Responses to Review Anonymous Referee 1

Dear Reviewer anonymous referee 1,

Thank you for your observations regarding our preprint. Your suggestions helped to improve our manuscript. See below our responses marked in blue for each of your questions (marked in black).

The manuscript presents an interesting approach to deriving intertidal bathymetry from the waterline method through multispectral images, covering four (4) estuarine study areas on the east coast of Aotearoa New Zealand's North Island (Tauranga, Ohiwa, Maketu and Whitianga harbour). It represents a current thematic area, and it can be particularly useful to be applied in remote or inaccessible areas or where the bathymetric or cartographic data is very outdated. The main objectives of the study are to determine if multispectral images can be used to extract accurate intertidal bathymetric area and to assess the use of the SDB for hydrodynamic modelling of estuarine.

Good English level however the manuscript is not well-structured, quite confusing and the reader easily misses the main guidelines and the aim of the study. In section 1 (Introduction) is very difficult to establish a connection between the different ideas and paragraphs. A deeper revision of the state of the art is needed to bring the reader into the SDB theme and waterline method. The flow chart in chapter 2 is useful but does not really explain the methods used by the authors. Furthermore, the Methods Chapter establish that the main method was divided into 2 steps (1-SDB estimation and 2-Hydrodynamic modelling assessment) and that step 1 is also two methods for removing the bias, but a clear explanation of the methodology is not present in this section of the manuscript. A very short discussion and a shorter conclusions section are shown, where no clear main findings can be found. Modelling Storm surge is only referenced in the title of the manuscript.

The manuscript shows that a lot of work has been made, however, a big gap throughout the presented structure is noticed and the methodology used is not well described, creating a lot of misunderstanding between the methods applied and the different steps described by the authors. I, therefore, do not recommend the publication of this manuscript as it was presented. A major revision of the structure and methodology form is recommended.

Based on your revue and those provided by the other reviewers, we understand that we need to modify the structure of the paper because the current format is confusing. We have undertaken a deeper revision of the state of the art on SDB (adding new references and text to the introduction section). We have added a much clearer aim to the introduction, and worked on linking the methods to the aim in a much more clear and logical order. In the methods section, we added further explanations about the different methods implemented to remove the bias (i.e., statistical and dynamical methods). In the discussion and conclusion sections, we built further on the context provided in the new references added in the introduction part. Please note that we did not model the storm surge, but we analyzed the maximum astronomical tide in all simulation scenarios and compared the outputs between scenarios using only surveyed bathymetry, only SDB, and mixed surveyed bathymetry combined with SDB. In terms of coastal flooding, the maximum water level is the main parameter studied and in most places in the world, the water level is dominated by the tide. In summary, we are happy to modify the paper structure as you and other reviewers recommend.

My main critics are the following:

1. In the Introduction section the theme is not quite explained, and only part of the aim of the study is presented in the last sentence of the last paragraph. In this section is expected that the authors explain the reasons that have motivated this study, as well as what will be presented in the different sections of the entire manuscript.

We will add a motivation paragraph linking the importance of SDB to enable hydrodynamic modelling of water level variations in shallow intertidal estuaries, and how and why it can be difficult to obtain information on bathymetry using traditional surveying methods. We will also add sentences providing an overview of the material presented in each of the following sections of the manuscript.

2. The different figures do not follow a consistent presentation. The geographic coordinates in some cases are presented as latitude/longitude with no reference datum associated (Fig.2(a)); others as X/Y coordinates (km) WGS84/UTM60S (Figs. 2 (b), (c), 3 (a)) and even other examples as X/Y coordinates NZGD2000 (km).

All figures will be changed so that they use the same SI units.

3. The same Figures, presented in different sections, have different SI unit references, like Fig.2 (b) and (c) are expressed in X/Z coordinate (km) and Figures S1 and S2 in X/Z coordinate (m) – show a lack of consistency.

All figures will be updated to use the same SI unit references.

7. The areas A, B, C and D depicted in Figure7 (central figure) are not quite perceptible, and the small figures (a1, a2, b1, b2, c1, c2, d1 and d2) do not have geographic coordinates associated, neither the scale factor.

We will modify the colour scheme and sizes to make the Figure more readable. We will make the ABCD areas easily visible. We will also add the coordinates and a scale factor.

5. The profile lines drawn in Figure 9 (m1) are barely noticed. Maybe the authors could choose a different colour palette.

The colour and the thickness of the profile will be modified to make it more legiable.

6. In the text, the figures are not correctly cited, like Fig 2A (line 85); Fig 2B and 2C (line 88). In the Figures, the panels are mentioned with small letters (a, b and c), as well as in the figure capture.

We will change all the labelling to the format of the journal (always using small case letters).

7. The data access information at the reference links (lines 94-97) is missing.

We will add the links.

8. I do not understand how the intertidal area is identified, the method is not well explained. Is used the tidal level at the time of the acquisition of each image? Or is used an average tidal range (tidal amplitude?) for all the images. Is also not clear the tidal level for each image, as depicted in Figure 2(d). All images are used to generate the intertidal area presented in Figure 3(a)?

The intertidal area is identified by calculating the standard deviation of NDWI over the whole collection of images, at each pixel (this is described in section

2.2, using equation 1). Because the water level changes substantially through time (because the tide completely drains and inundates these areas), these areas are easily identified, in a collection of images, by the high standard deviation of NDWI. We use a threshold to find the areas with high standard deviation and define the 'intertidal' area as being the area of high NDWI standard deviation. We will make this more clear in the text. We did not use the level of the tide to demarcate the intertidal region, because this would require apriori knowledge of the elevation of the intertidal. (The tide level is not used to generate Figure 3, only the satellite reflectance). We have added the level of the tide to Figure 2, and also marked the times that these two images were collected on the timeseries shown in Panel D.

Once the intertidal region of interest is demarcated, then the x,y coordinates waterline is extracted separately from each image in the correction, using the NDWI to determine the location between wet and dry pixels. The threshold between wet and dry pixels is determined using the Otsu threshold. In the final step, the x-y coordinates are associated with a water level height (z), which we assume to be equivalent to the level of the tide when that image was collected. The x,y,z coordinates from all the images are then collected into one dataset, which is then gridded to make a bathymetric map. We will make this much more clear.

9. The threshold value used, and all the contour extraction method (lines 153-159) are quite confusing. And which values of threshold and water level were used for the other study areas, regarding that Figure 4 presents the water level and threshold values for each image. A table with this information, for all the different study areas, as supplementary information could be very useful.

We will make this more clear (see response to comment #8). A table will be added containing the information in the supplementary material.

10. What do you mean with the Stumpf-ratio method was applied for deeper areas (lines 164-165). The Stumpf ratio method (Stumpf et al., 2003) is not quite good for all different benthic areas and for very deeper areas. What was the maximum depth value which the authors have used this method?

The waterline method can only be applied in the intertidal zone. When we refer to deeper areas, we refer to all areas within the estuary that are not intertidal zones or land. We are aware of the Stumpf-ratio limitations. One of our main

aims is to determine whether, despite the limitations of both waterline and Stumpf-ratio methods, we can predict reasonably the water level (using numerical model). We will rewrite the aims to make this more clear, and to review the limitations of the Stumpf method.

11. It was not explained by the authors all the pre-processing steps applied to the multispectral images, such as sun glint correction (for example Hedley, J.D.; Harborne, A.R.; Mumby, P.J. Simple and robust removal of sun glint for mapping shallow-water benthos. Int. J. Environ. 2005, 113, 2107–2112). If this step was considered, it should be enunciated in the manuscript. The authors described that Level 2 image was used, with BOA values corrected for the effects of the top-atmosphere (lines 103-104), but it was not explained why they used these images rather Level 1 with atmospheric correction.

We used the level 2 images because they were already corrected for the effects of the top of the atmosphere, and we did not believe it necessary to undertake our own correction. We did not apply a sun glint correction because the Otsu algorithm could detect the waterline well without this correction.

12. I can not understand if the evaluation of the model performance in section 2.4 is one of the results of this study. And if they are, why not present them in the results section? Lines 201-215 have a challenging interpretation.

We can move this to the results. We will make the explanations on these lines more clear.

13. Why an" Average" line in table 3. Does not make sense.

The "average" refers to the average of the error metrics over all the estuaries for the corresponding parameter (MAE, RMSE, R2).

14. Lines 234-239 should be included in the Discussion section, not here, where the results are presented.

We will move the referred lines to the discussion section.

15. In the ESA Sentinel 2A images used as background in several figures are missing the data acquisition time and the water-level information (Figures 2, 7, S1, S2, S3, S5, S6, S7).

We will add the information required to the figures.

16. The authors cannot quantify as good or strongly correlated/related the R2 achievements (lines 242-245). Why R2=0.70 should be considered as strongly related? Once more the authors are discussing the presented results in the Results section, and it is a recurrent procedure throughout this section. Perhaps if the authors had previously described in section 1 the contents of each section, the reader could understand better the manuscript. The structure of each section is quite confusing.

We will describe the contents of each section in the introduction part as required. We will also make sure that each section is started with a clear topic sentence.

17. Lines 274-278: R2 values assumption/classification (low/higher). And R2 is referred to as the coefficient of determination (line 276) and a coefficient of correlation (line 278) in the same paragraph. Is not coherent.

We will change it.

18. The authors do not explain why the results and the application of the methodology were only presented for one study area (Tauranga Harbour). They are free to do it, even for editorial figures or pages restrictions, however, this fact should be mentioned and explained in the manuscript and the main results for each area should be resumed (table format perhaps) in the supplementary material section.

The results were presented for just one study site because of limitation number of pages/figures, and we have just Tauranga Harbour with a numerical model already validated. The results of the SDB estimates for each estuary are presented in the main manuscript (table 3) and in the supplement material (Figures S5, S6, and S7). We will change the text to note this explicitly.

19. What is the spatial grid resolution value (line 298)? Is 20 m as assumed in line 336?

The grid resolution we applied here was 20 m. We have added this to the text.

20. Lines 313-316 are quite confusing. A better explanation is needed.

We will change the sentence to: “Otsu threshold works well to bimodal distributions (when dry and wet pixels are presented in the image), however,

the algorithm is limited when the distribution is not bimodal (when most of the pixels are dry or wet)."

21. The prediction of water level using the SDB is presented in section 3.4 for the 3 tide gauges (Omokoroa, Hairini and Oruamatua) (lines 323-331). The average error parameter presented is for each tide gauge and Figure 10 shows the average between all the tide gauges. Was this methodology that was used? I am confused.

We meant the average values between the three tide gauges records and not the average values for each tide gauge. We will reformulate the sentence to make it clearer.

22. Can I assume that, for lower tide values images, the presented methodology can not be used? Or only for the Stumpf ratio method application (SDB)? Lines 338-341. The Stumpf ratio method can not be directly applied to intertidal areas, exactly due to the image reflectance of the dry pixels (low water level images).

The model results for lower tide simulations showed the worst results. Thus, yes, it is not recommended to use SDB if the focus of the work is the processes occurring around the low tide, however for purposes of coastal flooding studies, usually, the highest values are of interest. The STUMPF-SDB is calculated using an image acquired at high tide. It is shown in the Methods (section 2) and in the supplementary material (Figure S2). We will make this more clear in the general discussion.

23. What represents the rectangle-shaped figure in Figure 11? Survey bathymetry data or LIDAR data?

The bars represent the comparison between the in-situ observed water level at each of the 3 sites where there are water level sensors, and the hydrodynamic model output at those same sites, where the hydrodynamic model is run using 4 different bathymetries (S1, S2, S3, S4, are described in the text). We will change the figure caption to make it more clear.