the paper by McRobie et al. (2013) in which they extended the earlier Willems model to generate spatially distributed Gaussian rainfall cells (alternatively, this can go to the last model type you are suggesting in this paragraph).

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.

[4; 8-10] There is a repetition with the previous sentence.

[4; 16] Typo: double bracket.

[4; 30-31] "… as, for example the approximation presented by Gericke and Smithers (2014), for which tlag = 0.6tc" – consider deleting this sentence, I don't see how this example can contribute to the reader.

[5; 9] "… the behaviour of four Israelian catchments" – instead: "… the behaviour of four rural catchments in Israel".

[5; 20] Tab. -> Table. Also when tables 2 and 3 are mentioned.

[5; 24] Typo: double "and".

[6; 3] You are referring to five papers as an example to "urban catchments" while not referring at all to studies on "natural watershed", although there are plenty of papers to choose from. I would suggest adding 2-3 references to benchmark papers discussing the use of weather radar in rural catchments as well.

If already mentioning papers that are related to radar and urban hydrology, there is also the paper by Thorndahl et al (2016) which is part of the special issue and I think should also be mention in this review paper.

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.

[6; 8-9] Consider also to add to this references the paper by Fencl et al. (2016), which is going to be published as part of this special issue.

Fencl, M., Dohnal, M., Rieckermann, J., and Bareš, V.: Gauge-Adjusted Rainfall Estimates from Commercial Microwave Links, Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2016-397, in review, 2016.

[6; 20-21] “To solve the problem of spatial representation, interpolation techniques are used to obtain distributed rainfall fields…” – good. But sometimes you wish to do the opposite, go from a data obtained by a dense rain—gauge network to the areal rainfall that represents the catchment. This is the upscaling paper by Muthusamy et al. (2016) that was mentioned on [3; 13].

[6; 25-26] “A second problem is introduced by hard surfaces, that may cause water splashing into the gauges” – I thought that the recommendation of the WMO are to mount the gauges at an elevation of 1.2 m above ground. If this is the case, I don’t think water splashing is an issue.

[6; 32] “F. and A.” – please correct.

[6; 33] Typo: double bracket.

[7; 6-7] Consider presenting the comparison between the different band widths in a table. Maybe add price estimation for each radar type?

[7; 14] Limitations of rain—gauges are not discussed in this section. Please remove “abd rain gauges” from the section title.

[7; 19-20] "…and to define the uncertainty related to radar-rainfall estimation (Mandapaka et al., 2009; Overeem et al., 2009a)" – I suggest the authors to remove the reference to Overeem from this sentence (but to keep this reference when it cited next in the paragraph) and to replace it with other studies that were more focusing on rainfall-radar uncertainties, such as: Ciach and Krajewski (1999), Villarini et al. (2008) and Peleg et al. (2013).

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.

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.

[7; 32-33] A repetitive sentence. Consider deleting.

[8; 7-8] I think that an operative rainfall forecast based on weather radar has been activated in Belgium (using STEP model). Please check the following paper:

Foresti, L., M. Reyniers, A. Seed, and L. Delobbe. "Development and verification of a real-time stochastic precipitation nowcasting system for urban hydrology in Belgium." Hydrology and Earth System Sciences 20 (2016): 505-527.

[8; 10-12] Pollution due to urbanization also affects rainfall. Check for example the paper mention below. I would also suggest add to modify the sentence in line 11 accordingly: "Increase in heat and pollution produced by human activities …".

Givati, A., & Rosenfeld, D. (2004). Quantifying precipitation suppression due to air pollution. Journal of Applied meteorology, 43(7), 1038-1056.

[8; 25] Urban areas? You have a word missing.

[9; 6-23] This read to me as a separate subsection, entitled as "rainfall variability at the urban scale", or alike.

[9; 16-17] Not necessarily, the setup needed for deployment of a dense rain-gauge network at the urban scale that can well represent the rainfall spatial variability can be calculated using the variance reduction factor. See papers by Villarini et al. (2008) and Peleg et al. (2013) that were suggested above.

[9; 23] Please also have a look at the recent paper by Peleg et al., whom examined the spatial distribution of extreme rainfall intensity for the same scale and using similar methods (but with different rainfall model) as Gires et al. mentioned here. They found that the spatial distribution of extreme rainfall over small domains (1 x 1 km^2) can be very high.

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.

[9; 27] What do you mean by common? C-band radars?

[10; 27-28] Please delete. It repeats what is already mention.

[10; 29] Consider changing the title to: "Groundwater recharge and subsurface processes in urban areas". Infiltration is already discussed in the previous paragraph.

[11; 10-12] Please revise this sentence.

[12; 22] "Fr" in italic.

[13; 20] A reference is needed here.

[13; 21] Delete "Recent", a study from 1991 cannot be consider as recent…

[13; 23] Typo: delete the commas.

[13; 30] Why the catchments needs not to be placed on concrete or asphalt?

[15; 2-7] Please give references and examples to the two types of models used in urban studies.

[16; 14-18] Please indicate full names for UDTM and EPA SWMM models. A reference for the SWMM model should also be added.

[16; 2-24] It can be useful to add a table with the most common hydrodynamic models that are been used in urban studies (including full name, abbreviation, reference and the model type).

[17; 12] There is another relevant paper that is a part of this special issue (see below). It deals with the effect of spatially distributed rainfall on the flow total variability in an urban catchment.

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.

[17; 30] Should be “authors”.

Figure 2 – Consider changing the pixel to a point for the point value (or add a point within the pixel).

Table 1 – Notatains as missing in the box of the Response time scale.

Table 3 – Correct to “(m x m)”.