Replies to the reviewers' comments on "Non-stationary extreme value analysis applied to seismic fragility assessment for nuclear safety analysis". (nhess-2019-400)

We would like to thank referee #3 for his/her constructive comments. We agree with most of the suggestions and, therefore, we have modified the manuscript to take on board their comments (outlined in green). In the following, we recall the reviews and we reply to each of the comments in turn (outlined by "**<Authors' reply>**").

<u>Please note that the line numbers of changes are indicated and correspond to the revised manuscript with marked changes.</u>

Referee #3:

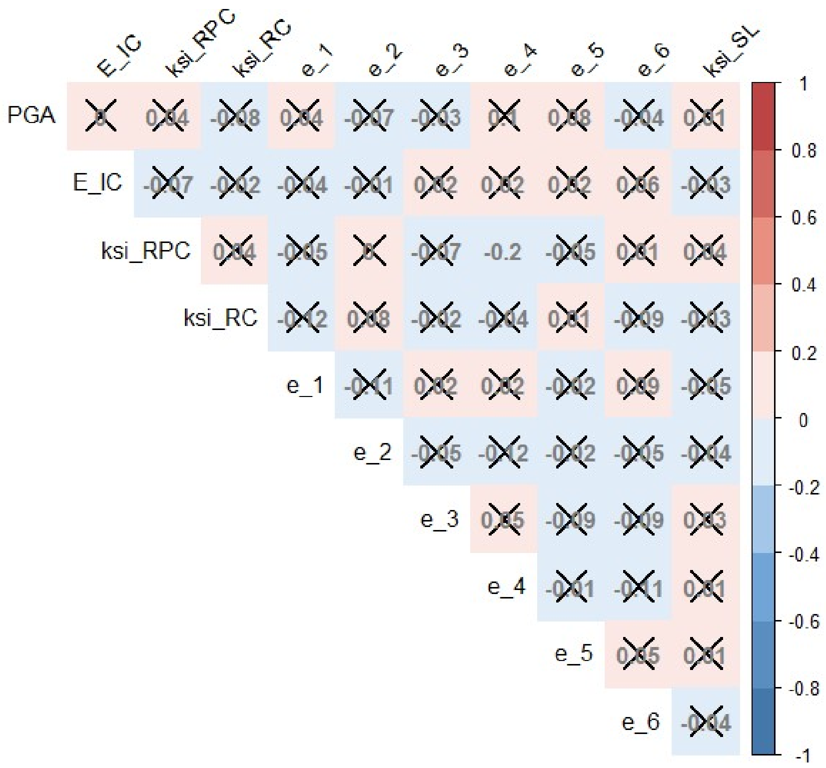
In this paper, the authors investigate how the tools of non-stationary extreme value analysis can be used to model in a flexible manner the tail behaviour of the engineering demand parameter as a function of the considered intensity measure. The focus of the analysis is the dynamic response of an anchored steam line and of a supporting structure under seismic solicitations.

I recommend the publication of this paper after minor revisions

Comments:

1. The paper describes very carefully all the assumptions and drawbacks of the proposed method, compared to the traditional strategy to compute Fragility Curves.
I believe that section 3 can be improved by supporting the choice of the mechanical and geometrical parameters of interest for the quantification of the epistemic uncertainty, with some sensitivity analysis (Sobol's indices for instance). In this way, the influence of each parameter can be assessed and the whole problem dimensionality (maybe) reduced before hand (as the authors recognized in section 4.2). Is there any correlation between EDP and the key mechanical and geometrical parameters?
<Authors' reply> Thank you for the suggestion that we find very valuable. We totally agree that a global sensitivity analysis would be useful to identify beforehand some key mechanical/geometrical parameters. This is now clearly outlined in the discussion section 5, page 28, lines 544-546 as follows "The latter approach [variance-based global sensitivity analysis] opens promising perspectives to ease the fitting process by filtering out beforehand some negligible mechanical/geometrical parameters. It is also expected to improve the interpretability of the procedure by clarifying the respective role of the different sources of uncertainty i.e. related to the mechanical/geometrical parameters, but also to the fitting process, which appears to have a non-negligible impact in our study".

Using linear correlation may be a solution to achieve this objective, but unfortunately, in our case, the matrix of Pearson correlation coefficient clearly indicates the lack of such linear relation. See figure below where the color indicates the magnitude of the coefficient, and the cross-like marker indicates where the coefficient is insignificant (at 1% level).



3. It would be very interesting to see whether synthetic input ground motion time-histories can improve the database concistency, especially for larger values of PGA, where the EDP dispersion seems larger.

<Authors' reply> We agree that using synthetic input ground motion time histories could be an alternative approach. It has been decided however to use only natural records in the present application, in order to accurately represent the inherent variability of other ground motion parameters such as duration. This is now clearly indicated in Sect. 3.2, page 11, lines274-276.

We also added two references on those aspects, namely:

Pousse, G., Bonilla, L.F., Cotton, F., Margerin L.: Nonstationary stochastic simulation of strong ground motion time histories including natural variability: application to the K-net Japanese database, Bull. Seismol. Soc. Am., 96, 2103–2117, 2006.

Boore, D.M.: Simulation of ground motion using the stochastic method, Pure and applied geophysics, 160(3-4), 635-676, 2003.

4. I suspect that the large influence of the damping coefficient on the GEV model might hide some non-linear effects taking place and/or some simplified assumption in the coupling method between structural dynamic response and anchored steam line. Could you clarify on this?

<Authors' reply> Thank you for this comment and for suggesting the possible explanation. We however recognize that the interpretation is difficult to conduct and further investigations are here necessary. At least, this exemplifies one advantage of the proposed procedure; this problem could not have been identified if the analysis of the partial effect had not been done.

We clarify this aspect as follows (Sect. 4.2.1, page 23-24, lines 465-475) "We show here that a larger number of input parameters were filtered out by the selection procedure i.e. only the thickness e_5 is selected as well as the damping ratios of the concrete structures ξ_{RPC} and ξ_{RC} (related to the containment building). The partial effects are all non-linear, but with larger uncertainty than for the location parameter (compare the widths of the red-coloured uncertain bands in Fig. 12 and 13). In particular, the strong non-linear influence of ξ_{RPC} and ξ_{RC} may be due to the simplified coupling assumption between structural dynamic response and anchored steam line (i.e., the displacement time-history at various points of the building is directly used as input for the response of the steam line). Identifying this problem is possible thanks to the analysis of the partial effects, though it should be recognized that this behavior remains difficult to interpret and further investigations are here necessary".

4. Finally, I believe that the final discussion should provide some hints on the use of surrogate/multi-fidelity modelling to fasten the sampling task and increase the number of realizations instead.
We agree with this suggestion. We added in the discussion section the following aspects (page 28, 549-554): "The treatment of this type of uncertainty can be improved on two aspects: 1) it is expected to decrease by fitting the FC with a larger number numerical simulation results. To relieve the computational burden (each numerical simulation has a computation time cost of several hours, see Sect. 3.2), replacing the mechanical simulator by surrogate models (like neural network, Wang et al., 2018 or using model order reduction strategy, Bamer et al., 2017) can be envisaged; 2) the modelling of such uncertainty can be done in a more flexible and realistic manner (compared to the Gaussian assumption made here) using Bayesian techniques within framework of GAMLSS (Umlauf et al., 2018)".

Added reference:

Bamer, F., Amiri, A. K., and Bucher, C.: A new model order reduction strategy adapted to nonlinear problems in earthquake engineering, Earthquake engineering & structural dynamics, 46(4), 537-559, 2017.

April 3[th], 2020

Jeremy Rohmer[1], Pierre Gehl[1], Marine Marcilhac-Fradin[2], Yves Guigueno[2], Nadia Rahni[2], Julien Clément[2]

[1]BRGM, 3 av. C. Guillemin, 45060 Orléans Cedex 2, France
[2]Institute for Radiological Protection and Nuclear Safety, Fontenay-Aux-Roses, 92262, France