

Reviews of: A combined hydrological and hydraulic modelling approach for the flood hazard mapping of the Po river basin.

Answers to Reviewer 2:

General Comments

This paper presents very interesting work on the topic of flood risk assessments using novel hydraulic and hydrological modelling techniques. The paper is well written, referenced and structured. The results are presented clearly, and are honest (perhaps even modest) about their performance. However, while the methods are innovative, the major contribution developed is described as "an innovative approach which reshapes the digital elevation models". Despite this being the crux of the work, this digging method is not described at all, other than calling it an 'ad hoc' process in the abstract.

Answer: We thank the reviewer for this comment, it was not clear and we have added a new subsection with the description of how the digging method was performed (Subsection 2.4.2)

The resolution used was 90m, and the main purpose of the method is to "apply it also in those regions where there is [limited information]". In regions with limited information, river channels are very likely to be less than 90m wide, so this raises some difficult questions about the 'digging' process.

Answer: The lack of information about the river channels is actually not related with their size. For instance, several large rivers in South America and Africa have very few or no surveyed river sections. Moreover, there are specific approaches (e.g. sub-grid treatments) that allow to consider river channels having a width smaller than grid resolution (e.g Neal et al., 2012; Dottori et al., 2016). Finally, we chose the 90 m resolution because it is a standard resolution for global-scale DEMs (HYDRO-Sheds but also the more recent Tandem-90m)

Due to the lack of explanation on this vital component, I am suggesting this paper needs 'major revisions' before it can be accepted. However, in reality, it is only this point that needs to be revised, rethought and clearly explained. For example, a simple fix would be to conclude the innovation of the work as a 'an innovative combined hydraulic and hydrological modelling process' which shows good results. In this case, however, the computational efficiency and performance advantages over other methods (such as JRC) should be clearly explained.

Answer: The revised version of the paper includes now the more accurate explanation of the innovation in the Introduction, in the Subsection 2.4.2 and in the conclusion is highlighted how "the DEM-reshaping method improves the sensitivity to return period of CA2D flood extent maps compared to the JRC maps"

Specific Comments

Title: "...over THE Po River basin".

Answer: Corrected.

Page 1, Line 27: "the results ARE less satisfactory..."

Answer: Corrected.

P2 L37: "which mandate is" (English)

Answer: Corrected.

P2 L41: "for A few regions of the globe"

Answer: Corrected.

P2 L70: I am not sure if these drawbacks are relevant. 1D schemes are rarely described as computationally expensive. Also, the fact that areas between cross-sections are not represented is true of any model that uses discretisation (i.e. all numerical models). A 2D model also discretises an area into uniform blocks that don't represent variation within the blocks.

Answer: Following the Reviewers' advice, we rewrote parts of the introduction. We first focus on existing research gaps and on the status of flood hazard map availability in Italy, providing more recent references. Then, we describe how the present paper addresses the mentioned issues, presenting the innovations proposed by the modelling framework and clearly stating research aims.

P4 L122: I assume D8 relates to the deterministic eight nodes method (Martz and Garbrecht 1992), but this should be stated and referenced.

Answer: The Introduction has been substantially rewritten following the comments of Reviewer 1. We put a specific reference to the 8-direction link network in Section 2.3 (lines 265-266).

P4 L125: No mention is made as to how CHyM handles evapotranspiration.

Answer: Added in the text (lines 169-172).

P4 L130: Although 9 domains were simulated in the overall project work done, I don't think it is relevant to the story here, which focuses on the Po / Tanaro. This is also true for Figure 1.

Answer: The Figure was removed as also suggested by other reviewers.

P4 L131: "The domains are matching the..." I think 'match' is better here, but in general the sentence is a bit long and awkward, and could be rethought.

Answer: Corrected.

P6: L170: "(flatter) rising (falling) limbs of..." The authors are trying to be less verbose here, but the resulting is just confusing. Perhaps 'vice-versa'?

Answer: Corrected.

P6 L176: Even though I am familiar with Maione's work, this description was hard to follow. Perhaps it could be explained with reference to the diagram below;

Answer: The description has been revised and re-organized, referring explicitly to Figure 1, Maione et al., 2003.)

P7 L196: Apologies if I am incorrect here, but as I understand it, CA hydraulic modelling is simply finite volume modelling in which the volumes are balanced over a group of neighbouring cells for each cell, rather than over the whole domain. Given that the definition of a cellular automaton is (basically) a set of rules for a domain of grid cells, surely all 2d hydraulic models could not be called 'cellular automata', and the name is not required.

Answer: We modified the description of the CA2D model, excluding the mention to CA structure which is not exploited in this study. Note that we also added more details on the model setup, following a specific request of another Reviewer.

P7 L208: "..., as expected, ..." or "... (as expected) ..."

Answer: Corrected.

P9 L 213: interested river network? This sounds strange

Answer: Corrected.

P9 L214 "the following section" is ambiguous here, as it does not refer to the actual next (sub)section 2.4.

Answer: Corrected.

P9 L242: As mentioned above, does a 90m DEM allow for this digging? What is the 'ad-hoc' process? Does this work-around mean the process is only suited to the presented application?

Answer: We added a detailed description of how the digging process was performed. The digging method is not limited by the resolution but by construction we are of course only able to reproduce the river channel from 90m resolution and above (so no higher resolution are allowed). But since the digging method is an objective method that is only determined by the evaluation of the 1.5y RP, if in the future an higher resolution DEM will be available, the same method can be applied by evaluating the 1.5yRP of the new river channel network.

P10 L268: The SDHs are built using observed data, so how exactly does using a model validate them?

Answer: Corrected.

P10 L272: This should be 'area under the curves' However, given this is Q for a set period, I think it would be better to simply use 'total volume' as the metric.

Answer: Corrected.

P12 Figure 7: This figure is poor. The elevation legend has no units, and has too large a range. The flood legends are similar in both the aerial and GIS images, but represent different things.

Answer: We have corrected the figure, changing the color of the flood respect to the GIS images and adding the units to the legend.

P12 L287: Where is it catalogued as such? 100 year rainfall or 100 year level at a certain location?

Answer: According to local reports, the discharges recorded during the event may have reached a return period of 100 years However, we have no specific information on how the return period was estimated,

P13 L294: I think the problems of SAR should be mentioned (double-bounce etc.) as they can be seen in the satellite image.

Answer: In the revised version we will take into account this suggestion and mention some issues visible in the figure.

P13 L317: How are the AdbPo maps produced?

Answer: We have reviewed the documentation available online and included a short description of AdbPo maps. According to the Po River Basin Authority [AdBPo 2012], the flood hazard maps related to the main river networks have been calculated using 1D hydraulic models, integrated by 2D simulations in specific areas of interest (e.g. near bridges or hydraulic structures). All simulations were based on surveyed topography and river bathymetry. Delineation of flood-prone areas outside of river embankments have been derived using GIS interpolation and considering terrain altimetry and geomorphologic features.

P15 L328: This part raises more questions about the dug channels. Why was 1.5 years chosen? Why not do a second 'dig' in the areas between main levees (or minor levees) to the same conveyance as the protection level. In other words, why not dig a conveyance of 200yrs in the area of Fascia B?

Answer: The 1-in-1.5-year discharge is usually considered an indication of bankfull discharge, as stated in references already cited in the text. Digging the channel is applied to include the river bed permanently covered by water, which is not represented in the DEM. Conversely, representing embankments would require to "raise" DEM pixels corresponding to river banks in order to reproduce the blockage effect. Such technique has been applied by Wing et al. (2017) in the United States, using the national US catalogue of flood defences (2017). The same could be done over the Po River where the

level of flood protection is known, but this is not the case in a majority of river basins in Italy and Europe. Given that our goal is to develop a methodology applicable everywhere, we opted for not using local information for the model setup.

P16 Conclusion: As Maione's RP method is used in the overall combined method presented, it is limited to producing flood maps, which should be mentioned. Furthermore, such maps don't allow for spatial homogeneity issues (for example, a 100yr event doesn't produce a 100yr level at all locations).

Answer: Indeed, the method here applied allows to derive “theoretical” flood maps under the assumption of a uniform return period (i.e. the same flood frequency) everywhere in the river network. This is the standard approach used for flood hazard mapping and has been applied by the River Po Basin Authority for their hazard maps. We reckon however that in real flood events flood frequency may be highly variable across space, especially in large river basins such as the Po River. This is now mentioned in the conclusions as a limitation of the model

P16 L360: The fact that the method is developed for regions with limited information seems to be mentioned here for the first time.

Answer: We have rewritten the Introduction and added more information about the application of this method (lines ...)

P16 L362L: Which hydrographs?

Answer: Corrected in the text