Reviewer #1

This paper examines the extent of deep uncertainty in studies on projections of shoreline changes. First of all, I find elegant the definition of deep uncertainty based based on the concept of "possibility" in an "extra-statistics" context.
This could be indeed an interesting tool to assess more correctly the variability of predictions, when we have a reasonable range for the epistemic uncertainty.
The paper is well written and well structured. The explanation of what possibility is and of the model(s) used for shoreline predictions and their parameters is clear.
I believe a few lines would be useful, summerizing how the montecarlo over the "possibility", possibly with references. Is a possibility distribution treated mathematically like a probability distribution? Or is it used to select a CDF?
Apart from this request of clarification, I have only minor comments.

We thank the reviewer for her/his insightful comments that, we believe, will contribute to improve the clarity of our manuscript. Please find below our responses (in blue) and how the manuscript will be revised (preceded by an arrow).

I believe a few lines would be useful, summerizing how the montecarlo over the "possibility", possibly with references. Is a possibility distribution treated mathematically like a probability distribution? Or is it used to select a CDF?

The procedure for jointly propagating probability and possibility distributions builds on the combination of random sampling of the inverse of the cumulative probability distribution functions for random parameters and of the α-cuts (intervals associated to a level of confidence of 1-α) from the possibility distributions using the Independent Random Sampling (IRS) algorithm of Baudrit et al. (2007). The IRS algorithm is described below.

Consider k random input variables X_i (i=1,...,k), each of them associated to a cumulative probability distribution F, and n-k imprecise input variables X_i (i=$k+1$,…,n), each of them associated to a possibility distribution π. In this situation, the IRS procedure holds as follows:

- Step 1. Randomly generate from uniform probability distributions, m vectors of size n: $\{\alpha_i\}$, i=1,…,n, such that $0 \leq \alpha_i \leq 1$. For each realization:
- Step 2. Generate k values for the random input variables by using the inverse function of F_i: $x_i = F_i^{-1}(\alpha_i)$, i=1,...,k and sample n-k intervals I_i corresponding to the cuts of the possibility distributions (as defined in Sect. 2.1 and illustrated in Fig. 1) with level of confidence 1-α_i, i=k+1,…,n;
- Step 3. Evaluate the interval $[\underline{h};\overline{h}]$ defined by the lower and upper bounds associated to the model output h (in our case, the shoreline change) using the impact assessment model f as follows:

$$\underline{h} = \inf_I\left(f(x_1; \dots; x_k; I_{k+1}; \dots; I_n)\right);\ \overline{h} = \sup_I\left(f(x_1; \dots; x_k; I_{k+1}; \dots; I_n)\right)$$

Figure R1 schematically depicts the main steps of the propagation procedure considering a random and an imprecise variable. The output of the whole procedure then takes the form of m random intervals $[\underline{h};\overline{h}]$, with k=1,...,m. This information can be summarized within the formal framework of the evidence theory (Dempster, 1967; Shafer, 1976) as proposed by Baudrit et al. (2006) to bound the exceedance probability associated to the event "$h \geq t_h$" with t_h a given threshold. The result then takes the form of the probability-boxes as depicted in Fig. 5.

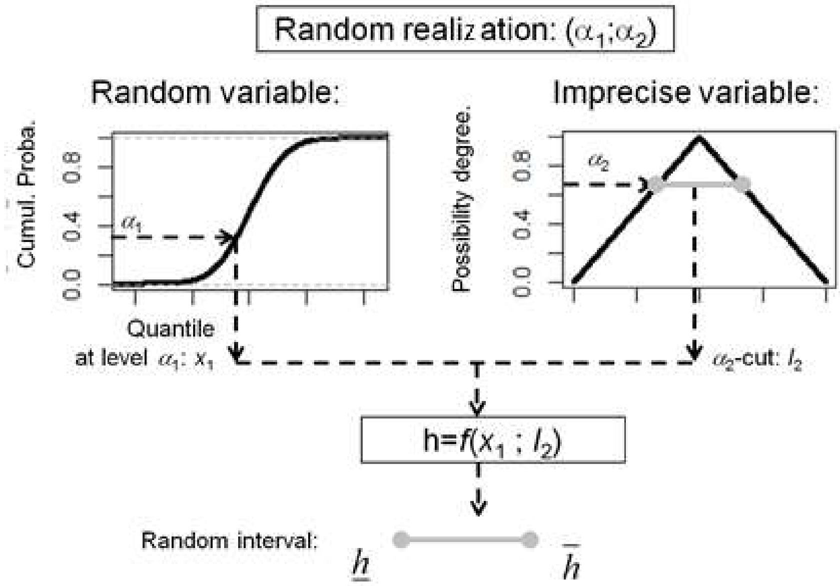

Figure R1. *Overview of the main steps for joint propagation of possibility and probability distributions.*

- ⇨ The manuscript will be revised by adding few lines of clarification about IRS procedure near L200-207 and by adding an Appendix at the end of the manuscript describing the IRS algorithm.

- formula 1: the angle is missing after tan. I would suggest to call the angle "beta" as "alpha" can be confused with the confidence level used earlier, and beta this is the symbol generally used in the Bruun formula.

Thank you for noticing.

- ⇨ We'll change α for β in the revised version of the manuscript and correct the formula.

- line 156, a brief explanation of what nx, Tx and lvar are should be given here, mentioning that the terms will be explained later in more detail.

We agree that the term *n Tx* can be better defined.

- ⇨ We'll now write: " *Tx* is the linear trend of shoreline changes over multi-decadal shoreline change and *n* the number of years relative to the baseline"

We do not want however to enter too much in details here since in the subsequent paragraph (starting at line 164), we provide additional explanations on these terms, mentioning that they correspond to evolutions over different timescales, and are not associated to particular physical processes. We remind also that relying on observations to assess trends and modes of variability of shoreline change is common practice in operational shoreline change management.

- line 157, substitute "in the following" with "below".

- ⇨ This will be corrected in the revised version of the manuscript.

- figure 2: I would appreciate a brief summery on how the hybrid montecarlo works.

Please refer to the 1st comment above.

- ⇨ The manuscript will be revised by adding few lines to clarify the IRS procedure near L200-207 and by adding an Appendix at the end of the manuscript describing the IRS algorithm.

- line 173-174: is lvar an uncertainty term, with and unknown sign? It would look like this, as it is computed as a standard deviation. This should be made more clear, for example writing +/- lvar in the formula.

In fact, Lvar is a particular realization of a random variable, and not a random variable itself. Although we prefer keeping the formula as it is, we agree that this deserves being clarified in the paper.

- ⇨ We'll include a sentence clarifying the issue of the sign just after describing how Lvar is derived.

- line 277: the acronym GNSS should be defined.

GNSS stands for Global Navigation Satellite System.

- ⇨ This will be added in the revised version of the manuscript.

- line 308: the acronym SONEL shoudl be defined.

SONEL stands for "Système d'Observation du Niveau des Eaux Littorales".

- ⇨ This will be added in the revised version of the manuscript.

- table 1: I would suggest to indicate also the possibilistic choice of the model here.

Our apologies but we are not sure to understand well the suggestion. Actually the choice of the model is already transformed into a possibilistic framework through the possibility distribution built for the tan α parameter.

- ⇨ We can propose to clarify this by adding a note to the tan α row in Table 1.

- line 240 and elsewhere: check what sign you use to indicate erosion/accretion. Here and in figure 4, a positive change is erosion. But looking at figure 5, it looks that the reverse convetion is used (a negative shoreline change where you have erosion).

Thank you for this comment. Assuming an observational reference near present (~2015 for Aquitaine and 2020 for Castellon), Figure 5 shows that when moving backward in time, we indeed have – relatively - an accretion in the past compared to the reference period (so increasingly negative values when moving further in the past). In contrast, when moving forward in the future, both sites are eroding (so increasing positive values when moving further in the future). Thus, in principle, the same convention appears to be used everywhere. We recognize however that this can be confusing and will make sure that the same convention is used throughout the revised manuscript.

⇨ Just before presenting any result, we'll include a statement clarifying the convention we use such as: "Thereinafter, positive and negative values represent erosion and accretion, respectively, with respect to the baseline (2015 for Aquitaine and 2020 for Castellon)"

- figure 6: I would suggest to add lines to identify the extent/position of the ambiguity and of the high/low ends.

As suggested, we re-designed Figure 6b (i.e. Aquitaine, 2100) in order to visualize the extent of the ambiguity and the position of high and low end values. The resulting Figure R2 appears heavier to us and we have the feeling that it does not bring real additional information since high/low-end and ambiguity values are already quoted in Table 3. Note also that Figure 6b is the panel of Figure 6 that offers the largest space to visually separate the vertical lines and bars with the suggested design; Figure 6a and c will look more loaded. An alternative could be to suggest to the journal a page layout joining Figure 6 and Table 3 on the same page. If the choosing the page layout is not possible, another alternative could be to include a sentence with additional information on these values in Figure caption.

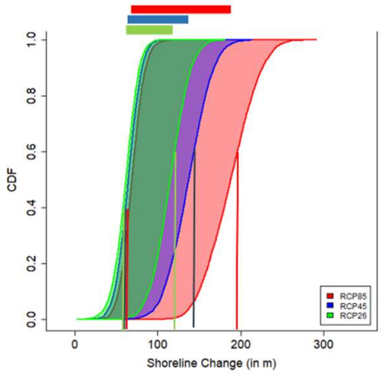

Figure R2. *Alternative design to Figure 6b, highlighting (i) the ambiguity by horizontal bars in the upper part and (ii) low/high-end values by vertical lines.*

- figure 7: Is it possible that fixing some param values the ambiguity increases? Maybe a line explaining this would be useful.

Thank you for noticing. Intuitively, we expect the ambiguity to decrease when we add knowledge i.e. when the epistemic uncertainty is decreased; for instance when SLR is fixed to a constant value. Yet, this is only valid if the IRS-based randomly generated random intervals (see step 3 in the IRS procedure; first comment) are of lower widths given the fixed value. This is not always the case and depends on how the characteristics of the mathematical function (i.e. given the fixed value) are optimized at step 3. In our case, Figure 7 shows that fixing the future SLR to very high values (e.g. 1.82 m) leads to an increase of the ambiguity and high-end values of a few percent. To illustrate this effect more clearly, Figure R3 below compares the resulting possibility box when considering either (a) the full SLR possibility distribution or (b) only a high-end fixed SLR value of 1.82 m. It shows that the shape of the possibility box is modified with an overall shift of the lower and upper CDF to higher values and a change in the width between the lower and upper CDF (note that this change also varies with quantiles).

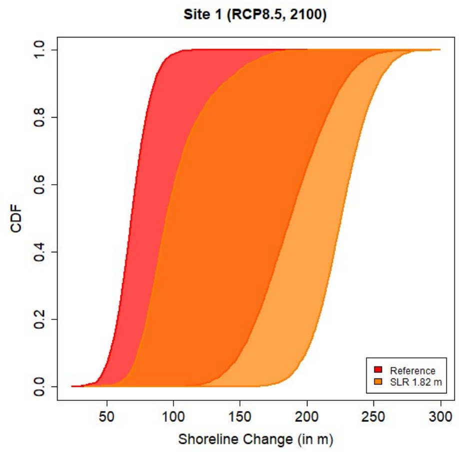

Figure R3. *Projected shoreline change probability boxes in 2100 in Aquitaine under the RCP8.5 scenario when (a) considering the full SLR possibility distribution or (b) fixing the SLR to a high-end value (i.e. 1.82 m).*

⇨ We will add few elements of explanation in the revised version of the manuscript where Figure 7 is discussed (L409-418) and will add the Figure R3 above as supplementary material.

- figure 8: the figure is truncated, the x axis is missing.

Thank you for noticing.

⇨ Figure 8 will be adjusted in the revised version of the manuscript.

References:

Baudrit, C., Guyonnet, D., and Dubois, D., 2006, "Post-processing the hybrid method for addressing uncertainty in risk assessments," Journal of Environmental Engineering, 131, pp. 1750-1754.

Baudrit C, Guyonnet D, Dubois D (2007) Joint propagation of variability and imprecision in assessing the risk of groundwater contamination. Journal of contaminant hydrology, 93(1):72-84.

Dempster, A. P., 1967, "Upper and lower probabilities induced by a multivalued mapping," Annals of Mathematical Statistics, 38, pp. 325–339.

Shafer, G., 1976, A Mathematical Theory of Evidence. Princeton University Press