<u>Authors' Responses to the Comments of Report #2</u>

hess-2019-28R3

Inundation analysis of metro systems using SWMM incorporated into GIS: a case study in Shanghai

Hai-Min Lyu, Shui-Long Shen, Jun Yang, and Zhen-Yu Yin

The authors would like to thank the constructive comments from the reviewers, which are very helpful to guide the authors' revision on the manuscript. The revised parts are <u>underlined in the revised manuscript.</u> Authors' responses to the comments of reviewers are detailed as below, in which the paragraphs in normal fonts (in Cambria) are the original comments and the authors' responses are written in <u>***italic fonts (in Times New Roman)***</u>.

Editor Comments

Please, address comments by Referee #2, who revised your manuscript twice and still is points at numerous necessary improvements.

Answer: Thanks for the Editor give us the chance to revise our manuscript and sincere thanks also for the second anonymous referee, who carefully revised our manuscript to improve the quality. We have revised our manuscript according to the reviewer's comments point by point.

Comments

Despite the changes carried out by the authors to the previous version of the manuscript, there are still a few points that I consider worth revising:

Q1- Line 18 (page 3) to line 3 (page 4): SWMM is not a 2D model. So, how can SWMM be limited by the 2D domain size and spatial res?

Answer: Thanks for the reviewer's comments. Yes, SWMM is a 1D model, which can be adopted to calculate the water flowing velocity in pipeline and water volume of each subcatchment. However, SWMM cannot be used to determine the surface water flowing and the redistribution of rainwater. Thus, in this study, we adopt SWMM to calculate water volume of each subcatchment and then proposed the algorithm to determine the spreading of the calculated water volume. With this spreading algorithm, we incorporated SWMM into GIS. We have revised this sentence from line 23 to line 24 in page 3.

Line 23-24 in page 3:

<u>However, the SWMM cannot be used to determine the surface water flows.</u>

Q2- In the answer to Q4: Is “113810” a large number of cells? I believe there are other studies that encompass a larger number of grid cells to simulate 2D surface flow.

Answer: Thanks for the reviewer’s comments. Yes, I agree with the reviewer that there are other studies, which include a larger number of cells to simulate 2D surface flow. Here, we would like to demonstrate that the simulation model with 113810 grid cells is enough to simulate the area in our case. The water depth (Fig. 5) is obtained from the calculated grid rather than from the subcatchment. The number of subcatchment is relatively small, but the study area is meshed into 113810 grids. The water depth is obtained from the calculated grids by using the proposed spreading algorithm in GIS.

Q3- In Answer to Q5: How is the resolution converted from 30m to 20m? what type of interpolation? Also, what level of accuracy is expected to have when adding the buildings to a raster of 20m spatial res??? More detailed is required and well as a discussion on this.

Answer: Thanks for the reviewer’s comments. The elevation of each grid was extracted from the DEM data with 30 resolution using the tool ‘from point to grid’ in GIS. The theory of this process is linear interpolation. Since the Shanghai is a flat region and the difference of elevation is only 2 to 3 m within a range of 25 km. Thus, the accuracy of linear interpolation will be very small, e.g., slope is less than 0.01%, the error from interpolation will be also less than 0.01% both horizontally and vertically. By using this process, each grid was given an elevation. Then, the elevation of each grid was modified by the distribution of building. The grids with building locations are modified to add the height of building. We overlaid the original DEM data and the distribution of the buildings with their corresponding heights. Of course, the surface slop will increase. The flood event is impossible to inundate the building. The area with the location of building will not inundated in flood event. Thus, the modification is reasonable and the data with 30 m resolution is enough to perform the rainfall spreading process with 20 m × 20 m grids in the study area. Since the study area is classified into grids with 20 m × 20 m in GIS, the calculated water depth is within 400 m^2. In other words, the surface water depth can be predicted in the accuracy of the area within 400 m^2. We have revised section from line 5 to line 11 in page 7.

Line 17 in page 7 to line 2 in page 8:

<u>During the reprocess of elevation data, the investigated area was divided into grids with 20 m × 20 m in GIS. Since the original elevation of each grid was extracted from the DEM data with spatial resolution of 30 m, the linear interpolation was conducted to convert it into 20 m size. Shanghai is a flat region with an elevation difference of only 2 to 3 m within a range of 25 km. Thus, the accuracy of linear interpolation is enough. Each grid was provided with building distribution data and a DEM. The grids with the original elevation were modified to include the building heights. Because the locations with buildings are not inundated, the modification is reasonable. Since the study area is</u>

classified into grids with 20 m × 20 m, the obtained distribution of water depth is within the area of 400 m^2. Therefore, the proposed method can achieve an accuracy of the inundation distribution within 400 m^2.

Q4- In point (2) of the conclusions: "... the calculated water volume in the SWMM..." refers to flooding volume, right? But how is water spread in the catchment grid cells?

Answer: Thanks for the reviewer's comments. Yes, the calculated water volume is flood volume of each subcatchment. The calculated water volume is used to perform the spreading process using the proposed algorithm. In this stage, it is supposed that the calculated water volume of each subcatchment is uniformly distributed on the grids of the study in GIS model at the beginning. After one cycle of iterative calculation, the water level will be not uniformly distributed and changed with the geographical information. The uniformed water depth is then adopted to perform the circulation of updating the water depth of each grids until the water level of each grind is stable. Finally, the water level of each grid is used to reflect the surface water depth. The detailed process about how to incorporate SWMM into GIS has been revised from line 6 to line 24 in page 8. The water volume is adopted to spread into each grid using interactive calculation with the proposed algorithm. We have revised this section from line 9 to line 10 in page 26.

Line 9-10 in page 26:

The calculated water volume was adopted to update the water level of each grid using iterative calculation with the proposed algorithm.

Q5- Lines 12-13 (page 3): difficult to model? most GIS software do it automatically based on DEMs-based algorithms.

Answer: This sentence is used to say that the numerical model is difficult to model the characteristics of landform. Yes, most GIS software can do it automatically based on DEMs-based algorithms. This study adopted the GIS software to reflect the characteristics of landform.

Q6- In Answer to Q8: The authors should not "delete" parts of the text to avoid confusion. They should instead clarify the steps and concepts used in the text.

Answer: Thanks for the reviewer's comments. We deleted the sentence "Moreover, the existing numerical studies cannot identify the boundary, resulting in a large error because the boundary is in extreme vicinity of the area centre.***". This original sentence did not express the correct meaning. Thus, we revised the context and added references to support our points. This section has been revised from line 16 to line 19 in page 3.***

Line 16-19 in page 3:

Many of the existing methods can only simulate inundation for small ranges (Naulin et al., 2013; Wu et al., 2018). Therefore, a new tool (e.g., the GIS technique) is required to consider variations in topographical elevations. Moreover, an integrated method is required to simulate regional-scale flooding.

Q7- In Answer to Q10 ("... instead we use the drainage capacity of the drainage system..."): This is a very strong assumption! replace the drainage system by the metro stations "hyd. capacity"? there are other methods, e.g. reduce a few mm from the rainfall.

Answer: We haven't used the metro station to replace the drainage system. Excuse our poor English to cause the misunderstanding. Since the distribution of the drainage network is complex in the study region with 120 km^2 so that we haven't considered the effects of the drainage network directly. Instead, we use the drainage capacity of the pumping station to reduce the calculated water quantity to indirectly reflect the effects of the drainage network. The calculated drained water volume was already deduced in SWMM model. The distribution of the pumping station is shown in Fig. 2. Moreover, there is a mistake for the term "drainage station", it should be "Pumping station".

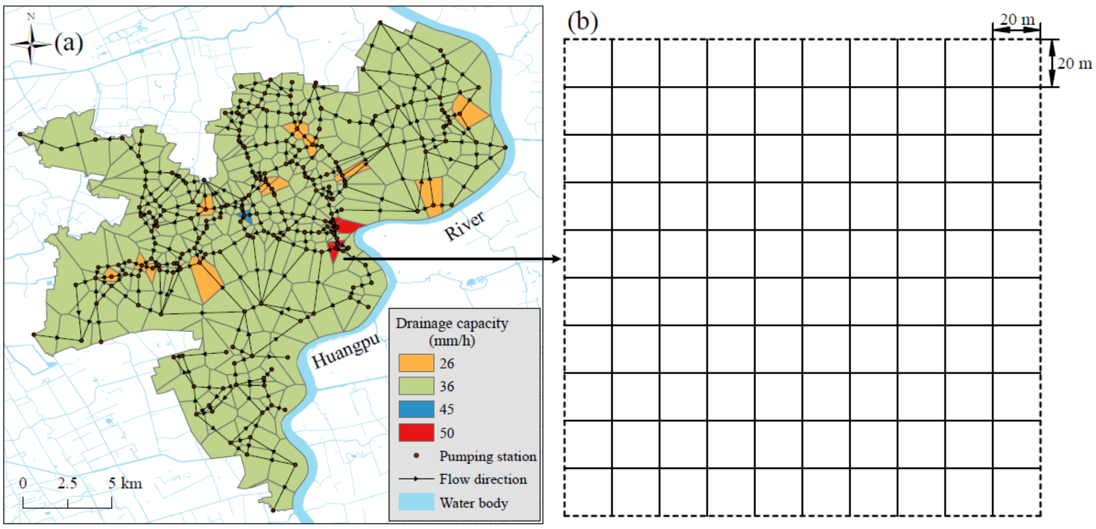

Figure 2: Calculated subcatchments and grids in SWMM and GIS: (a) drainage capacity and flow direction of each subcatchment; (b) calculated grid of each subcatchment

Q8- Line 3 (page 6): I think the authors mean "generate rainfall hyetographs" instead of "produce rainfall processes"

Answer: Thanks for the reviewer's careful check. We have revised it as "generate rainfall hyetographs" in line 6 (page 6).

Q9- Lines 1-2 (Page 24): "practical" interest??? the duration may be related to the catchment time of concentration... flash floods? ... I think the authors should describe this in more detail.

Answer: Thanks for the reviewer's comments. In realty, people paid more attention to the short-term rainstorm. Since a short-term rainstorm is more possible to induce flash floods in urban area. Therefore, in this study, we simulate a rainfall duration with 2 h under the rainfall intensity of 50-year, 100-year and 500-year. We have revised this section in more detail from line 13 to line 15 in page 24.

Line 13-15 in page 24:

In reality, a short-term rainstorm is easy to induce floods in urban area. The existing researches paid more attention to flash floods induced by short-term rainstorm within 2 h or 3 h (Yin et al., 2016a, b; Wu et al., 2017). Therefore, in this study, a rainfall duration of 2 h was selected to simulate.

Authors' Responses to the Comments of Report #1

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Comments

This manuscript aims to evaluate the flood risk of metro systems under different rainfall intensities of 50-year, 100-year and 500-year. The incorporation of SWMM and GIS is used to simulate the water depth. To achieve this goal, an algorithm to simulate the surface flow is proposed. The topic is interesting and within the scope of the journal of hydrology and earth system science. I carefully read the revised manuscript as well as the interactive comments of the discussers and reviewers and the responses of the authors. The proposed comments are suggestive and helpful to improve the quality of the manuscript, and the authors have answered the questions carefully. Therefore, I suggest the current version of the revised manuscript can be accepted. In addition, one question is launched for the authors to consider in their future research activities: what is the effect of the land subsidence on the flood risk and how to simulate this effect?

Answer: Thanks for the reviewer's constructive comments. This is a useful suggestion for the future studies. Yes, in the present study we did not considered the effect of land subsidence on flooding directly. Land subsidence is a slow process of loss of elevation and this is a dynamic process so that further detailed study (calculation algorithm) is required to consider the interaction between elevation loss and flooding.