Future perspectives on multibeam backscatter (and seabed classification)

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Future Perspectives:

Why we want to do this?

Common Approaches to Classification/Characterization

- Textural
- Angular Response

The Challenges:

- Topographic or Textural Signature?
  - Slope Corrections
- Roughness v. Volume v. Impedance
  - Why we need near normal incidence.
  - If we can't have that, why changing wavelength could help.

What goes wrong with surface-based surveys

- Unavoidable Altitude (Depth) Dependence

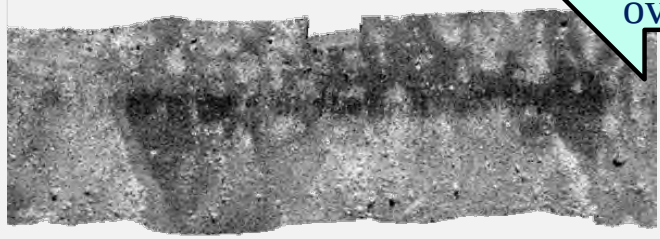
How you can quantify this using AUVs

Multi-Spectral – a means of resolving the ambiguities.

NOAA's two seabed mapping mandates:

Nautical Charting
(Hydrography)

bathymetric terrain delination

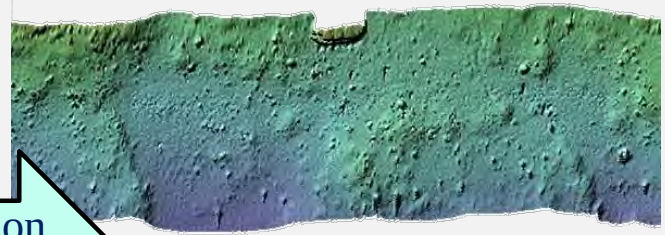


Mission overlap

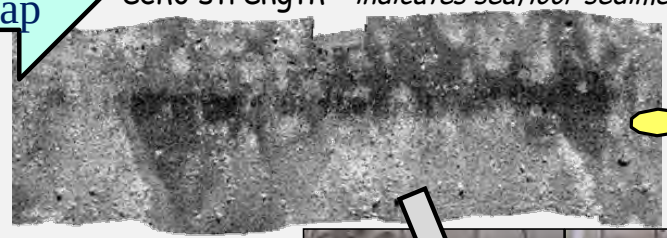
Safety of Navigation

Precisely referenced to **Lower Low Water**
With coverage, accuracy and resolution
defined by the
International Hydrographic Organization

Seabed Ecosystem Surveys
(Habitat Definition)



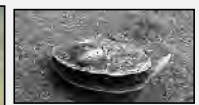
echo strength - *indicates seafloor sediment*

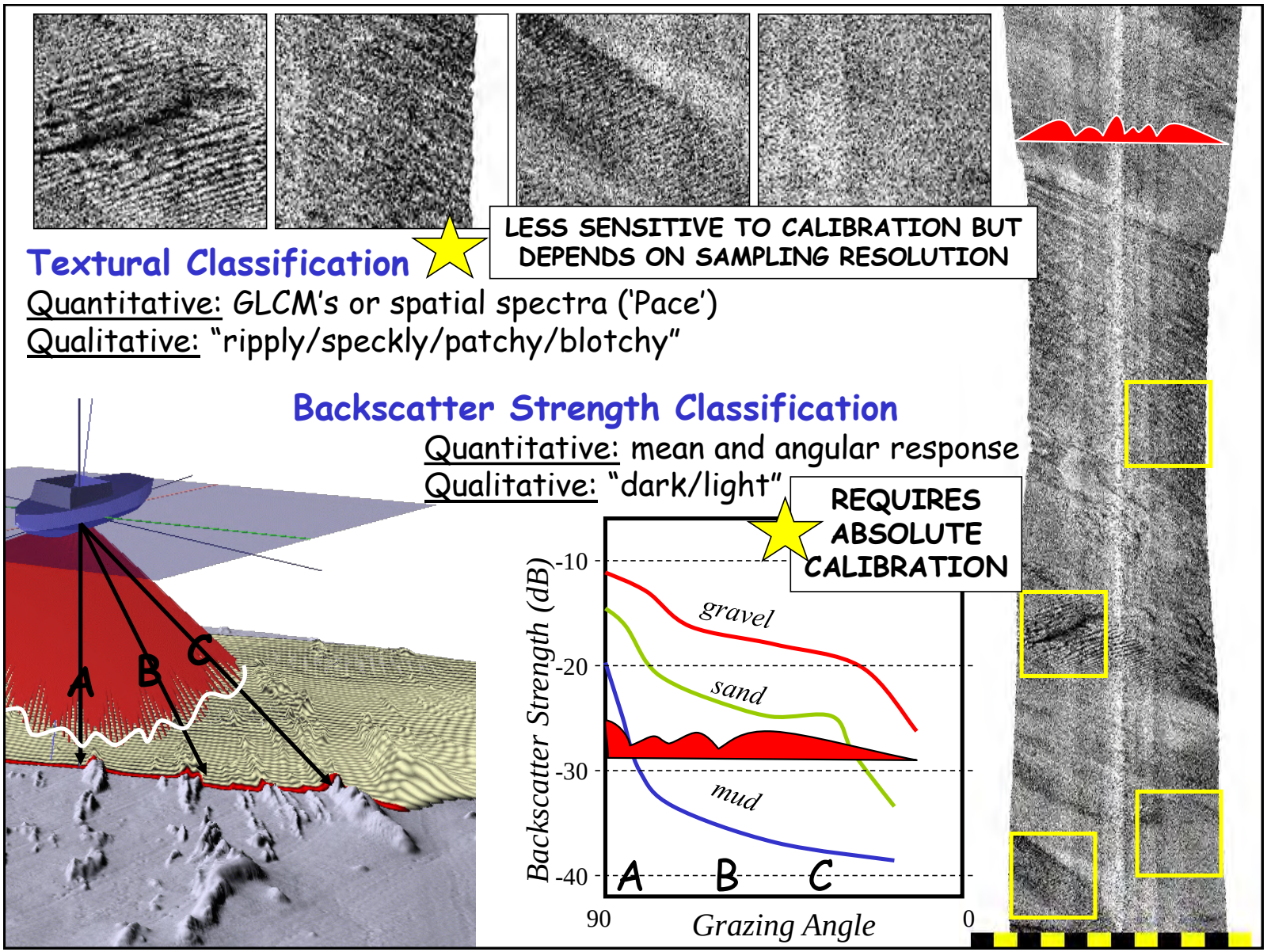


+camera +grabs
+biology +chemistry

Living Resource Habitat
(Ecosystem Studies)

Magnuson-Stevens Act,
Endangered Species Act,
Marine Mammal
Protection Act.



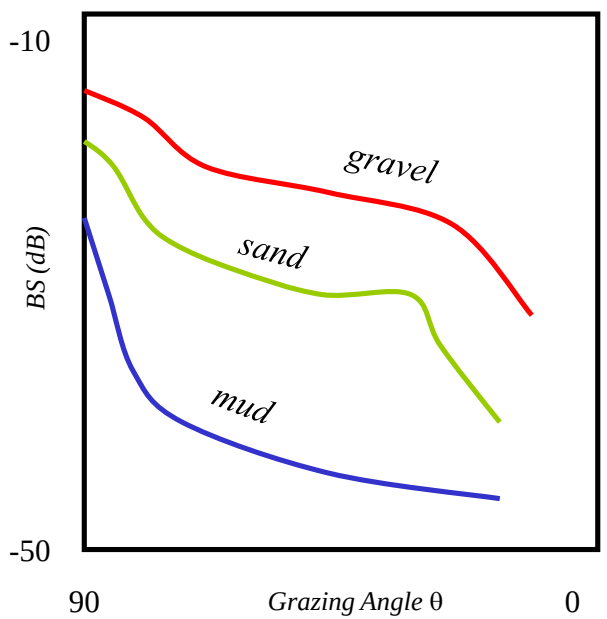

LESS SENSITIVE TO CALIBRATION BUT DEPENDS ON SAMPLING RESOLUTION
Textural Classification
Quantitative: GLCM's or spatial spectra ('Pace')
Qualitative: "ripply/speckly/patchy/blotchy"
Backscatter Strength Classification
Quantitative: mean and angular response
Qualitative: "dark/light"
REQUIRES ABSOLUTE CALIBRATION
A
B
C
Backscatter Strength (dB)
-10
-20
-30
-40
gravel
sand
mud
90
Grazing Angle
0

How the shape of the :

Angular Response Curve

varies with the

Driving Physical Properties.



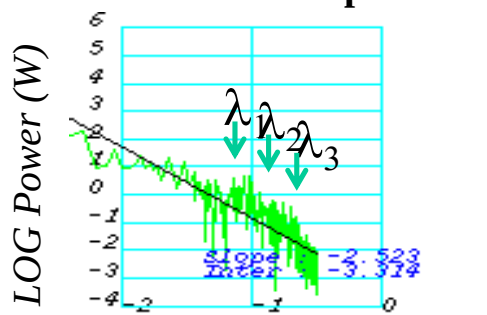
Symbol	Definition	Short Name
ρ	ratio of sediment mass density to water mass density	density ratio
v	ratio of sediment sound speed to water sound speed	sound speed ratio
δ	ratio of imaginary wave number to real wave number for the sediment	loss parameter
σ_2	ratio of sediment volume scattering cross section to sediment attenuation coefficient	volume parameter
γ	exponent of bottom relief spectrum	spectral exponent
W_2	strength of bottom relief spectrum (cm^4) at wave number $2\pi/\lambda = 1\ cm^{-1}$	spectral strength

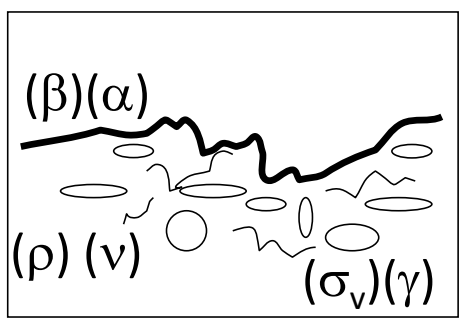
Controlling Sediment Physical Properties

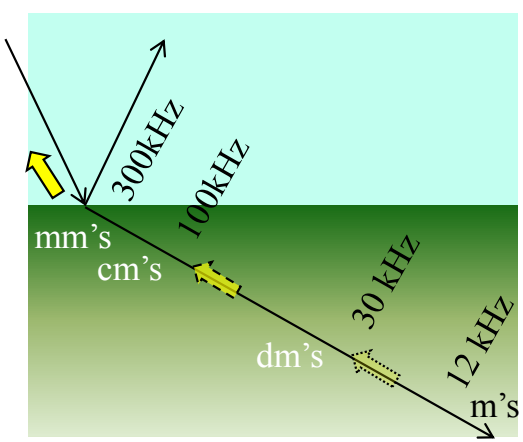
- Impedance Terms
  - sediment bulk density (ρ)
  - sediment sound speed (ν)
- Roughness Terms
  - spectral strength (β)
  - spectral exponent(α)
- Subbottom Terms
  - volume parameter (σ_v) *(scattering due to heterogeneity)*
  - Loss parameter (γ) *(sediment attenuation coefficient)*

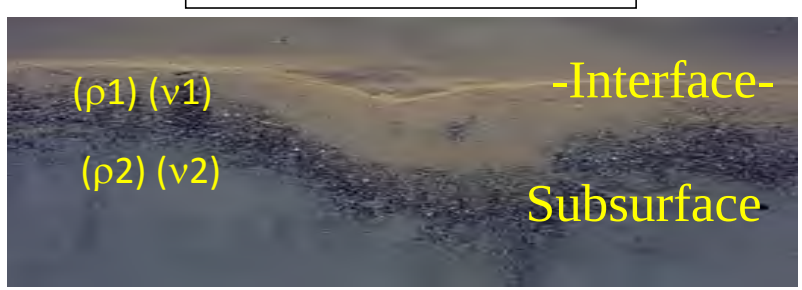
Frequency Dependent

Interface Power Spectra



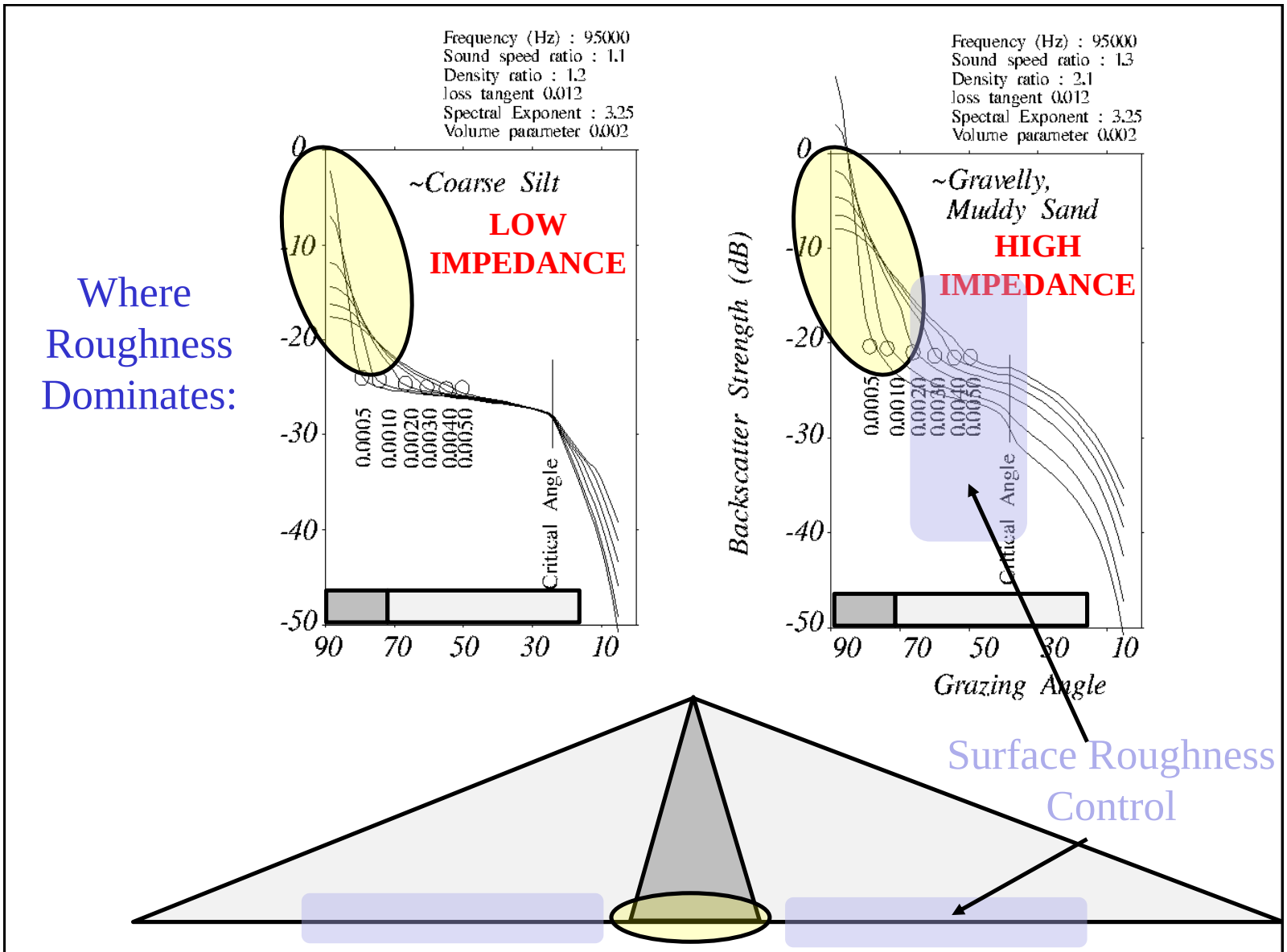






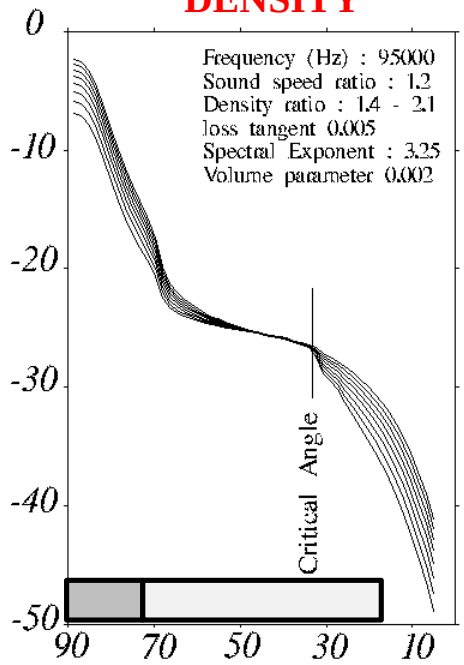
Hydro 2016 Rostock

Where Roughness Dominates:

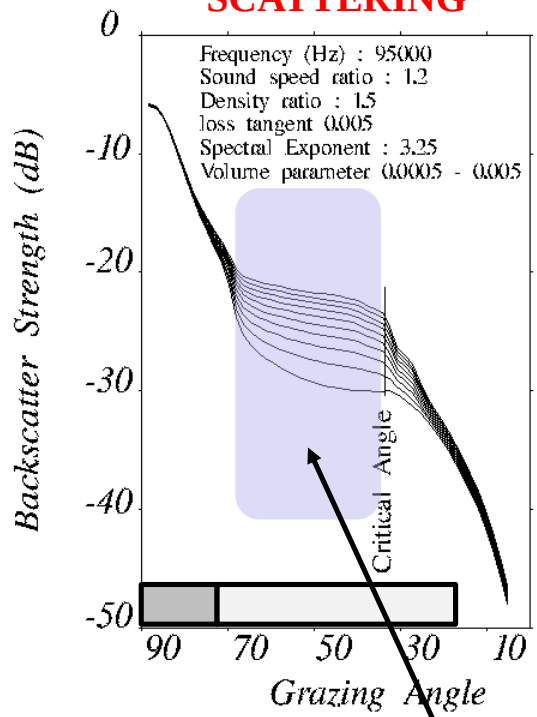


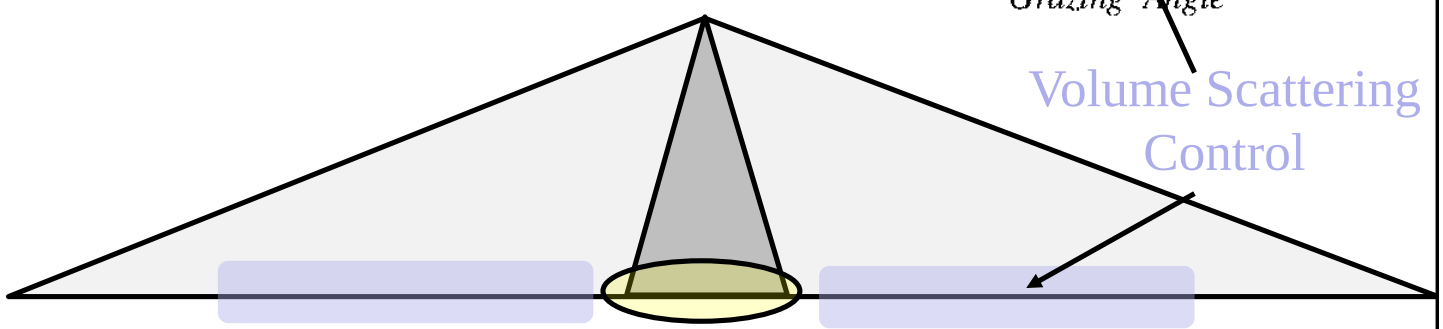
Where Impedance And Volume Scattering Dominate:

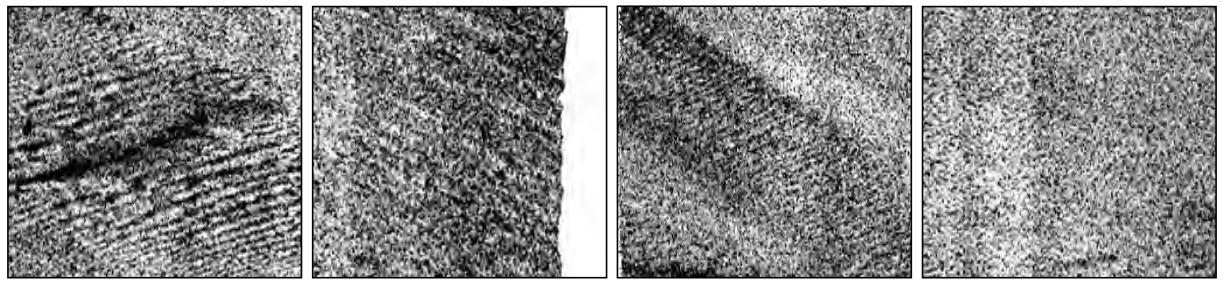
VARYING DENSITY



VARYING VOLUME SCATTERING





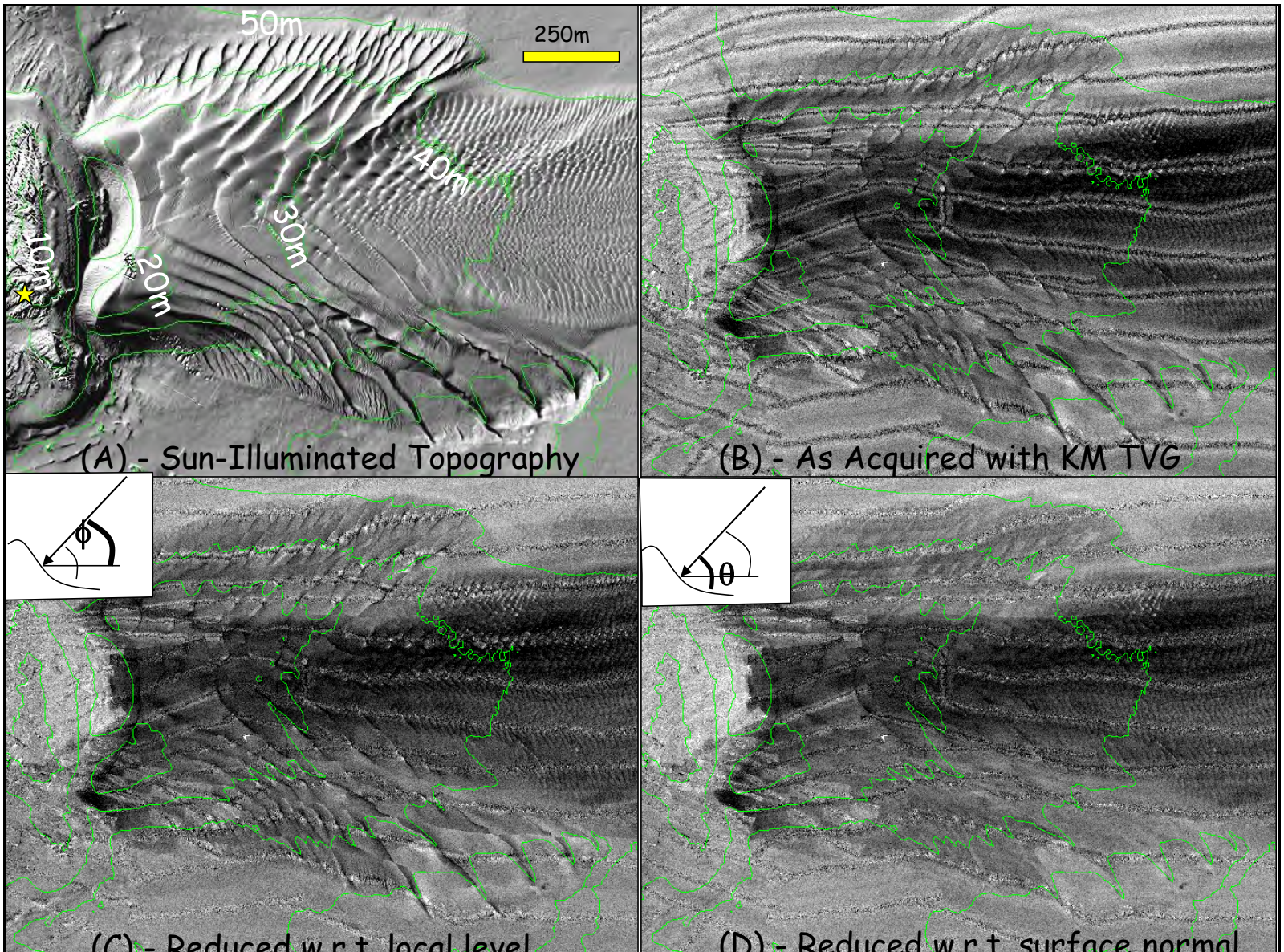


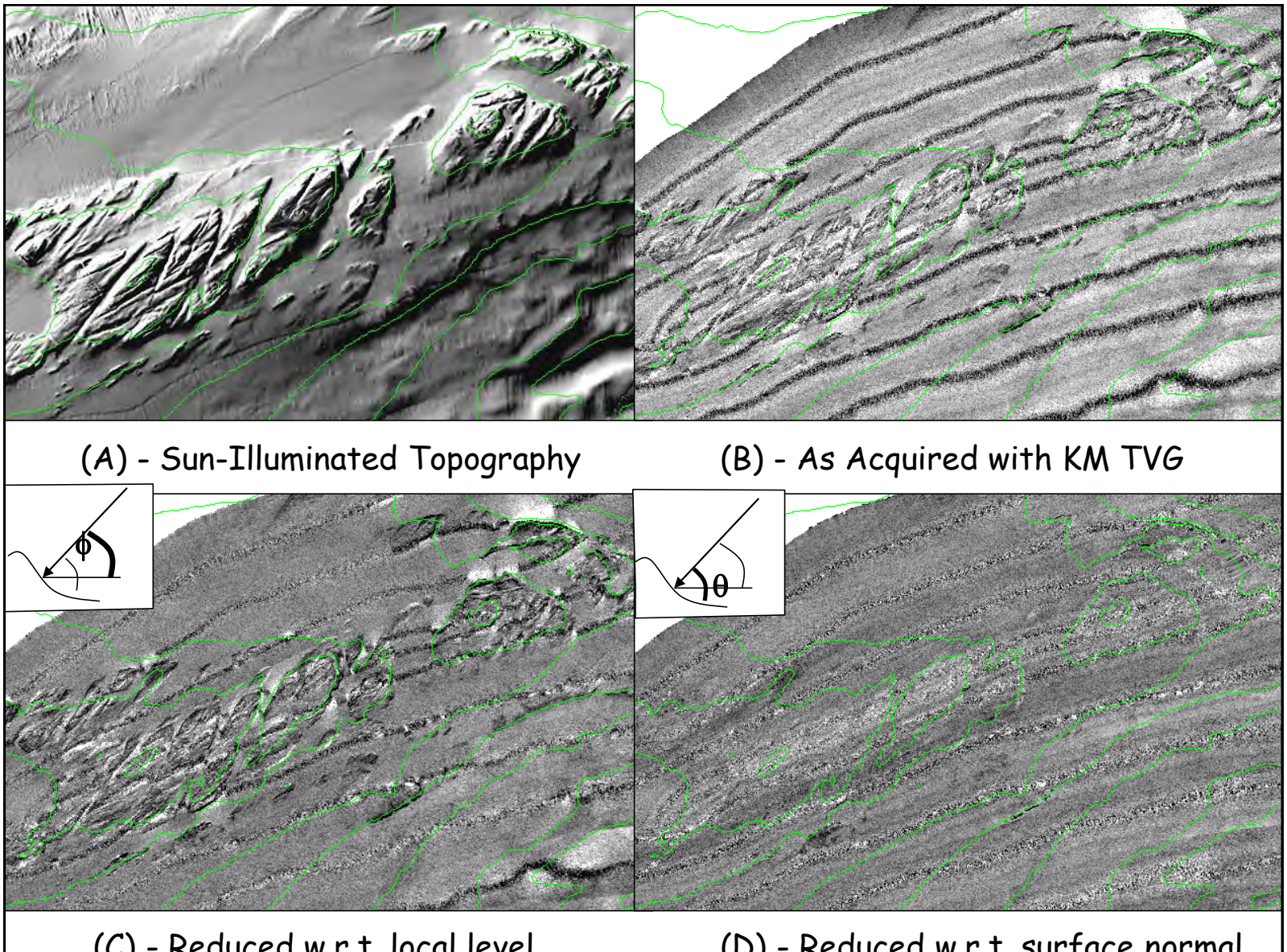
Textural Classification

What controls Texture?

1. Patchiness (lateral heterogeneity)
2. Short Wavelength topography
3. Speckle

ALL 3 PRESENT ABOVE


50m
250m
40m
30m
20m
10m
(A) - Sun-Illuminated Topography
(B) - As Acquired with KM TVG
ϕ
θ
(C) - Reduced w.r.t. local level
(D) - Reduced w.r.t. surface normal


(A) - Sun-Illuminated Topography
(B) - As Acquired with KM TVG
ϕ
θ
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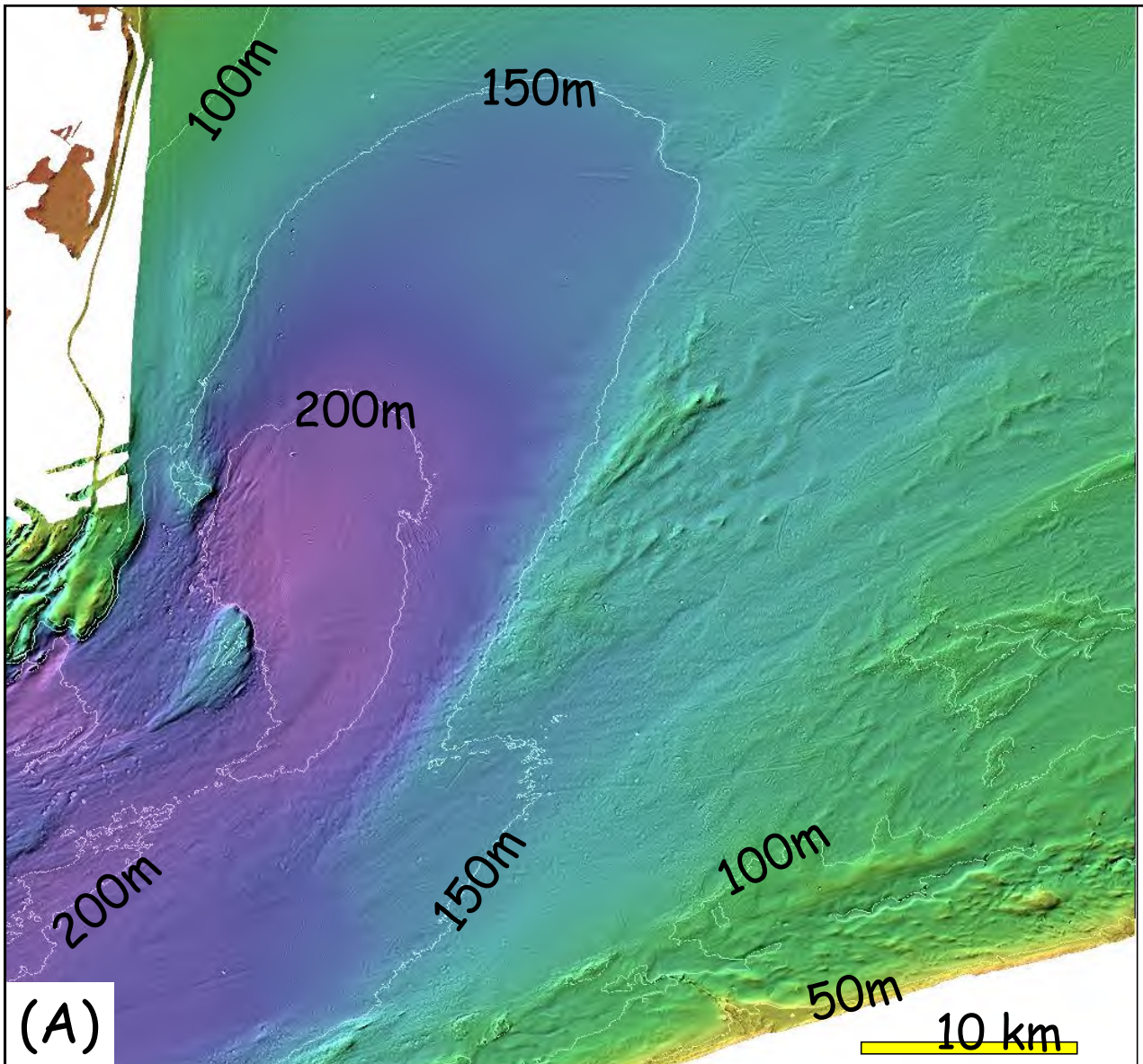
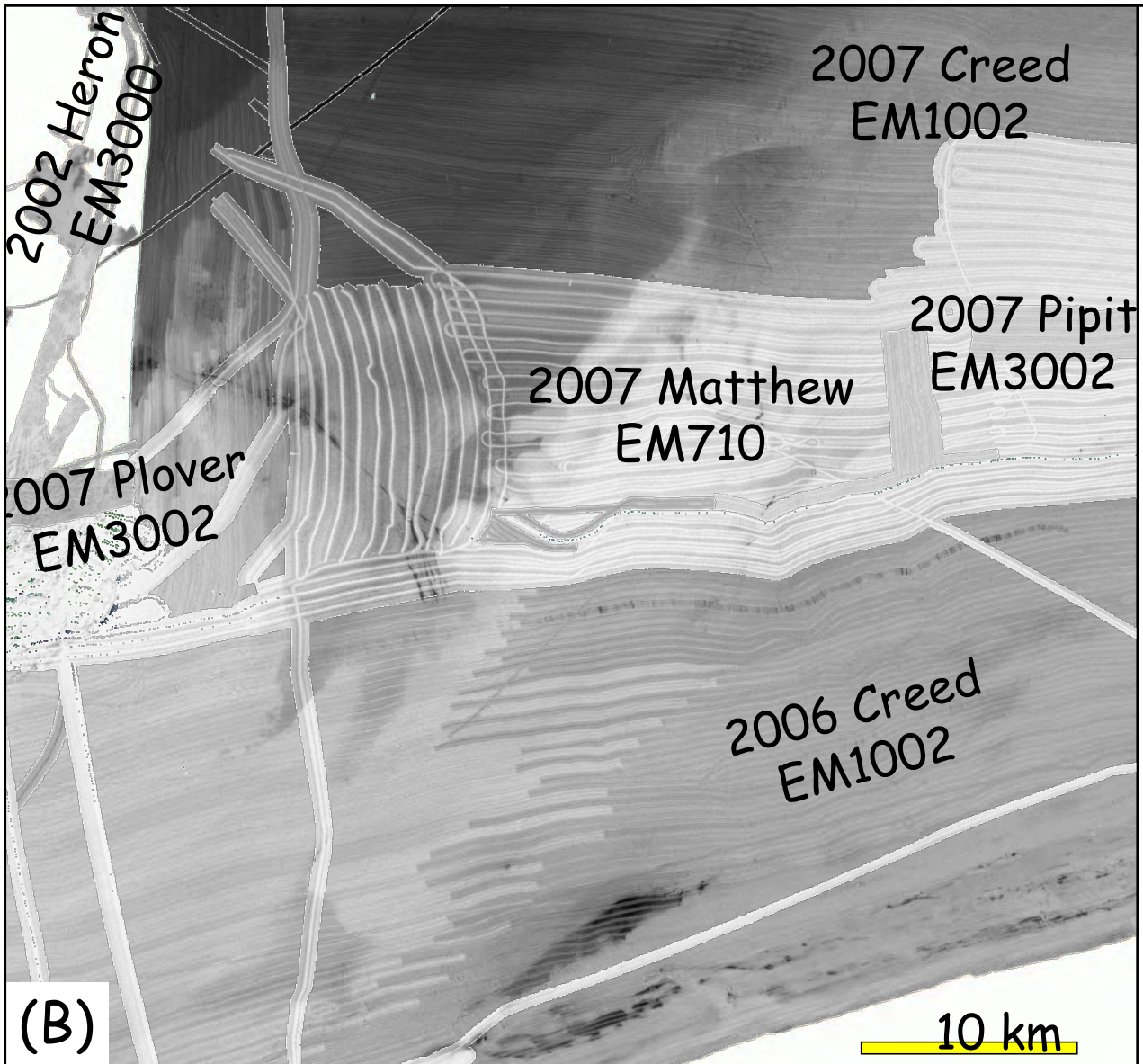
(D) - Reduced w.r.t. surface normal



Depth Related Residual Pulse Length Corrections

As the systems start to become attenuation limited.



Depth-Related Residual Pulse Length Corrections

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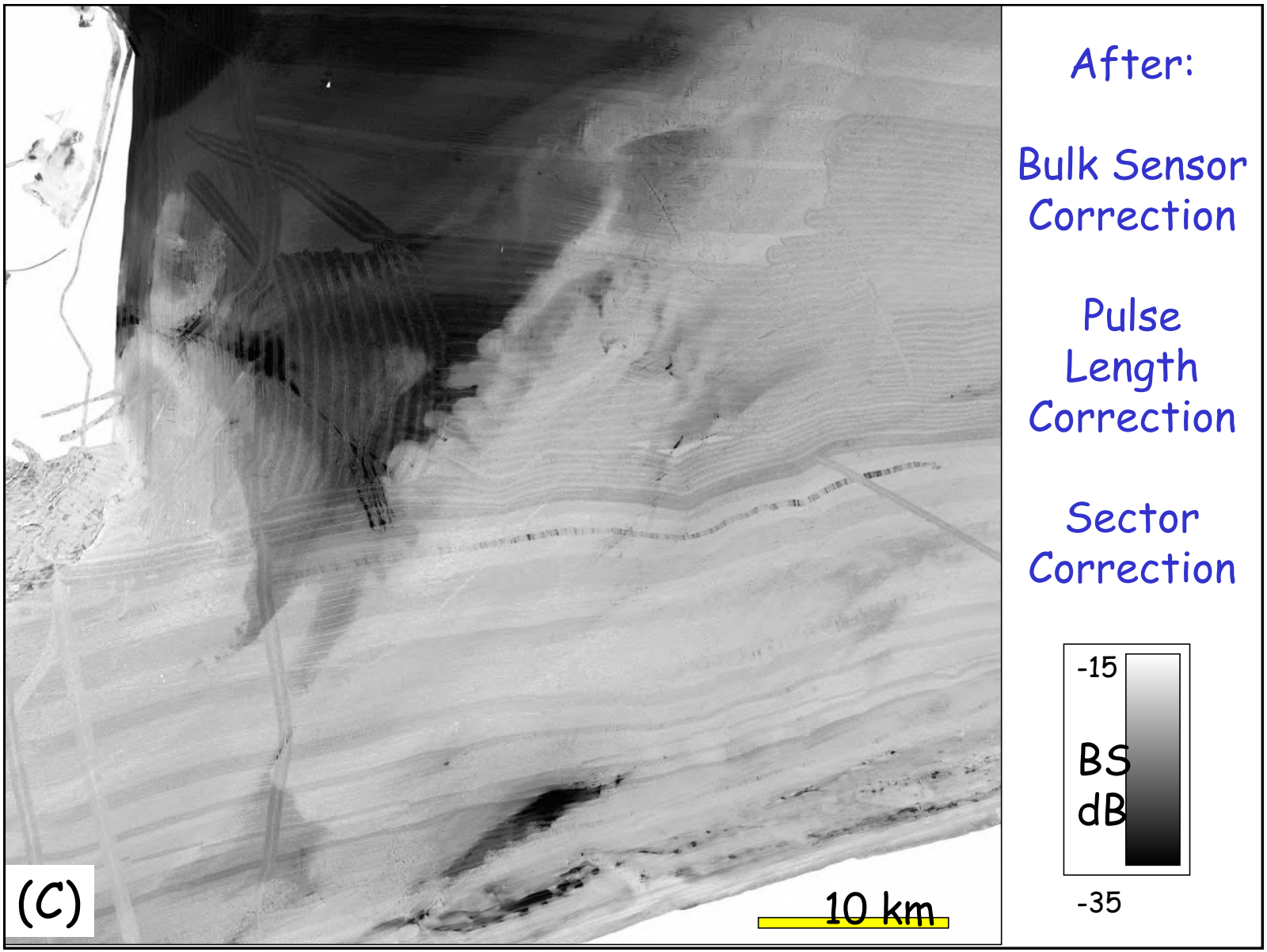
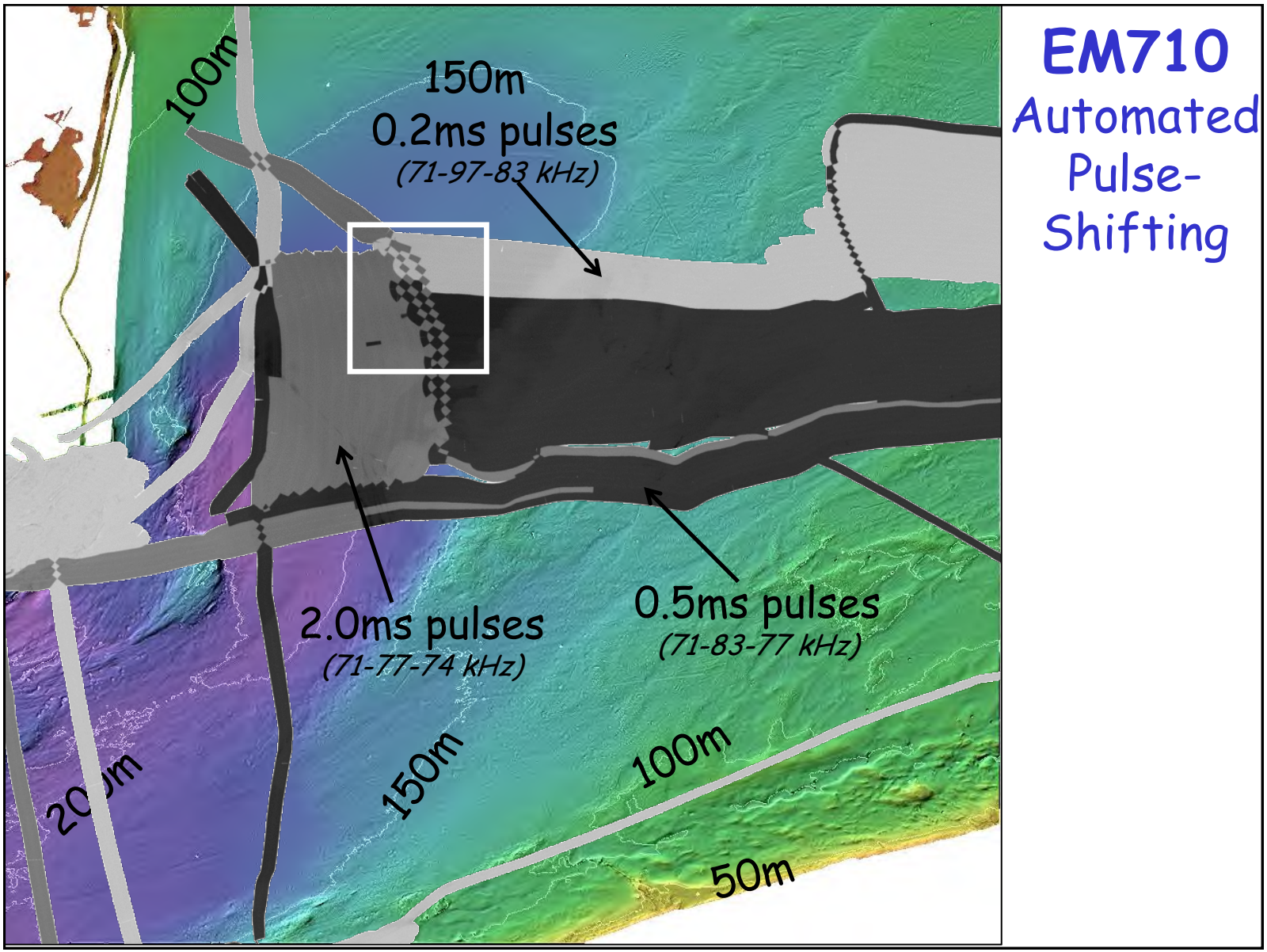
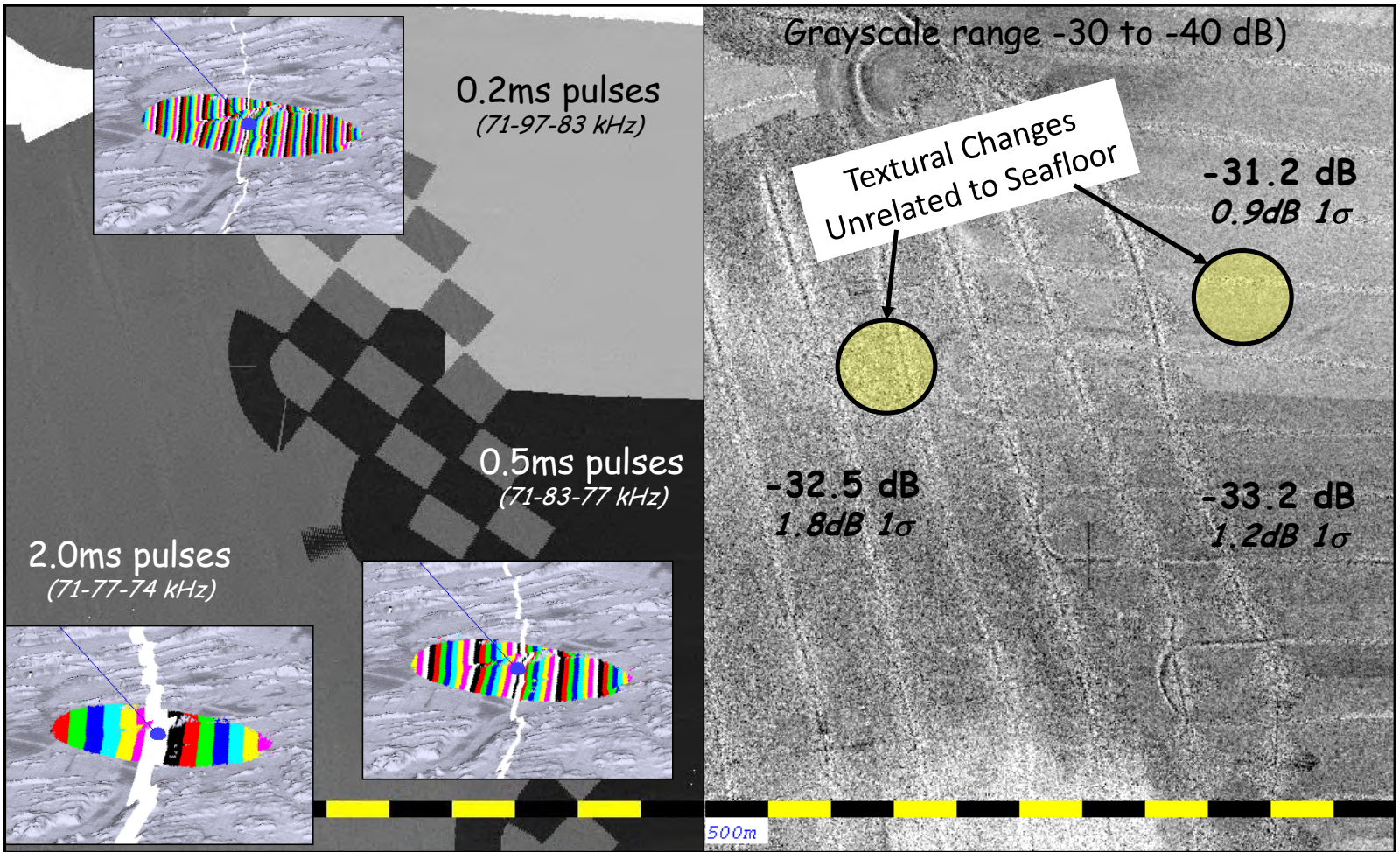
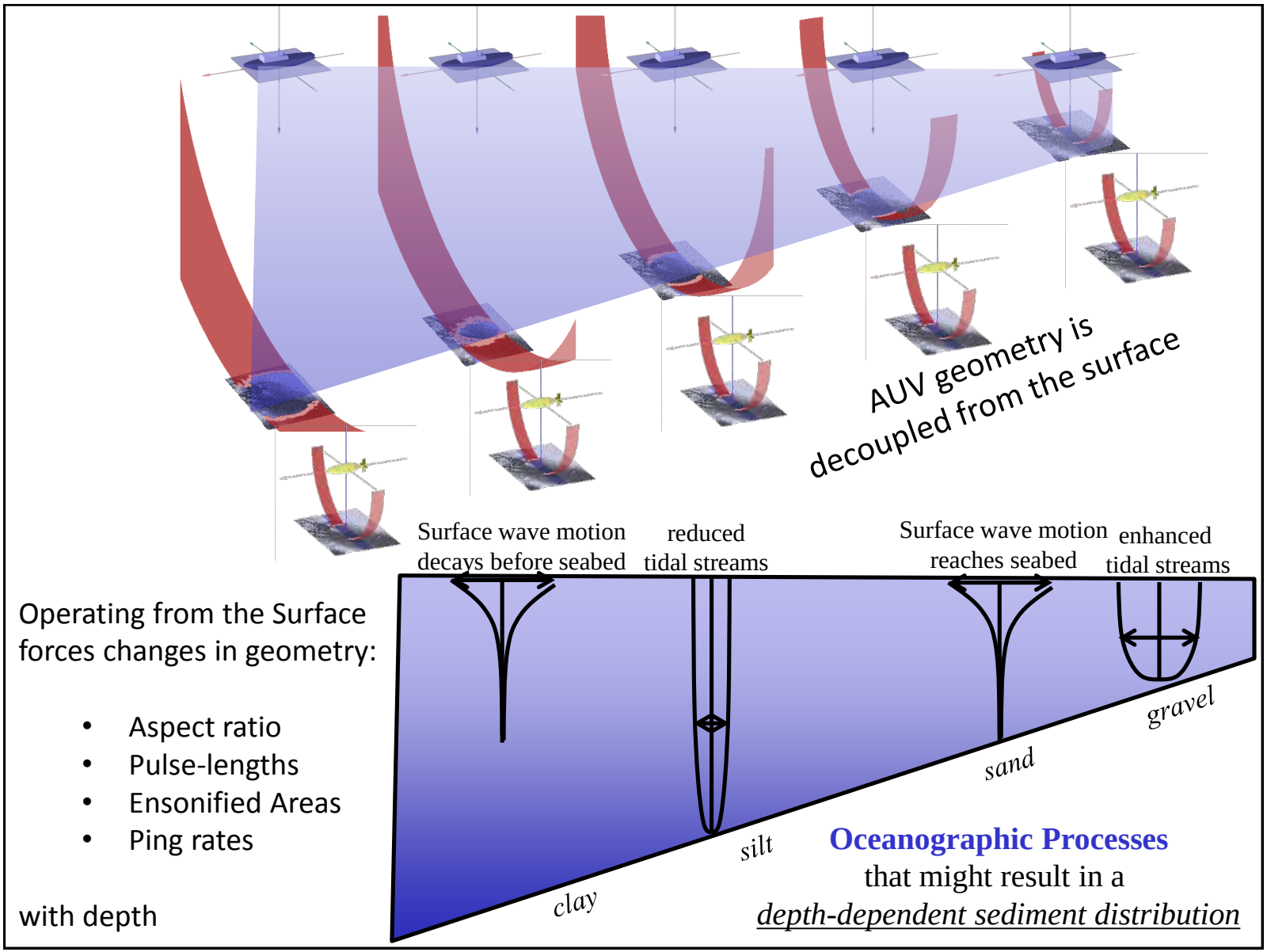

After:
Bulk Sensor Correction
Pulse Length Correction
Sector Correction
-15
BS dB
-35
(C)
10 km


EM710
Automated
Pulse-
Shifting
100m
150m
0.2ms pulses
(71-97-83 kHz)
2.0ms pulses
(71-77-74 kHz)
0.5ms pulses
(71-83-77 kHz)
150m
100m
50m


0.2ms pulses
(71-97-83 kHz)
0.5ms pulses
(71-83-77 kHz)
2.0ms pulses
(71-77-74 kHz)
Grayscale range -30 to -40 dB)
Textural Changes
Unrelated to Seafloor
-31.2 dB
0.9dB 1σ
-32.5 dB
1.8dB 1σ
-33.2 dB
1.2dB 1σ
500m
EM710 Automated Pulse-Shifting
2.0ms pulses
71 - 77 - 74 kHz
19.7 - 21.1 - 20.4 dB/km
0.5ms pulses
71 - 83 - 77 kHz
20.1 - 23.0 - 21.6 dB/km
0.2ms pulses
71 - 97 - 83 kHz
20.1 - 25.8 - 23.0 dB/km

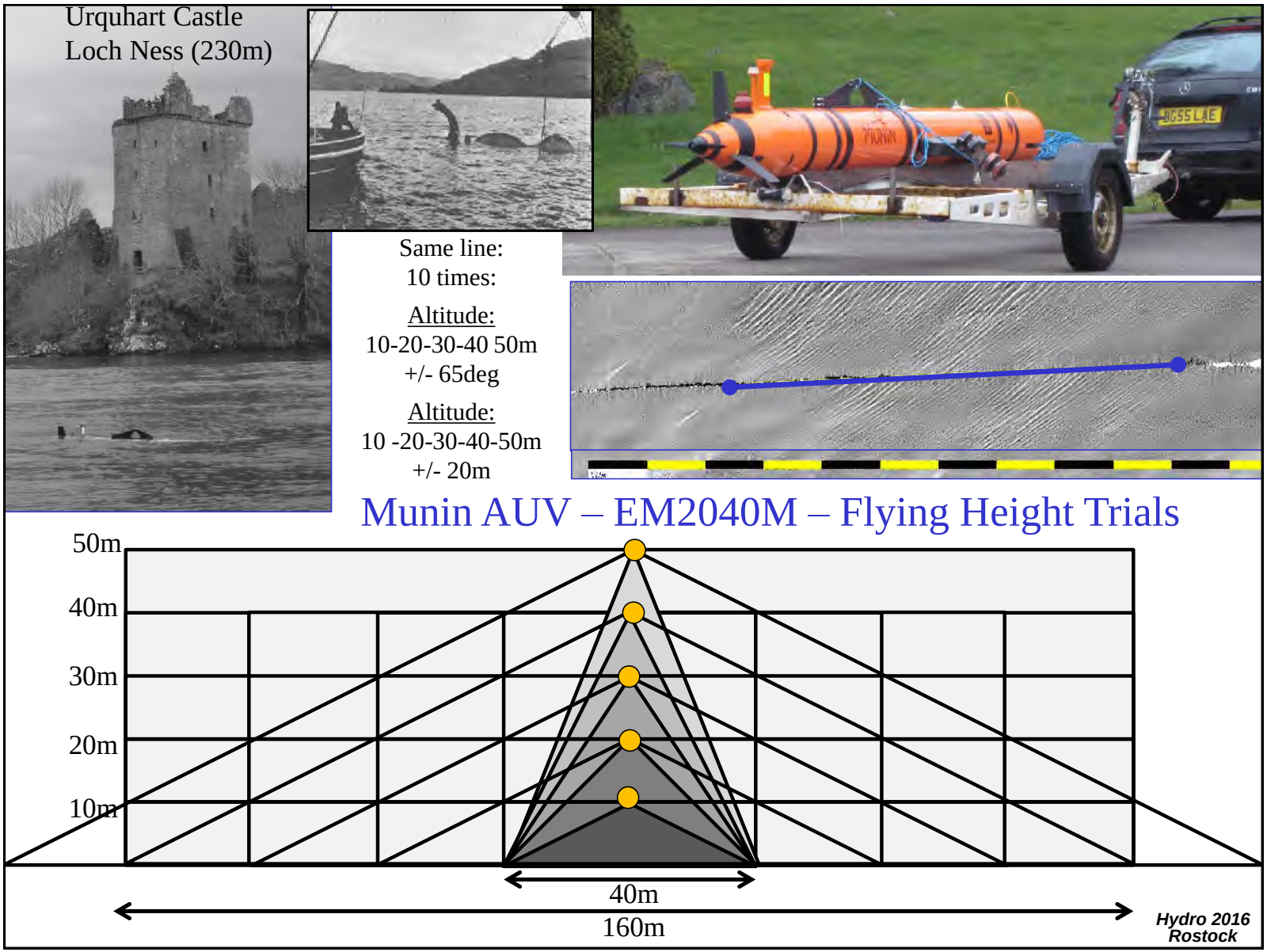


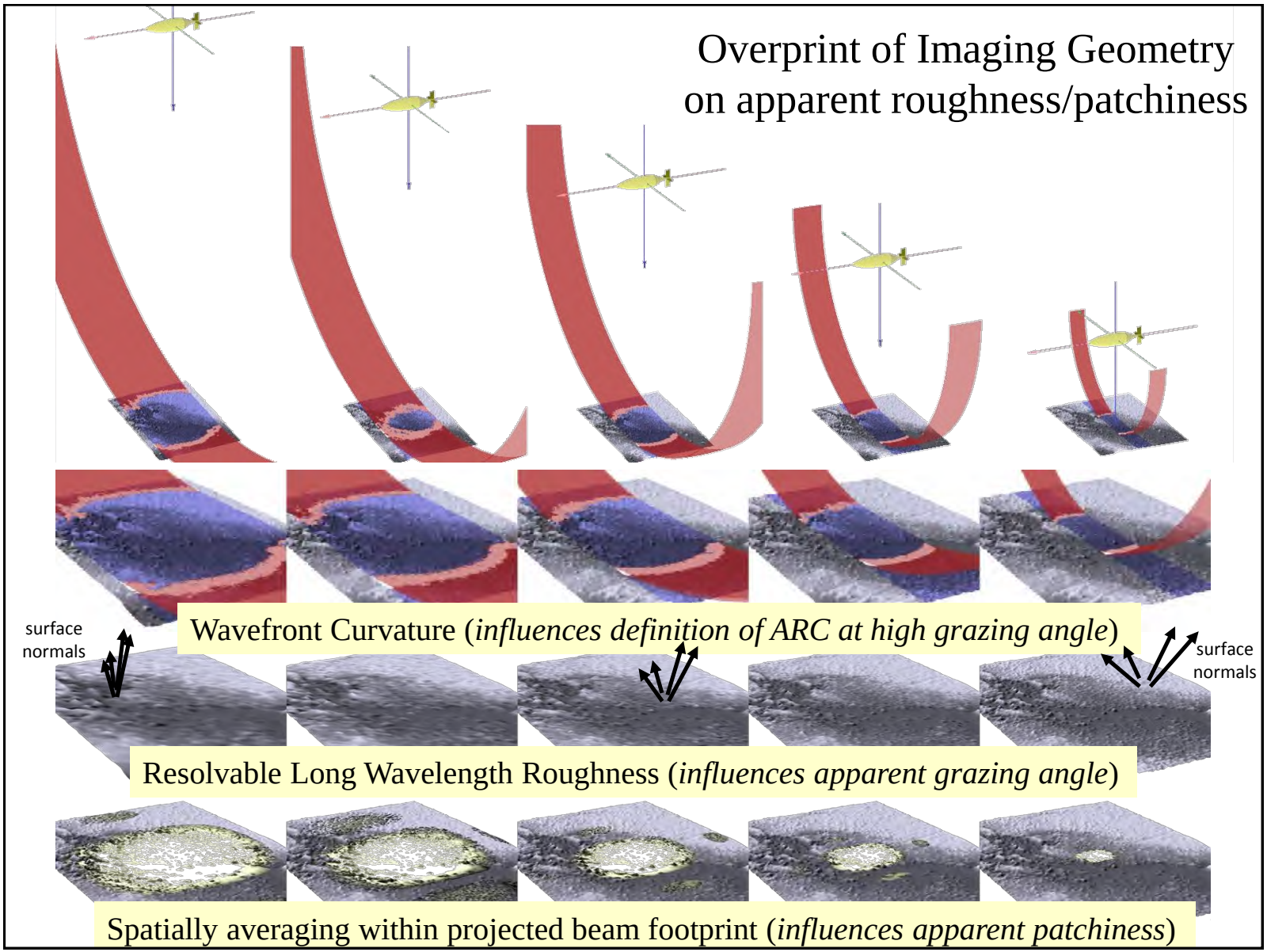
Operating from the Surface forces changes in geometry:

- Aspect ratio
- Pulse-lengths
- Ensonified Areas
- Ping rates

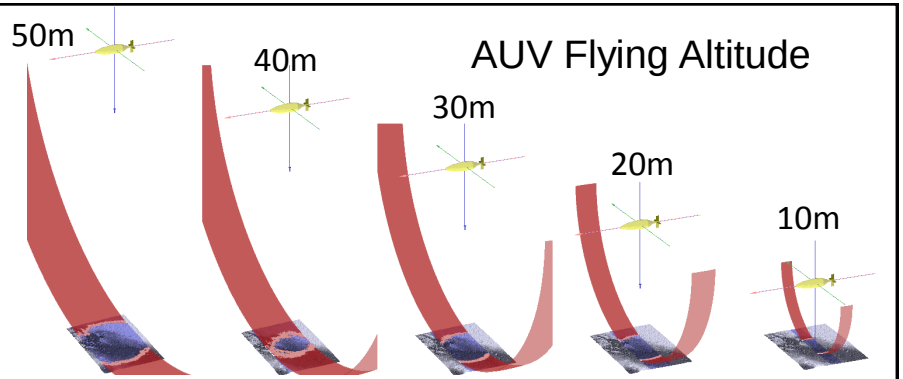
with depth

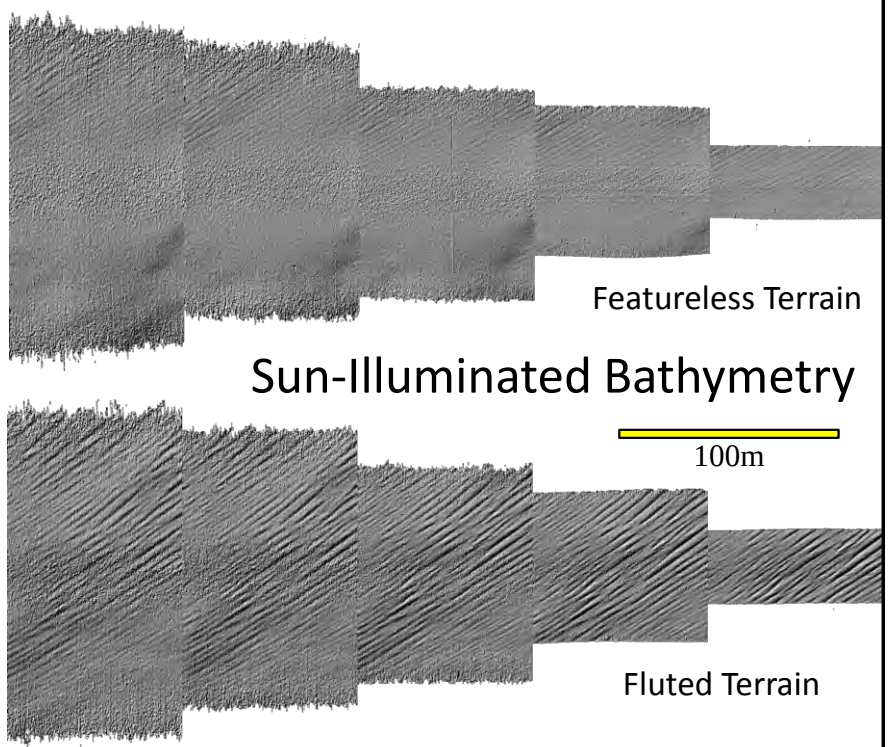
Oceanographic Processes
that might result in a
depth-dependent sediment distribution


Urquhart Castle
Loch Ness (230m)
Same line:
10 times:
Altitude:
10-20-30-40 50m
+/- 65deg
Altitude:
10 -20-30-40-50m
+/- 20m
Munin AUV – EM2040M – Flying Height Trials
50m
40m
30m
20m
10m
40m
160m
Hydro 2016
Rostock

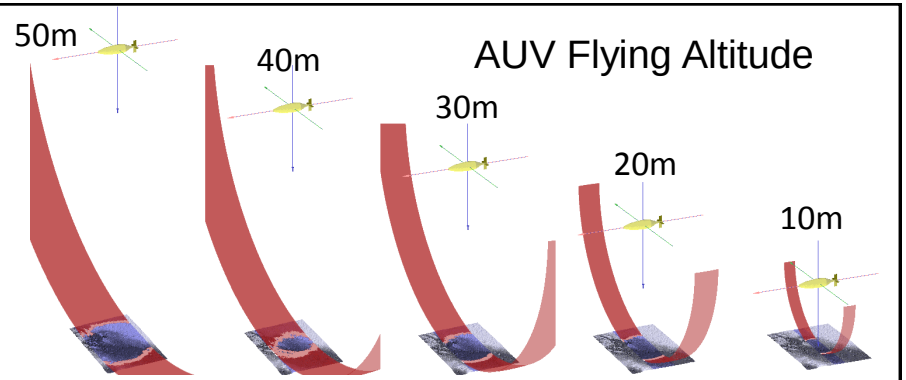

Overprint of Imaging Geometry
on apparent roughness/patchiness
surface
normals
Wavefront Curvature (*influences definition of ARC at high grazing angle*)
surface
normals
Resolvable Long Wavelength Roughness (*influences apparent grazing angle*)
Spatially averaging within projected beam footprint (*influences apparent patchiness*)

Impact of Flying Altitude on Resolved and Apparent Seabed Roughness

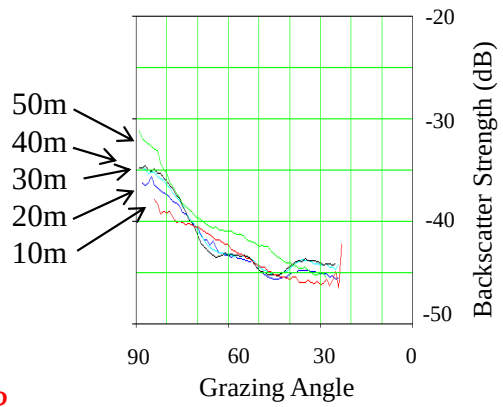


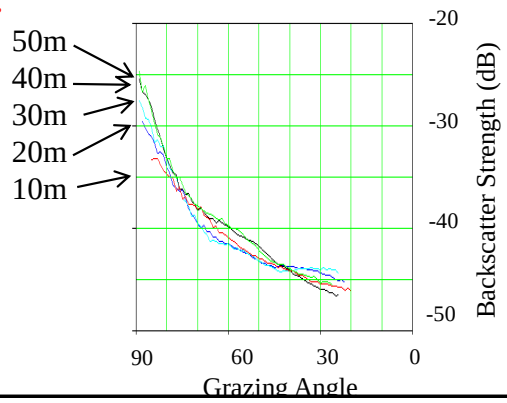


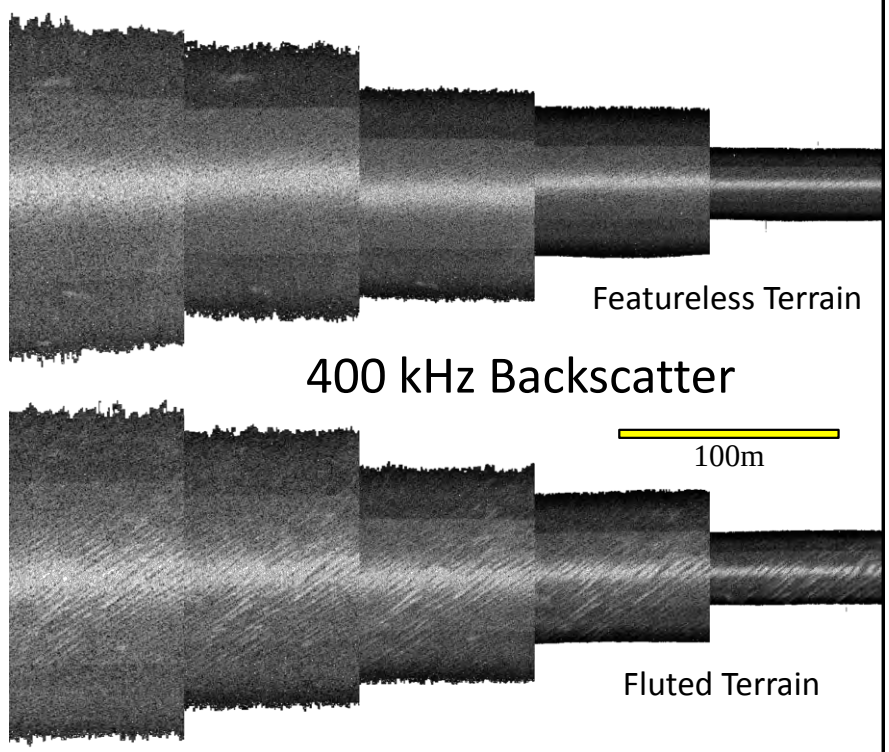
Impact of Flying Altitude on ARC shape close to normal incidence



REAL? or an imperfect algorithm?





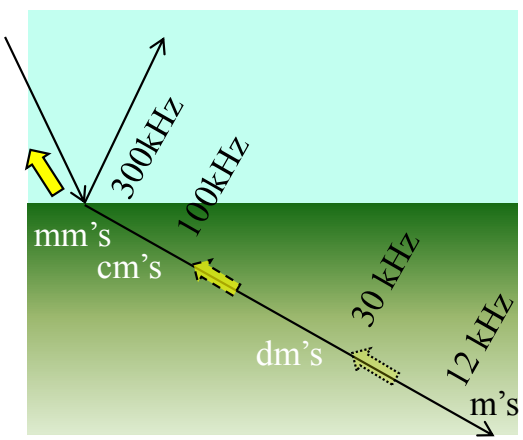


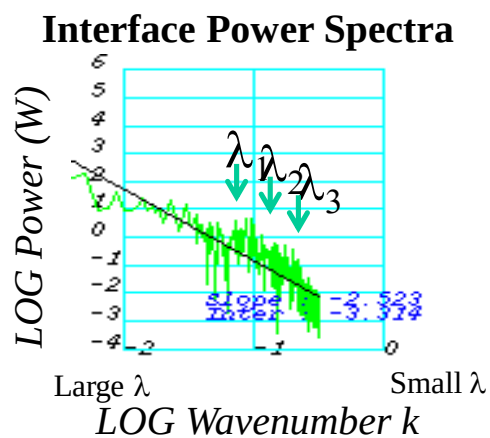
If we're stuck at the surface,

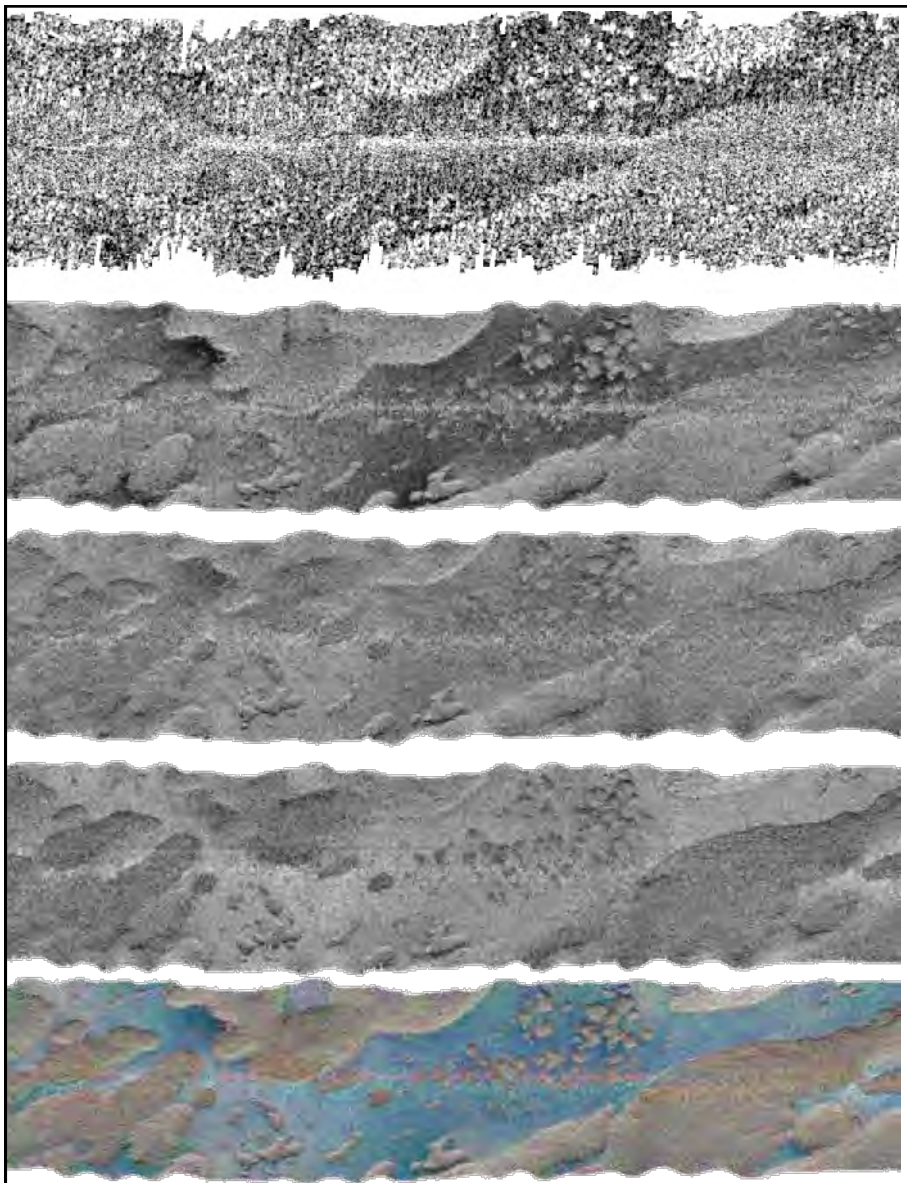
how else might we separate

surface v. volume scattering?

Multi-Frequency Backscatter







12 kHz

100 kHz

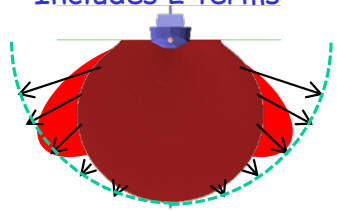
200 kHz

300 kHz

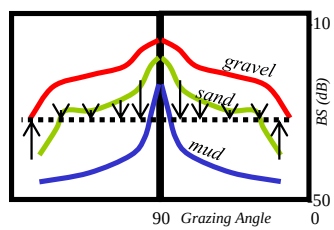
USNS Mary Sears, Saipan Reef 2012, EM2040 and EM710

"Across-Track Imaging Geometry"

Includes 2 terms



1: Acoustic Radiation



2: Angular Response

False Colour Composite:

- RED - 70-100 kHz
- GREEN - "200" kHz
- BLUE - "300" kHz

Multi-Frequency Backscatter

MultiSpectral Platforms:

Providing ***Simultaneous*** dual (or triple) frequency Ensonification

2016

R2Sonic 2026

100 kHz
200 kHz
400 kHz

USNS Mary Sears 100m

EM2040S
200-400 kHz

EM710
70-100 kHz

EM12
11-13 kHz

RV Celtic Explorer 65m

EM2040S
200-400 kHz

EM1002
93-98 kHz

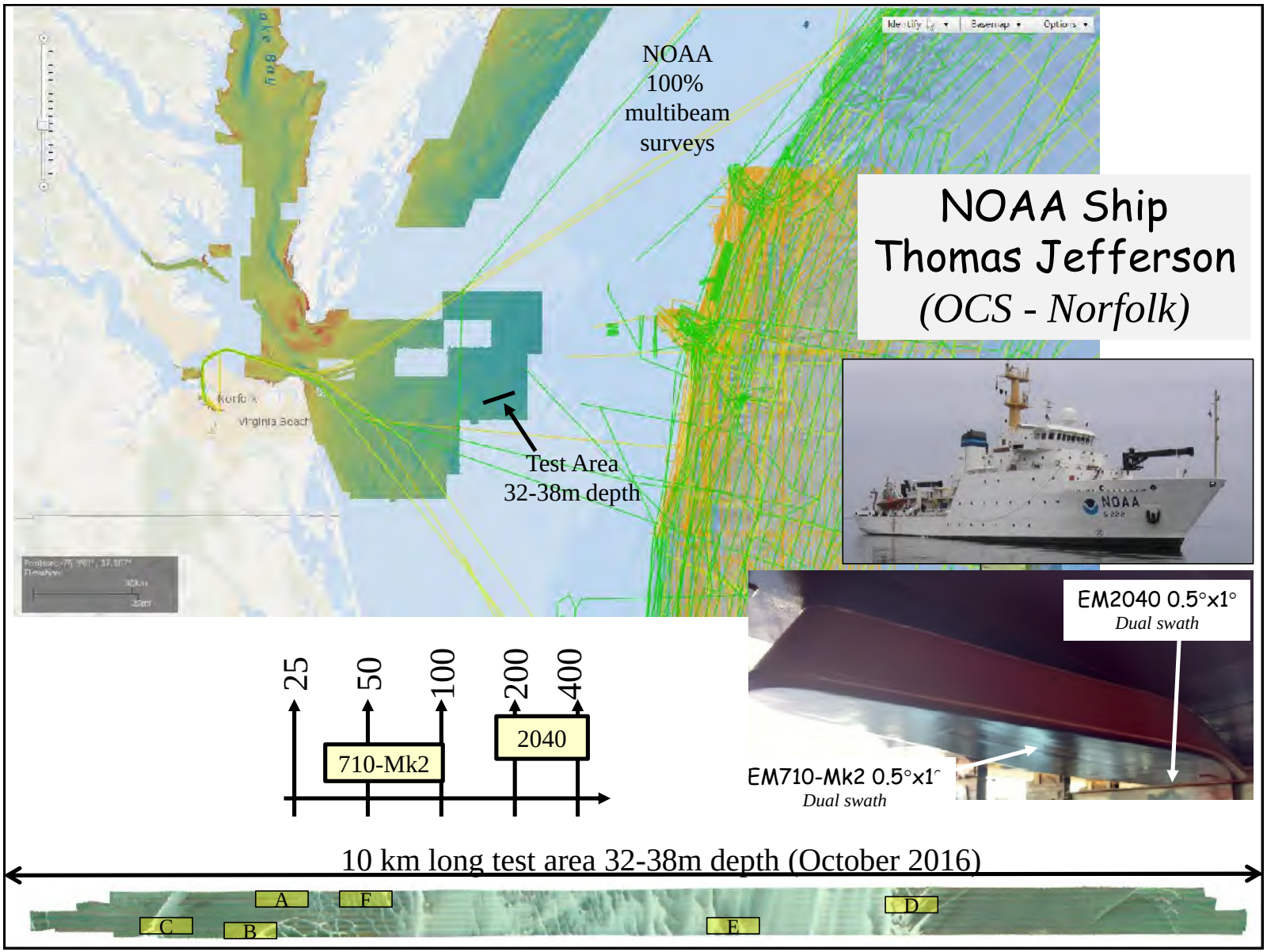
EM302
27-34 kHz

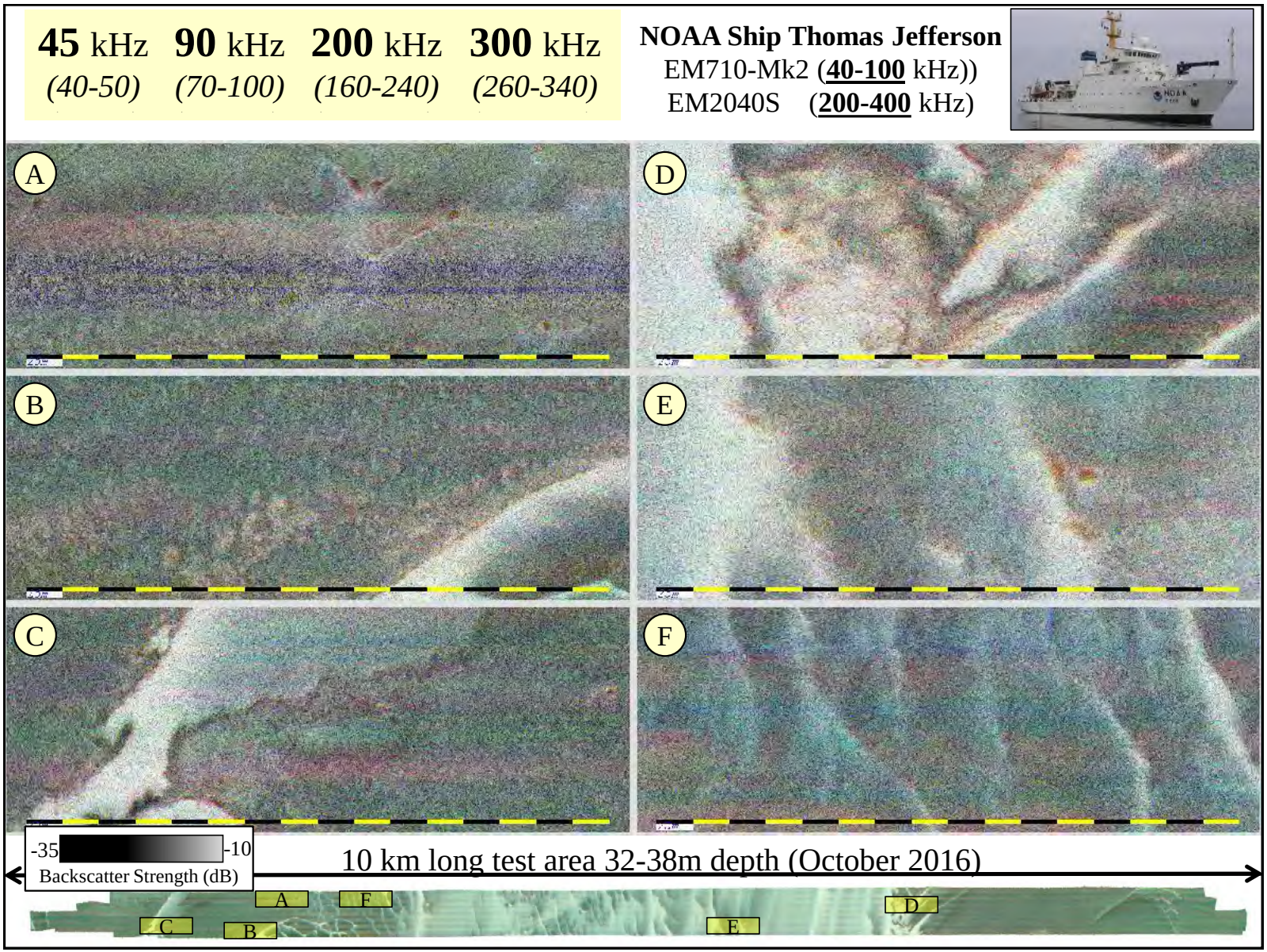
CSL Heron 10m

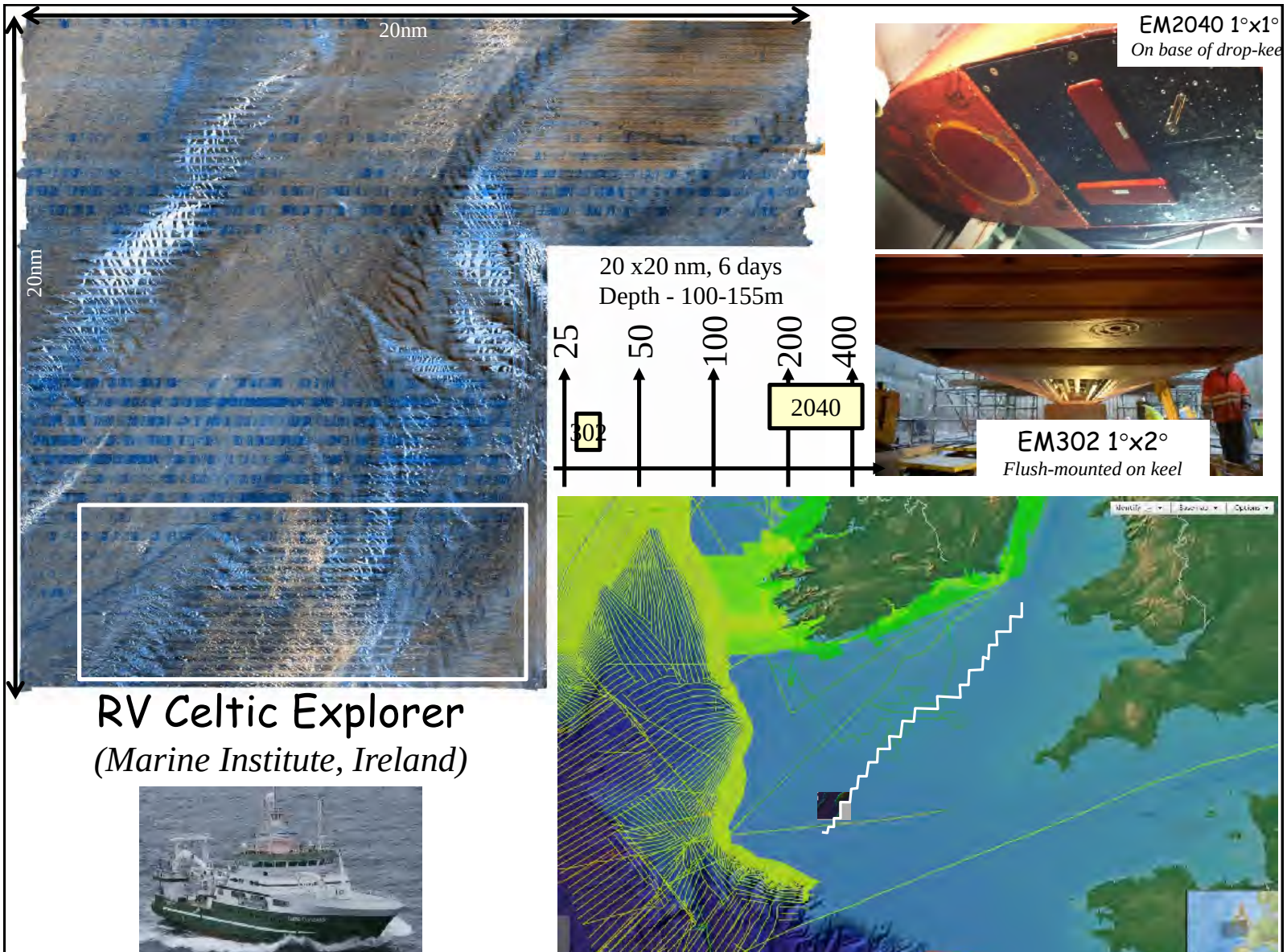
EM2040C
200-400 kHz

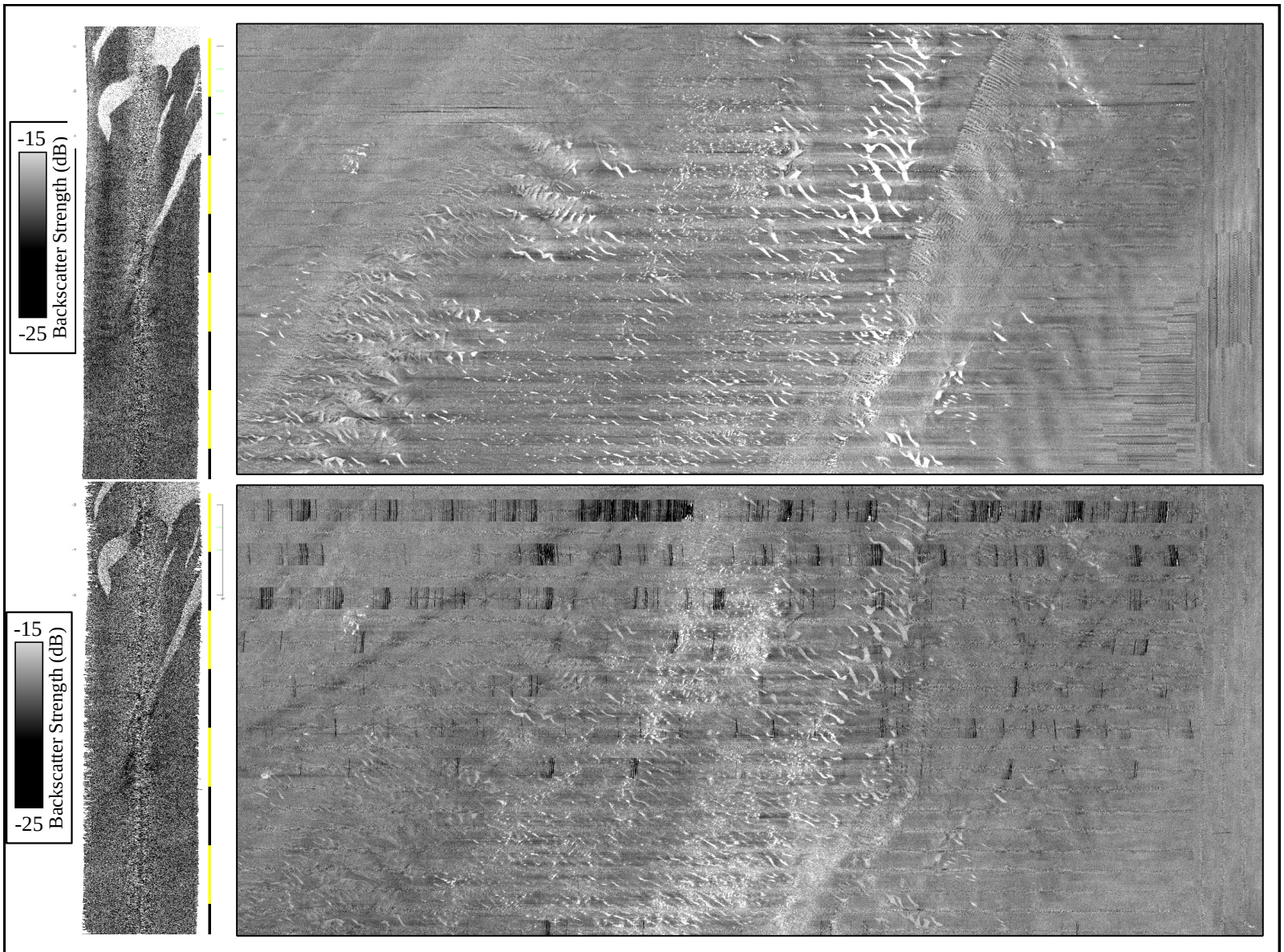
EM710
70-100 kHz

Hydro 2016 Rostock


NOAA
100%
multibeam
surveys
NOAA Ship
Thomas Jefferson
(OCS - Norfolk)
Test Area
32-38m depth
25
50
100
200
400
710-Mk2
2040
EM2040 0.5°x1°
Dual swath
EM710-Mk2 0.5°x1°
Dual swath
10 km long test area 32-38m depth (October 2016)
A
F
C
B
E
D


45 kHz (40-50)
90 kHz (70-100)
200 kHz (160-240)
300 kHz (260-340)
NOAA Ship Thomas Jefferson
EM710-Mk2 (40-100 kHz))
EM2040S (200-400 kHz)
A
B
C
D
E
F
-35
-10
Backscatter Strength (dB)
10 km long test area 32-38m depth (October 2016)

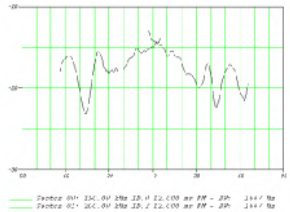

20nm
20nm
20 x20 nm, 6 days
Depth - 100-155m
25
50
100
200
400
302
2040
EM2040 1°x1°
On base of drop-kee
EM302 1°x2°
Flush-mounted on keel
RV Celtic Explorer
(Marine Institute, Ireland)

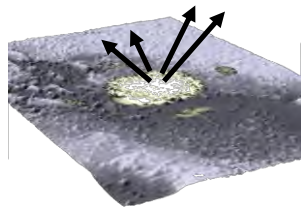

-15
-25
Backscatter Strength (dB)
-15
-25
Backscatter Strength (dB)

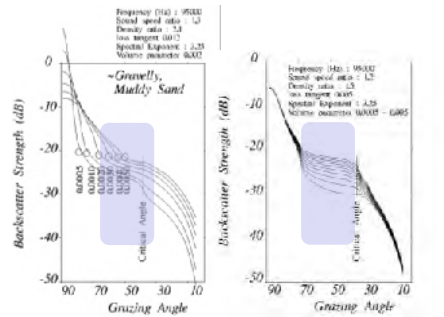
Bi-spectral Product (30 and 200 kHz)

Bubble washown

Conclusions:





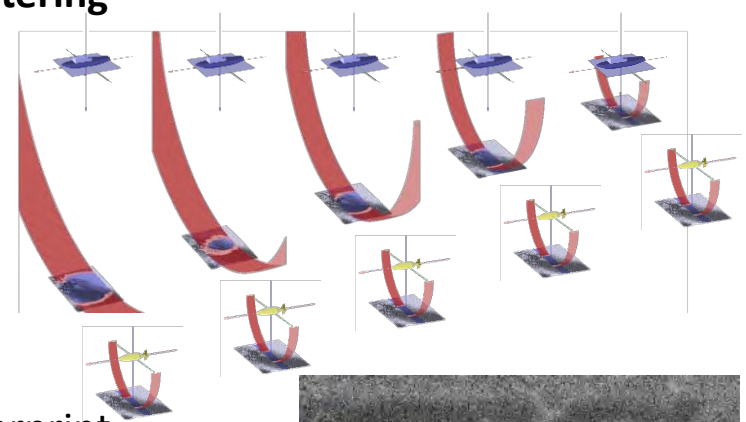


Continued need for:

- Absolute SL, Beam Pattern, Ensonified Areas, Grazing Angles

Biggest challenge in classification (for monospectral) is:

- **Separating roughness from volume scattering**



Surface Mounted:

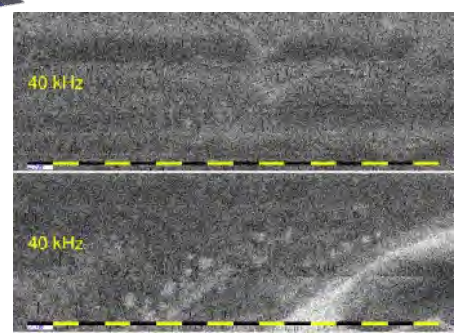
- Unavoidable geometric variations
- Prone to bubble washdown

AUV provide:

- Reduced geometric variations
- Ability to better calibrate
- Immune to surface noise/bubble overprint.

Multi-Spectral:

- potentially separate surface from volume
- Now operational
- Much to be learnt



Questions?