Comment on nhess-2021-329

Anonymous Referee #2

Referee comment on "Storm surge hazard over Bengal delta: A probabilistic-deterministic modelling approach" by Md Jamal Uddin Khan et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-329-RC2, 2021

I commend the authors on this mammoth work on a topic that is highly relevant and much needed for Bangladesh and this region. The work has been performed well and described thoroughly. I believe that the paper will be ready to publish after the authors clarify a few doubts and questions.

The issues that require clarification center on two points: 1) the embankments ; 2) the cyclone ensemble and return periods.

Re. the embankments:

1. The authors should explain exactly how the information on embankments has been integrated and should provide a map and/or more information showing embankment heights within their dataset (this can be smoothed out if there are copyright or other data concerns). As the authors state, these embankments are critical in controlling flooding.

However, I do not know if these embankments are wider than 250 m, and it is not clear if/how these can be captured by the bathy-topo datasets if the minimum resolution is 250 m.

Reply:

The bathy-topo dataset used in this study is an assembly of several bathy-topo dataset for which the maximum resolution amounts to 50m and indeed does not capture these embankments as their typical width is 10-20m. The original embankment datasets were provided by Bangladesh Water Development Board (BWDB) as polygon shapefiles. A figure showing the embankment outlines and heights are now added in the supplementary materials. The correct characterization of the embanked areas would be - polder - e.g, a region surrounded by embankments. One such region is shown in Figure C1. In local use, the polder became synonymous with the embanked region as well as the embankment themselves.

To incorporate the shapefile dataset into the grid, from the original line shapefiles, a buffered polygon is first created. The lines from the shapefile are taken as the outer edge of the polder during this process. The buffer size is controlled by the target mesh resolution. In our case, we took a buffered area of 300m - and assigned all the mesh node points inside this buffered area to have the height corresponding to the respective embankment height. Additionally, during mesh generation, we have forced the mesh generator to follow the embankment shapefile while assigning the position of the nodes. This process assigns the embankment heights along the edge of an element. This process sets the embankment height to one or two nodes of a triangular element, sometimes all three (for example, when the embankment has a strong curve, or two side-by-side embankments are separated by sub-resolution distance.).

In this study we used 10cm as the threshold for the wetting drying algorithm. That means, if all nodes of a given mesh element have a water level above 10cm, the element is considered wet, otherwise dry

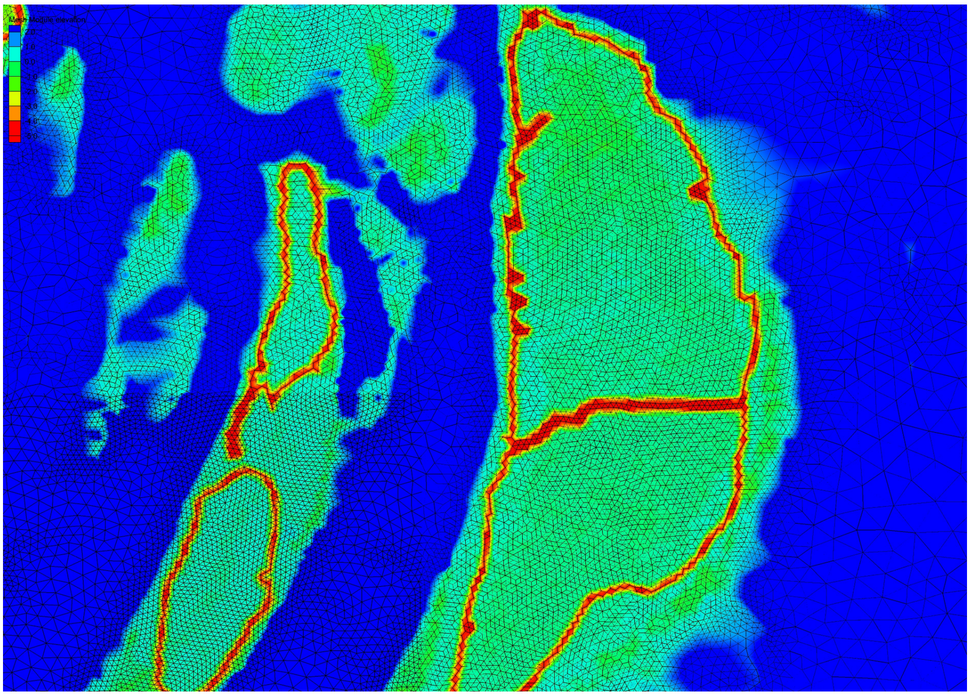

Figure C1. Embankments as incorporated into the model. Snapshot for Haitya Island (91.11°E, 22.24°N). Here the colour scale represents the bathymetry, and the red pixels are above 4mMSL.

We have also revised the manuscript with the following lines -

"...1.1 million triangular elements. In order to take into account the embankments information, we have aligned the mesh nodes along the contour of the embankments and set the height values of these nodes to the designed dikes levels provided by BWDB. The flow above the top of the embankments is controlled by the wetting-drying algorithm of SCHISM just like everywhere else over the modelling domain. The model transforms..."

2. The authors mention that the embankments appear to start overflowing at the 75-100 year RP water levels. Clarification on how the model "sees" these embankments will be

useful. I assume that overtopping processes are not included in the model but this will be worth stating.

Reply:

In application, the embankments are seen realistically as a series of sharp-crested blocks. The flow over the embankments is controlled by a wetting and drying scheme, just like everywhere else in the model domain. The water can pass freely from one element (outside an embankment) to another element (inside an embankment) when all of the nodes in the first element are registered as "wet".

The model does account for the surface waves through its online coupling between SCHISM and WWMIII. Hence, we do account for the overflowing driven by wave setup. However, the waves being modelled in a phase-averaged framework (spectral), the model does not account for the swash and associated overtopping. To take into account your comments about the embankment we have added the following sentence to clarify the way the embankments have been taken into account.

"... 1.1 million triangular elements. In order to take into account the embankments information, we have aligned the mesh nodes along the contour of the embankments and set the height values of these nodes to the dikes levels provided by BWDB. The flow above the top of the embankments is controlled by the wetting-drying algorithm of SCHISM just like everywhere else over the modelling domain. The model transforms the coordinates..."

Re. the cyclone ensemble:

3. I understand and support the authors' decision to show water level variations based on RPs rather than events. While logical, this can however be confusing to interpret. The authors should add a few sentences explaining describing how the 100 year RP water level map (for example) is comprised of WLs from several cyclone events.

Reply:

We agree. We propose to add the following revision in the description of our 50-year return period map to make it clearer.

L337: "...topography. This water level at the 50-year return period is computed from the full ensemble of cyclone simulations using the empirical statistical method described in Section 3.3, pixel-by-pixel. As such, the total water level at the 50-year return period has contributions from hundreds of different cyclones of our ensemble. In our estimate, about 600 individual cyclones contribute to the 50-year return period water level over the illustrated region. ¶ The 50-year return period water level shows a ..."

Note: ¶ means a new paragraph.

4. Figure 4 indicates a significant spatial variation in the number of cyclones affecting the coastline, with the western coastal segments seeing a lot more cyclones. This could mean that coastal segments in the east, with far fewer cyclones, also have a much smaller range of WLs within the 5-500 year RPs. Can the authors clarify if this is the case, and whether/how the spatial variation in cyclone tracks can influence the spread and uncertainty around the WL results at the shoreline and inland?

Reply:

Note: Based on the referred figure, we interpret that you meant the opposite, as the spatial density of cyclones landfalls is superior in the east than in the west of the delta.

Cyclone distribution

We agree that the western segment (India coastline) has a lower number of cyclones per 20km box compared to the eastern segment (south-eastern Bangladesh). However, the density remains high in the west, in the range of 50-80 cyclones per 20km box along the shoreline. This results in a robust estimation of the water levels at a given return period, as shown by the confidence intervals that we incorporated in the revised manuscript (Figure 6a, d). The confidence interval is computed using a bootstrap method by sampling from the full ensemble with replacement. Hence, it also comprises the answer to the question regarding how the spatial variation of the cyclone tracks can influence the spread and uncertainty around the WL results at the shoreline and inland.

The number of cyclones south of 20°N does get significantly lower than the north of it. It is because of the selection process of the cyclone during the generation of the ensemble, where only the cyclones passing through a 300km radius circle centered on the central Bengal coast are retained. This selection criterion is due to the fact that our study has a focus on the Bengal delta only. We have already acknowledged this selection (L284), and in the results section, we limited all our figures analysing the storm surges to the north of 20°N.

Water level range

The water level range is not solely controlled by the storm surge but through a non-linear combination of tide, surge, and wave setup, which are all strongly controlled by local topography/bathymetry. We have stressed this point in our manuscript (L121-126), and we referred to Khan et al. 2021, and Krien et al. 2017 as well.

The hydrodynamic configuration is not the same for the East vs West side, as evident from the mean tidal range. The mean tidal range in the western side - around 87.75E, 21.5N - is slightly smaller (3m) than on the western side (4m) - around 91.75E, 22.25N (Khan et al. 2020). The same is seen for mean high water, shown in the revised Figure 5b. As such, it is not straightforward to comment on what part of the water level extremes results from the local hydrodynamics and what part results from the difference in storm distribution. One can also note that in Figure 4, the central part of the delta around 89.5E shows a similar density of cyclone landfalls as the eastern side, however, the total water level at the 50 year return period (Figure 5) is hardly half as much. This goes to show that a smaller range of water level can not be unequivocally explained by a lower density of cyclones' landfall.

References

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