**Title**

Assessment of beach face slope extraction and monitoring with ICESat-2: from local to global level

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**Abstract**

Coastal areas are appealing for human beings and are the most populated areas of the world. Therefore, coastal processes have large impacts on economy and on millions of people's lives. Not only processes such as erosion, extreme events, and flood events must be understood and monitored, but the uncertainty given by the rapid climate change on these processes and on coastal systems pose a bigger issue on these populated areas. One of the key parameters of coastal processes, which is notably required for modelling coastal floods, is the beach face slope. Unfortunately, there is a lack of a reliable global dataset of the steepness of the beach face, which has been indicated to be key limitation for developing operational coastal inundation forecasting systems, as well as for quantifying the run-up and set-up contribution at the shoreline relative to global sea-level-rise.

In this report, a methodology for providing this parameter at a global level by using a LiDAR-based satellite (ICESat-2) is presented. Here, the accuracy of the beach face slope estimation, its dependency on the angle and distance between ICESat-2 measurements (passes) and the transect perpendicular to the coastline they are projected into (transect), a spatial and temporal exploration of ICESat-2 measurements on world's coasts, as well as the limitations and opportunities of this methodology are presented.

The findings of this study reveal strong visual agreement between the beach profiles and beach face profiles obtained from the validation datasets and ICESat-2. Moreover, the computed metrics, including the Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE), present low values, indicating a high level of agreement. The MAE values, ranging from 9 to 34 cm, not only demonstrate good agreement within the beach and beach face profiles but also indicate that the errors fall within the inherent variability of the beach. For assessing the impact of the angle and distance between passes and transect on the beach face slope extraction, synthetic data is generated using Digital Elevation Models (DEMs). The results demonstrate that long and spatially homogeneous beaches withstand larger α, whereas smaller, more variable, and pocket-shaped beaches are more sensitive to large angles due to the rapid decrease of spatial information alongshore. Nevertheless, regardless of the beach type, the closer the synthetic ICESat-2 measurements intersect over the beach face, the more likely the extracted beach face slope is to match the actual one. For both analysed cases, the beach face slope can be extracted with a tolerable level of uncertainty up to 60 degrees, and if the synthetic data is close to the beach face, the angle that it bears can be increased up to 70-80 degrees.

The novel methodology for upscaling the beach face slope extraction is validated using the Dutch yearly coastal dataset, JARKUS. The results reaffirm the dependence of the beach face slope on the angle between pass and transect. It is concluded that even though further refinement of the algorithm for demarcating the beach face is necessary, the extraction of beach face slopes can be implemented on a global scale, if some challenges are overcome. Moreover, this methodology yields a valuable byproduct in the form of cross-shore profiles, which can be extracted globally with high accuracy. This additional output enhances the utility and versatility of the methodology. Additionally, a spatial and temporal exploration of ICESat-2 ATL03 data on the world's coasts, by globally sampling boxes of 20 km2, is implemented. Then, by analysing the preliminary results from boxes already processed, it is observed that these boxes can encompass anywhere from 0 to 160 passes over the course of the available 5-year data. On average, approximately 63 passes are recorded within each box. From this analysis, it is concluded that particular coastal stretches, depending on their geometry and cloud coverage, can be effectively monitored for beach face slope changes using ICESat-2. Moreover, from the information extracted from these boxes, a map is being constructed for the purpose of revealing potential areas where the extraction of beach face slopes are possible given the beach geometry and availability of data. In summary, this study provides a novel methodology that sets the basis for a new era of coastal management and monitoring using LiDAR-based satellites at a global level.