THE HIGH RESOLUTION BATHYMETRY OF THE LAGOON OF VENICE: A BASE MAP FOR INTERDISCIPLINARY RESEARCH

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Gebco Science Day 2013
Venice.

OUTLINE

- Introduction
- Motivation
- The challenge of bathymetry in super shallow environments
- Multi beam bathymetry of the lagoon of Venice
- Case study of the Scanello Channel as ideal laboratory for a multidisciplinary approach
- Discussion and Conclusions

INTRODUCTION

-The lagoon of Venice is the biggest lagoon in the Mediterranean area with a surface of about 550 km^2

-It communicates with the Adriatic Sea through three inlets.

-It has an average depth of about 0.8 m

-The *typical morphological features* are:

- navigation canals (20 m deep at the inlets up to 2 m deep)
- natural tidal channels and creeks (few m to few dm deep)
- tidal flats (often less than 1 m deep)
- intertidal areas
- salt marshes

MOTIVATION

THE LAGOON OF VENICE IS IN RAPID EVOLUTION:

- salt marsh areas decreased by more than 50% in the last century
- deepening trend in some parts of the lagoon was observed with a net sediment flux exiting from the inlets.
- Major engineering interventions ongoing at the inlets
- impact of large ships

THE NEED OF MONITORING: .

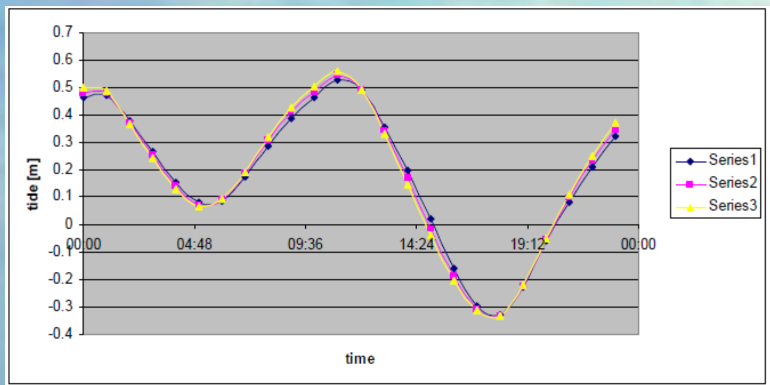
- Transitional environments undergo strong natural and human induced action.
- The changes can be assessed by repeated bathymetric surveys
- Extremely shallow environments are a challenge for acoustic bathymetric surveys

BATHYMETRY IS ONE OF THE MAIN FACTOR IN MULTIDISCIPLINARY STUDIES

- Habitat mapping
- Sediment budgets
- Geo-archaeology
- Hydrodynamic modelling

THE CHALLEGE OF BATHYMETRY IN THE LAGOON OF VENICE

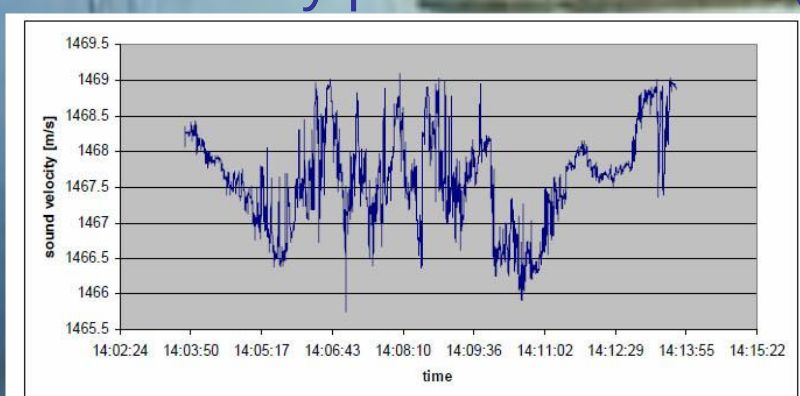
- Extremely shallow water (~1 m) – Multipath effect and reverberation
- High turbidity – no transparent water



•High tide excursion (about 1m) – operational problems and need for tide correction

•Current speed (about 1 ms^{-1} in the Lido inlet and 0.2 ms^{-1} in the Scanello channel, Northern Lagoon)

•Sound velocity profile variations (variation in salinity and temperature)



***Scanello channel** svp vs time*

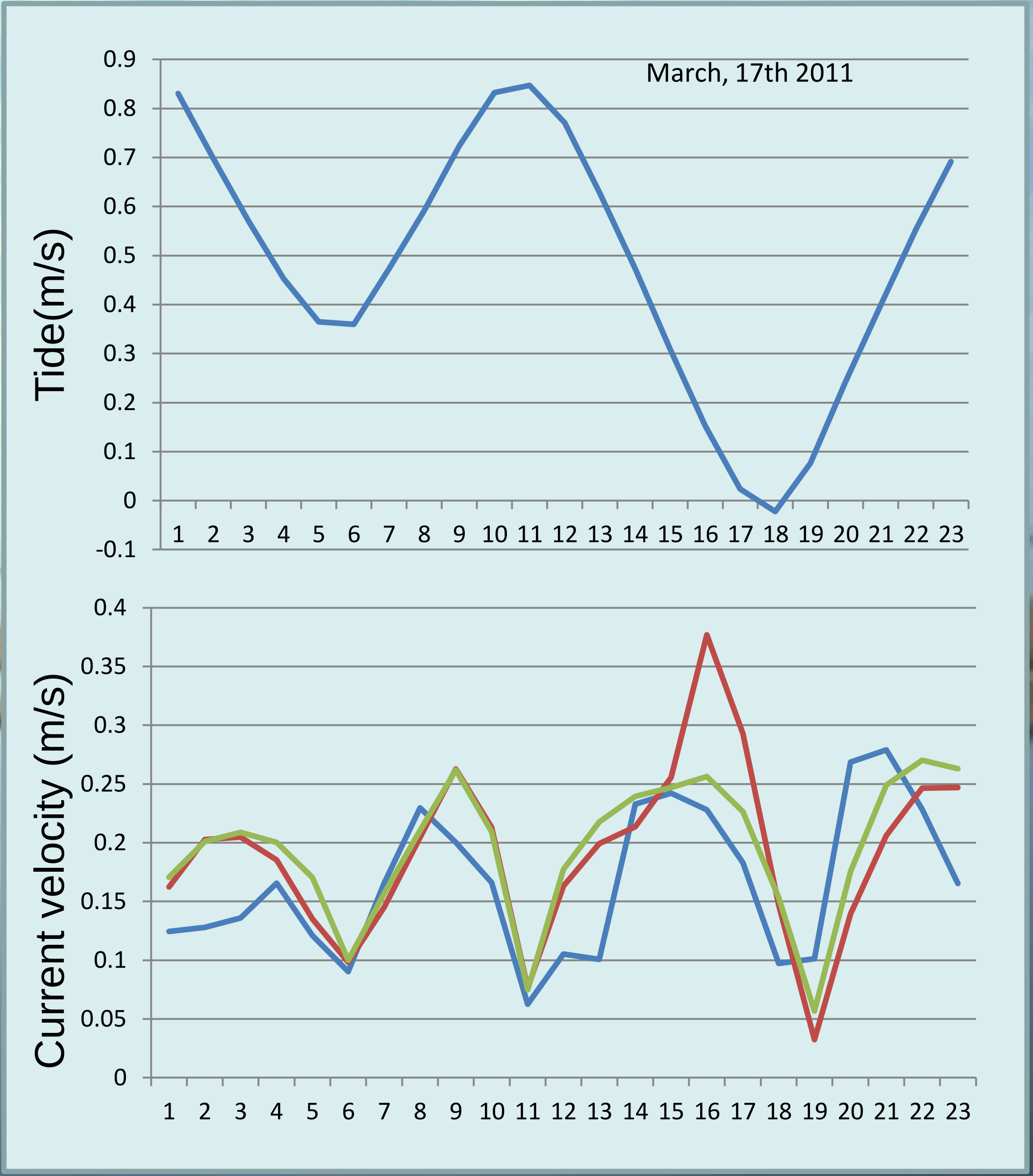
***From Dese to Torcello** svp vs space*

THE CHALLEGE OF BATHYMETRY IN THE LAGOON OF VENICE

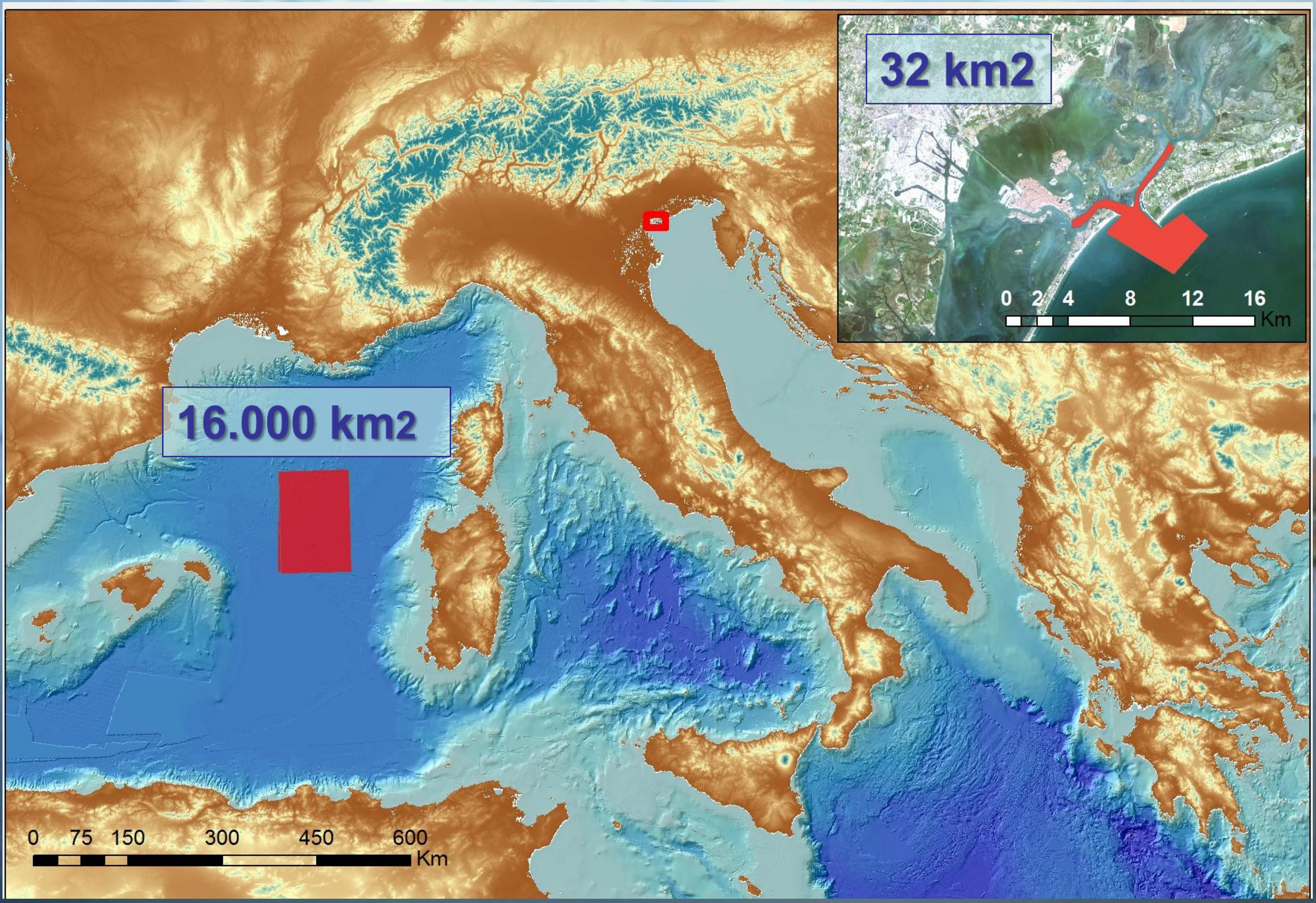
Current and tide data from the hydrodynamic model of the Venice Lagoon in the day of the survey

(data courtesy of Dr M. Bajo- ISMAR Venice)

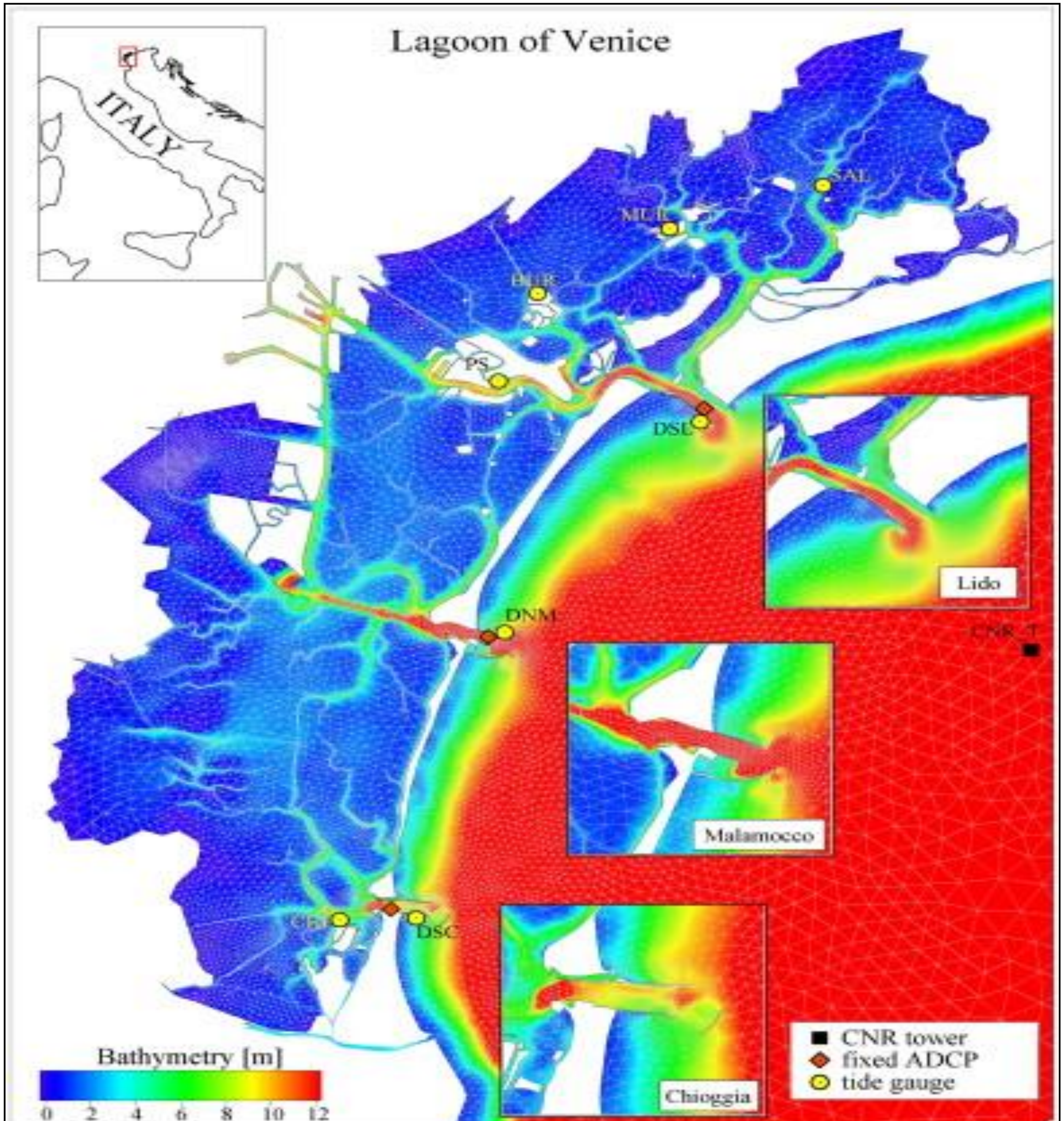
Average currents ranging from 0.17 to 0.2 m/s



THE CHALLENGE OF BATHYMETRY IN THE LAGOON OF VENICE



BATHYMETRY IN THE LAGOON OF VENICE
METHODOLOGY



PLANNING

Investigate all channels key areas in the shallowest water

STARTING WITH 6 MONTHS OF SURVEY FOR 8 HOURS A DAY

More than 20 people and 5 different groups involved

BATHYMETRY IN THE LAGOON OF VENICE: EQUIPEMENT

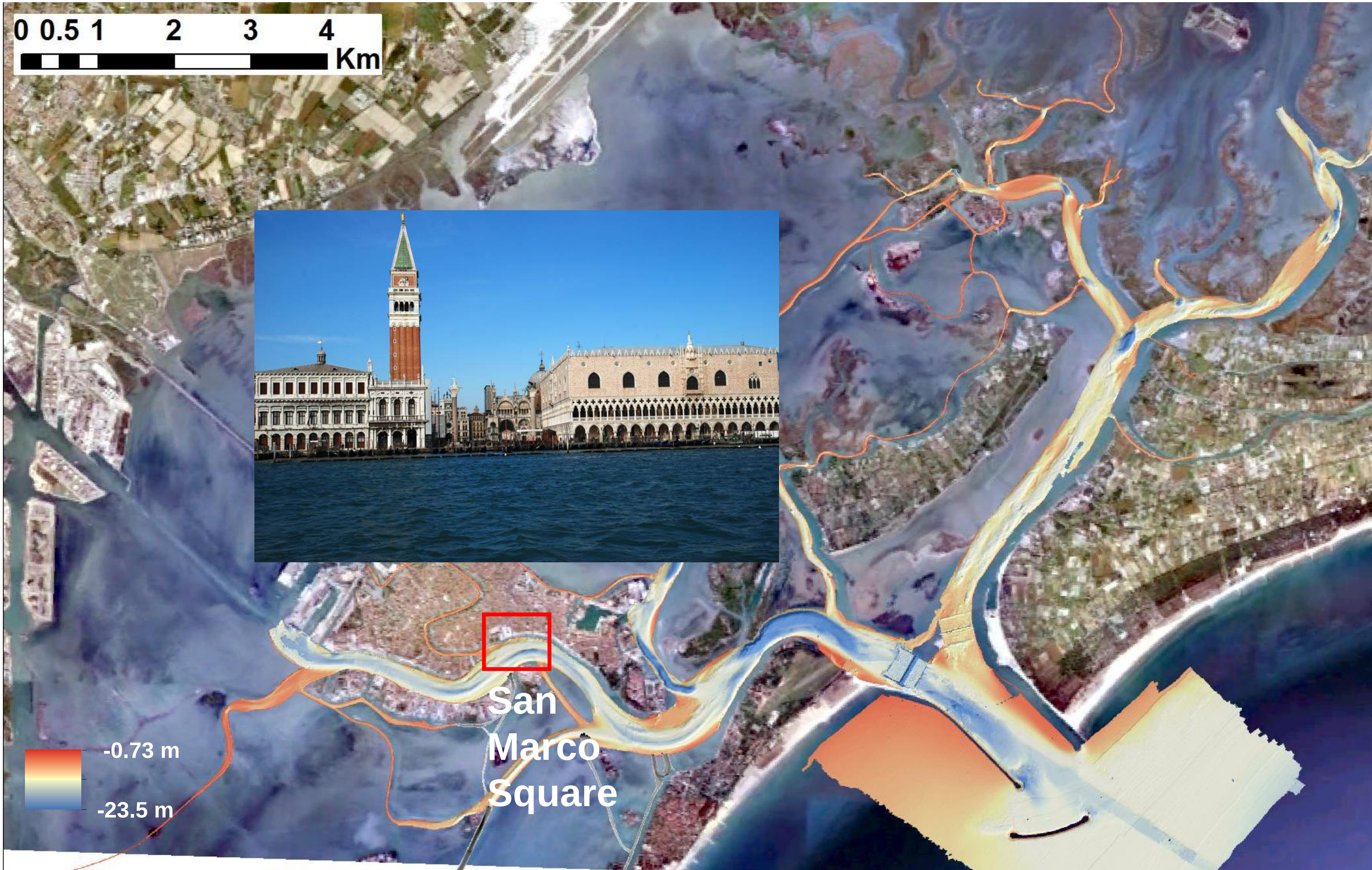
Multibeam System Kongsberg EM 2040D-C

Positioning system Kongsberg Seapath 300

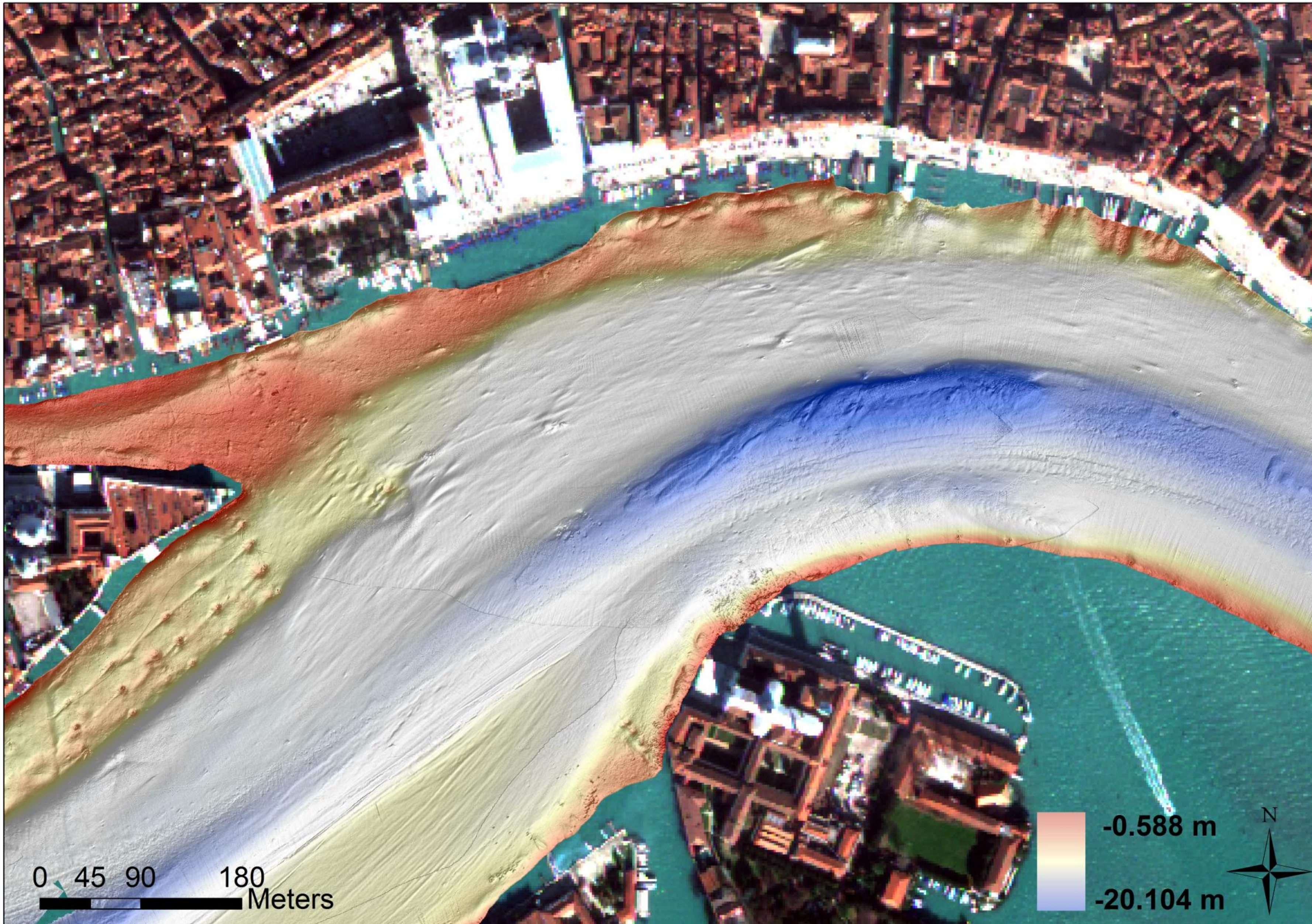
Motion sensor Kongsberg Seatex MRU 5

Valeport Mini SVS and AML Ocenographic SV Profiler

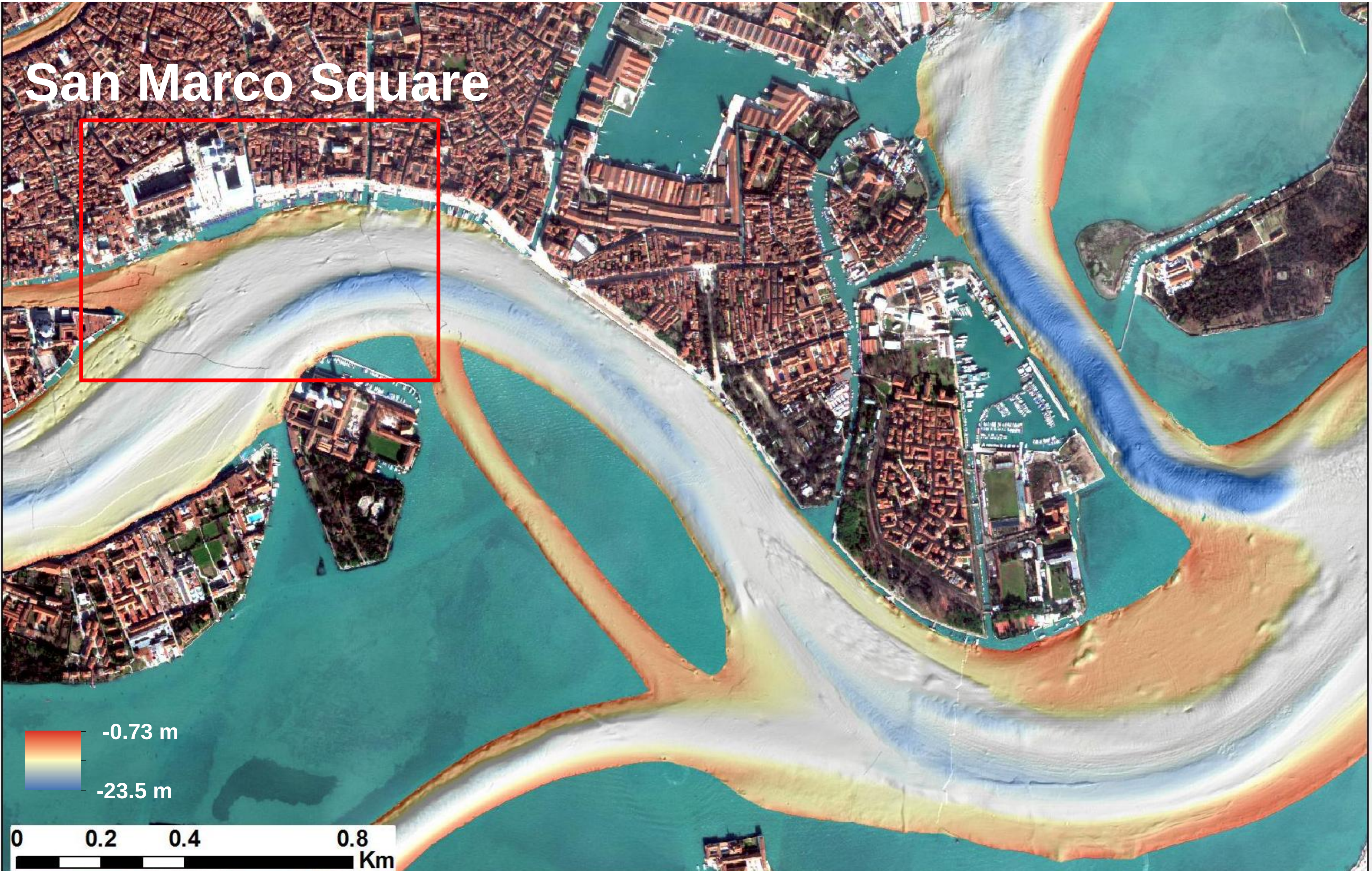
SURVEY AREAS – THE CITY OF VENICE



SURVEY AREAS – San Marco square (DTM 0.2m V.E:5X)



SURVEY AREAS – The city of Venice

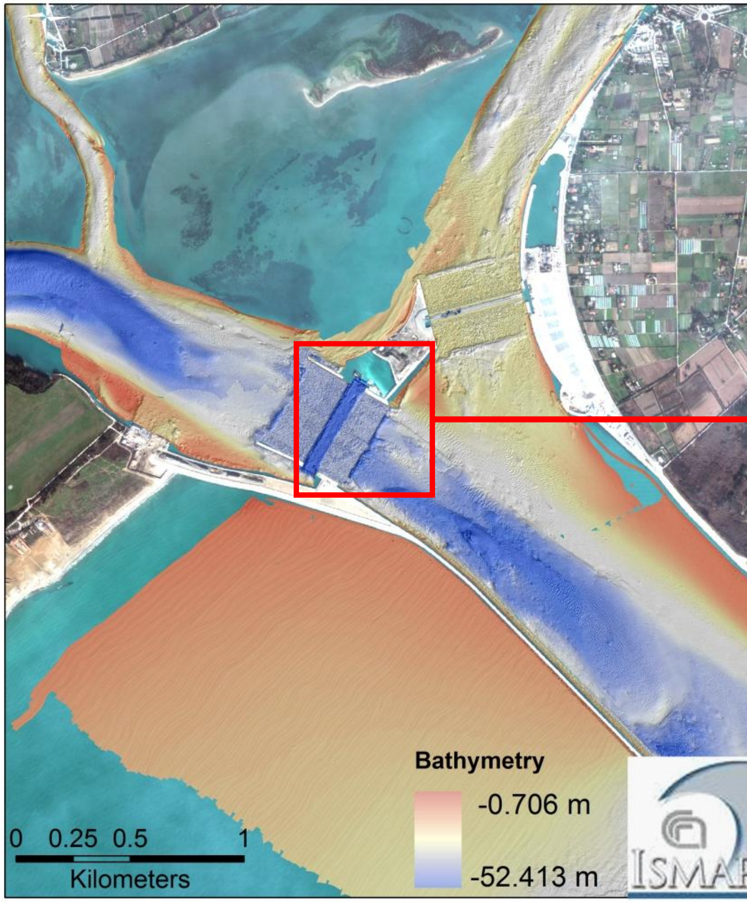


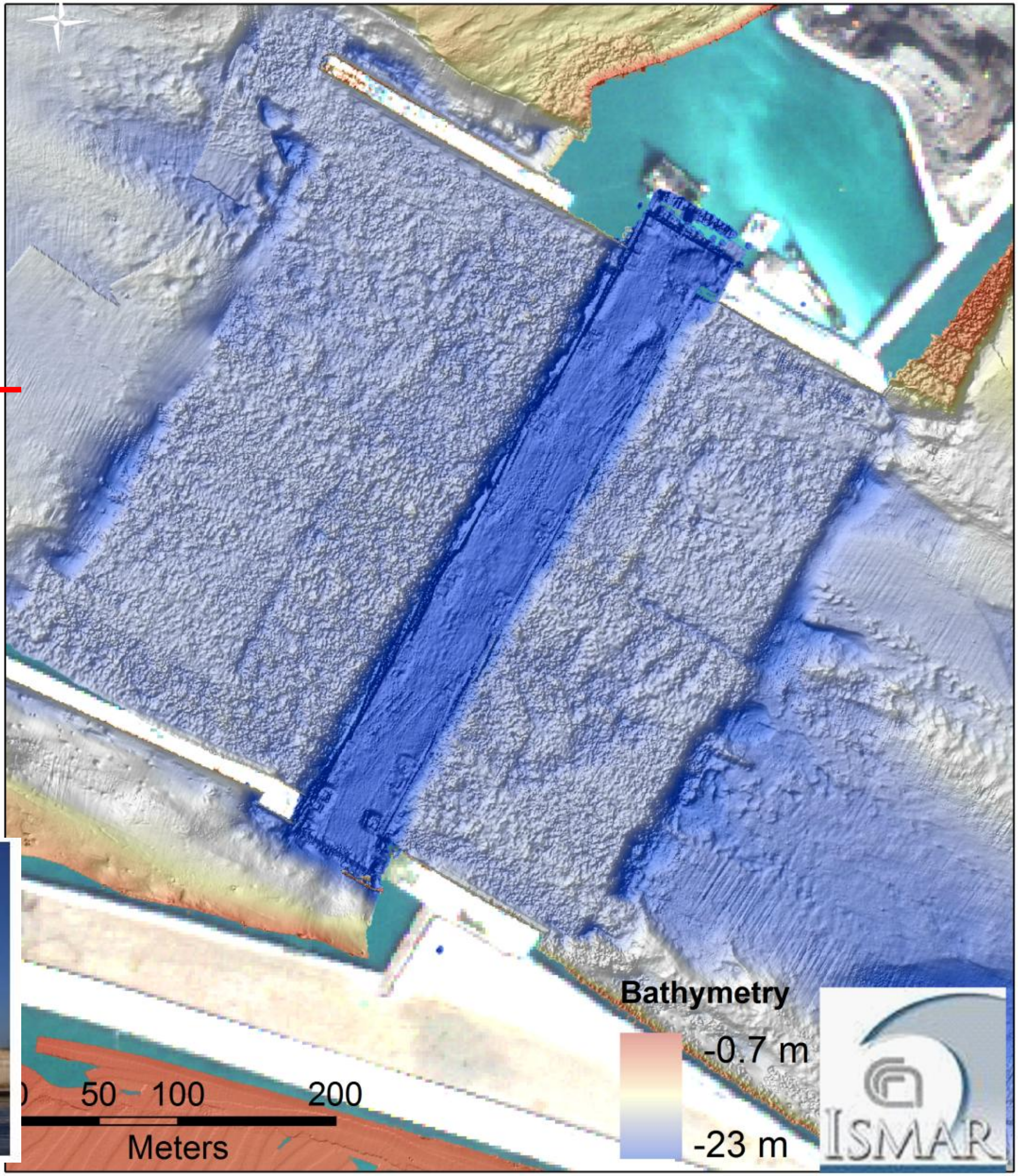
SURVEY AREAS – The city of Venice
BIG CRUISE SHIPS AND HIGH WATER

SURVEY AREAS – The city of Venice
BIG CRUISE SHIPS AND HIGH WATER

SURVEY AREAS - DIFFERENT ENVIRONMENTS
MOSE CONSTRUCTION

MOSE CONSTRUCTION SITE

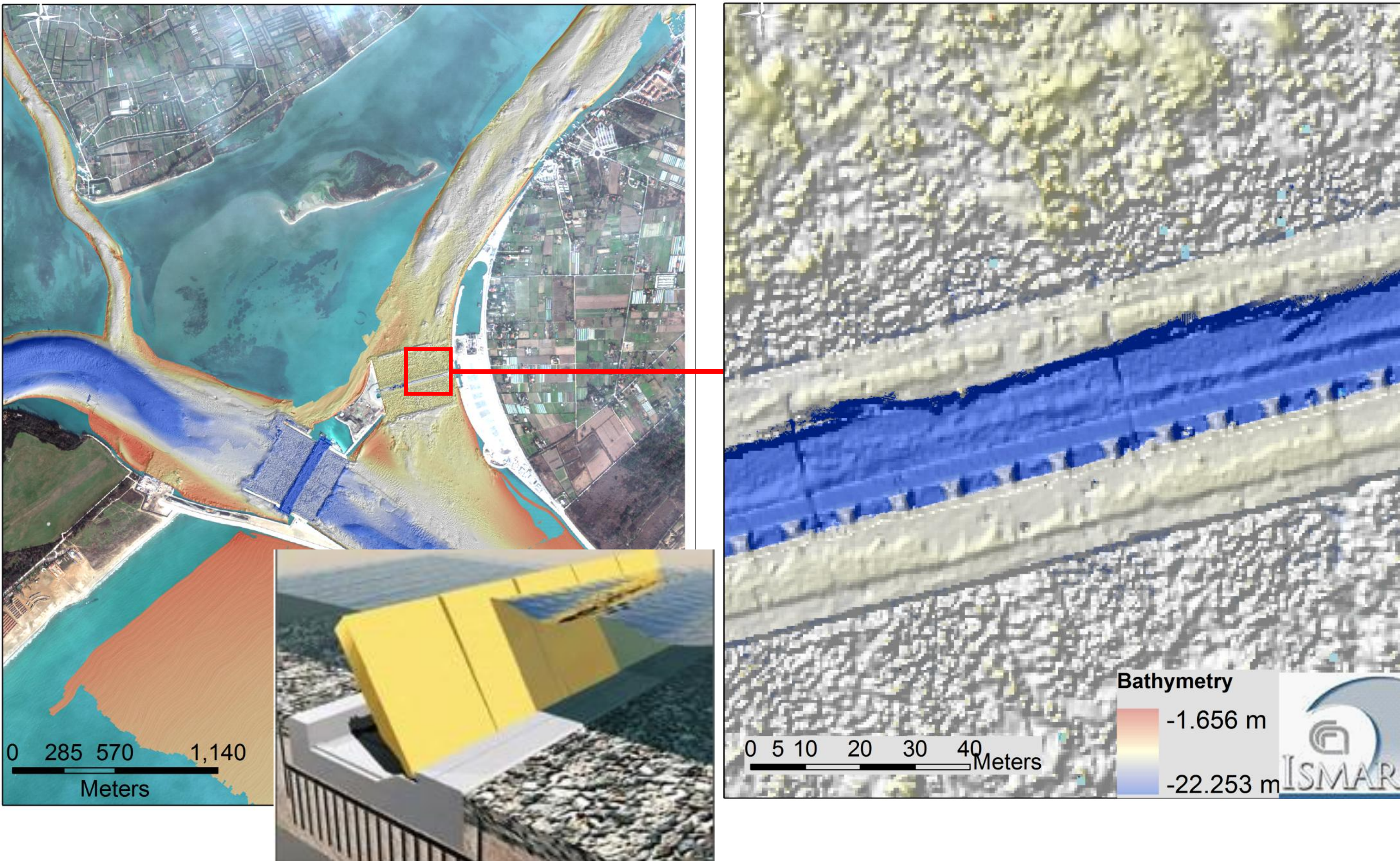




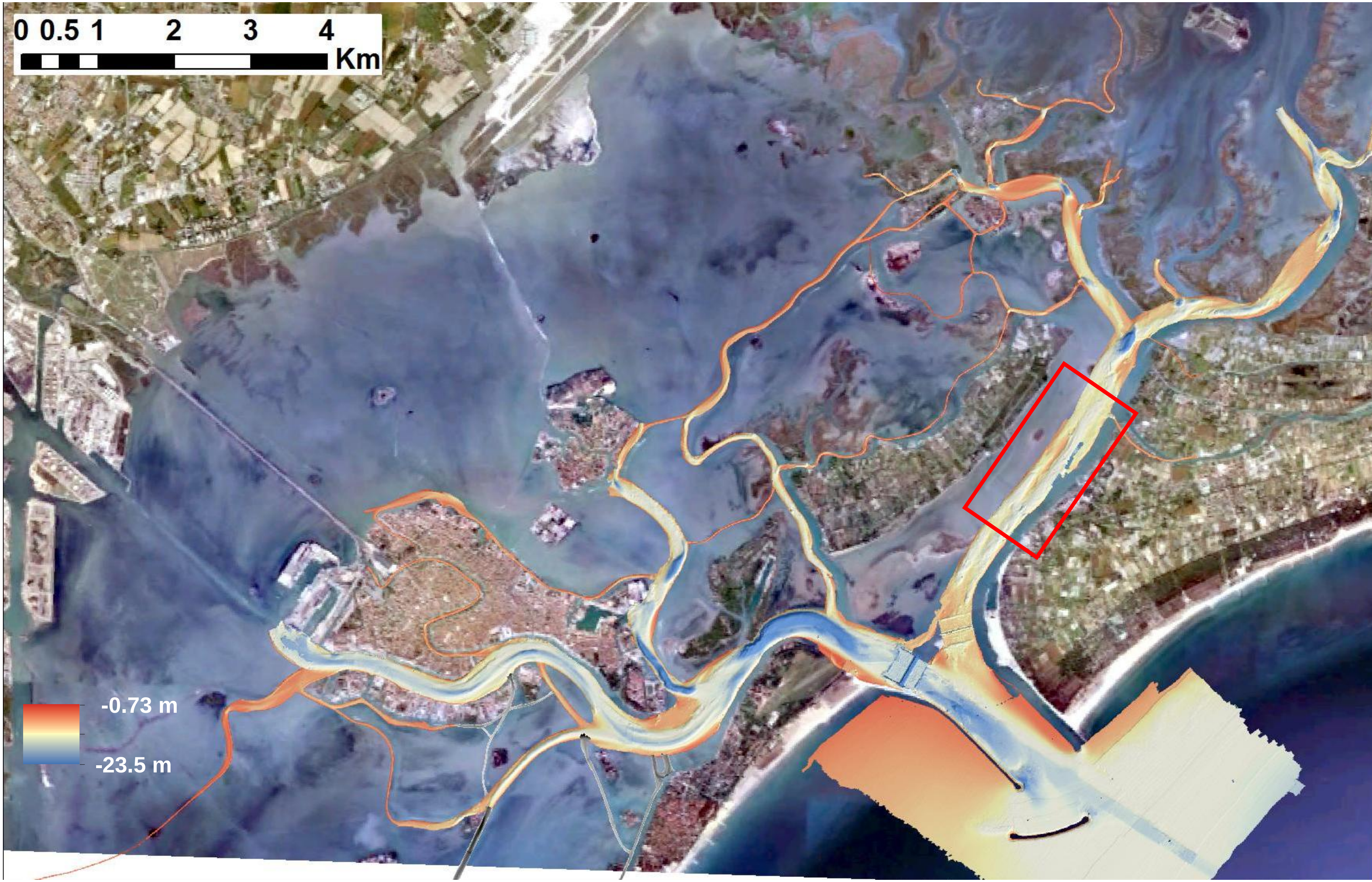
Resolution 0.5 M

V.E. 5X

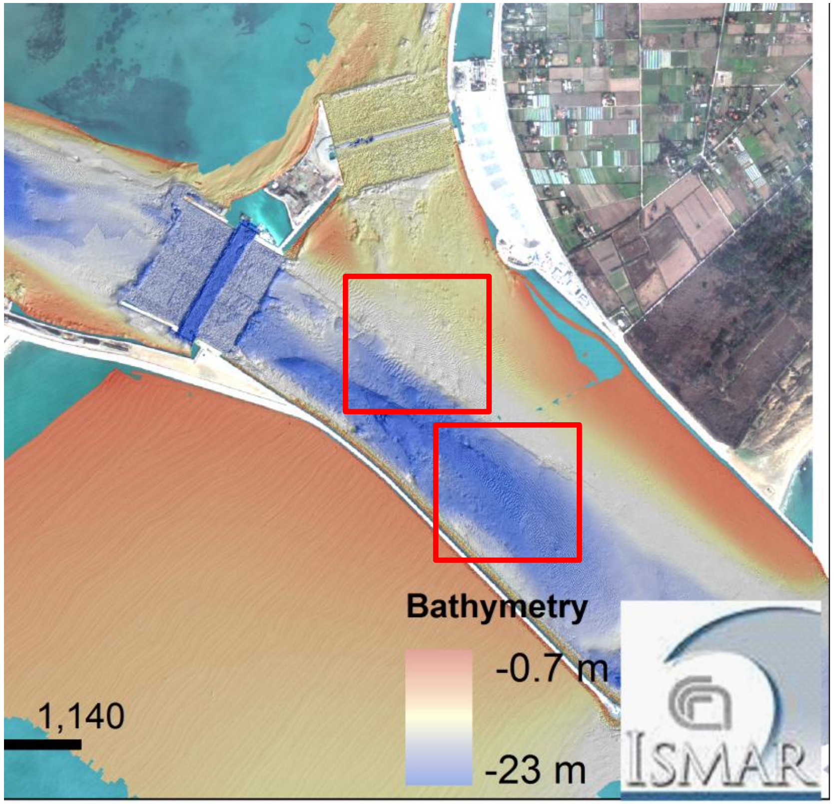
MOSE CONSTRUCTION SITE

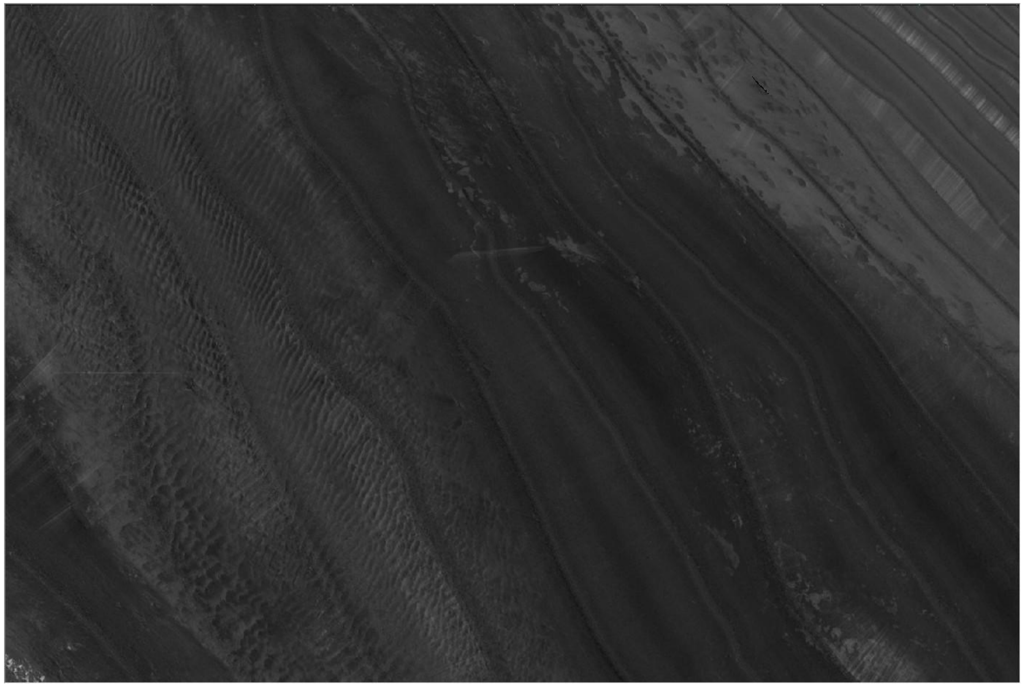


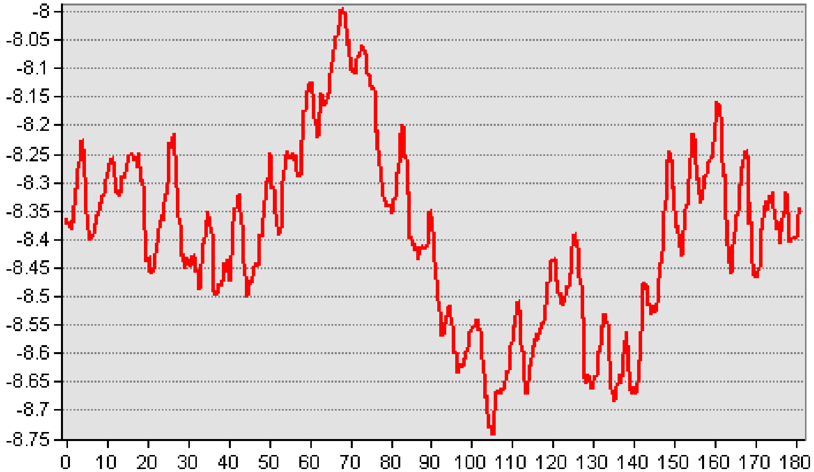
SURVEY AREAS - DIFFERENT ENVIRONMENTS
TRE PORTI CHANNEL



LIDO INLET


Bathymetry
-0.7 m
-23 m
1,140
ISMAR




-8
-8.05
-8.1
-8.15
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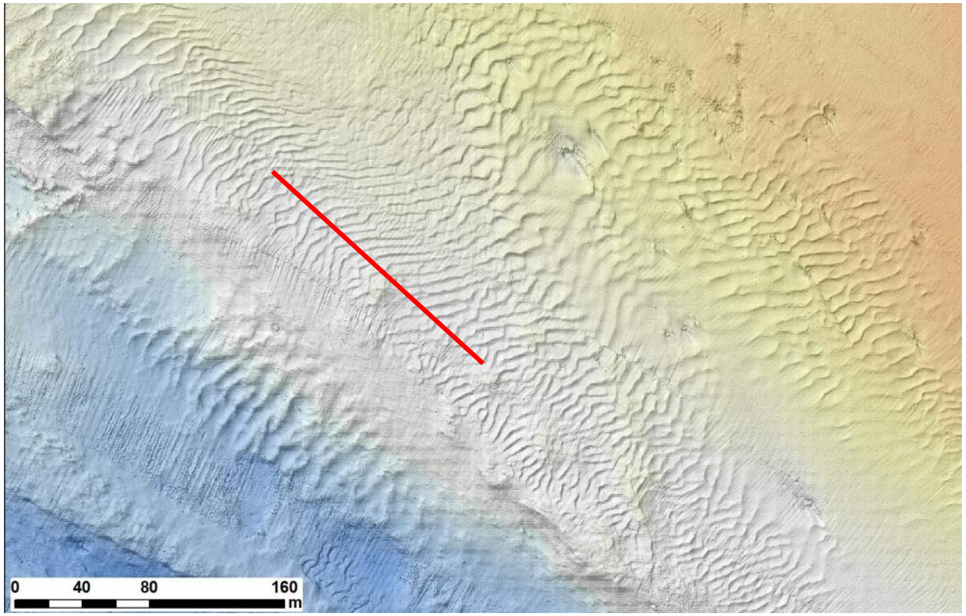
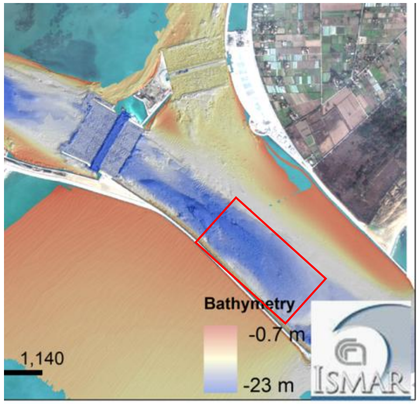
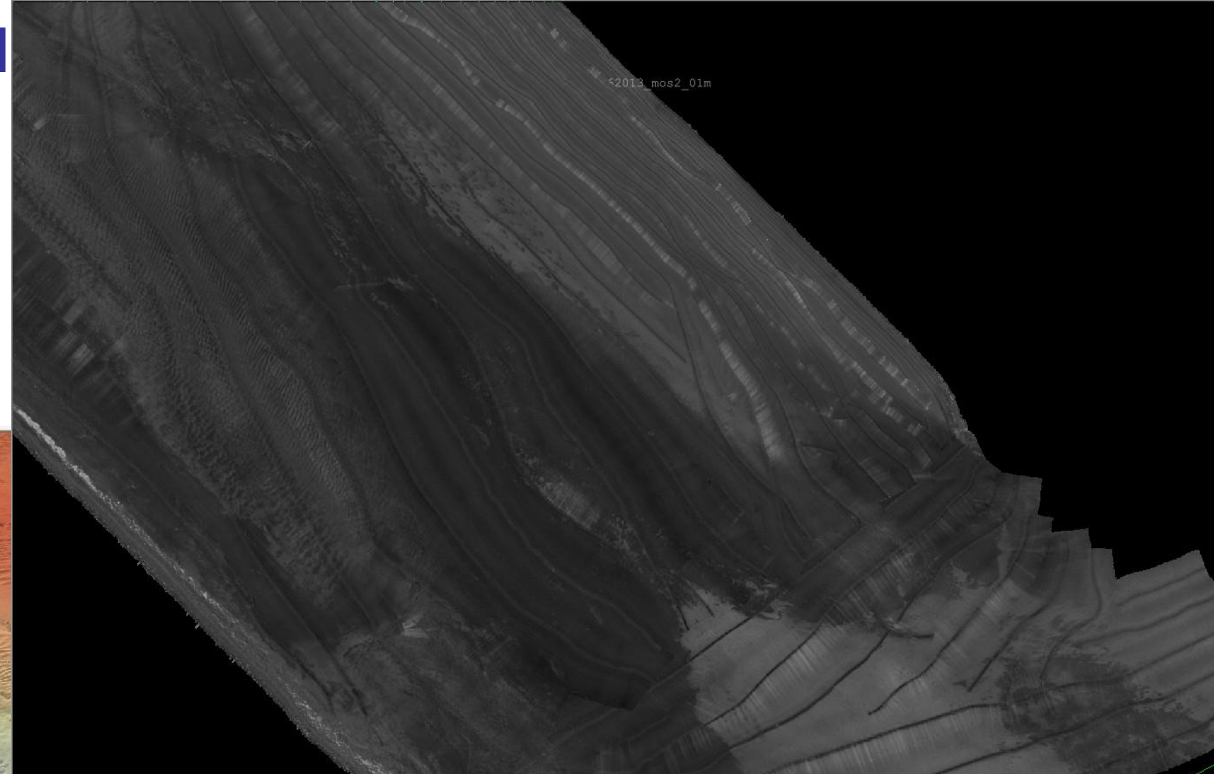
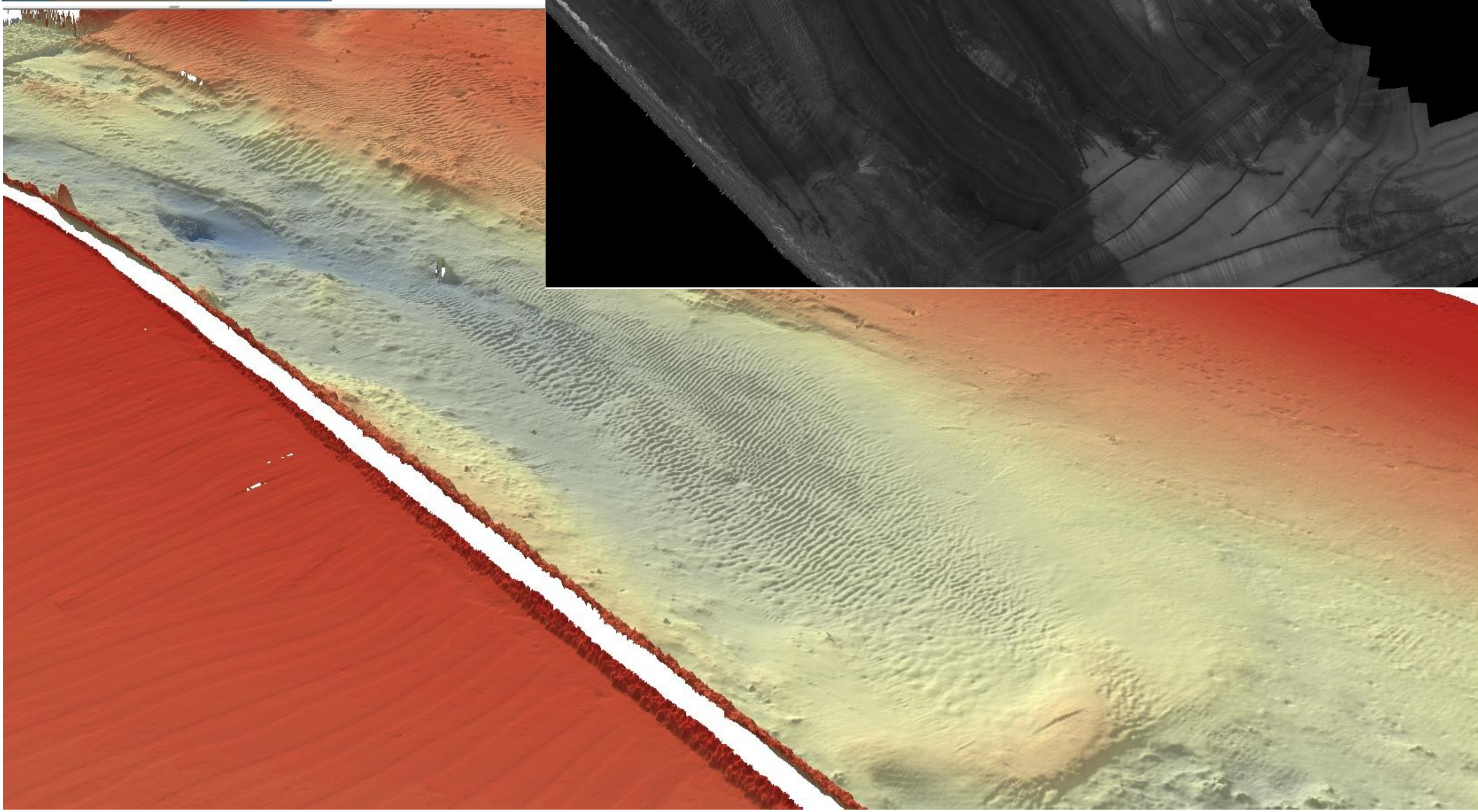
-8.55
-8.6
-8.65
-8.7
-8.75
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180


0 40 80 160
m

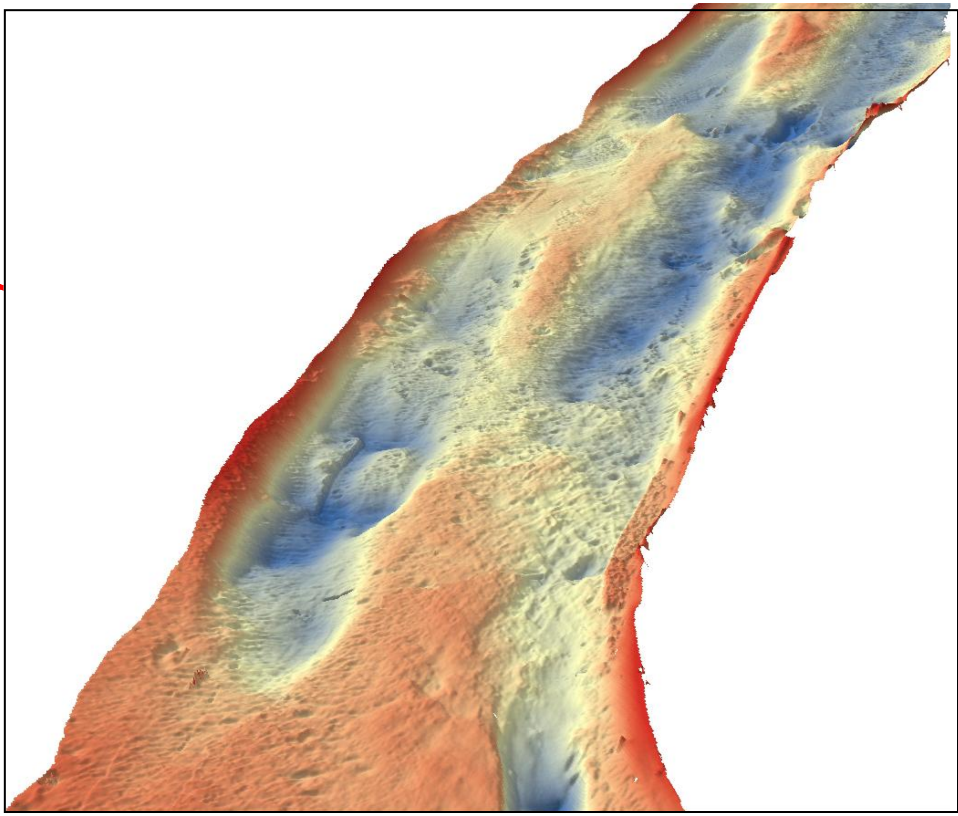
LI

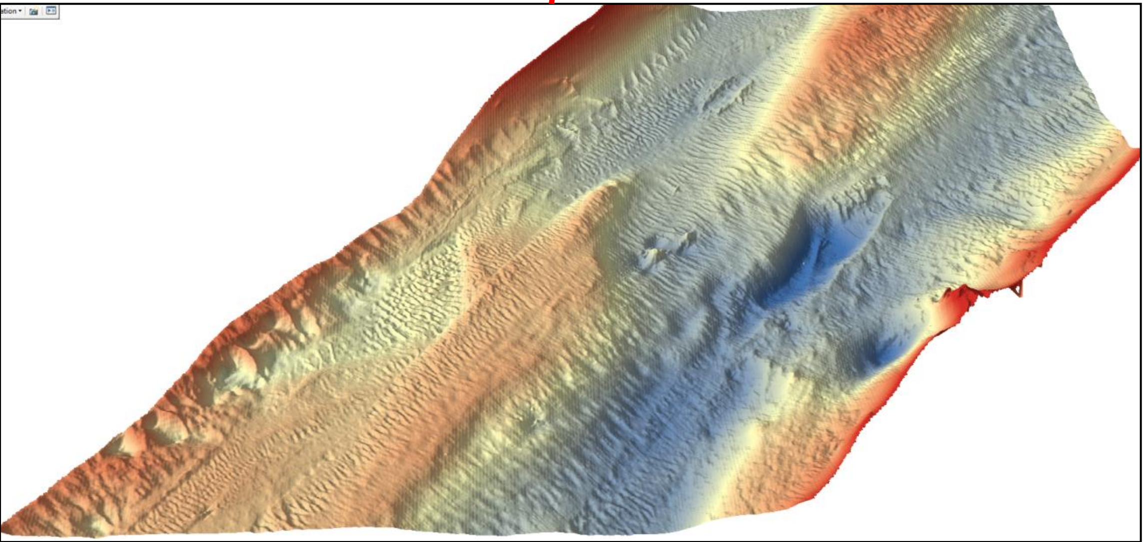






Treporti channel

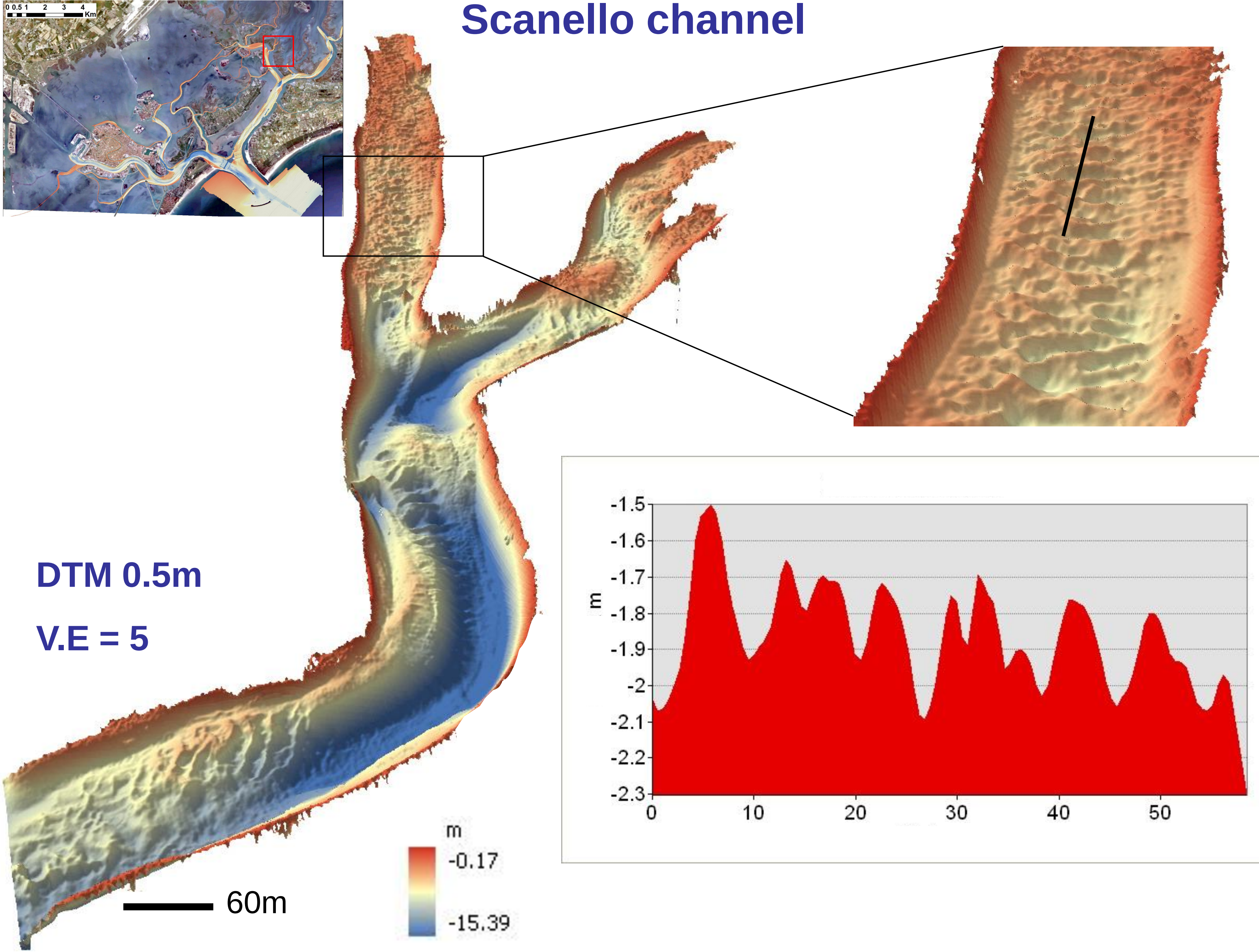




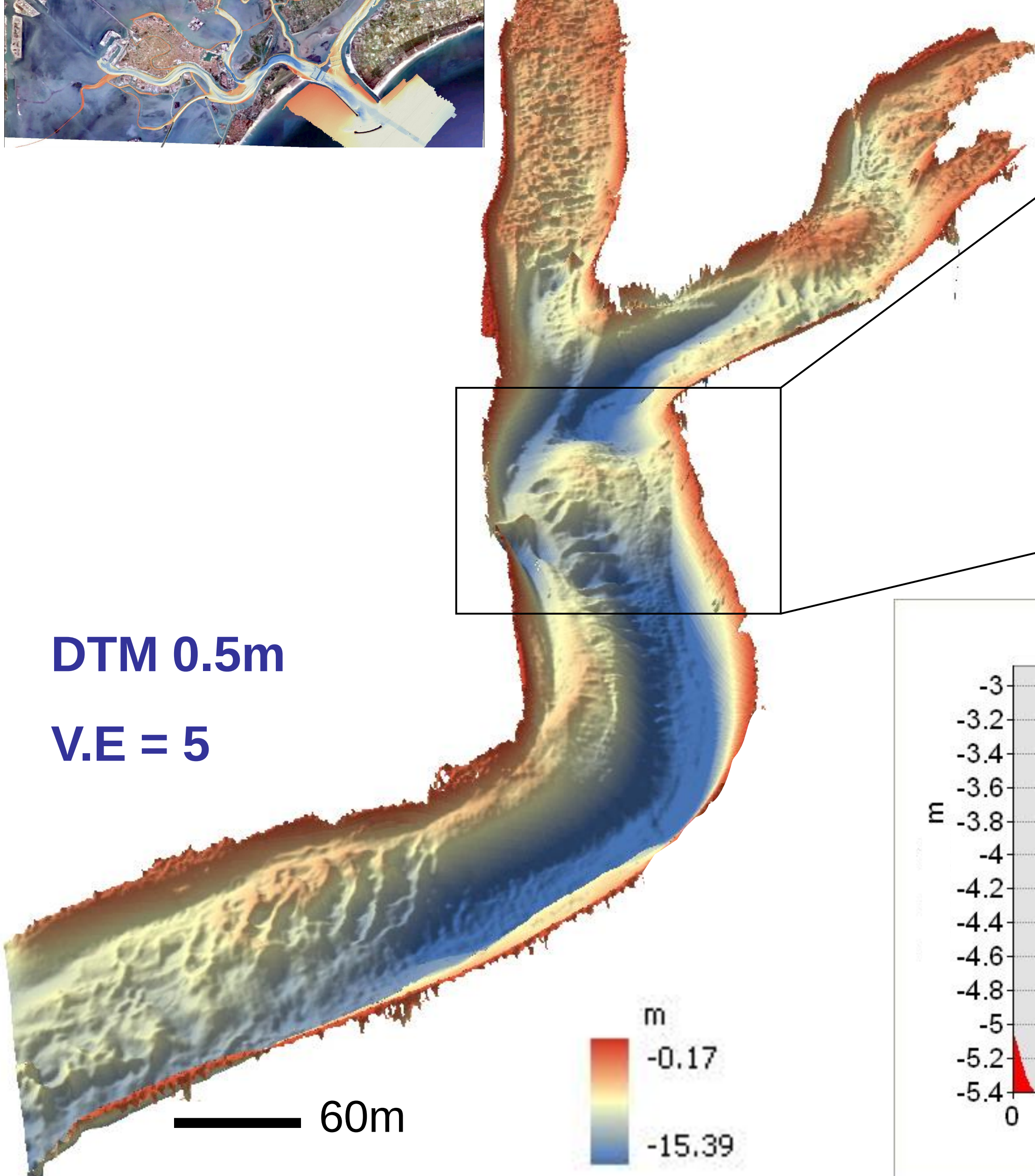
DTM 0.2 m
v.E 5 x

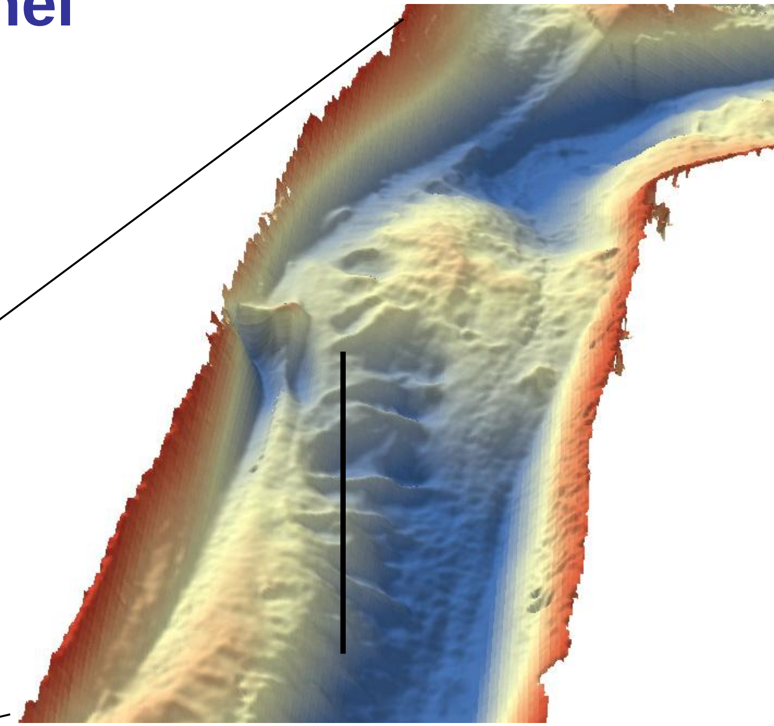
RESULTS: SURVEY AREAS DIFFERENT ENVIRONMENTS

Scanello channel



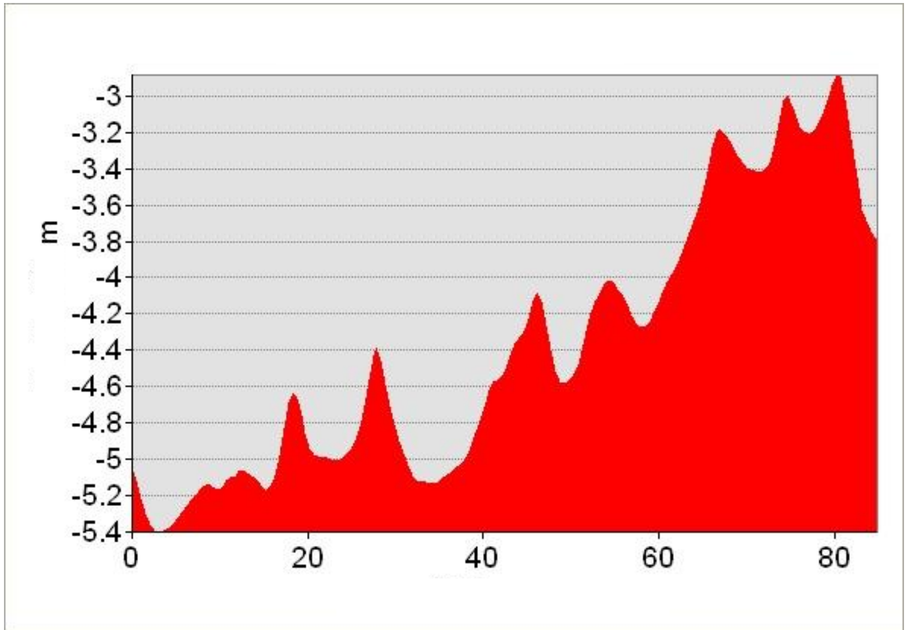
Scanello channel





DTM 0.5m

V.E = 5

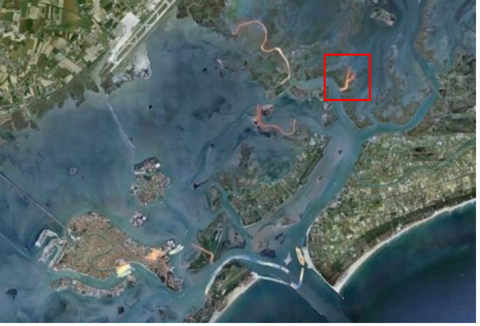


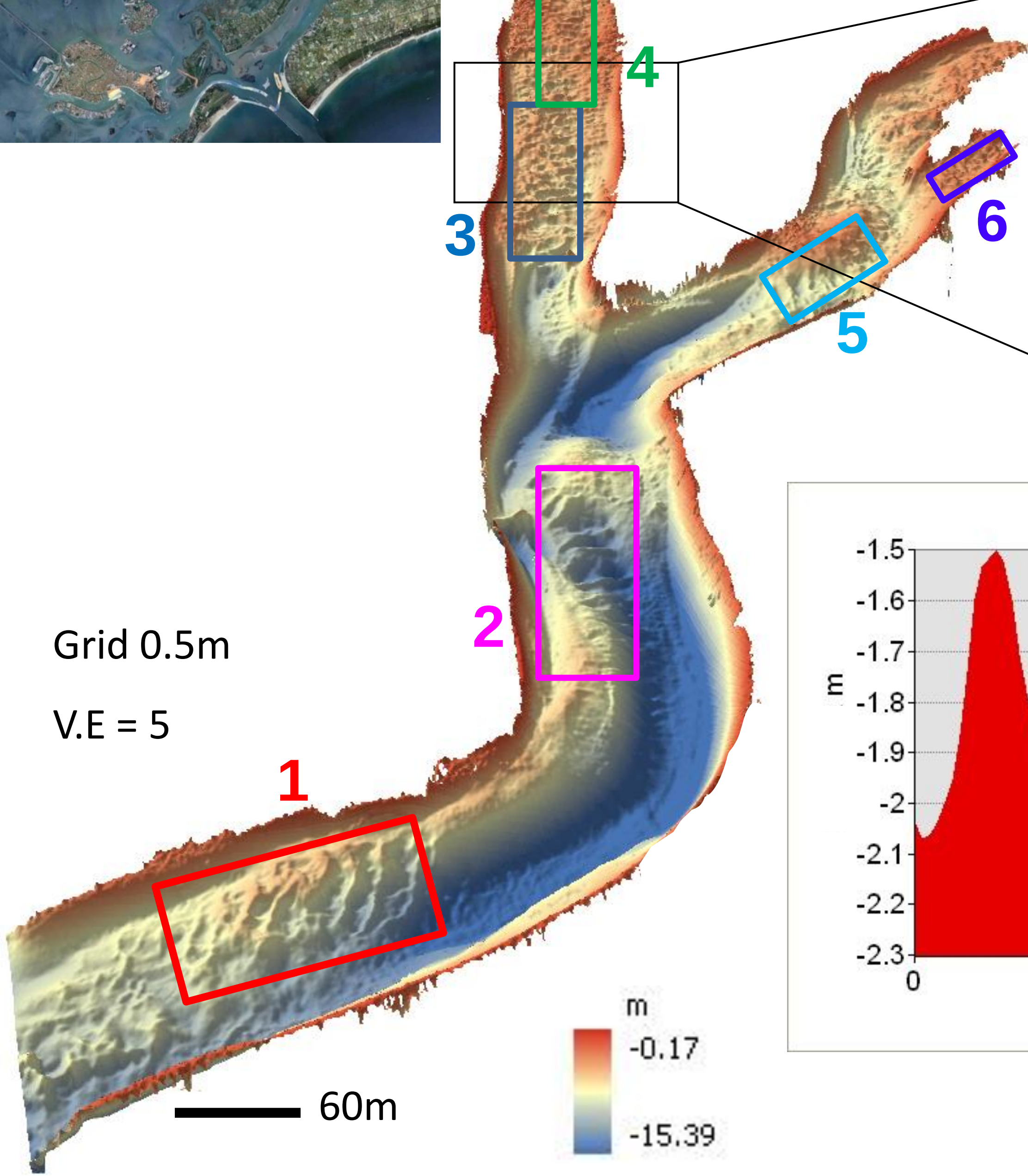
Case study of the Scanello Channel:
ideal laboratory for a multidisciplinary approach

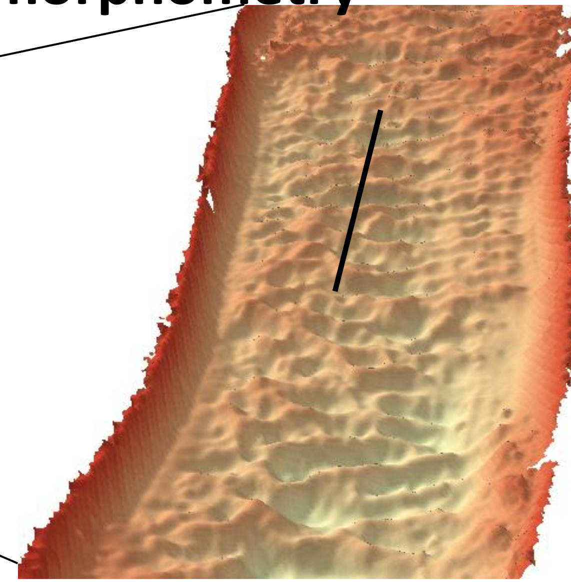
- Bathymetry – geomorphometry (roughness, …)
- Sediment sampling (grain size, …)
- Benthos sampling (habitat, …)
- Current measurements (ADCP)

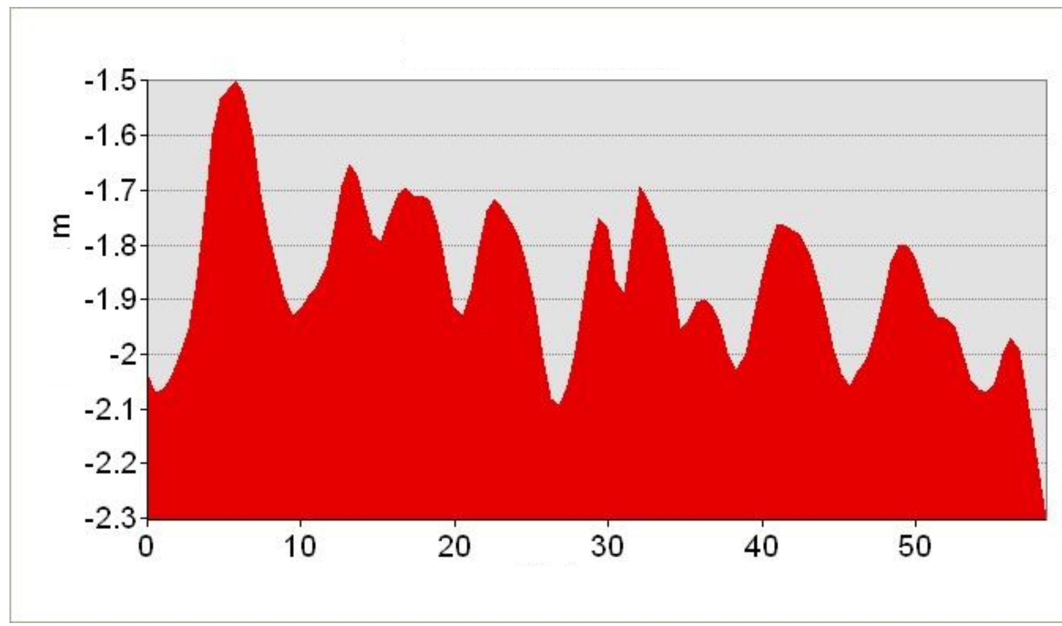
- High spatial resolution modelling of the hydrodynamics

SCANELLO Channel, geomorphometry

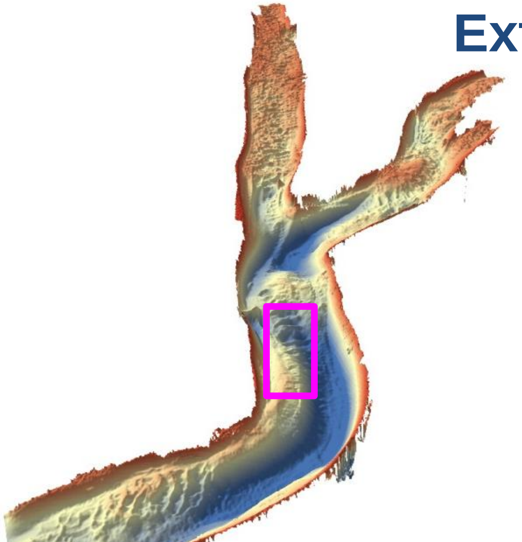








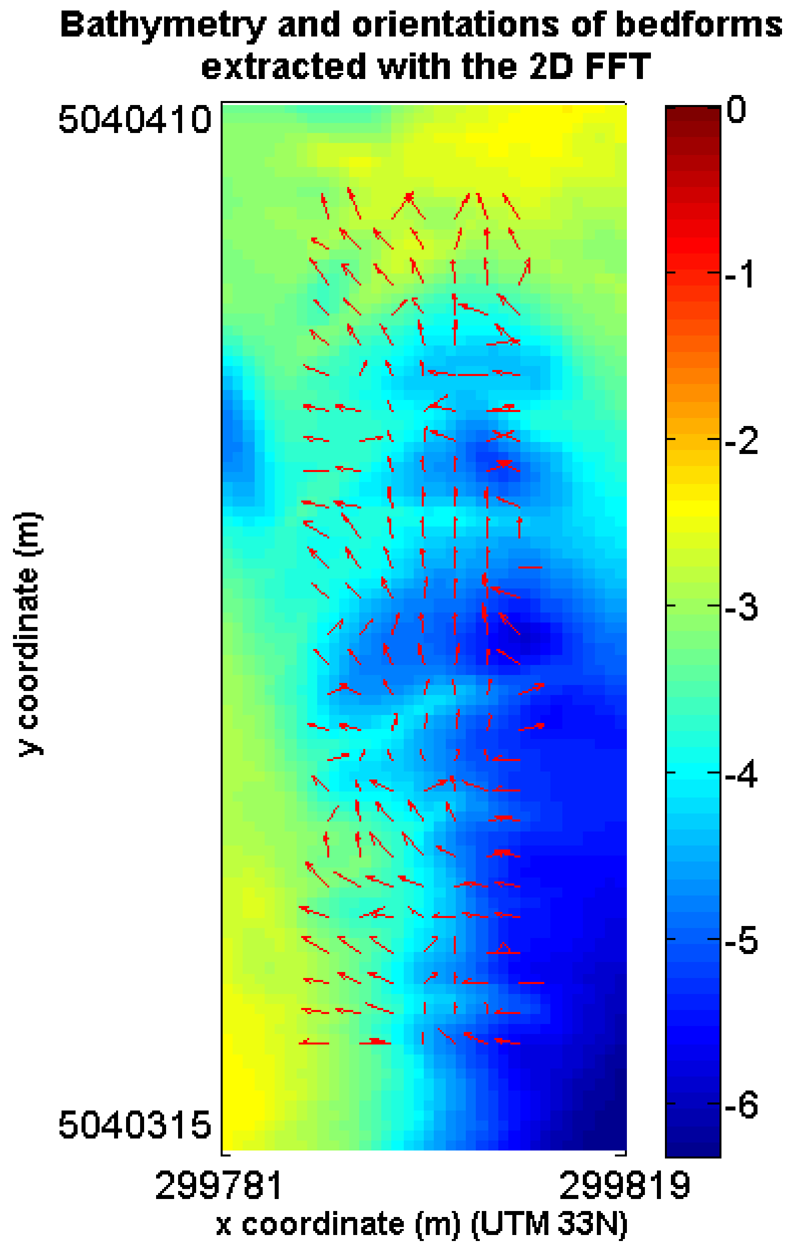
Extraction of bedform wavelengths and orientations from the 2D FFT (dune field 2)



After computation of the 2D FFT of partially overlapping 20mx20m windows of the bathymetry we obtained average orientation and wavelegth for each dune field.

For example for the dune field 2:

- Average orientation **α = 88°**
- Average wavelength **λ=10 m**



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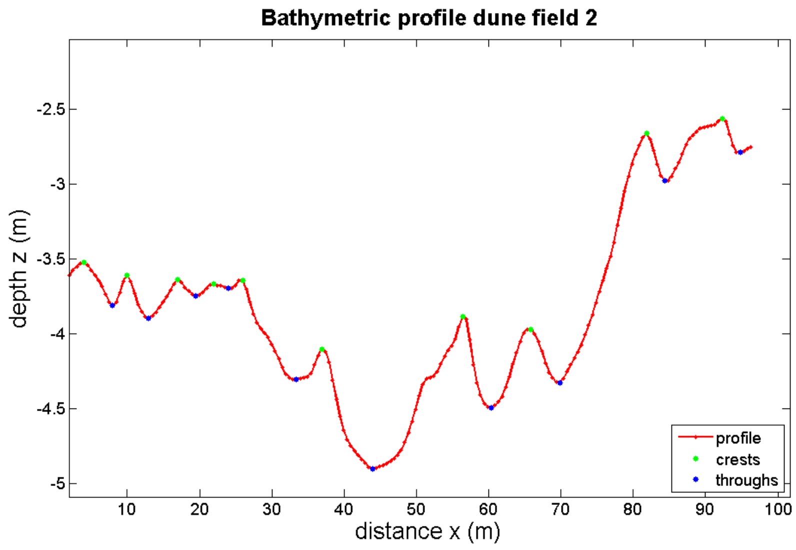

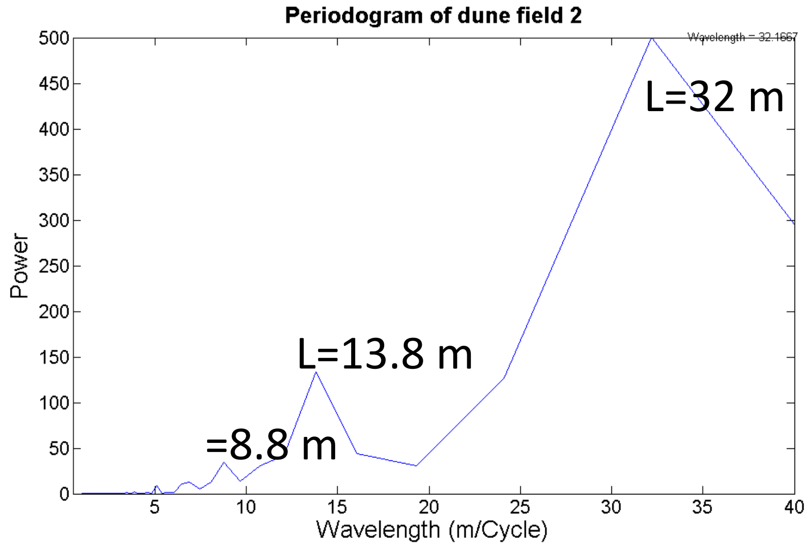

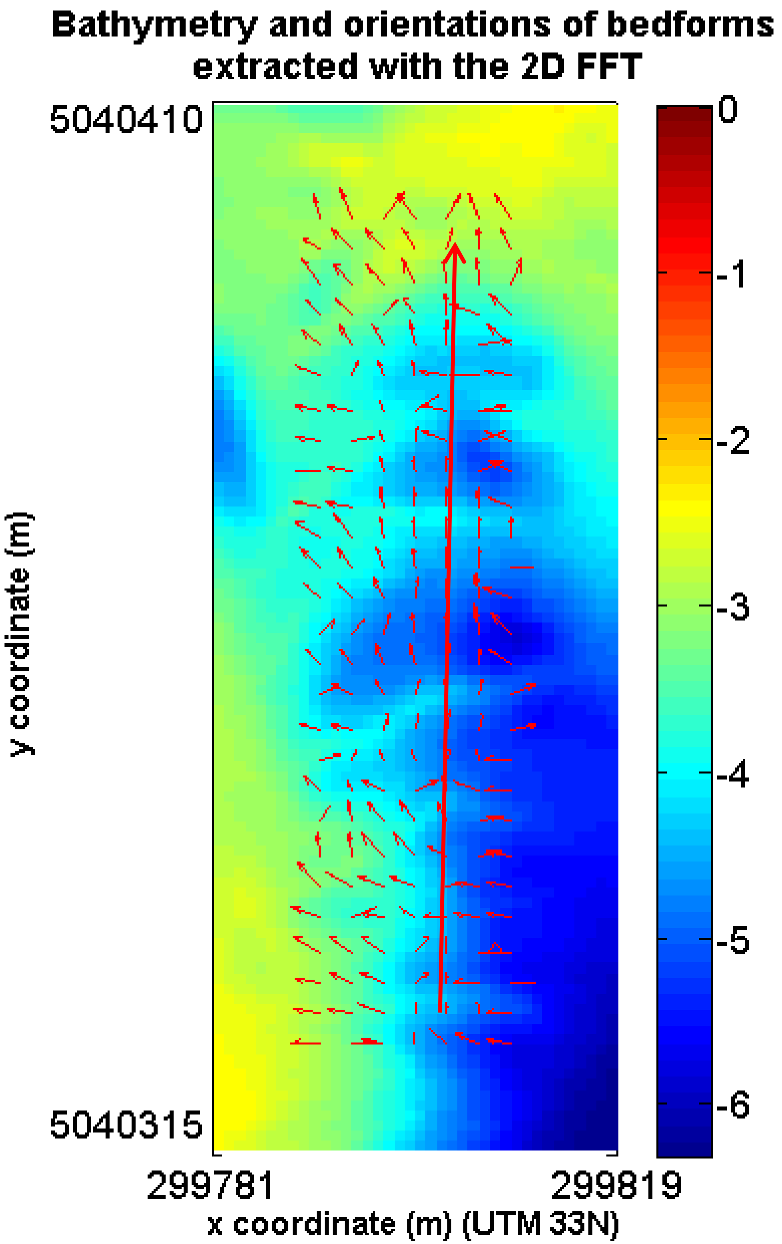

Classification of subacqueous bedforms through 1D profiles to compute the roughness

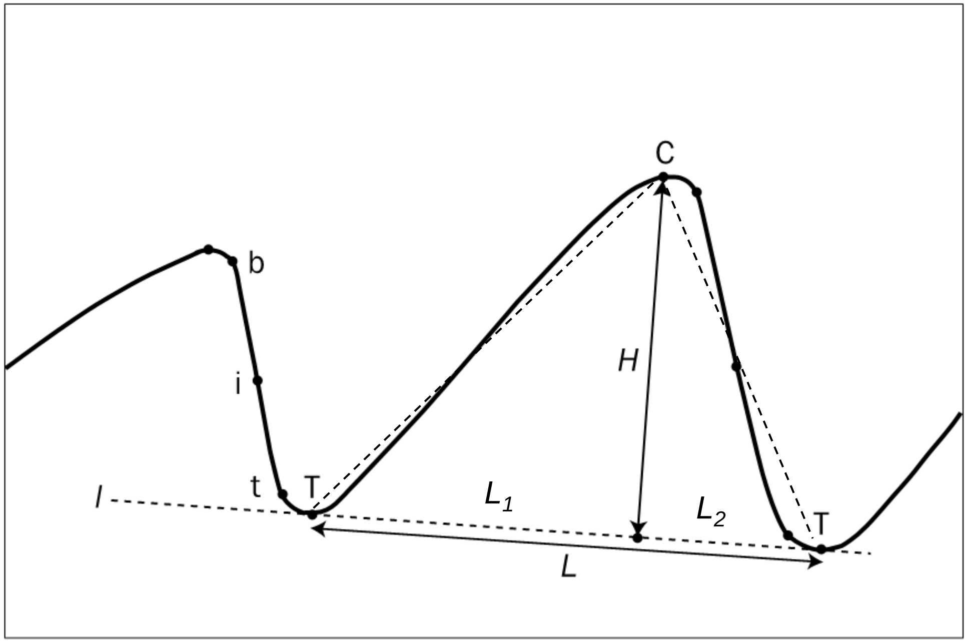

Figure 1. Definition of the morphologic parameters wavelength and height and characteristic morphologic points of bed forms, the crest point, C; trough point, T; inflection point of the lee side, *i*; brink point, *b*; and toe point, *t*. (modified from Van Dijk et al. 2008)

Approximating the dune with a triangle, we can define the dune height H, wavelength L, asymmetry index L1/L2 and steepness L/H

Dune field parameters

Type of subacqueous dunes	Medium dunes				Small dunes	
Dune field	1	2	3	5	4	6
Wavelength L (mean)	9.18 m	9.43 m	6.389 m	7.06 m	5 m	5.08 m
Wavelength L (range)	2.49-13.97 m	4.49-16.46 m	3.49- 9.47m	4.48-9.95 m	2-8.5 m	2.99- 7.96 m
Height H (mean)	0.45 m	0.37 m	0.32 m	0.36 m	0.19 m	0.26 m
Height H (range)	0.04-0.84 m	0.06- 0.74 m	0.06-0.7 m	0.16- 0.67 m	0.01- 0.52 m	0.11- 0.54 m
Asymmetry index L_1/L_2 (mean)	1.32	1.79	1.32	1.26	1.99	1.04
Asymmetry index L_1/L_2 (range)	0.33-4.02	0.25-5.1	0.12-5.1	0.5-2.5	0.14-5.06	0.39-2.03
Steepness H/L (mean)	0.044	0.037	0.047	0.039	0.035	0.043
Steepness H/L (range)	0.01-0.08	0.051-0.013	0.076- 0.014	0.068- 0.006	0.065- 0.006	0.090- 0.006

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- From the wavelength **L** and the height **H** one can estimate the roughness length
- From the asymmetry index **L1/L2** one can determine the dominant dune direction

Roughness estimation

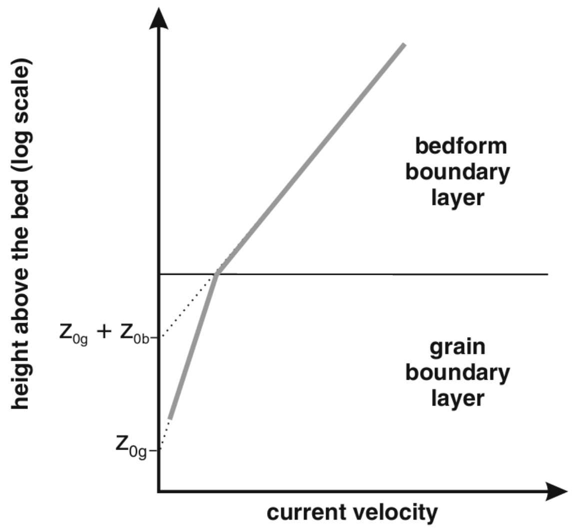


Fig. 1 A typical velocity profile over subaqueous bedforms. The velocity profile is segmented; the lower log-linear segment is related to the grain boundary layer, whereas the upper segment is controlled by the bedform boundary layer

Table 1 Some bedform roughness predictors

Authors	Validity	Expression
Swart (1976)	Wave-formed ripples	$z_0 = 0.83\frac{H^2}{L}$
Grant and Madsen (1982)	Wave-formed ripples under oscillatory flow or combined waves and currents	$z_0 = 0.92\frac{H^2}{L}$
Nielsen (1992)	Roughness of rippled bed under waves	$z_0 = 0.27\frac{H^2}{L}$
Soulsby (1997)	Generalization of previous equations	$z_0 = a_b\frac{H^2}{L}$ and $a_b = 1$
Van Rijn (1984)	Ripples, dunes and large dunes $0.01<H/L<0.2$	$z_0 = 0.04H\left(1 - e^{-25H/L}\right)$
Bartholdy et al. (2010)	Dunes under currents	$z_0=0.019H$

(from Lefebvre et al. 2011)

$$u(z) = \frac{u_*}{\kappa} \ln \frac{z}{z_0}$$

z_0 is the ***roughness length***, i.e. the height where the current velocity tends to zero.

•If the bottom is flat it is related to the drag of the single grains (**grain roughness**)

•If the bottom has beforms it is also related to the bedform friction (**bedform roughness**)

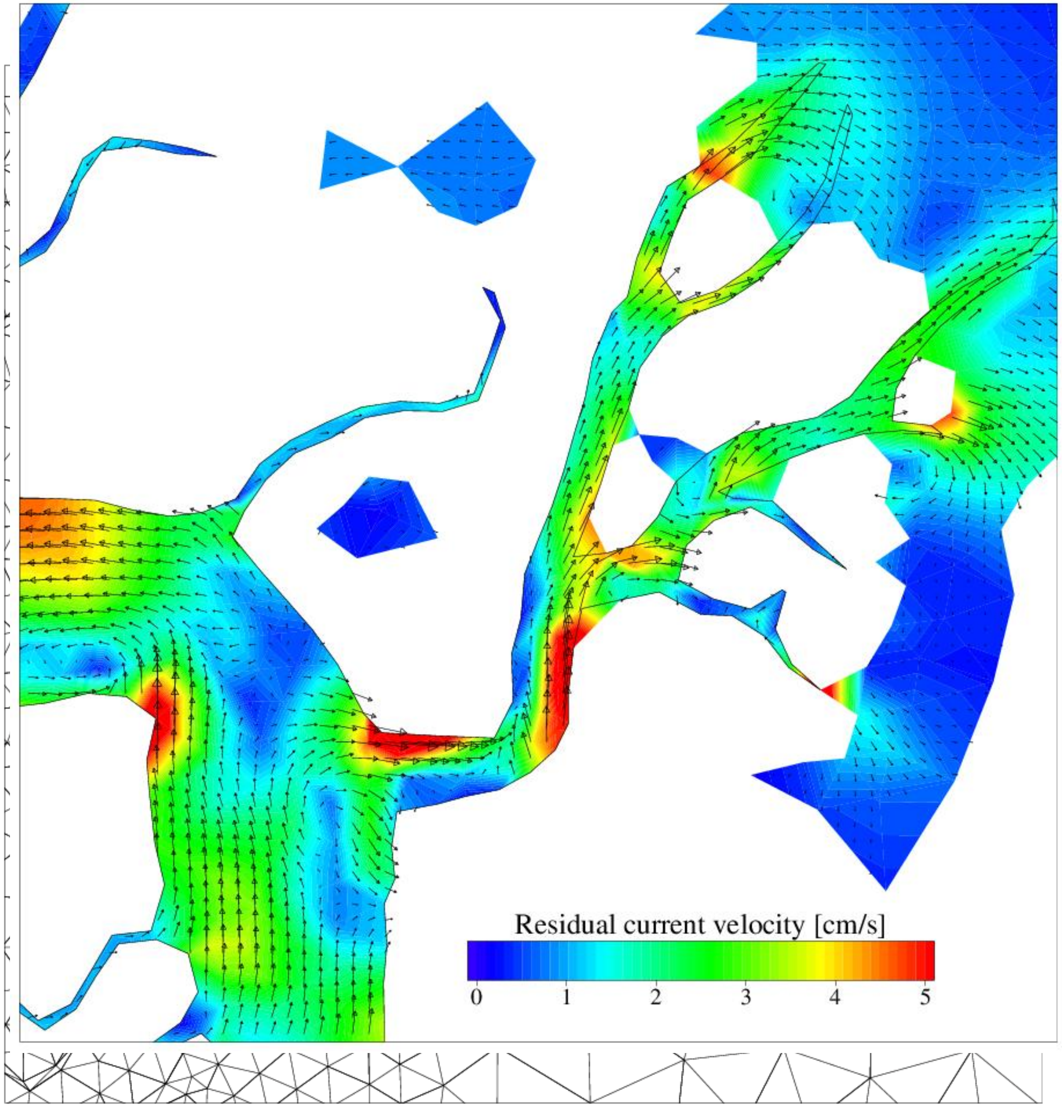
•It is used to estimate the **bed shear stress** which is an essential parameter in boundary layer dynamics, hydrodynamics, and sediment transport calculations and modeling

Bedform roughness estimation

Type of subacqueous dunes	Medium dunes				Small dunes		
Dune field	1	2	3	5	4	6	Lefebvre et al 2011
Wavelength L (mean)	9.18	9.43	6.39	7.06	5.00	5.08	5.40
Height H (mean)	0.45	0.37	0.32	0.36	0.19	0.26	0.40
Roughness z_0 (cm) (Soulsby 1997)	2.206	1.452	1.603	1.836	0.722	1.331	2.9630
Roughness z_0 (cm) (Van Rijin 1984)	1.271	0.925	0.914	1.038	0.466	0.751	1.349
Roughness z_0 (cm) (Bertholdy et al. 1997)	0.855	0.703	0.608	0.684	0.361	0.494	0.76

The roughness associated with the bedforms ranges **from 0.36 to 2.2 cm**.

Model results- residual currents SHYFEM

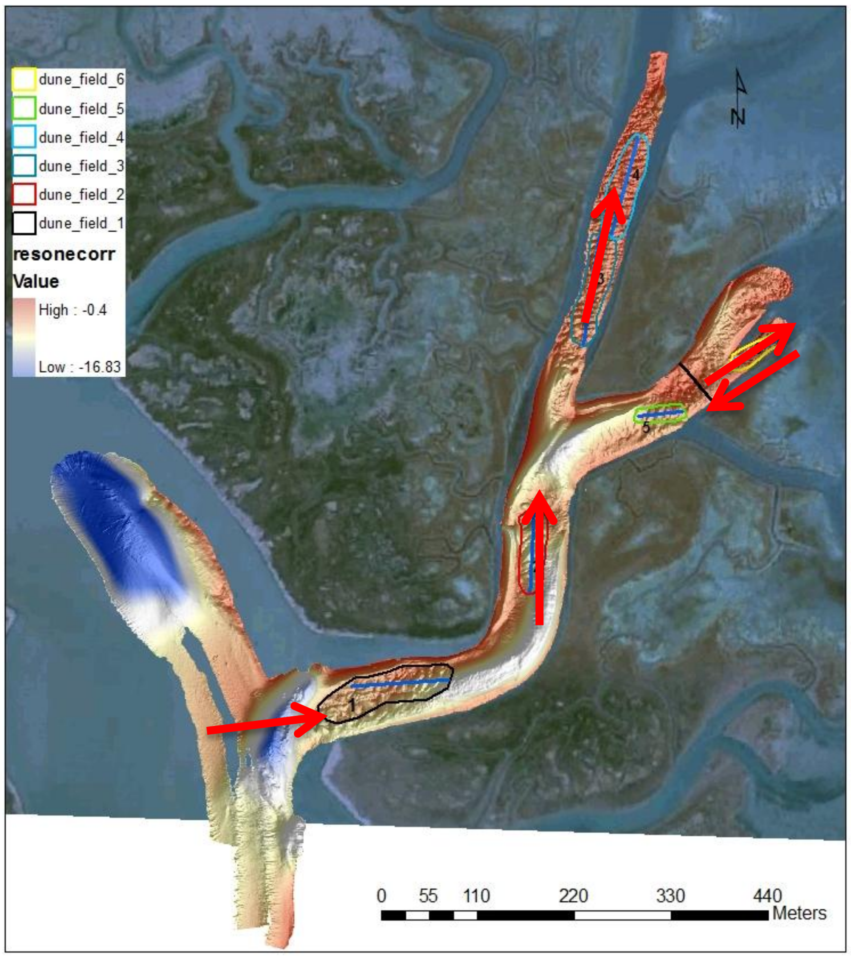


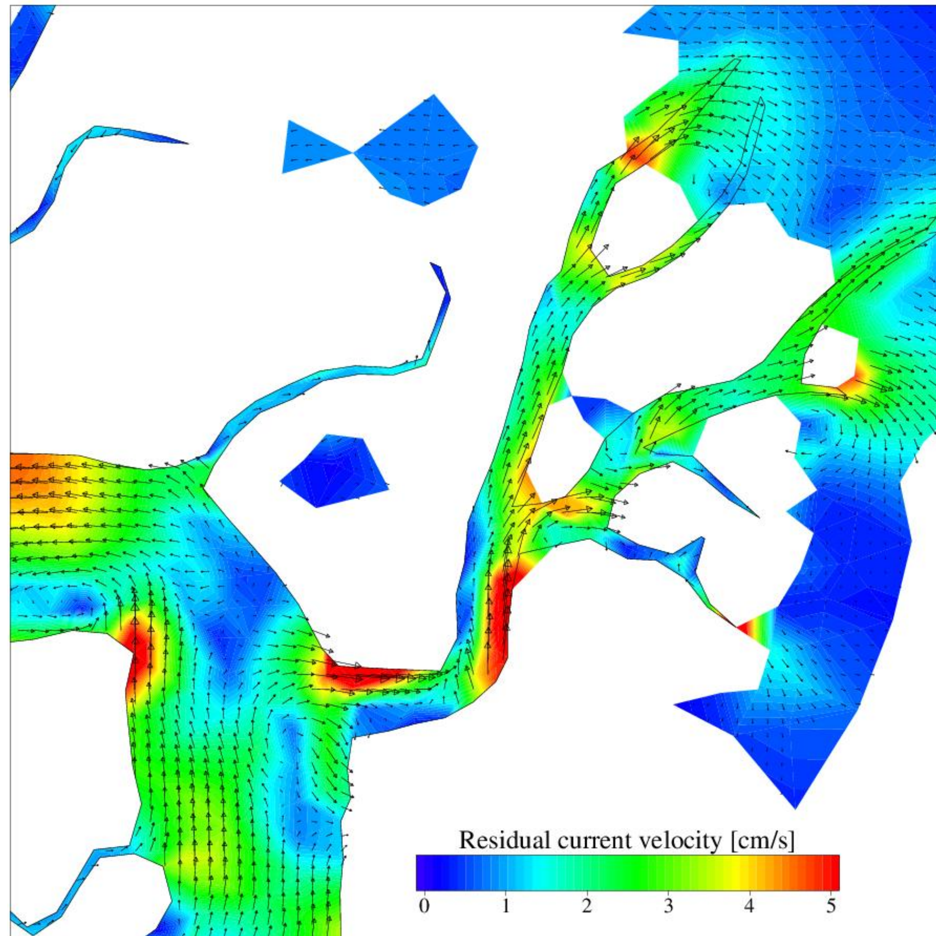
One year-long simulation was carried out forcing the model with real wind and water level data.
The **residual current distribution**, computed averaging model results over the whole investigated period, displayed a circulation pattern with **inflow** into the Scanello channel system. The residual currents, which highlight the influence of the wind and tides as non-linear and topographic induced effects, give the net water movement and they determine the predominant spreading of a dissolved or particulate substance inside the lagoon.

www.ismar.cnr.it/shyfem

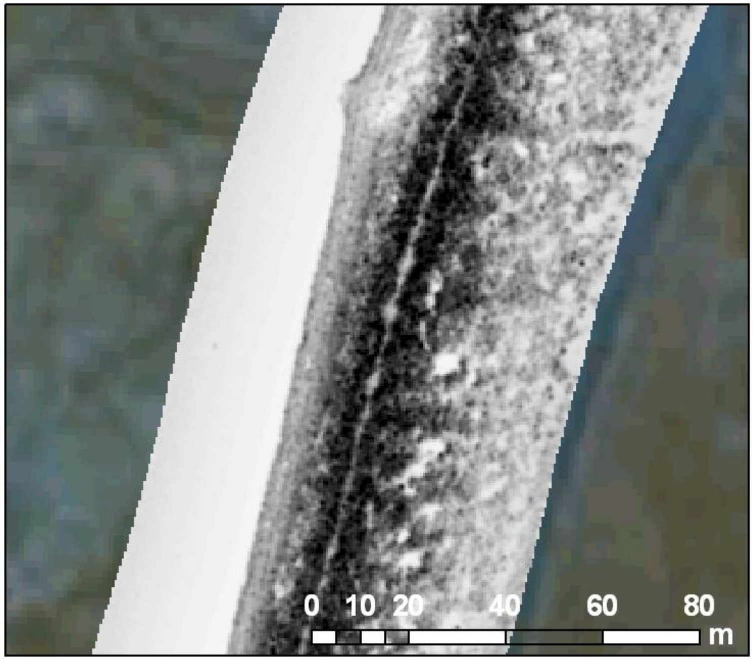
Model results- residual currents:

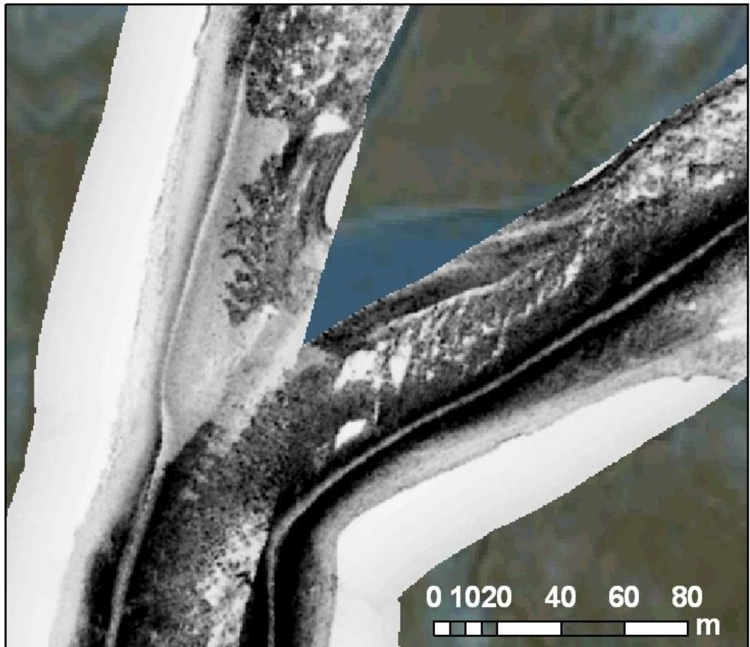
The bed-form orientation generally follows the direction of the residual currents.



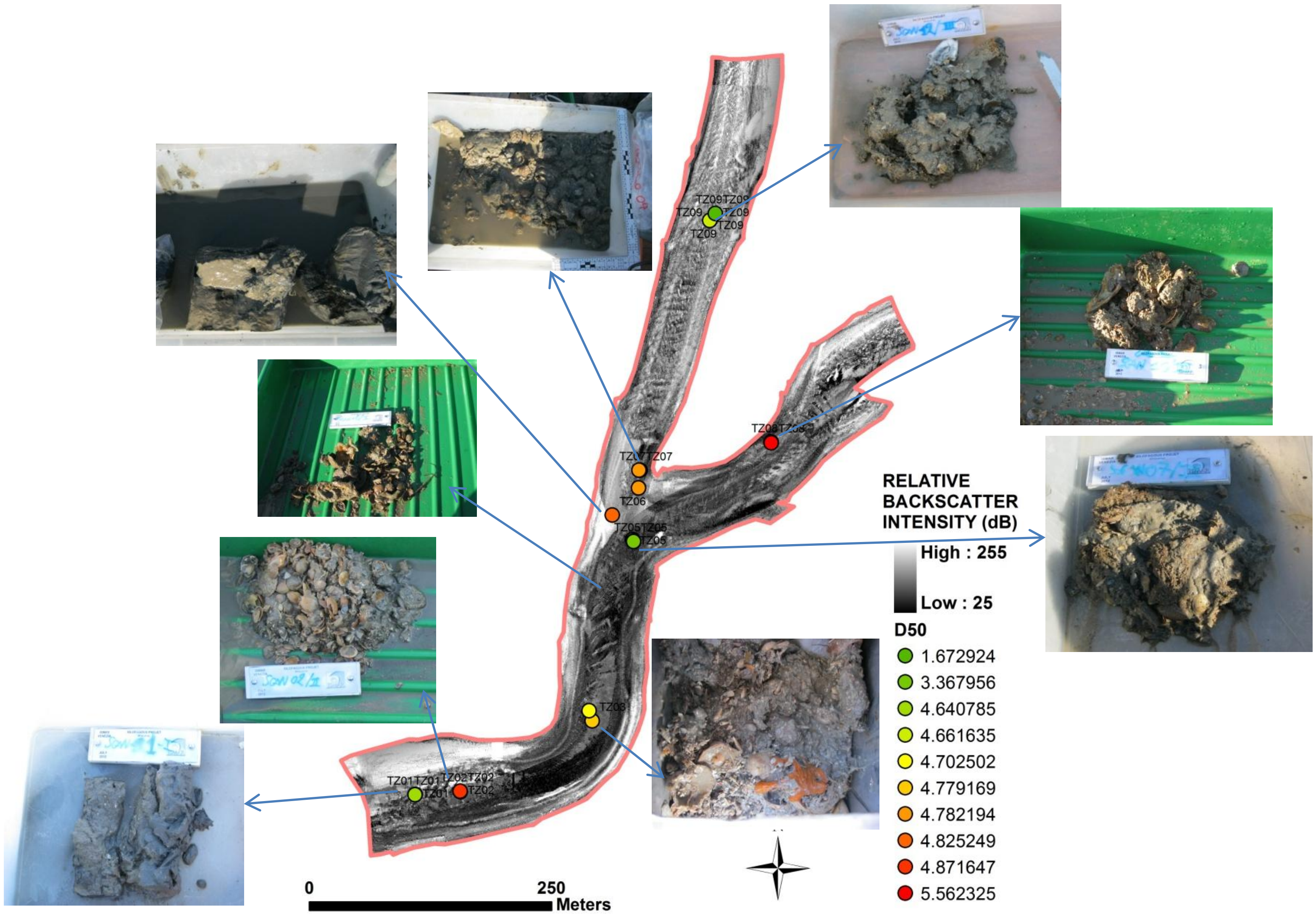


Backscatter data





Backscatter intensity and sediment sampling



Backscatter intensity and sediment sampling

The **grain roughness** z_0 = d_{50} /12

(Engelund and Hansen, 1967)

ranges from

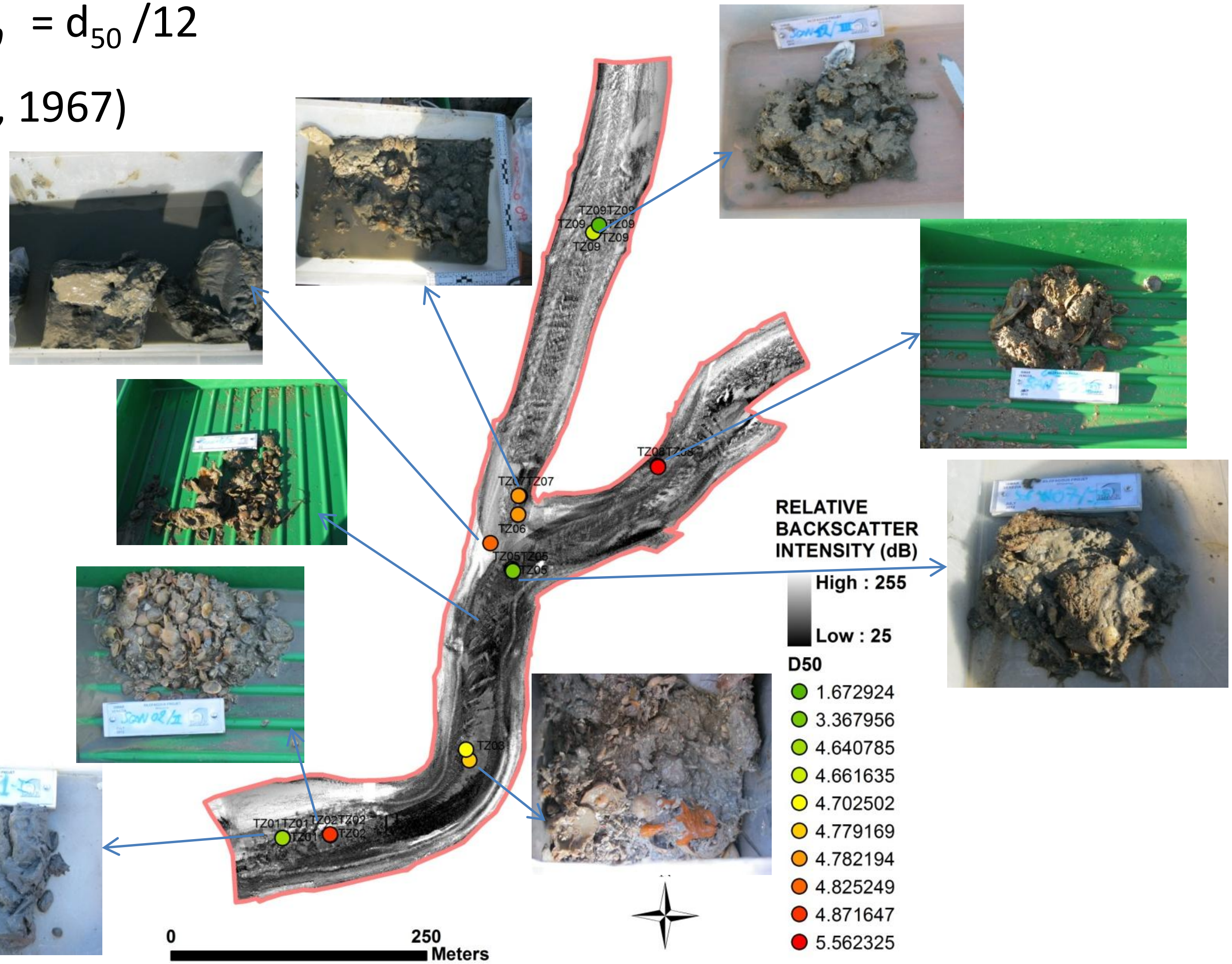
0.003 to 0.026 mm

(2 order of magnitude

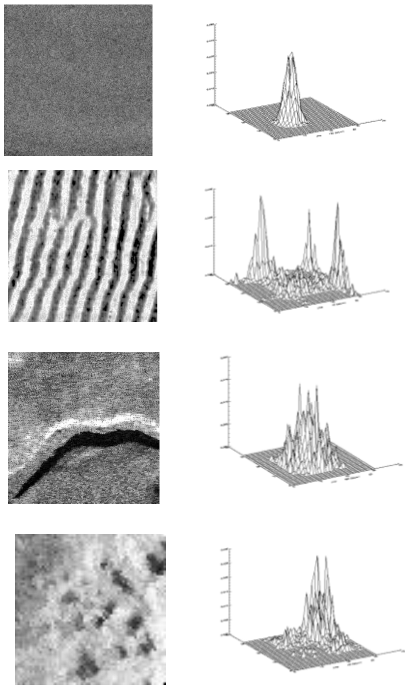
smaller than

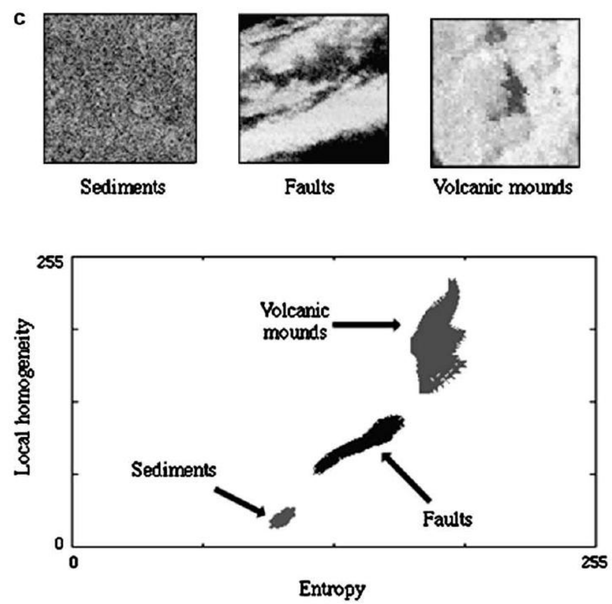
the bedform

roughness)



Backscatter intensity sediment classification by TexAN Software by ***Philippe Blondel***





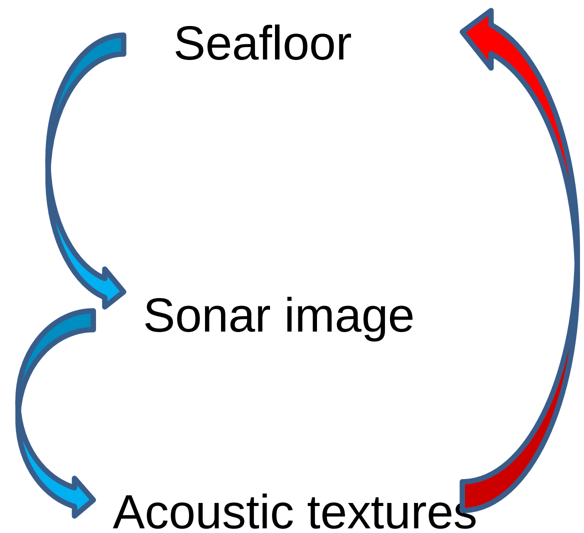
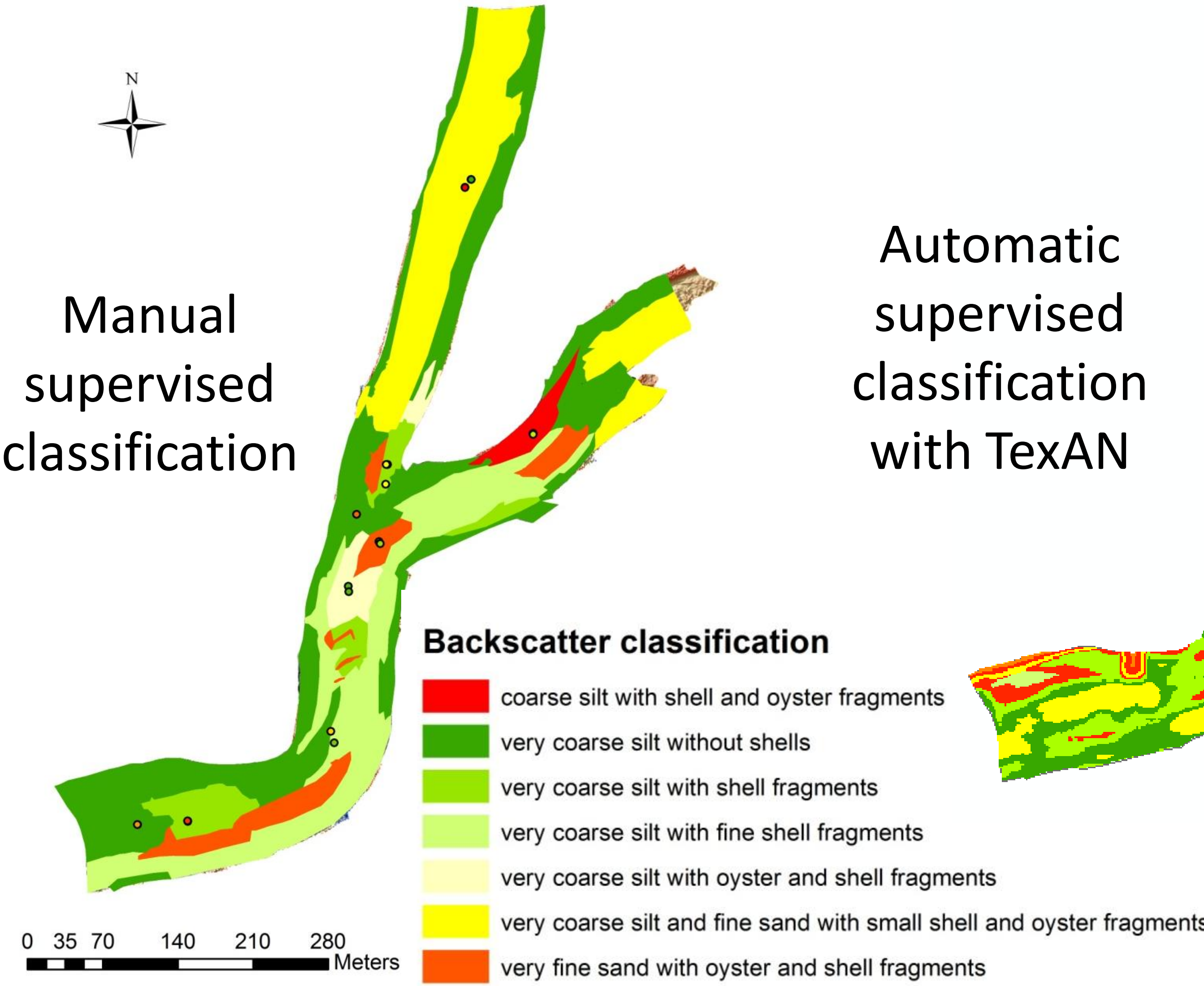


Image GLCMs Textual descriptors Classification

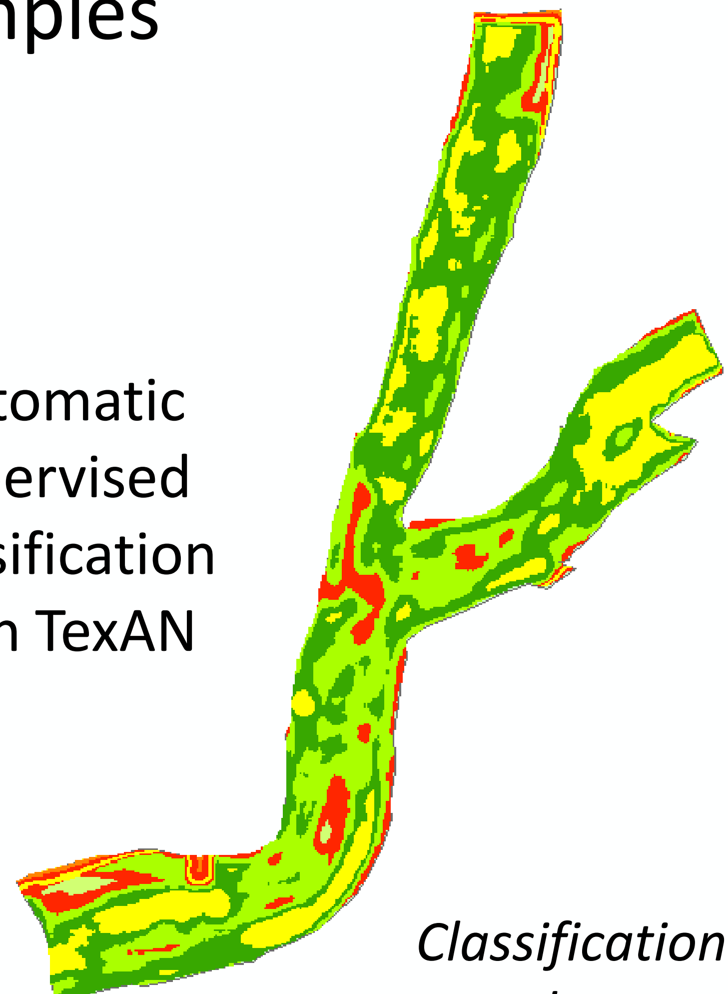
- Acoustic images of the seafloor will show variations in grey levels.
- Some of the more subtle variations can only be detected numerically (using second-order statistics) Grey-Level Co-occurrence Matrices (GLCMS) calculate the number of times particular grey-levels occur together.
- GLCMs can be described with statistical parameters (e.g. entropy, homogeneity).
- These parameters describe the textures. From these, one can (hopefully) characterise the type of seafloor.

Sediment classification with TexAN analysis and sediment samples

Manual supervised classification



Automatic supervised classification with TexAN



Classification by Philippe Blondel

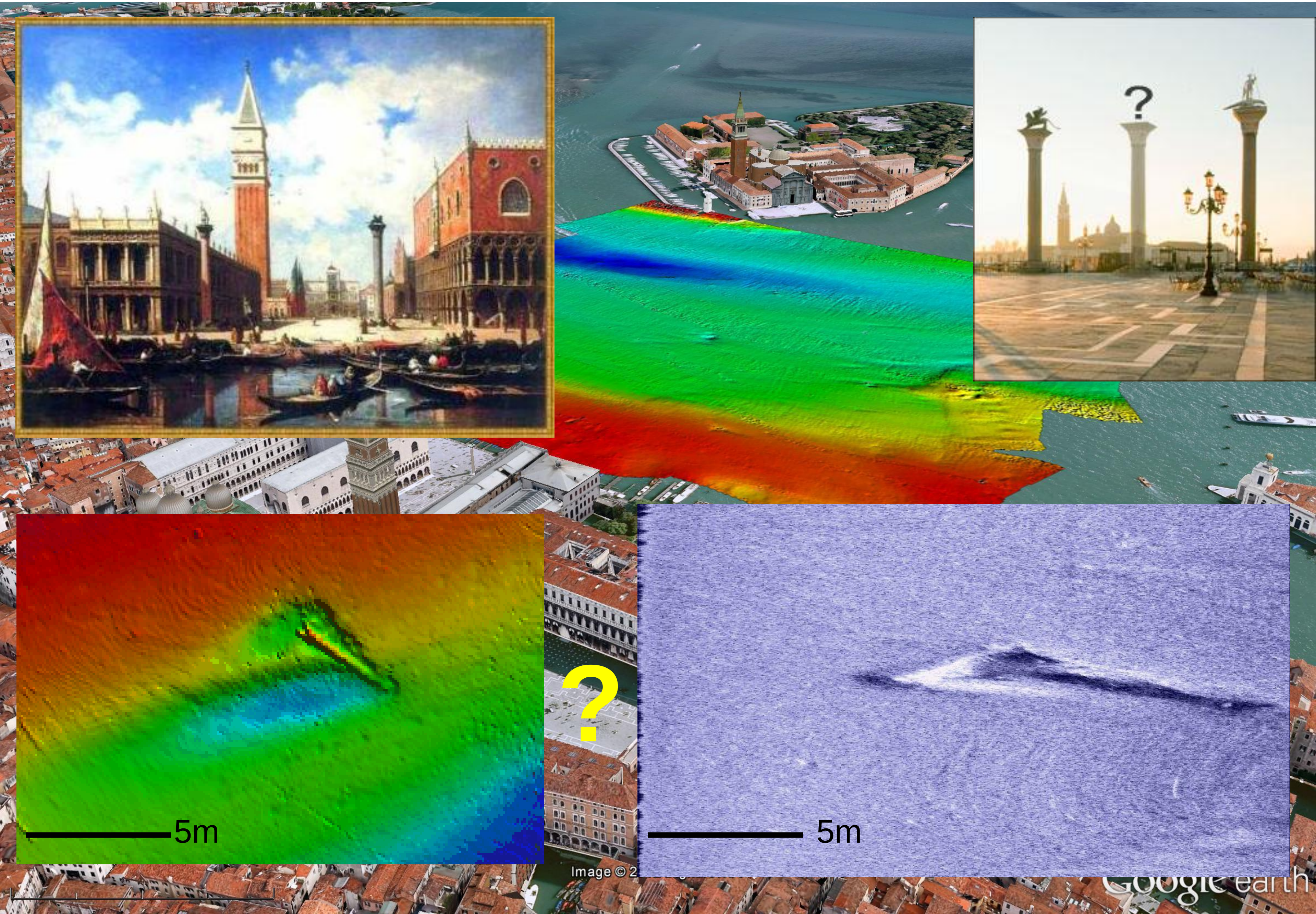
Conclusions

- ISMAR has a new TEAM able to collect and processes High resolution bathymetric data
- Snapshot of the lagoon morphology to assess the long term changes induced by engineering works and ship traffic
- Starting from bathymetry we carried out a multidisciplinary experiment in order to:

1. Develop a methodology to quantitatively describe the lagoon geomorphology for future comparisons
2. Compare the hydrodynamic model with high resolution bathymetry
3. Develop a methodology to automate bottom sediment classification for habitat mapping


THANKS FOR YOUR ATTENTION
QUESTIONS?
LITUS

SAN MARCO SQUARE - The Third Column legend or reality?



SAN MARCO SQUARE - The Third Column legend or reality?