

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

### **Answers to Reviewer 1**

The manuscript "An integrated hydrological and hydraulic modelling approach for the flood risk assessment over Po river basin" presents a chain of models for producing flood hazard maps in northern Italy. The paper is interesting and touches an important topic, but has many issues in terms of writing, analysis and underlying modelling work. Firstly, I will list my major concerns in the order of appearance in the paper. Then, I will list some minor comments and suggestions to improve the text.

**Introduction:** the introduction gives little information on the research gaps that exist and which the authors are trying to address. No research goals are stated, and no clue is given what innovation or contribution to the field is introduced by the paper. Most of the introduction is a general overview of history of flood modelling, though interesting by itself, is mostly not too relevant for the study, and it barely cites any literature from the past 10 years. A revised introduction should clearly state what the study contributes and which research gaps it addresses, and the literature overview should be focused on those aspects, and cite more recent papers given the enormous developments in the field in the past decade. Also, it should be explained what is the existing flood hazard map availability for Italy and why new maps are needed (especially since, as described later in the paper, national maps are already available!).

**Answer: *Following the Reviewer's 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.***

**Methods (2.1):** the main innovations here, i.e. the use of a new precipitation dataset and a new implementation with a high-resolution DEM, are very briefly described. The resolution of the DEM and precipitation data should be clearly written, as should the information about other necessary inputs for hydrological modelling (evapotranspiration, snowmelt, infiltration etc.), model set-up (e.g. timestep) and model calibration.

**Answer: *Added in the text: lines 169-171, lines 182-194, lines 197-198***

**Methods (2.3):** from the text it seems that the only change in the hydraulic model is the parallelization. This should be clearly written, and more details should be provided as this is an important addition. It would be particularly useful to describe to what simulation set-up Fig. 3 pertains to. If other changes were made to the model they need to be described.

**Answer: *Added in the text in Section 2.3***

Methods (2.4): most of all, the method “digging” the channel in the DEM is not well described. Was the bankfull depth used directly for the lowering grid cells in the 3” resolution DEM, or the resolution of the DEM (which is coarser than width of most rivers in the study area) was accounted for by reducing the depth accordingly to achieve the same wetted perimeter? If the former, then the conveyance of the rivers will be vastly overestimated and needs to be corrected. If the latter, then it needs to be properly described. Also, what does the “ad hoc” re-shaping of HydroSHEDS in the abstract actually refer to? Further, there is too little information about the simulation set-up, such as timestep, spin-up time, simulation time, calibration procedure (if there was any) or roughness coefficient selection (was it spatially-variable? was it adjusted by calibration?).

***Answer: We agree with the reviewer: the method was poorly described. We have added in the text a subsection 2.4.2 with a more detailed description.***

Validation (3.1): the validation mentions “tuning” the model (line 264), but no information about calibration procedure were provided.

***Answer: “Tuning” removed***

Also, the text mentions “Due to the relatively small size of the simulated domains, the duration of all flood simulations was set to 240 h” (line 266). Does this refer to simulation domains from Figure 1? Or the sub-domains mentioned in the previous section? (line 259). This should be clarified to avoid confusion. Still, if the simulation was done over the whole Po river, isn't 240 hours far too low to capture the response of the catchment (I made a quick check with an empirical equation, which suggests so)?

***Answer: Here when we talk about “simulations” we refer to the 0.3x0.3 degrees sub-domains, not the entire Po river domain. (Added in the text). Following Alfieri et al (2014) we derived a common duration period of 240 h, compatible with the flood peak over the main stem of the Po River.***

Validation (3.2): the validation here is only visual, but as Figure 7 shows flooded areas extracted already from the satellite images, it would be possible to apply the method of comparing flood maps from section 3.3 to compute the different indices. Also, the impression of good match between the modelled and observed flood extents partially stems from showing a 500-year flood map for comparison, instead of only 100-year flood. Finally, given that the hydrological simulation made by the authors cover the time of the event, wouldn't it be a better comparison by running the hydraulic model specifically for the 2016 event?

***Answer: A representation of the single flood events that are happening is beyond our scope as we are not interested in real-time flood estimations. The case study is just an example of how our results compare with a real case situation. Unfortunately, the data necessary for reproducing this image and assessing the performance of the methods using hard metrics is not currently publicly available to our knowledge. COSMO-SkyMed only provided these images in graphical format. We have removed the 500-year flood map from the lower panels as suggested by the reviewer (see new Figure 6).***

Validation (3.3): official hazard maps are used here for comparison, but no information how they were produced are provided. This is important in order to assess the source of differences with the authors maps. Also, the authors only show the results for a 500- year flood map, while discussing other return periods as well. Those results should be shown. Especially as authors claim there maps being better than JRC's , but the results for the 500- year maps are actually worse. Also, it is well possible that the authors' models underestimate flood hazard severely – but that could be made clearer by information how the reference Italian maps were made. Also, the JRC maps might not include channel geometry, but account for this by removing mean discharge from the design hydrographs, as I did in my pan-European flood modelling work, too (Paprotny et al. 2017, cited by authors). Other researchers (Ward et al., 2013; Sampson et al., 2015) accounted for this by removing 2-year discharge.

***Answer: We thank the Reviewer for pointing out the inaccurate definition of JRC maps regarding channel geometry. We now explicitly mention the JRC approach to highlight the difference with the digging method that we used. We also 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.***

Finally, there is no discussion section in the paper, hence missing many important aspects. Uncertainties and limitations are not discussed (e.g. related to the channel "digging" or design hydrographs). Ways to further improve the work and next steps are not discussed too, and neither is relevance of the work for making projections of flood hazard under climate change. But most importantly, the issue of flood protection is ignored. Though the authors write that the channel "digging" accounts for "man-made" banks, but a return period of 1.5 years is below even the most meagre flood defences. In practice of flood hazard modelling, assumptions about the level of flood protection has very strong influence on the results, as I show in Paprotny et al. (2017). Without this, any improvements to the hydrological or hydraulic modelling are mostly lost. If this is not addressed by the authors in their model, it needs to be at least extensively discussed.

***Answer: We thank the reviewer for this suggestion. We have now included these points in the Conclusion section.***

#### **Minor comments:**

Title: the authors write "integrated hydrological and hydraulic modelling" but in reality the two are run entirely separately. Also, the work relates to flood hazard mapping in the Po river basin and not "flood risk assessment" (risk is not addressed by the paper) "over" Po river basin. The authors should propose a new title that includes only items that are covered by the paper.

**Answer: We have changed the title to “A combined hydrological and hydraulic modelling approach for the flood hazard mapping of the Po river basin.”**

L14: typo “gom”

**Answer: Corrected.**

L26: should be “are” not “and”

**Answer: Corrected.**

L37: “Flood Risk Management Directive” is not an official name, hence it should be refer to as “Floods Directive” in parentheses.

**Answer: Corrected.**

L52: “For limited area gauged basins” is not understandable, probably should be “For small, gauged basins”

**Answer: Corrected.**

L110-111: a large-scale map, in geography, covers a small area (large amplification). Mixing “scale” as in maps, and “scale” as in process is commonplace and should be corrected to “. . . assumes that flood hazard maps over a large domain can be derived from an ensemble of smaller sub-simulations. . .”

**Answer: Corrected.**

L122: “D8” should be explained.

**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)**

Figure 1: the map lacks legend, grid or scale. Also, the source of the underlying map should be identified in the caption.

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

Section 2.2: throughout, authors use multiple letters for a single variable. A single letter should be used e.g. S instead of SDH. Subscripts could be also used instead to differentiate.

**Answer: We have changed the notations as suggested by the reviewer.**

L172 and subseq.: it should be clearly merged that eq. 3-5 are directly taken from Maione et al. (2003).

**Answer: Added in the text.**

179-L180: the authors mention and show equation for the falling limb, but shouldn't there be also an equation for the rising limb of the hydrograph?

**Answer: We have added the rising limb equation.**

L186: what method was used for fitting?

**Answer: *The fit was performed by means of the maximum likelihood estimation (added in the text).***

L191: write specifically which station.

Figure 3 and others: the size of figures, their labels and general appearance should be synchronized throughout the paper, as at the moment they give a very messy appearance together.

**Answer: *All the figures, besides actual Figure 1, were performed with the same graphic tool (NCL). We don't understand what the reviewer is suggesting.***

L232: "for larger domains" not "on large scales".

**Answer: *Corrected.***

L247-L249: this is the part where it is particularly unclear how the "digging" was made.

**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)***

L274: the results referred to by authors were actually presented in [Paprotny D., Morales Nápoles O. (2017) Estimating extreme river discharges in Europe through a Bayesian Network. Hydrology and Earth System Sciences 21, 2615–2636.] rather than in Paprotny et al. (2017) cited here.

**Answer: *Corrected.***

Figure 6: a 1:1 line should be added to the graph.

**Answer: *Done.***

Figure 7: "meters" is missing in the lower legend.

**Answer: *Done.***

Section 3.3: again, a single letter (with possible subscript) should be used per variable.

**Answer: *We have changed the notations as suggested by the reviewer.***

L321: Alfieri et al. (2014, 2015) should be cited here regarding the methodology of the JRC maps.

**Answer: *We thank the Reviewer for this suggestion, the two references have been added***

L338: typo "STRT".

**Answer: *Corrected.***

L351-352: rather due to lack of flood defences in the model

**Answer: *Corrected.***

L361: as noted above, the authors do not really account for "man-made banks", if those are formed by flood defences.

***Answer: We thank the Reviewer for this suggestion, we have removed "man-made banks" in the text as we only account for natural river banks.***

L363-364: authors write that "[t]he evaluation of the produced flood maps was performed through some case studies of observed flood extent", but actually only one case study is shown (Nov. 2016).

***Answer: Corrected to "one case study".***