Mapping seabed sediments with single- and multifrequency multibeam backscatter data

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Hydrographic Society Benelux Workshop

6th of March 2019

Overview

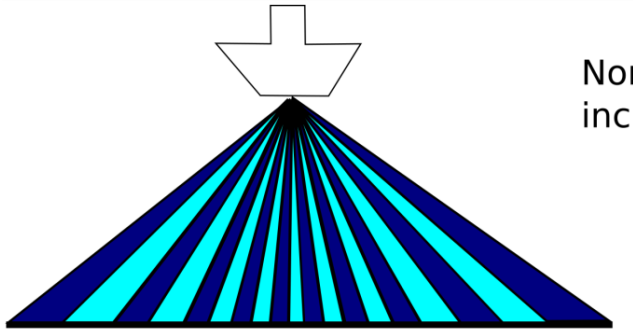
1) **Introduction**
   - Acoustic Backscatter
   - Sediment Classification

2) **Single-frequency backscatter classification**
   - Cleaverbank (Dutch North Sea)

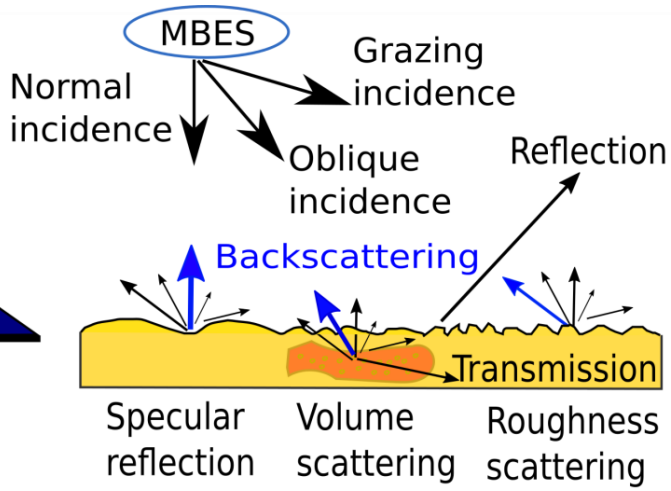
3) **Multi-frequency backscatter classification**
   - Bedford Basin (Canada)

Multibeam echosounder (30 – 700 kHz)

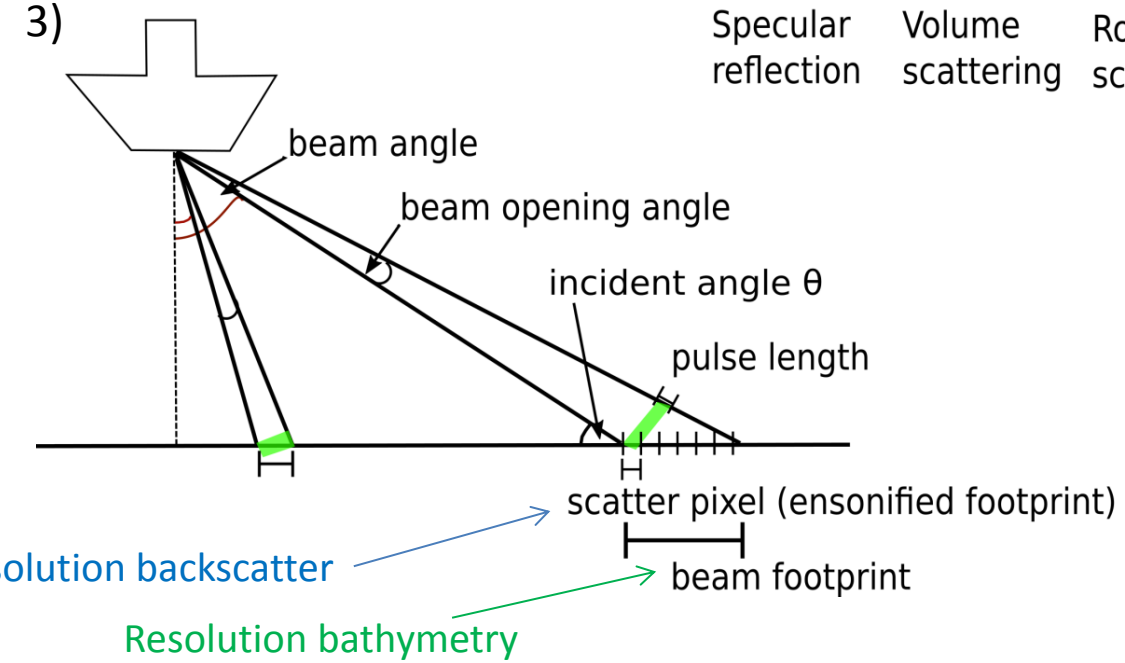
1)



2)

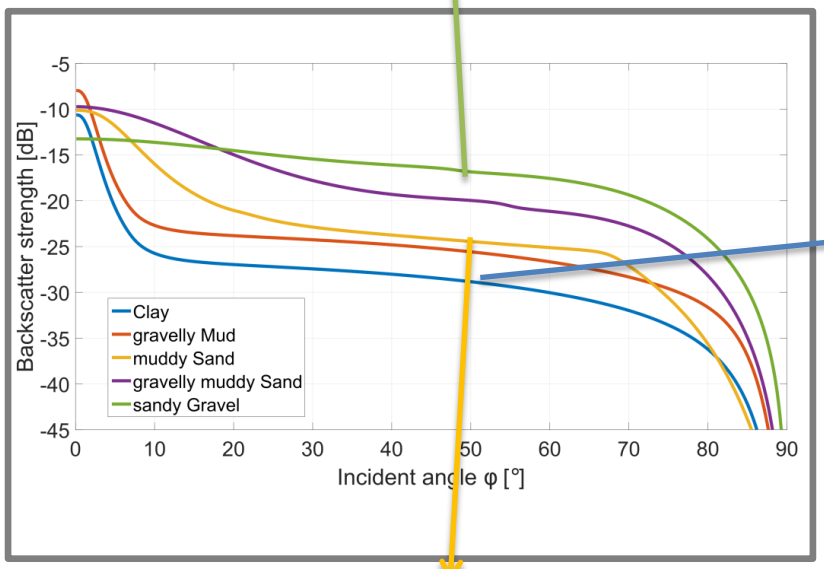


3)



Backscatter strength is dependent on

- **seabed properties**
- **incident angle**
- **frequency**



Classification

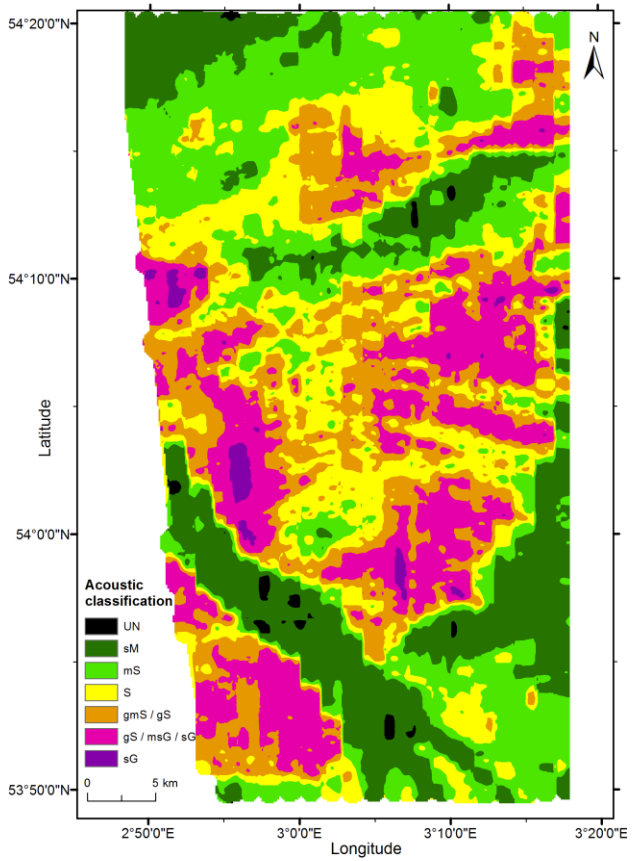
Uses *features* or *parameters* to characterize an object

Features: backscatter, bathymetry, slope etc.

Object: sediment types, benthic habitats

Method: unsupervised (e.g. TU Delft methods)

supervised (e.g. machine learning)



Reference: [1]

Unsupervised seabed classification

BS is dependent on seabed properties, ~~incident angle~~ and ~~frequency~~

Reference: [2]

Applied to:
- Backscatter from a single frequency
- Backscatter from a single beam angle

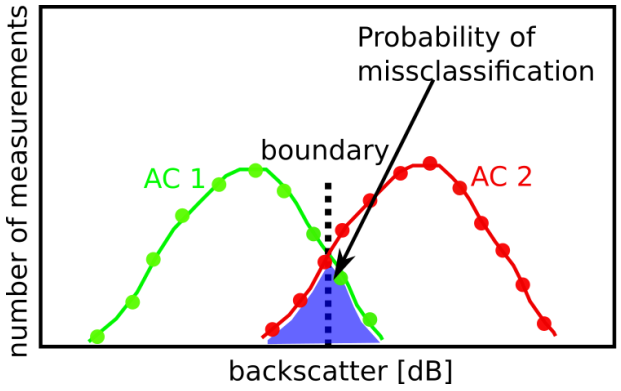
>>> sediments along the swath can be resolved

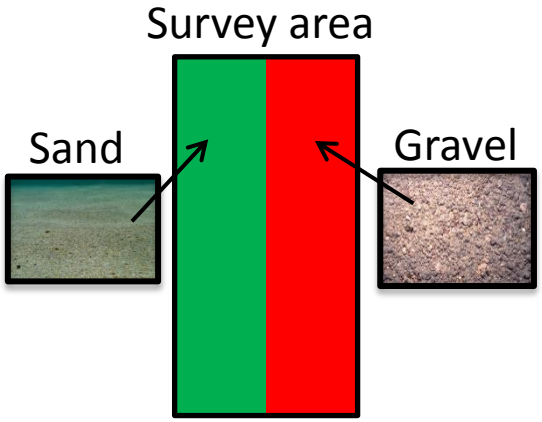
Theory

Requirement:
Sufficient number of measurements
⟶ follows Gaussian distribution

Result:
Gaussian = specific substrate

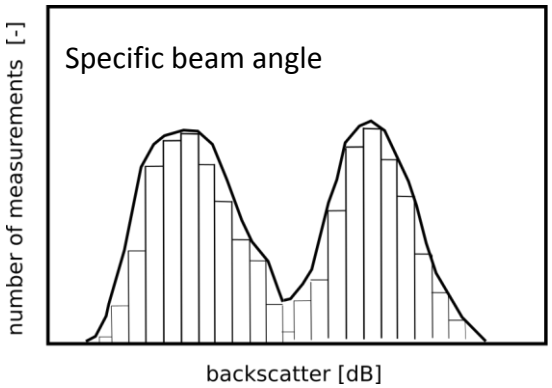
Statistical estimates:
-BS boundaries between sediment types
⟶ Acoustic class (AC)
-probability of missclassification



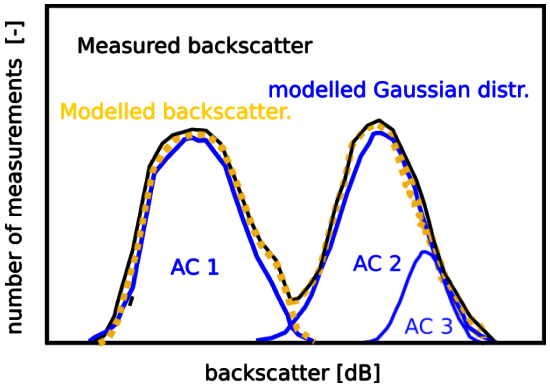


Example

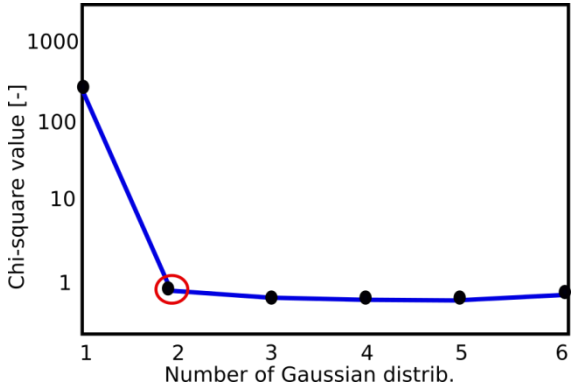
Measured backscatter histogram



Fit of Gaussian distribution



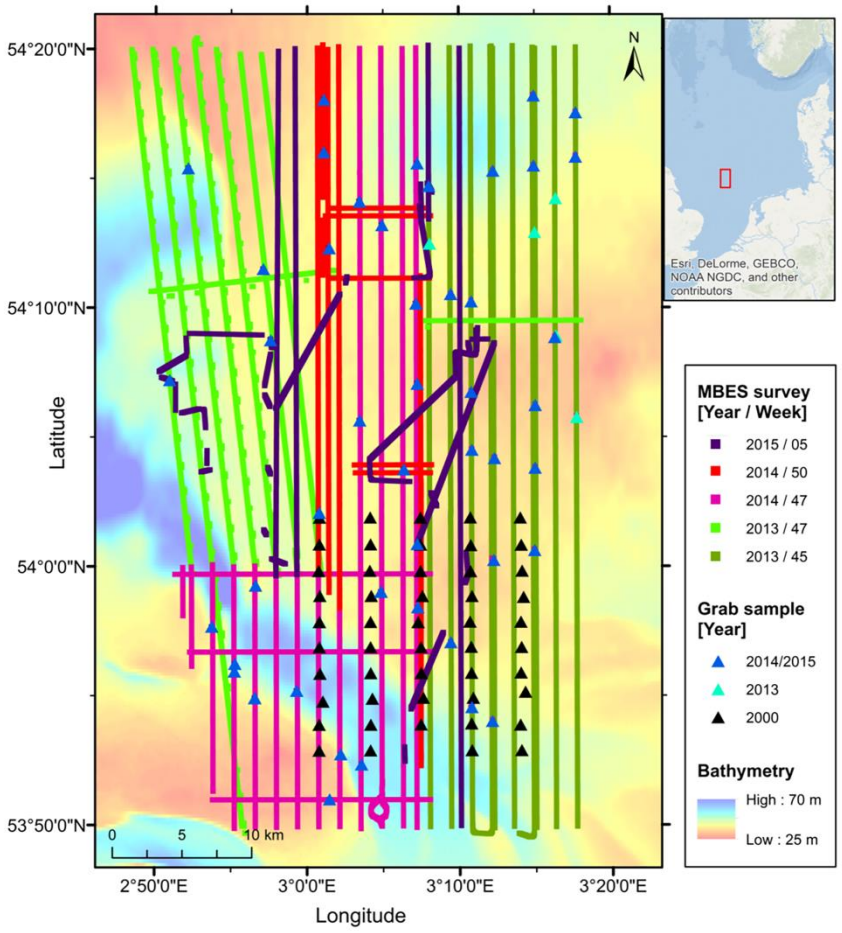
Chi-square test



Single-frequency Classification

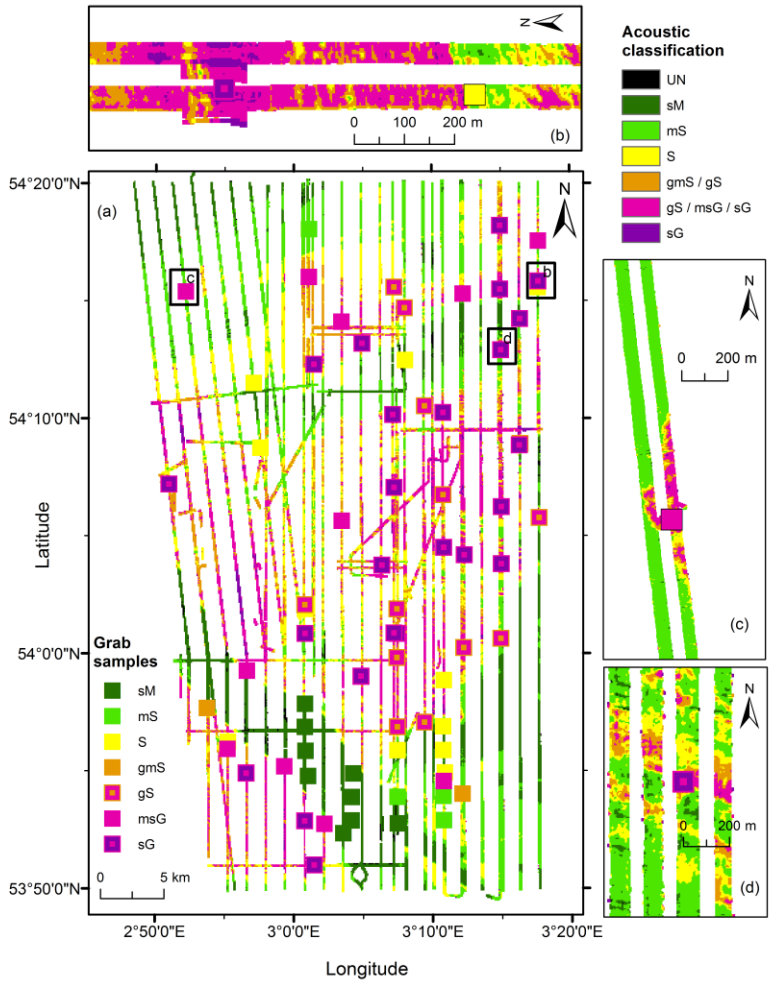
Cleaver Bank –Survey area

- Kongsberg EM 3002 – 300 kHz



Seabed substrate maps

- Multibeam backscatter
- Ground truth samples
  - ➢ Acoustic seabed classification

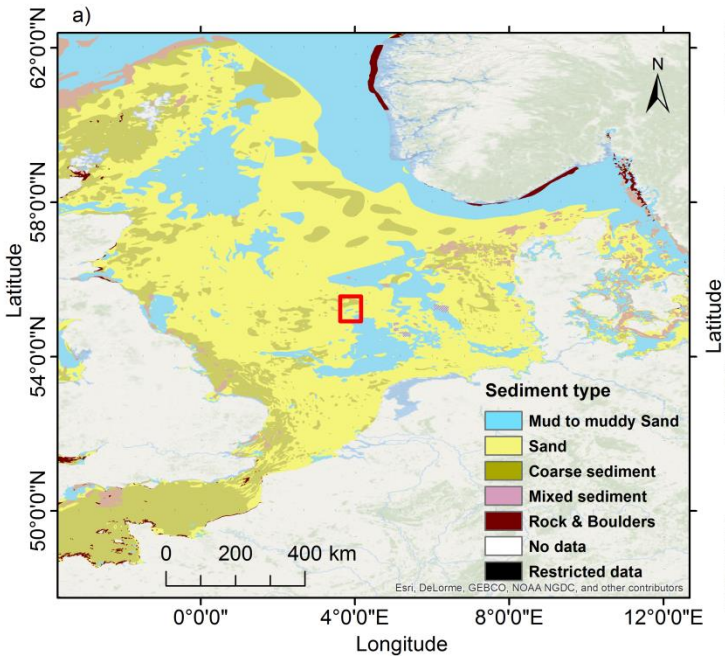


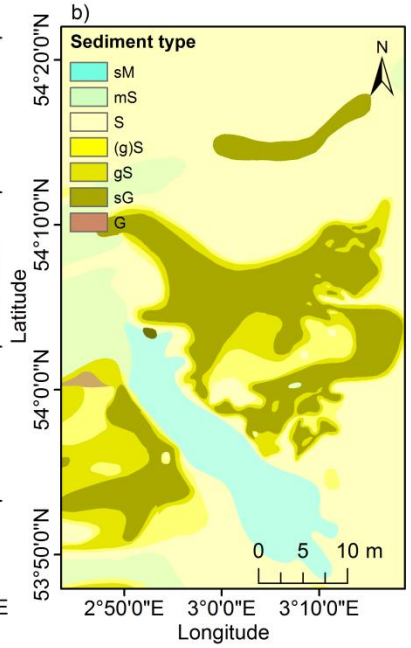
Reference: [3]

Single-frequency Classification

Seabed substrate maps (EMODnet portal)

- Samples
- Bathymetry
- Seismic
  - ➢ Manual interpretation





Seabed substrate maps

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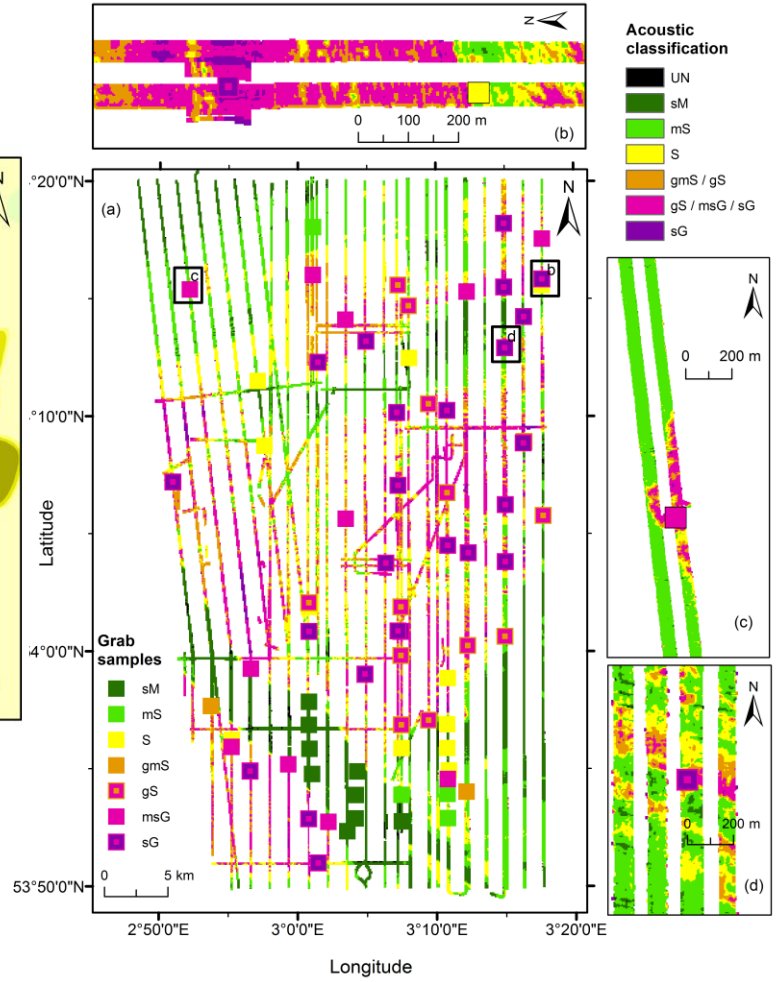
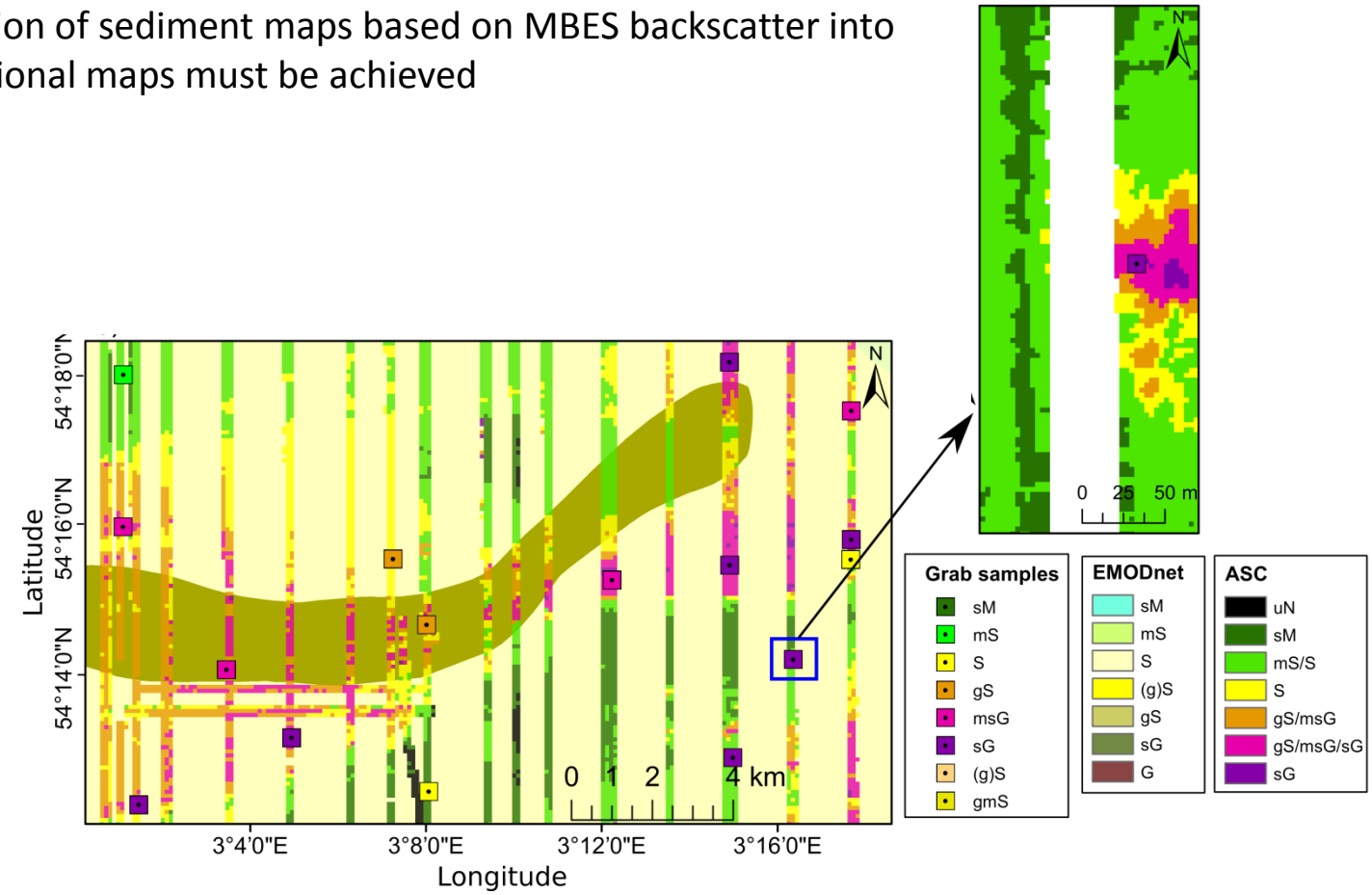


Reference: [1], [3]

Traditional vs. Acoustic sediment maps

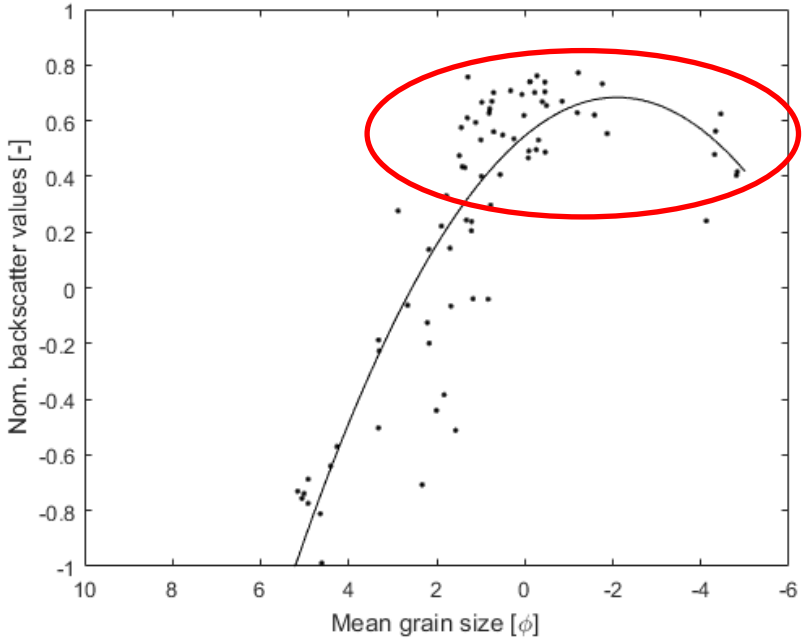
Sediment classification based on MBES backscatter yields to much finer spatial discrimination of sediments

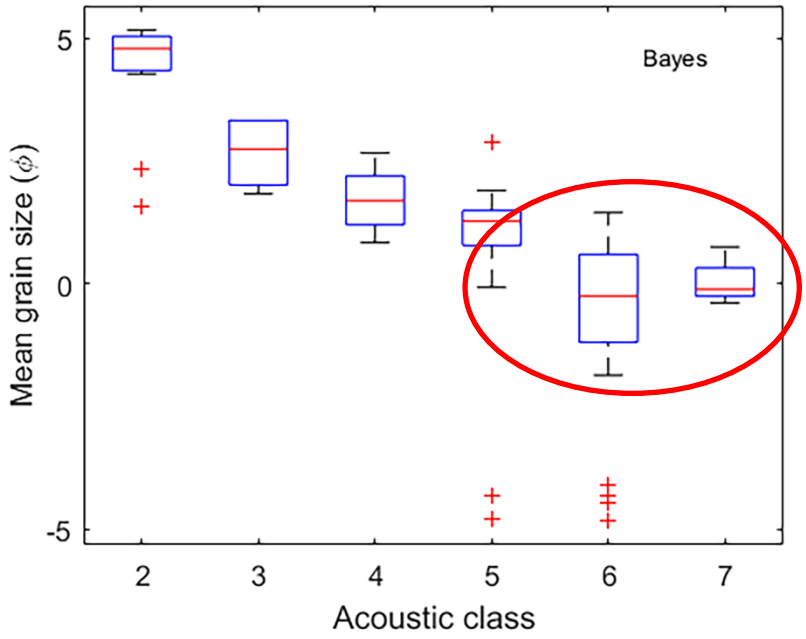
- Enables sediment maps with high spatial coverage and resolution
- Integration of sediment maps based on MBES backscatter into conventional maps must be achieved



Reference: [1]

Correlation between Acoustics and Ground Truth





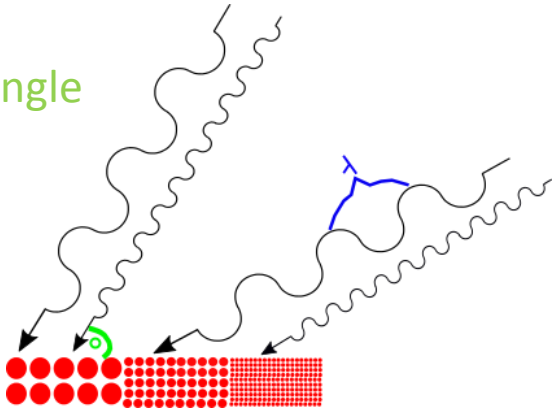
- Ambiguity observed for coarse sediments (~gravelly sand to sandy gravel)

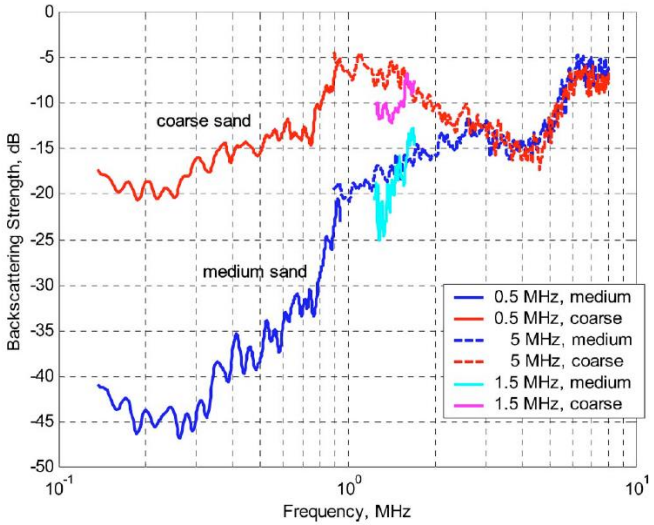
➡ Multifrequency backscatter might be a solution to solve this ambiguity

Reference: [3]

Increasing the acoustic discrimination by using multi-frequency backscatter

Acoustic backscatter is dependent on seabed properties, incident angle and **frequency**





Reference: [4]

<u>Frequency dependency of acoustic backscatter</u>

Acoustic wavelength influences:

(1) Relationship to (seabed) roughness

(2) Signal penetration depth (Volume scattering)

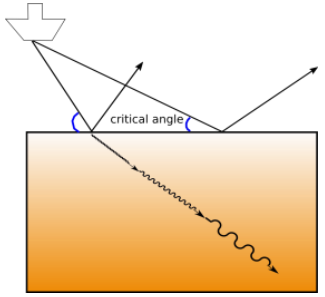
(3) Scattering regime (Rayleigh to geometric scattering)

What are the challenges?

1) Appropriate data processing for multi-frequency data

2) Classification method to combine information from different frequencies in a single map

3) What part of the seabed is represented per frequency



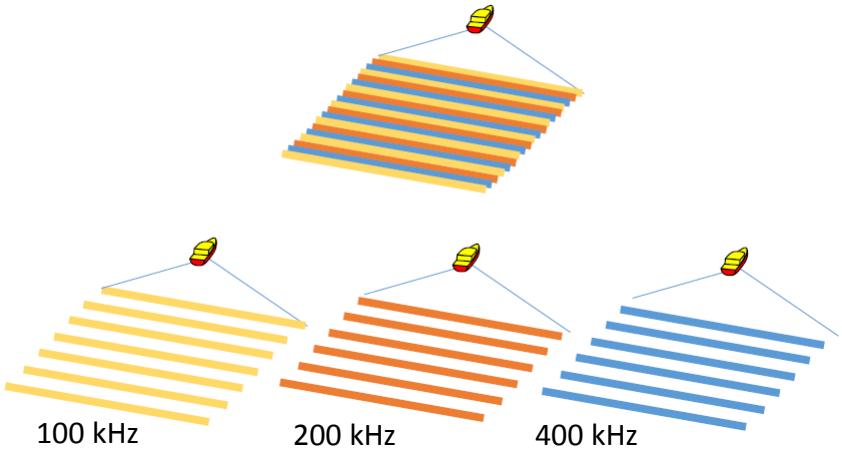
R2 Sonic 2026

Broadband multibeam system

- 90 kHz
- 200-450 kHz, 1 Hz granularity
- Up to 5 frequencies on a ping-by-ping basis

Single mapping campaign, Single vessel, single sensor provides sampling over widely spaced frequencies

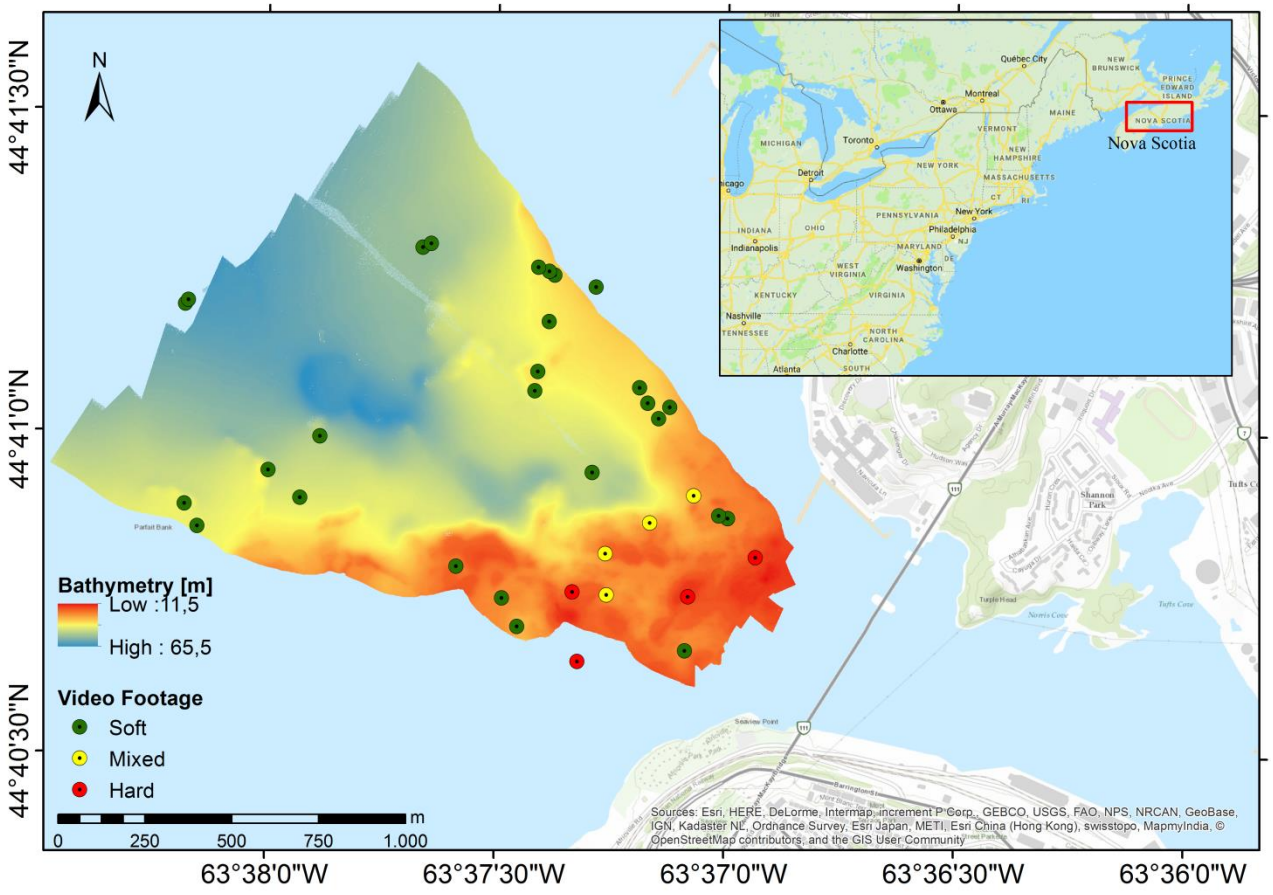
Multispectral mode



Survey area – Bedford Basin (Canada)

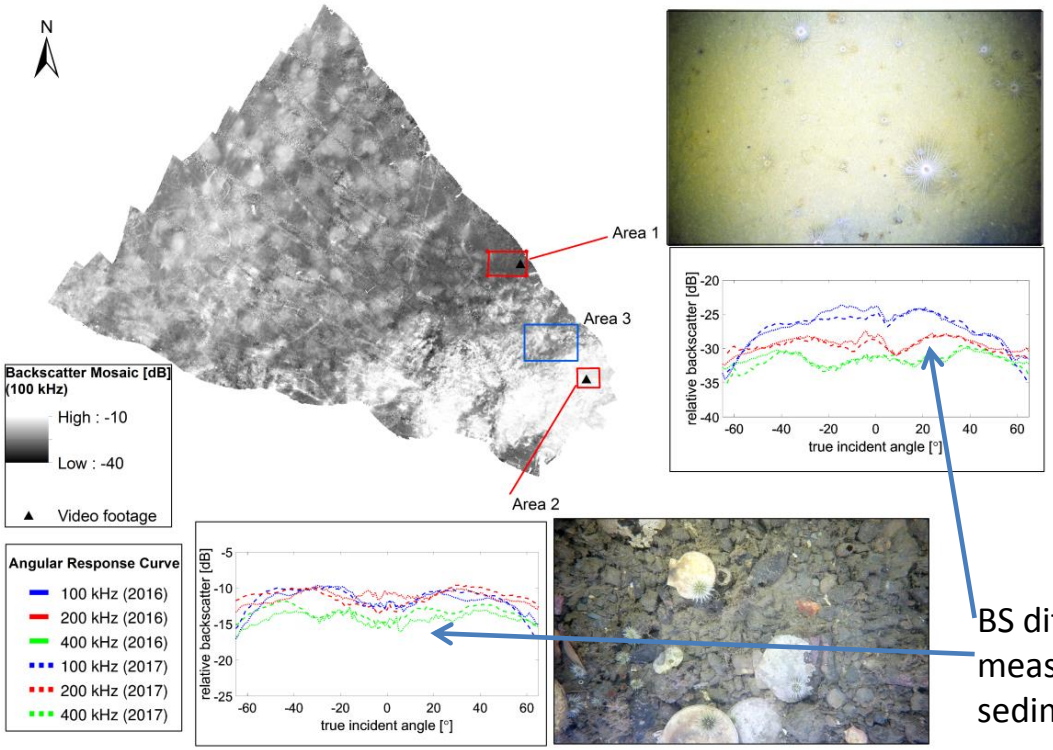
- 2 surveys in 2016 and 2017
- 100, 200 and 400 kHz
- Video footage

Bathymetry map 2016



Influence of frequency on:

- Receiver sensitivity
- Ensonification area of signal
- Absorption
- Directivity pattern at transmission
- Directivity pattern at receptions
- Gains



Verification of data processing

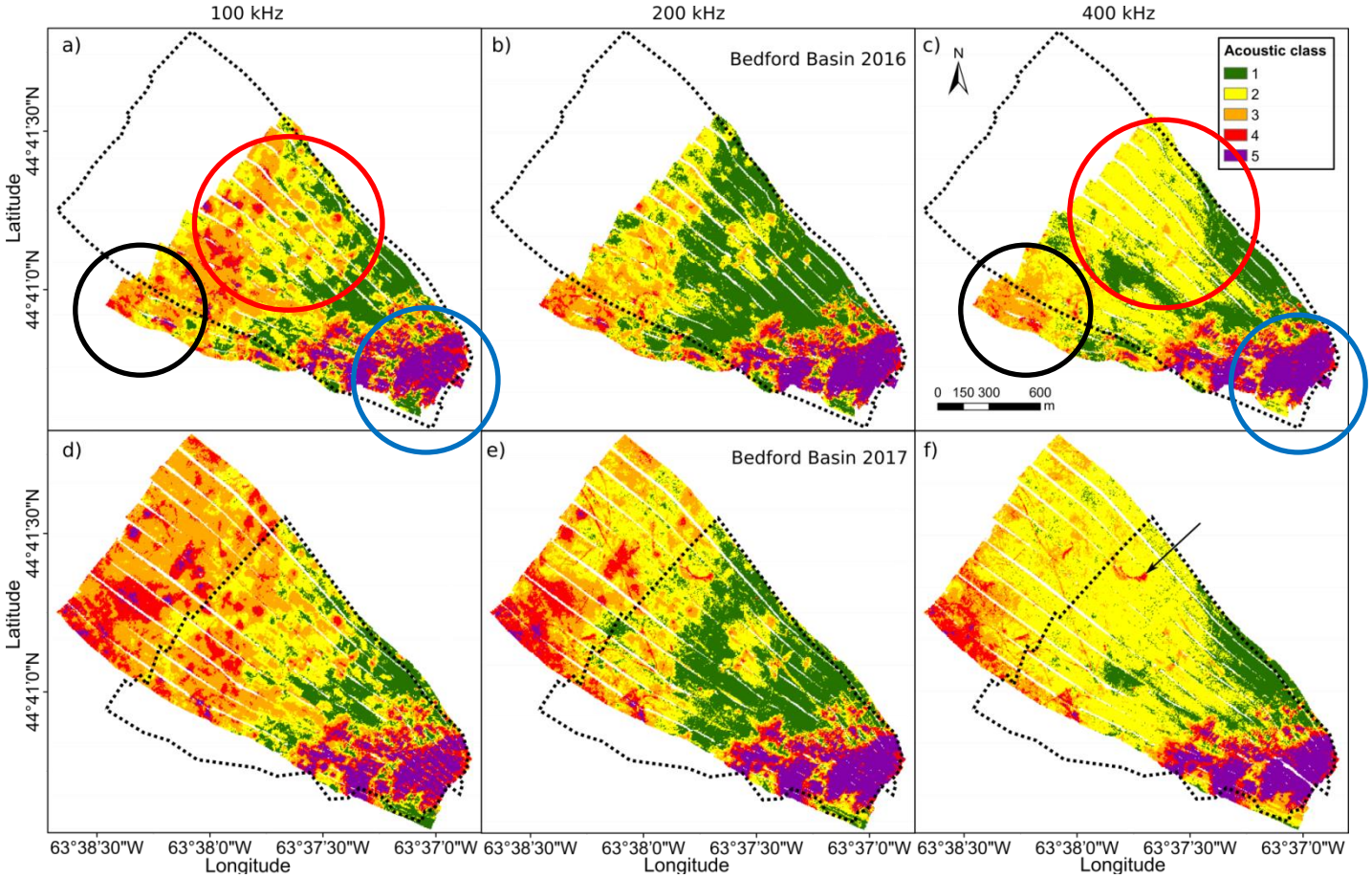
- 2 homogeneous areas (soft and hard sediment)
- Consistent ARC's between MBES backscatter measurements in 2016 and 2017
  >>>indicates correct processing

BS difference between 2016 and 2017 measurements per frequency and sediment type lower than 1 dB in average

Reference: [5]

Multispectral classification

Single-frequency classification maps



Reference: [5]

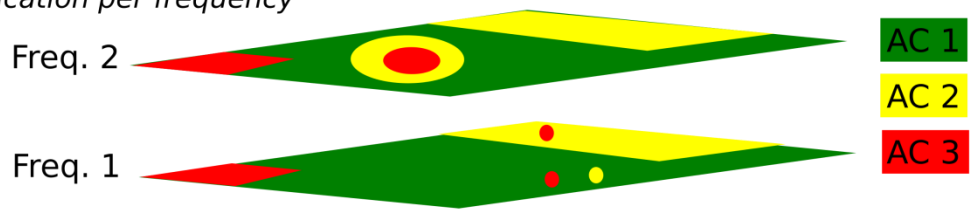
Observations

- Different spatial acoustic patterns at each frequency
- Observed frequency dependency of BS
  - Fine sediment (~mud)
  - Coarse sediment (gravel, shell, reef)

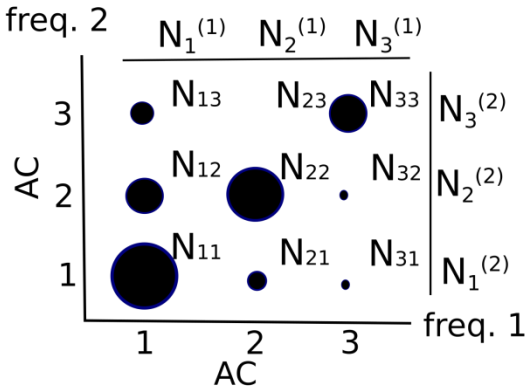
How to combine these information into a single map?

Multispectral Bayesian Classification - Workflow

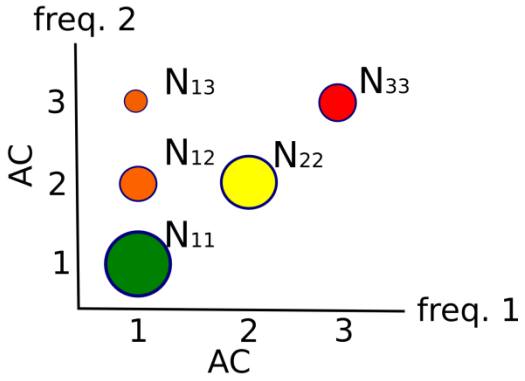
Step 1
Classification per frequency



Step 2
Error matrix



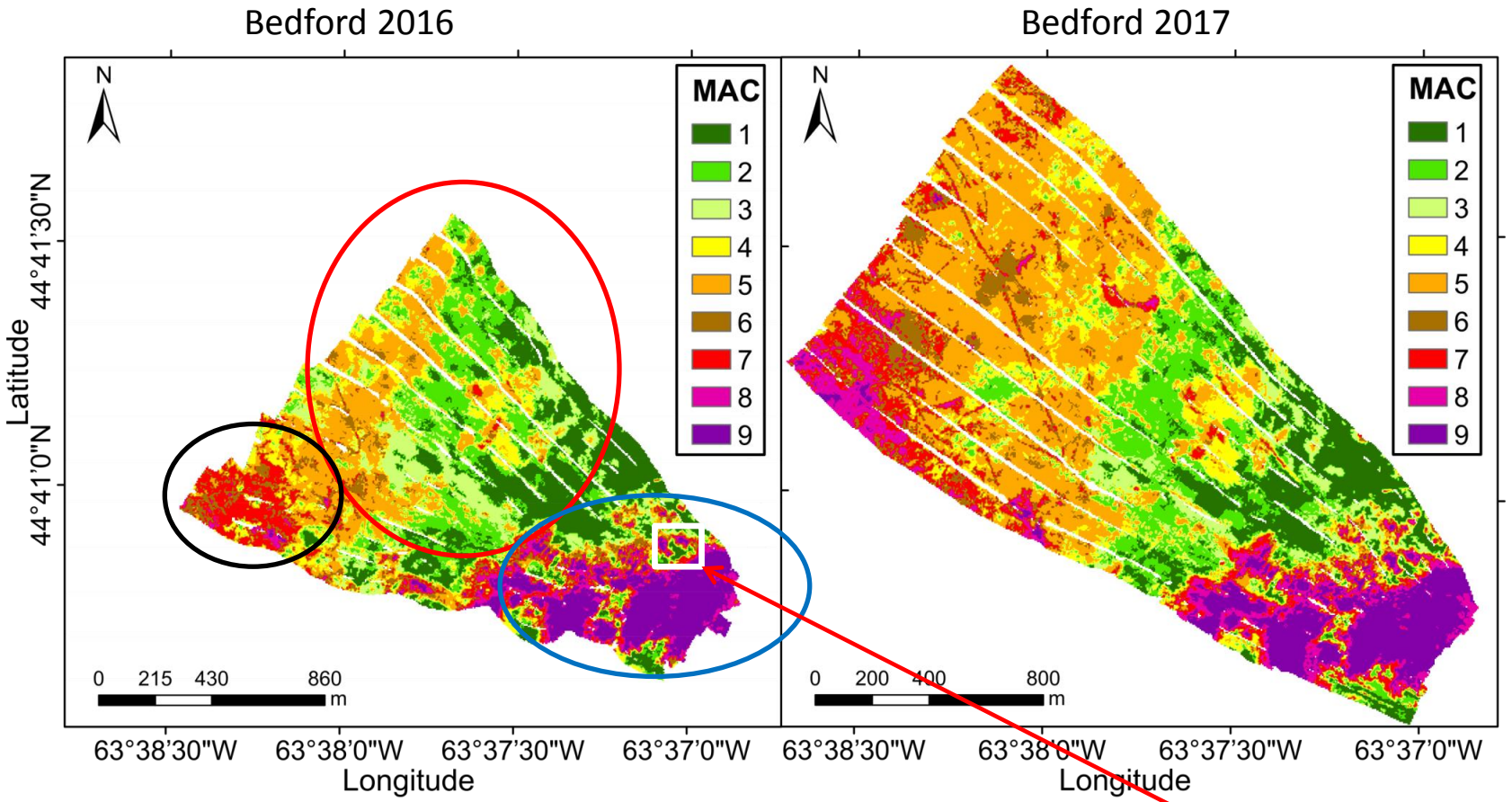
Step 3
Statistical significane test



Step 4
Classification based on multiple frequencies

Reference: [5]

Multi-frequency classification maps

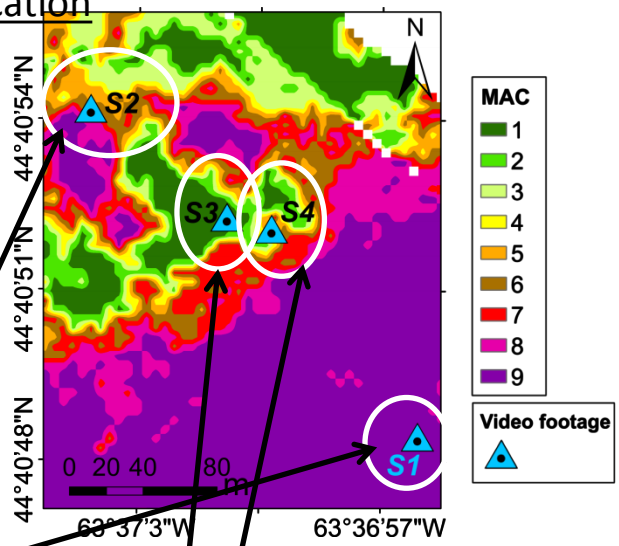


- Acoustic information per single frequency are combined in a single map
- Robust and repeatable classification method for multispectral backscatter data
- Most benefit is visible for fine sediments (for this specific survey area)

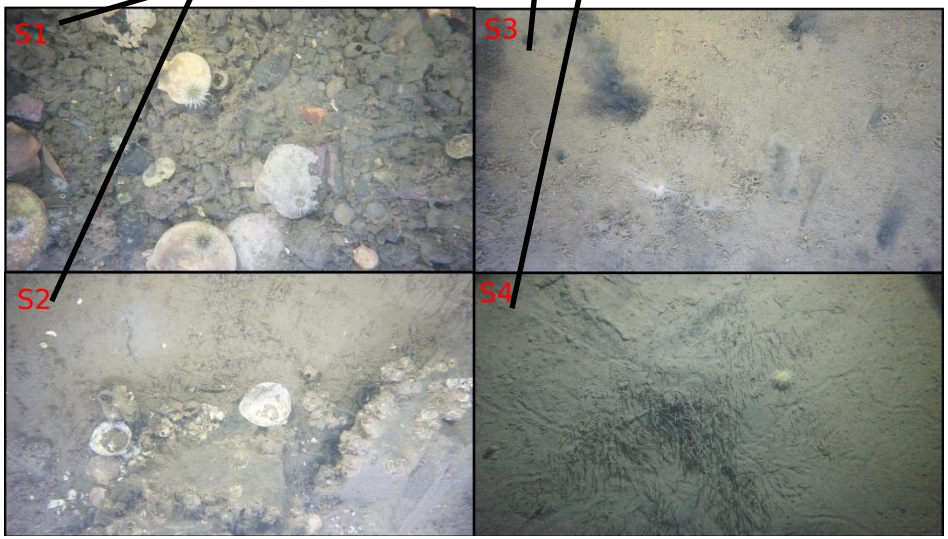
Reference: [5]

Qualitative comparison with video footage

Multispectral acoustic classification



Video footage



S1 extensively hard sediment (gravel, boulders, shell, coral)

S2 mix hard (gravel, boulders, shell, coral) and soft sediment (mud, fine sand)

S3 soft sediment (mud, fine sand) with flora and gas seeps

S4 soft sediment (mud, fine sand) with flora and fauna

Reference: [5]

Reference List

[1] Gaida, T.C.; Snellen, M.; van Dijk, T.A.G.P.; Simons, D.G. Geostatistical modelling of multibeam backscatter for full-coverage seabed sediment maps. Hydrobiologia **2018**, 1–25

[2] Simons, D.G.; Snellen, M. A Bayesian approach to seafloor classification using multi-beam echo-sounder backscatter data. Appl. Acoust. **2009**, 70, 1258–1268.

[3] Snellen, M.; Gaida, T.C.; Koop, L.; Alevizos, E.; Simons, D.G. Performance of multibeam echosounder backscatter-based classification for monitoring sediment distributions using multitemporal large-scale ocean data sets. IEEE J. Ocean. Eng. **2019**, 44, 142–155.

[4] Ivakin, A.N.; Sessarego, J. High frequency broad band scattering from water-saturated granular sediments: Scaling effects. J. Acoust. Soc. Am. **2007**, 122, 165–171.

[5] Gaida, T.C.; Tengku Ali, T. A.; Snellen, M.; Amiri-Simkooei, A.; van Dijk, T. A. G. .P.; Simons, D.G. A multispectral Bayesian Classification method for increased discrimination of seabed sediments using multi-frequency multibeam backscatter data Geoscience **2018**, 8, 455

Thank you very much for your attention

The research was supported by following organisations and companies:

TU Delft

Boskalis

Deltares
Enabling Delta Life