Space for shore
Final Meeting

esa Coastal Erosion Project

European Space Agency

i-Sea Brockmann Consult GmbH Terra Spatium SA TerraSigna Kapitech Universität Hamburg universidade de aveiro

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WELCOME WORDS

PROJECT MANAGEMENT

A look back at our history

01 – 2019 T1
Birth of the Space for Shore consortium

02 – 2019 T2
Collection of needs and preparation of the roadmap

Definition of sites of interest, erosion monitoring indicators, time periods and frequencies, issues

Development and validation of algorithms on pilot sites

A total of 30 end users

03 – 2020 T1
Mid-term review and large-scale deployment

Production and evaluation phase by local experts

04 – 2021 T1
Regional demonstrations Users' feedback

In total, 1445 results over ~1500 km

05 – 2021 T3
Start of third year of the project – CCN1

Updating monitoring at the initial pilot sites until 2022

Addition of 300 km in each consortium member country

Integration of a new country: Norway

Start with new collection of needs (new end-users!)

New sites

A total of 47 new end-users

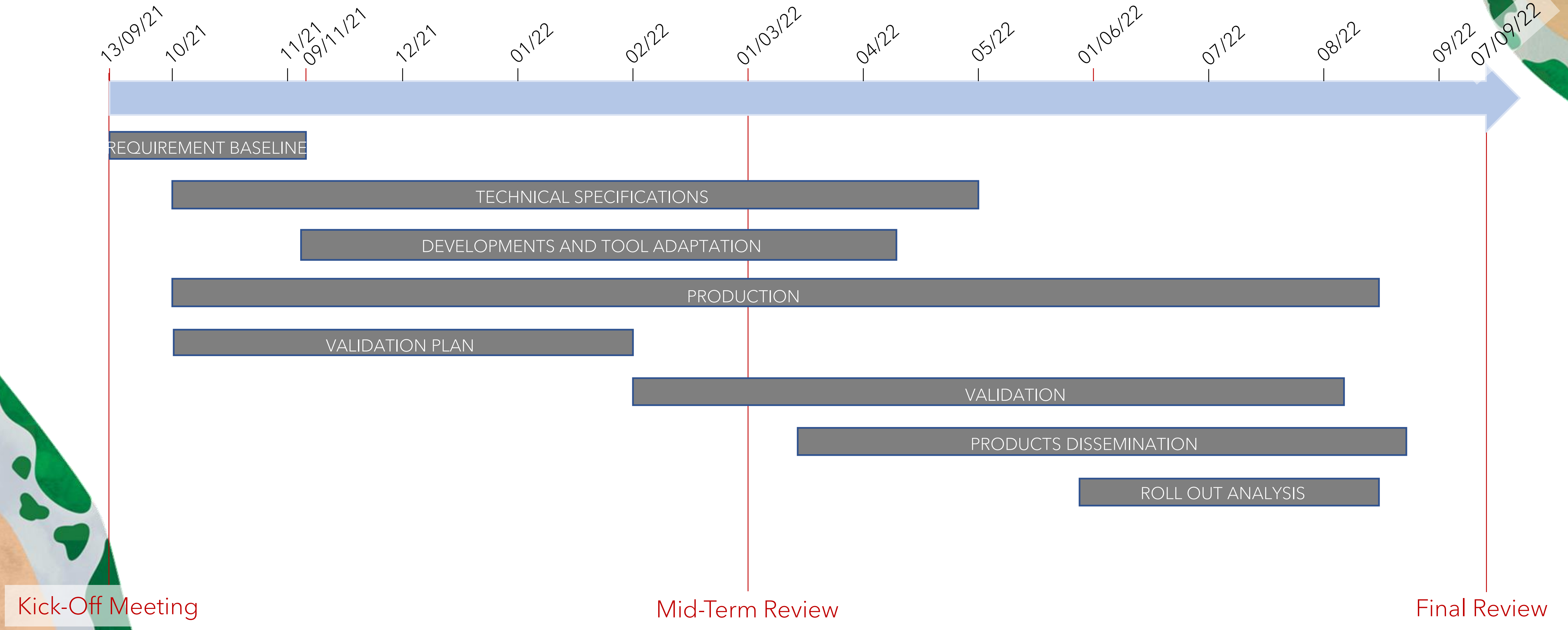
08 – 2022 T3
Regional demonstrations Users' feedback

In total, ~2500 results over ~2600 km

2022 T4
New service offer

2019: T1 T2 T3 T4 | 2020: T1 T2 T3 T4 | 2021: T1 T2 T3 T4 | 2022: T1 T2 T3 T4

A look back at our history



Deliverables

DIL	Deliverable	Delivery Date	Status
Management Deliverables			
PMP	Project Management Plan	Kick-Off meeting	DELIVERED (early sept/21)
	Bi-monthly progress reports	Every 2 months, at the end of the calendar month	DELIVERED (every 2 months)
AIL	Action Item List	After each progress meeting/review and together with the bi-monthly Progress Reports	DELIVERED (last one 08/25/2022)
MoM	Meeting Agenda	One week prior to each progress meeting/review	
	Minutes of Meeting	At the end of the progress meetings / project reviews.	
	Meeting Hand-outs	At the end of the progress meetings / project reviews.	
	Executive Summary	Final Review	
Technical Deliverables			
RB	Requirement Baseline	Mid-Term Review	DELIVERED & UPDATED (v1, 11/03/21; v2, 15/12/21; v3, 10/02/22)
TS	Technical Specification	Mid-Term Review	DELIVERED & UPDATED (v1,15/12/21; v2, 20/07/22)
PVP	Product Validation Plan	Mid-Term Review	DELIVERED (v1,15/12/21; v2, 10/02/22)
Prod	Product Delivery	Time wise (to users) MTR and Final Review (to ESA)	1st set, 03/03/22 (revised 15/03/21), 2nd set 08/31/22
PVR	Product Validation Report	Final Review	DELIVERED (09/08/22)
FR	Final Report	Final Review	DELIVERED (08/28/22)
SRA	Service Roll-out Analysis	Final Review	

Major risks anticipated

	Where the problem was encountered	How we managed
• Avorted end-users' collaboration	Norway	
• Uncomplete user forms	Portugal, France	Individual phone calls
• ~~Technical partner abandon~~		
• Misunderstanding between partners	Consortium	Regular meetings to ajust the steps
• Inconclusive results from algorithms	Portugal	Cliff lines tested, timeseries shortened Coastlines: new dev in France
• Constrains in uploading results in new platform	Deimos platform	Renaming the products & negociations
• ~~User requirement late delivery~~		
• Inhomogeneous validation actions	Germany, Romania	Correspondence from other regions
• Uncertainty on the market potential targeted	Portugal	Improve visibility & continue discussions
• Unavailable validation data	Germany	Qualitative assessment from local experts
• Insufficient spatial resolution	Portugal	
• Too much production considered	France, Norway	Reinforcements hired & automation
• End-users' participation delayed or canceled	Norway	Negociations in progress
• Changes in ROIs	Greece	Roadmap adjusted
• Delay in production	France	Reinforcements hired

STARTING POINT

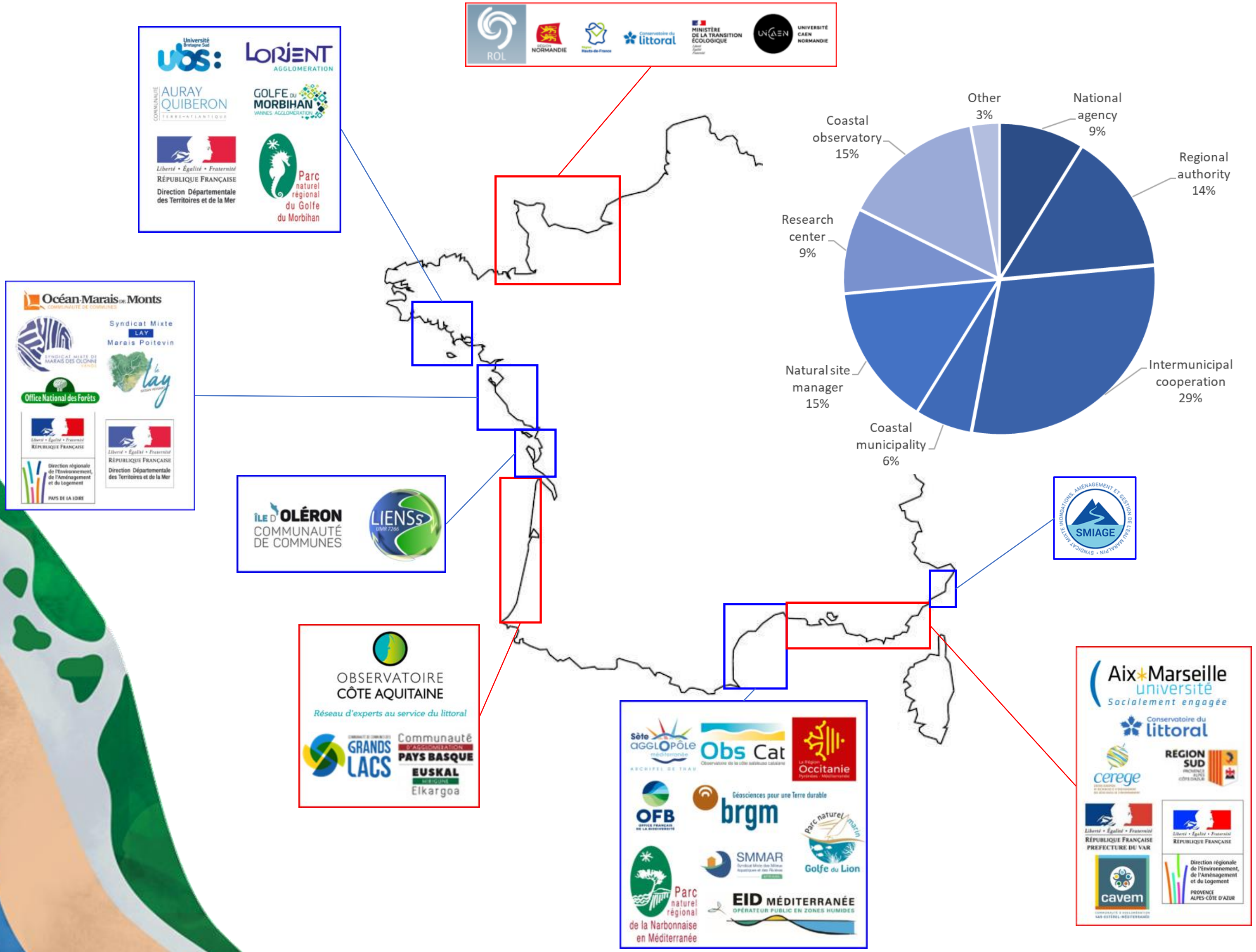
END-USER NEEDS

INDICATORS

TECHNICAL SPECIFICATIONS

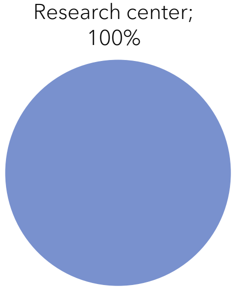
France

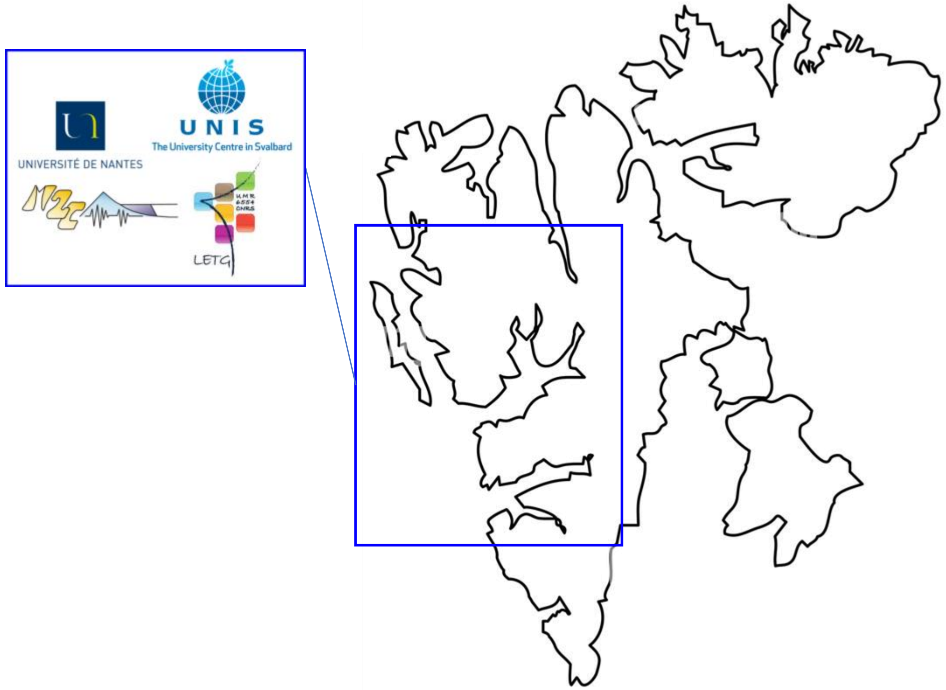
34 engaged end-users



Norway

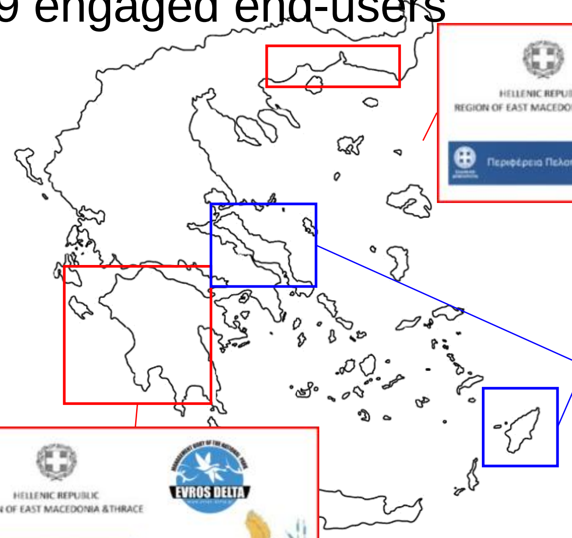
2 engaged end-users





Greece

9 engaged end-users



HELLENIC REPUBLIC
REGION OF EAST MACEDONIA & THRACE

EVROS DELTA

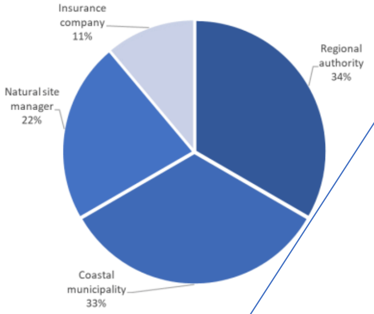
Περιφέρεια Πελοποννήσου

ΔΗΜΟΣ ΧΑΛΚΙΔΕΩΝ

Municipality of Rhodes

INTERAMERICAN INSURANCE COMPANY

REGION OF CENTRAL GREECE

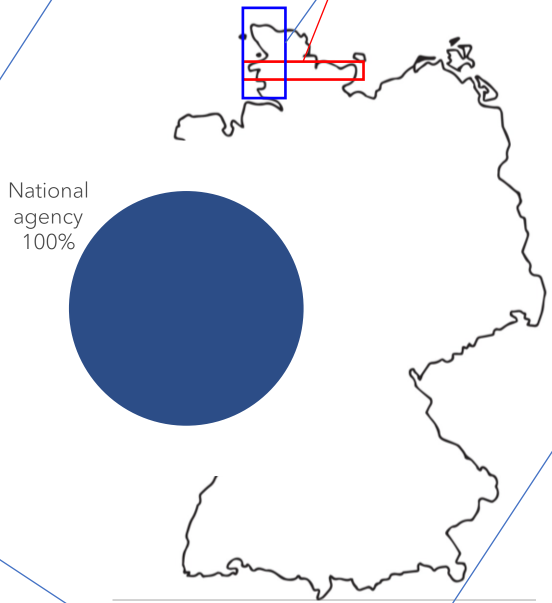


Germany

2 engaged end-users

LKN.SH
Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein

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



Portugal

13 engaged end-users

cesam

AGÊNCIA PORTUGUESA DO AMBIENTE

OVAR CÂMARA MUNICIPAL

ALCOBAÇA

apa

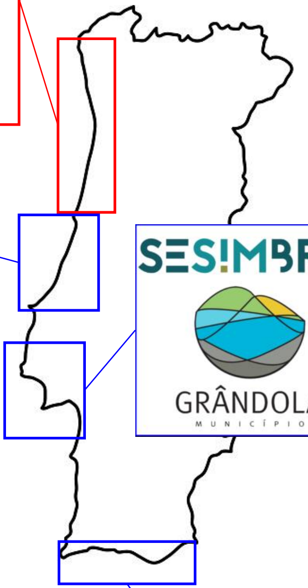
MARINHA GRANDE

Torres Vedras Câmara Municipal

Sines

SESIMBRA

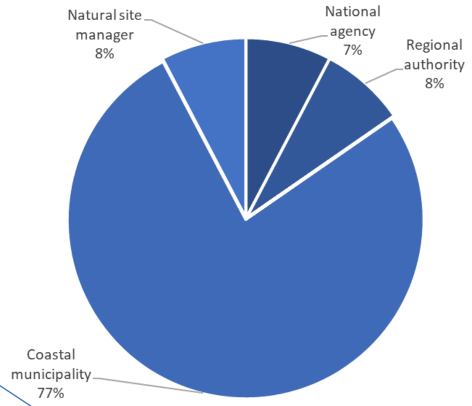
GRÂNDOLA MUNICÍPIO

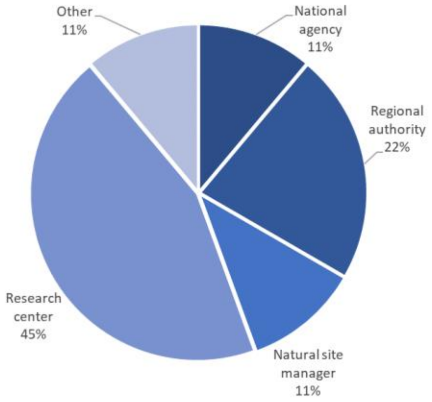


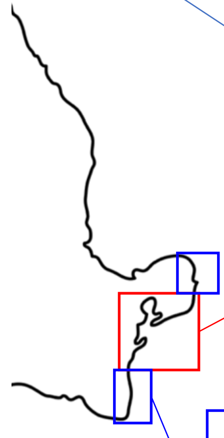
LOULÉ

ARH ALGARVE

Faro







SFÂNTU GHEORGHE MARINE AND FLUVIAL RESEARCH STATION

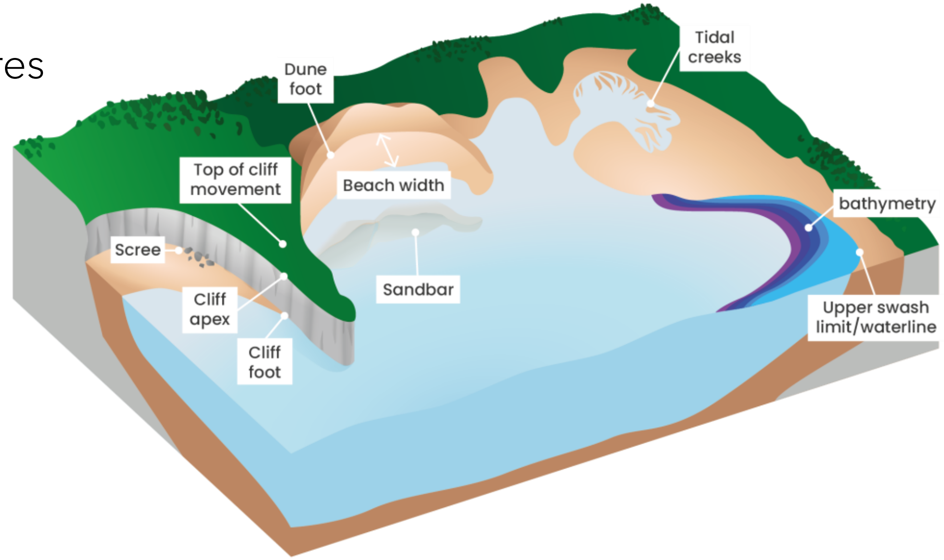
INCDM

Romania

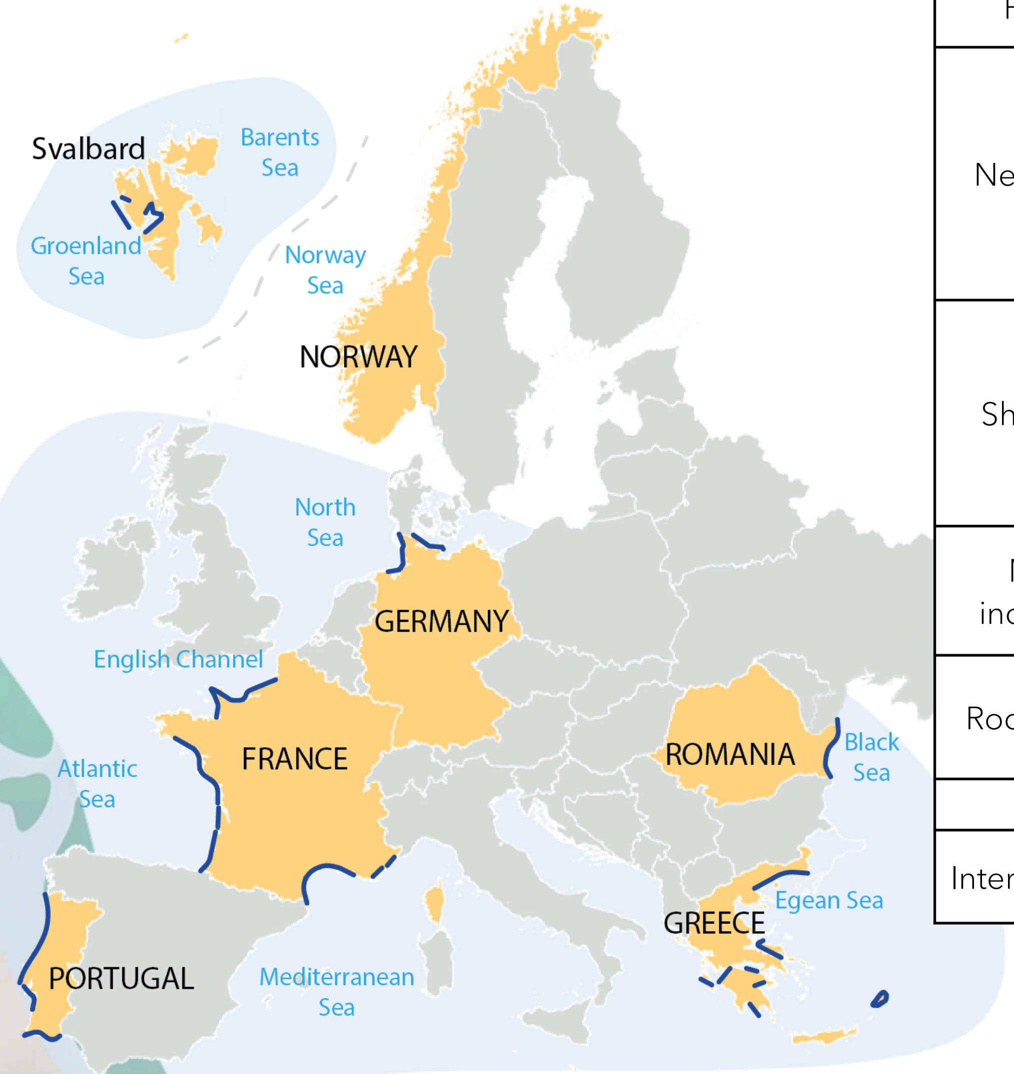
9 engaged end-users

Requirements - Key numbers Phase 3

- 6 countries: France, Germany, Greece, Portugal, Romania, and Norway (Svalbard)
- 35 interviews
- 47 new end-users,
  - Public sector:
    - National governmental agencies, regional authorities and municipalities, as well as Natura site managers, research centres and coastal observatories
  - Private sector:
    - Insurance company
- 6 product families, 10 high priority indicators
- ~ 1800 products were requested to support current and future practices
  - Fully described in terms of product accuracy, update and delivery frequency
  - Some often requested, other rarely cited



User needs and match with indicators & technical specifications



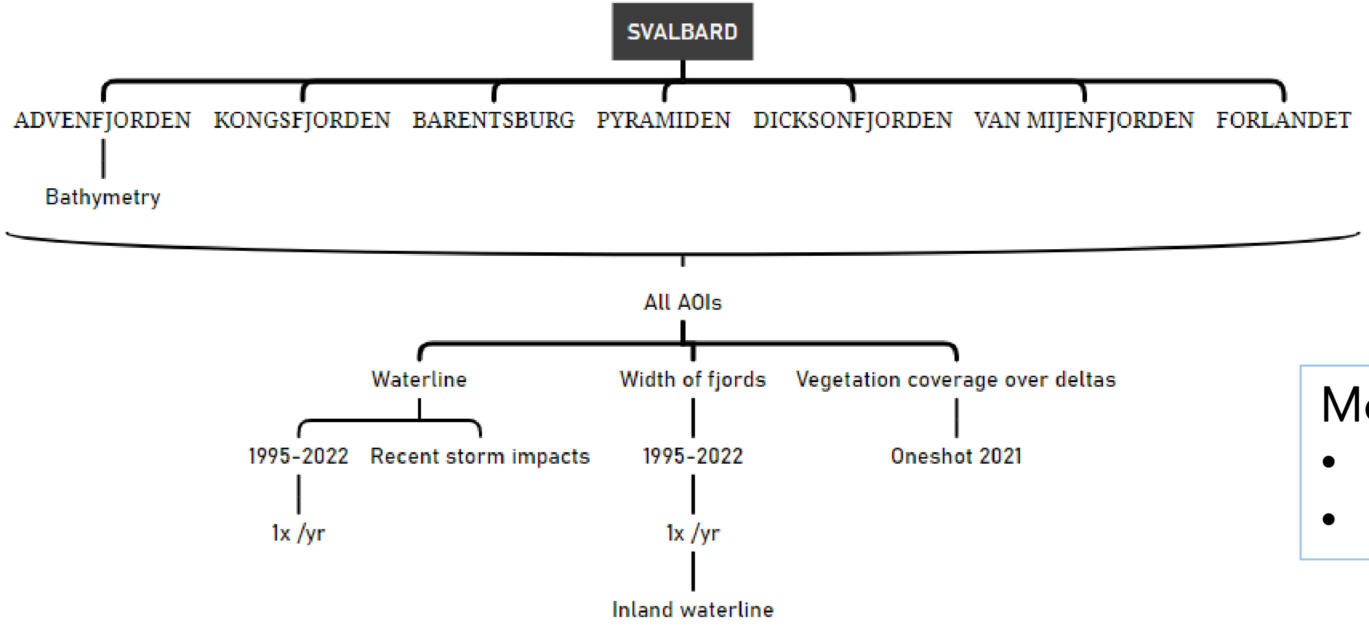
Family	Indicators	FRANCE	NORWAY	GERMANY	ROMANIA	GREECE	PORTUGAL
Nearshore	Bathymetry	3	0			0	3
	Nearshore sandbars	2		3	3		3
	Shallow water sand detection	1		3			
	High sands			3			
Shoreline	Dune foot	3	0				2
	Upper swash limit	3					0
	Waterline / HWL limit	3	3	3	3	2	3
	Vegetation limit	2	0				0
Multi-indicators	Beach width	1				2	2
	Erosion/vulnerability index	2	0	2			
Rocky coast	Cliff lines	0					2
	Top of cliff movement						2
Fjord	Width of fjords		2				
Intertidal area	Intertidal banks	1					
	Tidal creeks		0	3			0

	High priority	No high priority
Validation data	3	1
No validation data	2	0

France

Monitoring more requested:
- Short-term (2015-2022)
- Seasonal (2x/yr)

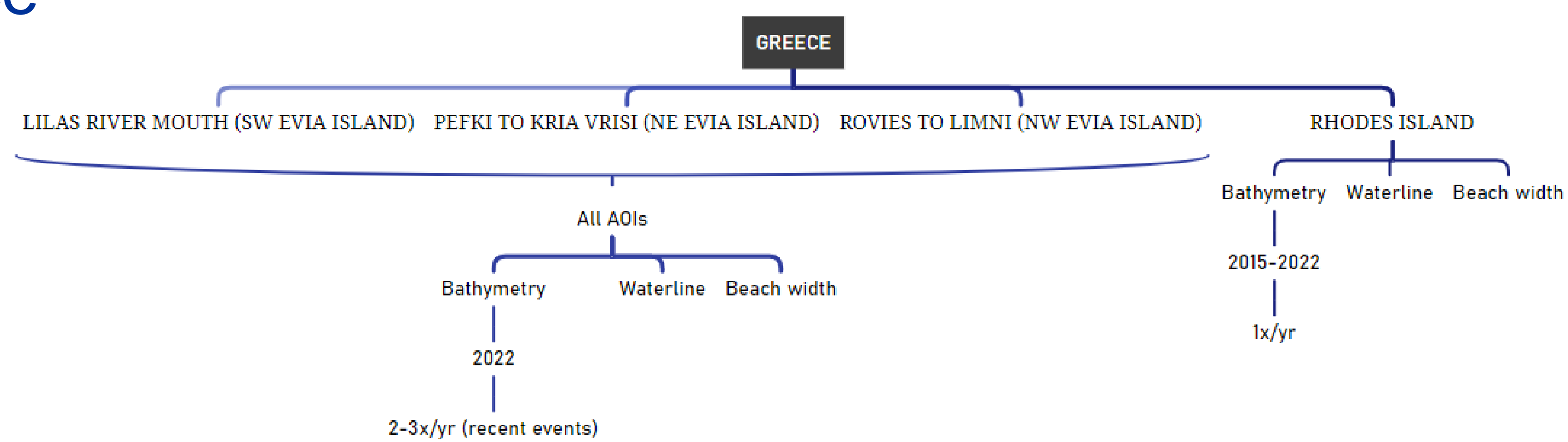
Svalbard



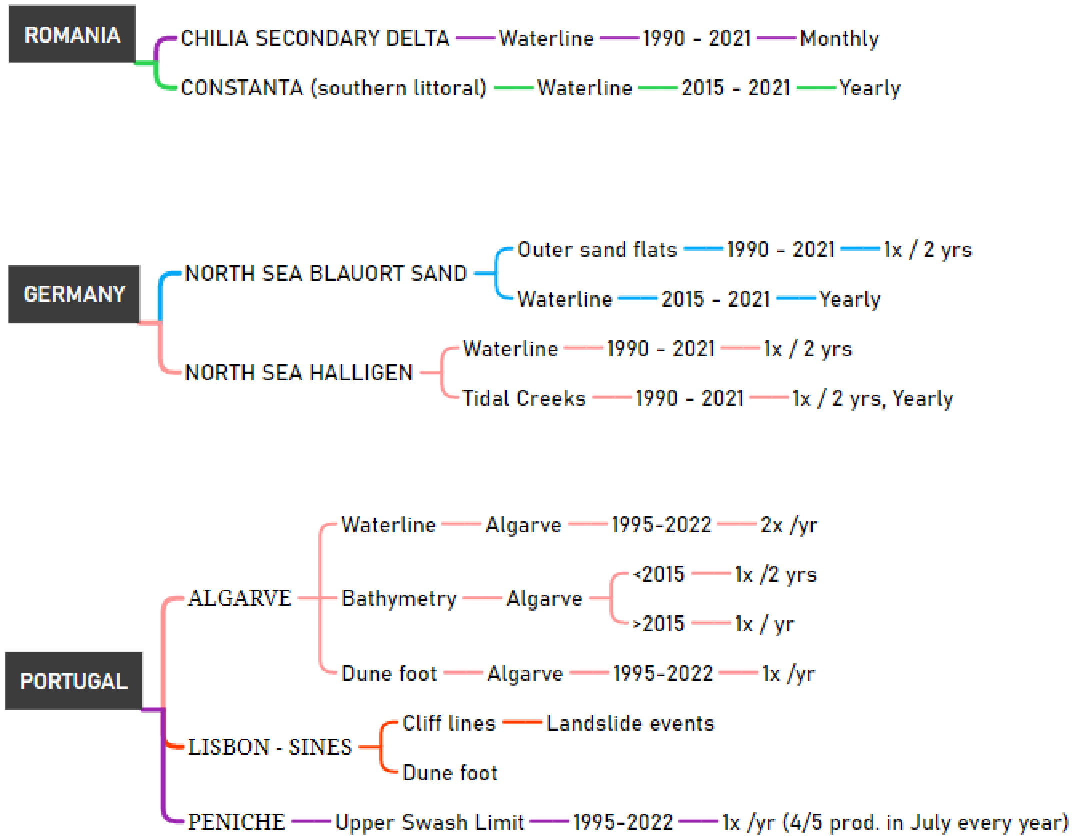
Monitoring more requested:

- Long-term (1995-2022)
- Annual (1x/yr)

Greece



Romania, Germany, Portugal



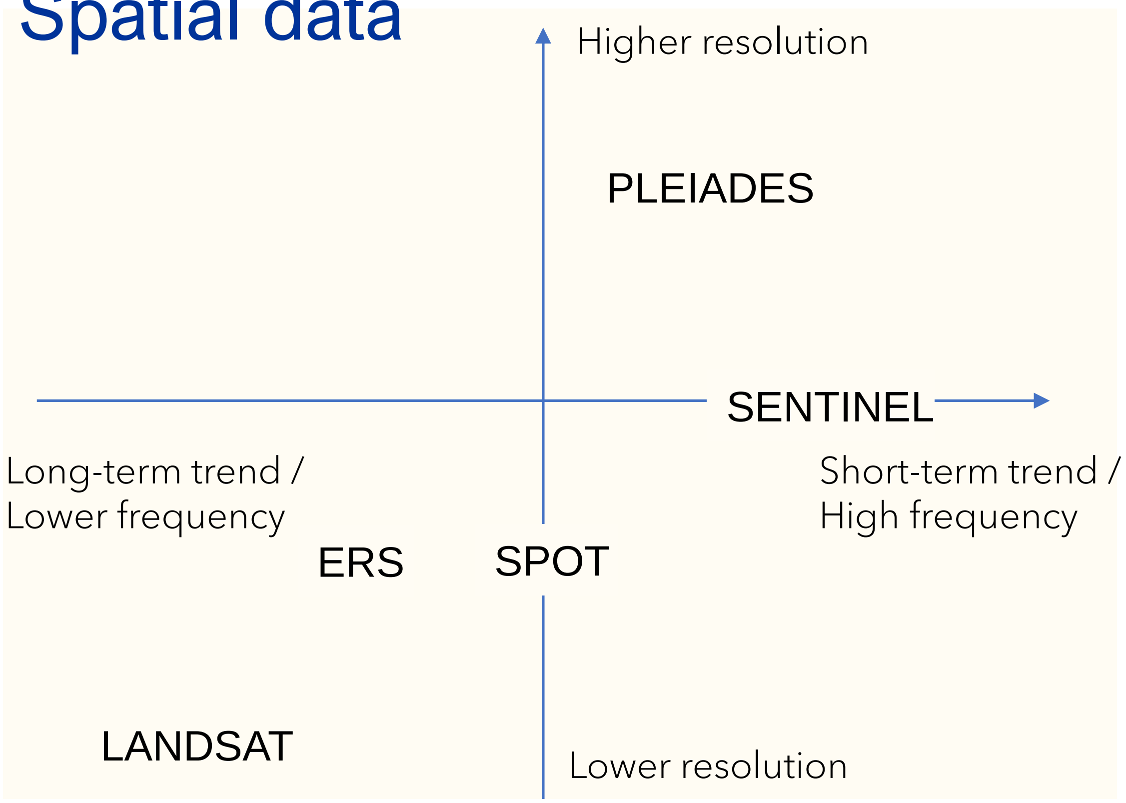
Monitoring more requested:
- Annual (1x/yr)

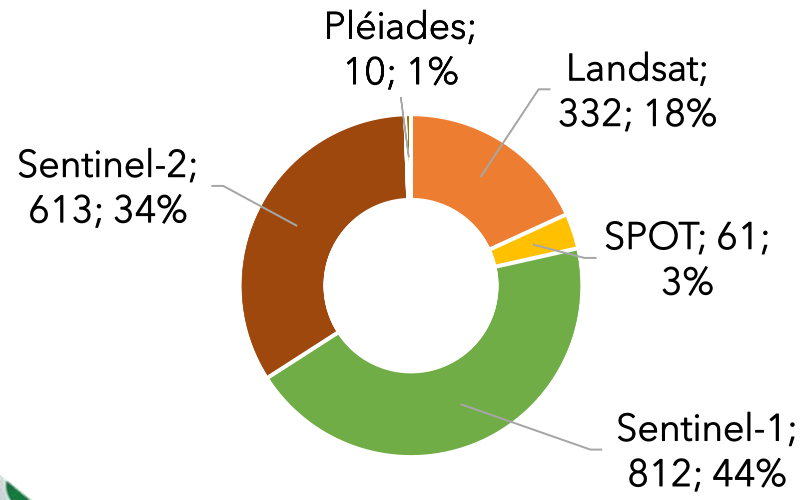
MAIN TRAJECTORIES

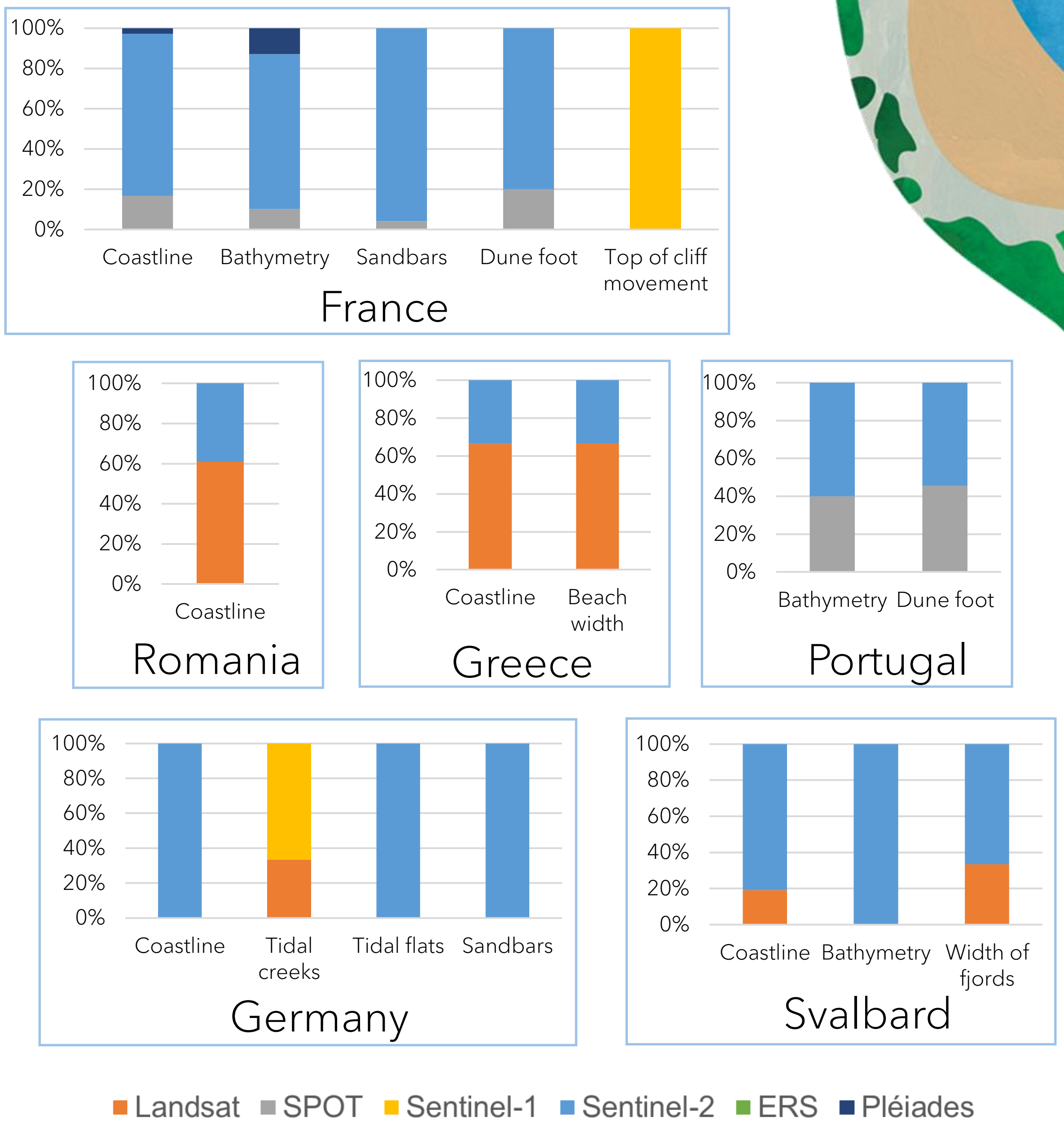
SPATIAL DATA USED

STRATEGIES AND APPROACHES ADOPTED

Spatial data

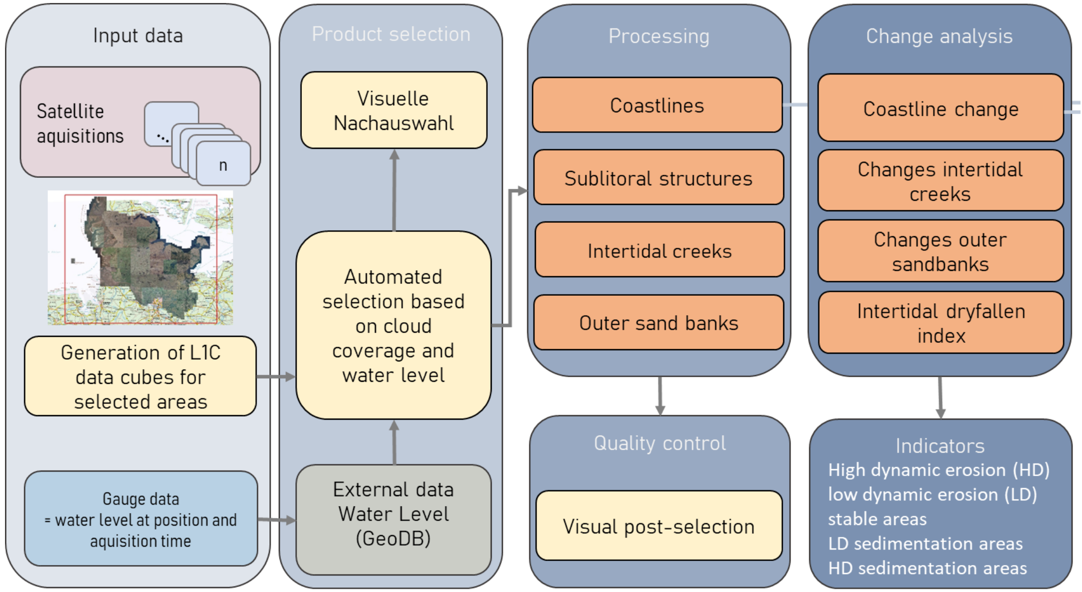




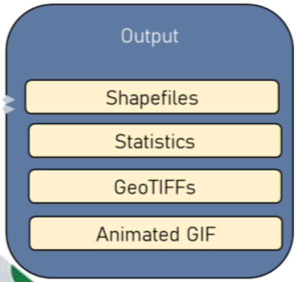


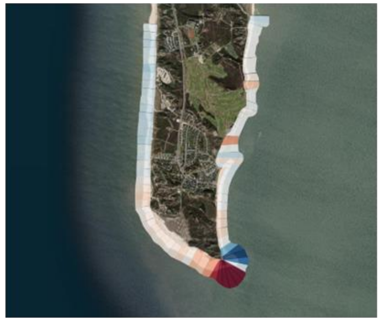
IDEAS MADE REAL

Automate

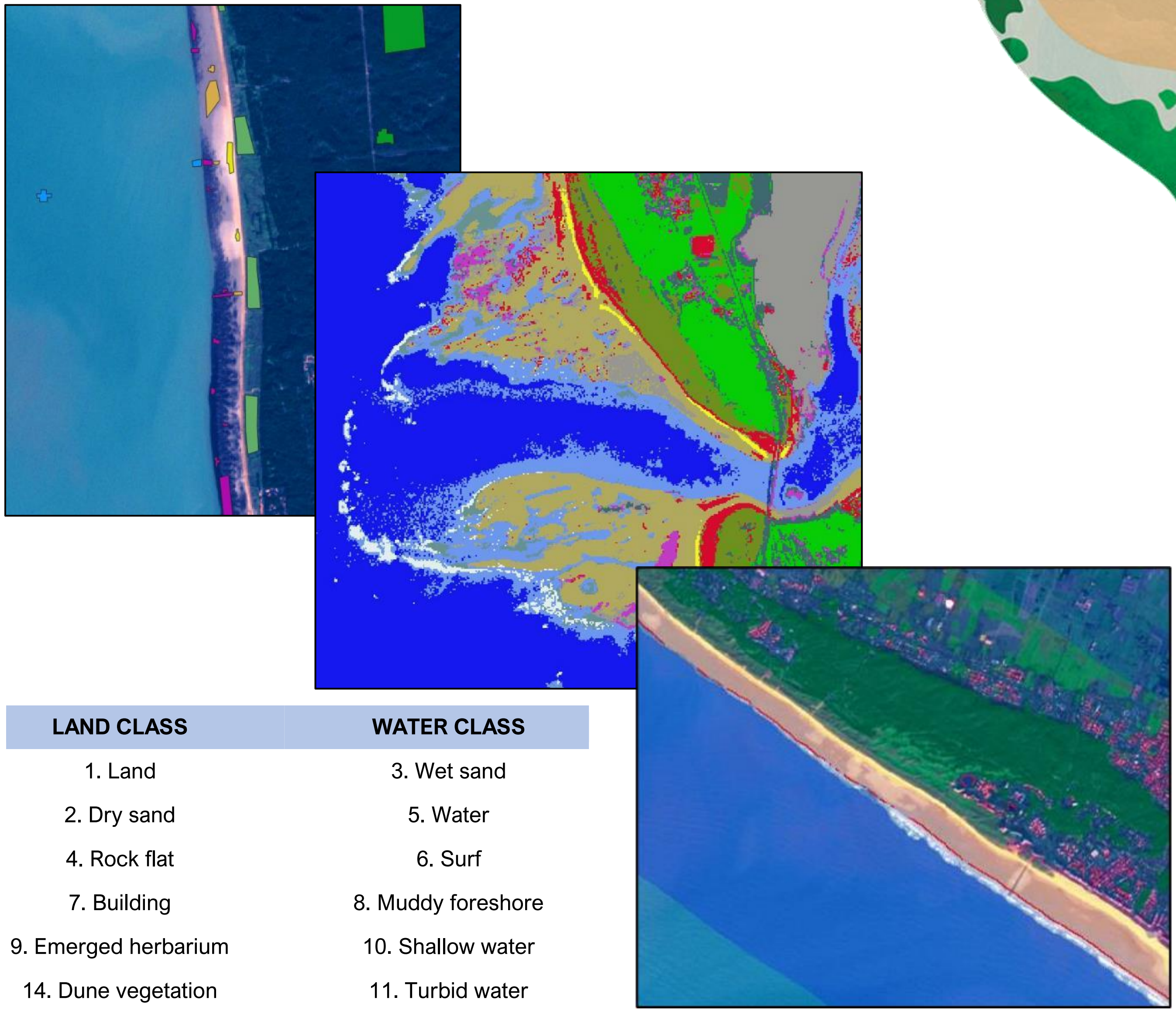


- Work carried out in close collaboration with end-users
- Well-documented code
- Mix from interactive and automated steps
- Parametrisation for optimal adaptation
- Visual inspection allowed at various steps





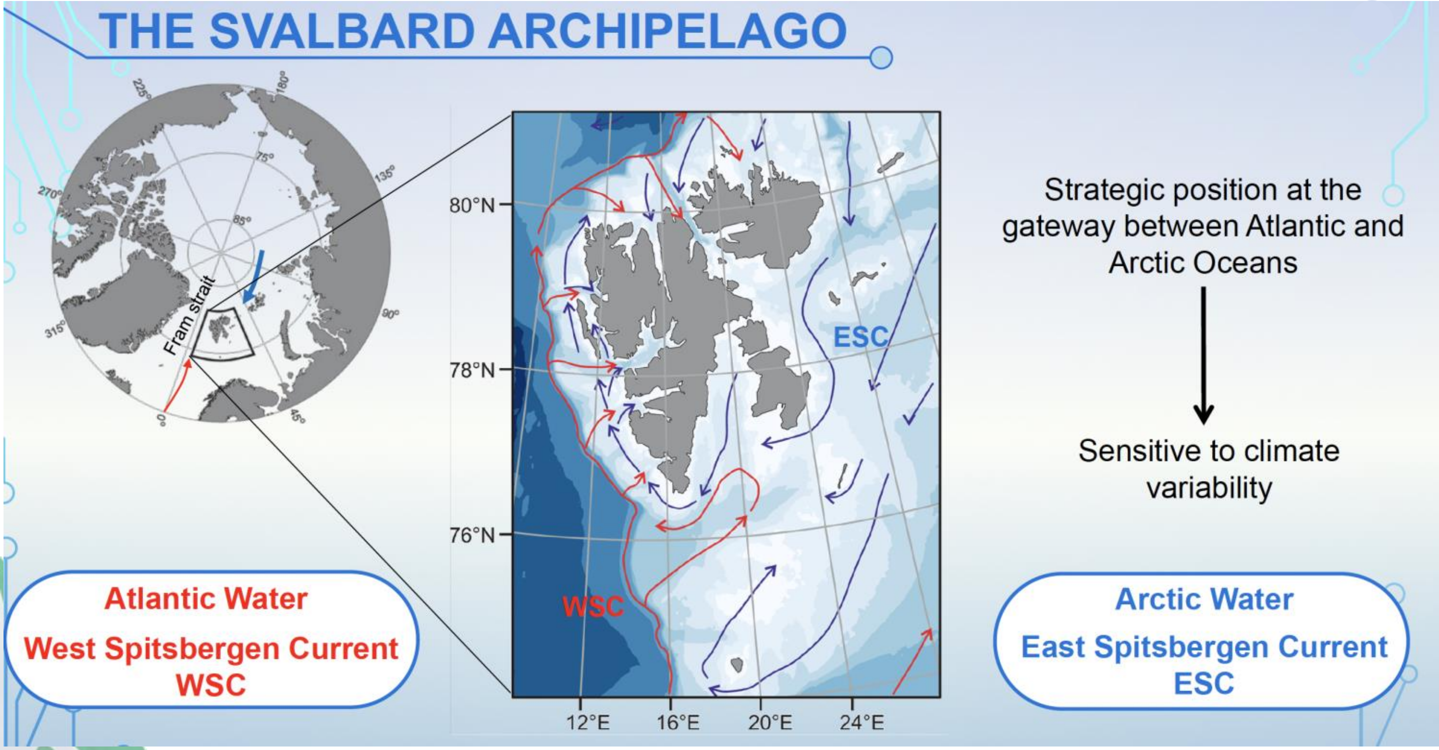
Generalise



LAND CLASS	WATER CLASS
1. Land	3. Wet sand
2. Dry sand	5. Water
4. Rock flat	6. Surf
7. Building	8. Muddy foreshore
9. Emerged herbarium	10. Shallow water
14. Dune vegetation	11. Turbid water
	12. Water on rock
	13. Submerged herbarium

IDEAS MADE REAL

Reach inaccessible areas



- Assessing the relevance of our tools to new coasts
  - highly dynamic
  - Poorly mapped
  - Limited spatial data
  - Complex environments

Cross the boundaries

- Favour the natural geomorphological continuum instead of administrative borders

IDEAS MADE REAL

Share

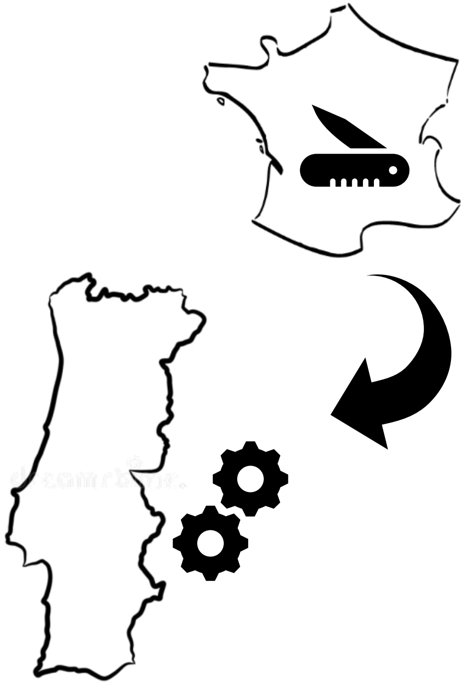
Space for Shore

ESA EOEP-5

ESA Coastal Erosion – CCN n°1

Contract n° 4000126776/19/I-LG

Coastal Tool Tutorial
Upper Swash Limit



Promote

on-line SafeGreece 2021
new technologies & civil protection
& 2022

living planet symposium | BONN 23–27 May 2022
TAKING THE PULSE OF OUR PLANET FROM SPACE

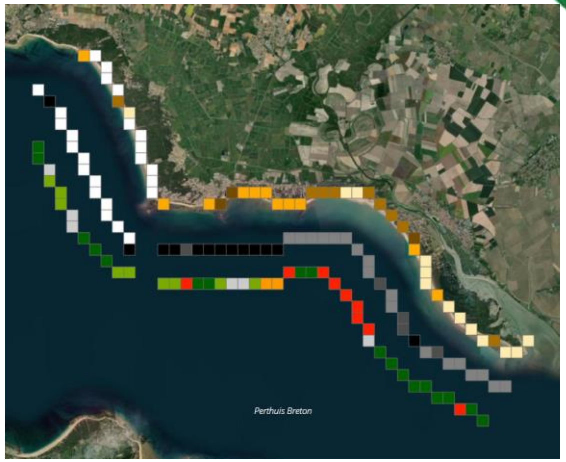
16TH INTERNATIONAL CONFERENCE
LITTORAL 22
12 - 16 SEPTEMBER | COSTA DA CAPARICA, PORTUGAL
ADAPT OUR COAST FOR A SUSTAINABLE FUTURE

HEALTHY OCEANS TECH AND FINANCE FORUM
Innovative Solutions for Asia and the Pacific | 26-28 JANUARY 2022
ADB

XVIème JOURNÉES NATIONALES
GÉNIE CÔTIER - GÉNIE CIVIL

Etc....

Vulgarise



Low erosion — Strong erosion

Low issues — High issues

Low risk — High risk

PORTFOLIO OF PRODUCTS

COASTLINE INDICATORS

Dune foot

A relevant but complex indicator

- Coastline reference commonly used on sandy coasts
- Complex: there is no consensus on its definition even in the field

Upper swash limit

To monitor the trends only, not the instantaneous variations of coastline positions

- Over an entire region
- Closest to the in-situ measurements

Waterline

The most commonly used indicator, the most frequent monitoring

- 1 satellite image can become 1 waterline positioning
- Opens the possibility to monitor tidal fluctuations overs the beach morphologies

Dune foot evolution : example in Vendée (FRANCE)

Dune foot position

1995

2022

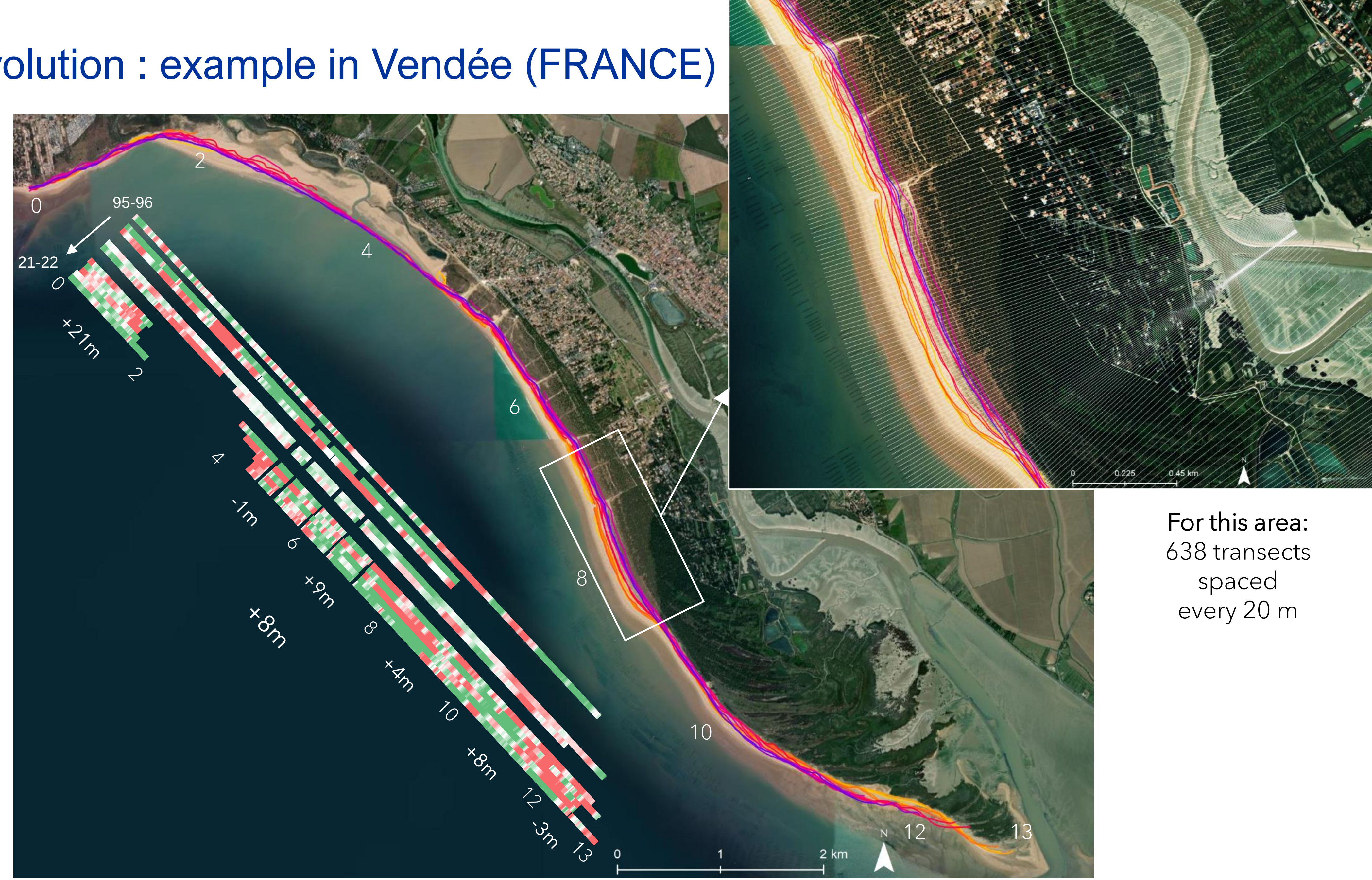
Annual change

Accretion

Erosion

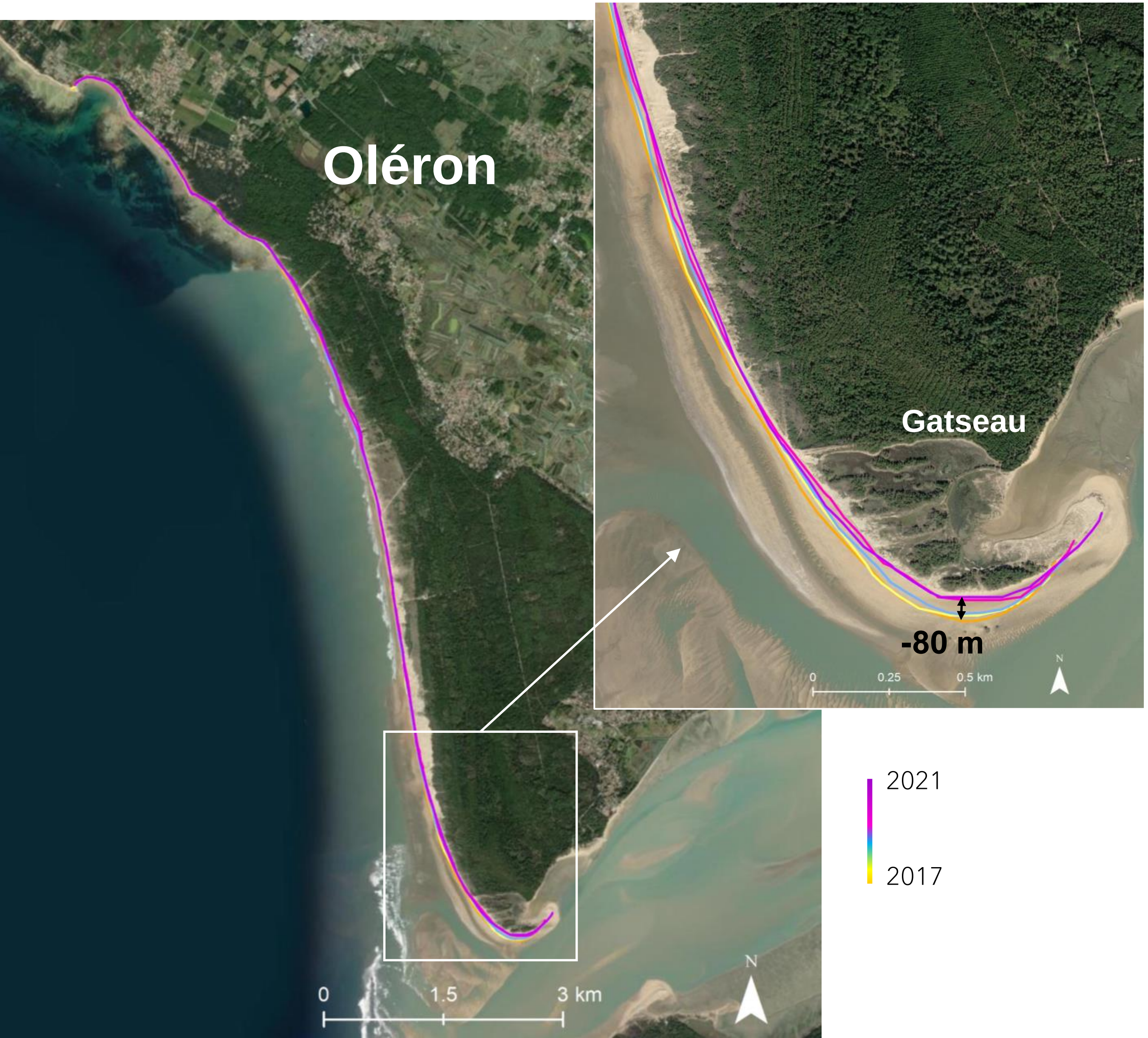
Average:
0.45 m/an

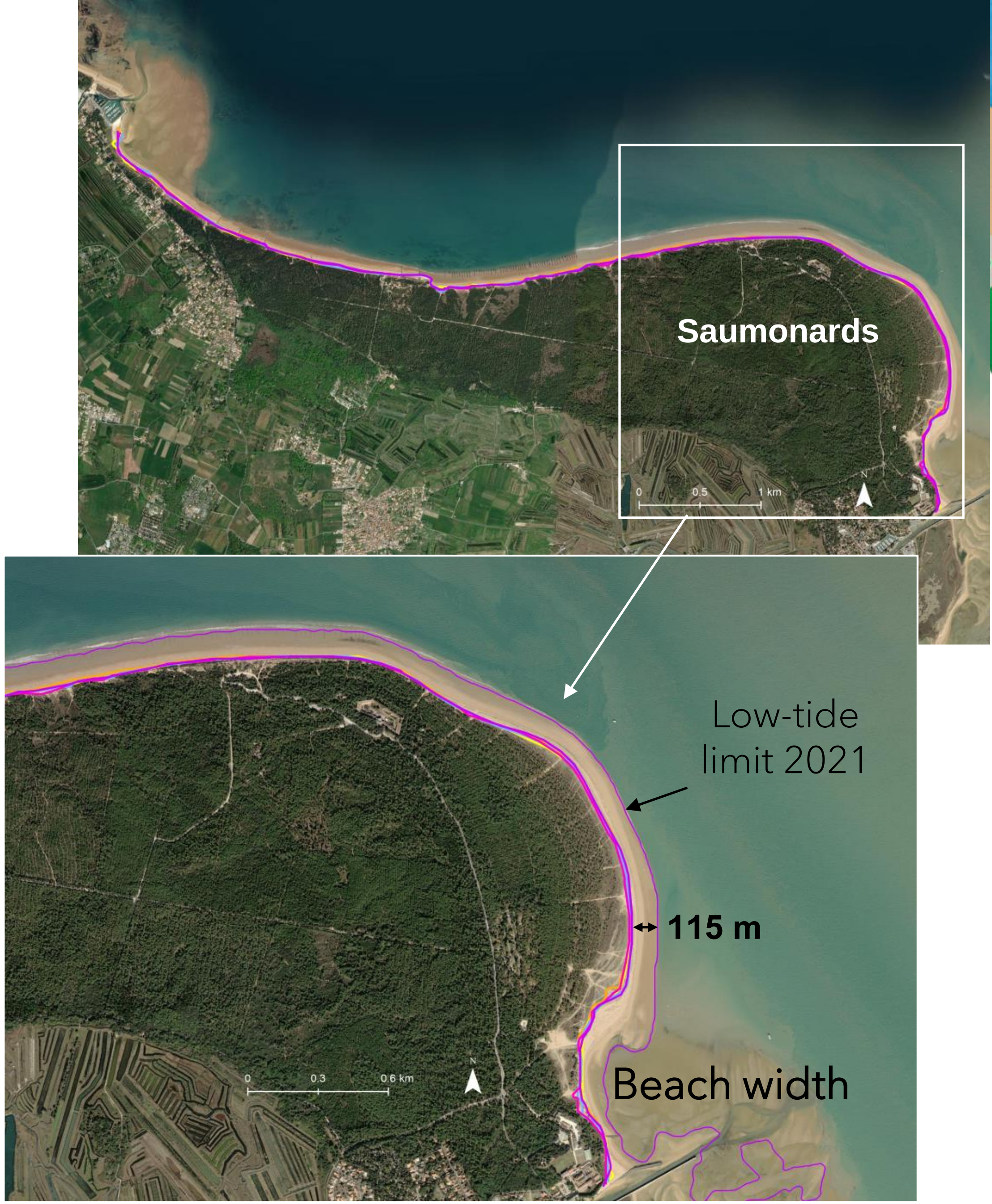
Min : -6 m/yr
Max : + 15 m/yr



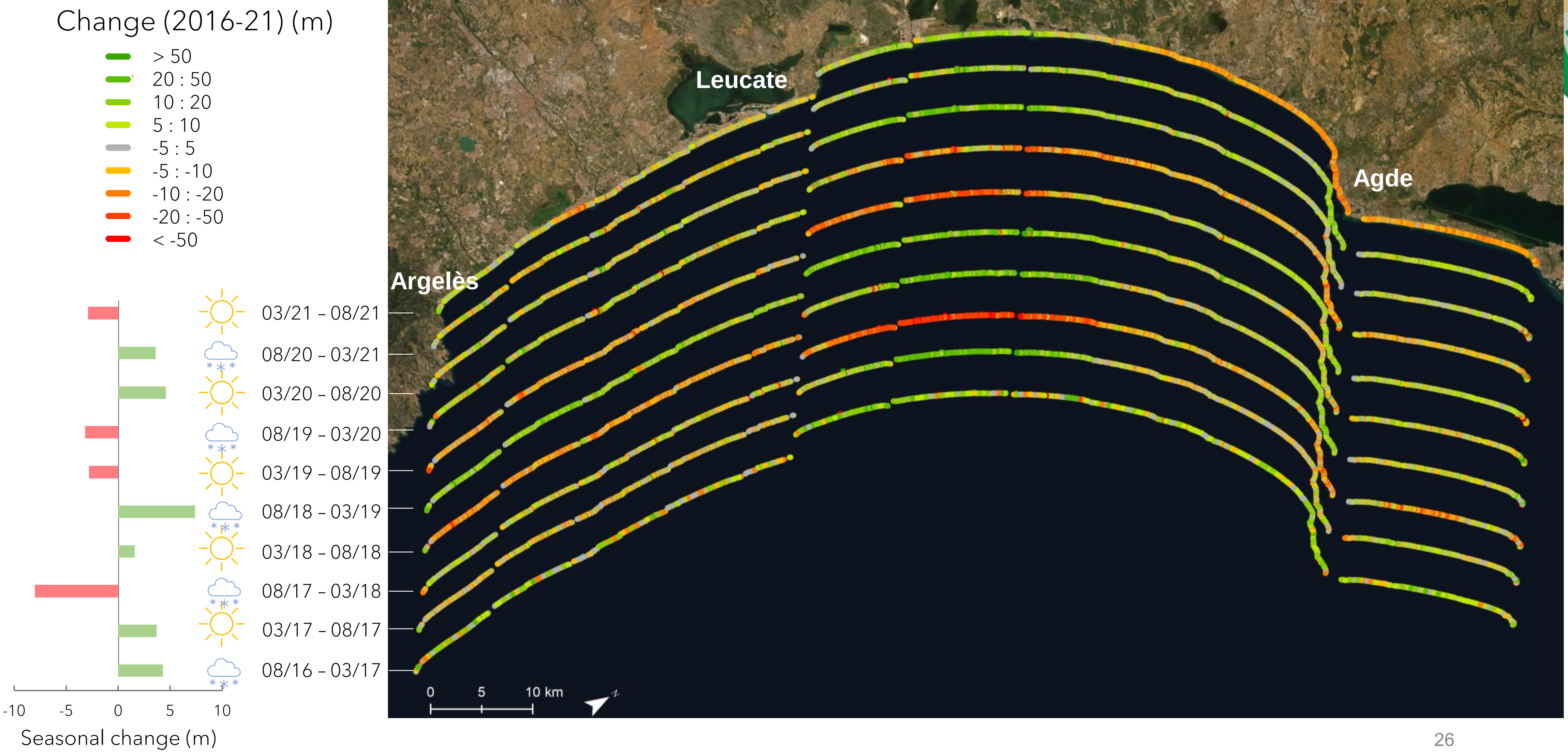
For this area:
638 transects
spaced
every 20 m

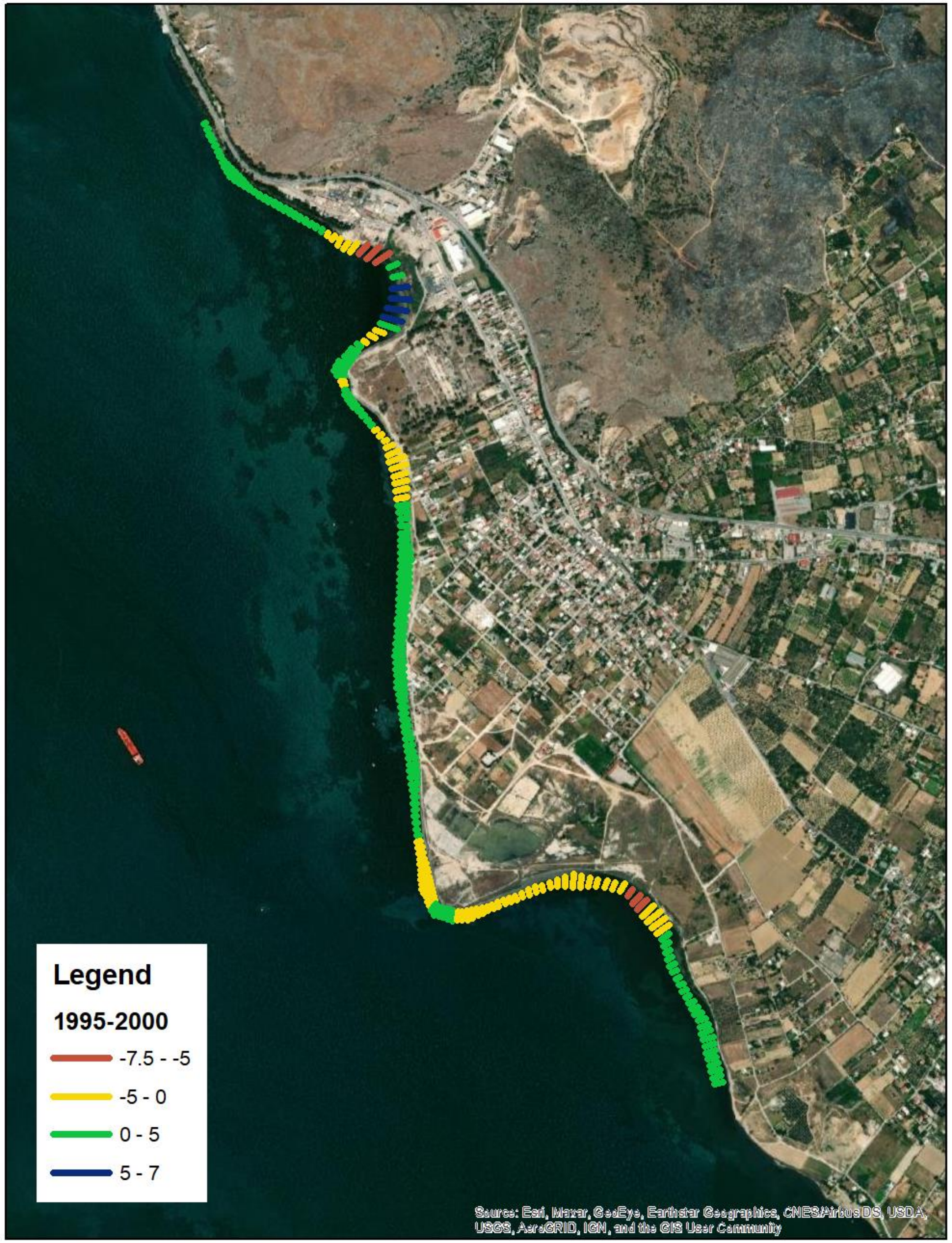
Dune foot extraction for estimating the beach width and sandy budget

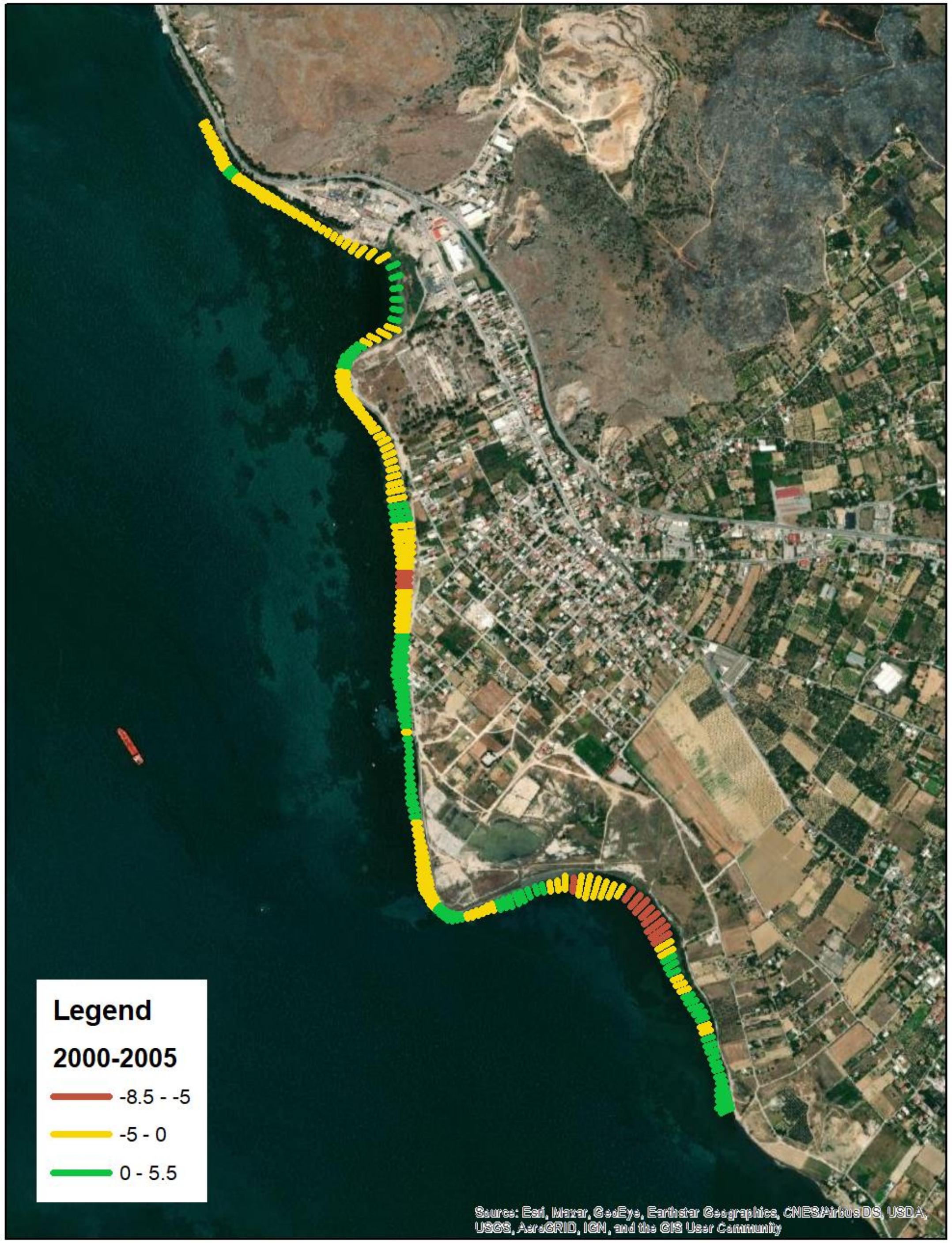




The upper swash limit
Regional and seasonal evolution







ion

Waterline Trend:

Erosion both for 1995-2000 and 2000-2005,
at a constant rate.
It appears more intense in specific areas.

Waterline Changes, 5-year evolution

Waterline Trend:

Accretion for 2005-2010, due to in-situ interventions with technical works of beach nourishment.

tion

Waterline Trend:

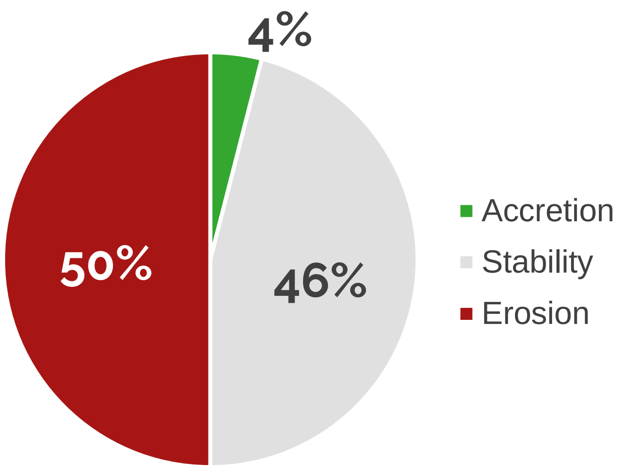
Erosion for 2013-2015
The works were not enough to defend the coast!

Erosion continues for 2015-2020,
at a constant rate.

Beach Width, microtidal, every 5year

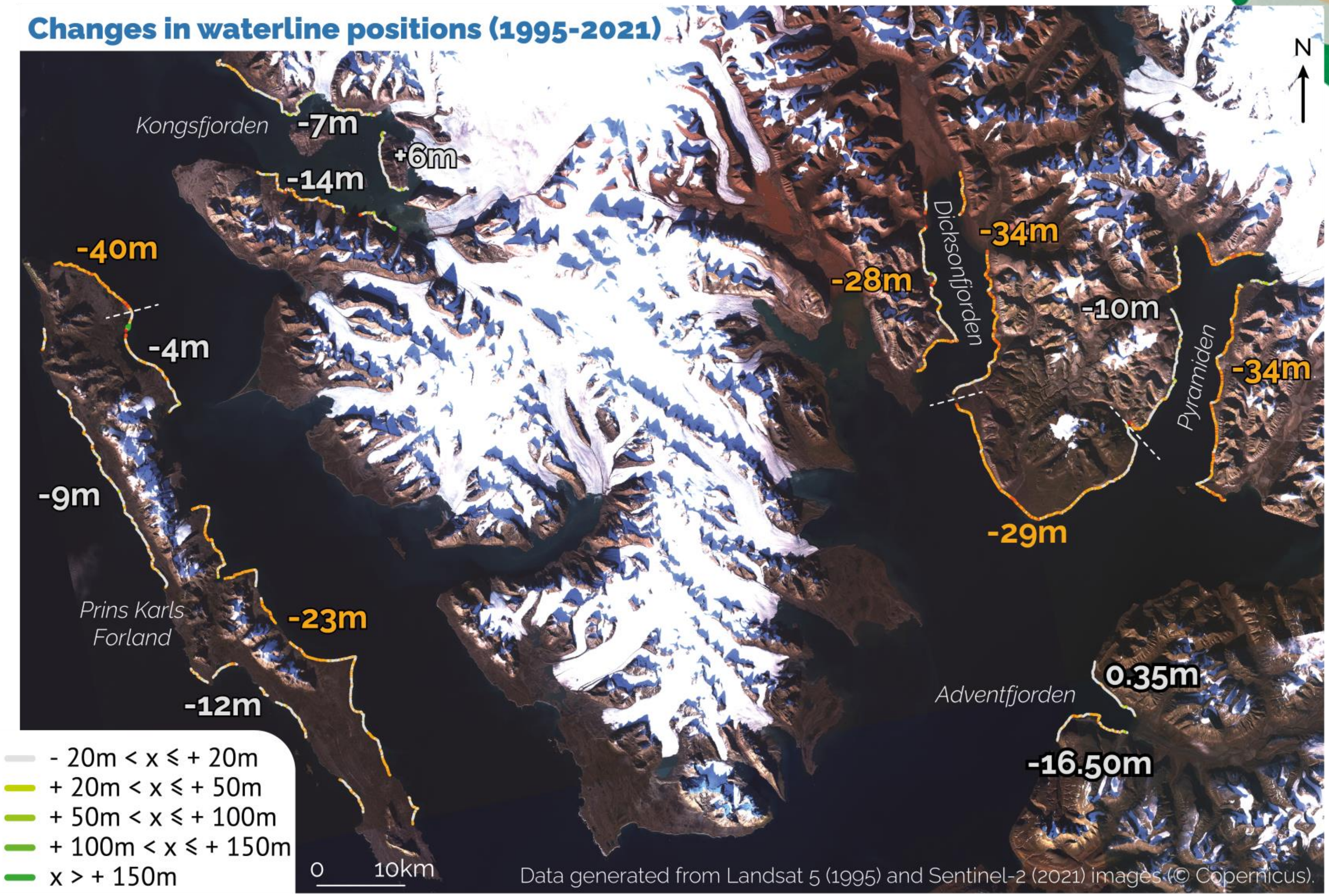
The coastline changes somewhere in Arctic...

- **Shoreline retreat** = main pattern of change

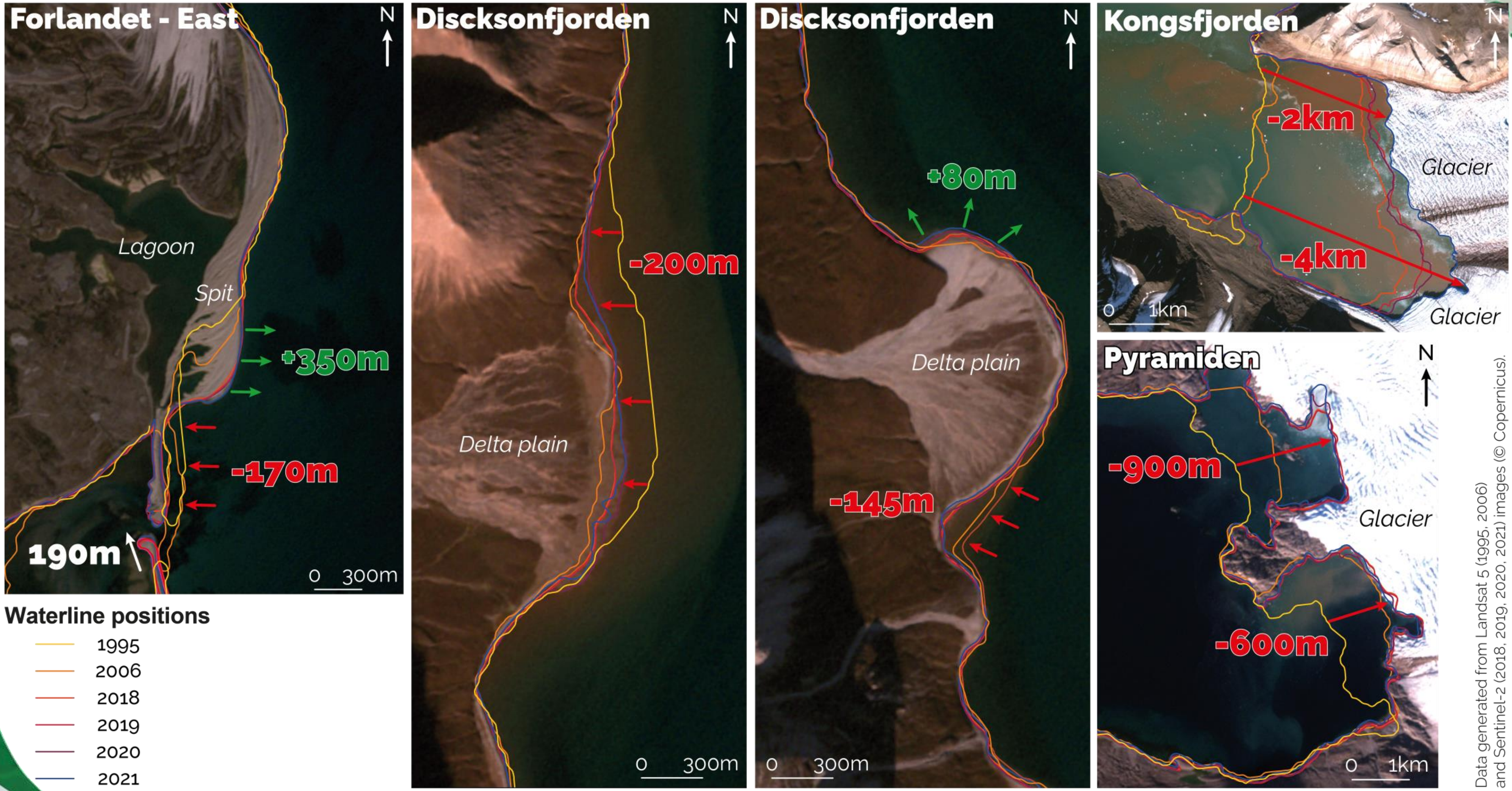


Extreme values :

- **-200m** (Dicksonfjorden)
- **+350m** (Prins Karls Forland)



Rapid evolution due to climate change (melting ice, SLR...)



Data generated from Landsat 5 (1995, 2006) and Sentinel-2 (2018, 2019, 2020, 2021) images (© Copernicus).

PORTFOLIO OF PRODUCTS

INTERTIDAL INDICATORS

Tidal Flat areas and TFFI

How often is an area exposed?

- Using all acquisition representing different water levels
- If related to water level (gauge measurements), bathymetry can be derived by applying water line method
- Plus of SAR images because of max possible number of acquisitions

Tidal creek morphology and changes

How stable is the system? Were happens erosion / accretion?

- Only low tide images can be used -> reduces number of suitable acquisitions
- New information from satellite data – never received this information before

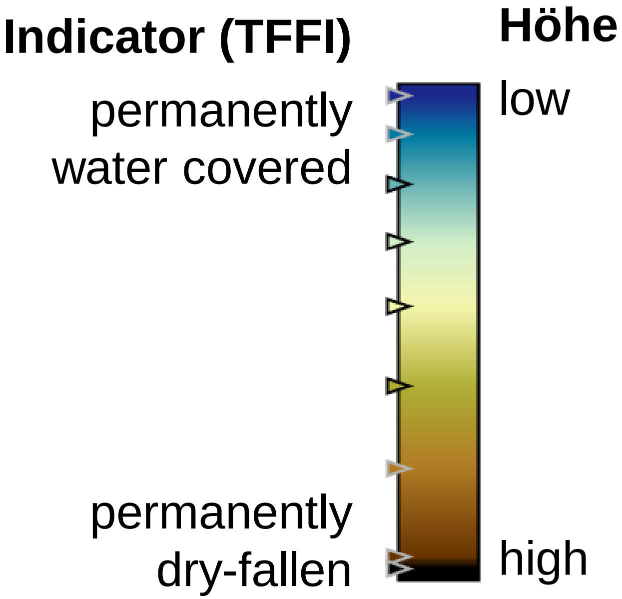
Outer sandbanks movements

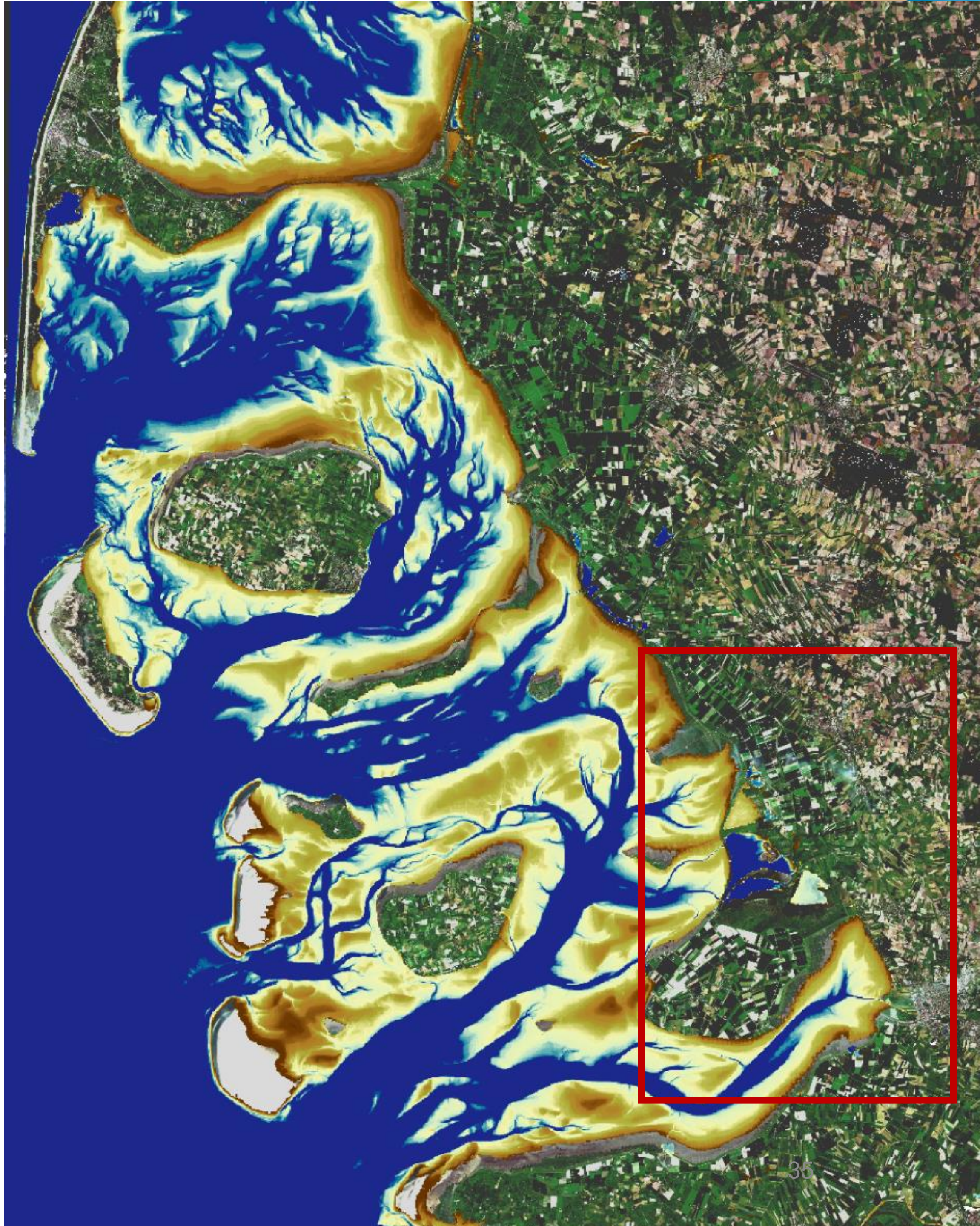
Where do the outer sandbanks move to? Are there new formations developing?

- New information from satellite data – never received this information before

Tidal Flat areas and TFFI

- Automated selection of cloud-free images for all water levels
- Identification of water-covered and dry-fallen areas per image
- Calculation of frequency of dry-falling per year and for all years.



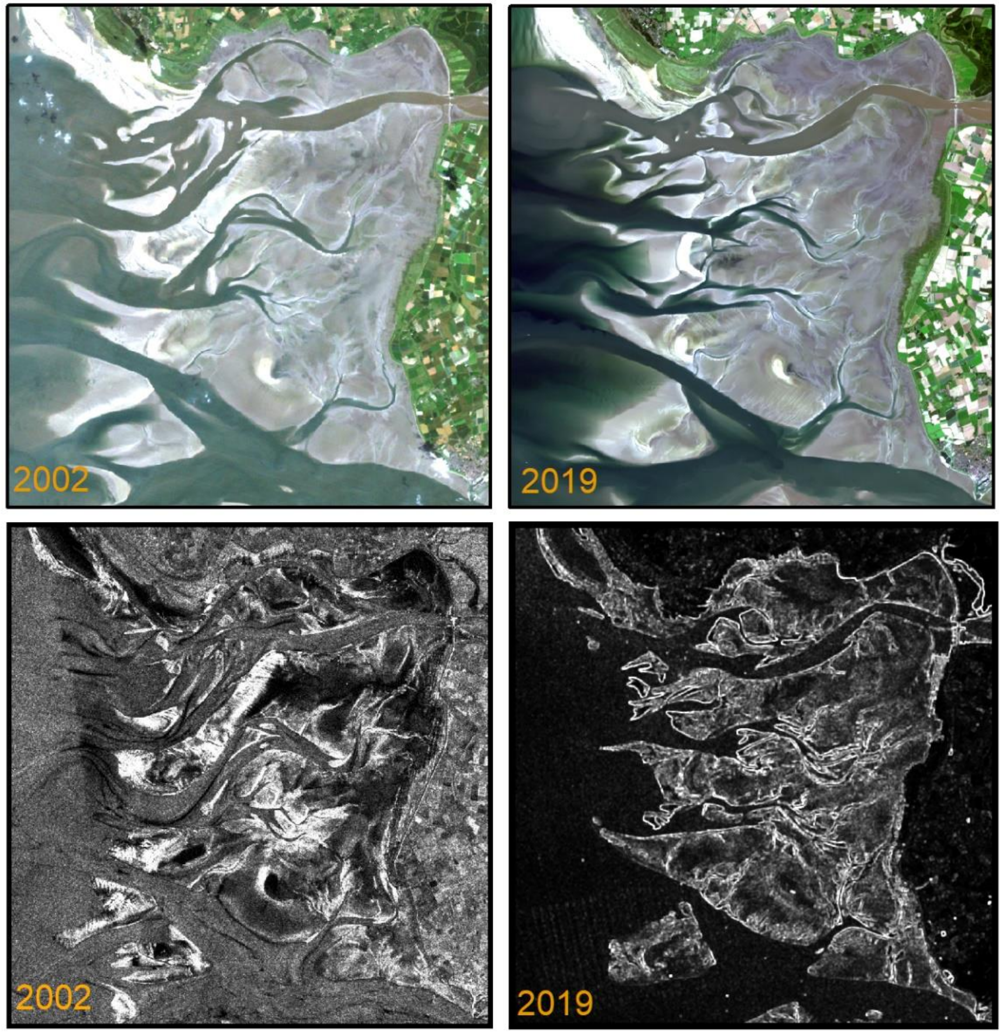


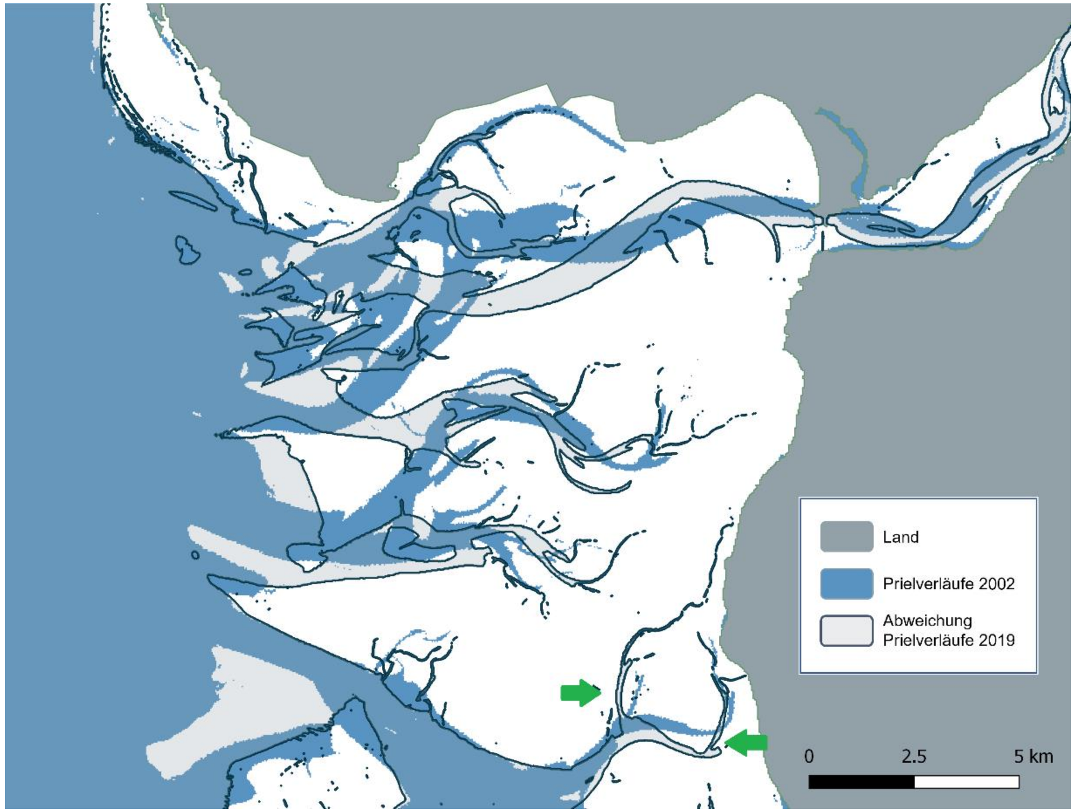
Application by Users

- Some areas which were identified as dry-fallen all the time were unknown for the users
- They visited the spots and recognised a growing of the saltmarshes.

- Important future application: will the intertidal flats manage to grow with sea-level rise?

Tidal creek morphology and changes





Photos: Christian Reimers

Changes 2017 - 2021

Application Marner Plate

- Observation first in SAR images
- Users were informed and trips were organized to investigate this phenomena
- Potentially anthropogenic influence – not proven
- Observation over the last year and documentation of the developments
- Usage of information for next survey

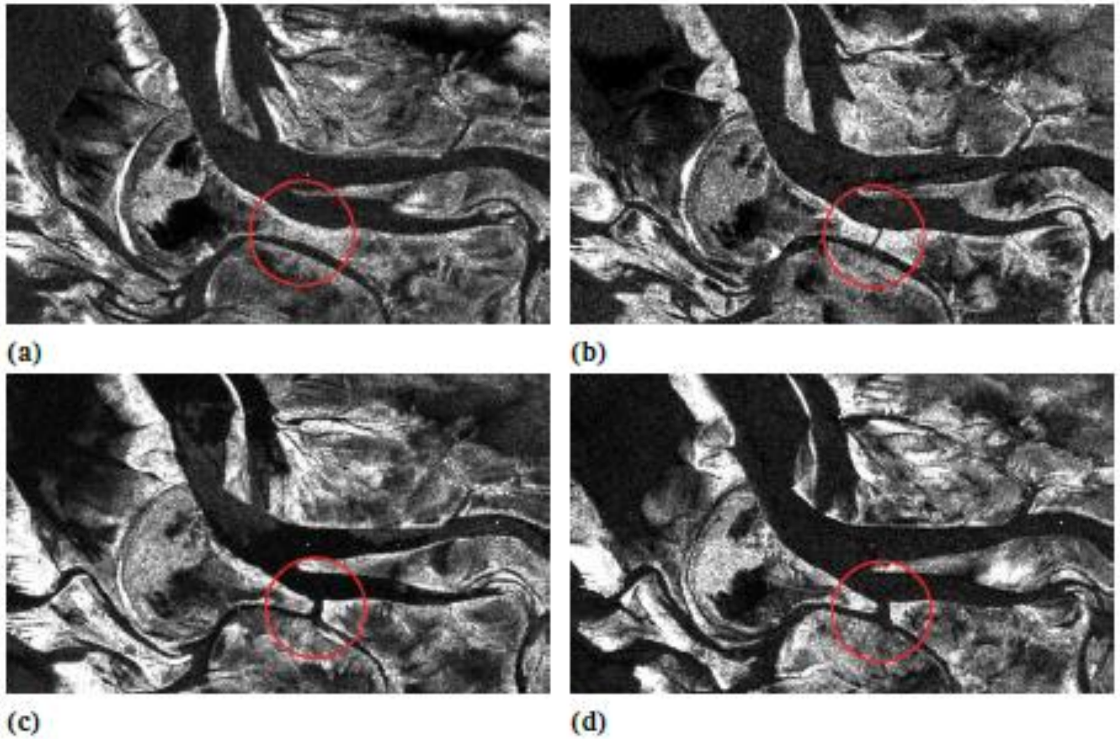
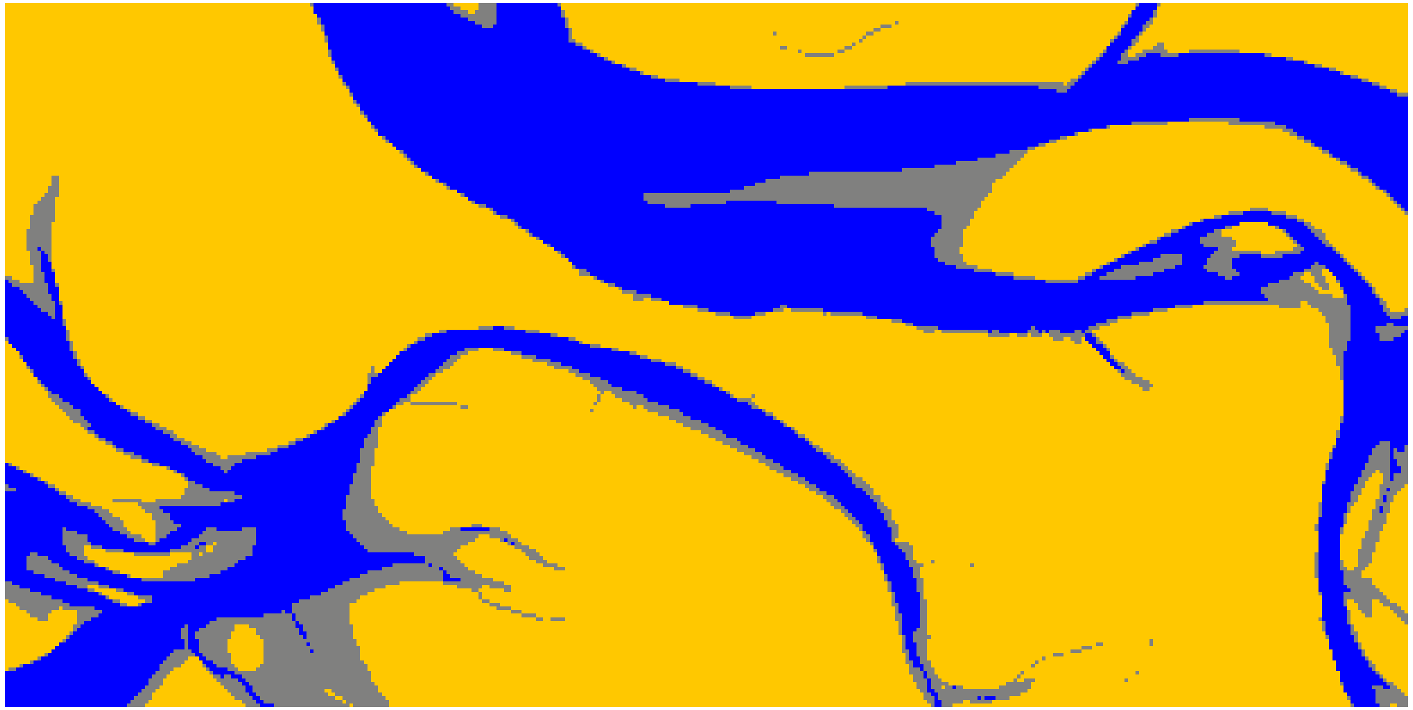


Abb. 5: SAR-Aufnahmen von jeweils Juli 2017 (a), 2018 (b), 2019 (c) und 2020 (d) von der Marner Plater bei Niedrigwasser. Markiert ist jeweils der Ort des Durchbruchs. Ausschnitt von ca. 10 km × 6 km.

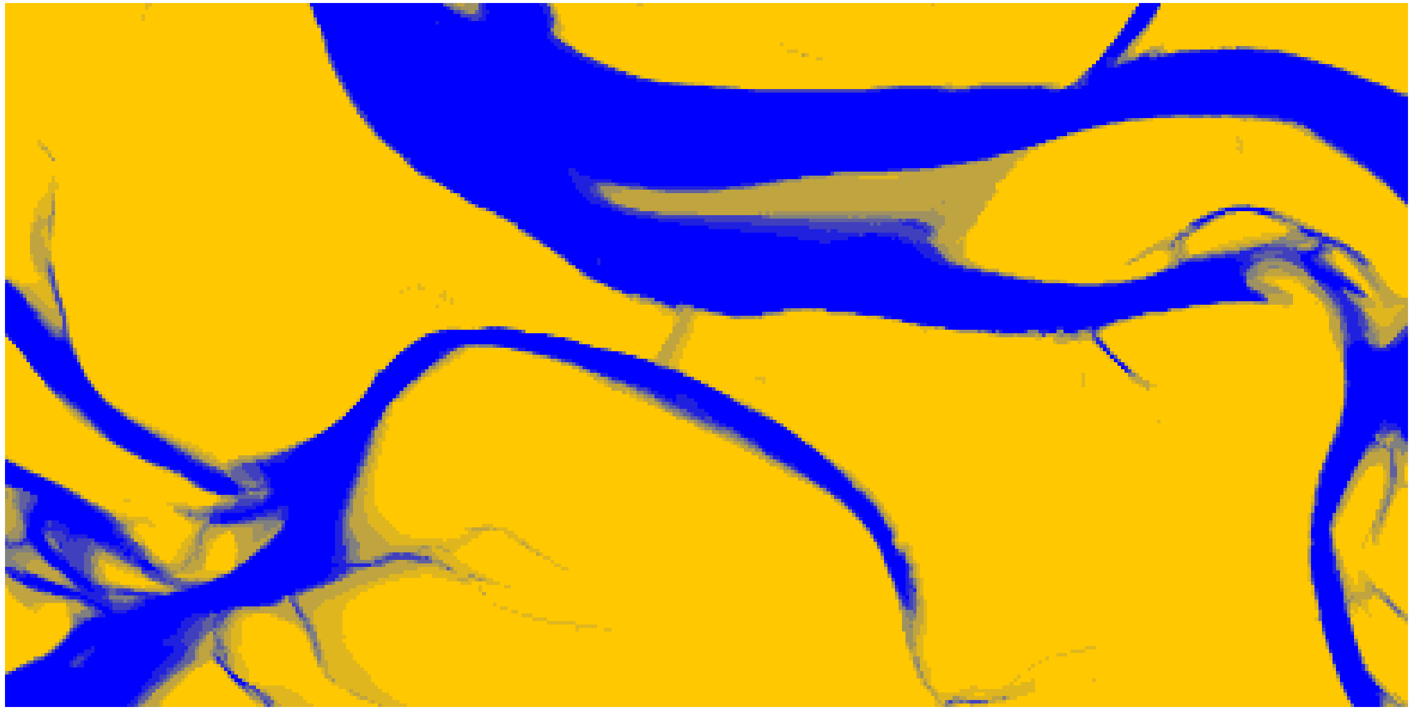
Source: Sebastian Peters, Bachelor Thesis University Hamburg

2017



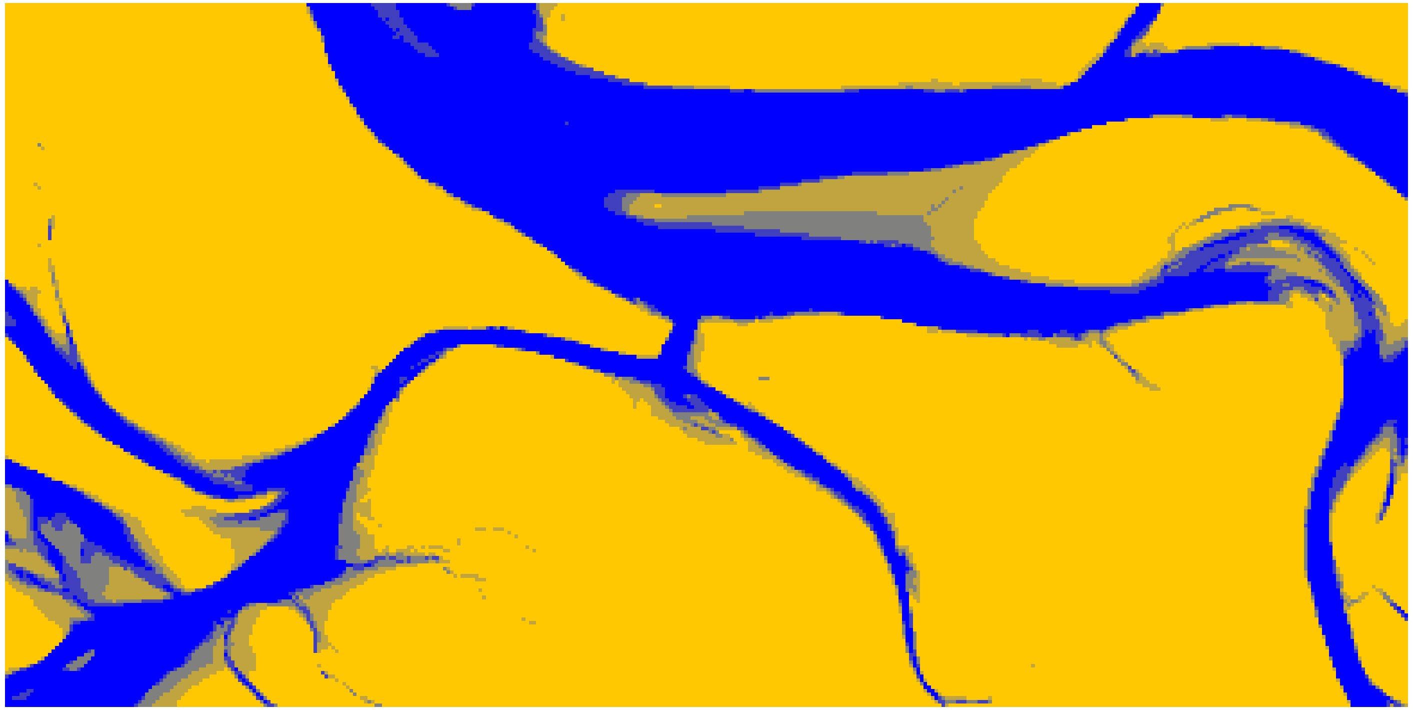
TFFI 2017 derived from S-2

2018



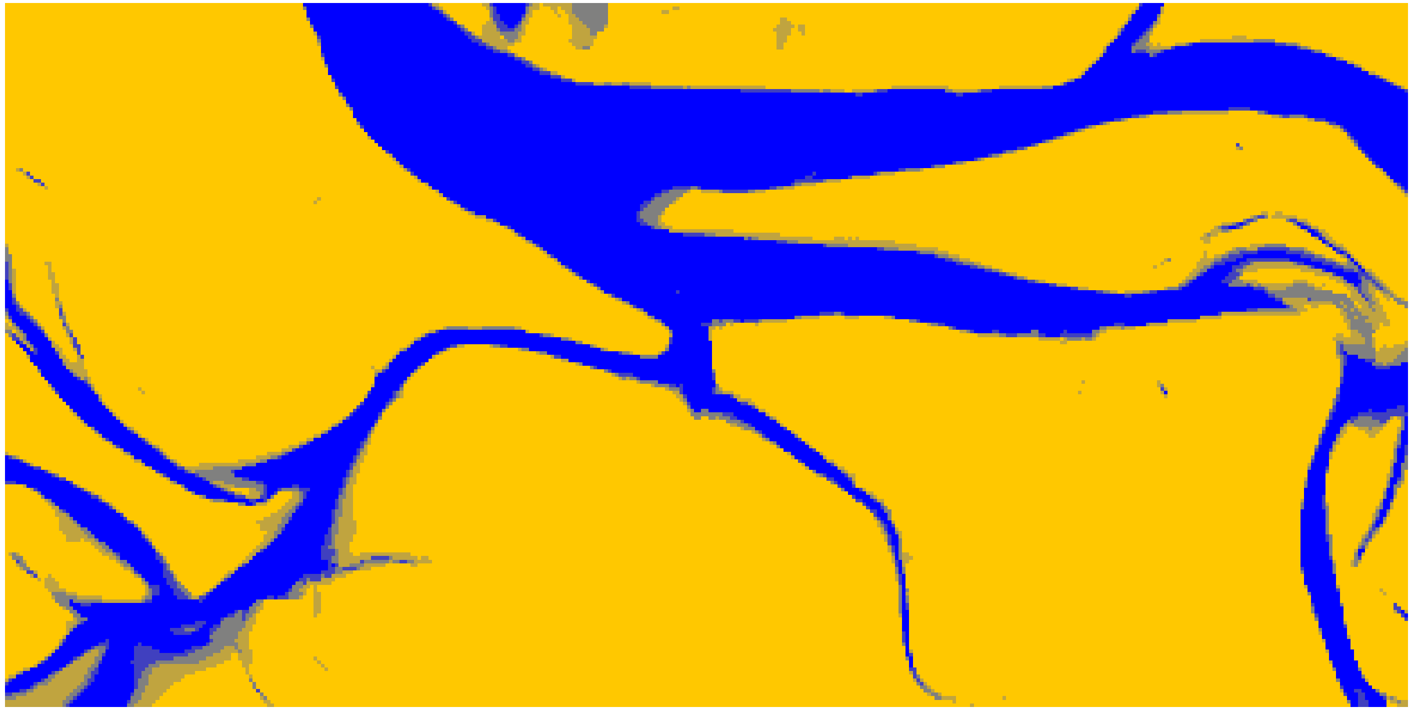
TFFI 2018 derived from S-2

2019



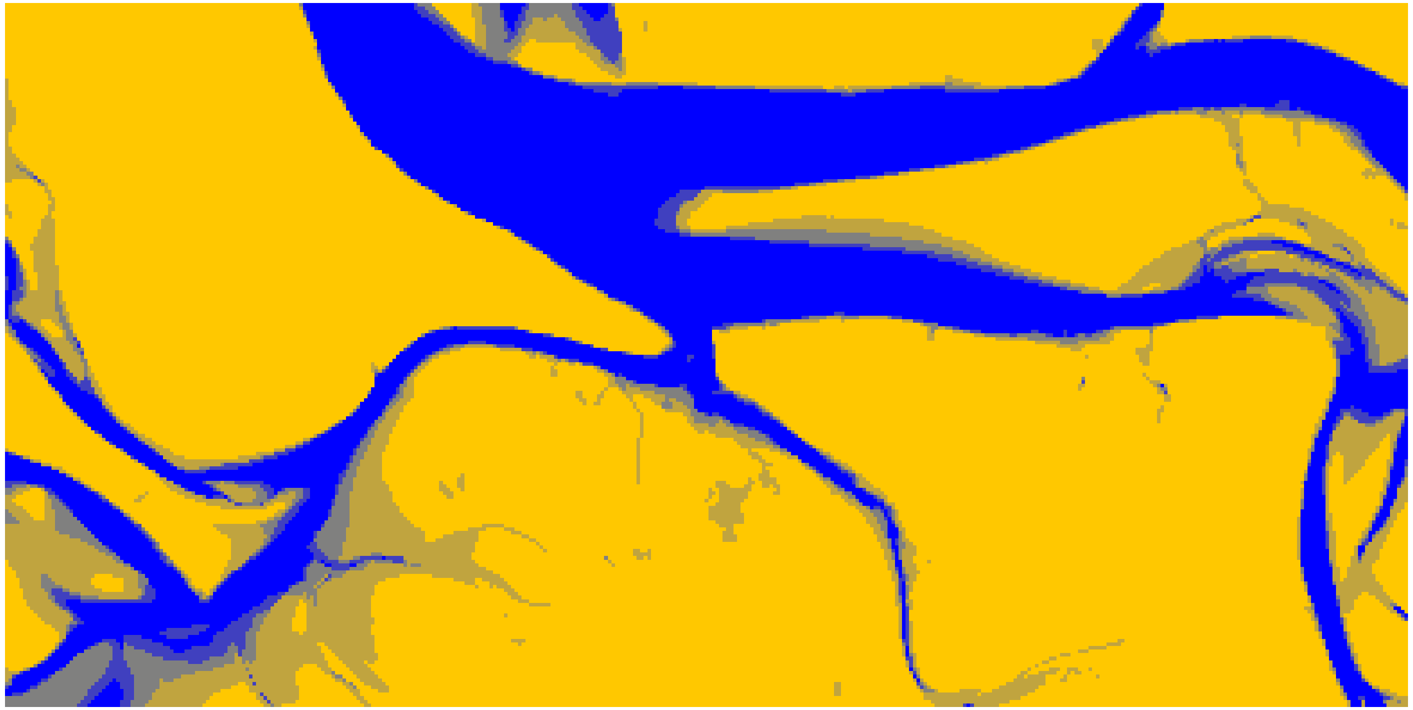
TFFI 2019 derived from S-2

2020



TFFI 2020 derived from S-2

2021



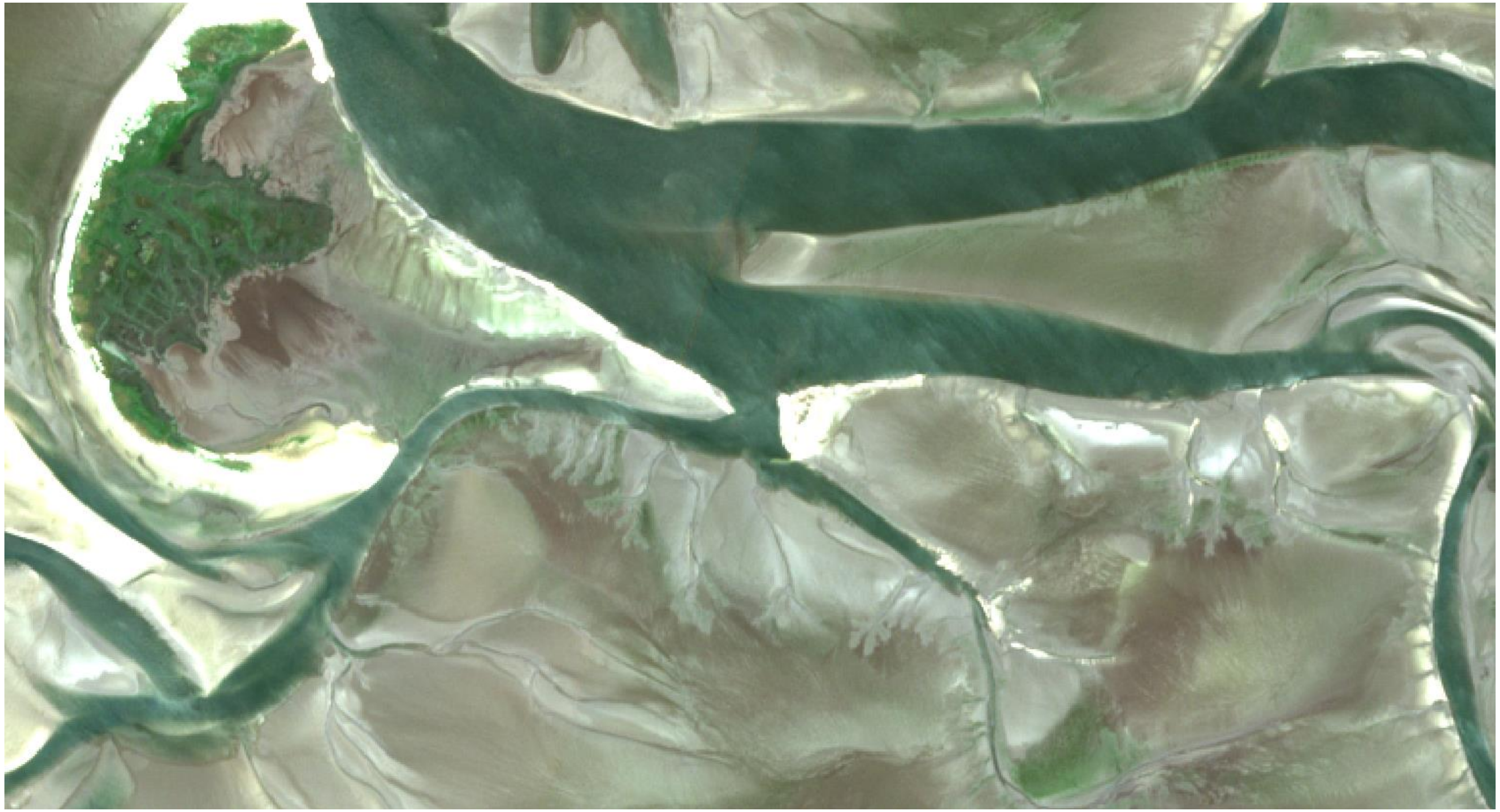
TFFI 2021 derived from S-2

2022

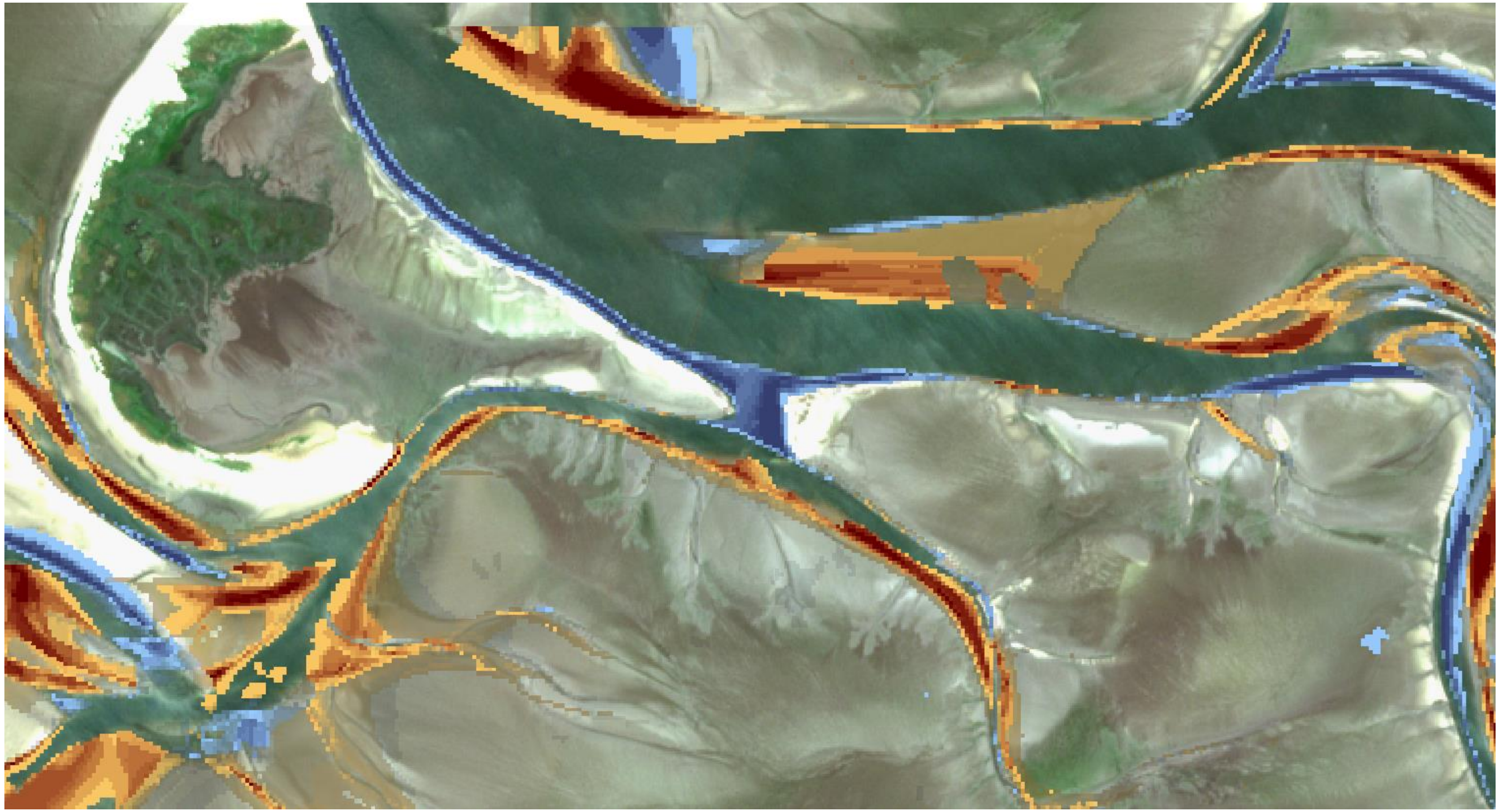
TFFI 2022 derived from S-2

2017

2021



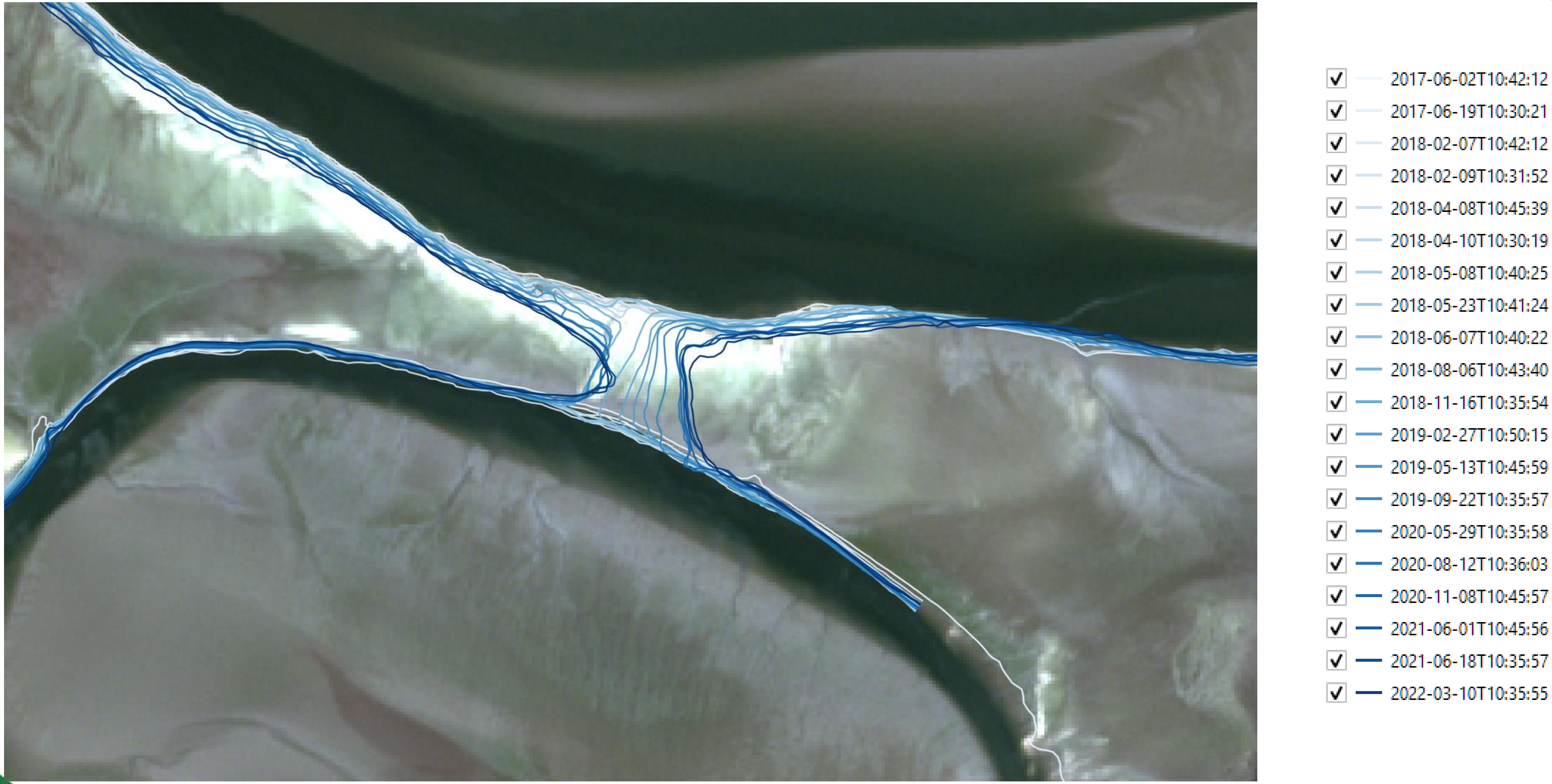
2017-2021



Wasserline extraction Marner Plate

- 2017-06-02T10:42:12
- 2017-06-19T10:30:21
- 2018-02-07T10:42:12
- 2018-02-09T10:31:52
- 2018-04-08T10:45:39
- 2018-04-10T10:30:19
- 2018-05-08T10:40:25
- 2018-05-23T10:41:24
- 2018-06-07T10:40:22
- 2018-08-06T10:43:40
- 2018-11-16T10:35:54
- 2019-02-27T10:50:15
- 2019-05-13T10:45:59
- 2019-09-22T10:35:57
- 2020-05-29T10:35:58
- 2020-08-12T10:36:03
- 2020-11-08T10:45:57
- 2021-06-01T10:45:56
- 2021-06-18T10:35:57
- 2022-03-10T10:35:55

Wasserlinienextraktion Marner Plate



Application by Users

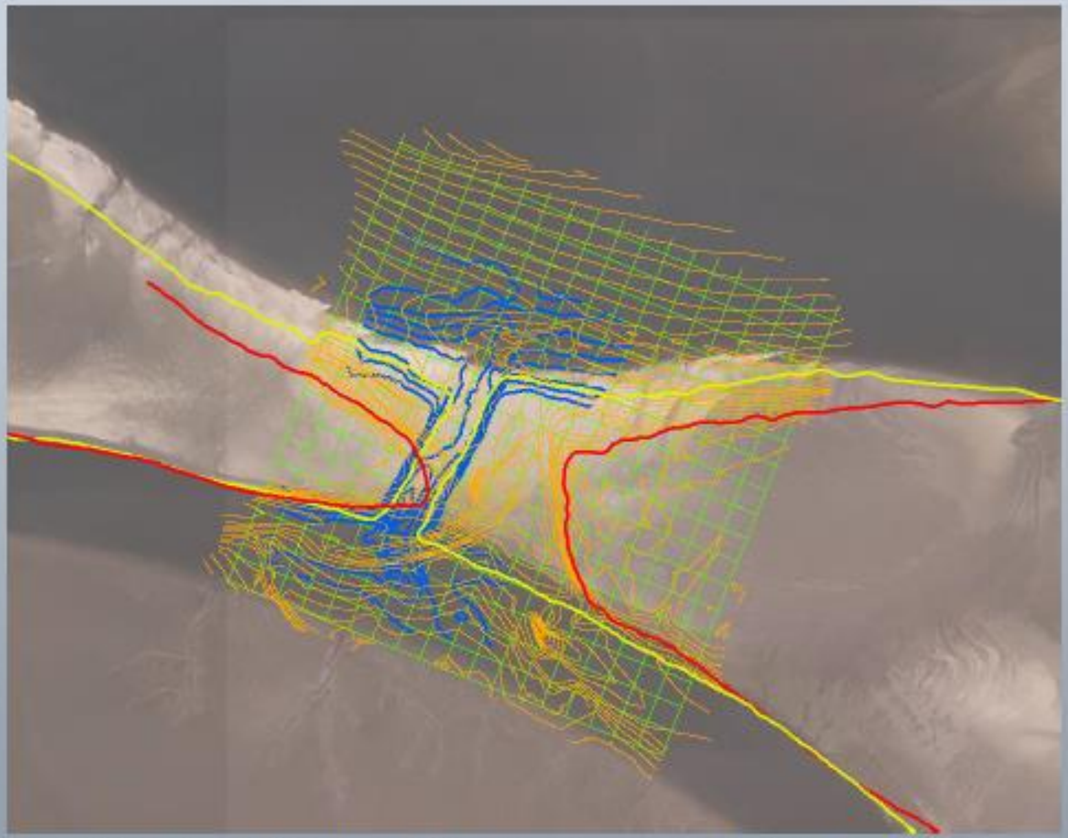
Example how the users are integrating Space for Shore data into their workflows

Satellitendaten
- Ergebnisse aus Space for Shore

LKN.SH

Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein

Beispiel Planung Vermessung → Example for planning surveys



Einbinden aktueller Niedrigwasser-Linien für Vermessungsplanung

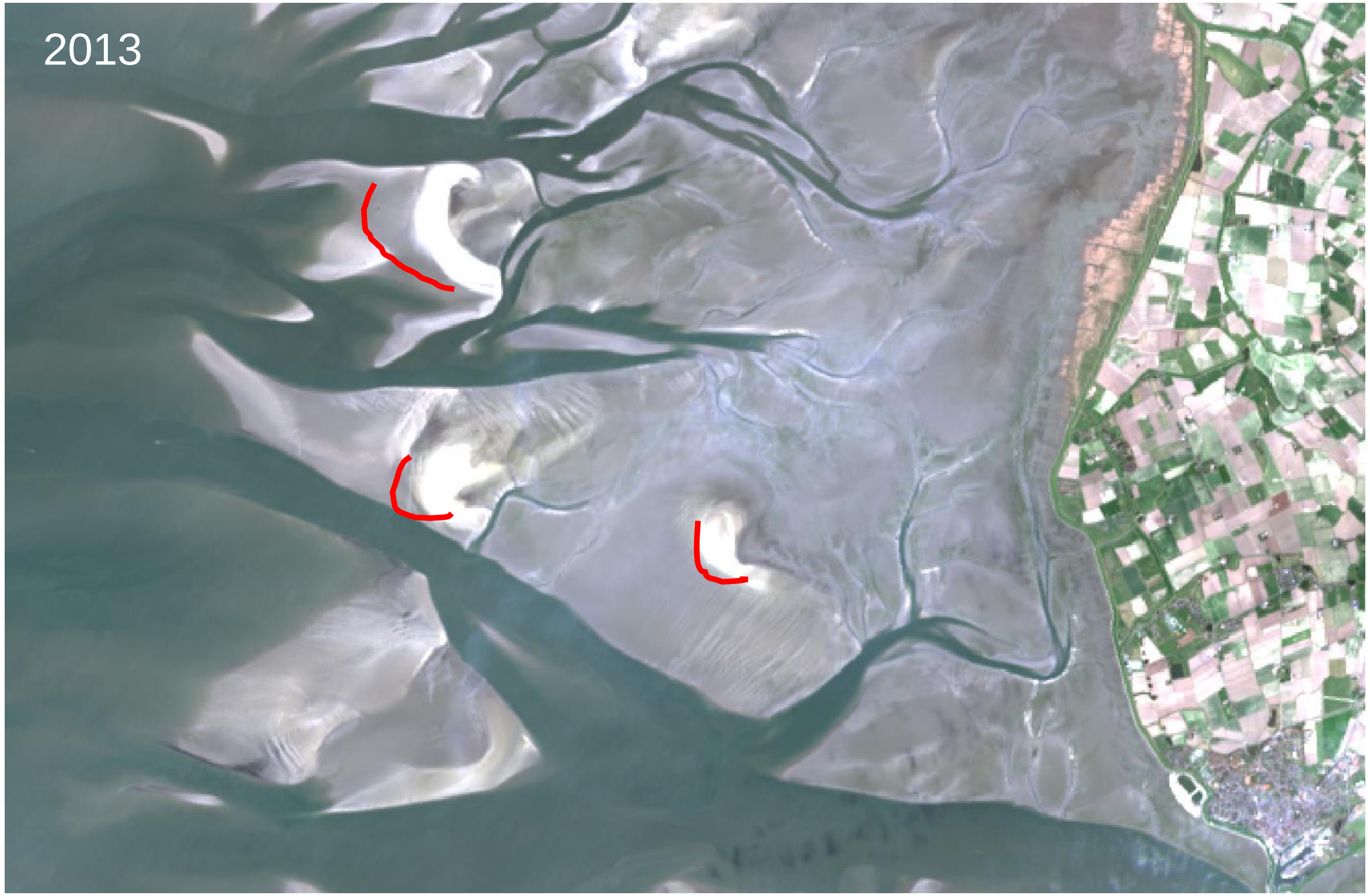
→ Integration of the most recent low-tide water lines for planning next surveys

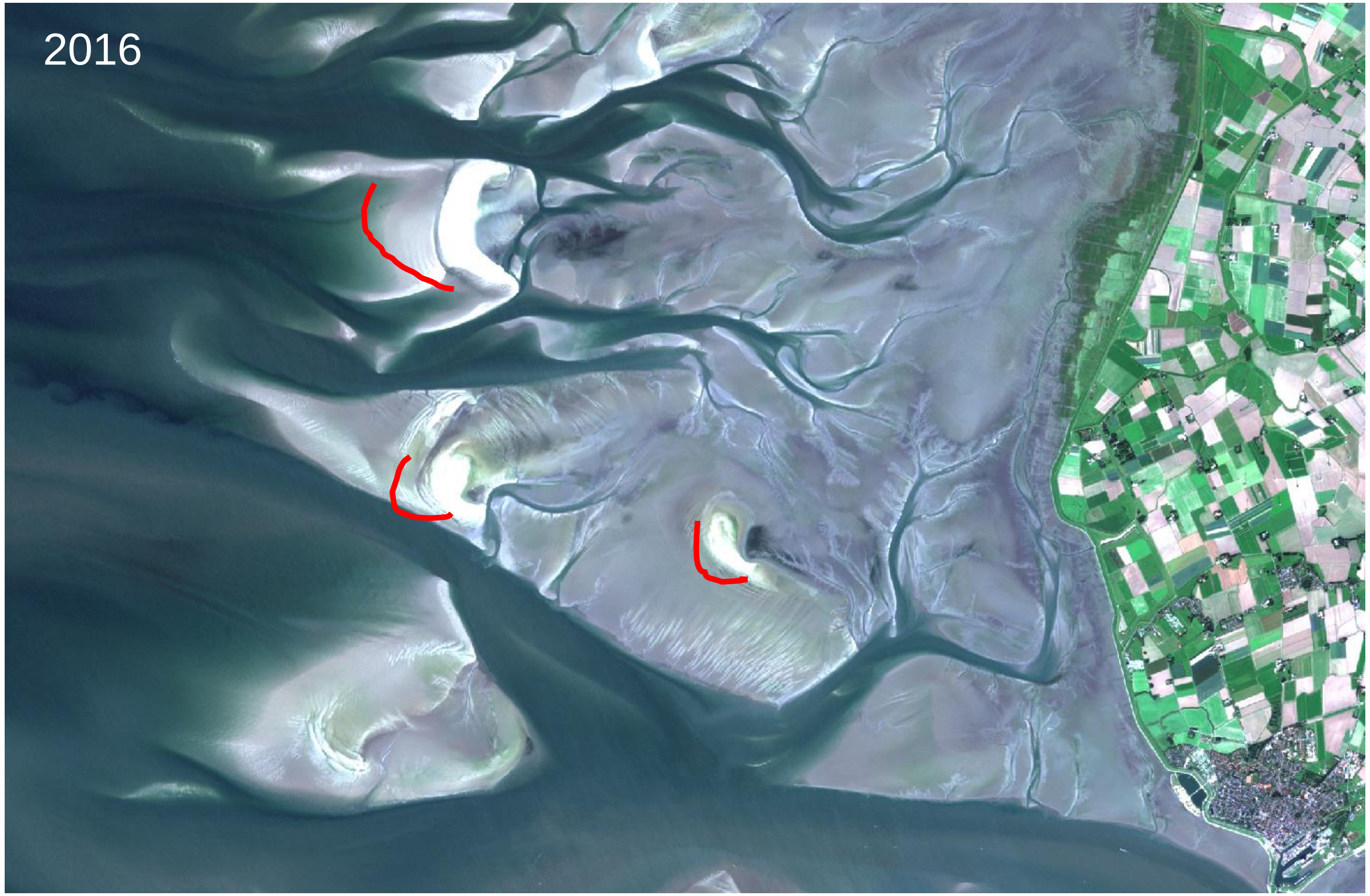
Außensande

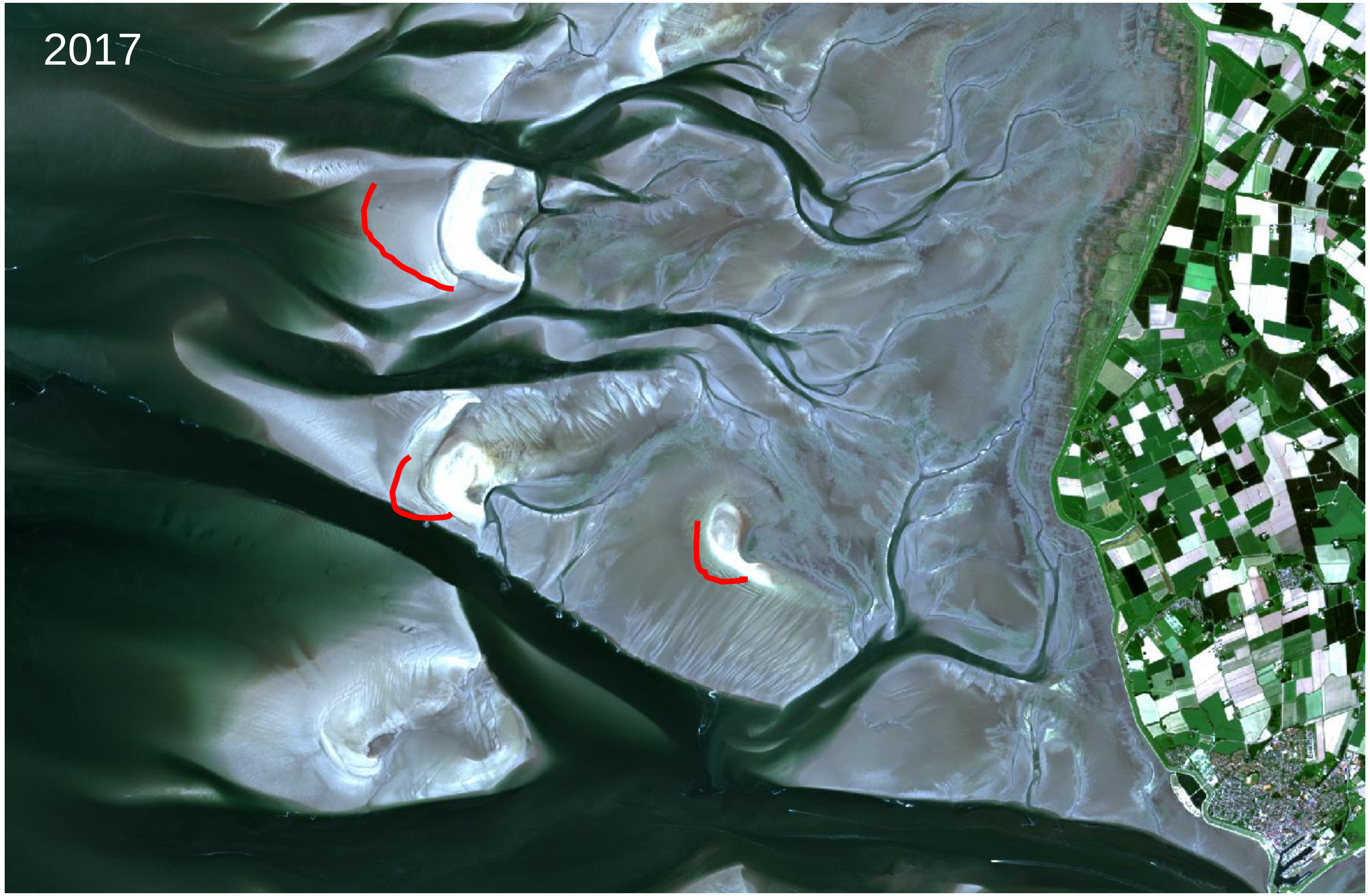
- **User requirements: Monitoring of outer sand banks and their developments**
- New developments of outer sand banks
- Movements of outer sand banks

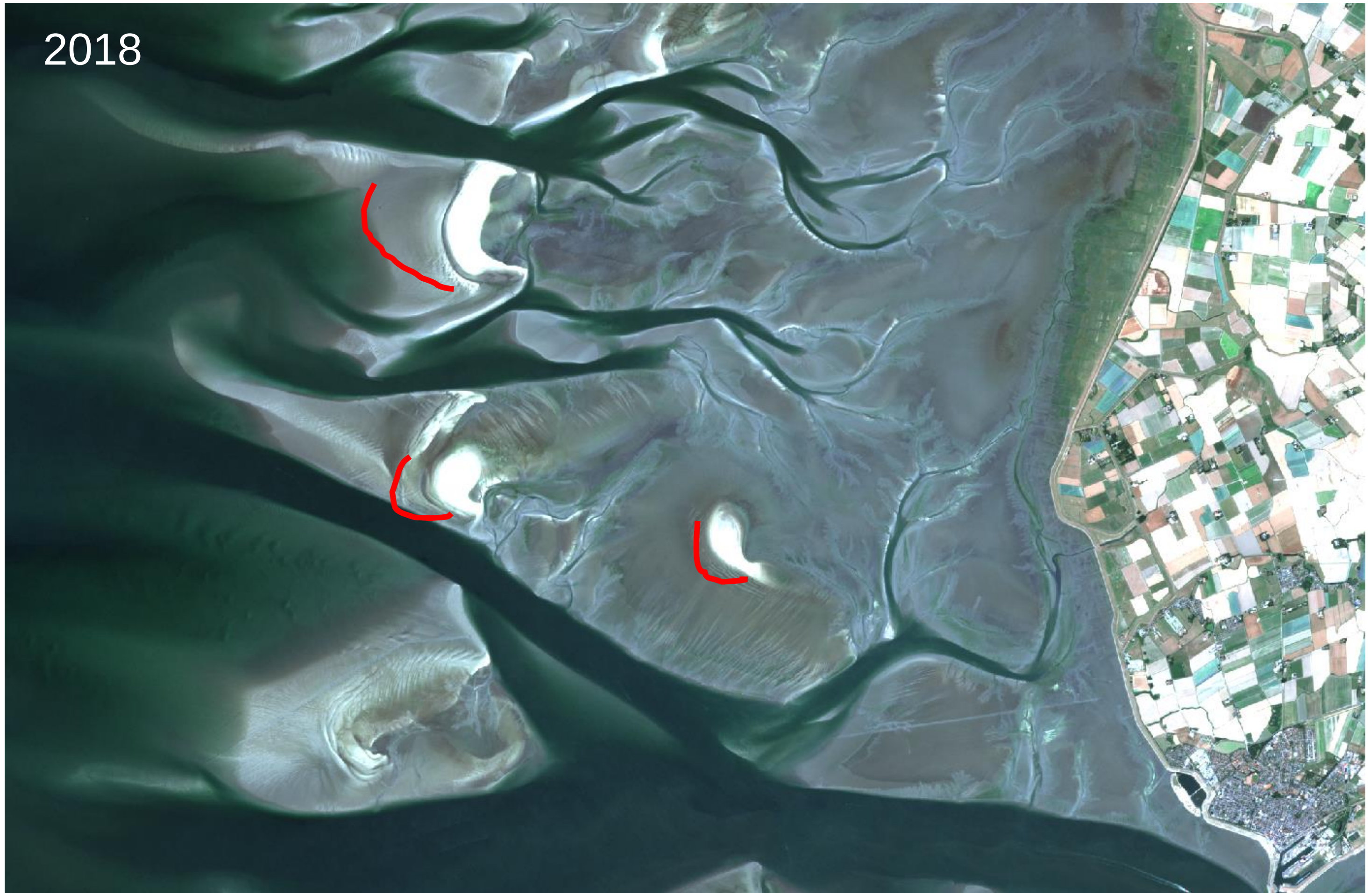
- Automatic selection of cloudfree acquisitions; preferably high tide
- Identification of bright sand areas, sediment and water covered for each acquisition
- determination of water covered cases compared to sand-covered cases


2006


2013

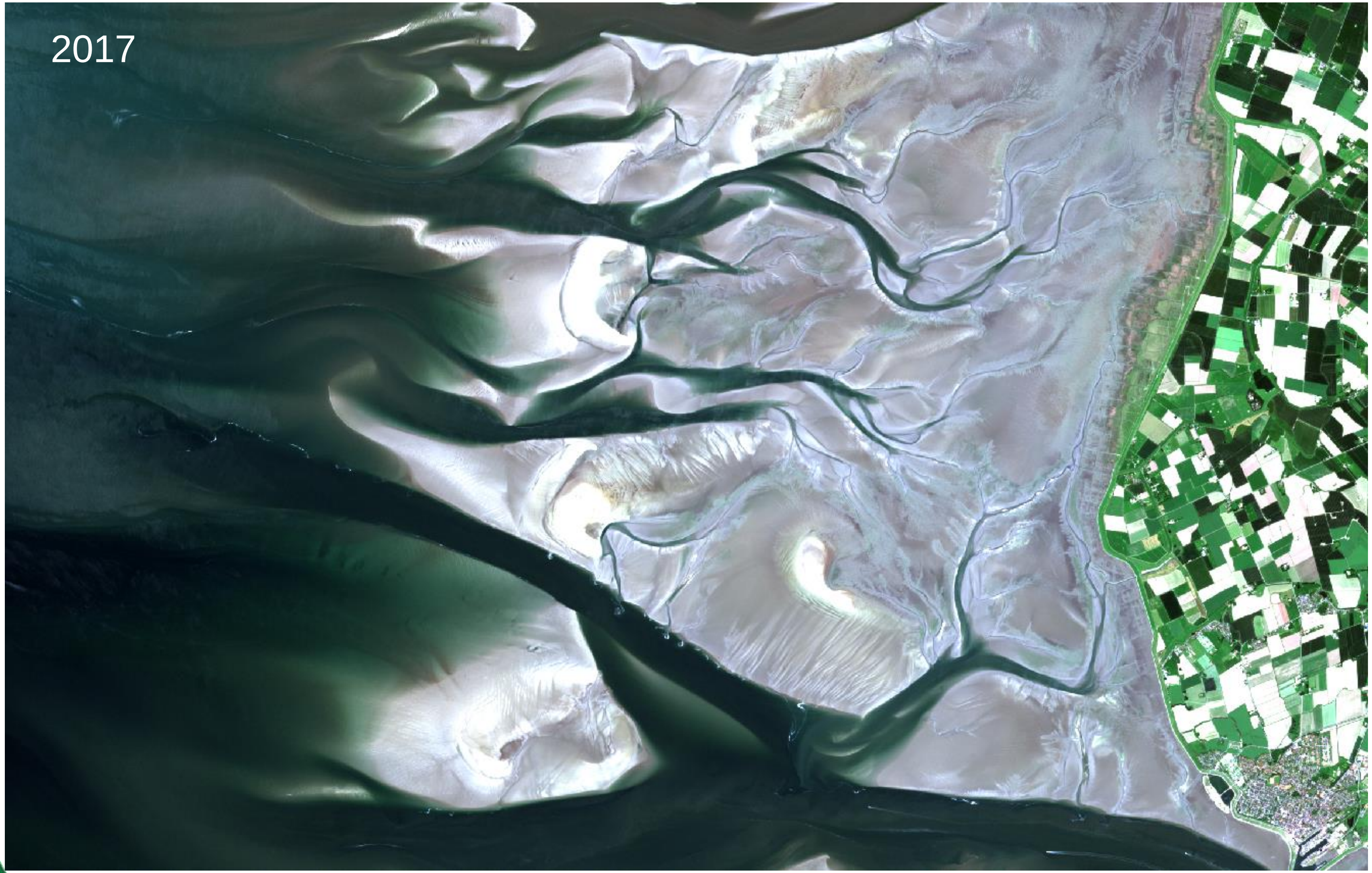

2016


2017


2018


2020
New outer sand bank

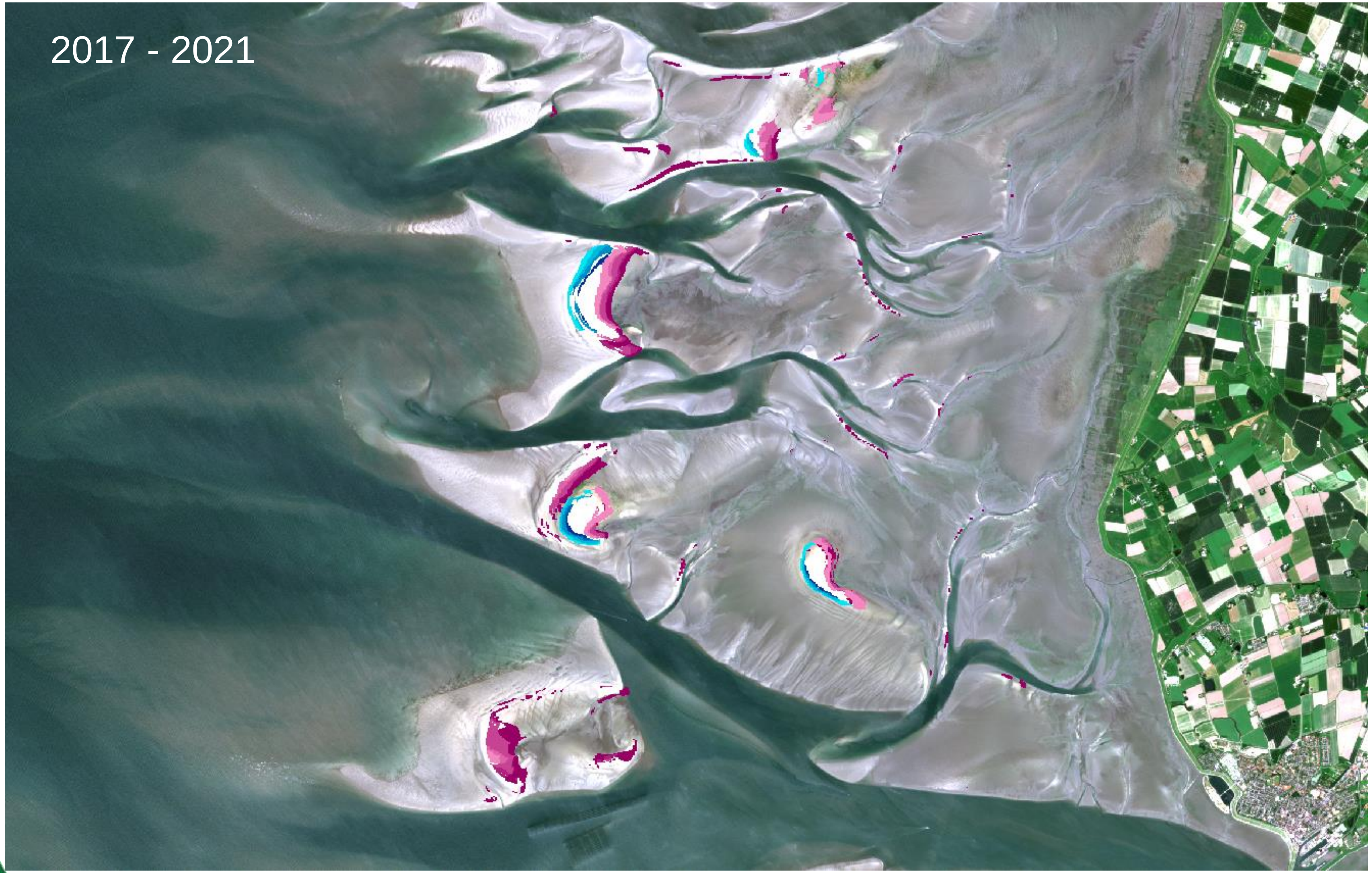
Changes outer sandbanks Wesselburener Watt

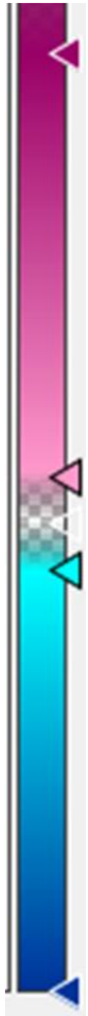


Veränderungsanalyse Außensände Wesselburener Watt

Veränderungsanalyse Außensände Wesselburener Watt

Veränderungsanalyse Außensände Wesselburener Watt





SeaCAT Tool

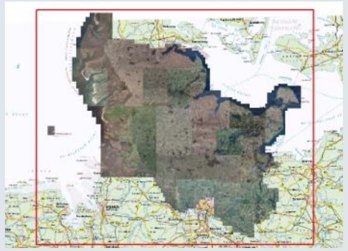
Tools to generate and analyse the results

esa Coastal Erosion Project

European Space Agency

Input data

- Satellite aquisitions (1 … n)



- Generation of L1C data cubes for selected areas
- Gauge data = water level at position and aquisition time

Product selection

- Visuelle Nachauswahl
- Automated selection based on cloud coverage and water level
- External data Water Level (GeoDB)

Processing

- Coastlines
- Sublitoral structures
- Intertidal creeks
- Outer sand banks

Quality control

- Visual post-selection

Change analysis

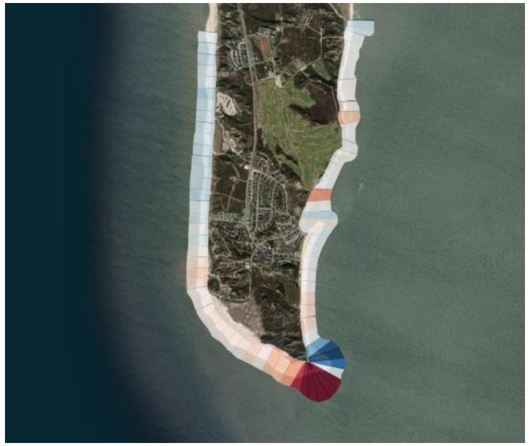
- Coastline change
- Changes intertidal creeks
- Changes outer sandbanks
- Intertidal dryfallen index

Indicators

High dynamic erosion (HD)
low dynamic erosion (LD)
stable areas
LD sedimentation areas
HD sedimentation areas

Output

- Shapefiles
- Statistics
- GeoTIFFs
- Animated GIF



SeaCAT – Processing with jupyter notebooks

import logging logger = logging.getLogger() logger.setLevel(logging.CRITICAL)Installation of python leaflet packages needed.

[30]:
```
#!conda install -c conda-forge --yes eo-learn
#!jupyter labextension update --all
#!jupyter labextension install @jupyter-widgets/jupyterlab-manager jupyter-leaflet
#!jupyter labextension install @jupyter-widgets/jupyterlab-manager js
#!jupyter labextension list
```

Space4Shore - Küstenlinienveränderungen entlang der Nord- und Ostseeküste

Zur Analyse von Küstendynamiken und Trends werden räumlich hoch aufgelöste Geodaten der Küstenlinie über einen Zeitraum von Jahren oder Jahrzenten benötigt. Bisher stützten sich solche Studien oftmals auf die Interpretation von Orthophotos der vergangenen Jahre, um langfristige Veränderungen zu erkennen, und/oder GPS basierte Feldstudien zur Untersuchung der jährlichen Variabilität oder einzelnen Sturmereignissen. Besonders über hoch dynamischen Gebieten können zudem hochaufgelöste Satellitendaten als Datenquellen genutzt werden, um Trends und Variabilität zu erkennen. Mit einer Auflösung von 10/20 m und einer Wiederkehrdauer von 3 Tagen über der deutschen Küste eignen sich insbesondere die Sentinel-2 Satelliten der ESA für diesen Einsatzzweck

1. Was enthält dieses Jupyter Notebook?

In diesem Notebooks wird die Küstenlinienveränderungsanalyse durchgeführt. Basierend auf den Küstenlinienverläufen zu verschiedenen Zeitpunkten werden Basislinie und Transekte generiert, mithilfe derer die eigentliche Veränderungsanalyse durchgeführt wird.

Die Ergebnisse der Veränderungsanalyse werden können anschließend als Shapefile oder GeoJSON exportiert werden.

Alle Schritte können über Auswahlmöglichkeiten und Parameter an die Bedürfnisse des Nutzers angepasst werden.

SeaCAT – selection of the area

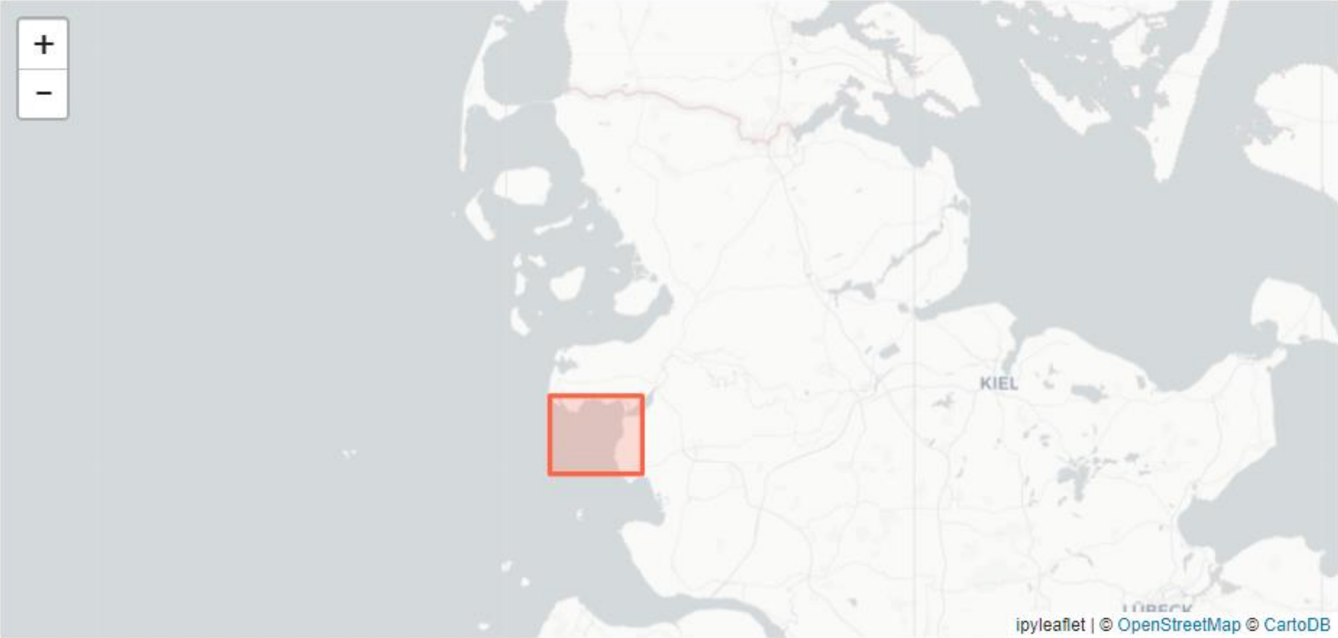
Choose AOI: Wesselburener Watt

Schritt 1b: Erstellung und Ansicht des Untersuchungsgebiets

Das Untersuchungsgebiet wird auf der interaktiven Karte unten ausgewählt.

Bitte nutzen Sie die *Draw a Polygon* Funktion in der Karte, um das Untersuchungsgebiet auszuwählen

```
# Plotte die Karte und füge die Funktion zur Auswahl der ROI hinzu.
m, draw_control, aoi = prodid.draw_map(saved_aois, options_widget.value)
if draw_control:
    draw_control.on_draw(prodid.handle_draw)
    m.add_control(draw_control)
m
```



SeaCAT – search criteria for satellite data

[74]:
```
# Auswahl des Untersuchungszeitraum und der räumlichen Auflösung
time_range = ['2016-01-01', '2021-09-30']
spatial_res = 10
```

[75]:
```
# Auslesen der bounding box aus der interaktiven Karte
geom = Polygon(draw_control.last_draw['geometry']['coordinates'][0])
# Konfiguration des Cubes
cube_L2A, cube_L1, bbox, epsg = prodid.configure_cubes(
                                    sentinelhub_client_id = sentinelhub_client_id,
                                    sentinelhub_client_secret = sentinelhub_client_secret,
                                    geom = geom,
                                    time_range =time_range,
                                    spatial_res = spatial_res)

# ein Blick in den L1C Cube
cube_L1
```

[75]: xarray.Dataset

► Dimensions: (**time**: 659, **y**: 1536, **x**: 1536, bnds: 2)

▼ Coordinates:

time	(time)	datetime64[ns]	2016-11-01T10:31:56 ... 2021-09-...
time_bnds	(time, bnds)	datetime64[ns]	dask.array<chunksize=(659, 2), meta=np.ndarray>
x	(x)	float64	4.793e+05 4.793e+05 ... 4.946e+05
y	(y)	float64	6.017e+06 6.017e+06 ... 6.001e+06

▼ Data variables:

B02	(time, y, x)	float32	dask.array<chunksize=(1, 512, 512), meta=np.nd...
B03	(time, y, x)	float32	dask.array<chunksize=(1, 512, 512), meta=np.nd...
B04	(time, y, x)	float32	dask.array<chunksize=(1, 512, 512), meta=np.nd...
B08	(time, y, x)	float32	dask.array<chunksize=(1, 512, 512), meta=np.nd...
B11	(time, y, x)	float32	dask.array<chunksize=(1, 512, 512), meta=np.nd...
B12	(time, y, x)	float32	dask.array<chunksize=(1, 512, 512), meta=np.nd...
crs	()	int64	...

▼ Attributes:

Time selection and spatial resolution

Generation Datencube

SeaCAT – search criteria for satellite data

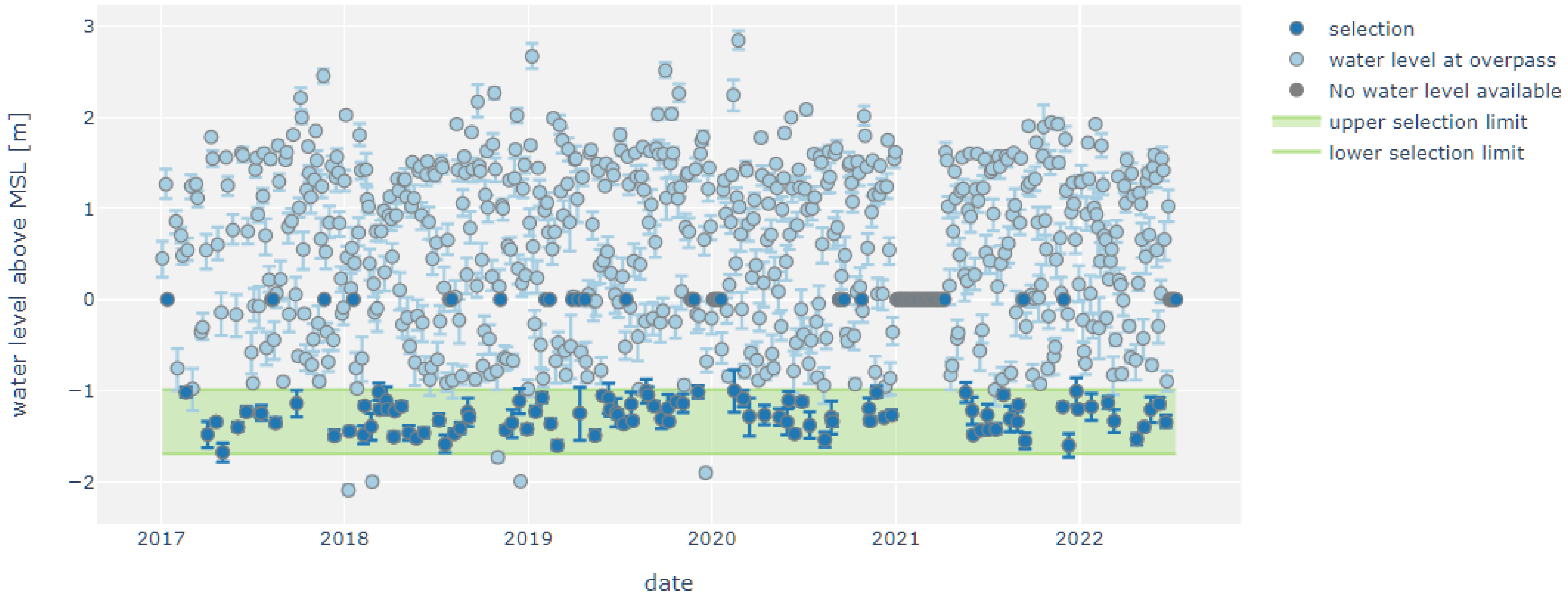
Filter method: Mean

Water level: -1.69 – -0.99

☑ Include scenes with missing water level data

24 % of all scenes selected

Selection of input products depending on water level



SeaCAT – search criteria for satellite data

Schritt 2b: Festlegen des Schwellenwertes für Wolkenbedeckung

Im nächsten Schritt werden alle verfügbaren Satellitenszenen im Untersuchungsgebiet auf die Wolkenbedeckung getestet. Bitte passen Sie den maximal erlaubten Wolkenanteil in der nächsten Box an Ihre Bedürfnisse an.

cloud_cover_perecentage: Maximal erlaubter Anteil an Wolken innerhalb des Untersuchungsgebiets in %. Hierbei wird nur der Bereich in einem Puffer von 300 m um die Küste berücksichtigt. Standardwert ist 0.1 (10 %)

country: Land in dem die Analyse stattfindet. Über diesen Parameter wird der passende Puffer um die Küstenlinie für die Wolkenerkennung ausgewählt. Derzeit werden "Germany" und "Sweden" unterstützt. Liegt die ROI außerhalb dieser Länder, muss None angegeben werden. Dann wird die Wolkenbedeckung nicht nur in einem Puffer um die Küstenlinie, sondern in der gesamten ROI berechnet.

Selection based on cloud coverage

[222]:
```
# Parameter zur Produktauswahl
cloud_cover_percentage =  0.1
country = None # "Germany"
```

[*]:
```
# Filtern aller nutzbaren Szenen basierend auf der Wolkenbedeckung
val_dates, val_ccs, output = prodid.identify_cloudless_products(cube_L2A=cube_L2A_wl,
                                                                bbox = bbox,
                                                                cloud_cover_percentage = cloud_cover_percentage,
                                                                country = country)
prodid.date_eventhandler(datetime.date(2021, 6, 1), output, val_dates, val_ccs)
# Anzeigen von Zeitserie der Wolkenbedeckung
display(output)
```

```
The selection of valid dates can take some time. Please wait.
The country: None is not supported. No buffer will be used and the cloud detection will be performed on the whole AOI.
Computing: [##.........................................................] 6/179
```

SeaCAT – visual inspection of results

Schritt 2c: Überprüfen der Auswahl mit RGB Bildern

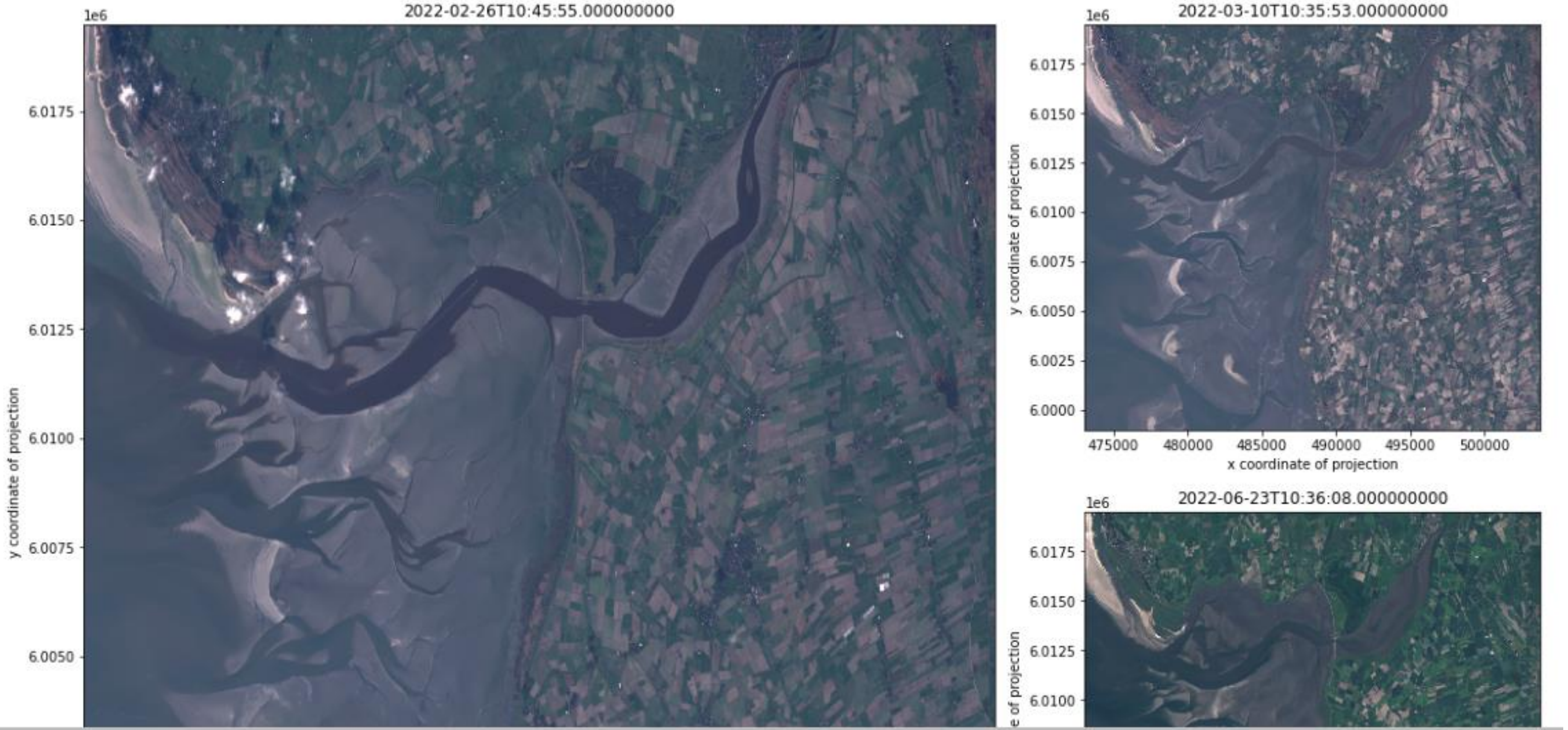
Die Zeitserie oben zeigt den Wolkenanteil für jede automatisch gewählte Szene.

Um das RGB der entsprechenden Szenen anzuzeigen, führen Sie die folgende Zelle aus. Sie können im Dropdown-Menü jedes Bild der automatischen Selektion auswählen. Außerdem werden die RGBs der folgenden zwei Daten gezeigt. Das Erstellen der Bilder kann einen Moment dauern.

[19]:
```
# Anzeigen der RGB Bilder der gewählten Tage
prodid.show_RGBs(cube = cube_L1_wl,
                 val_dates = val_dates)
```

Datum 2022-02-26T10:45:55.0000000(

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).
```



SeaCAT – calculation of coastlines

Schritt 3a: Identifizierung der Küstenlinie

Zunächst werden in jedem ausgewählten Satellitenbild die Küstenlinien gesucht und extrahiert. Dafür müssen einige Parameter durch den Nutzer festgelegt werden.

- *water_index* - Wichtigster Parameter ist der Wasserindex. Mit diesem Index sollen die Kontraste zwischen Land und Wasser verstärkt werden, was eine Klassifikation ermöglicht. Derzeit werden NDWI, MNDWI, ANDWI, NBNI und $AWEI_{nsh}$ angeboten. Die Indices benutzen verschiedene Bänder/Wellenlängen für die Kontrastspreizung und funktionieren deshalb in unterschiedlichen Umgebungen unterschiedlich gut. Sofern mit einer 10 m Auflösung der Daten gearbeitet wird, sollte der NDWI genutzt werden, da dieser nur Bänder benutzt, die auch in einer 10 m Auflösung messen. Allerdings kann es mit diesem Index Probleme bei der Klassifikation von z.B. trübem Wasser geben. Wird eine 20 m Auflösung genutzt, ist der ANDWI eine robuste Wahl für die meisten Umgebungen. "bright" ist ein Index, um Sandbänke in Wattgebieten zu identifizieren (threshold Empfehlung: -0.15)
- *contours_thresh* - Schwellenwert bei der Land-Wasser-Klassifikation. Die Werte von NDWI, MNDWI und ANDWI reichen von -1 bis 1, sodass häufig 0 als Grenze zwischen Land und Wasser genutzt wird. Eine Möglichkeit den (nahezu optimalen) Schwellenwert in jedem Bild automatisch zu ermitteln ist der Otsu-Schwellenwert, der die Varianz zwischen den "Wasser" und "Land"-Klassen maximiert. Standardwert ist "otsu".
- *min_length* - Die minimale Länge eines Segments der Küstenlinie in Metern. Dies ist ein simpler, aber effektiver Filter, um zum Beispiel Küstenlinien an Seen oder Wolken über Land oder Wasser zu entfernen.
- *coreg_time* - Datum, dass als Referent für die co-registrierung dient. Folgende Werte sind möglich:
  - "2019-04-07" - Wahl eines konreten Datums im Format "Y-m-d"
  - "first" - Die erste Aufnahme im Cube wird zur co-registrierung genutzt.
  - "last" - Die letzte Aufnahme im Cube wird zur co-registrierung genutzt.
  - None - Es wird keine co-registrierung durchgeführt.

```
water_index = "NDWI" #"bright" #"NBNI" #"NDWI" #ANDWI" #"bright (-0.15 needed for sandbars)
contours_thresh = 0.2 #"otsu" #-0.15 #"otsu" #"0.2"
min_length = 3000
coreg_time = None
```

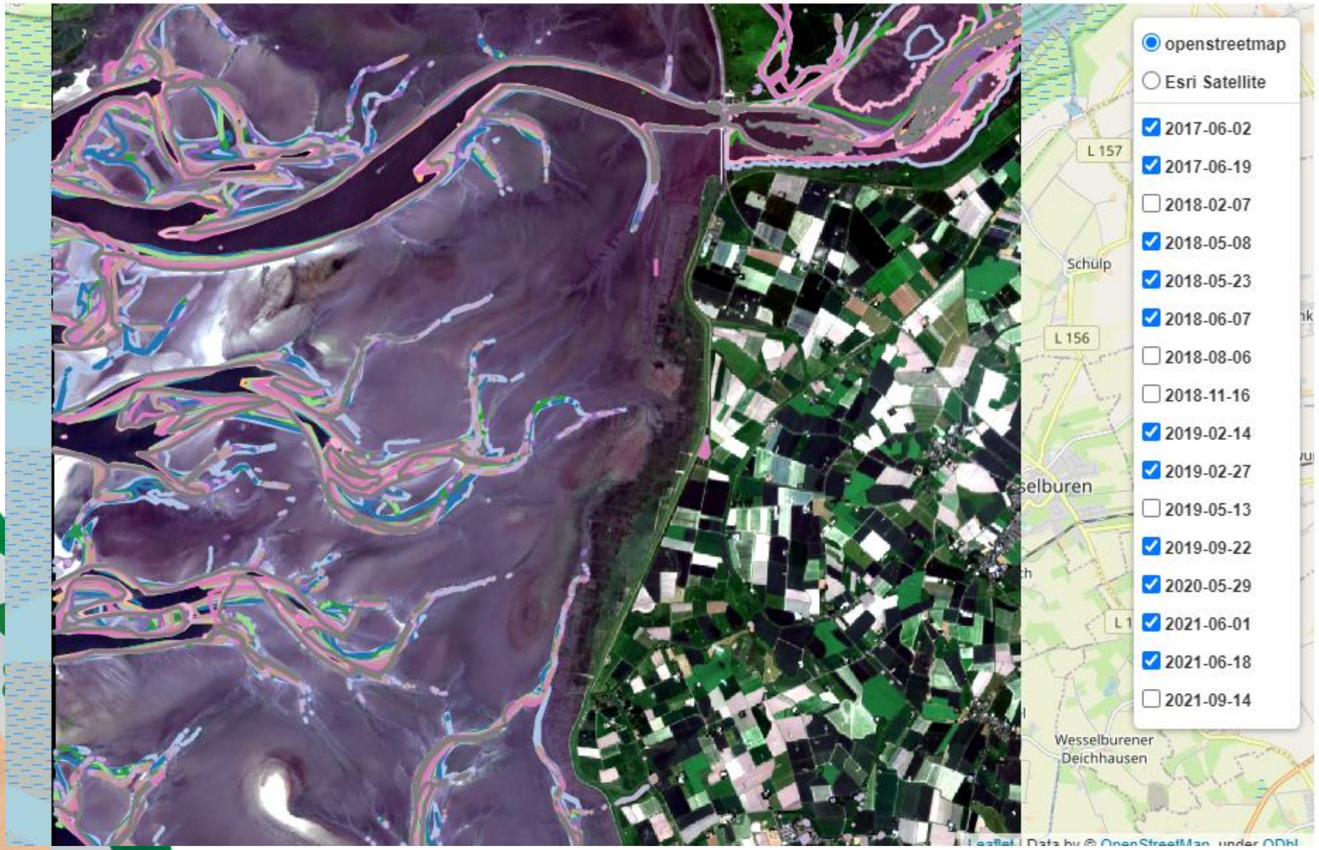
SeaCAT – visual inspection of generated coastlines

Plotte Küstenlinien und RGBs...

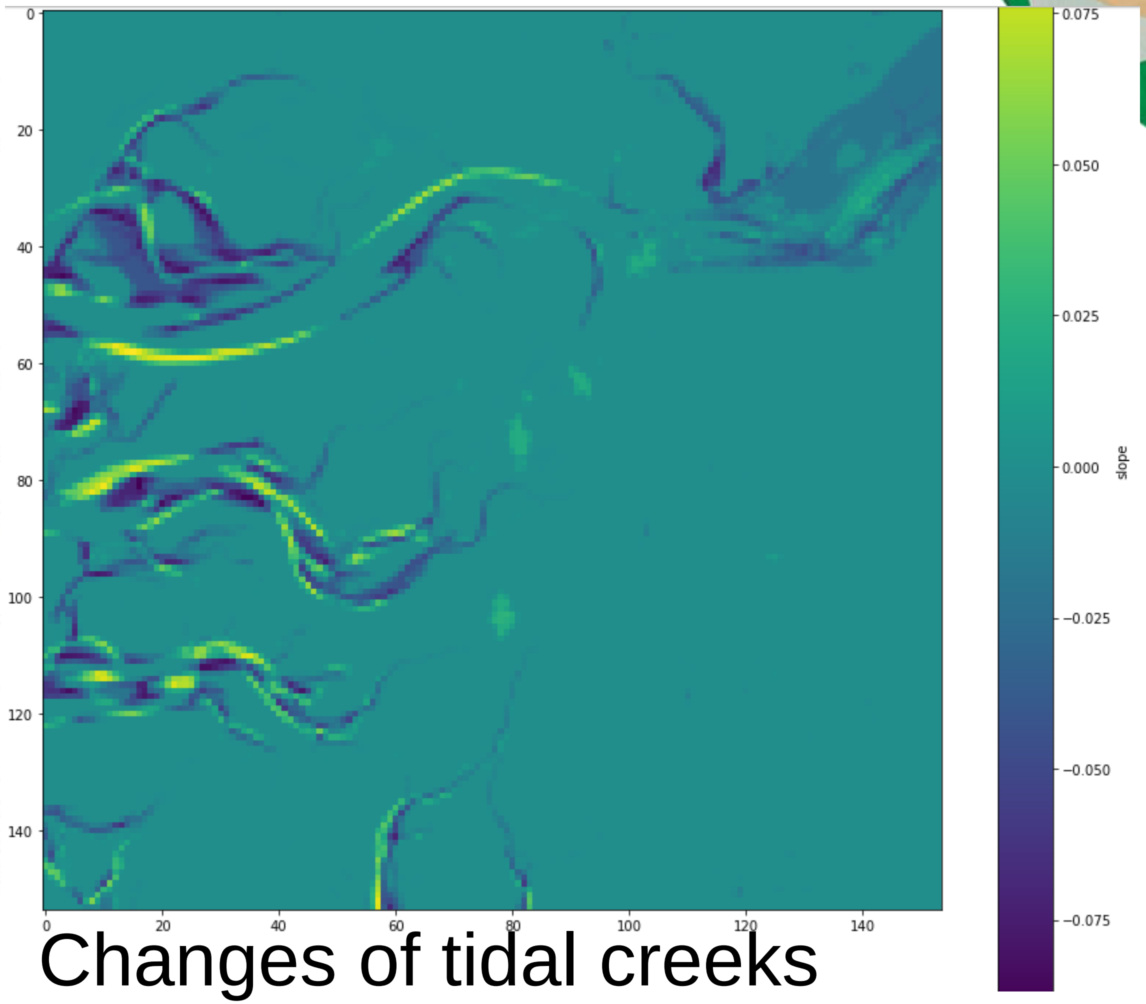
[24]:

lotte Küstenlinien und RGBs...

Results for changes of intertidal creeks



Water lines (final selection after quality control)



Changes of tidal creeks based on water lines

Usage of results in QGIS for further analysis by users

Summary

- Different indicators are available for intertidal flat areas
- Users were closely involved in the development of the indicators
- They also provided user requirements and feedback for the tools developed (SeaCAT)
- They were very happy with the outcome and opportunities opened up by the work performed in Space for Shore
- Indicators provide information that has not been available before
- Users want to continue and get services providing area-wide and regular information products

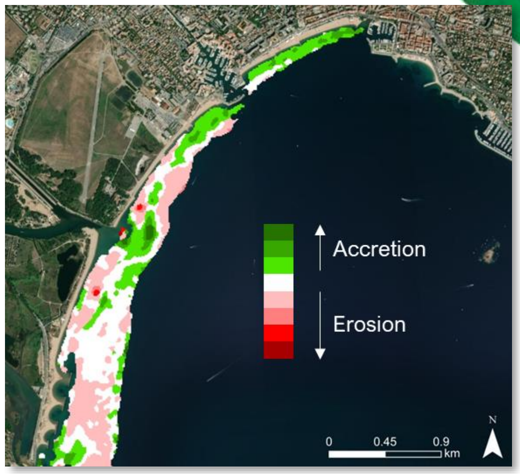
PORTFOLIO OF PRODUCTS

SUBMERGED INDICATORS

Bathymetry

To monitor the foreshore evolution and to integrate vertical dimension

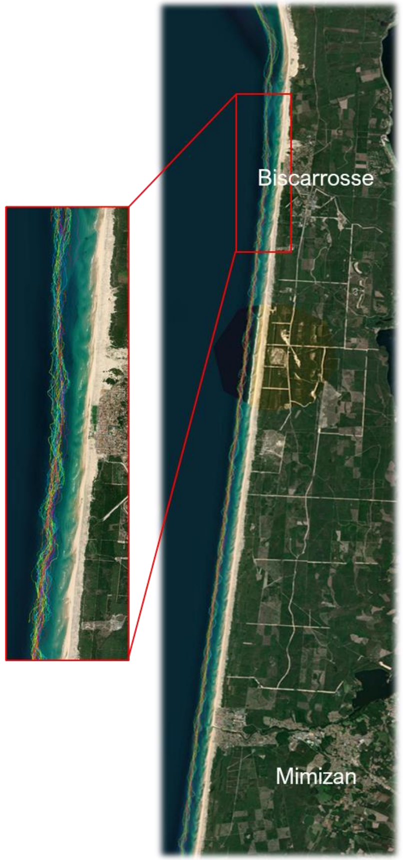
- Complementary to the planimetric approach related to coastline detection
- A key indicator for end users and for coastal management



Submerged Sandbars

Useful for integrated coastal zone management

- Beach continuity (sediment stock)
- Assessment of the nearshore dynamics



Bathymetry

Multispectral satellite data

Pre-processing (atmospheric & sunglint corrections, masks)

Water surface reflectance

Quasi-analytical model

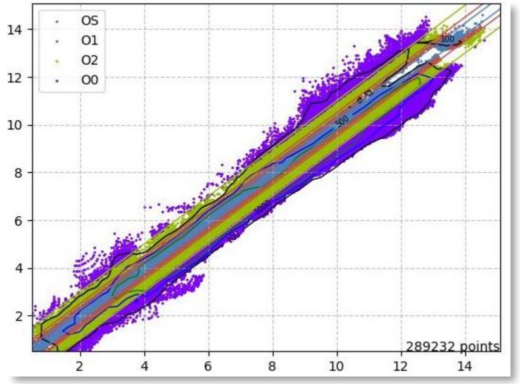
Water depth

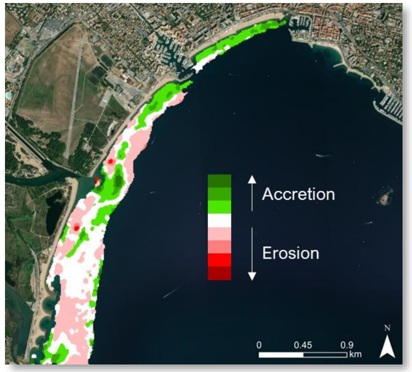
Post-processing (tidal correction, interpolation, validation)

Bathymetry

Vertical and volumetric change calculations

Morphosedimentary evolution



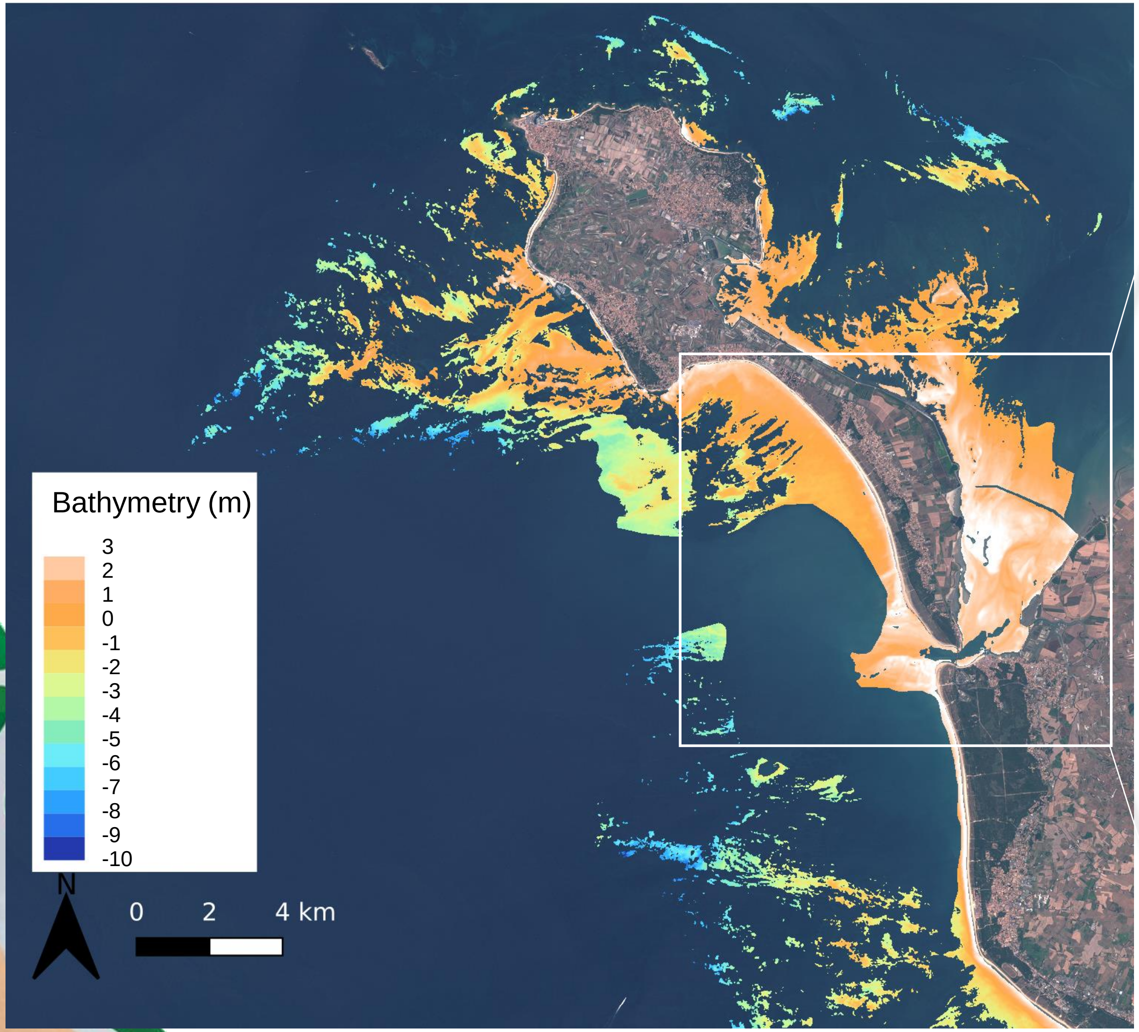


Bathymetry – Vendée (France)

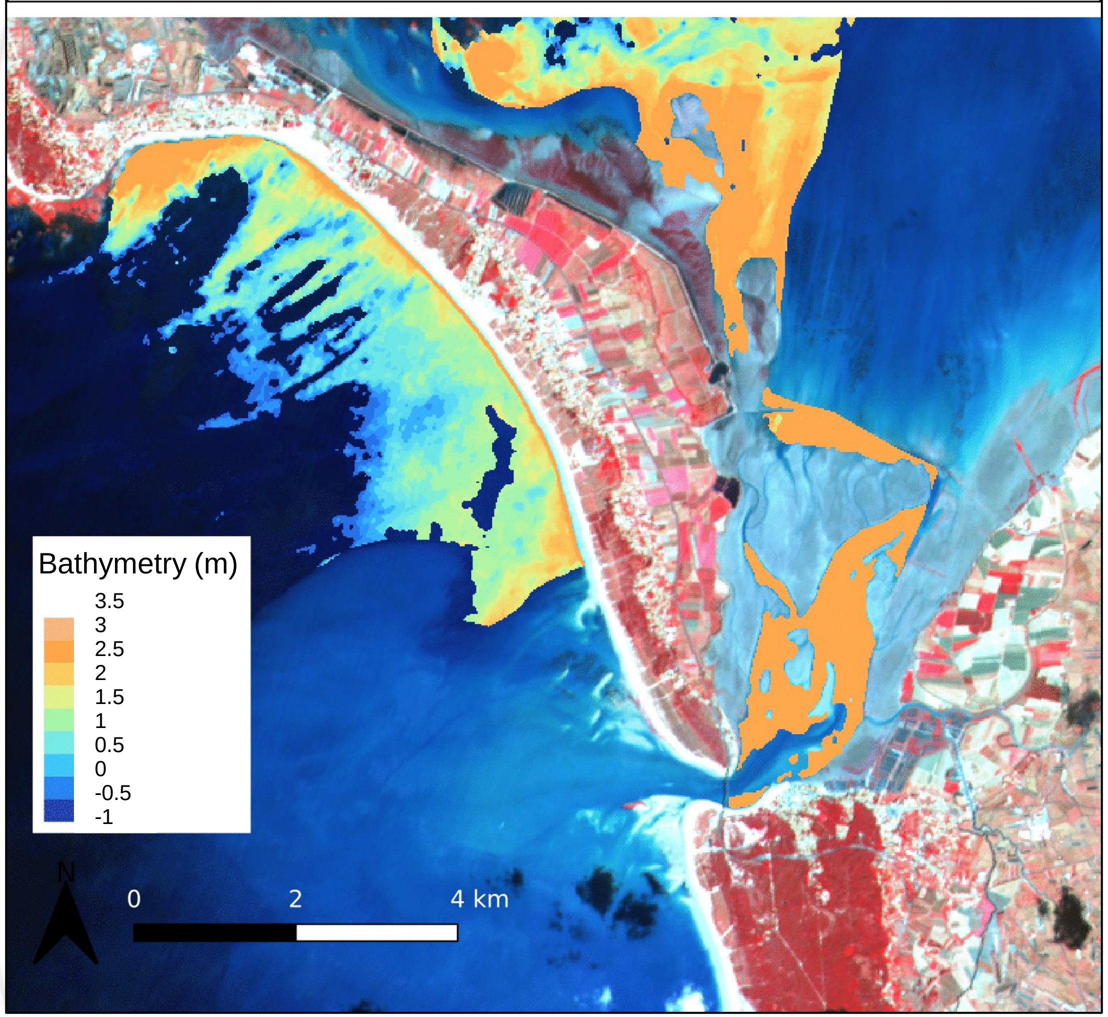
Challenge : high turbidity beyond 3 m depth, tide, heterogeneous seabed

Succès : Detectable foreshores in the shallow waters several kilometres from the coast

Bathymétrie satellite - Ile de Noirmoutier
Sentinel-2 - 15/08/2016

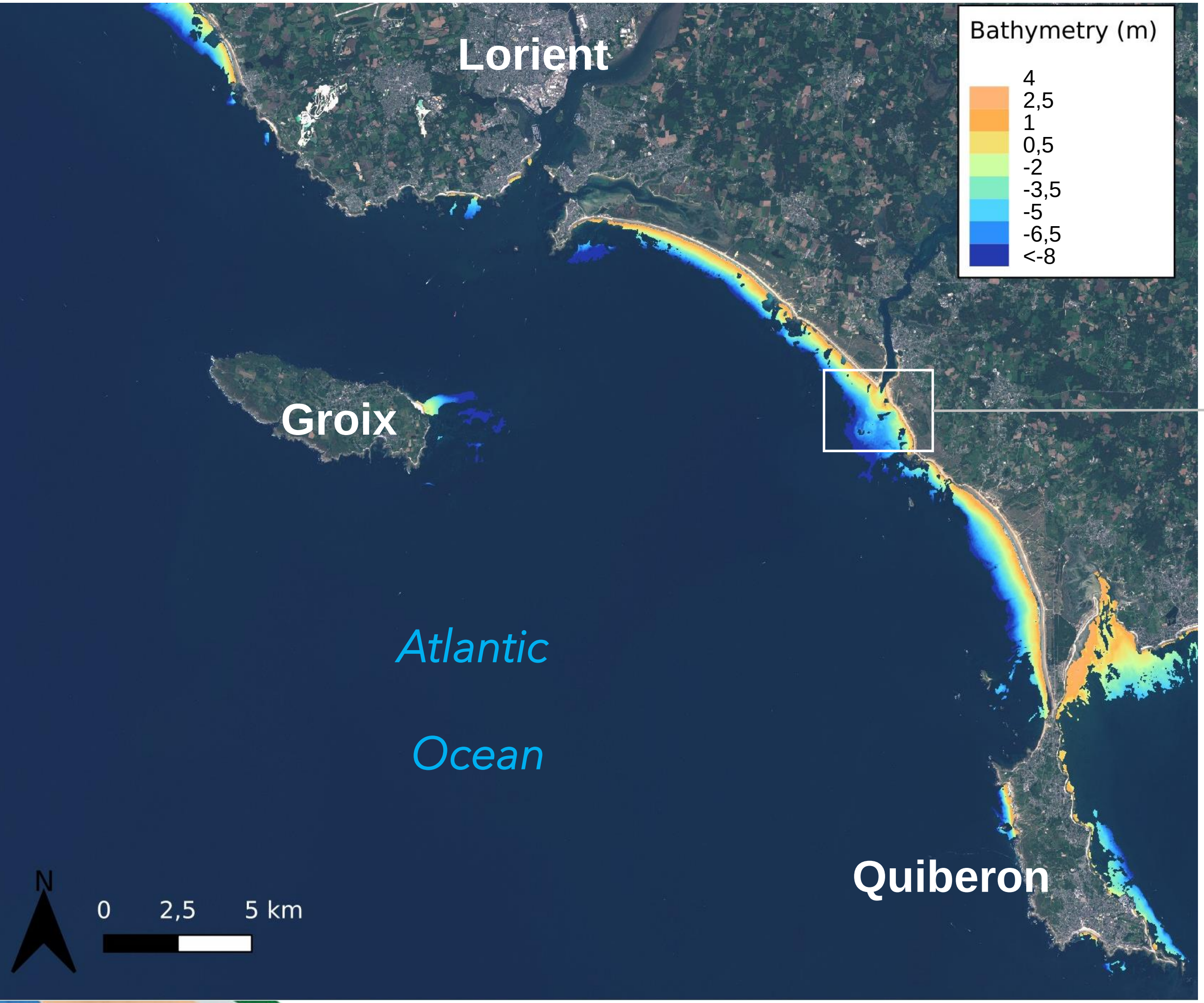


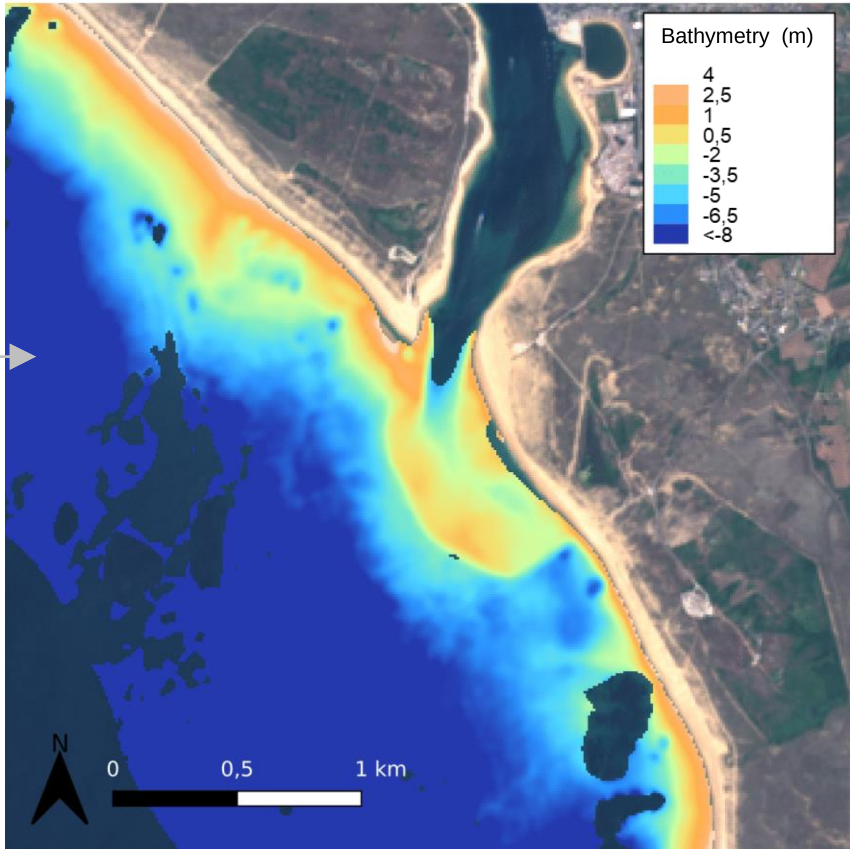
SPOT-4 - 28/08/1998



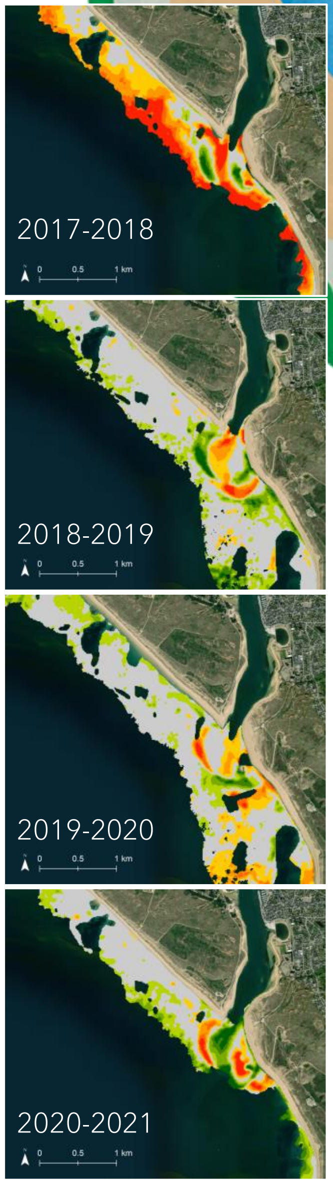
Bathymetry – Morbihan (France)

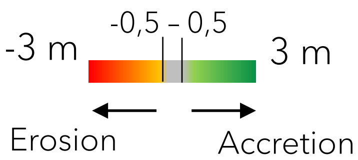
14/08/2021 - Sentinel-2





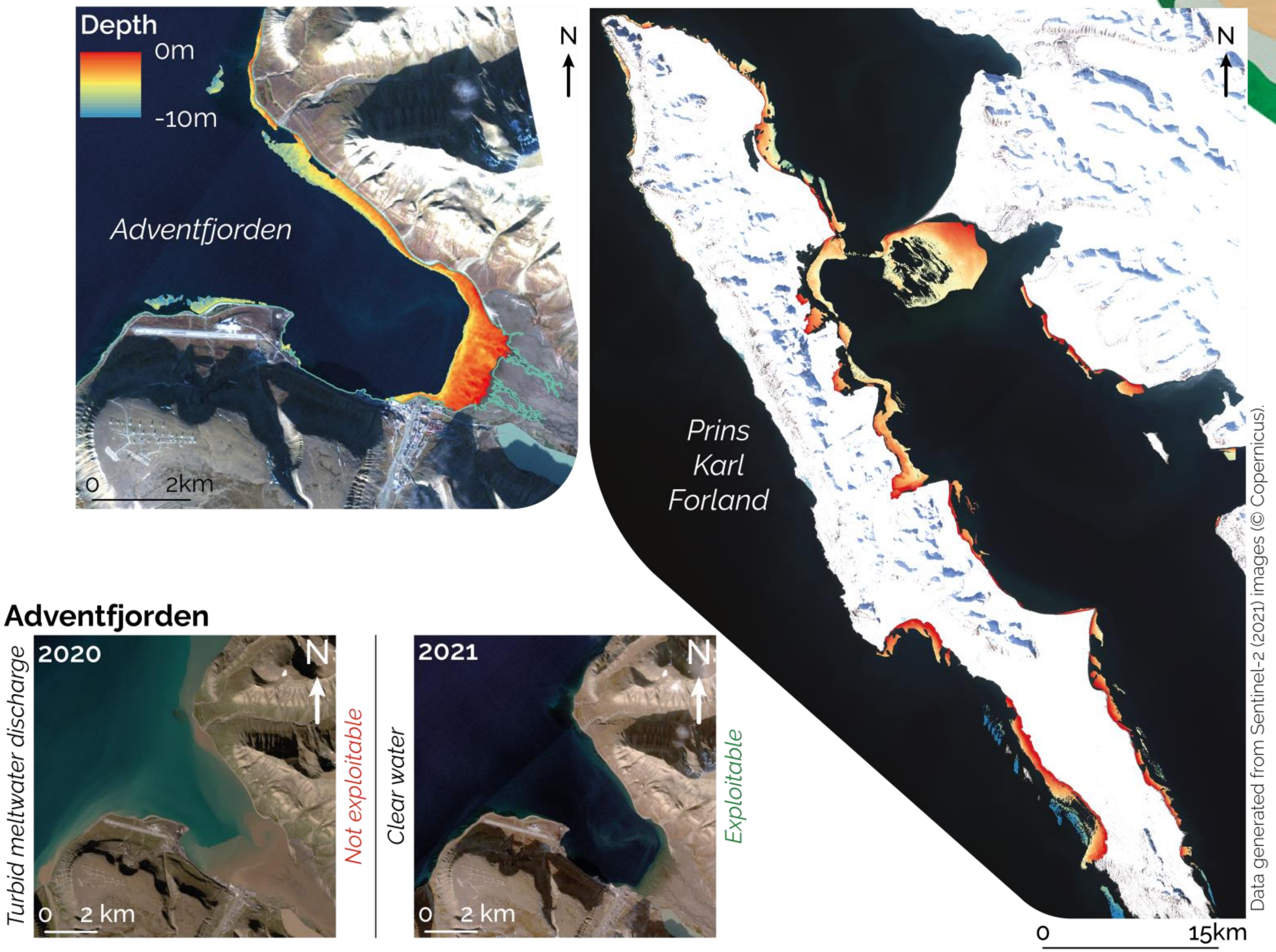
Extraction in highly dynamic areas





Bathymetry – Svalbard (Norway)

- Shallow water mapping (0 / -10m)
- Complements field data (start below -10m)
- Mapping changes in the foreshore

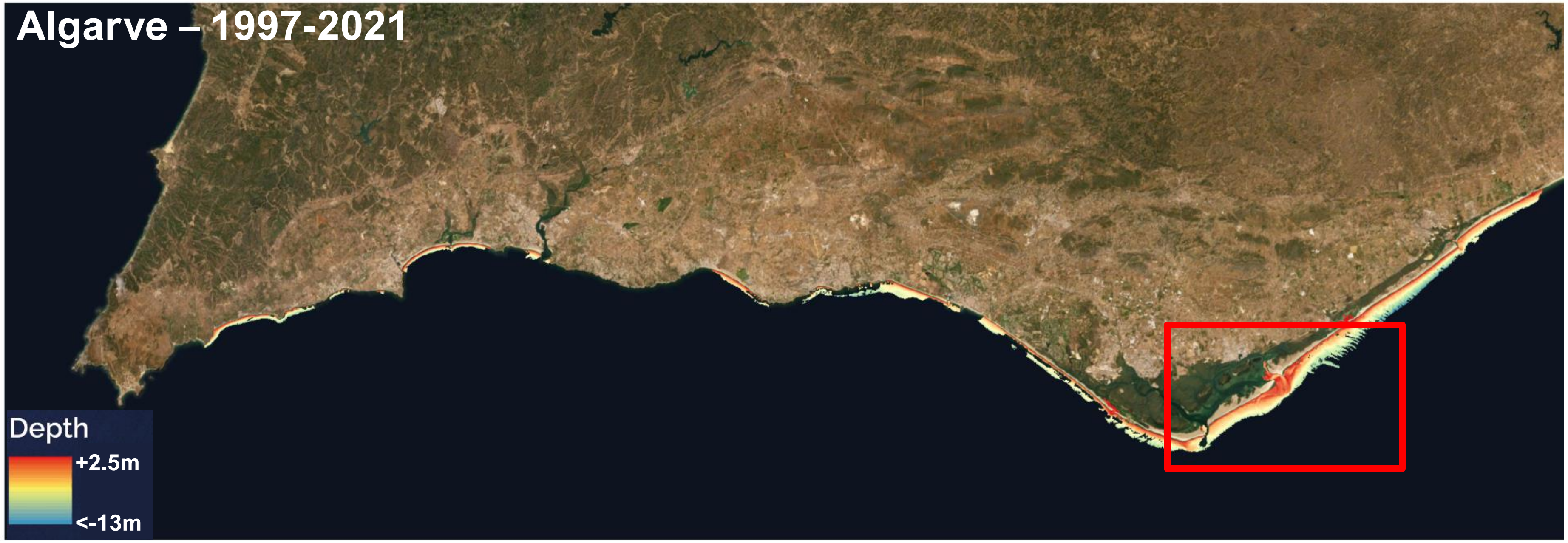


Some limitations

- Context-specific (Fjords)
  - step fore beach slopes
- Not context-specific:
  - Turbidity
  - Cloud
  - Ice

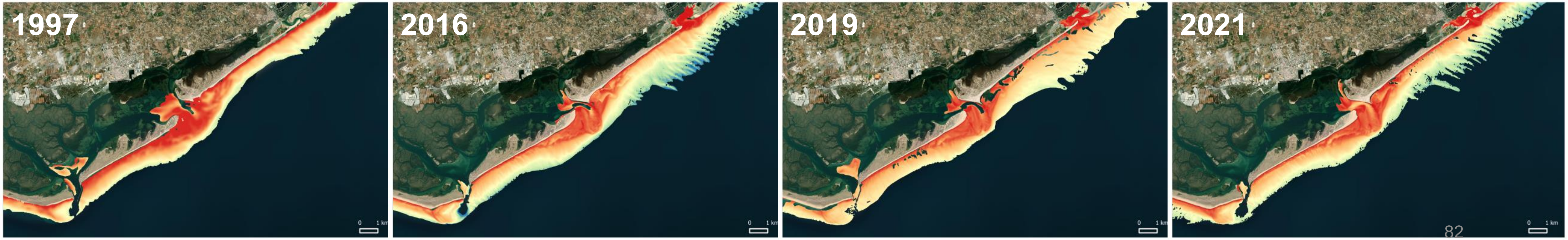
} Few usable images

Bathymetry – Algarve (Portugal)



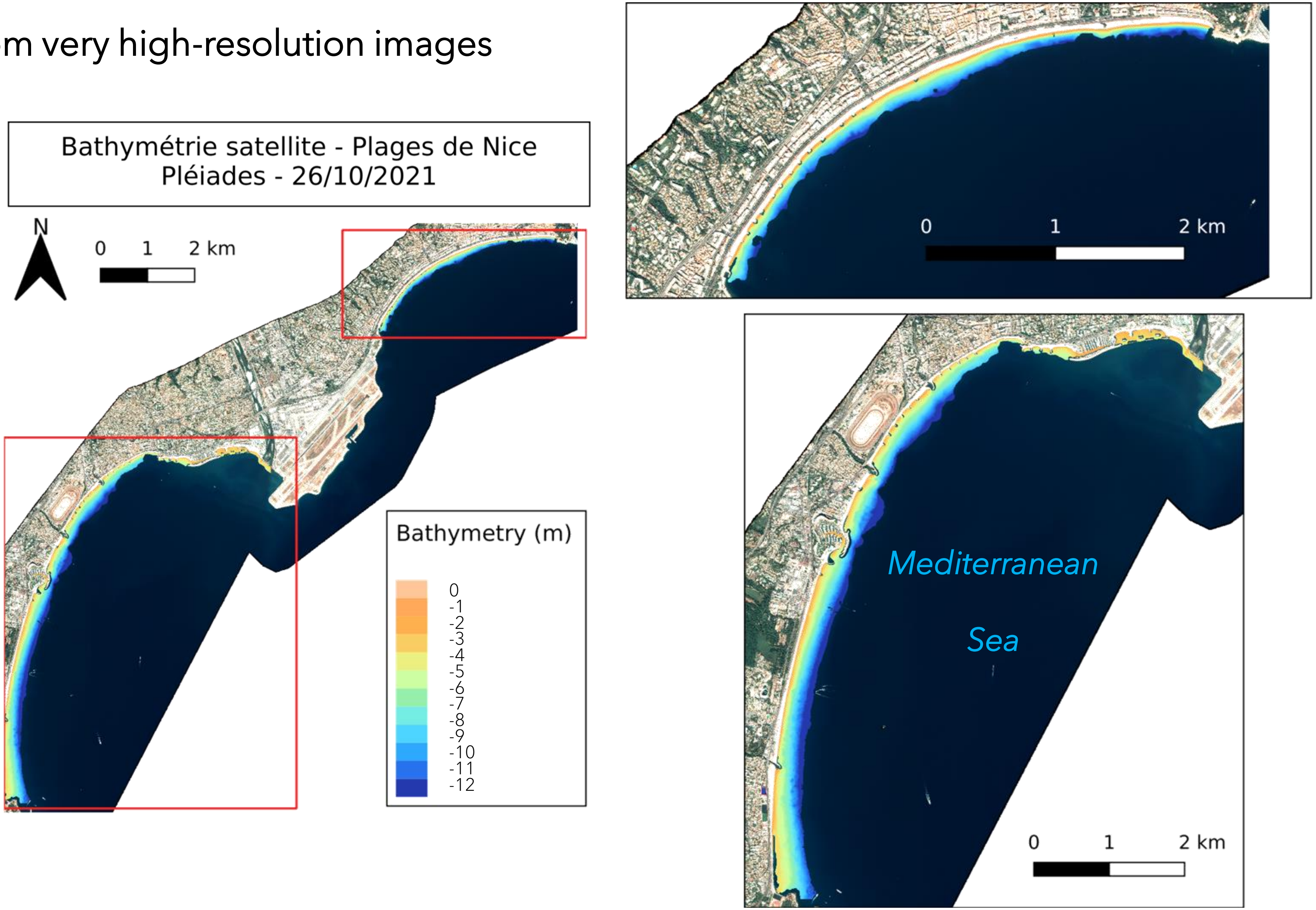
Extracted at the regional scale
- 26 yrs. of retrospective
- 136 km of coast

Detection of changes in the Flood and Ebb tidal delta.



Bathymetry – Nice (France)

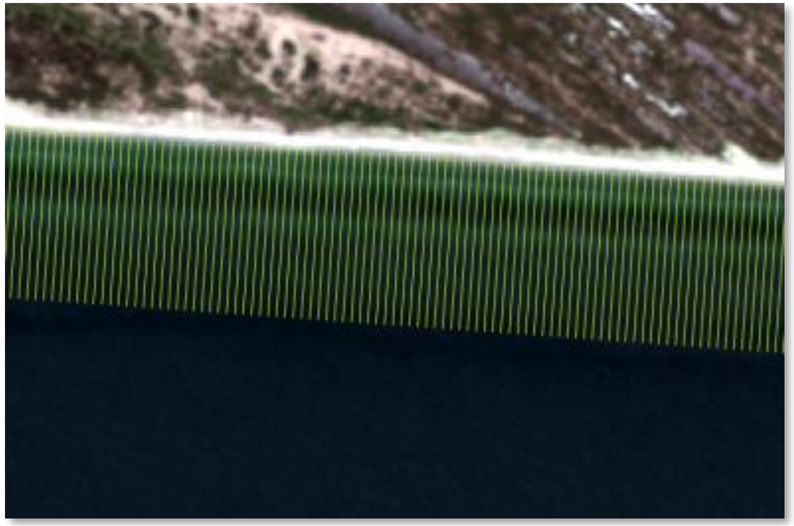
Extraction from very high-resolution images

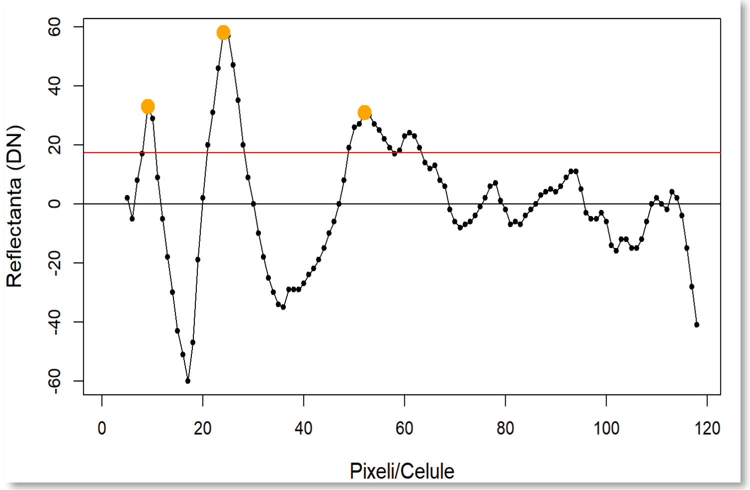


Submerged sandbars

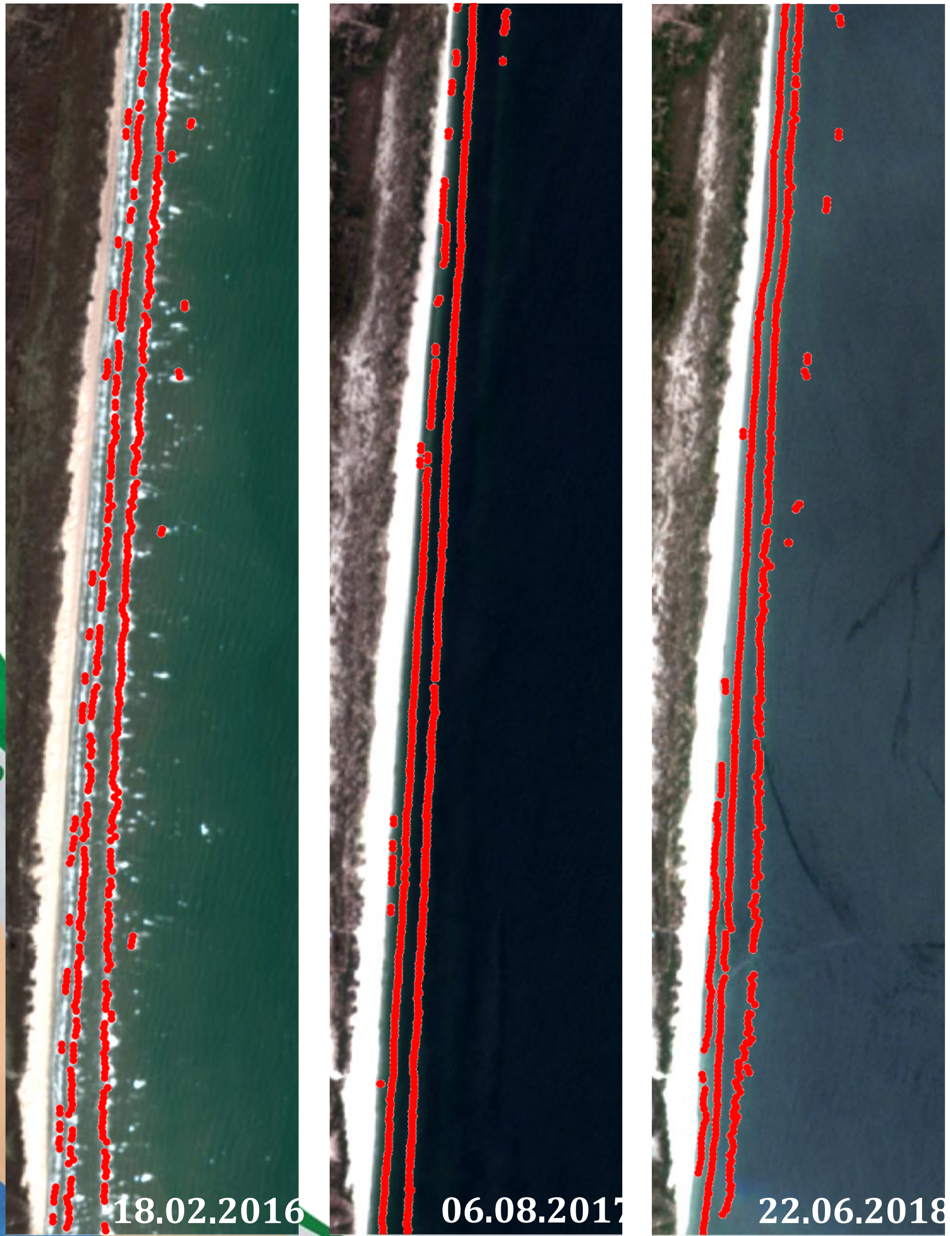
Approach based on
- the spectral response of sandbars locations
- multispectral satellite data.

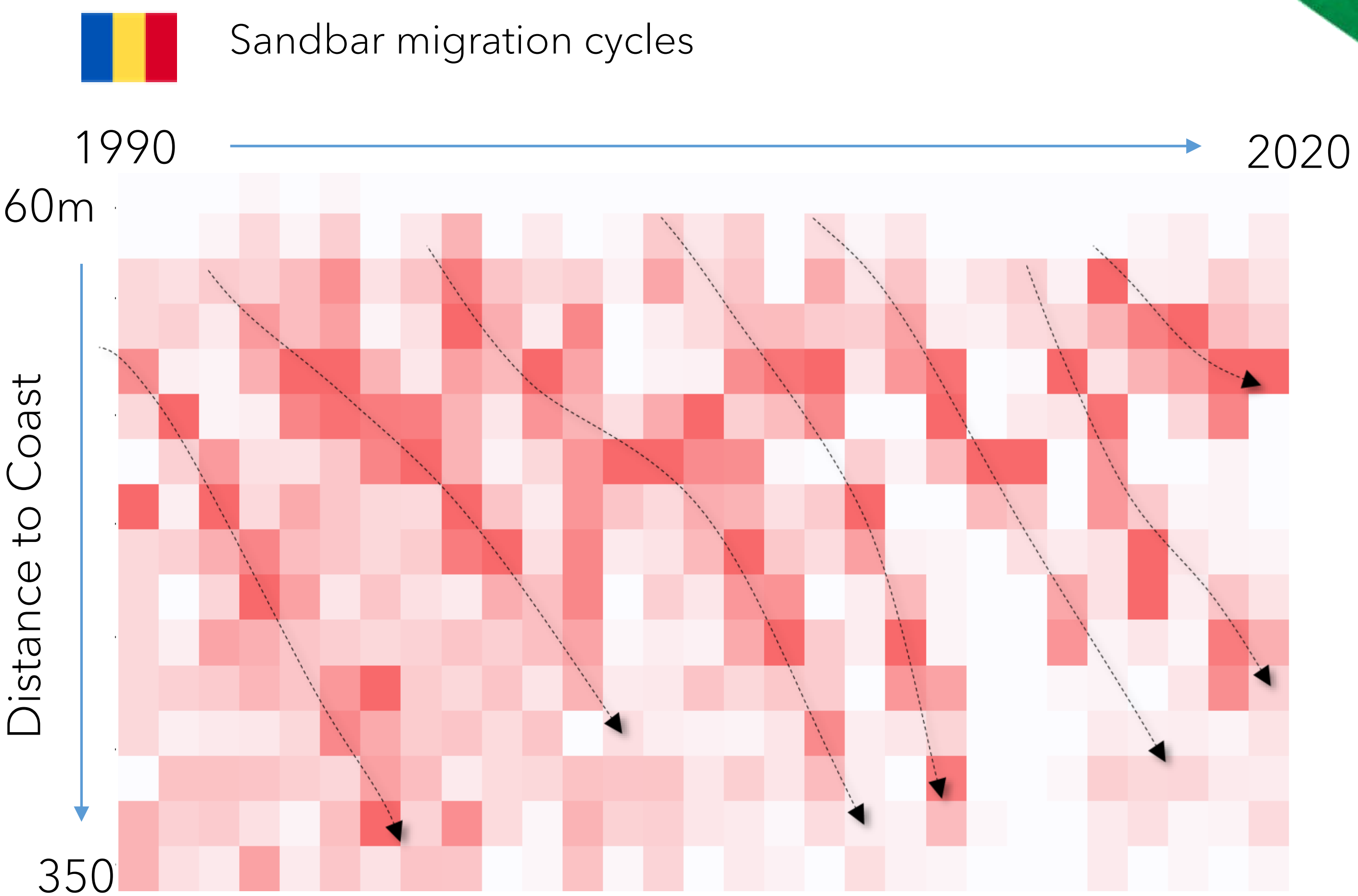
Each submerged sandbar position extracted using perpendicular profiles along the shoreline.
- For each profile, **reflectance values** are extracted, thus taking advantage of all information in the visible part of the electromagnetic spectrum.





Submerged sandbars

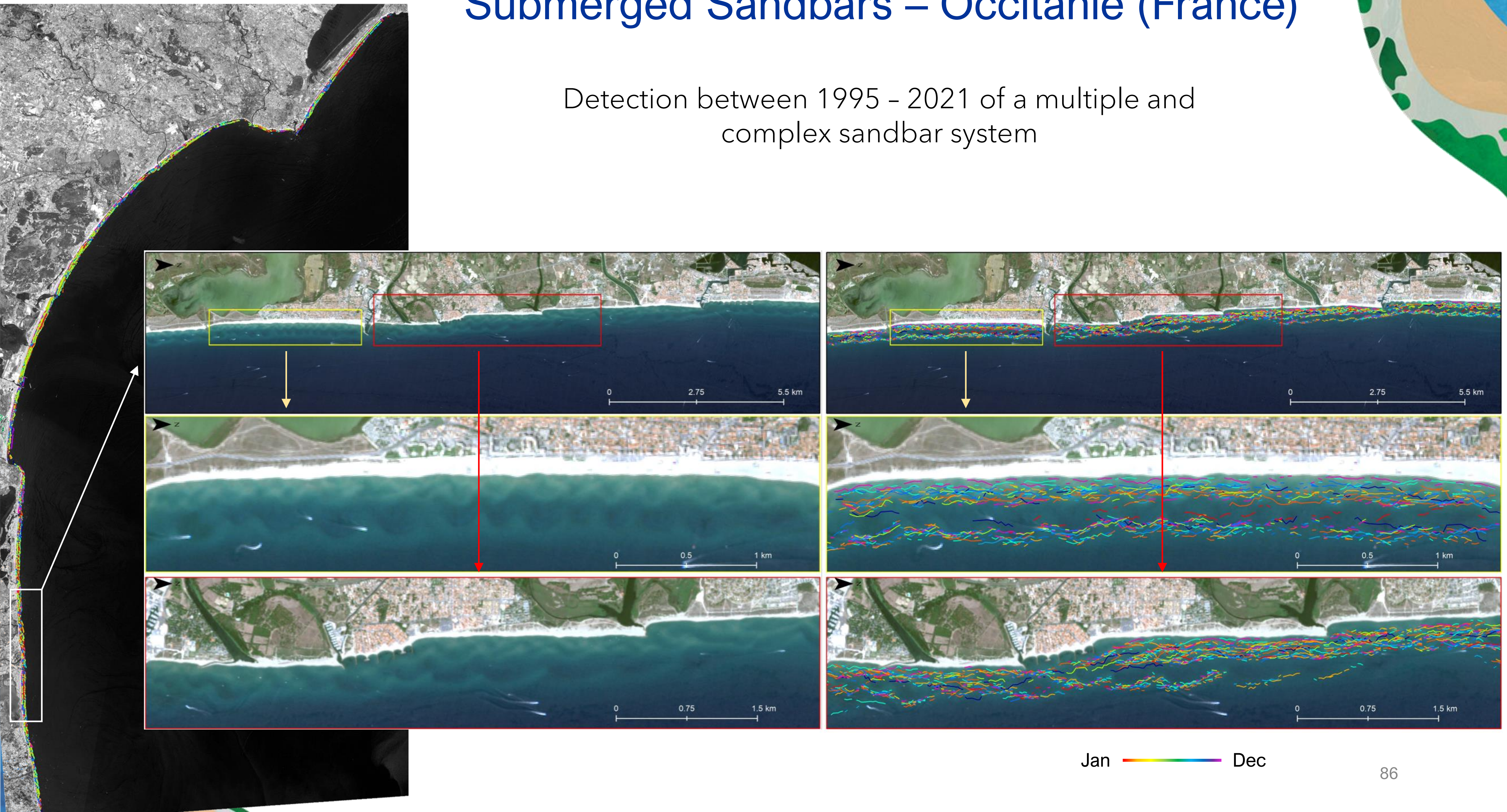




Occurrence of sandbars signal along a sample of 11 profiles (1 km alongshore, 20 m crosshore interval) every study year

Submerged Sandbars – Occitanie (France)

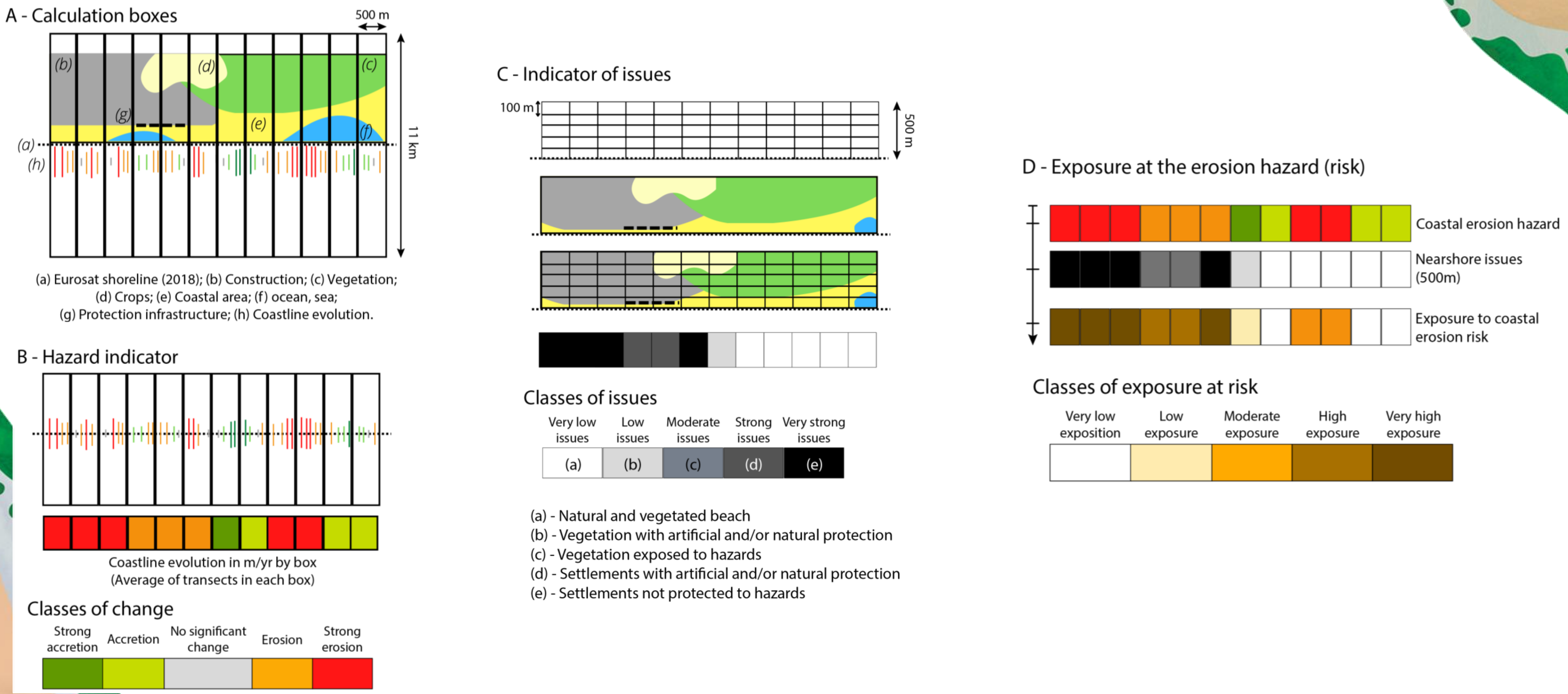
Detection between 1995 – 2021 of a multiple and complex sandbar system



PORTFOLIO OF PRODUCTS

COASTAL EROSION HAZARDS AND RISKS

Coastal classification based on the level of erosion hazard exposure

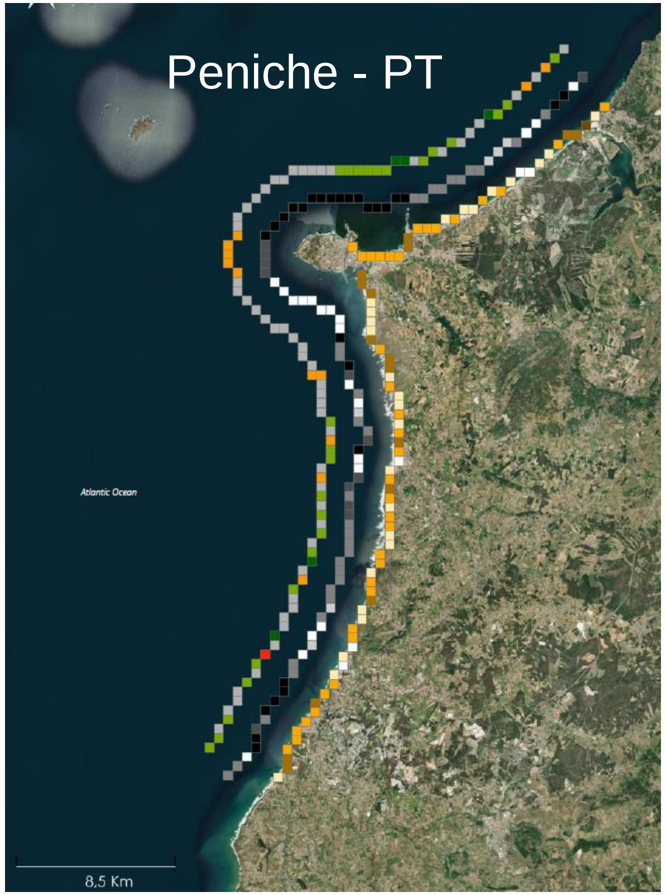


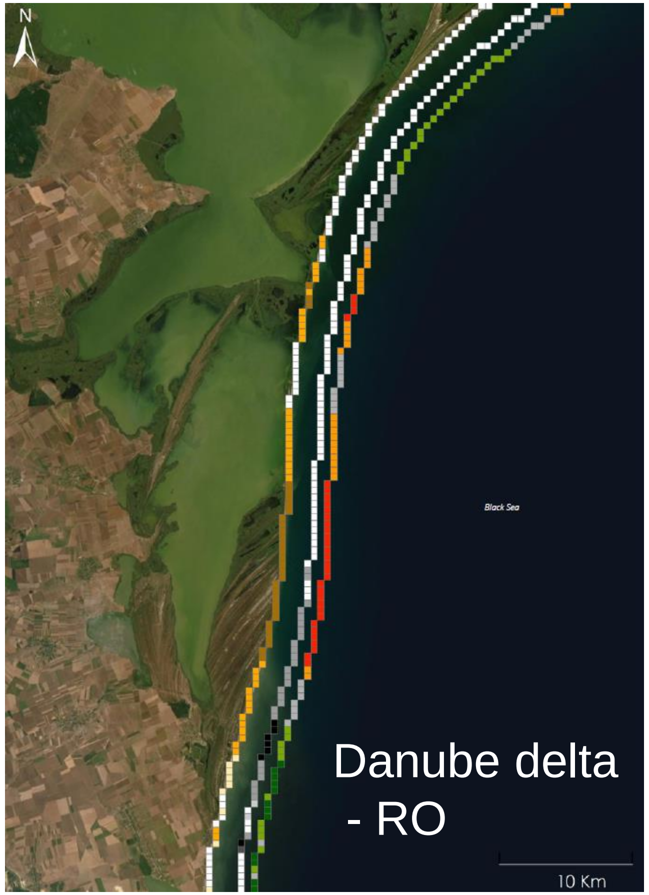
European pictures

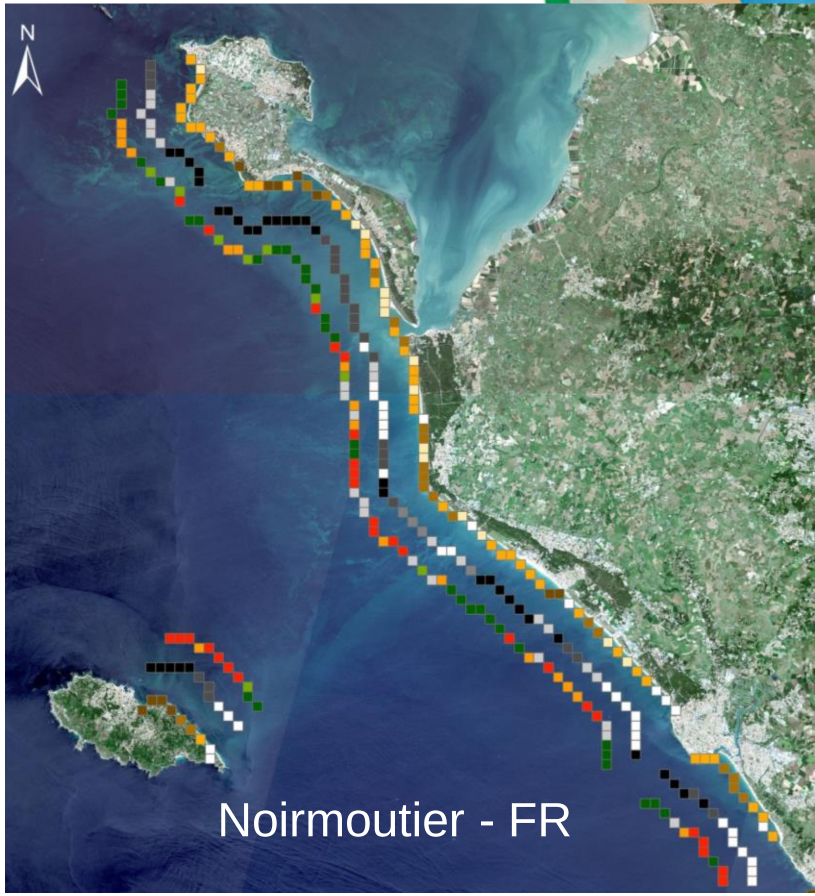
Strong accretion — Strong erosion

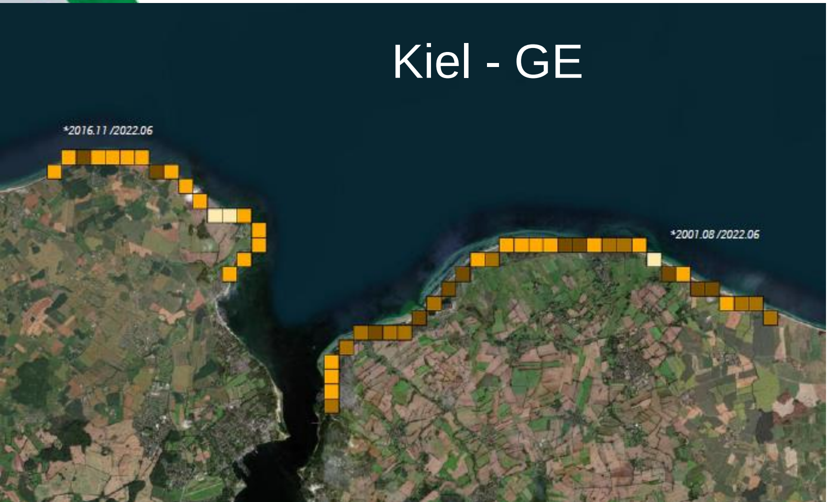
Low issues — High issues

Low risks — High risks









PORTAL OF DATA DISSEMINATION

Space for Shore Geoportal

Development of a custom geoportal for Space for Shore consortium

- Contract with DEIMOS including:
  - Geoportal development for user experience
  - Data Services (data dissemination and data collection)
  - Processing Services

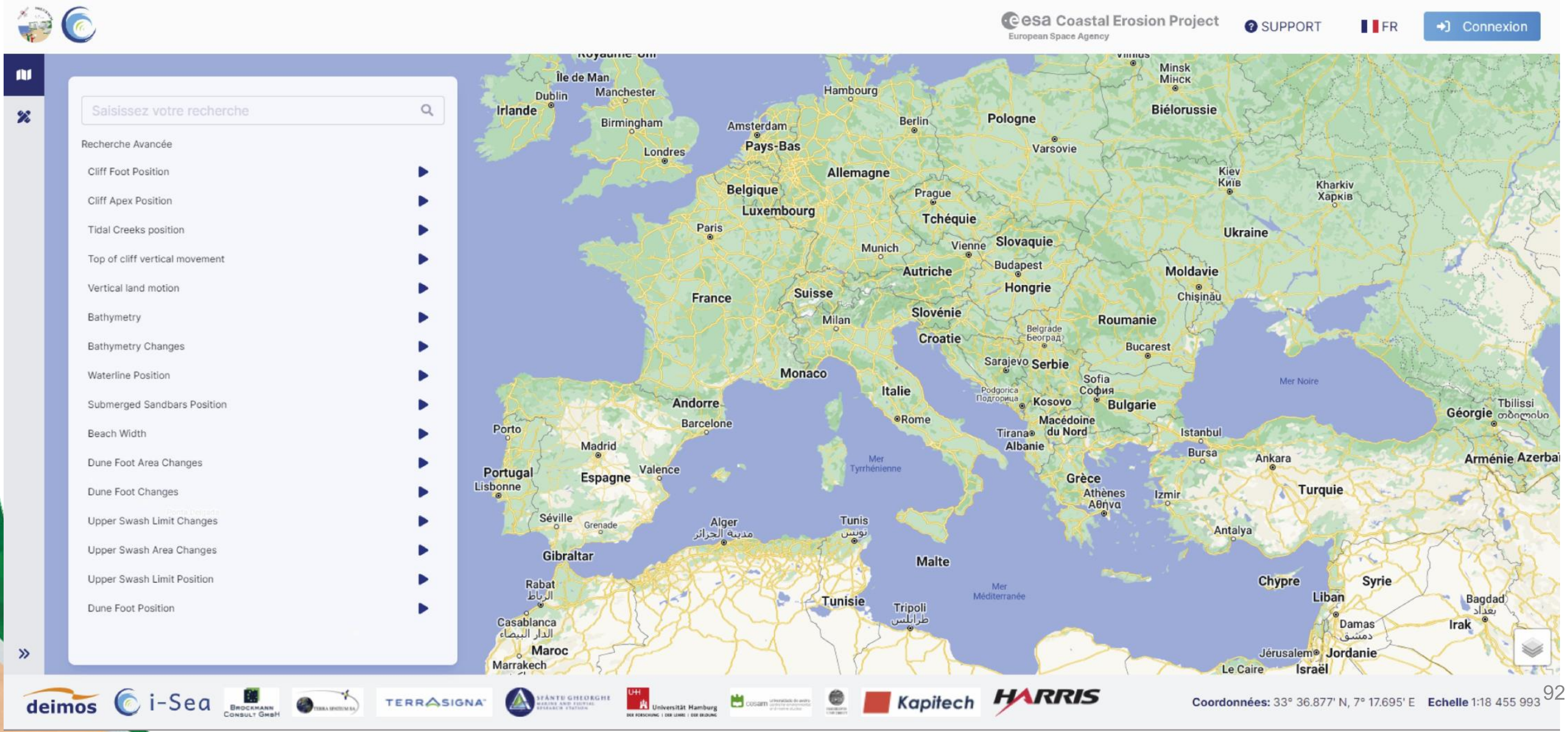
Kick-off meeting held on 17 March

- Objectives:
  - **Integrate all the results** obtained by the consortium during the three years of the project
  - Develop a **user-friendly interface**
  - Enable end-users to **easily access the data** available on their territory

Space for Shore Geoportal

Development of a custom geoportal for Space for Shore consortium

- Integration of all results into the portal (2019-2022) through more than twenty data collections
- User-friendly : translation into all the languages of the consortium

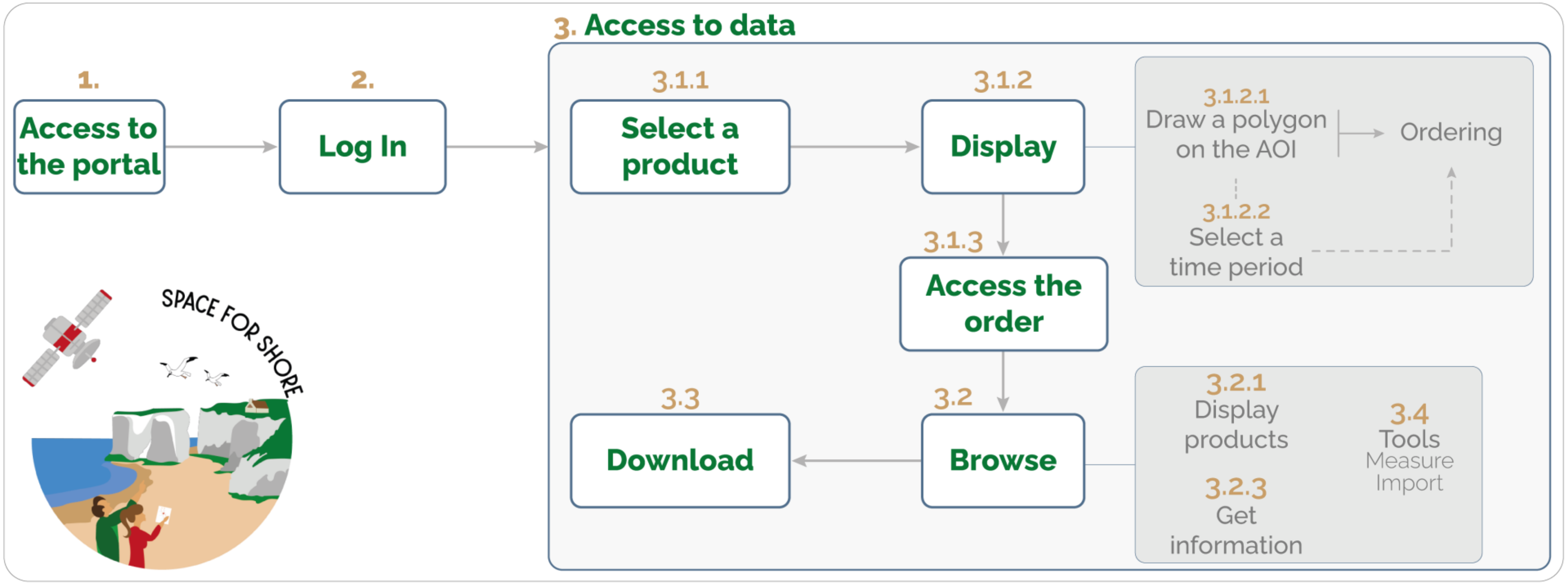


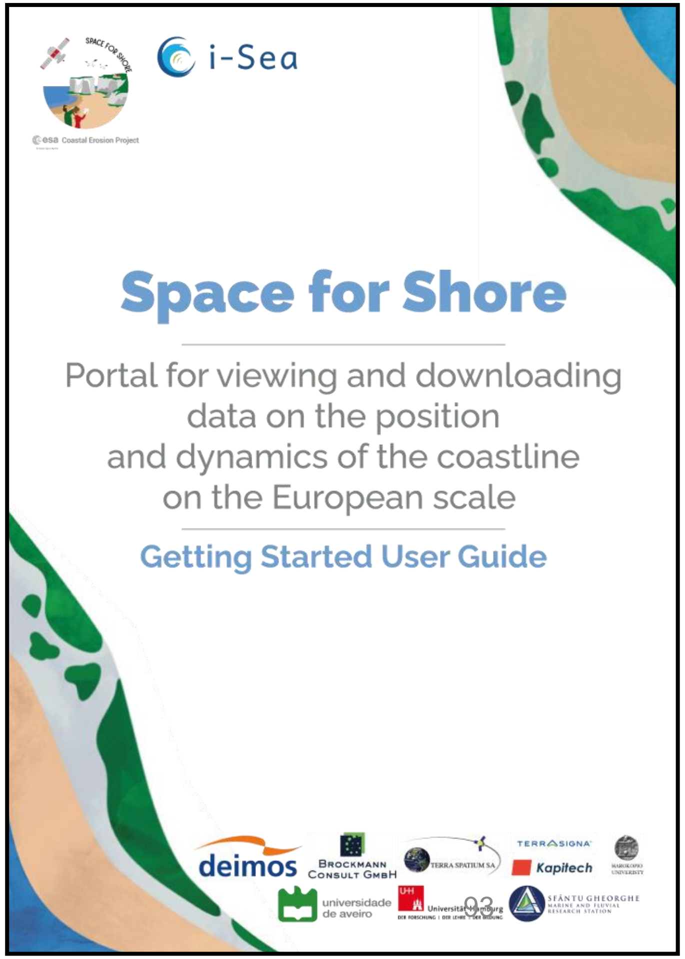
Space for Shore Geoportal

Development of a custom geoportal for Space for Shore consortium

- User-friendly : a simple three-steps process to display or download the data

User Guide



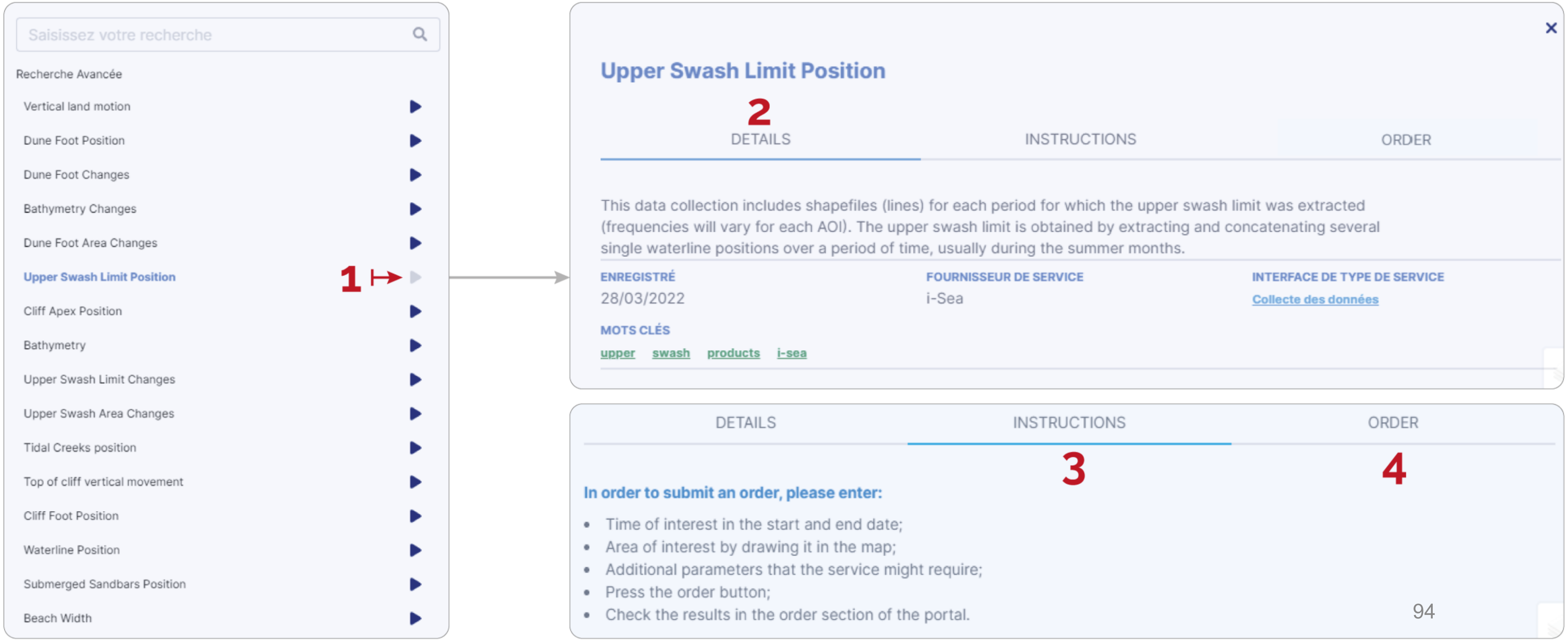


Space for Shore Geoportal

Development of a custom geoportal for Space for Shore consortium

- Data collections: one per product type (1)
- For each data collection : a simple description is provided (2)
- At any time: the end user can access the instructions (3) to consult the data (4)

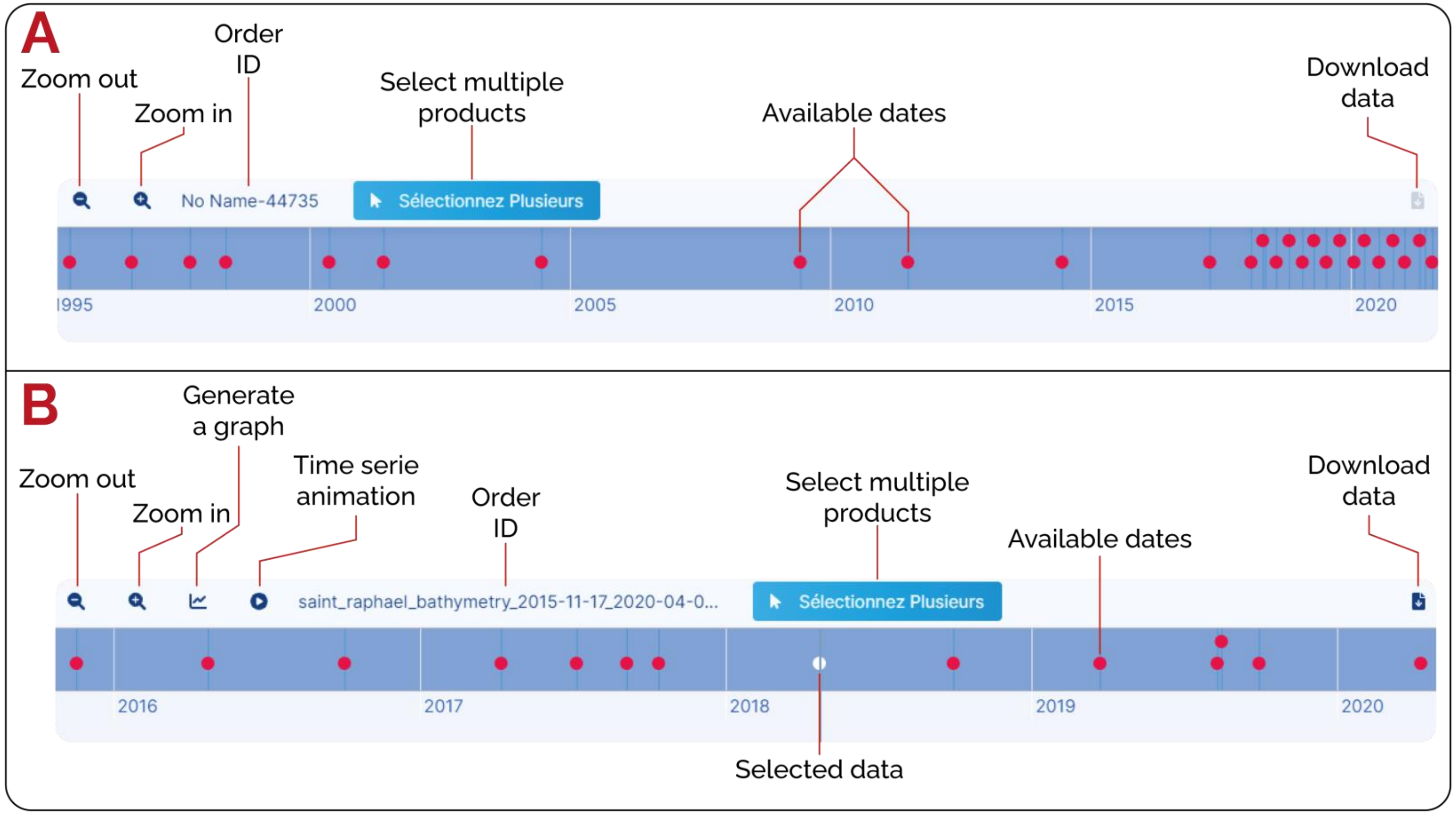
Data collections | Information window



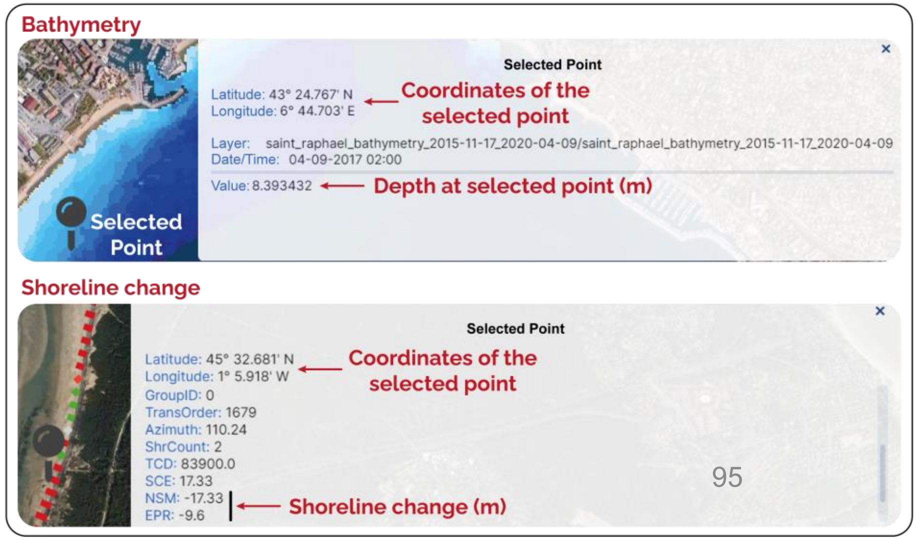
Space for Shore Geoportal

Development of a custom geoportal for Space for Shore consortium

- An interactive and intuitive timeline that allows you to see at a glance all available dates for a given product. (A)
- Multiple products can be displayed at the same time to visualise changes
- For the bathymetry product: creation of graphs and temporal animations (B)



Pop-up information boxes for all products



Space for Shore Geoportal

What is the next step?

- Continue the collaboration with DEIMOS to improve and finalize the portal :
  - The most recently produced data are not yet integrated into the portal
  - Improvements are possible and necessary in order to achieve a fluid and user-friendly use of the portal
  - Moving towards wider dissemination of results

COMMUNICATION

Communication actions

- ❑ Participation to conferences
    - ☑ International Congress for Nature Conservation (Marseille, FR, Sept. 2021)
    - ☑ ESA Phi Week 2021 (Oct. 2021)
    - ☑ ANEL 2021 (FR, Mayors' event), (Oct. 2021)
    - ☑ Safe Greece 2021 (Marseille, FR, Nov. 2021)
    - ☑ ESA Ocean Science Cluster Workshop (Dec. 2021)
    - ☑ ADB Healthy Oceans Tech and Finance Forum (Jan. 2022)
    - ☑ Living Planet Symposium (Bonn, GE, May 2022)
    - ❑ EUCC Littoral 2022 (Portugal, 12-16 Sept. 2022)
    - ❑ Safe Greece 2022 (Salonica, GR, 29/09-01/10/2022)
    - ❑ National Days of Coastal Engineering in France (JNGCGC, FR, Oct. 2022)
    - ❑ Salon des maires (Paris, FR, Nov. 2022)
    - ❑ EuroGEO workshop (Athens, GR, 7-9 Dec. 2022)
    - ❑ UN Cop15 Biodiversity (Montréal, CA, Dec 2022)

- ☑ Website updated
- ☑ Newsletter October 2021
- ☑ Romanian webstory (May 2022)
- ☑ Regional Demonstration meetings in June/July 2022
- ☑ 1 article for the JNGCGC proceedings
- ☑ 1 article for the Littoral 2022 proceedings

Communication

16TH INTERNATIONAL CONFERENCE
LITTORAL 22
12 - 16 SEPTEMBER| COSTA DA CAPARICA, PORTUGAL
ADAPT OUR COAST FOR A SUSTAINABLE FUTURE

The ESA Coastal Erosion project: on how the Copernicus Earth Observation program benefits coastal managers around Europe

Valentin Pillet[1], Virginie Lafon[1], Aurélie Dehouck[1], Manon Besset[1], Olivier Regniers[1], Georgia Kalousi[2], Georgiana Anghelin[3], Sorin Constantin[3], Florin Tatui, Kerstin Stelzer[4], Martin Gade[5], Paulo Baptista[6], François Sabatier, Stéphane Costa, Alexandre Nicolae Lerma, Christian Reimers, Celso Pinto, Olivier Arino.

[1] i-Sea, Bordeaux, France, [2] Terra Spatium, Athens, Greece, [3] Terrasigna, Bucharest, Romania, [4] Brockmann consult, Hamburg, Germany, [5] University of Hamburg, Germany, [6] University of Aveiro, Aveiro, Portugal.

(Corresponding author: valentin.pillet@i-sea.fr)

Keywords: Coastal erosion, shoreline, nearshore bathymetry, sediment budget, satellite remote sensing, Earth Observation, Copernicus.

Extended abstract

The objective of ESA Coastal Erosion is to demonstrate the potential of Earth Observation data (Sentinel-1 and -2, SPOT, Landsat, ERS-Envisat missions) to derive coastal changes over the past 25 years throughout Europe. To address this challenge, an international community of about 50 end-users (e.g., governmental authorities, coastal cities, natural protected areas) and coastal experts was surveyed to represent all European coastal types. They selected various pilot sites (micro/macrotidal range, wave/low wave exposure conditions, sandy beaches backed by dunes/coastal cliffs…) and expressed their needs in terms of data to monitor coastal changes. Technical aspects such as data acquisition frequency or accuracy have been specified. Then, the most promising methods to extract coastal erosion proxies were identified, tested and their performance was controlled.

This communication develops the main results obtained in 3 of the 6 engaged European countries (Germany, France, Portugal, Greece, Romania and Svalbard archipelago Norway). A particular focus will be made on the accuracy and robustness of the coastal erosion satellite-based products, although being mostly based on 10-m resolution observations. It will give first insights on the level of interest of the coastal managers to use EO-based products to increase knowledge about coastal erosion. The focus will also be on the efforts that need to be undertaken to make these approaches ready for large-scale deployment.

Oral communication
+
Paper

Journées Nationales
Génie Côtier - Génie Civil

La donnée spatiale au service de la gestion intégrée des zones côtières : de l'observation globale à l'action locale – L'ambition du Projet ESA Coastal Erosion

Valentin PILLET [1], Oscar VOISIN [1], Manon BESSET [1], Virginie LAFON [1], Aurélie DEHOUCK [1], Olivier REGNIERS [1], Nicolas DEBONNAIRE [1], Stéphane COSTA[2]

1. i-Sea, 30 avenue de Canteranne, 33600 Pessac, France.
   valentin.pillet@i-sea.fr
2. Université de Caen, CNRS, LETG, 14000, Caen, France.

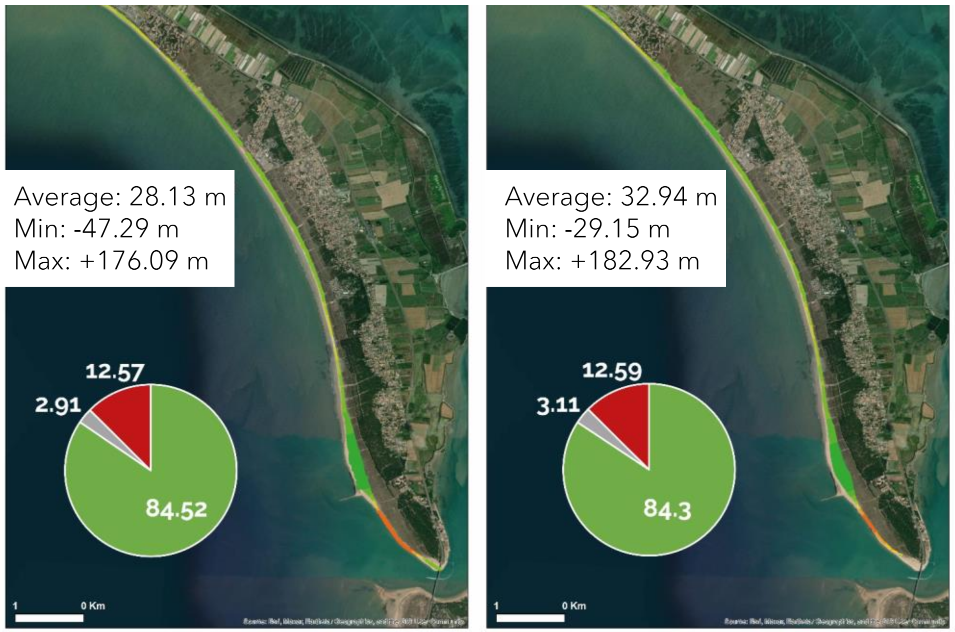
Résumé
De nombreux outils et méthodes d'observation (GPS, LiDAR…) sont déployés pour assister les acteurs en charge de la gestion des littoraux dans leurs politiques de réduction des risques et apporter des connaissances robustes sur la dynamique côtière. Si ces données offrent une excellente précision verticale et/ou horizontale, leur déploiement est limité à des zones restreintes et leur coût est généralement élevé. Dans le cadre du projet de ESA *Coastal Erosion*, le consortium *Space for Shore* propose une stratégie complémentaire, reproductible et abordable déployée à grande échelle ; elle repose sur la télédétection satellitaire et l'extraction automatique d'indicateurs de suivi morphologiques côtiers (trait de côte, bathymétrie…) à différentes échelles spatio-temporelles. Au total, et sur la base de milliers d'images satellites, l'évolution de 4500 km de côte a été suivie et analysée dans 6 pays européens (France, Norvège, Allemagne, Portugal, Grèce et Roumanie) sur les 25 dernières années. Pour répondre au mieux aux attentes des gestionnaires du littoral, l'ensemble des indicateurs repose sur les besoins exprimés et l'évaluation des produits par une soixantaine d'utilisateurs impliqués dans le projet (agences gouvernementales, autorités régionales, élus locaux, scientifiques). Sur ces bases, l'objectif est de proposer un outil d'aide à la décision fiable et abordable pour (1) servir de système d'alerte précoce permettant d'identifier les secteurs où une attention particulière doit être portée à l'érosion et à la vulnérabilité physique du système côtier, pour (2) optimiser les coûts relatifs au suivi de la dynamique côtière et connexes au déploiement d'instruments de mesure in situ en identifiant à l'échelle locale, régionale ou nationale les secteurs les plus dynamiques et (3) pour accompagner les acteurs locaux dans la gestion des risques littoraux en proposant une actualisation cartographique constante et rapide.

SCIENTIFIC ASSESSMENT

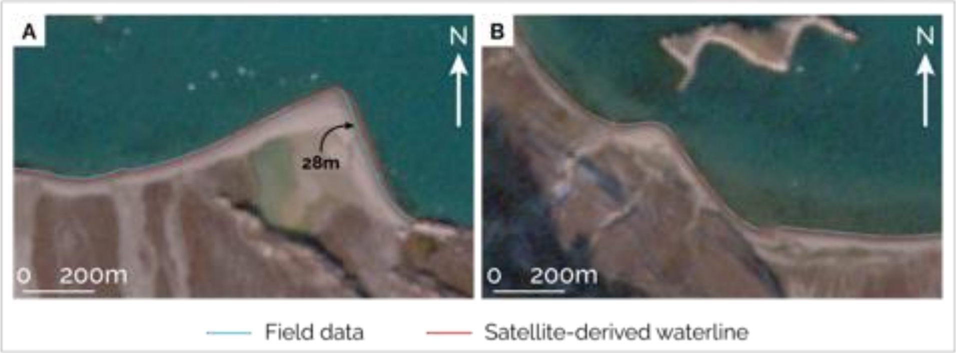
Quality of results in France and in Norway

Average errors	Upper swash limit	Dune foot	Bathymetry
PACA	1.52 m - 3.44 m (Pléiades)	/	0.50 m (Pléiades) 0.42 m - 0.68 m (Sentinel-2)
VENDEE	/	11.57 m (SPOT1) 6.57 m (SPOT 2) 3.33 m - 3.79 m (SPOT-5) 6.5 – 7.2 m (Sentinel-2)	/
MORBIHAN	/	/	0.99 m (Sentinel-2)
OCCITANY	2.78 m – 4.65 m (Sentinel-2)	/	0.31 m – 1.09 m (Sentinel-2)

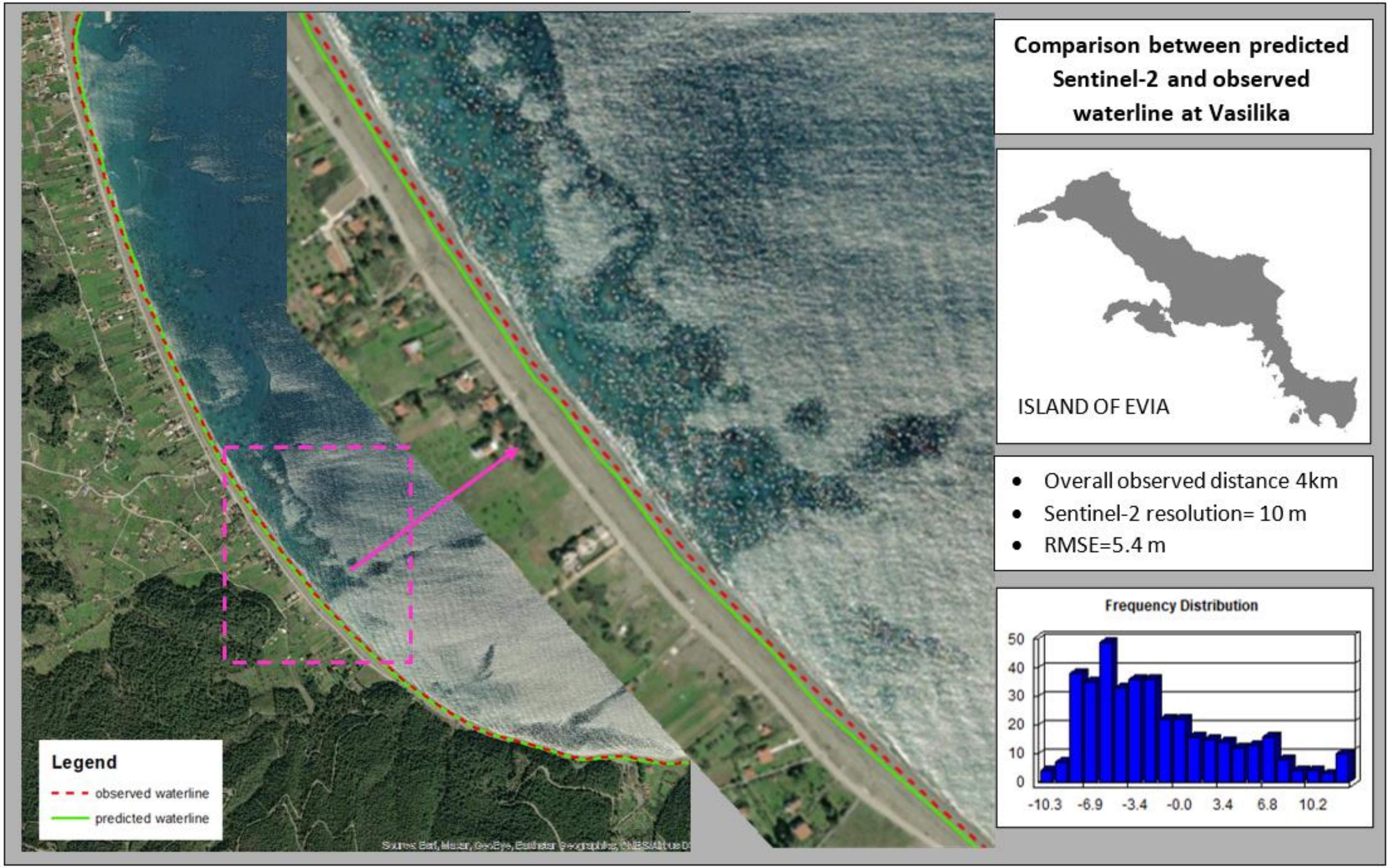
Values of dune foot mobility very close to those from field surveys



Average errors	Waterline
SVALBARD	4.73 m (Sentinel-2)



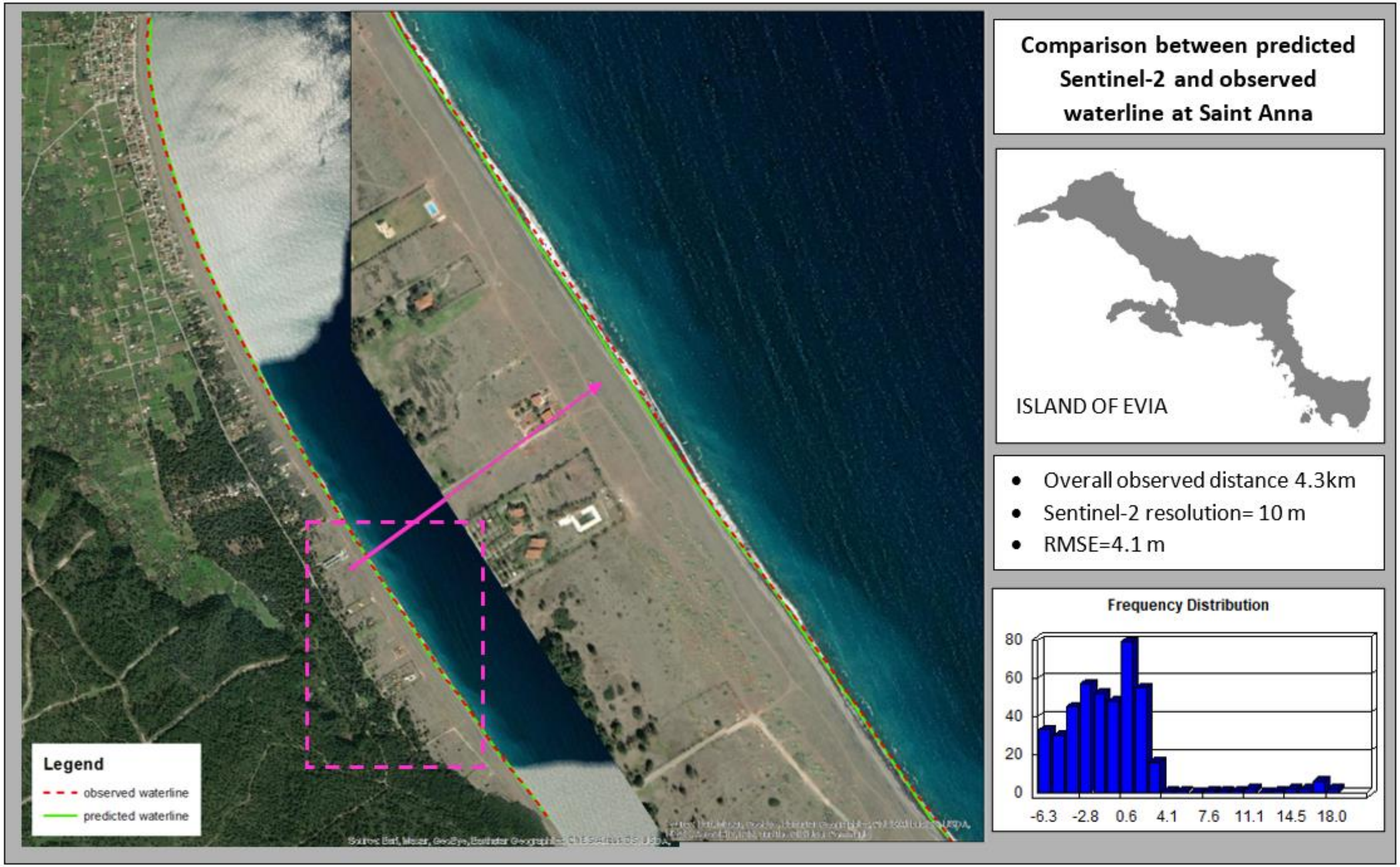
Quality of results in Greece



Validation Results

- Sub-pixel accuracy
- RMSE=5.4m
- Best performances (0.1m)

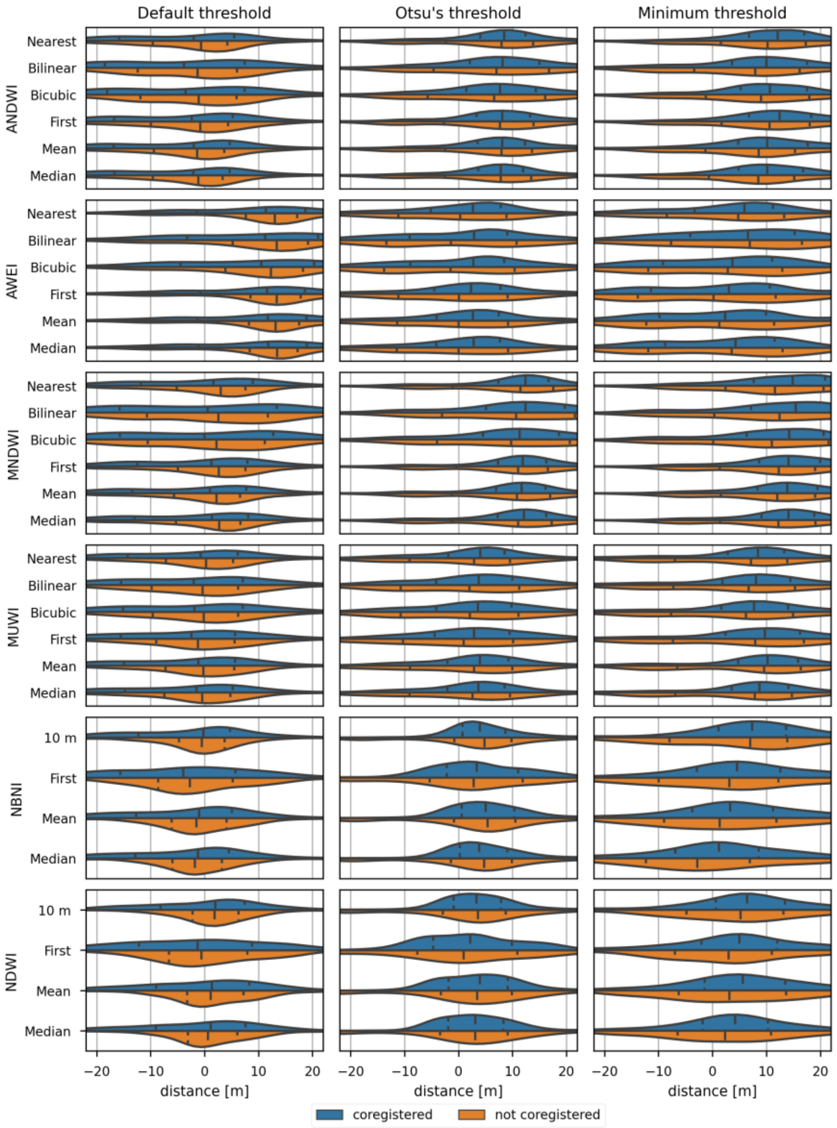
Quality of results in Greece



Validation Results

- Sub-pixel accuracy
- RMSE=5.4m
- Best performances (0.1m)

Quality of results in Germany



Schütt, 2022, Master Thesis

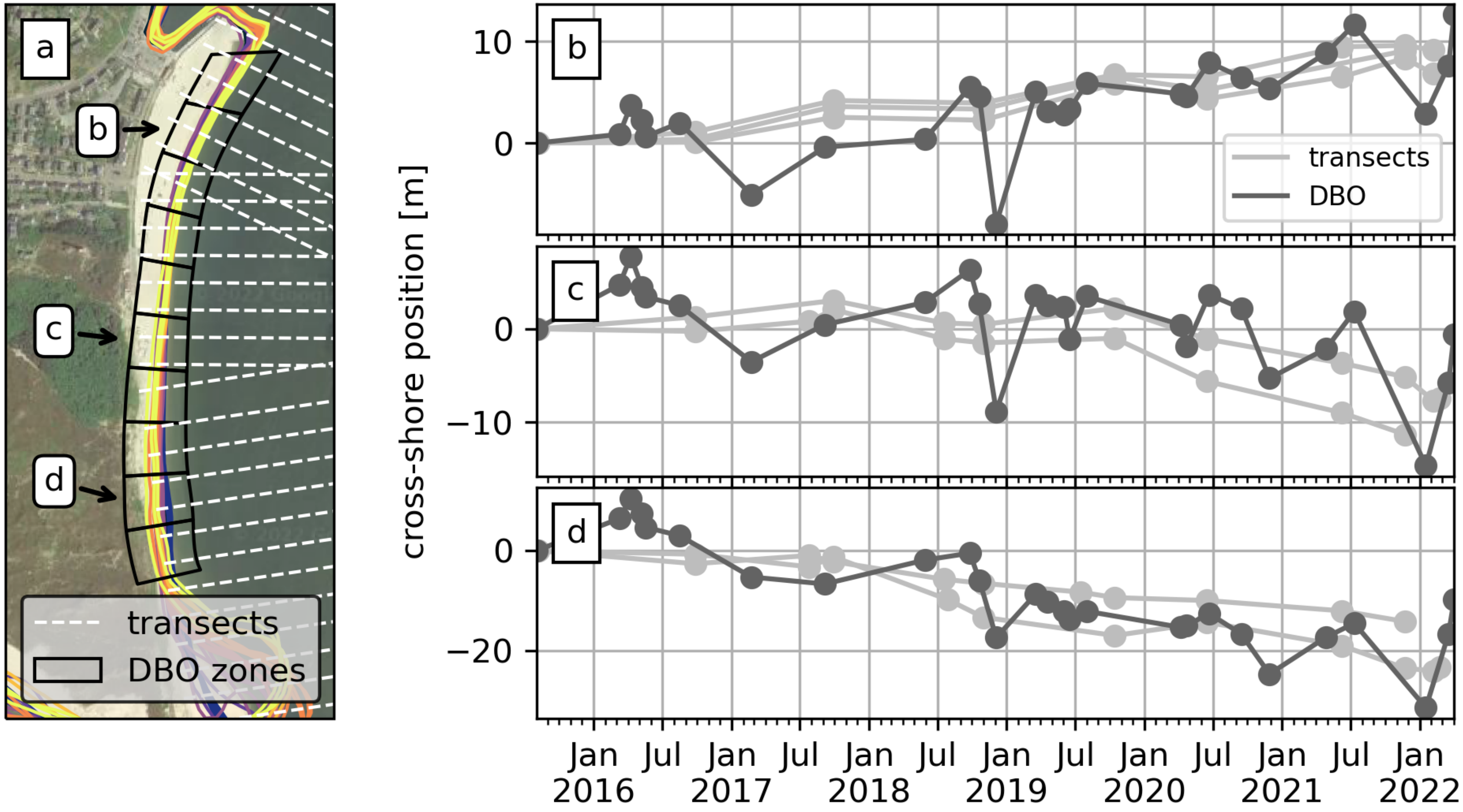
Validation Results (method)

Performance in dependency of

- Band ratio Indicator
- threshold method
- Resampling method

- Analysed under consideration of different coastal habitats

Quality of results in Germany



Schütt, 2022, Master Thesis

Validation Results (coastal change)

Shoreline change along

- In-situ transects (light grey)
- Satellite transects (dark grey)

END-USERS ASSESSMENT

Assessment from coastal managers and authorities

END USER ASSESSMENT // France

St Jean-de-Monts, Vendée 1/07/22

storm impact quantification *enabling filling the gap with traditional surveys that cannot be as reactive*
seasonal monitoring *of beach/shoreline changes*
the update of long-term shoreline change

Next step is to go deeper into the validation exercise and the group to provide (at last ;) their data

Enhance the analysis about method complementarity (ground/photo/lidar)

Work closely in partnership with the coastal regional observatory

Océan-Marais de Monts
COMMUNAUTÉ DE COMMUNES

PRÉFET DE LA RÉGION BRETAGNE — Direction régionale de l'environnement, de l'aménagement et du logement

Université Bretagne Sud — ubs

COMMUNAUTÉ AURAY QUIBERON TERRE-ATLANTIQUE

ORIC

Région PAYS de la LOIRE

RÉPUBLIQUE FRANÇAISE — Direction régionale de l'Environnement, de l'Aménagement et du Logement — PAYS DE LA LOIRE

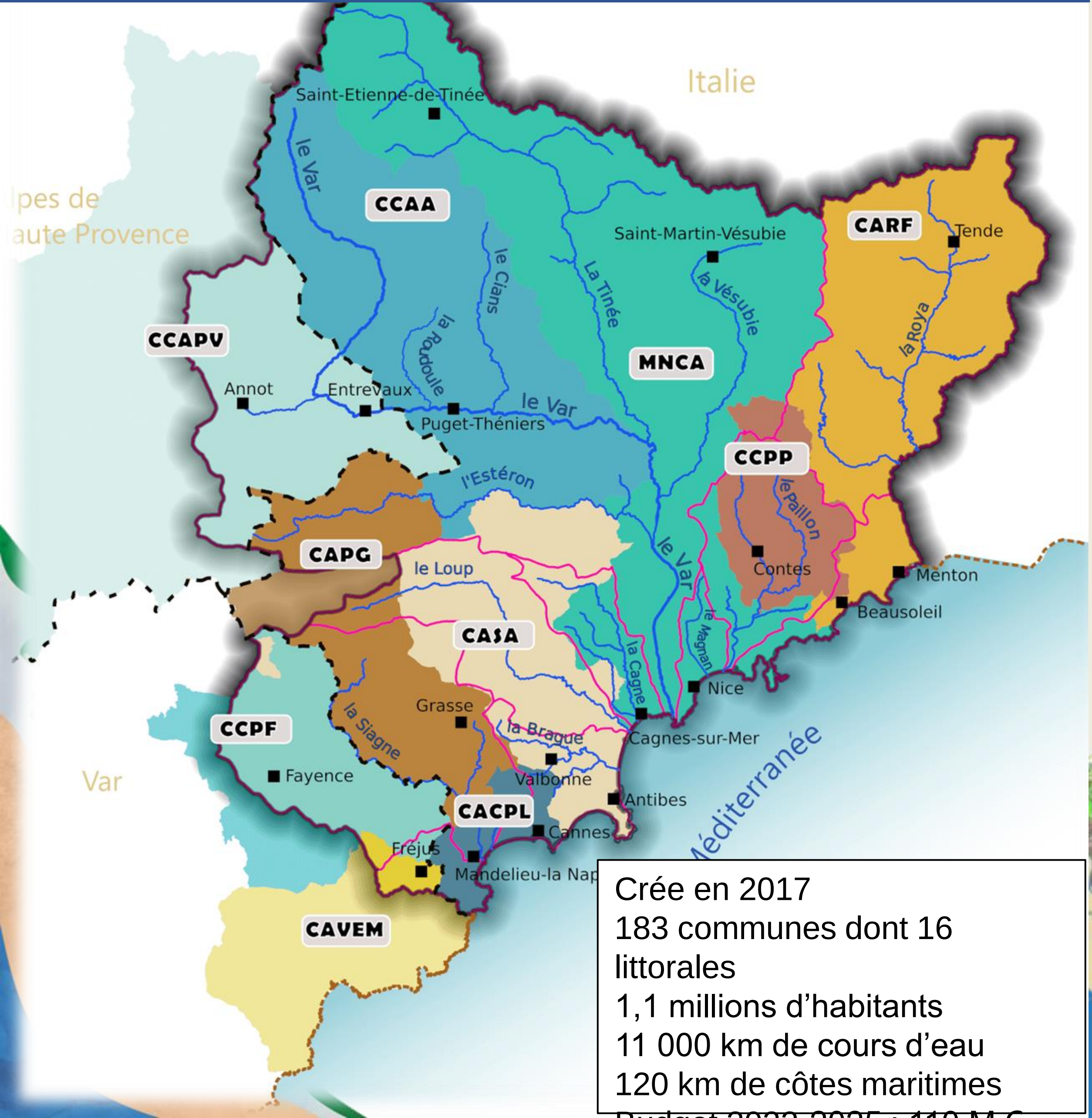
RÉPUBLIQUE FRANÇAISE — PREFECTURE DE LA VENDEE

PAYS DE SAINT GILLES CROIX DE VIE AGGLOMÉRATION

ÎLE DE Noirmoutier

Office National des Forêts

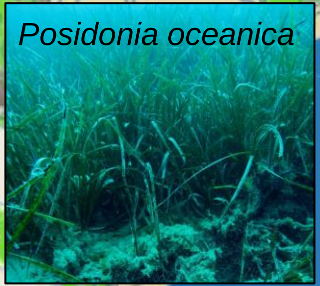
SMIAGE Maralpin, Syndicat GEMAPI
Département des Alpes Maritimes, France



Crée en 2017
183 communes dont 16 littorales
1,1 millions d'habitants
11 000 km de cours d'eau
120 km de côtes maritimes

Nature des fonds diversifiés
Soumis aux risque érosion et submersion marine
Enjeux balnéaires et sécuritaires
Forte anthropisation du littoral

Mise en place depuis 2022 d'un Observatoire (500 000€) :
1° Suivi sur le long terme du trait de côte et du stock sédimentaire
2° Préconisation en matière de gestion



Posidonia oceanica

Cymodocea nodosa

Assessment from coastal managers and authorities - **Greece**

ΔΗΜΟΣ ΧΑΛΚΙΔΕΩΝ
Municipality Of Chalkis

Municipality of Chalkis:

- *"It is impressive the level of accuracy provided via the satellite observations for the coastal erosion monitoring for this long period of 25 years".*
- *"We intend to make use of these tools, in the near future, for other areas of interest that are suffering from coastal erosion and monitor the way that the interventions are successful or not".*

INTERAMERICAN

Interamerican, Insurance Company:

- *"The waterline change indicator provides an insight on the coastal trend and hotspots over a wide area of interest and for a long timespan".*
- *"We are looking forward to the production of the coastal risk indicator, to be produced in Q4-2022, and trying to find ways to integrate this directly in our model for risk calculation".*

Assessment from coastal managers and authorities - **Germany**

Schleswig-Holstein
Der echte Norden

LLUR / LKN (closely linked users)

- *"It is impressive what can be derived form satellite data meanwhile with adequate tools".*
- *"Those tools were the missing link we were looking for since a long time.*
- *"Those results (information about intertidal flat areas) are very impressive and provide information we never received so far".*
- *"I am flashed"*

Feedback from user workshop:

- *„a really nice workshop dealing with an exciting topic!"*
- *„very good and consice – very positive"*
- *„Very good explanations for somebody without much knowledge in satellite data"*