SOUTH WEST COASTAL MONITORING

making space for sand



Making Space for Sand – Crackington Haven Beach Report

LiDAR Data Analysis

SWCM | TBR37 | 14/11/2023

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Summary

This report utilises Light Detection and Ranging (LiDAR) and aerial imagery data collected by the South West Coastal Monitoring (SWCM) Programme to analyse beach and dune volume at Crackington Haven. The aim is to highlight coastal change at Crackington Haven using SWCM data since 2007, focusing on beach and dune areas categorised into four zones: Beach, Mobile, Fixed, and Developed. Crackington Haven Beach is a west-northwest facing cove approximately 260 m wide. LiDAR data from each available flight is compared to create difference models of the intertidal area, compare volumetric data over time and to show change in Mean Seal Level (MSL) and dune toe contours over time.

Beach volume extracted from 6 LiDAR flights since 2007 within the Mobile Zone showed no significant long-term trend for change. However, the 2013/14 winter storms notably impact the Mobile Zone, causing a loss of 33% of beach material above Mean High Water Springs between the 2012 and 2014 surveys. The lowest volume in the Mobile Zone was recorded in February 2016 but has since returned to pre-2014 levels. The Beach Zone equally showed no significant trend in volumetric data change since 2007, with the lowest volume observed in 2016 but returning to pre-2013/14 levels by 2019.

Overall Crackington Haven has remained relatively stable between 2007 and 2024 despite large fluctuations in material from the 2013/14 and 2016 winters.

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1.0 Introduction

The aim of this report is to highlight beach and dune change at Crackington Haven using data collected as part of the South West Coastal Monitoring (SWCM) Programme since 2007. Four zones have been identified to define the beach/dune area and are defined as:

- **Beach Zone** – The wet beach area has been defined using Mean Low Water Spring (MLWS) and Mean High Water Spring (MHWS) contours extracted from all LiDAR data captured by SWCM. The Beach Zone will therefore encompass the area between the MHWS and MLWS contours, with volumes for this area extracted from each LiDAR surface.
- **Mobile Zone** – This area is defined as the active dune face and embryo dune[1] from MHWS +1 m to the back of the mobile area, often distinguished by vegetation depth or urban development. The Mobile Zone has been defined using aerial imagery from 2007 to 2021 and historic OS maps and has been verified through site visits.
- **Fixed Zone** – This area is defined by permanent dune vegetation that may also include scrub or invasive species, effectively denoting vegetation atop sandy soil.
- **Developed Zone** – This is defined as urban development areas (i.e., car parks, unnatural grassy areas, roads, houses etc.) which have been built atop previously present dune systems.

1.1 Study Site

Crackington Haven is a west-northwest facing cove, consisting of gravel material on the upper beach and sandy material across the mid-lower beach. The cove is backed by a sea wall towards the north, a small dune system in the centre and rocky cliffs on the outer edges (Fig.1). A large stream flows north of the dune system, pooling at the back of the beach. Crackington Haven has a cross-shore distance of ~260 m and longshore distance of ~200 m, with an average spring tidal range of 6.6 m.



Figure 1 - Location Map of Crackington Haven Beach and Dune System, indicating the four defined zones outlined in section 1.0.

[1] An embryo dune, or yellow dune, is the earliest stage of dune growth, usually found along the seaward extent of a dune system or newly formed dune.

2.0 Methods

Data utilised in this report was collected by SWCM between 2007 and 2024. Information on topographic and LiDAR data collection and specifications can be found on the Website for the National Network of Coastal Monitoring Programmes.

2.1 LiDAR Data

Airborne Light Detection and Ranging (LiDAR) data have been captured as part of the SWCM since 2007. Products include a point clouds, from which filtered and unfiltered 1 m^2 gridded surface models are derived:

- Unfiltered (Digital Elevation Model) representing the earth's surface including natural and artificial features such as trees and buildings.
- Filtered (Digital Terrain Model) representing the bare earth surface, with trees, buildings, cars etc. removed.

LiDAR is captured between September and March to minimise vegetation capture. Data is captured between MLWS and up to approximately 500 m inland. This report utilises "filtered" LiDAR data.

2.1.1 LiDAR Data Analysis

LiDAR data analysis is presented as the following:

Difference Modelling – Separate LiDAR surfaces are compared to produce a difference model of change based on gridded spot height elevations. The raw spot height data is processed into a gridded digital terrain model (DTM) and successive models are subtracted from one another to produce a difference model for the survey unit. Change in elevation is shown for values +/- 0.25 m and is represented by a colour scale bar.

Volume Extraction - Net sediment volume (m^3) is extracted for each LiDAR surface from the Beach Zone above MLWS and Mobile Zone above MHWS for trend comparison over time.

Contour Analysis – Contours are mapped from four LiDAR epochs spanning from 2007 to 2023, representing Mean Sea Level (MSL) and dune toe (calculated using the Stockdon equation by UoP, 2023[2]).

The 2013/2014 Storms – The winter period between September 2013 and April 2014 was, for many beaches in Cornwall, the most destructive period since SWCM records began in 2007. An abnormal number of significant storms, occurring in quick succession, heavily impacted many beaches, causing the loss of sediment from the intertidal area and dune face. This period is extensively discussed throughout this report and will hereinafter be referred to as the 2013/2014 winter period.

2.2 Accuracy Statement

LiDAR Data – Each LiDAR point cloud dataset has an average point density of 1.5 points per square metre. The digital terrain surfaces provide a minimum accuracy in elevation data of +/- 0.10 m RMSE with a minimum horizontal standard deviation as < 0.05 m. Please note that while every endeavour has been made to capture LiDAR as far seaward as MLWS, tidal and weather restrictions may in some instances have precluded this and coverage may be slightly reduced.

[2] Please refer to the following for Dune Toe elevation calculation: UoP, 2023. MS4S: Contemporary Dune Evolution and Future Predictions, Report, University of Plymouth, 33 pp.

3.0 Results

3.1 LiDAR Data Analysis

There has been a total of 6 LiDAR flights captured at Crackington Haven since 2007 through the SWCM Programme.

3.1.1 Difference Models

Difference models between each epoch of LiDAR data are presented here. Accretion and erosion values observed behind the dune system can be attributable to noise in the filtered LiDAR data or man-made changes in elevation and should be dismissed as such.

Figure 2 shows the difference in elevation between the first filtered LiDAR data from March 2007 compared with the most recent, captured in March 2022. Observed is a large area of erosion along the middle of the beach, as well as the beach face. The rest of the beach remains relatively stable, apart from the strip of accretion, where the stream flows and should be discounted from this analysis.

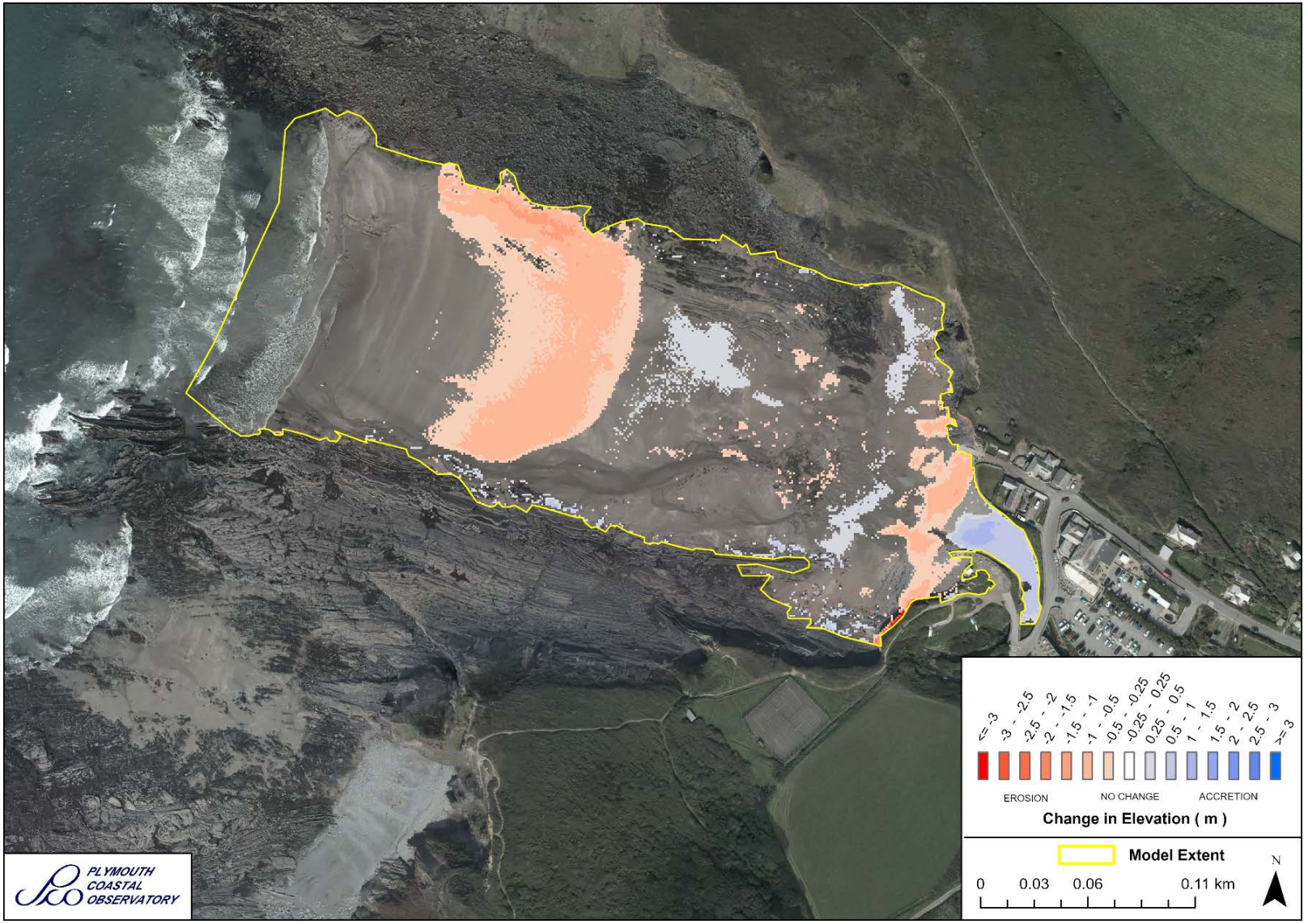


Figure 2 – Difference model indicating the changes in elevation observed between the March 2007 and March 2022 filtered LiDAR datasets within the yellow model extent.

Figure 3 shows differences in elevation between filtered LiDAR data from March 2007 compared to September 2007. The lower beach has seen minimal to no change, whereas an intertidal bar has formed in the middle-to-upper beach. Some erosion is seen on the beach face and the mouth of the stream.

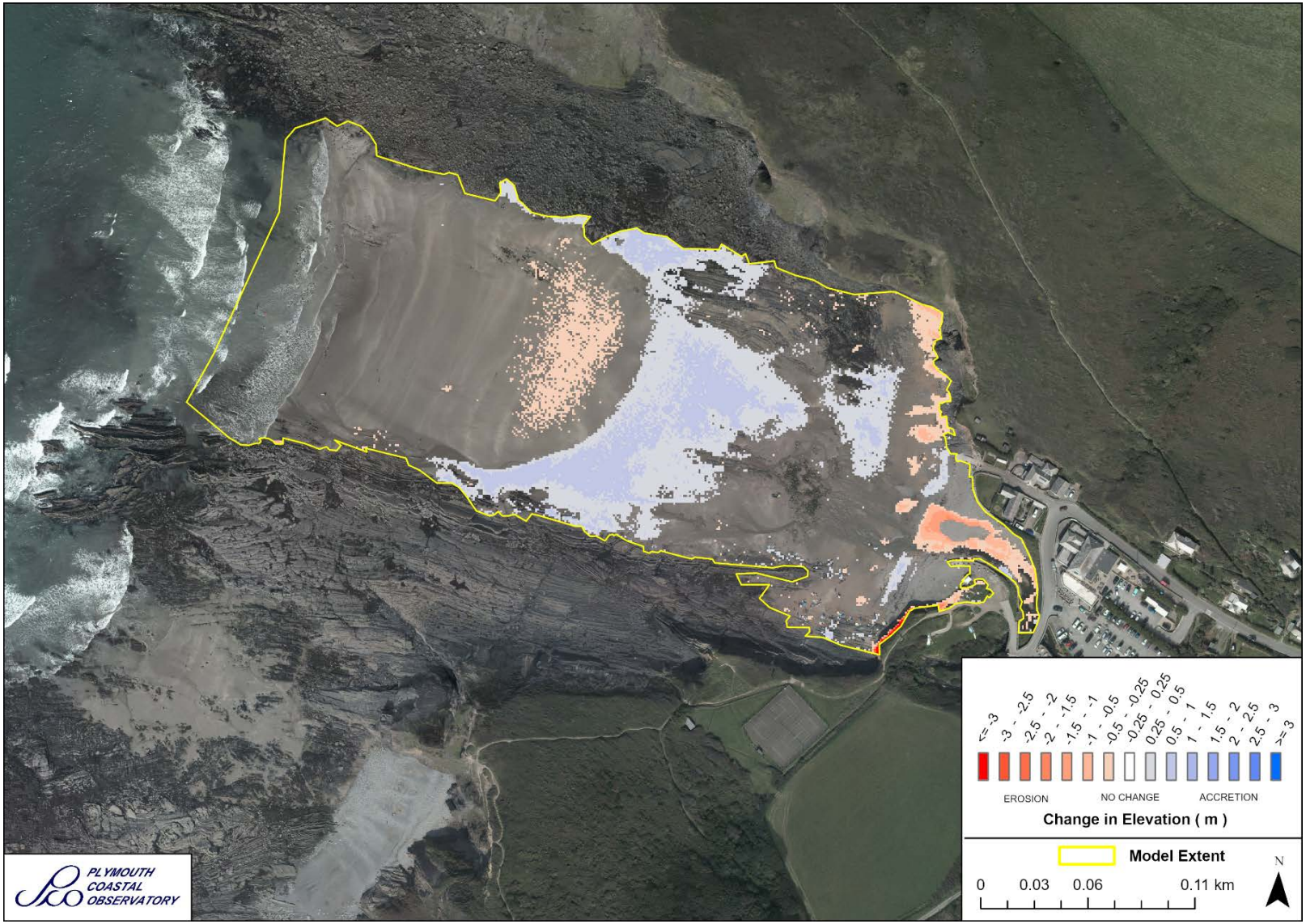


Figure 3 - Difference model indicating the changes in elevation observed between the March 2007 and September 2007 filtered LiDAR datasets within the yellow model extent.

Figure 4 shows differences in elevation between filtered LiDAR data from September 2007 compared to March 2011. The majority of the beach has seen accretion of up to 1.5 m, particularly on the southern half of the beach. The beach face, however, has seen erosion along the whole unit, suggesting the seaward drawdown of material; the dune system has remained relatively stable.

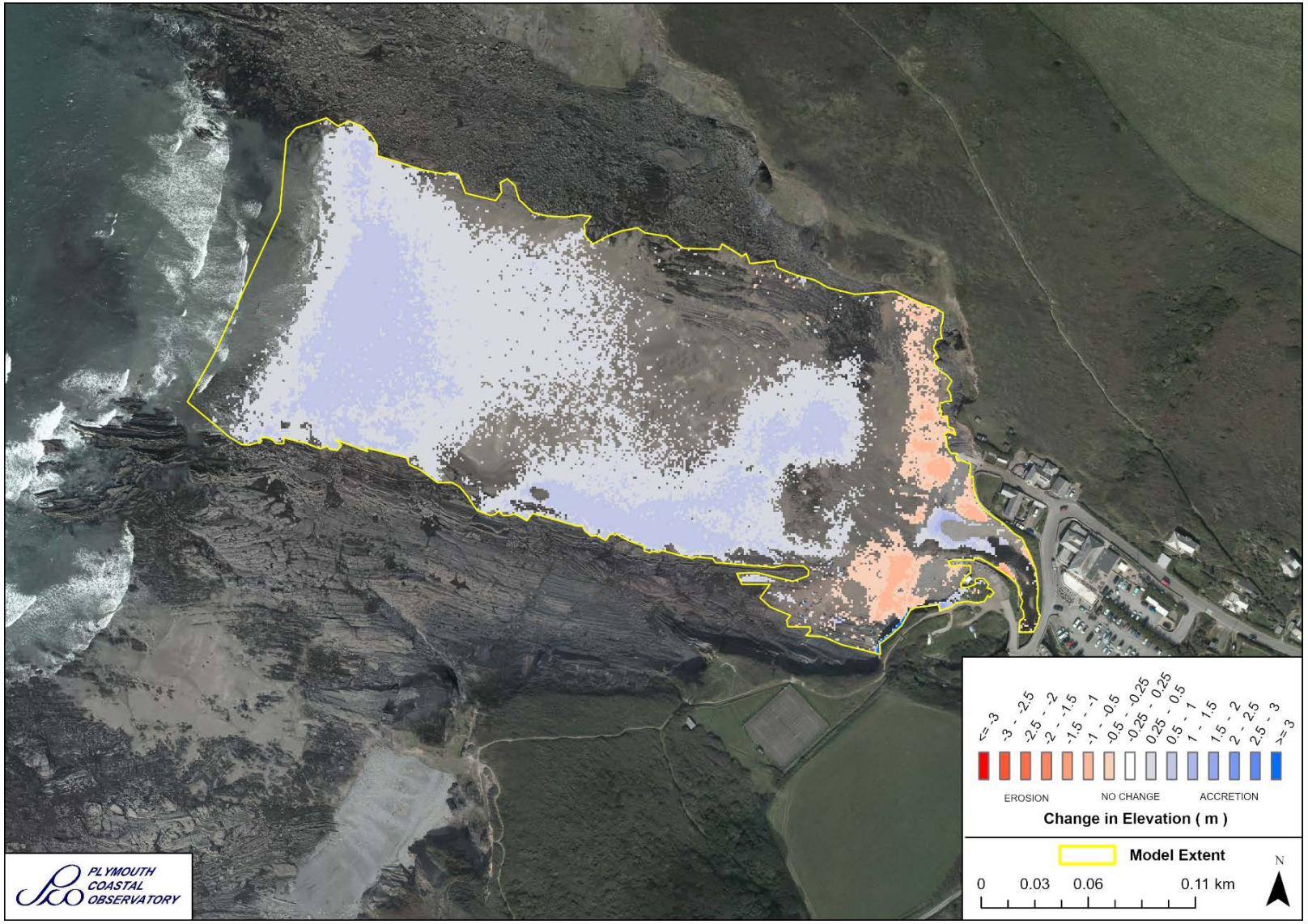


Figure 4 – Difference model indicating the changes in elevation observed between the September 2007 and March 2011 filtered LiDAR datasets within the yellow model extent.

Figure 5 shows differences in elevation between filtered LiDAR data from March 2011 compared to April 2014. This epoch indicates large areas of change, seeing erosion of up to 2 m observed across most of the beach. However, the entirety of the beach face has seen a build-up of material with a pocket of erosion measured at the dune system.

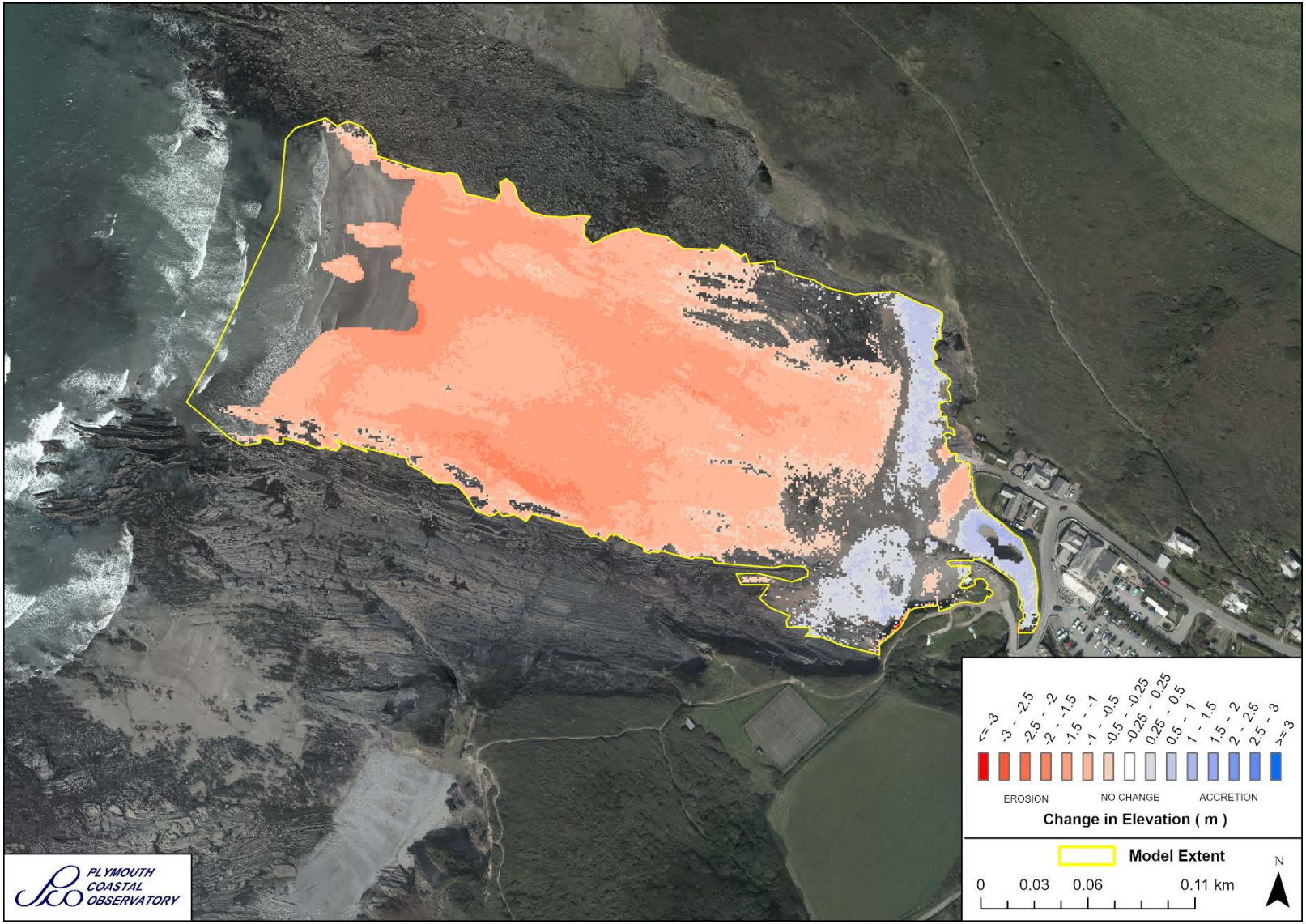


Figure 5 - Difference model indicating the changes in elevation observed between the March 2011 and April 2014 filtered LiDAR datasets within the yellow model extent.

Figure 6 shows differences in elevation between filtered LiDAR data from April 2014 compared to April 2019. Despite the impact of the 2013/14 winter storms, the majority of the beach shows accretion, with up to 1.5 m gains observed across most of the low-tide terrace as well as the beach face.

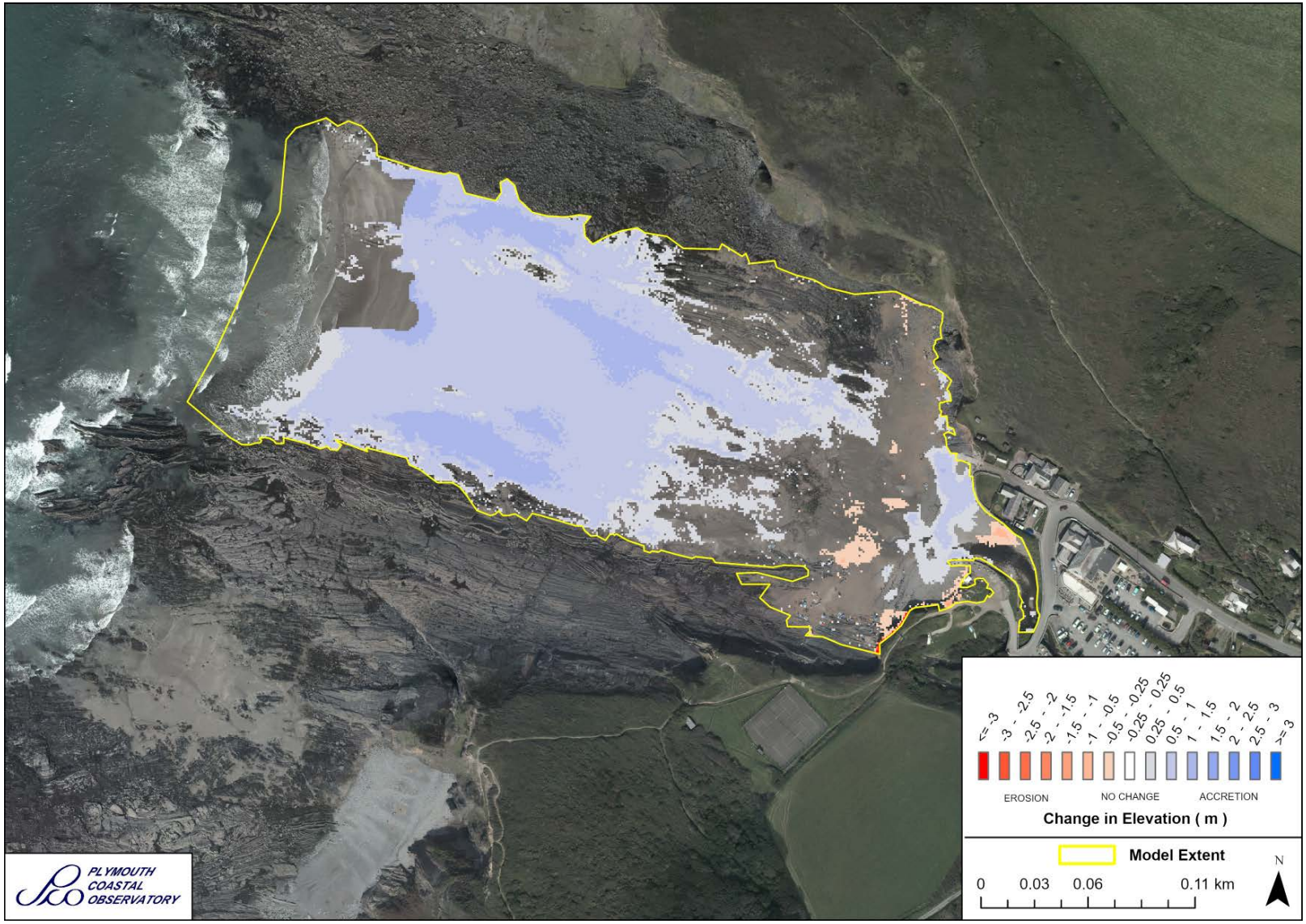


Figure 6 - Difference model indicating the changes in elevation observed between the April 2014 and April 2019 filtered LiDAR datasets within the yellow model extent.

Figure 7 shows differences in elevation between filtered LiDAR data from April 2019 compared to March 2022. Erosion has been measured along the middle section of the beach as well as the beach face, with up to 1.5 m of material lost. Small areas of accretion are located along the toe of the beach as well as the beach face at Crackington Haven.

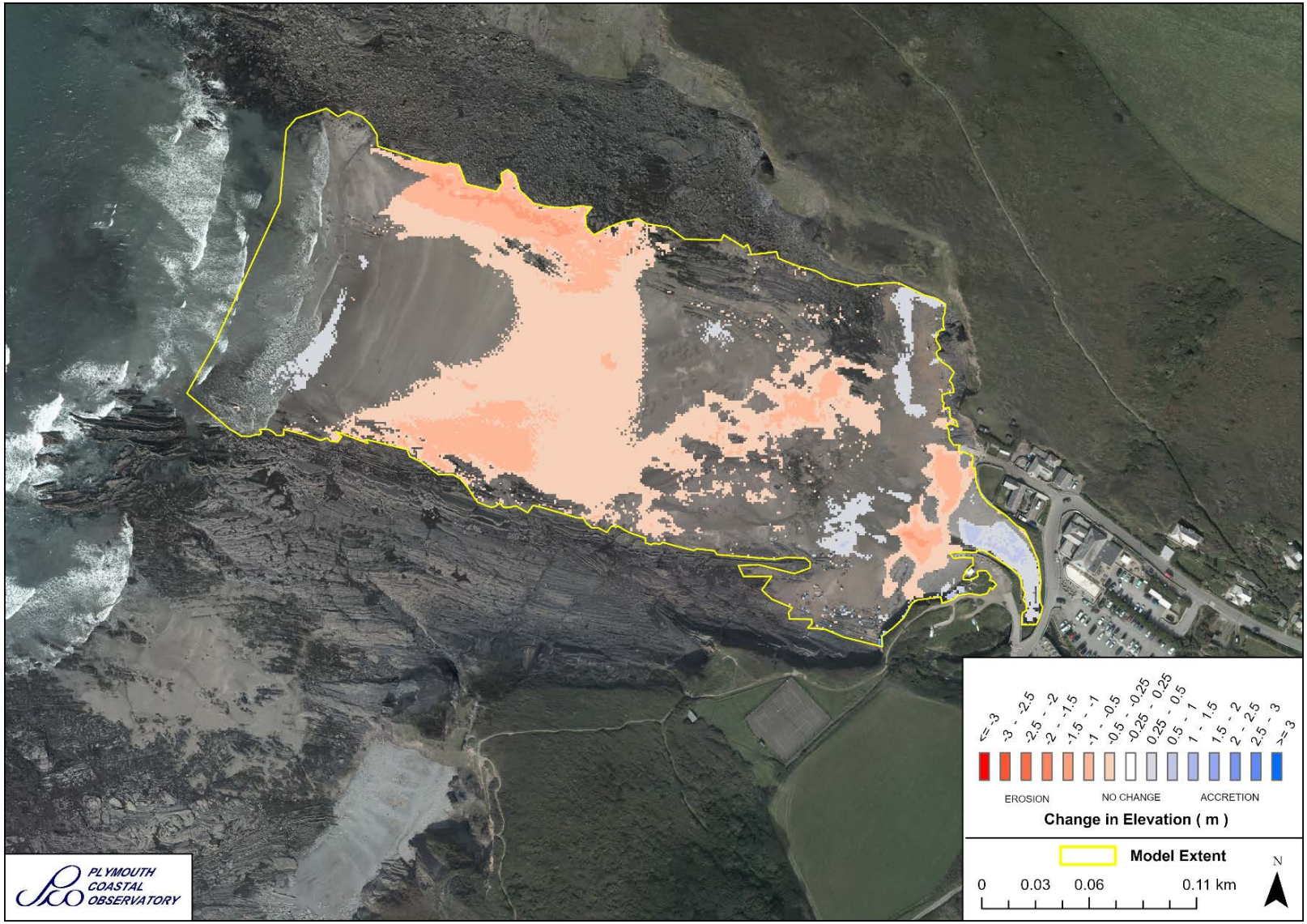


Figure 7 - Difference model indicating the changes in elevation observed between the April 2019 and March 2022 filtered LiDAR datasets within the yellow model extent.

3.1.2 Beach and Dune Volume Extraction

Surface volume extracted from each available LiDAR dataset from the Mobile Zone above the MHWS contour (3.50 m OD) are shown in Table 1. The Mobile Zone has fluctuated in volume between 2007 and 2022 (Fig.8), with the lowest recorded in April 2014 (6,492 m^3). The March 2022 dataset recorded the highest volume (Table 1), increasing by 28% since the 2014 survey.

Surface volume extracted from each LiDAR dataset from the Beach Zone above the MLWS contour (-2.90 m OD) are also shown in Table 1. The Beach Zone between 2007 and 2022 has remained stable despite fluctuating in volume considerably (Fig.9). The lowest Beach Zone volume was recorded in April 2014 which saw a 25% decrease in material within the zone from the previous data in March 2011, which also recorded the highest volume.

Table 1 – Surface volume values (m^3) extracted from all available filtered LiDAR datasets for the Mobile Zone above MHWS (3.50 m OD) and for the Beach Zone above MLWS (-2.90 m OD).

Date	Mobile Zone Volume (m^3)	Beach Zone Volume (m^3)
03/2007	7,987	107,820
09/2007	7,899	112,955
03/2011	6,959	125,322
04/2014	6,492	938,21
04/2019	7,651	114,645
03/2022	8,302	105,332

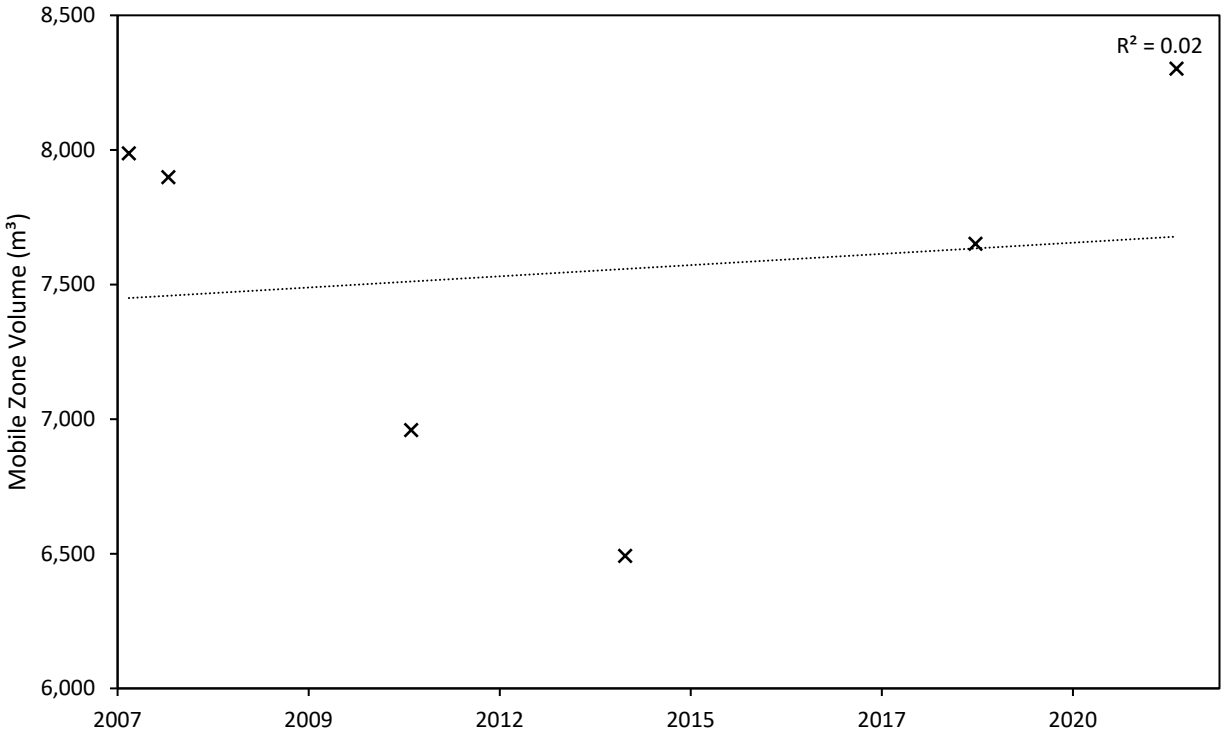


Figure 8 - Plot indicating beach volume (m^3) recorded in the Mobile Zone above MHWS (3.5 m OD) for each filtered LiDAR datasets between 2007 and 2022.

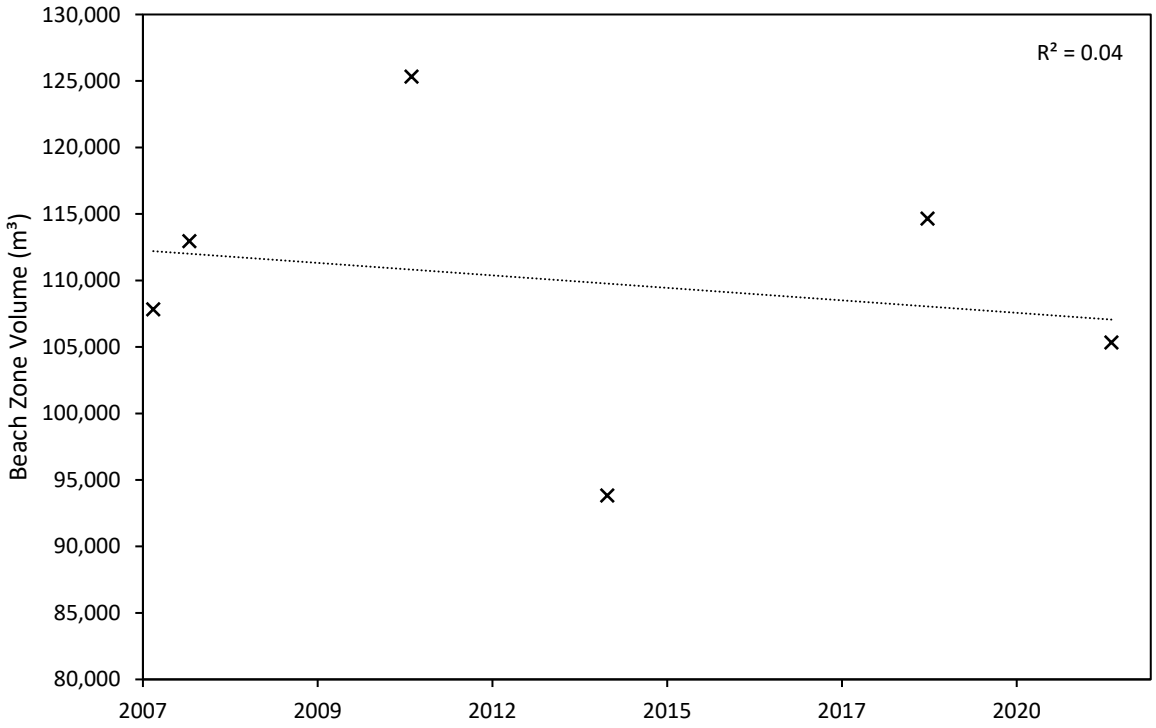


Figure 9 – Plot indicating beach volume (m^3) recorded in the Beach Zone above MLWS (-2.90 m OD) for each filtered LiDAR datasets between 2007 and 2022.

3.1.3 Contour Comparison

Figure 10 indicates the Mean Sea Level (MSL) and Dune Toe contours from 2007, 2014, 2019 and 2022 LiDAR datasets, projected onto aerial imagery captured in 2022. MSL contours indicate a narrowing of the beach from 2008 to 2020 of up to 24 m. The Dune Toe contours have remained relatively stable in comparison, retreating by ~4 m.

3.2 Historic Aerial Maps

Historic aerial photography captured in 1947 by the RAF, in 2001 by the Environment Agency and from 2007 onwards by the SWCM are presented here.

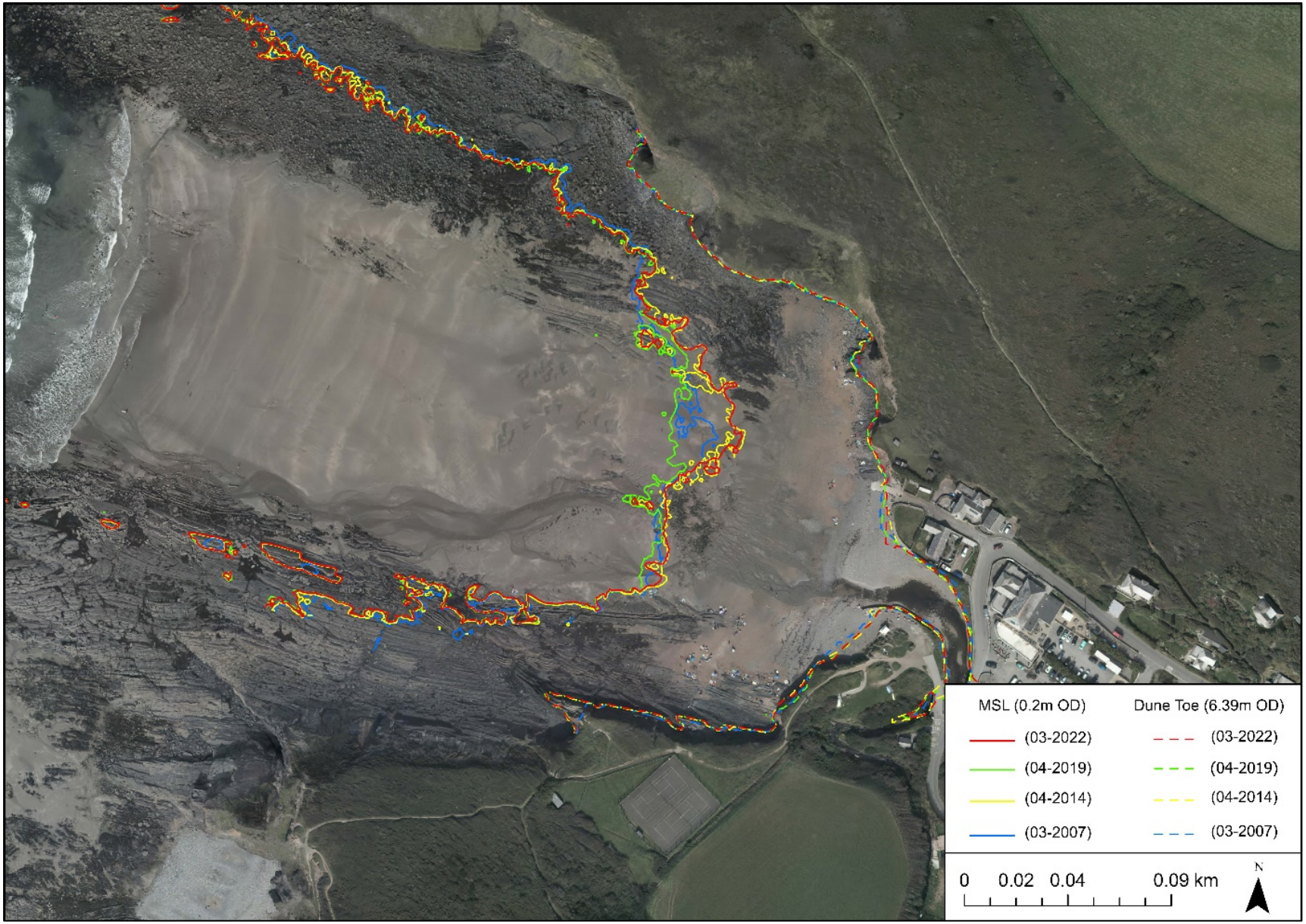


Figure 10 – Contour map indicating Mean Sea Level (solid line) and Dune Toe (dashed line) extracted from 2007, 2014, 2019 and 2022 LiDAR datasets.



Figure 11 – Aerial imagery from 1947.

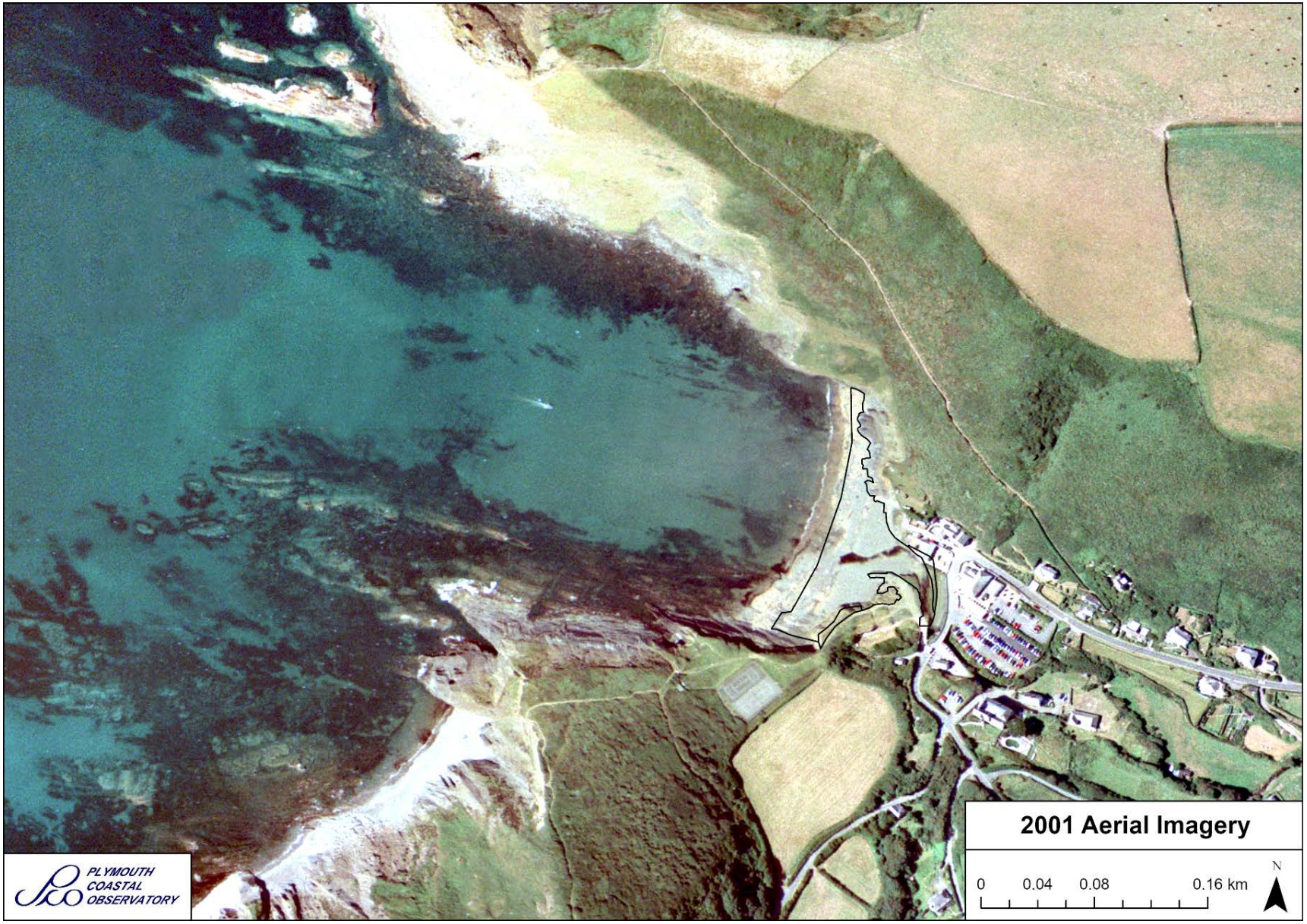


Figure 12 – Aerial imagery from 2001.

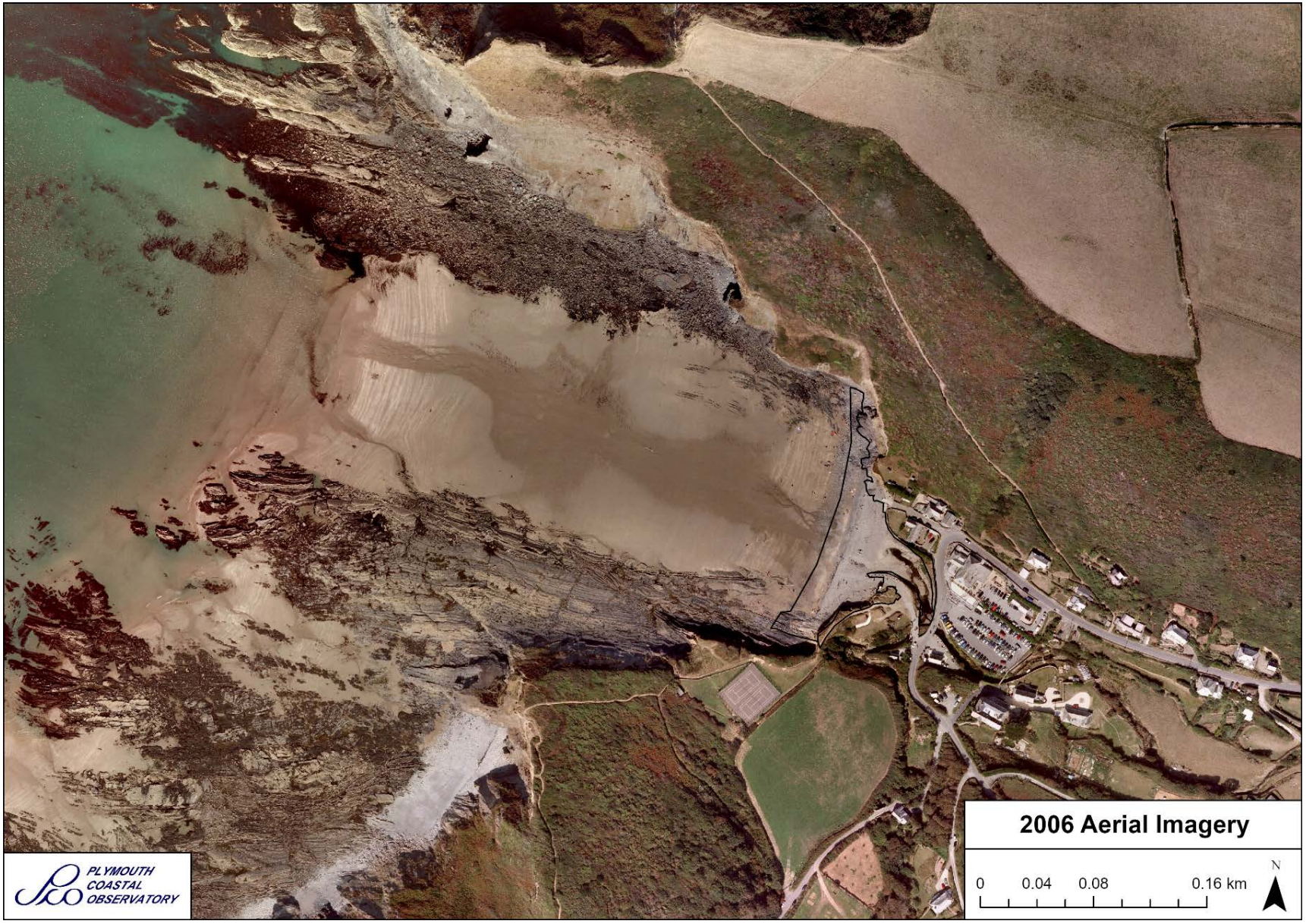


Figure 13 – Aerial imagery from 2006.



Figure 14 – Aerial imagery from 2010.



Figure 15 – Aerial imagery from 2014.



Figure 16 – Aerial imagery from 2017.

Glossary

1. Accretion: The net accumulation of deposited sediment, deposited by waves, tides or current.
2. Coastal Morphodynamics: The study of changes in coastal landforms and landscapes over time.
3. Contour Analysis: Mapping of contours from LiDAR datasets to represent Mean Sea Level (MSL) and Dune Toe elevations.
4. Cross-Sectional Area (CSA): The area of a two-dimensional cross-section of a cross-shore beach profile, running between Mean Low Water Spring and the back of the beach.
5. Developed Zone: Areas of urban development built atop previously present dune systems.
6. Difference Modelling: Comparison of separate LiDAR surfaces to produce a difference model of change based on gridded spot height elevations.
7. Digital Elevation Model (DEM) and Digital Terrain Model (DTM): DEM represents the Earth's surface with all features, while DTM represents the bare earth surface, excluding vegetation and structures.
8. Embryo Dune: The earliest stage of dune growth, typically found along the seaward extent of a dune system or newly formed dune.
9. Erosion: The process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and sands along the coast.
10. Fixed Zone: Area defined by permanent dune vegetation, including scrub or invasive species, denoting vegetation atop sandy soil.
11. Intertidal Bar: A ridge or mound of sand, gravel, or other sediment deposited in the intertidal zone along a shoreline.
12. LiDAR: Light Detection and Ranging, a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth.
13. Mean High Water Spring (MHWS): The height of mean high-water springs is the average throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
14. Mean Low Water Spring (MLWS): The height of the mean low-water springs is the average height obtained by the two successive low waters during the same period.
15. Mobile Zone: The area including the active dune face and embryo dune that is in motion due to wind action or other factors.
16. Root-Mean-Square Error (RMSE): A measure of the differences between values predicted by a model and the observed values.
17. Tidal Range: The vertical difference between high tide and low tide during a tidal cycle.