Dear Pro. Dr. Ilhan,

The authors would like to thank you for your time and constructive comments. Our point-to-point responses are listed below, where our responses are in blue, and the reviewers' comments are in black.

Kind regards, all authors

General comments

Yi et al. propose a novel method for computing unit hydrographs that can better account for spatial heterogeneity. For this, they relate the unit hydrograph to the dynamics of the saturated area inside the catchment, computed through the topographic wetness index for unit precipitation. The exploration of unit hydrographs and hydrological response units is an important research direction in hydrological modelling. Here, especially the impact of spatial heterogeneity is---in my opinion---underexplored. The topic of the paper is thus timely and relevant to the readership of this journal.

My main issue is with the presentation of the results and subsequent discussion. I hope that this is not nitpicking, but the current organization of the manuscript made reading, understanding, and evaluating the novelty and the methodology difficult to me. I therefore suggest revision as discussed below. Because the revision might become substantial, I recommend major revision of the current manuscript.

Response:

Thank you for your constructive comments, we will rewrite the discussion based on your comments. The revised discussion will include two parts:

1) Section 4.3 will be moved into the discussion part. In this section, we focus on "Errors due to spatial scale mismatch between runoff generation and runoff routing", and we will add the reasons for the potential improvements presented in the two real case studies;

2) The second part, advantages and limitations. In this section, we will summarize the advantages of the proposed method over the TDUH, as well as the potential limitations. We will make the connection to the test cases more obvious. In addition, relevant literature will be added in this Section.

Minor comments

Comment 1:L11: "... challenging hydrological modelling" reads a bit awkward. Rethink or remove "challenging."

Thank you for your comments. It will be revised as ": The spatial scale mismatch between runoff generation and runoff routing is an acceptable compromise but a common issue in hydrological modelling."

Comment 2: Table 6: The phrase "A typical hydrograph of direct runoff which gets generated from one centimeter of effective rainfall falling at a uniform rate over the saturated drainage basin uniformly during a specific duration." is not very clear to me. Does "uniformly" mean "spatially uniform" as implied in the Assumptions?

Sorry for being unclear here. It means spatially uniform here. To ensure the accuracy of the definition, we have read the relevant literature carefully. The unit hydrograph of a watershed is defined as a direct runoff hydrograph that results from 10 mm of excess rainfall that is generated uniformly over the drainage area at a constant rate for an effective duration (Sherman, 1932). Straub et. al. (2000) defined unit hydrograph as a discharge time graph (hydrograph) of a unit volume of direct runoff resulting from a spatially uniform distributed effective precipitation with a uniform intensity over a given duration. Bedient and Huber (2002) defined unit hydrograph as basin outflow resulting from 1.0 inch of direct runoff generated uniformly over the drainage area at a uniform rainfall rate during a specific period of rainfall duration. DTDUH is similar to the definition above, and the differences lie in that DTDUH is computed based on the generating area instead of the whole basin. However, its assumptions remained unchanged as the traditional unit hydrograph, such as a spatially uniform distributed effective precipitation.

References:

Bedient, B. P., Huber, C. W., 2002. Hydrology and Floodplain Analysis. Prentice-Hall, Upper Saddle River, United States of America.

Sherman, L. K, 1932. Streamflow from rainfall by the unit-graph method, Eng. News-Rec., 108, 501–505.

Straub, D. T., Melching, S. C., Kocher, E. K., 2000. Equations for Estimating Clark Unit-Hydrograph Parameters for Small Rural Watersheds in Illinois. U.S Department of the Interior U.S Geological Survey, Water- Resources Investigations Report 00-4184.

Comment 3: It may always be debatable whether a certain part goes into the Discussion or somewhere else. Nevertheless, I have some suggestions. In my opinion, the Discussion section should focus on discussing the presented data and results and perhaps generalize some key insights if the data permits. The authors do this, for example, in L562-565 in the Conclusions. Based on this reasoning, I suggest a thorough rewrite of the discussion in this paper. The aim of this rewrite should be to support the discussed points with data generated in the test cases.

Thank you for your constructive comments, we will rewrite the discussion based on your comments. The revised discussion will include two parts:

1) Section 4.3 will be moved into the discussion part. In this section, we focus on "Errors due to spatial scale mismatch between runoff generation and runoff routing", and we will add the reasons for the potential improvements presented in the two real case studies;

2) The second part, advantages and limitations. In this section, we will summarize the advantages of the proposed method over the TDUH, as well as the potential limitations. We will make the connection to the test cases more obvious. In addition, relevant literature will be added in this Section.

Specifically, I have the following comments:

Comment 4:L498: The title "Forecasting performance advantage analysis of the proposed DTDUH" sounds a bit strange. I think it is the advantage over the TDUH algorithm? If this is the case, it should be in the title. But the advantage is not very clear to me. It is related to how the water is redistributed and how it connects to the unit hydrograph, but there is no indication what the reference hydrograph should look like.

Thank you for your suggestions. This section will be integrated into Section 5.2 "Advantages and limitations", as we cannot provide the reference hydrograph, we will add some relevant literature to explain the rationality of the proposed method.

Comment 5:L501-509 including Table 6: This reads as introductory information rather than a discussion. Perhaps move it into the Introduction of the paper or make the connection to the test cases more obvious to the reader.

Thank you for your comments. Table 6 will be integrated into Section 5.2 "Advantages and limitations", and we will make the connection of Table 6 to the test cases more obvious. The revised sentences are as follows:

"There are many reasons why DTDUHs simulation is superior than others, and we summarized the main differences of the TDUH and DTDUHs, including their definition and assumptions. The DTDUH was defined as a typical hydrograph of direct runoff which gets generated from one centimetre of effective rainfall falling at a uniform rate over the saturated drainage basin uniformly during a specific duration. This realization was significant different with the understandings from Sherman (1932), who defined the unit hydrograph of a watershed as a direct runoff hydrograph that results from 10 mm of excess rainfall that is generated uniformly over the drainage area at a constant rate for an effective duration. The proposed DTDUH was computed based on the runoff generation areas instead of the whole basin, and this is the main advantages of DTDUH over TDUHs. Simultaneously, the assumption of the DTDUH remained unchanged as the traditional unit hydrograph, such as a spatially uniform distributed effective precipitation. Some researches also did similar research. For example, Andrieu et al. (2021) proposed an Event-specific Geomorphological Instantaneous Unit Hydrograph (E-GIUH), and the method relies on the width function-based GIUH (Rigon et al., 2016), as adapted to take into account the spatial variability of rainfall through replacing the width function by the rainfall width function."

Comment 6:L512-530 including Figure 15: This entire discussion is disconnected from the test cases. I have no doubt the discussion is valid, but I wonder if this could be better connected to the test cases. Instead of the idealized basin with 24 cells, can you show and discuss these effects in the test cases you have shown? This would be the best option. Otherwise, include a modelling test case with the idealized basin at the beginning of your test cases and then discuss it in the Discussion section where you show these effects.

Thank you for your comments. We will move Fig. 15 into methodology, and Section 5.1 in the original manuscript will be replaced by Section 4.3, and we think it will be more relevant here.

Comment 7:L531-549: This section is also not supported by data shown. These generalized shortcomings seem to belong in the conclusions. I suggest discussing these limitations in the context of the test cases you show. For example, if the unit hydrograph in your test case deviates from the reference hydrograph, you may show that this is most likely due to hybrid runoff generation. This would support the discussed points in this section.

Thank you for your comments. We will discuss these limitations in the context of the test cases in more detail. The revised Section 5.2 is as follows:

5.2 Advantages and limitations of the proposed DTDUH

We found that the accuracy of DTDUHs varies in different basins, specifically, performances of the DTDUH in Longhu Basin are more similar to that of the TDUHs, while the simulation results in Dongshi Basin are more consistent with that of the LR method. In general, the DTDUHs performed the best over the three runoff routing methods for both test cases. There are many reasons why DTDUHs simulation is superior than others, and we summarized the main differences of the TDUH and DTDUHs, including their definition and assumptions. The DTDUH was defined as a typical hydrograph of direct runoff which gets generated from one centimetre of effective rainfall falling at a uniform rate over the saturated drainage basin uniformly during a specific duration. This realization was significant different with the understandings from Sherman (1932), who defined the unit hydrograph of a watershed as a direct runoff hydrograph that results from 10 mm of excess rainfall that is generated uniformly over the drainage area at a constant rate for an effective duration. The proposed DTDUH was computed based on the runoff generation areas instead of the whole basin, and this is the main advantages of DTDUH over TDUHs. Simultaneously, the assumption of the DTDUH remained unchanged as the traditional unit hydrograph, such as a spatially uniform distributed effective precipitation. Some researches also did similar research. For example, Andrieu et al. (2021) proposed an Event-specific Geomorphological Instantaneous Unit Hydrograph (E-GIUH), and the method relies on the width function-based GIUH (Rigon et al., 2016), as adapted to take into account the spatial variability of rainfall through replacing the width function by the rainfall width function.

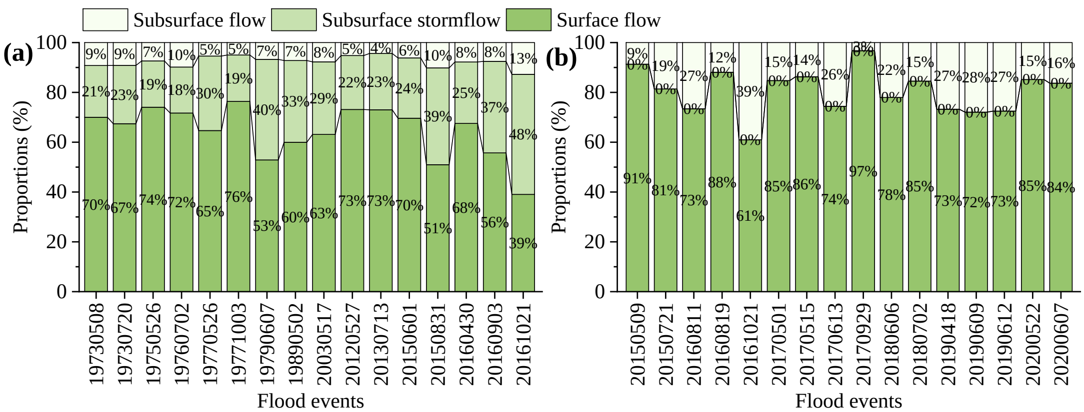

Figure 3. Details of the runoff components of the 16 flood events for the (a) Longhu River basin. (b) Dongshi River basin.

Although DTDUH showed advantages in both basins, the degree of improvement compared with TDUH was not consistent. Therefore, we summarized the potential limitations of the DTDUH. First, we utilized the DTDUH only for the surface runoff in the both basins, proportions of the subsurface storm flow and subsurface runoff may cause considerable interference to the simulation results. Runoff components of the Longhu and Dongshi River basins are as given in Fig. 1. Results shown that the average surface runoff ratio in Longhu Basin and Dongshi basin is 64.4% and 80.3%, respectively. This result suggested that the improvement in accuracy caused by DTDUH may be more significant in the Dongshi basin. And, this conclusion is consistent with the calibration and verification results. Second, a hybrid runoff generation process pattern formed by more than one mechanism can often be identified in semi-humid, semi-arid and mountain watershed, because of the heterogeneity of underlying surface conditions and meteorological factors (Hu et al., 2021; Yi et al., 2023). When there occurs more than the saturation-excess rainfall, the saturated area extraction method based on the TWI will not be applicable as the excess rainfall can also be generated from the unsaturated areas. Fig. 2 shows the antecedent soil moisture conditions for the Longhu and Dongshi River basins. It can be found that the antecedent soil moisture can be low for some flood events, such as No. 19790607, 19890502, 20150509 and so on. When the antecedent soil moisture is low and the rainfall intensity is high, the drainage basin may produce not only the saturation excess, which results in low accuracy of the DTDUH method.

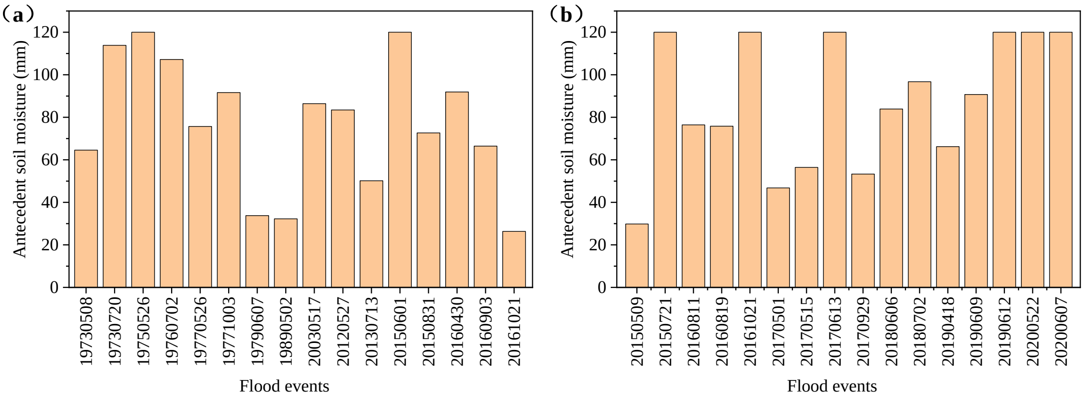

Figure 4. Details of the antecedent soil moisture of the 16 flood events for the (a) Longhu River basin. (b) Dongshi River basin.

References:

Andrieu, H., Moussa, R., Kirstetter, P.-E., 2021. The Event-specific Geomorphological Instantaneous Unit Hydrograph (E-GIUH): The basin hydrological response characteristic of a flood event. Journal of Hydrology, 603: 127158. https://doi.org/10.1016/j.jhydrol.2021.127158

Hu, C. H., Ran, G., Li, G., Yu, Y., Wu, Q., Yan, D. H., Jian, S. Q., 2021. The effects of rainfall characteristics and land use and cover change on runoff in the Yellow River basin, China. Journal of Hydrology and Hydromechanics, 69(1): 29-40. https://doi.org/10.2478/johh-2020-0042

Yi, B., Chen, L., Liu, Y., Guo, H., Leng, Z., Gan, X., Xie, T., Mei, Z., 2023. Hydrological modelling with an improved flexible hybrid runoff generation strategy. Journal of Hydrology, 620: 129457. https://doi.org/10.1016/j.jhydrol.2023.129457

Rigon, R., Bancheri, M., Formetta, G. and de Lavenne, A., 2016. The geomorphological unit hydrograph from a historical-critical perspective. Earth Surface Processes and

Landforms, 41(1), 27-37. https://doi.org/10.1002/esp.3855

Sherman, L. K, 1932. Streamflow from rainfall by the unit-graph method, Eng. News-Rec., 108, 501–505.