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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Assessing storm surge hazard and impact of sea level rise in Lesser Antilles-Case study of Martinique" *by* Yann Krien et al.

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"The introduction must be consolidated. Many studies using modelling tools and coupled models were achieved last years. The methods and tools used in this paper must be contextualize relative to the abundant bibliography on the topic. The paper deal with the influence of sea level rise on storm surge. Nevertheless there is no considerations made about climate change manifestations on coastal hazards especially on inundation risk."

=> Following the advice of the reviewer, we expanded the introduction and quoted a number of papers relative to coupled numerical models and impacts of climate change

on storm surges.

"No information either on sea level rise trends in the Caribbean basin"

=>This information was given at the end of section 3 ("Considering that the sea level trend in the Lesser Antilles is very similar to the global mean rate (Palanisamy et al 2012)". But for the sake of clarity, we also added the reference (Palanisamy et al 2012) in the introduction and in section 2.

"A more in deep presentation of historical cyclones knowledge will be useful for the reader"

=>We included a figure representing the track of historical cyclones since 1900 (figure 2). We also gave more details in the text.

"p.2/l.15 : Harmonize and correct citation form"

=> We corrected the citation form, here and in other places in the manuscript

"p.2/l.30 : Replace heart by center"

=>Corrected

"Figure 1 : The figure need to be rework. Location are not readable, scale are not homogeneous. The figure don't look realized from raw data. Site the source of the maps if there are not fully realized by the authors"

=> Figure 1 has been modified and should be now more readable

"p.3/l.9 : What about tsunami potential impact ?"

=>Indeed, Martinique is prone to tsunamis. We mentioned that and added a reference in the new version of the manuscript.

"p.3/l.16 : Precise that Dean were a category 5 hurricane but only category 2 when it circulate near to the Martinique island."

=>we clarified this in the new version

"p.3/l.20 : The logical connection between the two sentences is not appropriated."

=>Indeed, we corrected this in the new version

"p.4/l.8-9 : Can you plot the historical track for comparison ? Land fall simulated tracks are not clearly visible on the figure."

=>Historical events are too far from Martinique to be plotted on this Figure. However, we added a new figure displaying the historical tracks, so that it will be easier for readers to compare. The thickness of tracks was modified to make them more visible.

"p.4/l.39-43 : Unless I am misinterpreting, the full data base contain various cyclone intensity and trajectory. We suggest that it will be relevant to illustrate the track and the intensity of the cyclone contained in the data base."

=>we added a figure displaying a few examples of synthetic hurricanes contained in the database (figure 3)

"p.5/l.3 :Tightly don't look as the proper term."

=>corrected

"p.5/l.7 : You speak about sensitivity tests, explain more in detail what was the objective of the test and what elements are validated and what deduction are made."

=>we explained this in more details (lines 193-194)

"p.5/l.20 : LIDAR data to what depth ?"

=>Up to about 40m depth. We specified this in the new version of the manuscript (line 212)

"p.5/l.22 : Are also available/used ?"

ïČđ Yes, they are available and included in the DEM. We specified this more clearly.

=>"p.5/l.25 : Integration in Figure 1 of the mesh and the a representation of the special variability of the friction coefficient would be very interesting for interpretation of the results."

=>The mesh is too highly resolved to be integrated in Figure 1 (the reader will not be able to distinguish between two different elements). Instead, we included a figure with a contour plot of the mesh resolution near Martinique, as well as a contour plot of the friction coefficient (figure 4).

"p.5/l.30 : Modify reference Lerma et al 2014 to Nicolae Lerma et al., 2014"

=>corrected

"p.5/l.35-38 : It is not clear whether the model reproduces correctly the observations made during the hurricane Dean (even if an only small storm surge was recorded). The model does represent this small storm surge or a more important values? In this section, the author need to be more explicit even if the validation is only qualitative. Please explain more in detail the conclusion of the report Krien 2013."

=>We significantly modified this section in order to be more explicit

"p.6/l.7 : Locations mentioned in text must be placed on the plot (figure 2)."

=>We modified the figure accordingly

"p.6/l.3-8 : Is not clear why the storm surge is so much higher in the Bay of Fortde-France for northern track than for the southern. Please, give a more complete explanation."

=>The reason is due to the direction of the wind when hurricanes pass over Martinique (offshore for southern tracks, onshore for northern track). We explained this more clearly in lines 248-249

"p.6/l.13 : The values of 1m was used arbitrarily or based on some references ?"

=>We explain this in lines 178-180: " Considering that the sea level trend in the Lesser Antilles is very similar to the global mean rate (Palanisamy et al., 2012), this value of 1 m roughly corresponds to the global projections of IPCC by 2100 in case of a high emission scenario (IPCC, 2013)."

" Figure 2 please put the main location in the figure"

=>We modified the figure accordingly

"Figure 2,b,d,f : There is some strange pattern in the northern coast. Are they artefact due to the computational mesh? Please explain this."

=>Indeed, these patterns are probably due to small numerical instabilities in SWAN, in a region where lateral bathymetric gradients are strong. However, these errors are small since they do not exceed 1cm, so they are not expected to be an issue in our study. We added a comment on this in the figure legend. NB: these numerical instabilities in unstructured SWAN were identified earlier by several authors. As far as we know, corrections have been made in the last versions of ADCIRC-SWAN to solve this issue.

"Figure 3 : Based on the figures, the model look to allow inland overflowing (i.e. there is no inland boundaries). If this true, it would be relevant to mention it.

=>Indeed, the model includes a wetting-drying algorithm to allow inland overflowing. We mentioned this in the new version (line 192).

"It would be also important to figure the coastline without surge on the plot."

=>the coastline is already represented by a thin black line. But we admit that it is not always easy to distinguish from the contour plots, so we increased its thickness in the figures.

"p.8/l.13-14 : Please be more precise about this. Is this an historic reference ? Why this reference is relevant instead of indicate a % of flooded urban areas, for example?"

=>In Figure 3b, we wanted to show that there was a relatively significant area in Fort-de-France where a 1m sea level rise was expected to induce flooding. This was not clear enough apparently so we modified the figure to make it easier to understand.

"p.9/l.15-17 : not clear, please reformulate."

=>We modified the text to make things clearer

"p.9/l.23 : What do you mean by Â′n simply changing manually the elevation data ÂËŹz ?"

=>We made this clearer in the new version of the paper: "These results provide further evidence that drawing inundation maps for the future without considering non-linear effects of sea level rise on water levels can lead to significant errors".

"p.10/l.1-3 : This affirmation should be illustrated by a figure. A zoom on the mentioned area for example."

=>We illustrated this with a zoom in Figure 6(b).

p.10/l.4-5 : Do you think the spatial resolution of your model (50 m at the coast) is in accordance with this perspective (i.e. evacuation plan, coastal urbanism: : :) ?

=>This resolution is definitely not sufficient to represent inland flooding properly. However, the water levels at the coastline should be relatively accurate in low-lying and shallow areas where surges are highest. This information is crucial for coastal urbanism or evacuation plans to identify the areas where vulnerable buildings should not be built, and to identify potential shelters for populations leaving close to the shoreline. To our knowledge, this work is so far the most elaborate study that can be used by coastal planners in France (even if we are fully aware of its limits!)

"Discussion: An extended chapter must be dedicated to discuss the results and the methodology. Did you test the impact of a West to East track hurricane? In reference to historical events, the authors must consider the impact of this kind of event?"

=>A few west to east hurricanes are contained in the database, and are thus taken into account in the results presented in figure 7. However, we did not study specifically the impact of this kind of event for several reasons:

1- As far as we know, a west to east track hurricane passing nearby Martinique has never been observed (according to historical data). Events passing farther from Martinique were recorded (e.g Lenny, or Omar), but they induced very low surges in low-lying and vulnerable areas (such as bay of Fort-de-France). Hence, the probability that the extreme levels presented here will be significantly exceeded in low-lying areas by this kind of event can be considered very low.

2-Most of the damages due to hurricanes such as Lenny or Omar where due to wave impacts (overtopping) at the shoreline along the north-western coast. The study of these processes are beyond the scope of this paper, which essentially concentrate on low-lying (and surge prone) areas. We discuss this matter in greater details in the new version of the manuscript.

"More generally, what can be the effect of a different track than considerate here?"

=>According to Sansorgne (2013), a report written in French, the effect of track angle and translation speed for Martinique are of second order compared to hurricane intensity and distance to the area of interest (typically, a few percent of the total surge) . We mentioned this in the new version of the paper.

The affirmation of the integration of the wave setup or wave process must be tempered. A 50 m mesh resolution at the coast can be insufficient ton properly represents wave setup component(in steep beach or in coral reef area for example)

=>Indeed, we already pointed this limitation in section 5.1 in the first version of the paper. This is true in particular in the north-western coast, where the slope is strong. In this case however, the stakes are more exposed to wave impacts (overtopping) than surges. As for the coral reefs, it is also true, although it seems to be less an

issue, probably because: 1-the reefs are strongly eroded, so that bathymetric gradients are relatively mild 2-we ensured that the unstructured mesh captures the bathymetry in areas where the water depth is the lowest. We performed a few tests with better resolutions (e.g. 30m), without any significant changes. We included a section on this matter in the new version of the discussion.

Furthermore, spectral wave model do not deal with infragravity wave which can be important in reef coast.

=>Again, you are right. Although large IG waves were not reported as such in Martinique, we see no reason why they should not occur. This has to be further investigated in the future. We included a section on this matter in the new version of the discussion.

It is surprising to refer to very precise urban site in order to describe results in case of seal level rise scenario. What is the purpose? The model is it considerate as efficient to simulate floods?

=>We performed sensitivity tests with higher resolutions, up to 10m in some specific areas. In a quasi-systematic manner, flooded areas are larger in these cases. We also used phase-resolving models (SWASH) with extremely high resolutions (1m), with the same conclusion. Furthermore, the urban sites mentioned in the paper are very close to the shoreline, so even if the flooding dynamics is not perfectly well captured, our conclusions are expected to be correct. However, we understand your point, so that we modified the way to present our results in the new version of the manuscript.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2017-148/nhess-2017-148-AC2-supplement.pdf

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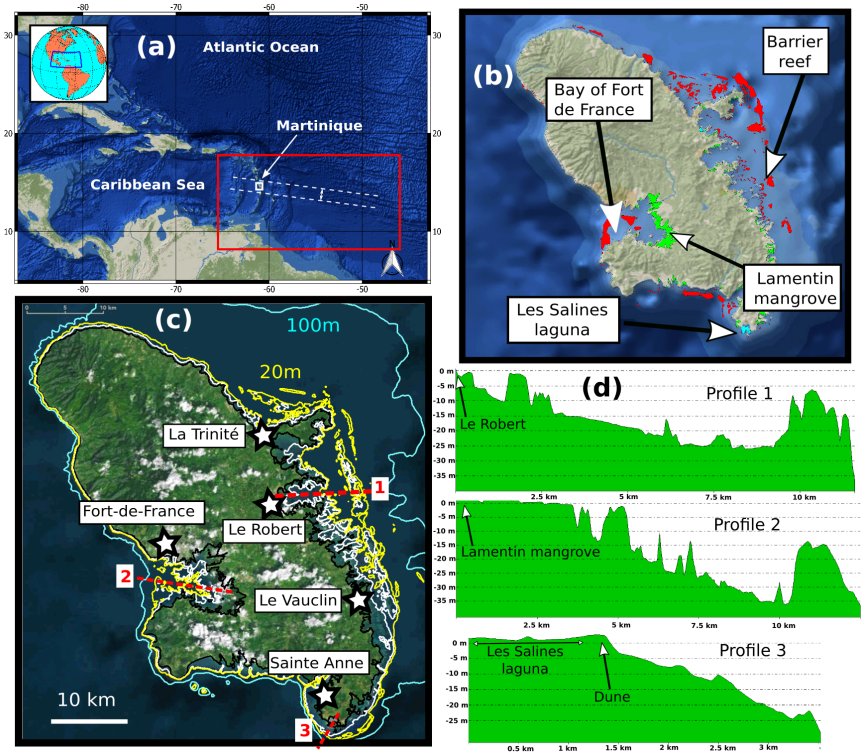

Fig. 1. Modified version of Figure 1 including location of coral reefs and mangroves, as well as bathymetric profiles

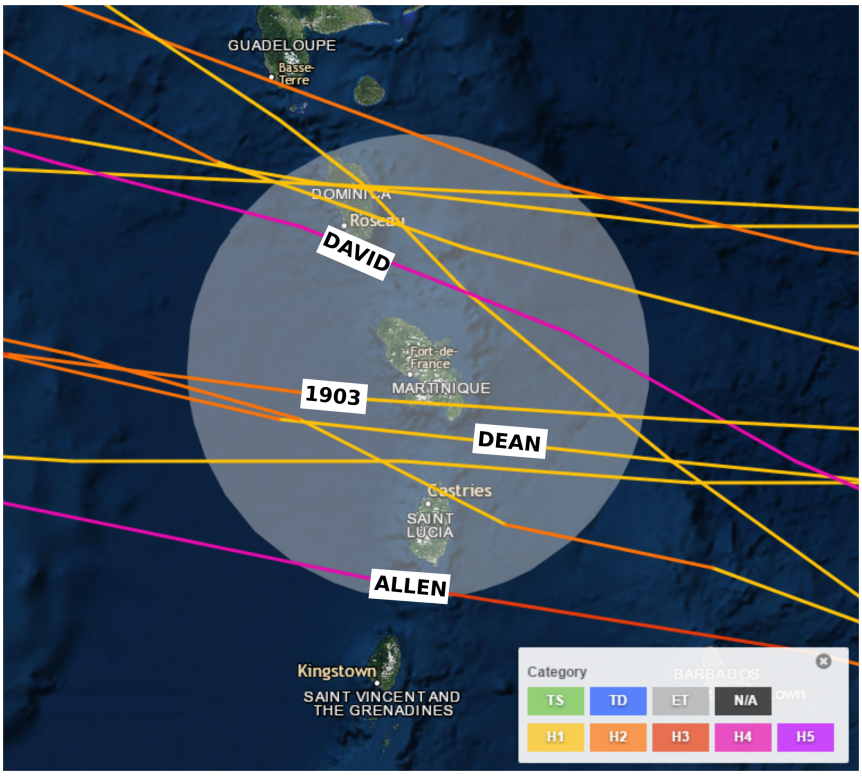

Fig. 2. and intensities of historical hurricanes passing within 65 nautical miles from Martinique, since 1900

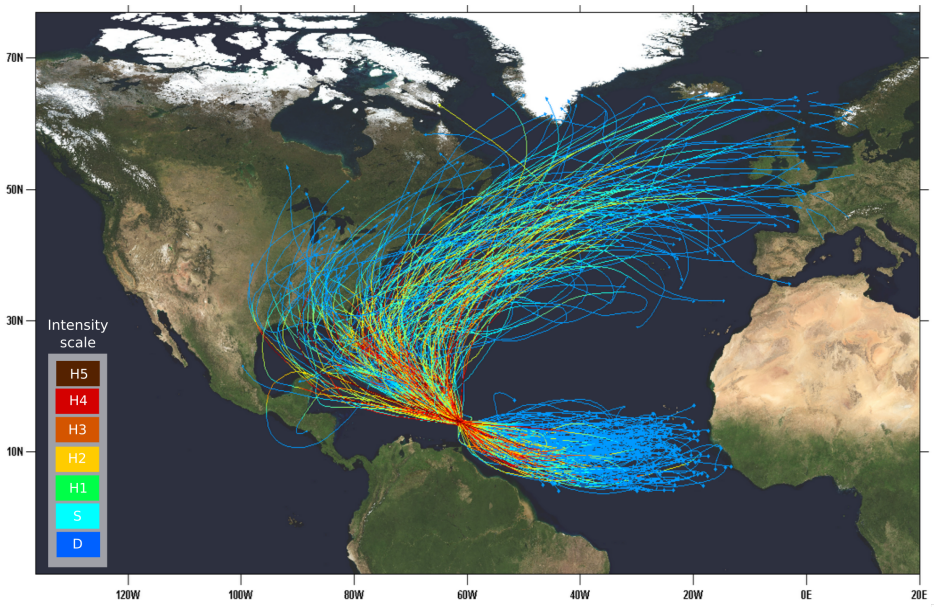

Fig. 3. A few examples of synthetic hurricanes generated for this study, using the statistical-numerical approach of Emanuel et al. (2006).

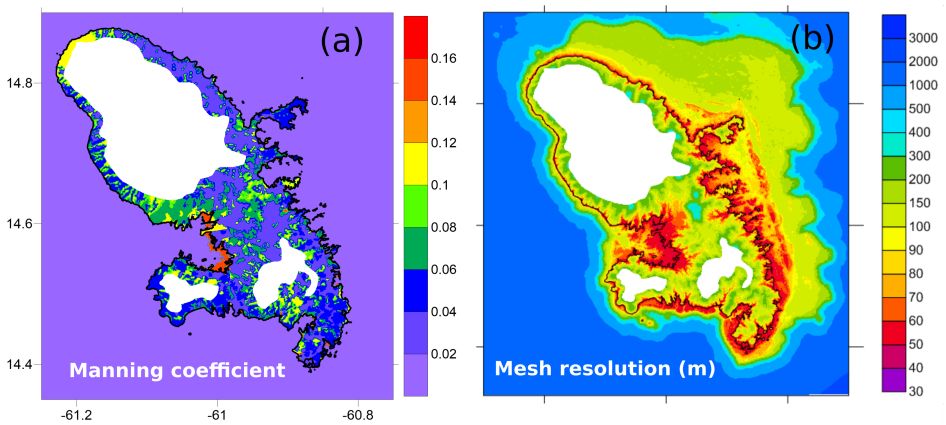

Fig. 4. -(a): spatial variation of the Manning coefficient n, based on land cover data (Union Europeenne, 2006). (b): spatial variation of the mesh resolution in the vicinity of Martinique.

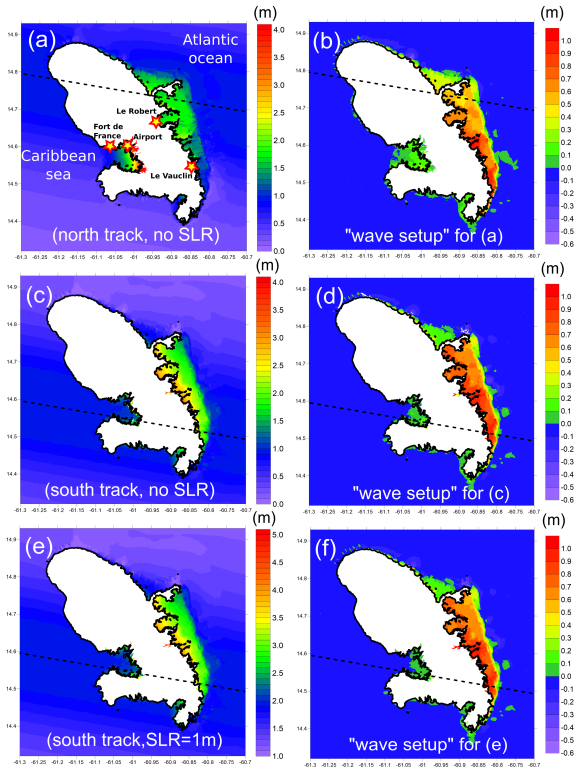

Fig. 5. Modified figure of maximum water levels and wave setups for a few synthetic extreme events

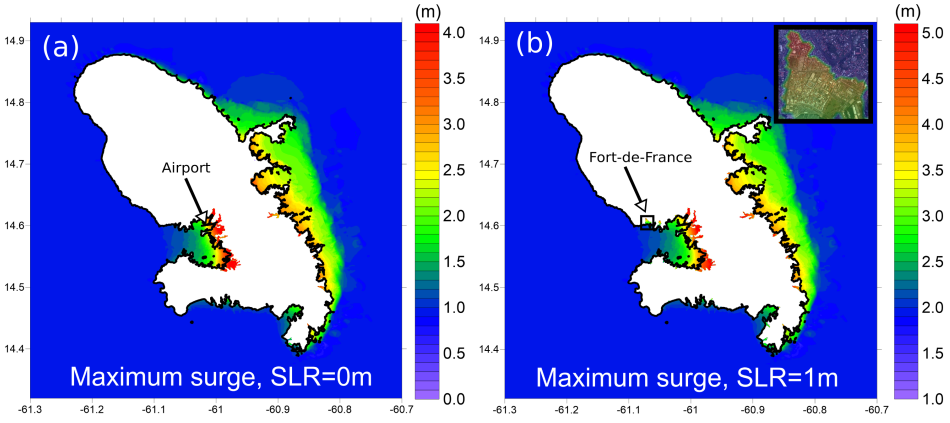

Fig. 6. Maximum surges obtained by considering Âń worst case Âż (category 4-5) hurricanes hitting Martinique, without (a) et with (b) sea level rise.

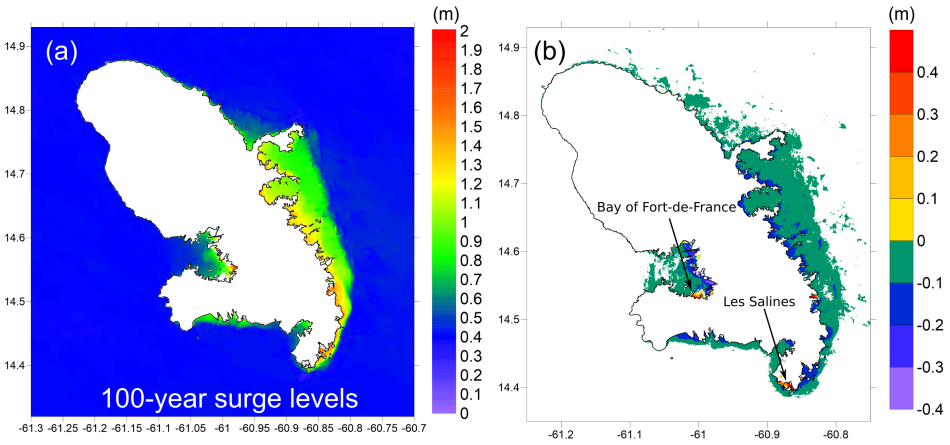

Fig. 7. 100-year surge levels for present climate and no SLR (a), as well as difference between 100-year surge levels for present climate when considering a 1m-sea level rise (b).