

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

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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 km²

-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: .

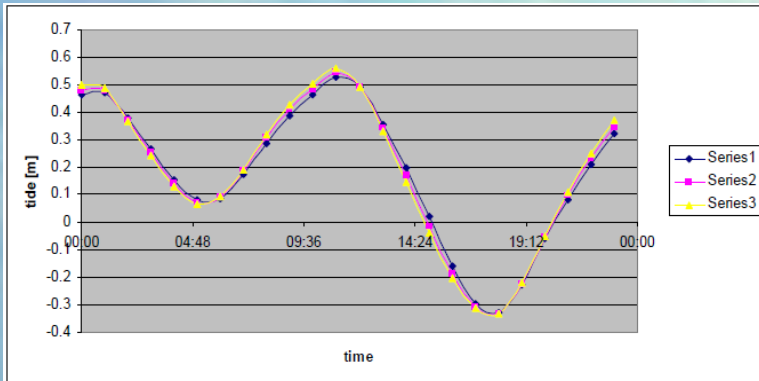
- Transitional environments undergo strong natural and human induced action.
- The changes can be assessed by repeated bathymetric surveys
- Extremely shallow environments are a challenge for acoustic bathymetric surveys

BATHYMETRY IS ONE OF THE MAIN FACTOR IN MULTIDISCIPLINARY STUDIES

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

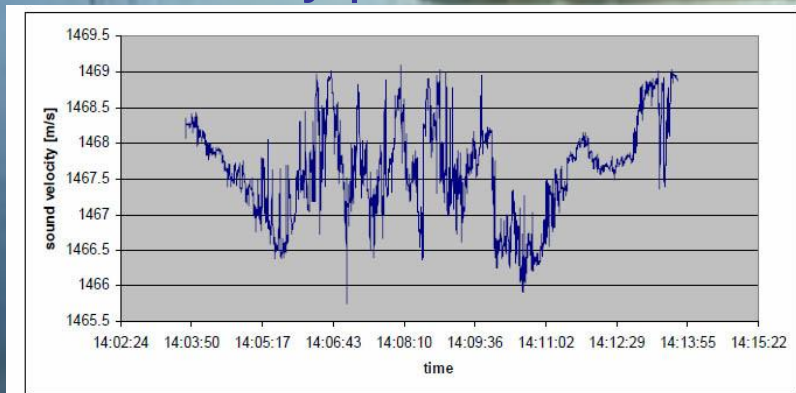
THE CHALLENGE OF BATHYMETRY IN THE LAGOON OF VENICE

- 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



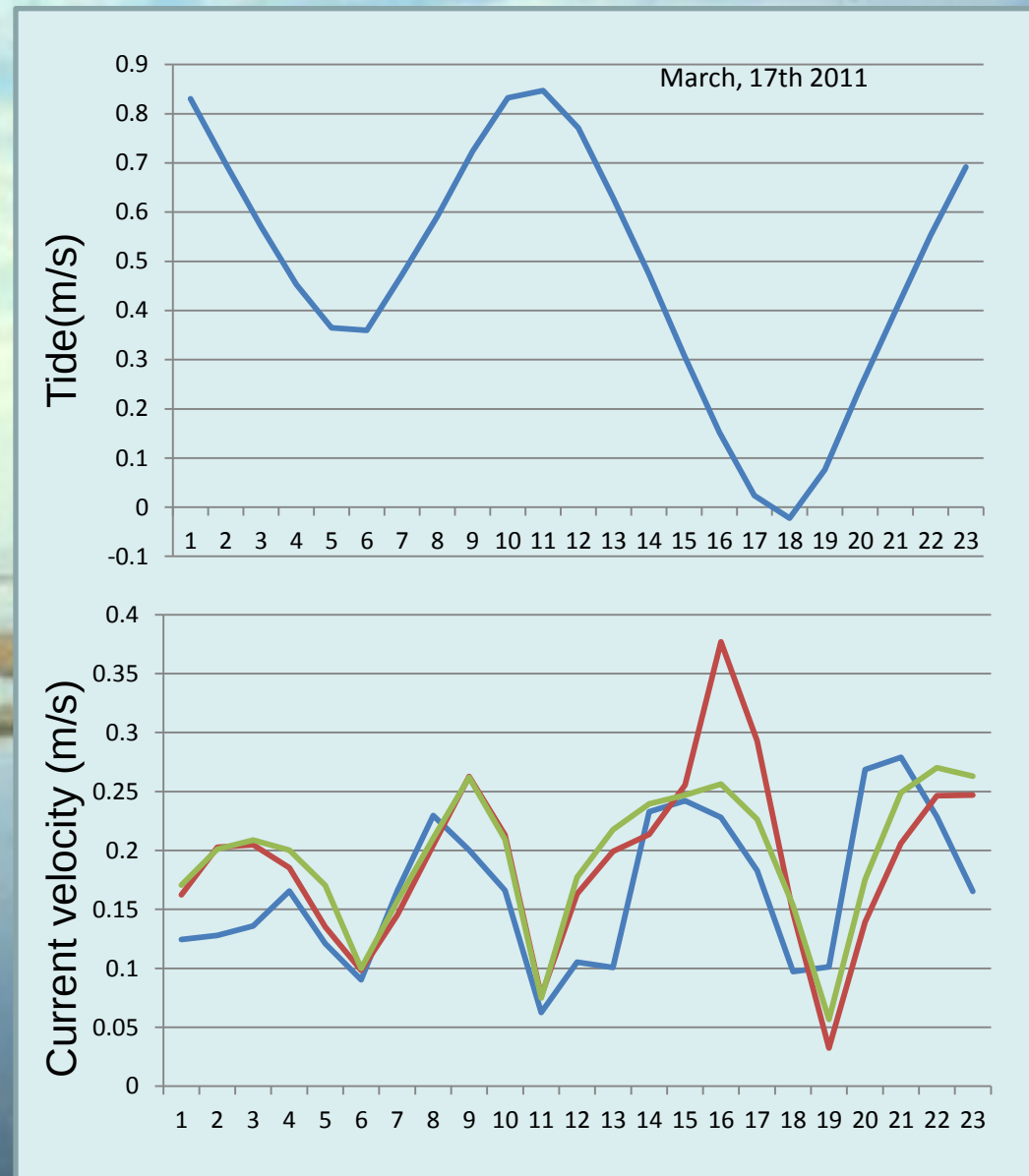
From Dese to Torcello svp vs space

THE CHALLENGE OF BATHYMETRY IN THE LAGOON OF VENICE

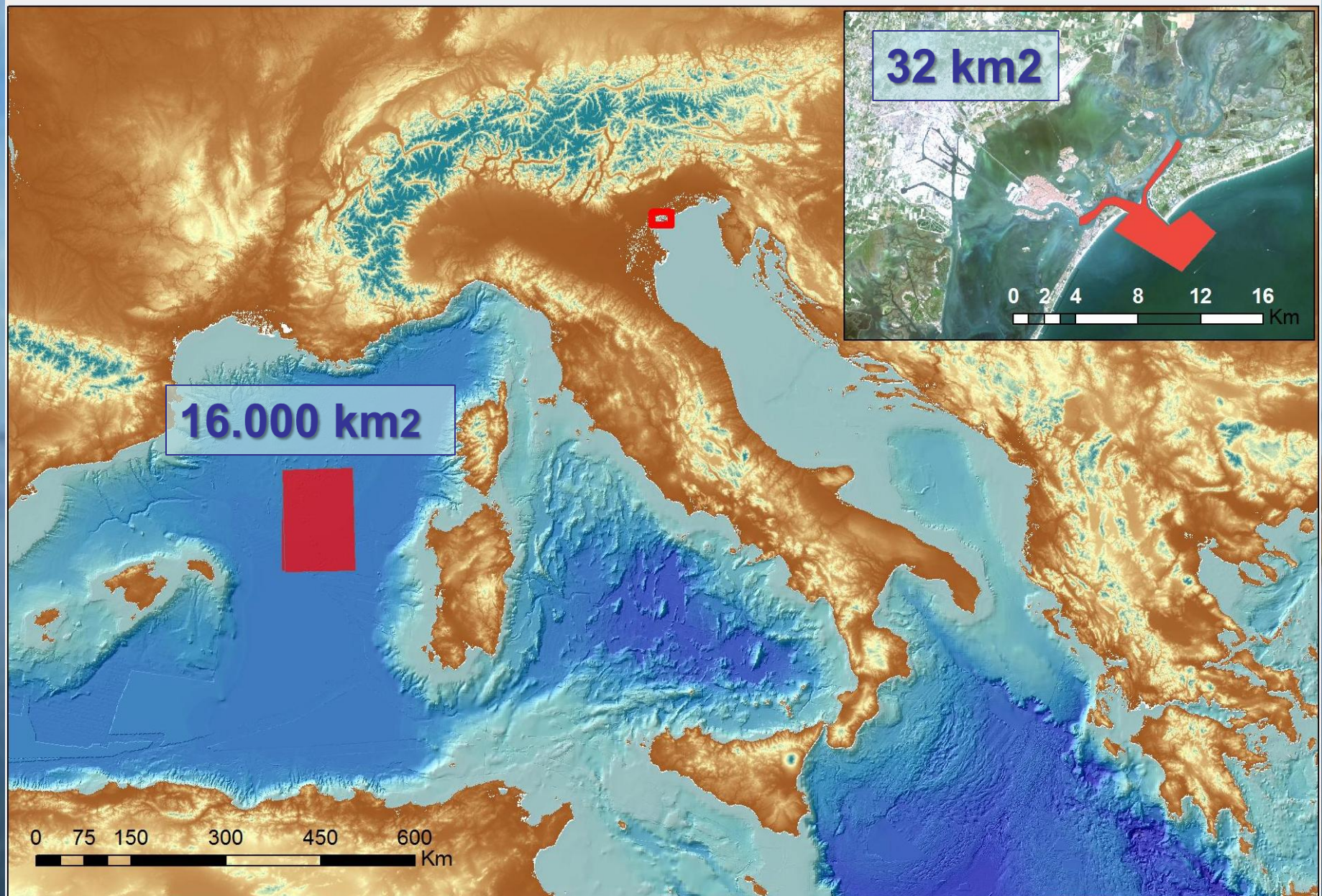
Current and tide data from the hydrodynamic model of the Venice Lagoon in the day of the survey

(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

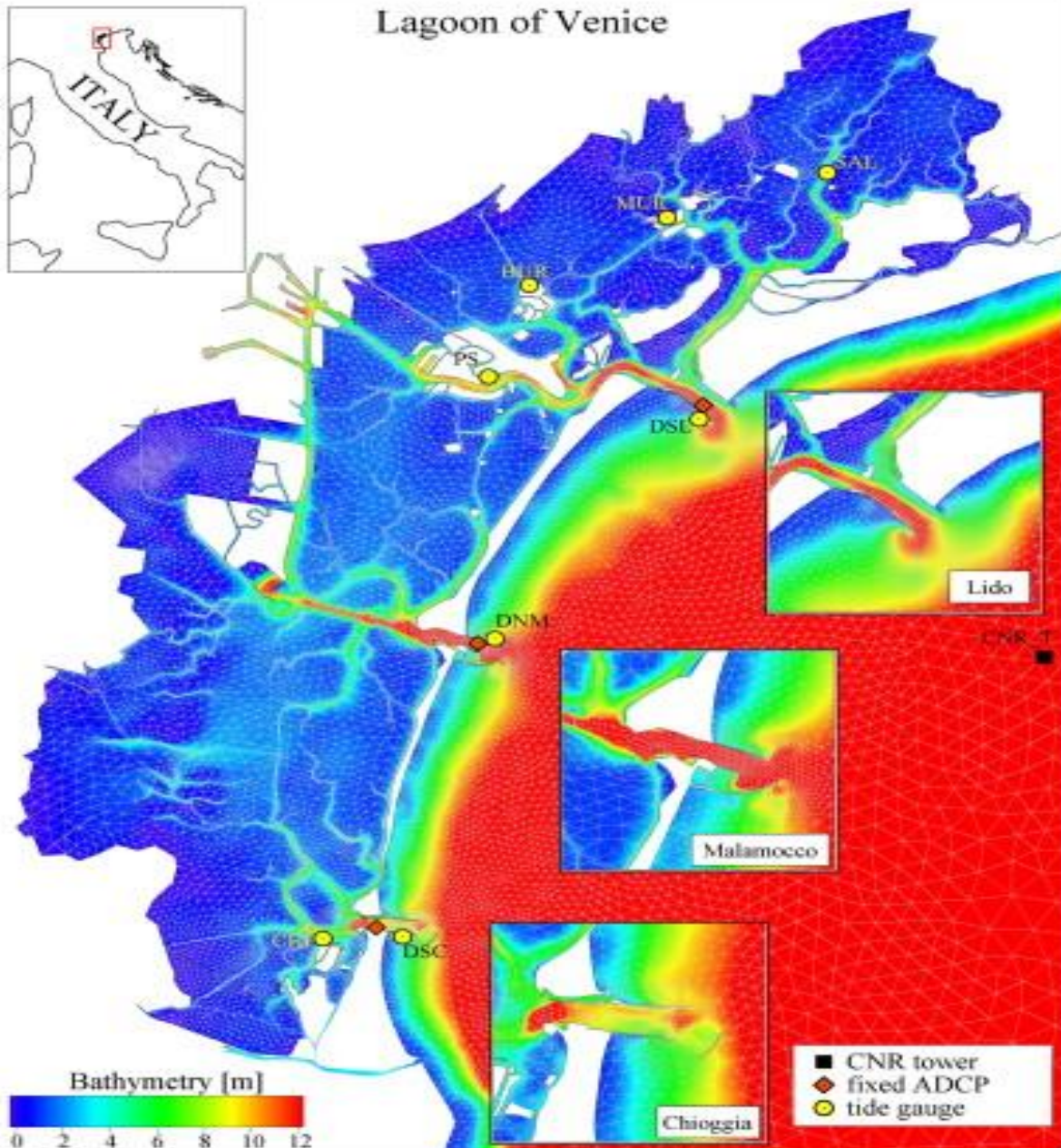
METHODOLOGY

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



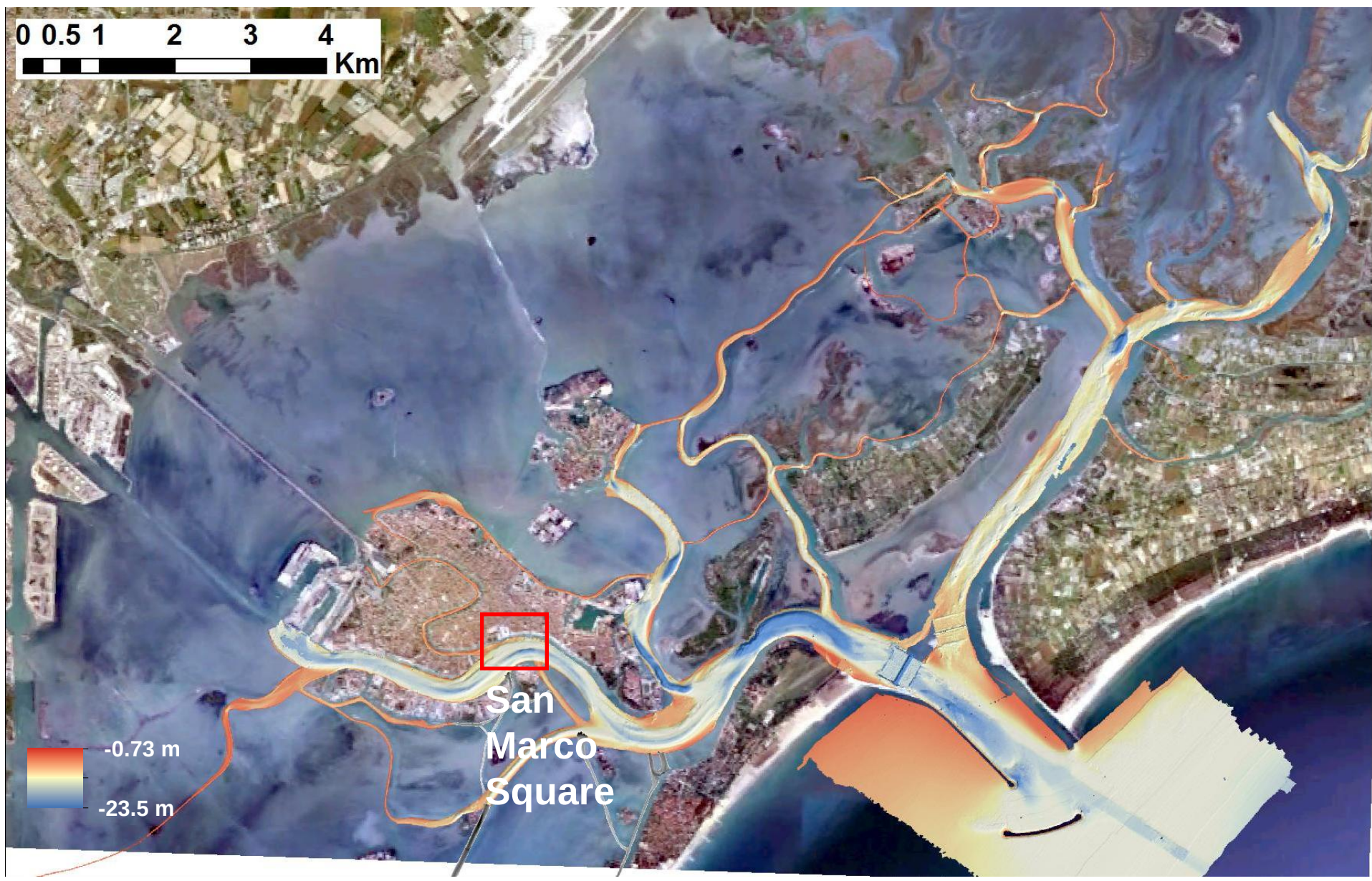
Multibeam System Kongsberg EM 2040D-C

Positioning system Kongsberg Seapath 300

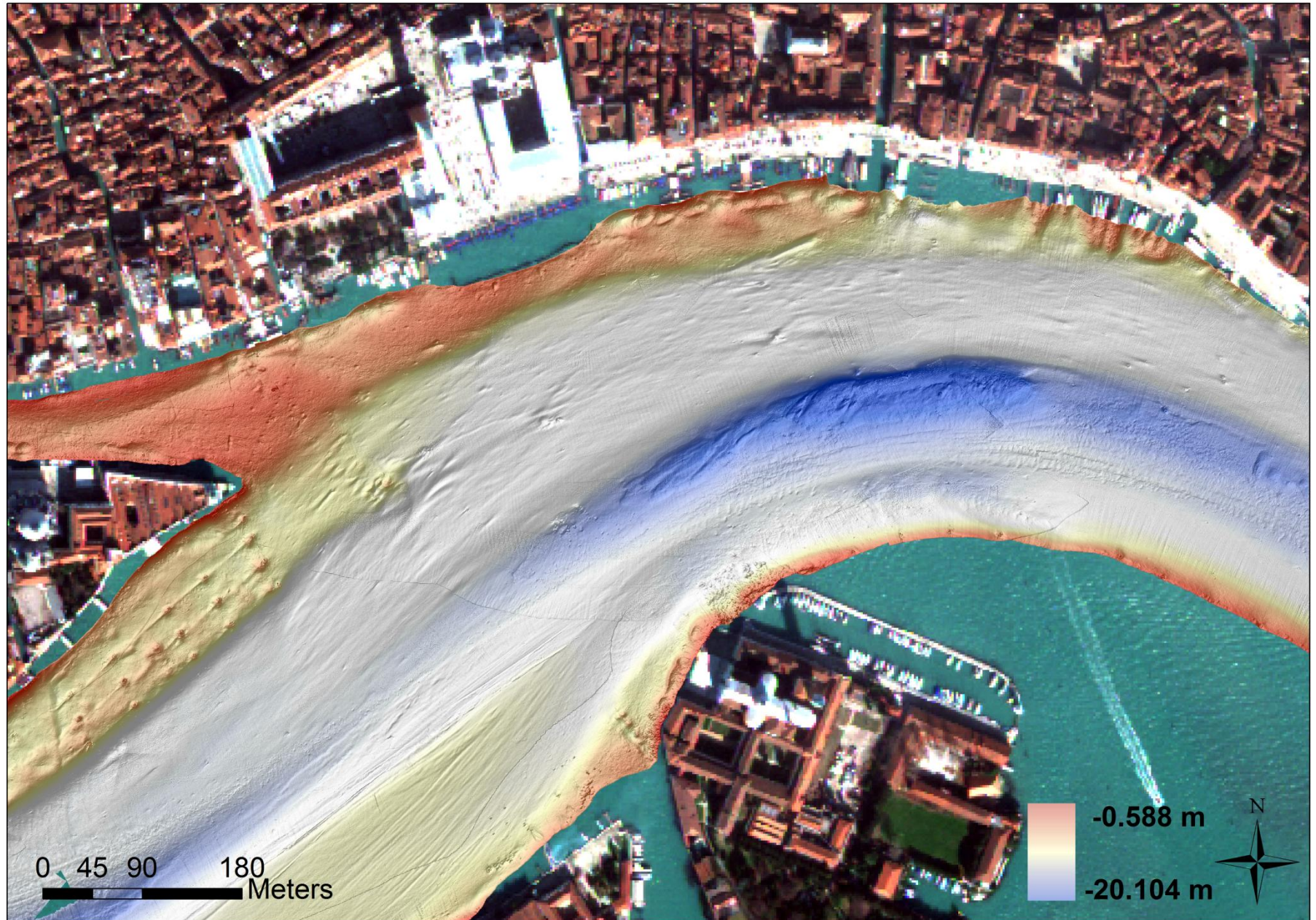
Motion sensor Kongsberg Seatex MRU 5

Valeport Mini SVS and AML Ocenographic SV Profiler

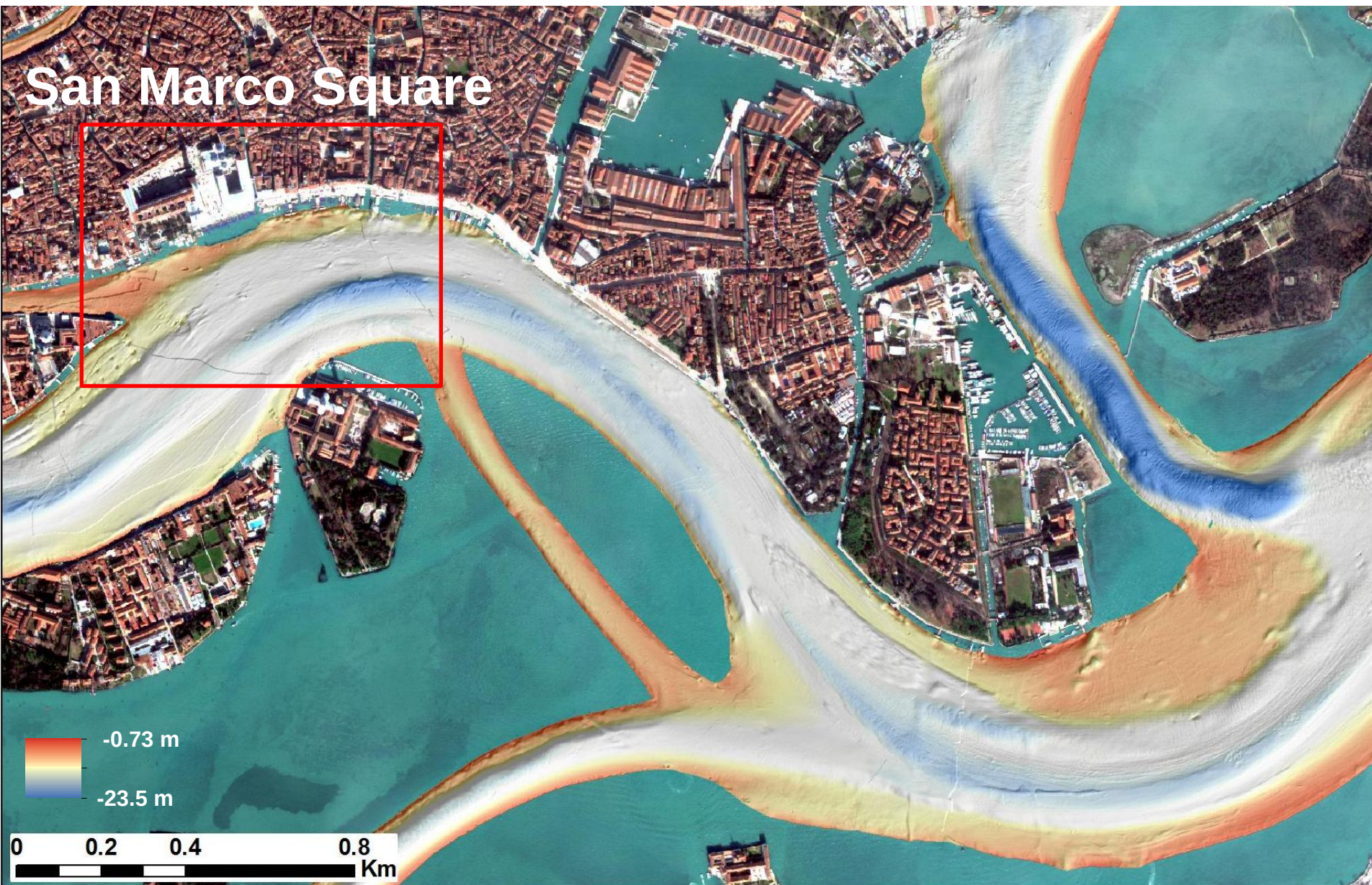
SURVEY AREAS – THE CITY OF VENICE



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



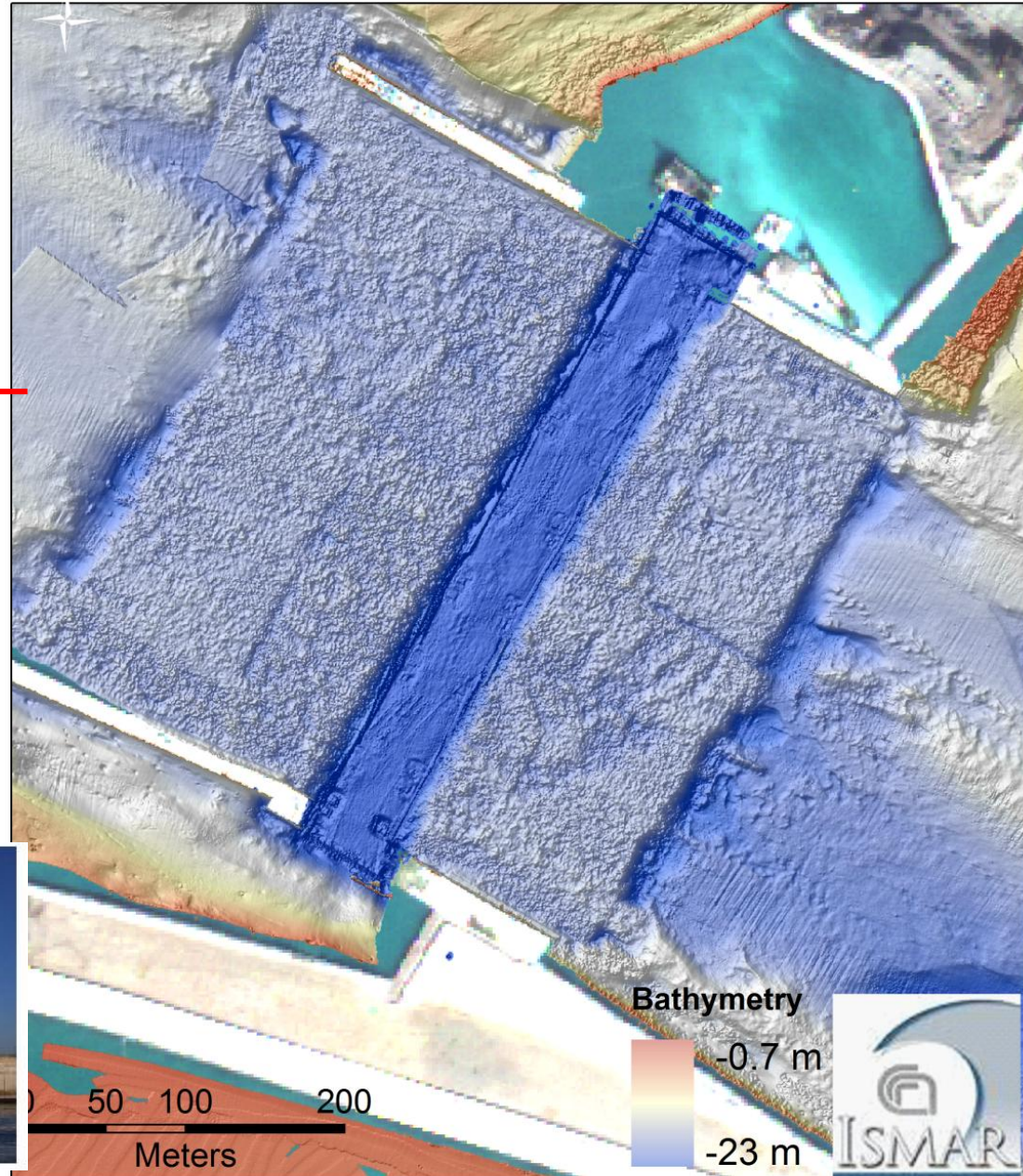
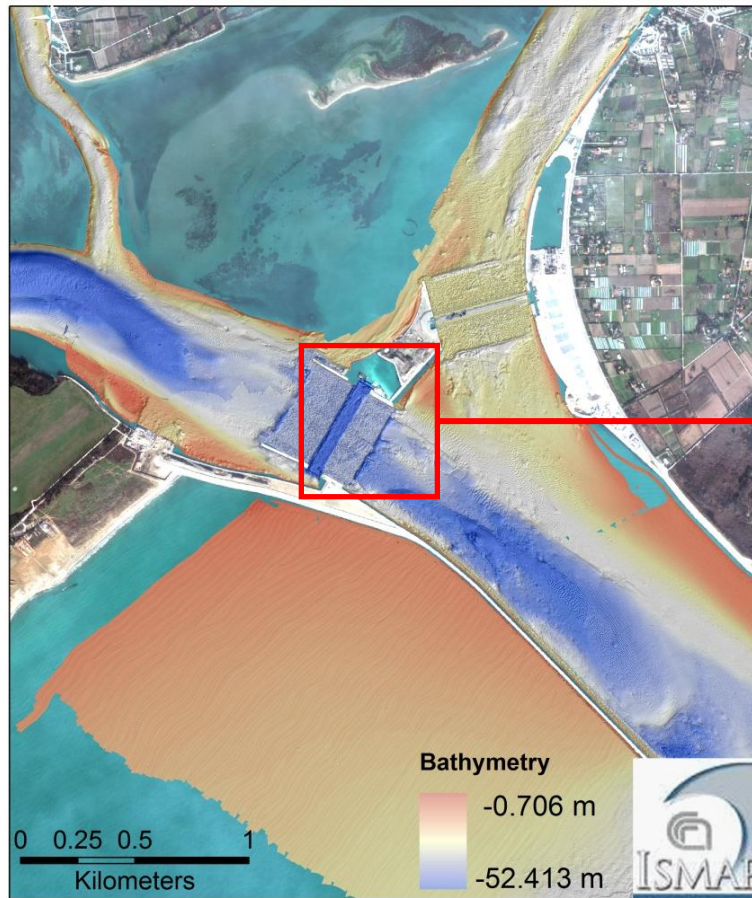
0 0.2 0.4 0.8 Km

SURVEY AREAS - DIFFERENT ENVIRONMENTS

MOSE CONSTRUCTION



MOSE CONSTRUCTION SITE

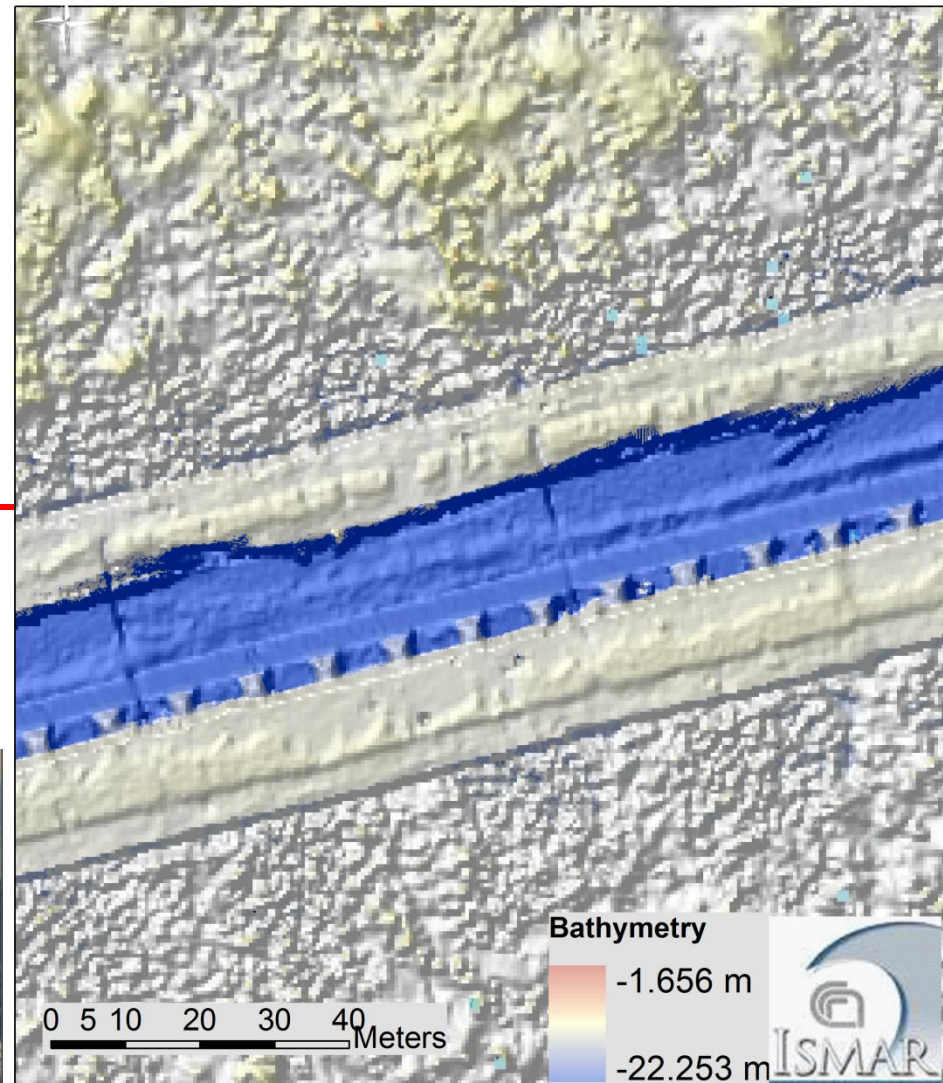


Resolution
0.5 M

V.E. 5X

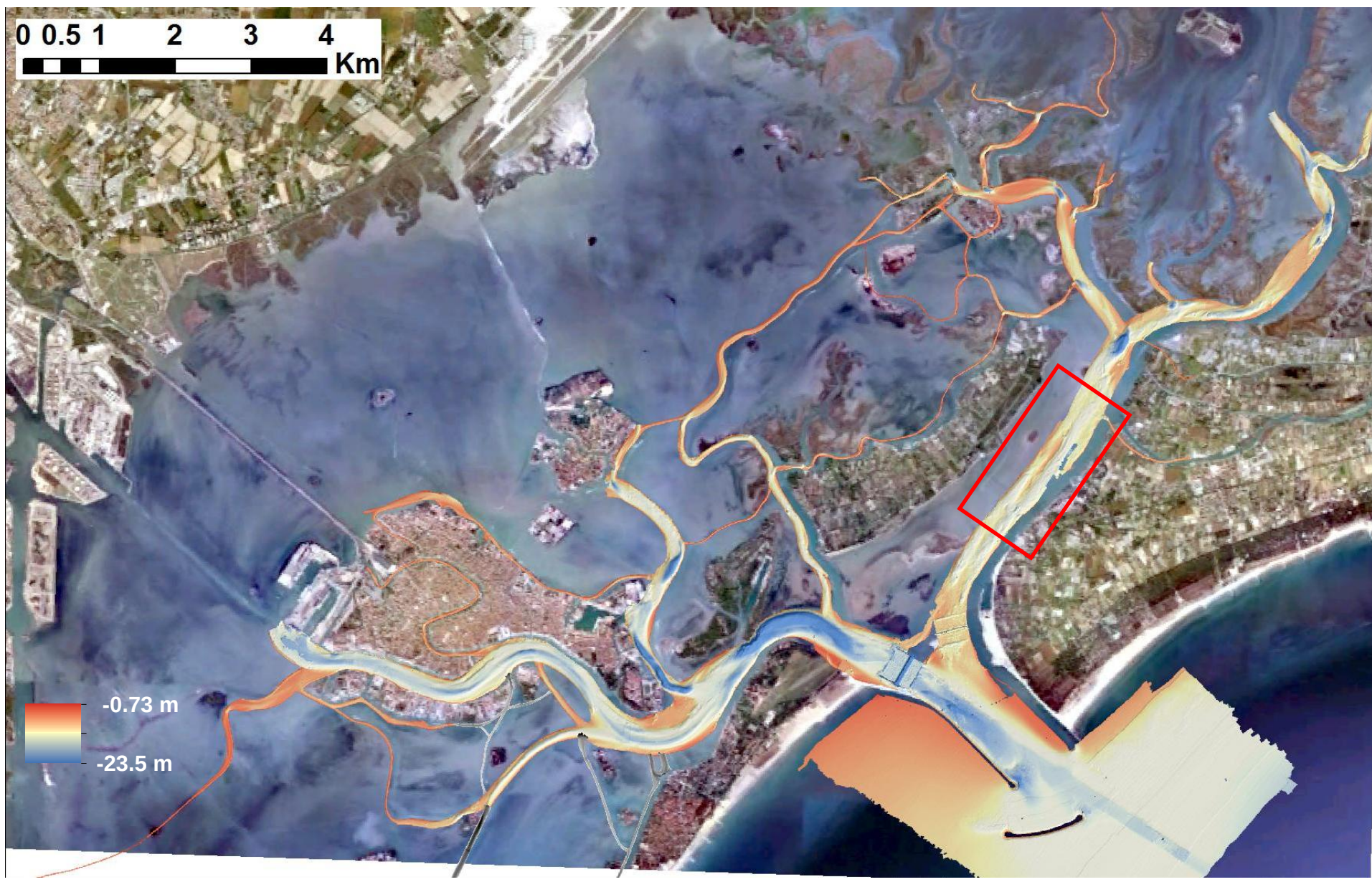


MOSE CONSTRUCTION SITE

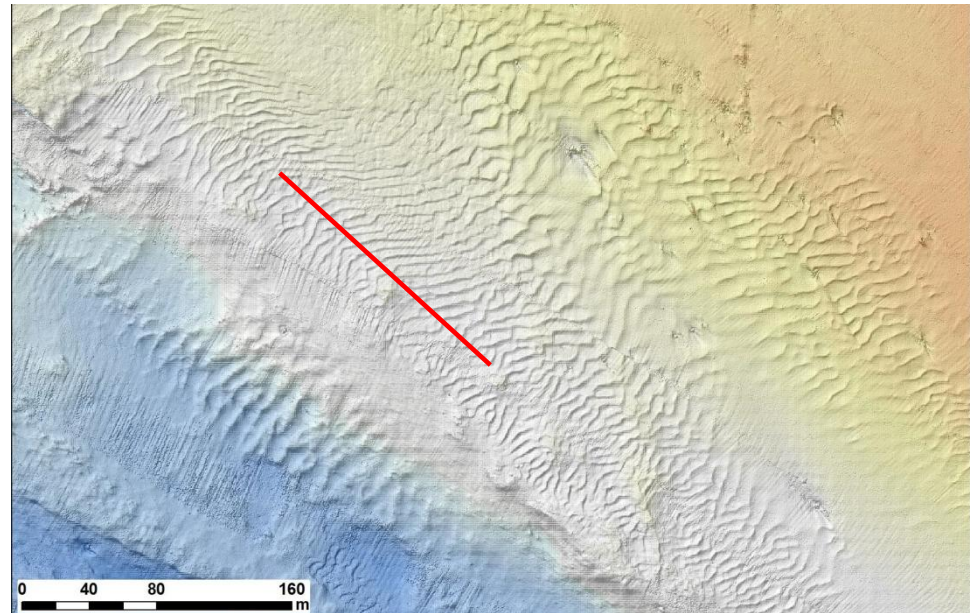
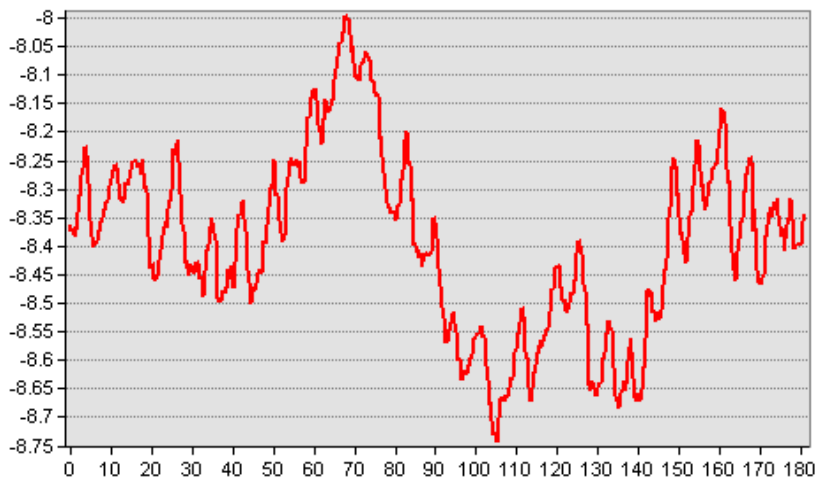
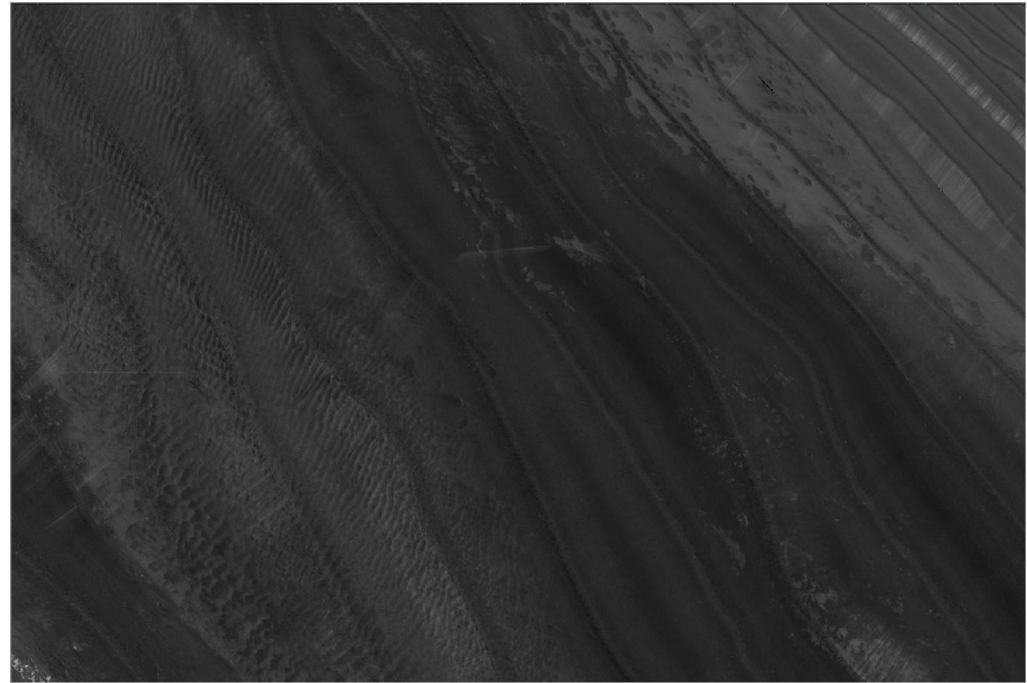
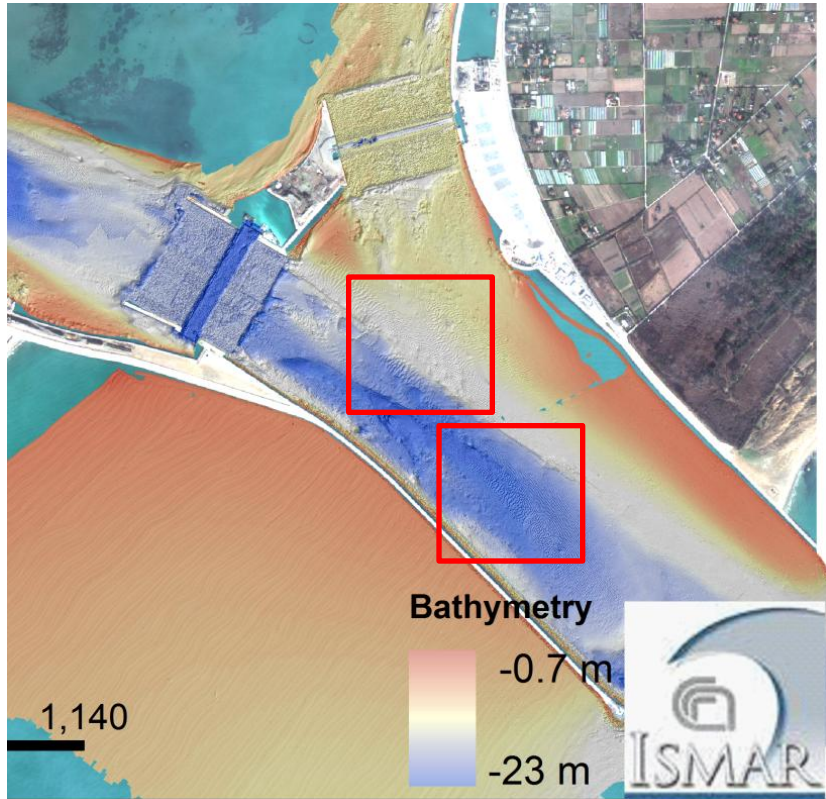


SURVEY AREAS - DIFFERENT ENVIRONMENTS

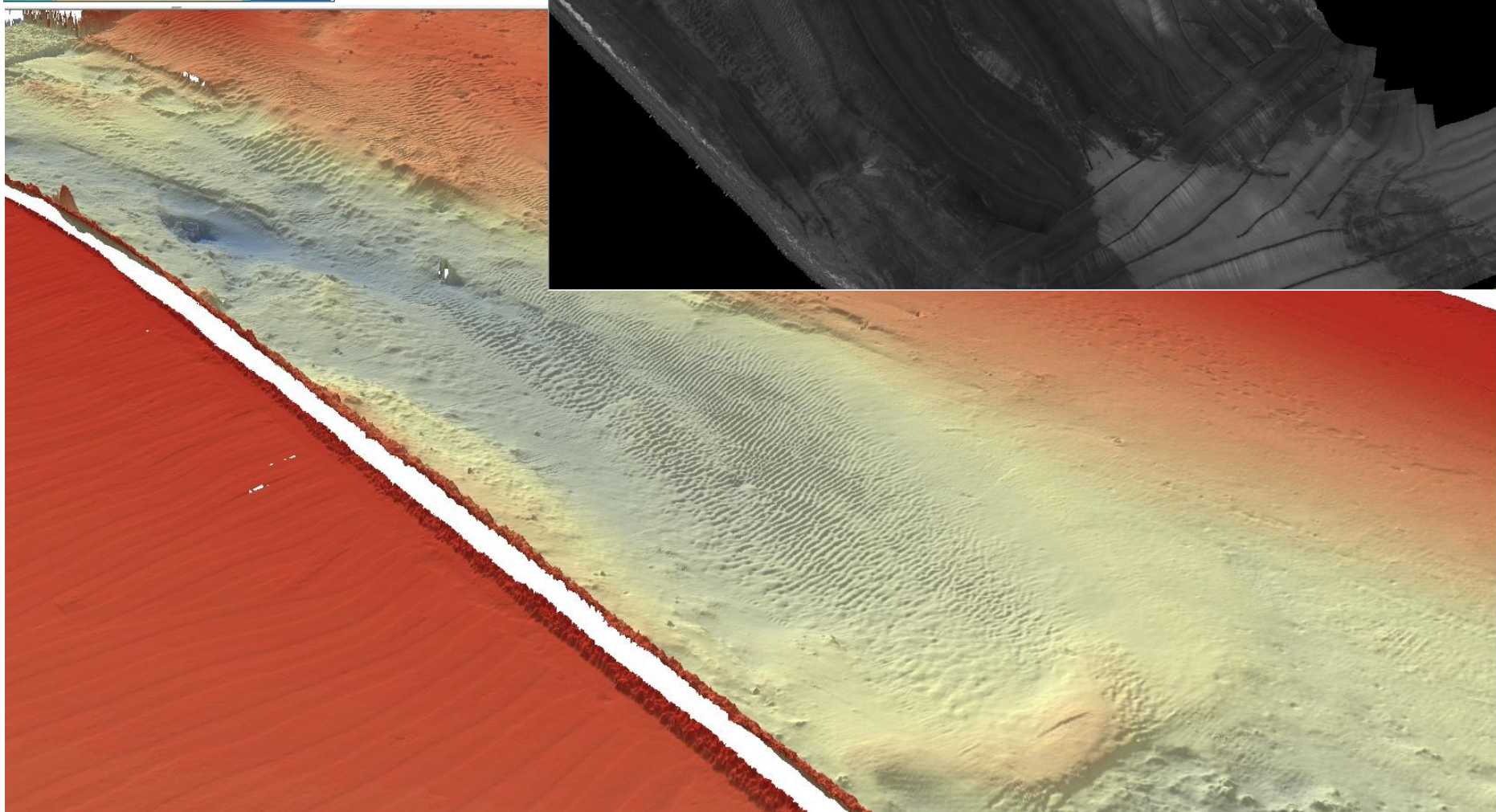
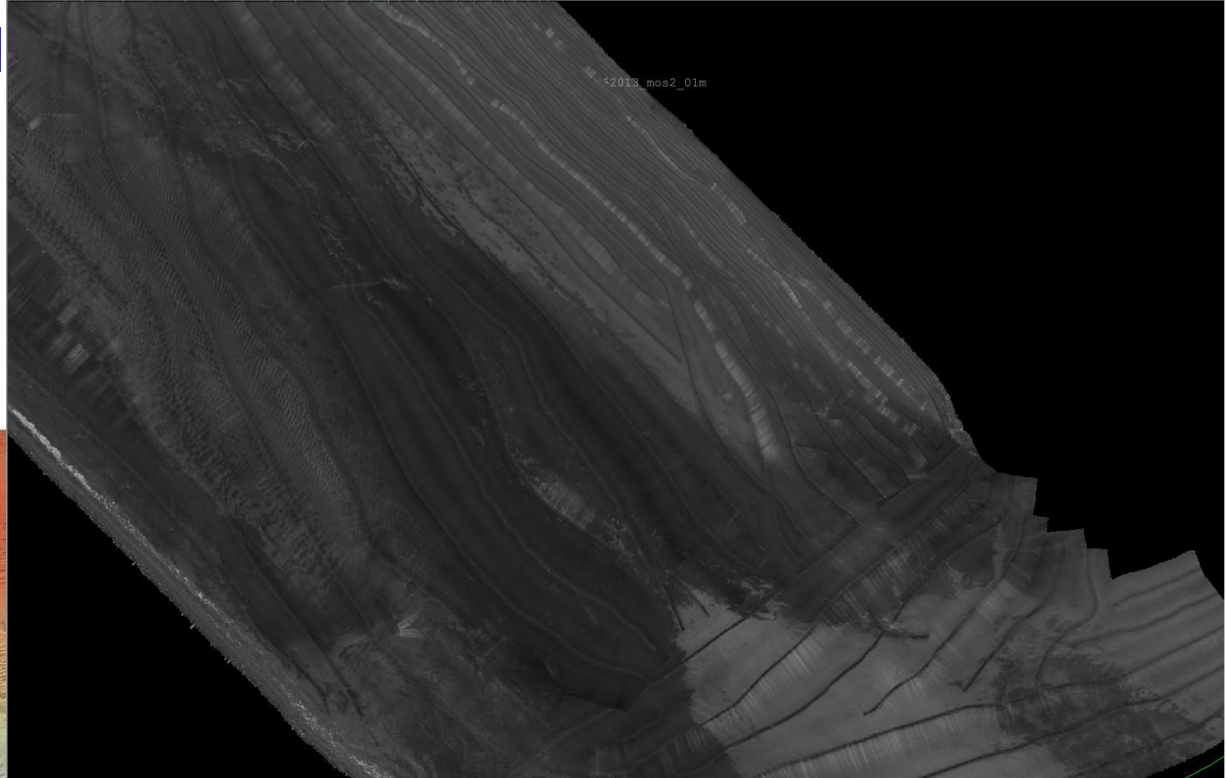
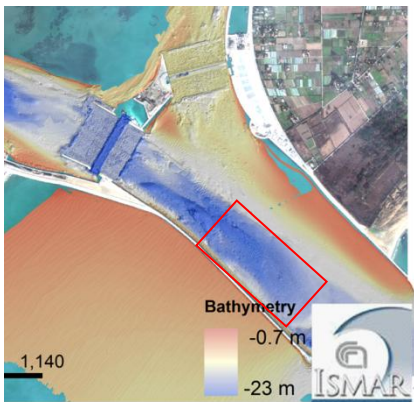
TRE PORTI CHANNEL



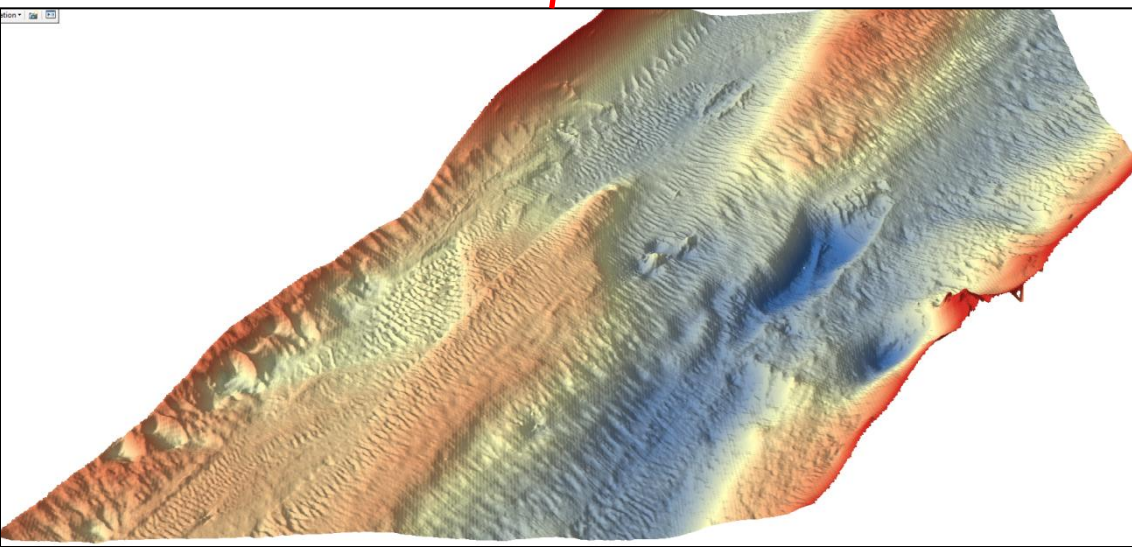
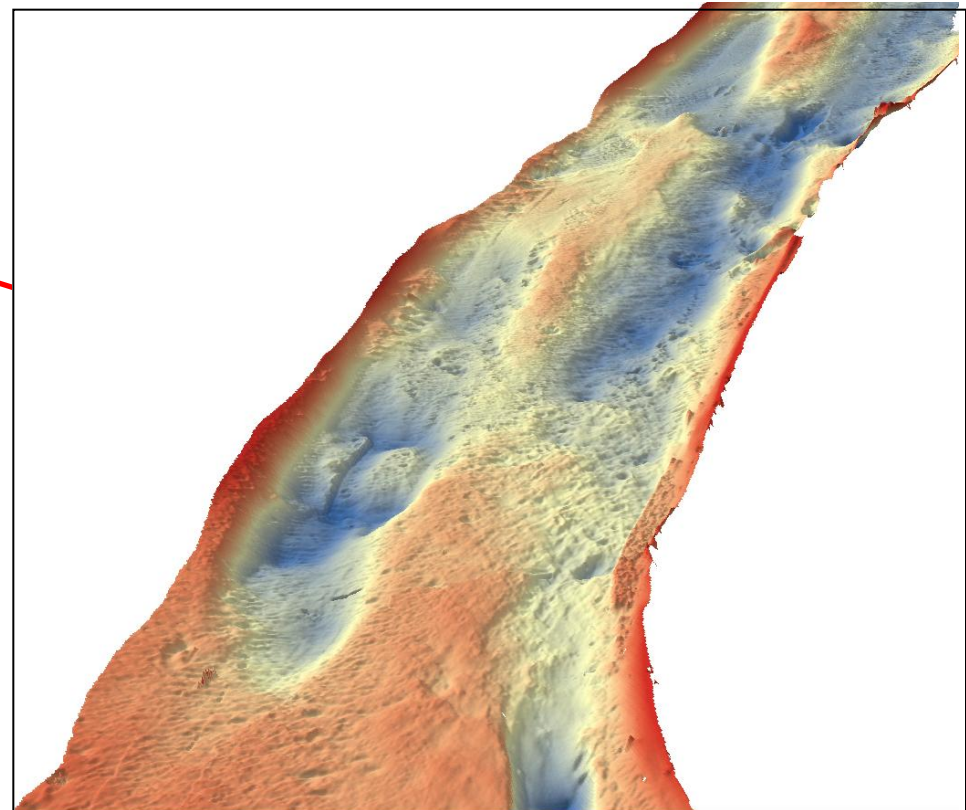
LIDO INLET



LI



Treporti channel

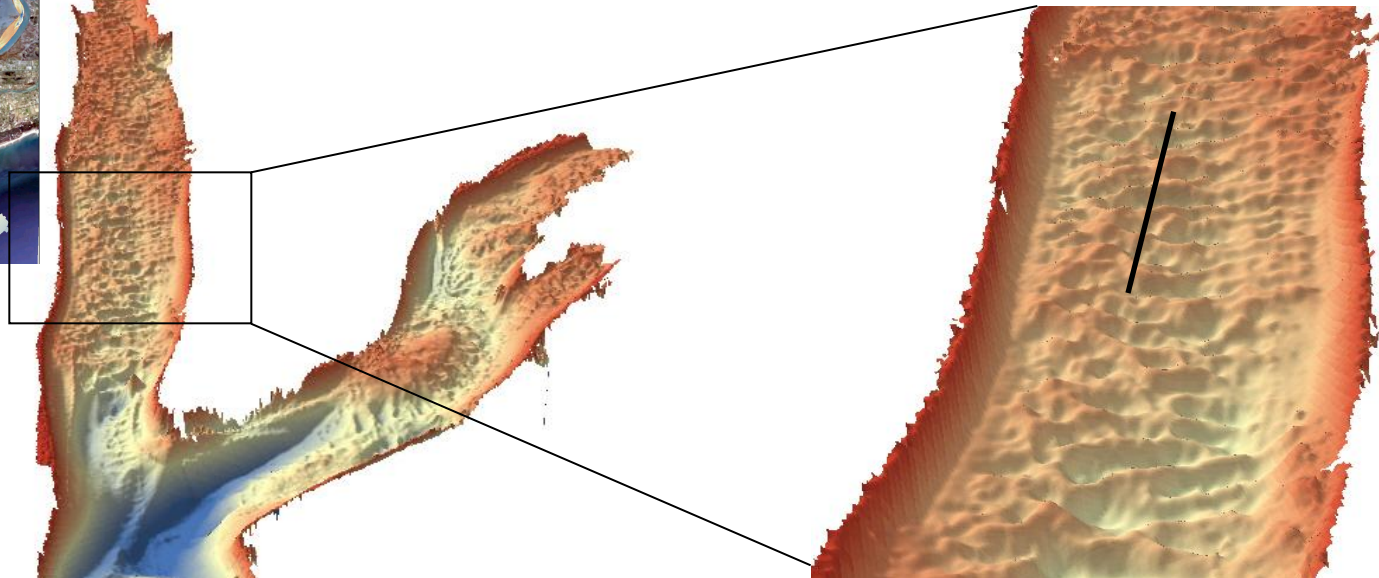


DTM 0.2 m
v.E 5 x

RESULTS: SURVEY AREAS DIFFERENT ENVIRONMENTS



Scanello channel



DTM 0.5m

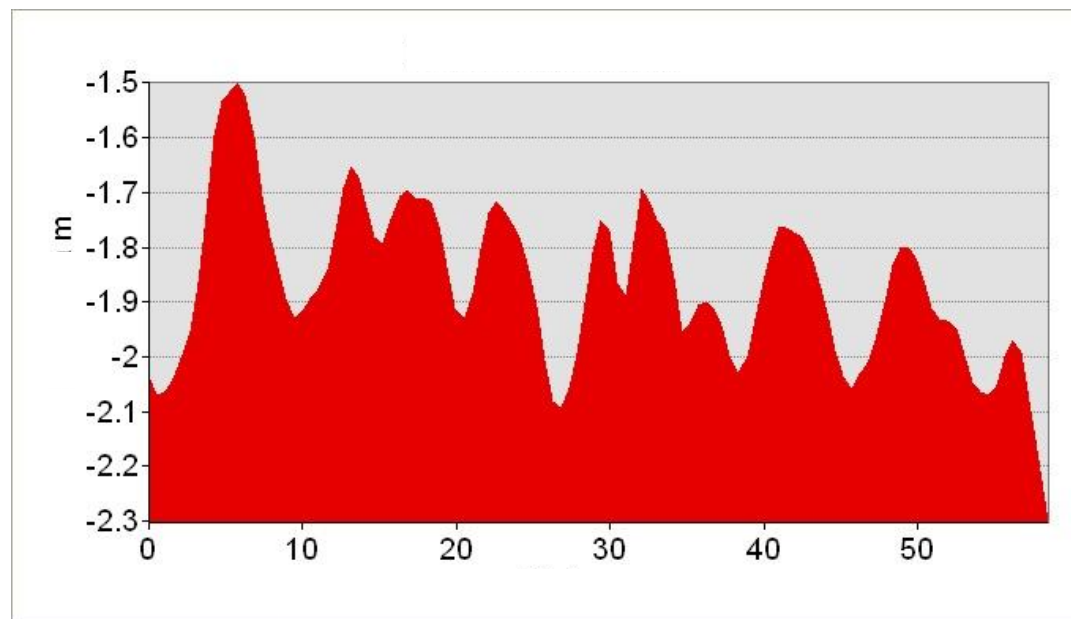
V.E = 5

m

-0.17

-15.39

60m

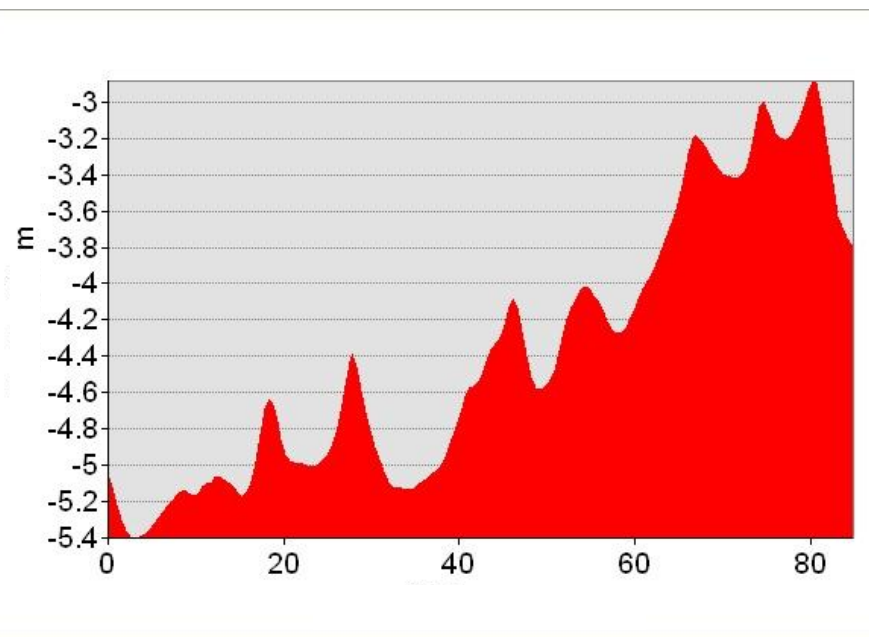
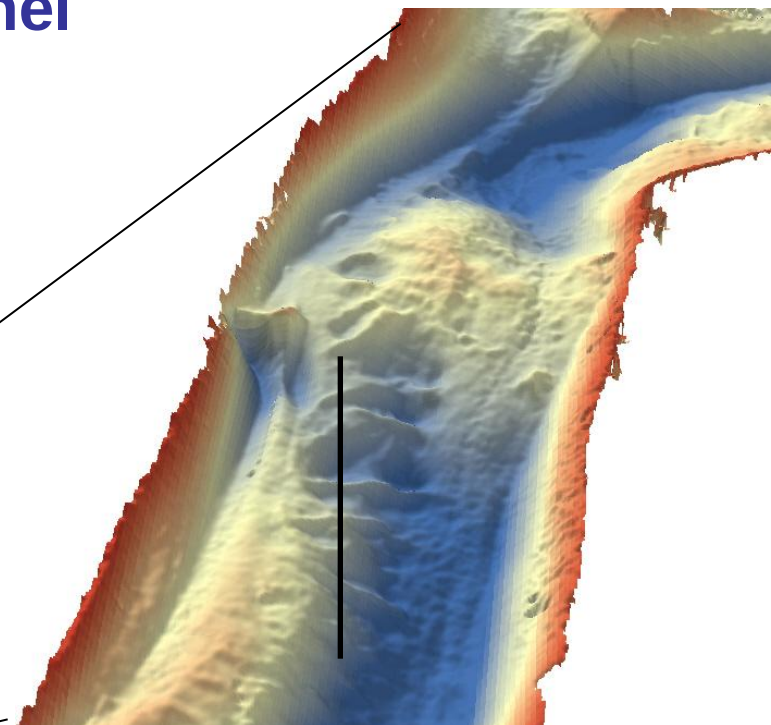
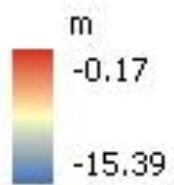
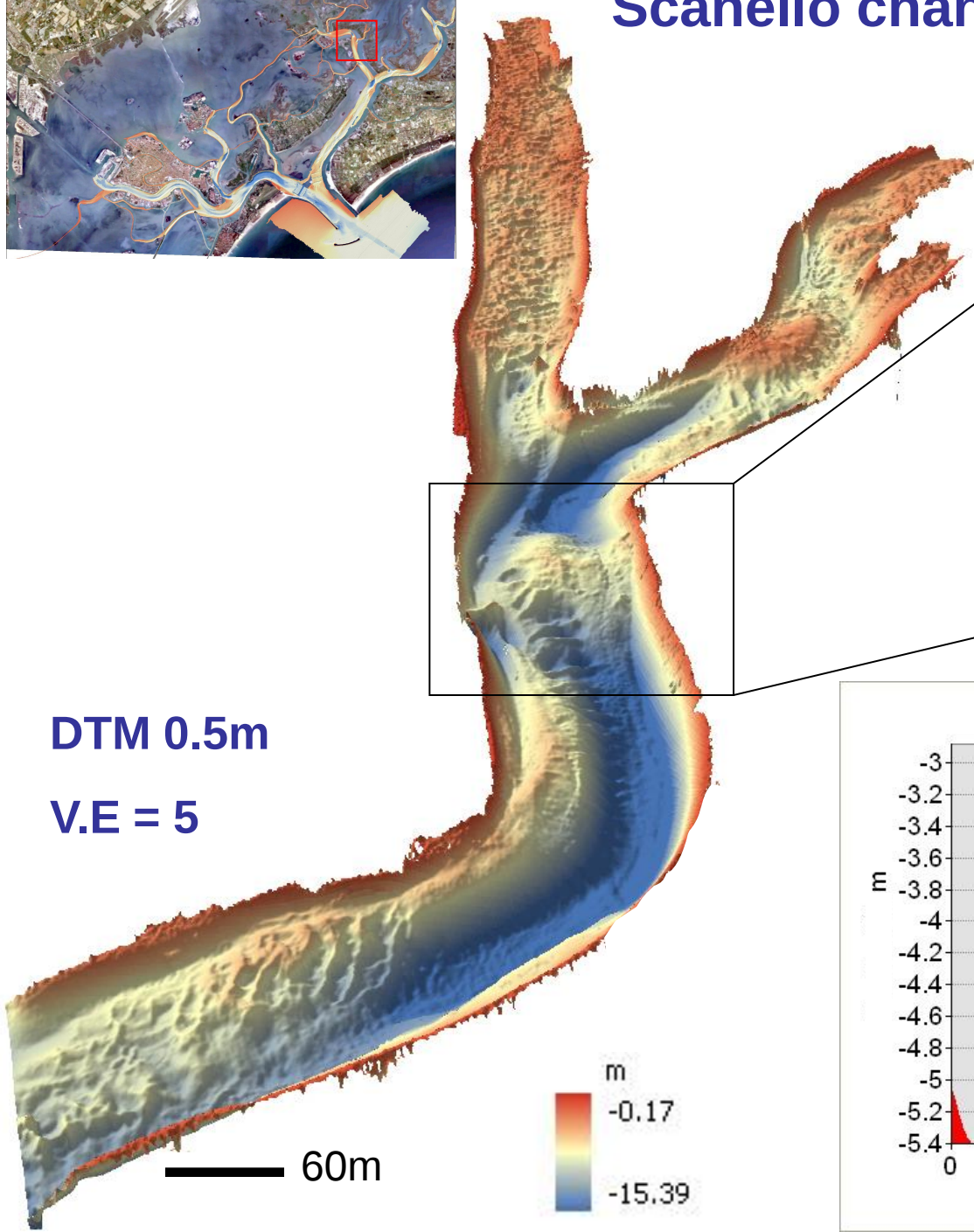




Scanello channel

DTM 0.5m

V.E = 5



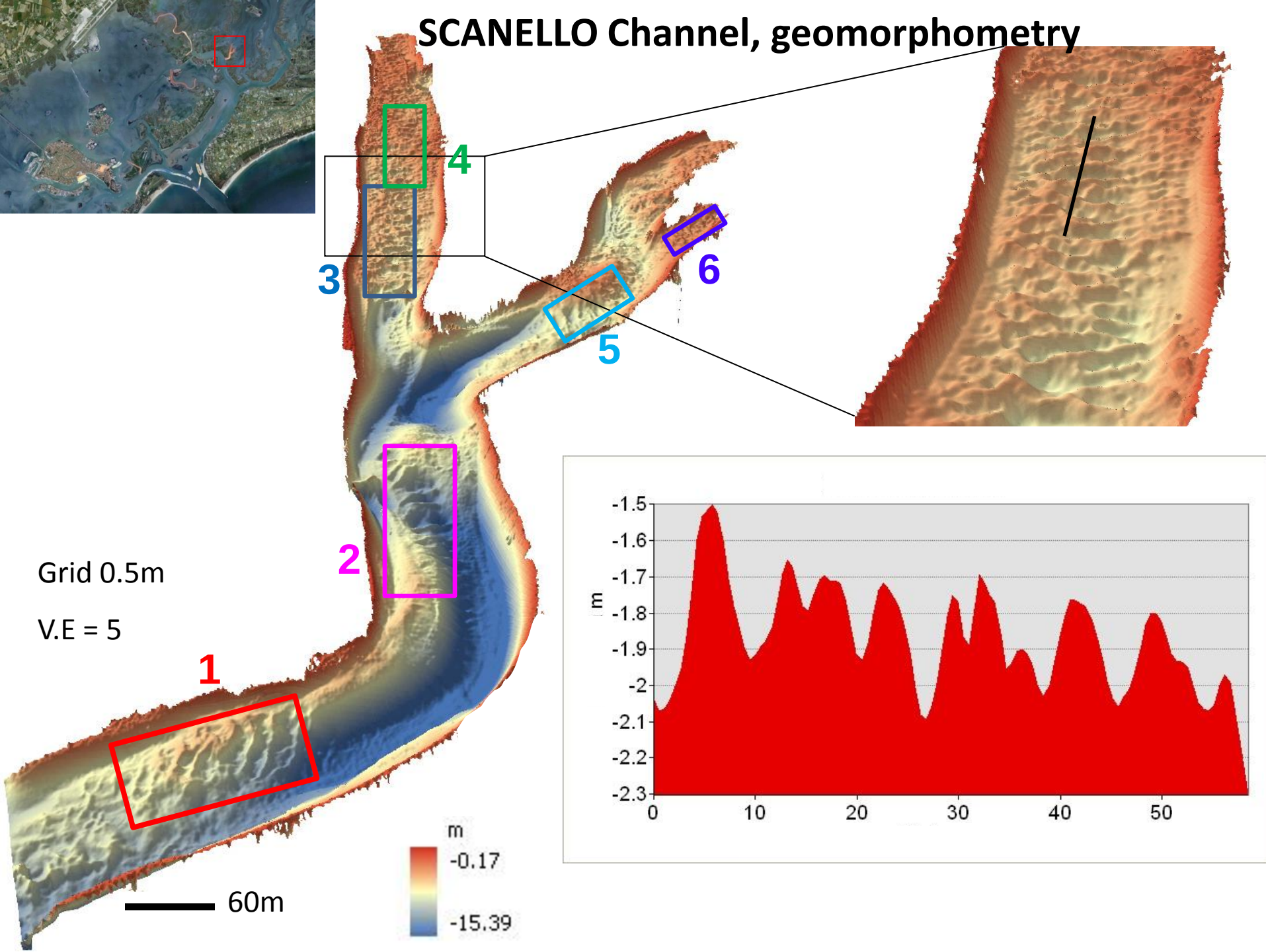
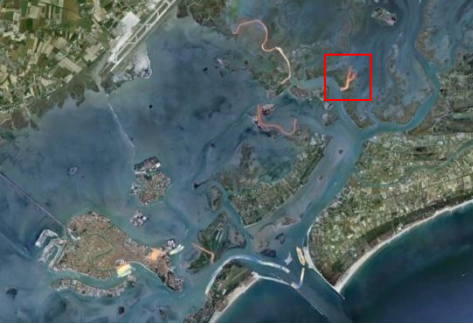
Case study of the Scanello Channel: ideal laboratory for a multidisciplinary approach

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

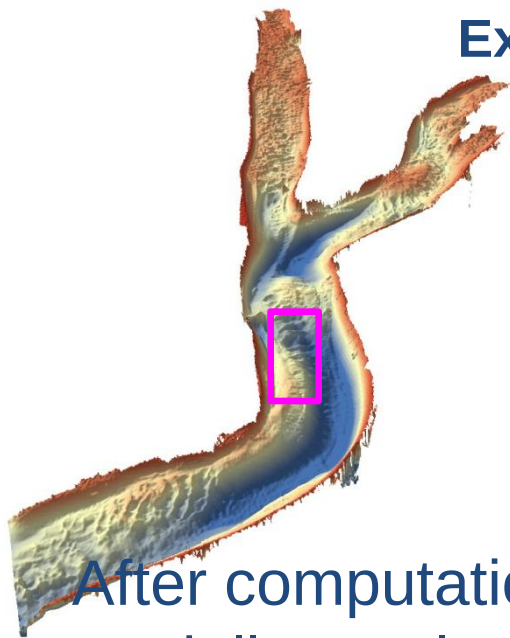


- High spatial resolution modelling of the hydrodynamics

SCANELLO Channel, geomorphometry



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

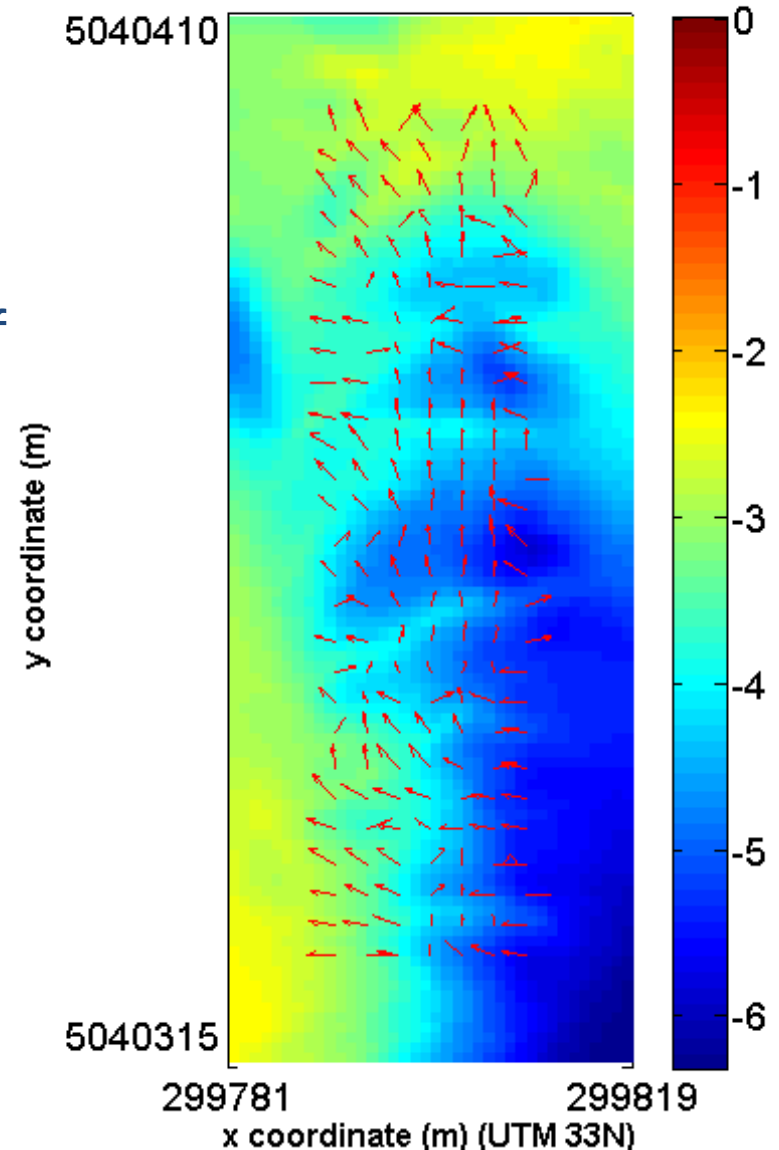


After computation of the 2D FFT of partially overlapping 20mx20m windows of the bathymetry we obtained average orientation and wavelength for each dune field.

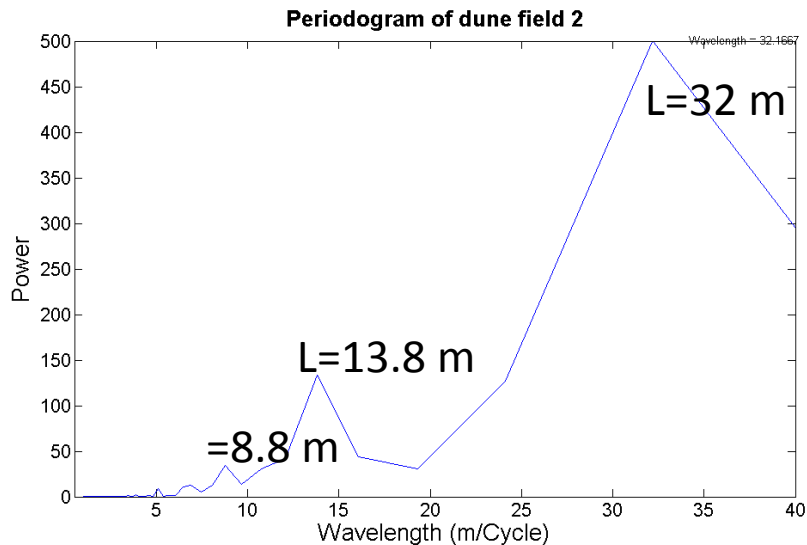
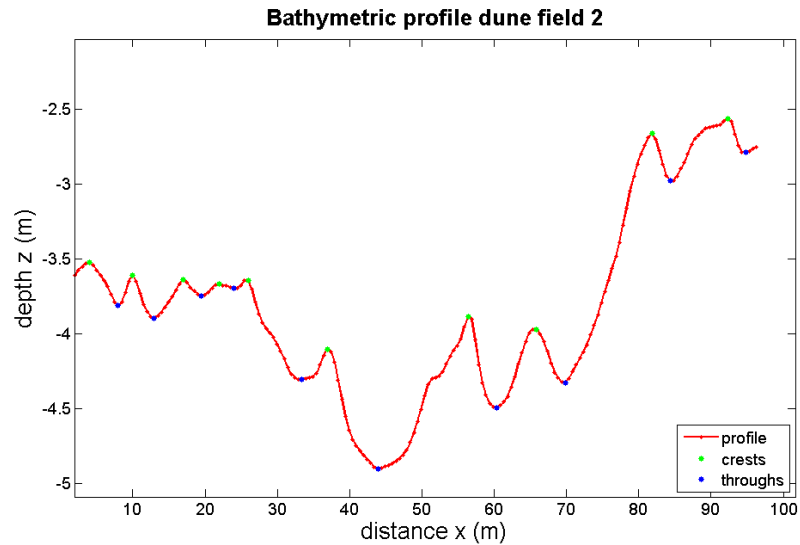
For example for the dune field 2:

- Average orientation $\alpha = 88^\circ$
- Average wavelength $\lambda = 10$ m

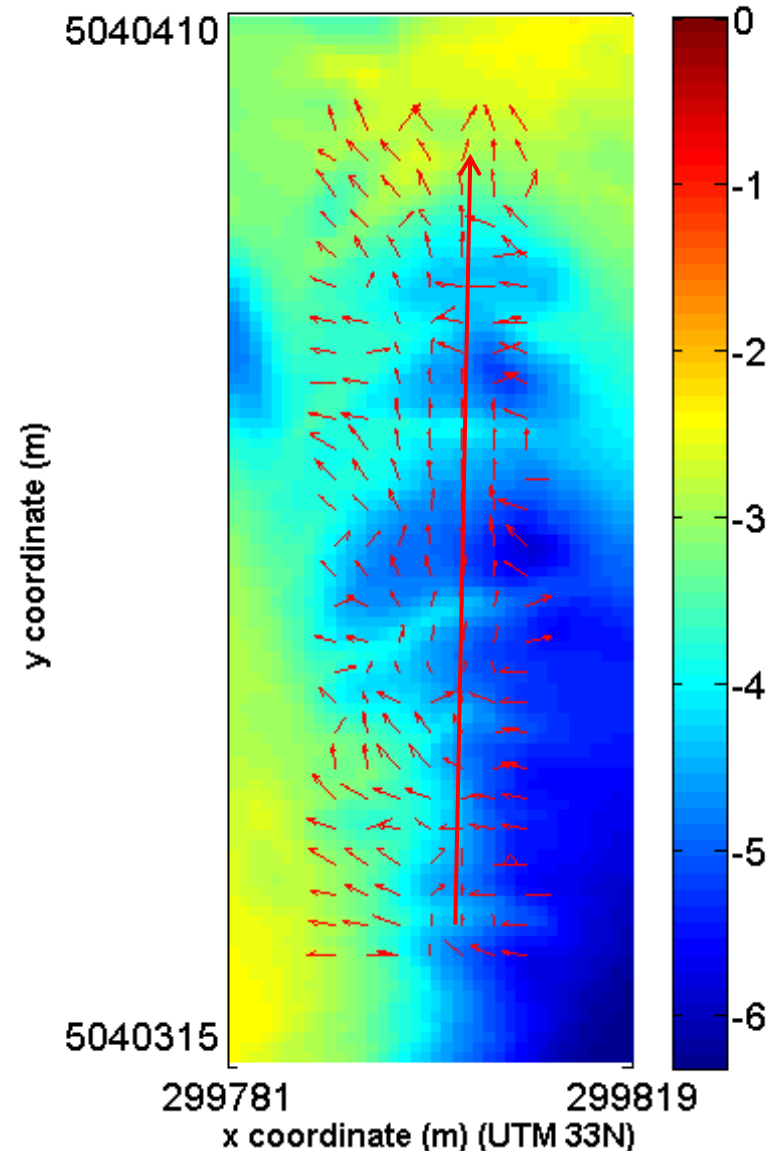
Bathymetry and orientations of bedforms extracted with the 2D FFT



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



Bathymetry and orientations of bedforms extracted with the 2D FFT



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

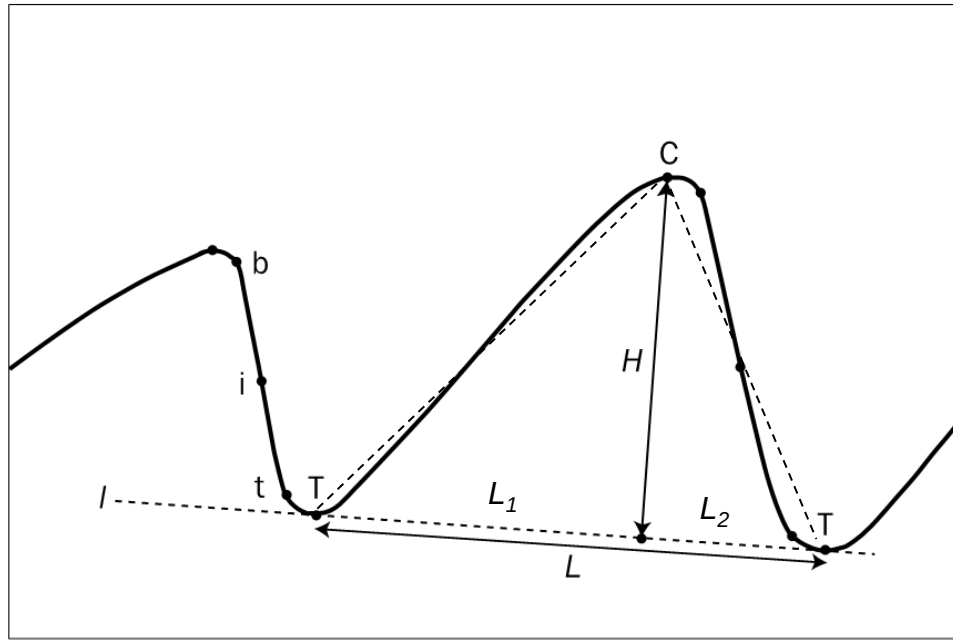


Figure 1. Definition of the morphologic parameters wavelength and height and characteristic morphologic points of bed forms, the crest point, C; trough point, T; inflection point of the lee side, *i*; brink point, *b*; and toe point, *t*. (modified from Van Dijk et al. 2008)

Approximating the dune with a triangle, we can define the dune height H , wavelength L , asymmetry index L_1/L_2 and steepness L/H

Dune field parameters

Type of subaqueous 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 **L_1/L_2** one can determine the dominant dune direction

Roughness estimation

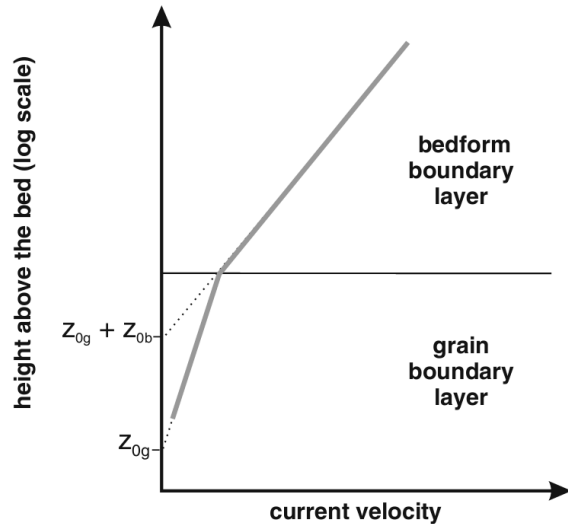


Fig. 1 A typical velocity profile over subaqueous bedforms. The velocity profile is segmented; the lower log-linear segment is related to the grain boundary layer, whereas the upper segment is controlled by the bedform boundary layer

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 $0.01 < H/L < 0.2$	$z_0 = 0.04H (1 - e^{-25H/L})$
Bartholdy et al. (2010)	Dunes under currents	$z_0 = 0.019H$

(from Lefebvre et al. 2011)

$$u(z) = \frac{u_*}{\kappa} \ln \frac{z}{z_0} \quad z_0 \text{ is the } \textcolor{red}{\text{roughness length}}, \text{ i.e. the height where the current velocity tends to zero.}$$

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

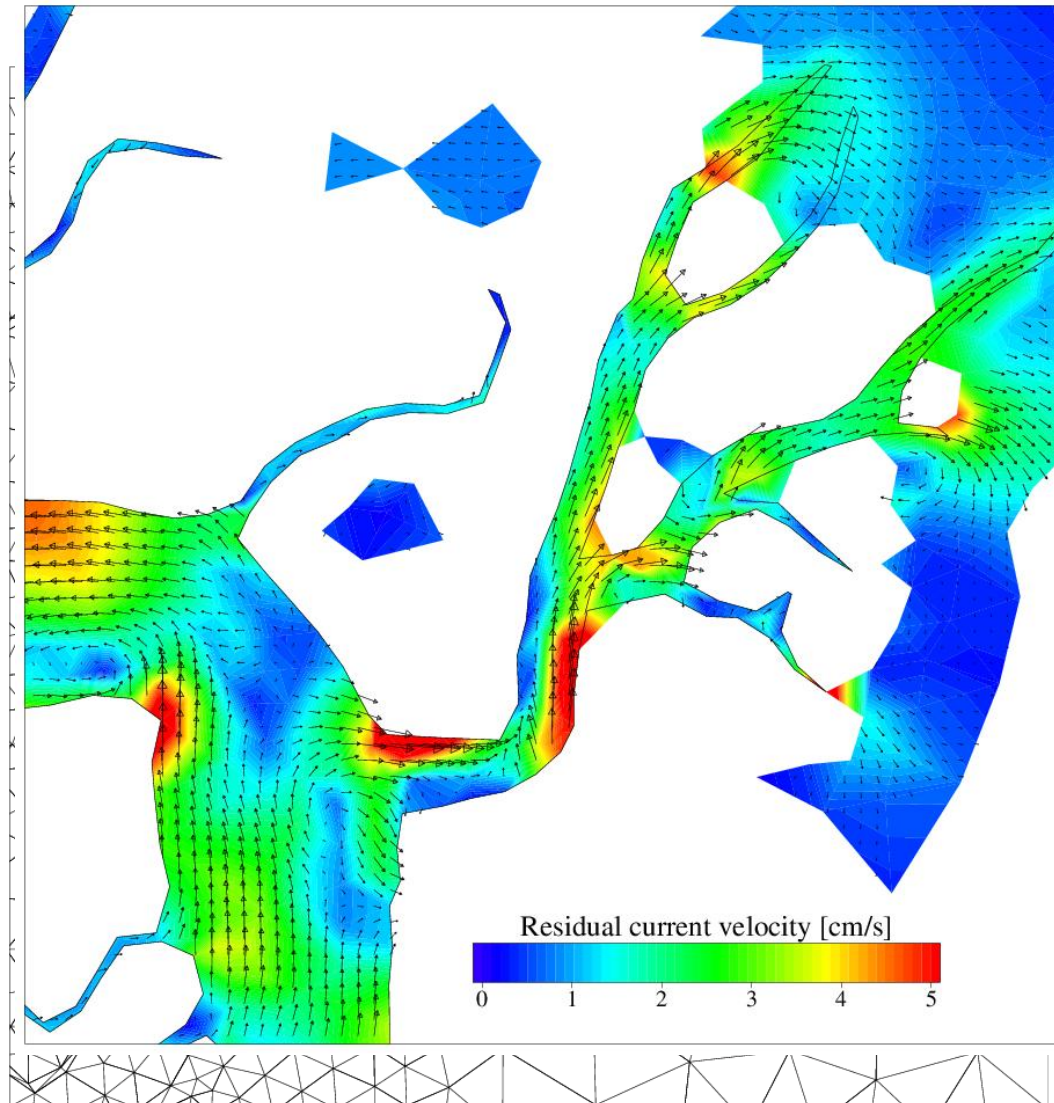
Bedform roughness estimation

Type of subaqueous dunes	Medium dunes				Small dunes		
Dune field	1	2	3	5	4	6	Lefebvre et al 2011
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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 Rijn 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



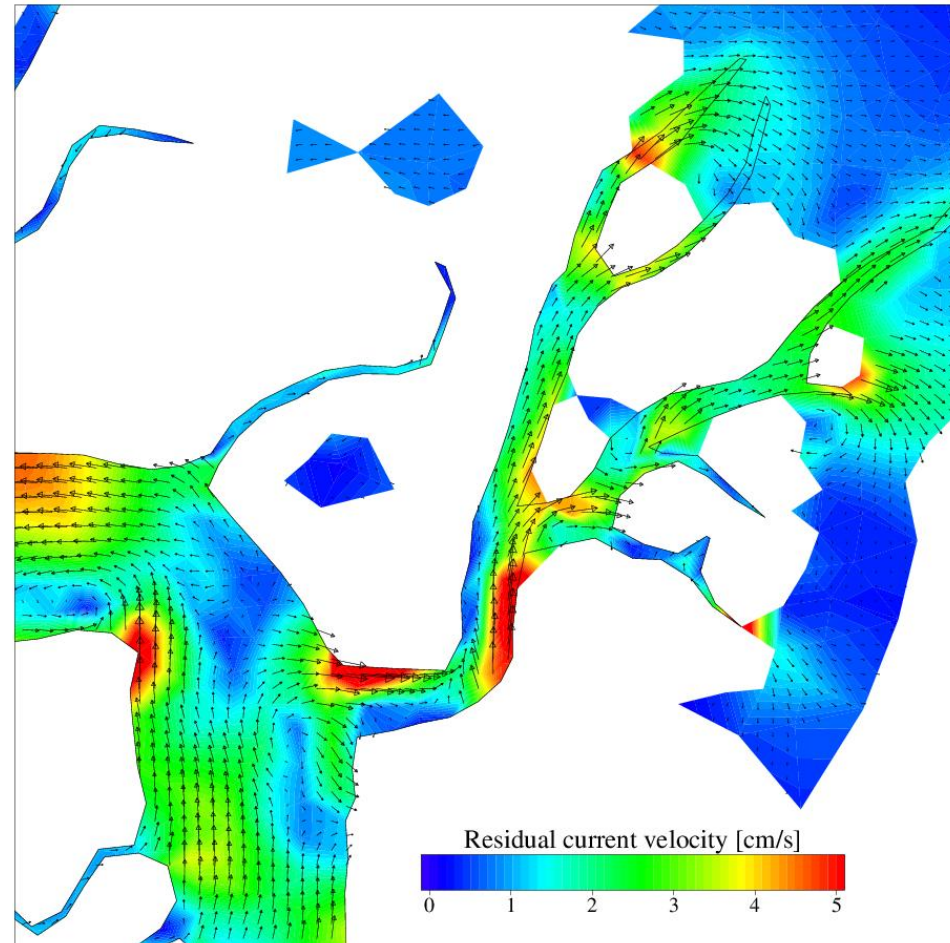
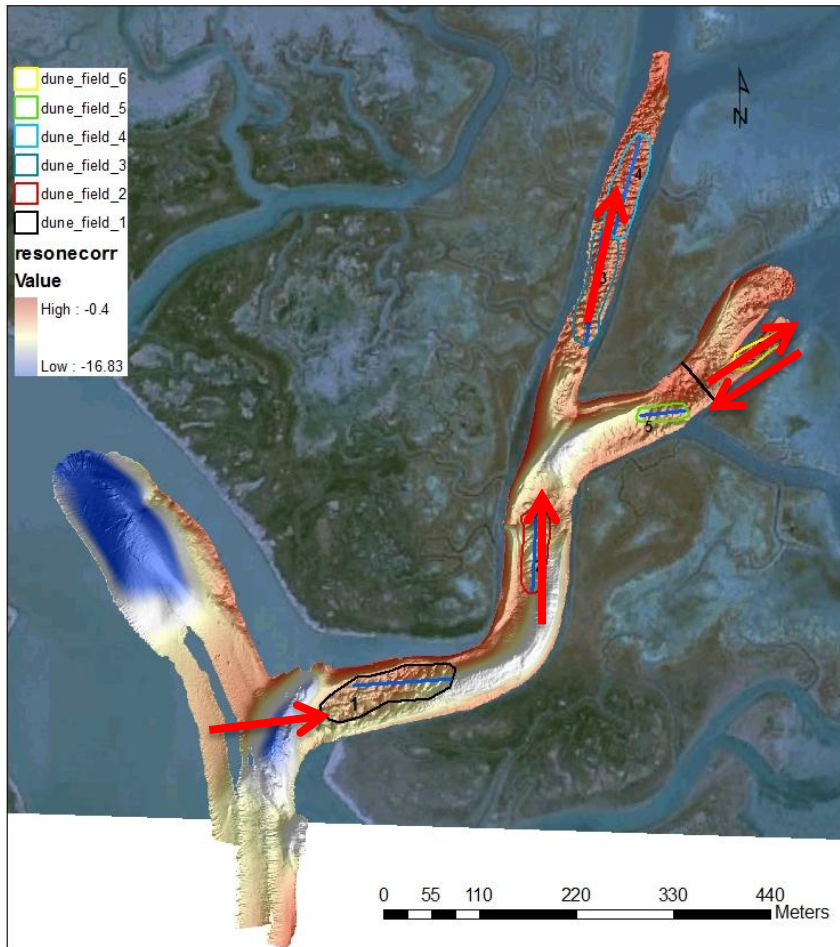
One year-long simulation was carried out forcing the model with real wind and water level data.

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.

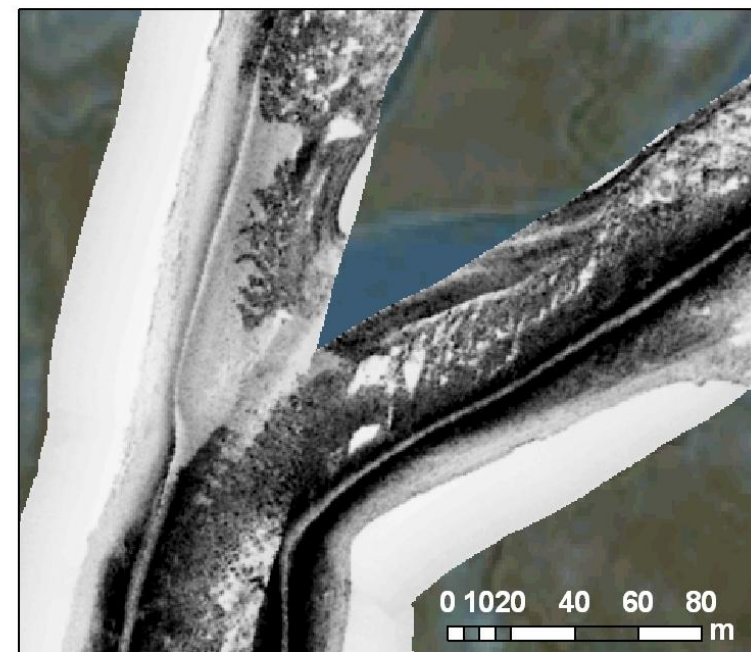
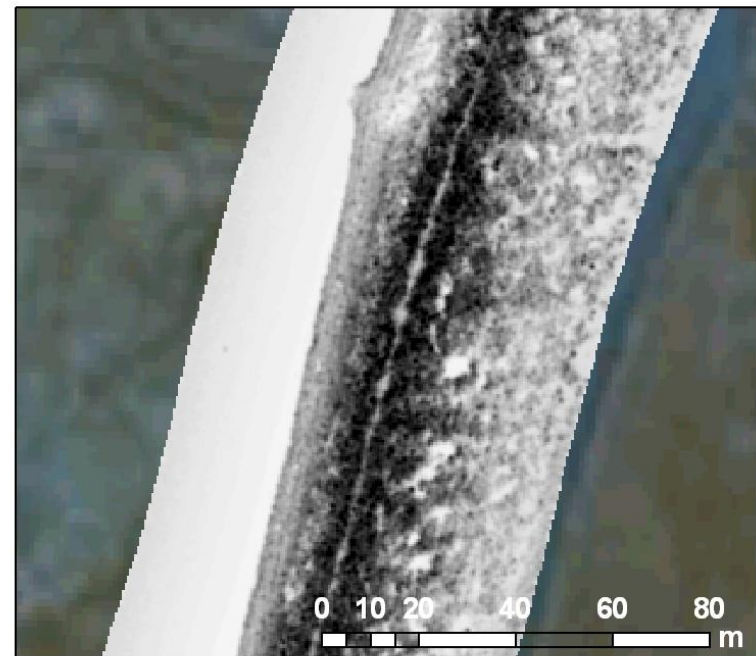
www.ismar.cnr.it/shyfem

Model results- residual currents:

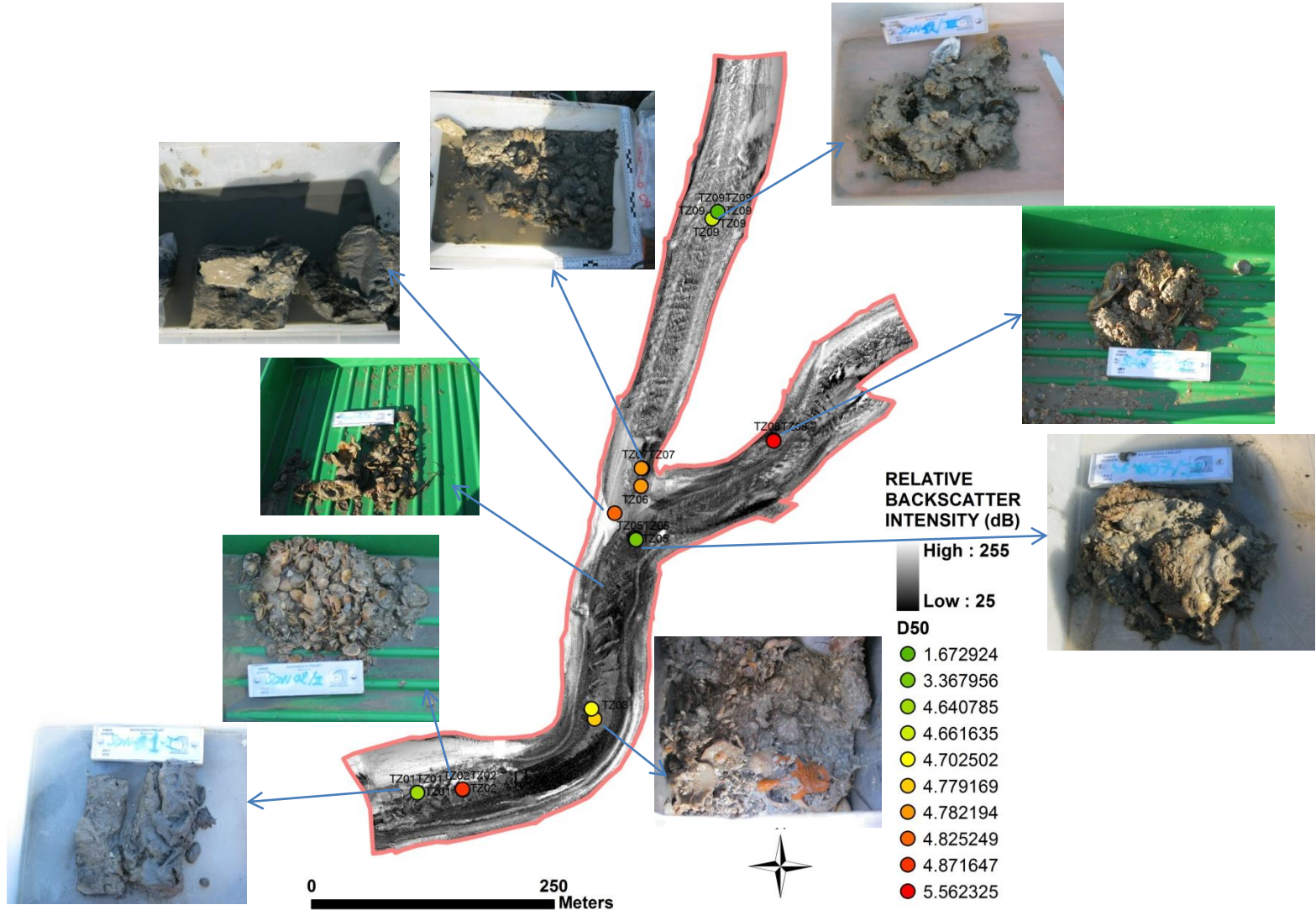
The bed-form orientation generally follows the direction of the residual currents.



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

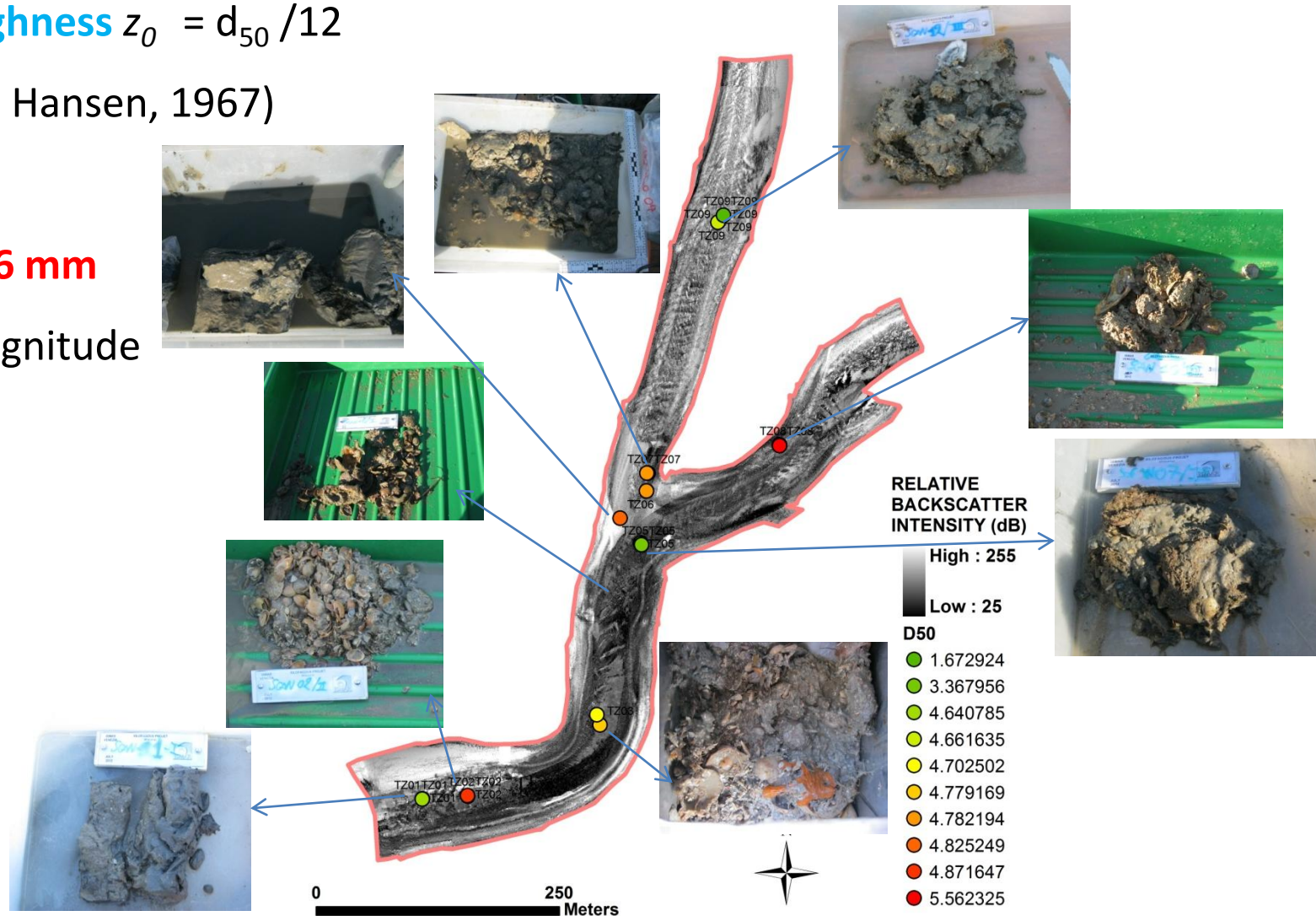
0.003 to 0.026 mm

(2 order of magnitude

smaller than

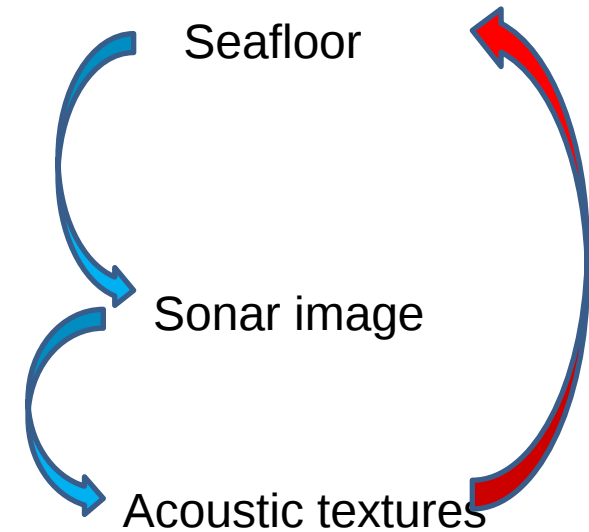
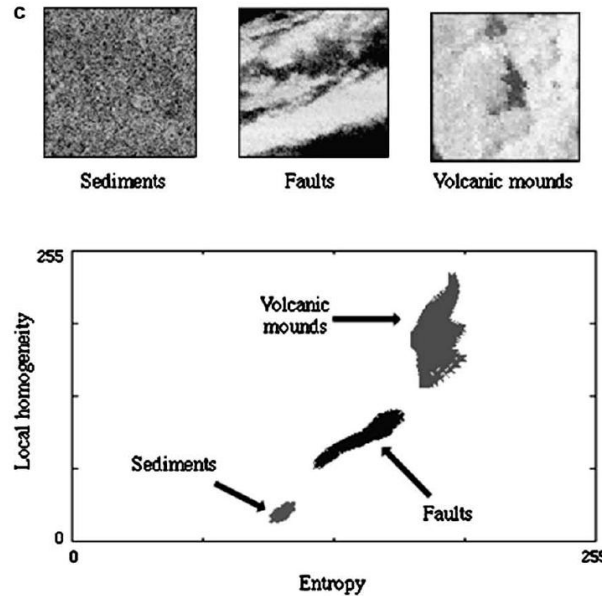
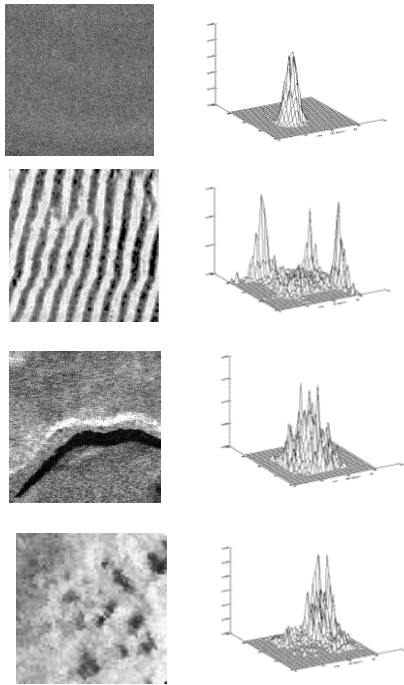
the bedform

roughness)



Backscatter intensity sediment classification by TexAN

Software by *Philippe Blondel*



Image

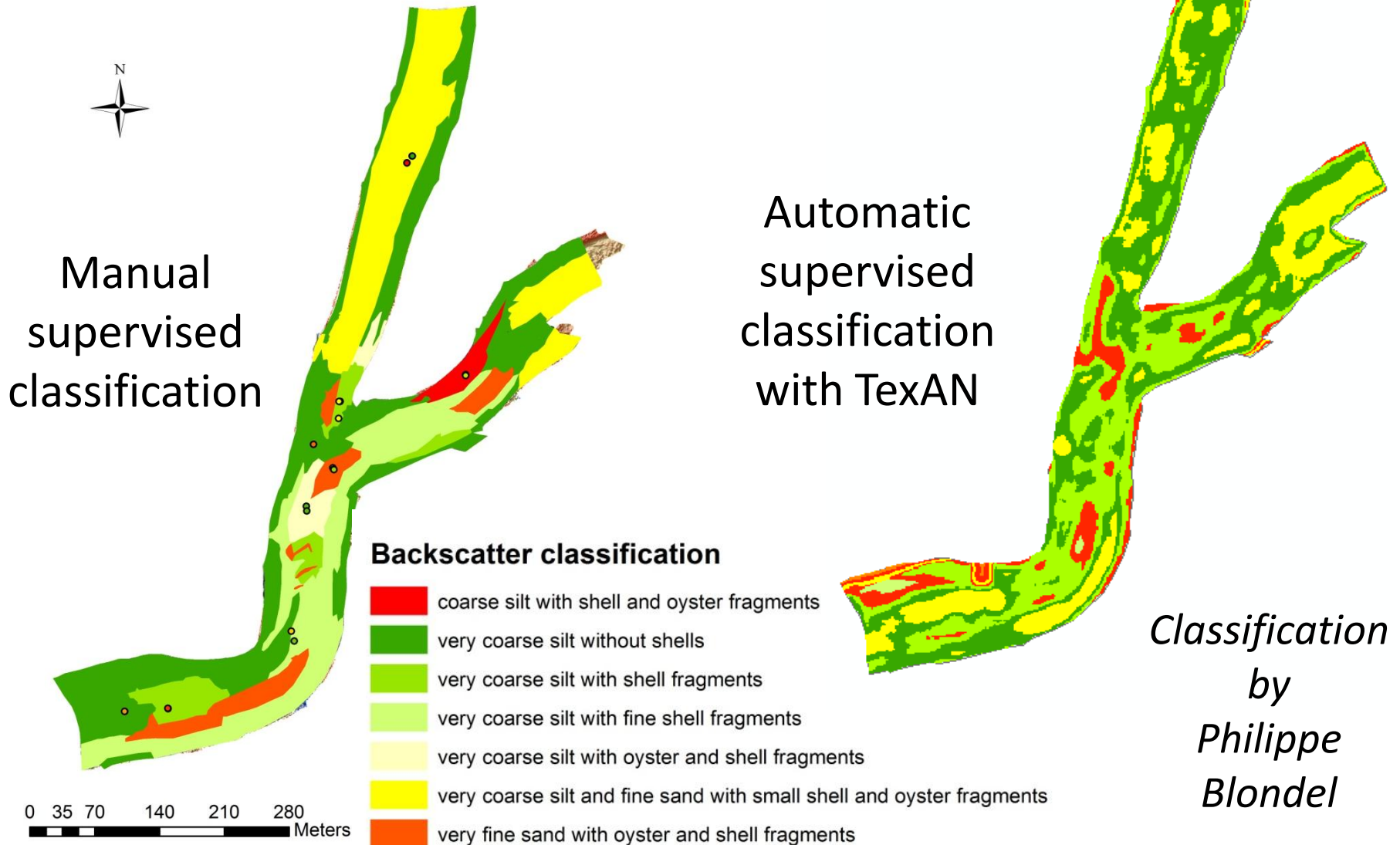
GLCMs

Textural 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



Conclusions

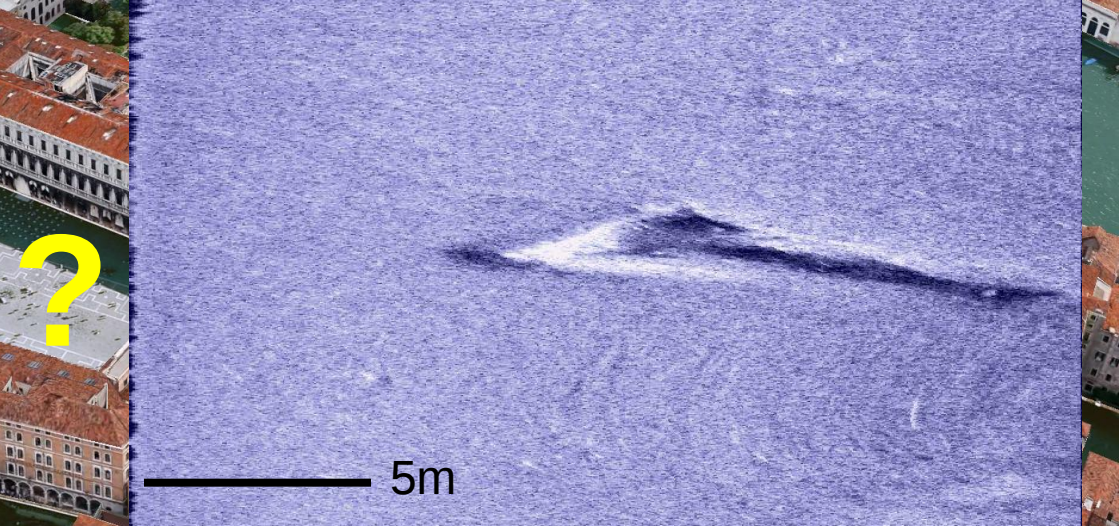
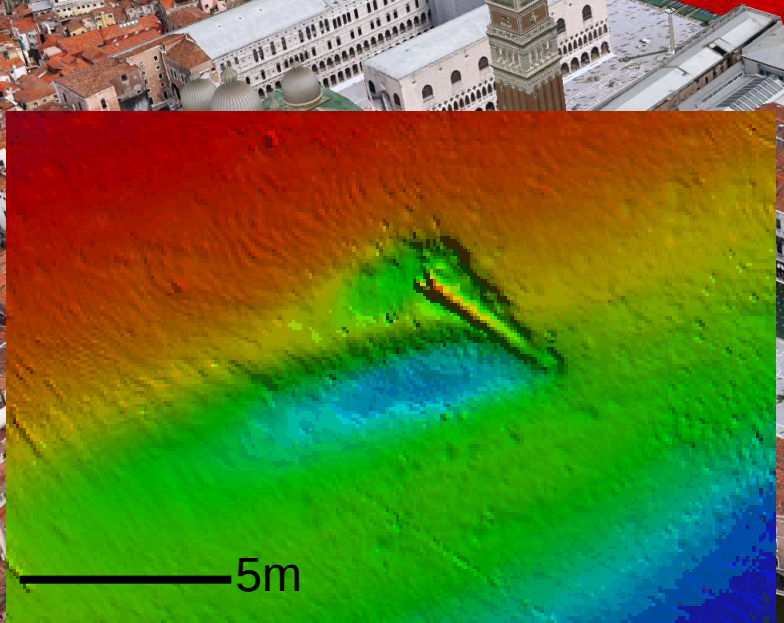
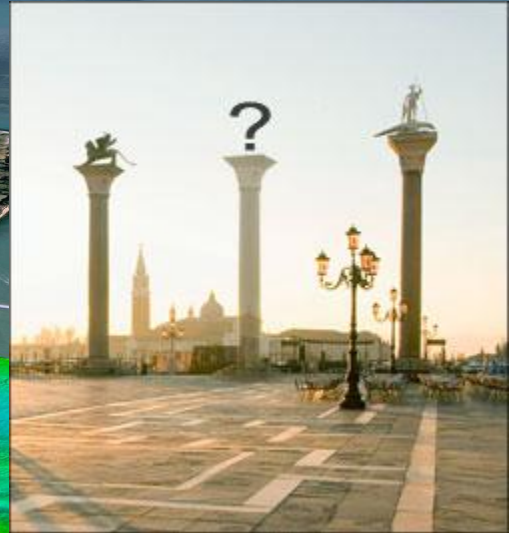
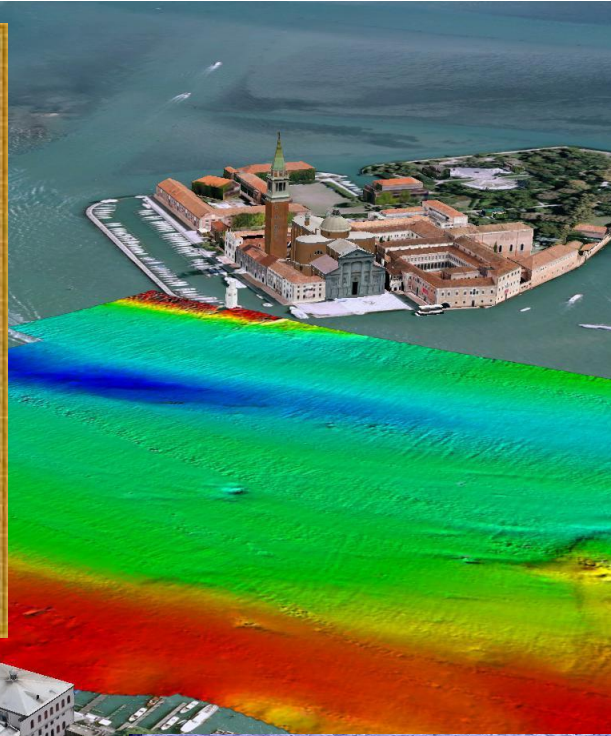
- ISMAR has a new TEAM able to collect and processes High resolution bathymetric data
- Snapshot of the lagoon morphology to assess the long term changes induced by engineering works and ship traffic
- Starting from bathymetry we carried out a multidisciplinary experiment in order to:
 1. Develop a methodology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



SAN MARCO SQUARE - The Third Column legend or reality?



SAN MARCO SQUARE - The Third Column legend or reality?

The image is a composite of four panels illustrating the 'Third Column' legend of San Marco Square in Venice.

- Top Left:** A technical drawing of an anchor, labeled 'Ancora comune con una sola marna' (Common anchor with a single fluke). It includes various dimensions and labels: 'Cicole' (flukes), 'Coppo' (crown), 'Fuso' (shank), 'Linghia' (fluke), 'Diamante' (diamond), and 'Diametro' (diameter). The drawing is attributed to '1831 (Ancorassa)'.
- Top Right:** An aerial view of San Marco Square and the surrounding buildings, showing the square's layout and the Venetian architecture.
- Bottom Left:** A bathymetric map of the square area, showing the depth of the water. A scale bar indicates 5m.
- Bottom Right:** A Google Earth satellite view of the square and surrounding buildings, showing the square's layout and the Venetian architecture.

