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

Answers to Anonymous Referee #3

Overall evaluation: The aim of the manuscript is to provide a combined approach for mapping flood hazard for different return periods, starting from a precipitation dataset and using a statistical procedure to design synthetic hydrographs, to be then used to simulate inundation scenarios in the floodplain.

Although the topic is interesting, the manuscript is well written and structures and the its scope is in line with the journal, I don't find this study innovative enough to be published in NHESS. The methodology, as described in the manuscript, is the one developed in Maione et al. (2003) and used to map European flood hazard in Dottori et al. (2006), who also use the identical approach for simulating the flooding dynamics, with the only difference in reducing the flood hydrograph discharges by subtracting the estimated average daily discharge, instead of "digging" the DTM as stated in this manuscript. The main differences declared in this study are the different database and DTM used that just characterize an application of the cited methodologies on different case studies. This is the main reason why I would reject the manuscript in its current form. Some other concerns about the manuscript are listed below. I hope the authors will find them useful and I encourage them to resubmit a thoroughly and carefully revised version of the present study, clearly specifying the innovations made.

Answer: We agree with the reviewer that the JRC and our modelling framework use the same methods to determine flood hydrographs and calculate flood maps. However, we believe there are also major differences, which are highlighted in the revised paper. Hydrological and hydraulic models applied are different, as is the climate and topographic databases and the characterization of the river channel, to name just the most relevant differences. Many papers work on the same problem trying to investigate which is the best way to achieve a common goal. Indeed, the comparison in figures 7 and 8 demonstrates that the two methods produce quite different results. On this point, it is important to note that all existing large-scale flood models share relevant parts of models and datasets. For instance, all existing global flood models are either based on hydrological models or regional frequency analysis to calculate river discharges (Trigg et al., 2016).

Major comments:

Title: I don't think this can be defined as an "integrated" approach, because the two models (hydrological and hydraulic), as I understand from the description, run separately. I would relate to a "combined" approach instead. In addition, flood risk in literature is defined as the combination of flood hazard, exposure and vulnerability, while the manuscript refers to hazard only.

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

Introduction: I would add a part about flood hazard maps, investigating how they are currently designed, which is the situation in Italy (where you focus your study), etc**.**
Answer: 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.

Section 2.3: I find this part too short and less detailed, it becomes clearer only after reading the paper of Dottori et al. (2016). Details about boundary conditions, roughness coefficients and other useful details for modelers should be added.
Answer: Following the requests of the Reviewer, we added additional information on the model setup in Sections 2.3, while further details on the setup of simulations are now added to Section 2.4.3. We refer the reader to the original works for the complete descriptions.

In the last part of the section, the reader is expected to find how the following sections are organized, but the list of the steps here stated don't agree with the chapters.
Answer: We thank the reviewer for this comment, it was definitely not clear, we have re-organized the sections in a more coherent way.

Section 2.4: the main lack here, and in the whole manuscript, is the description of the digging method. Being one of the few modifications of the cited methodologies, it needs to be clearly described (included the motivation of this choice instead of following Dottori's methodology), in order to justify the application of this approach.
Answer: This point was highlighted by all the reviewers, we have added a new subsection with the description of the digging method, how it was performed and why (Subsection 2.4.2)

Again, details need to be added, such as how the model works in the external areas, how the different flood maps of the virtual stations are merged, levees breaching mechanisms (if any), etc.
Answer: We added in the text the missing information requested by the reviewer. The model uses the same flow equations both for channel flow and floodplain flow (section 2.3). We do not include levees in the model domain, as the information on their geometry is usually not available, therefore we assume that overflow occurs when channel conveyance is exceeded. We performed the merging of maps of the virtual stations by taking the maximum depth value where more maps overlap (section 2.4).

Case studies and study areas: They need to be better described and motivated, included the choice to refer to three different studies areas. "Upper Po basin", "the area in the south of

Turin", "the area of Alessandria" are too general, please specify where they are (also with Figures), how big they are, etc.
Answer: Added in the text, added boxes in Figure 3.

Is the area in Figures 8 and 9 the same as in Figures 4 and 5? If yes, why is it cut in the northern and southern part? If not, why not?
Answer: Added box in Figure 4. As explained in the test "To perform the indexes calculations, we have focused our analysis on a smaller portion of the domain, centred on the main river, removing flooded areas originating from river sections with an upstream area smaller than 500 km2 since they are not simulated and therefore not included in the JRC maps."

Section 3.1: Please pay more attention in the terminology used: the SDHs cannot be validated using observations from the gauging stations for Tr 50, 100 and 500 years. . . there are not observations for 500 years return period!!!
Answer: Text corrected

These values are extrapolated from statistical studies starting from observation, but it needs to be clarified. In addition, I would not say "tuning" the model, because the model was already developed by Maione et al. (2003), maybe it was applied to the new data. If there are substantial modifications instead, please clarify it, because it is not evident up to now.
Answer: Deleted "tuning".

Section 3.2: Why do authors refer also to Tr = 500, when they write that the November 2016 event was catalogued as a 100years return period event? In addition, I think that the sentence "We can see that the observed event, associated to a return period of 100 years, is fairly good represented by the model (Fig. 7 (b) and (d)) as the maps include the particular events observed" cannot be accepted in a scientific manuscript as a valid result of a study. The judgment of the validity of the approach cannot be based on the impression of the reader that looks at the two maps and conclude that they are similar!
Why authors didn't use the same indices as in Section 3.3? I would provide a initial Section in Chapter 3 where describing the indices used, and then perform all the comparisons using this indices.
Answer: The real validation of the method is done later, this is just an example of comparison with a real case study, as is now clearly specified in the text. Unfortunately, the data necessary for reproducing this image and assessing the performance of the methods using hard metrics is not currently publicly available. COSMO-SkyMed only provided these images in graphical format. (Added in the text)

Section 3.3: In order to better understand and discuss the results of the study, an explanation on why authors chose River Po Basin Authority and JRC maps as comparison must be added, and also how they are derived.
Answer: The maps produced by the River Po Basin Authority are the official flood hazard maps and are based on detailed surveyed datasets, including river channel bathymetry

and geometry of levee systems [AdpPo, 2012]. Therefore, they constitute the reference for this region. We reviewed the documentation available online and included a short description of these maps in the text.
The JRC flood maps are the only publicly available maps based on a well documented modelling framework. It is important to note that, while the JRC and our framework share a number of methods (e.g. to determine flood hydrographs and calculate flood maps), they use different models and datasets and diverge in other modelling solutions. Therefore, we are interested to investigate whether the proposed changes can improve results. Although we added a short description of each of these products, there are a number of references in the text to point the reader to existing literature for a more detailed description

Why authors say that it is possible to calculate indices only for Tr = 500 years but then show and comment results also for Tr = 50 and 100? It is not clear, in addition and related to this comment, which models consider the embankment system. Po river has an important levee system, which has a very important influence on the results of hydraulic simulations (see, e.g., Wing et al. (2019)*). This issue must be considered at least in the discussion result. In addition, there are no references at water depth results in the study, that's why the sentence at P. 15 L. 352-354 is not correct.
Answer: Neither the JRC nor CA2D maps consider the embankment system, due to absence of information. According to the available information [AdbPo, 2012], the embankment system is designed to allow flooding only in a limited portion of the river floodplain (i.e. the berms) for discharges with return periods up to 200 years. Therefore, any statistical evaluation for return periods below RP 500y. has no significance This is now specified in Section 3.3 Nevertheless since the new method (mettiamo qui il nome dopo) it is producing results for any RP it is worth comparing the maps for RP lower than 500 to show and confirm the differences among the methods.

In general, results in Section 3 have to be deeper investigated (e.g. in Figure 9, the explanation of the differences between CA2D and JRC maps are not taken into consideration at all).
Answer: It is now made clear in the paper what is the role of JRC maps and how the new methods is different from the JRC one and which are the improvement (line 387-392) This is also further highlighted and explained in the conclusion section.

Figures 8 and 9: I find the way to visualize results in Fig. 8 very unrepresentative. I would, instead, represent maps in Figure 8 as in Figure 9, in terms of comparison of CA2D and JRC maps, respectively, with AdB maps, following the representation of results in Table 1. The same for Figure. 4.
Answer: The figure was changed according to the reviewer suggestion

Minor comments:

P. 1 L. 26: results ARE less satisfactory. . .
Answer: Corrected.

P. 2 L. 36: the development of flood hazard maps is only one of the mandates of the European Flood Directive (better than "European Union Flood Risk Management Directive")
Answer: Corrected.

Among 2d models, I would mention also the 2d version of Hec-Ras, very used in the last years.
Answer: We have rewritten the Introduction removing this part as suggested by other reviewers.

Figure 1: this is unnecessary, it doesn't add anything interesting to the study.
Answer: We thank and we agree with the reviewer: we have removed the Figure 1

P. 6 L. 163: the right reference is Alfieri et al. (2014) instead of 2013, if I understand what authors refer to.
Answer: Corrected.

P. 7 L. 211 – P. 9 L. 213: Please rephrase, it is not clear.
Answer: Done.

P. 9 L. 213-214: the following Section is 2.4, but this is not the section in which the results are shown. Please correct.
Answer: We thank the reviewer for pointing this out. We have corrected the text.

Figure 4: y-axis label is missing.
Answer: Corrected.

Figures 4, 5, 7, 8, 9: scale bar and north arrow are missing.
Answer: Added.

P. 10 L. 266: add reference
Answer: Added.

P. 10 L. 267: "small size": please specify quantitatively.
Answer: Corrected in the text.

P. 10 L. 267-268: please explain better, with references. Please provide reference for "observational data" in the Po River.
Answer: Corrected in the text.

Figure 5: Please specify in the caption which model is used to map hazard areas.
Answer: Added.

Figure 6: a) and b) labels are not shown in the figure.
Answer: Added.

Figure 7: what does the legends refer to?
Answer: We have corrected the figure, changing the color of the flood respect to the GIS images, adding the units to the legend and removing the flood relative to the Return Period of 500 years.

P. 13 L. 300: perform a COMPARISON BETWEEN existing. . .
Answer: Corrected.

P. 13 L. 314: I would use the terminology "CA2D maps" from the beginning of the manuscript.
Answer: We have changed the name of the maps and used the same name throughout the manuscript.

P. 13 L. 315: PO RIVER BASIN AUTHORITY instead of River Po Authority.
Answer: Corrected.

P. 15 L. 338: the SRTM used. . .
Answer: Corrected.

P. 16 L. 362: which hydrographs?
Answer: Corrected.

P. 16 L. 365: the comparison is not in the ENTIRE domain, please clarify**.**
Answer: Corrected and clarified.