MASTER SML
SCIENCES DE LA MER ET DU LITTORAL

MENTION
Sciences de la Terre, des Planètes et de l'Environnement – Géosciences Océan
SPÉCIALITÉ
Sédimentologie et Paléoenvironnement

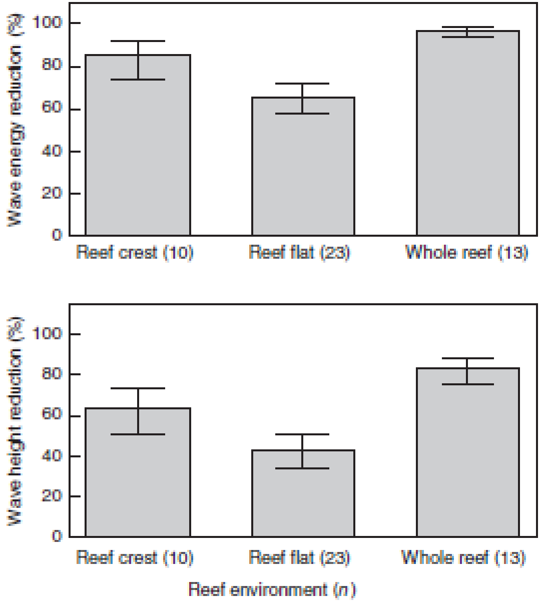
Development and deployment of an optical micro-bathymetry platform for roughness measurement

Simon DELSOL

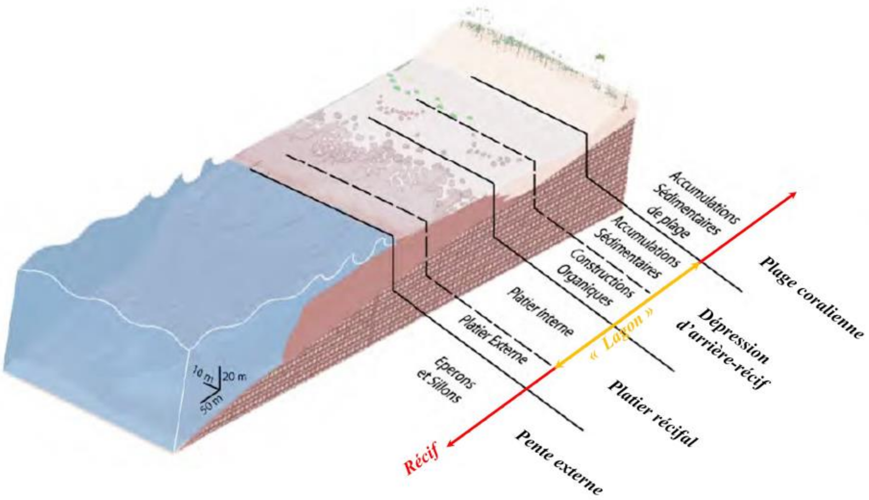
Master 2 internship thesis
Academic Year 2022-2023
Academic tutor : LE DANTEC Nicolas
Intership supervisor : JAUD Marion

18/09/2023

Coral Reef



Quantification graph of coral reef impacts on swell, Ferrario et al. (2014)



Geomorphological distribution of a coral fringing reef: from outer slope to beach, after Montaggioni & Faure (1980)

60 to 97% reduction in incident swell (Ferrario et al., 2014)

Importance of the reef bed as a protective agent

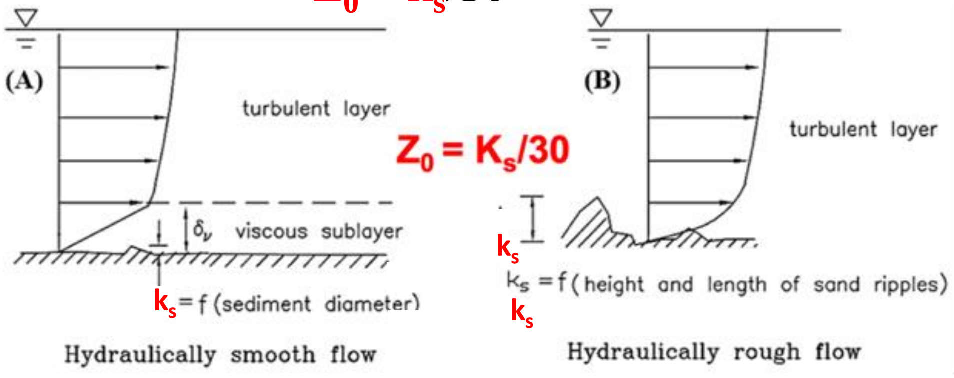
Rugosity

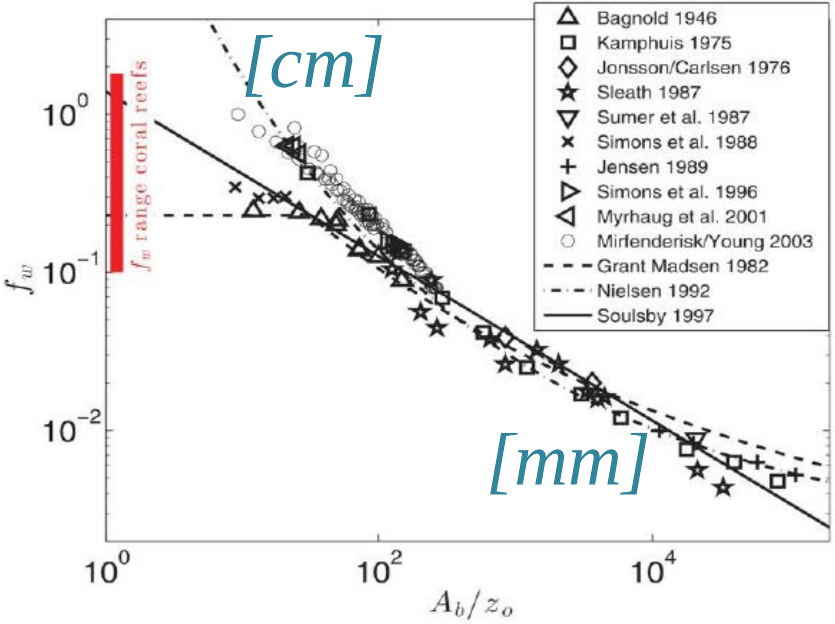
Hydrodynamic parameters

Wave energy dissipation coefficient : $f_w = A_b/Z_0$

Nikuradse coefficient : k_s

$Z_0 = k_s/30$

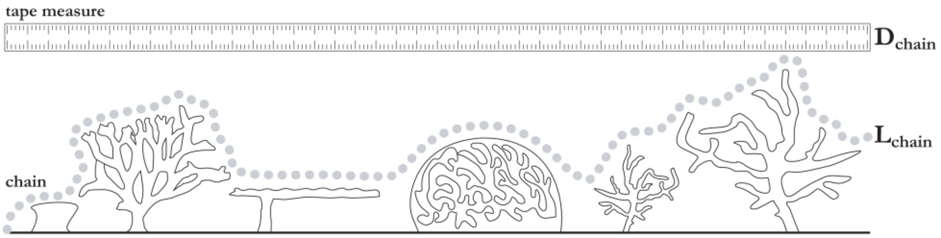




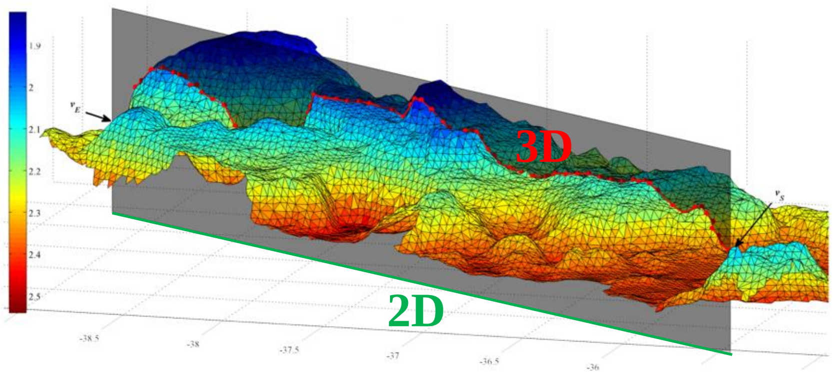
Sructural Complexity

f_w linked to Structural Complexity (SC) ?
Relation between k_s and SC ?

Indicator of reef microtopography,
measured by the ratio
SC = 3D Length/2D Length



« Chain and Tape » in situ (*Risk*, *1972*)



« Chain and Tape » over 3D model (*Friedman et al.*, *2012*)

Photogrammetric method

"*Structure-from-Motion*" (SfM) Photogrammetry (Friedman et al., 2012 ; Westoby et al., 2012)

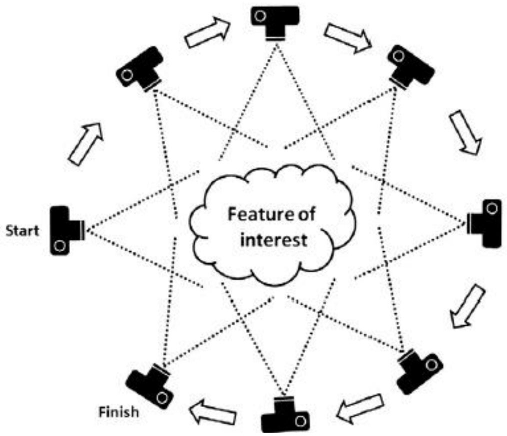


Diagram of the theoretical acquisition procedure (Westoby et al., 2012)

→ is based on the idea that the 3D structure of the imaged object can be reconstructed from a series of images acquired from different viewpoints

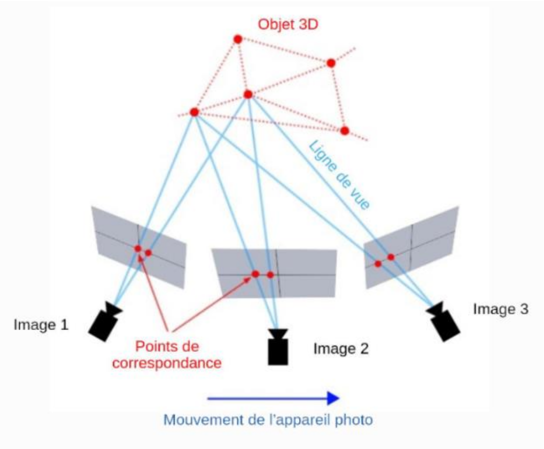
→ requires the acquisition of a **set of photographs with a high degree of overlap** (ideally 80%)

→ requires **multiple points of view to optimize coverage** of the three-dimensional structure of the object under study

Photogrammetry applied to reefs

Aerial (flat) : drones (*Casella et al., 2016*), kites (*Bryson et al., 2016*)

→ **Refraction and reflection of light at the air-water interface** = Underestimation of coral structure heights...



Underwater photogrammetry acquisition principles (*Abadie et al., 2018*)

Underwater (slope or depth > 2m) : divers (*Burns et al., 2015* ; *McCarthy et al., 2023*)

→ **Complicated georeferencing...**

POSEIDON®

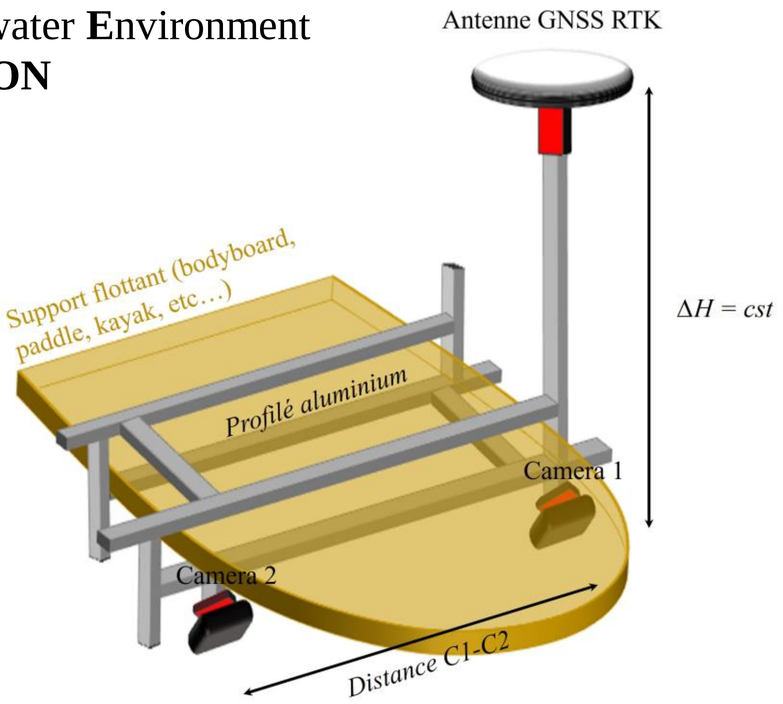
Platform **O**perating in **S**hallow-water **E**nvironment for **I**maging and 3**D** reconstructi**ON**

Low-cost (1400€) & low-tech platform, fully modular

Underwater mapping using **optical bathymetry** ~~(refraction)~~, at (sub-)centimeter resolutions

GNSS - RTK (Global Navigation Satellite System - Real Time Kinematic) for **centimeter-precision georeferencing** and **geometrically accurate photogrammetric reconstruction** (*Jaud et al., 2020*)

Deployable in shallow water environments (30 cm < d < 5 m)

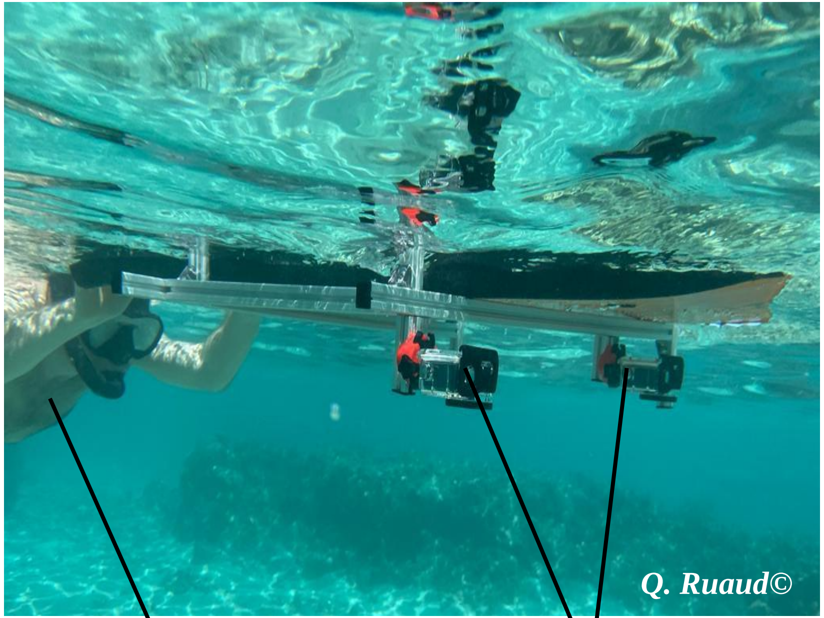


Platform schematic

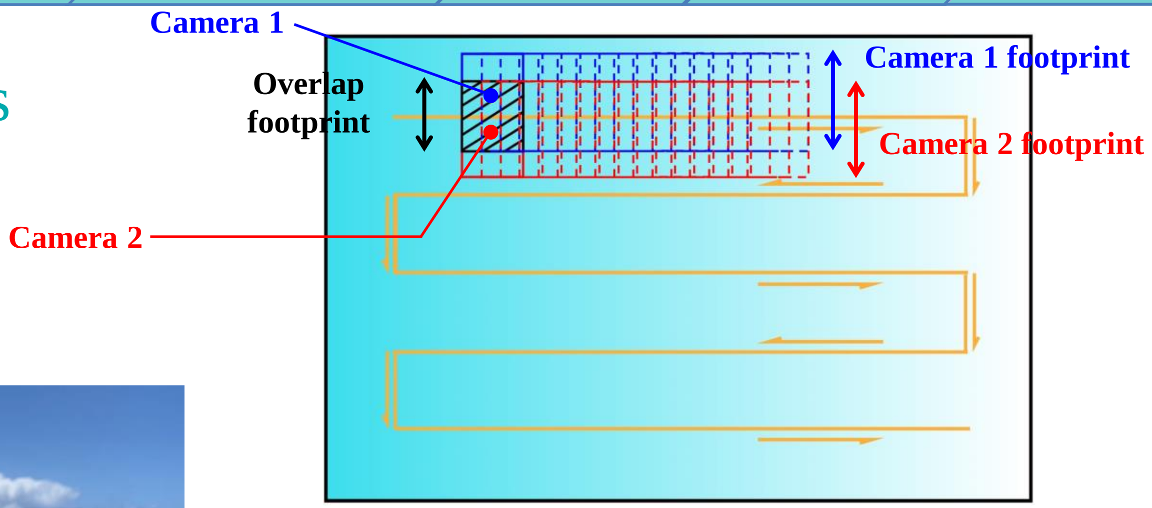
POSEIDON

POSEIDON in its stand-up paddle (SUP) configuration

POSEIDON in its bodyboard configuration



Acquisition constraints



Standard acquisition path diagram

Clear water (no turbidity)

Low swell

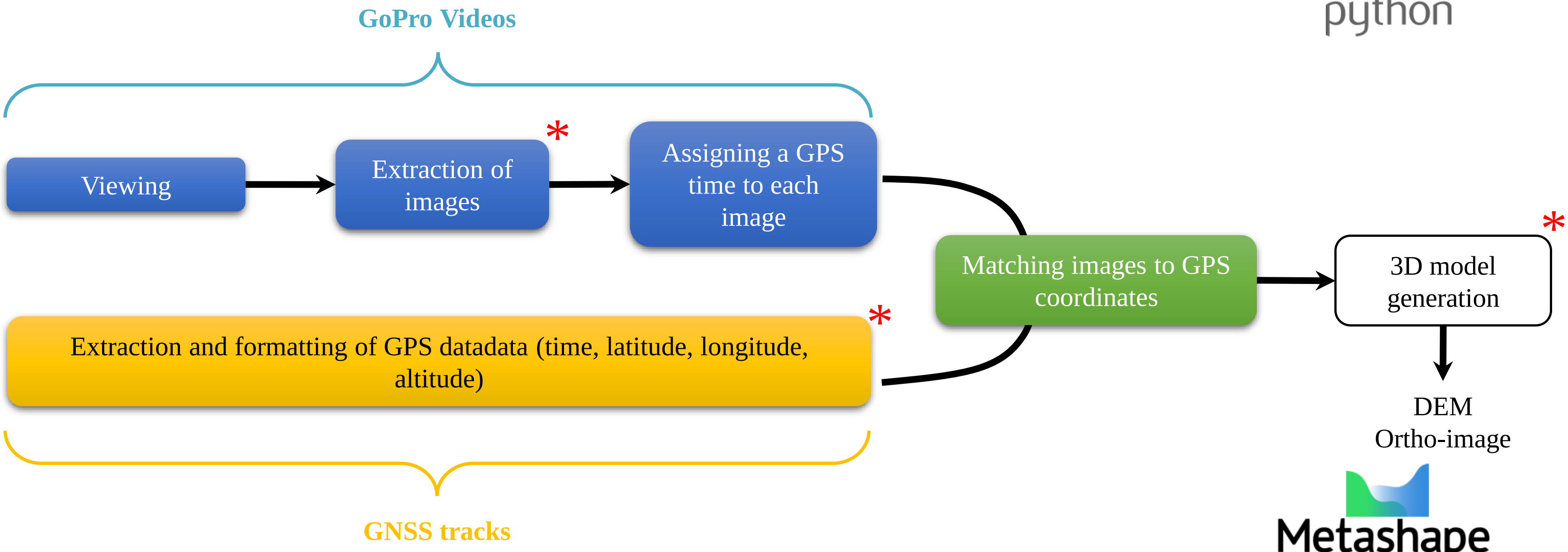
Good light conditions

Coverage > 80%

Processing procedure

Data processing

* (Steps automated during internship)



Rugosity measurement : → **from Digital Elevation Model (DEM)**

Rugosity measurement : from DEM

Topographic Roughness Index $= \overline{\Delta Z}$ (3 pixels radius)

Rugosity $= Z_{max} - Z_{min}$ (5 pixels radius)

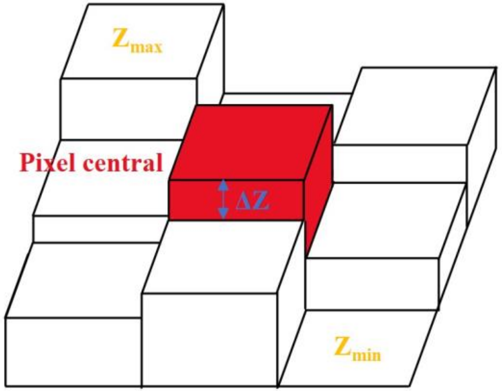


Diagram of roughness calculations in **QGIS** (*Riley et al., 1999* ; *Wilson et al., 2007*)

Rugosity measurement : from DEM

Indice topographique de rugosité = $\overline{\Delta Z}$ (dans un rayon de 3 pixels)

Rugosité = $Z_{max} - Z_{min}$ (dans un rayon de 5 pixels)

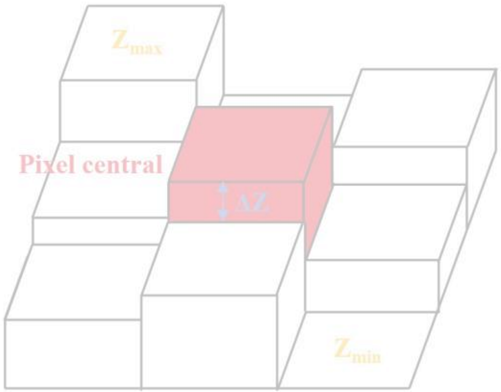


Schéma des calculs de rugosité sous **QGIS** (*Riley et al., 1999* ; *Wilson et al., 2007*)

Structural Complexity = 3D/*2D*

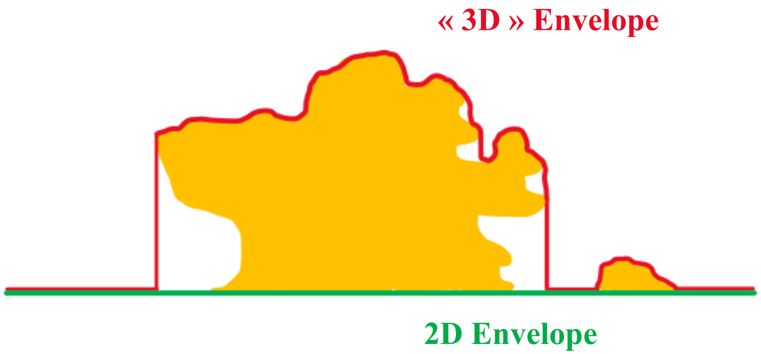


Diagram of structural complexity calculation in **R** (***Fukunaga et al., 2019***)

Anse du Dellec

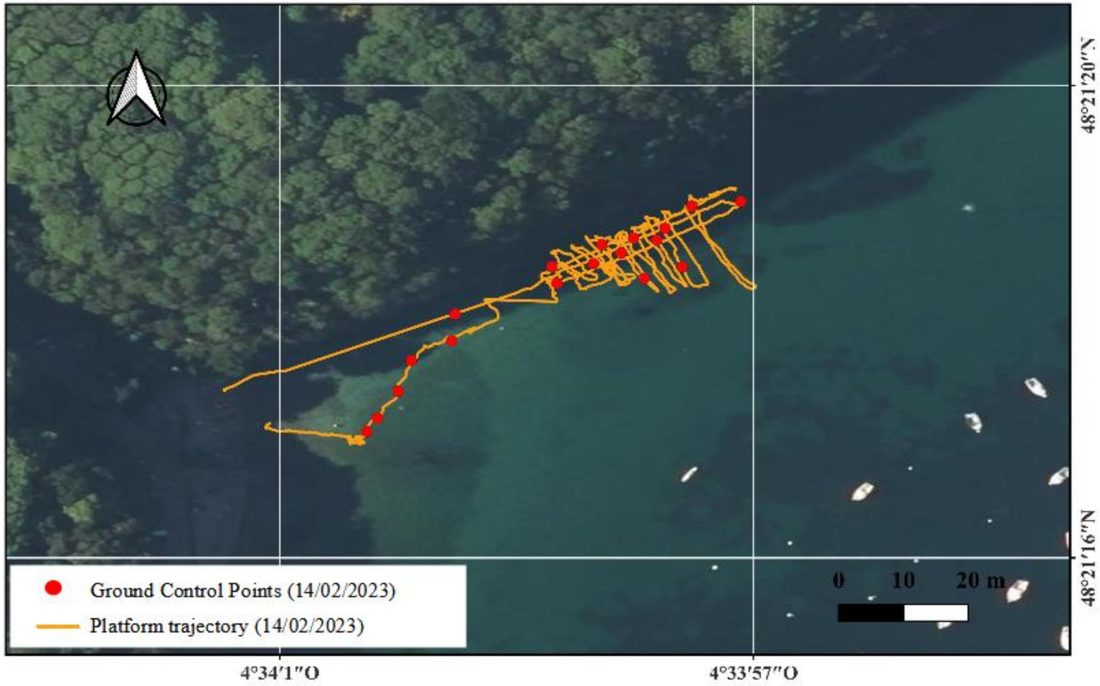
Macrotidal zone = partial emersion during low spring tides

Site available for terrestrial and bathymetric surveys

Mean depth on site : 2.2 m

Comparison of 3D models (point clouds) obtained with CloudCompare

b)



Map of the platform's trajectory during the February 2023 optical bathymetric survey and terrestrial topographic acquisition

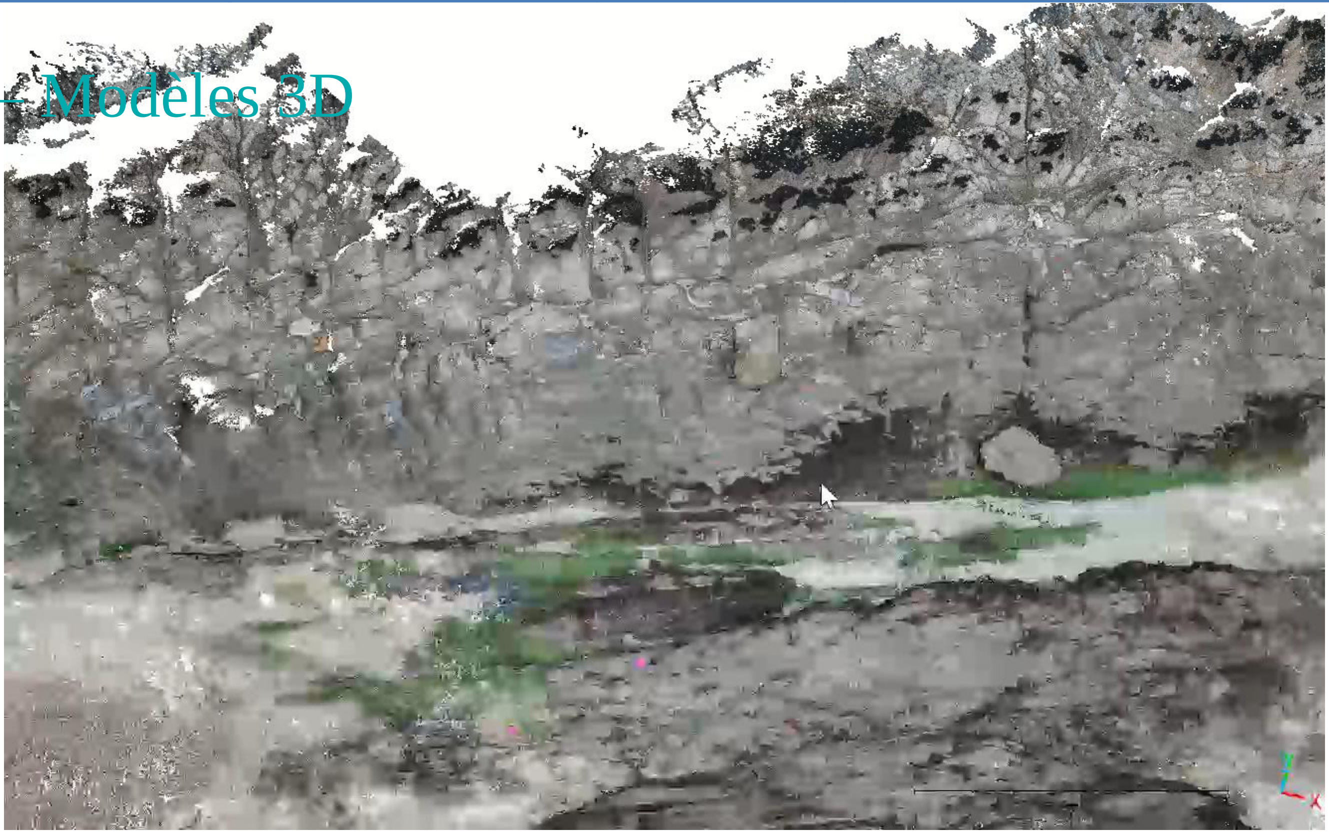
Anse du Dellec – Modèles 3D

+ de 400 000 000 points

7.68 points/cm²

Resolution
3.61 mm/px

61 m x 26 m



Dense point cloud from **terrestrial topographic survey** (Y = Northing ; X = Easting ; Z = height)

Anse du Dellec – Modèles 3D

+ de 450 000 000 points

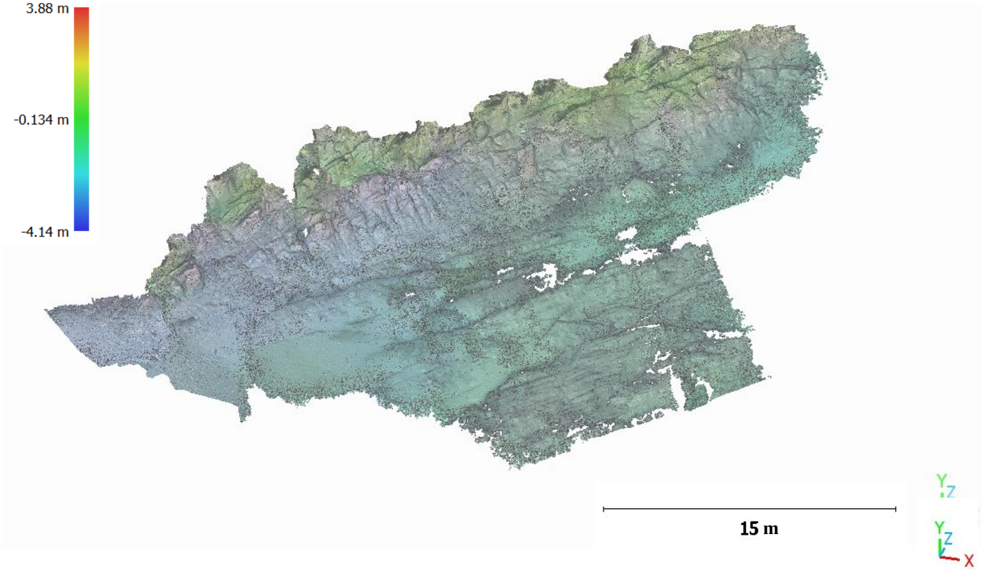
37.8 points/cm²

Resolution
1.63 mm/px

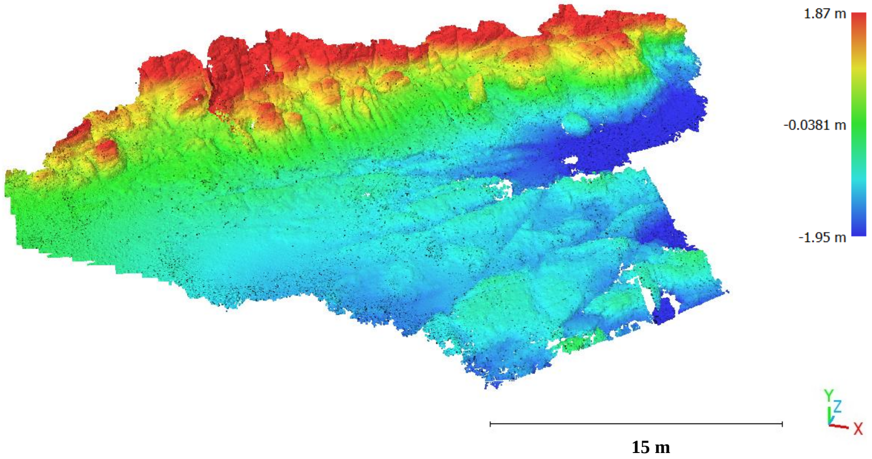
45 m x 18.5 m

Dense point cloud from **optical bathymetric survey** (Y = Northing ; X = Easting ; Z = height)

Anse du Dellec – Modèles 3D



Dense point cloud from **optical bathymetric survey**, coloured with RGB filter



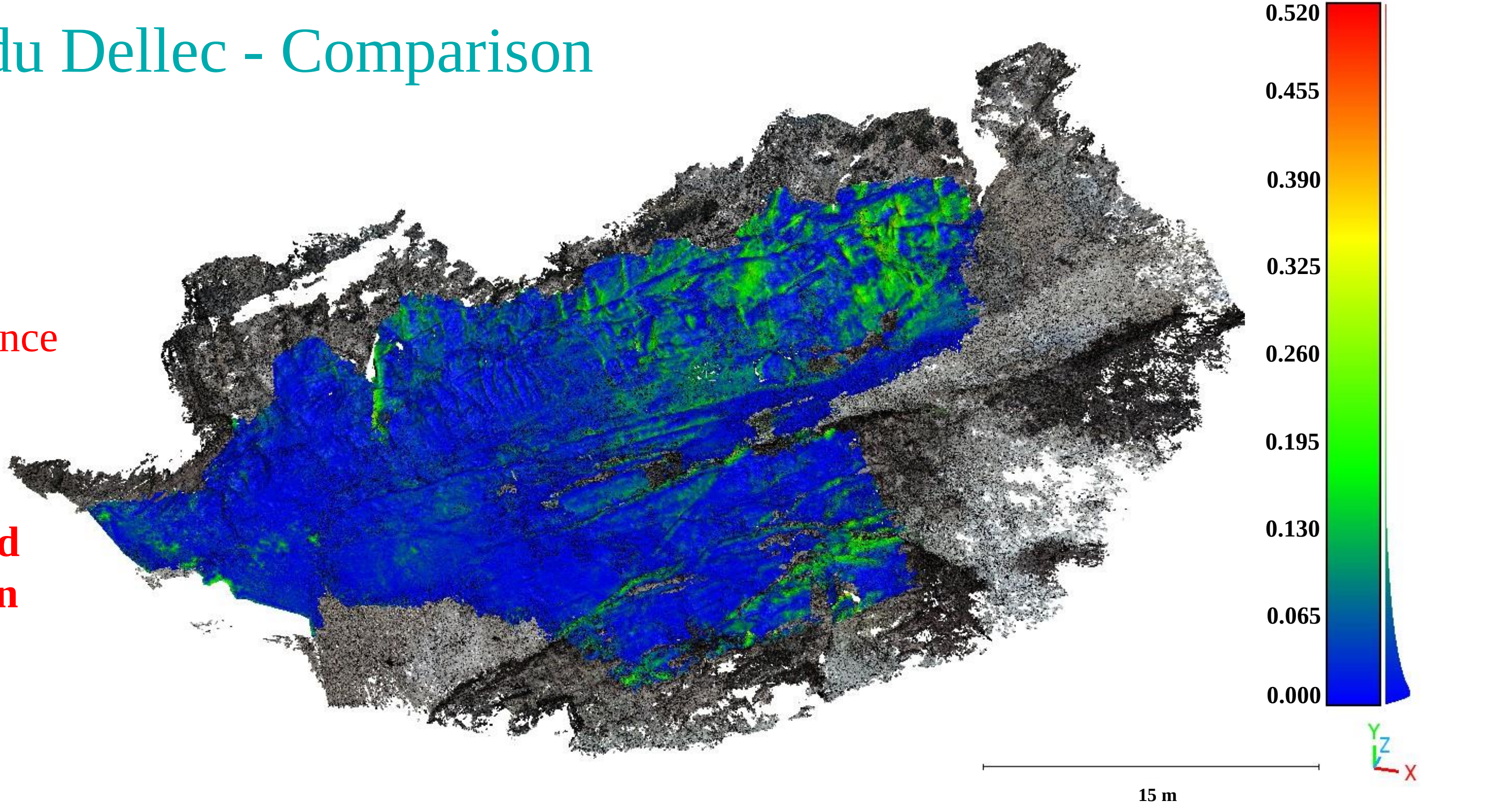
Dense point cloud from **optical bathymetric survey**, coloured by elevation

Y = Northing ; X = Easting ; Z = height

Anse du Dellec - Comparison

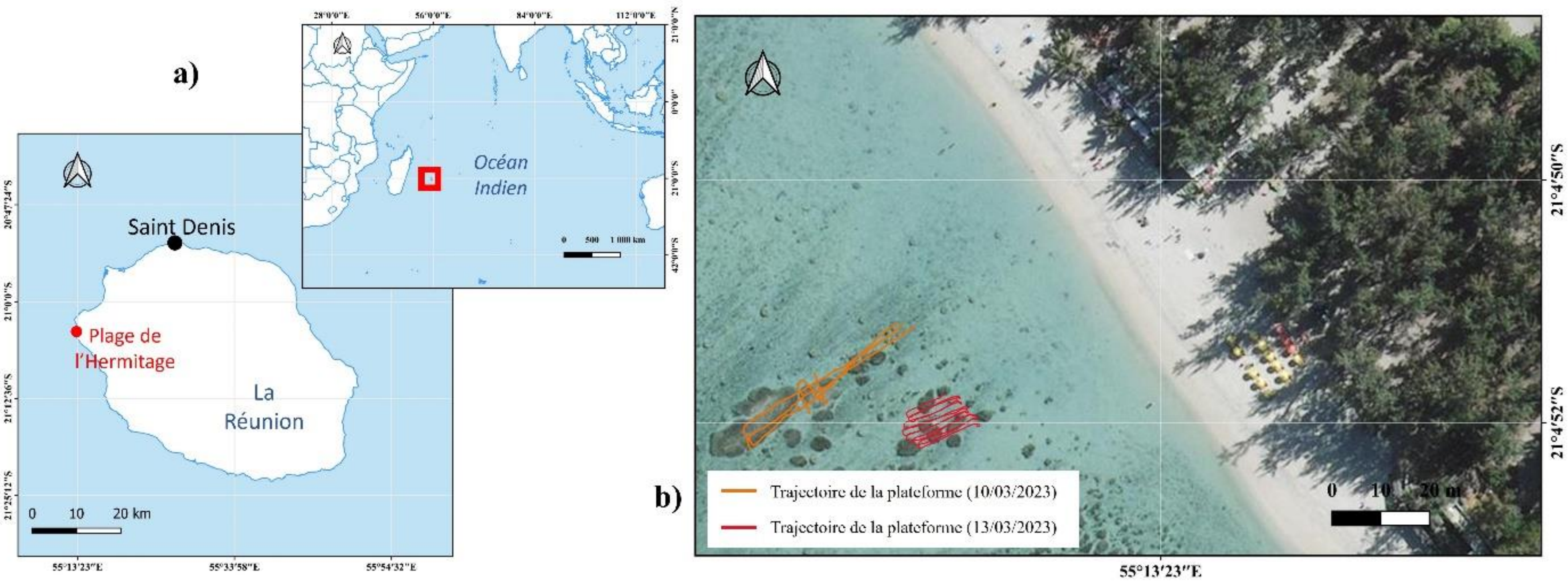
Mean distance
5.2 cm

Standard deviation
4.6 cm



Compared dense points clouds (Y = Northing ; X = Easting ; Z = height)

Hermitage site



Location and trajectory maps of the platform during the March 2023 optical bathymetric survey at l'Hermitage

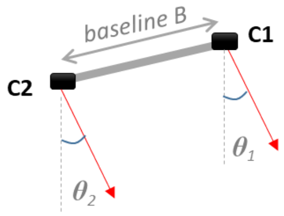
Acquisition at l’Hermitage

Different camera configurations to compare reconstruction qualities

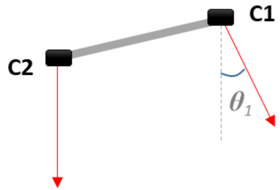
Mean depth on site : 0.9 to 1 m

Test 1

B = 58 cm
θ_1 = 23°
θ_2 = 25°



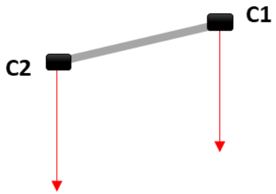
Test 2



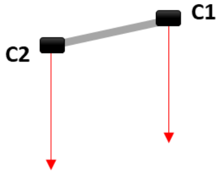
B = 58 cm
θ_1 = 23°
θ_2 = 0°

Test 3

B = 58 cm
θ_1 = 0°
θ_2 = 0°



Test 4



B = 40 cm
θ_1 = 0°
θ_2 = 0°

External platform parameters for March 2023 acquisitions at the Hermitage site

Hermitage site – 3D Model

≈ 590 000 000 points

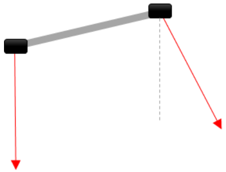
185 points/cm²

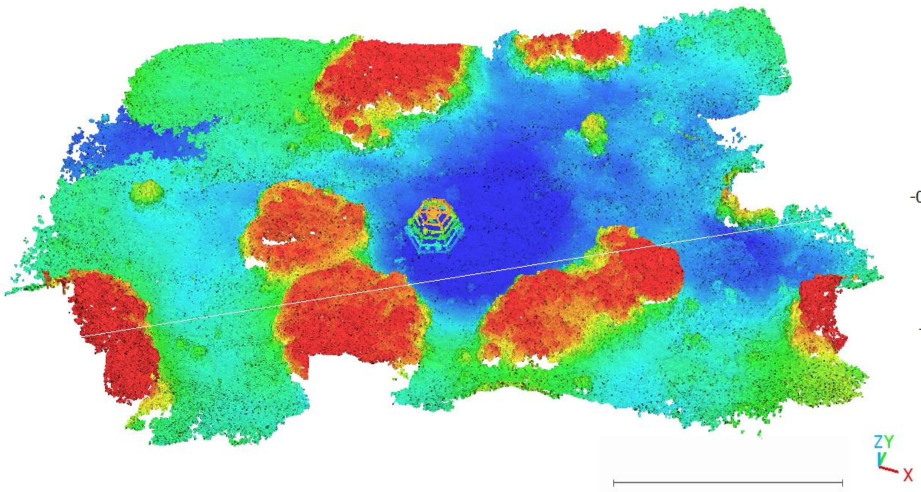
Resolution
0.74 mm/px

18 m x 10 m

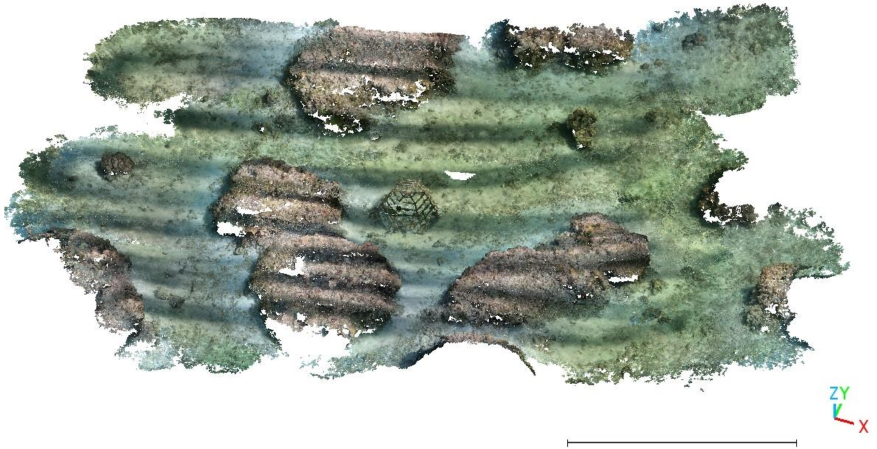
Dense point cloud from **Test 2** (Y = Northing ; X = Easting ; Z = height)

Hermitage site – 3D Model





Dense point cloud from **Test 2**, coloured by elevation



Dense point cloud from **Test 2**, coloured with RGB filter

Y = Northing ; X = Easting ; Z = height

Hermitage site – Rugosity

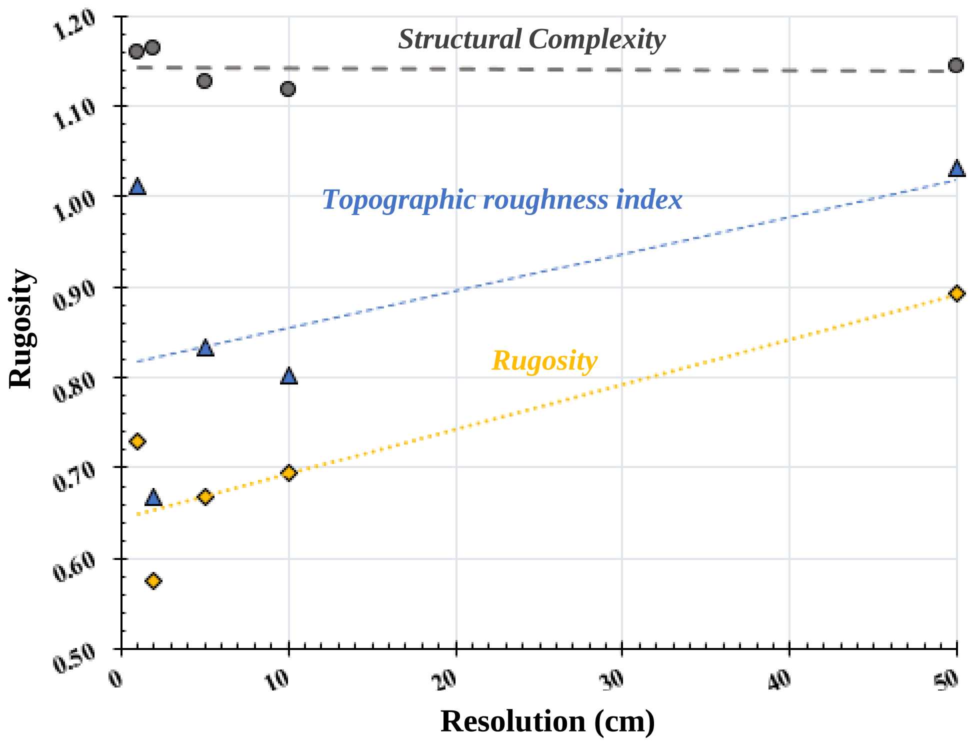
Little variability in structural complexity

Topographic roughness index high at highest and lowest resolutions, increases with decreasing resolution

Same for Roughness

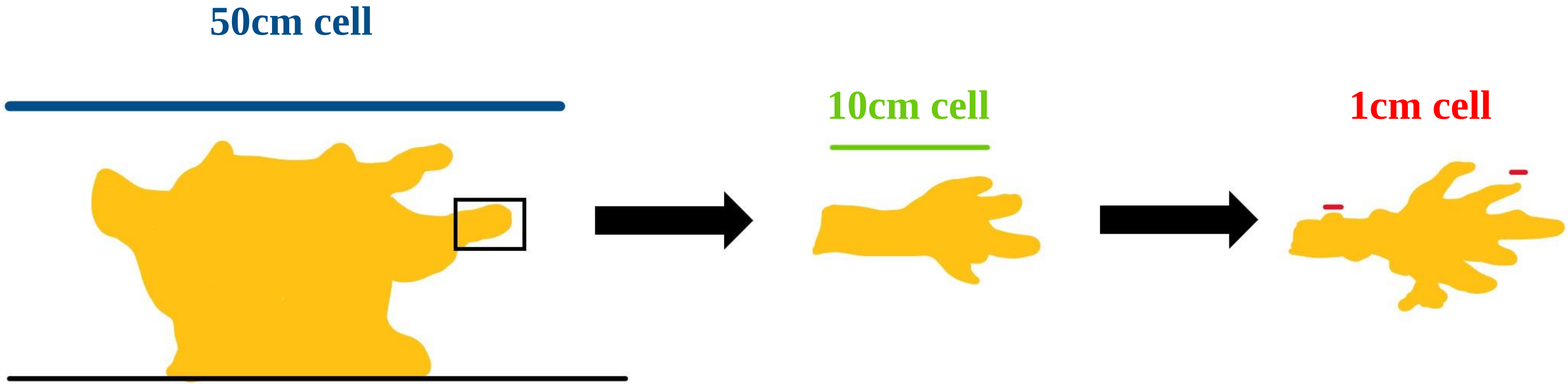
« Chain and Tape » in situ ≈ 1.22

Rugosity graph based on resolution – Test 2



Rugosity – 3D Model

Résolution (cm)	Topographic Roughness Index	Rugosity	Structural Complexity
1	1.01	0.73	1.16
2	0.67	0.58	1.16
5	0.83	0.67	1.13
10	0.80	0.69	1.12
50	1.03	0.89	1.14



Structures impacting rugosity recorded by digital elevation model cells at different resolutions

Rugosity – 3D Model

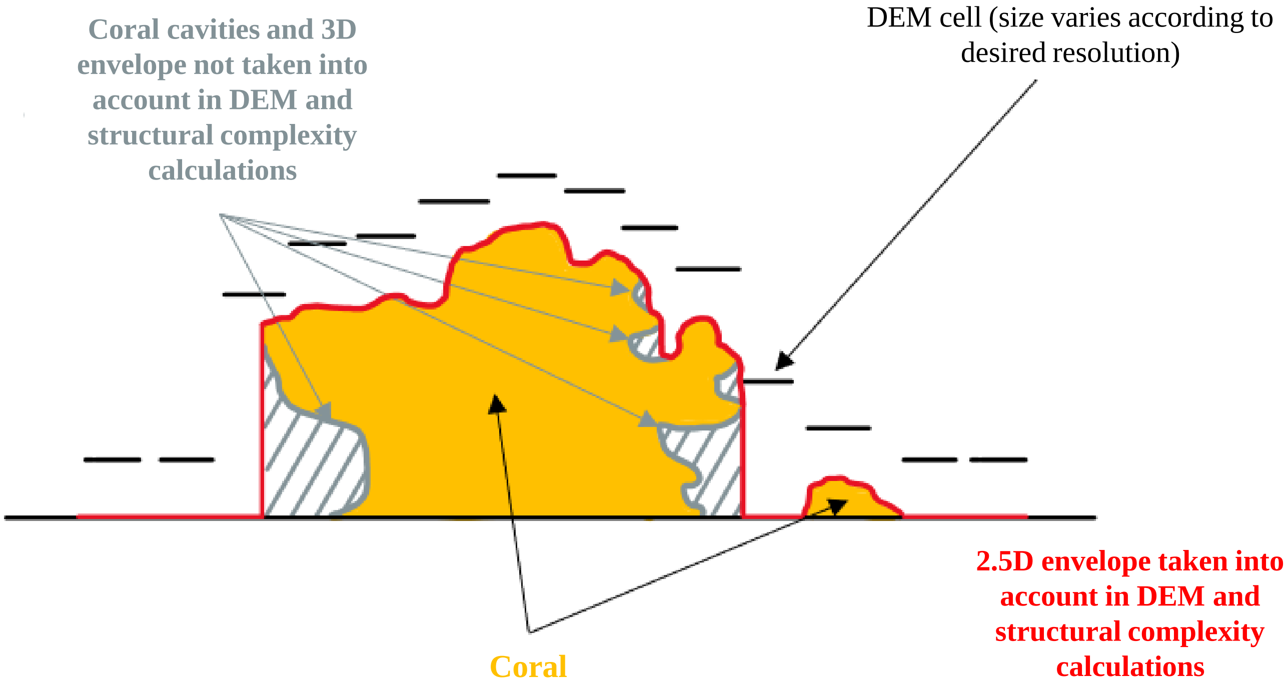


Diagram of the problem of areas not considered in the 3D model during DEM generation (2.5D model)

What should we remember?

- POSEIDON is a **working prototype** and offers a platform for **optical bathymetry**
- Possible improvements to the platform (motorization: Ifremer Plancha) and protocol (automated image processing)
- Quid about modeling tabular corals ? Importance of resolution? Need for 3D vs. 2.5D?
- The use of POSEIDON and work on roughness will be continued in the **interdisciplinary Futurisk project**

Thanks for your attention

&

Good day

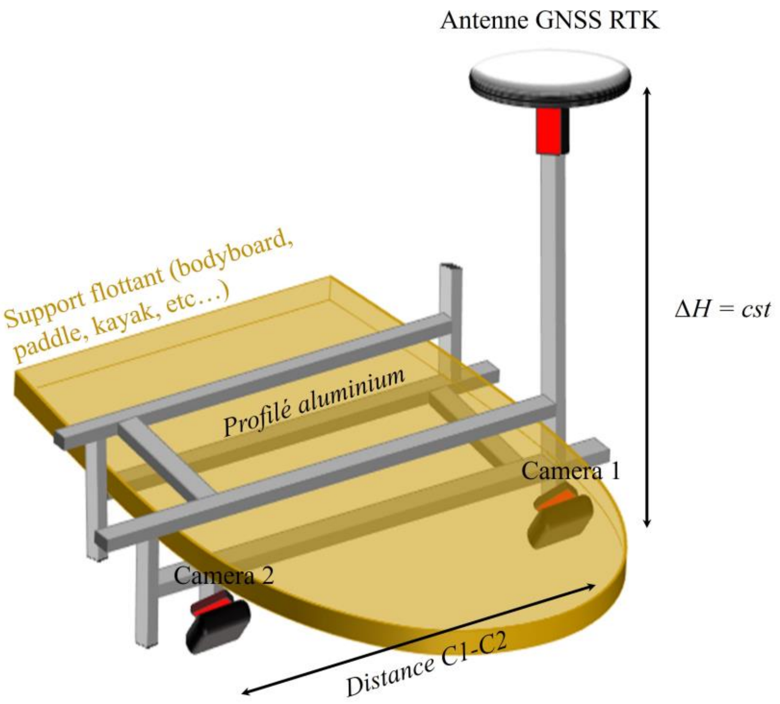
M. Jaud©

Underwater photogrammetry

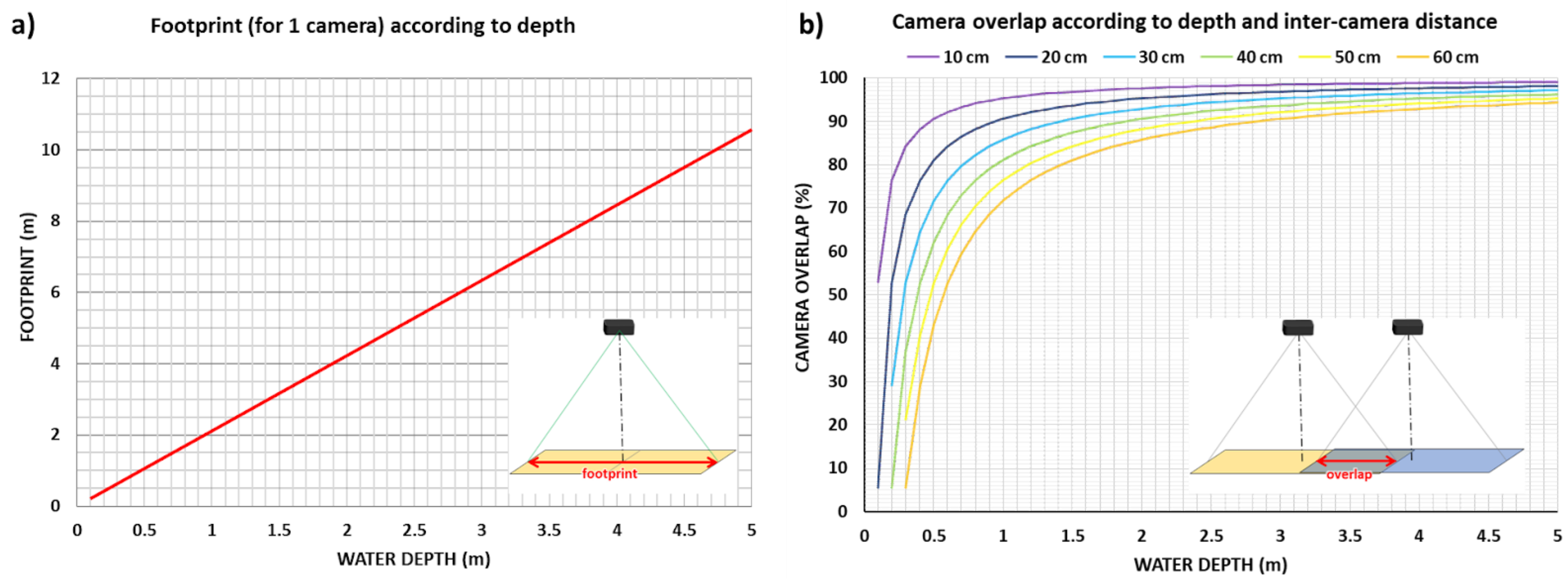
Modèle	Créateur/Fabricant	Année	Prix ($)	Usage	Profondeur
Reef Rover	*Raber et Schill (USA)*	**2019**	3426	Scientifique	< 20 m
Blueye Pionner	*Blueye (Norvège)*	**2021**	7000	Industriel / Scientifique / Etat	< 300 m
Seaviews	*Photocean (France)*	**2018**	4350	Industriel / Scientifique	< 15 m
SQUID-5	*USGS (USA)*	**2020**	Non-communiqué	Scientifique	Dépend de la turbidité
SeaArray	*Marine Imaging Technology (USA)*	**2020**	500/jour	Scientifique	Dépend de la turbidité
BlueROV2	*Bluerobotics (USA)*	**2022**	5720	Industriel / Scientifique / Etat	< 300 m
Perception ROV Skids	*Voyis (Canada)*	**2020**	Non-communiqué	Industriel / Scientifique / Etat	< 1000 m
Seaeye Falcon	*Saab (Royaume-Uni)*	**2020**	106 000	Industriel	< 300 m

POSEIDON

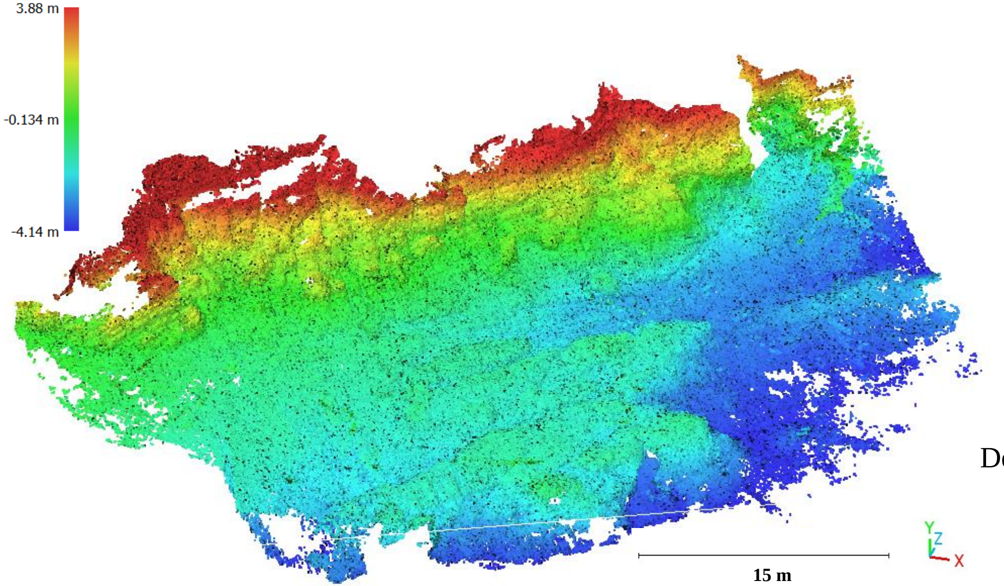
Matériel	*Unité*		*Prix (€)*
	Achetée	*Utilisée*	
GoPro Hero Black 7	2	2	550
Caissons étanches GoPro	2	2	50
Cartes SD 128 Go	2	2	30
Sparkfun Rover RTK Facet	1	1	600
Bodyboard	1	1	30
Profilés aluminium 20mm	3 x 3 m	1 x 50 cm 4 x 70 cm 2 x 40 cm 3 x 15cm 2 x 6cm	91
Embouts plastique	1 sachet de 10	9	10
Équerres de fixation	1 sachet de 20	14	12
Écrous à tête marteau	4 sachets de 10	34	19
Boulons poêlier	1 boite de 50	34	13
Rondelles plates	1 boite de 100	28	6
Support GoPro	2	2	/
Support GPS	1	1	/
		Total	1411



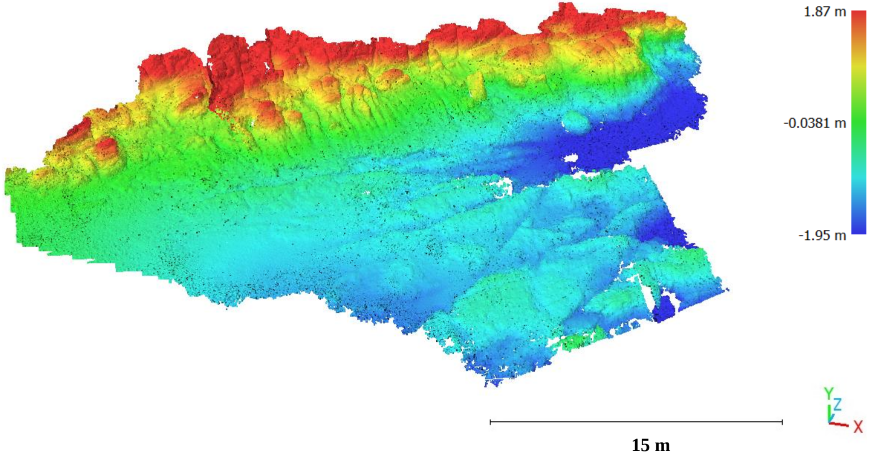
POSEIDON – Abaque



Anse du Dellec – 3D Model



Dense point cloud from **terrestrial topographic survey**, coloured by elevation

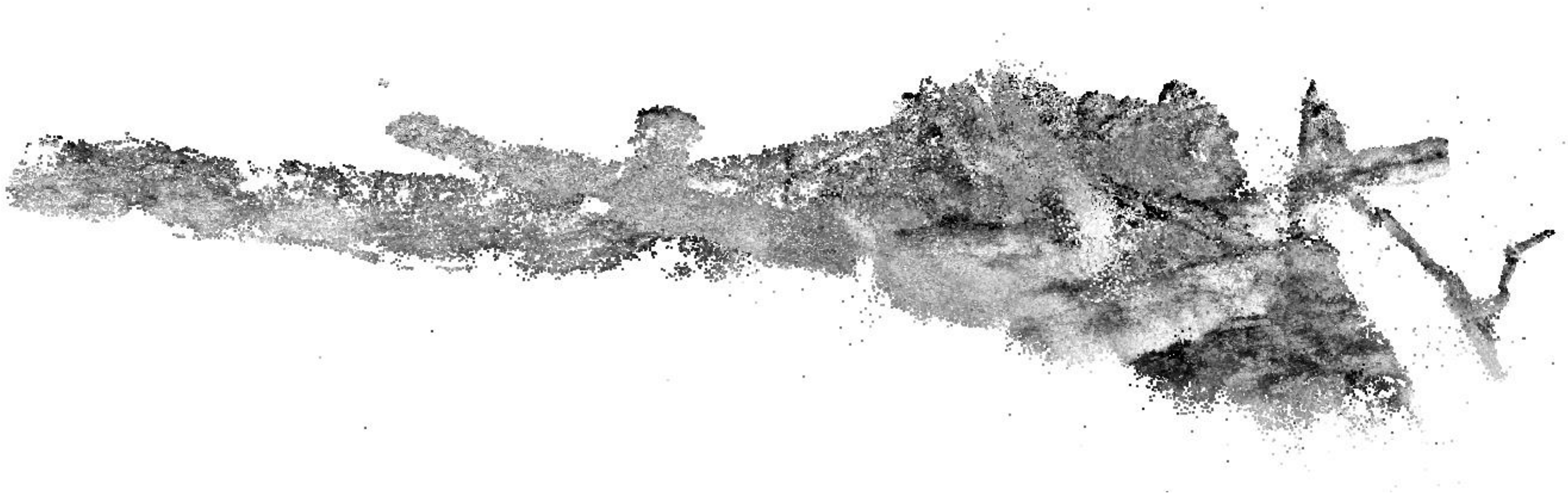


Dense point cloud from **optical bathymetric survey**, coloured by elevation

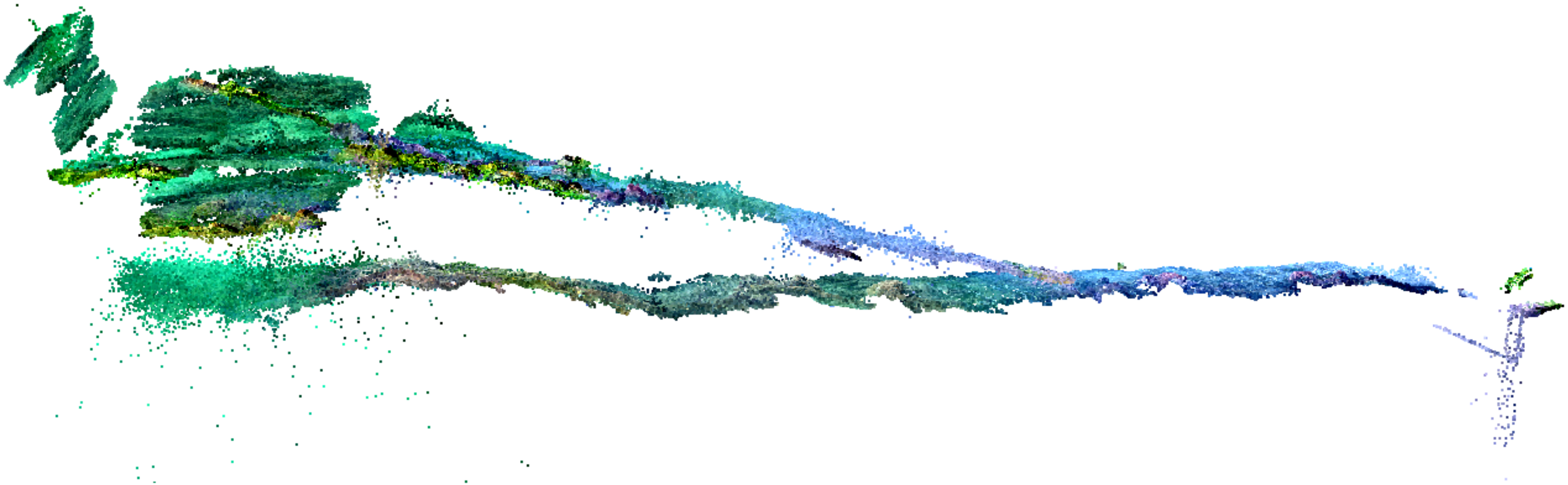
Y = Northing ; X = Easting ; Z = height

Anse du Dellec – Modern Art

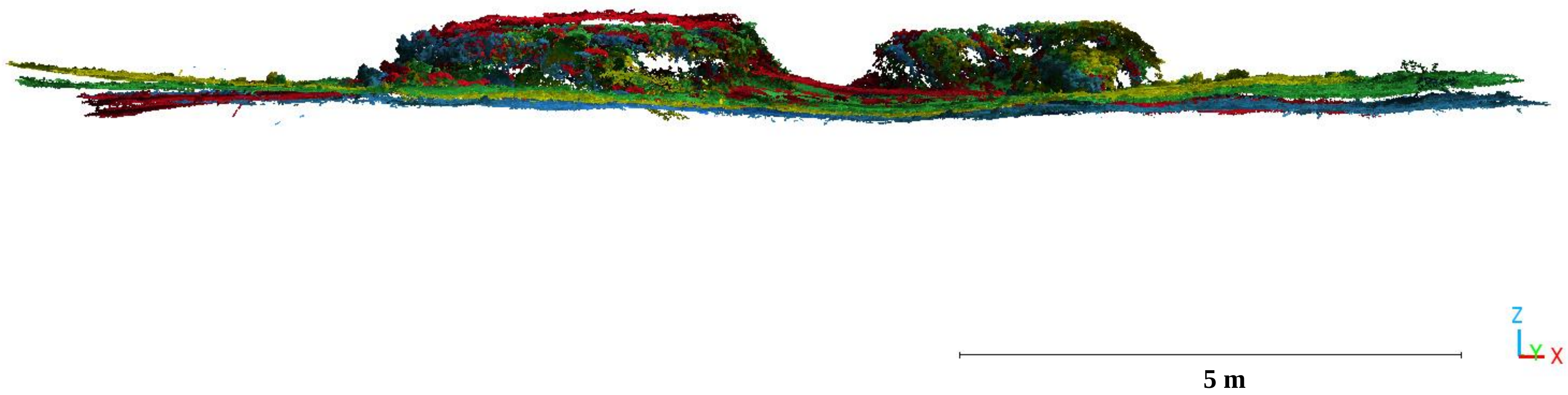
Anse du Dellec – Modern Art



Anse du Dellec – Modern Art



Site de l'Hermitage – 3D Models



Superimposing a section of the dense point clouds from each **test** (Y = Northing ; X = Easting ; Z = height) – **Lateral view**