Reply on RC2

General comments

The study titled "NZ-BeachTopo30: A national-scale and full-coverage 30 m beach topography dataset for New Zealand reconstructed by fusing ICESat- 2 and Sentinel-2" presents a novel and robust methodology for generating topography for beaches and then develop a useful and national-scale dataset across New Zealand. Please find my revision suggestions below.

Reply: We sincerely thank you for your highly positive evaluation and constructive comments on our manuscript. We deeply appreciate your recognition of our methodology as "novel and robust" and the resulting dataset as a "useful and national-scale" contribution. Your detailed suggestions regarding the introduction's logical flow, figure improvements (Figures 1, 2, and 14), quantitative explanation of percentile denoising, and the expansion of our discussion on limitations and potential applications are incredibly valuable. Incorporating your feedback has significantly enhanced the clarity, comprehensiveness, and readability of our manuscript.

Below, we provide a point-by-point response to your comments. For your convenience, our direct responses are formatted in blue text, while the specific new content incorporated into the revised manuscript is highlighted in *blue italics*.

Comment 1:

I suggest adding one sentence at the end of the second paragraph in the introduction to summarize the current status and limitations of remote sensing techniques for beach topography reconstruction. Moreover, the first sentence of the third paragraph in the introduction should be revised to provide a general overview of mainstream DEM datasets, so as to improve the logical coherence of the paragraph.

Reply 1:

Thank you for this excellent suggestion. We agree that adding a concluding summary to the second paragraph and a broader overview sentence to the beginning of the third paragraph greatly improves the logical transition and coherence of the Introduction. We have revised both paragraphs accordingly.

Modifications in the revised manuscript (Section 1, Introduction):

Added to the end of the second paragraph:

In summary, while current remote sensing techniques have significantly advanced coastal monitoring, achieving national-scale, high-resolution, and seamless beach topography reconstruction remains fundamentally constrained by the trade-offs between spatial coverage, temporal revisit frequency, and observation continuity.

Revised the first sentence of the third paragraph:

Currently, several mainstream global or regional Digital Elevation Model (DEM) datasets (e.g., SRTM, Copernicus DEM, and DeltaDTM) are widely utilized for coastal studies; however, they often struggle to accurately capture the dynamic and frequently inundated *intertidal zones.*

Comment 2:

I suggest that ICESat-2 track information should be added in Figure 1 to better illustrate its spatial distribution across the study area.

Reply 2:

We completely agree with your suggestion. Visualizing the ICESat-2 ground tracks provides readers with a clear understanding of the spatial density and distribution of our training data across the study area. To ensure the original map remains clear and readable without becoming overcrowded, we have updated Figure 1 by adding a dedicated subpanel (panel b) that explicitly illustrates the spatial distribution of the ICESat-2 tracks across New Zealand. The figure caption has also been updated accordingly to reflect this addition.

Modifications in the revised manuscript:

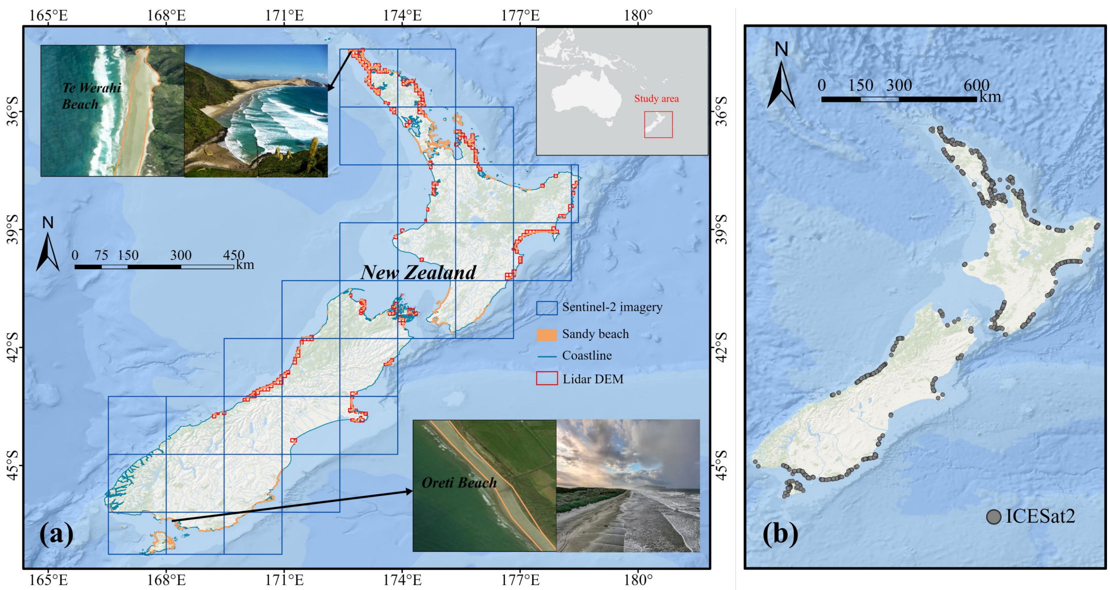

Fig. 1 Geographical information and dataset distribution across the study area (New

Zealand). (a) The main map displays the spatial distribution of the study datasets: Sentinel-2 image footprints (n = 31; blue boxes), beach polygons (n = 1,713; orange), coastline (cyan lines), and Lidar DEM footprints (n = 309; red boxes). The inset panels, linked by arrows to their corresponding locations, illustrate two representative beaches selected from the North Island (Te Werahi Beach) and South Island (Oreti Beach). In each inset, the left subpanel displays high-resolution satellite imagery of the beach extent, while the right subpanel shows a corresponding field photograph. (b) The spatial distribution of the spaceborne ICESat-2 ground tracks utilized in this study. The background map for the main map and the high-resolution imagery for the insets are World Ocean Base and World Imagery, respectively, both served by Esri via ArcGIS Pro software.

Comment 3:

In Figure 2 workflow diagram, I suggest that the authors explicitly indicate that airborne LiDAR was used for validation; otherwise, it could easily be confused with the spaceborne ICESat-2 LiDAR data also employed in this study.

Reply 3:

Thank you for pointing out this potential source of confusion. We have updated the flowchart in Figure 2. The text block for airborne Lidar has been explicitly relabeled as "Airborne LiDAR (Validation Data)" to clearly distinguish its role from the spaceborne ICESat-2 Lidar used for model training.

Modifications in the revised manuscript:

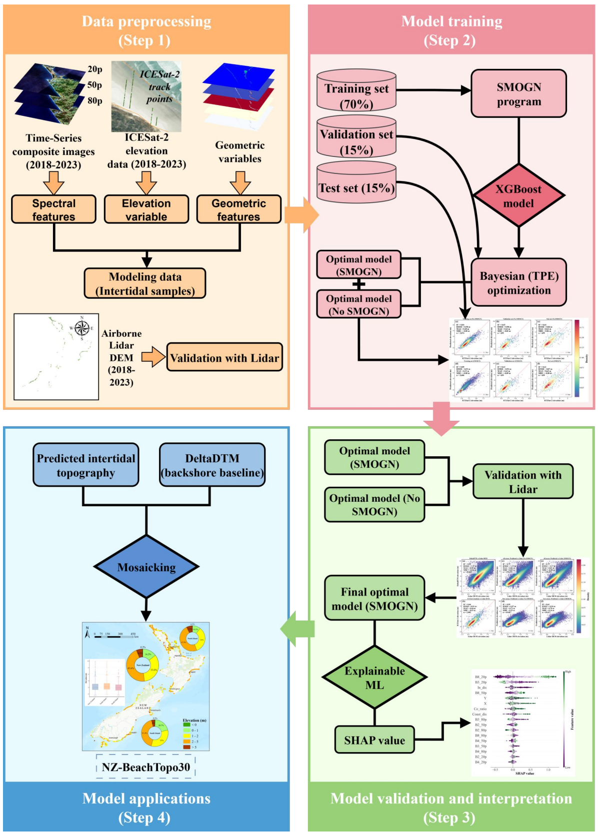

Fig. 2 Workflow used to reconstruct beach topography: (1) Data preprocessing (where 20p, 50p, and 80p refer to the 20th, 50th, and 80th percentile composite images, respectively); (2) Model training; (3) Model validation and interpretation; (4) Model applications.

Comment 4:

The authors used composite remote sensing imagery of different quantiles to represent states at various tidal levels and claimed that this method can achieve denoising effects. I recommend the authors provide more quantitative evidence to demonstrate the rationality of this approach used in this study.

Reply 4:

Thank you for your constructive comment. We understand that the use of multi-quantile composites requires robust justification both in terms of physical tidal representation and statistical denoising effectiveness.

Firstly, regarding the physical rationality, we conducted a quantitative verification using 1-minute interval sea-level records from 12 permanent tide gauge stations across New Zealand (2018–2023). As shown in Fig. 3 (taking Auckland and Napier stations as examples) and Table 1 below, the tidal level distributions at Sentinel-2 overpass times perfectly align with the full continuous tidal cycle. The 20th, 50th, and 80th percentiles derived from satellite overpasses are nearly identical to the true natural tidal percentiles (with biases typically < 0.1 m). This proves that the 20th and 80th percentile spectral composites genuinely represent the physically wet/inundated and dry/exposed states, respectively.

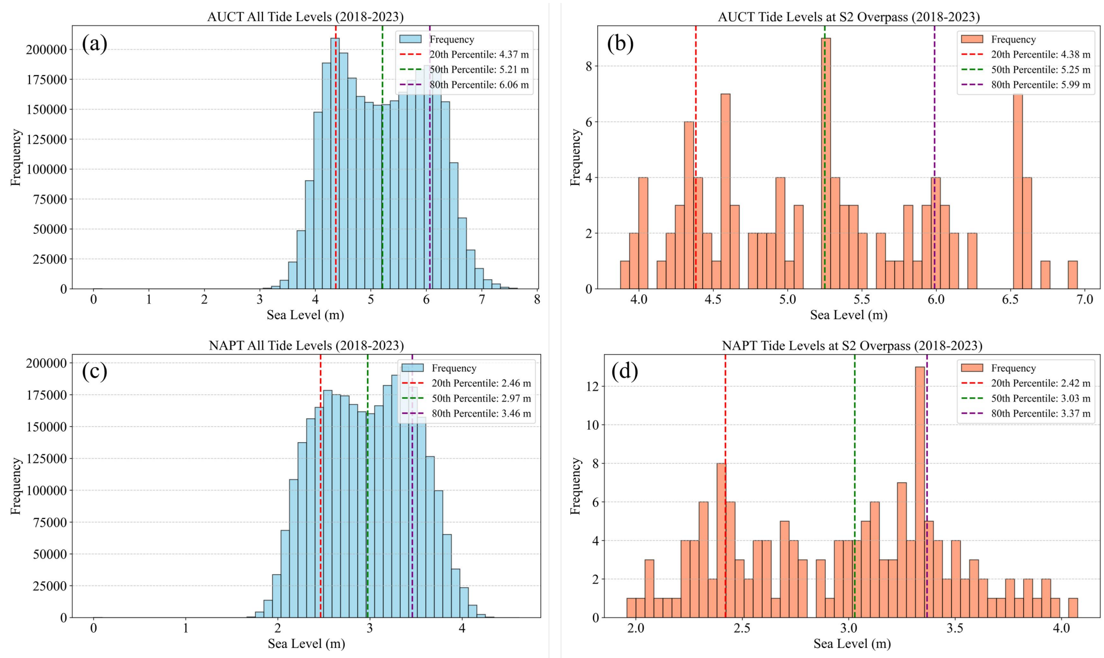

Fig. 3 Frequency histograms of tidal levels comparing continuous full-tidal records and Sentinel-2 (S2) overpass moments. Panels (a) and (b) represent the total observed tide level frequency histogram and the S2 observed tide level frequency histogram for the AUCT (Auckland) tide gauge station, respectively. Similarly, panels (c) and (d) display the total

observed tide level frequency histogram and the S2 observed tide level frequency histogram for the NAPT (Napier) tide gauge station. The dashed vertical lines indicate the 20th, 50th, and 80th percentiles.

Table 1 The recorded values corresponding to the three percentiles (20th, 50th, and 80th) of the total continuous observations and the S2 overpass times across 12 representative tide gauge stations in New Zealand (2018–2023). This table also lists the geographic coordinates (longitude and latitude) where each station is located. The 12 analyzed stations are: AUCT (Auckland), CHIT (Chatham Islands), CPIT (Castlepoint), GBIT (Great Barrier Island), GIST (Gisborne), KAIT (Kaikoura), LOTT (Lottin Point), NAPT (Napier), OTAT (Port Chalmers), PUYT (Puysegur Point), TAUT (Tauranga), and WLGT (Wellington).

Station	Continuous tidal record (m)			Sentinel-2 overpass (m)			Lon (°)	Lat (°)
	20p	50p	80p	20p	50p	80p		
AUCT	4.37	5.21	6.06	4.38	5.25	5.99	174.79	-36.83
CHIT	2.22	2.57	2.96	2.21	2.50	2.82	-176.37	-44.02
CPIT	2.51	3.55	4.34	2.45	3.65	4.30	176.23	-40.90
GBIT	5.20	5.78	6.44	5.14	5.73	6.31	175.49	-36.19
GIST	3.41	3.88	4.37	3.50	3.83	4.31	178.02	-38.68
KAIT	1.49	2.00	2.54	1.40	1.89	2.49	173.70	-42.41
LOTT	2.99	3.54	4.06	3.02	3.59	4.12	178.16	-37.55
NAPT	2.46	2.97	3.46	2.42	3.03	3.37	176.92	-39.48
OTAT	3.83	4.39	5.00	3.83	4.29	4.78	170.63	-45.81

PUYT	5.78	6.37	6.96	5.79	6.29	6.78	166.59	-46.08
TAUT	4.37	4.94	5.47	4.41	4.98	5.49	176.18	-37.64
WLGT	2.52	2.88	3.29	2.53	2.86	3.21	174.78	-41.28

Secondly, regarding the denoising effect, the choice of intermediate percentiles (e.g., 20th and 80th) instead of absolute extrema (0th or 100th) is a widely recognized statistical strategy in coastal remote sensing to exclude episodic outliers (Bishop-Taylor et al., 2019; Zhao et al., 2020). In long-term time-series optical data, the 0–10th percentiles are frequently contaminated by residual cloud shadows or sensor anomalies (extreme low-reflectance noise), while the 90–100th percentiles often capture transient sunglint, whitecaps, or missed cloud pixels (extreme high-reflectance noise). By trimming the extreme 20% at both ends of the distribution, our method quantitatively suppresses these transient noises while robustly retaining the stable spectral signals of the tide-affected beach surface.

To transparently address your comment in the text, we have added a new paragraph in Section 3.1.2 of the revised manuscript to explicitly explain this denoising rationale. Additionally, we have compiled the quantitative validation results of the tide gauge stations into a newly created Supplementary Material file.

Modifications in the revised manuscript (Section 3.1.2):

This percentile compositing serves as both a physically meaningful stratification and a robust statistical denoising mechanism. Quantitative validation using 12 tide gauge stations across New Zealand confirms that the 20th, 50th, and 80th percentiles of Sentinel-2 overpass tidal *levels closely match the full natural tidal range (biases < 0.1 m; see Fig. S1 and Table S1 in the Supplementary Material). From a statistical perspective, extracting specific intermediate quantiles rather than absolute extrema (0th or 100th percentiles) is a widely recognized method for effectively filtering out episodic noise in time-series satellite imagery (Bishop-Taylor et al., 2021; Zhao et al., 2020). Specifically, trimming the extreme tails of the distribution removes residual cloud shadows (low-reflectance outliers) and sunglint or whitecaps (high-reflectance outliers), thereby ensuring that the machine learning model is trained on stable, tide-representative spectral features.*

Reference:

Bishop-Taylor, R., Sagar, S., Lymburner, L., and Beaman, R. J.: Between the tides: Modelling the elevation of Australia's exposed intertidal zone at continental scale, Estuarine Coastal Shelf Sci., 223, 115-128, https://doi.org/10.1016/j.ecss.2019.03.006, 2019.

Zhao, C., Qin, C.-Z., and Teng, J.: Mapping large-area tidal flats without the dependence on tidal elevations: A case study of Southern China, ISPRS J. Photogramm. Remote Sens., 159, 256-270, https://doi.org/10.1016/j.isprsjprs.2019.11.022, 2020.

Comment 5:

I suggest the authors add boxplots for the X-axis and Y-axis corresponding data in panels a and b of Figure 14 in Section 5.2, to enable a more intuitive comparison. In addition, In Figure 14, it is evident that DeltaDTM systematically omits low-lying areas of beaches as well as regions adjacent to the ocean. I suggest that the authors emphasize this point in their discussion.

Reply 5:

We greatly appreciate these insightful suggestions.

First, we have updated Figure 14 by adding marginal boxplots to both the X and Y axes in panels (a) and (b). As you rightly anticipated, these boxplots make the density and distribution comparisons much more intuitive.

Second, your observation regarding DeltaDTM's systematic omission is remarkably acute and is now perfectly visualized by the newly added boxplots. In panel (b), the Y-axis boxplot (representing DeltaDTM inundated areas) is heavily compressed near zero, whereas the corresponding X-axis Lidar boxplot shows a wide distribution of actual inundation. This quantitatively confirms that DeltaDTM systematically assigns 'NoData' or positively biased elevations to low-lying beaches and regions immediately adjacent to the ocean, preventing accurate simulated inundation.

We have explicitly emphasized this critical point in the Discussion (Section 5.2) to highlight the value of our newly generated dataset in bridging these specific nearshore data gaps, and updated the caption for Figure 14 accordingly.

Modifications in the revised manuscript (Section 5.2):

As intuitively demonstrated by the scatter distributions and the newly added marginal boxplots in Figure 14, it is evident that the baseline DeltaDTM systematically omits low-lying beach areas and regions immediately adjacent to the ocean (often returning 'NoData' or severely positively biased elevations). This systematic omission highlights the limitations of traditional global DEMs in capturing the intertidal zone. In contrast, our proposed *framework successfully reconstructs these missing nearshore gradients, effectively bridging the critical data gap between the ocean and the backshore.*

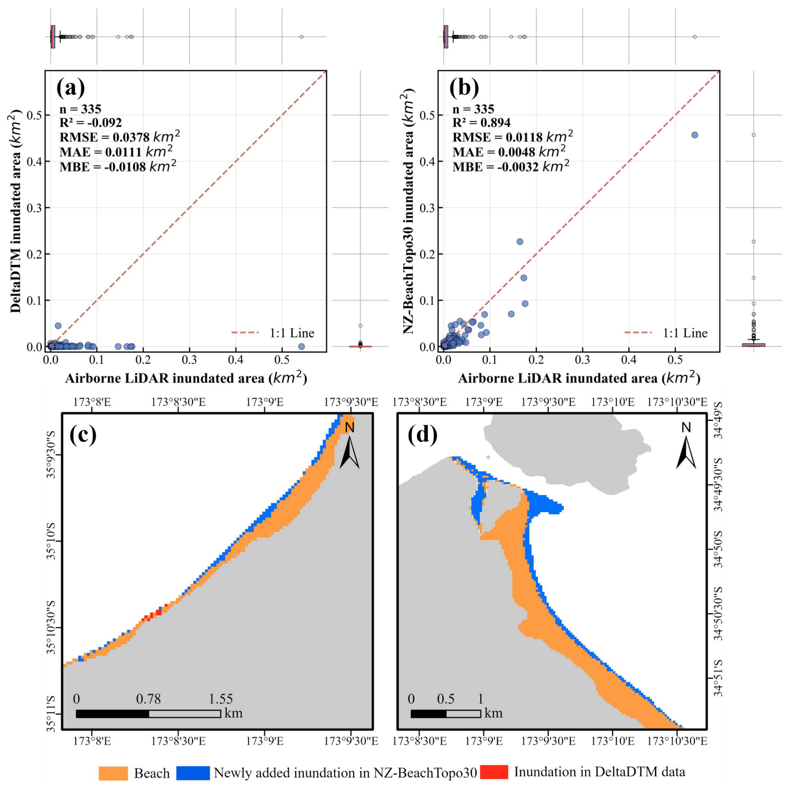

Fig. 4 Comparison of estimated inundation area and spatial patterns under a 1 m sea-level rise scenario. (a) Scatter plot and marginal boxplots of inundation area derived from the NZ-BeachTopo30 dataset versus the Lidar DEM reference. (b) Scatter plot and marginal boxplots of inundation area derived from the baseline DeltaDTM versus the Lidar DEM reference. The marginal boxplots intuitively illustrate the data distribution along the corresponding axes. (c) and (d) Spatial inundation patterns for two representative beach units. Orange areas indicate the beach extent, red areas indicate inundation simulated by the original DeltaDTM (inundation in DeltaDTM data), and blue areas indicate additional inundation identified by NZ-BeachTopo30 (newly added inundation in NZ-BeachTopo30). The land masks used as the background in panels (c) and (d) are from OSM.

Comment 6:

I suggest that the authors add a discussion in this section addressing potential limitations of this study. For example, the use of OSM data to delineate beach extents may introduce errors inherent to the baseline data itself. Beaches undergo long-term evolution, and their temporal changes are also critical. Additionally, the 10 m spatial resolution may be insufficient for accurately representing narrower beaches. In summary, I would like to see the authors expand the discussion to include these considerations in the manuscript.

Reply 6:

We sincerely thank you for highlighting these important aspects. Discussing these limitations provides a much more comprehensive and objective perspective for the readers. We have added a dedicated paragraph addressing the inherent OSM baseline errors, the masking of temporal morphodynamics due to our 5-year time-series compositing, and the spatial resolution constraints (please note that our dataset has a spatial resolution of 30 m, aligning with the Sentinel-2 feature integration and DeltaDTM baseline, which, as you correctly pointed out, may still be insufficient for extremely narrow beaches).

Modifications in the revised manuscript (Section 5.3):

While our framework successfully generates national-scale beach topography, several limitations must be acknowledged. First, the spatial extent of the modeled beaches is inherently constrained by the baseline OpenStreetMap (OSM) polygons. Consequently, any existing omissions or geometric inaccuracies within the crowdsourced OSM data may propagate into our final maps. Second, our dataset represents a temporally composited 'mean *state' generated from a 5-year observation window (2018–2023). Because sandy beaches are highly dynamic environments undergoing continuous morphological evolution (erosion and accretion), this static dataset cannot capture short-term temporal changes or extreme storm-induced morphodynamics. Finally, while the 30 m spatial resolution of the NZ-BeachTopo30 dataset is highly suitable for national- and regional-scale assessments, it may be insufficient for accurately resolving the micro-topography of extremely narrow or pocket beaches, where higher-resolution imagery would be required.*

Comment 7:

This study presents a useful and large-scale dataset that fills an important gap in coastal elevation data for New Zealand. Hence, I suggest that the authors provide a more systematic explanation regarding the advantages, significance, and potential application scenarios of the data.

Reply 7:

Thank you for this encouraging comment. To better underscore the value of the NZ-BeachTopo30 dataset, we have expanded the conclusion section to systematically outline its advantages and explicitly list its potential application scenarios for downstream users.

Modifications in the revised manuscript (Section 7, Conclusion):

In conclusion, the NZ-BeachTopo30 dataset fills a critical coastal elevation data gap by providing a seamless, high-accuracy, and spatially continuous 30 m topographic product for

New Zealand's sandy beaches. Its primary advantage lies in overcoming the systematic omissions of low-lying intertidal zones typical of existing global DEMs. This dataset holds significant potential for a wide range of downstream applications. It provides essential baseline data for precise coastal hydrodynamic modeling (e.g., wave run-up and inundation models), regional vulnerability and risk assessments under future sea-level rise scenarios, and the strategic planning of coastal engineering and ecological conservation efforts.

Thank you very much for all the comments on this manuscript, which have significantly improved it. If any issues still need to be addressed in the revised version, we would greatly appreciate the opportunity to further revise and improve the manuscript.

Best regards.