

## Reply to reviewer comments

We thank the Reviewer for this additional round of feedback, which has helped us to further improve the manuscript. We have addressed all of the comments and revised the manuscript accordingly. We also took this opportunity to carefully proofread the manuscript, correct any remaining typos, and rephrase some sentences to improve its overall readability.

A detailed response to each comment is provided below. **Line numbering refers to the updated version of the manuscript (without track changes).**

### Comment 1

#### Clarification of the interpretation of Section 2.3

Section 2.3 presents a structured exploration of model behaviour under different parameter assumptions rather than empirical insights about real-world hazard impacts. The analysis is useful because it quantifies how recovery dynamics and vulnerability interactions can influence cumulative damage.

However, some statements in the manuscript read as if the results demonstrate general properties of real multi-hazard systems. For example, the manuscript states that (L387) “the results confirm that multi-hazard impacts are path-dependent” and that the Puerto Rico case (L368) “confirms that neglecting residual damage persistence leads to systematic underestimation of cumulative impacts.” These conclusions arise primarily from model experiments under stylised parameter assumptions rather than from direct empirical inference. The authors may therefore wish to review the wording in this section to ensure the interpretation remains consistent with the model-behaviour nature of the analysis.

### Response 1

We thank the Reviewer for raising this valuable point. We agree that the discussion on both the model and the case study in Puerto Rico reports some statements that were too general and could be interpreted as empirical evidence rather than as insights derived from the proposed modelling framework.

Following this suggestion, we revised the interpretation of the results provided in the manuscript to ensure that it remains consistent with the exploratory nature of the model behaviour analysis.

At the end of Section 3 (Forensic multi-hazard damage analysis in Puerto Rico), the sentence “*The Puerto Rico case confirms that neglecting residual damage persistence leads to systematic underestimation of cumulative impacts...*” has been revised to:

***"The Puerto Rico application illustrates, within the explored modelling framework, that accounting for residual damage persistence improves the representation of cumulative impacts in consecutive multi-hazard sequences, as neglecting recovery processes may lead to lower damage estimates."*** [L 374 - 376],

explicitly framing the case study as an illustration of the proposed methodology rather than as a general empirical confirmation.

In the Discussion:

- *"Overall, the results confirm that multi-hazard impacts are path-dependent..."* has been rephrased as ***"Overall, the model effectively captures the path-dependent nature of multi-hazard impacts, showing how ..."*** [L 394 - 395];
- *"The results confirm that damage is not just additive..."* has been revised to ***"The results show that, within the explored modelling framework, cumulative damage estimates are strongly influenced by event order, timing, and recovery dynamics..."*** [L 407 - 409].

In the Conclusions, the sentence *"The results highlight that neglecting recovery dynamics or state-dependent vulnerability adjustments..."* has been revised to ***"The model experiments highlight that, under the explored parameter configurations, neglecting recovery dynamics or state-dependent vulnerability adjustments..."*** [L 552 - 553] to explicitly clarify that these findings originate from the systematic exploration of the proposed modelling framework rather than from direct empirical inference.

## Comment 2:

### Choice of the 5–30% range

The manuscript suggests using a range of 5–30% for one of the key parameters when exploring possible outcomes. It is not entirely clear to me how this range was chosen. Is this range based on empirical evidence or literature, or is it primarily intended as an illustrative range for exploring possible model outcomes? If the latter, it might be helpful to state explicitly that this represents a modelling choice (i.e., a form of normative uncertainty) rather than an empirically constrained parameter range. Alternatively, if there is literature supporting this choice, a short justification would strengthen the argument.

## Response 2

We thank the reviewer for raising this important point. We agree that the rationale behind the 5–30% range was not sufficiently clear in the manuscript.

This range represents an exploratory modelling choice used to investigate how different levels of residual vulnerability influence cumulative damage estimates within the proposed cumulative damage framework based on state-dependent fragility curves. It is intended to represent a spectrum of plausible residual vulnerability conditions for

future ex ante applications, in the absence of spatially explicit information on residual damage.

The selected range was partially informed by an empirical calibration against reported losses from the Puerto Rico case study, which identified a 15% vulnerability modification as the value most consistent with the observed losses. This value falls within the proposed range and corresponds to the level of residual vulnerability that best reproduces the observed losses in this specific case. The lower bound of 5% captures a limited but non-negligible residual effect, while the upper bound of 30% allows more substantial effects to be explored.

Accordingly, we have revised the manuscript:

*"In the absence of spatially explicit residual damage data, a predefined range of vulnerability modifications (5–30%) was considered. This range provides an exploratory basis for investigating how different levels of residual vulnerability influence cumulative damage estimates. An empirical calibration against reported losses from the Puerto Rico case study identified a 15% vulnerability modification as the value most consistent with the observed losses. This value falls within the proposed range, which is intended for future ex ante applications to account for a broader spectrum of plausible residual damage conditions. The lower bound of 5% captures a limited but non-negligible residual effect, while the upper bound of 30% allows more substantial effects to be explored."* [L 336 - 342]

### Comment 3:

Minor comment

The manuscript frequently uses the term "forensic" (e.g., "forensic insights"). I understand the intended meaning as a detailed post-event reconstruction of damage dynamics. However, the term may not be immediately clear to all readers in this context. The authors may wish to briefly clarify the meaning of this term when it first appears in the manuscript.

### Response 3

Following the reviewer's suggestion, we have clarified the meaning of the term "forensic" at its first occurrence in the Introduction by adding the following sentence:

*"This detailed post-disaster reconstruction of damage dynamics is referred to in the following as a 'forensic' approach."* [L 65-66]

We have also reviewed the Abstract by revising the sentence describing the Puerto Rico application. Specifically, the expression *"The forensic reconstruction highlights..."* has been modified to *"The detailed reconstruction of past damage dynamics highlights..."*.