Responses to Anonymous Referee #2

MS No.: hess-2020-59

General comments

The authors present a case study where UAV and VGI photos are used to run a CFS including a coupling between surface and sewer system flows and they evaluate the influence of the DEM resolution on simulation results. The UAV images are processed to create a high resolution DEM. Results of the numerical simulation are compared to VGI photos in terms of water depth to assess its correctness. A comparison is made between 2 DEM resolutions, and the conclusion is that higher resolution yields better results. The ideas developed in this paper are interesting, and are a useful contribution towards simple and flexible hydraulic numerical simulation by using remote sensing and crowdsourcing. Nevertheless, the paper has to be improved in many points. There is a global lack of scientific rigor, of precision. Many important details are not mentioned, whereas some parts are out of the scope of the paper. Furthermore, the overall English quality is poor. Because of all the weaknesses, both on form and content, I suggest this paper should not be accepted for publication.

Response: The paper has been thoroughly revised by adding necessary details and correcting the errors in English according to the reviewer's comments point by point. Hopefully, these revisions will make this paper more acceptable for publication.

Specific comments

Many remarks are written in the technical corrections part, but in this part I sum up comments on three major issues:

2.1 DEM generation

This section should be totally rewritten. General considerations about DEM generation and application to the case study are mixed, and not put in a correct and logical order. Camera calibration should be addressed before absolute positioning of images. The authors should consider being shorter on generalities and give more information about their own input during this step. The authors do not say how they replace the DEM parts they remove: motorway bridge and vegetation. How is the new altitude chosen? Don't bridge pillars or vegetation have an influence on the surface flow? How do the authors apply the method from Rabatel et al. without removing the NIR filter of the camera in the first place?

Response: Thanks for the reviewer's suggestion. The Section 2.1 has been reorganized by moving forward the camera calibration before image positioning and adding the instructions on how to generate the DEM and consider the roughness after removing the viaduct and vegetation regions (please see the responses to Technical corrections #12 and #13 for detail). Since the elevations of the pillars are higher than the surrounding road surface, it has no impact on the flow. The removal of NIR filter is not necessary because an ExG-ExR binary index is applied to detect the region of vegetation. To prevent confusion, the citation of Rabatel et al.'s method has been removed (please see the response to Technical corrections #15 for detail).

2.2 CFS model

Very little information about the model is given in the paper. The reader is referred to 2 other papers (Jang et al. 2018 & 2019). The effort made not to be redundant is appreciated, but some more details are needed about: 1) the numerical coupling 2) the manholes location and implementation in the model 3) the chosen hydraulic parameters, roughness distribution, boundary conditions. . . 4) the time extent of the simulation.

Responses:

(1) When rain drops, the OFM is firstly initiated for surface water routing. Then, the surface runoff travels for a distance and enters the sewer pipes via the street inlets to trigger the SFM. When the sewer pipes get full, the sewer water surcharges back onto ground surface via the manholes or inlets. In the simulation process, the water exchanges between the two models are realized by adding a source/sink term in the continuity equations which can be determined by weir and orifice functions via one-to-one relationship as shown in the schematic diagram Fig. 1.

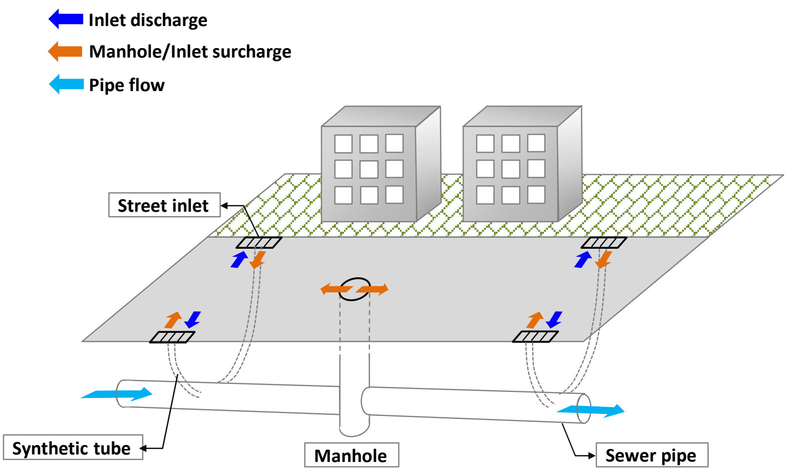


Fig. 1 Illustration of the water simulation process between ground surface, inlet, sewer pipe and manhole.

(2) The pipelines and manholes of the sewer systems are obtained from governmental filed survey data and are displayed in Fig. 2.

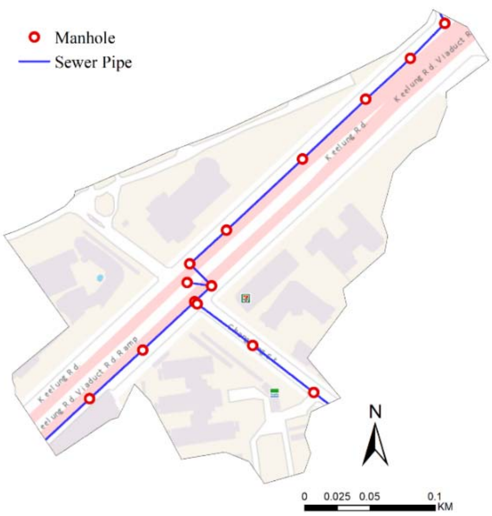


Fig. 2 The pipeline and manholes of the sewer systems in the study area.

(3) The weir coefficient and the orifice coefficient are set as 0.48 and 0.57, respectively, according the suggestion by Lee et al. (2013). The Manning's coefficient n is used to represent the surface roughness subject to land covers. Since the land covers are mostly concrete and short grass, the value of n slightly varies from 0.03 to 0.04 according to Chow, V.T. (1959). Although the skin friction represented by Manning's n changes little, the form frictions caused by road curbs and building walls can be more significantly presented as DEM resolution increases. At the boundary of the simulation domain, the water is allowed to outflow freely.

(4) The time extents for the CFS are 1,127 mins and 16 mins (with Intel I7 processor at 4.2 GHz) for the cases with 0.5m and 5.0m grid size, respectively.

Reference:

Lee, S.S., Nakagawa, H., Kawaike, K., and Zhang, H., 2013. Experimental validation of interaction model at storm drain for development of integrated urban inundation model, J. Jap. Soc. Civil Eng. Ser. B1 (Hydraulic Engineering), 69(4), I_109-I_114.

Chow, V.T., Open-channel hydraulics. McGraw-Hill, New York, 1959.

2.3 Results

The DEM accuracy is checked on the same points that were used to do its absolute georeferencing, which does not prove anything. The authors' assertion that coarser resolution leads to lower quality results is not confirmed by the presented arguments. Water depths of both simulations are compatible with all the VGI photos. Water depths on rooftops are not measured nor observed (or some information is missing in the paper). Flood duration differs between resolutions, but none is contradicted by some observations. The conclusion concerning the DEM resolution is not supported enough to be stated as it is.

Response: For the issue of DEM accuracy, please refer to the specific comments #24. Our study indicates that the building sidewalls and terrain depressions have a great influence on flood extent, depth, and occurrence which can only be simulated by the CFS with high-resolution DEM. Please see the response to the specific comments #35 for detail. The flood duration issue, please refer to the specific comment #32. We also revised the conclusion concerning the DEM in the revised manuscript.

Technical corrections

1. title . . . to sophisticated urban
   l.15 . . . flash flood event that occurred on
   l.17 . . . network are used to establish
   l.18 . . . data is resampled
   l.21 . . . and VGI lowers the
   l.26 Flash floods resulting from extreme rainfall

   Response: Revisions have been made according to the suggestions above.

2. l.28-29 & Table 1: What is the point of this table? Is it really needed in this paper?

   Line 29 mentions life losses, but no figures about it in the table. The authors should consider deleting this table and modifying the text accordingly

   Response: Table 1 and relevant texts have been removed from the revised manuscript.

3. l.52-53 Citations only refer to VGI, not UAV techniques

Response: Thanks for pointing this out. The citations have been moved to the paragraph where only VGI is mentioned as the following:

"The VGI considers every citizen as a sensor to acquire spatial data on a wide range of phenomena via crowdsourcing the keywords on social media such as Facebook, Twitter, Instagram, etc. (Le Coz, et al., 2016; Michelsen, et al., 2016; Starkey et al., 2017; Tauro et al., 2018; Goodchild and Glennonm, 2010)."

4. l.63 . . . can be used as

Response: Revised accordingly.

5. l.63-64 Does "boundary conditions" mean "hydraulic boundary conditions"? More explanations are needed here to understand the link between boundary conditions and spatial resolution

Response: The original statements is not clear and has been revised as "The DEM generated from UAV provides detail terrain of an urban area which significantly increases the spatial resolution of CFS compared to traditional practices."

6. l.69 . . . event that occurred on
l.70 . . . occurred between 13:00 and 18:00
l.71 . . . 131.5 mm/h from 14:30 to 15:30
l.72 . . . rainfall intensity exceeded
l.73 . . . Chanxing street near the National
l.75 VGI are used to establish

Response: Revisions have been made according to the suggestions above.

7. l.79 "finally, the simulated results are compared" Contradiction with fig. 3 where VGI seems to be an input to the CFS.

Response: Thanks for pointing this out. The revised figure is shown in Fig. 3.

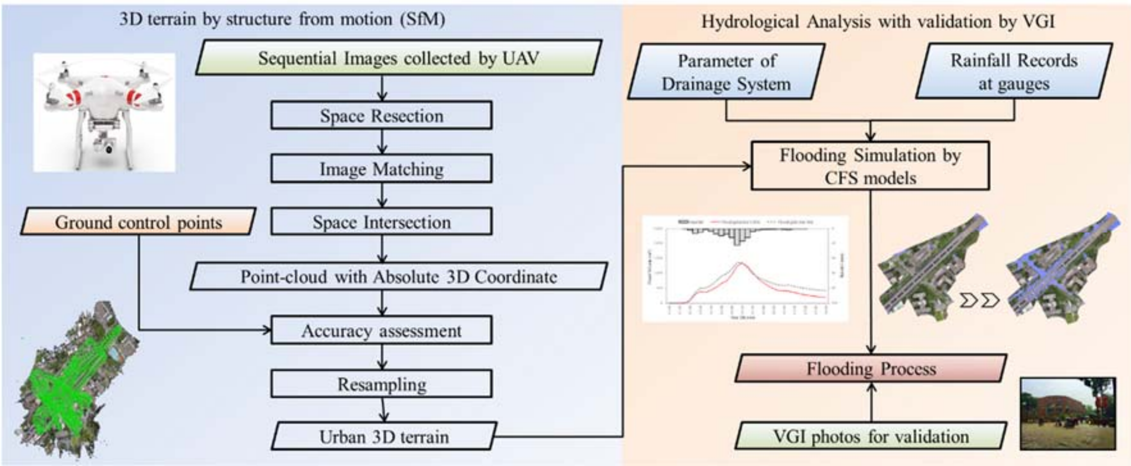


Fig. 3 Conceptual flowchart of this study (the VGI photo was adopted from PTT, Taiwan)

8. Section 2.1 This section should be totally rewritten. DEM generated General considerations about DEM generation and application to by UAV the case study are mixed and not put in a correct and logical order. Camera calibration should be addressed before absolute positioning of images. The authors should consider being shorter on generalities and give more information about their own input during this step

Response: Thanks reviewer's suggestions. The authors have reorganized Section 2.1 by adding the instructions on how to generate the DEM and consider the roughness after removing the viaduct and vegetation regions. The part of camera calibration has been moved forward to the part of image positioning. Meanwhile, the flight regulations for conducing the UAV survey are also mentioned in the revised Section 2.1.

9. l.82 . . . left side of Fig. 3
l.82-83 . . . methods for generating a DEM
l.84 . . . 2004). They are based
l.86, 92, 93 . . . coordinates
l.90 The six parameters [. . .] are determined during exterior orientation

Response: The manuscript has been revised according the above suggestions.

10. l.96 What resolution is chosen for resampling?

Response: After space intersection, the average ground sampling distance of point cloud is 0.03m. The UAV images were processed to generate orthomosaic image and digital surface model (DSM) with Pix4Dmapper Pro Version 1.4.46 (Pix4D). The orthoimage and the DEM are then resampled under spatial resolutions of 0.5 m and 5 m for CFS.

11. l.100 . . . condition from 06:00

Response: Revised accordingly.

12. l.117 Vegetation is removed: how the new ground altitude is computed? With which roughness? Does vegetation have no impact on the flow? How the results are biased by this removal?

Response: The regions of vegetation are detected using the ExG-ExR binary index (Meyer and Neto, 2008) by subtracting the alternate excess red vegetative index (ExR = 1.4r−b) from the excess green vegetation index (ExG = 2g−r−b), where r, g, and b are the chromatic coordinates. To consider the friction effects by the roughness of vegetation, the Manning's coefficient is set as 0.04 for CFS.

Reference: Meyer, G. E. and Neto, J. C.: Verification of color vegetation indices for automated crop imaging applications. Computers and electronics in agriculture, 63(2), 282-293. https://doi.org/10.1016/j.compag.2008.03.009, 2008.

13. l.117The viaduct is removed: how the new ground altitude is computed? With which roughness? Do the viaduct's pillars have no impact on the flow?

Response: The freeway is elevated and supported by the pillars at the centerline of the Keelung Road. Since the elevations of the pillars are higher than the surrounding road surface, it has no impact on the flow. The freeway is removed for CFS because flood water is allowed to flow across underneath the viaduct. Since the ground elevations were observed by the UAV from the divisions between the two viaduct lanes and those between viaducts and the buildings on the roadsides, the DEM underneath the conduct can be estimated. For CFS, the roughness are estimated by setting

Manning's coefficient equivalent to 0.035 according to Chow, V.T. (1959). The discussions above have been added to the revised manuscript.

Reference: Chow, V.T. (1959) Open Channel Hydraulics. McGraw-Hill, New York.

14. l.118. . . shrubs and grass

    Response: Revised accordingly.

15. l.120-121 The authors did apparently not fully understand the publication by Rabatel et al., which needed a removal of the NIR blocking filter inside the camera. This paper does not mention this removal, nor gives any detail about the specific linear combination.

    Response: Thanks for pointing this out. Since the regions of vegetation are detected using the ExG-ExR binary index (Meyer and Neto, 2008) by subtracting the alternate excess red vegetative index (ExR = 1.4r−b) from the excess green vegetation index (ExG = 2g−r−b), where r, g, and b are the chromatic coordinates, and there is no need for removing NIR blocking filter inside the camera. To prevent confusion, the citation of Rabatel et al.'s method has been removed.

16. l.121-122 Some of the surrounding buildings must have heights above the 9 m threshold. However the authors claim that they remove the viaduct, but not the buildings (l. 124-125)

    Response: The distances between the viaduct and the surrounding buildings are about 10m, so the elevation information of the buildings can be retained. This missing explanation has been added.

17. l.124 . . . flow smoothly on ground surface

    Response: Revised accordingly.

18. l.125 Transverse is not the adequate word

    Response: The word "transverse" is revised as "traverse".

19. l.125 There is no mention of (parked) cars and street furniture. They might have an influence on the flow. Are they in the DEM or not? The authors should give a comment on this.

    Response: UAV is applied to collect images at off-peak traffic time (6-7 am), and UAV images show no parked cars and street furniture in the experimental area (Keelung Road). Terrain models built by UAV only reflect the static and stable ground features, which is why UAV-based DSM and orthophotos only show roads (sign lines), buildings and vegetation.

20. l.133 . . . these photos are used to

    Response: Revised accordingly.

21. l.135 The described hydrological event lasts for a few dozens of minutes. A slight shift in the image timestamp could lead to totally wrong information. The authors should only take into account photos for which the timestamp corresponds to the moment when it was taken, not when it was posted on a social network.

    Response: The VGI photos acquired from internet, for example from the PTT in this study, are usually not the original photos and therefore the EXIF information is not available (We have checked it using http://metapicz.com). However, the differences between the timestamp of VGI photos and the time they were taken should not be significant due to the timeliness requirement on social media.

22. l.135-136 The authors should give an idea of uncertainties yielded by manual flow depth estimation. What about an automatic water level estimation?

    Response: The yellow triangles in Fig. 6 show the reference positions for flooding. Based on the elevation of the ground, road curbs, and buildings and wheel size of bikes, the observed flooding depths are estimated. The depth of 0.05m (about the ankle height) is used as a reference indicator to show the flood situation, which in a way includes the uncertainty of the water depth estimation.

23. Section 2.3 This section lacks details about the chosen hydraulic parameters CFS model (roughness, boundary conditions) for both OFM and SFM. It is not clear how the manhole positions are determined: DEM and water levels are obtained from images, why not the manholes? It is also not clear which type of interaction between OFM and SFM is applied. The authors should also give the time limits of their simulations.

    Response: The pipelines and manholes were obtained from the field survey data provided by the local government. Please see the responses to the specific comments about Section 2.2 for details.

24. l. 153 The DEM accuracy is checked on 3 GCPs. The same 3 GCPs were used to perform the DEM georeferencing (see lines 104-108). The authors should use a different set of control points than those who were used to process the data, with a better spatial distribution in the modeled area. Furthermore, 2 DEM are created, with distinct resolutions. Accuracy should be checked for both.

    Response: The coordinates of the three GCPs were obtained by referring to the publicly released values of Taipei City Government and using the static positioning of Global Navigation Satellite System (GNSS) with positional accuracy in centimeter level. The difference between the coordinates obtained by these two methods can be used to evaluate the accuracy of the ground control points. The 0.5m and 5m DEMs are created and validated according to the initial UAV-based DEM with resolution of 0.03m. We have added more discussion on the GCP requirement in the revised manuscript. The reasons we used only three GCPs are (1) the study area is relative small (0.0637 km^2) and the GPS information on the UAV could produce 3D coordinate with certain degree of accuracy; (2) there are exactly three GCPs released by the Taipei City Government in this study area and we also double check the released values with the static positioning of Global Navigation Satellite System (GNSS) with positional accuracy in centimeter level; (3) The number of GCP depends on the surveying areas, flight altitudes, resolutions and application goals. According to the user manual of Pix4D (https://support.pix4d.com/hc/en-us/articles/204272989-Offline-Getting-Started-and-Manual-pdf), a minimum number of 3 GCPs is required.

25. l. 156 The authors did not give the initial DEM resolution

    Response: The original DEM resolution is the same as the average ground sampling distance of point cloud equivalent to 0.03m.

26. l. 159 . . . simulation, the grid meshes

    Response: Revised accordingly.

27. l. 167-169 The authors state that water on rooftops is better simulated by the fine resolution model. Could they give some validation criteria to explain this statement? Could they explain why water should be on rooftops? Does their model take water evacuation from rooftops into

account?

Response: The water accumulated on rooftop because there are usually parapet walls with about 1 meter height on the rooftops around the borders of buildings in Taiwan. When the DEM resolution is high enough, the elevations of parapet walls can be represented by the grid-based mesh system in CFS and the water detention on the rooftops can be simulated. The rougher the grid/DEM resolutions, the faster the stored water will evacuate through the gaps between two adjacent grid cells. This discussion has been added to the revised manuscript.

28. l.173 Higher: not much higher. The authors should give the values.

    Response: Revised accordingly.

29. l.174 Lower resolution implies that small terrain features are not represented, so the topography should be smoother. The authors observe the opposite. The authors should check the DEM resampling, and give more comments about their observation.

    Response: Because the ground levels are given in grid unit in CFS, there exists an invisible wall between two adjacent grids with different elevations. When DEM resolutions decrease, these walls become higher which result in larger blocking effects that reduce inter-cell water communications. This phenomenon explains why the flood water travels slower in the simulated results. Relevant discussions have been added.

30. l.178 . . . results. It can be seen

    Response: Revised accordingly.

31. l.180 . . . At the remaining points, the simulated

    Response: Revised accordingly.

32. l.184-186 I cannot see the causal relationship between the fact that there are no VGI photos after 15:40 and the overestimation of flood duration. Since there are no photos, it is not possible to conclude in a way or another.

    Response: Indeed, to be more precise, the original statement has been modified as "At point #2, the flood duration may be overestimated under 5 m DEM resolution because the flood depth at point #2 does not decrease with time at all even when the rainfall has stopped for one hour."

33. l.195 . . . than that that. . ..

    Response: Revised accordingly.

34. l.207-208 DEM updates, and resulting CFS are not in real time, since weather conditions generally prevent UAVs to fly during or just after heavy rainfalls.

    Response: The original sentence has been modified as "Aided by the rapid growing technologies of remote sensing and crowdsourcing, it is possible to efficiently update DEM data and record the flood depth by UAV and VGI <u>in a short time after heavy rainfalls</u>".

35. l.211 It has not been demonstrated in the paper that fine resolution modeling results are better. The comparison presented in table 4 shows that both resolutions give results consistent with VGI photos. Other validation data is needed to be able to draw this conclusion on this case study.

    Response: Thank you for the comment. The main attention of this study is to extract useful information by image processing technologies from VGI photos and UAV data for an urban flooding event. In such events, it is very common that onsite water level observations are unavailable which raises the difficulty of CFS validation. However, from the comparison of CFS results with VGI photos, this study indicates that the building sidewalls and terrain depressions have a great influence on flood extent, depth, and occurrence which can only be simulated by the CFS with high-resolution DEM. The original statements have been revised according to the above discussions.

36. Table 1 What is the point? The list of flash floods that occurred in 2019 is not relevant to the paper. Moreover, events after July, 8th are not listed.

Response: Table 1 has been deleted and the relevant sentences in the Introduction have been rewritten.

37. Table 3 The accuracy is checked on the very same points used in the DEM production process. Low error values are thus expected. It gives no information on the accuracy of the DEM everywhere else.

Response: The coordinates of the three GCPs were obtained by referring to the publicly released values of Taipei City Government and using the static positioning of Global Navigation Satellite System (GNSS) with positional accuracy in centimeter level. Since the two coordinates are determined from different methods, they can be compared to evaluate the accuracy of the ground control points.

38. Figure 1 Caption: rain gauge (as in the text). In the bar chart, times are written above bars, I guess they should lie between bars

Response: Thank you for the comment. The term "rain gauge" and the revised figure is shown in Fig. 4.

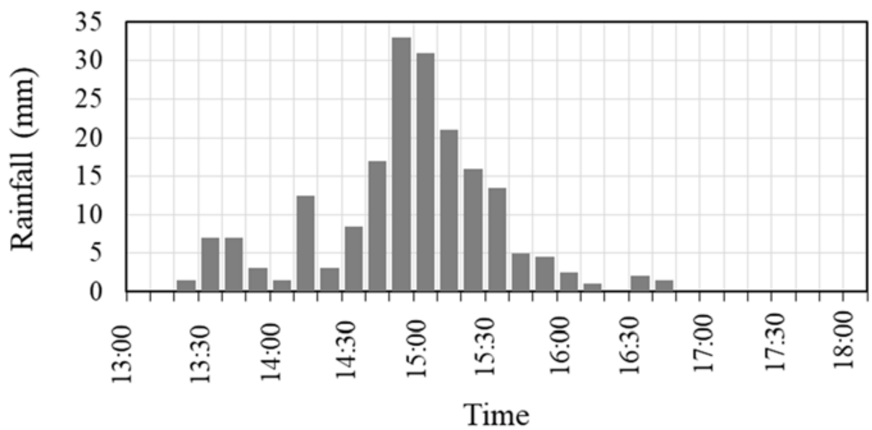


Fig. 4 The rainfall hyetograph on 14 June 2015 at GongGuan rain gauge station (C1A760).

39. Figure 2 Rain gauge (as in the text). Top left image is not necessary. I do not understand the gray levels in top right image : shade or altitude? Bottom image is very dark, authors should improve brightness and contrast. The cartographic scale is indicated only for the bottom image Figure 3. The right part is not consistent with the paper. VGI seems to be an input of CFS. Parameter of Drainage system: is there only one parameter? This parameter is not even mentioned in the paper.

Response: Thank you for the comment. Rain gauge has been corrected.

The Top left image is aiming to show the location of Taipei City in Taiwan. The gray levels in top right image shows the hillshade as it presented in the legend of this image. The bottom image has been adjusted to improve its brightness and contrast. A cartographic scale is also added to all the images (please see Fig. 5). The VGI is not an input of CFS so that the Fig. 3 is revised (see the response to Technical corrections #7). The parameters of the drainage system have been added (Please see the responses to the Specific comments about Section 2.2).

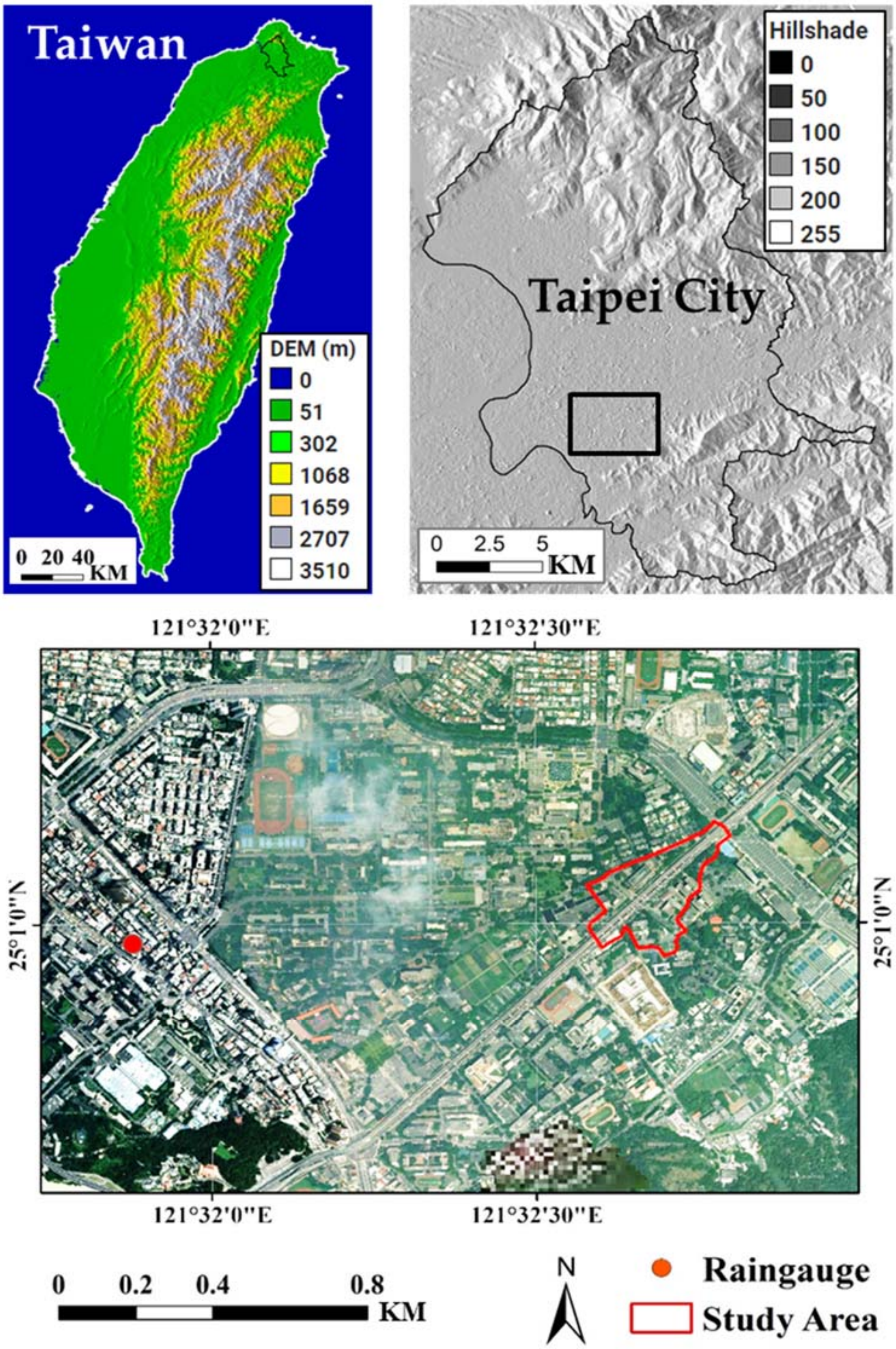


Fig. 5 Study area (red polygon) at GongGuan, Taipei, Taiwan (the Google Earth images sourced from © Google, Landsat/Copernicus and the DEM in the top left image and the hillshade in the top right image were derived from SRTM with 30 meter resolution).

40. Figure 4 Not necessary in this paper

Response: The original figure has been removed.

41. Figure 5 The caption reads: "images taken", but they must have undergone some processing. The authors should tell readers what is exactly displayed in fig. 5. The image is distorted compared to the area shown in the following figures (stretched along Y axis). Why? GCP #1 is located just next to the viaduct, so there is a discontinuity in altitude just nearby. It is recommended to select clear zones for GCPs

Response: Thank you for the comment. The caption has been revised. We noticed that the image is distorted and it has been corrected (see Fig. 6). Since GCP #1 is about 10 m away from the viaduct, there is enough room to display the continuity of altitude.

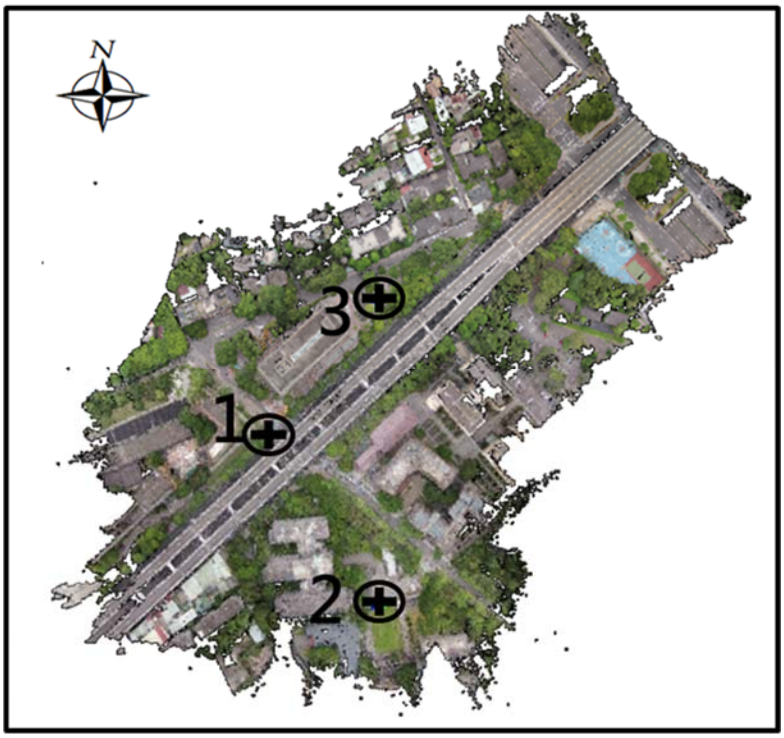


Fig. 6 Images taken by UAV and the distribution of the ground control points

42. Figure 6 All minutes in timestamps seem to be rounded to the nearest 10. Why? How water depths could possibly be estimated from photo #1?

Response: Thank you for the comment. Because all the photos were collected from internet and meanwhile the time step for rainfall observation and flood simulation is 10 minutes. So we added the timestamps for all photos to the closest 10 minutes before the photos were posted online. In photo #1, we noticed that the water level is very close to the surface of sidewalk along the road and the sidewalk is generally 0.1 m higher than the road in Taiwan.

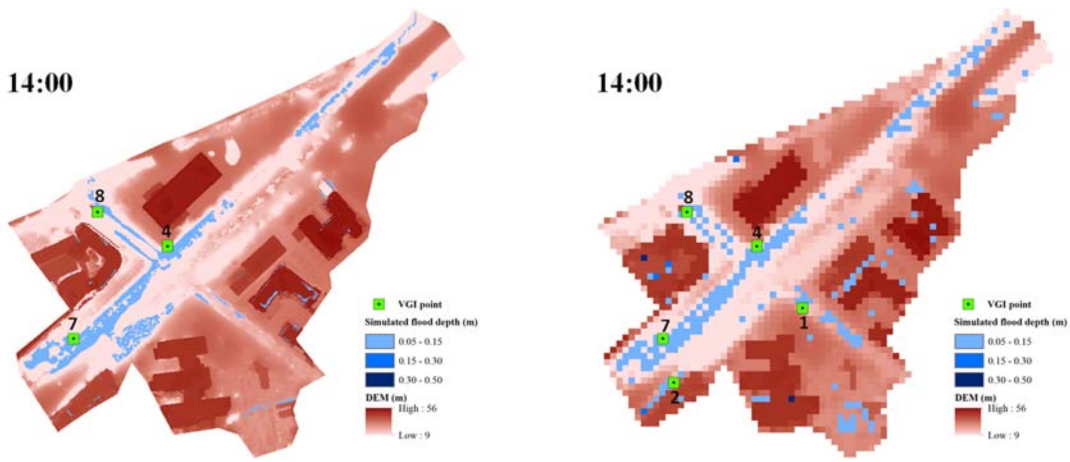
43. Figure 7 The choice of the color scale is not adequate to allow a good perception of low value altitudes (everything is blue). Moreover, the rainbow color scale should be avoided: https://www.nature.com/articles/519291d https://www.climate-lab-book.ac.uk/2014/end-of-the-rainbow/

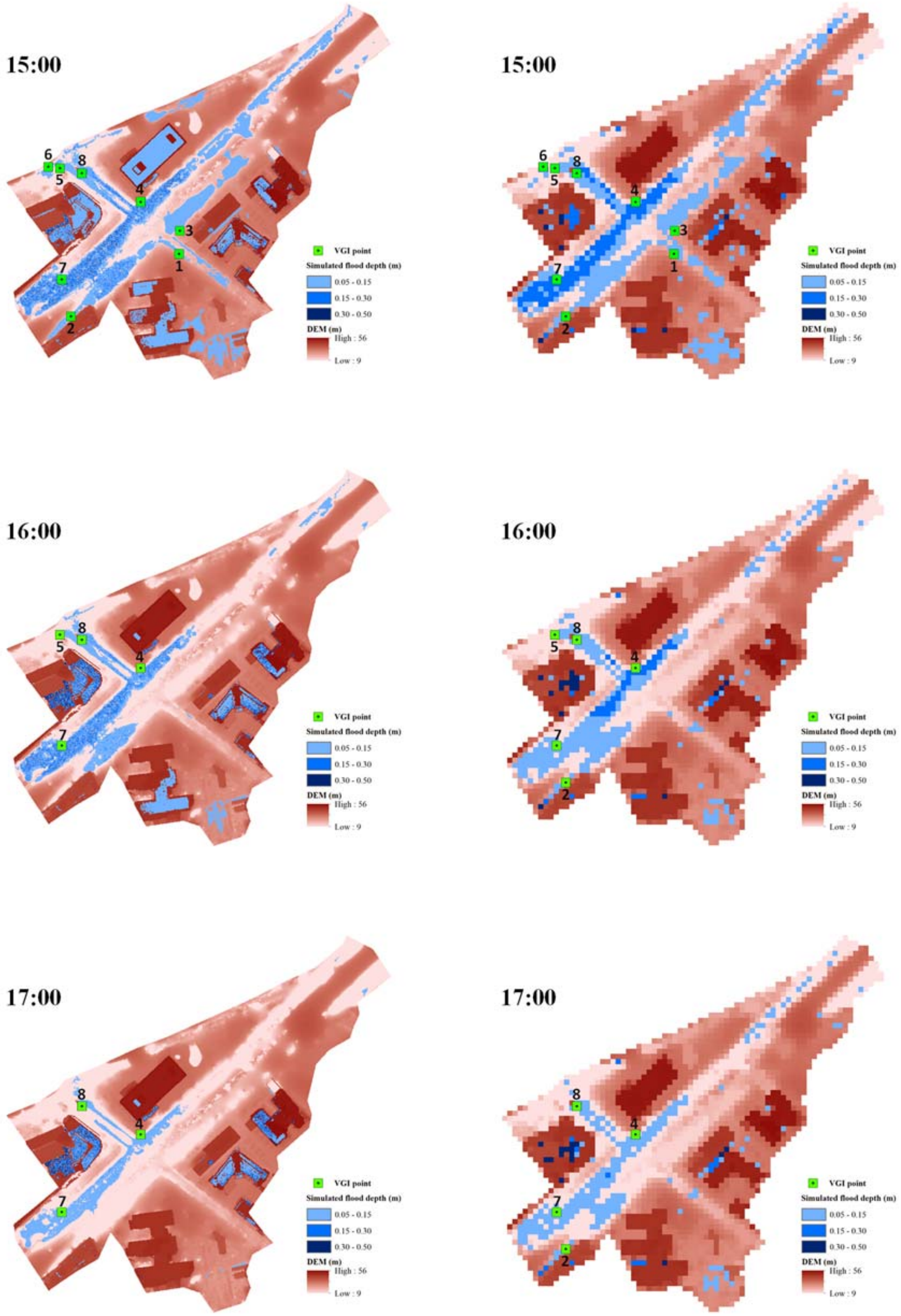
Response: We have changed the color scale of this figure and also checked the image on the Coblis (https://www.color-blindness.com/coblis-color-blindness-simulator/). The revised figure is shown in Fig. 7.

Fig. 7 (a) Orthoimage; (b) the DEM with spatial resolution of 0.5 m; (c) the DEM with spatial resolution of 5 m

44. Figure 8 Water depths between 0.00 and 0.05 m should appear in white according to the caption. I can not see any white pixel. Why? The difference between the colors corresponding to 0.15-0.30 and 0.30-0.50 water depths is too small to be distinguished. Water accumulates on roofs, especially for the fine resolution model. It seems very unlikely, especially for the building lying in the left.

Response: Thank you for the comment. The depths between 0.00 and 0.05 m should appear as no color. We have corrected it and adjust the scaling of the figure to highlight the DEM characteristics on road surface (the revised figure is shown in Fig. 8). The difference between the colors corresponding to 0.15-0.30 and 0.30-0.50 water depths has been adjusted.




15:00
6
5
8
4
3
1
7
2
VGI point
Simulated flood depth (m)
0.05 - 0.15
0.15 - 0.30
0.30 - 0.50
DEM (m)
High : 56
Low : 9
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7
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VGI point
Simulated flood depth (m)
0.05 - 0.15
0.15 - 0.30
0.30 - 0.50
DEM (m)
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Low : 9
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VGI point
Simulated flood depth (m)
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0.15 - 0.30
0.30 - 0.50
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VGI point
Simulated flood depth (m)
0.05 - 0.15
0.15 - 0.30
0.30 - 0.50
DEM (m)
High : 56
Low : 9

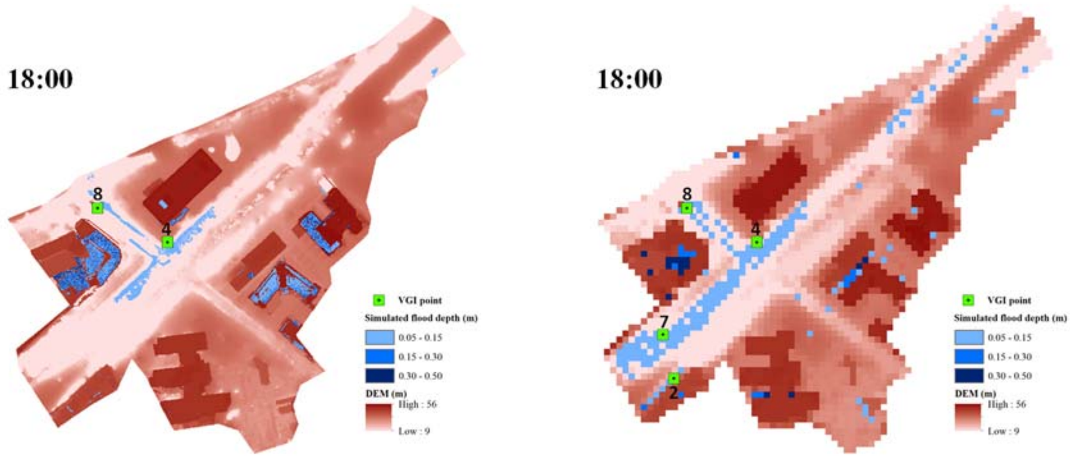

Fig. 8 Simulated flood extents at different time under DEM resolution 0.5 m (left) and DEM resolution 5 m (right).

The water accumulated on rooftop is because there are solid parapet wall with about 1 meter height around the borders of these buildings. For example, it just like the parapet wall in Fig. 9.

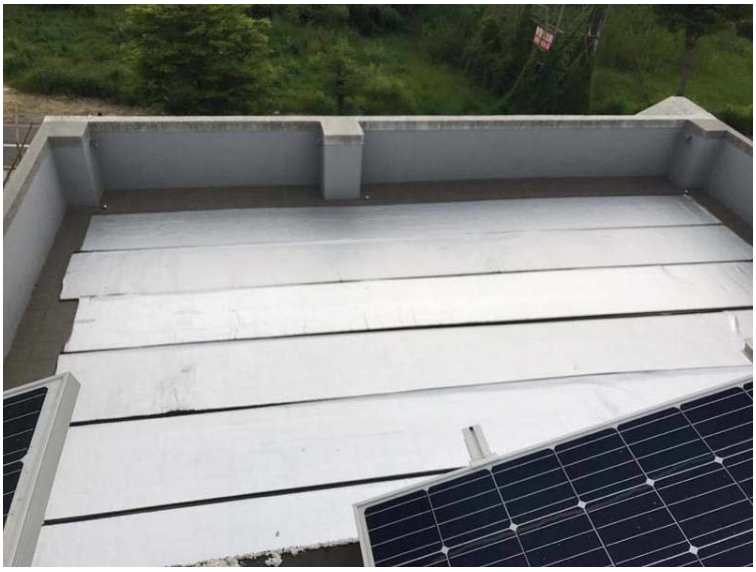

Fig. 9 Parapet wall around the border of building. (Image credit: good.ruten.com.tw)