Dear Reviewer, first we want to thank you for your constructive, in-depth and clear questions and comments. Below you can find our answers point-by-point to your comments. We also highlight (where possible) the part of the original submitted manuscript that have been modified to address your comments. To facilitate the reading, we added our responses to your comments in red. If changes to the text are proposed, changes are underlined.

Major Reviews:

The author are using an interesting and complex combination of hydrodynamic models to simulate the flood hazard in Venice; yet, the authors are also only using water depth as the descriptor of flood damages in the case study area. One of the main advantages of hydrodynamic models is the capability of providing information pertaining to the duration and velocity of a flood event, which however are not considered in the damage modelling framework. As such, the value-added of utilising the nested hydrodynamic models is not clear in the current version of the manuscript, and seems to only be adding to the complexity of the proposed methodological framework. While the authors are already using a hydrodynamic model to simulate the dynamics from the Adriatic sea to the Lagoon of Venice (i.e. parent model), I would strongly suggest the authors to highlight the benefits of using the nested hydrodynamic models over a more simplistic bathtub approach for the studied application.

Thank you very much for this question. Based on your comment, we clarified our motivation for applying a 2D-hydrodynamic model in line 135ff :

"Studies looking into the distribution of flood depths in Venice have used a static model, also called bathtub model (Cellerino et al., 1998). It uses the water level at the tidal gauge of Punta della Salute and compares it with the surface elevation of the old-town of Venice to identify the flood extent and depth. <u>A bathtub model assumes instantaneous flooding. It neglects the process of flood wave progression and therefore could overestimate the flood depths inside the city. Using a 2D hydrodynamic model might be able to capture the flood progression into the city, the role of sewage networks and other processes more realistically while also providing the appropriate framework to account for other flood parameters such as flow velocity.</u> <u>Moreover, the hydrodynamic model can be forced with variable water levels at the boundaries of the nested sub-models, thus accounting for strong water level gradients over the city registered by the observations during the 12 November 2019 event.</u>"

To address the relevant comment about the flood velocity as a damage descriptor, we added the following in line 414: "*<u>It is important to note that damages were only caused by the inundation depths and not by flow velocities or flood duration according to the INSYDE model. Flow velocities inside Venice and near its buildings were lower than the required threshold (0.5 m/s) for more than 95% of the buildings, as shown in Figure S13 in the supplementary material. Similarly, inundation duration had no damage-mediating effect because it did not exceed the pre-defined threshold of eight hours for the analysed flood events as shown in Fig. 9.</u>*

In the same topic of the last point, it would be interesting to provide a table similar to Table 7 but comparing the results of the hydrostatic and the hydrodynamic models, in terms of R and RMSE.

Thank you for this comment. Table 7 only refers to the parent model (covering the Venetian lagoon). The stations mentioned in the table are tidal gauge stations spread over the lagoon. However, we did not apply the bathtub model for the entire lagoon but only inside the city of Venice. A comparison of flood depth-estimates derived from the bathtub model and from the nested hydrodynamic model is shown in Figure 6a.

As Figure 6a shows an underestimation flood depth bias by the d3dfm model with respect to the bathtub approach, It would be interesting to include also the damage results from the bathtub flood model, if possible, so to provide a meta-model comparison. The same rational is valid for Tables 9 and 10.

We thank the reviewer for this suggestion. We added the information to the respective tables and also added some additional textual analysis along with them.

Table 8. Comparison of damage claims and estimates based on hydrodynamic (d3dfm) and bathtub (btb) flood depth estimates [EUR million]

		INSYDE		claims
		d3dfm	btb	
sub-set of structures	risk averse IPS	12.9	13.1	
	medium IPS	42.0	47.5	25.7
	risk taking IPS	63.1	65.8	
all structures	risk averse IPS	52.3	53.8	
	medium IPS	166.3	193.1	56.2
	risk taking IPS	253.6	269.9	

New text added in line 312: *"It can also be seen that in line with the lower level of flood depth estimations by the hydrodynamic model, damage estimates based on the bathtub calculations are generally larger. The difference increases with decreasing level of individual protection."*

Table 9. Performance indicators of damage estimates based on hydrodynamic (d3dfm) and bathtub (btb) flood depth estimates for structures with immediate response claims

		risk averse IPS	expected IPS	risk taking IPS
d3dfm	R [-]	0.22	0.26	0.26
	RMSE [EUR]	19,382	22,158	29,332
	RE [%]	308.9	87.8	55.5
btb	R [-]	0.22	0.25	0.26
	RMSE [EUR]	19,384	23,298	30,122
	RE [%]	304.9	71.5	51.8

New text added in line 317: "*Both indicators suggest that the damage claims might be slightly better estimated for damages computed based on bathtub flood estimates. Furthermore, claims might be slightly better estimated based on an expected IPS or risk taking IPS for most buildings.*"

Table 10. Flood peak level at Punta della Salute [m ZMPS] and damage estimates [EUR million] for different scenarios

		d3dfm			bathtub		
scenario	peak level	risk averse IPS	expected IPS	risk taking IPS	risk averse IPS	expected IPS	risk taking IPS
SLR0-allopen	1.89	52.2	166.3	253.6	53.8	193.1	269.9
SLR0-lidoopen	1.56	37.1	95.0	132.0	39.7	119.7	156.9
SLR0-allclosed	0.82	0.0	0.0	0.1	0.0	0.0	0.1
SLR1-lidoopen	1.62	42.6	129.4	166.7	46.8	165.3	201.1
SLR1-allclosed	0.87	0.0	0.0	0.2	0.0	0.0	0.2
SLR2-lidoopen	2.10	179.7	289.6	309.4	196.3	300.8	320.0
SLR2-allclosed	0.81	0.0	0.0	0.1	0.0	0.0	0.1

During recent MOSE activations, the Malamocco inlet was left open, while both Lido and Chioggia were closed, as this is the main inlet for commercial and industrial ships. While the scenario "lidoopen" is certainly very interesting and capable of providing much appreciated information to decision-makers and to the general public, it would be also interesting to consider, if possible, a more plausible and realistic scenario were the Malamocco inlet only is left open.

We thank the reviewer for this suggestion. We indeed considered to investigate a larger set of alternative closing scenarios, but due to time constraints we limited ourselves to two closure states. With the paper we wanted to focus on possible, critical scenarios (unintentional non-closure of one of the barrier gates) rather than most likely scenarios (open closure for shipping purposes). In a preliminary a-priori assessment we identified the Lido inlet as the possible critical one given its proximity to the old-town and the larger cross-section compared to the other two inlets. This choice is in line with previous works using the same line of argumentation (Umgiesser, 2020) or providing evidence that partial closure of the MOSE barrier (closing Lido & Chioggia inlet) can have a relevant water level managing effect (Cavallaro et al., 2017)

To be more explicit on the motivation of choice, we added a sentence in line 123: "*Regarding the MOSE barrier, two closure states are considered: a fully functioning MOSE barrier ('allclosed') and a set-up where all inlets but the Lido inlet close ('lidoopen'). Previous works (Mooyaart & Jonkman, 2017; Vrancken et al., 2008), and experiences from practice in Venice (Colamussi, 1992; Umgiesser and Matticcio, 2006) have shown that there is a probability of (unintentional) non-closure of storm surge barriers resulting in possible, critical scenarios. In an a-priori assessment of the inlets with regards to their dimensions and proximity to the old-town of Venice, we identified that non-closure of the Lido inlet ('lidoopen') is likely the most critical partial-closure scenario. This choice in line with previous studies indicating the prominent importance of this inlet to manage water levels in Venice (Cavallaro et al., 2017; Umgiesser, 2020).*"

The authors of this work agree that this framework could be further used to analyse alternative closure scenarios.

In line 142, the authors mention that the d3dfm model "allows to account for additional processes like wave action or 1D flow of the sewage system". From the manuscript's text, these are not taken into consideration. In the specific case of Venice, it could be relevant to consider the effects of the sewage and drainage system when modelling high tide floods, as during high tide events water may come directly from underneath the city instead of overflowing from the canals. The non-consideration of such phenomena might lead to the underestimation of flooded areas, especially in a scenario such as Venice, where buildings are often attached to one another, leading to significant areas isolated from overland flow in the perspective of the hydrodynamic model. Indeed, this might be the case why Figure 6a shows that the hydrodynamic model underestimates flooding in the majority of cells with respect to the hydrostatic (bathtub) approach. Could the authors better explain why this option has not been included in the flood modelling framework?

We thank the reviewer for their relevant question. Indeed, we initially planned to account for alternative processes (including the sewage system). For clarification we added the following additional sentence starting in line 394: *"Those elements were not considered as no data on the 1D-network of the sewage systems and the other processes were available in due time and resources to investigate these data in field trips were not available."*

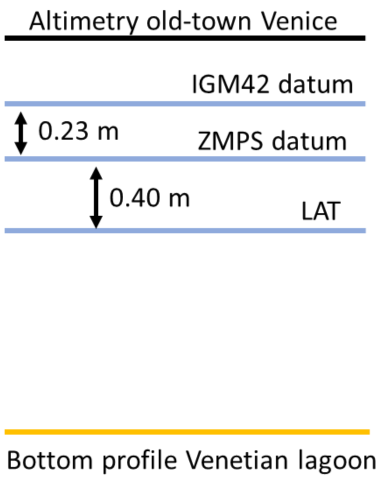
It is not clear from the text if the seven nested sub-models exchange information among themselves as boundary conditions or just with the parent model? Please better explain the nested setup.

We thank the reviewer for spotting this unprecise formulation. We have modified the sentence in line 149 as follows: *"Water level time-series from the parent model simulation were extracted at 168 locations inside and around the old-town of Venice. Every nested model is enclosed by a sub-set of these locations. Consequently, for every nested model, the water level time-series of the enclosing locations were used as the boundary inputs driving the hydrodynamic simulation. As such, the sub-models did not exchange information among each other but were run independently."*

Regarding the altimetry data that has been used in this study, has the correction to the ZMPS datum been done within the work developed in this manuscript or is it a data that has been obtained as already published from other sources? If the correction to the reference ZMPS level has been done as part of the work developed in this manuscript, please add a methodological description on how this has been performed (I suggest adding it in the supplementary material if possible).

The correction to ZMPS datum has been done within this work. We added a new sub-section "Conversion of altimetry data" and add an explanatory schematisation:

"Altimetry data were derived from various sources with varying reference datum as shown in Tab.2 of the main paper. Conversion of the altimetry to the ZMPS datum were performed by adding or subtracting the absolute difference between the respective datum and ZMPS as conceptualised in Fig. X. Accordingly, the bathymetry information of the Venetian lagoon and the canals within the old-town (both available in IGM42, where 0m IGM42 corresponds to + 0.23 m ZMP) were corrected by subtracting 0.23cm from the original IGM42-referenced altimetry data. The surface of the old-town of Venice (also provided in IGM42) was corrected by adding 0.23 cm given that the surface was generally located above the respective MSL. Altimetry information of the Adriatic shelf were provided with reference to the LAT datum which was assumed in this work to approximately correspond to -0.4m ZMPS. Consequently, bathymetry of the Adriatic shelf was corrected by adding +0.4 m."



The authors refer to "grid instabilities" in lines 298 and 299. Could the authors better explain what are those instabilities and how are they defined? Also, it is not clear if the whole Castello sub-model was affected or just part of it (14% of total, where total refers to the Castello sub-model or to Venice?). Please better explain.

We thank the reviewer for this in-depth question. When referring to "grid instabilities", we mean that during the model run to compute water level time-series in all grid elements, water levels start to increase locally to extreme levels. In the 'Castello' sub-model these instabilities were locally extreme (in the order of 10-20 meters (ZMPS)). At other locations, they only had a minor effect. According to the D3DFM-documentation, such instabilities can occur at dry cells that contain only a very limited amount of water. Also, from modelling experience it has been found that instabilities could occur if grid element resolution is varying strongly at a certain location, or altimetry information is changing too drastically.

Although many attempts were made to solve these instabilities (going even so far to re-create the entire sub-model 'Castello'), no reason/solution could be found. Finally, we decided to ignore the hydrodynamic results for sub-model 'Castello' and use the bathtub information instead. Consequently, for all 2,098 buildings located in sub-model 'Castello' (about 14% of all buildings in the old-town of Venice) flood depth estimates could only be derived using the bathtub model.

Minor Reviews:

Some of the graphics are difficult to read due to their low quality and/or small font size (e.g. Figure 9).

Thank you for highlighting this, we have updated all the graphics to .eps and partially increased font sizes.

I might be wrong, but Figure 8 may be out of scale on the y-axis for the variable F2 (risk taking IPS).

Thank you very much for spotting this. Indeed, the figure was out of scale. The figure has been updated.

Figure 9a, as a suggestion to improve the readability of the figure, it would be interesting to add some indications on when MOSE is activated and deactivated.

Thank you for this comment. Since the figure is already rather complex, we decided to add an elaboration in the caption text instead. It was changed to: *"Flood depths for scenarios. a: Modelled flood peaks at Punta della Salute. MOSE barrier activation for the different scenarios was 12/11/19 18:40 (SLR0), 12/11/19 18:10 (SLR1) or 11/11/19 18:10 (SLR2) according to Tab. 4."*

Line 2-3, sentence "limited scientific knowledge of flood hazard and flood damage modelling of the old-town of Venice is available to support decisions to mitigate existing and future flood risk."; I would suggest to rephrase the sentence, as flood hazard information is available, including publicly-available flood maps and walking paths covering the historical city centre of Venice for different flood quotas. Instead, information about flood risk is definitely much less available.

Thank you for this comment. We rephrased line 2-3 to: *"Despite this existence-defining condition, limited scientific knowledge on flood risk of the old-town of Venice is available to support decisions to mitigate existing and future flood impacts."*

Some sentences are unclear and/or could be better structured (e.g. line 1, "Flooding has been a serious struggle to the old-town of Venice, its residents and cultural heritage and continues to be a challenge in the future."). Also, spelling is mixed between British and American styles (e.h. behaviour vs. behavior; analyse vs. analyze). An in-depth proof-reading of the manuscript is recommended.

Thank you for this comment. We reviewed the manuscript thoroughly and corrected spelling errors. We changed the sentence in line 1 to: *"Flooding causes serious impacts to the old-town of Venice, its residents and cultural heritage."*

Line 2 and line 51; is the term "existence-defining" correctly employed (particularly in the phrase of line 2)? Or should be "existence-defying"?

Thank you for this comment. We think that both terms are usable. The situation is existence-defining as a lot of daily life is affected (and partly limited) by flood risk. But it could also be interpreted as existence-defying because of the struggle caused by flooding that makes the old-town rather inhabitable. From our perspective, the narrative along the lines of existence-defining makes more sense, since people still choose to live there, even though limited knowledge is available on the (development) of flood risk.

Line 24; please correct the definition of exposure as, following the IPCC definition, it is not only related to human systems, but to the "inventory of elements in an area in which hazard events may occur". The next phrase on the manuscript highlights this, and the text should be consistent (i.e. "human health, environment, cultural heritage and economic activities").

Thank you for this comment. We reviewed the manuscript thoroughly and corrected spelling errors. The definition of exposure terminology has been adjusted in line 24 as follows: "*According to the IPCC, flood risk is defined as the combination of a specific hazardous flood event, elements (i.e. infrastructure, people, livelihoods, environment, and cultural, social and economic assets) which might be exposed to a hazard in a certain area, and the vulnerability of these elements, meaning predisposition to be adversely affected \citep{Field.2012}."*

Line49: The phrase "Additionally, intangible damages to cultural heritage sites and their meaning for the cultural identity of the region and nation can be expected (Wang, 2015)" is not very informative and could either be removed or extended with some examples of intangible damages to cultural heritage sites.

We extended the existing sentence in line 49 with a few examples which have been reported for the disastrous flood of 1966 in Florence as follows: *"Additionally, intangible damages to cultural heritage sites (e.g. loss of historic books or documents, damage to iconic paintings) and associated effects on the cultural identity of the region and nation can be expected \citep{Wang.2015, Arrighi.2018}."*

Please define all acronyms in the main text (e.g. ZMPS, IGM42, etc.).

We added the definition for the acronyms ZMPS, IGM42, LAT and RMSE.

As a suggestion, the paragraph between lines 69 and 75 could be moved to the methods section.

We thank the reviewer for their suggestion and agree with it. We therefore moved the paragraph between l.69 and l.75 along with figure 1 to the methods sections.

Please better explain the phrase in line 150 “All grid points inside a 4m buffer around each structure were used to derive an average water level”. Does this means that water level per building considers only the surrounding flooded pixels or all pixels? Please clarify?

To clarify, we modified the sentence in line 150: *“Within each nested model, the maximum water level per building was derived by taking into account the maximum water levels of every grid point within a 4m distance from the building perimeter.”*

Unless supported by a reference or data, I would suggest renaming the "Expected IPS" scenario to something else that better fits with the assumptions and discussions, such as "Risk neural IPS".

We want to thank the reviewer for this comment and totally agree. Expected IPS has been renamed to medium IPS throughout the manuscript (and figure legends). We did not use the term risk neutral as it is also used to define indifference about risk.