Reply on RC1

General comments

I have reviewed the manuscript “NZ-BeachTopo30: Bridging the Intertidal Data Gap by Fusing ICESat-2 and Sentinel-2”. Overall, this paper presents a novel and valuable dataset for New Zealand beach topography, filling an important data gap. The manuscript is generally well structured, and the methodology is clearly described. However, some revisions are still required to enhance the quality of the manuscript, and my specific comments are detailed as follows.

Reply: We sincerely thank you for your highly positive evaluation and constructive comments on our manuscript “NZ-BeachTopo30: A national-scale and full-coverage 30 m beach topography dataset for New Zealand reconstructed by fusing ICESat-2 and Sentinel-2”. We deeply appreciate your recognition of the novelty and value of our dataset. Your detailed suggestions regarding the distinction of LiDAR systems, dataset URLs, explanation of spectral quantiles, the SMOGN algorithm, and the discussion on tidal flats are incredibly valuable. Incorporating your feedback has significantly enhanced the clarity, completeness, and rigor 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:

In the introduction, the authors discuss the characteristics and limitations of airborne LiDAR and spaceborne LiDAR together. I recommend discussing them separately to better distinguish between the two in the manuscripts.

Reply 1:

Thank you for pointing out this important distinction. We fully agree that grouping airborne and spaceborne LiDAR together obscures their distinct operational characteristics and limitations. Airborne LiDAR provides dense, continuous 3D point clouds but is often limited by high costs and regional coverage. In contrast, spaceborne LiDAR (such as ICESat-2) offers global coverage but only provides sparse, along-track elevation profiles rather than continuous wall-to-wall mapping.

To accurately reflect these differences, we have rewritten the corresponding paragraph in the Introduction to discuss them separately.

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

Airborne and spaceborne Lidar are widely regarded as the “gold standard” for elevation data, yet they possess distinct characteristics and limitations. Airborne laser scanning directly generates high-precision, dense three-dimensional point clouds that capture beach microtopography at centimeter-level resolution (Schmelz and Psuty, 2022; Stockdon et al., 2006). However, its application for rapid, country-wide beach monitoring is hindered by limited, strip-based coverage and high operational costs. Conversely, spaceborne Lidar (such as ICESat-2) offers unparalleled global coverage and frequent revisit cycles (Markus et al., 2017). While it provides highly accurate elevation control points, its measurements are *confined to sparse, along-track profiles rather than spatially continuous surfaces (Markus et al., 2017), making it challenging to generate seamless wall-to-wall beach topography mapping independently.*

Reference:

Markus, T., Neumann, T., Martino, A., Abdalati, W., Brunt, K., Csatho, B., Farrell, S., Fricker, H., Gardner, A., Harding, D., Jasinski, M., Kwok, R., Magruder, L., Lubin, D., Luthcke, S., Morison, J., Nelson, R., Neuenschwander, A., Palm, S., Popescu, S., Shum, C. K., Schutz, B. E., Smith, B., Yang, Y., and Zwally, J.: The Ice, Cloud, and land Elevation Satellite-2 (ICESat-2): Science requirements, concept, and implementation, Remote Sens. Environ., 190, 260-273, https://doi.org/10.1016/j.rse.2016.12.029, 2017.

Schmelz, W. J. and Psuty, N. P.: Application of geomorphological maps and LiDAR to volumetrically measure coastal geomorphological change from Hurricane Sandy at Fire Island National Seashore, Geomorphology, 408, 108262, https://doi.org/10.1016/j.geomorph.2022.108262, 2022.

Stockdon, H. F., Holman, R. A., Howd, P. A., and Sallenger, A. H.: Empirical parameterization of setup, swash, and runup, Coastal Eng., 53, 573-588, https://doi.org/10.1016/j.coastaleng.2005.12.005, 2006.

Comment 2:

I suggest the authors ensure the completeness of information for all datasets used, as I noticed that some data sources do not have corresponding URLs provided. This is essential to guarantee data accessibility and the reproducibility of the methodology.

Reply 2:

We appreciate your meticulous review. We completely agree that providing data access links is essential for ensuring the transparency and reproducibility of the methodology. In the original manuscript, while the airborne Lidar link was provided, the URLs for other public datasets were inadvertently omitted. We have now systematically reviewed Section 2 and added the official data access URLs for DeltaDTM, Sentinel-2, ICESat-2, and OpenStreetMap (OSM) to the revised manuscript.

Modifications in the revised manuscript (Section 2):

We have added the following URLs to their respective subsections:

Section 2.2.1 (DeltaDTM): Added the data source link: "(available at https://doi.org/10.4121/21997565)".

Section 2.3.1 (Sentinel-2): Added the platform link: "The Sentinel-2 Level-2A products were accessed and processed via the Google Earth Engine (GEE) platform (https://earthengine.google.com)."

Section 2.3.2 (ICESat-2): Added the data source link: "This study employed the ATL03 Global Geolocated Photon data product (available at National Snow and Ice Data Center, NSIDC: https://nsidc.org/data/ATL03)."

Section 2.4 (Ancillary data): Added the OSM link: "...incorporated coastal geographic information from OpenStreetMap (OSM, https://osmdata.openstreetmap.de/)..."

Comment 3:

Sentinel-2 composite images serve as the foundation for beach topography modeling in this study. Hence, I recommend that the authors provide a more detailed explanation of the meaning of different quantiles derived from Sentinel-2 optical imagery.

Reply 3:

Thank you for this constructive recommendation. You are entirely correct that the percentile composites are the cornerstone of our modeling framework. We realize that the physical implication of these spectral quantiles needs to be articulated more explicitly, as the relationship between reflectance percentiles and tidal states can vary depending on local coastal environments and water turbidity.

To clarify this for the readers, we have expanded our explanation in Section 3.1.2. For the majority of open sandy beaches in New Zealand, where coastal waters are relatively clear, water and saturated sand tend to absorb solar radiation (resulting in lower reflectance), while exposed dry sand is highly reflective. Therefore, sorting the time-series observations into percentiles naturally stratifies the tidal conditions: the low-percentile composites (e.g., 20th percentile) typically capture the darker observations, which generally correspond to inundated or wetter states. Conversely, the high-percentile composites (e.g., 80th percentile) typically capture the brighter observations, generally corresponding to drier, exposed states. We have also added a nuance to acknowledge that while this relationship might be complicated in highly turbid waters, it holds as a robust general pattern for the open sandy beaches targeted in our study.

Modifications in the revised manuscript (Section 3.1.2):

This percentile compositing serves not only as a noise-filtering method but also embodies a physically meaningful grouping of tidal states. By aggregating multiple observations across the tidal cycle, the composite layers effectively capture the amplitude of reflectance variability caused by tidal inundation and moisture fluctuations. For most open sandy beaches characterized by relatively clear waters, water and saturated sand tend to absorb optical radiation (yielding lower reflectance), whereas exposed dry sand is typically highly reflective. Consequently, low-percentile composites (e.g., 20th percentile) typically isolate darker observations, which generally correspond to more frequently submerged or wetter states during high tides. Conversely, high-percentile composites (e.g., 80th percentile) tend to capture brighter observations, representing drier and more exposed states during low tides. While this reflectance-moisture relationship might be inverted or complicated in highly turbid coastal waters, it remains a robust general pattern for the open sandy beaches targeted in this framework. Feeding this consistent gradient of multi-percentile features allows the machine learning algorithm to implicitly deduce the topographic elevation gradient from the shoreline to the backshore.

Comment 4:

I suggest the authors supplement the paper with an explanation of the applicability of the SMOGN algorithm to regression tasks, or add relevant clarifications.

Reply 4:

Thank you for this valuable suggestion. It is indeed necessary to clarify this, as data-balancing techniques (like SMOTE) are widely known for classification tasks, but their application in continuous regression tasks is less commonly understood. SMOGN (Synthetic Minority Over-Sampling Technique for Regression with Gaussian Noise) is specifically tailored for imbalanced regression problems. We have added a brief explanation in Section 3.2.1 to clarify how SMOGN accommodates continuous elevation variables by utilizing a relevance function.

Modifications in the revised manuscript (Section 3.2.1):

Unlike traditional SMOTE, which is restricted to categorical classification tasks, SMOGN is specifically tailored for continuous regression problems. In topographic modeling, the target variable (elevation) is continuous. SMOGN addresses this by employing a user-defined relevance function to map the continuous elevation values into a bounded range [0, 1], identifying the rare extreme values (e.g., extreme low elevations in the subtidal zone) as the 'minority' cases. It then combines over-sampling and under-sampling strategies to generate synthetic samples...

Comment 5:

I suggest the authors also provide the latitude and longitude information for the beaches corresponding to panels a-f in Figure 5.

Reply 5:

Thank you for pointing out this omission. Providing the exact geographic coordinates will certainly help readers locate these specific validation beaches. We have updated Table 3 to include the central latitude and longitude for each of the six selected beaches (panels a-f in Figure 5).

Modifications in the revised manuscript (Table 3):

Table 1. Detailed information of the 6 randomly selected beaches for validation

Beach FID	***Geographic location (island)***	***Proportion of predicted pixels.***	***Longitude, Latitude (°)***
220	*South island*	*54.1%*	*171.626°E, 41.737°S*
222	*South island*	*75.9%*	*171.549°E, 41.749°S*
678	*South island*	*31.7%*	*170.199°E, 43.186°S*
343	*North island*	*35.2%*	*173.375°E, 34.931°S*
418	*North island*	*63.5%*	*177.304°E, 39.089°S*
421	*North island*	*39.6%*	*177.698°E, 39.053°S*

Comment 6:

It is suggested that the authors add relevant discussion and outlook in the discussion section regarding whether the proposed approach can be applied to the inversion of muddy tidal flat topography in the future.

Reply 6:

This is an excellent and forward-looking suggestion. Extending this topographic inversion method to extensive muddy tidal flat environments is highly feasible and represents the most important next step for our research. However, muddy tidal flats exhibit fundamentally different spectral-elevation relationships compared to sandy beaches, largely due to much gentler gradients, distinct sediment properties (mud/silt), and higher moisture retention capacities.

Following your suggestion, we have added a dedicated paragraph in the Discussion section (Section 5.3) to provide an outlook on how our proposed approach can be adapted for muddy tidal flat topography inversion in the future.

Modifications in the revised manuscript (Section 5.3):

Furthermore, while the current framework is specifically optimized for open sandy beaches, extending this topographic inversion approach to extensive muddy tidal flat environments is highly feasible and represents a critical future direction. Because tidal flats exhibit much gentler gradients, distinct sediment properties (mud/silt), and significantly higher moisture retention due to more frequent inundation, their spectral-elevation relationships differ fundamentally from those of sandy beaches. To successfully apply this approach to tidal flats, specific methodological refinements are required. Accurate retrieval in these wetter environments would necessitate the introduction of additional feature variables, such as multi-percentile statistics of the Modified Normalized Difference Water Index (MNDWI) and Normalized Difference Vegetation Index (NDVI), to better capture complex moisture and *transient biological dynamics (e.g., algal mats). Additionally, implementing a regionalized modeling framework based on coastal geomorphological classification would be essential to accurately map these distinct intertidal environments without introducing cross-domain prediction errors.*

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.