



# Cliff lines and rocky landslides volumes

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# An exhaustive review of end-users' requests

## INTERMEDIATE ENDUSERS COASTAL EROSION EXPERTS



## WHO

## HOW

	Revisit	Horizontal accuracy
France Normandy	1/year	2 m
France New Aquitaine	1/year	2 m
Germany	Every 2 years	2 m
Portugal	Every 2 years	2 m

## FINAL END USERS



## WHY

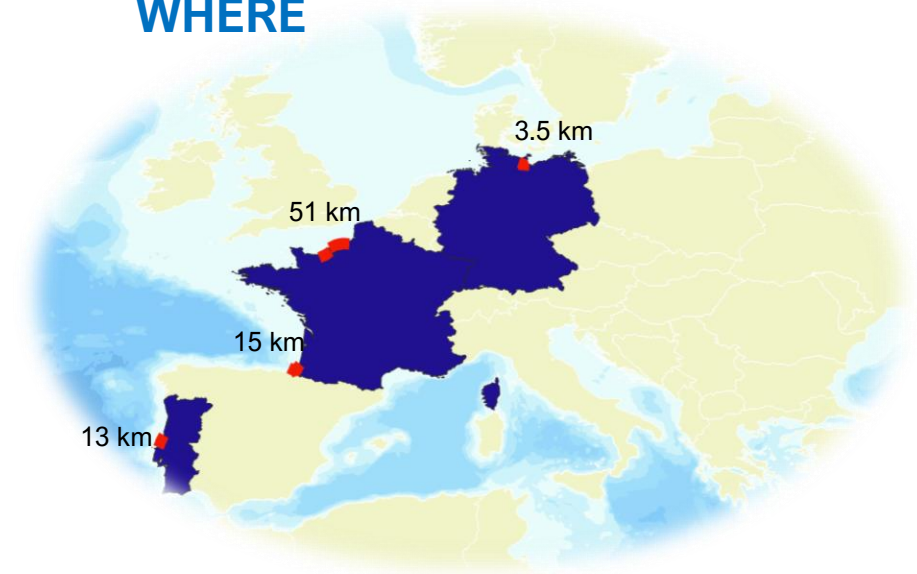
Monitor the cliff changes, the cliff foot and the cliff apex are the main reference indicators.

Localise and identify significant retreats of cliffs over large areas and large periods.

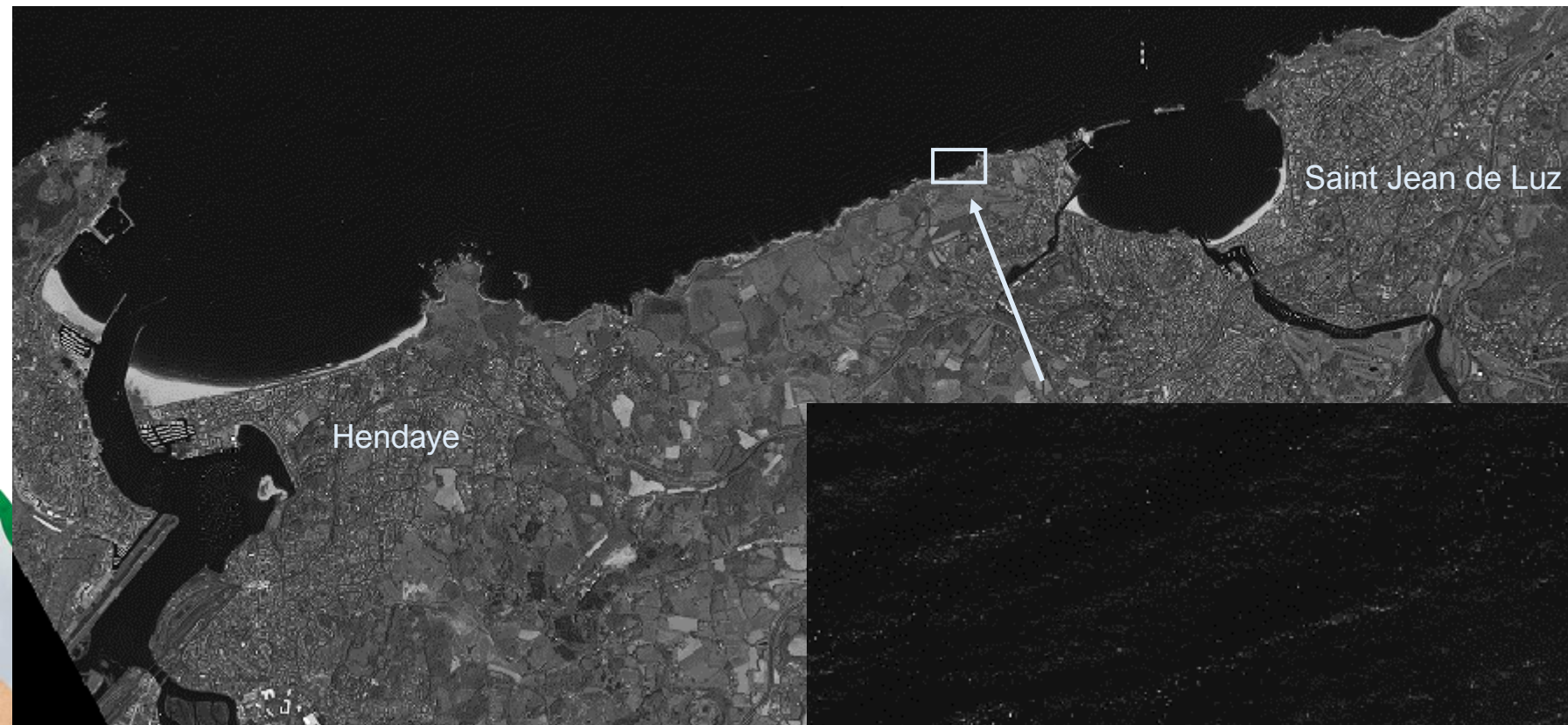
Estimate cliff retreats for major events.

Estimate landslides volumes.

## WHERE



Pléiades panchromatic image of the New Aquitaine south coast in France: the example shows the slope of the cliff between the road and the ocean – 27/07/2017



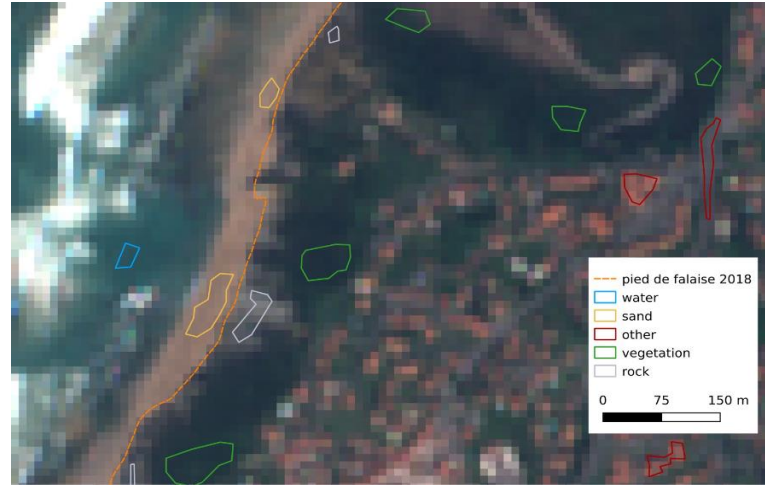
21/01/2021

Space for Shore - Final Meeting

3

# Methods

- Optical approach based on machine learning to derive cliff foot and cliff apex



Sentinel-2 image 2018

- Optical approach based on VHR images (Pléiades), using DEM:
  - Satellite photogrammetry to extract DEM
  - Landslides volumes by subtracting 2 DEM
  - Cliff lines extraction on DEM
- SAR approach (Sentinel-1) using DEM:
  - DEM extraction from a SAR time series
  - Slope detection from DEM profiles

# DEM intermediate product validation

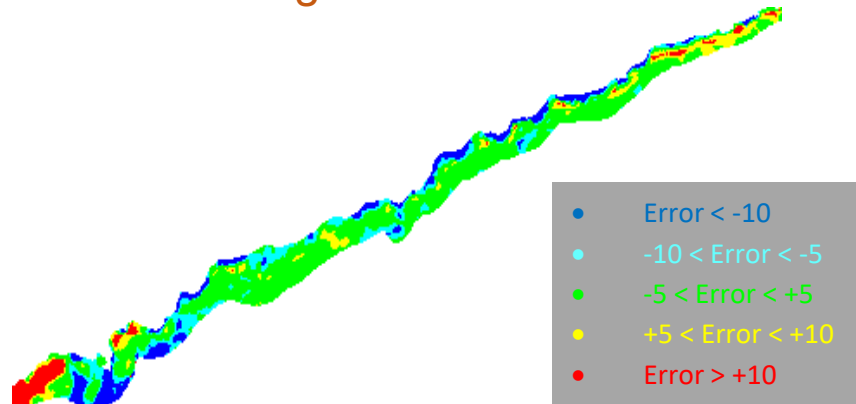
## ■ Pleiades DEM vs Lidar:

- **Mean absolute vertical error: 0.92 m**
- **Accuracy sufficient** to exploit DEM for cliff lines and landslides volumes

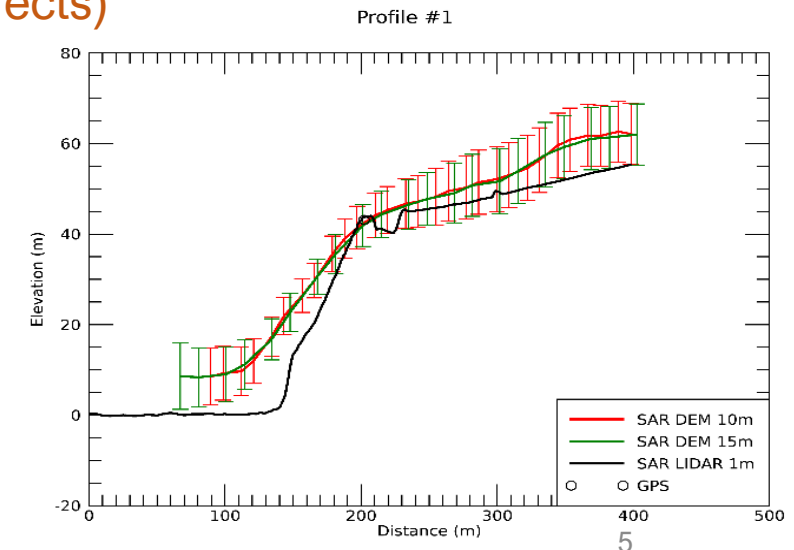
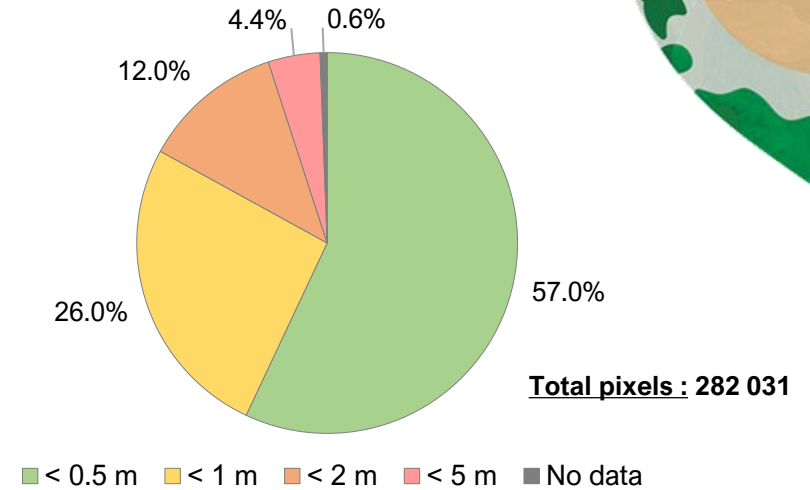


## ■ SAR Sentinel-1 DEM vs Lidar:

- **Mean absolute vertical error: 6.14 m**
- Cliff slopes close to SAR incidence angle (layover and shadow effects)
- **Accuracy not sufficient** to go further



Absolute Vertical error distribution



# Databases exploited

SPOT-1/2/3/4/5 (resolution 10-20 m)



Sentinel-2 (resolution 10 m)



Pléiades (resolution 0.5 m)

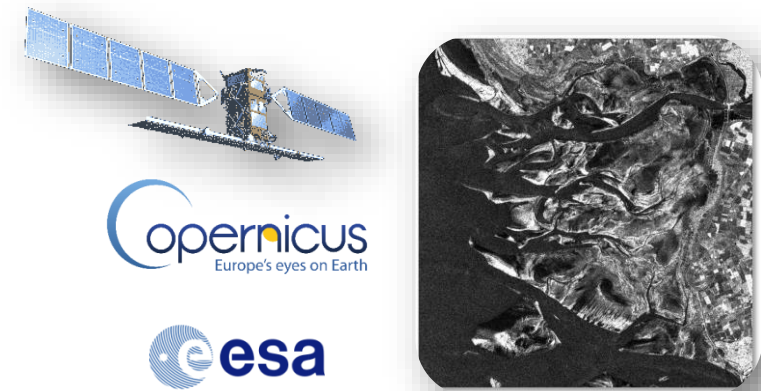


21/01/2021

Worldview-2 (resolution 0.5 m)



Sentinel-1 (10m resolution)



# Demonstration areas and periods

## Normandy Region

-  51 km alongshore
-  1995 - 2020
-  ~ every 3 years
-  43 products



## Leiria Region (Portugal)

-  13 km alongshore
-  2011 - 2020
-  -
-  5 products







## New Aquitaine Region

-  15 km alongshore
-  1995 - 2020
-  ~ every 3 years
-  26 products



## Brothener site (Germany)

-  3.5 km alongshore
-  2018
-  One shot
-  1 product

# Product display: Cliff lines using machine learning

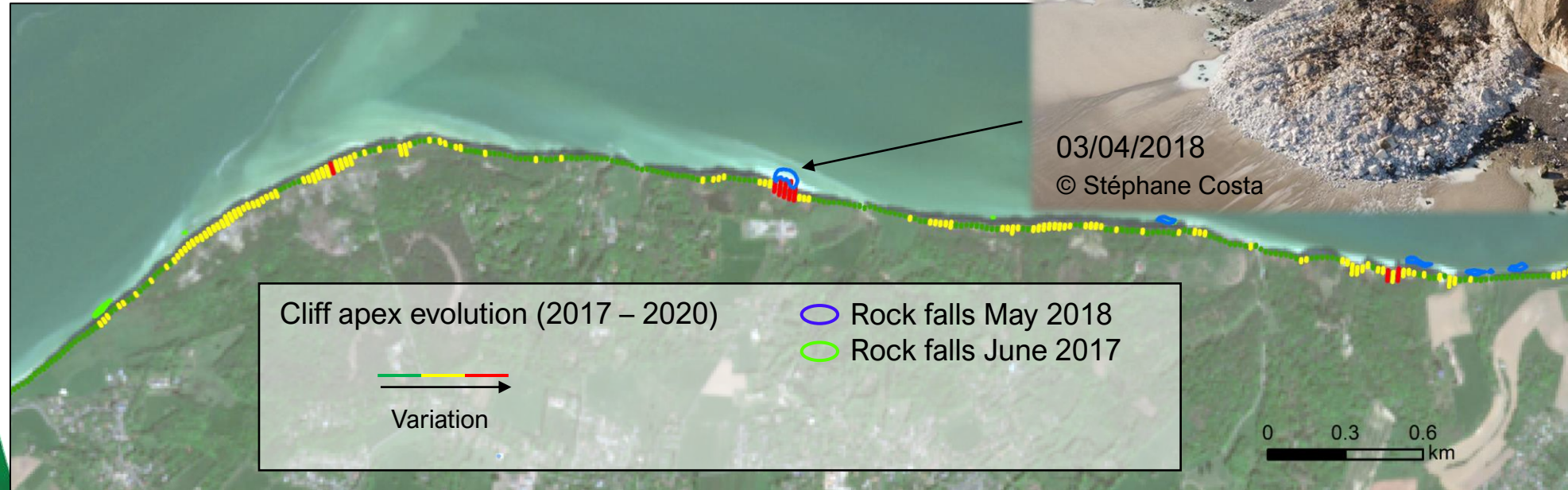
10 Cliff foots with Sentinel-2 and SPOT: 1995 - 2020



# Product display: Cliff lines evolution using DSAS



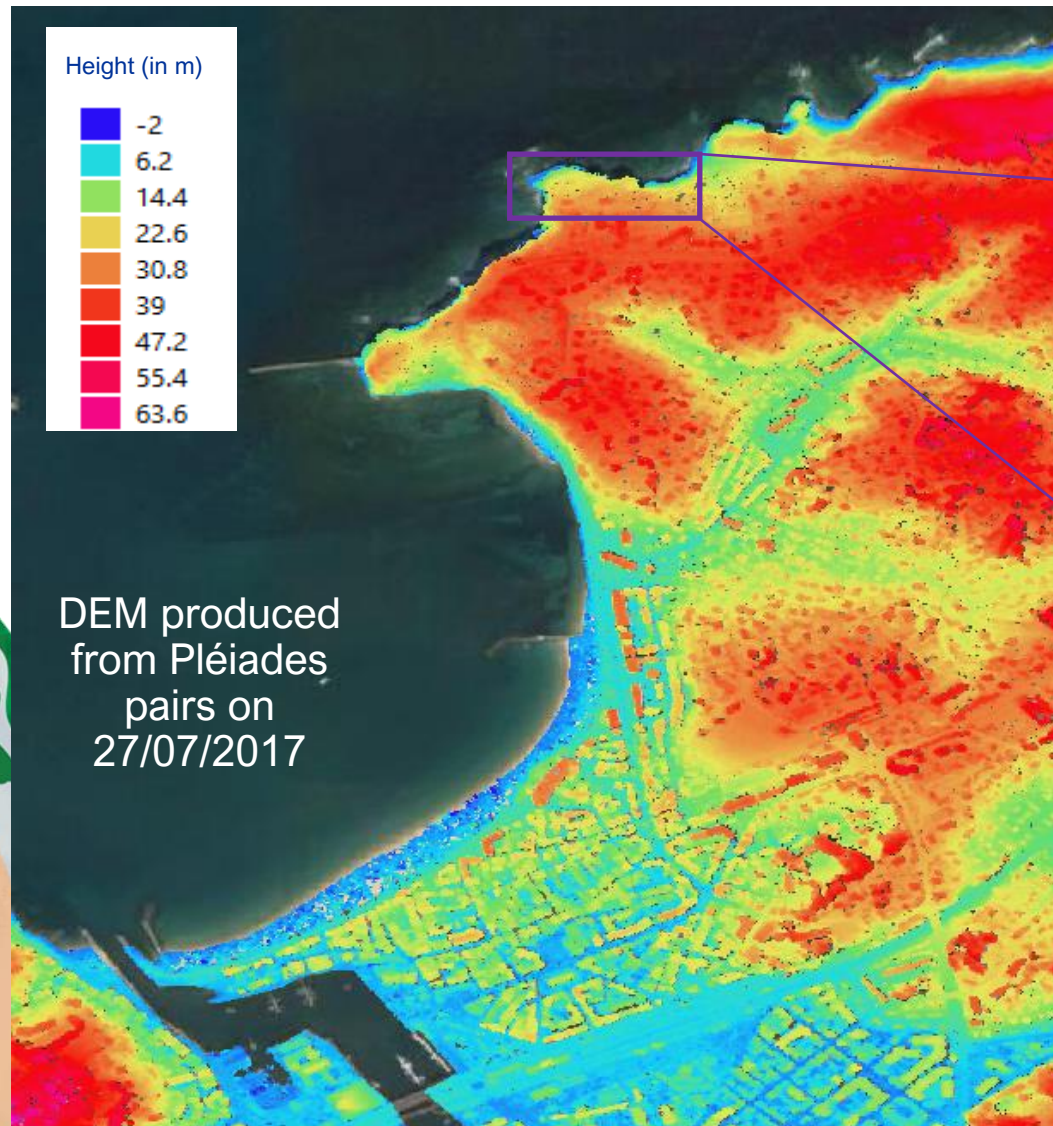
- Identify and localize rock falls



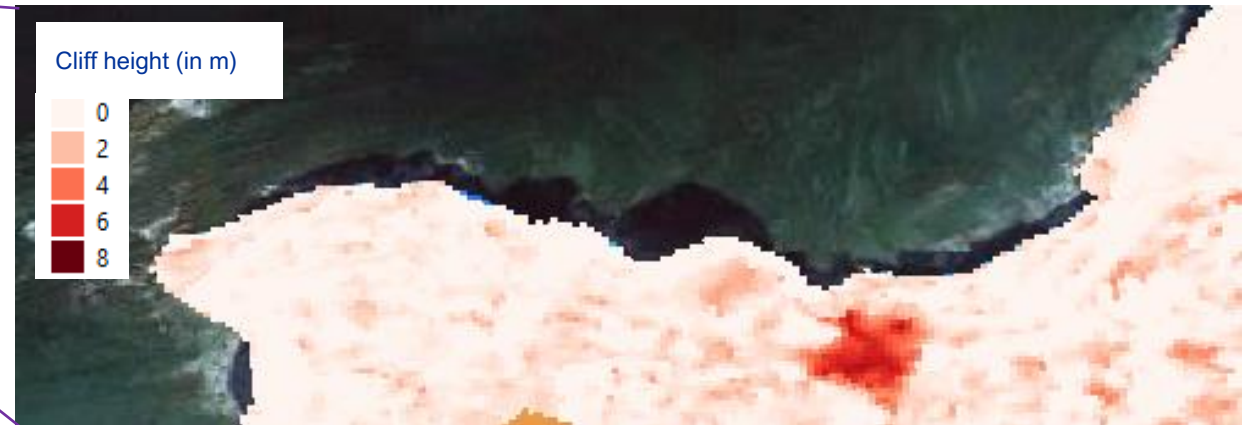
# Product display: Cliff lines from DEM Pléiades



# Product display: Landslides volumes from Pléiades DEM

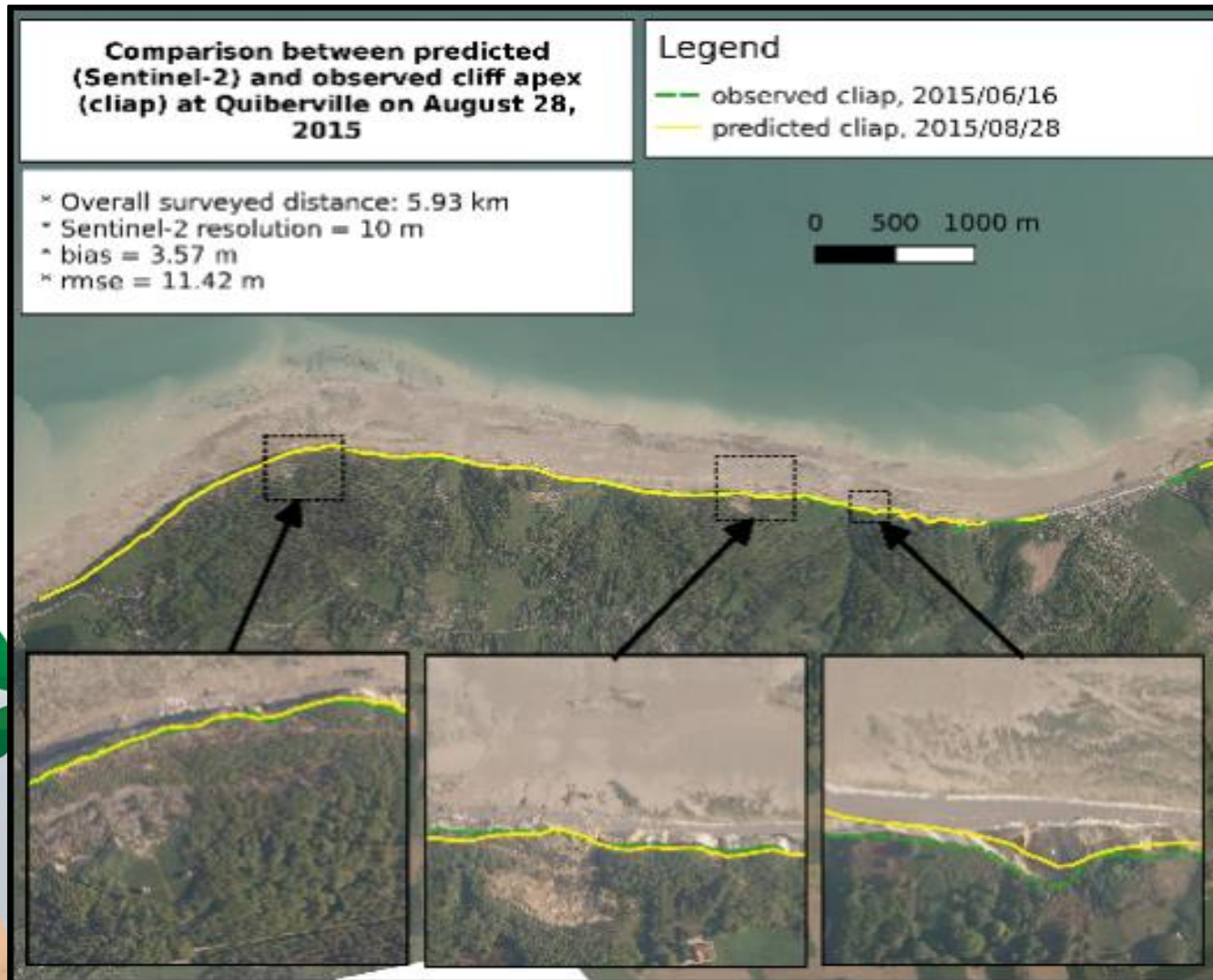


## DEM 2017 vs DEM 2014



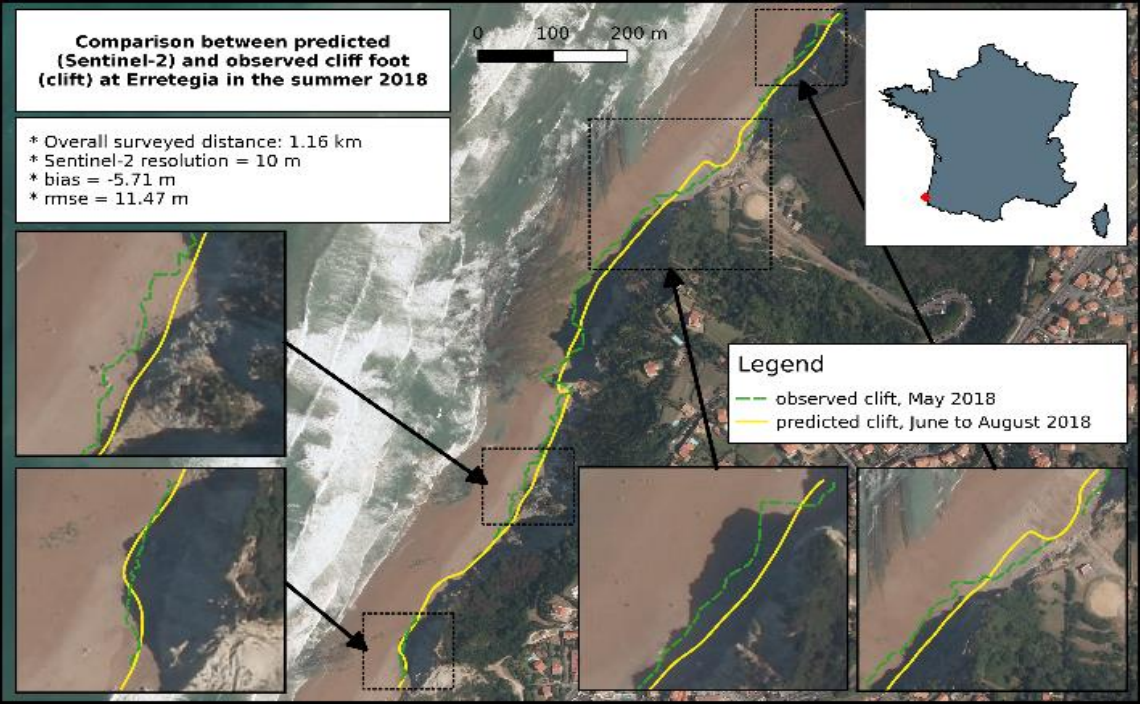
Difference between 2 DEM produced in 2017 and 2014: the red area shows losses of height from 4 to 7 meters. It corresponds to a landslide that happened on 21/03/2015, in Saint-Jean-de-Luz, New Aquitaine.

# Validation experiments



- Validation dataset of Lidar acquisitions
- Validation of the cliff lines by comparing with cliff lines extracted from Lidar
- Control points generated along the cliff lines every 20 m using a baseline

# Validation results



## Cliff apex

Site	Satellite	Validation data		Mean absolute error (m)
		Type	Source	
New Aquitaine	Pléiades	Lidar	OCA	2.3
Normandy	SPOT 5	Lidar	ROL	6.6
	Sentinel-2			5.7
				6.5
				8.4
				5.1

## Cliff foot

Site	Satellite	Validation data		Mean absolute error (m)	
		Type	Source		
Portugal	Sentinel-2	Lidar	APA	13.9	
Normandy	SPOT 3	Lidar	ROL	8.5	
	SPOT 2			12	
	SPOT 5			9.2	
	Sentinel-2			2.3	
	Sentinel-2			2.4	
	Sentinel-2			5.6	
New Aquitaine	SPOT 2	Lidar	OCA	8.2	
				11.7	
	SPOT 4			10.9	
	SPOT 4	Lidar		13.5	
	Sentinel-2			11.6	
					5.5
					6.1
	Pléiades	Lidar		1.8	

Product	Global mean absolute error
Cliff lines using Pléiades DEM	2 m
Cliff lines using Sentinel-2 and Machine learning	9 m

# Approval from scientists



*S. Costa (LETG/Caen Univ.): "A derivative product of the cliff lines using Sentinel-2 to localize areas of rock falls, it could be complementary to in-situ studies. **The high frequency capacity opens interesting perspectives for scientific usage.**"*



*A. Robinet (BRGM/OCA): "For Pléiades DEM derivative products, **it is less accurate than Lidar but easier to be operated more frequently and less expensive. It deserves to be developed for full operationality**"*

*A. Nicolae-Lerma (BRGM/OCA): "For Pléiades DEM derivative products it is interesting because we can follow dune foot and cliff apex simultaneously and the landslides volumes ... . **Cost of acquisition are reasonable, ..., Precision is better than Sentinel-2.**"*



# Users' requirement achievement level

	Horizontal accuracy		Revisit		Production area	
	Request	Achieved	Early request	Produced after POC	Requested	Achieved after POC
<b>France New Aquitaine</b>	2 m	9 m (Sentinel-2) 2 m (Pléiades)	1/year	~ every 3 years from 1995 to 2020	New Aquitaine (Basque coast)	New Aquitaine (Basque coast)
<b>France Normandy</b>	2 m	9 m (Sentinel-2)	1/year	~ every 3 years from 1995 to 2020	Normandy (Vaches Noires, cap d'Ailly)	Normandy (Vaches Noires, cap d'Ailly)
<b>Germany</b>	2 m	-	Every 2 years	One shot VHR Pléiades	Brothener, Schoenhagener	Brothener
<b>Portugal</b>	2 m	13.9 m (Sentinel-2)	Every 2 years	5 products from 2011 to 2020	7 sites near Alcobaça	3 sites near Alcobaça

# End-users' testimonies



*C. Sarrade (BRGM/OCA): "The use of the Pleiades-derived cliff lines products might be very interesting for future projects."*



*C. Pinto (Portuguese Environmental Agency): "Cliff foot Sentinel-2: In the framework of their current monitoring works about cliff evolution, these lines are not of interest to APA. **Cliff apex Sentinel-2: this technique might be useful in places where cliffs have a quick evolution.**"*



*S. Costa (LETG/Caen Univ.): "For Sentinel-2 cliff lines, the resolution of Sentinel-2 is not sufficient for most of French coastal managers monitoring cliffs. **This indicator is more suitable for worldwide monitoring of areas with no data.**"*

# ESA's expectation achievement level



Cliff lines extraction with accuracy below the pixel size.



Long-term monitoring (25 years) analysed over large areas (>50 km). To improve knowledge on sea-cliff dynamics, it is recommended to use at least 10-m resolution optical imagery (e.g. SPOT-5, S2) and only where erosion is fast.

HR imagery, more probably SPOT-5 or S2, seems relevant to detect rock fall positions.

VHR products accuracy sufficient to monitor cliff lines dynamics and even landslides volumes: need to be further developed for full operability.



## Ground microdeformation