We would like to thank the Reviewer for his/her interest in our work and for carefully reading our manuscript; we greatly appreciate the insightful comments as they contribute to increase the manuscript robustness and, in general, to improve its quality. In the following, we provide a point-by-point reply to the general and specific comments raised.

REVIEWER 2

The paper introduces INSYDE 2.0, a flood damage modeling tool that integrates ultra-detailed survey and desk-based data to enhance the reliability and informativeness of flood damage predictions. By incorporating a probabilistic module, it addresses missing input data and provides transparent information about uncertainties arising from limited knowledge of damage explicative variables. This integration significantly improves the reliability and robustness of flood damage assessments. While the extensive use of ultra-detailed data contributes to the model's reliability and the importance of accurate damage estimation, the logical coherence and readability of the manuscript still require significant improvement. Therefore, a major revision is necessary to strengthen the manuscript for potential publication.

Major comments:

R2.C1. One of my main comments is regarding the dataset used in this study. The manuscript introduces various datasets, such as synthetic datasets, observed datasets, survey datasets, auxiliary datasets, specific datasets, and empirical datasets. However, it is unclear what each dataset represents and how they are related. Are these datasets intended to establish the functional relationships between building parameters, serve as reference data, or facilitate model validation? The lack of clarity regarding the nature and relationships of these datasets, as well as their correspondence with the terms used in Figure 1, significantly hampers readability. I think it's good to provide a bit more information on the construction of all these datasets. Particularly since this manuscript focuses on uncertainty analysis.
Reply: We agree with the Reviewer that the original description of the various datasets involved in our study may lead to confusion. In the revised version, we will provide a more precise and clear explanation of each dataset's purpose and how they interrelate. This clarification will be particularly emphasized in the revision of Figure 1, ensuring a better understanding of the roles these datasets play in establishing functional relationships between building parameters, serving as reference data, and facilitating model analysis and application. This adjustment will aim to enhance the overall readability and coherence of the manuscript.

R2.C2. The description of building damage in the paper is not very intuitive, and the location distribution information of buildings is hardly mentioned, so it is difficult for readers to apply INSYDE 2.0 to their examples. In my opinion this question - how do we sample complex and spatially distributed variables in a meaningful way? - is one of the key research questions that the uncertainty and sensitive analysis community will need to work on if we want to move on to the next stage of applying this type of technique to complex models. I am not suggesting the authors should solve this issue, but I think they should point out this is a very important and critical step and a big area for future research and development.
Reply: In the revised manuscript, we will enhance the description of the study area, including the incorporation of a map to provide a clearer understanding of the geographical context. We acknowledge that addressing the question of how to effectively sample input variables for damage models is a key challenge and an area for future research and development within the community. In our paper we have proposed an attempt for solving this issue (with a framework that can be replicated also in other areas), by deriving representative distributions from multi-source data, which allow to sample unknown input features at the local scale.

R2.C3. In Section 2.2, the meaning of "specific catchments of the district representing the distinctive inundation types occurring in rural or urban areas as well as in flat or steeper regions within the Po River district" is unclear. It would be beneficial to include a spatial distribution map or a dem illustrating the Po River district to provide a better understanding of the study area.
Reply: A map of the Po River District will be incorporated in the revised version of the manuscript to provide a visual representation of the study area.

R2.C4. While it is described that nearly 5000 hypothetically flooded buildings are analyzed, the manuscript does little to explain or describe the building characteristics involved. Numerous contributing factors affect

economic loss. Given the primary objective of this manuscript is to quantify loss, it would be necessary for the authors to describe the 5000 hypothetically flooded buildings in more detail.
Reply: In the revised manuscript, we will make clear that the 5000 hypothetically flooded buildings are sampled from the empirical distributions presented in the original Table 2, which already comprehensively describes the housing stock in the Po River District.
R2.C5. In lines 298-301, I guess the authors mean that high variability in certain parameters leads to significant deviations in loss estimation. If so, this issue represents a substantial portion of the cases and should be addressed. The authors may consider discussing potential measures to reduce such errors.
Reply: In the specified lines, the text indeed addressed the fact that high variability in certain parameters can lead to significant deviations in loss estimation. This issue was thoroughly explored in the section discussing the feature importance, where it was acknowledged that certain variables carry more importance than others due to their role played on damage mechanisms. Additionally, another aspect is also discussed: it points out that variations in input parameters may only result in damage variations if certain conditions on other parameters are met.
Regarding the suggestion to identify measures to reduce "errors," it is important to note that these are not errors, but uncertainties. Instead of aiming to reduce uncertainty, the focus of the study is on providing explicit information about it and highlighting the importance of the features that contribute to this uncertainty and this perspective will be maintained in the revised version of the manuscript.

Minor comments:

R2.C6. Language and Sentence Structure: Please carefully review the manuscript for sentence clarity and readability. Some long sentences, such as lines 301-303, are difficult to follow. Consider breaking them into two sentences or rewriting them for better readability.
Reply: In revising the manuscript, we will enhance the overall readability of the text, by paying particular attention to longer sentences to make them clearer, potentially by breaking them into two sentences or rephrasing them for better readability.

R2.C7. Line 154: Typo - "250.000" should be corrected.
Reply: This will be fixed in the revised version of the manuscript (250'000).

R2.C8. Line 156-158: Please describe the meaning of values "c_1-c_5."
Reply: They are constant values introduced in the expert-based approach to obtain the desired functional relationships among the variables. We acknowledge that this may not have been explicitly mentioned in the original manuscript and we will therefore clarify it in the revised version.

R2.C9. Line 163-164: Clarify the meaning of "to obtain the correct distributions without losing information on the interdependence among the variables, the values of d*, v*, and s* were then replaced with the correspondent percentiles from the datasets of d, v, and s."
Reply: This sentence will be improved for clarity in the revised version of the manuscript as follows:
"[…] More in detail, probability distributions were first retrieved independently for the hazard variables based on detailed data when available (he, v) or upon expert-based assumptions derived from aggregated or approximated data (d, s, q), and used to sample sets of 250.000 elements; furthermore, the following functional dependencies were assumed to describe the correlation among the features, based on the values sampled for he, d and v:

$$d^* = c_1 + c_2 \cdot \sqrt{he} \cdot N(\mu = 1,\ \sigma = 0.2)$$

$$v^* = c_3 - d/\max(d) \cdot N(\mu = 1,\ \sigma = c_3 - d/\max(d))$$

$$s^* = c_4 + c_5 \cdot \sqrt{v} \cdot N(\mu = 1,\quad \sigma = 0.2)$$

with N being a random number from a normal distribution with mean μ and standard deviation σ, while the coefficients c_i are constant values introduced in the expert-based approach to obtain the desired functional relationships among the variables. q was instead assumed independent from the other hazard features.
Although the resulting d*, v* and s* account for the correlation among the hazard variables, they do not follow the probability distributions retrieved independently for the variables d, v and s; on the contrary, the latter were sampled independently from the correct distributions but they do not provide information on the rank correlation among the variables.

To obtain a dataset with both the mentioned properties, the values of d*, v* and s* were then ranked and replaced with the corresponding percentiles derived from the ordered versions of d, v and s."

R2.C10. Table 2: Define "ECDF" in the table or provide the abbreviation at the end of the table for better understanding.
Reply: We will include the definition of "ECDF" (empirical cumulative distribution function) at the end of the table to enhance clarity.

R2.C11. Line 174 and 177: Clarify the difference between hypothetically flooded buildings and the generated synthetic dataset. Consider listing the involved datasets in a table or figure and explaining their significance.
Reply: As in the general comment raised by the Reviewer, we recognize the need for clarity regarding the various datasets used in this study, which will be handled in the revised manuscript, by explicitly distinguishing and explaining the significance of each dataset involved in the study. Specifically, concerning lines 174 and 177, we underline that the 5000 hypothetically flooded buildings are directly sampled from the synthetic dataset, the characteristics of which are detailed in Tables 1 and 2.

R2.C12. Figure 3: Provide further explanation for the labels in the figure.
Reply: The figure labels represent various building parameters such as footprint area (FA), basement area (BA), external perimeter (EP), internal perimeter (IP), and basement perimeter (BP). The explanations for each label are already shown in the original figure caption.

R2.C13. Line 235: Explain the diagonal axis of Figure 2, including the value of the y-axis.
Reply: The diagonal of Figures 2 and 3 shows the density plots for the different variables; in the revised version of the manuscript we will amend the figures by fixing the label of the y-axis for the plots on the diagonal by reporting density values.

R2.C14. Line 255: In Figure 4, clarify the meaning of the bar colors and the red dots. Additionally, explain the color progression from dark blue to light blue and indicate if it represents a rank sequence. Complete all figure labels or provide the necessary information in the figure caption.
Reply: In Figure 4, the bar colors and color progression represent a rank sequence based on the median value of the damage difference, with darker blues indicating higher variable importance. This ranking information was already outlined in the original figure caption. The red dots within the figure represent outlier values, a detail that will be explicitly included in the revised figure caption for a better clarity.

R2.C15. Figure 7: Increase the resolution of the figure.
Reply: The figure is originally generated in high resolution (600 DPI). The observed issue with resolution is likely related to the rendering during the generation of the PDF file.