Tracking submarine sandbar movements and morphological changes

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esa Coastal Erosion Project

European Space Agency

An exhaustive review of end-users' requests

WHO

INTERMEDIATE ENDUSERS
COASTAL EROSION EXPERTS

SFÂNTU GHEORGHE MARINE AND FLUVIAL RESEARCH STATION

OBSERVATOIRE CÔTE AQUITAINE

GRANDS LACS

FINAL END USERS

GRANDS LACS

OBSERVATOIRE CÔTE AQUITAINE

SFÂNTU GHEORGHE MARINE AND FLUVIAL RESEARCH STATION

INCDM

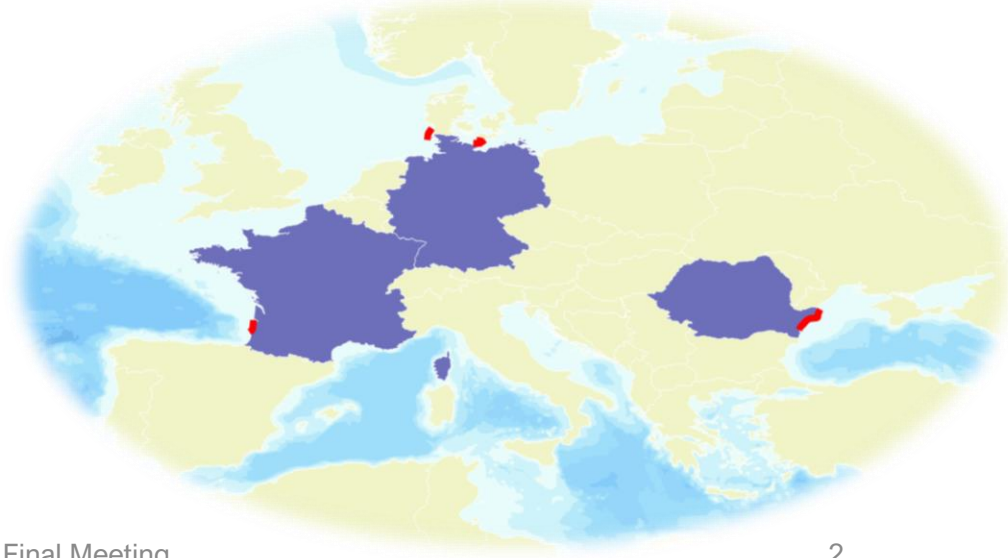
APELE ROMÂNE

HOW

	Revisit	Horizontal accuracy
Romania	Monthly from 2015 to present	10 m
France	Monthly from 2019 to 2020	n/a
Germany	Monthly/yearly 2015 to present	10 m

WHERE

Romania - Sulina – Sfantu Gheorghe: ~ 30 km
France - Nouvelle-Aquitaine: ~ 40 km
Germany – Sylt Odde (North Sea), Kiel Probstei (Baltic Sea), Heiligenhafen (Baltic Sea) and Fehmarn (Baltic Sea)



WHY

Coastal areas, especially beaches, are more and more threatened by the complex effects of climate change, which induces stresses such as increased storminess and overall, more frequent extreme events that can lead to pressures that can take the form of increased erosion or modification of the maximum run-up limit.

Nearshore sandbars represent a natural defense system against these phenomena, monitoring the dynamics and behavior of such morphological features can help coastal managers better prepare for coastal protection actions.

Example of a multispectral Sentinel-2 image (Romania) – 07/04/2020

Example of a multispectral Sentinel-2 image (Germany)

Method

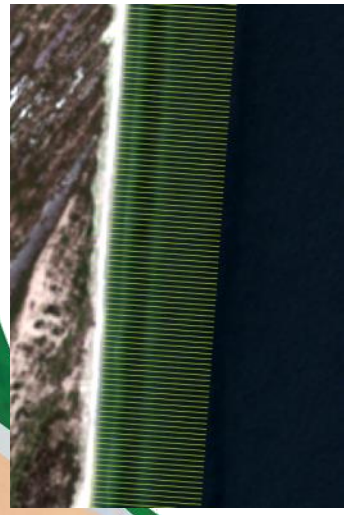
Approach based on the spectral response of sandbars locations

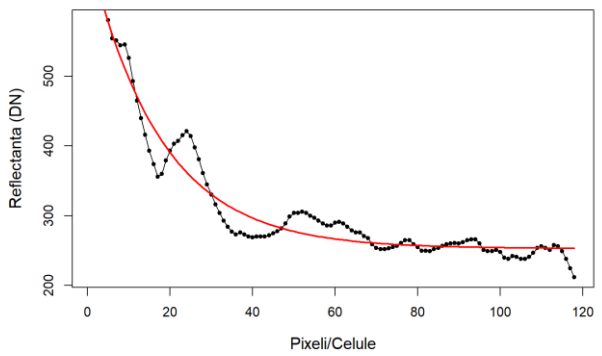
Purpose of the Indicator: Automatically detection of submerged sandbars crests positions in the proximity of the coastline, based on multispectral satellite data.

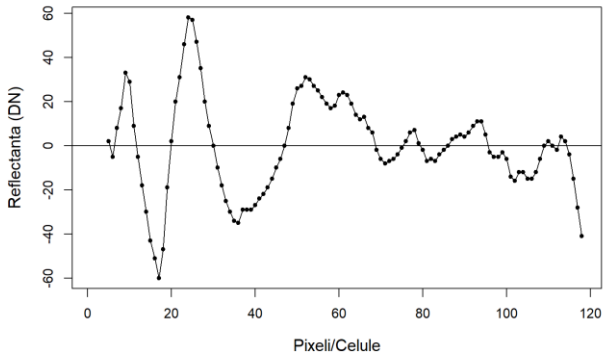
Performs satisfactory compared to image-by-image extraction. Highly efficient when satellite time series are considered.

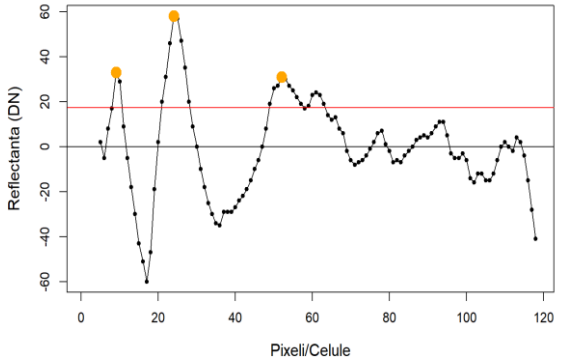
The algorithm is used to extract **each submerged sandbar** position using perpendicular profiles along the shoreline, based on multispectral satellite imagery.

- For each profile, **reflectance values** are extracted, thus taking advantage of all information in the visible part of the electromagnetic spectrum.









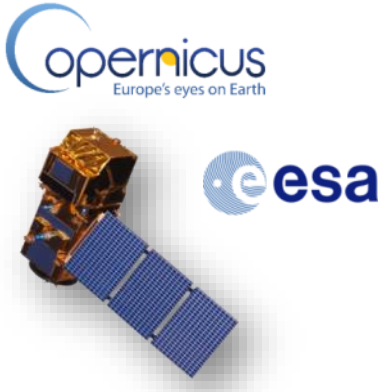
Method

Approach based on brightness differences

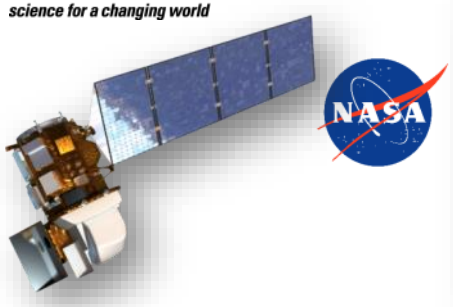
- Brightness differences in 10-m bands of S-2
- Identification of local maxima by spatial gradient analysis
- Multi-temporal approach to find stable and instable areas

Databases exploited

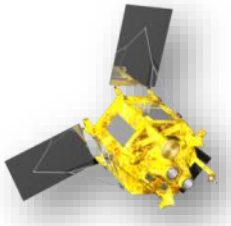
Sentinel-2 (resolution 10 m)



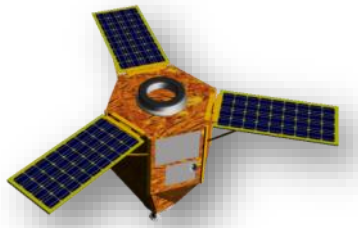
Landsat 5 and 8 (resolution 15 - 30 m)



SPOT- 7 (resolution 1.5 - 6 m)



Pléiades 1B (resolution 0.5 – 2 m)



Demonstration areas and periods

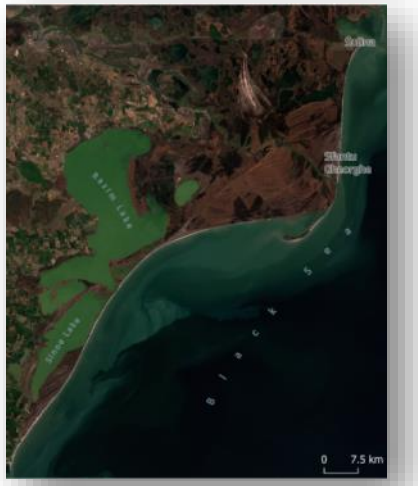
Romania: Sulina – Sfantu Gheorghe

~ 140 km

1990 - 2020

~ one image / month

200 products



France: Nouvelle-Aquitaine

~ 40 km

2015 - 2020

Every 2 months to every month

35 products

Germany: Sylt, Kiel Probstei, Heiligenhafen and Fehmarn

~50 km

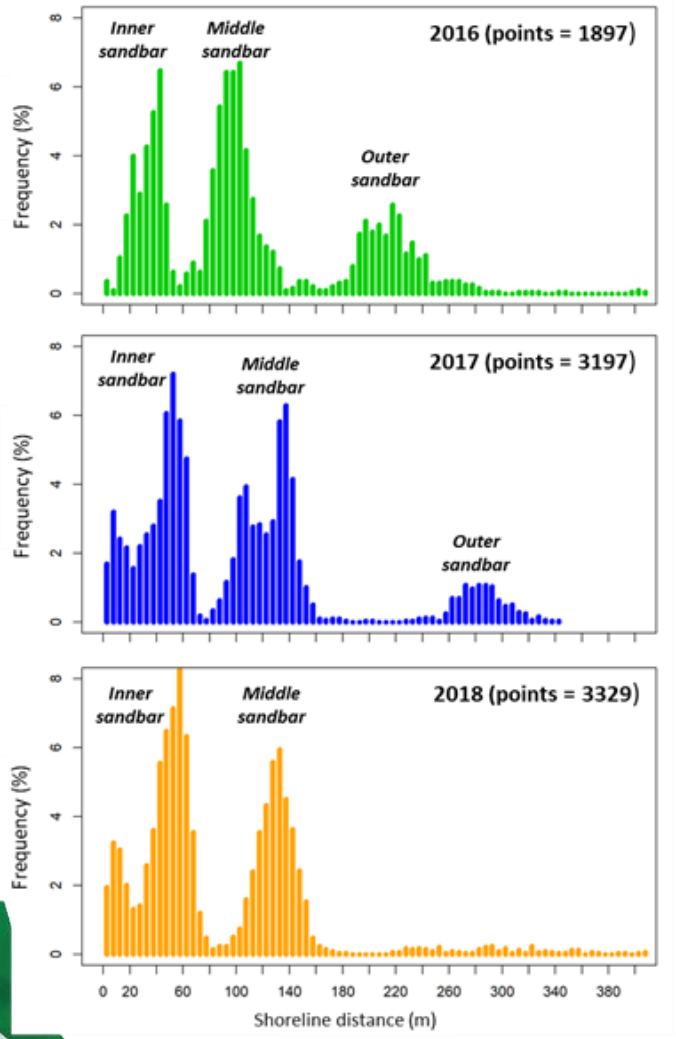
2015 - 2020

Each suitable acquisition / yearly averages

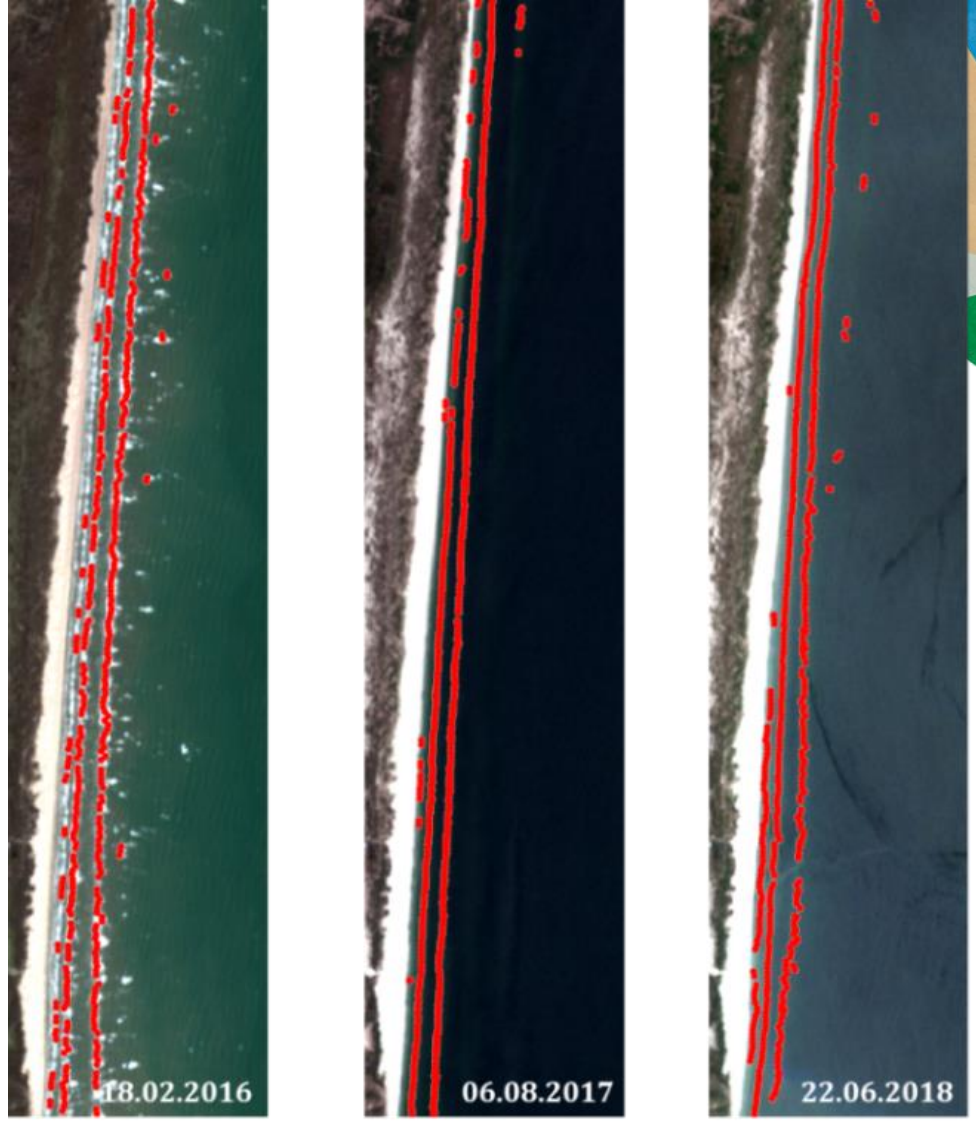
10 - 40 products per year

Product display

Romania



Annual sandbars dynamics over a 1 km sector between Sulina and Sfantu Gheorghe.



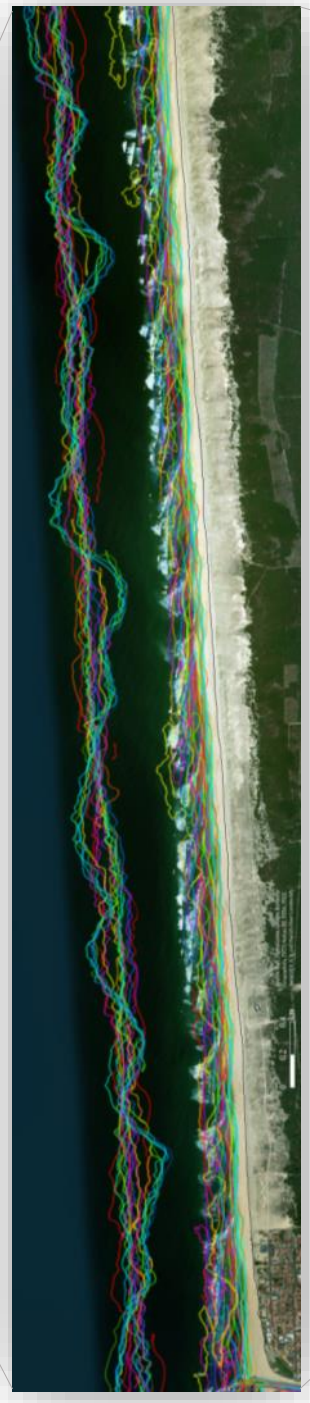
Sandbar position extracted during the first phase of the project from Sentinel-2 images over different moments in time.

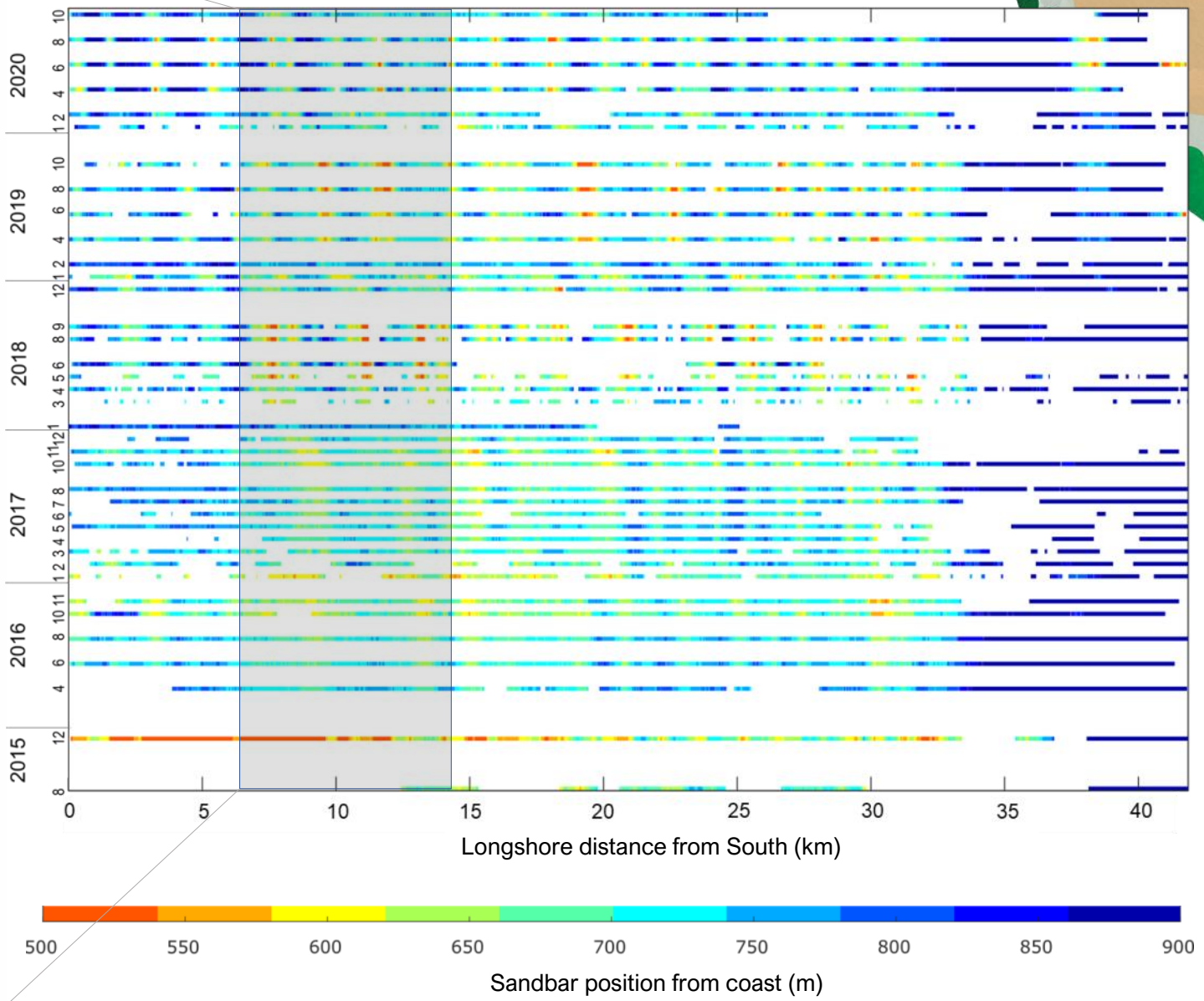
During the second phase of the project the indicator was derived for the entire deltaic coastline from Landsat 5, Landsat 8 and Sentinel 2 data.

Product display

France

High frequency for strong dynamics

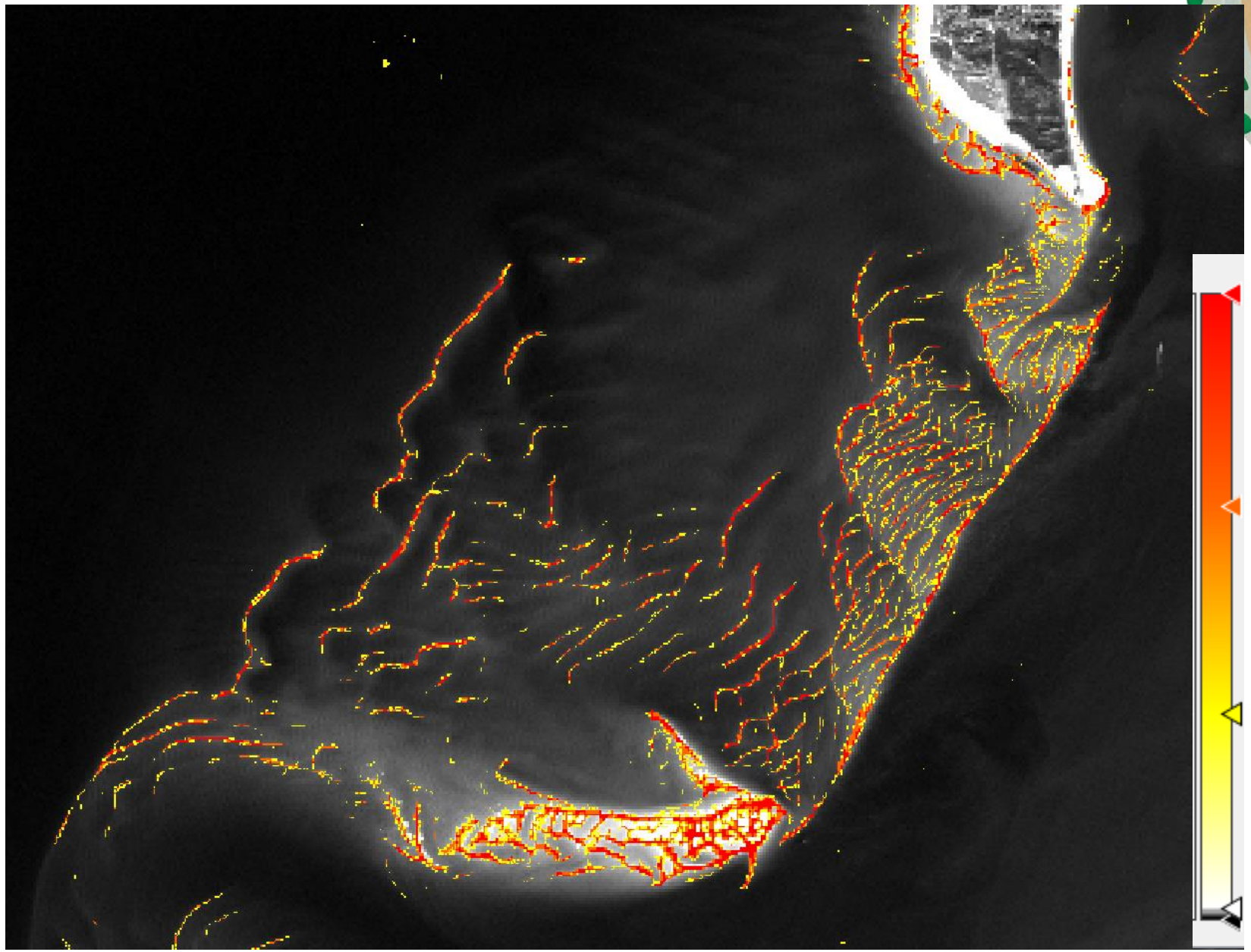




Product display

Germany

Example of submerged sandbar product from 2018 derived from Sentinel-2 data for Germany's area of interest (North Sea, Sylt).



Validation experiment

Romania

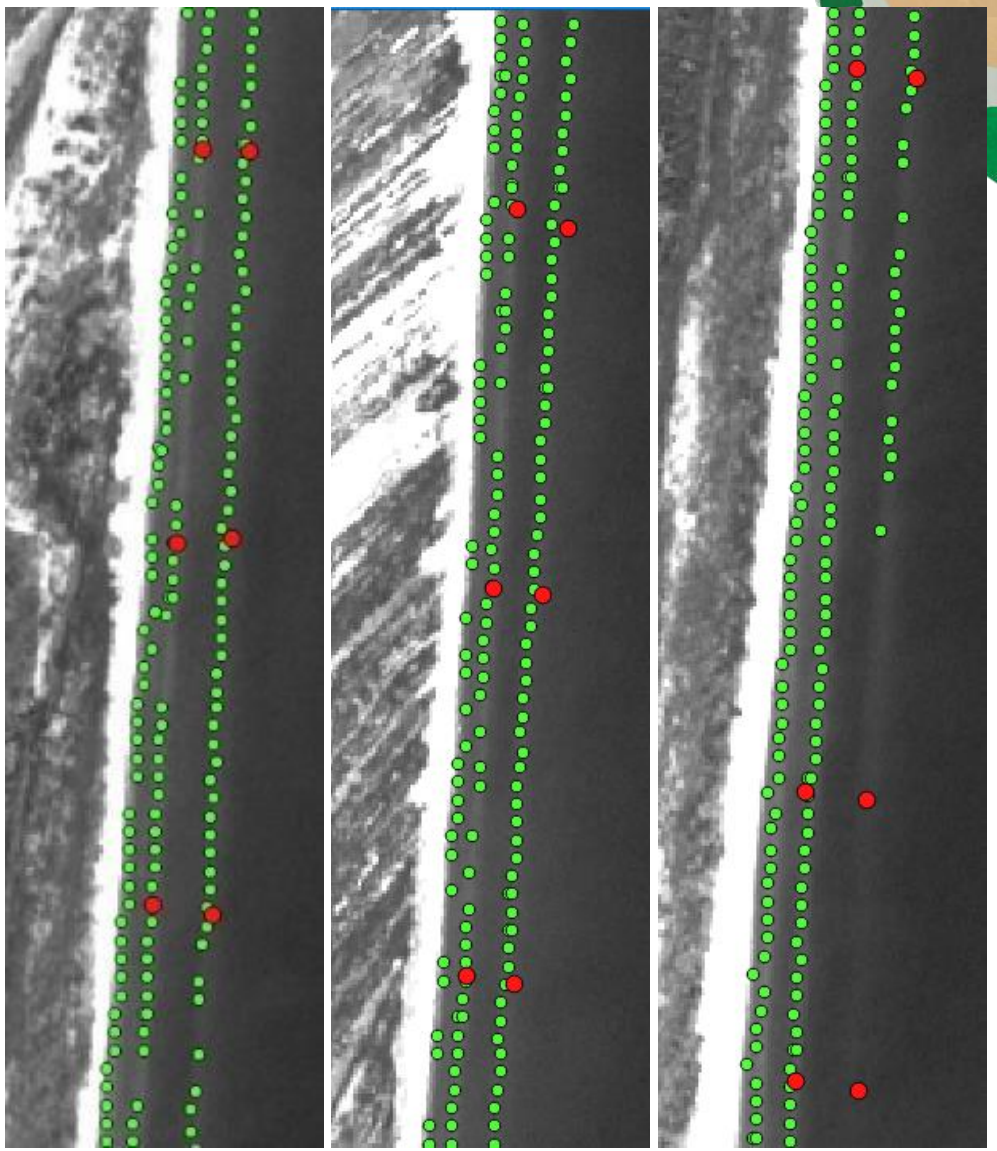
In-situ data based on bathymetric measurements performed by the Sfantu Gheorghe Marine and Fluvial Research Station (SCMF).

170 individual pairs of satellite in-situ match-up pairs used to quantify the accuracy of the algorithm and the capabilities offered by different Earth Observation data sources.

↳ **Very good correlation**, expressed in high coefficients of determination.

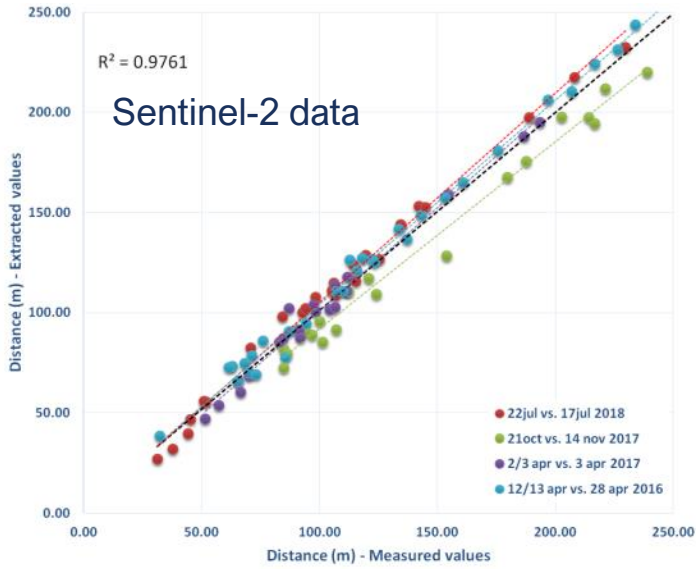
Site	Satellite	Date	Validation dataset		
			Type	Source	Date
Sulina - Sfantu Gheorghe	Sentinel 2A	4/28/2016	Bathymetric survey	SCMF	4/13/2016
	Sentinel 2A	4/3/2017			4/3/2017
	Sentinel 2B	11/14/2017			10/21/2017
	Sentinel 2A	7/17/2018			7/22/2018
	Landsat 5	5/22/2011			5/25/2011
	SPOT 7	10/18/2017			10/21/2017
	Pleiades 1B	6/22/2018			7/22/2018

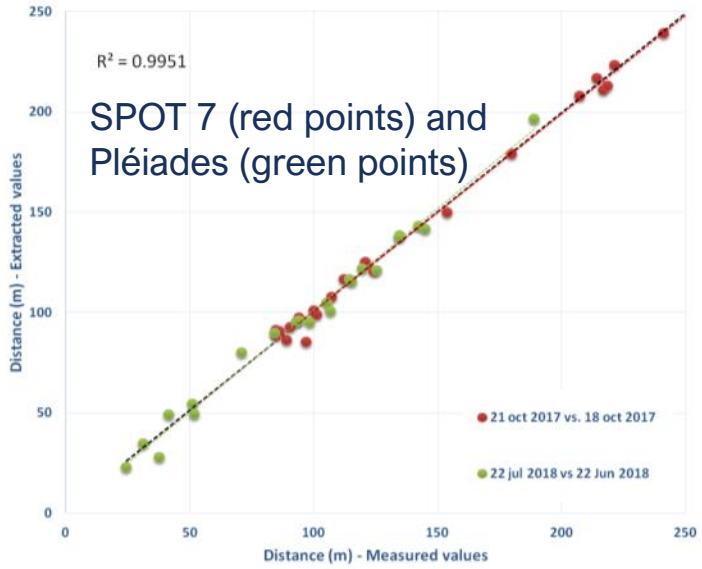
Sandbars positions obtained from a Sentinel-2 image (green dots, 15/09/2017) and measured in-situ, one month later (red dots, 21/10/2017)

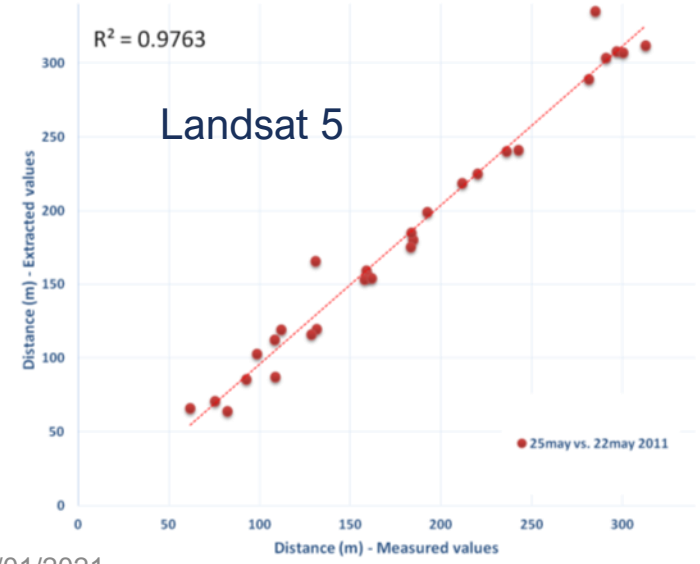


Validation results

Romania







Match-ups between satellite extracted and in-situ measured sandbars locations

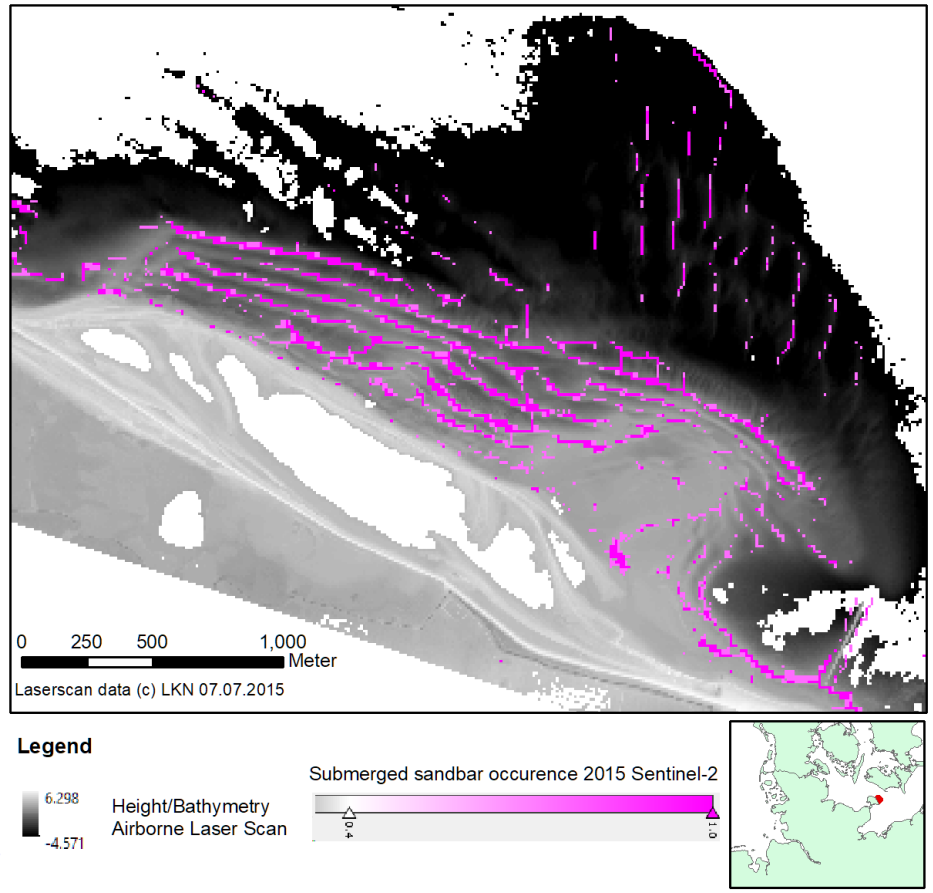
Period	Satellite	n	ΔT days	R^2	MAPD (%)	MB (m)
22 Jul vs 17Jul 2018	Sentinel-2	25	5	0.992	7.41	6.64
21 Oct vs 14 Nov 2017	Sentinel-2	20	24	0.985	7.75	10.79
3 Apr vs 3 Apr 2017	Sentinel-2	20	0	0.985	4.36	3.82
13 Apr vs 28 Apr 2016	Sentinel-2	31	15	0.994	5.64	5.64
21 Oct 2017 vs 18 Oct 2017	SPOT 7	23	3	0.996	2.84	3.35
22 Jul 2018 vs 22 Jun 2018	Pleiades 1B	22	30	0.989	5.73	3.87
25 May 2011 vs 22 May 2011	Landsat 5	29	3	0.98	6.26	9.37

Validation results

Germany - Comparison with Laserscan Data – Fehmarn

For validation of the extracted sand ridges from satellite, visual comparisons have been performed with bathymetry patterns from airborne laser scan data.

Submerged Sandbars Fehmarn North (Baltic Sea)



Approval from scientists

Romania

Demo meeting

October 22nd 2020

(online event)

- **17** participants from **12** potential intermediate and end users, most of them scientists;
- **positive** feedback especially due to the novelty of the proposed methodology;
- the **algorithm** developed and validated for the submerged sandbars position proved to be a **valuable** one for **long-term analysis**. It represents the first approach, based on satellite images, to detect these important coastal geomorphologic features, of utmost importance for beach protection against erosion.

Germany

Demo meeting

October 30th 2020

(online event)

- **21** participants from **11** potential intermediate and end users;
- **positive** feedback especially due to the novelty of the proposed methodology, interest in remote sensing in general as technique; suggestions for further application areas/regions were made
- Understanding hydrodynamic processes in the fore-shore is of great interest in order to understand the processes at the coastline.

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Géosciences pour une Terre durable brgm

“ **No validation** today [in New Aquitaine Region], we can envisage **many usages**, we believe it ! **Very interesting to improve knowledge**.”

Users' requirement achievement level

	Horizontal accuracy		Revisit		Production area	
	Requested	Achieved	Early request	Produced after POC	Requested	Achieved after POC
Romania	10 m	Overall, MAE of 7.25 m (for Sentinel-2 and Landsat); Overall, MAE of 3.35 m (for SPOT 7); Overall, MAE of 3.87 m (for Pleiades 1B).	Monthly from 2015 to present	Monthly from 1990 until June 2020	The area between Sulina and Sfantu Gheorghe (Danube Delta coast)	Entire deltaic coastline (between Sulina and Cape Midia
Germany	10m	10m for Sentinel-2	experimental	Single acquisition and yearly averaged products since 2015	Sylt (North Sea) and Kiel Probstei (Baltic Sea)	four test sites along North- and Baltic Sea

Concerning the French site experiment, requests have been done during the Mid-Term Review to test the algorithm developed for the Romanian sites along the French Atlantic Coast.

End-users' testimonies

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Confidence in the product quality (including accuracy)

"After making some tests and validating some of the obtained data by the product (with in-situ measurements), we are highly confident in the product quality and we can say that the overall accuracy is very good and surpasses our initial expectations."

Probability of service integration into existing practices

"This kind of service can be integrated in the future into early warning systems for various coastal sectors."

Overall service and products evaluation

" The service and products fulfil completely our requirements and offers high quality data with very good accuracy at large spatial and temporal scales. It is highly beneficial for scientists, coastal managers, policy makers and other types of stakeholders."

COMMUNAUTÉ DE COMMUNES DES GRANDS LACS

V. Bawedin (Communauté des Grands Lacs): " *Getting kowledge about the sandbar location at the beginning of winter-time (plus intertidal sandbars and bathymetry) would be a determining factor* ***to anticipate erosion events***."

ESA’s expectation achievement level

- Detection of submerged sandbars methodology developed under Space for Shore is a fully automated procedure, ready to be used as independent building block for further developments (e.g. added-value services for coastal zone stakeholders).

- It was proven that the algorithms can be succesfully applied to a large scale analysis (both temporal and spatial) – 30 years of data, > 300 images, more than 230 km of shoreline.

- The approach can be used to derive complex information regarding the erosion and accumulation rates over large periods of time and geographical areas. Thus it can significantly contribute to an improved strategy for the application of the Integrated Coastal Zone Management principles.

Publications & Conference Presentations

Publications:

- Tătui, F., Constantin, S., 2020. *Nearshore sandbar crest position dynamics analysed based on Earth Observation data*. Remote Sens. Environ. 237. doi:10.1016/j.rse.2019.111555

Conference presentations:

- Tătui, F., Anghelin, G., Constantin, S., 2021. *Satellite-derived shoreline reveal fascinating dynamics for the last three decades on Danube Delta coast*. EGU General Assembly, 19-30 April (abstract submitted)

Intertidal creeks and intertidal flats