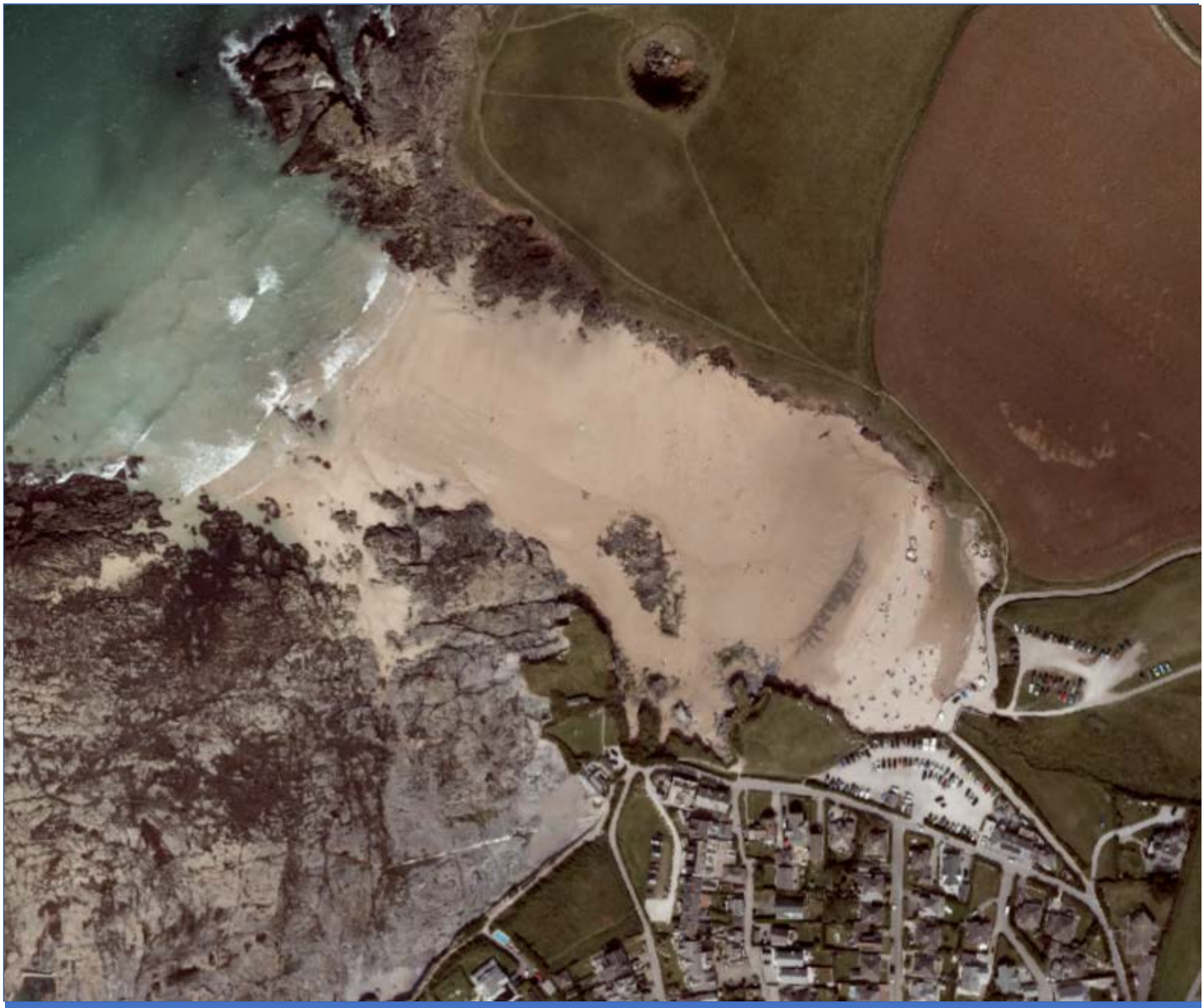
SOUTH WEST COASTAL MONITORING

making space for sand



Making Space for Sand – Trevone Beach Report

LiDAR Data Analysis

SWCM TBR32 09/01/2024

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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 Trevone. The aim is to highlight coastal change at Trevone using SWCM data since 2007, focusing on beach and dune areas categorised into four zones: Beach, Mobile, Fixed, and Developed. Trevone is a large west-northwest facing sandy beach backed by a sea wall, main road, and car park (Fig.1). This very long and narrow beach has hard rocky cliffs on either side and small stream flowing from the back of the beach to the south. The beach has a cross-shore distance of ~400 m and longshore distance of ~150 m with an average spring tidal range of 6.5 m. 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 volumes are extracted from 6 LiDAR flights since 2007. The lowest volume in the Mobile Zone was recorded in April 2014 but has since returned to pre-2014 levels. Similarly, the Beach Zone also saw an impact from the 2013/14 winter storms, causing a loss of 7% of beach material above Mean High Water Spring between the 2011 and 2014 surveys, but returning to pre-2013/14 levels by 2019.

Overall Trevone beach has remained relatively stable between 2007 and 2022 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 Trevone Beach 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

Trevone is a west-northwest facing large sandy beach backed by a relic dune system, sea wall, main road, and car park (Fig.1). This very long, narrow beach has hard rocky cliffs on either side and small stream flowing from the back of the beach to the south. The beach has a cross-shore distance of ~400 m and longshore distance of ~150 m with an average spring tidal range of 6.5 m. The four beach and dune zones are represented in Figure 1.



Figure 1 - Location Map of Trevone 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 Trevone since 2008.

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 February 2008 compared to the most recent, captured in October 2022. There is considerable accretion observed along the upper beach, which has accreted by up to 2.5 m. An intertidal bar has formed at the seaward extent of the unit, and a depression in the centre of the beach. The top of the beach and dune system has remained stable.

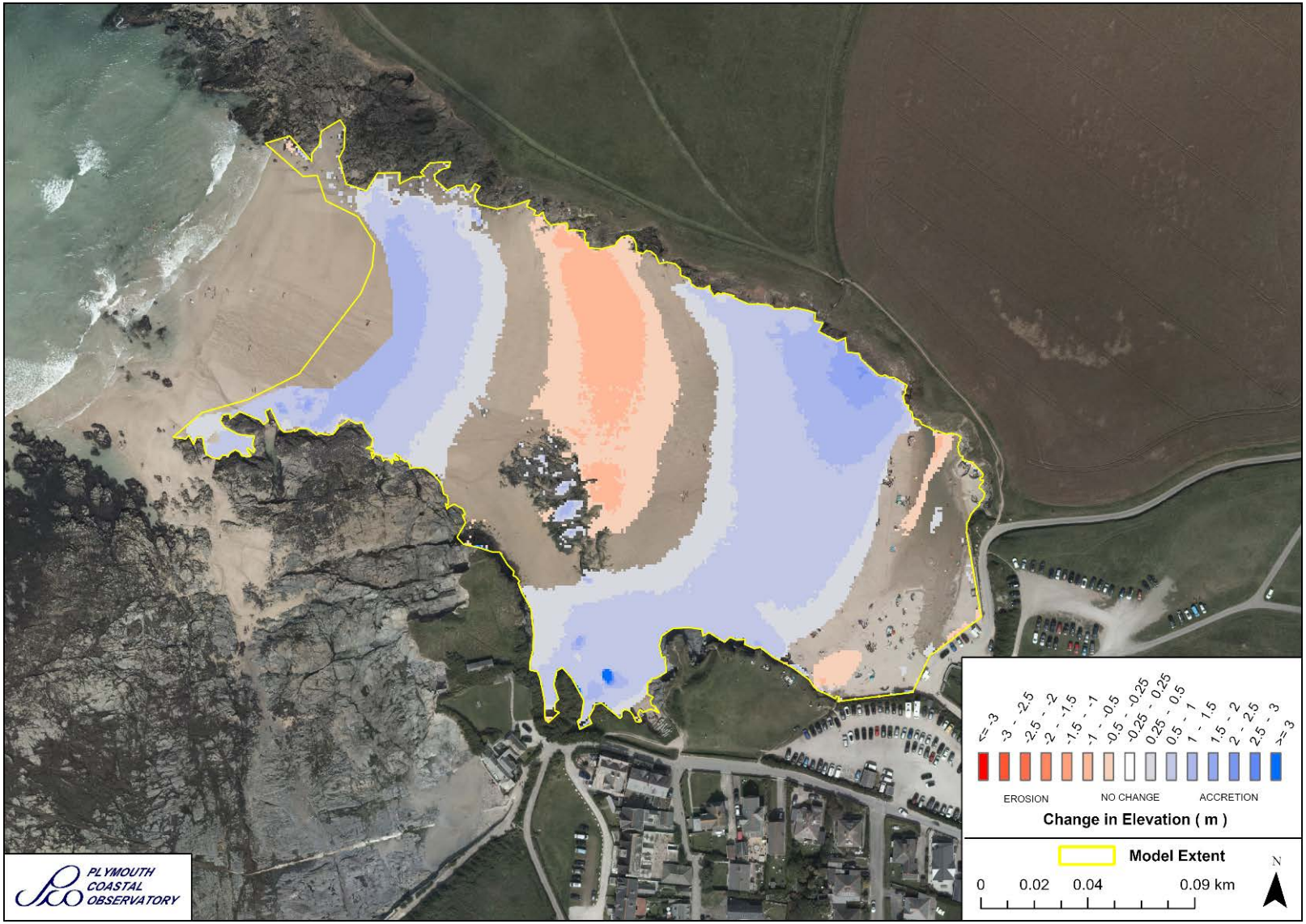


Figure 2 – Difference model indicating the changes in elevation observed between the February 2008 and October 2022 filtered LiDAR datasets within the yellow model extent.

Figure 3 shows differences in elevation between filtered LiDAR data from February 2008 compared to March 2009. Over the year, Trevone has seen mostly accretion within the unit. The top of the unit has seen patches of accretion, as well as the lower half of the beach. The upper and low-tide terrace has remained stable.



Figure 3 - Difference model indicating the changes in elevation observed between the February 2008 and March 2009 filtered LiDAR datasets within the yellow model extent.

Figure 4 shows differences in elevation between filtered LiDAR data from March 2009 compared to March 2011. Unlike the last epoch, figure 4 has seen a lot of change. The lower extent has seen accretion of up to 2 m, creating an intertidal bar, whereas the upper half has experienced up to 1 m of erosion, to the north side, mostly below the rocky cliff.

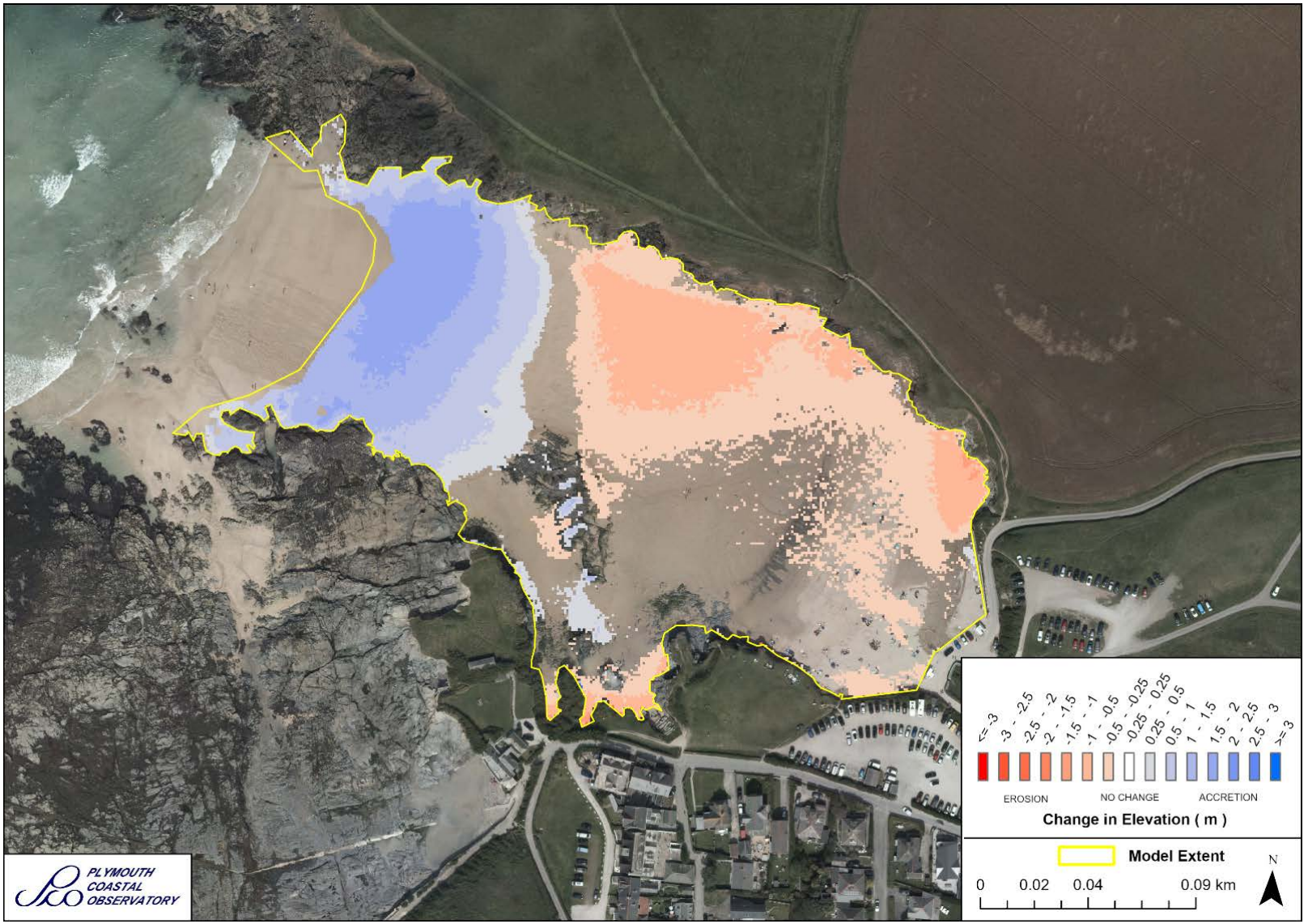


Figure 4 – Difference model indicating the changes in elevation observed between the March 2009 and March 2011 filtered LiDAR datasets within the yellow model extent.

Figure 5 shows differences in elevation between filtered LiDAR data from March 2011 compared to April 2014. After the 2013/14 storms, unsurprisingly the beach has experienced erosion, particularly at the lower extent, of up to 2 m. The top of the beach has also seen some erosion, in front of the sea wall, seeing a lowering of up to 1.5 m. The main section of the beach has remained stable.

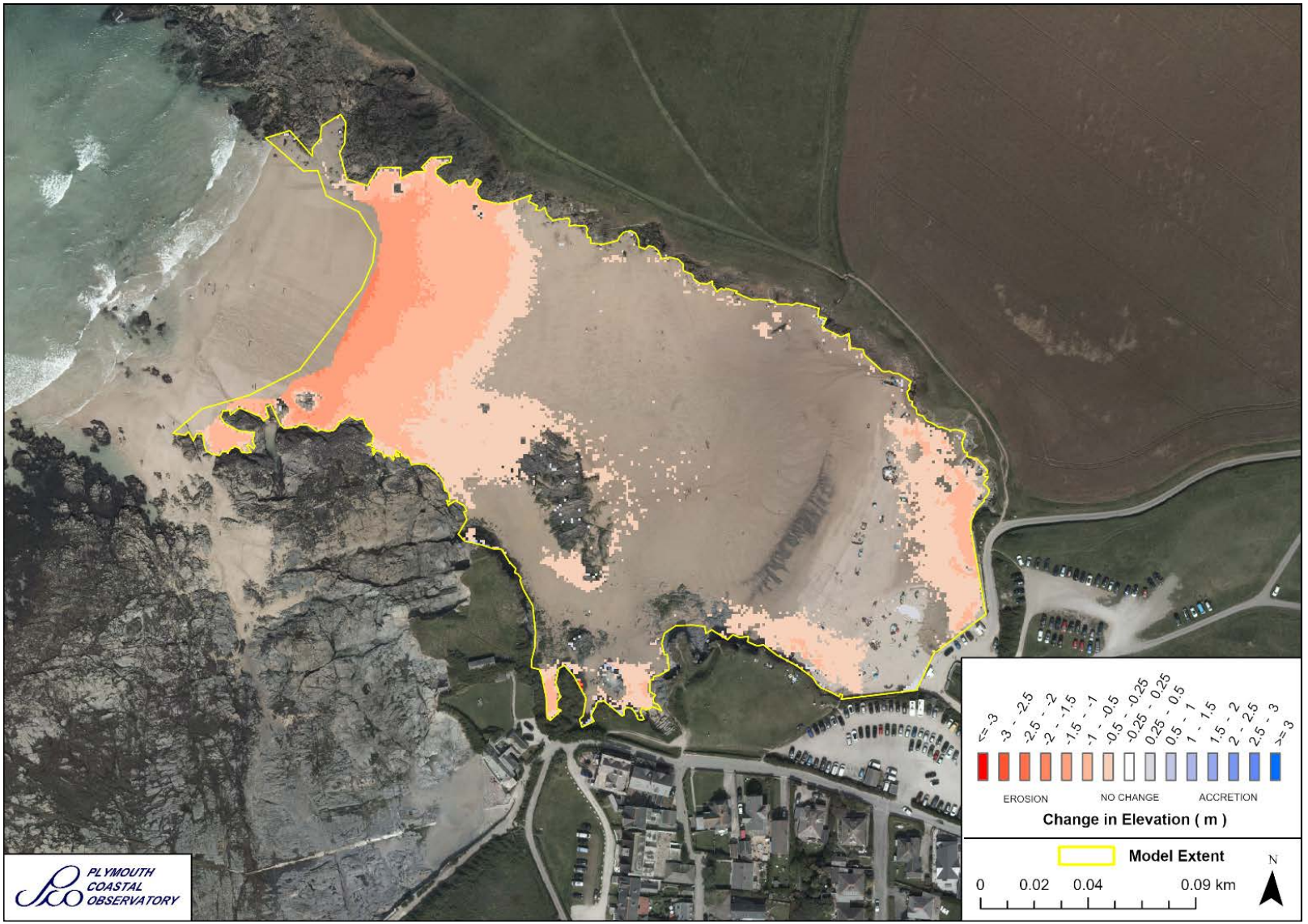


Figure 5 - Difference model indicating the changes in elevation observed between the March 2011 and April 2014 filtered LiDAR datasets within the yellow model extent.

Figure 6 shows differences in elevation between filtered LiDAR data from April 2014 compared to April 2019. Unlike the previous epoch, figure 6 shows a period of accretion, with the seaward extent gaining up to 1.5 m of material. The upper beach has also seen an increase in material stretching down to the beach face.

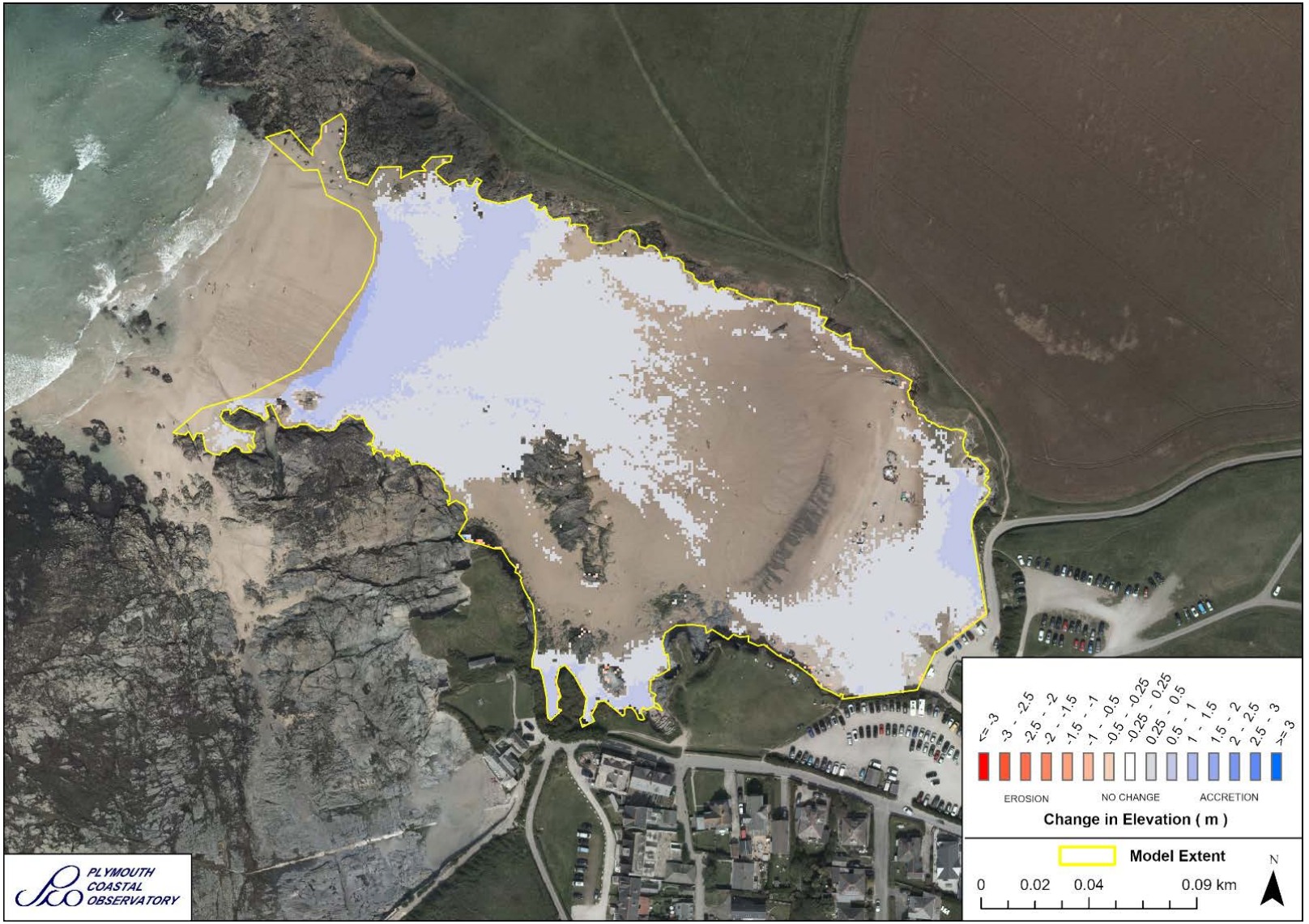


Figure 6 - Difference model indicating the changes in elevation observed between the April 2014 and April 2019 filtered LiDAR datasets within the yellow model extent.

Figure 7 shows differences in elevation between filtered LiDAR data from April 2019 compared to October 2022. A low-tide terrace bar has formed below the beach face, seeing an increase of up to 2.5 m up against the cliff. Some erosion, however, can also be measured on the upper and beach face of Trevone, as well as the lower half of the unit, seeing a loss of up to 1.5 m.

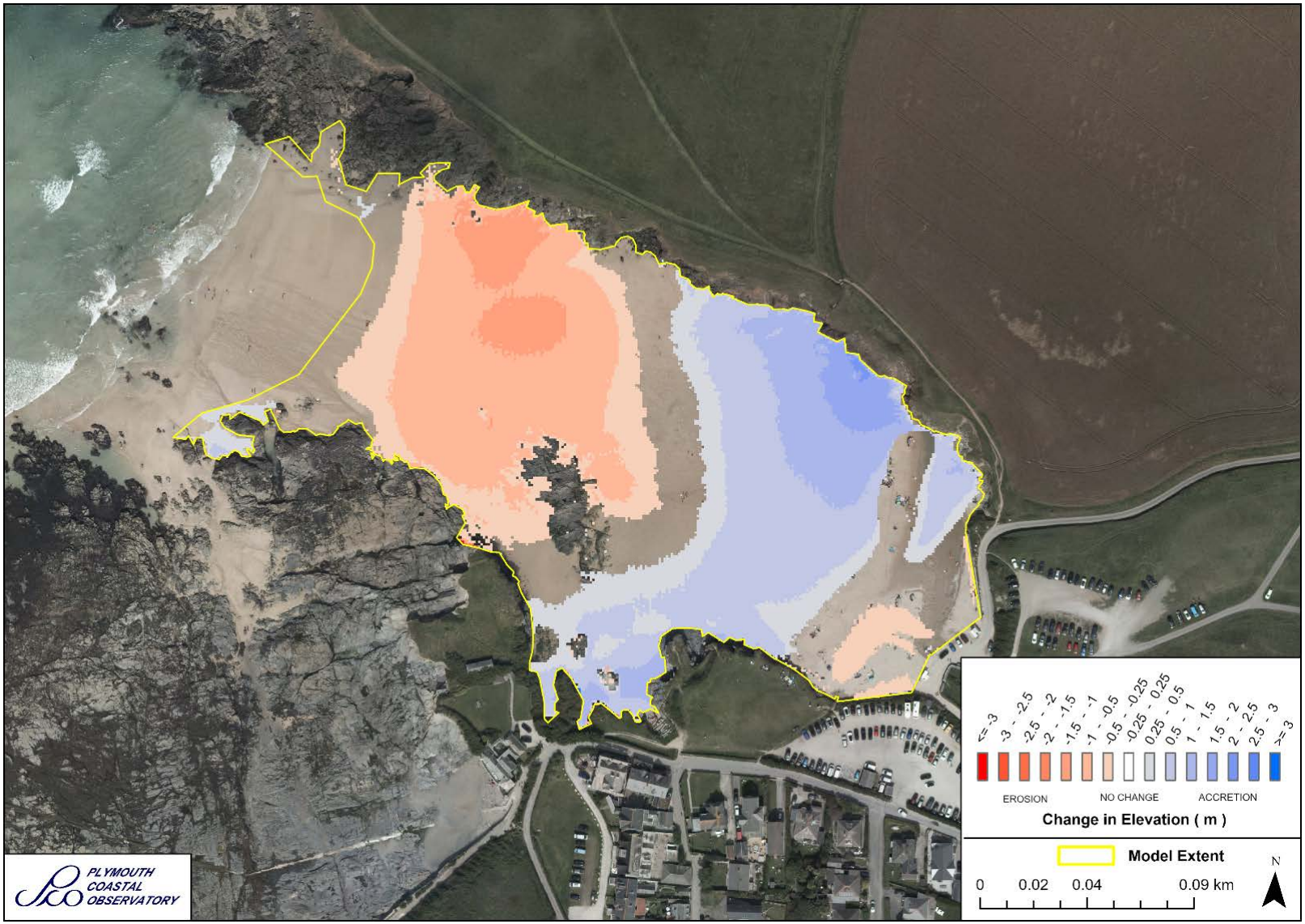


Figure 7 - Difference model indicating the changes in elevation observed between the April 2019 and October 2022 filtered LiDAR datasets within the yellow model extent.

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 remained relatively stable between 2008 and 2022 (Fig.8), however the area was impacted by the 2013/14 winter storms. Despite the lowest volume recorded in April 2014 (1,612 m^3, Table 1), the Mobile Zone returns to pre-2013/14 winter levels.

Surface volume extracted from each LiDAR dataset from the Beach Zone above the MLWS contour (-3.00 m OD) are also shown in Table 1. Beach Zone volume has gradually accreted between 2008 and 2022, despite seeing a 7% loss in volume between 2011 and 2014 following the 2013/14 winter (Fig.9), with material levels recovering by the following LiDAR survey in 2019.

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 (-3.00 m OD).

Date	Mobile Zone Volume (m^3)	Beach Zone Volume (m^3)
02/2008	2,825	142,982
03/2009	3,127	147,404
03/2011	2,231	153,496
04/2014	1,612	142,929
04/2019	2,720	154,115
10/2022	2,756	151,970

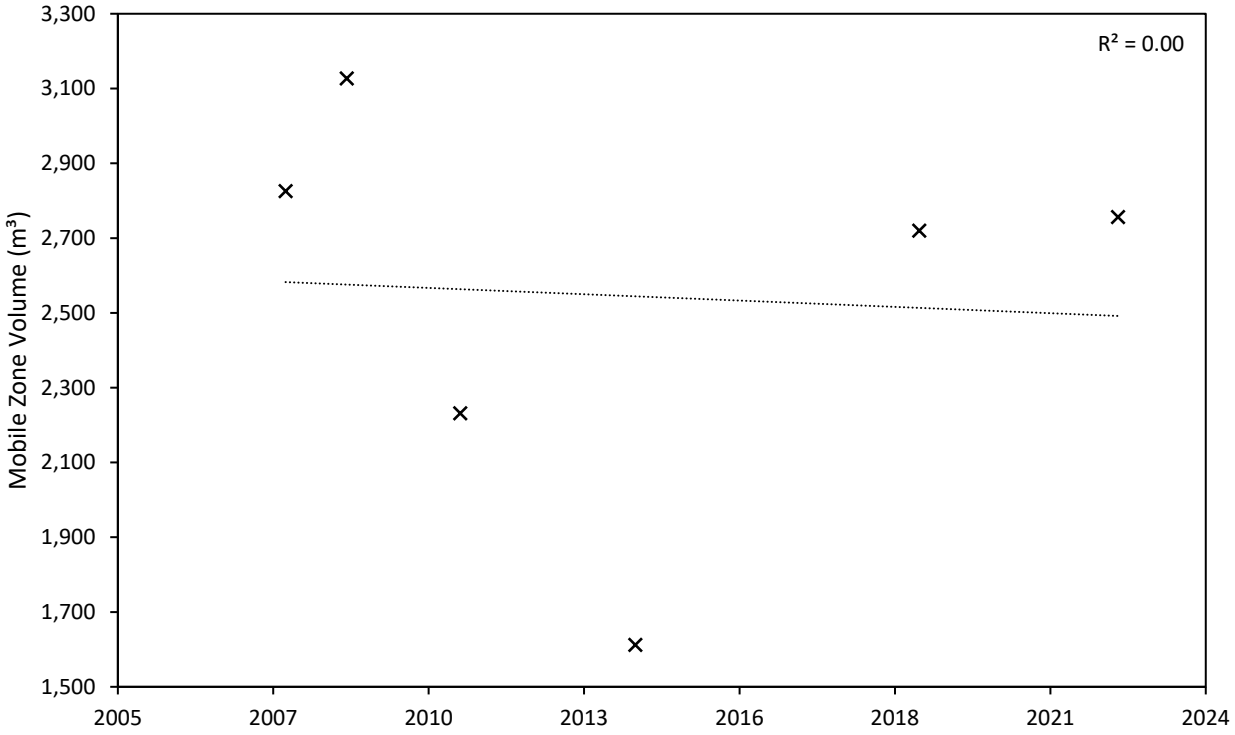


Figure 8 – Plot indicating beach volume (m^3) recorded in the Mobile Zone above MHWS (3.50 m OD) for each filtered LiDAR datasets between 2008 and 2022.

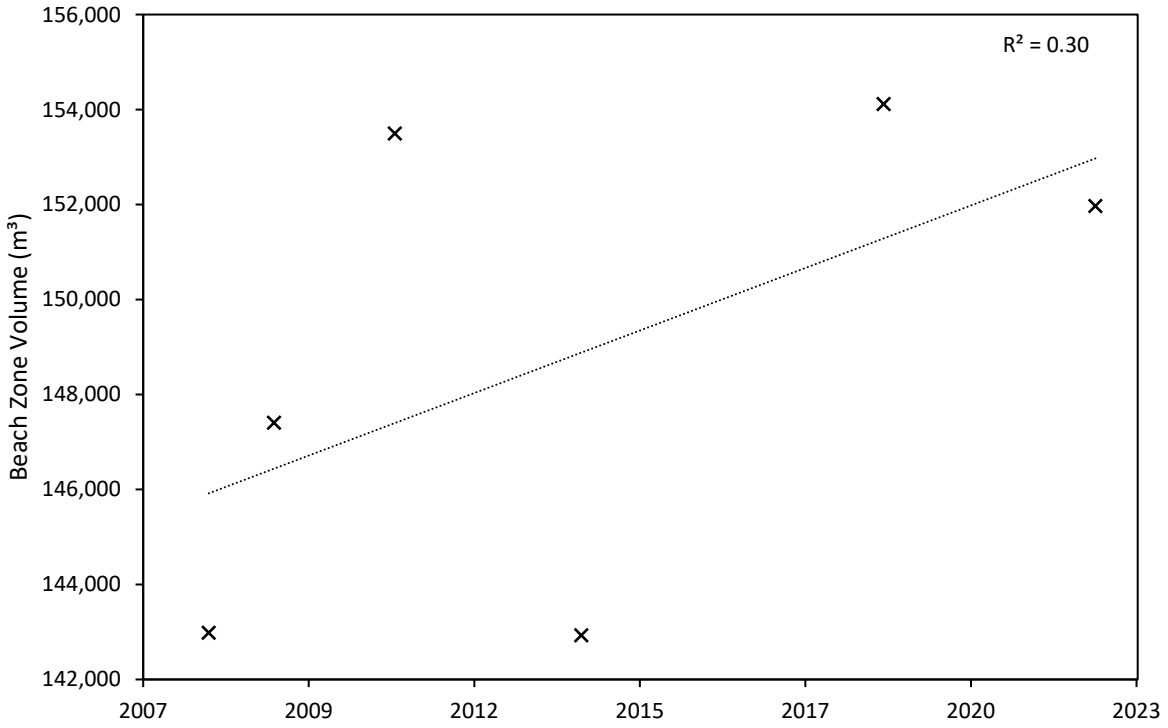


Figure 9 - Plot indicating beach volume (m^3) recorded in the Beach Zone above MLWS (-3.00 m OD) for each filtered LiDAR datasets between 2008 and 2022.

3.1.3 Contour Comparison

Figure 10 indicates the Mean Sea Level (MSL) and dune toe contours from the 2008, 2014, 2019 and 2022 LiDAR datasets. MSL contours agree with volumetric data, indicating a widening of the beach from 2008 to 2022 by approximately 12 m, but a total variation of ~40 m since 2008. The dune toe contours have remained relatively stable, only varying by ~6 m.

3.3 Historic Aerial Maps

Historic aerial photography captured in 1947 by the RAF, in 2001 by the Environment Agency and from 2006 onwards by the SWCM are presented here.



Figure 10 – Contour map indicating Mean Sea Level (solid line) and Dune Toe (dashed line) extracted from 2008, 2014, 2019 and 2022.



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 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.