Response to RC2 on nhess-2021-251

Review “Tropical cyclone storm surge probabilities for the east coast of the United States: A cyclone-based perspective”

General comments

In their manuscript “Tropical cyclone storm surge probabilities for the East Coast of the United States: A cyclone-based perspective”, the authors seek to identify relationships between tropical cyclone (TC) characteristics and storm surge heights along the US coastline. While I believe this is a relevant topic to study, I recommend additional analyses to improve on the novelty of the research. Please find below my reasoning:

1) The authors consider the TC distance to tide gauge station, TC intensity, and TC angle at landfall in their analysis. I feel it’s debatable whether the distance to a tide gauge station is something that can be truly attributed as a TC characteristics (why not consider TC size?). In addition, various past studies have (extensively) discussed similar characteristics. Many of them are already cited in the text (Lines 44 – 52) so I will not repeat them here, but these could be added for a more comprehensive overview of what’s already been done:

- Needham & Keim (2014) (https://doi.org/10.1175/2013EI000558.1) who assessed the influence of storm size on hurricane surge;

- Ramos-Valle et al (2020) (https://doi.org/10.1029/2019JD031796) who extensively studied the influence of TC landfall angle on storm surges along the Mid-Atlantic Bight;

- Bloemendaal et al (2019) (https://doi.org/10.1007/s00382-018-4430-x) who also assessed the influence of various different TC and geographical characteristics on storm surges;

- Peng et al (2006) (https://doi.org/10.1016/j.ocemod.2006.03.004) on the asymmetry of storm surges and TC wind fields;

- Akbar et al (2017) (https://doi.org/10.3390/jmse5030038) on the influence of wind drag coefficients and bottom friction on Hurricane Rita’s storm surge height

While I welcome research seeking additional answers to explain storm surge heights, I would strongly recommend the authors to improve on the novelty of the research to make this research truly stand out compared to the literature that’s already out there.

This can be achieved through (for example) 1) including more TC and landfall (coastal slope/coastal complexity/terrain features near the tide gauge station) characteristics 2) extensively seeking for multivariate relationships 3) and to also trying different types of relationships rather than just a linear one.

Thank you for this suggestion. Since the focus of this research is from the perspective of TCs and based on your comment about excluding TCs that underwent extratropical transition, we will include some analysis on comparing TCs that do and do not transition for select locations. Additionally, we will include an additional figure that is referenced as "not shown" in the last paragraph of the results section to highlight the distribution of TC tracks that do and do not produce surge exceeding the 1-yr return period. Lastly, we have included exponential fits in addition to linear fits of our data. We believe the inclusion of these items enhances the quality of this research.

2) Throughout the manuscript, it seems like the authors are solely looking at TCs in their analysis. However, in the Methods-section, they say that they also include TCs that have undergone extratropical transition. These systems can no longer be considered tropical by nature (rather, extratropical), hereby having different characteristics than TCs and they should thus be excluded from the analysis.

This is an important caveat -- thank you for bringing it to our attention. We have gone back and removed all TCs from our analysis that were classified as extratropical in HURDAT2 while the TC was within 500 km of a location.

3) The authors use daily maximum storm surge heights and couple this with 6-hourly TC data. I don't see the added value of using daily maximum storm surge heights when the tide gauge data is provided in hourly data (see line 85) and TCs are characterized by strong spatial and temporal gradients that can strongly vary within hours.

Since we are interested in identifying the maximum surge height produced by a TC, we believe the use of daily maximum storm surge is relevant. We are not examining aspects of surge related to the duration of surge in connection with the evolution of a TC, in which case, we agree that it would be important to utilize the original hourly surge data due to the strong spatial and temporal gradients observed in TCs. However, we are identifying the highest storm surge produced per day (while retaining the hour at which this occurred) and then associating that with the nearest 6-hourly TC observation. For the purpose of our research, this method allows us to examine the TC characteristics around the time the surge maximum occurred at a location.

4) The results-section could benefit from some in-depth discussion of why the spatial differences emerge in relation to typical TC behavior/patterns.

We will include further discussion on this topic.

Introduction – specific comments

Nowhere in the introduction is there any mention of the TC characteristics that will be under consideration in this manuscript. Please add this description.

We do mention these characteristics in the second to last paragraph of the introduction. However, we will be even more specific in the characteristics under consideration and add that in the introduction.

The introduction (more specifically, the second paragraph, lines 33 – 44) makes it seem like there will also be a focus on ETCs. Please make it explicitly clear you will solely focus on the TCs.

We will explicitly state that ETCs are not the focus of this research.

Line 24-25: exposure is not the same as vulnerability

This is an important differentiation and we will address the usage of these terms.

Line 29-30: The amount of destruction is also influenced by changes in exposure and vulnerability

We will add this into our introduction.

Line 30-31: What do you mean with this sentence?

We mean that the relationship between surge and atmospheric/oceanic variables may not be linear. We will replace the use of the word "monotonic" with this description.

Line 35: Could you please elaborate on what these differences exactly are?

This sentence was updated to: "For ETCs, different atmospheric circulation patterns can produce large surge, with the highest median surge occurring with a slow-moving ETC in conjunction with an anticyclone located to its north (Catalano and Broccoli, 2018)."

Line 36 – 38: Please explain to the reader why these cities have less TC-related storm surge extremes (along the lines of ocean waters are colder + more wind shear, so less favorable for TCs), that will also help the reader understand why this Boston example is noteworthy.

We have included more information as: "This is because at higher latitudes, TCs encounter unfavorable environmental conditions that promote sustainability of TCs, including cooler sea surface temperatures and increased wind shear associated with the fluctuating jet stream, particularly later in the Atlantic hurricane season."

Line 38 – 44: Please fill in the gaps that are left in this paragraph: 1) what are the differences in storm dynamics? 2) What are the different characteristics of the flood exceedance curves? 3) What exactly is the frequency of TCs compared to ETCs? 4) How can they cause more damage?

We will address all of these important topics and include them in this paragraph.

Line 45 – 54: Could you please summarize this in a few sentences? Also: the term "noisy" is very vague. I also feel like the literature is very tailored towards US case studies and misses some other relevant studies (see my earlier comment)

We will summarize these statements and include the other relevant studies suggested earlier. Additionally, we have removed the use of the term "noisy" and include better descriptions of the data where applicable. Since our research focuses on surge along the east coast of the US, this literature is most relevant in describing the motivation for our research.

Line 54 – 56: I strongly disagree with the wording here. The authors make it seem like they will overcome the regional scale, but they still perform a regional assessment (namely, the US East Coast).

Our suggestion was to imply that not many studies have used past observations and connected them to TC characteristics. Many of the studies cited here have adjusted TC tracks or used model simulations as opposed to what we are doing in utilizing past observations, isolating the maximum surge produced by a TC and examining what characteristics those TCs exhibited at the time of the surge maximum. We will rephrase this section to describe this aspect of our research in addition to our exploration of storm surge exceedance probabilities.

Line 59 – 60: Perhaps good to also mention coastal complexity here (Bloemendaal et al 2019)

We will include this.

Methods – specific comments

Line 86 – 87: This is quite a bold statement to make, without any additional clarification. How big is the contribution of TC waves to total water levels?

We have reworded this sentence to account for the complexities associated with the wave setup and its contribution to surge: "While the wave setup is an important component in the water level (e.g., Phan et al., 2013, Marsooli and Lin, 2018), we neglect this component in our calculation of storm surge due to its overall complexities and its variations based on location and storm intensity."

Table 1: Please round the pressure to one decimal place

We will make this change.

Line 104: What do you mean with wind intensity? Wind speed? What is the time reference for this wind speed? (1-min, 10-min, 3-sec?) Please also add units with every TC characteristic listed here.

Wind intensity is the maximum sustained surface wind speed, as defined in the HURDAT2 database. We have added this information to the methods.

Line 105: Please state the exact dimensions of the "specified distance"

We have clarified this.

Line 123: Why are you solely testing for linear relationships?

We expanded this to other fits and will now include information about both linear and exponential fits.

Line 130: Please explain to the reader what these results are

We have included this now.

Figure 2: Why are you differentiating between a radius of 250 km (in Figure 2) and 500 km (in the text)? Also, how did you derive the track angle? To me it seems like one of the

green tracks for Charleston has a N-NNW angle upon approaching the landfall location, but it is listed as SW.

Figure 2 has been updated to be for a radius of 500 km. This is described in paragraph 5 of section 2. The calculated track angle is not relative to landfall location, it is relative to the time of the surge maximum, so depending on when the surge maximum occurs, the TC can be moving in various directions. Additionally, we average the track angle over the time period from 18 hours prior to the surge maximum to 6 hours post surge maximum. We will add further clarification to this section regarding the calculation.

Results – specific comments

To me, a 0.5-yr return level of 0.8m seems like a lot. This implies that (assuming the authors correctly identified individual storm surge events) Sandy Hook is affected by TC storm surges of this height on average twice per year! Could you please validate these results against other studies?

Thanks for alerting us of this. We found in our calculation of return periods that we were using hourly data and the independence threshold was in hours not days, so this obviously skewed our results. We have now updated this for daily data and include an independence threshold of 2 days and the results make more sense now.

Please quantify the statistical significance and correlation throughout the results-section.

We will address this in the results section.

A lot of results aren't shown (indicated by "not shown" in the text). Could you please add these results to the supplementary materials, so that the reader can have a look at these results?

We will include these figures in the supplemental material.

The continuous switching between a 500 km and 250 km radius is highly confusing – please re-read this section carefully and try to homogenize this usage of radii.

The point of using these different radii is to illustrate the importance of distance with respect to surge, with closer (and stronger) TCs more frequently associated with higher surge. We will clarify any confusion in this section.

Conclusions

Line 329 – 333: Please check the work of Ramos-Valle et al (2020); they synthetically changed details of various storms in the Mid-Atlantic Bight.

We have included this citation now in our discussion.