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Natural Hazards and Earth System Sciences
Discussions
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Interactive comment on "Quantifying processes contributing to coastal hazards to inform coastal climate resilience assessments, demonstrated for the Caribbean Sea" *by* Svetlana Jevrejeva et al.

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Reply to Reviewer 1 comments

Anonymous Referee #1 Received and published: 9 April 2020 Jevrejeva et al., assess coastal impact of waves, storm surges and sea level rise in the Caribbean region, with a focus on coastal impacts in the eastern Caribbean islands (St Vincent and the Grenadines). The proposed methodology can aid in decision-making about coastal adaptation strategies, especially in these small island developing states. This work addresses relevant scientific questions and of interest to the NHESS journal's audience. Although I'm positive, a few issues should be addressed before accepting this work,

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Discussion paper

which I have summarized below.

1. The main challenge to estimate the vulnerability of the Lesser Antilles is linked to the very contrasting morphologies of these small islands, which influence the submersion dynamics significantly along the coastline (see for example Duvat et al. 2019). An accurate bathymetry is a key factor in this region. The authors used GEBCO, which has a resolution of the order of the kilometer and a very low precision in shallow water. In this context, could the authors explain what is the accuracy/representativeness of their model's outputs and their vulnerability index estimate? Reference: Duvat, V., Pillet, V., Volto, N., Krien, Y., Cécé, R., & Bernard, D. (2019). High human influence on beach response to tropical cyclones in small islands: Saint-Martin Island, Lesser Antilles. Geomorphology, 325, 70-91.

Reply:

Thanks for pointing out this paper, which explores detailed coastal impacts for the Lesser Antilles French/Dutch island of Saint-Martin/Sint Maarten at the northern end of the Antilles arc (at 18N). While we fully accept that the coastal impacts on each island are governed by their coastal morphology (and intend to explore this in a second paper, referring in more detail to St Vincent); in the present paper we are focussing on the exposure of the whole Caribbean Sea to marine hazards rather than trying to examine the detailed impacts for individual islands (although we do refer to the case study for SVG to illustrate local impacts as a consequence of regional processes). This does present a challenge, particularly for estimating coastal storm surges as we discuss in section 4.4, but there are other reasons for the small non-tidal residuals, apart from the resolution of GEBCO, including the resolution of the wind fields and the steep coastal topography, meaning there is only a limited near-shore shallow water zone. The resolution of the regional model is limited to $\sim$12km (as stated in the manuscript), which means this nearshore zone is hardly resolved at the regional scale.

2. In the same way, how can the authors be sure that the changes in the non-tidal

residuals (section 4.4) during Hurricane Tomas and Ivan were mainly caused by the inverse barometer effect and not due to the model's low resolution (wind+bathymetry)?

Comparisons with measurements are too qualitative. The buoys used for validation seem to be very far from the cyclone tracks. Could the authors please comment on this?

Reply:

Much of the modelled non-tidal residuals appear to have been generated by the inverse barometer. Visually, this can seen by the shape of the non-tidal residual matching the low pressure area and changing very little with changes in ocean depth. However, some additional experiments were performed (but not included in this study) which omitted wind stress. In these experiments, there were some small changes to non-tidal residuals in grid cells very close to islands, however the order of magnitude of the surge remained the same and conclusions unchanged. We have used the existing wave buoy network in the Caribbean, which shows good agreement at the regional scale. Tide gauge data is more problematic, because of the very local scale of the signal, as discussed in 4.4. Limited observations is another point raised in this manuscript (e.g., Line 44, 204, 244, 455, 460, 461). Our aim is to highlight the importance of observations in this publication while supporting local capability through the provision of an AWAC in SVG (see wolf et al., Deployment of an AWAC off the east coast of St Vincent, 2018-2019, http://nora.nerc.ac.uk/id/eprint/525933/)

3. Line 175: the radius of maximum winds for Ivan could be estimated from the HURDAT Re-analysis dataset (https://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html)

Reply:

We have been using the Holland parametric model to build the wind and pressure field, which requires as input the along track observations of maximum wind, central pressure and radius of maximum wind. The latter was not available in the IBTRACS dataset for hurricane Ivan. The IBTRACS dataset is a merge of data from different data centers including HURDAT. We have further checked directly on the HURDAT2 website and the radius of maximum wind speed is not a variable provided. HURDAT2 provides instead the 34 kt wind radii maximum extent, 50 kt wind radii maximum extent and 64 kt wind radii maximum extent.

4. How are the inputs from rivers and rainfall incorporated into the model grid? (boundary conditions?). What about other factors that contribute to total water levels such as vertical land movement (tectonic/seismic activity and anthropic) and wind waves (setup and runup) ? Could the authors provide more details/discussions on that? What are the consequences on their results of not considering these important processes? The literature review seems poor, I suggest to enlarge it looking at the recent advances in this region.

Reply:

Discussion session is rewritten (lines 486-510) to address these comments. No rainfall or runoff data are included at this stage in our work. While these effects can be important for impacts in the coastal zone of SIDS e.g. causing combined flooding and landslides, these are not marine hazards, although they can combine with marine hazards to produce multi-hazard impacts of hurricanes, which are of course very important for coastal communities. No VLM data have been included. We intend to include calculations of wave runup, setup, erosion and geomorphology in a paper looking at the local scale for St Vincent, to be submitted shortly. We have included the suggested papers in the literature review, while clarifying the distinction between external drivers and local scale effects a bit more in section 5. We have noted the criticism of the literature review in general and have included several more papers, including those suggested by the reviewer and others.

5. In addition, there is no scientific comparison/discussion in respect of recent storm surge research. Among others: Zahibo, N., Pelinovsky, E., Talipova, T., Rabinovich, A.,

Kurkin, A., & Nikolkina, I. (2007). Statistical analysis of cyclone hazard for Guadeloupe, Lesser Antilles. Atmospheric research, 84(1), 13-29.

Krien, Y., Dudon, B., Roger, J., & Zahibo, N. (2015). Probabilistic hurricane-induced storm surge hazard assessment in Guadeloupe, Lesser Antilles. Natural Hazards & Earth System Sciences Discussions, 3(1).

Krien, Y., Dudon, B., Roger, J., Arnaud, G., & Zahibo, N. (2017). Assessing storm surge hazard and impact of sea level rise in the Lesser Antilles case study of Martinique. Natural Hazards & Earth System Sciences, 17(9).

Kennedy, A. B., Gravois, U., Zachry, B. C., Westerink, J. J., Hope, M. E., Dietrich, J. C., ... & Dean, R. G. (2011). Origin of the Hurricane Ike forerunner surge. Geophysical Research Letters, 38(8).

Reply:

We have added some text, e.g. lines 75-80, 334, 340, 465 and 487-526 to address these comments.

We thank the reviewer for pointing out these other studies and have included them in the literature review. Again, these are mainly local scale studies for the islands of Martinique and Guadeloupe and also for the Louisiana/Texas coast, which is a different situation, on the USA continental shelf. As previously stated, we have concentrated on assessing the external drivers at the regional scale, and focussing on SIDS, while recognising that the local response is important in terms of the impacts. Note that one of our points is the small size of surges in steep islands like Guadeloupe. Referring to the work of Zahibo et al. (2007), although observed surges are stated to be quite large, there is also a lot of variability and the modelled surge in tropical storm Lili (2002), although for a relatively low intensity event, was only about 10cm. We think some of the reported historical water levels may be due to waves and part is no doubt due to limited spatial resolution of the coastal bathymetry. Krien et al (2015; 2017) show 1 in 100y surges of up to 2m and 1 in 1000y surges up to 3m in the shallow water areas around Martinique and Guadeloupe, which are similar to our estimates, for an estimated severe event near St Vincent, allowing for our limited spatial resolution.

6. The vulnerability definition that is used by the authors remains vague. Please, elaborate more on the concepts of risk, exposure, vulnerability... In the last section, a Coastal Vulnerability Index (CVI), based on the methodology used by Thieler and HammarKlose (1999) is presented, gathering six variables : geomorphology; coastal slope; shorline erosion/accretion/ relative slr; mean tide and mean wave. However, geomorphology is not considered in the study, slr is constant for all the study region (1.8mm/yr), no justification/references is given for the choice of the shoreline changes (between - 1.0 and +1.0m yr-1), so only mean weight height and tidal range provide relevant information to compute the CVI. The same observation is made concerning the choice of the CVIPP from OE210, where the human interventions at the coast and the coastal geomorphological factors are ignored. At the end, what is the meaning of this vulnerability index (figure 11)?

Reply:

Session 5 has been improved following reviewers' comments.

In section 5 we initially stated that we have adapted the CVI method of Thieler and Hammar-Klose (1999), in other words we have used the concept but not exactly followed the methodology. We have added some clarification to the section on Coastal Vulnerability Index, indicating the difference between external physical drivers (addressed here) and local coastal variables including geomorphology, beach slope and rate of retreat, for which we do not have data on the whole Caribbean scale. Some attempts could be used to get these data from a global model like DIVA (Dynamic Interactive Vulnerability Analysis, although the data would need to be check to ensure the islands are resolved), but this was not the purpose of the present paper, which was to quantify the exposure to marine hazards, rather than the local response. We will quantify these local variables in a second paper for St Vincent. We have modified the text at line 400 to clarify that sea level rise and erosion rates applied are defined by the approach of THK. We use these as thresholds to rank the variable rates of sea level and shoreline change in our study (Table 6).

Minor comments:

a) The figures 1 and 11 are not well constructed neither clear for understanding. For example, in Figure 1 : the names of countries and the names tide gauge stations are missing...

Reply: Done

b) L217 : please correct : Is the comparison made with Pointe-à-Pitre tide gauge located in Guadeloupe or with the Port au Prince tide gauge located in Haiti ?

Reply: Pointe-a-Pitre in Guadeloupe

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