Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2020-460-SC1, 2020

Hydrology and Earth System Sciences Discussions

Open Access

HESSD

Interactive comment

Interactive comment on "Modeling and interpreting hydrological responses of sustainable urban drainage systems with explainable machine learning methods" *by* Yang Yang and Ting Fong May Chui

Yang Yang

yyang90@connect.hku.hk

Received and published: 16 October 2020

We would like to thank the reviewer for providing insightful comments for improving the quality of the paper. Our short response to the comments is as follow, which outlines our plans to revise the paper.

1. We agree with the reviewer that the connections between the SHAP values of the hyperparameters and the hydrological processes are hard to understand. In the original submission, in addition to the rainfall-runoff machine learning models, we built

Printer-friendly version

Discussion paper

models to predict the accuracy of rainfall-runoff models using their feature engineering hyperparameter values. And then identified the impact of each hyperparameter on the accuracy of rainfall-runoff models using SHAP. The premise is that the hyperparameters control what information of the rainfall to be passed into the rainfall-runoff models. Thus, if the information to be passed resulted in models with high prediction accuracy, we consider such information to be relevant to the runoff generation processes. However, we found this connection to be indirect and affected by the learning ability of the rainfall-runoff machine learning models. We also did not explain the connections clearly in the original submission. Thus, we plan to remove or significantly shorten the content on this point.

The SHAP method is also used to explain the basis of the predictions made by the rainfall-runoff machine learning models, i.e., the impact of rainfall at each time steps to runoffs at subsequent steps were quantified. Such information was then used for determining catchment response time and hydrograph separation (see Figures 9-11, line 475 to 530). As stated in line 497 to 498, "As SHAP values satisfy local accuracy property, it is possible to decompose a flow rate prediction into flow rates contributed by each feature." The SHAP values of rainfall depth features can be further attributed to each rainfall depth record, which measures its contribution to a rainfall record. We understand that the other hydrometeorological variables are not considered, the rainfall-runoff correlation presented in the models is only a simplified representation of the true processes. As the models have good prediction accuracies, we may say that the models learned a good approximation of the major processes in the real-world. We will further discuss this point in the updated manuscript and remind the readers that this is a modeling result and further verifications are needed.

2. The reviewer suggests that more physical observation variables could be considered, as they are influencing factors of the hydrological processes. We agree with this point. Unfortunately, we do not have other physical observation data, i.e., only rainfall and runoff time series are available. The design configurations of the drainage

systems of the first study site are also unavailable. Thus, it is very difficult, if not impossible, to set up process-based models. The lack of data is also a motivation for using machine learning methods. To address this shortcoming, we included two additional hyperparameters, account_season and account_CumRain, to let the machine learning method explore whether there are seasonality or changes in the long-term performance of the sustainable drainage systems. We will further clarify this point in the updated manuscript.

3. We claimed that our framework is useful for catchments with insufficient data for setting up process-based models. However, more justifications could be provided, e.g., our method does not require the measurements of the physical properties of the catchment but does require rainfall-runoff time series. We will add more explanations.

4. The proposed feature engineering algorithm corresponds to the method to derive rainfall depth features (Dt-a,t-b) and the nested cross-validation procedures to select the optimal set of features and the hyperparameters of machine learning methods. To make the logic of the section 2 clearer, we will add a short summary before introducing the detailed methods.

5. The “fine-temporal scale” refers to “sub-hourly”. We will use this more specific term throughout the paper.

Modeling the rainfall-runoff correlation at a sub-hourly scale (i.e., 10-min) is quite difficult, as the dimension of the input variable (“rainfall”) could be a few thousand. To solve this problem, we propose a feature engineering method to reduce the dimension of the input variable and a method to select the optimal features.

6. The use of Dt-a,t-b: we mentioned the meaning of using them in line 155, “The collection of Dt-a,t-b are a compact representation of the original rainfall time series. The resolution and the encoded information of this representation are controlled by m, l, and q.” The other reasons for using them include the preservation of the temporal distribution of the rainfall and the direct connection to the raw rainfall input. However,

as the reviewer pointed out, the reason for using Dt-a,t-b is presented after it has been defined, which makes it hard to understand. We plan to rewrite some sections to improve the readability of this paper, especially for the method section.

7. We will add quantitative summaries of the experiments to the conclusion section, as suggested by the reviewer. Qualitative descriptions will also be updated, e.g., the reasons for using machine learning models over the conventional process-based model and shortcomings of not including other hydrometeorological variables.

8. The advantage of the proposed method to the conventional processed-based method is that it does not require measurements of the physical properties of the catchment or assumptions regarding the hydrological processes. Basically, it provides an opportunity for finding statistical connections between two variables without knowing the underlying processes. We present the difficulties in applying process-based models in line 42 to 56. The challenges of using process-based models for the two study sites are lack of information on the physical properties of the catchment and complexities in parameterizing the drainage systems, as discussed in line 279 to 283 and line 323 to 324. However, we regret have not discussed it again in the results and the conclusion section.

The disadvantage of machine learning models is that they are hard to interpret or lack of transparency, i.e., we do not know why a certain prediction is made. Thus, in this research, we propose to use SHAP to analyze the basis of each prediction. The other disadvantage is that they are difficult to model high-dimensional input-output correlation. Thus, a new feature engineering method for reducing the dimension of the input variable is proposed in this research.

9. The cited literature is formatted automatically using a reference management software with the HESS style selected, and we are sorry for the mistakes in the format. We will check the citation style manually to avoid mistakes. We also plan to update the structure of the manuscript to make it more concise and easier to understand and hire

a professional English editor to correct grammar mistakes.

In summary, we understand the reviewer's concerns on only using rainfall time series as the input variable. However, the other hydrometeorological variables for the two study sites are unavailable. The runoff responses to storms of the two catchments are investigated in this study, which is useful for understanding the effectiveness of sustainable urban drainage systems. As the two catchments are very small (1,000 m2 and 1 km2) and good prediction accuracies are achieved by machine learning models, we may consider the models have learned a reasonably good approximation of the runoff-generation processes (see our response #1). Does the reviewer suggest additional analysis or case studies? We would highly appreciate it if the reviewer could further comment on our revision plan or provide additional feedback.

Any comments on the manuscript or this response letter from anyone are appreciated.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2020-460, 2020.