

## ***Interactive comment on “Coastal flooding risk associated to tropical cyclones in a changing climate. Application to Port of Spain (Trinidad and Tobago)” by Cristina Izaguirre et al.***

### **Anonymous Referee #1**

Received and published: 29 May 2017

General Comments In this paper the authors present a methodology to determine flood risk caused by Tropical Cyclones for the East of Port of Spain (Trinidad and Tobago). They focus on present day conditions and assess the possible impact of future relative sea level rise in addition to major flood drivers, such as storm surges and precipitation accompanying Tropical Cyclones. They take into account a wide range of factors constituting the local flood risk. While the authors' broad approach presented in the manuscript promises a thorough investigation I am hesitant to recommend publication based on the fact that, apart from its application to the Port of Spain, the presented methodology does not per-se seem new or innovative. Previous studies applied similar approaches for other geographical regions, e.g. Neumann et al. (2015) for the Red

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River Delta in Vietnam and Feng et al. (2016) for the Zhejiang Province in China. The author should state clearly which part of their analysis constitutes the novelty of their approach and compare their approach to that made by previous, related studies. Also the authors' conclusion that climate change related relative sea level rise is aggravating the hazard in coastal areas in 2050 is not new or overly surprising and should be set in relation to findings of other studies. Additionally the manuscript tends to be challenging to follow in some parts due to errors in language, sentence structure and a missing flow between subsections. The latter could be improved by including a preceding explanation of the structure of the individual sections, e.g. in the opening paragraph of a section. This is particularly true for Section 3 – Methods and Data. Also the figure captions tend to be unclear and often do not provide sufficient explanation to understand what is illustrated without referring to the main text. I therefore recommend major revisions of the manuscript before considering publication.

#### Specific comments

##### /Introduction/

In the introduction the authors state that the main aim of their study includes “accounting for climate change”. This statement is misleading since the study only takes into account rising sea levels but neglects changes in TC activity, tracks or intensity/severity. While neglecting changes in TC characteristics due to climate change is justified due to inconclusive predictions in the literature, the introduction should state clearly that only the change in sea level is taken into account and avoid mentioning changes in TC activity due to global climate change. Another shortcoming is the lack of mention of previous studies assessing flood risk caused by storm surges, precipitation (caused by TCs) and sea level rise. A thorough presentation of previous work in this field is essential to introduce the reader to the framework of this study and allow the reader to assess the novelty of the presented work.

##### /Study area/

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Section 2 gives a first insight into the studied area. It would help to get a better picture of the study area if the general economic importance of this part of Port of Spain and its importance in terms of population density were mentioned in this section already.

#### /Methods and Data/

This section is somewhat confusing to read. The reader should be guided more clearly through the section by indicating the author's approach to present the applied data, models and concepts in the subsections of this part. This could be achieved by adding an explanatory sentence at the beginning of the section. The authors could also use references to Figure 2 (schematic of the methodology) to guide the reader through this section. Further there are several points in this section that need improvement and/or further explanation:

- The caption of Figure 2 needs to include more information on what is shown in this illustration. With the current caption it is not clear how the different parts of the graphic are related and what the overall meaning of the figure is. The abbreviations used in the figure need to be defined in the caption additionally to the main text (or at least refer to the main text for an explanation of the abbreviations).
- It is unclear how the rainfall run off (RO) and river discharge (RD) are calculated. While the authors state how they determine the rainfall fields they do not include an explanation how this is translated into RO and RD, which together determine inland flood levels and are two of the six factors governing their definition of Hazard (Figure 2 and the beginning of Section 3).
- In regards to the interpolation of sea level projections, is the value for the period of 2046 – 2065 determined assuming a linear rise in sea level?
- The equation to determine total water levels should be written as a proper equation with a label and be referred to accordingly in the remainder of the manuscript. The explanation of the different variables in the equation is complicated to read and the authors do not state clearly if they derived this equation themselves or if they got it from another study.
- Further it would help if it was stated clearly how the output of the different models was used as input for the next, e.g. the wind fields from Hydromet-Rankine Vortex model as input for wave and storm surge model, which

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in turn provide the input for the equation for the total water level. This would make the workflow and connection between the different models and end result clearer. - The authors state that they provide the flood model with time series of the total water level at specific points along the coast. How were these points chosen? How is the total water level determined between these points? Why not provide a continuous field along the coast? - The authors state that they used historic storms (one hurricane and four tropical cyclones) to validate their flood model. For the four tropical cyclones they did this by comparing the modelled flood extents to graphical documents. What kind of graphical documents did the authors use and where did they obtain them? Also there is no mentioning of how the validation was executed for the hurricane, which the authors state was not validated using graphical documents? Why was the hurricane not validated like the other events? - In the equation to linearly combine the mean with the two extreme damage functions, what does alpha stand for? Also this equation should be written as a proper equation and include a label/number. - The motivation for including subsection 3.5 “Sources of uncertainties” in the methods section is not clear to me. While the discussion makes valid points about uncertainties the final results do not seem to refer to them later in the manuscript. In my opinion this section should either be included in the Discussion section or contain a clear explanation of how the authors accounted for these uncertainties in their results. However, the section should be changed to contain a logical flow and eliminate unclear/vague statements like: “[. . .] which will be associated to [. . .] but also to a cascade effect in the integration of several and complex models, data and methods to estimate risk.” or “The number and models considered as well as the ensemble itself introduce uncertainties in the process.”

/Results/

The authors should include the reason behind their choice of focussing on the results for a 1/100 flooding event in this section. How do the numbers of affected population and exposed assets change if different probabilities are chosen?

Figure 4: In the text the authors state that “Figure 4 shows the differences in flooding

extent [...] for a 1/100 flooding event” while the caption of Figure 4 states that the figure compares the extent of “flooding events with a 100-year return period”. Which of these descriptions is correct? The authors should also be clearer on what Figure 4 shows exactly, i.e. the red shading indicates the flooded area under present day conditions while blue shading highlights the regions that are flooded additionally (!) to that for a similar event under future conditions. Another option would be to change the figure and only shade the flooded area for year 2050 and indicate the extent of the present day flood using only a black contour overlaying the shaded area.

Figure 5: The grey shaded areas indicating the uncertainties of the flood extent in Figure 5 seem to be unsymmetrical with the uncertainties towards the lower limit of the mean sea level rise being smaller than those to the higher limit at most points of the graph. A brief comment on the reason for this dissimilar uncertainty would be a valuable addition. Also Figure 5 includes a lot of white space. Limiting the upper boundary of the y-axis to 350 Ha and moving the legend to the lower left of the figure would improve the illustration. The caption should be adjusted and made clearer.

Figure 6: (left) What are the upper and lower limits of the alpha coefficient? Also the difference in the colour shading of lines is not clear. This is particularly true for the blue lines where all shadings look similar. (right) The figure caption and main text state different explanations for the dotted, red lines. The main text states this is the uncertainty resulting from RSLR and vulnerability while the figure caption itself states the lines indicate uncertainty caused by vulnerability only. The figure includes a lot of unnecessary white space.

/Conclusion and discussion/ This section is missing (i) a clear discussion of the shortcomings and limitations of the study, (ii) an outlook of possible extensions of this work and (iii) an explanation of the added value of the presented methodology/results for the research community. A clear comparison to previous studies should also be added to highlight the value of the presented study and the novelty of the applied methodology. Without these elements the discussion is incomplete and makes this section

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seem rather poor. The authors should also discuss the potential influence of climate change induced changes in TC frequency and severity on their results. By neglecting changes in TC track and activity it is not surprising that relative sea level rise is identified to aggravate the hazard. I also don't follow the argumentation that the one of the main strengths of this work is based on its application to Port of Spain. Do the authors imply that in this study applied methods and models perform there the best and are less appropriate for other geographical regions?

Technical corrections General: Total numbers with more than three digits should include a “,” to make the text more readable, e.g. instead of 10000 use 10,000.

The uncertainties of values should be indicated using the format: (value  $\pm$  (maximum value – minimum value)/2), e.g. on p. 6 line 2: RSLR of (2.50  $\pm$  0.08) m or p. 10 line 19: population affected [ . . ] is (10,142  $\pm$  221)

When referring to figures or other sections it is customary to make the first letter a capital letter, e.g. “as shown in Figure 4” or “as stated in Section 2”.

Equations should be included on separate lines and have a label/equation number.

Specific: p. 1 line 7: add "s" to Cyclones, i.e. Tropical Cyclones (TCs)

p.2 lines 2 – 3: "observational data" instead of “observation data” and “number of observed TCs” instead of “number of TCs”; also this sentence does not make sense.

p. 2 lines 29 – 33: The sentence structure is wrong. The beginning of the sentence is a list, while the last part is as an independent sentence. Consider to split this in two sentences.

p. 4 lines 7 – 11: These lines should use a proper mathematic format for this equation with the equation on a separate line. It should also include a label/equation number and the explanation of the different variables in the equation should be made clearer.

p. 4 line 8: Reference Stockdon et al. (2006) is not included in the Reference list

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p. 4 line 18: change to “[. . .] the islands, with hurricanes Flora (1963) and Ivan (2004) being the most [. . .]” (“being” is used after the nouns)

p. 4 line 20: “constitute a shortage database” does not make sense; maybe change to “contain a shortage in the database”

p.4 line 24: change “than” to “as”

p. 5 line 2: begin new paragraph before “The wind and rainfall fields [. . .]”

p.5. line 4: add “, respectively” to end of the sentence

p. 5 line 10: change “no conclusive” to “inconclusive”

p.5 line 13: change “[. . .] being the natural climate variability the main source [. . .]” to “[. . .]with the natural variability being the main source [. . .]”

p. 5 line 16: change “This agrees with Bender et al. (2010) that estimates [. . .]” to “This agrees with Bender et al. (2010) who estimate [. . .]”

p. 5 line 19: delete “the” before “global mean sea level rise”

p. 5 line 23: Change “We have taken as a starting point [. . .]” to “As a starting point we have taken [. . .]”

p. 5 line 24: add “,” after “However”

p. 5 line 27: change “boundary where” to “boundary that”

p. 5 line 28: change “[. . .], makes especially important the [. . .].” to “[. . .], makes the [. . .] especially important.”

p. 5 line 29: change “[. . .] South West Trinidad is about four times than [. . .]” to “[. . .] South West Trinidad is about four times bigger than [. . .]”

p. 5 line 31: change “[. . .], that North Trinidad and the region [. . .]” to “[. . .], than between North Trinidad and the region [. . .]”

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- p. 5 line 33: change “closely” to “close”
- p. 6 line 3: These lines should use a proper mathematic format for this equation with the equation on a separate line
- p. 6 line 7: change “km2” to include superscript (i.e. km<sup>2</sup>) or use Ha, which would be more consistent with the result section
- p. 6 lines 20 – 21: sentence is unclear and should be rewritten
- p. 6 line 23: add a source for the damage functions
- p. 6 line 25: change “...”) to “etc.)”
- p. 7 line 6: add a reference for the weight proposed by the EU-RAMSES project
- p. 7 line 7 – 8: change “[...] we combine the three DFs defined [...]” to “[...] we combine the three defined DFs [...]”
- p. 7 line 13: define abbreviation SWE
- p. 8 line 5: change to “[...] simulation of the 300 selected TCs and [...]”
- p. 8 line 9: change “[...] by weighting with the distance the most [...]” to “[...] by weighting with the distance to the most [...]”
- p. 8 line 29: change “[...] we can obtained [...]” to “[...] we can obtain [...]”
- p. 9 line 2: equation should be on a separate line and include a label/number
- p. 9 line 3: change “[...] reduce and increase.” to “[...] reduced and increased.”
- p. 9 lines 7 – 8: unclear sentence, consider reformulating
- p. 9 lines 13 – 14: unclear sentence, consider reformulating
- p. 9 line 29: change “A problem” to “One cause”(?)
- p. 10 line 11: change “introduce changes” to “introduces changes”

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- p. 10 line 11: add “ in present day.” To the end of the sentence
- p. 10 line 12: change “[...] present climate being reduce to a 146-year [...]” to “[...] present climate is reduced to a 146-year [...]” p. 10 lines 19 – 20: change to “(an increase of 3% in [...]) for an event with the same probability.”
- p. 10 line 31: change “[...] yields to [...]” to “[...] yields [...]”
- p. 11 line 2: change from “(from 32 to 16 MUSD)” to “(from 32 MUSD to 16 MUSD)”
- p. 11 line 5: change “red dash lines” to “red dashed lines”
- p. 11 line 6: change to “result when taking into account uncertainties in RSLR and vulnerability information [...]” (in contradiction to figure caption which states that this is uncertainty in vulnerability information only)
- p. 11 line 13: Change beginning of sentence to “From the application to Port of Spain arises he main [...]”
- p. 11 line 18: delete “Besides,”
- p. 11 line 19: change “[...] is used to obtain efficiently impact [...]” to “[...] is used to efficiently obtain impact [...]”
- p. 11 lines 22 – 24: Sentence is unclear. What do the authors want to express?

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