QUANTIFYING AND CLASSIFYING COASTAL CHANGE IN SCOTLAND USING SATELLITE-DERIVED COASTAL BOUNDARIES

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RISKS AND MEASURES OF COASTAL CHANGE

Global sea levels and the frequency and severity of coastal storm events are both predicted to rise with anthropogenic climate change. Coastal storms are often accompanied by intense wave energy producing large waves which lead to impact damage, wave overtopping and flooding of coastal infrastructure Erosion of soft coasts can cause instability and infrastructure damage, and exacerbate flood risk with weakening of natural protective features like dunes. To plan effectively for a changing climate and increased coastal risks, coastal managers require continuous, repeatable datasets on past coastal change to anticipate potential future changes and assess adaptation options.

Shoreline positions reflect the underlying morphology of the beach and can act as an indicator of changes in wave climate and sediment transport across a beach system. However, the ever-moving nature of the shoreline means the instantaneous measure can pose tidal biases and noise problems in seasonal timeseries. The seaward-most boundary of vegetation reflects a steadier soft-coast boundary which shifts on both event–seasonal and longer annual–decadal timescales, and reflects storm damage, sediment availability and overall beach health. When coupled together, shorelines and vegetation edges can provide a holistic record of coastal change across interacting processes. The distance between the vegetation edge and shoreline can also be used as a proxy for beach health.

SATELLITE-DRIVEN APPROACHES

Ground-based approaches to collecting vegetation edges and shoreline positions are notoriously difficult, costly and limited in repeatability and spatial coverage. The almost four decades of near-global multispectral satellite imagery, freely available at moderate to high spatial resolutions, now offers an exciting opportunity in coastal change monitoring. Multiple algorithms now exist to semi-automatically extract shorelines from satellite imagery using supervised and unsupervised machine learning approaches. However, the amount of literature on coastal vegetation edges derived from satellite imagery remains limited (Rogers, 2021).

COASTAL MONITORING FROM SPACE

We present an algorithm for extracting vegetation edges from moderate (10-30 m) and high (3 m) resolution satellite imagery. The methodology is based on the CoastSat toolkit (Vos, 2019), but with enhancements to streamline access to imagery using entirely cloud-based processes and Google Earth Engine/Planet APIs. Images are classified using supervised machine learning and dynamic thresholding to extract line features along land-vegetation and land-sea boundaries (Figure 1).

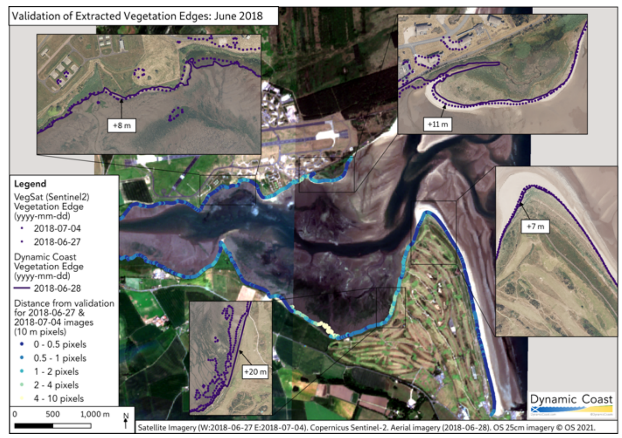

Figure 1 – 2018 Sentinel-2 image with extracted veg edge as pixel-width distance from validation edge.

Validation is performed at St Andrews, UK, which is home to world-class golf but also varying vegetation types and a complex coastal change history. The complexity is due in part to nature-based management such as dune grass and saltmarsh replanting and dune feeding, and to its position where estuarine tides meet open-coast wave action. Validation against ground surveys and manually digitized vegetation edges shows successful vegetation boundary detection to within 1 pixel across 76% of Sentinel-2 imagery (RMSE of 14.3 m) and 52% of Landsat 5 imagery (RMSE of 24.5 m) (Figure 2).

This study quantifies vegetation edge response in comparison to shoreline response across daily-multiannual timescales, to investigate storm response, seasonal variability and long-term change. The validation highlights that different geomorphic environments produce different spectral signatures, which is used to further automate the previously user-driven thresholding process (Figure 3). Quantifying past coastal changes across a range of timescales using satellite-derived vegetation edges can help train data-driven models, and serve as a classification of coastal typology for coastal change predictions.

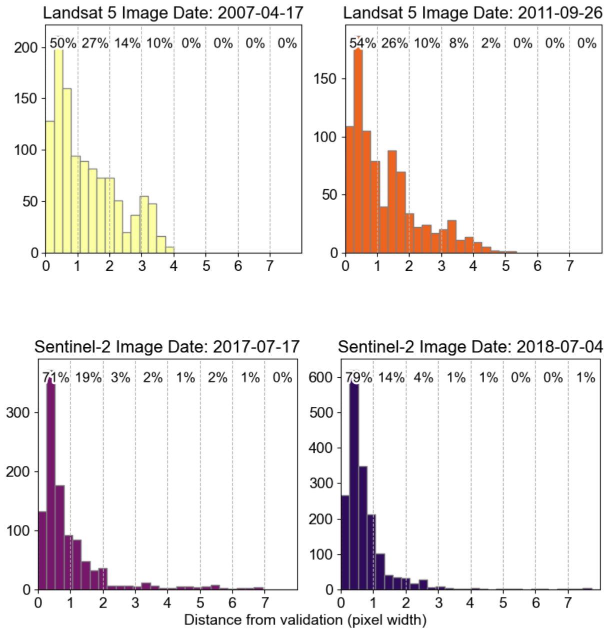

Figure 2 – Distribution of distances between Landsat 5 and Sentinel-2 extracted boundaries and validation ground survey edges.

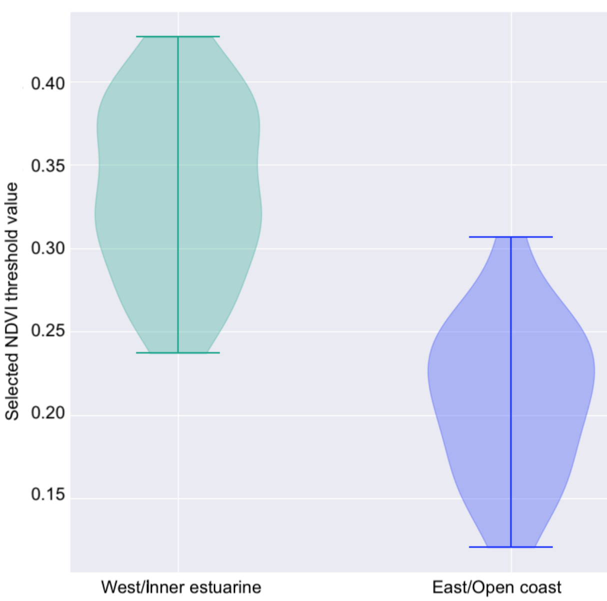

Figure 3 – Distribution of Normalised Difference Vegetation Index values used as thresholds for extracting vegetation edges, across inner Eden Estuary (west) and open coast of St Andrews Peninsula to Tentsmuir (east).

REFERENCES

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