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Reply on RC2

Francesco Fatone et al.

Author comment on "Advanced sensitivity analysis of the impact of the temporal distribution and intensity in a rainfall event on hydrograph parameters in urban catchments" by Francesco Fatone et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-99-AC2, 2021

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General notes:

Review of the manuscript: "Advanced sensitivity analysis of the impact of the temporal distribution and intensity in a rainfall event on hydrograph parameters in urban catchments: a case study" by Fatone et al.

This manuscript assesses an interesting and pertinent topic. The research proposes a method to determine a novel sensitivity coefficient to assess the variability in hydrodynamic model outflows for calibration purpose based on rainfall intensity and distribution as well as the uncertainty in model parameters. The analysis is based on the application of a SWMM model of the southeastern part of the city of Kielce (Poland). The authors provided an extensive literature review of their topic and methodology, and systematically compared their results to previous works, which add a broader perspective on their research results and increased the value of their results.

I recommend the publication of this paper in HESS, however, some improvements in the manuscript structure and discussion as described below could help improve its quality and clarity.

Additionally, the paper should be reviewed thoroughly by a Native English speaker in order to improve its style and clarity. I am not a native English speaker, but below are some adjustments I do suggest.

Review 1

Be more specific on how your results can improve real-world applications of hydrodynamic models in order to further highlight the benefits of your results in the field of hydrodynamic modeling.

Comment 1

Thank you for your valuable comment. The following fragment was introduced into manuscript: "The original version of the manuscript has been modified. The results of the calculations obtained in this paper indicate the desirability of including rainfall genesis in the sensitivity analysis and calibration of hydrodynamic models, which results from the different sensitivity of models for normal, heavy, and torrential rainfall types. In this context, it is necessary to first divide the rainfall data by genesis, for which analyses – including sensitivity analysis and calibration – will be performed. Bearing in mind the obtained results of calculations at the stage of identification of hydrodynamic model parameters and their validation, it is necessary to take into account the precipitation conditions, as much smaller values of sensitivity coefficients have been found for heavy rainfall than for torrential. Considering the obtained values of sensitivity coefficients, model calibration should not include only the episodes of high rainfall intensity, which may lead to calculation errors at the step of model application in practical considerations (assessment of sewer network operation conditions, design of reservoirs, flow control devices, green infrastructure, etc.)."

Review 2

Study object: Can you be more specific on how the water is flowing in your SWMM model, i.e. water from pervious area flow toward impervious area or is it the contrary?

Comment 2

Stormwater runoff is modeled independently for impervious and pervious areas. The total outflow from the catchment to the sewer nodes is the sum of the flow for the impervious and pervious areas.

Specific information was added into manuscript in lines 369-371.

Review 3

Regarding the sensitivity of the model sensitivity coefficient to the rainfall spatial distribution and intensity; the section 4.2 (p. 6) describes well the first aspect, but the method describing how the rainfall intensity was assessed only come later.

Comment 3

The manuscript details aspects related to the description of the influence of rainfall genesis and mean rainfall intensity on the results of the sensitivity analysis. "Sumner's classification is universal in its nature and – like the Chomicz classification – it expresses the qualitative relationship between the category of rainfall and its intensity. Hence, belonging to the appropriate rainfall class can be associated with the average rainfall intensity. The rainfall classes at the Sumner scale determine the extremely different hydraulic conditions prevailing in the stormwater network, which may not always be used in practice for measurements and calibration. In the case of the Chomicz classification, a number of rainfall categories were introduced, ranging from normal to heavy rain and ending with torrential rain. This approach makes it possible to identify the operating conditions of the stormwater network and facilities located in it, taking into account the rainfall data, i.e., rainfall duration (t_r) and rainfall depth (P_{tot}) within the appropriate range of variability. This is important because it enables the identification of the average intensity of rainfall ($i=P_{tot}\cdot t_r^{-1}$) as a parameter connected with the operation of the stormwater system, which can be associated with runoff from the catchment and hydrograph parameters (volume and maximal flow rate).

In the present study, the reference rainfall values determined at the regional classification scale proposed by Chomicz (1951) were the basis for the selection of threshold values (maximum instantaneous flow and hydrograph volume) in accordance with the following equation:

(1)

where t_r is the rainfall duration, P_{tot} is the rainfall depth equal to its efficiency, and α_0 is the rainfall efficiency coefficient taking into account the normal, heavy, and torrential rain types.

Based on the Chomicz (1951) classification of rainfall, outflow hydrographs were calculated, their parameters (Q_m and V) were determined, and classification variables were defined. The outflow hydrographs and their parameters (volume and maximum flow rate) were calculated for the set values $P_{tot} = f(t_r, \alpha_0)$, which matched the assumed categories of rainfall and the temporal distribution of rainfall in the rainfall episode".

Review 4

Can you review the structure of the text to present how the variability of the different rainfall parameters are taken into account and compared closer together? Maybe you could start by presenting the general methodology applied, and then be more specific in each section.

Comment 4

The following sections discuss the subsequent computational steps: "In the deterministic solution, the values of the sensitivity coefficients (S_{xi}, where: x_i is α, n_{imp}, d_{imp}, n_{sew}) are calculated from equation (4) for the successive parameters included in the calibration in the SWMM model for the assumed rainfall characteristics (section 5.1), the temporal distributions of rainfall and the boundary values of xi set in such a way that p = 0.50. For the solution taking into account the uncertainty of the estimated coefficients in the logistic regression models, the values of the sensitivity coefficients are also calculated from equation (4). In addition, the error of the estimated coefficients (standard deviation) is taken into account and MC simulations are performed for subsequent parameters included in the calibration, sensitivity coefficients are calculated and empirical distributions are determined."

Review 5

Can you explain why the pervious coefficients had smaller impact on the results and were not calibrated?

Comment 5

To explain mentioned issue the following fragment was introduced into manuscript: "Computer simulations (Szeląg et al. 2016) conducted using the considered catchment model (SWMM) integrated with MATLAB, in which the GLUE + GSA method was implemented (involving global sensitivity analysis and uncertainty analysis), indicated that the Horton model parameters, retention depth and Manning's roughness coefficient of pervious areas have a negligible effect on the modeled catchment outflow hydrogram. These results were also confirmed through the simulations carried out by other researchers (Thorndahl. 2009; Fu et al. 2011; Fraga et al. 2016) for urban catchments in Belgium, Great Britain, Italy, etc. using the methods of local and global sensitivity analysis. These results were also confirmed by the analyses conducted by Zawilski (2010) and Mrowiec (2009) for the catchments in Poland. The dependencies between the parameters calibrated in SWMM and the modeled outflow hydrogram parameters are complex and depend on numerous factors, i.e. spatial distribution of impervious areas, geometry and retention of the stormwater network, catchment surface etc. (Razavi and Gupta, 2015). Due to the catchment size, limited outflow from pervious areas in relation to the impervious areas (Szeląg et al. 2016, as well as the Manning roughness values and retention of impervious area showed their negligible impact on the catchment outflow hydrogram compared to the remaining parameters calibrated in SWMM"

Review 6

Can you move the section 4.6 closer to the case study section as those two are related.

Comment 6

Thank you for your comment. The hydrodynamic model section has been moved closer to catchment characteristics.

Review 7

Can you further discuss why the parameters sensitivity varies from one SWMM parameter to the other according to the type of rainfall distribution (Fig. 4. e)-h)

Comment 7

To discuss mentioned issue the following fragment was introduced into manuscript: "The curves in Fig. 4e-4h show that apart from the rainfall origin (average rainfall intensity as a result of normal, heavy, and torrential rainfall), the temporal distribution of rainfall has an impact on the values of the determined sensitivity coefficients. This result is the effect of the fact that the temporal distribution of rainfall and the intensity of rainfall have a significant impact on the values of the modeled maximum flow rates, which was confirmed by the analysis by Schilling (2011). The obtained curves (Fig. 5) prove that the volume of the outflow hydrograph depends on the origin of rainfall and hence the variability of the determined values of the sensitivity coefficients for normal, heavy and torrential rainfall."

Review 8

Usually, modelers should calibrate hydrodynamic models for rainfall events that are relevant to the water management/design problems that the model will be applied to solve. For instance, if the model is used to simulate intense rainfall events for pipe design, the calibration should take into account these types of events. How your results relate to the type of rainfall events that will be used in modeling applications? In other words, are your results more relevant for hydrodynamic models calibrated with less intense rainfall events, such as those used in the design of green infrastructure and/or for simulation work based on more intense rainfall events such as those used in the design of pipe diameter or storage tank volume? Can you develop on real-world applications in your discussion or conclusion?

Comment 8

To discuss mentioned issue the following fragment was introduced into manuscript: "The analyses performed in this work showed that the origin of rainfall and the temporal distribution of rainfall in the event have a large impact on the sensitivity of the model. However, this aspect has been neglected until now in sensitivity analytical methods. The results of the calculations showed that the lowest values of the sensitivity coefficients were obtained for the outflow hydrographs resulting from heavy rainfall, while the highest values of the sensitivity coefficients were obtained for normal rain. In the context of the currently used methods of sensitivity analysis and calibration, it seems advisable to modify them by introducing an additional calculation step consisting of the classification of the measured rainfall data in terms of the origin of rainfall (accounting for average rainfall intensity) and the temporal distribution of rainfall. For this purpose, it is possible to use unsupervised machine learning methods (e.g., hierarchical cluster analysis, Kohonen neural networks, etc.). In the context of the obtained calculated results, it is advisable to select the rainfall-runoff events for calibration and validation in such a way that the determined sensitivity coefficients do not show significant variability. It is important for the appropriate selection of the values of calibrated parameters and their potential correction at the stage of model validation."

Review 9

[1, 24-25] In the abstract, you use the term "greater the intensity and temporal distribution of rainfall". What do you mean by greater temporal distribution?

Comment 9

Thank you for your comment. It has been introduced in the manuscript.

Review 10

[2, 40-50] Introduction: This paragraph presents some redundancies and could be shortened.

Comment 10

Review 11

[4,101] Study object: Rename the section as "Case study".

Comment 11

The comment was implemented in the manuscript.

Review 12

[9, 207] All rainfall events are 15 minutes in duration? It seems short even for small catchment. Can you justify this choice?

Comment 12

Assuming the rainfall intensity values corresponding to normal ($P_{tot,u}$=3.7 mm), heavy ($P_{tot,m}$=5.8 mm), and torrential ($P_{tot,g}$=21.9 mm) rain, the outflow hydrographs were determined for t_r=15 min; the Q(t) values were determined with at 10s resolution. "The abovementioned assumption is made because the area under consideration is a small urban catchment, where the time of stormwater runoff is relatively short, and the stormwater retention time is limited due to the significant slope in the channels, reaching 3.9%. Moreover, the stormwater system model is simplified and limited to the main channels. In the context of the adopted assumptions (catchment retention resulting from land development and topography), the value of the rainfall duration (t_r = 15 min) theoretically including the concentration time, the pipe retention time seems to be representative for small urban catchments, considering that the measure of the influence of rainfall origin on the model sensitivity is primarily to be differentiated by the mean intensity of rainfall (Meynink and Cordery, 1976; Watt and Marsalek, 2013; Krvavica and Rubinić, 2020). Appropriate selection of the duration of rainfall and classification of rainfall for calculation purposes may result from the local rainfall parameters and the climatic conditions shaping the dynamics of rainfall-runoff processes". Marked by "" fragment was introduced into manuscript.

Review 13, 14, 15

[14, 344] Can you further explain this sentence: "The poorer performance for 30 July 2010 results from the bias of the model output, whereas the maximum stormwater flows were predicted correctly".

[1, 26-28] In the abstract, please reformulate and clarify this sentence (maybe use two sentences): "Additionally, the calculations confirmed the significant impact of the uncertainty of the estimated coefficient in the simulator on the sensitivity coefficients, which has a significant effect on the interpretation of the relationships obtained. ''

[2, 33] Introduction: "[...] there is a need to runoff model." Replace by something like "there is a need to apply runoff models".

Comment 13, 14, 15

Thank you for comments. They have been included in the manuscript.

Review 16

[3, 85] Introduction: Please add the word "and" in the parenthesis: "(maximum instantaneous flow, hydrograph volume)".

Comment 16

Thank you for your comment. It has been implemented in the manuscript.

Review 17

[3, 90] Introduction: Change paragraph when starting the sentence "Summing up, […]"

Comment 17

Thank you for your comment. Changes has been implemented in the manuscript.

Review 18, 19

[5,116] Study object: Use a hyphen to presents the Manning coefficient range rather than using the symbol of division. Please review as other division signs were found later in the text.

[5,142] Same as above. Change the symbol "÷" for "-" when presenting a range of values.

Comment 18, 19

Thank you for your comment. It has been implemented in the manuscript.