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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "High-resolution marine flood modelling with coupled overflow and overtopping processes: framing the hazard based on historical and statistical approaches" *by* Alexandre Nicolae Lerma et al.

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We would like to thank the reviewer for his constructive criticism and support for publication. Below you will see that these comments have been addressed carefully:

- Reviewer comments

Our response

"Change in the text"

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- 1. Line 11, expected frequency of occurrence or the probability that the event will be exceeded in any year.

We clarify the text with this proposition:

Coastal flooding risks are usually defined by the intensity of flooding (spatial extent, water height, flow speed, etc. or a combination of these parameters) associated with the probability of occurrence, usually defined as the "return period".

- 2. Line 25, Expand the term SWASH model.

“the SWASH model (Simulating WAves till SHore)”

We also expand in text the MARS and SWAN model abbreviations

“(. . .) by coupling a hydrodynamic model (MARS, hydrodynamical Model for Applications at Regional Scale, Lazure and Dumas, 2007) with a spectral wave model (SWAN, Simulating WAve at Nearshore, Booij et al., 1999) (. . .)”

- 3. Line # 15 – 21, authors pointed that it does not require any assumption of dependence structure and extended to higher dimension. However, they only multivariate GPD model in their analysis. On the other hand, the marginal variables can follow any distributions, and copula modeling offers this advantage over other multivariate distributions. In addition, they also offers tail dependency through various metrics, such as,CFG, LOG or SS estimators. Extension to higher dimension is feasible using Vine or t-copulas. We agree with the referee that copulas also offer a suitable framework to model multivariate dependency. However we believe it is somewhat more complex and also more subjective since a dependence structure exhibiting either asymptotically dependence or independence between variables is assumed beforehand. Although statistical tests exist to help selecting the best model among many, a given parametric form has to be chosen eventually even though there are usually few observation data in the region of interest (extremes). As this is rather a personal point of view, we decided to remove the passage mentioning copulas.

In our methodology, only GPD are used to model marginal distributions. This is because GPD is the most general model for the distribution of excesses over a suitably chosen high threshold whatever the variable under study (Pickands, 1975). It is also widely used in the coastal and ocean scientific community. However, the semi-parametric model for conditional extreme values of HT04 is not limited to GPD margins. Any other marginal distribution can be used since it is transformed into Gumbel margin before fitting the dependence model.

- 4. Line 19, is the peak period unit is in 'seconds'?

Yes, we clarify this point

- 5. Some of the references are missing, such as, Stepanian et al. 2014, Lazure and Dumas, 2007. Please check others.

We are confused for this error, we include the references in the list and we checked all others

- 6. Line 25 _ 30, will land cover and land use data remain stationary since 2006 even if considering impact of urbanization?

New urbanizations or land use changes from 2006 were also updated using orthophotographs and field observations. This is now notified in text.

- 7. Line 6, 'Nord' is to be replaced with 'north'.

It was modified

- 8. Line 7, 'IFREMER MEDNORD' model. In summary, it would be good to give short description of the various models used in this analysis either in the Appendix or in Supplements. Further, in all cases, only abbreviation of the model names are used. It would be nice to include full model name for the first time and use the abbreviation subsequently.

We tried to be more explicit in text in order to describe succinctly the characteristics of

the used models. Particularly, we expand all the model abbreviations, we give the type of model, the source code and the resolution and for each, the main publication that supports the developments

- 9. Line 31, please provide information regarding temporal resolution of the data here. The period of data (1996-2015) used are of 20-years, but it is mentioned as 16.4 years. Is this due to a few years of missing data?

Yes, it is due to record data interruptions and buoy maintenance.

We now precise it in text

- 10. Line 4 – 5, no autocorrelation, cross correlation analyses are shown to prove independence.

We selected this temporal criterion of 3 days based on previous research in the same area. The manuscript has been updated to mention it.

“Concerning storm dynamics in the Gulf of Lion, focusing respectively on surges and waves, Ullmann (2008) and Gervais (2012) showed that marine storms do not last longer than 3 days. We therefore decided to select the maximum Hs values per 3-day block, with a minimum of 1.5 days between peaks to make sure of their independence.”

- 11. Wave angles between 60_ and 210_ were kept for the analysis. Do they represent extreme scenario?

Yes it is, given the exposure of the coastline and the wave direction during storms, only waves from the 60°-210° sector were kept for the analysis. The text was updated to be more precise.

- 12. Does threshold of the GPD model is kept as a fixed value throughout or it is considered as variables based on moving window time frame?

Once the independent events set has been derived, the threshold of the GPD for each variable is chosen based on visual tools and statistical tests. It is therefore a constant

value and not a distribution parameter.

- 13. Line 14, “To finish” could be replace with “Finally” or “The next”

We modified the text.

- 14. The joint exceedance can be calculated using ‘AND’ and ‘OR’ cases. In general, the joint probability is underestimated in ‘OR’ case and overestimated in ‘AND’ case. When author(s) said ‘the response variable is an underestimation’ I presume calculation of return periods are performed using ‘OR’-case. Refer foll. for details: Ganguli and Reddy (2013), Probabilistic assessment of flood risk using trivariate copulas. Theoretical and Applied Climatol.

Here the joint exceedance probability is calculated using ‘AND’ case (survival function). We thank the referee for this comment that pointed out a mistake in the manuscript. We indeed wanted to say that the joint exceedance probability of input variables (in ‘AND’ case) is an underestimation of the exceedance probability of the response variable.

“As underlined previously, this approach rests on the assumption that the return period of the response is equal to the return period of joint exceedance of the input variables. In reality, the joint exceedance probability of the input variables is an underestimation of the true exceedance probability of the response.”

- 15. Line 26, explain the term ‘instationary’ in this case. In general, instationary refers to transient or quasistationary. Do authors perform nonstationary simulation in this case?

In fact, with the term in ‘instationary’, we mean evolutionary conditions in time representing the increasing and decreasing conditions relative to a classical storm for this area. We modified the term in order to be clearer.

“For each scenario, a 24-hour period of evolutionary conditions (water level, waves, overtopping and propagation of inland flooding) was taken to simulate the storm conditions (including a 2h spin-up period for water level and wave conditions). This sim-

ulation time corresponds to the duration of the peak of the storm conditions regularly observed at the study site. For each scenario, the mean water level and wave dynamics at the Rank 0 limits are modelled following the shape of the 2013 storm, with concomitant water level and wave peaks at t+12h."

- 16. To analyze impact of climate change, a scenario-based analysis is performed based on earlier literature, which might carried out using older generation climate models. It would be nice to see climate change impact using finer resolution regional climate models considering future change using set of RCP scenarios after employing an appropriate bias correction scheme.

We agreed with the comment of the reviewer that it would be interesting to investigate various finer scenarios relative to climate change impact like mean sea level rise, increase of storm surge or wave peak intensity. Nevertheless, as mentioned in the text there are very important uncertainties on the impact of climate change at local scale due to the complex ocean processes taking place in the Gibraltar Straits. We think that a more in deep analysis would be out of the scope of the paper. That is why we limited the analysis to commons scenario used for example in French National Directive on coastal flood risk.

- 17. Page 16, Line 2, "Results of the SWASH model simulations concur with these observations". Refer to appropriate figure number.

We added a new figure (figure 9) in order to illustrate the results

- 18. In section marginal distribution, no model fitting is shown either graphically or using KS-statistics at an appropriate significance level.

PP-plot and QQ-plot as well as p-values for KS and χ^2 tests have been added for model fitting of SWL. (figure 6 a and b)

- 19. Some of the limitations of the study include: first, this study uses a multiple model chain which itself can lead to propagation of cascade of uncertainty based on model

parameterization and initial and boundary condition of the models. Secondly, one of the assumption of development of environmental contour is environmental variables are considered as independent of time or stationary.

In the discussion, we evocate the potential error relative to the use of multiple model. For example, most of the discussion section is dedicated to the explanation of the observed errors and to the mains sources of these errors.

“Besides the errors inherent to the simulation method, there may be several reasons for the differences of a few centimetres that appeared between observations and modelling results. These include a lack of precise forcing data, the used of fixed bathymetry and potential resonance effects in the harbour that are not reproduced by the models used. Furthermore, sea levels in the northernmost pass are substantially underestimated (by 0.25 to 0.30 m). The underestimation is mainly due to the narrowness of the pass (15 to 20 m) and the potentially highly changeable bathymetry. These characteristics are the reason for the poor reproduction of water flows and levels in this sector, but do not appear to alter the results for the other sectors in the studied area. “

We also speak about the quantification of overtopping volumes which is an important field of research in the bibliography.

We agree with the second referee comment that stationarity is a fundamental assumption required by classic extreme value analyses, unless specific non-stationary methods are used to capture time dependence. In study, we assumed stationarity in the marginal distributions as well as in the dependence model. Deriving time-dependent ENC and JEC was indeed beyond the scope of the study. We completed the manuscript to discuss this point.

“Additionally, the statistical model contains uncertainties that need to be outlined. In the GPD model, a main source of uncertainties is the choice of the statistical threshold above which the distribution is fitted to the data. Estimated quantiles are indeed highly dependent on the threshold, the selection of which is sometimes difficult and

often subjective despite existing statistical tools to help threshold selection (Li et al., 2012). A second source of uncertainty comes from the potential non-stationarity of the environmental variables under study. Stationarity is a fundamental characteristic of variables required by classic extreme value analysis. Here, we assumed stationarity in the marginal distribution parameters as well as in the dependence structure of the variables Hs and SWL. Long-term trend from the SWL time series was removed before conducting the analysis but seasonal and interannual variability of SWL and Hs have not been dealt with, although this can lead to significant variations of extreme values in time (see e.g. Menéndez et al., 2009a, 2009b). However deriving time-dependent ENC and JEC (see e.g. Bender et al., 2014) was beyond the scope of this study."

- 20. In Figure 7, environmental contours are calculated at five different points. âËŸA ′c Authors have not mentioned the list of angles at which the calculations are performed. âËŸA ′c Also, please mention the number of Monte Carlo simulations to derive these contours. âËŸA′c In x-axes of the diagram what the unit (m/0 hydro) signifies?

We selected five different combinations on JEC and ENC in the upper-right quadrant which is the most important (both variables are high). We do not think it is necessary to provide the list of angles associated with the ENC combinations.

We added a precision in the text to mention the number of MC simulations used in the study: For our case study, we simulated 1 110 000 events, representing a fictitious 10 000 year period.

Thanks to the referee's comment, we modified several figures of the article that were partly displayed in French.

- 21. In Table 5, what CE1, : : :., CE5 infer? Univariate probability?

The table 5 was modified

- 22. Some of the words in the manuscript appears little non technical, such as "to bracket 100-year flood hazard".

We update the manuscript changing the term.

- 23. Instead of percentage increase in flood risk in the order of 200th or 300th, which appears little unrealistic, the statistic could be presented in the form of ratio. for example, 3.84 or so. Thank you for this suggestion, we now present the results in the form of ratio.

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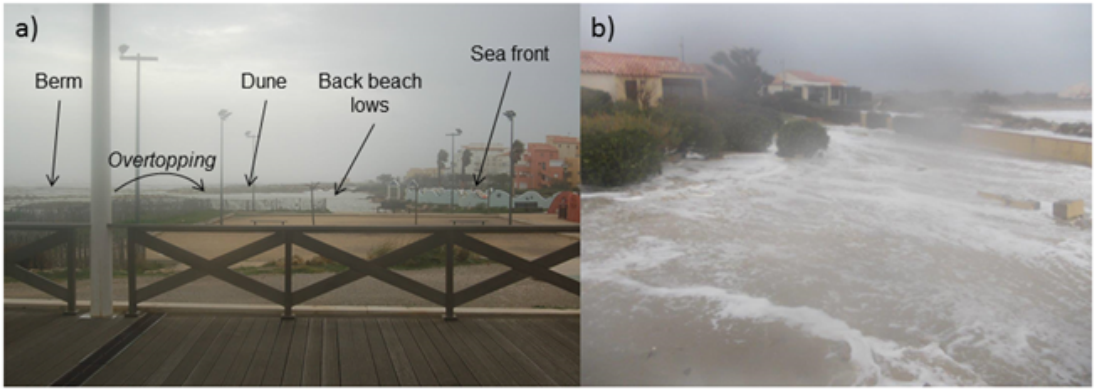

Fig. 1. Figure 9 : Overtopping observed at zone C (a), and zone B (b) sea front.

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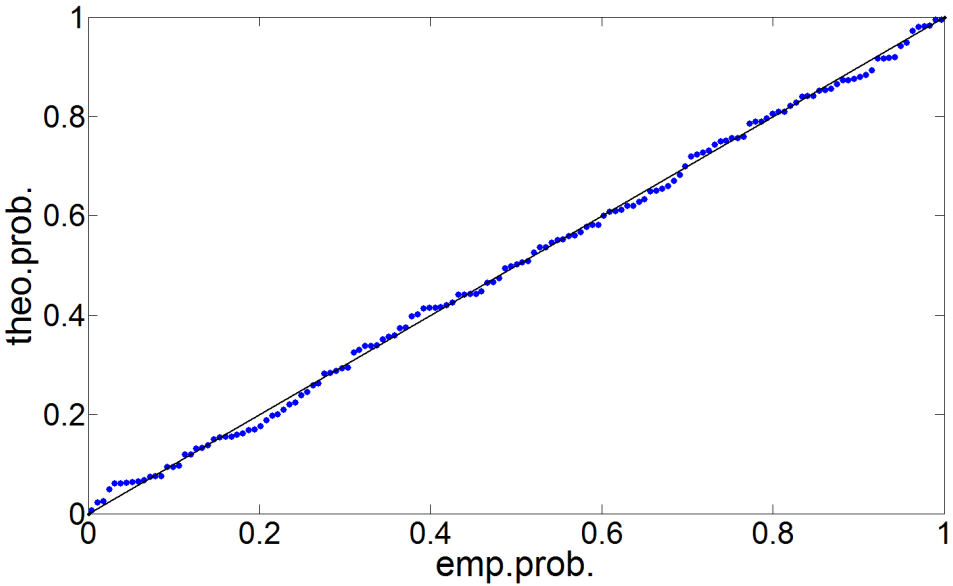

Fig. 2. Figure 6a : PP-plot for GPD of SWL (threshold at 0.96 m Z.H.), Hazen plotting position is used for empirical distribution

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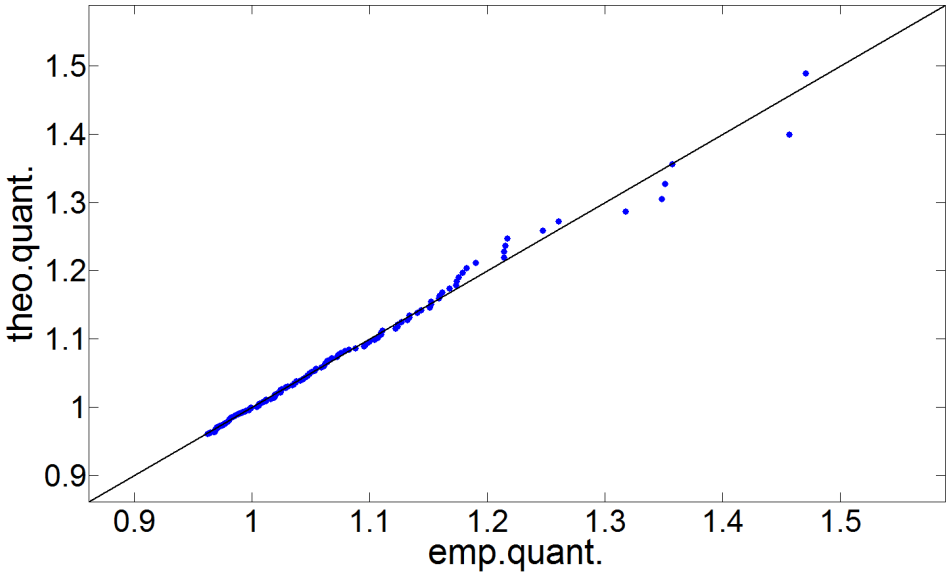

Fig. 3. Figure 6b : QQ-plot for GPD of SWL (threshold at 0.96 m Z.H.), Hazen plotting position is used for empirical distribution

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