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

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Answer to the review comments by Renata Romanowicz

The authors would like to thank Prof. Renata Romanowicz for her precise comments on the article which will undoubtedly help to improve the quality of the manuscript. We hope this discussion will answer the concerns about the methodology.

Specific comments

1. Page 10, section 4: The validation procedure is based on the maximum inundation area. However, it is not clear which data were chosen for the calibration and validation stages. The authors are asked to explain this point in detail.

   The description of the validation procedure was indeed slightly ambiguous. The title of the subsections should be changed to “Calibration procedure” and “Parameterisation” since no real validation was performed in the study, because of a lack of data. We only had one inundation event on the Loing catchment which allowed us to parameterise the model but not to validate it on a second event. The data used for the calibration were the observed discharges that led to the simulated inundation map which was then compared to the observed inundation extent from the activation EMSN028 of the Copernicus Emergency Management Service.

   That being said, we parameterise our model at the catchment scale (i.e. with one set of parameters for the whole catchment), which is different from using the best combination calculated for each reach (which would be a true calibration). Thus, when we analyse the reach-scale performance with the catchment-scale parameters, we do some sort of validation analysis, proving that with one combination (which is not the reach-scale optimum) we can still perform well.

2. Pages 10, 11 and 12, section 4.1: A number of different criteria were used but the description is very vague.

   To evaluate the performance of our methodology, we based our analysis on four classic criteria extracted from inundation and forecast studies. The POD (Probability of detection), which is also called $Correct$ (Alfieri et al., 2014) or $M1$ (Teng et al., 2015), calculates the percentage of observed inundated pixels intersected by the simulation map. Its main drawback is that it does not take into account the

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false alarms and thus it can give good results for a clearly overstimating inundation extent. On the contrary, the FAR (False alarm ratio) or $M2$ (Teng et al., 2015) computes the proportion of cells wrongly flooded by the model. But similarly, if the model does not flood anything, the FAR can reach its optimal value. The CSI, also known as Fit, F index or FAI (Alfieri et al., 2014; Bates and De Roo, 2000; Falter et al., 2015), is a criterion which tries to give an overall performance of the simulation by calculating the percentage of correctly flooded cells above the total number of flooded cells (observed and simulated). In this way, the score is penalised by the over- and under-estimation. However, this criterion does not specify if the model is over- or under-estimating the observed extent. This is why we also looked at the $BIAS$, which computes the ratio between the simulated and observed flooded cells. If it is above 1, the model over-estimates, and if it is below 1, it under-estimates. However, a value of 1 does not equal a perfect simulation since there may be a balance between the misses and the false alarms. This complete description of the criteria shall be added in the manuscript.

3. Page 15, section 4.2 : The illustration map presented in Fig. 11 does not give enough detail. Perhaps the authors could present a larger scale map focussing on some specific area?

   We could, for example, present the overall view of the flood and then focus on the downstream part of the catchment (Fig.1), which is quite interesting. Indeed, there is a majority of green reaches but also some examples of why the model can perform badly.

   - 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.
   - 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

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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 Management 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.

- 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.
- 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.

These comments should be added in the article with the corresponding map.

4. Page 14, Section 5 : The authors stress the importance of the DEM in the derivation of inundation maps. Perhaps some sensitivity studies could be performed to assess that influence in a quantitative way.

   We can assess the sensitivity to the DEM with two ways : first by aggregating our DEM from 5 m to various resolutions (10, 25, 50 and 100 m) and then by changing the source of the DEM. Figure 2 and 3 provides the CSI scores obtained by the model while changing the resolution. It shows that the resolution has relatively

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little effect on the optimal value, which varies between 0.65 and 0.69. However, the position of this optimal, i.e. the combination of parameters (K_{ch} and K_{fp}) leading to it, changes. We can also see that for some resolutions, such as 25 or 50 m, the equifinality zone is much smaller than the one for the 100-m resolution, for example. If we also look at the “physical” set of parameters we identified in the article ($Kch = 10$ and $Kfp = 5m^{1/3} \cdot s^{-1}$), we can see that the CSI reached by the model for this combination varies between the resolutions. Nevertheless, the result still seems satisfying so it could be used as a “default” parameterisation, for instance for ungauged catchments. But this should be tested on other catchments with observed data to lead to a more comprehensive conclusion.

Before using the RGE 5-m DEM from IGN, we tried to use the 25-m EU-DEM from the European Environment Agency, and it showed poorer results, because it was not precise enough. Figure 4 shows the evolution of CSI for the same combinations of parameters as before. We see that the best combinations of parameters only lead to a 0.53 maximal CSI, which is more than 10 points below what we can obtain with the RGE DEM. There is also strictly no connection between the best values of $BIAS$ and those of CSI, the latter being obtained for a clear overestimation of the flood extent ($BIAS \sim 1.5$). These results are due to the lack of precision of the EU-DEM, which does not distinguish the channel from the floodplain, leading to a 2-km wide channel in some parts of the river.

5. Page 14, Section 5 : I am also worried about the possible inconsistency between flood inundation assessment on adjacent reaches of the same river. The authors are asked to discuss that point.

As the overall view of the simulated inundation extent shows in the article, two adjacent reaches may not have the same CSI, one being very good while the other has a poor performance, despite their proximity. This is mainly due to local specificities, such as the railway in the DEM, the man-made waterway which is not taken into account in the model, or an urban area which is harder to model

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because it is not natural and can have been modified by man.

One way to adress this issue could be to add a continuity equation between the reaches, which might increase the overall coherence of the flood. However, at this point of the development of the model, we do not have included this specificity.

6. Finally, the authors are asked to compare the inundation mapping using MHYST with the straight-forward DEM based mapping in order to show the advantages of the proposed method to the simplest possible, “filling the volume” approach.

   We compared our methodology with the traditional HAND approach, using a single threshold height for the whole catchment. According to the observed data, the maximal height reached at the outlet is 4 m, so we used this threshold to simulate an inundation map. The simple HAND model reached $CSI = 0.49$, $BIAS = 1.55$, $POD = 0.84$ and $FAR = 0.46$. The HAND model is clearly penalised by the overestimation (almost 50% of false alarms), which is not surprising according to other studies (e.g. Nobre et al., 2016).

   In comparison, for the “physical” set of parameters identified with MHYST, ($K_{ch} = 10$ and $K_{fp} = 5$), we obtained $CSI = 0.66$, $BIAS = 0.86$, $POD = 0.74$ and $FAR = 0.14$. Here, the issue is the underestimation, but MHYST reduces the false alarm ratio while increasing the overall performance (CSI), which means that the part of missed observed flooded cells decrease only slightly (we reduce 30% of FAR while losing only 10% of POD).

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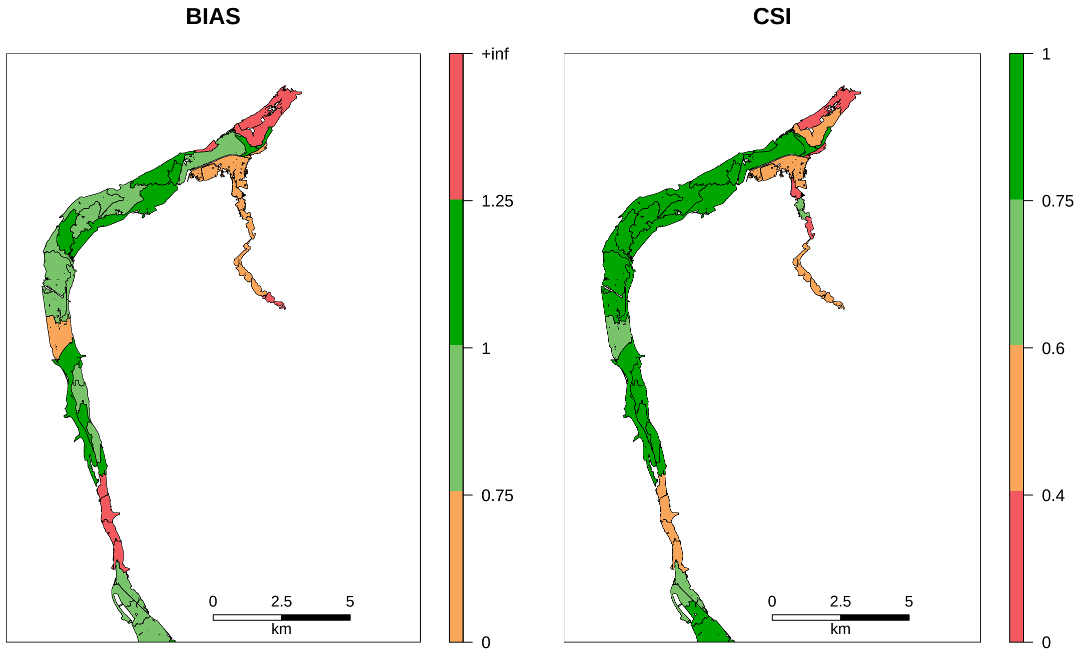

Fig. 1. Reach-scale performance for the physical combination of parameters, for the downstream part of the catchment.

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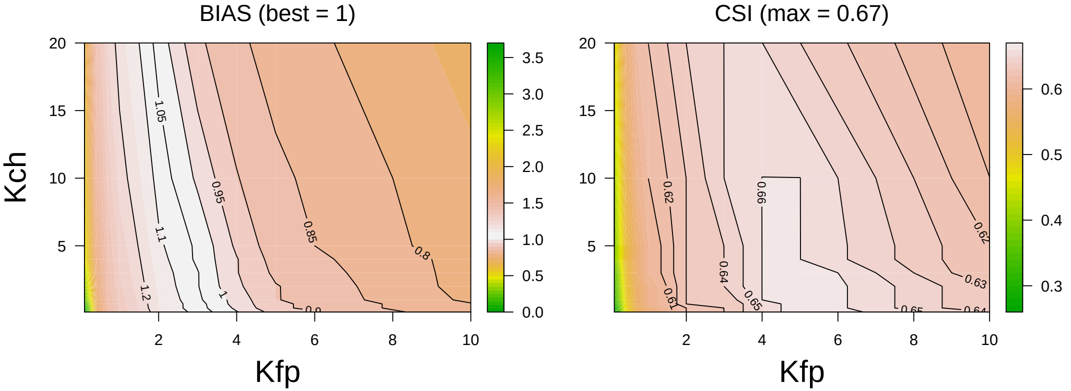

Fig. 2. CSI scores obtained by the model on the River Loing versus Copernicus data for all the parameter values tested and for a 5-m resolution DEM.

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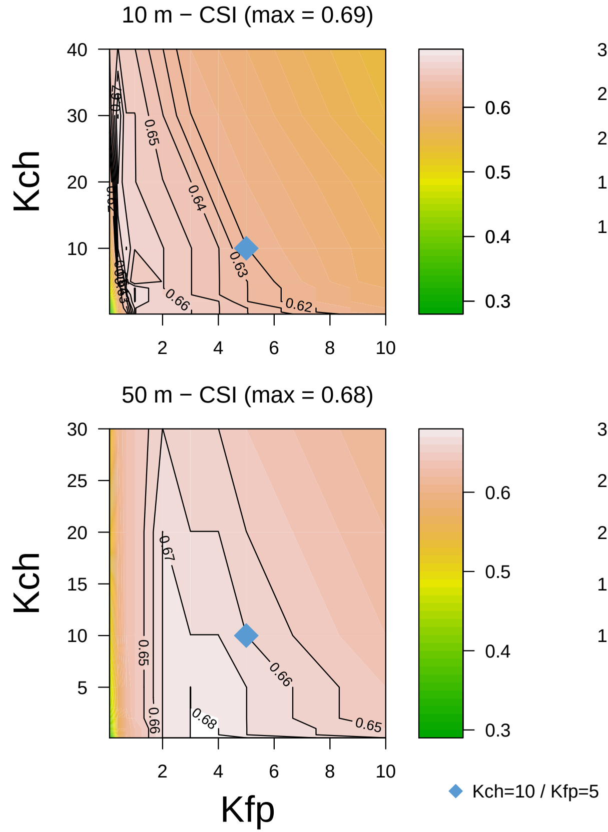

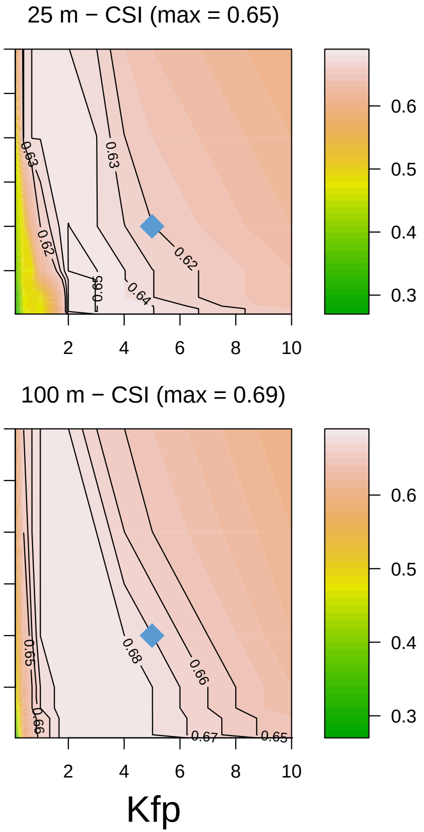

Fig. 3. CSI scores obtained by the model on the River Loing versus Copernicus data for all the parameter values tested and for various resolution of the DEM.

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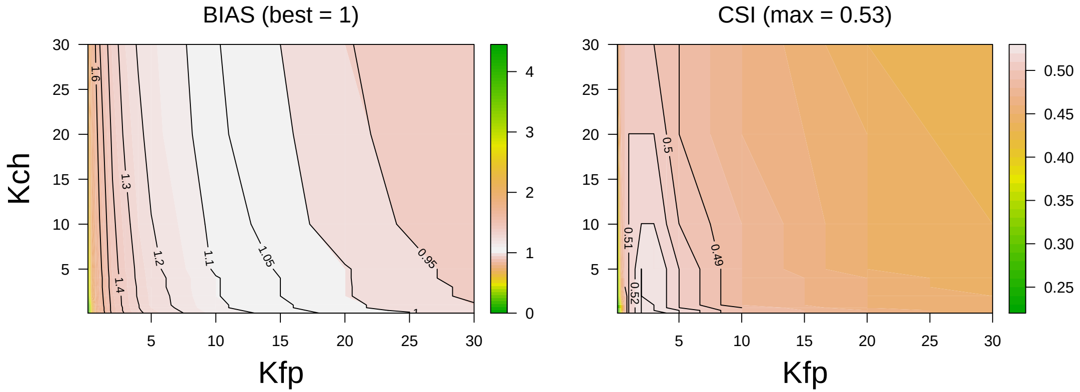

Fig. 4. CSI scores obtained by the model on the River Loing versus Copernicus data for all the parameter values tested and for another source of data : EU-DEM.