SOUTH WEST COASTAL MONITORING

making space for sand



Making Space for Sand – Hawker's Cove Beach Report

LiDAR Data Analysis

SWCM | TBR33 | 15/12/2023

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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 Hawker's Cove. The aim is to highlight coastal change at Hawker's Cove using SWCM data since 2007, focusing on beach and dune areas categorised into four zones: Beach, Mobile, Fixed, and Developed. Hawker's Cove Beach, a southwest-facing gravel sand beach approximately 300 m wide, is detailed as the study site. 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 10 LiDAR flights since 2007. The Mobile Zone volume suggests accretion between the first flight in 2007 and 2022. Beach Zone volume also suggests a progressive accretion between 2008 and 2022. The trend for continuous accretion is less noticeable than that of the Mobile Zone, as can be expected from the more exposed area. Neither the Mobile Zone nor the Beach Zone were significantly affected by the 2013/14 winter storms. The main beach had widened by ~150 m, since 2007, whilst the Dune Toe had advanced by ~50 m.

Overall, Hawker's Cove beach has seen a trend for accretion between 2007 and 2022, seeing no significant impact from the 2013/14 winter storms.

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1.0 Introduction

The aim of this report is to highlight beach and dune change at Hawker's Cove 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

Hawker's Cove is a large north facing sandy beach backed by dune system, located in the mouth of the Camel Estuary. (Fig.1). The Camel runs along the eastern edge of the beach, whilst a hard rocky cliff runs along the west. The beach has a cross-shore distance of ~800 m and longshore distance of ~700 m with an average spring tidal range of 6.5 m.



Figure 1 - Location Map of Hawker's Cove 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 10 LiDAR flights captured at Hawker's Cove 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.

Please note that the difference models below (figures 2 - 11) display the analysis for the whole system, encompassing Hawkers Cove, Rock and Daymer Bay. Analysis specific to Rock and Daymer Bay are available in reports TBR34 and TBR35 respectively.

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. Hawker's Cove has observed extensive amounts of accretion across the entire unit. Up to >3 m of increased elevation can be seen along the dune face, expanding down onto the beach face and the seaward extent. Some erosion can be observed along the edge of the river, leading to significant erosion on the opposite side of the river, where Rock Dunes as seen a large redistribution of material.

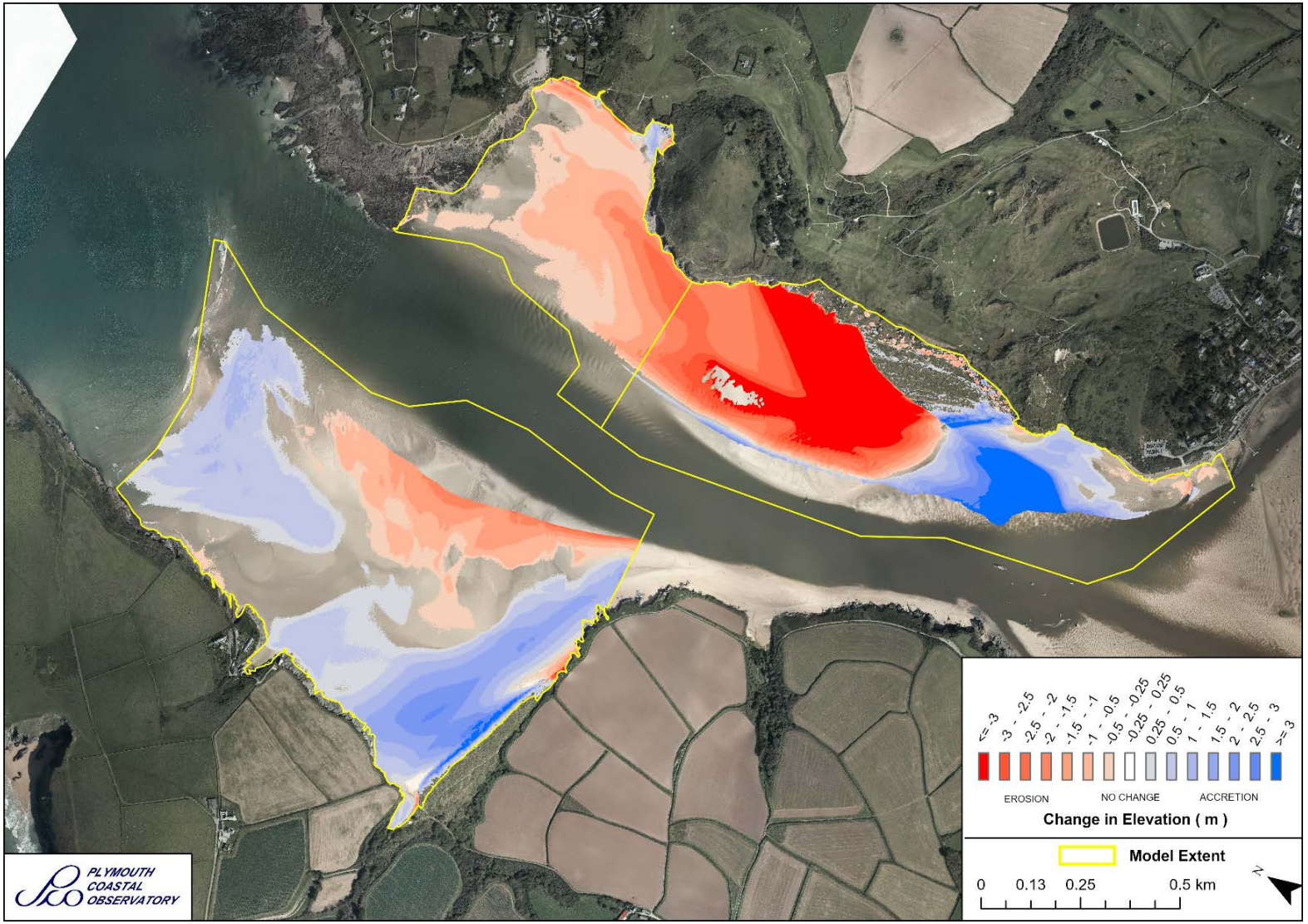


Figure 2 – Difference model indicating the changes in elevation observed between the February 2008 and October 2022 filtered LiDAR datasets within the yellow model extent.

Figure 3 shows differences in elevation between filtered LiDAR data from March 2003 and February 2008. Unlike Figure 2 this epoch shows much less movement. A build-up of material can be observed along the dune face and crest, whereas the river side of the beach has lost up to 2 m in elevation. The low-tide terrace has seen a mixture of erosion and accretion, as expected in an estuarine system. February 2008 compared with March 2009. Again, accretion/erosion can be observed across the river side of the beach, whereas the cliff side has remained stable. Hawker's Cove has seen some accretion on the dune crest and beach face, whereas Daymer Bay and Rock Dunes have seen small amounts of change with strips of erosion and accretion measured across the low-tide terrace.

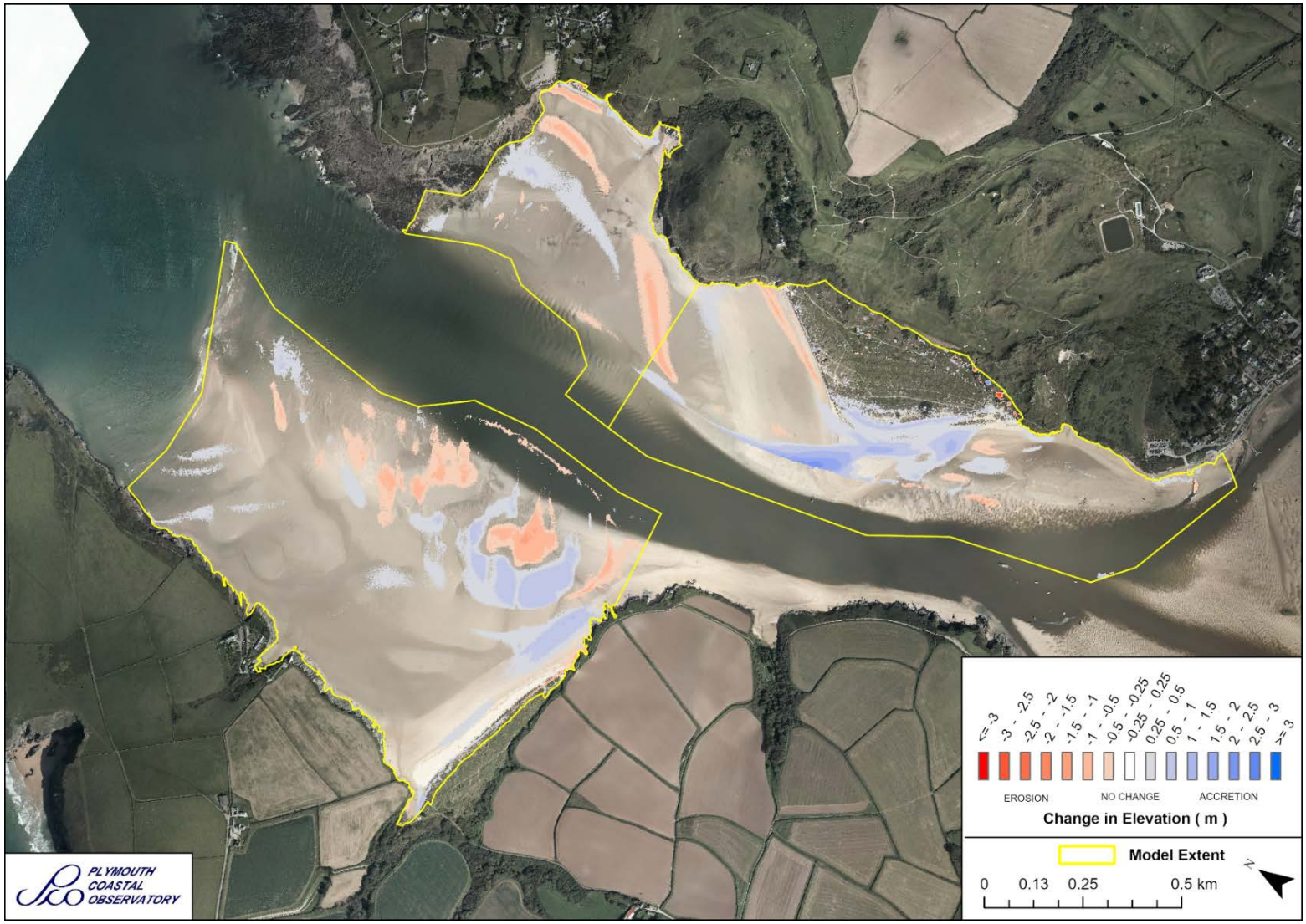


Figure 3 - Difference model indicating the changes in elevation observed between the February 2008 and March 2009 filtered LiDAR datasets within the yellow model extent.

Figure 4 shows differences in elevation between filtered LiDAR data from March 2009 compared with March 2011. Accretion continues on the dune crest of Hawker's Cove, whereas the riverine side of the beach has seen a mixture of erosion and accretion over the 2-year epoch.

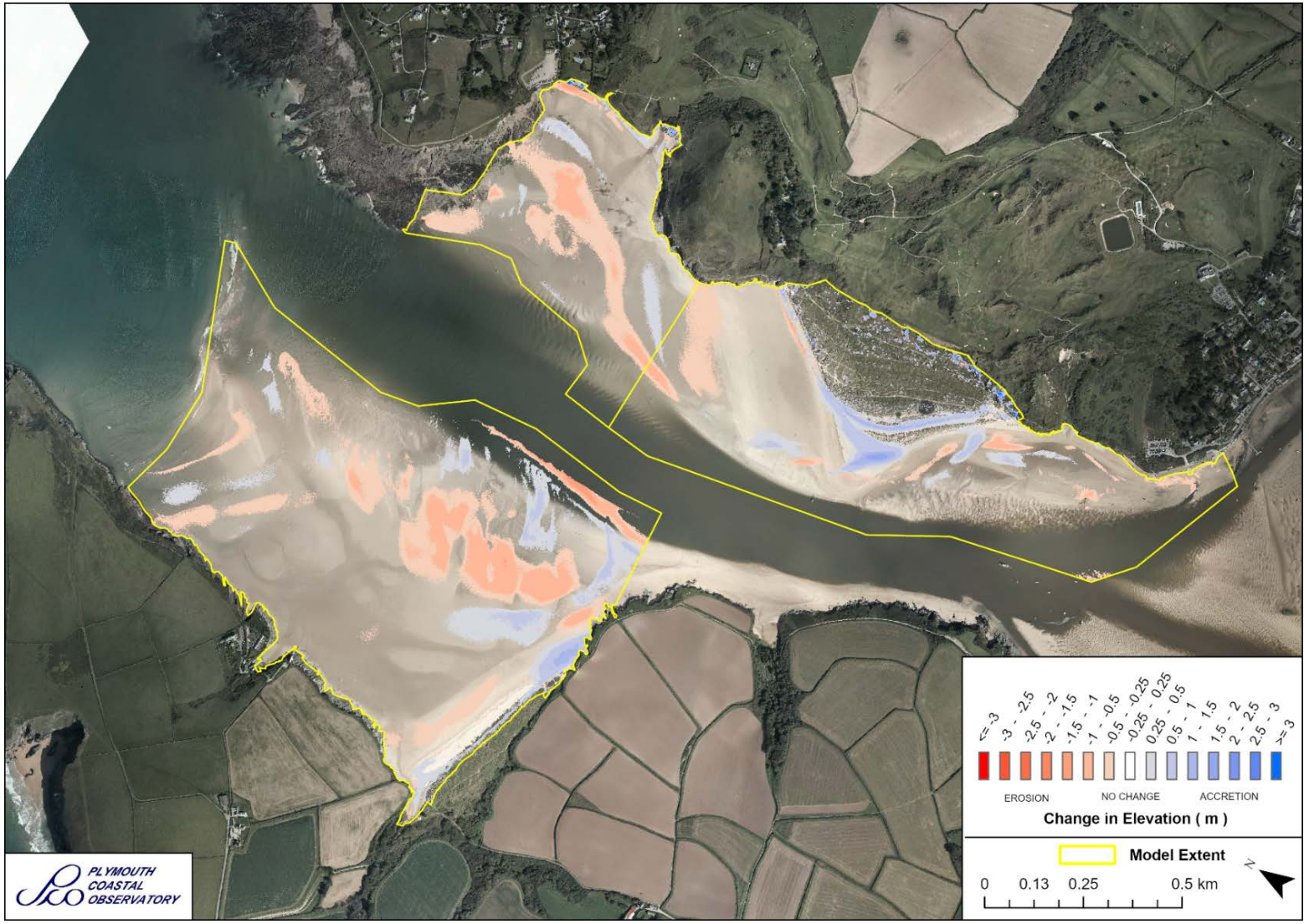


Figure 4 – Difference model indicating the changes in elevation observed between the March 2009 and March 2011 filtered LiDAR datasets within the yellow model extent.

Figure 5 shows differences in elevation between filtered LiDAR data from March 2011 compared with April 2012. Similar change has occurred in this epoch, seeing accretion of up to 1 m on the dune face and a patch of erosion on the low-tide terrace. Pockets of both erosion and accretion can be seen on the river side of Hawker's Cove.

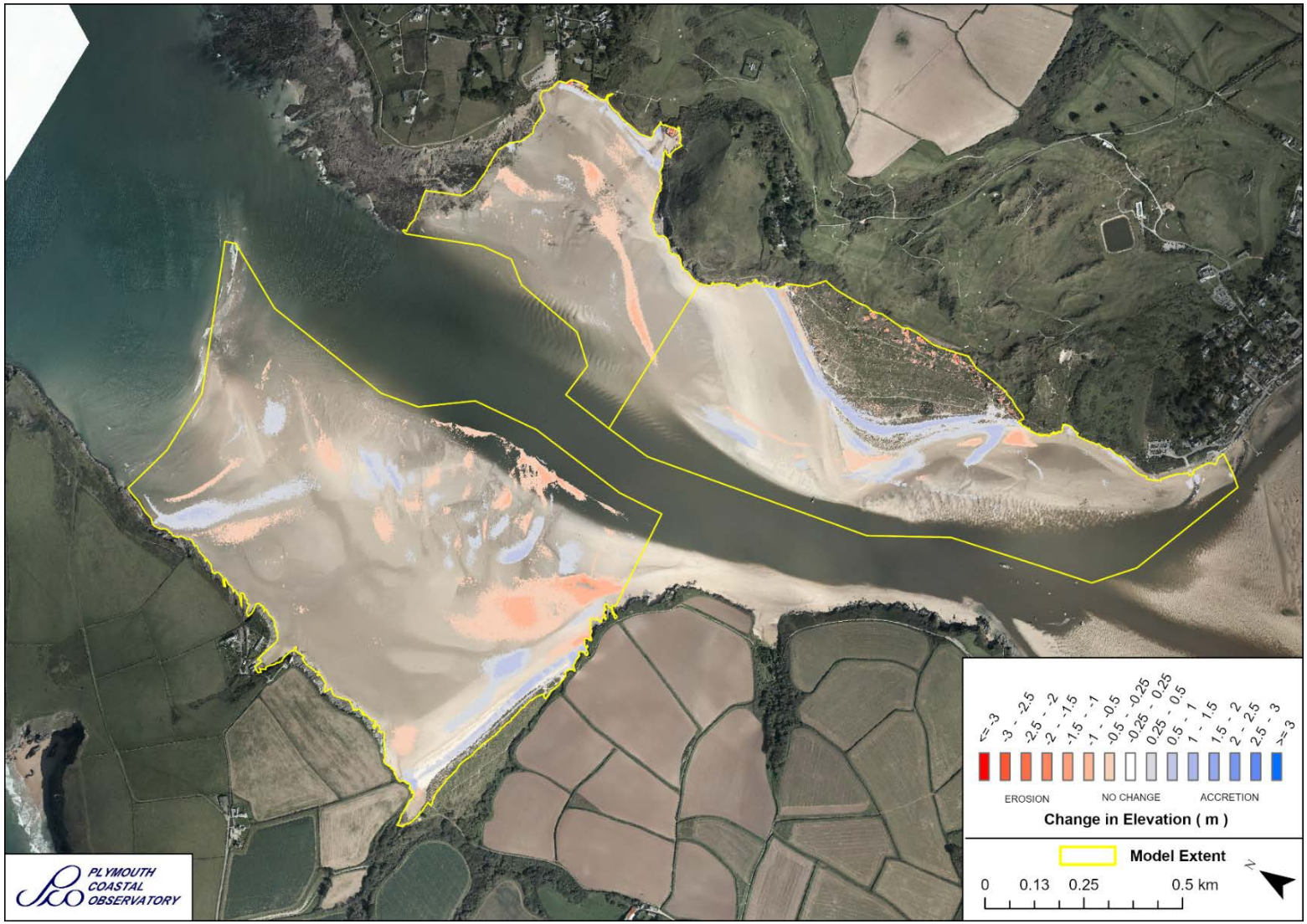


Figure 5 - Difference model indicating the changes in elevation observed between the March 2011 and April 2012 filtered LiDAR datasets within the yellow model extent.

Figure 6 shows differences in elevation between filtered LiDAR data from April 2012 compared with March 2014. The impact of the 2013/14 winter storms has seen the dune face at Daymer Bay erode at the outer edges; the dune face/crest has accreted by up to 1.5 m. Hawker's Cove has seen erosion along the river edge but a build-up of up to 2.5 m of sediment along the upper beach.

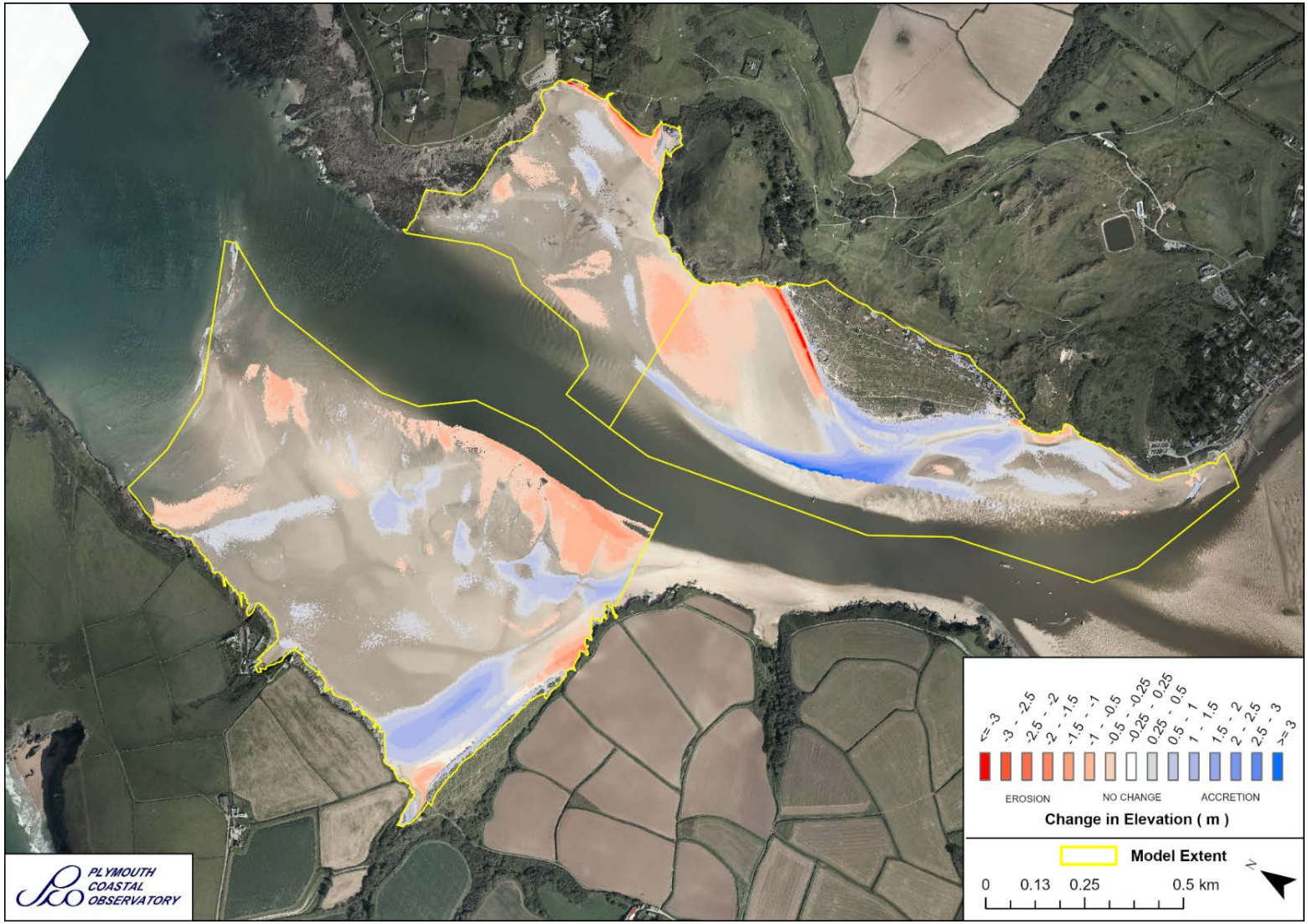


Figure 6 - Difference model indicating the changes in elevation observed between the April 2012 and March 2014 filtered LiDAR datasets within the yellow model extent.

Figure 7 shows differences in elevation between filtered LiDAR data from April 2014 compared with March 2016. Less movement has occurred in this epoch, but up to 1.5 m of material has been gained along the dune face, whilst a strip of erosion can be observed along the mean sea level line, towards the east of the unit. Pockets of erosion and accretion can be seen across the eastern half of the unit. The opposite side of the river, at Rock Dunes, has seen large scale material redistribution.

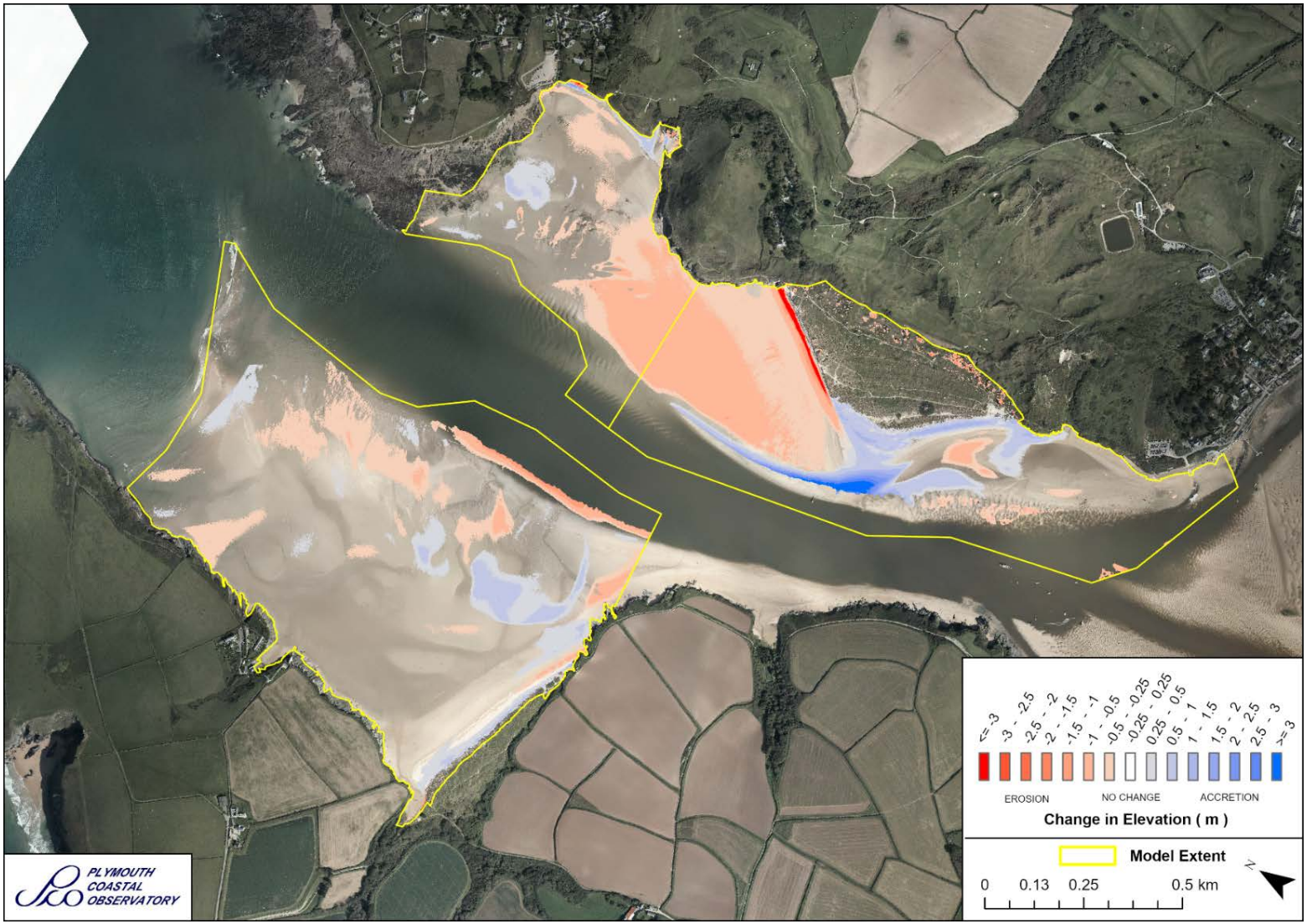


Figure 7 - Difference model indicating the changes in elevation observed between the April 2014 and March 2016 filtered LiDAR datasets within the yellow model extent.

Figure 8 shows differences in elevation between filtered LiDAR data from March 2016 compared to March 2017. As Figure 7, Hawker's Cove has seen a build-up of material along the beach face. Pockets of erosion and accretion can be seen across the eastern half of the unit. The opposite side of the river, at Rock Dunes, has seen large scale material redistribution.

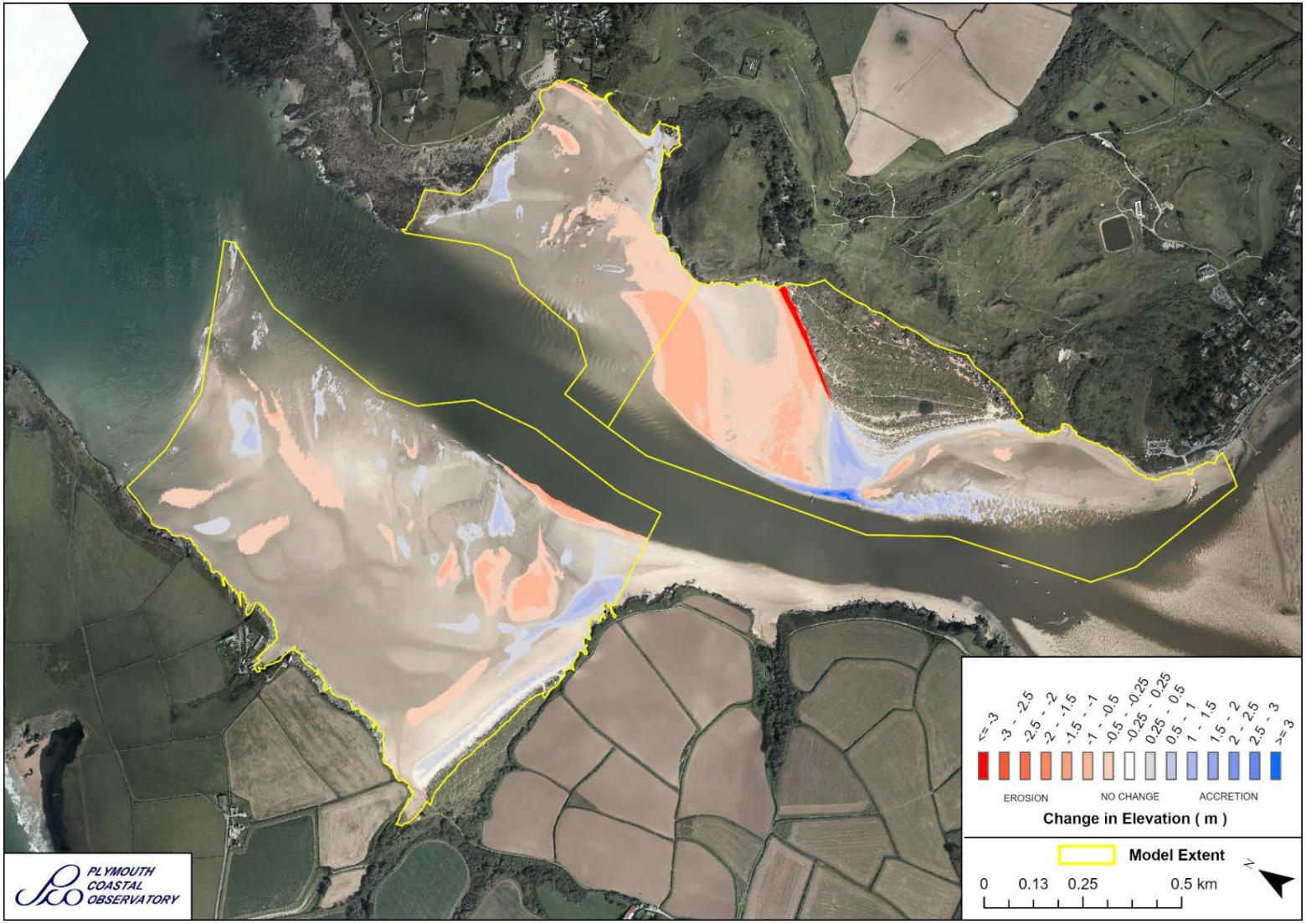


Figure 8 - Difference model indicating the changes in elevation observed between the March 2016 and March 2017 filtered LiDAR datasets within the yellow model extent.

Figure 9 shows differences in elevation between filtered LiDAR data from March 2017 compared with April 2019. A mixture of erosion and accretion can be seen on Hawker's Cove with the western half of the upper beach experiencing large-scale accretion of up to 2 m. Similarly, the dune crest has also seen material build-up. The eastern end of the upper beach has observed up to 2.5 m of erosion. The rest of the beach has experienced a mixture of erosion and accretion across the intertidal zone.

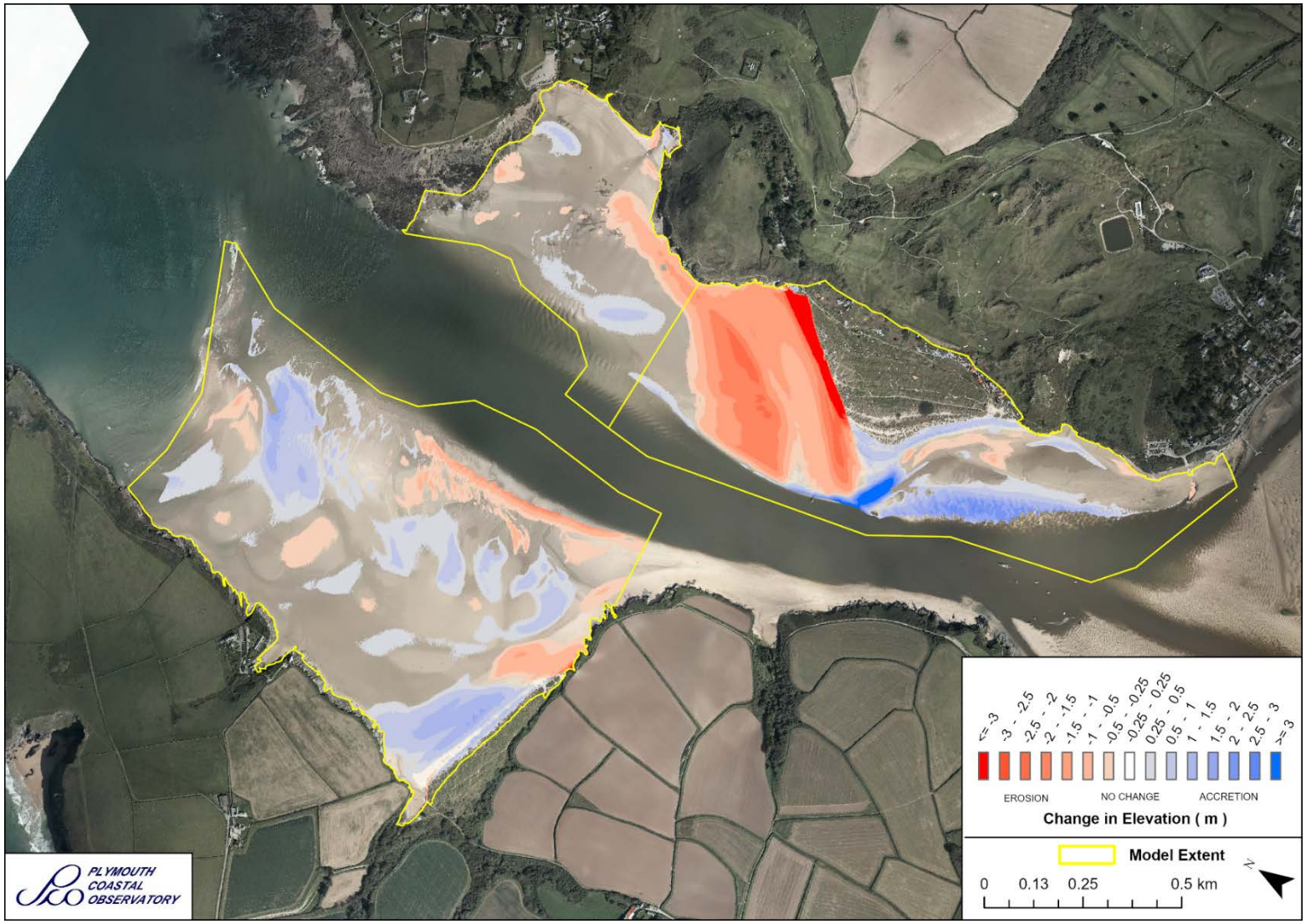


Figure 9 - Difference model indicating the changes in elevation observed between the March 2017 and April 2019 filtered LiDAR datasets within the yellow model extent.

Figure 10 shows differences in elevation between filtered LiDAR data from April 2019 compared with November 2020. Hawker's Cove has experienced some accretion along the dune face but significant erosion on the very eastern end of the dune system. Up to 2 m of accretion is seen in the middle of the unit, whereas 1.5 m of erosion is present along the edge of the river. Rock Dunes, on the opposite side of the river, have experienced large scale sediment redistribution along the dune system, seeing >3 m elevation loss.

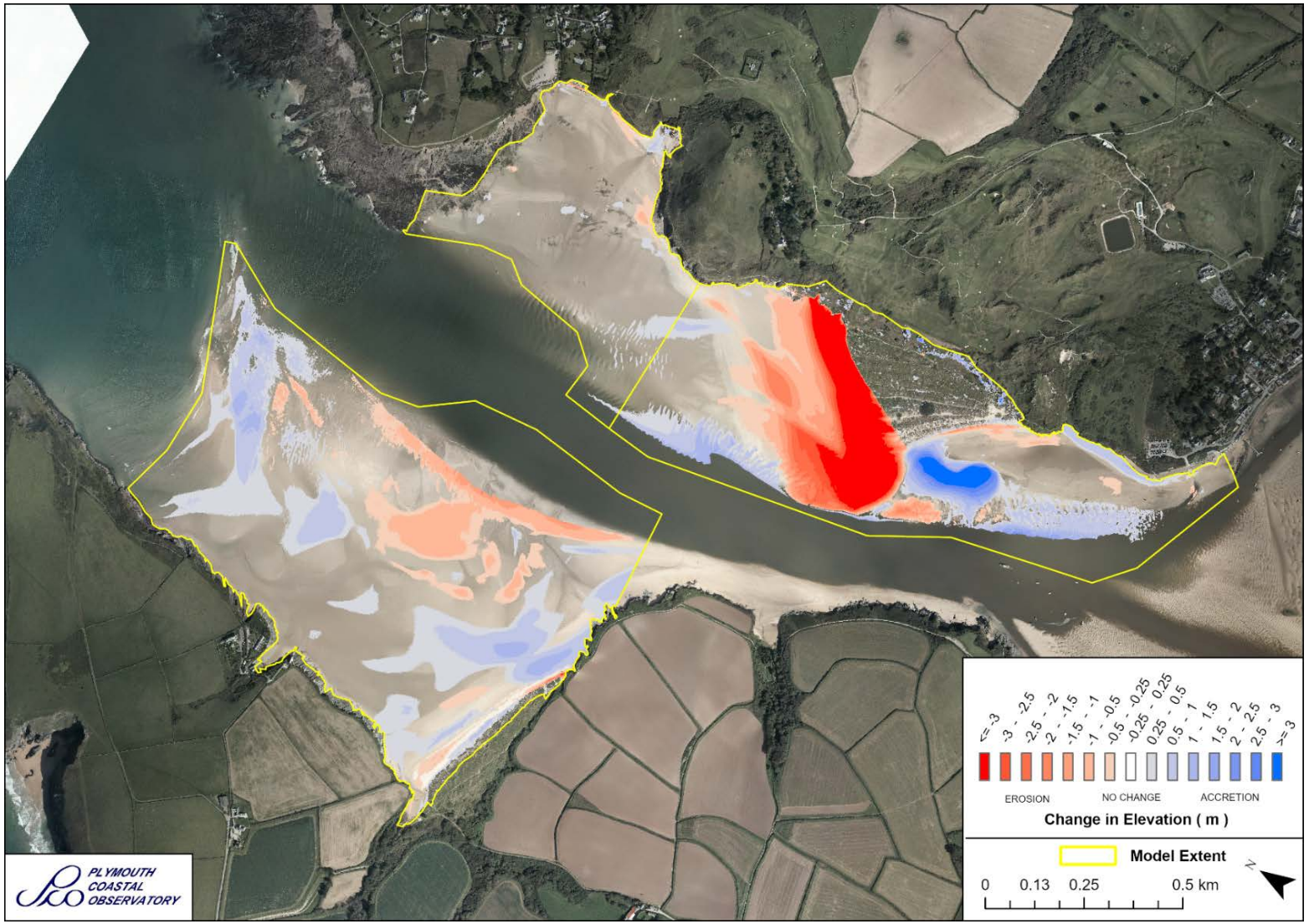


Figure 10 - Difference model indicating the changes in elevation observed between the April 2019 and November 2020 filtered LiDAR datasets within the yellow model extent.

Figure 11 shows differences in elevation between filtered LiDAR data from November 2020 compared with October 2022. Similar to the last epoch, Hawker's Cove has also seen a build-up of material along the dune face, whilst erosion takes place along the beach face. An intertidal bar has built-up to the west of the unit, whereas the river edge has seen erosion across the length of the beach. Again, significant erosion can be seen at Rock Dunes, losing >3 m on the dune system and curving round to the southern beach behind it.

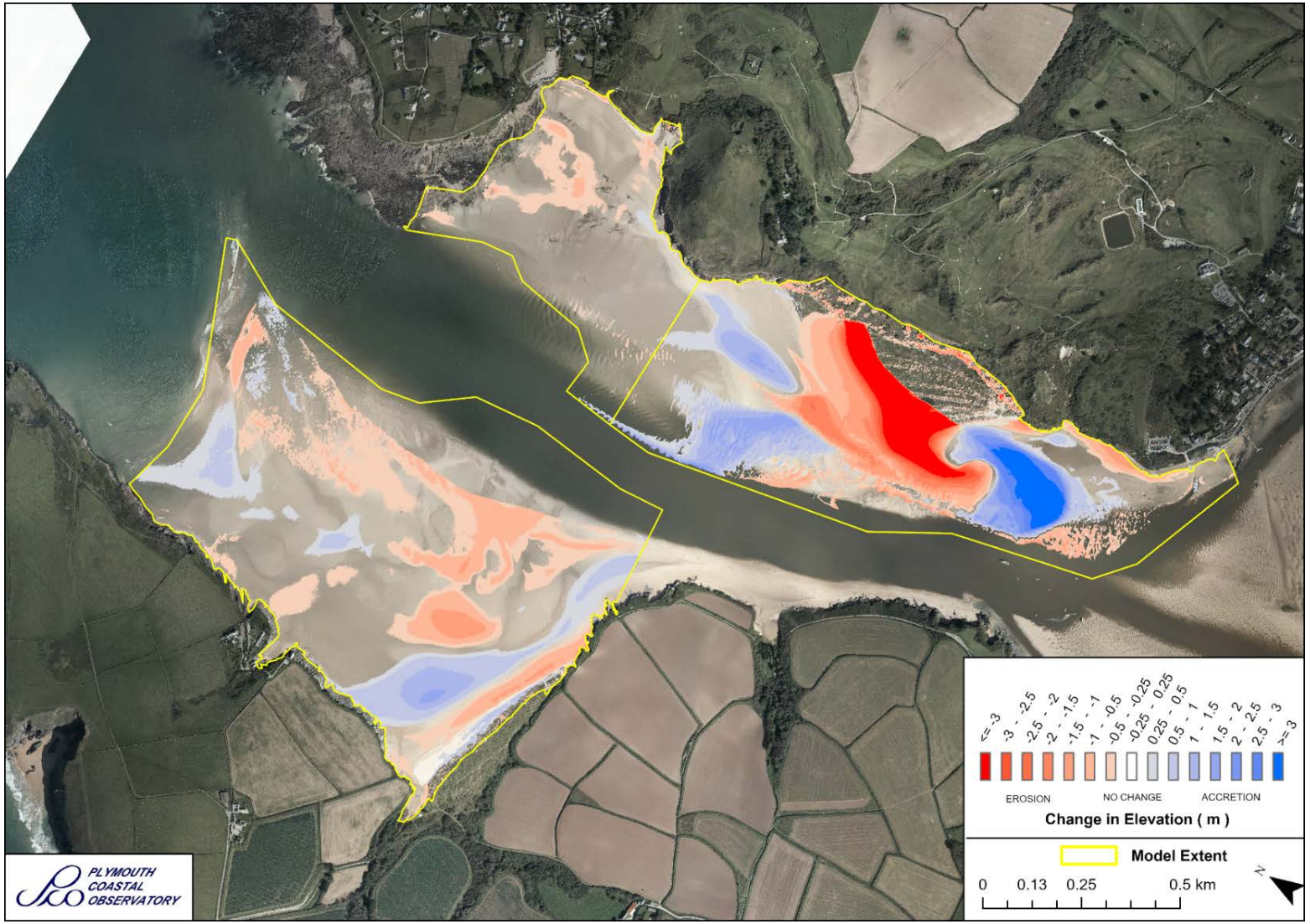


Figure 11 - Difference model indicating the changes in elevation observed between the November 2020 and October 2022 filtered LiDAR datasets within the yellow model extent.

3.1.2 Beach and Dune Volume Extraction

Surface volume extracted from each available LiDAR dataset from the Mobile Zone above the MHWS contour (2.35 m OD) are shown in Table 1. Mobile Zone volume suggests progressive and even accretion since the first flight in 2007, accreting at a rate of 3,607 m^3 y^{-1} (equating to a 1.1% increase in volume per year) to the most recent survey in 2022 (Fig.12).

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 also suggests a progressive accretion between 2008 and 2022 (Fig.13), with an accretion rate of 8,330 m^3 y^{-1} (equating to a 0.7% increase in volume per year). The trend of continuous accretion is less noticeable than that of the Mobile Zone, as can be expected from the more exposed section. Neither the Mobile Zone nor Beach Zone were significantly affected by the 2013/14 winter storms.

Table 1 – Surface volume values (m^3) extracted from all available filtered LiDAR datasets for the Mobile Zone above MHWS (2.35 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	321,206	1,228,191
03/2009	326,126	1,266,273
03/2011	334,910	1,227,447
04/2012	338,572	1,202,320
04/2014	349,281	1,254,604
03/2016	353,501	1,241,738
03/2017	360,077	1,233,570
04/2019	374,716	1,319,113
11/2020	382,417	1,385,273
04/2022	372,332	1,346,257

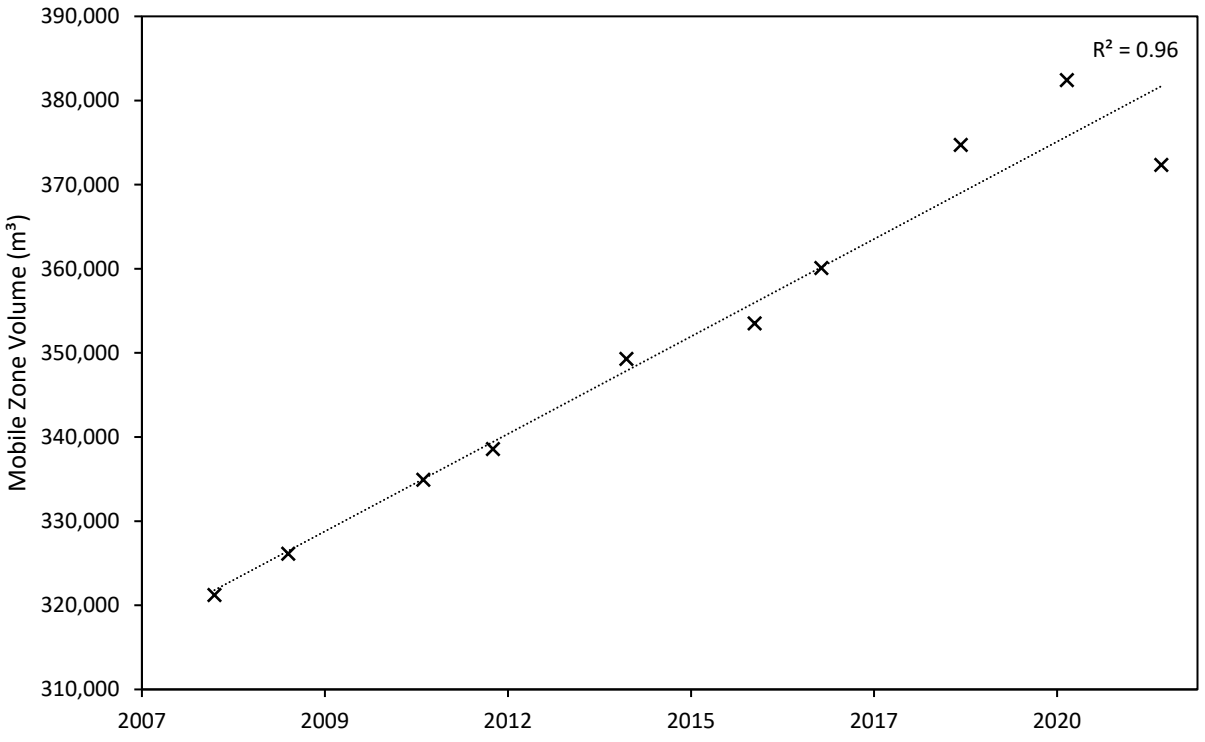


Figure 12 – Plot indicating beach volume (m^3) recorded in the Mobile Zone above MHWS (2.35 m OD) for each filtered LiDAR datasets between 2008 and 2022.

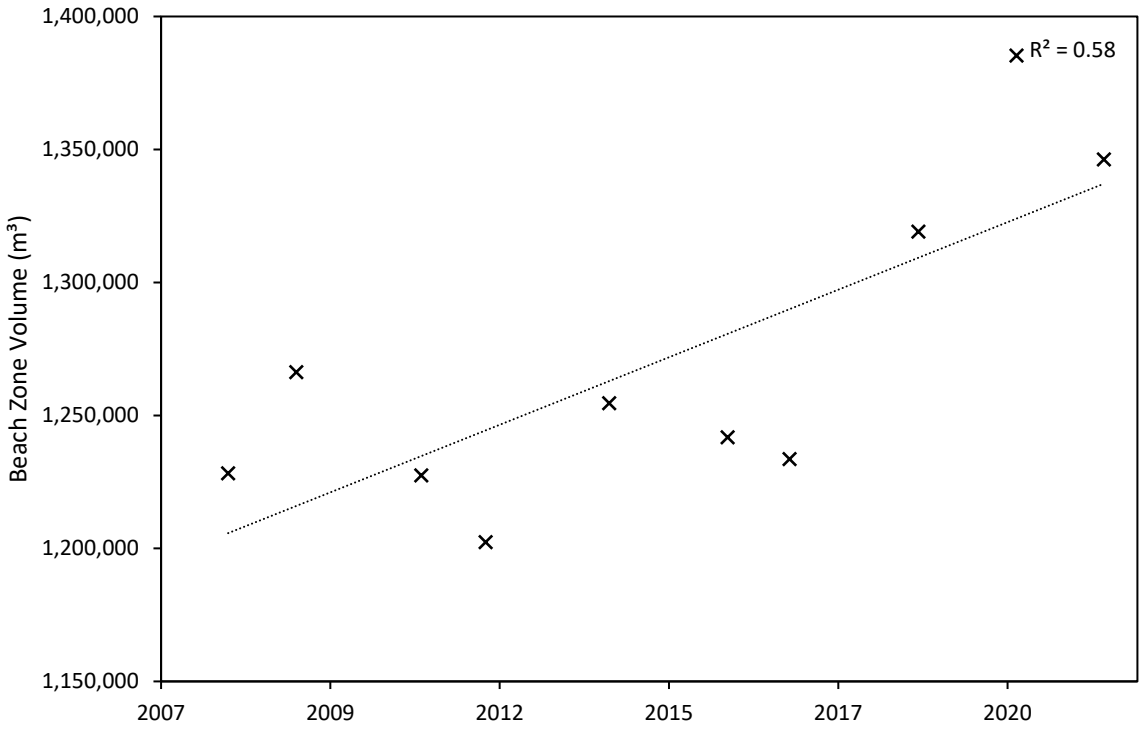


Figure 13 - Plot indicating beach volume (m^3) recorded in the Beach Zone above MLWS (-3.00 m OD) for each filtered LiDAR datasets between 2008 and 2022.

3.1.3 Contour Comparison

Figure 14 indicates the Mean Sea Level (MSL) and Dune Toe contours from the 2008, 2014, 2019 and 2022 LiDAR datasets. MSL contours indicate a widening of the beach from 2008 to 2022 by approximately 150 m. The same is true of the Dune Toe contours, which have advanced by up to ~50 m in the middle section of the beach.

3.3 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.

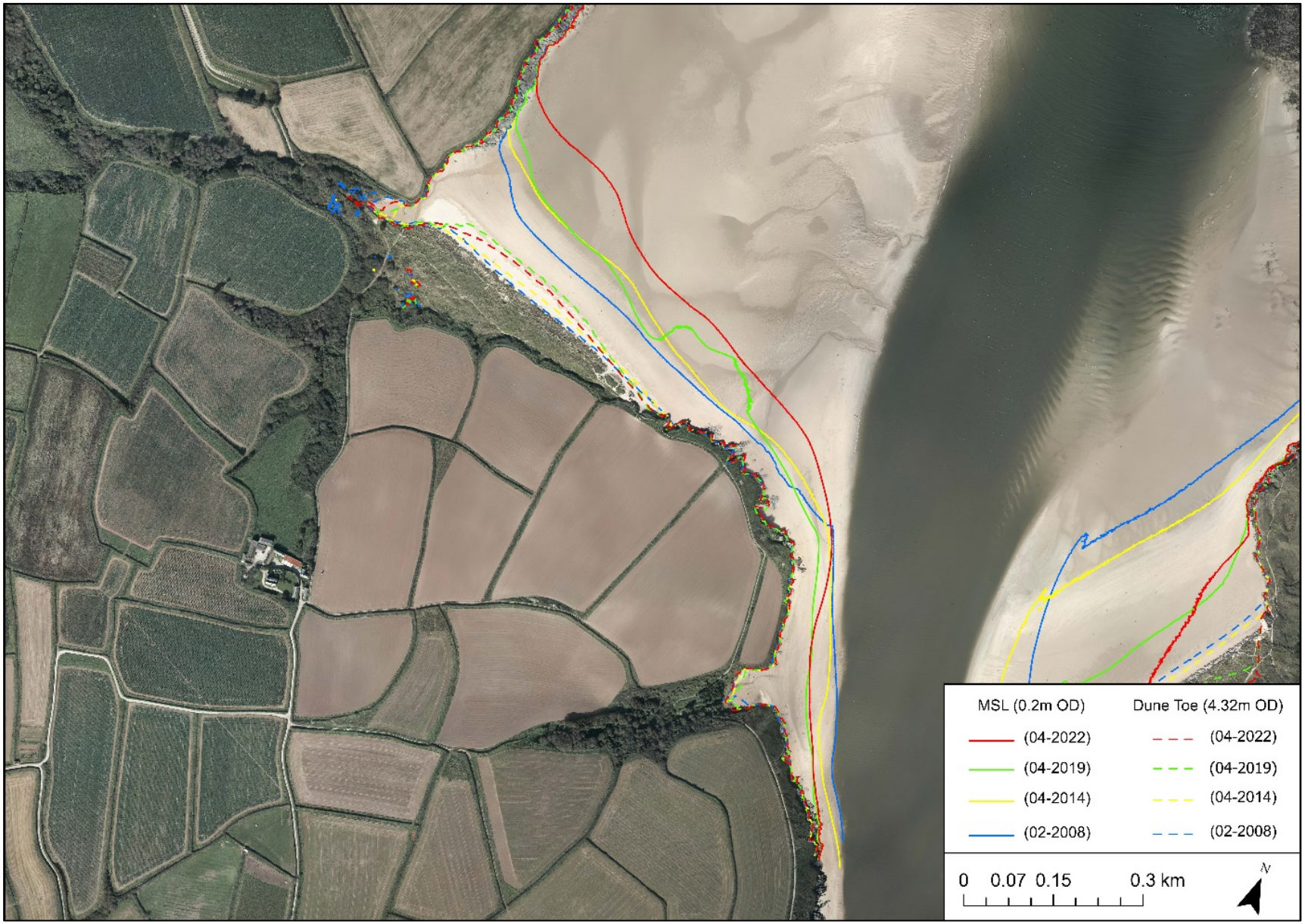


Figure 14 – Contour map indicating Mean Sea Level (solid line) and Dune Toe (dashed line) extracted from 2008, 2014, 2019 and 2022.



Figure 15 – Aerial imagery from 1947.



Figure 16 – Aerial imagery from 2001.



Figure 17 – Aerial imagery from 2006.



Figure 18 – Aerial imagery from 2010.



Figure 19 – Aerial imagery from 2014.



Figure 20 – 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.