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Data Descriptor

A Database of Topo-Bathy Cross-Shore Profiles and Characteristics for U.S. Atlantic and Gulf of Mexico Sandy Coastlines

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Abstract: A database of seamless topographic and bathymetric cross-shore profiles along with metrics of the associated morphological characteristics based on the latest available lidar data ranging from 2011–2020 and bathymetry from the Continuously Updated Digital Elevation Model was developed for U.S. Atlantic and Gulf of Mexico open-ocean sandy coastlines. Cross-shore resolution ranges from 2.5 m for topographic and nearshore portions to 10 m for offshore portions. Topographic morphological characteristics include: foredune crest elevation, foredune toe elevation, foredune width, foredune volume, foredune relative height, beach width, beach volume, beach slope, and nearshore slope. This database was developed to serve as inputs for current and future morphological modeling studies aimed at providing real-time estimates of coastal change magnitudes resulting from imminent tropical storm and hurricane landfall. Beyond this need for model inputs, the database of cross-shore profiles and characteristic metrics could serve as a tool for coastal scientists to visualize and to analyze varying local, regional, and national variations in coastal morphology for varying types of studies and projects related to Atlantic and Gulf of Mexico sandy coastline environments.

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Dataset License: CC0

Keywords: topography; cross-shore profile; dune morphology; beach morphology

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1. Summary

Sandy coastlines along the United States (U.S.) Atlantic and Gulf of Mexico coasts are exposed annually to tropical and extratropical cyclones, which can drastically alter the morphology of these environments over short time scales (hours to days). The dataset provided here is an amalgamation of the most recent available lidar (Light Detection and Ranging) derived topography and published bathymetry combined to produce seamless cross-shore profiles for open-ocean sandy beach coastlines on the coasts of the U.S. Atlantic and the Gulf of Mexico. At approximately 4000 locations, cross-shore lidar topography and publicly sourced bathymetry were merged to provide a continuous profile from the 20-m offshore depth to a location landward of the coastal foredune (distance variations are described in Section 3) [1,2]. From the combined topo-bathy product, there are associated morphological metrics that have been derived from each profile, such as foredune crest elevation, foredune volume, beach width, beach slope, and nearshore slope, among many others described in Section 2.

Specifically, the database described here was developed to serve as initial conditions for an ongoing study focused on real-time modeling of coastal change during extreme storms at the national scale. The profiles and the associated characteristics not only describe the initial state of the coast but are also used as inputs to model storm-driven morphological change. By releasing this dataset, it can be used as source material for other local, regional, or national scale projects associated with morphological modeling. The database could provide coastal scientists with a rich data source of coastal morphological factors that can inform geological, hydrodynamic, ecological, and engineering studies. Additionally, it can be accessed to visualize and to assess regional variations and patterns of morphological characteristics for monitoring and analysis. For example, the database could be used to inform coastal geomorphic trends over varying spatial scales—identify regional transition points in morphology and their environmental impacts on important coastal species—or to help to categorize sediment budgets for individual features across local, regional, and national scales associated with restoration studies.

2. Data Description

The data are provided in the hierarchical data format version 5 (HDF5) which is an open-source format that supports large, heterogenous datatypes such as what is provided here; more information on how to access data in HDF5 format is available here: [3]. All data are provided in a single file and publicly available [4]. Each profile within the HDF5 is considered a 'group' and designated by a specific number (syntax example 1: '/Profile/ID_1'), while each profile group contains a 'dataset' of the profile's associated topo-bathy elevations (syntax example 1: '/Profile/ID_1/Elevation'), coordinates, and morphological characteristics. Section 2.1 provides a description of the variables associated with an individual profile (group) within the HDF5 file.

2.1. Variable Name, Syntax, and Variable Description

- lon: longitude coordinate of the topo-bathy profile location
- lat: latitude coordinate of the topo-bathy profile location
- date: lidar survey date of the topographic data portion of profile (YYYYMM)
- Xshore: cross-shore distance coordinate of the topo-bathy profile
- Elevation: cross-shore elevation and depth of the topo-bathy profile
- UTM_X: cross-shore UTM Easting coordinates of the topo-bathy profile
- UTM_Y: cross-shore UTM Northing coordinates of the topo-bathy profile
- UTM_zone: cross-shore UTM Zone for coordinates of the topo-bathy profile
- zdatum: elevation of the shoreline
- Dhigh: elevation of the foredune crest
- Dlow: elevation of the foredune toe
- DuneWidth: width of the foredune
- DuneRelHeight: relative elevation of the foredune crest
- DuneVolume: volume of the foredune
- BeachWidth: width of the beach
- BeachVolume: volume of the beach
- BeachSlope: slope of the beach
- NearshoreSlope: slope of the nearshore

All elevation data are relative to NAVD88 unless otherwise stated. The elevations/depths, distances, and width are provided in meters, and volumes are provided in cubic meters. Please see the Methods section for descriptions of calculations for characteristic width, height, and volume.

3. Methods

3.1. Topo-Bathy Data Location and Extraction

The location of topographic and bathymetric data extraction was prescribed at the shoreline coordinate locations associated with the U.S. Geological Survey's Total Water Level (TWL) prediction operational model [5]. Predictions for TWL are made at 4140 locations spanning the Atlantic and the Gulf coastlines (Figure 1). The model locations range in alongshore resolution from 0.5 km (km) to 2.5 km, and each location has an associated shoreline coordinate and 20-m (m) depth coordinate (derived from Nearshore Wave

Prediction System by National Oceanic and Atmospheric Administration) [5,6]. Figure 1 shows the most recent lidar survey acquired by the USGS for feature extraction, which ranges from 2010 to 2020 [1]. The TWL predictions are made only for sandy coastlines which is why there are gaps at rocky coastlines in Maine, reef lined coasts in the Florida Keys, and marsh areas along the Big Bend region of Florida and the Mississippi delta region of Louisiana and Mississippi (Figure 1). Additionally, Louisiana barrier islands and South Texas barrier islands that have open ocean sandy beaches were not included as part of the original TWL model sites at the time of publication.

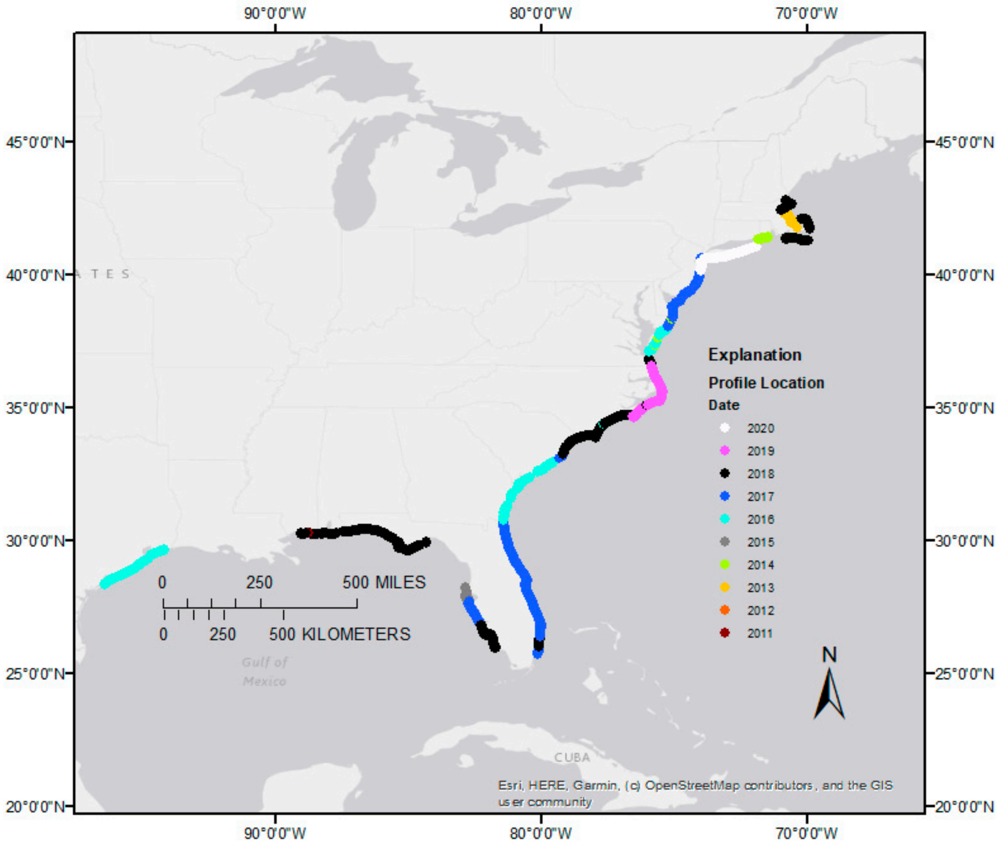

Figure 1. National coverage of the cross-shore profile locations across the Atlantic and the Gulf coasts of the United States. Circle position indicates location of profile and color indicates the year of the most recent lidar survey for that site.

3.1.1. Topographic and Bathymetric Data Extraction

The topographic lidar spans approximately 10 years, and it was collected for the U.S. Geological Survey via airborne systems at vertical resolutions on the centimeter scale ([1] in metadata) [7]. Topographic lidar data used for this database consisted of three-dimensional data that have been gridded to allow for cross-shore and alongshore variability with resolutions of 2.5 m and 10 m, respectively [7]. The lidar data are made up of multiple localized alongshore grids that permit cross-shore profiles to be analyzed and individually tracked. Topographic data were extracted from the lidar surveys using the TWL model point's shoreline coordinate as a reference. Once the closest lidar shoreline was identified, its corresponding lidar grid segment and profile number were used to extract the closest lidar topographic profile associated with the TWL model shoreline location. This extraction method was automated to extract topographic data at all 4140 TWL model locations. Each lidar profile has a previously calculated foredune crest elevation (Dhigh; Figure 2, red circle) and location, foredune toe elevation (Dlow; Figure 2, blue circle) and location, and regional datum for shoreline (mean sea level; MSL; Figure 2, horizontal red line), which were extracted and preserved along with each profile's topographic elevations and cross-shore coordinates [1] (Figure 2).

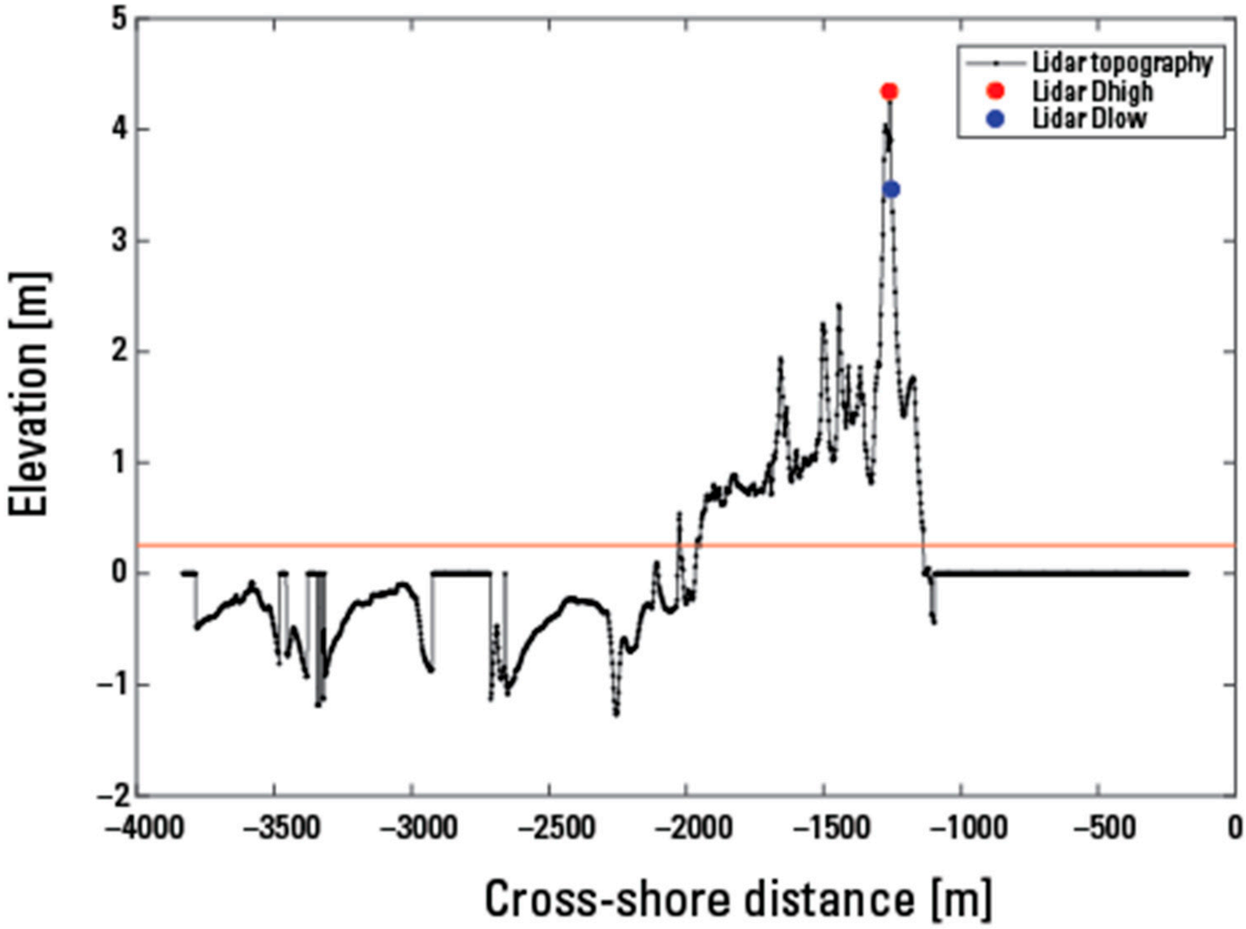

Figure 2. Example of lidar derived topographic profile (black dotted line) extracted at the position of a TWL viewer shoreline point. The red circle indicates the lidar derived foredune crest elevation/location, the blue circle indicates the foredune toe elevation/location, and the horizontal red line indicates the shoreline elevation; note offshore is to the right and elevations set as 0 are indicative of missing data, not actual elevations.

In morphological modeling applications, hydrodynamic forcing is typically applied outside of the surf zone at the ~20 m bathymetric depth contour [5]. Because lidar data are confined to subaerial and shallow nearshore areas, the topographic profiles need to have associated bathymetry. To create a seamless topo-bathy profile (Figure 3), bathymetric data associated with each topographic profile were extracted from the Continuously Updated Digital Elevation Model (CUDEM)—1/9 Arc-Second Resolution Bathymetric-Topographic Tiles dataset [2]. Coordinates of the topographic profile were initially extended offshore to the same distance as that of each TWL model location's 20 m depth, with an additional 1 km added as buffer. Profile coordinates were extended to this offshore location with varying resolution for the nearshore (defined from the shoreline to 100 m offshore) at 2.5 m (consistent with gridded lidar cross-shore resolution) and from there to the offshore 20-m depth at a 10 m resolution. The maximum latitude and longitude coordinates for the extended topo-bathy profile were used to identify the associated CUDEM tile, which was then downloaded from the National Oceanic and Atmospheric Administration's File Transfer Protocol (NOAA FTP) site.

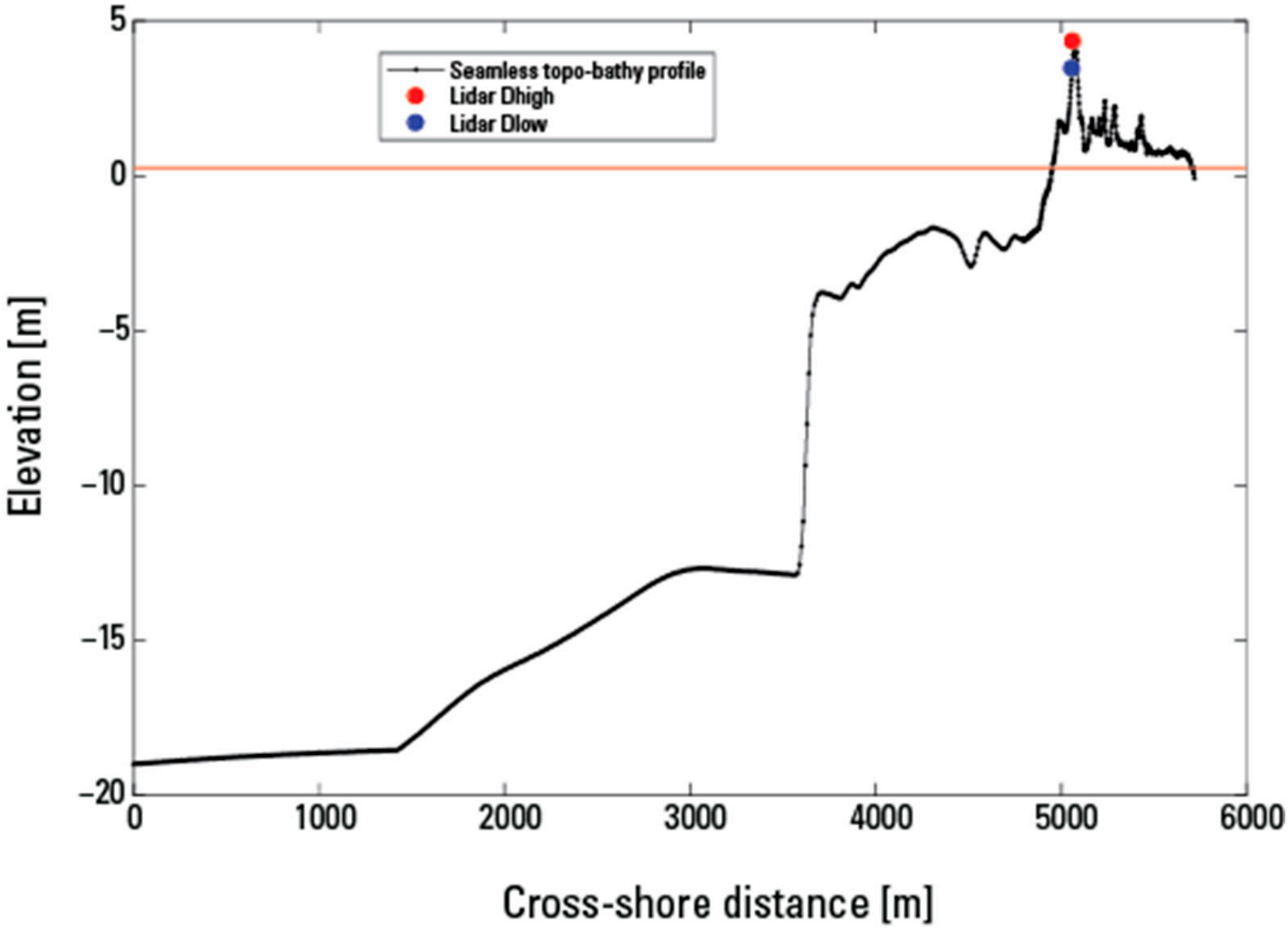

Figure 3. Example of merged lidar topographic and CUDEM bathymetric profile (black dotted line) extracted at the position of a TWL model shoreline point. The red circle indicates the lidar derived foredune crest elevation/location (Dhigh), the blue circle indicates the foredune toe elevation/location (Dlow), and the horizontal red line indicates the shoreline elevation; note offshore is to the left.

3.1.2. Topo-Bathy Profile Generation

The CUDEM topo-bathy data were interpolated to the extended lidar topo-bathy profile coordinates. The original topographic lidar profile was then stitched to the CUDEM interpolated profile at the shoreline datum elevation provided for each lidar derived profile. An analysis of slope at the merging point for the lidar topography and the CUDEM bathymetry was made for all profiles. Statistical comparison for the slope of the lidar topography from the shoreline point to ~15 m landward to the slope of the CUDEM bathymetry from the shoreline to ~15 m offshore found reasonable agreement across the data set (Figure 4; bias of −0.02, root mean square error [rmse] of 0.07, r-squared of 0.78). For profiles where the lidar defined shoreline elevation and the corresponding CUDEM shoreline elevation did not match in cross-shore position, the CUDEM bathymetry was shifted shoreward or landward based on the difference in cross-shore position of the lidar datum elevation (Figure 3). This methodology assumes that while this shifting of bathymetry does not represent the actual morphology and position associated with the lidar at its survey date, the stitching of these two temporally different datasets provides a reasonable representation of topo-bathy morphology for modeling efforts at the specific location. Additionally, with these assumptions in mind, data gaps within the lidar topographic data (shown as 0 elevation values in Figure 2) were filled with CUDEM topographic data when available to provide a better representation and complete profile for modeling purposes.

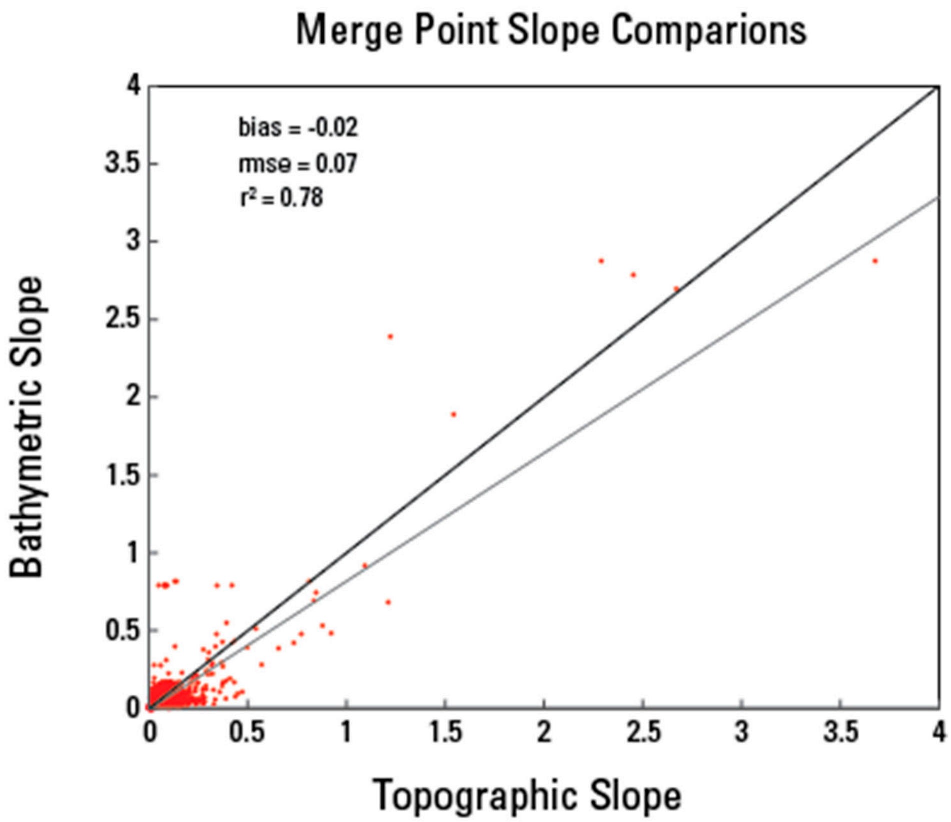

Figure 4. Comparison of the topographic lidar slope (shoreline to 15 m landward) to the bathymetric slope (shoreline to 15 m offshore); red solid point indicates the comparison slope values. The gray line represents linear best fit of the data, and the black line represents 1:1 reference line.

In many cases, this initial offshore extension of the lidar topographic profile did not reach the 20 m depth in the CUDEM bathymetry, which required profiles to be extended an additional 10–20 km. Furthermore, in some areas where there is a wide, shallow (<20 m) continental shelf and oblique shorelines, the extended cross-shore coordinates did not reach the 20 m depth over this extended distance; for these profiles, it was not feasible to extend the profile more due to profile lengths reaching greater than 50 km, which is not reasonable for this modeling application. For these cases, which account for ~35% of the profiles, the offshore depths were artificially extended with a 50 m cross-shore resolution to the 20 m depth over varying distances that correlate to differences in depths obtained in CUDEM bathymetry and the ideal 20 m depth (extended distance decreases as CUDEM offshore depths reach the 20 m depth). For offshore maximum depths less than 7 m, profiles were extended 5 km; profiles with maximum depths between 7 m and 10 m were extended 4 km; profiles with maximum depths between 10 m and 15 m were extended 3 km; and profiles with maximum depths between 15 m and 19 m were extended 2 km (profiles with depths between 19 m and 20 m were considered acceptable). This idealized extension provides a consistent maximum profile depth across all coastlines of ~20 m for 1D simulation of wave transformation from the offshore to the onshore.

Of the 4140 TWL model locations for topo-bathy profile generation, 242 profiles (5.8% of total) were excluded for various reasons, including location among rocky shoreline coasts (TWL model locations in New Hampshire), no CUDEM or lidar data available, or differences in elevations greater than 1 m at the lidar-CUDEM merging position, leaving a final database of 3898 topo-bathy profiles. This bathymetric data download, interpolation, extraction, and stitching methodology was automated for full topo-bathy profile derivation. The generated topo-bathy profiles along the Atlantic and the Gulf coasts account for one major part of the morphological database generated for this study.

3.1.3. Topo-Bathy Characteristic Extraction

The other major part of the morphological database is the quantification of the different morphological characteristics of each profile. The profile characteristics derived for this dataset include foredune crest elevation (Figure 5A, red circle), foredune toe elevation (Figure 5A, blue circle), foredune width (Figure 5B, cross-shore distance between blue and red circle), foredune volume (Figure 5B, red shaded area), beach width (Figure 5A, cross-shore distance between blue circle and shoreline elevation [horizontal red line]), beach volume (Figure 5A, red shaded area), shoreline elevation (Figure 5A,C, horizontal red line), beach slope (Figure 5C, sloped orange line), and nearshore slope (Figure 5C, sloped red line). Foredune crest and toe elevations, along with shoreline elevation, were previously quantified and extracted from the lidar [1]. In some cases, foredune crest or toe may not have been previously extracted, and it was therefore extracted from the lidar profile following previously developed methods [7]. Beach width was measured as the distance between shoreline and foredune toe, and beach volume was calculated as the volume of sediment over the derived beach width (height relative to shoreline elevation). Foredune width was measured as distance between foredune toe and crest, with foredune volume calculated as the sediment volume over the derived foredune width (height relative to foredune toe elevation). The beach slope was measured as the ratio of the elevation of dune toe above the shoreline elevation over the horizontal distance between shoreline and the foredune toe [7]. The nearshore slope was measured as the ratio of the depth of closure over the horizontal distance between the depth of closure and the shoreline, with depths of closure provided from another study [8].

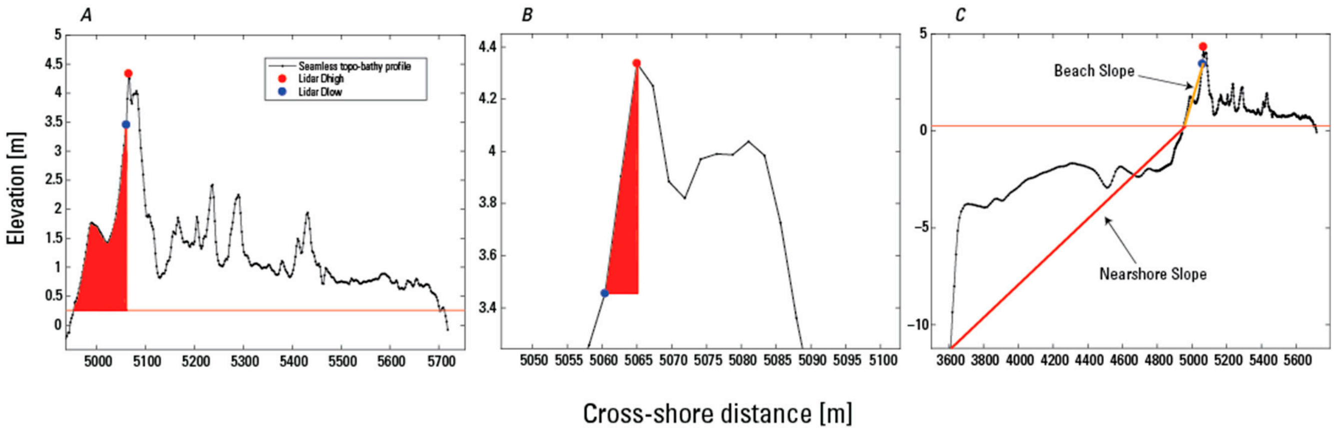

Figure 5. (**A**) Indicates the foredune crest, toe, and shoreline (similar to Figure 2), with the area for beach width and volume filled in red; (**B**) Indicates the foredune crest and toe, with the area for dune width and volume filled in red; (**C**) Indicates the different areas of the topo-bathy profile used to derive nearshore slope (red line) and beach slope (orange line).

4. Conclusions

As stated previously, this database of seamless topo-bathy cross-shore profiles could provide scientists studying different aspects of the coastal environment with a useful data source of coastal morphology for various local, regional, or national projects. By providing the full topo-bathy profile, others can utilize the data to derive other morphological metrics beyond what has been provided here to help to inform their own specific projects. While this database is exclusive to sandy coasts along the Atlantic and the Gulf of Mexico, these methods could be easily applied with past, current, and future topographic datasets to update this current database and to extend it to other areas, such as the Pacific sandy coasts, and other environment types, such as reef lined, rocky, marsh, and estuarine coastlines.

5. User Access

The database and its associated metadata can be downloaded at https://doi.org/10.5066/P9838KPW (accessed 5 July 2022).

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Abbreviations

U.S.	United States
lidar	Light Detection and Ranging
HDF5	Hierarchical Data Format version 5
NAVD88	North American Vertical Datum of 1988
TWL	Total Water Level
km	kilometer
m	meter
Dhigh	foredune crest elevation
Dlow	foredune toe elevation
MSL	Mean Sea Level
CUDEM	Continuously Updated Digital Elevation Model
NOAA FTP	National Oceanic and Atmospheric Administration File Transfer Protocol

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