Answer to Referee Comment #1

Thank you for your encouraging comments and the suggested modifications that will improve the quality of the paper and its readability. Please find below a point-by-point answer to the comments you raised. Please note that, as suggested by Referee #2 and #3 the structure of the paper will be rearranged. The updated structure is presented p4 of this document.

Minor Corrections

Comment 1: Often loss models in the insurance industry are often referred to Catastrophe models. Was there a reason not to use this terminology in the paper?

Thank you for raising that point. It is correct, and I should be more explicit on the reasons why I choose the term natural hazard modelling instead of catastrophe modelling.

Using the term catastrophe modelling implies that only events causing extreme damages are considered in the model. At the beginning, focus was made on high return-period loss events, driven by an extreme hazard intensity, an accumulation of exposure and/or vulnerable buildings. Catastrophe models were then used to assess the risk for a given portfolio. As more and more data has been included in the calibration of the models, they now capture much more than just extreme loss events. In the hazard module, all the spectrum of events (i.e. moderate/intense; frequent/rare events) is considered. In the vulnerability module, vulnerability curves cover all value of hazard intensity. In terms of usage, "catastrophe models" are now used to estimate budget and premium, mainly driven by smaller events, meaning that (re)insurers are interested in capturing small / frequent events in addition to large/rare ones.

I suggest evolving towards the use of the term natural hazard modelling as it widens the scope of events considered, compared to the term catastrophe modelling. In addition, as catastrophe models now include models for man-made perils (e.g. cyber risk, terrorism…), the term natural hazard modelling allows for more precision on the scope targeted by the model.

Line 6. I'm not sure what this means can you rephrase "of the development of a wide community around natural hazards as well as of the occurrence of natural hazards."

Agreed and modified

Line 10. It would be useful to be specific and say "financial protection"?

Insurance protection goes beyond the financial aspect of the risk transfer (i.e. the payment of a premium by the policy holder against the payment of future claims by the insurance company); it also includes prevention actions such as increasing risk awareness and proposing adapted protective solutions. I suggest to develop this point in the paper by giving two examples:

1) For the commercial business (corporates' policy holders): technical risk experts perform on-site visits to evaluate buildings' conditions and identify potential vulnerabilities to natural hazards. The objective is to assess how natural hazards could generate damage either to the building itself (e.g. storage warehouse, data center, shopping centers) or to its contents (e.g. machineries, production chain, products' stock…), and if such damages could cause business interruption (e.g. employees / clients cannot access the building for 10 days leading to a loss of turnover or profits). Following such assessment, prevention measures are then suggested or imposed to reduce the risk (e.g. elevate goods or machinery in the case of a flood event or reinforce some key components of the building to reduce the impact of ground shaking).
2) For the retail business (individual policy holders) : in this case, as protection actions cannot be tackled individually because of the mass of clients, they are taken globally. For example, after the Great Fire of London in 1666 that destroyed most of the buildings of the City -made of wood at that time-, insurance premium rates were lowered for building made of brick in order to encourage the use of bricks instead of wood and therefore reduce the fire risk in London.

Line 11. Presumably you mean "insurance company" here?

Agreed and modified

Line 26. This sentence is very difficult to parse. I would suggest simplifying "keep refining what we know on one hand and, on the other hand, increasing insurers' preparedness to what we do not know" to "keep refining what we already know and to increase insurers preparedness for the unknown."

Agreed and modified

Line 37 Incorrect grammar. Perhaps rephrase "did not enable to seize the impact of growing exposure in particularly risk prone areas" to "were not able to assess the impact"

Agreed and modified

Line 41 "…work of characterization of the here before cited four components for various.." I'm not sure what this means can you rephrase.

To give more clarity to this point, I have included more details on the loss modelling framework and each of the 4 components. This sentence is also rephrased.

Line 42 Spelling mistake? "Each peril x region"

Agreed and modified

Line 43-47 The text here on the data formats used seems rather irrelevant for a brief history of loss modelling. There could be removed to make the paper more concise and improve readability, without affecting the main message of the manuscript.

This is a key aspect of natural hazard modelling and one of the challenges faced today by the community. Data format is just the tip of the iceberg and refers to the way data is gathered and organized in each component of the loss modelling framework with the objectives of optimizing the run time (i.e. results are expected to be available after a few hours of run time) while dealing with IT constraints (i.e. memory limit, CPU/GPU…).

There is therefore a gap between the quality and the sophistication of modelling produced by research and the derivative data compiled to meet the requirements of the loss modelling framework. As an example, the severity of natural events is captured in the hazard component through the use of hazard footprints, defined as the maximum hazard value (e.g. windspeed, flood depth, peak ground acceleration…) at each grid cell of the considered area over the duration of the event. The information relative to the event duration and to the evolution of the hazard value over time are lost, while they are parameters that impact the assessment of buildings' damage.

As part of the restructuring of the paper (as presented in the supplement document), more details on why the transmission and the intersection of information from one component to the other is crucial.

Line 48 "highlighted on one hand the non-modelled effects of the drivers of risk and on the other hand the insurance protection gap that was existing in Florida and the inefficiency of private and public mechanisms (McChristian, 2012)."

This sentence needs rephrasing – it's not clear what the "inefficiency of private and public mechanisms" is referring to.

This will be rephrased.

Line 60. I'm not sure what is meant here, are there missing words? "...notably the location at (longitude, latitude) granularity and the physical properties of buildings."

More details will be given.

Line 65 "observation data" should be "observational data"

Agreed and modified

Line 69. I'm not sure what is meant here, are there missing words? "…less structural damages on buildings and population is evacuated."

Understood, it will be rephrased to explain better why there are less observational data of building damages following flood or windstorm events.

Line 93 "This enables to identify sensitive components which may…" should be "This enables sensitive components to be identified, which may…"

Agreed and modified

Line 95. "Such an analysis requires first to run the production of the hazard catalogue several times…" should be "Such an analysis first requires the production of the hazard catalogue to be run several times…"

Agreed and modified

Line 116. "identified evolutions" perhaps should be "identified improvements"?

Agreed and modified

Line 127 Delete second repetition of "in the world" for readability.

Deleted

Line 128 Could you rephrase or expand on what is meant by "suppliers' default"?

Agreed and rephrased. Suppliers' default, in the context of natural hazards, refers to the situation when a supplier is not able to provide its clients in the aftermath of a natural event.

Line 131 "while making a research progress" should be "while making research progress"

Agreed and modified

Line 137 "insurers do not only need to" should be "insurers need to not only"

Agreed and modified

Line 137 The recent Fiedler et al. (2021) does a good job of outlining the challenges for climate change analytics and could be cited here.

I completely agree and will refer to it.

Line 147. "Over the years…" The sentence here is overlong and could be improved by splitting into two.

Agreed and modified

Line 153 Spelling mistake? "peril x region"

Agreed and modified

Suggested structure following RC2 and RC3 comments:

(i)   Loss / risk model development from a historic perspective
- Example of Hurricane Andrew
- Detailed discussion on
  - the three components (hazard, exposure, vulnerability)
  - the loss simulation process (i.e. how the transmission and the intersection of information from one component to the other is performed)
- Details related to the (re)insurance market and its evolution regarding natural hazard risk modelling

(ii)   Uncertainty in each of the components (current state) and its quantification / how we improve and measure what we know
- Uncertainty driven by data quality and availability by component (exposure, hazard and vulnerability), some are inherent, some can be improved (e.g., uncertainty in hazard modelling due to a lack of appropriate observations and/over observation data over longer time periods is not mentioned). Include examples such as:
  - Improvement of exposure data to get precise information on buildings' coordinates and physical characteristics
  - The access to various type of hazard measurements, the availability of reanalysis datasets for atmospheric hazards
- Uncertainty caused by modelling assumptions and approaches. Include examples such as:
  - Improvement of the modelling of serial clustering of European Windstorms
  - The impact of parameters setting in hydrologic tools (Kaczmarska et al. 2018)
- Uncertainty caused by the implementation in the loss modelling framework

(iii)   Perspectives: Challenges, further needs, and expected developments to address these needs
- Need for systematic analysis and quantification of uncertainties, component by component and on the overall loss simulation process
- Identified challenges (e.g. how to model interrelated hazards and their impacts, how to model the impact of natural hazards on supply chain, the role of machine learning…)
- Management of unknown unknowns in natural hazard modelling