Monitoring coastal erosion from space: what is feasible and how confident are we on the changes detected?

Andres Payo, PhD, MSc

British Geological Survey

Online lecture for THE CENTRAL SCOTLAND REGIONAL GROUP OF THE GEOLOGICAL SOCIETY

25 February 2021

THIS RESEARCH IS PART OF BGS COASTS & ESTUARIES PROGRAMME

BGS Coasts and Estuaries provides independent and expert geoscientific tools and advice for collaborative decision making to assess different adaptation options for coastal flooding and erosion.

FOCUS OF THIS PRESENTATION

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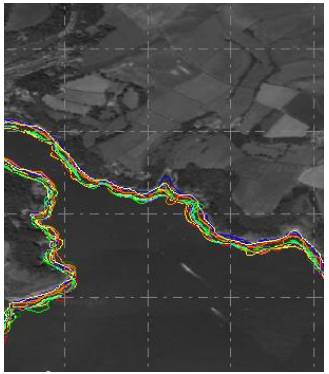
Coastal Change From Space

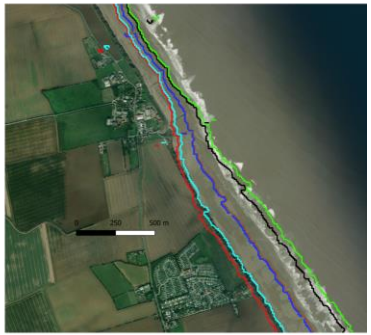
1D Vector

Waterlines OPTICAL

Waterlines SAR



Shorelines



S2 | WL | Spurn Head

S2 | SL | HAT

S2 | SL | MHWS

S2 | SL | MSL

S2 | SL | MLWS

S2 | SL | LAT

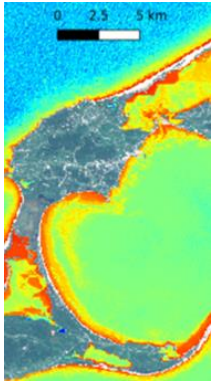
2D Raster

Land cover for backshore classification

Spurn Head
Industrial
Build up type 1
Build up type 2
Crop 1
Crop 2
Crop 3
Crop 4
Crop 5
Crop 6
Forest type 1
Forest type 2
Soft Cliff
SaltMarshes
Sandy Beach
Tidal areas
Sea

3D Raster

Bathy Morpho Terrain Model



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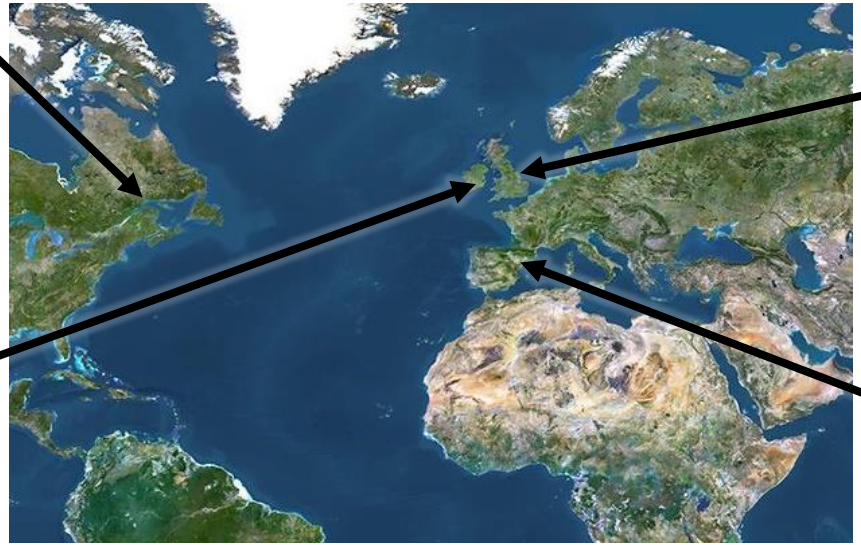
THE TEAM

British Geological Survey

Coastal Change From Space

ARCTUS UQAR



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isardSAT

ARGANS

adwäis EO

DEFINITIONS

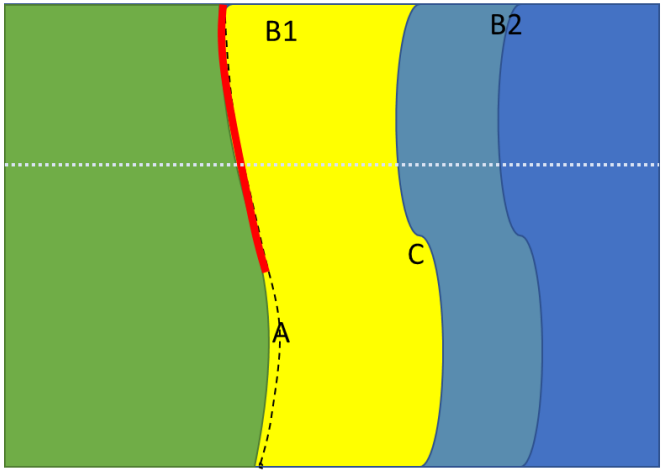
Waterline *– the edge of the sea at a snapshot in time*

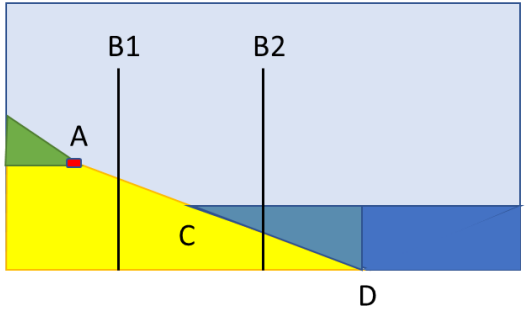
Shoreline *– the prediction of where the tidal waterline would be at a determined time*

Littoral Line *– a highwater line depicting a hard boundary where a fixed object*

Time Series *– a derived product based on a series of different shorelines or waterlines.*

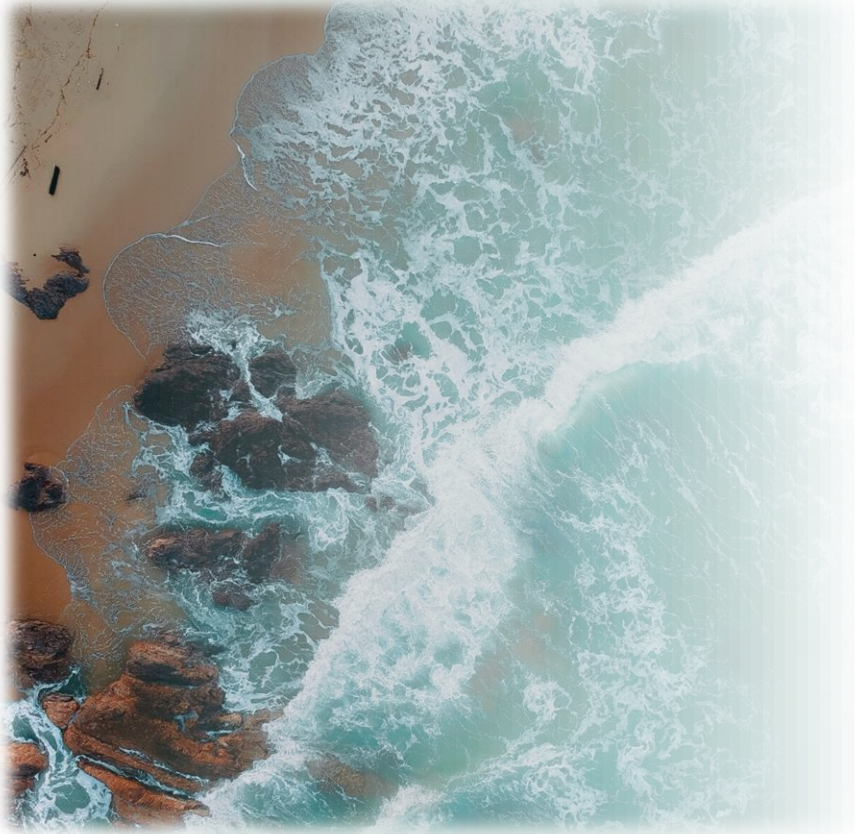
Depth of Closure *– the depth beneath which erosion is not significant*



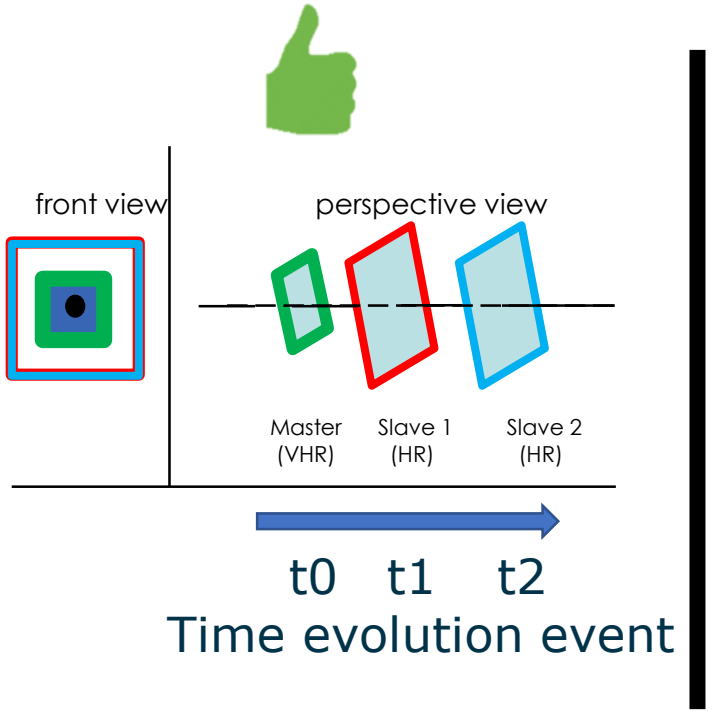


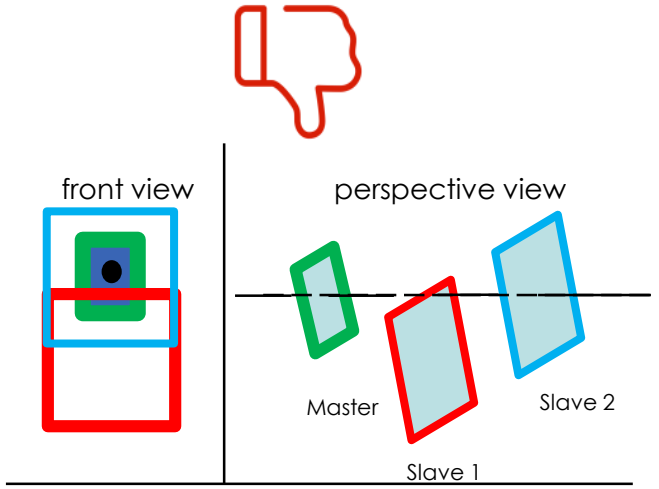
Vegetation
Beach
Nearshore
Offshore
Seawall
Littoral Line
A Shoreline
C Waterline
B1. MHWS
B2. MLWS
D Depth of Closure

OUR PROCESSORS AND PRODUCTS



GEOLOCATION PROCESSOR

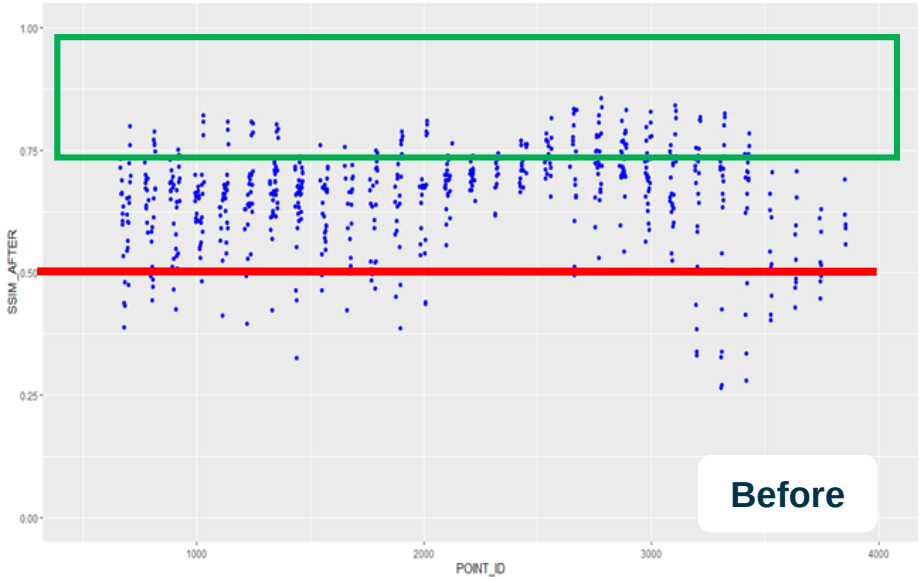


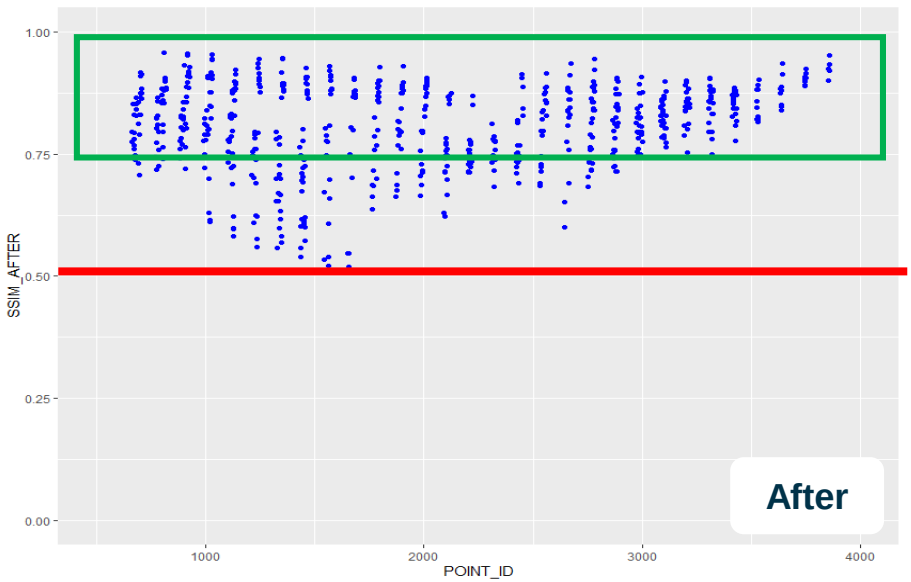


real case (different sensor)

GEOLOCATION PROCESSOR

GEOLOCATION PROCESSOR





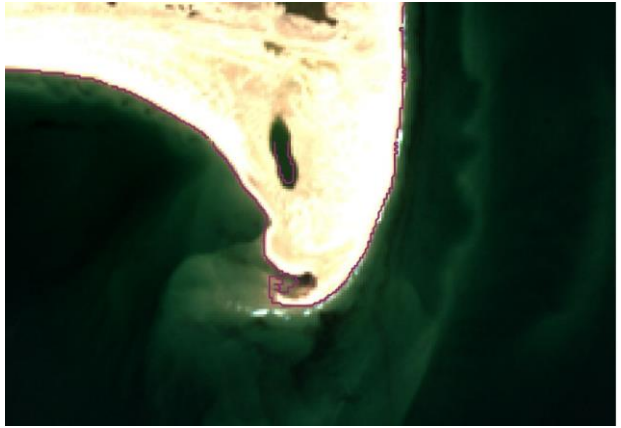
PRODUCTS

Optical Waterlines

PRODUCTS

Optical Waterlines

29 May
2016

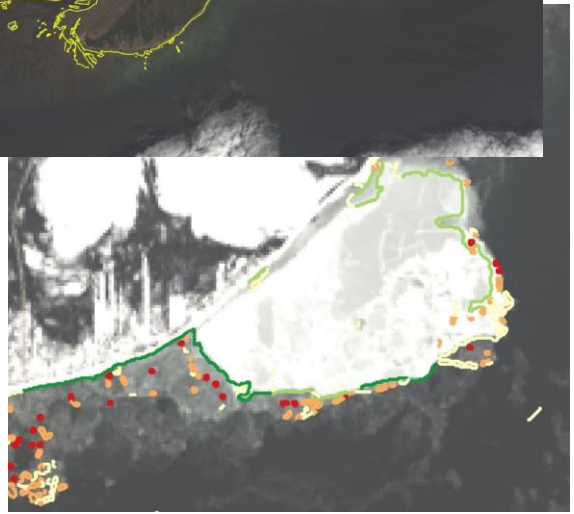


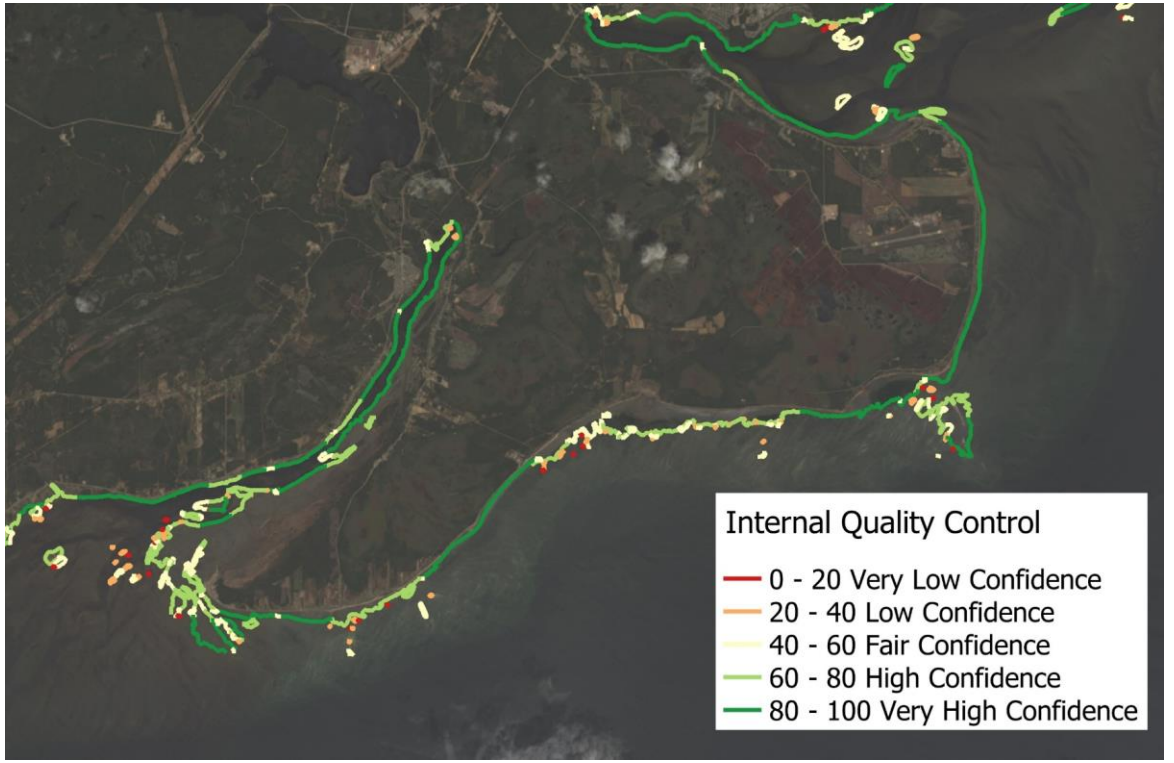
30 July
2017

14 August
2018

PRODUCTS

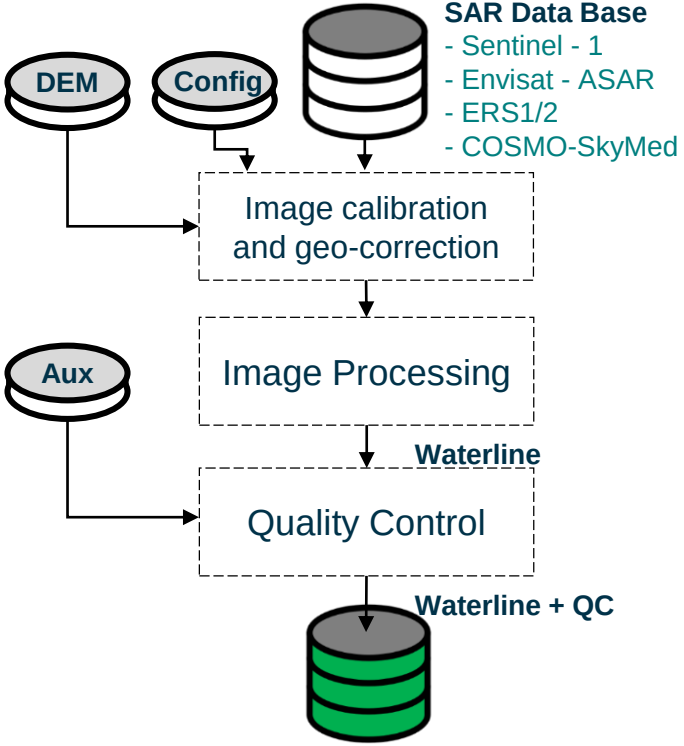
Optical Waterlines

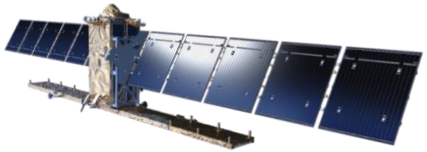


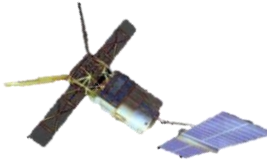


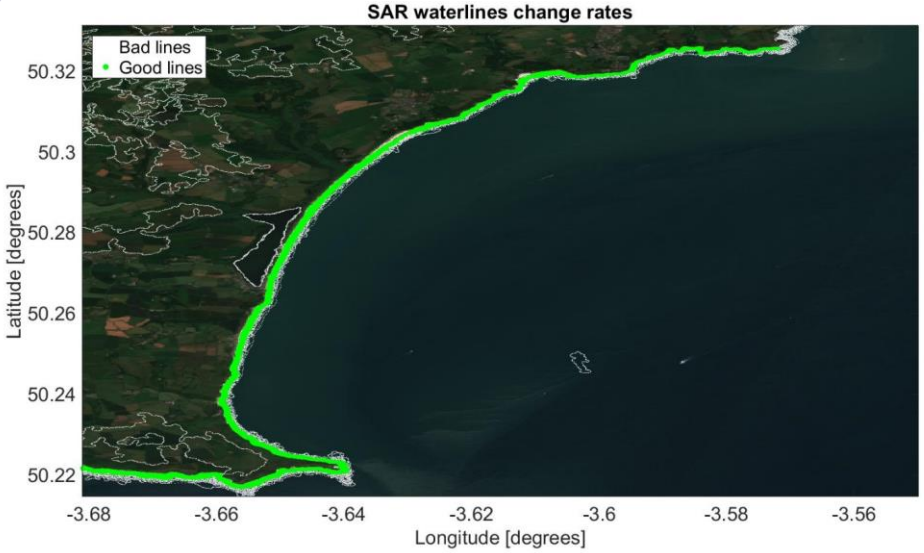
PRODUCTS

SAR Waterlines



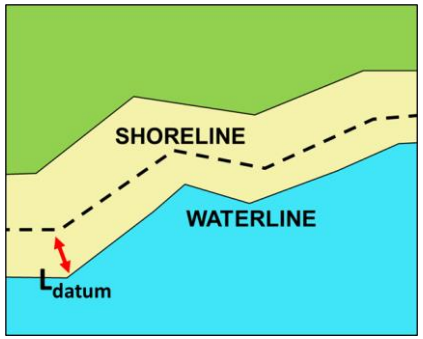


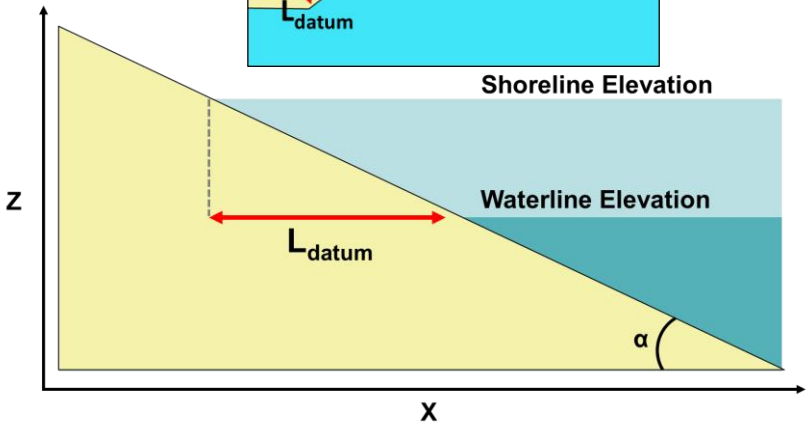


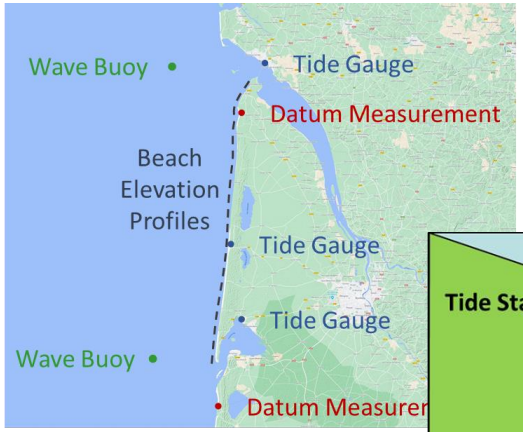


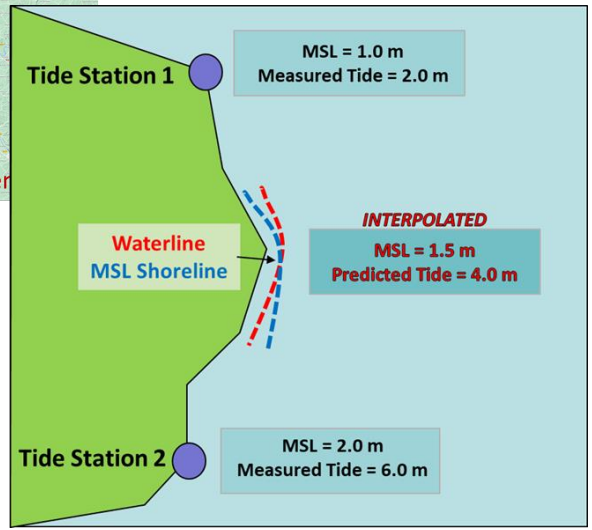
PRODUCTS

Shorelines





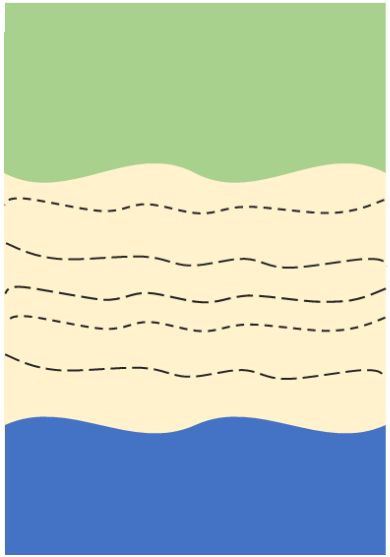




PRODUCTS

Shorelines

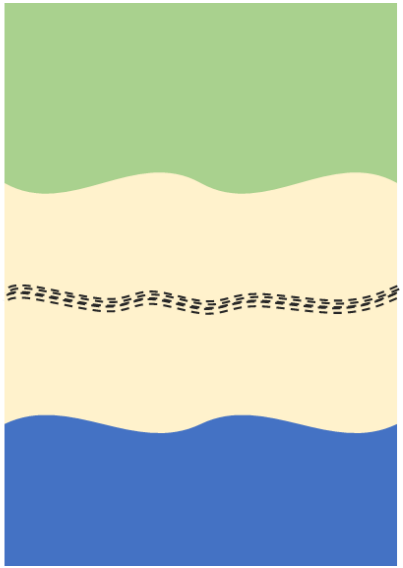
Instantaneous
Waterline

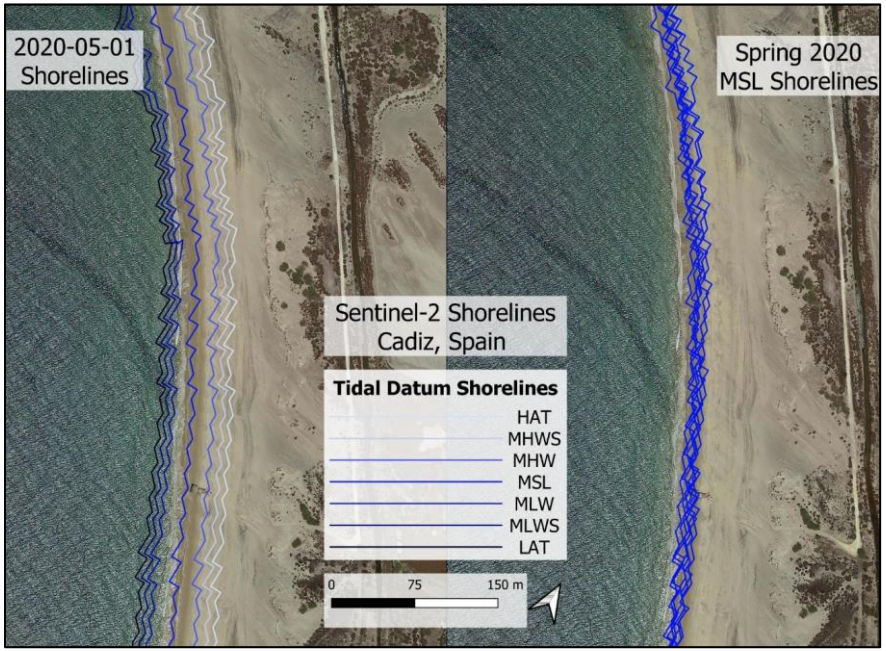


SHORELINE

PROCESSOR

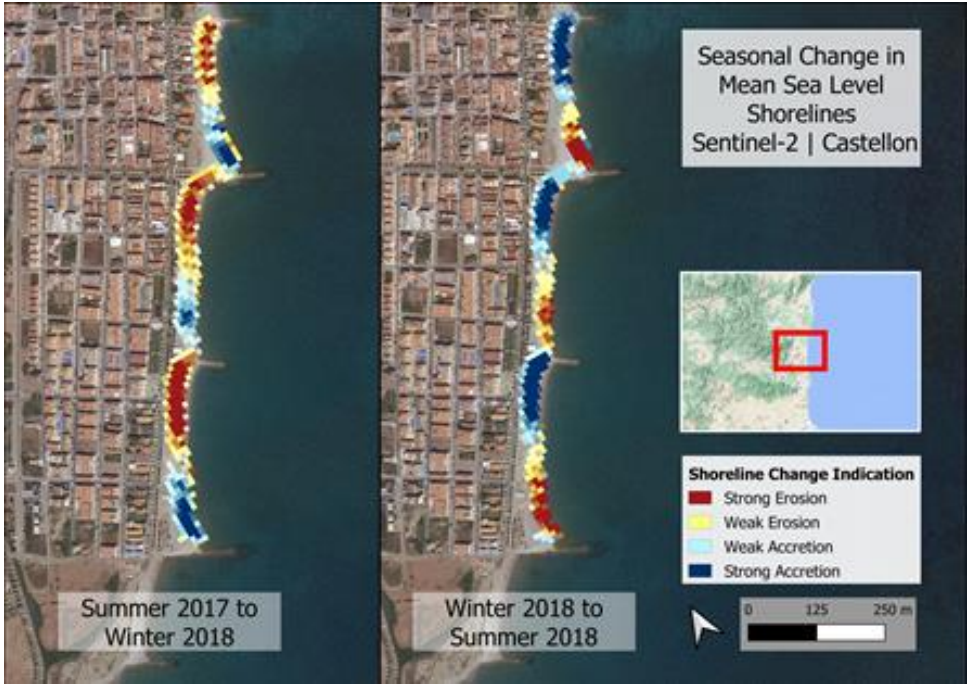
MSL Shorelines





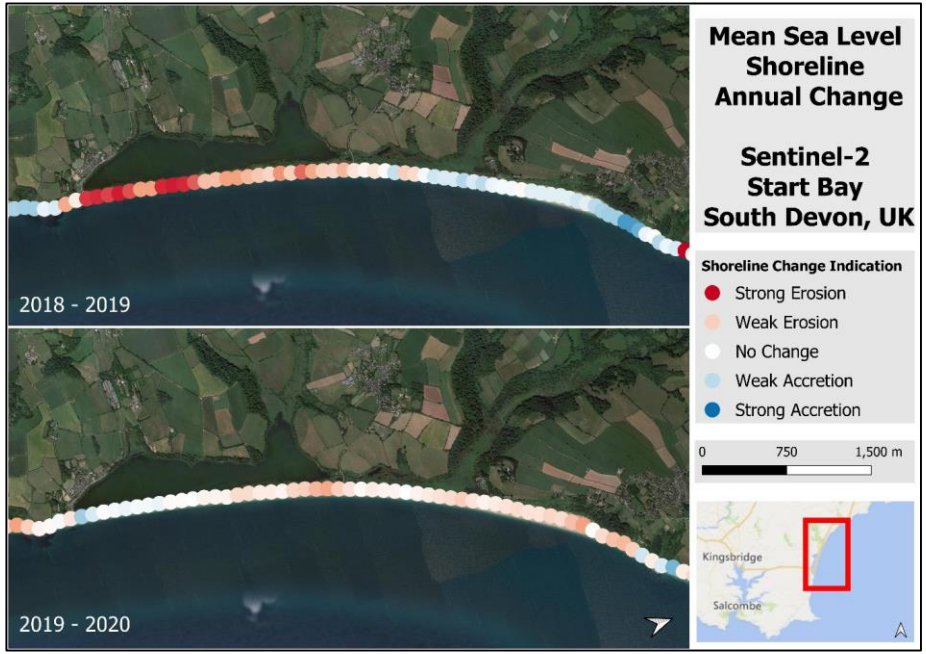
PRODUCTS

Shorelines



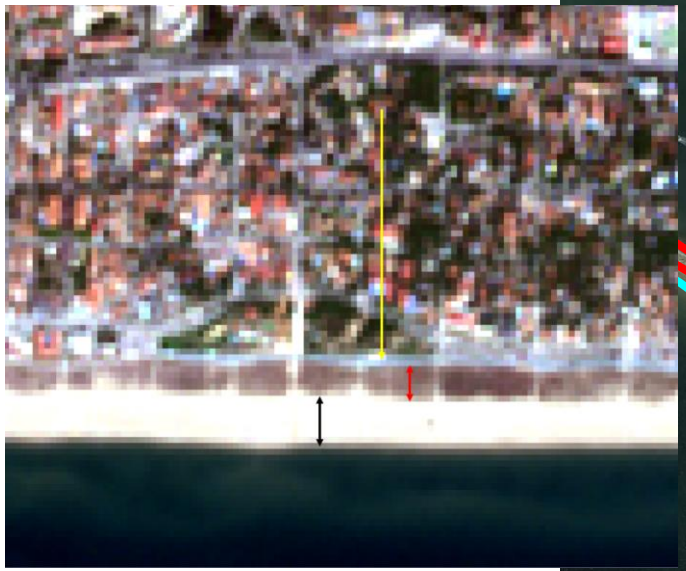
PRODUCTS

Shorelines



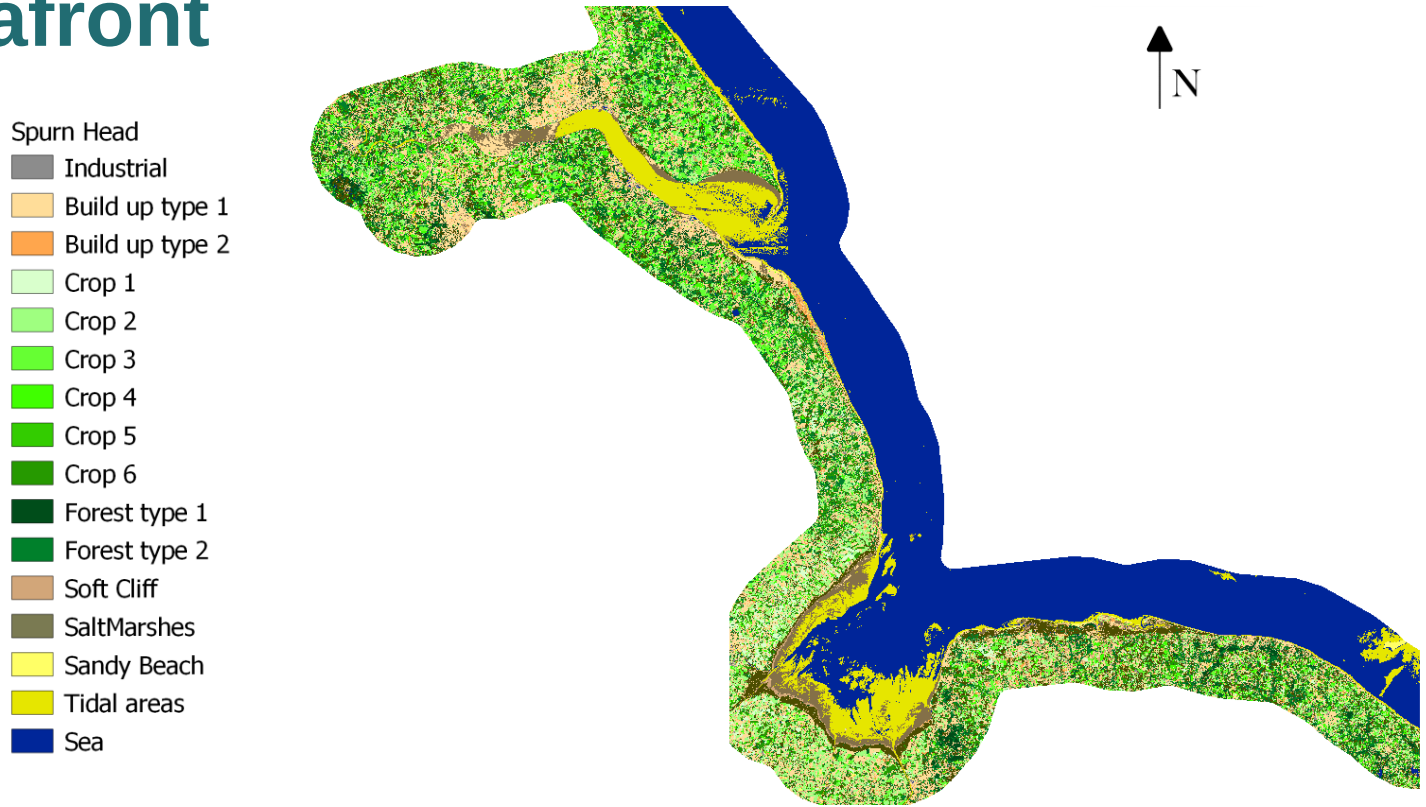
PRODUCTS

Seafront



PRODUCTS

Seafront

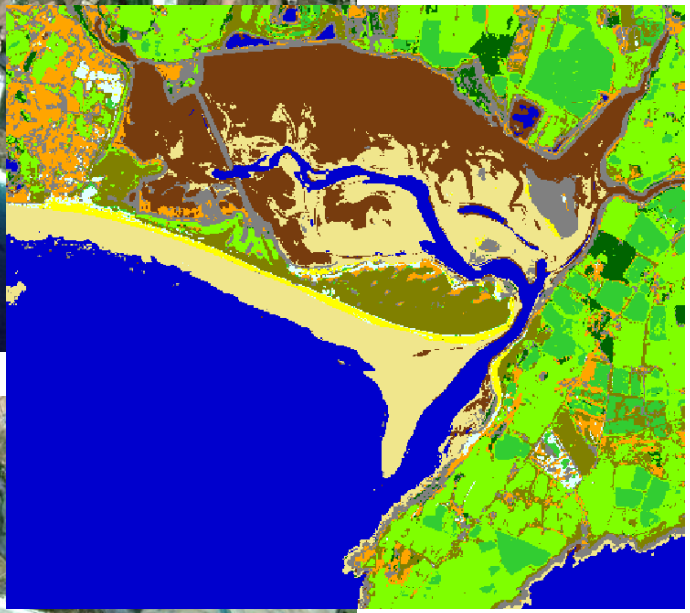


PRODUCTS

Seafront

PRODUCTS

Seafront

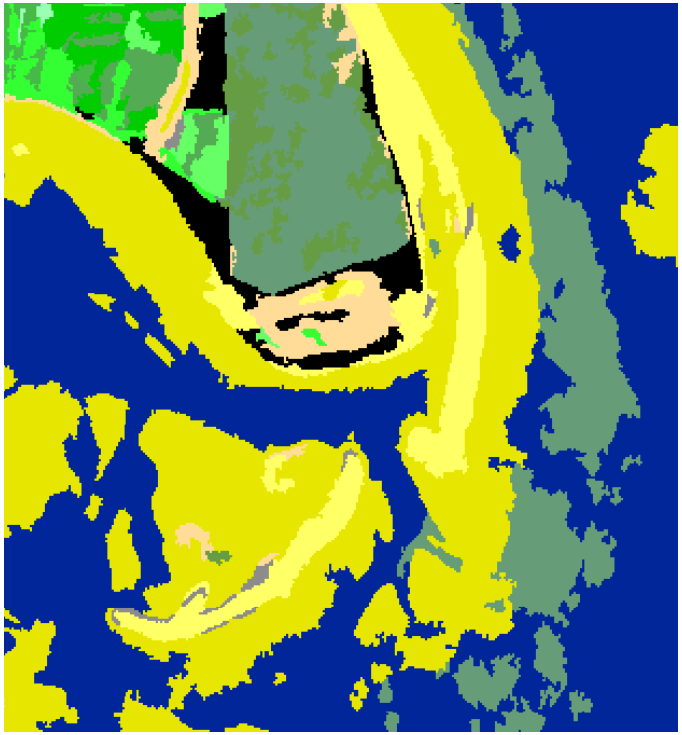


PRODUCTS

Seafront

2017

2019



PRODUCTS

Seafront

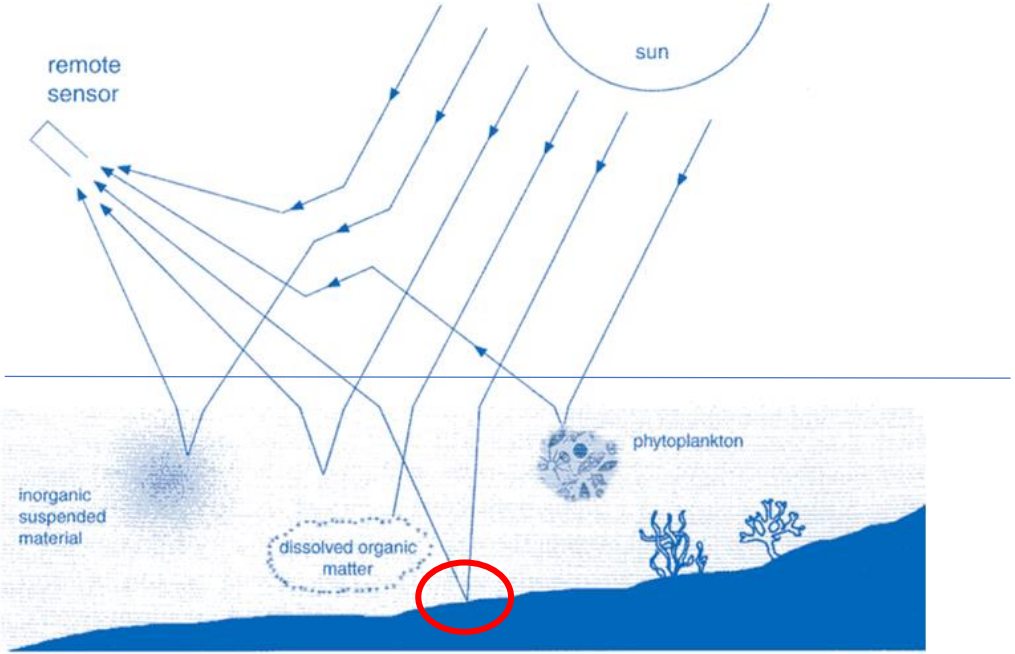
2017

2019

PRODUCTS

Bathy-Morpho Terrain Models

Estimation of ocean morphology using multispectral sensors



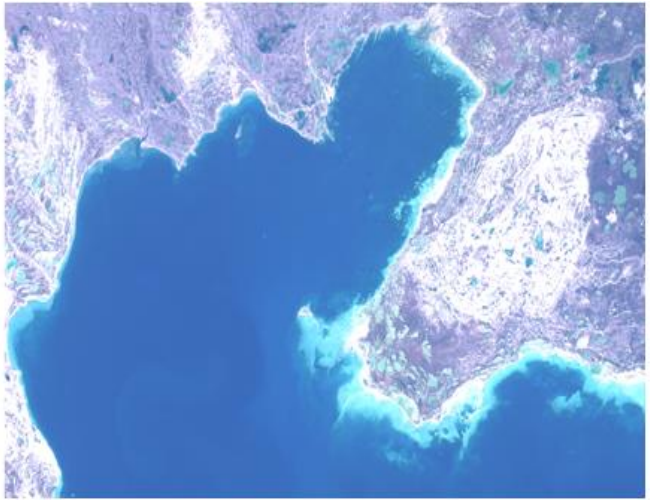
What we want :

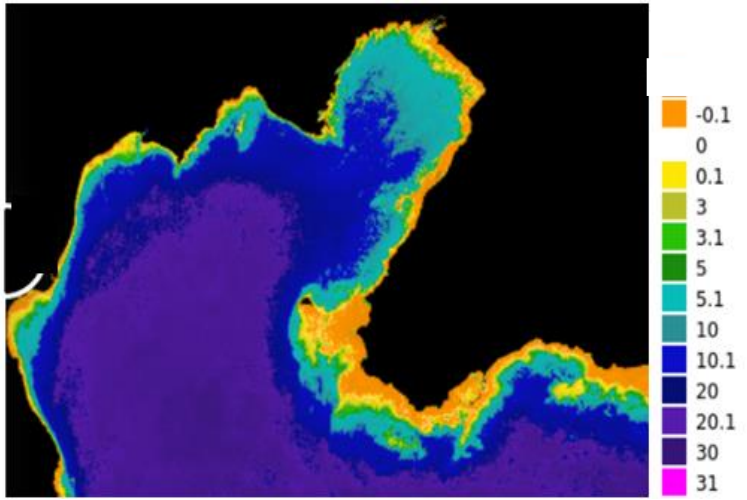
PRODUCTS

Bathy-Morpho Terrain Models

- Physics-based model, Method of Hedley et al., 2009
- Different method from Satellite Derived Bathymetry

Coral Harbour, Canada



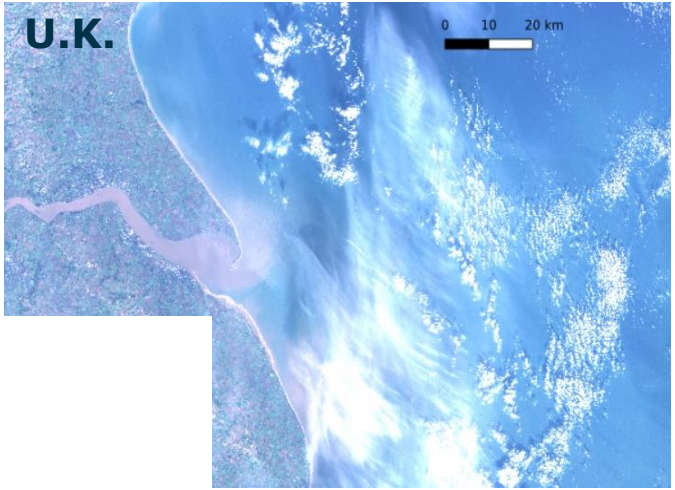


Coral Harbour SDB

Bathy-Morpho Terrain Models

1. Pre-Selection of images

One good single image – One Bathy-Morpho Terrain Model



Sediments and Clouds

Sediments and Glint

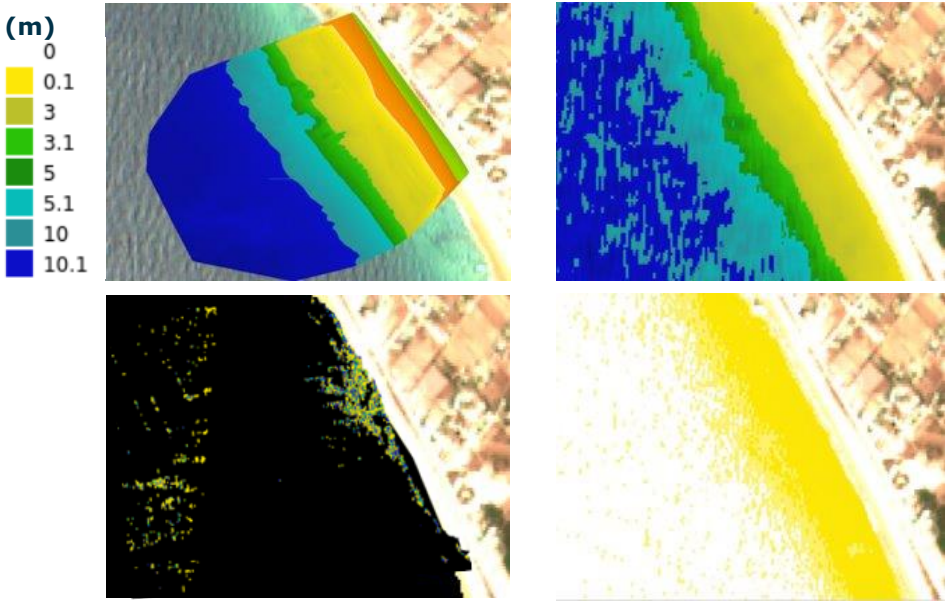
Ice

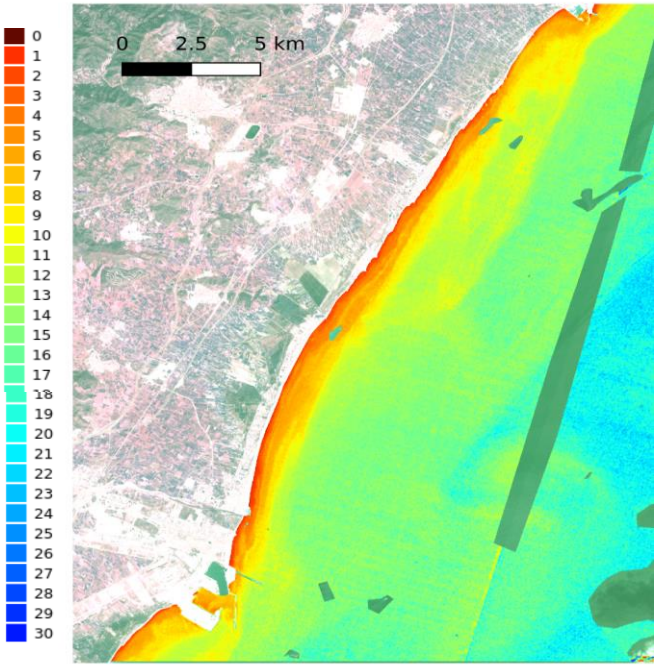
...and others

PRODUCTS

Bathy-Morpho Terrain Models

2. Atmospheric correction



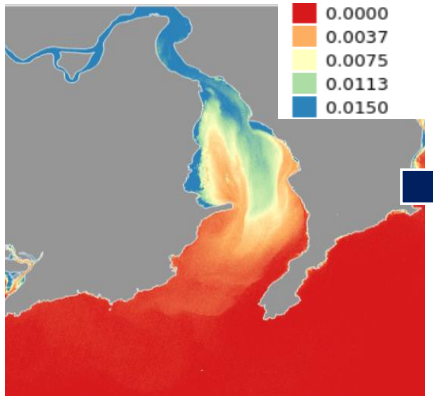


Cádiz, Spain

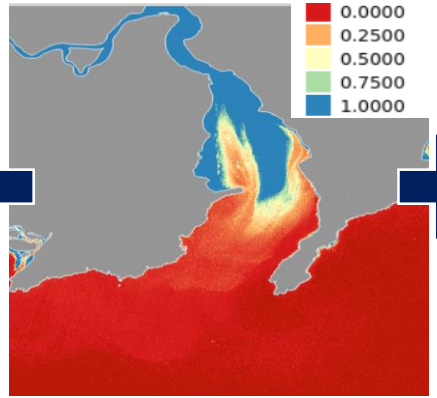
PRODUCTS

Bathy-Morpho Terrain Models

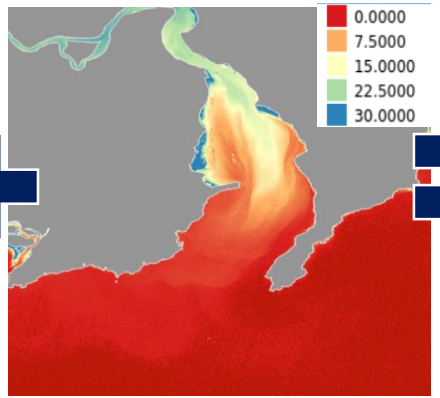
Reflectance



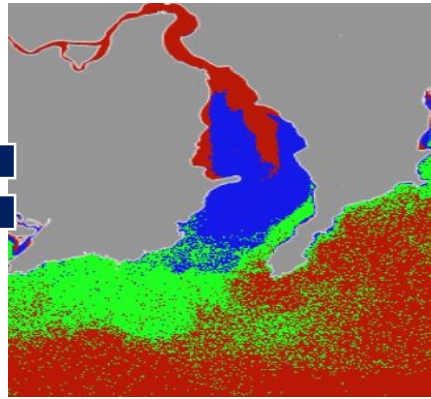
Coloured disolved organic matter



Suspended particulate matter



Confidence maps



Good

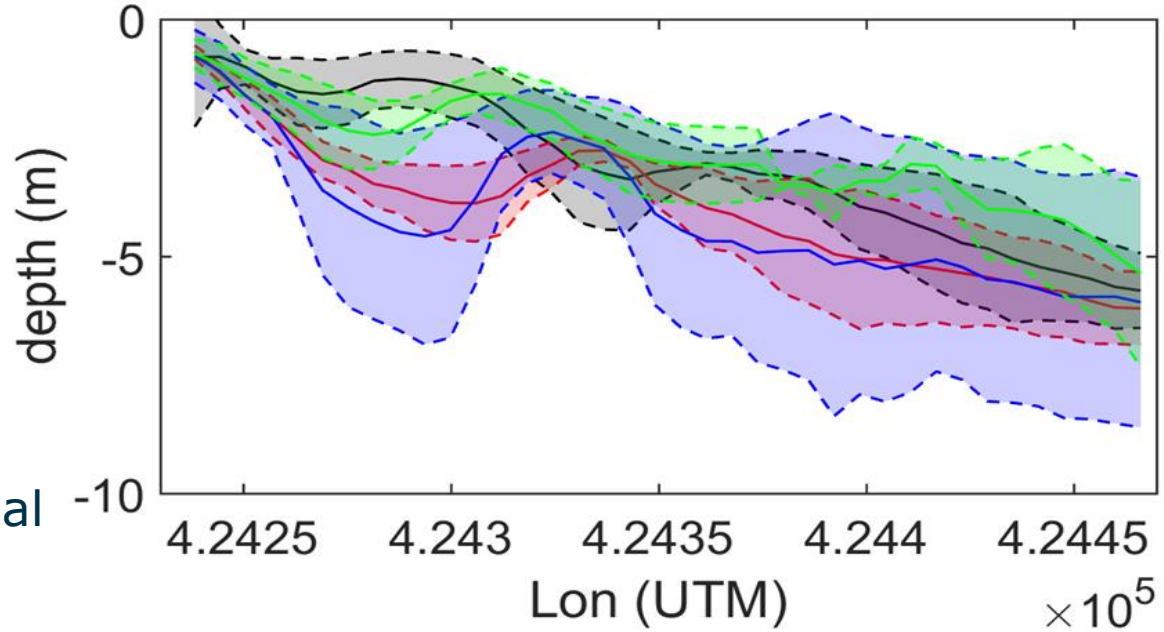
Intermediate

Bad

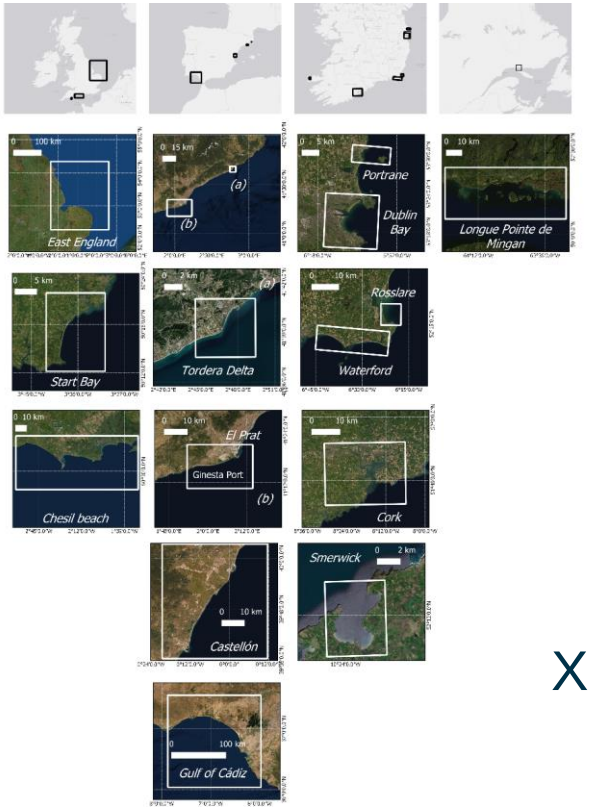
PRODUCTS

Bathy-Morpho Terrain Models

Potential time series analysis for the annual evolution 2016-2019



END USERS PRODUCT VALIDATION



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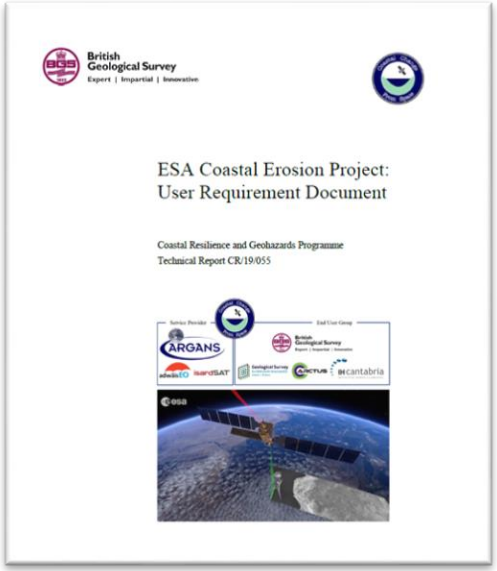
ARCTUS

x 4 products

1D x 2 | 2D | 3D

USER'S NEEDS DRIVEN PROJECT

What are the end users requirements?


British Geological Survey
Expert | Impartial | Innovative

ESA Coastal Erosion Project:
User Requirement Document

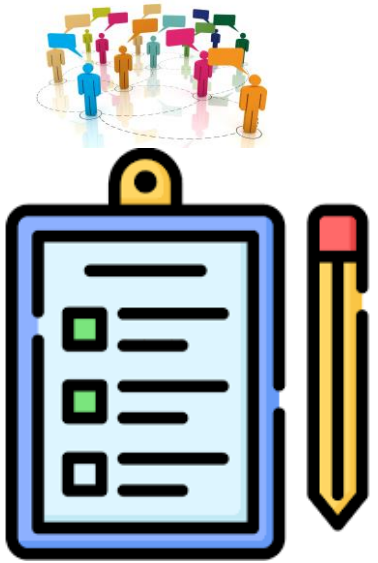
Coastal Resilience and Geohazards Programme
Technical Report CR/19/055

Full URD consolidated version (122 pp)
User Requirement Document_v2.pdf

PDF

Summary of URD & Feasibility study (10 pp)
Payo_et_al_ICE_2019_LaRochelle.pdf

Slides presented at ICE 2019



Broader end user community inputs

END USERS OVERARCHING & SPECI USER'S NEEDS

"*Any policy for coastal erosion should increase coastal resilience by restoring the sediment balance and providing space for coastal processes*"
(EUROSION, 2004)

\+ f(Country, site specific, End-User Type)

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ARCTUS

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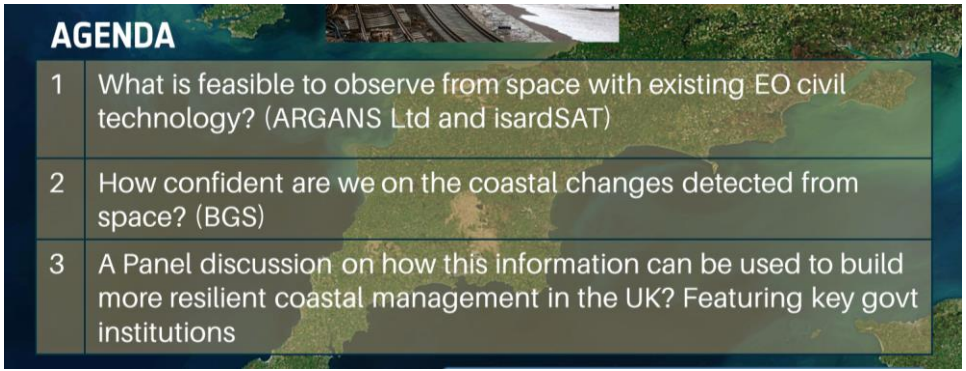
10th December 2020, recorded sessions here

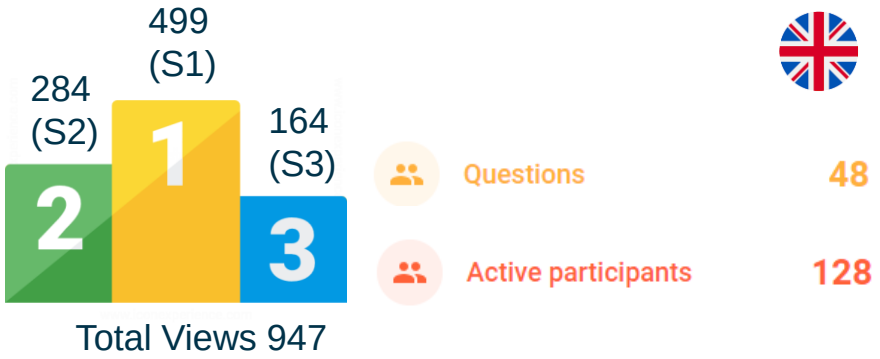
30th Nov, 14th December 2020, recorded sessions here

17th November 2020, recorded sessions here

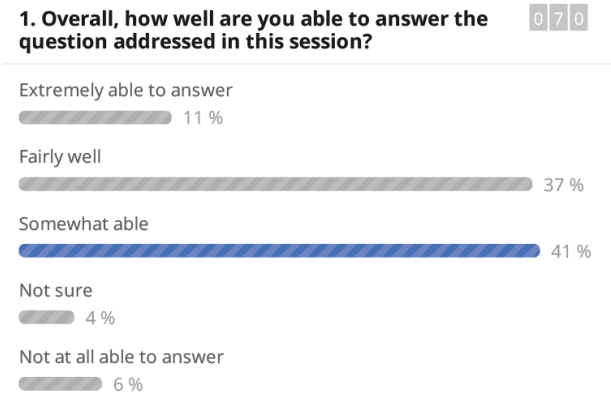
7th Dec 2020 recorded sessions here

https://bgscoastalerosion.siteonsite.es/





Before



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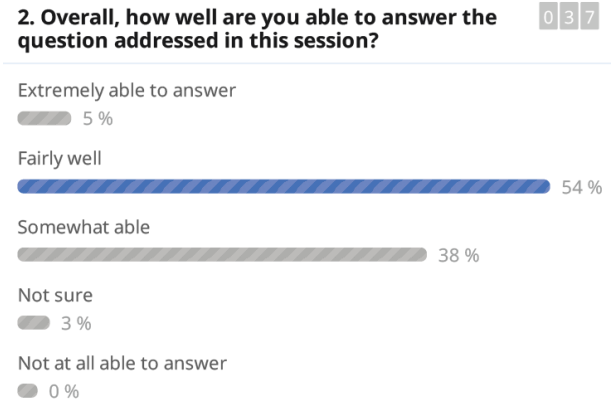
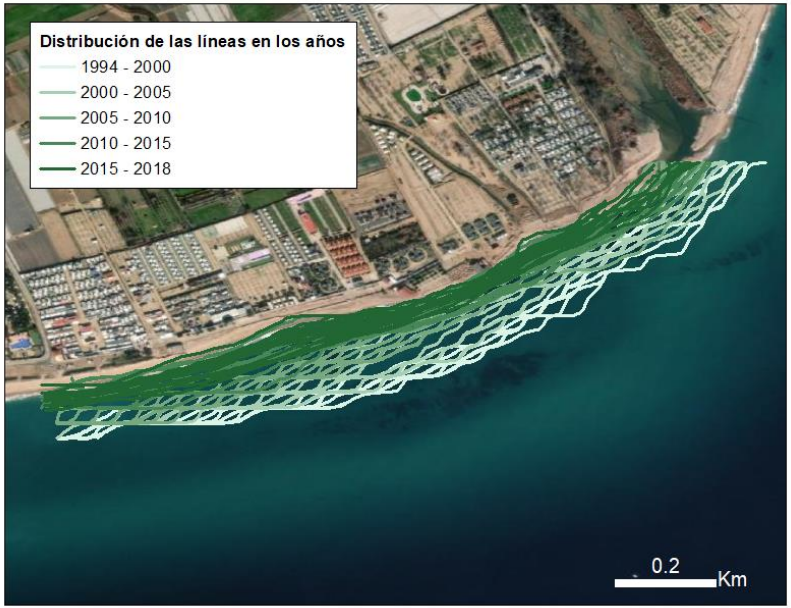
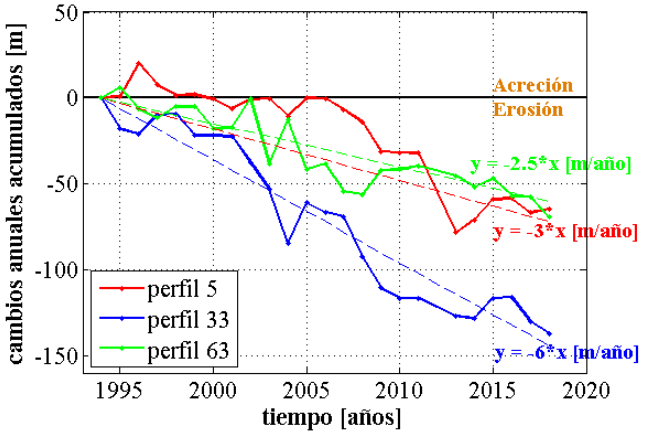


Change over 25 years using SL | OPT

Process: **long-term shoreline evolution in Tordera**

184 shorelines (1994 a 2018 – 24 years)



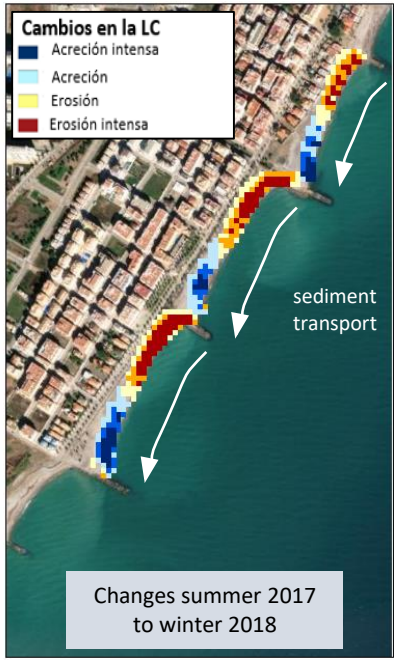


Source	Average erosion
Satellite	4.79 m/year
Aerial photogrametry	4.68 m/year

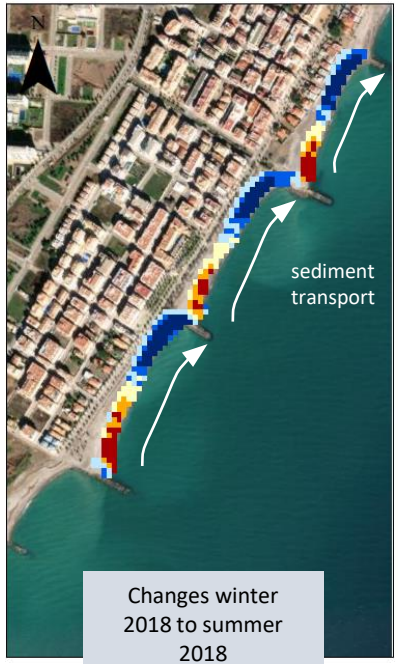
SL OPT able to detect seasonal change

Process: **seasonal beach rotation in Castellón**

Analysis of Sentinel 2 shorelines:
Seasonal cheanges and beach rotation



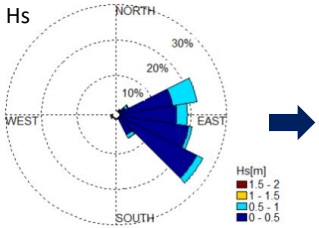
Changes summer 2017 to winter 2018



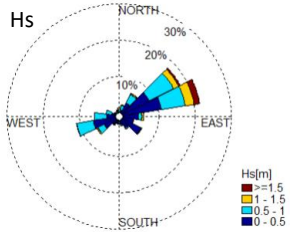
Changes winter 2018 to summer 2018

0.15 Km

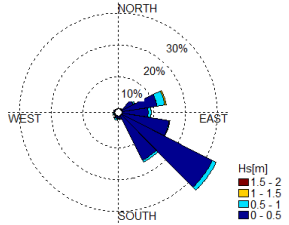
Summer 2017



Winter 2018



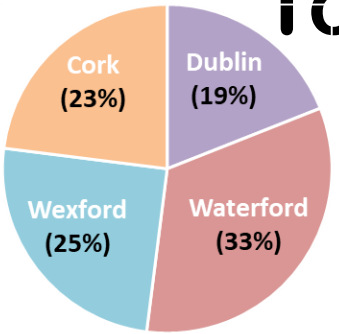
Summer 2018



We are still validating large SL archive produced

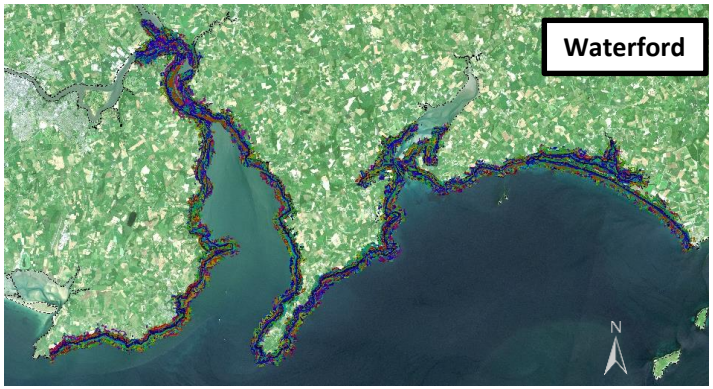
British Geological Survey

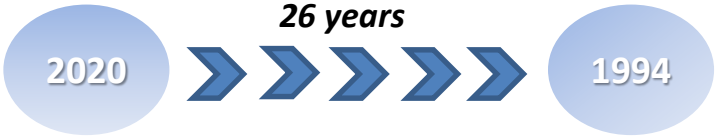
Total number of shorelines OPT

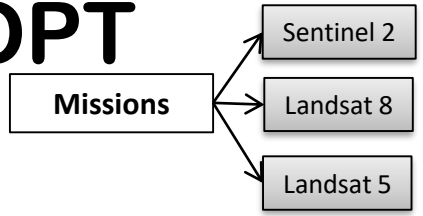


1760

Products





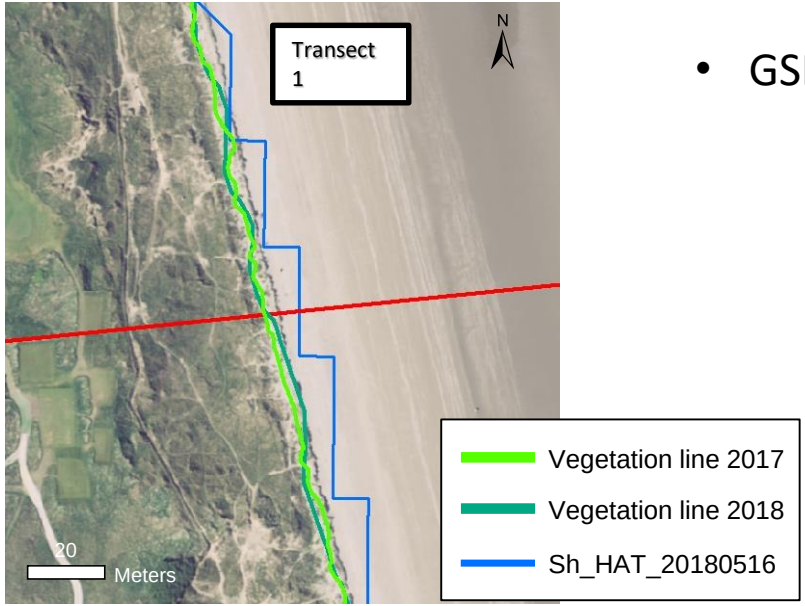


We use different ground truth data bases

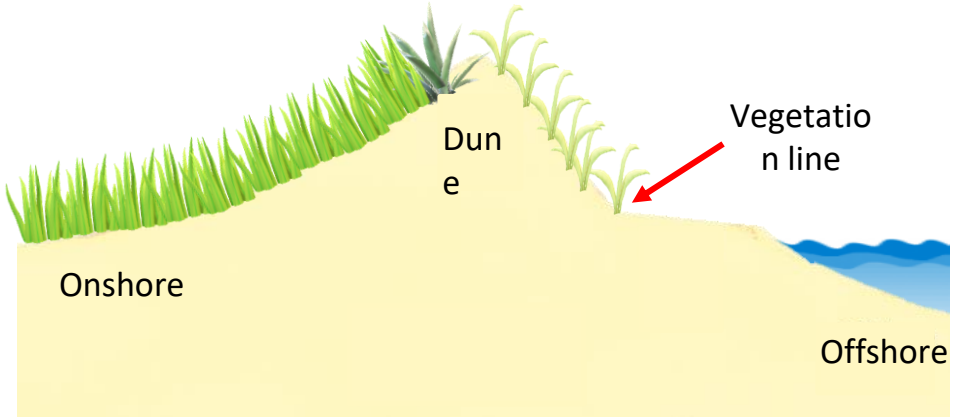
British Geological Survey

Coastal Change From Space

Shoreline validation vs Vegetation lines



- GSI Vegetation line series from 1995 to 2020



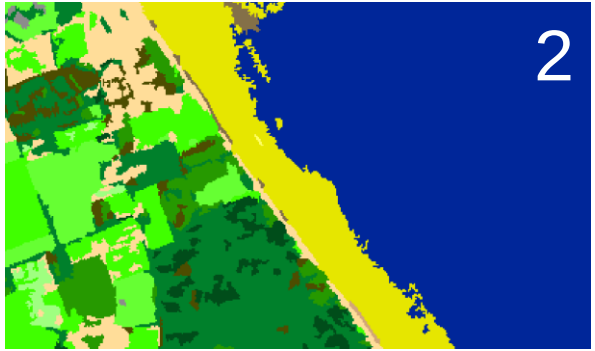
Littoral lines & backshore maps

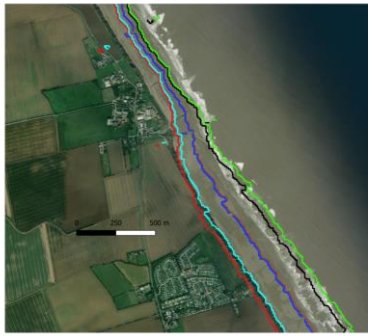
British Geological Survey

Coastal Change From Space

2D backshore maps are used to delineate the littoral line which helps the QA of WL to SL transformations

Properties at risk at Aldborough, East, England.





S2 | WL | Spurn Head

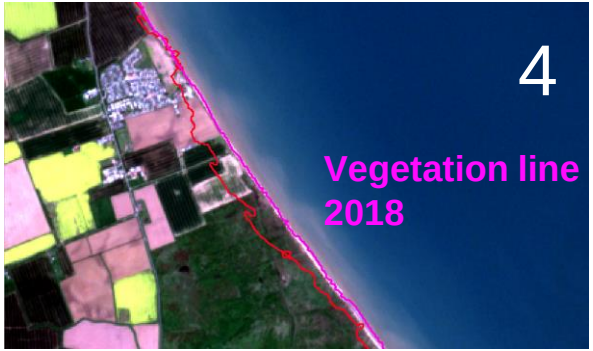
S2 | SL | HAT

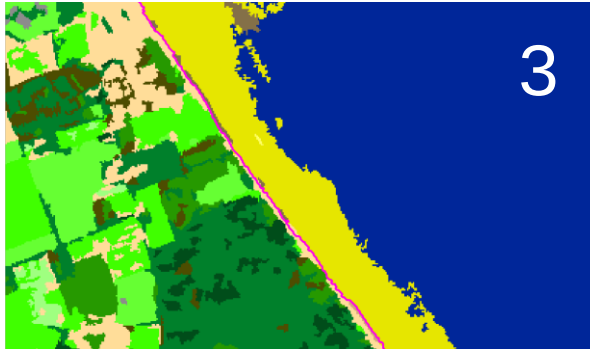
S2 | SL | MHWS

S2 | SL | MSL

S2 | SL | MLWS

S2 | SL | LAT





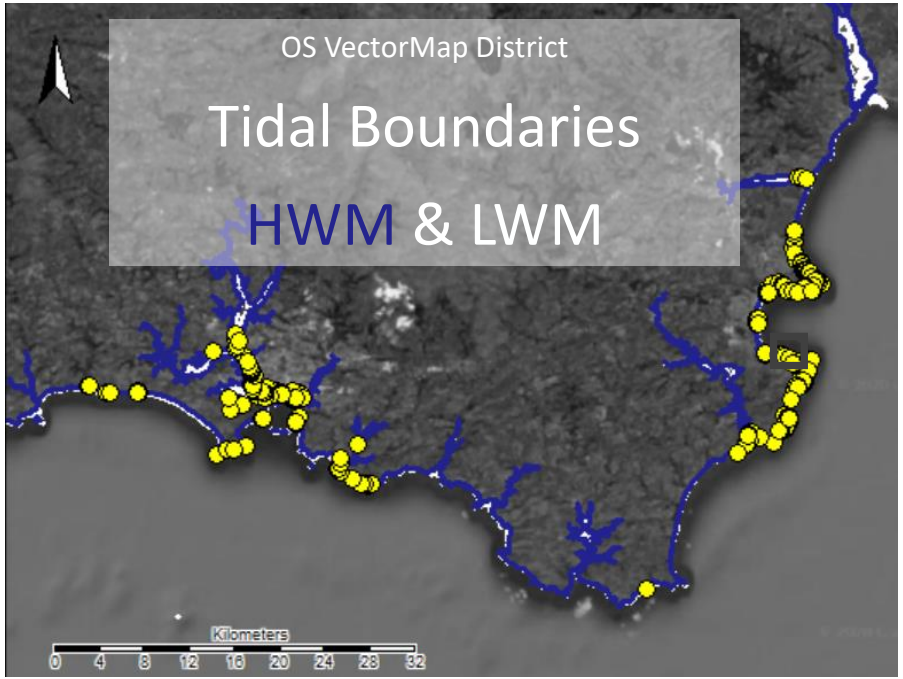
Old missions still require visual QA

Start Bay Area – OS data vs Landsat 8 WL 2016 - 2020

- OS HWM
- OS LWM
- Waterline is generally between the HWM and LWM.
  - Boats mapped as land
  - Pier /harbour breakwater = wider than it is

New methods developed for accuracy assessment

As no standard method exist to assess absolute accuracy of waterlines we have chosen points with no foreshore

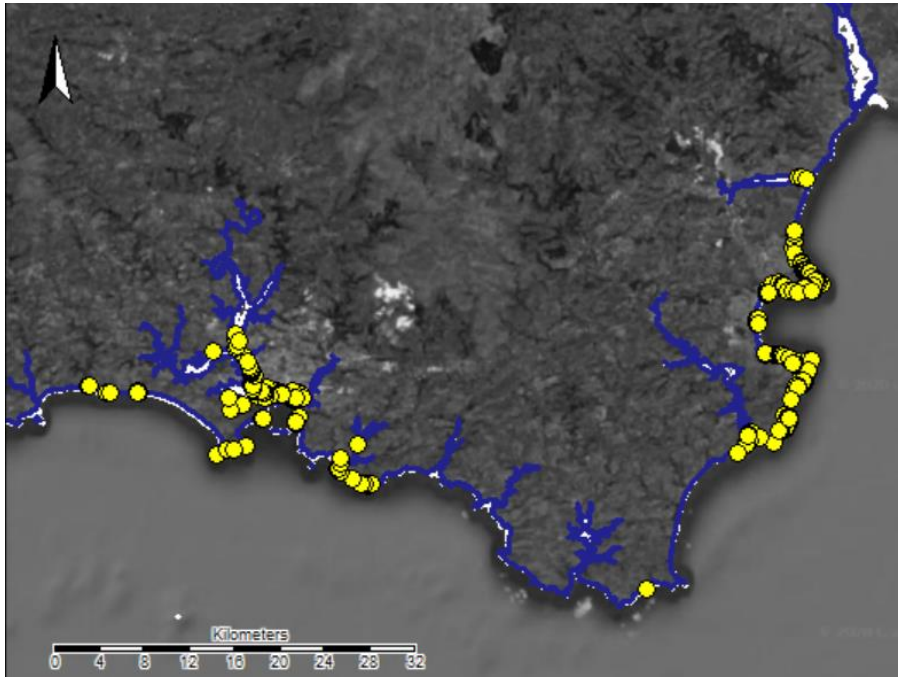


Accuracy

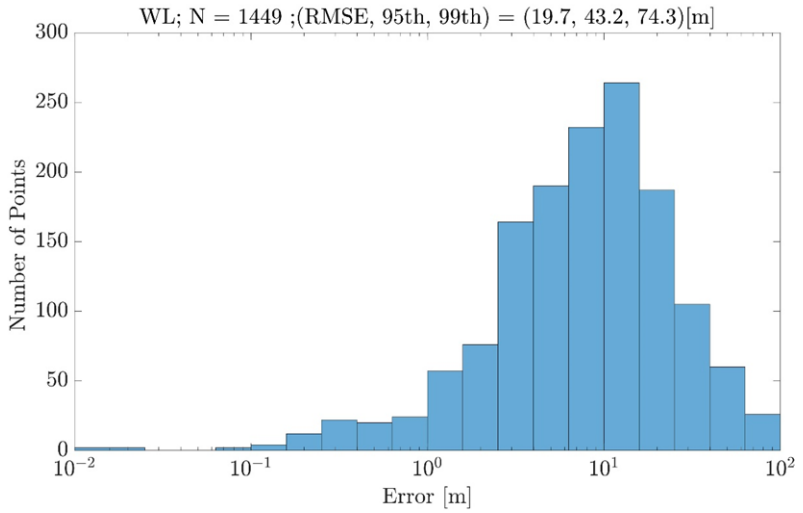
absolute, relative, geometric fidelity

New methods developed for accuracy assessment

As no standard method exist to assess absolute accuracy of waterlines we have chosen points with no foreshore



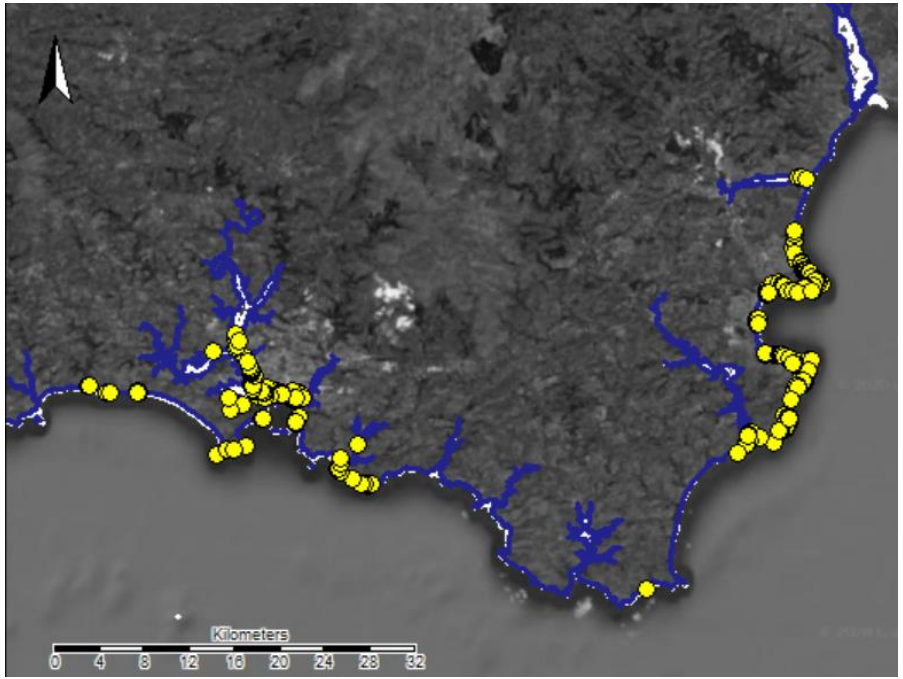
Absolute accuracy



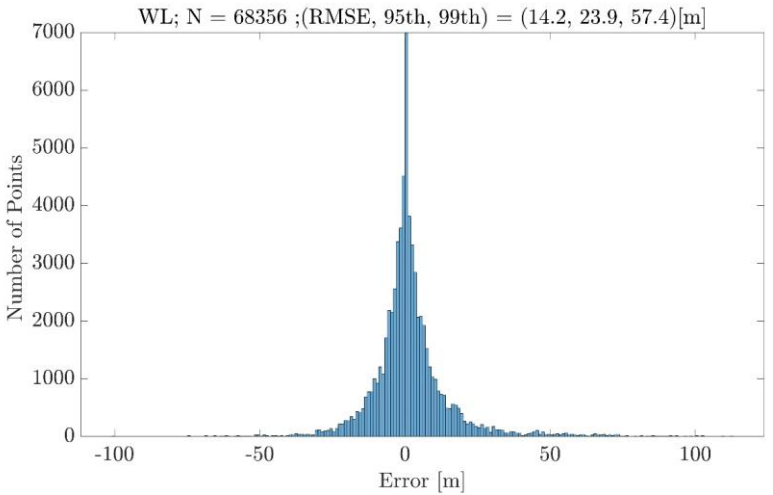
S2 | Start Bay | 2019-10-02

New methods developed for accuracy assessment

As no standard method exist to assess absolute accuracy of waterlines we have chosen points with no foreshore

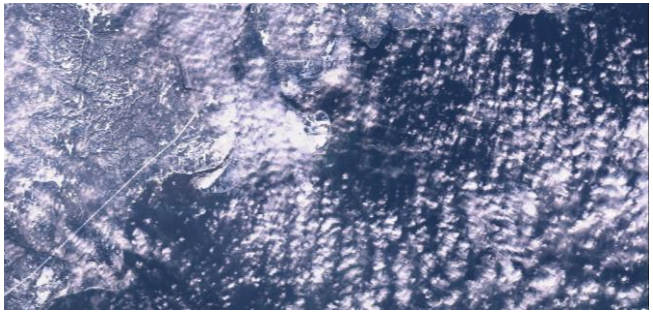


Relative accuracy



S2 | Start Bay | 2019-10-02

OPT WL extracted even in cloudy regions



Iles de la Madeleine:
122 Water lines
183 km

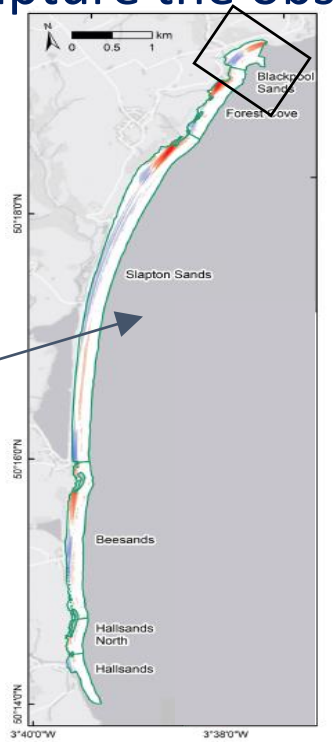
Mingan:
216 Water lines
112 kms

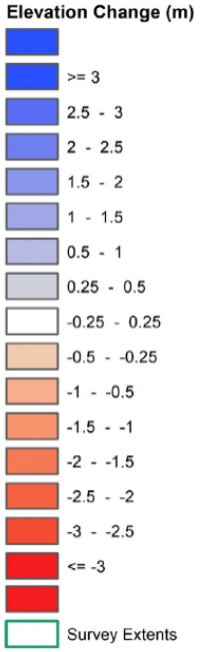
Manicouagan:
233 Water lines
163 kms

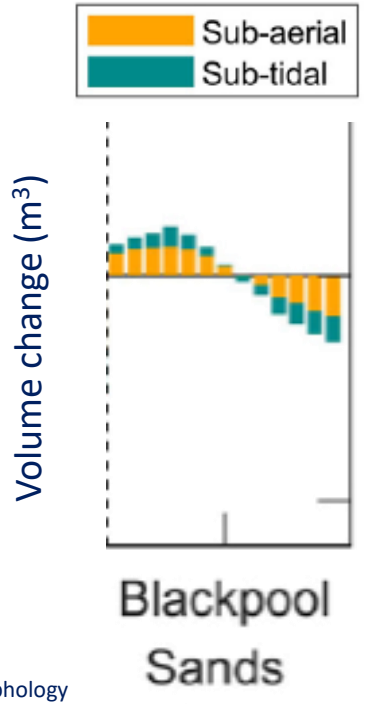
SAR is transparent to clouds so more WL can be extracted

Are SAR waterlines able to capture the observed beach rotation?

Slapton line Road damaged in 2018 causing local traffic disruption.







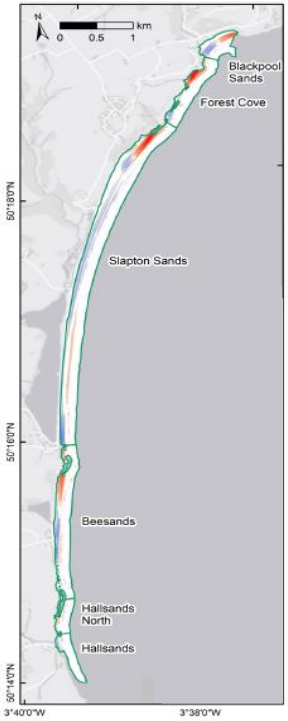
Wiggins et al. (2019) Geomorphology

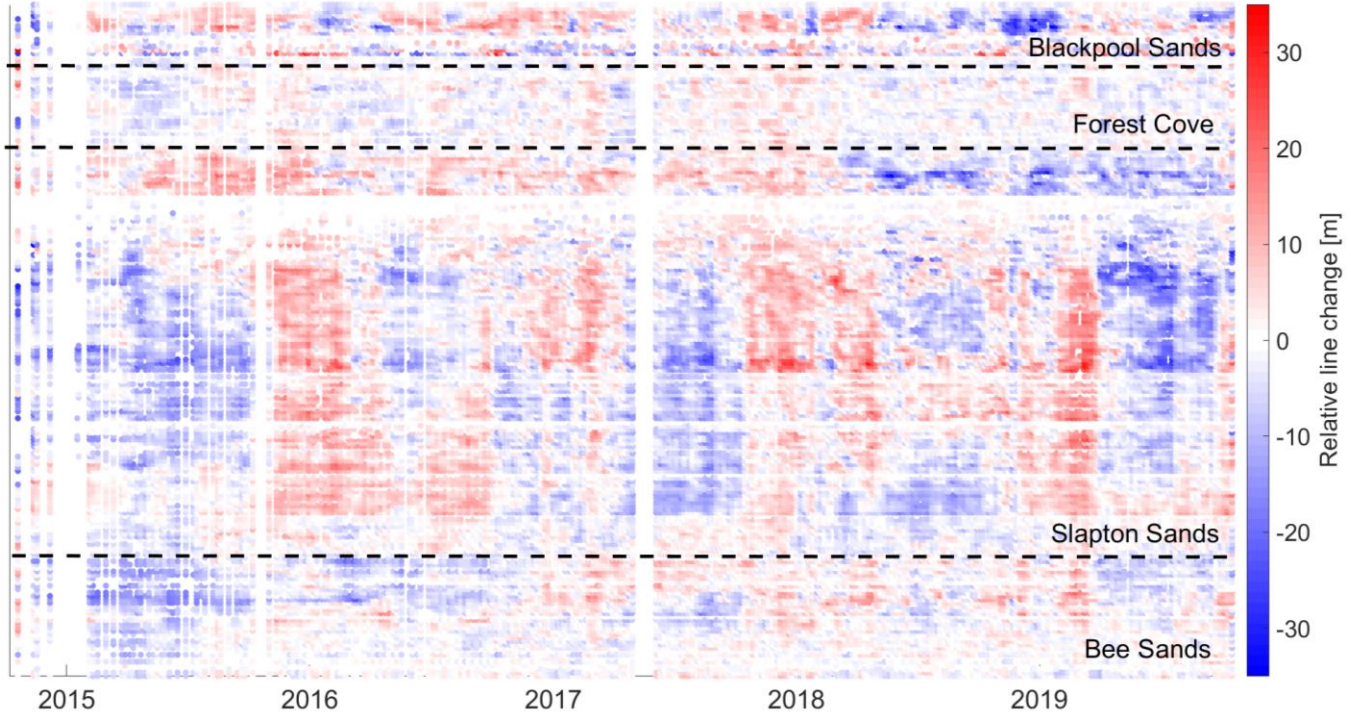
Are WL SAR able to detect beach rotation?

British Geological Survey

Coastal Change From Space

High frequency of SAR waterlines allows a more detailed analysis



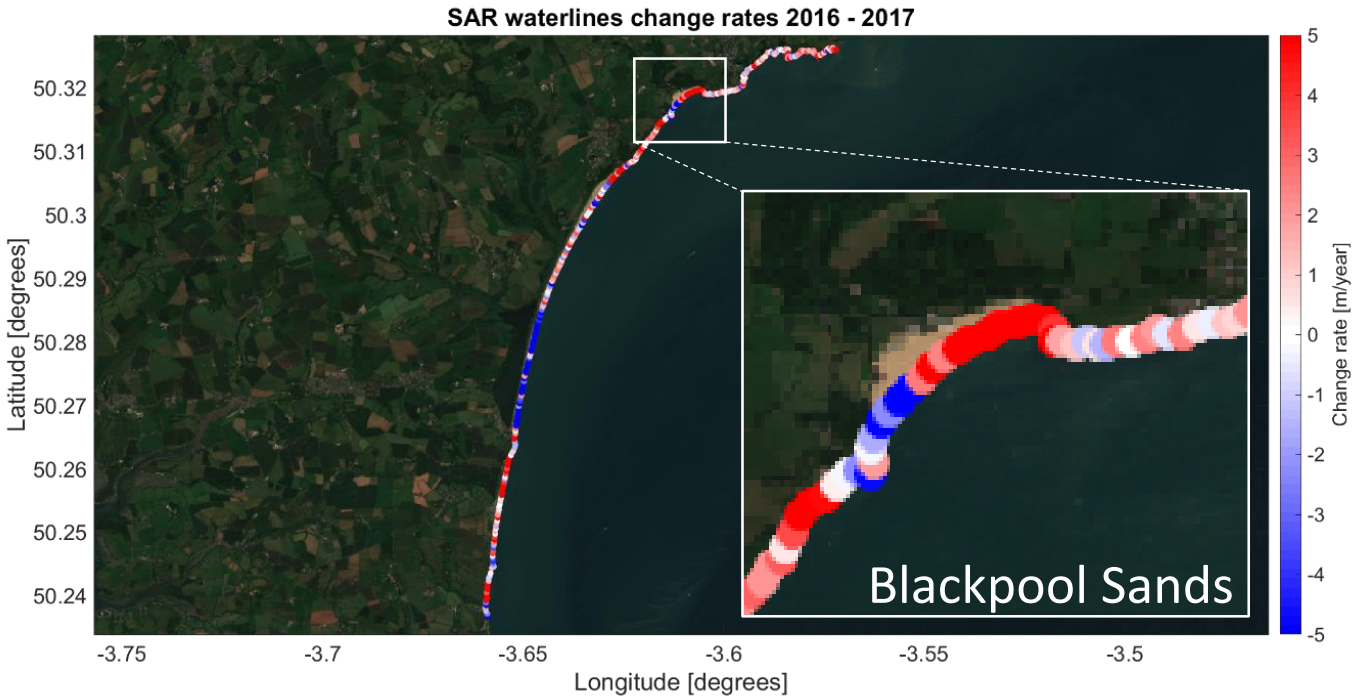


Are WL SAR able to detect beach rotation?

British Geological Survey

Coastal Change From Space

Rotation is clear when annual mean values of SAR WL for years 2016 and 2017 are used

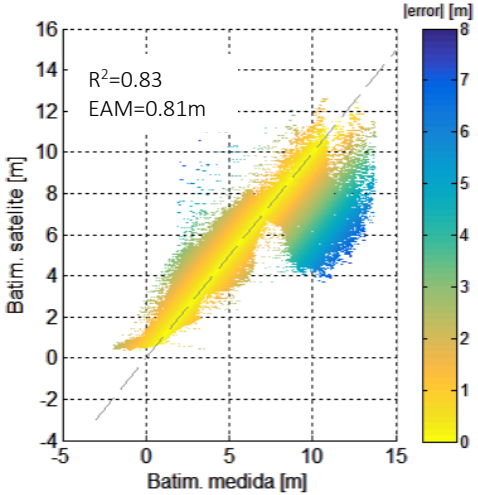


Validation
Bathy-Morpho Terrain Model

British Geological Survey

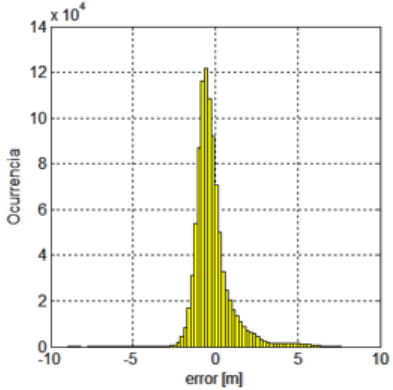
Coastal Change From Space

Example of results from Barcelona



Mean absolute error:

$MAE = 0.81\ m$

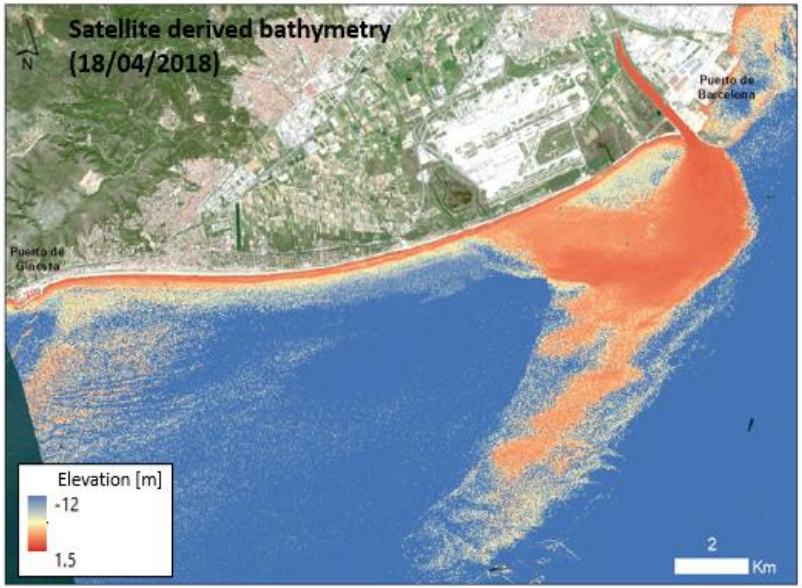


Confidence metadata prevent miss-interpretation

British Geological Survey

Coastal Change From Space

Confidence index

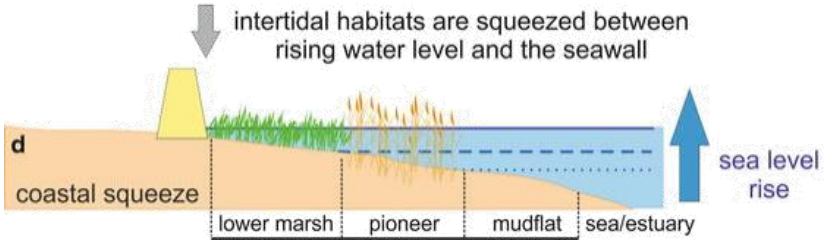


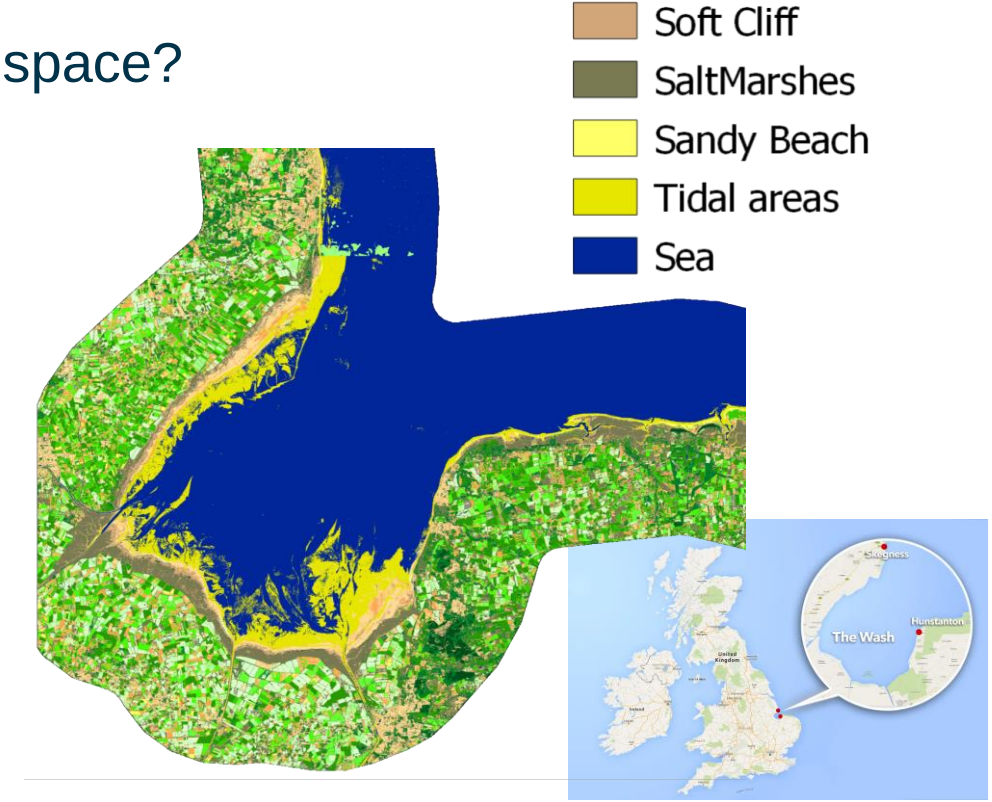
We are still exploring the potential of all EO products

British Geological Survey

Coastal Change From Space

Observing costal squeeze from space?





Thanks for your attention!

10th December 2020, recorded sessions here

30th Nov, 14th December 2020, recorded sessions here

17th November 2020, recorded sessions here

7th Dec 2020 recorded sessions here