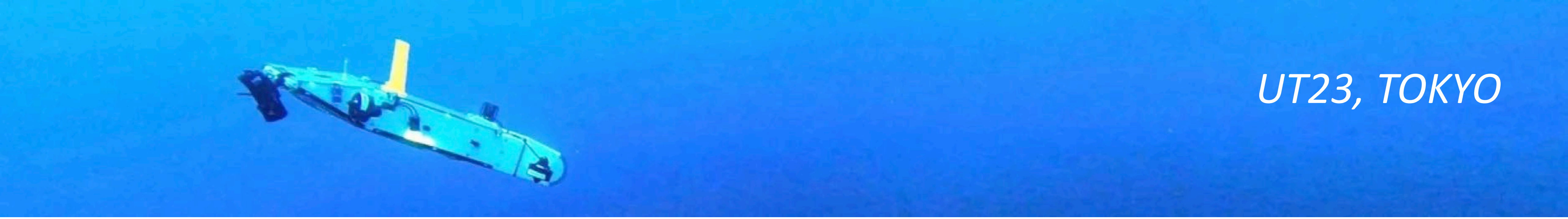

Multi-band, calibrated backscatter from high frequency multibeam systems as an efficient tool for seabed monitoring

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Polish Naval Academy in Gdynia

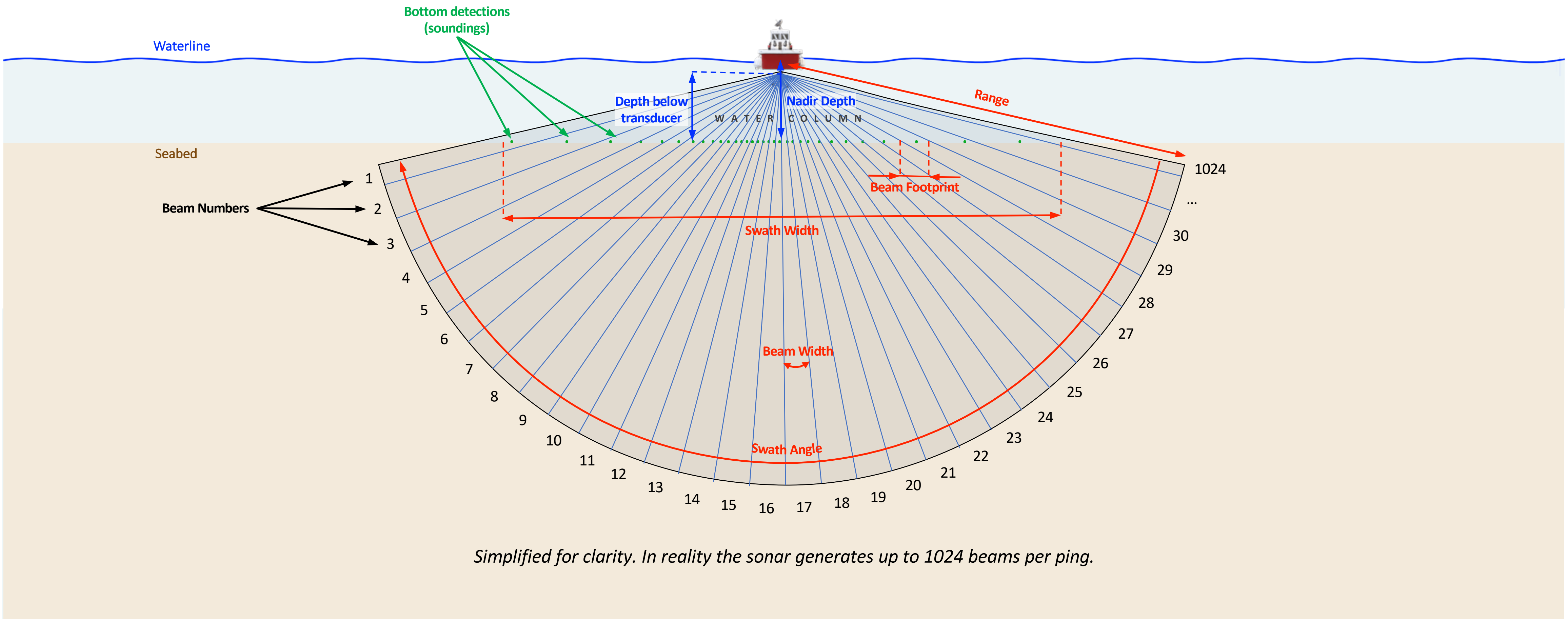
NORBIT
-explore more-

Introduction

- Multibeam echosounders (MBES) are widely used for mapping the seabed but these data allow for bottom classification and benthic habitat mapping as well
- Modern MBES systems record not only bathymetry but also seabed acoustic reflectivity that is related to physical properties of the seabed
- Backscatter is describing seabed acoustic reflectivity as the strength of reflected acoustic echo and can be registered at different frequencies, it is called **multi-spectral backscatter**
- Some multibeam units can be delivered with **calibrated backscatter** that is an absolute measure of acoustic reflectivity and can be compared with physical models for different bottom types and morphology

This study shows how those two developments can be used to improve bottom classification procedures and why they are beneficial

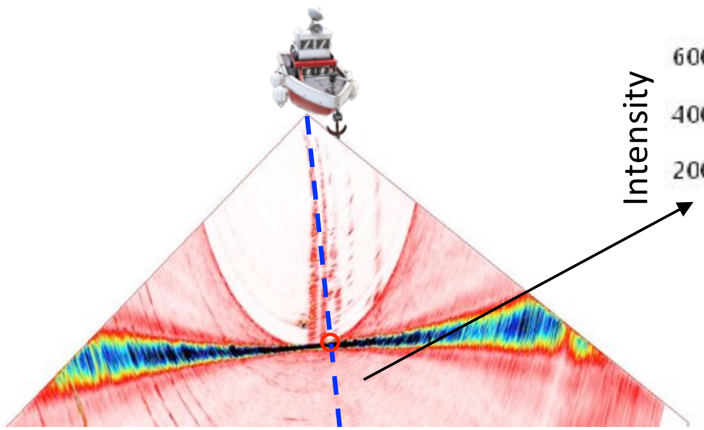
Multibeam Echosounder Swath Geometry



Simplified for clarity. In reality the sonar generates up to 1024 beams per ping.

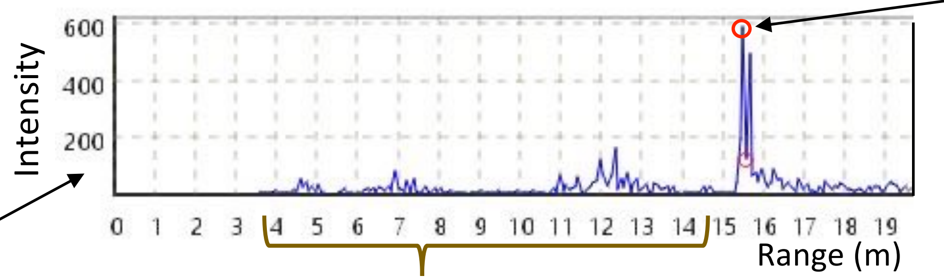
Multibeam Echo Signal

- Water column data contains beamformed magnitude data for each beam.
  - After acoustic transmission, echoes are reflected from everything in the water column – marine life, sediments, floating particles, bubbles, and of course the seafloor.
  - The strength of the return signal depends on the target type.
  - Water column data contains all of these signals, not just signals from the seafloor.
  - Useful for analyzing gas seeps, leakage detection, etc.
  - Historically very painful to record due to large file sizes, however NORBIT offers compressed water column.

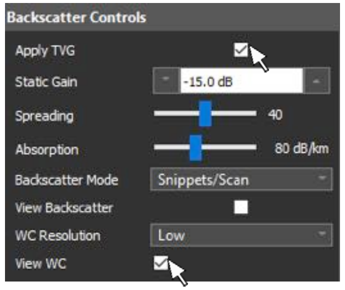


Intensity signal from one beam

Bottom detection point

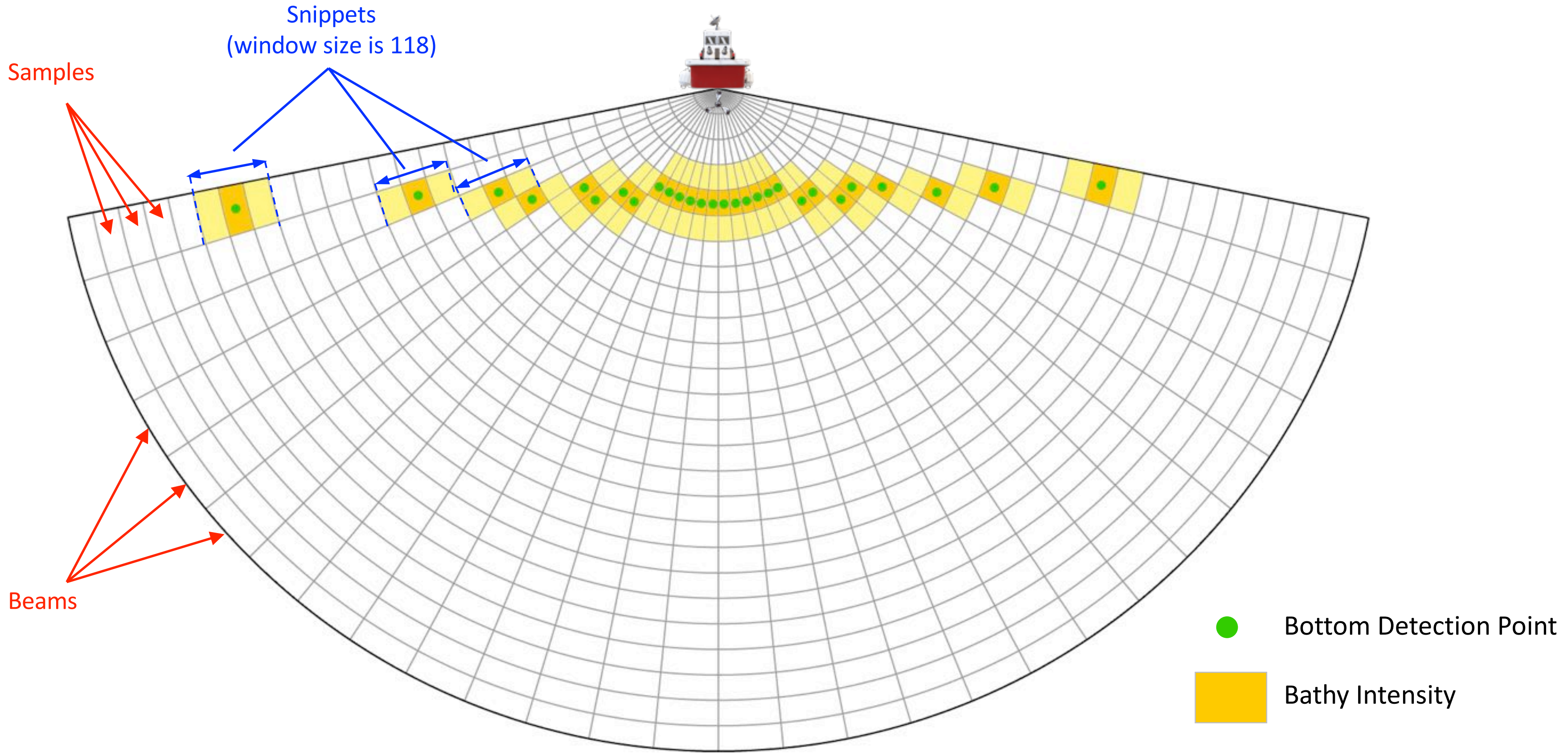


Water column intensity samples with gas seeps



Snippet is a Sample of Echo Signal

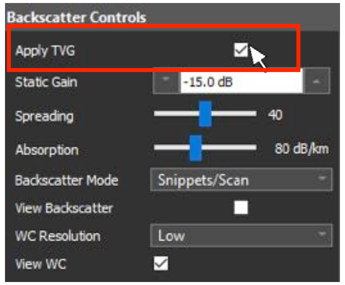
A very simple illustration…

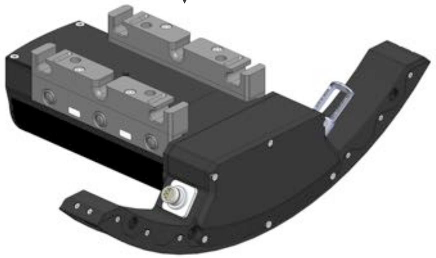


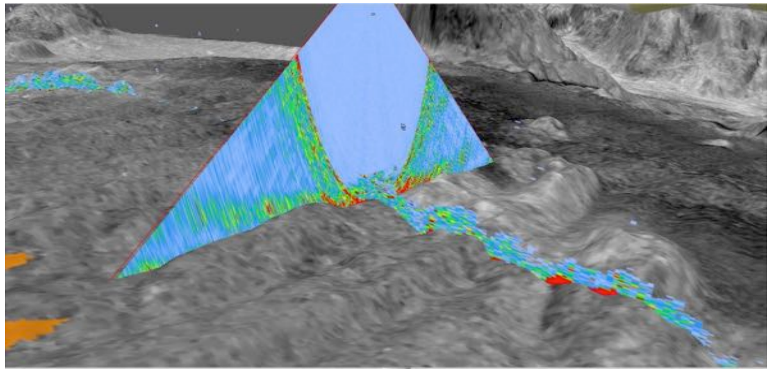
All intensity values for samples within the snippets window are recorded.

In reality, there are many more beams and many more samples.

Backscatter Data Acquisition and Acoustic Reflection Elements







1. System setup: pulse length, frequency, power, swath opening, incident angles

Known

2. Hardware electronics and performance

Calibration!

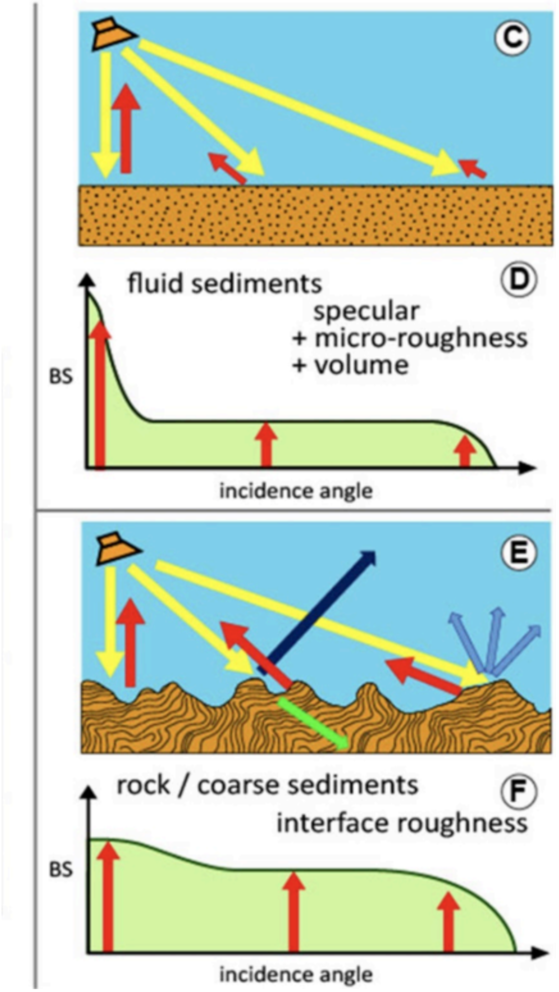
3. Water column properties e.g. temperature, salinity

Is always measured by CTD or SVP

4. Interaction of the acoustic pulse with the seafloor

That is what we are looking for

Backscatter, inherent capability for sending back acoustic energy to the sonar



Lamarche & Lurton 2017

<u>Bottom acoustic response depends on:</u>

+ frequency of acoustic signal

+ seafloor roughness

+ seafloor hardness related to different penetration and contribution of volume scatter to general reflection

+ angle of incidence of each beam

+ water parameters (temperature, salinity, depth)

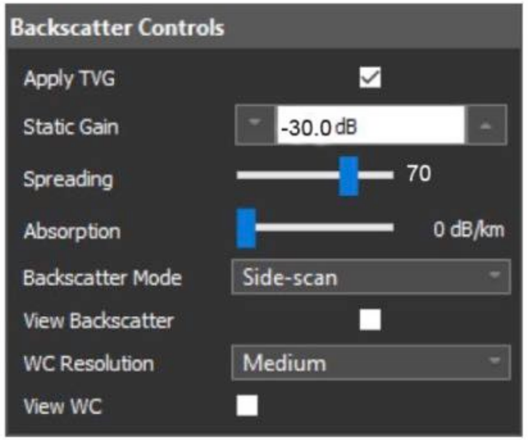
+ footprint area (related to depth and beam oppening angles)

Frequency and wave length

400 kHz:	0.37cm
100 kHz:	1.5cm
60 kHz:	2.5cm

Time Varied Gain – Signal Loss Compensation

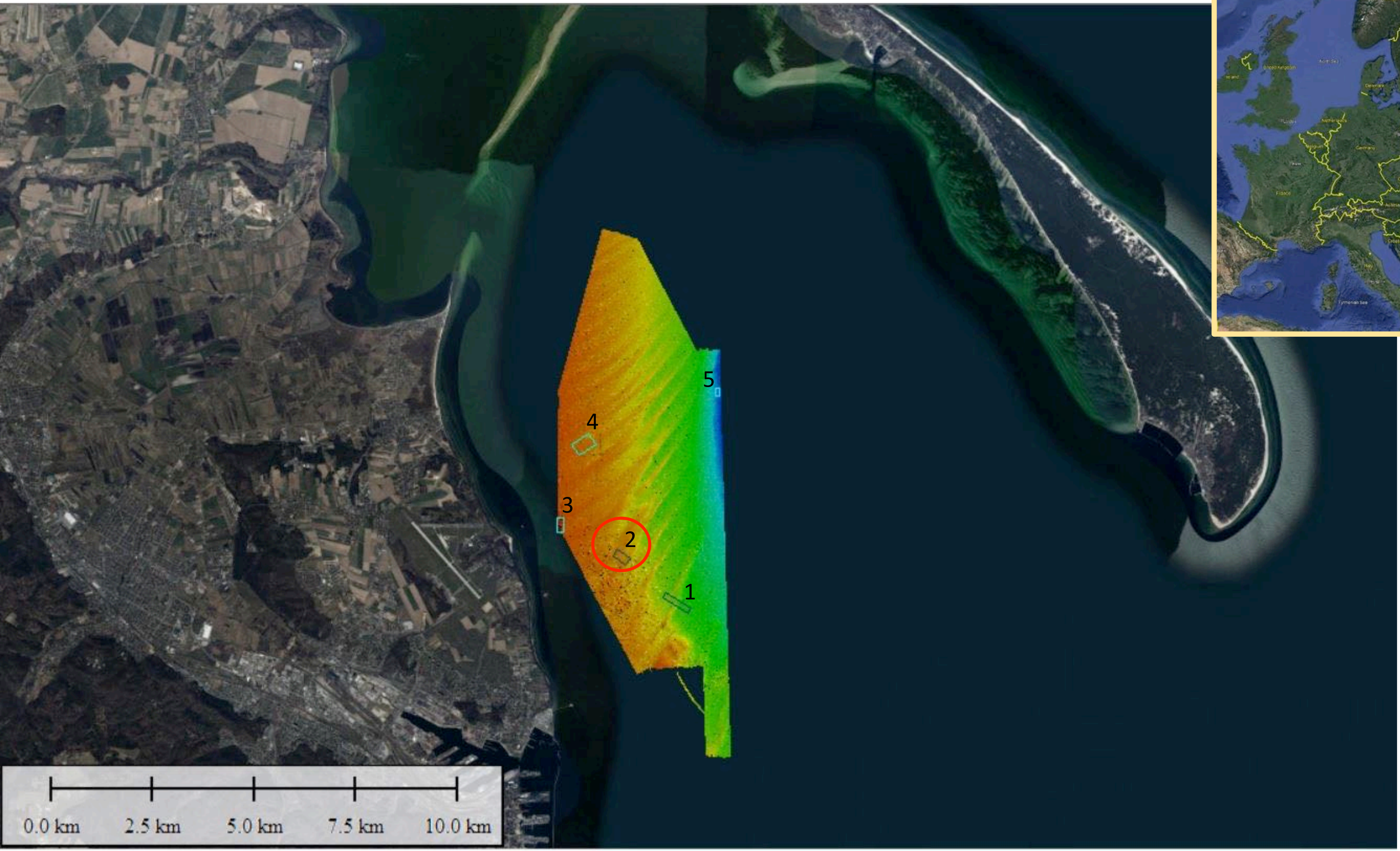
- Enabling TVG removes the native sonar TVG applied by the hardware (which operates up to around 30m) and applies the user specified TVG as computed by:

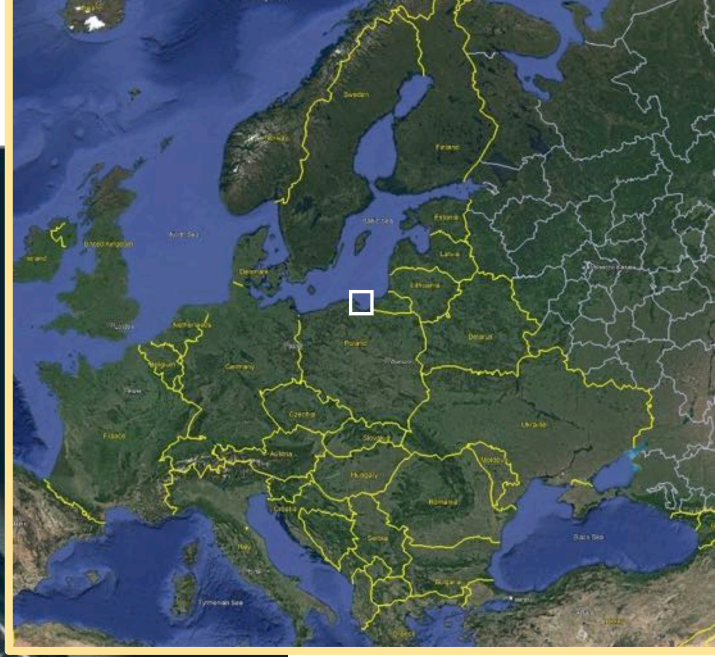


$$TVG = Spreading * Log_{10}(R) + 2 * Absorption * R/1000 + Gain$$

  - TVG is applied to all imagery outputs: Sidescan, snippets, snippet-sidescan and water column.
  - **Static Gain** sets a fixed gain value that is used together with **Spreading** and **Absorption** to form the TVG curve.
  - **Spreading** loss is a geometrical phenomenon in which signal intensity is reduced as range increases and wave fronts are spread over an increasingly larger area.
  - Transmission loss due to **Absorption** is caused by conversion of acoustic energy into heat. The rate of loss depends on the water environment.

Puck Bay, Baltic Sea, Poland

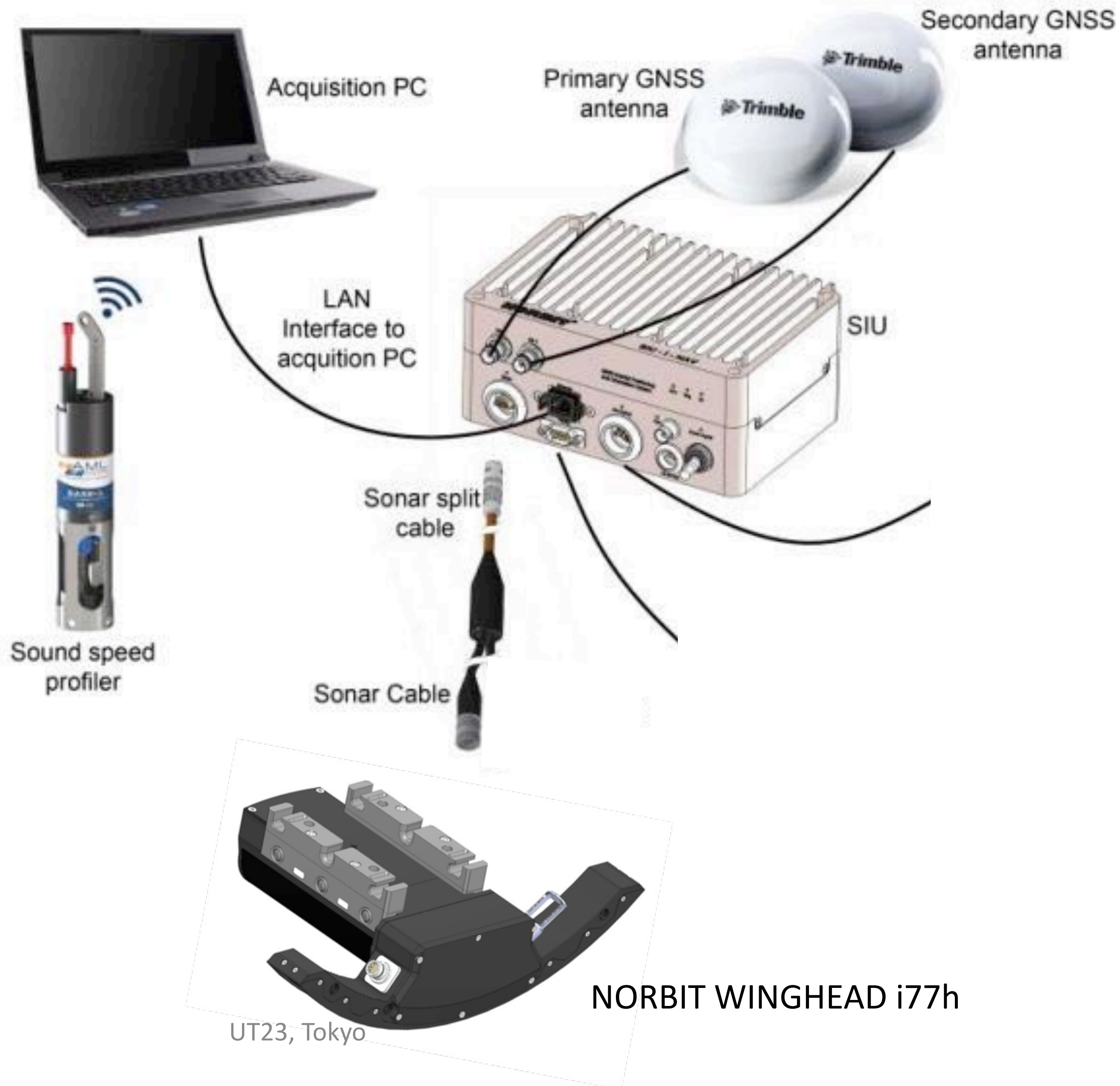




Equipment Setup

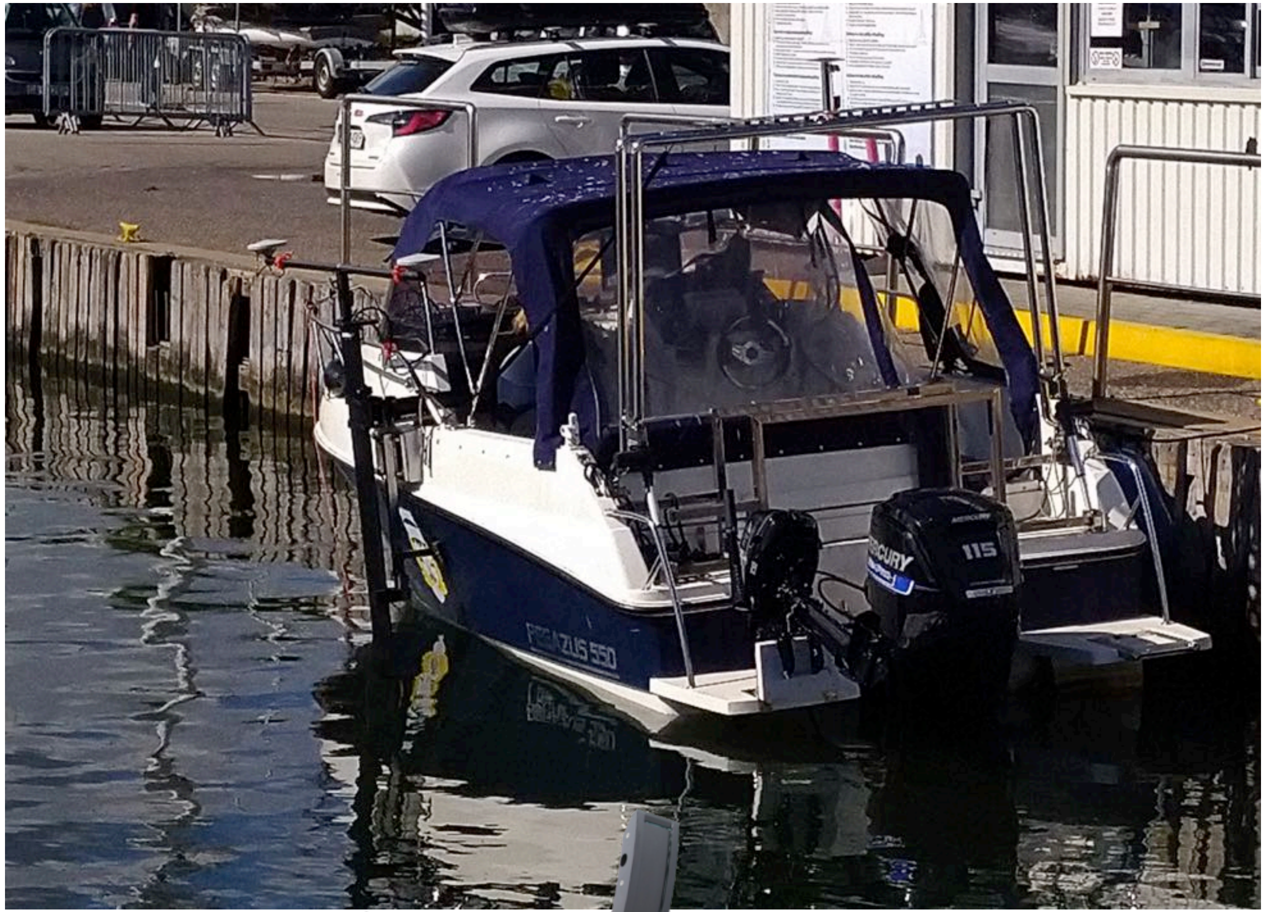
NORBIT WINGHEAD i77h:

- Frequency range: 200kHz-700kHz
- 1024 true beams
- Angular resolution 0.5° x 0.9°
- Swath opening: 5° - 210°
- FM pulse bandwidth: 80kHz
- Pulse length: 200μm and 500μm
- Applanix INS Ocean Master integrated



NORBIT WINGHEAD i77h

Acoustic data collection

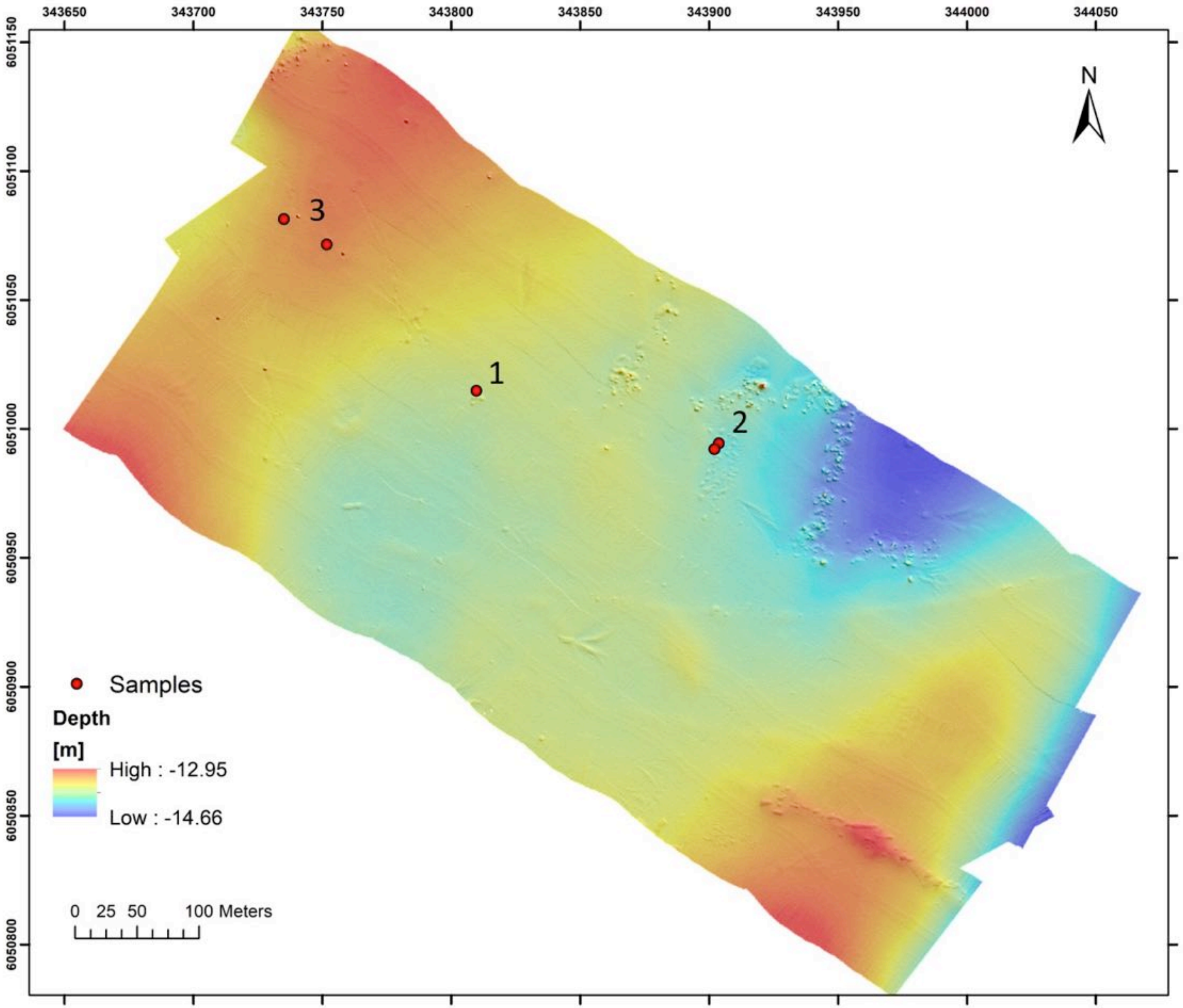


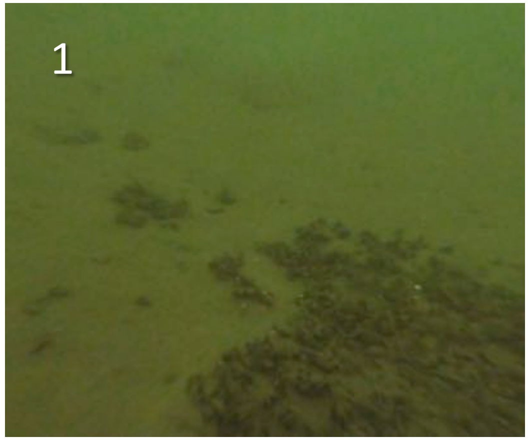
Ground-truth samples

Video, Go-Pro camera in waterproof housing with underwater lights

Sediment grabs

Bathymetry





Fine Sand

Ø=2.099

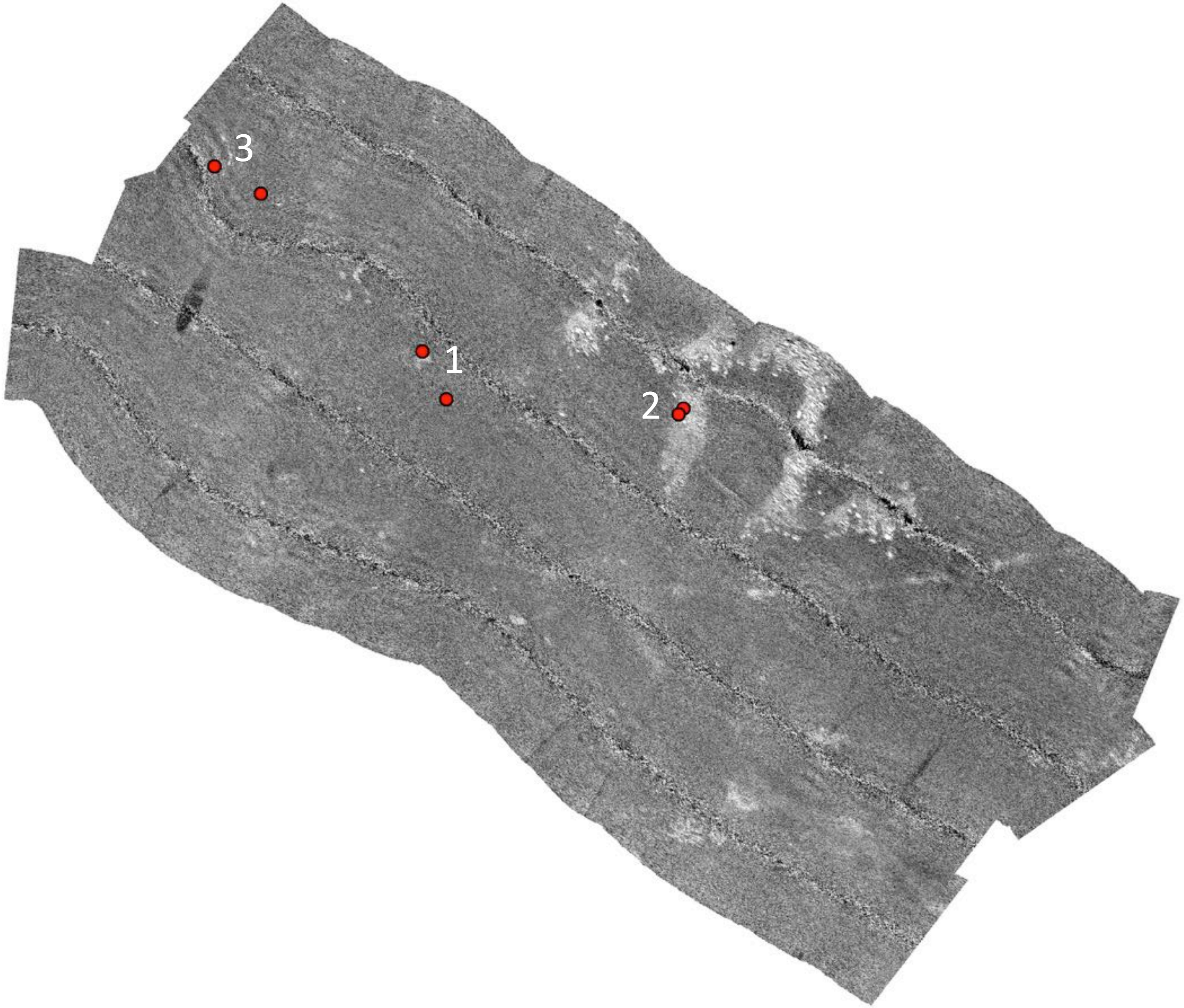
Fine Sand

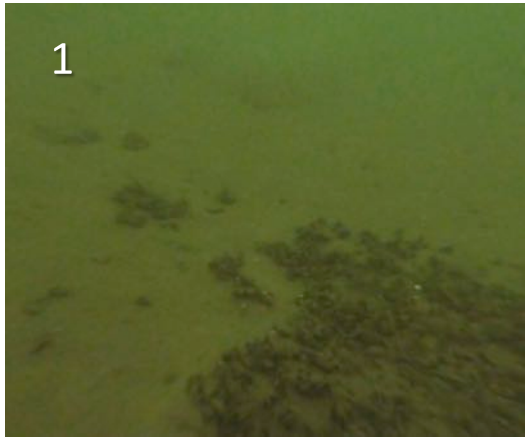
Ø=2.151

Fine Sand

Ø=2.102

Backscatter





Fine Sand with mussel patches

Ø=2.099

Fine Sand with mussels

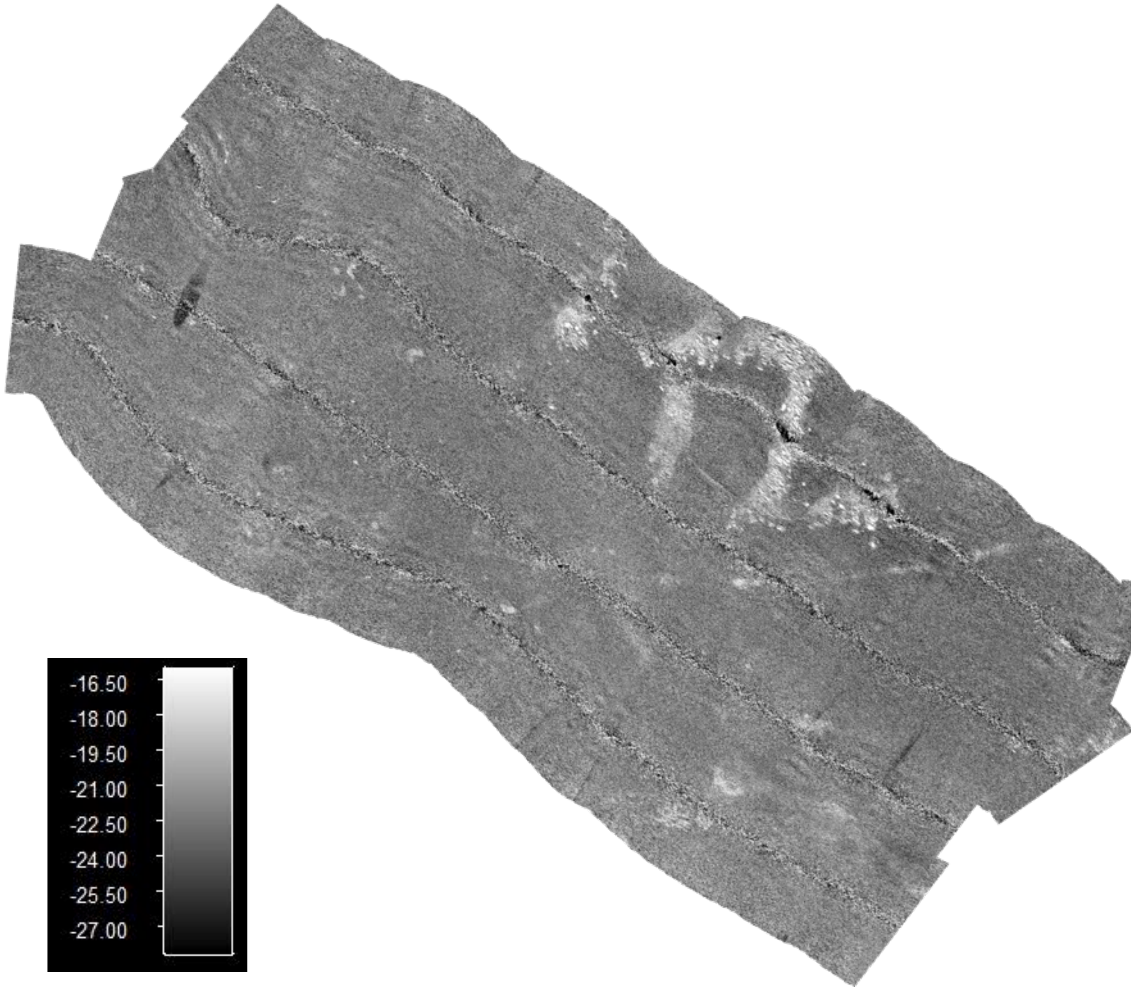
Ø=2.151

Fine Sand, bare bottom

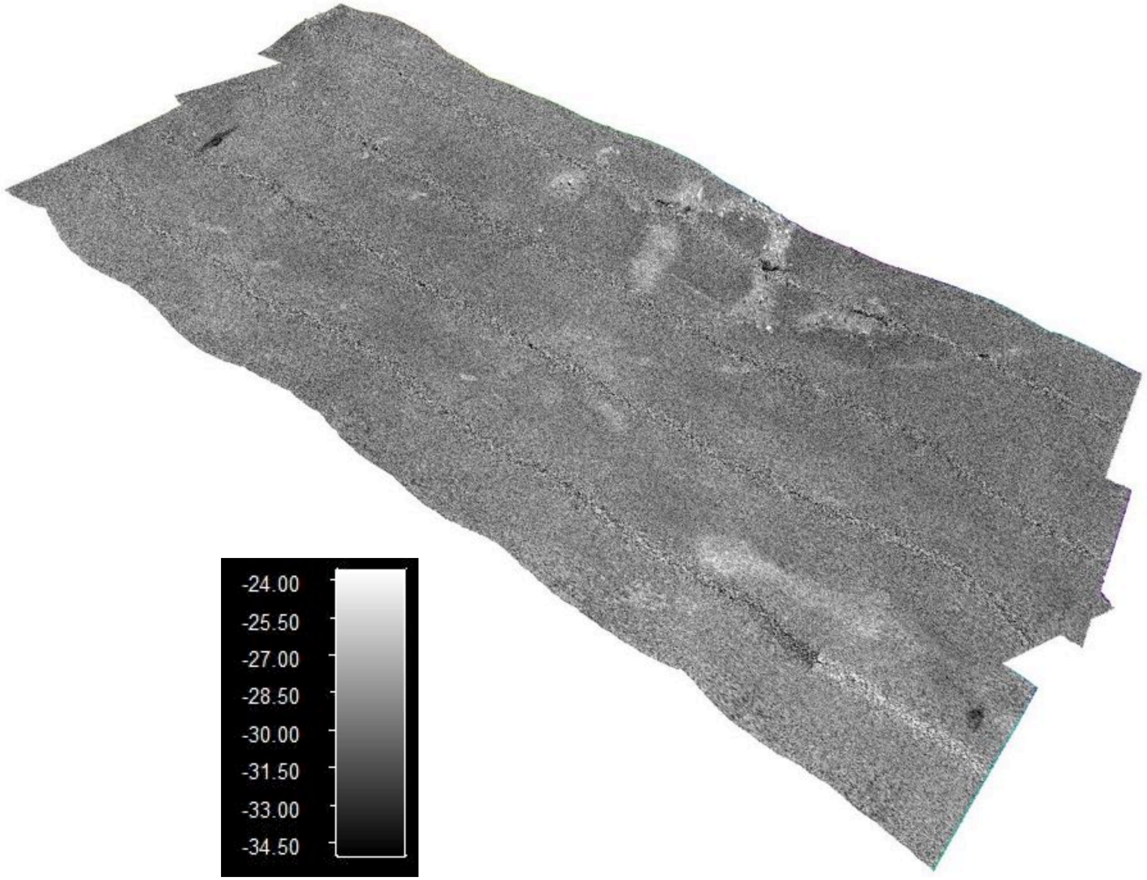
Ø=2.102

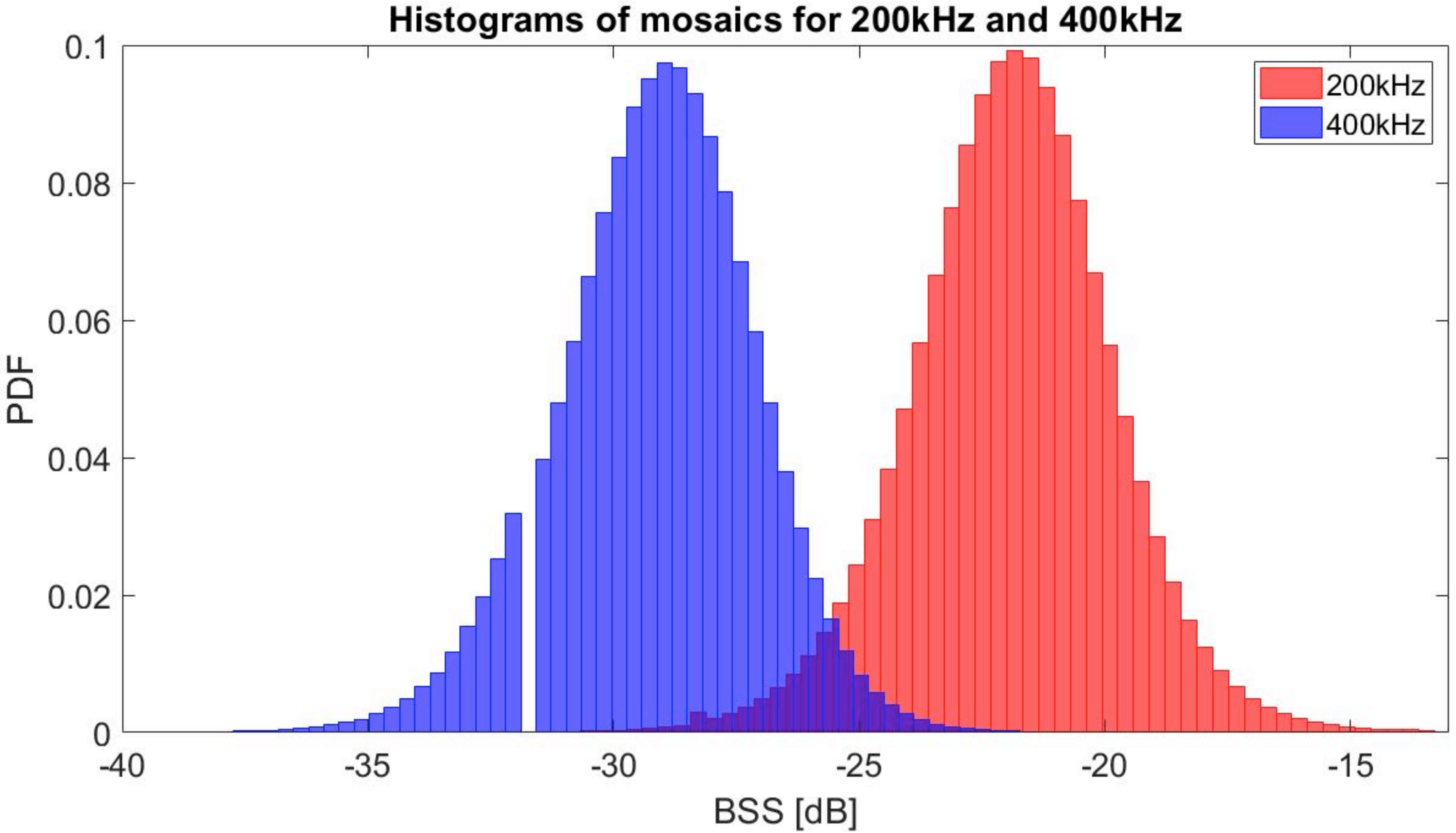
Backscatter mosaics

200kHz

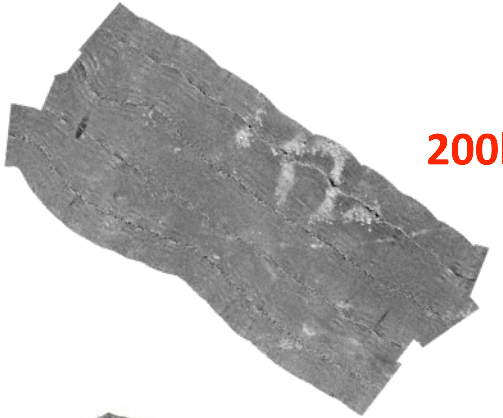


400kHz

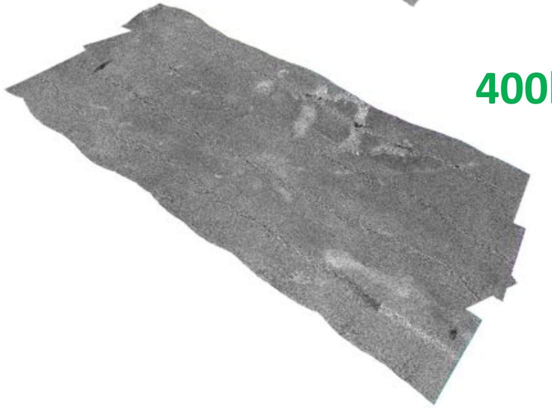



Histograms of mosaics for 200kHz and 400kHz
0.1
0.08
0.06
0.04
0.02
0
PDF
-40
-35
-30
-25
-20
-15
BSS [dB]
200kHz
400kHz

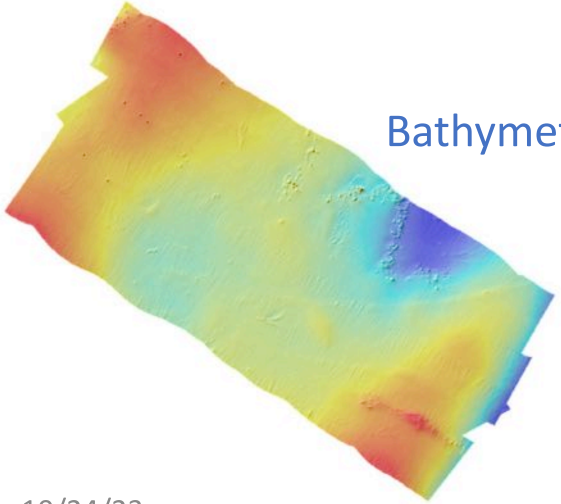
Multi-band backscatter idea



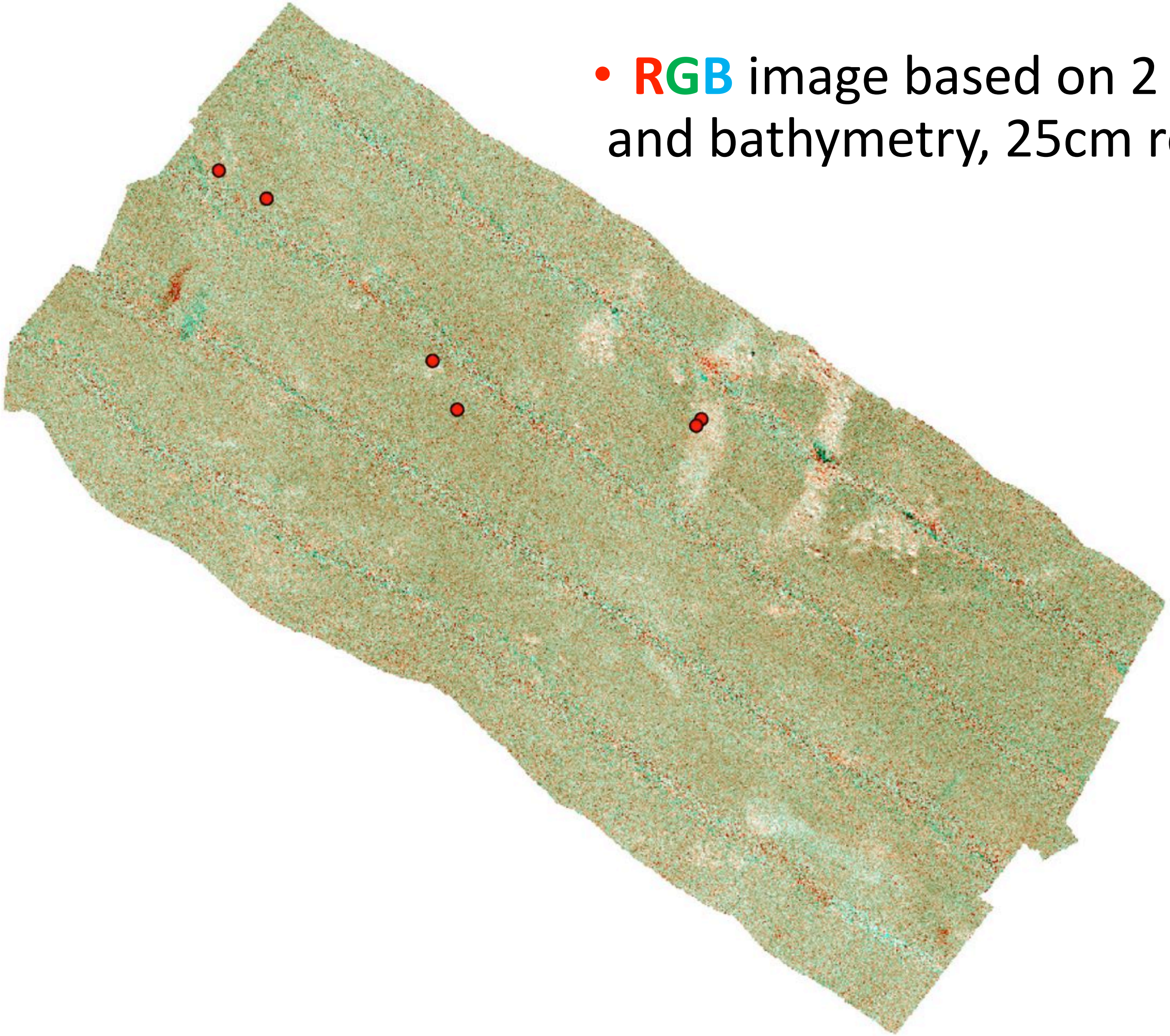
200kHz



400kHz



Bathymetry



- **RGB** image based on 2 mosaics and bathymetry, 25cm resolution

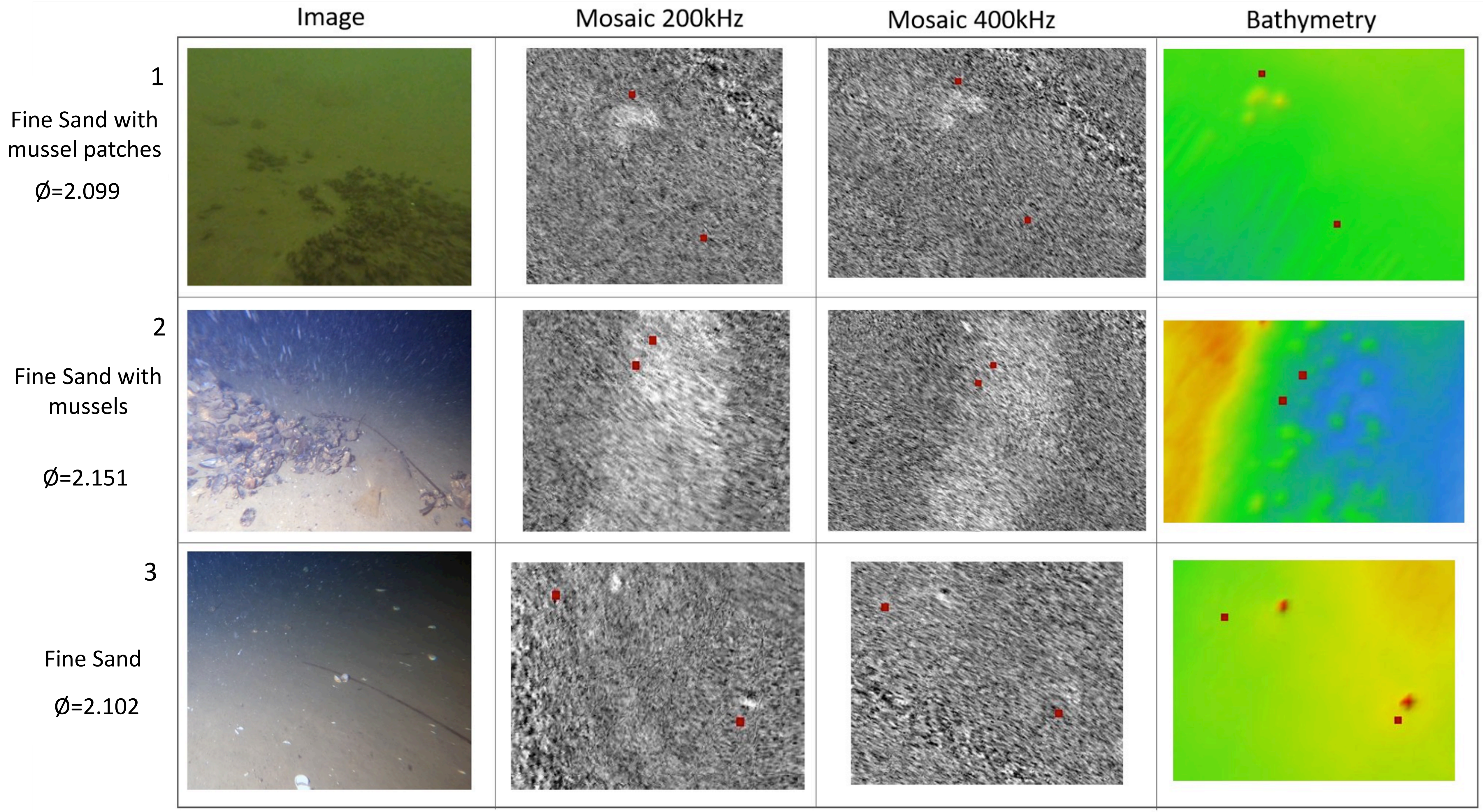
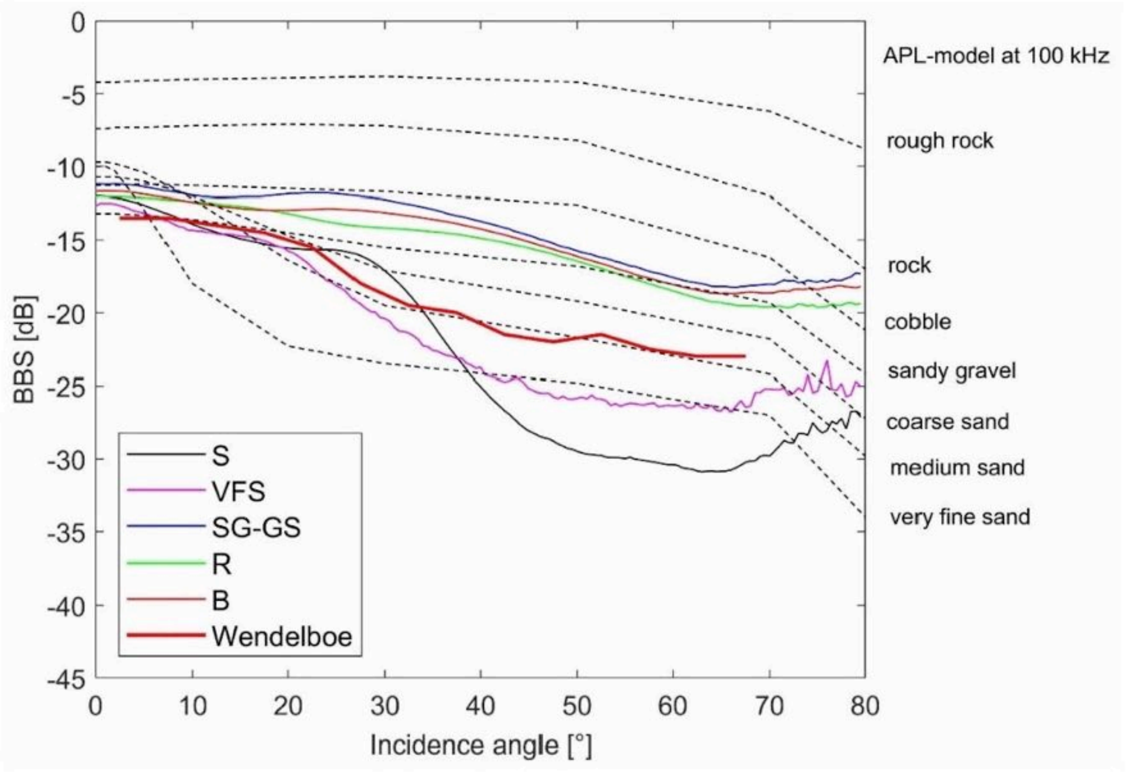


Image
Mosaic 200kHz
Mosaic 400kHz
Bathymetry
1
Fine Sand with mussel patches
Ø=2.099
2
Fine Sand with mussels
Ø=2.151
3
Fine Sand
Ø=2.102

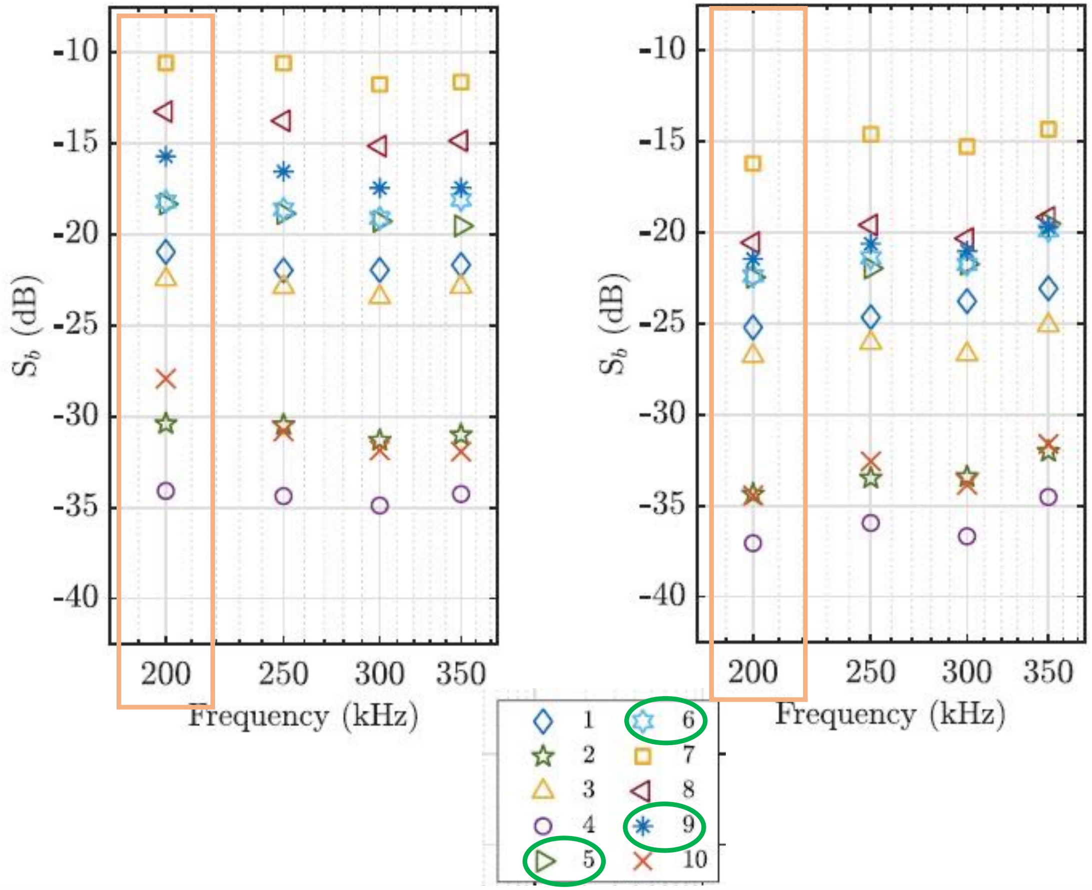
Backscatter angular dependance

Results from other articles



Trzcińska et al. 2021

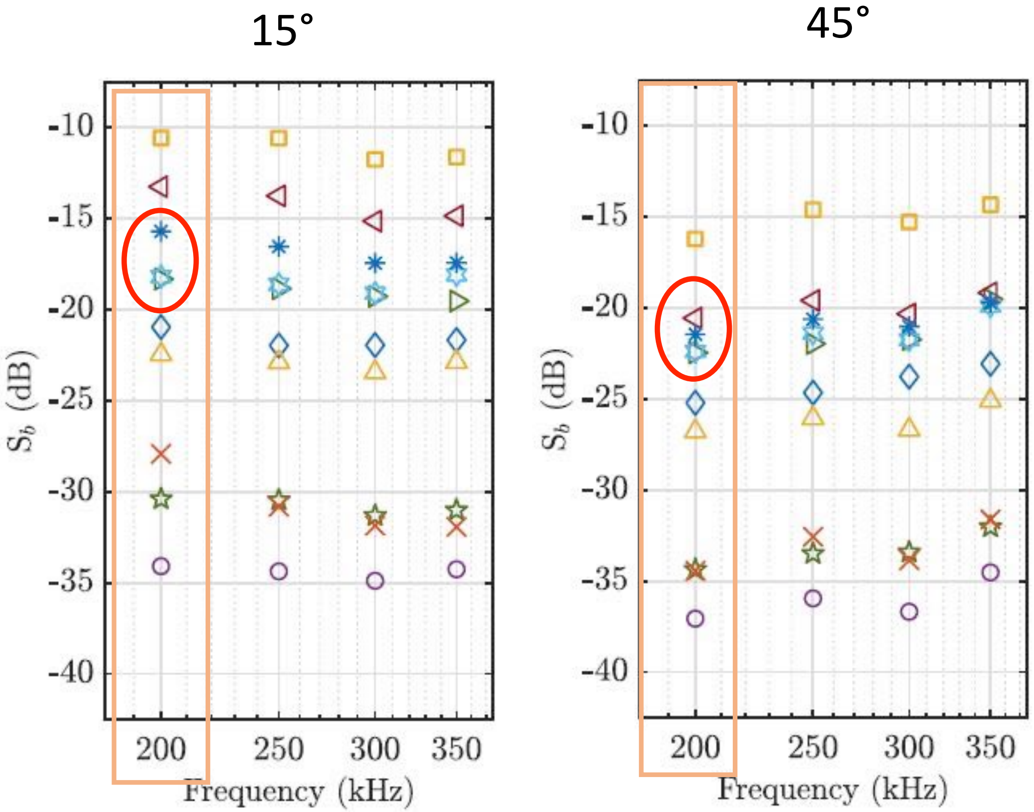
15° Incidence angle 45°



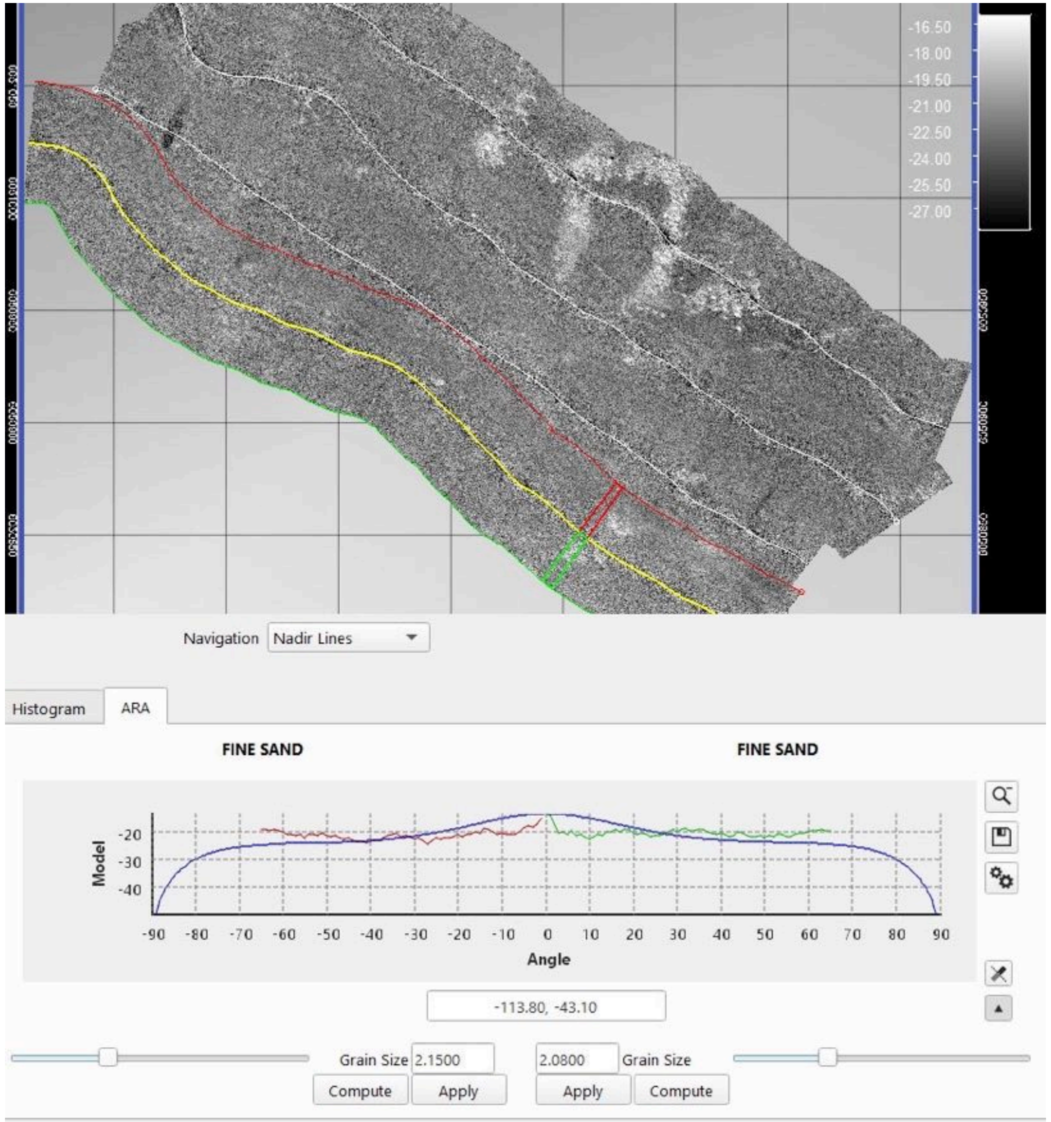
Site/DCSS number	1	2	3	4	5	6	7	8	9	10
M_z (ϕ)	3.14	6.14	3.54	7.11	2.11	1.91		1.28	2.08	5.92

Wendelboe et al. 2023

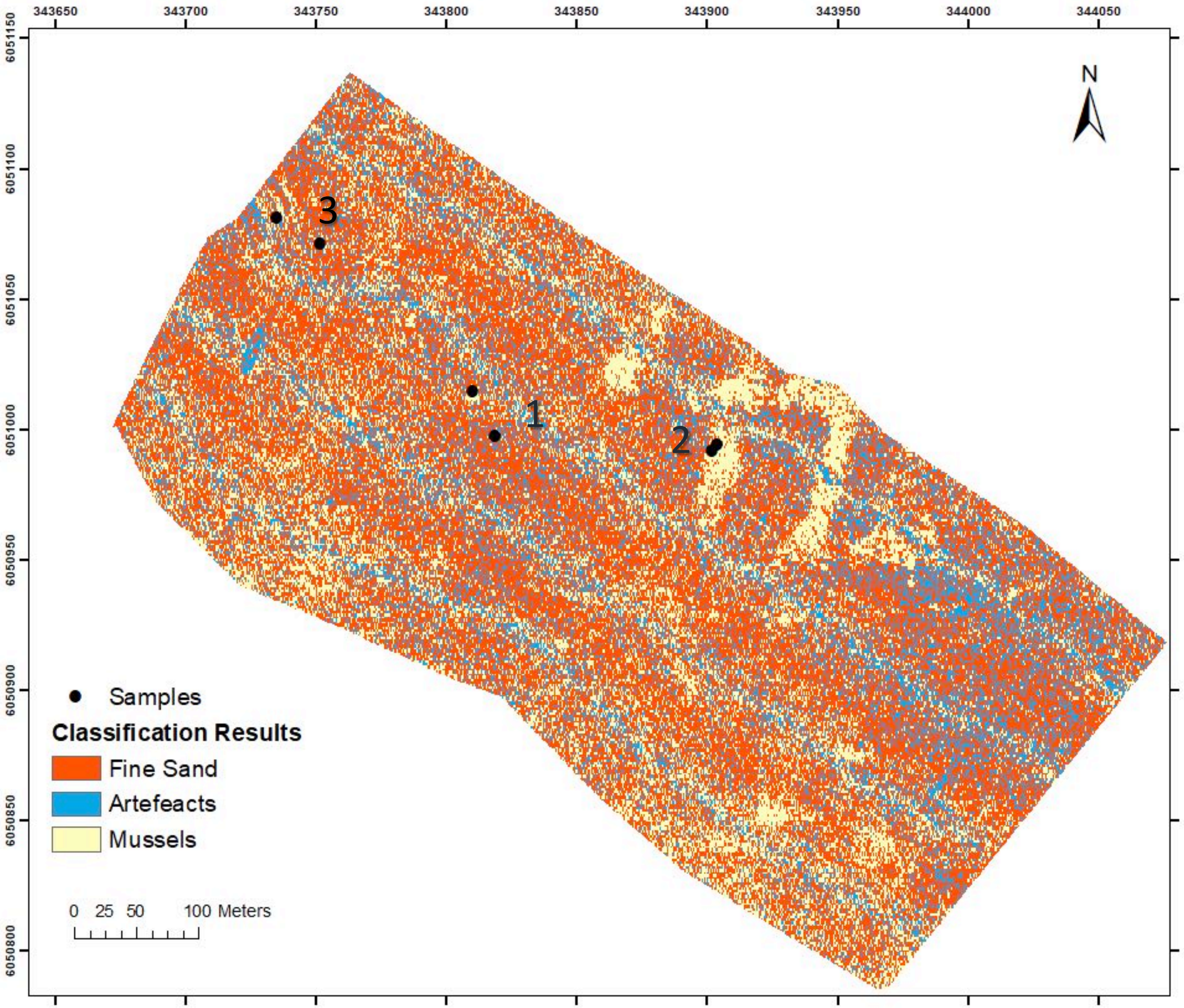
QPS FMGT Geocoder Sediment Type Estimation



Wendelboe et al. 2023



Classification results



Object Based Image Analysis with Bathymetry and Backscatter (200kHz & 400kHz) as input layers

Summary

1. Calibrated backscatter obtained during tests is in agreement with theoretical models.
2. Backscatter strength is reflecting seabed grain size composition.
3. Mussels are not included in theoretical model but they have different acoustic response comparing with bare bottom.
4. Using 2 frequencies and bathymetry layer it is possible to extract and distinguish areas with different habitats (sand or mussels colonies on sand).
5. Different frequencies give variable input to acoustic reflection of seabed thus support further classification algorithms .

Thank you for your attention