Extraction of Waterlines:

The key indicator to anticipate erosion hazard along microtidal areas

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esa Coastal Erosion Project

An exhaustive review of end-users' requests

WHO

INTERMEDIATE ENDUSERS
COASTAL EROSION EXPERTS

cerege

SH Schleswig-Holstein Landesamt für Landwirtschaft, Umwelt und ländliche Räume

Aix*Marseille université

SFÂNTU GHEORGHE MARINE AND FLUVIAL RESEARCH STATION

FINAL END USERS

RÉGION SUD PROVENCE ALPES CÔTE D'AZUR

Conservatoire du littoral

SH Schleswig-Holstein Landesamt für Landwirtschaft, Umwelt und ländliche Räume

ΔΕΛΤΑ ΕΒΡΟΥ

HELLENIC REPUBLIC
REGION OF EAST MACEDONIA &THRACE

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
PREFECTURE DU VAR

INCDM

APELE ROMÂNE

Περιφέρεια Αν. Μακεδονίας και Θράκης

Φορέας Διαχείρισης
ΔΕΛΤΑ ΝΕΣΤΟΥ
ΒΙΣΤΩΝΙΔΑΣ-ΙΣΜΑΡΙΔΑΣ ΚΑΛΑΜΙΤΣΙΟΥ
Delta Nestos Lakes Vistonida-Ismarida Management Body

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE

SFÂNTU GHEORGHE MARINE AND FLUVIAL RESEARCH STATION

ΠΕΡΙΦΕΡΕΙΑ ΔΥΤΙΚΗΣ ΕΛΛΑΔΑΣ
χέρι αντίδειξις!

Περιφέρεια Πελοποννήσου

WHAT

Over microtidal areas (tidal range below 1 m), the relevant shoreline proxy to be monitored is the waterline, i.e. the boundary between sea and land

Preferably monitored or extracted during low wave agitation conditions, in order to be relevant from one date to another and not to depend on sea level fluctuations due to wind/storm events

There are 2 types of waterlines mentioned by end users:

- the instantaneous interface between the sea and the beach (as expressed in Romania and Greece)

- the middle of the swash zone (asked by French and Romanian end users), i.e. an average position of the waterline as the swash is going up and down over the beach.

An exhaustive review of end-users' requests

HOW	Revisit	Horizontal accuracy
France	1-5/year, at least once or twice per year	1 m
Germany	1-5/year, at least once per year	1-10m
Greece	1-5/year, at least once or twice per year	1 m
Romania	1-5/year, at least once or twice per year	1-5 m

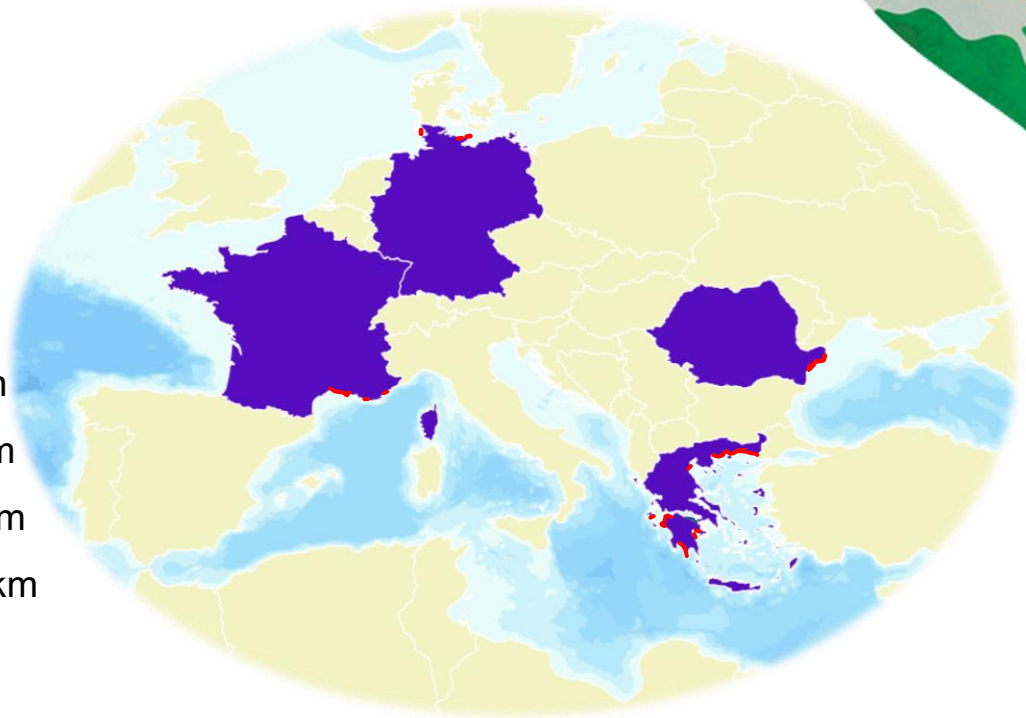
WHERE

France: 113 km

Greece: 900 km

Germany: 40 km

Romania: 140 km



WHY

Monitor the waterline as the main indicator of erosion or accretion of beaches.

Need at least once or twice per year.

Need more frequently during wintertime, particularly every month typically, plus a before/after diagnosis when major storms happen.

Open-source spatial data with morphological details:

The example of a multispectral Sentinel-2 image in Western Peloponnese (Kato Achaia)
01/08/2020

Visually not so obvious to delimitate the waterline with certainty...

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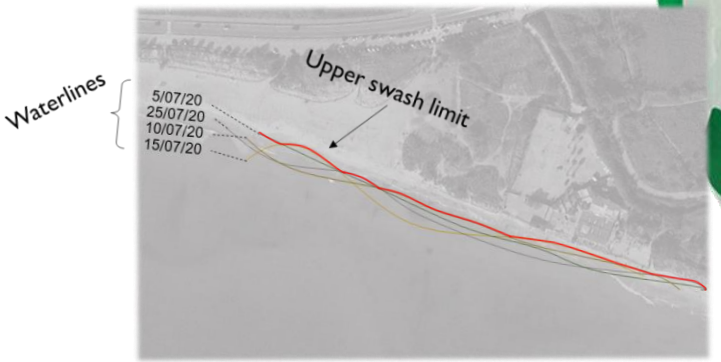
Visually not so obvious to delimitate the waterline with certainty...

Method

- French demonstration sites, for the extraction approach based on:
  - Optical:
    - ❑ waterline detection using NDWI2 (sand/water limit);
    - ❑ Upper swash limit : inner limit of marine excursion (waterline) among a set of short-period dates
- German demonstration sites, for the extraction approach based on:
  - Optical:
    - ❑ waterline detection using blue and nIR bands
- Greek demonstration sites, for the extraction approach based on:
  - Optical:
    - ❑ Waterline detection using NDWI and MNDWI;
  - SAR:
    - ❑ waterline detection using binary products from SAR amplitude data.
- Romanian demonstration sites, for the extraction approach based on:
  - Optical:
    - ❑ waterline detection using NDWI and MNDWI and AWEI;
    - ❑ waterline detection using a supervised classification process;
  - SAR:
    - ❑ waterline detection using binary products from SAR amplitude data.

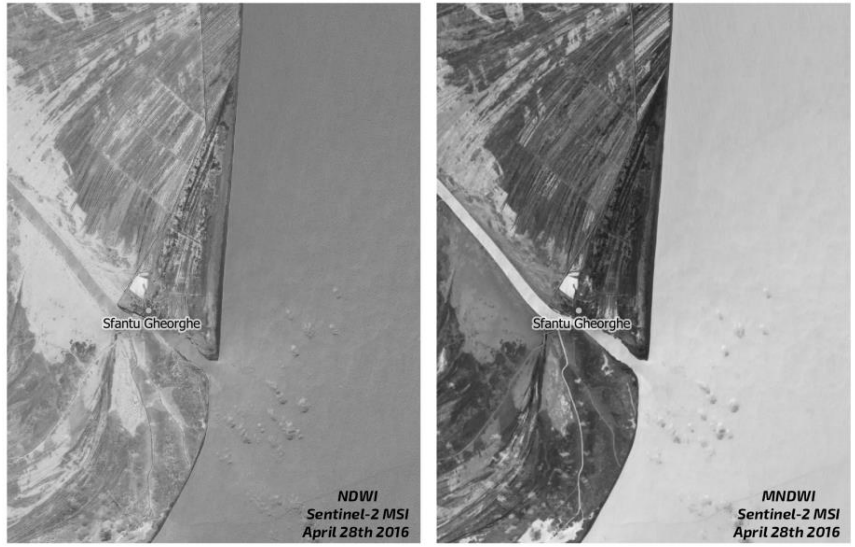
During **Phase 1** we tested all the above-mentioned approaches.
During **Phase 2**, according to the validation results the waterline indicator was derived from long time series using **AWEI**.



*Algorithm is based on **supervised classification** that differentiates **water** pixels from **others** located in the sub aerial domain.*

$$NDWI=\frac{Band_{Green}-Band_{NIR}}{Band_{Green}+Band_{NIR}}$$

$$mNDWI=\frac{Band_{Green}-Band_{SWIR1}}{Band_{Green}+Band_{SWIR1}}$$



NDWI and MNDWI – visual comparison

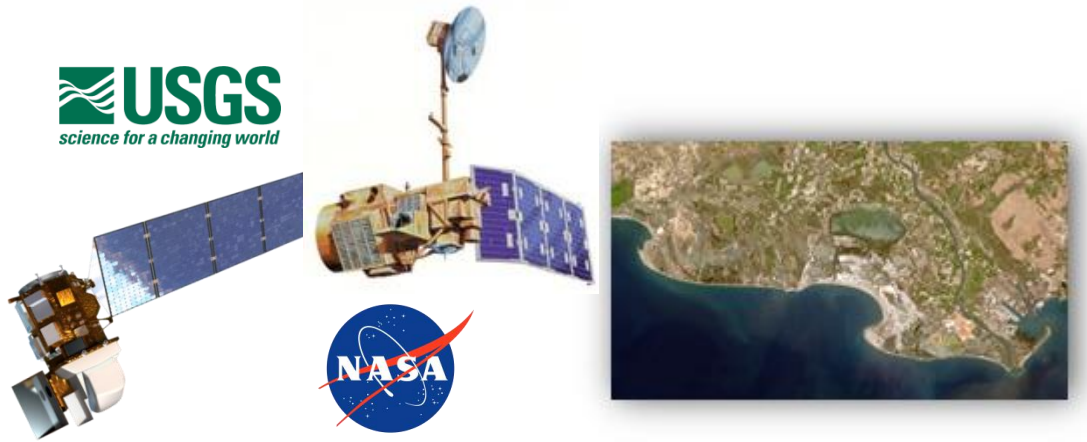
Databases exploited

SPOT-1/2/3/4/5 /6/7 (resolution 1.5-20 m)

Sentinel-1 & 2 (resolution 10 m)

Pléiades (resolution 0.5 & 2 m)

Landsat-5/6/7/8 (resolution 15-30 m)



Demonstration areas and periods

Vistonis-Maroneia
244 km
1995 – 2020
Yearly
24 products

Pieria
28 km
1995 – 2020
Yearly
33 products

Evros
300 km
1995 – 2020
Yearly
33 products

Laganas
25 km
1995 – 2020
Yearly
33 products

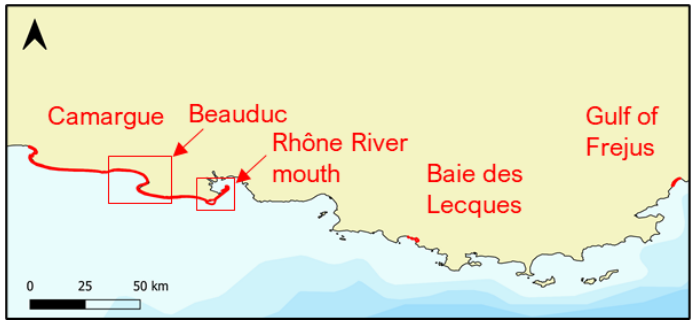
Kato Achaia
92 km
1995 – 2020
Yearly
31 products

Melissi
62 km
1995 – 2020
Yearly
31 products

Kandia
18 km
1995 – 2020
Yearly
31 products

Astros
14 km
1995 – 2020
Yearly
31 products

Lagkadas
117 km
1995 – 2020
Yearly
32 products



Instantaneous waterlines

Camargue	Beauduc	Rhône River mouth
90 km	30 km	19 km
2013-2020	2013-2020	1995-2020
1/yr (Summer)	2/yr (seasonal)	1/yr (Summer)
17 products	25 products	23 products

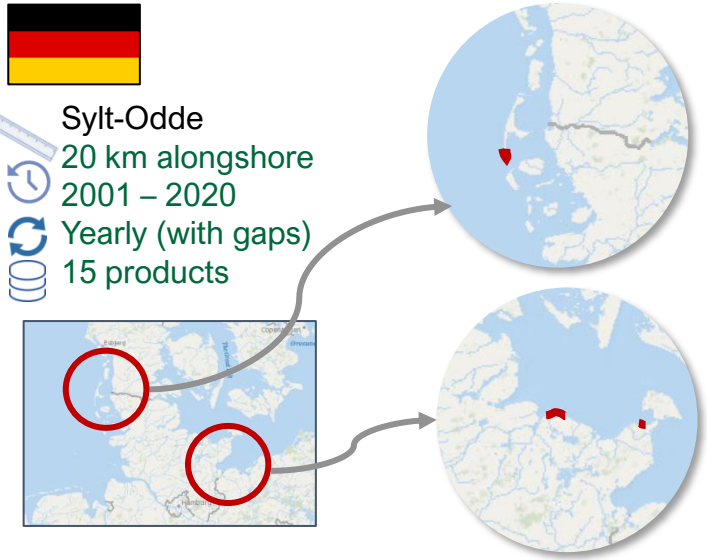
Baie des Lecques	Gulf of Frejus
16 km	7 km
2015-2020	2015-2020
2/yr (seasonal)	2/yr (seasonal)
10 products	28 products

Upper swash limit and changes

Camargue	Gulf of Frejus
90 km	7 km
2015-2020	2015-2020
1/yr (Summer)	2/yr (seasonal)
33 products	33 products

Entire Danube Delta coastline
~ 140 kms
1990 - 2020
~ one image / month
200 products

Sylt-Odde
20 km alongshore
2001 – 2020
Yearly (with gaps)
15 products



Kiel Probstei
30 km alongshore
2001 – 2020
Yearly (with gaps)
15 products

Heiligenhafen
10 km alongshore
2001 – 2020
Yearly (with gaps)
10 products

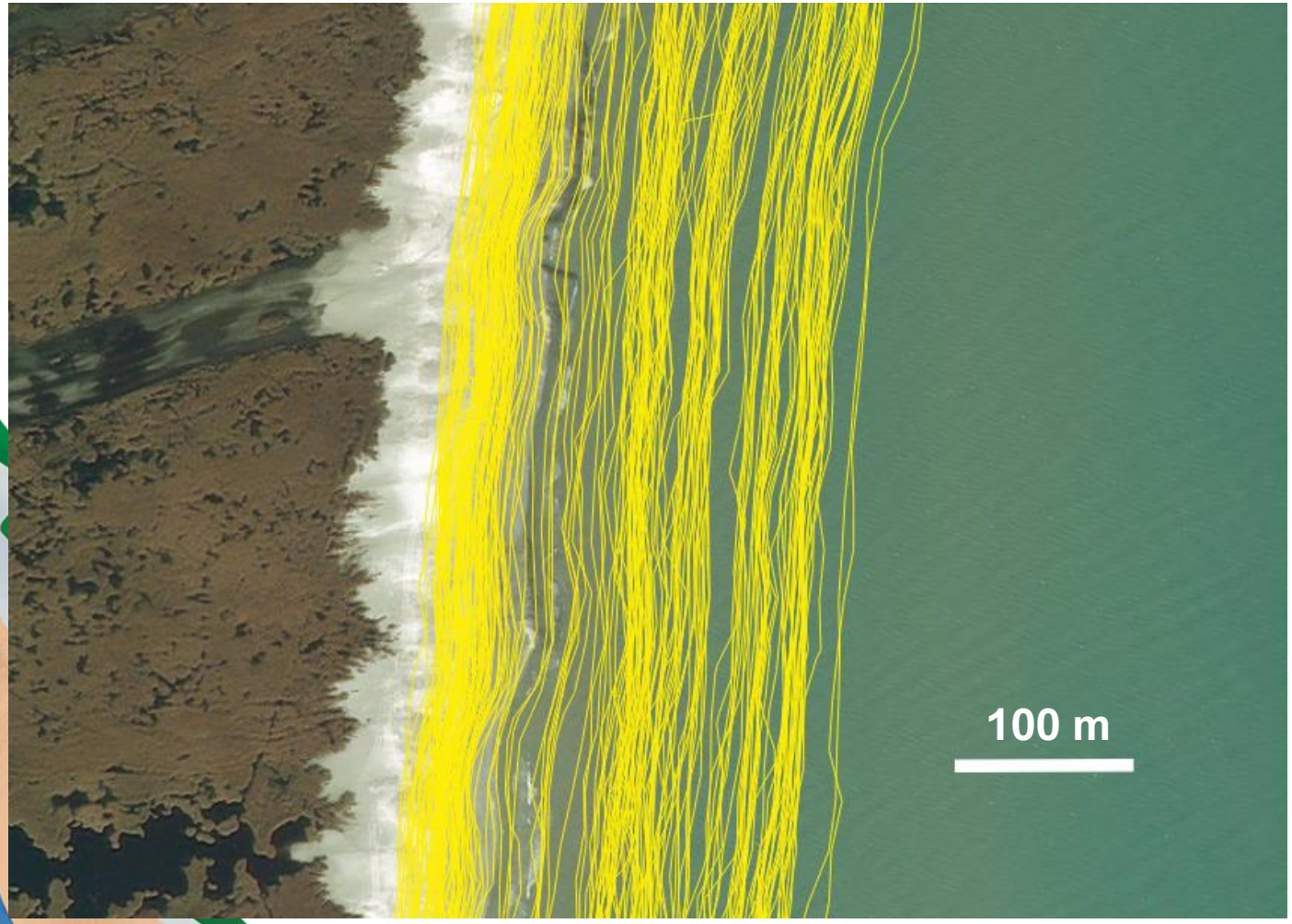
Product display

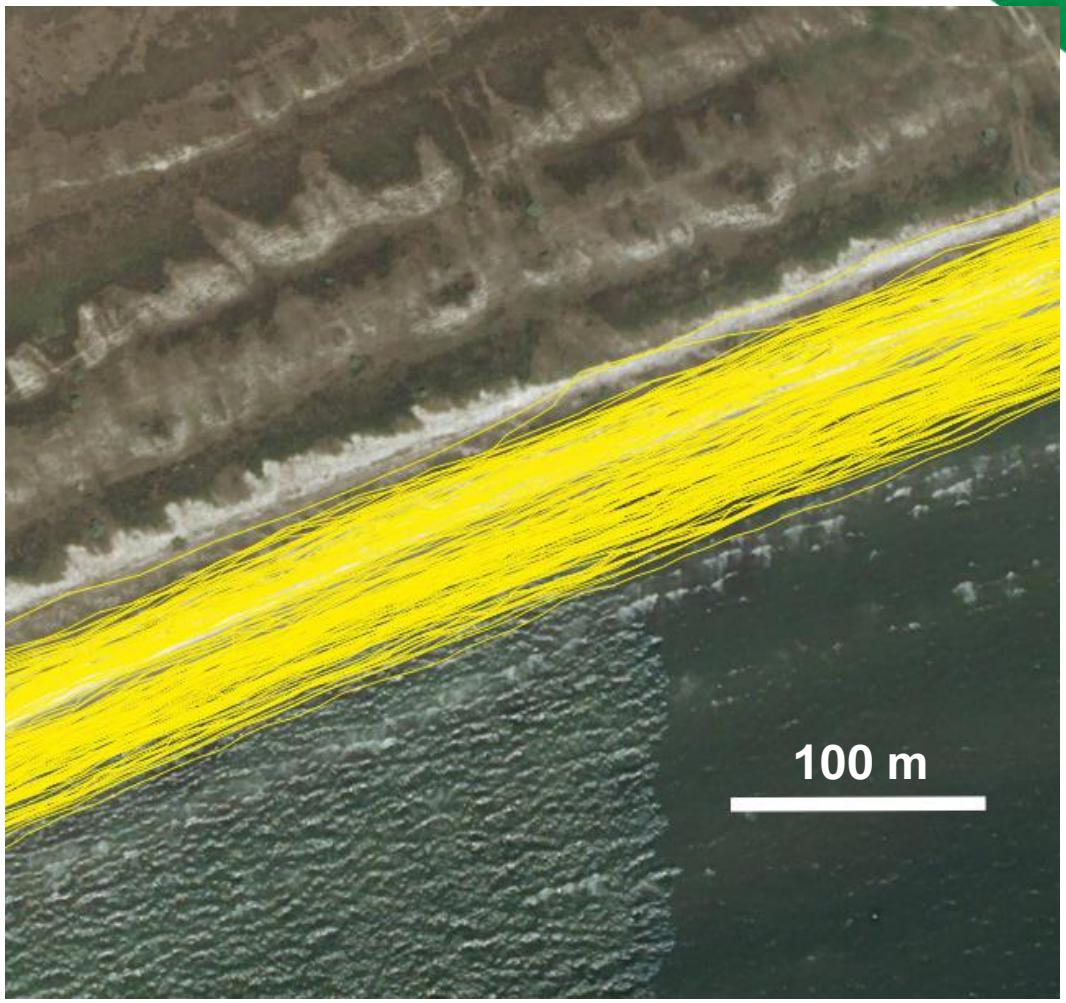
High frequency to analyse both long-term trends and short-term variability of the waterline...

Product Display – 30-year period, waterline change

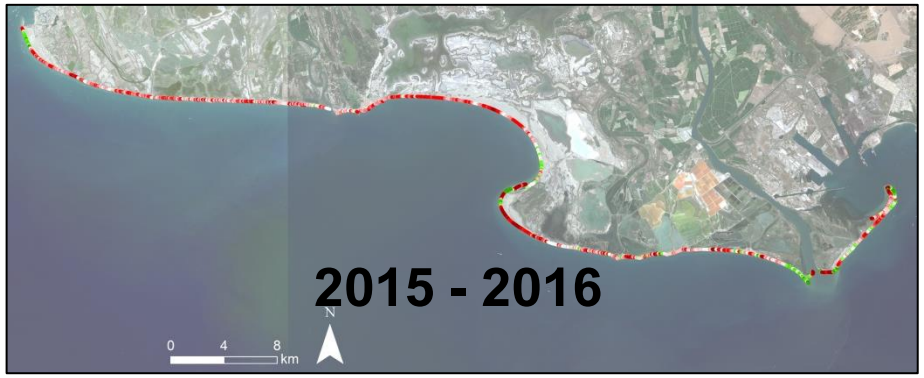
More than 200 Landsat (5 and 8) and Sentinel-2 images were processed.

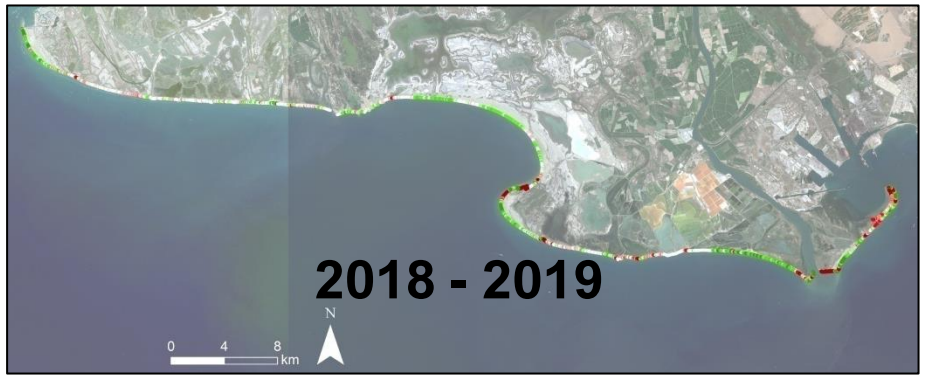
30 years of data, from 1990 to 2020, for the entire deltaic coastline.

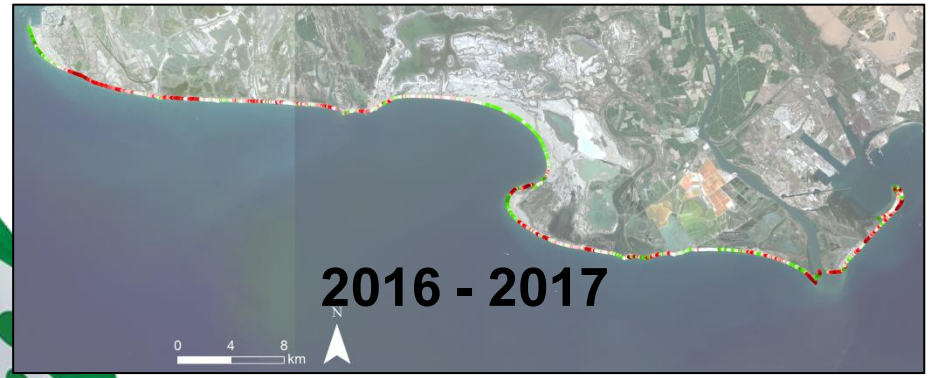


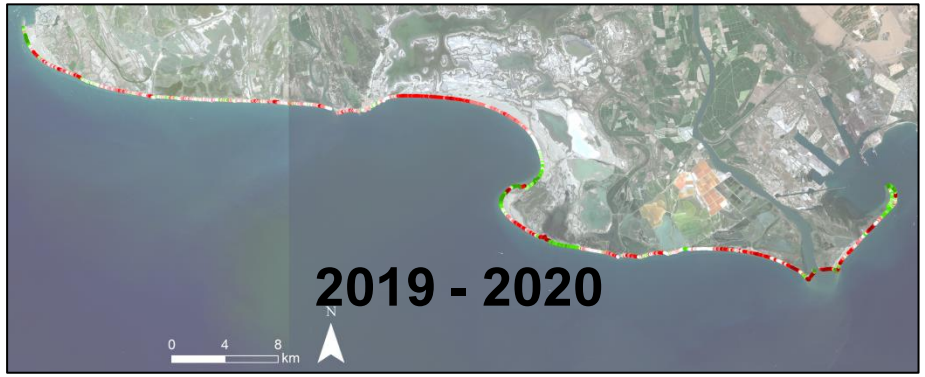


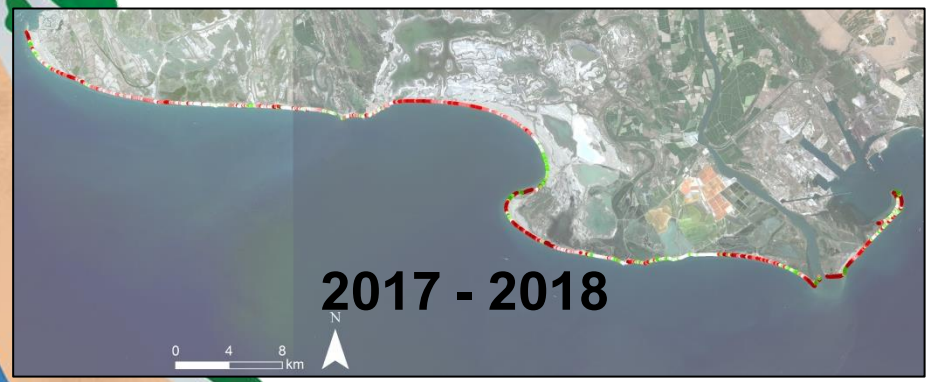
Product display – From yearly variability to longer-term trend









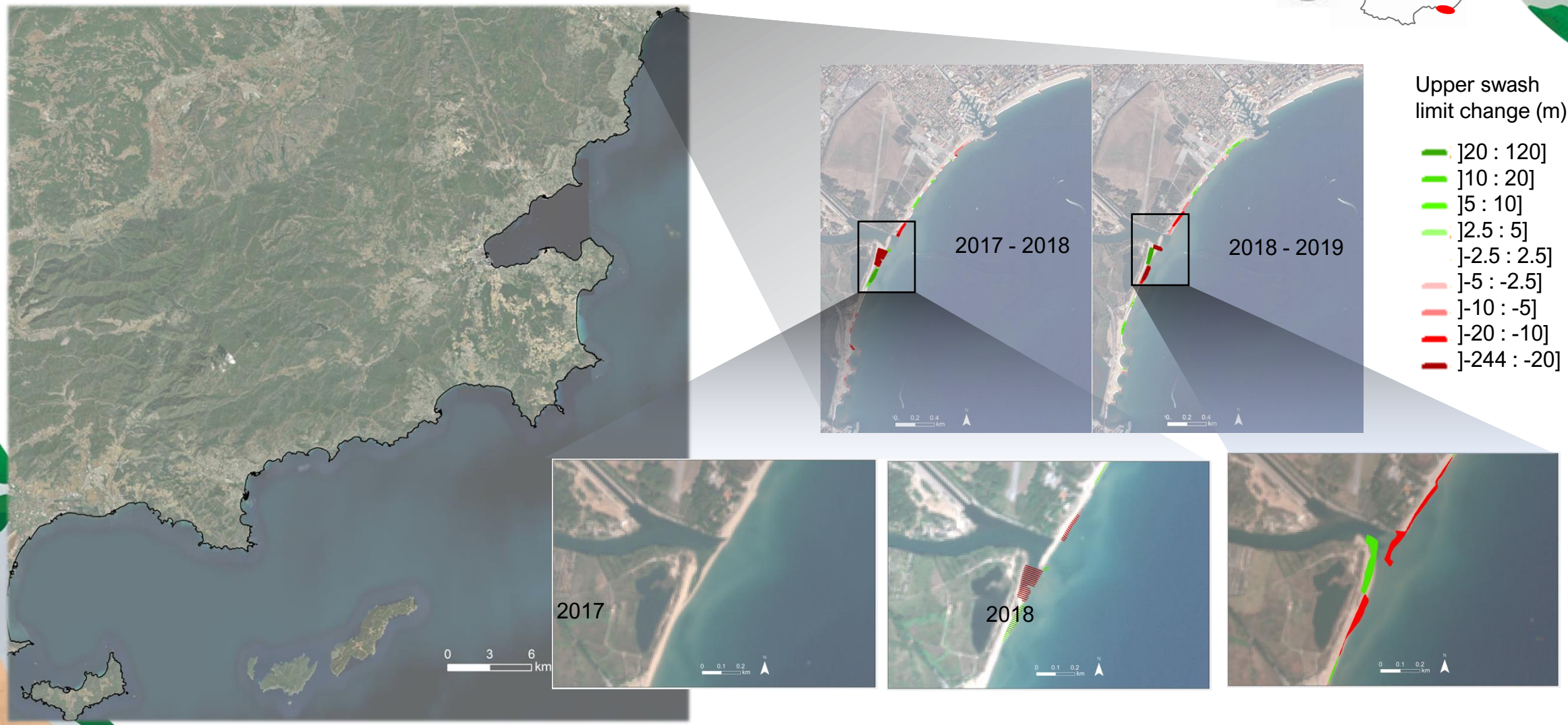


Change in upper swash limit

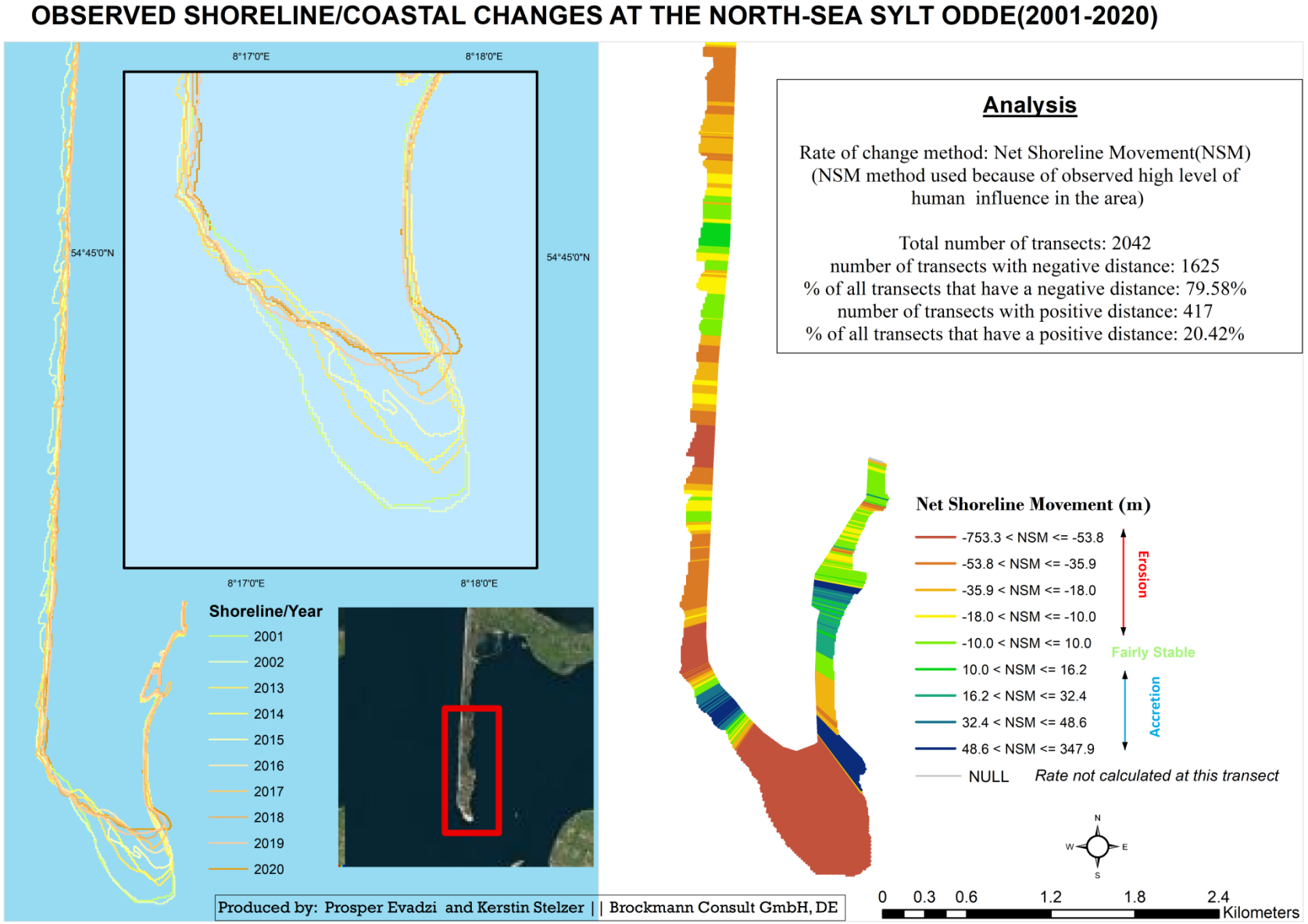
]20 : 120]
]10 : 20]
]5 : 10]
]2.5 : 5]
]-2.5 : 2.5]
]-5 : -2.5]
]-10 : -5]
]-20 : -10]
]-244 : -20]

Product display – VHR shoreline extraction

Upper swash limit and changes from Pléiades satellite imagery

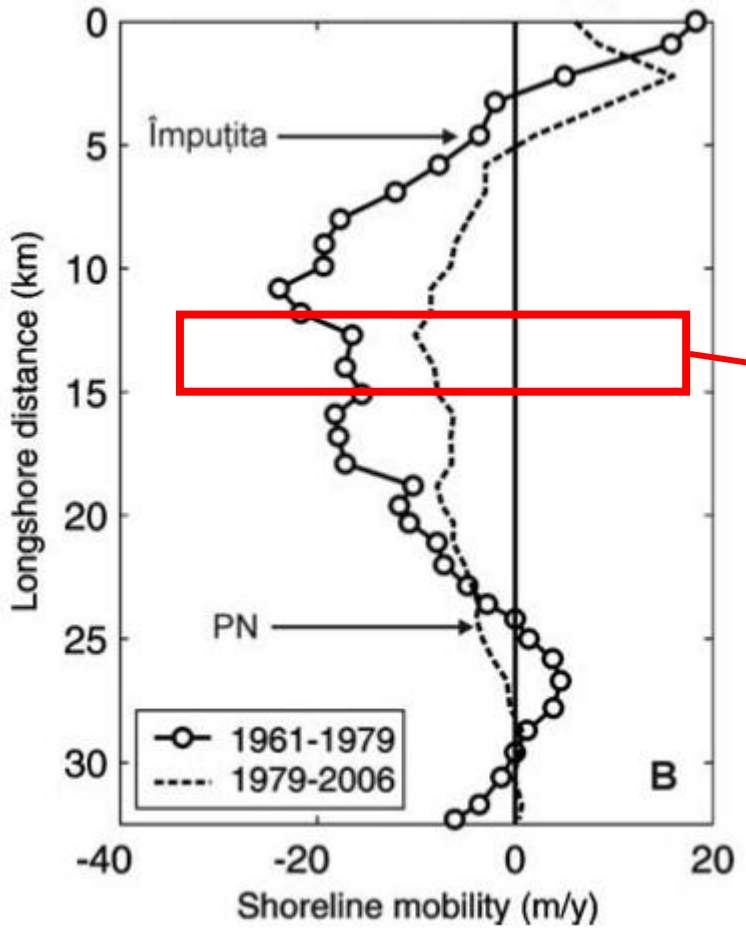


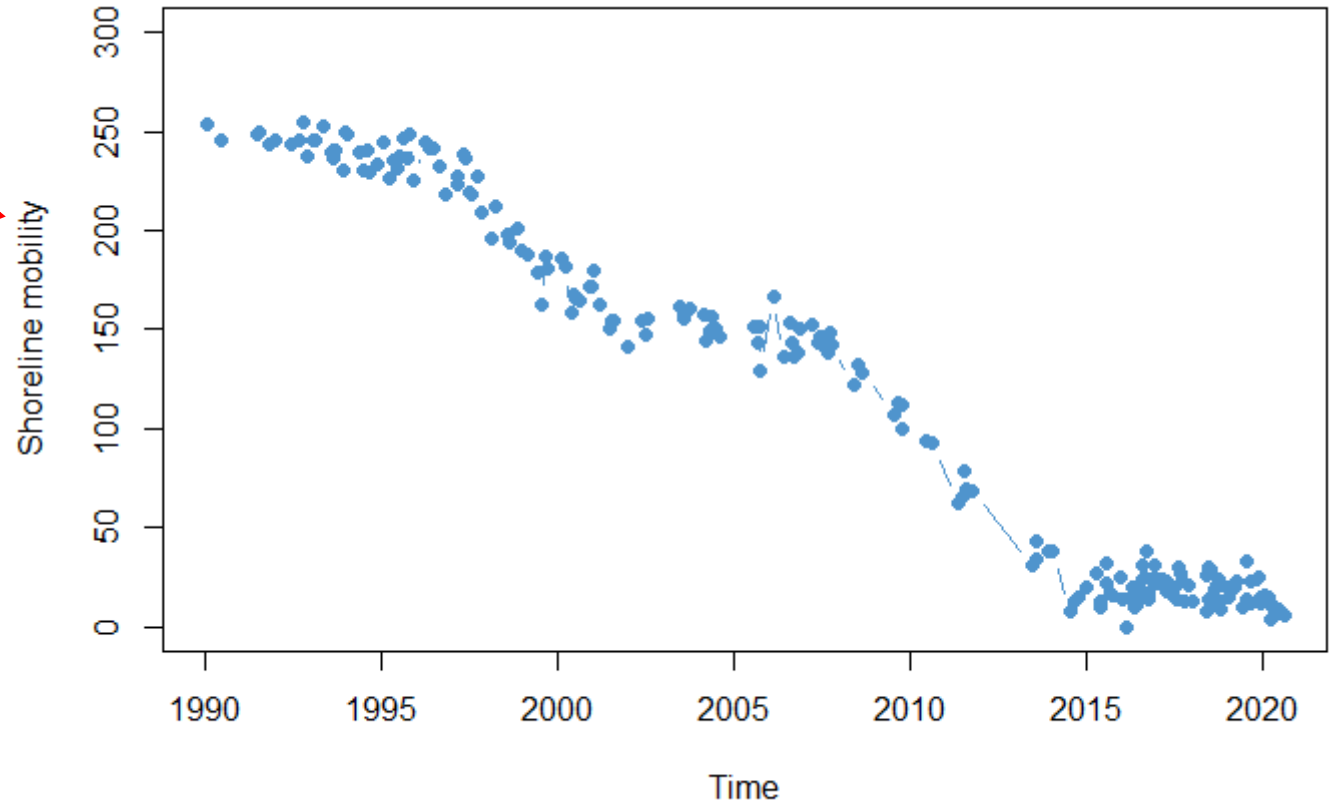
Product Display – Long-term time series of waterline change



Product Display – 30-year period, waterline change

Results – Sulina – Sfantu Gheorghe sector

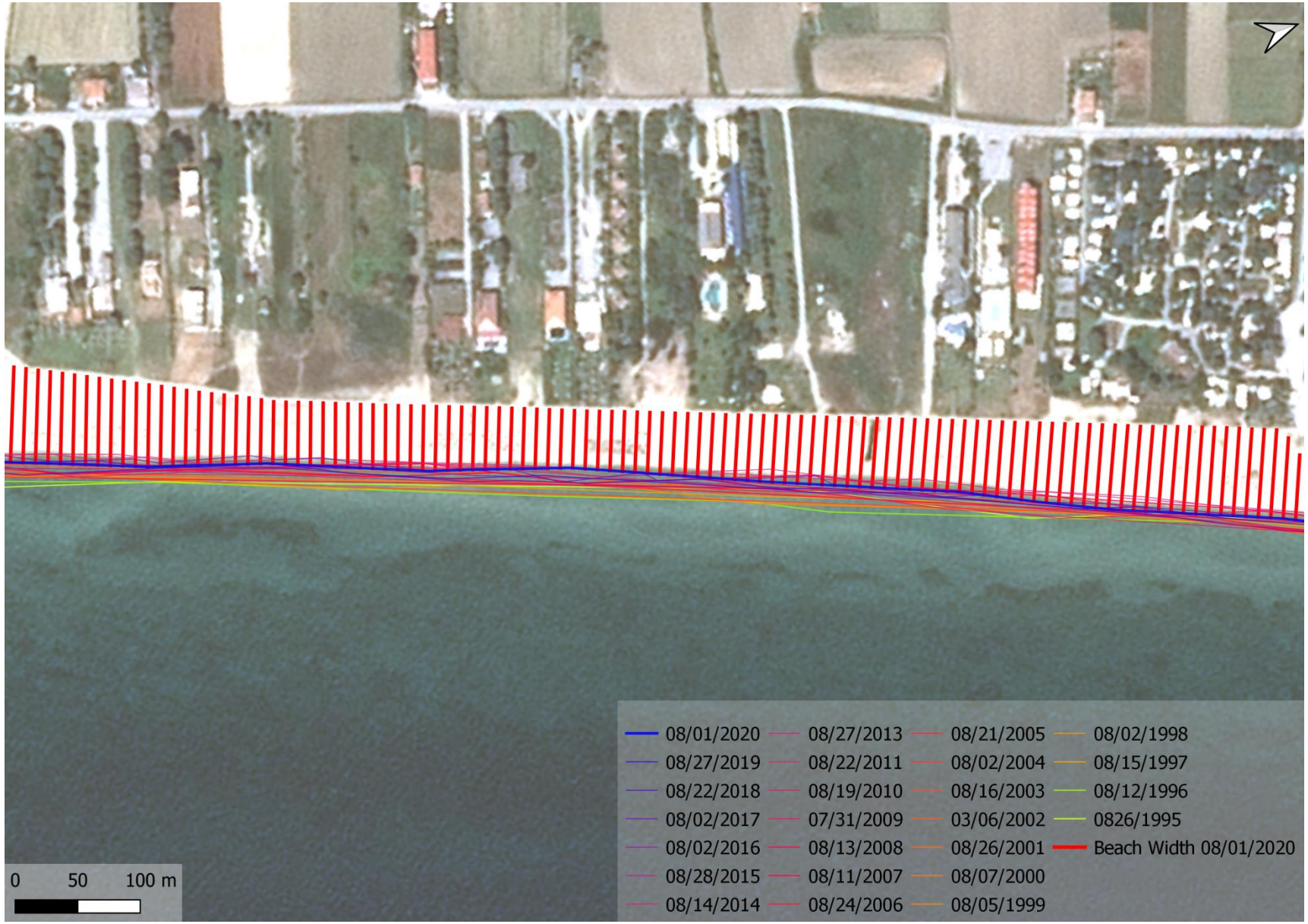




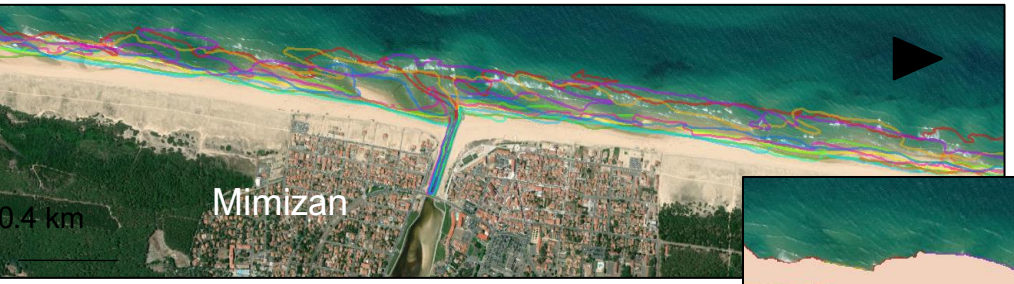
Vespremeanu-Stroe, A., Constantinescu, S., Tâtui, F., Giosan, L., Multi-decadal Evolution and North Atlantic Oscillation Influences on the Dynamics of the Danube Delta Shoreline. J. Coastal Res., 2007, ICS Proceedings

Product display – Derived product from waterlines: the microtidal beach width

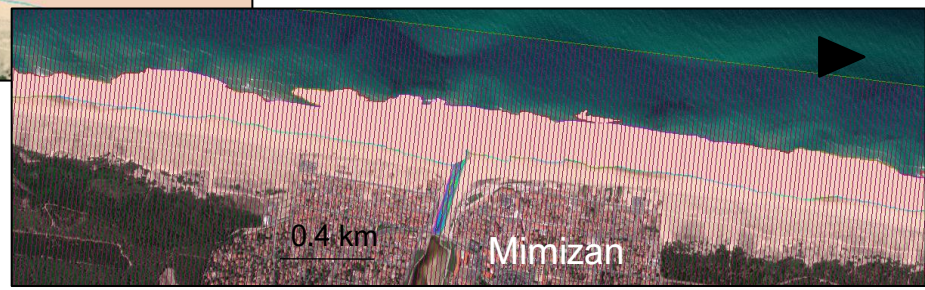
High frequency to analyse both long-term trends and short-term variability of the waterline...



Product display – Derived product from waterlines: the intertidal beach width



Over 42 km (New Aquitaine Region)



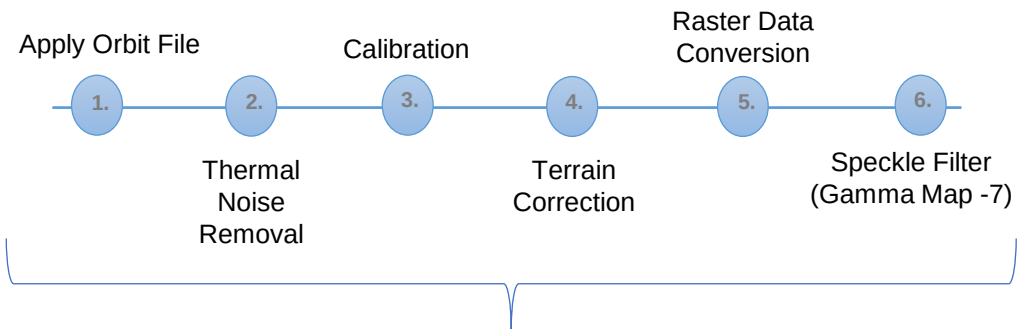
- Waterline extraction over different tide levels
- Measurement of the cross-shore extent of the waterline 2D coverage from high- to low tide

Intertidal beach width in 08/2018 (m)

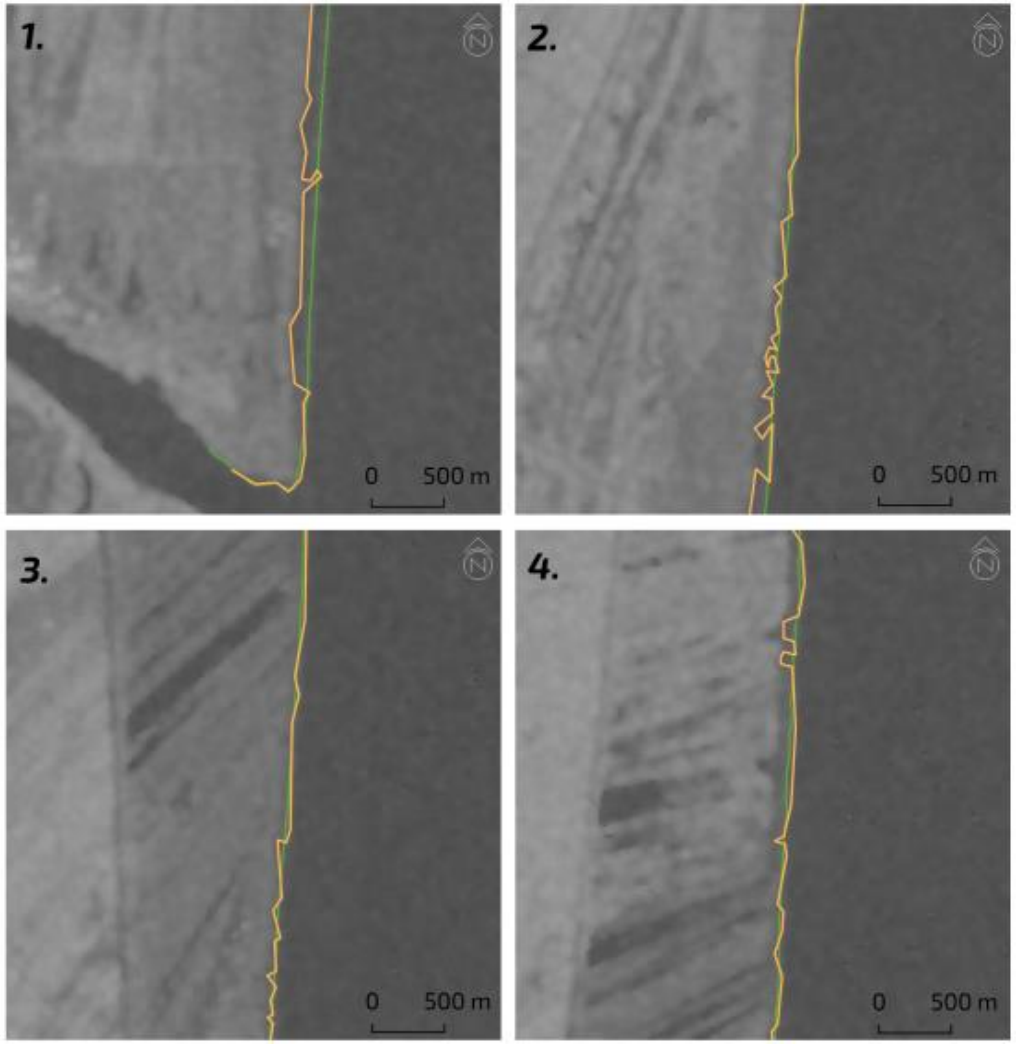
- 52 - 100
- 101 - 120
- 121 - 140
- 141 - 160
- 161 - 180
- 181 - 200
- 201 - 250
- 251 - 315

Product Display – SAR derived waterline

Waterline detection using binary products from SAR amplitude data



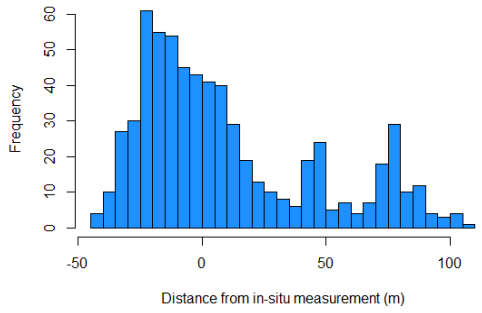
Minimum values between **VV** and **VH** polarizations were computed.
The **minimum** computed product, **VV** and **VH** were **multiplied** in order to augment the differences between water and land.



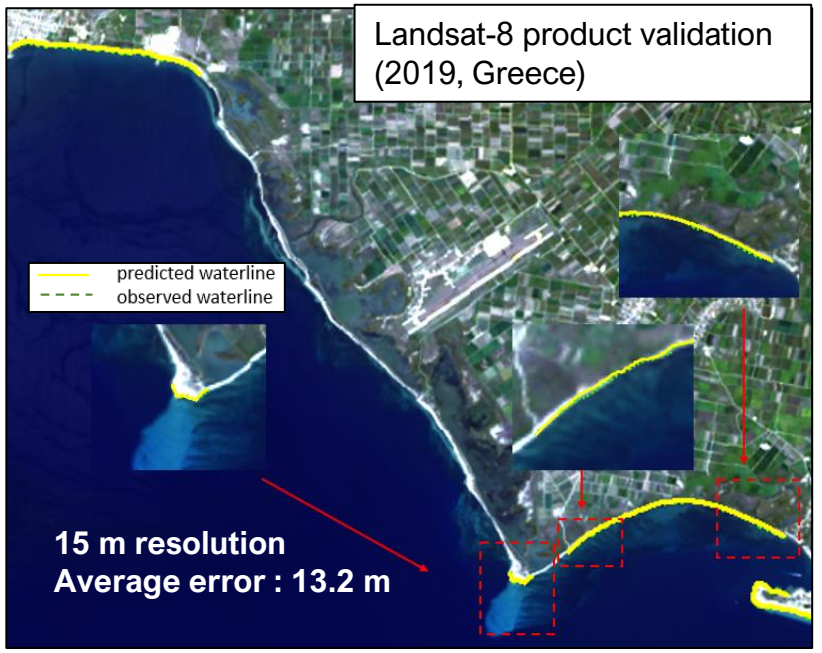
Validation Results

Validation of the waterline extraction by comparing with position measured on field

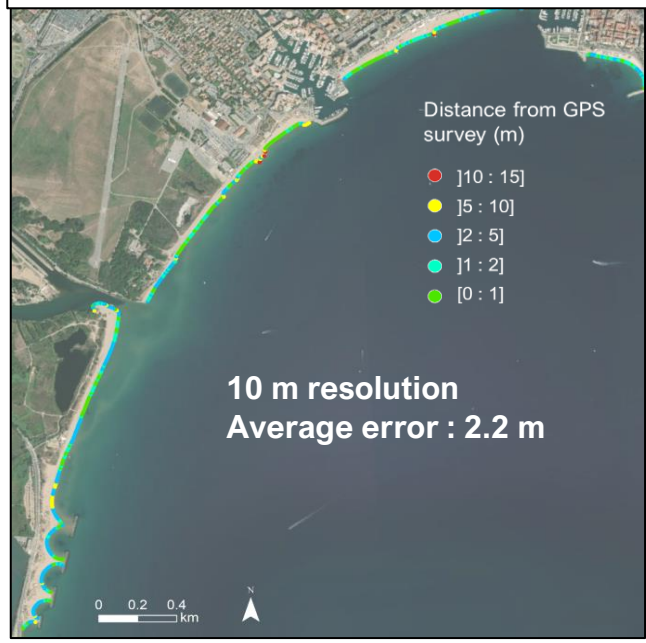
Sentinel-1 product validation (2016) = 1 m average accuracy

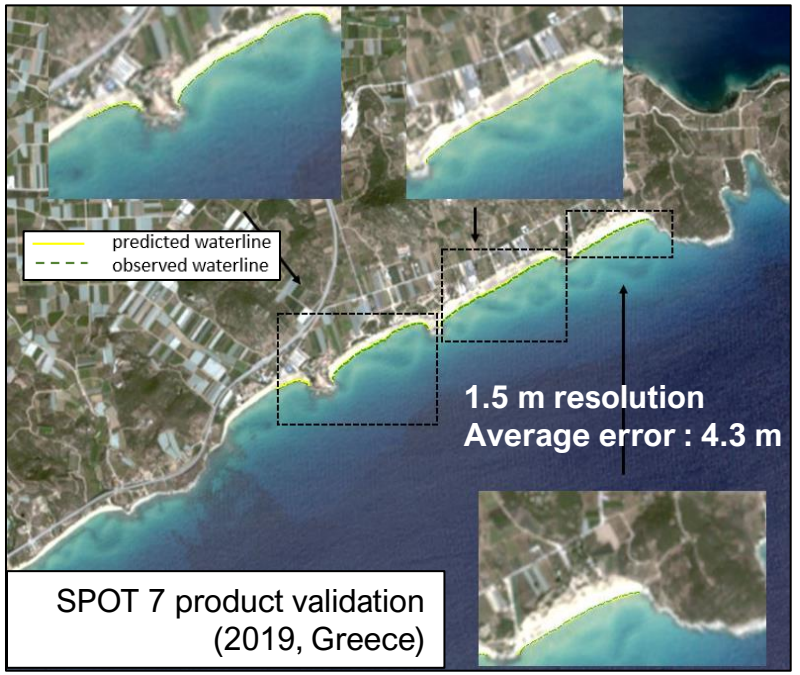


Landsat-8 product validation (2019, Greece)



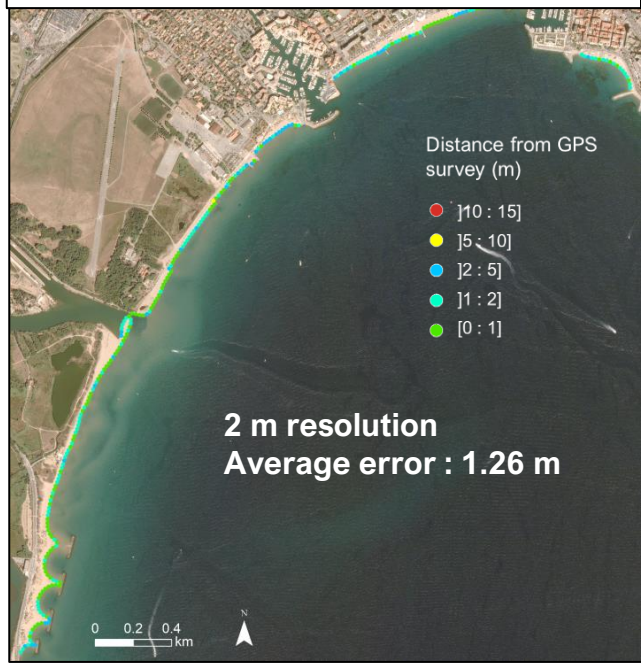
Sentinel-2 product validation (2019, France)





SPOT 7 product validation (2019, Greece)

Pléiades product validation (2020, France)



21/01/2021

Approval from scientists

F. Sabatier (Aix-Marseille univ/CEREGE): *"The performance achieved is **very very satisfactory**"*

Dr. H-C Reimers (LLUR): *" By comparison with other acquisition methods (LIDAR, orthophotos, in-situ campaigns) a **very good level of confidence** could be achieved."*

Dr. T. Papadopoulos (Peloponnese Technology and Innovation Centre):
*"**Outstanding first try**, you set up the road for the **coastal monitoring** in Greece"*

*Dr. Florin Tătui (University of Bucharest): "Based on the feedback from the participants to the demo meeting, **the algorithm developed and validated for the waterline position proved to be a valuable one for long-term analysis**. It represents the first approach, based on satellite images, to detect at **sub-pixel level and with such a great temporal resolution** these coastal changes. "*

Users' requirement achievement level

	Horizontal accuracy		Revisit		Production area	
	Requested	**Achieved**	**Early request**	**Produced after POC**	**Requested**	**Achieved after POC**
France	Waterlines: < 10 m Upper swash limit: 1-5 m	Waterlines:~20 m USL: •1.5 m with Pléiades •5.7 m with Sentinel-2	Waterlines: 2-4/year USL: 2-3/yr; 2/month in winter; before-after storms	Waterlines: yearly & 2/year (for each bathymetry produced USL: yearly	5 sites in PACA Region	5 sites in PACA Region
Germany	1-10	10-30m	1/year	1/year (with gaps for some years)	Sylt Odde Kiel Probstei	Sylt Odde Kiel Probstei Heiligenhafen
Greece	1 m	7.3 m (Sentinel-2) 4.3 m (SPOT) 13.2 m (Landsat)	1-5/year	Yearly from 1995-2008	Peloponnese, Eastern Macedonia &Thrace, Pieria, Zakynthos, Western Greeece	Peloponnese, Eastern Macedonia &Thrace, Pieria, Zakynthos, Western Greeece
Romania	1-5 m	App. 8 m for Sentinel-2 and app. 5 m for Landsat 8	Once per month	Once per month	Danube Delta coastal area	Danube Delta coastal area

End-users' testimonies

French

K. Bergeron (CAVEM): *"... **tool** essential for knowledge ... **to anticipate erosion and plan to relocate activities** [subject to strong hazards] ..." ; " **Robust communication tool** to plan and explain the coastal management ..."*

German

L. Christiansen, LKN: *"Especially the **frequent availability** as well as the **synoptic coverage** of large areas provide an **additional database** to laser data or hydrographic data."*

Romanian

Dr. Florin Tatui (University of Bucharest): *"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. 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."*

Greek

A. Nalmpantis (Region of Eastern Macedonia & Thrace): *"Through the Space for Shore project, **a comprehensive set of in situ scientific measurements, combined with numerous retrospective SAR remote sensing data were produced.** Thus, an evidence-based up to date assessment framework for the extent of coastal erosion was provided, rendering it **an extremely helpful and substantially incomparable toolkit to the coastal managers throughout the Region, both for present and future use**."*

ESA's expectation achievement level

- Semi-automated waterline extraction with accuracy below the pixel size.
- Retrospective products over the past 25 years, analysed over a thousand kilometres! (>1,000 km).
  - *Made possible thanks to a large open-source spatial dataset available*
- Based on past and recent images, covering all space resolution and time-revisit capacities.
- Large quantity of satellite data can be processed, over long periods of time.
- Analysis of large areas is possible.
- Errors, while still present, are systematic, due to low human intervention.
- Low to high frequency possibilities using satellite imagery to analyse the coastal dynamics according to the context.

Publications

- 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)
- Lafon, V., Dehouck, A., Robinet, A., Kalousi, G., Stelzer, K., Baptista, P., Costa, S., Echave, I., Gade, M., Tatui, F., Parcharidis, I., Sabatier, F., Serban, I., 2019. New trends in coastal erosion monitoring at the European scale: The Space for Shore comprehensive solution. ESA EO Φ-WEEK 2019.
- Débonnaire, N., Curti, C., Robinet, A., Echave, I., Sabatier, F., Lafon, V., Dehouck, A., Regniers, O., 2021. Comparaison de la performance de détection du trait de côte en Méditerranée à partir de différents capteurs satellitaires optiques et SAR. Contribution du spatial face aux enjeux de l'eau, 20 - 22 janvier 2021, Webinaire SHF CNES.
- K. Bantouvaki, M. Filaktos, G. Kalousi, K. Mytakidis, E. Fryganiotis, I. Parcharidis *"Shoreline mapping methods and validation using Sentinel 1 and GPS data"*, 2nd Remote Sensing and Space Applications Workshop, 2020.