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Comment on nhess-2022-120

Rafael Torres (Referee)

Referee comment on "Coastal extreme sea levels in the Caribbean Sea induced by tropical cyclones" by Ariadna Martín et al., Nat. Hazards Earth Syst. Sci. Discuss.,
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Review of the manuscript: "**Coastal extreme sea levels in the Caribbean Sea induced by tropical cyclones**" by Ariadna Martín et al.

The paper uses a synthetic hurricane database to obtain a set of 1000 tropical cyclones (TC) affecting the Caribbean Sea. This information is used to assess wind speed, wave height and extreme sea levels in the region using a high-resolution coupled hydrodynamic-wave model. Results allow identifying most exposed areas to these variables depending on the origin of the TC (Caribbean or Atlantic). Besides, wave, wind and atmospheric contributions to the extreme sea levels are assessed.

I find the aim of the paper interesting and scientifically relevant, especially for the use of coupled models to simulate a large number of present storm surges and waves in the Caribbean Sea forced by TC. I believe this is important as many areas in this region, lack of observational wave and sea level data to perform TC-related risk assessments. Therefore, these results are useful to assess coastal TC risks in the entire basin, but especially at places where data is not available. Besides, return levels of wave height and sea surface elevation for the Caribbean coasts are available in a data repository.

The paper has a good presentation quality and falls into the NHES scope. However, in my opinion some aspects need to be improved before considering its publication in the Natural Hazards and Earth System Sciences journal.

Main comment:

Buoy data from two real hurricanes (Willma and Tomas) are used to validate the modeled wave height, but authors claim that no sea level data is available to validate the sea

surface elevation (SSE, L171-172). This is not accurate. In fact, Figure 7 from a referenced paper (Torres and Tsimplis, 2014) shows the nontidal storm surge produced by Hurricane David (1979) as recorded by the Magueyes tide gauge. Besides, this hurricane is mentioned later in L262. In the context of the paper, any hurricane in the region could be used for validation purposes. I recommend the authors to select two hurricanes with available sea level and wave observed records, as these variables validation is important for this research. Besides, as the paper assess hurricanes formed in the Atlantic and in the Caribbean, I think it would be better to validate the model with two real hurricanes but from different origin.

Other specific comments:

L43. Please clarify if tropical cyclones from STORM database, include Tropical Depressions and Tropical Storms in addition to Hurricanes of all categories. If this is the case, the term "tropical cyclones" should not be replaced for "hurricanes".

L56. Maximum wind speed.

L57. Please clarify how the PDF was built. The dataset provide the TC track with a 3-hourly time step during its lifetime. For the PDF (and figures 1e and f) each TC was counted once at the time of its maximum wind speed or the entire track was used?

L 63. Please expand on the characteristics of the 1000 TC sub-set used. For example, indicate the % of TC with Atlantic or Caribbean origin, % or number of TC which reached the different hurricanes categories (for each origin), etc. This information might be useful to assess the results. Besides, explain how the TC were classified due to their origin, as this is discussed in the paper. E.g. in the case of TC of "Caribbean Origin", are they included if the track starts in this region (usually as a tropical depression), or depending on the place where the TC became a hurricane? (This is comment is related to comment about L43).

L83. Please clarify the area where the 47 buoys were available, as the reader can understand that these buoys were available in the Caribbean Sea.

L87. I suggest you clarify that "... surface wind fields for each TC were generated ...".

L89. Clarify the term "dominant circular component". Replace it for "a circular region affected by the cyclonic wind" or a similar expression that better explain the wind field configuration.

L194. Include a reference or explain why a 20% is a good choice.

L144-145. Please consider including a comment about the latitude of the southern Caribbean and its relation to the weak Coriolis Effect, which affects TC.

L155. A comment about intensities from both TC's families is presented based on Figure 3. Panels c) and d) in this figure are interesting as they show the coastal areas where strong TC induced winds are expected depending on their origin. Please consider to complement this figure with a panel of intensity (median of maximum wind speed) of all the cyclones regardless of their origin, as well as a second panel but with the intensity as the 95 percentile of maximum wind speed. This information can be useful for coastal planning and risk management, as coastal infrastructure should be prepared for strong TC winds regardless of the cyclone's origin. Include in the text an assessment based on these new panels.

L161. generated in the Caribbean; eastward; westward (check all the manuscript).

L162-163. The STORM database include 20 TC moving eastward. Although this is a very small number, they seem to be strong hurricanes when compared to other cyclones formed inside the Caribbean Sea (Fig. S1c). Is there a real hurricane that have shown this behavior? I think this is important in order to mention if this is a real possibility in an area dominated by north Trade winds or if this might be catalogued as an error in the database.

L172. To assess the hurricane effects on sea level, high frequency data is needed, which is not available from altimetry. Therefore, I recommend to delete this comment.

L176. Replace ten for tenth if it uses Hs from the TC in the tenth position (99th percentile). If Hs is computed from the ten most intense hurricanes, which is the "measure" (¿mean, median?). Please clarify the method used in this line for Hs and in L194 for SSE. Based on this clarification, update figure 5 and 6 legends.

L178. Wilma Cat 5 Hurricane recorded an 11 m Hs, while Tomas Cat 2 hurricane, recorded a 6 m Hs (Fig. 4). I think waves of almost 20 m are too high for the Caribbean Sea. I suggest you check Hs in the long time series available from the buoys used in Fig. 4, to assess the highest wave height recorded (and peak period – L188), and compare to the ~20 m value found with the model.

L178. Results indicate waves of nearly 20 m height in the West Indies eastern side induced by TC's. These results call my attention as major hurricanes, which can produce

such large waves, are uncommon in the West Indies (e.g., https://www.nhc.noaa.gov/climo/images/1851_2017_allstorms.jpg). Therefore, validating the model with a large hurricane from Atlantic origin is recommended (see main comment).

L185. The small fetch area inside the Caribbean Sea is proposed as the reason for smaller TC's induced waves in the western Caribbean. ¿How does the wave model forced by the hurricane wind field account for the fetch? I think wave height produced by a hurricane is related to the wind intensity, radius of maximum wind speed and the period this wind is transferring momentum to the sea surface, all of these variables forcing the model. Please consider which of the forcing variables of the wave model can be responsible for the smaller wave height seen in the western Caribbean.

L188. I think waves of 14 to 18 s period are too long to occur inside the Caribbean Sea. I suggest comparing these values with T_p recorded by the buoys and/or make a comment about the period in the validation section.

L199-200. I expected such behavior in the coast of Nicaragua, due to the large continental platform, but Belize bathymetry is not particularly shallow (Fig 2). In the case of Nicaragua I think this research is very useful, as to my knowledge there are no observed wave or sea level data in this region, what makes validation impossible. Can you think of a reason why wind setup does not cause higher SSE in Nicaragua when compared to e.g., Belize?

L204. Wave-setup is underestimated in your results. Through a numerical experiment (running a case with better spatial resolution in the model) can it be estimated the SSE underestimation? Besides, SSE validation can give an idea of the underestimation value (main comment).

L237. Summary and Discussion. I suggest rearranging this section as follows: 1) summary of the study. 2) Assessment of TC intensity and H_s results. 3) Assessment of SSE results. 4) Comparison of results with historical hurricanes as impacts are due to wind speed, H_s and SSE interaction. 5) Global warming probable effects in the Caribbean future hurricanes. 6) Closing paragraph.

L242. Hurricanes from Caribbean origin were only formed off the coast of Honduras? See comment of L63.

L266. Montoya et al., (2018).

L269. Consider to mention that, due to SST increase, the hurricane season will be probably extended. Doi: 10.1007/s10236-021-01462-z

L278. Make a comment about the differences between observed sea level extremes and SSE found in this work. The former will include the contribution from the tide, eddies and seasonal cycle, while the later only accounts for the TC forcing.

L295. Mean sea-level rise might cause a decrease in the contribution of wind setup, but it is responsible for positive trends observed in sea level extremes (Torres and Tsimplis, 2014).

L313. Include all available DOI to the references.

Comments to figures:

Figure 1. The last panels are e) and f) no f) and g). Update the legend based on comment about L57.

Figure 2. Include in the legend "The spatial resolution varies as a function of the depth". Name first Wilma (a,b) and then Tomas (c,d).

Figure 3. (i) I do not understand why some segments of the coast appear with no color, as the colorbar starts from zero (e.g., Darien Gulf). Besides, it is curious that in some coastal segments no color appear, while neighbor coasts show that are regularly affected by hurricanes. E.g., a segment of the southern coast of Dominican Republic. This seems to be a technical fault, as information about this segment is available in other figures. (ii) In panel b) I understand that a 20% of Caribbean origin (light yellow) will indicate that of 10 TC, 2 more (20%) TC were originated in the Caribbean; therefore 7 TC are of Caribbean origin while 3 TC are of Atlantic origin. I think this color scale is confusing for only two possible outputs. I recommend reporting only the % of Caribbean origin TC using a colorbar from 0 (blue) to 100% (red). Therefore, 70% will indicate the percentage of Caribbean origin, what easily indicates that 30% are from Atlantic origin. Besides, no color will indicate areas where TC do not affect the coastline. (iii) See comment about L155.

Figure 4. Consider including some marks in the dates to indicate the category of these hurricanes in this time span, as this would help to see the wave height relation to the hurricane category.

Figure 5. (i) Remove titles at the right side of the figure. (ii) Clarify the legend accordingly to comment about L176 (note that in the legend, both reported Dp and Tp are the median from a range of data). (iii) Inverse the order in the legend as panel c) is Dp. (iv) The color code of Dp is confusing. E.g. the coast of Nicaragua is blue (relative 180° shown at the left of the color circle); as wave direction is from where the wave comes, I assume that it indicates that the waves comes from the east (the opposite side of the circle). I recommend eliminating the relative degrees in the color circle, and flipping the circle, showing light blue colors at the left and yellow colors down. An explanation about the color code should be included in the figure's legend.

Figure 6. Clarify the legend accordingly to comment about L176.