Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2018-146-AC2, 2018

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "Inundation mapping based on reach-scale effective geometry" *by* Cédric Rebolho et al.

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Received and published: 18 July 2018

Answer to the review comments of Reviewer#2

The authors would like to thank Reviewer#2 for his analyses, questions and suggestions which will help to improve the quality of the manuscript, and the further developments of the method. We hope this discussion will answer the concerns about the methodology. Comments from the reviewer are in blue while our answers are in black.

General comments

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Discussion paper

- The procedure known as MHYST is not meant to be a surrogate to physics-based hydrodynamic modelling of flood inundation mapping, but it may turn out to be a valuable alternative to computationally-intensive models and in data-poor regions. MHYST has the potential to be applied under different reach-scale and flood plain conditions; that is from natural to urban river corridors. The procedure was validated using an extreme flood event in France. That being mentioned, the procedure has yet to be tested under these aforementioned conditions and, more importantly, to prove it can be useful for a wider range of flooding events.

  Reviewer#2 has perfectly underlined the challenges of our methodology. MHYST has a potential that still needs to be validated on a larger number of situations (urban areas, floodplains, mountainous regions, flat areas...) and on different types of events (small overflowing, flash floods...). This article provides the description of the methodology and its application on a major overflowing event on a catchment presenting both urban areas and floodplains. However, due to the scarcity of observed inundation mapping with corresponding distributed observed streamflows, MHYST was only applied on one example. Nonetheless, its application to a forecasting context on a larger sample of catchments and events is part of an ongoing research project and a beginning PhD thesis.

- There is a need to conduct formal sensitivity and uncertainty analyses (*e.g.*, Morris and Sobol) of key parameters (*e.g.*, K_{fp}, K_{ch}, α, β, ω, δ).

  In order to assess the sensitivity of the model to its parameters (K_{fp}, K_{ch}, α, β, ω, δ), we used the Morris method (Morris, 1991), which provides a qualification of the effect a parameter can have on the outputs. It is a OAT (one-at-a-time) methodology, which means that the effect of a parameter is measured by changing its value by adding $\pm\Delta$ without modifying the other parameters and by comparing the outputs. In order to provide a relevant analysis, we generated 160 sets of parameters, using the latin hypercube sampling method, which act as start points from where the Morris method can assess the significance of parameters by changing their values one-at-a-time. Thus, more than a thousand simulations are needed to conduct the analysis. By using the 5-m resolution DEM we used in this article, this study would take several days, if not weeks, to complete. Since we showed in the response to Reviewer#1 (Renata Romanowicz) that the performance of MHYST did not really change with the resolution, we chose to use a coarser version of our DEM, which was aggregated at a 50-m resolution, by simply averaging the elevations, allowing us to complete this sensitivity analysis in only a few hours. For each permutation and for each parameters, D_i, the difference of CSI divided by the computing step, is calculated. The results in terms of means and standard deviations are presented in Fig.1. The analysis shows that the model is very sensitive to changes of ω, the exponent in the calculation of the regionalised bankfull width (W_b). The assessment of W_b seems to be a major part of the model, but it is also the easiest, because it is easily feasible to compute a relationship between widths derived from satellite images of the river and drainage areas, which does not need any calibration. The most surprising part of the analysis is the fact that K_{fp} has little or no effect on the model, while K_{ch} has a moderate effect. This is contradicted by Fig.8 of the article, which clearly shows that for a given value of K_{fp} (e.g. 2), the CSI value varies only slightly for a K_{ch} between 0.1 and 20. K_{fp} is, contrary to what the Morris analysis shows, a significant parameter of the model, particularly in a major overflowing event such as the one studied in the article, where the channel only represents a fraction of the water.

The problem might be that despite the use of a latin hypercube sampling method, the “good” values of the parameters never meet, *i.e.* when ω has a sensible value, K_{fp} has not and inversely. And of course, if the ω value does not coherently represent the channel, the model is not able to conduct a correct simulation (*i.e.* little or no flooding), leading to little or no influence of the K_{fp} parameter.

Moreover, the issue with sensitivity analyses such as the Morris method is that the results can be very different depending on the catchment or the event modelled. Indeed, if the water is concentrated in the channel part for a very steep catchment, a very flat one will on the contrary rely on the floodplains, and so the parameterisation of the model will add more value to K_{ch} or K_{fp}. Thus, the conclusions one can make by interpretating one analysis of an example do not necessarily reflect the global behaviour of the model.

This analysis and the discussion about its conclusions will be added in the manuscript in order to discuss the sensitivity of the parameters.

- There is a need to include in the paper a comparison between an actual and a predicted inundation mapping of several continuous reaches (*i.e.*, flooding extent) for one, two or three days; that is the information required by key stakeholders and elected officials.

  In this paper, as we explained in Section 4.1, P.10, L.8-11, we used an observed maximum inundation extent provided by the Copernicus Emergency Management Service. This map is a composite for several dates and it only represents the inundation associated to the peak flow and is not dated. No other sources of data could provide dated observations so we had no choice but to use these data to calibrate our model, and we did not try to validate the temporal dynamic of the flood, but only its largest area.

  Reviewer#2 highlights here a global issue that exists, at least in France: the scarcity of dated observed inundation maps. Generally, observation data are provided for the maximum extent only. In most cases, dated maps corresponding to an event are generated using a complex 2D hydraulic model, which can be really precise, but does not provide observed data. Because our article deals with the development of MHYST we needed to validate it with a comparison to an observed inundation map, not to a simulated one.

  A solution to this issue could be the use of insurance damages data, which are relatively precise dated data. We did try to use that kind of information in order to calibrate our model and we found that it leads to different issues : comprehensiveness of the data (the damages of one insurer are not representative of a whole area), different insurance policies (cars, house, flat...), rights of use etc.

Given that there are no day by day observed inundation maps, we will not be able to assess the temporal performance of our model.

Specific comments

- P.3,L.28 Please specify the algorithm behind the flow direction function available in ESRI ArcGIS? Which software version?

  We used the D8 method from the Flow Direction function provided by ArcGIS 10.3. It computes the drainage direction by calculating the steepest slope from the eight possible directions for a given cell. This information will be added in the manuscript.

- P.8,L.19 What is the vertical resolution of the 5-m DEM?

  We used a 5-m resolution DEM from IGN (the French national institute for geographic information), which has a vertical resolution of 0.01m. This information will be added in the manuscript.

- P.15 Given Fig.11, is there any general observations about why and where MHYST performed either poorly or satisfactorily ? Furthermore, the performance accounts for how many days? Is it only the flood mapping associated with the peak flow ?

  Like we said in Section 4.1, P.10, L.8-11, and in the General comments section, the observed inundation mapping represents a "maximum flood extent", *i.e.* the map associated to the peak flow. Since no other sources of data were available, we chose to calibrate our model by using this image as a reference, and by combining all our simulated maps (which are produced for each day of the flood) into one maximum simulated extent.

However, we agree that it would be better to assess the performance day by day, but such maps are very scarce, at least in France, where our study was conducted.

Reviewer#1 (Renata Romanowicz) was also concerned by the details of Fig.11, and asked for a larger scale map that would focus on some specific area. We chose to respond to her concerns by focussing on the most downstream part of the flood and by identifying and explaining the reasons why the model had trouble modelling some areas. We finally propose to replace Fig.11 by three figures (Fig.2-4) focussing on three major parts of the catchment (and thus improving the resolution of the maps), and to identify and explain on each map the difficulties MHYST can have. The comments associated to each number in the maps are :

Figure 2:

1. For the most downstream part of the Loing, the reaches are red or orange because this area is only partially covered by the observation, which stops just after the confluence with the small tributary.
2. The small tributary is mainly red or orange for various reasons : downstream, at the confluence, the DEM is full of small high elevation zones (not corrected in the DEM) which the model cannot reach, thus degrading the simulation. Along the tributary, the reason can be either the observed discharge values which seem small compared to the rest of the catchment or simply the effective geometry defined by the model which do not correspond to the actual one. Finally, the upstream part of the tributary is not covered by the observation, which stops in the middle of what MHYST simulated. However, the study zone defined by the Copernicus Emergency Manage-

ment Service goes further, so we cannot know if it was not flooded or if the service did not map this part because it was too insignificant.

3. The orange part in the middle of the $BIAS$ map is due to a railway which acts like a wall in the DEM, preventing the model from reaching the other side (from east to west), where a small tributary, which looks like a partly subterranean urban stream, overflowed in its open air part.
4. Finally, the red and orange zones in the south of the presented map correspond to a part of the river where the Loing man-made waterway plays a major role, and is parrallel to the main river. This configuration is difficult for MHYST because we only consider the main river, defined by the DEM, with an effective reach-scale geometry and we cannot take into account such specificities, like a 2D hydraulic model would.

Figure 3:

5. The area identified shows a slight under-estimation leading to a moderate CSI. This issue can be explained by a motorway which is represented in the DEM by a more elevated area. This motorway seperates the reach into two parts linked by artificial openings made by the producers of the DEM. This, as well as the Loing waterway and another road act as dikes that prevent the model from reaching a further part of the reach. The parameterisation of the model is not suitable to address this difficulty.
6. Similarly to the previous area, a railway crosses the DEM from North to South with only one opening for the water. Given the parameterisation of the model, it is not possible to go over the railway to flood the missed area.
7. In that case, the model clearly overestimates the flood. The water fills a depression which looks like a tributary but is only a thalweg. Once more, the parameterisation of the model does not provide a adequate representation of this reach.

Figure 4:

8. In this area, MHYST underestimates the inundation extent due to a road that works like a dike. However, with another parameterisation, the model would be able to provide enough water to go over the road.
9. In the western part of the upstream area, MHYST overestimates the flood because it is a relatively flat zone. The exceeding water, still due to the parameterisation, is thus spread over the area.
10. This area is special because the overestimation of MHYST is due to a non-continuous observation map, creating large parts of reaches that are observed dry. However, since MHYST works at the reach scale, it necessarily floods the whole river reach. Moreover, one tributary, the Solin, is not defined in the hydrographic network used by the model, because no observed dicharges were available, whereas it appears in the observed map, leading to an underestimation of the flooded area.
11. The most upstream part of the simulated area suffers from an excess of water and a non-continuous observation, leading to similar effects. Moreover, several elevated roads appear in the DEM and force the model to flood the area using artificial openings accross the roads.

Editorial suggestions

We would like to thank Reviewer#2 for his remarks. We will certainly add the McGrath *et al.* (2018) reference, which is totally relevent. Concerning the Zheng *et al.* (2018) reference, it was still in review when we submitted this article, and we will of course update the citation now that it is finally published.

Figures

- Fig.3 For completeness sake, please identify A_b, A_{ch} and A_{fp}, I know it is trivial, but the figure might as well be as explicit as it can be.

  In order to not overload the figure, which is already quite dense, we propose to add Fig.5 into the manuscript : Fig.5 describes a typical cross-section and identifies the variables requested.

- Fig.11 The resolution of this map could be improved, perhaps one image per page.

  See the last point of Specific Comments.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-146, 2018.

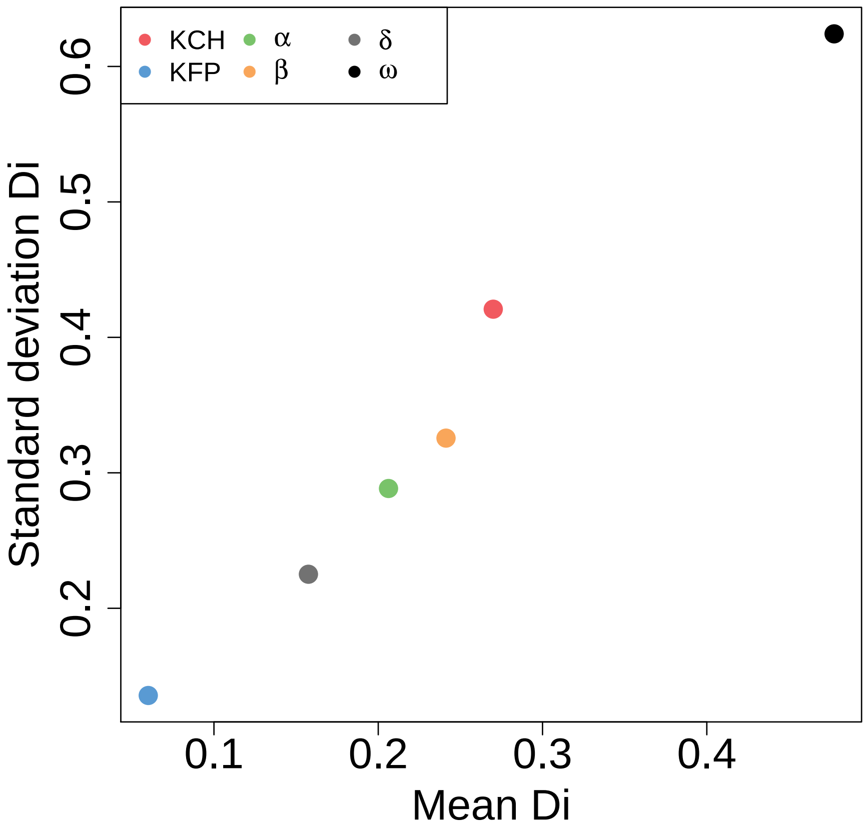

Fig. 1. Results of the Morris method applied to MHYST with a 50-m resolution DEM on the Loing catchment for the six parameters.

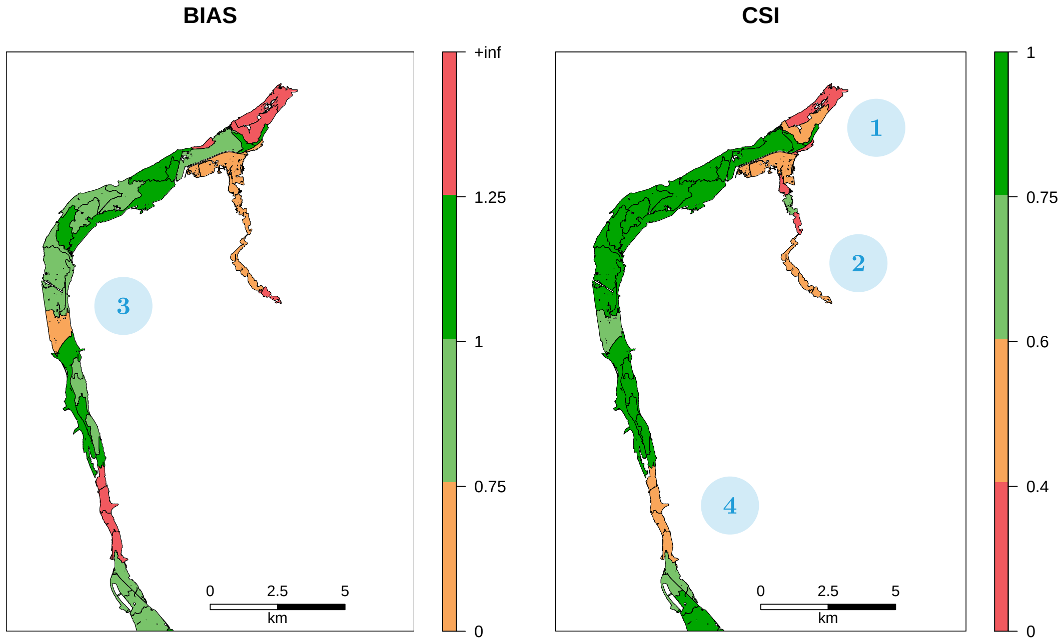

Fig. 2. Reach-scale performance for the physical combination of parameters, for the downstream part of the catchment.

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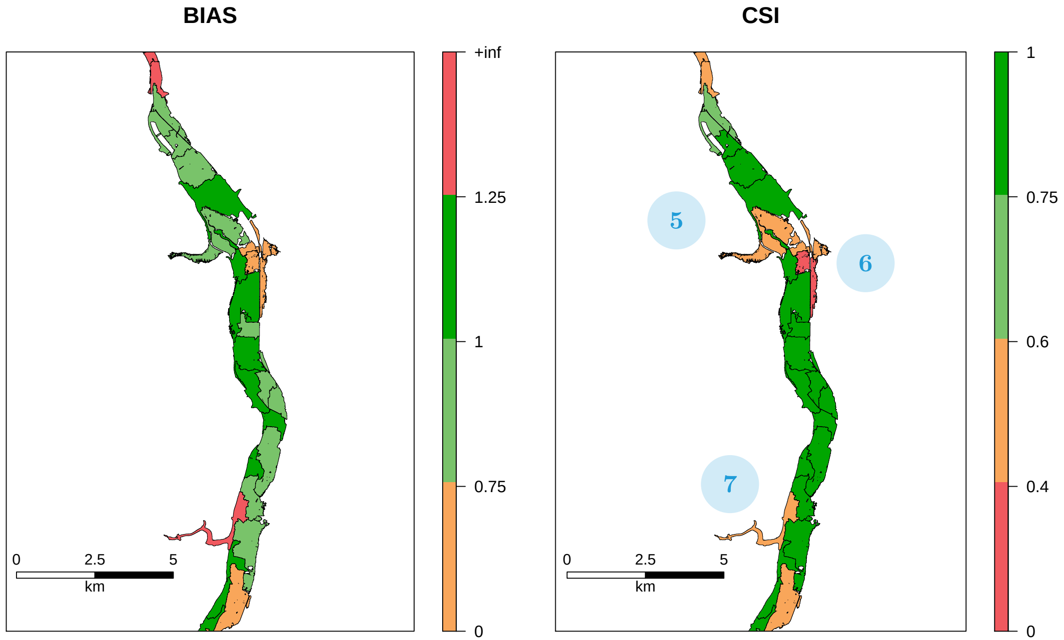

Fig. 3. Reach-scale performance for the physical combination of parameters, for the center part of the catchment.

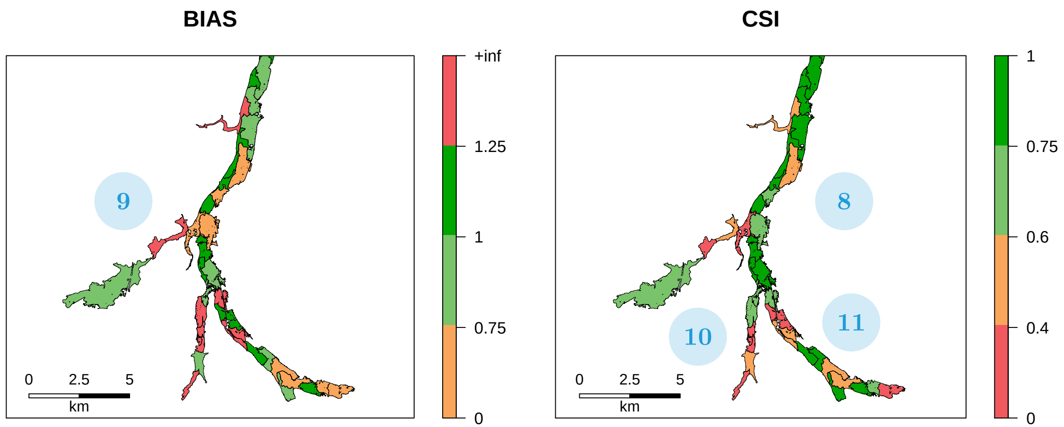

Fig. 4. Reach-scale performance for the physical combination of parameters, for the upstream part of the catchment.

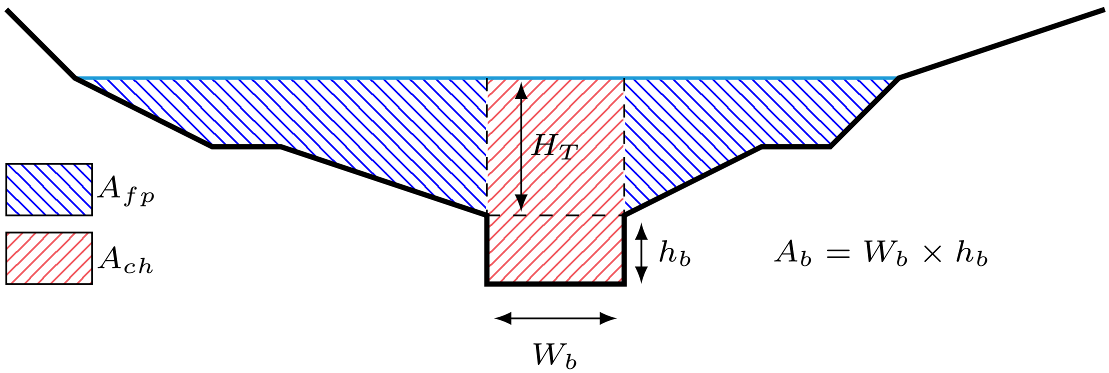

Fig. 5. Typical cross-section segmentation, with the cross-section area of the channel Ach, that of the floodplains Afp and the bankfull cross-section area Ab.

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