DETECTING COASTLINE CHANGES FROM SATELLITE IMAGERY

Using AI/ML to Detect Coastal Erosion

GRAHAM TECHNOLOGIES

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PROBLEM: COASTAL EROSION

Coastlines are highly dynamic systems in which the erosion – or conversely, advancement of coastlines – are influenced by numerous climatic, geological, biological, and anthropic factors. When marine abrasion is greater than the deposit, there are evident cases of coastal erosion that have led to the disintegration and demolition of the earth's surface. Coastal areas are very fragile landscapes, being among the most vulnerable to climate change and natural hazards. Coastline mapping and change detection are essential for safe navigation, resource management, environmental protection, and sustainable coastal development and planning.

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Graham Technologies Innovation Lab built a Coastline Detector tool for NOAA to monitor a broad geographic area at a relatively low cost using AI/ML imagery analysis of non-NOAA satellite images. This paper walks through a comprehensive approach to extract coastline data effectively and accurately from satellite imagery. A sequence of image processing and edge detection algorithms are used to analyze data over time to demonstrate how satellite imagery data input can be compared to baseline data to determine changes to the coastline over time. It is one example of how we can use AI/ML satellite imagery analysis applications to meet your mission.

METHODOLOGY FOR THIS ANALYSIS

1. Collection and aggregation of the data with acquisition registration and alignment

2. Subsetting of the data by removing data not relevant to the collection

3. Segmentation through clustering of algorithms to discriminate between land and sea areas

4. Utilization of the Canny Edge Detection algorithm applied to the images to obtain the gradient and further refine the results

5. Comparison of the visual results over time

INTRODUCTION

Coastline change detection using digital image data belongs to the boundary detection problem in the field of computer vision and image processing. Edge detection and image segmentation are two conventional approaches to boundary detection. In this particular use case, we utilized the Canny Edge Detection algorithm on satellite images acquired by the OLI (Operational Land Imager) sensor on the Landsat 8 platform. Through this methodology, we were able to visualize and estimate the progress of the coastline over time.

The following open-source packages were used:

- Rasterio to easily deal with raster images
- OpenCV to apply the Canny algorithm
- Scikit-Learn to segment images

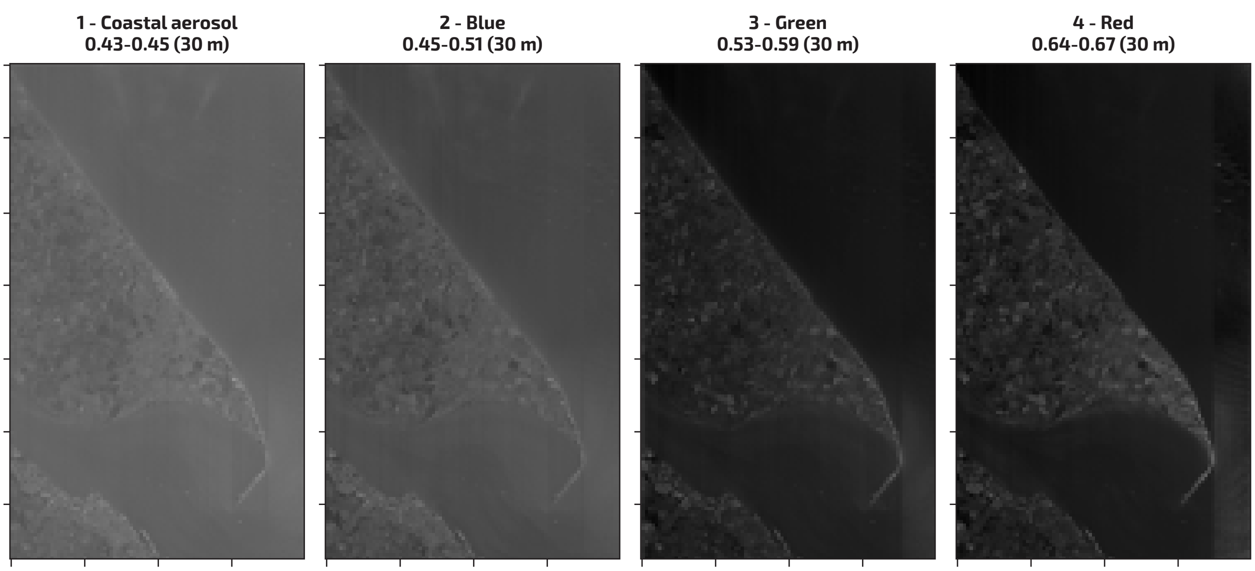
STEP 1 Collection and Aggregation of Data

In recent years, satellite imagery has been used in semi-automated or automated coastline extraction and mapping from high-resolution images. The Landsat 8 is an orbiting platform that mounts onboard an 11-band multispectral sensor called OLI (Operational Land Imager). Satellite imagery is used extensively to monitor changes that are happening everywhere on Earth. From observing the health of crops throughout a season to tracking the melting of glaciers over a decade, this imagery can be used to chronicle how objects on Earth change over time including coastline change. For this project, two high-resolution satellite images with different timestamps over a five-year period were used on a particular European area subject to strong erosion actions – the Holderness Coast. Two 7-band acquisitions from OLI images were loaded as inputs. During data preprocessing, some support functions were performed, such as acquisitions registration (alignment) in Step 1 and acquisitions subsetting in Step 2.

STEP 2 Acquisitions Subsetting

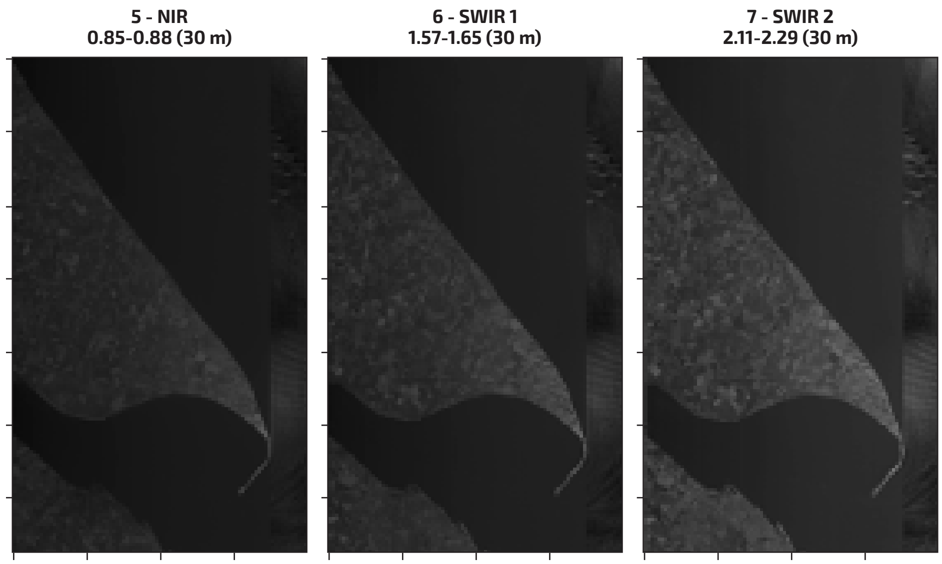
At this stage, after the alignment of the two multispectral cubes, we create a subset of our aligned acquisitions by cutting out the portion of the acquisition that does not interest us. We do this by defining the area of interest.

Data Exploration: Before making the image plot, we perform standardization of the images using the StandardScaler function in sklearn.

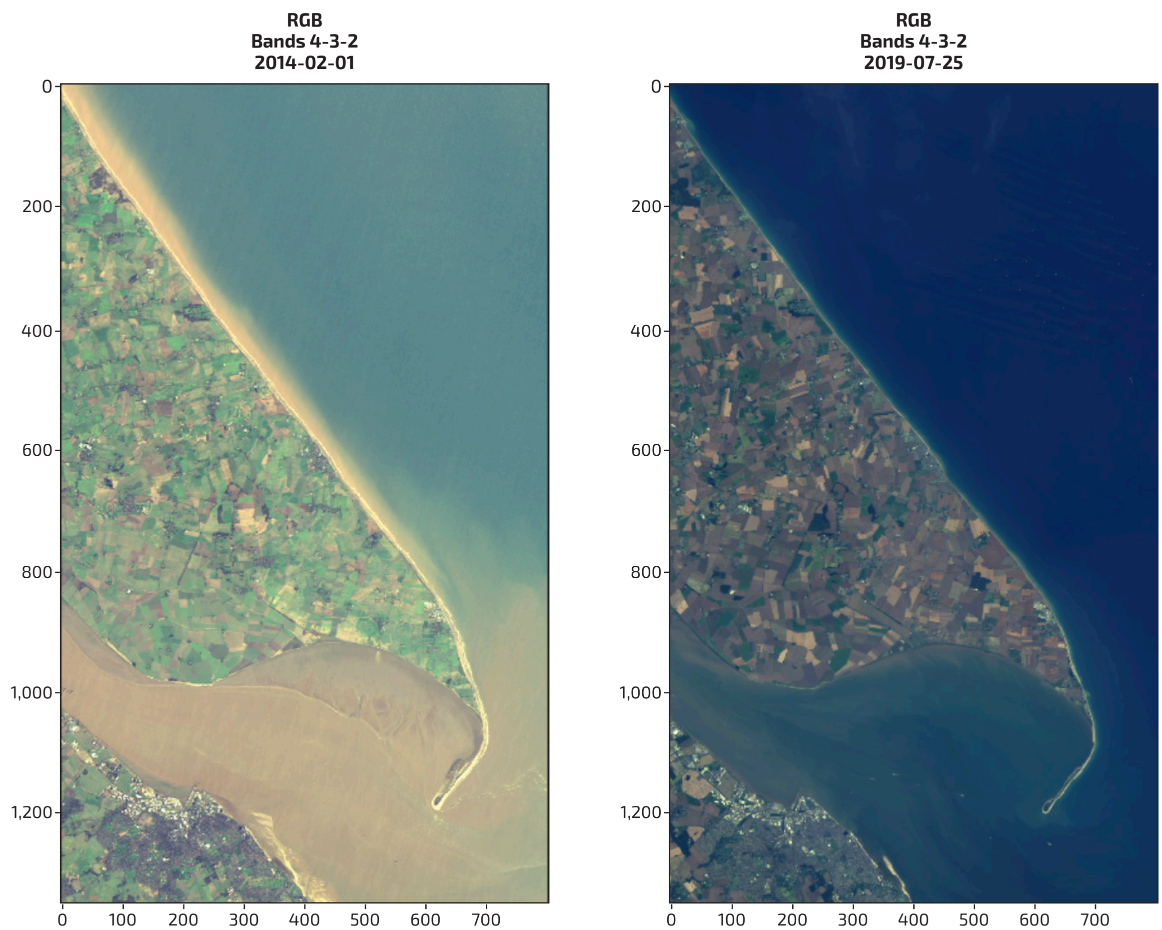


STEP 2

Acquisitions Subsetting (Continued)

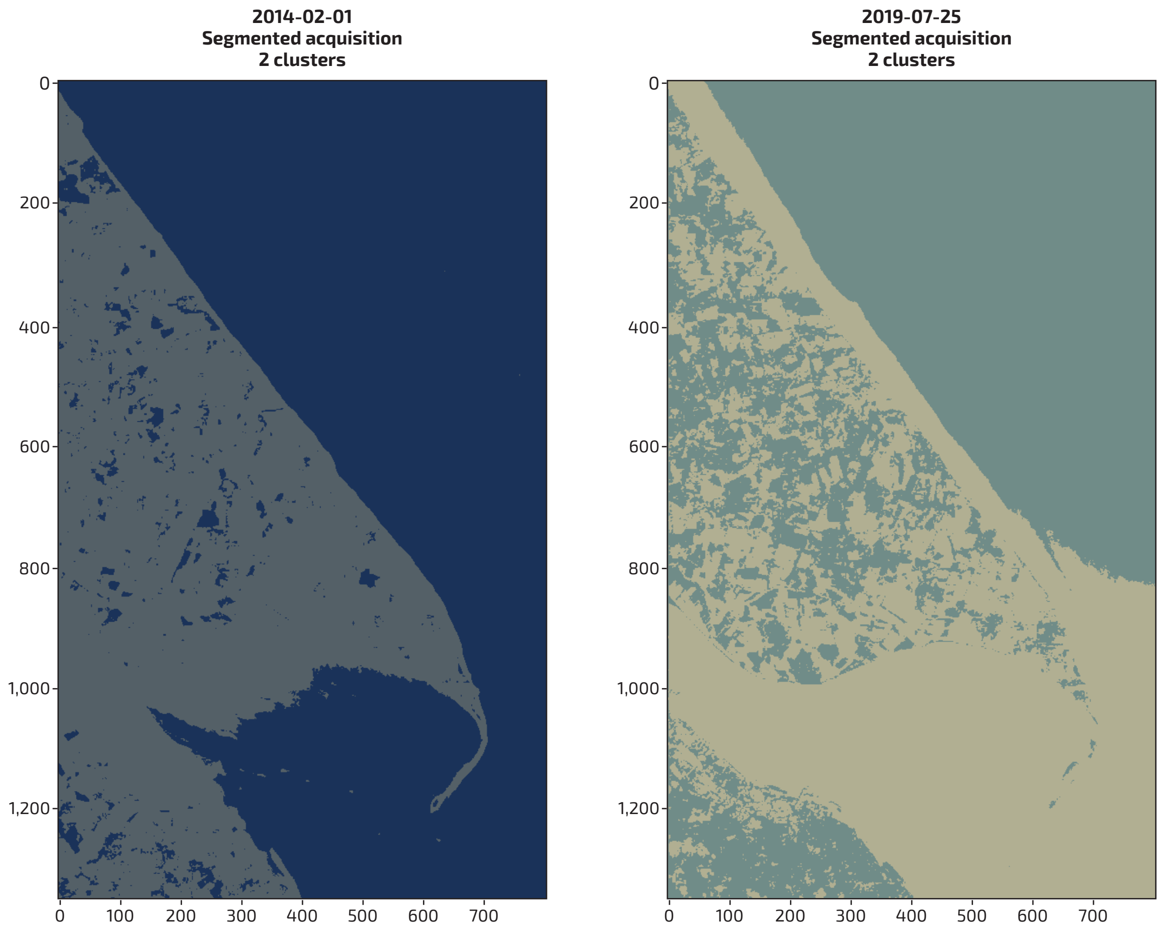


Our result demonstrates that some bands are brighter than others. However, this is not enough, so we then use RGB composite enhancement techniques to obtain bands 4 (Red), 3 (Green) and 2 (Blue). This technique adds color and clarity to our acquisition images.



STEP 3 Image Segmentation with K-means

We sampled the images using the K-means in the RGB space to split the image into two distinct colors. Segmentation is done using the clustering algorithm to discriminate between oceans and land mass. The K-means clustering model identifies and discriminates areas representing emerging land and water bodies.



STEP 4

The Canny Edge Detection Algorithm

This algorithm is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. It was developed by John F. Canny in 1986. The process of the Canny Edge Detection algorithm can be broken down into 5 different steps:

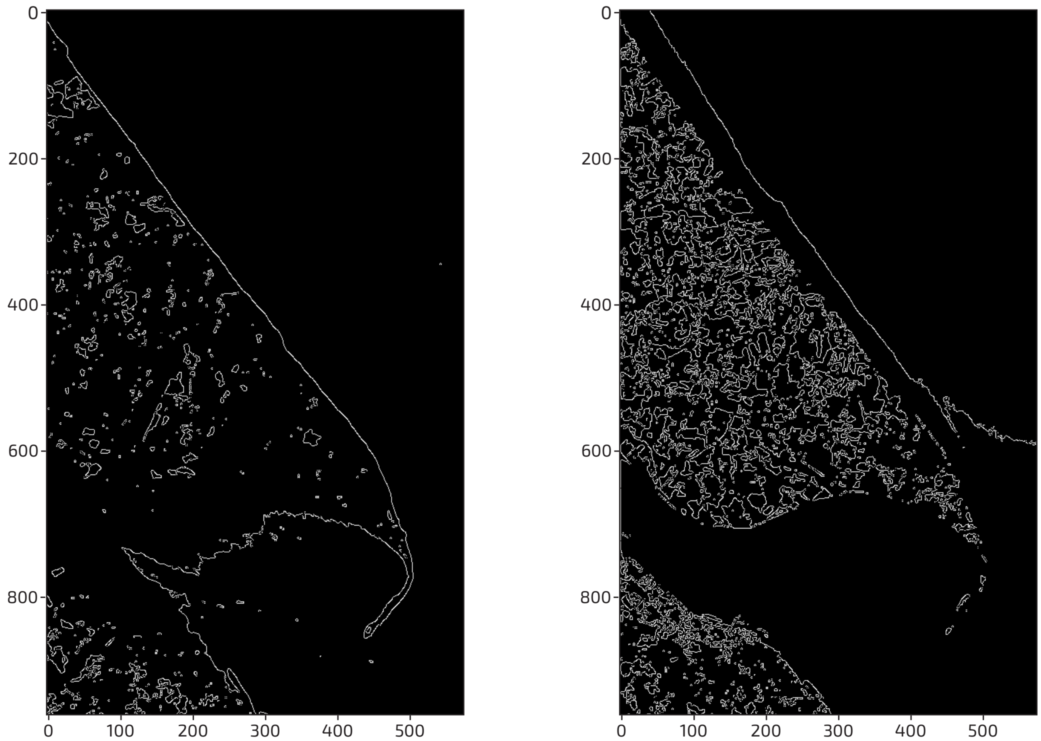
5-Step Canny Edge Detection Algorithm Process

1. Apply the Gaussian filter to smooth the image in order to remove the noise.
2. Find the intensity gradients of the image.
3. Apply non-maximum suppression to get rid of spurious response to edge detection.
4. Apply a double threshold to determine potential edges.
5. Track edges by hysteresis and finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

Comparison of Visual Results

STEP 5

After applying Gaussian smoothing to our segmented images and reducing the noise, we proceed to execution of the real Canny technique with the OpenCV Canny module. This step allows us to obtain the gradient, extract the local maxima and apply the threshold with hysteresis for each acquisition.



Summary of Results: Using artificial intelligence and machine learning (AI/ML), we can streamline satellite imagery analysis to detect coastal changes. Our results yield a visual of the two coasts over time demonstrating changes in the profiles of the coasts through the methodology described above.

NEXT STEPS

- Request a demo of our AI/ML Satellite Imagery Analysis capabilities
- Learn more about our capabilities to enhance NOAA's use of non-NOAA satellite imagery analysis: Contact William Graham to learn about our NOAA NMITS contract vehicle
- Schedule a discussion to hear how we can solve your next data challenge with AI/ML

REFERENCES

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