



Trends in Seabed Mapping Technology

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Hand lead-line



The Hand Lead-line

CHART OF MARKERS

- 2 fathoms - two strips of leather.
- 3 fathoms - three strips of leather.
- 5 fathoms - a piece of white cloth.
- 7 fathoms - a piece of red cloth.
- 10 fathoms - a piece of leather with a hole.
- 13 fathoms - a piece of blue cloth.
- 15 fathoms - a piece of white cloth.
- 17 fathoms - a piece of red cloth.
- 20 fathoms - a string with two knots.

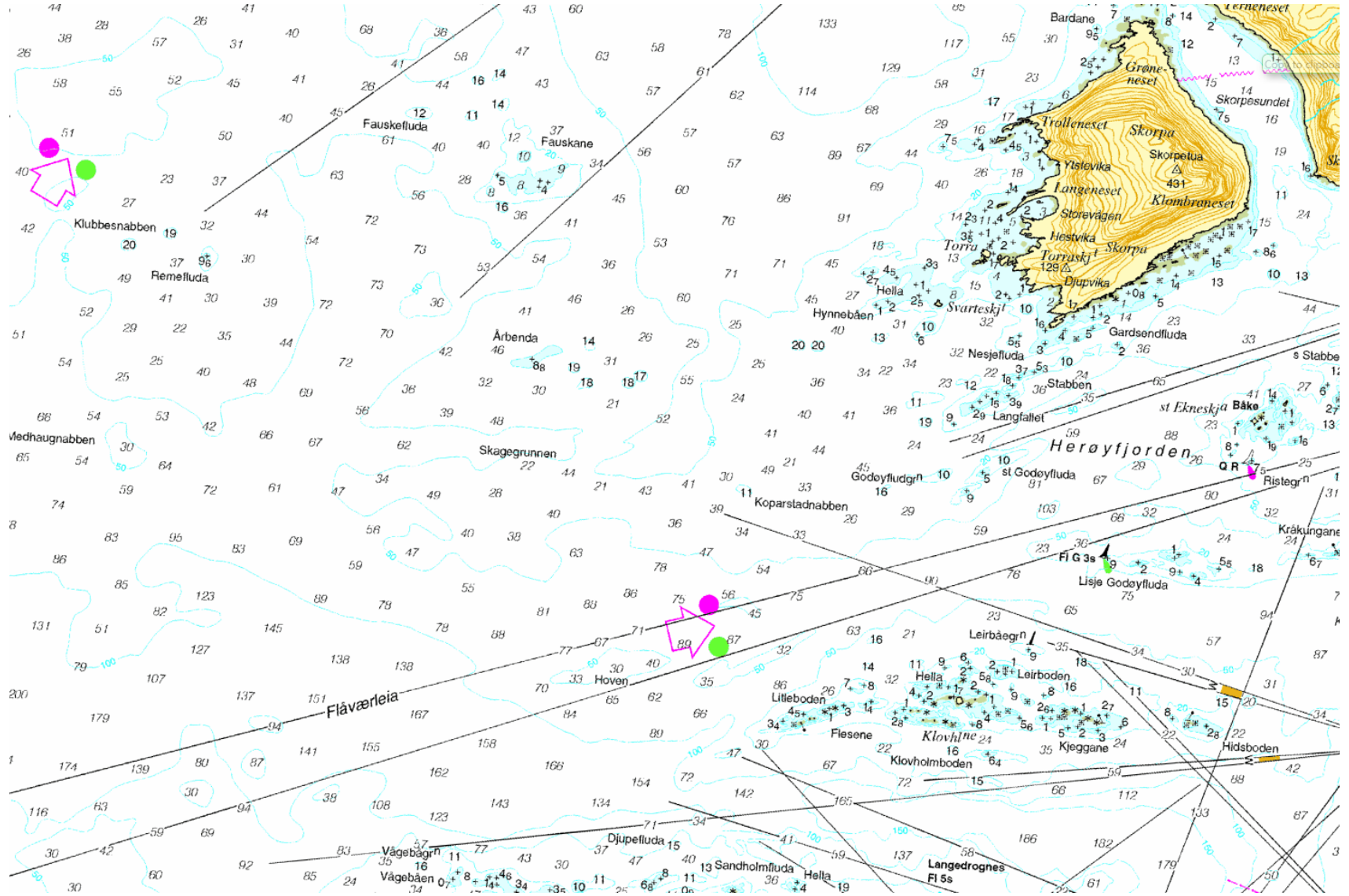
1. Color the spool brown.
2. Color the rope light brown.
3. Color the markers according to the chart above.
4. Color the weight gray.

1 fathom is equal to 6 feet.

If the sounding is 13 fathoms, how deep is the water in feet?
Try your skill at finding the depth at other soundings.



Nautical chart



Global Navigation Satellite System (GNSS)

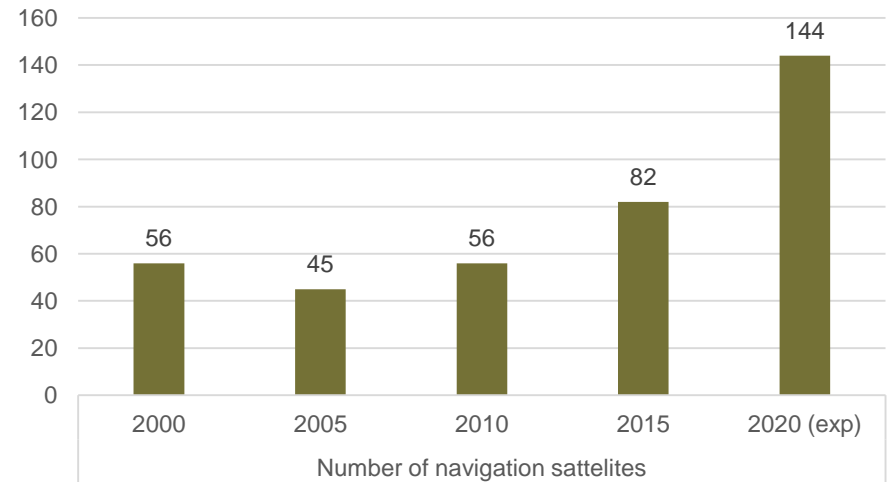


Seapath 1996: Tracked 25 satellites. 1.5 m position accuracy.



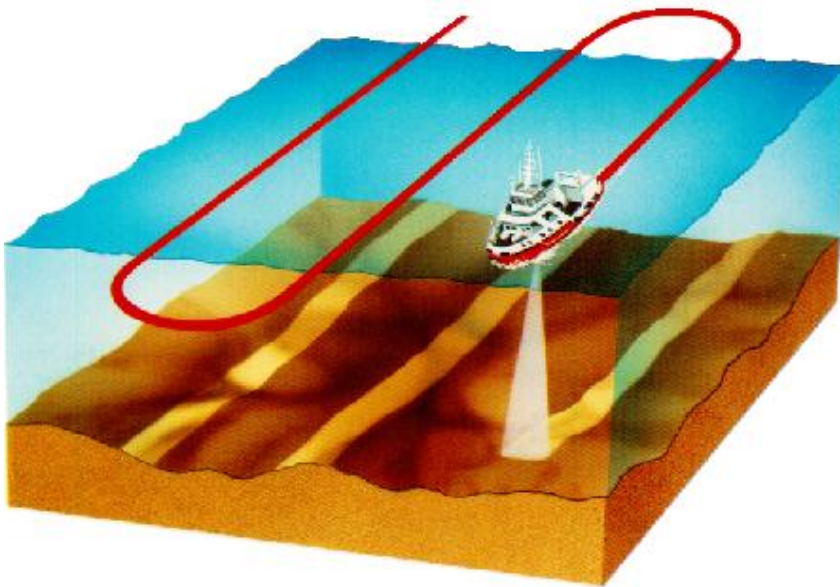
Seapath 2016: Tracks unlimited satellites. dm accuracy with differential GNSS and augmentation services. cm accuracy with RTK.

Number of satellites

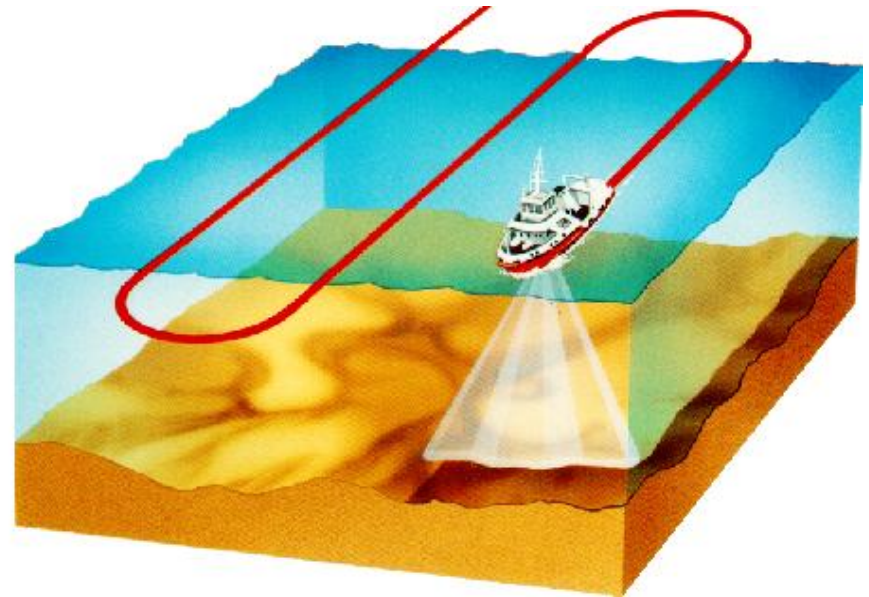


Multibeam versus single beam

Kongsberg introduced its first multibeam echosounder in 1986



Singlebeam survey:
Large unmapped gaps between lines

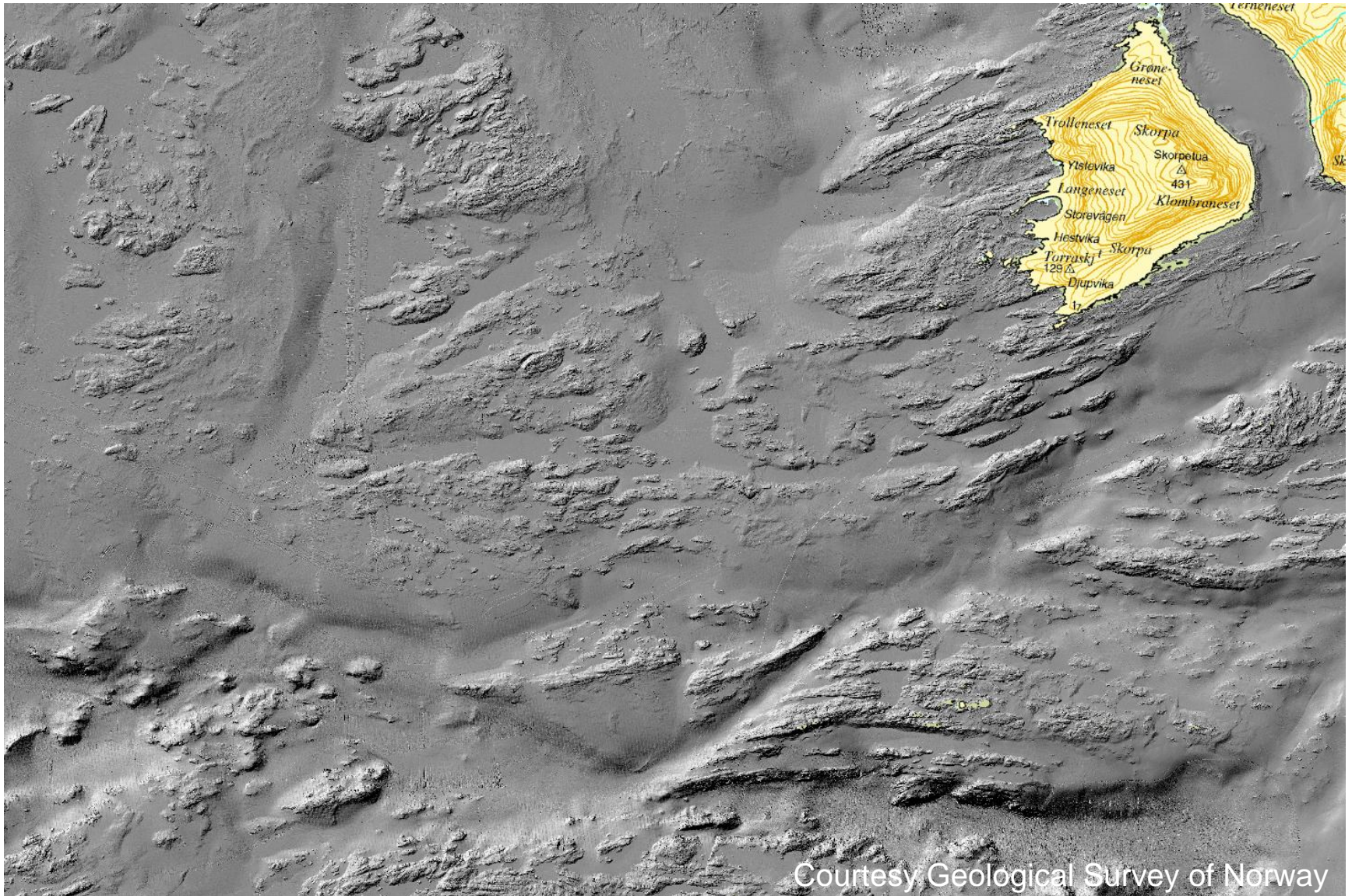


Multibeam survey:
100% coverage of seafloor

Resolution matters



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Courtesy Geological Survey of Norway



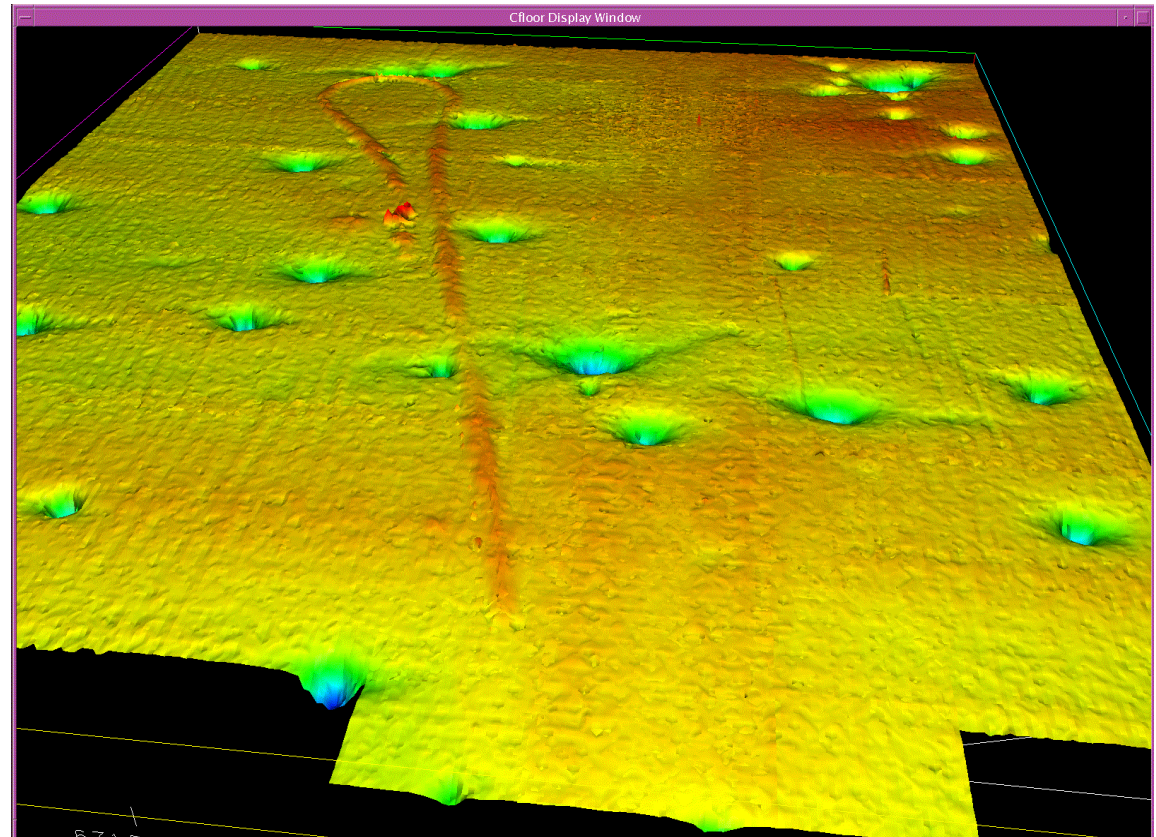
Multibeam echosounder 1986 - EM 100

- 95 kHz frequency
- 27 or 32 receiving beams
- Beam widths:
 - $2 \times 3^\circ$
 - $2.5 \times 3^\circ$
 - $5.5 \times 3^\circ$
- 100° coverage
- Stabilization
 - Roll: electronic
 - Pitch: mechanical



Multibeam echosounder 1999 - EM 1002

- 95 kHz frequency
- 111 receiving beams
- Beam width:
 - $2.0 \times 2.3^\circ$
- 150° coverage
- Stabilization
 - Roll: electronic
 - Pitch: mechanical



Pock marks at the Troll oil and gas field in the North Sea.

Multibeam echosounder 2016 - EM 712

- 40 to 100 kHz frequency
- 512 receiving beams
(max 1600 soundings/ping)
- Beam widths:
 - $0.25 \times 0.5^\circ$
 - $0.5 \times 0.5^\circ$
- 140° coverage
- Stabilization
 - Roll: electronic
 - Pitch: electronic
 - Azimuth: electronic

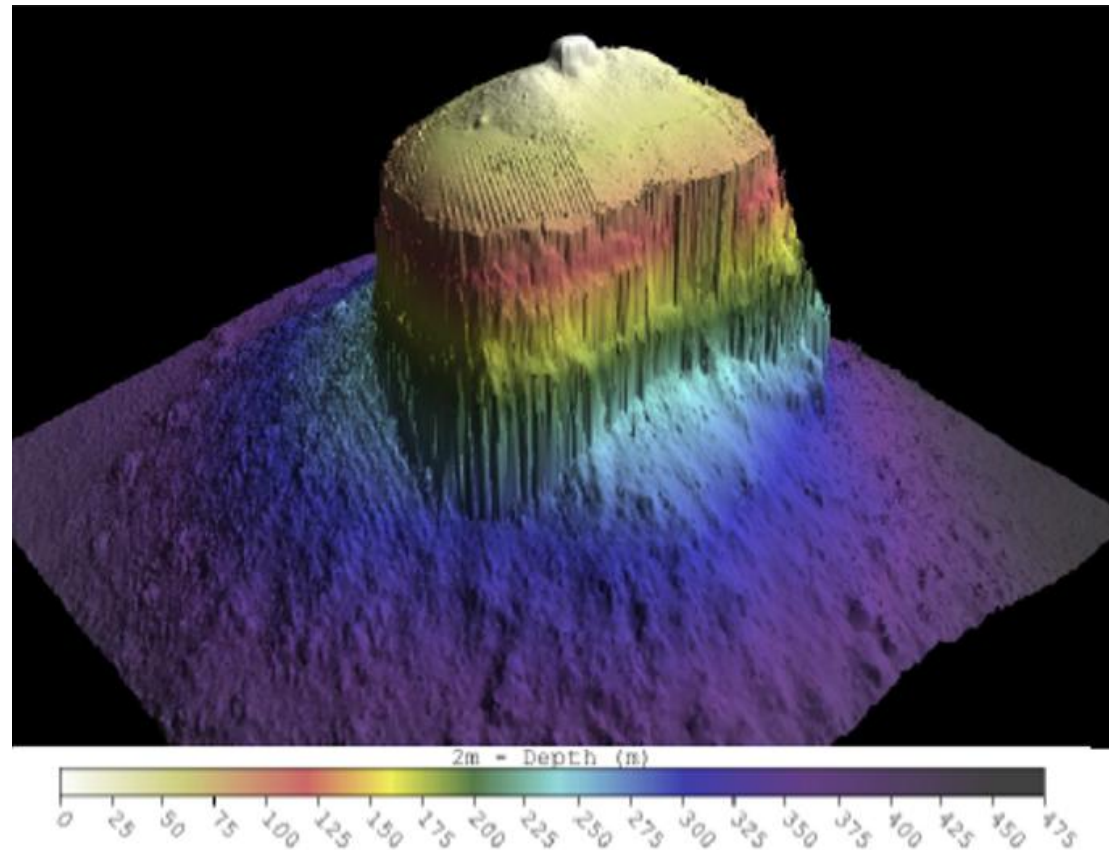


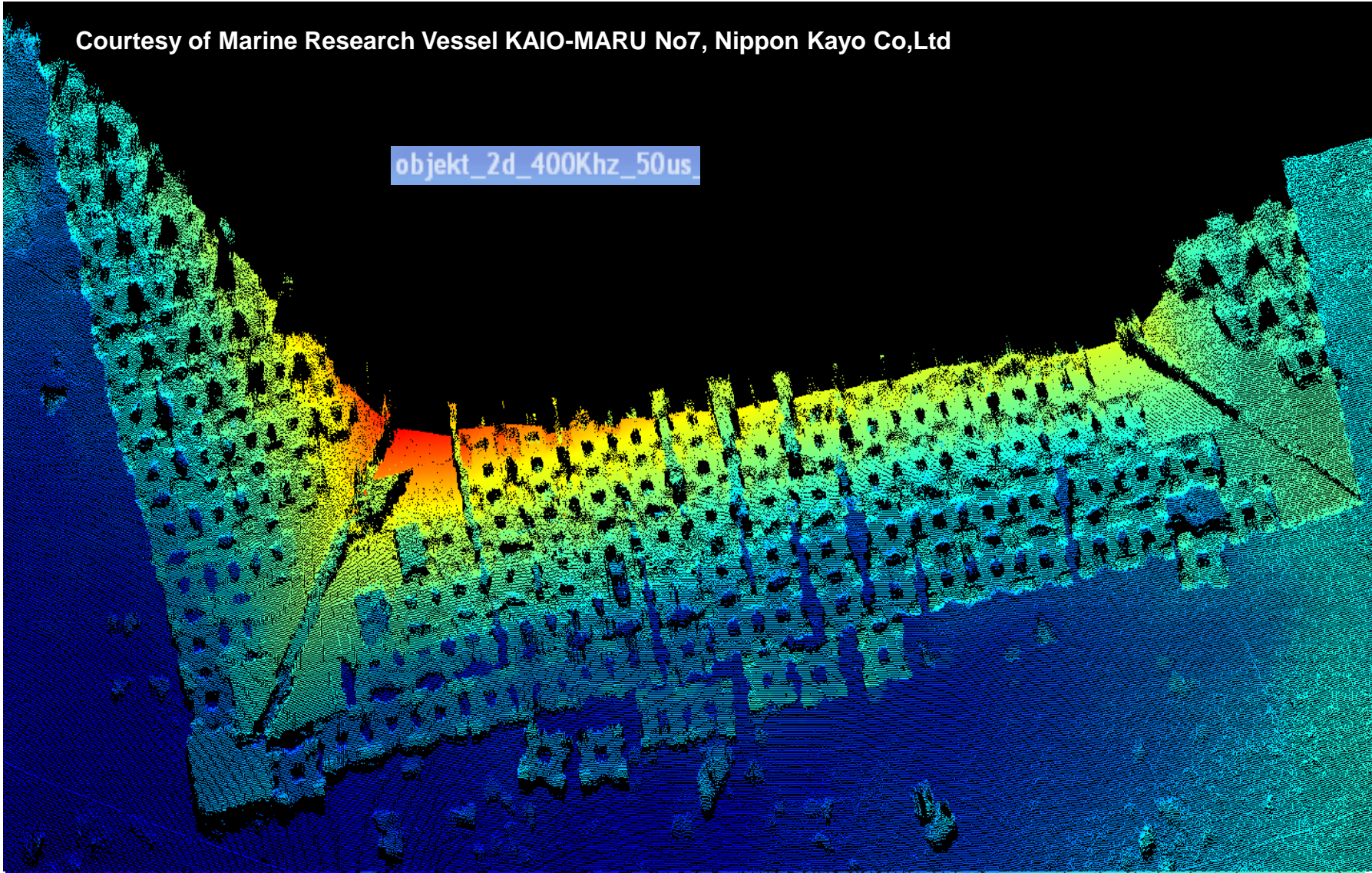
Image provided with permission of Fugro.



Wideband systems

Courtesy of Marine Research Vessel KAIO-MARU No7, Nippon Kayo Co,Ltd

objekt_2d_400Khz_50us_





Shallow to full ocean depth

THE COMPLETE MULTIBEAM ECHO SOUNDER RANGE

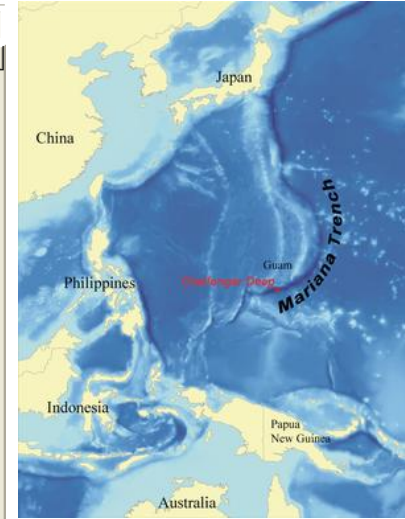
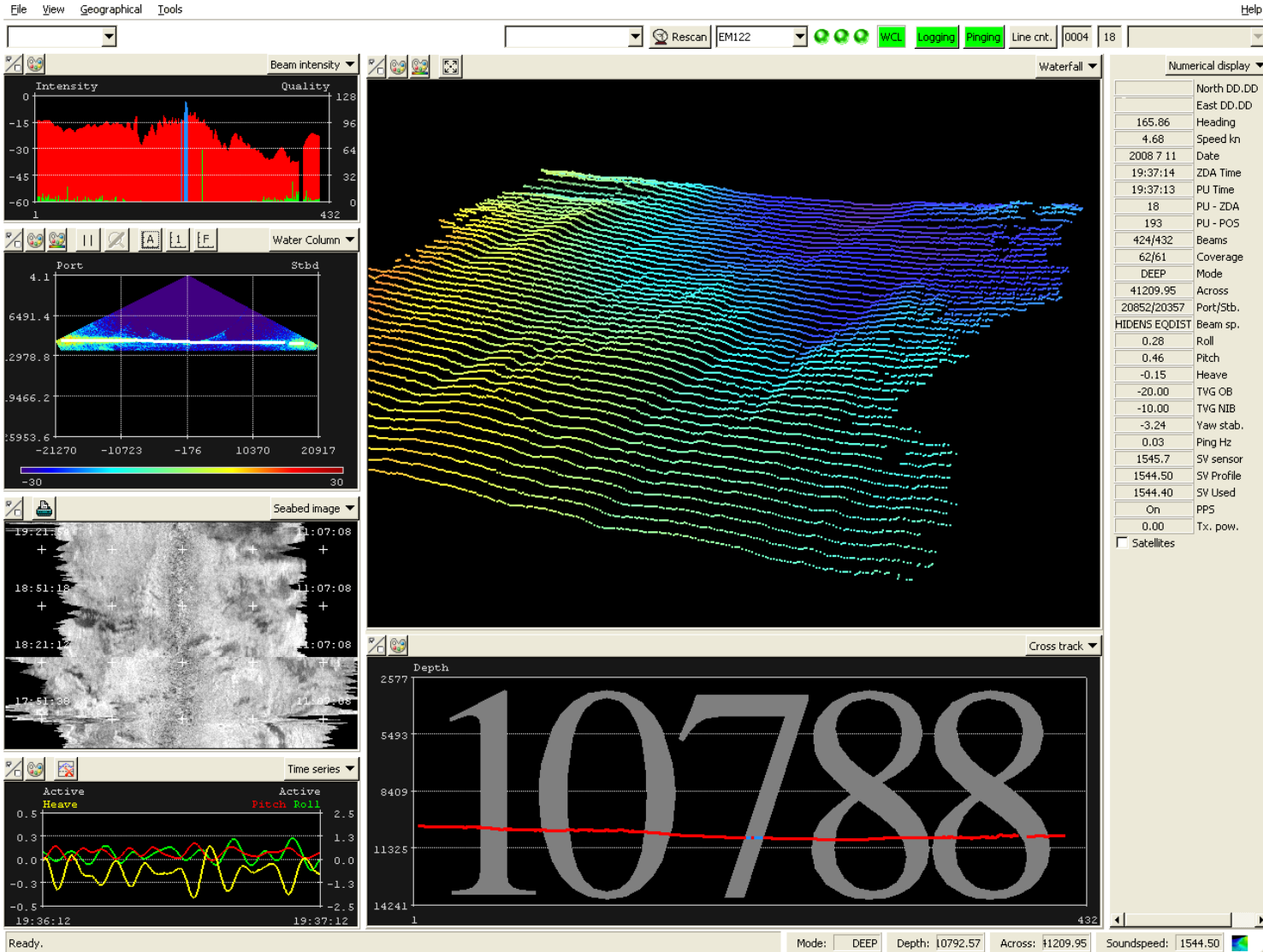


From the shallowest waters to full ocean depth, we've got it covered.

M3	50 m
GeoSwath Plus	200 m
EM® 2040C	500 m
EM® 2040P	550 m
EM® 2040	600 m
EM® 712	3600 m
EM® 302	7000 m
EM® 122	11000 m



Mapping the Mariana Trench

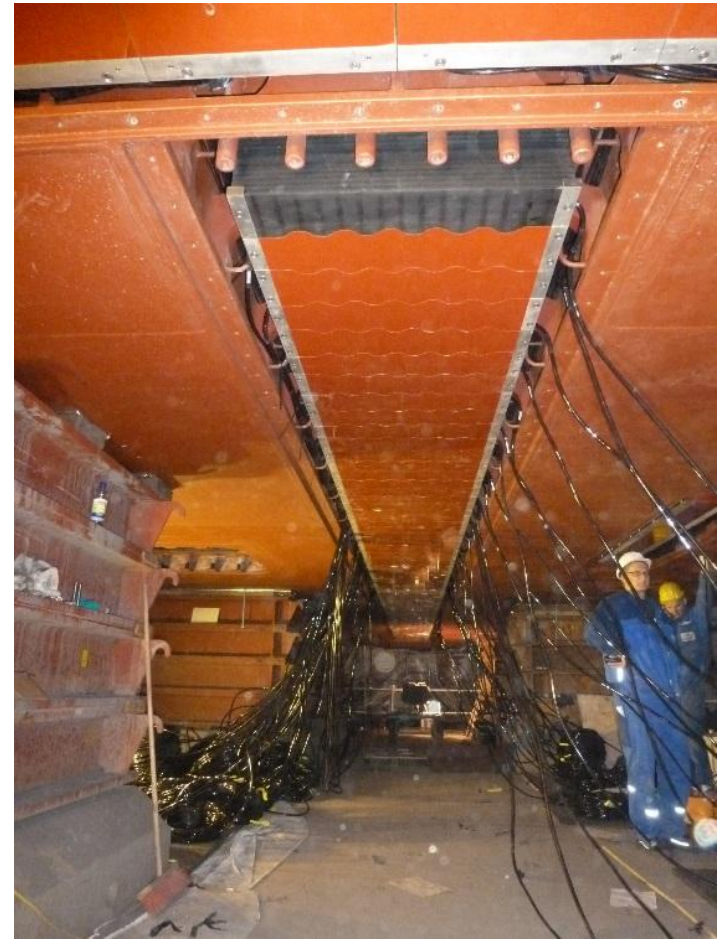


EM 122 data.
 Courtesy of
 Naval
 Oceanographic
 Office.

EM 122 on RV Sonne

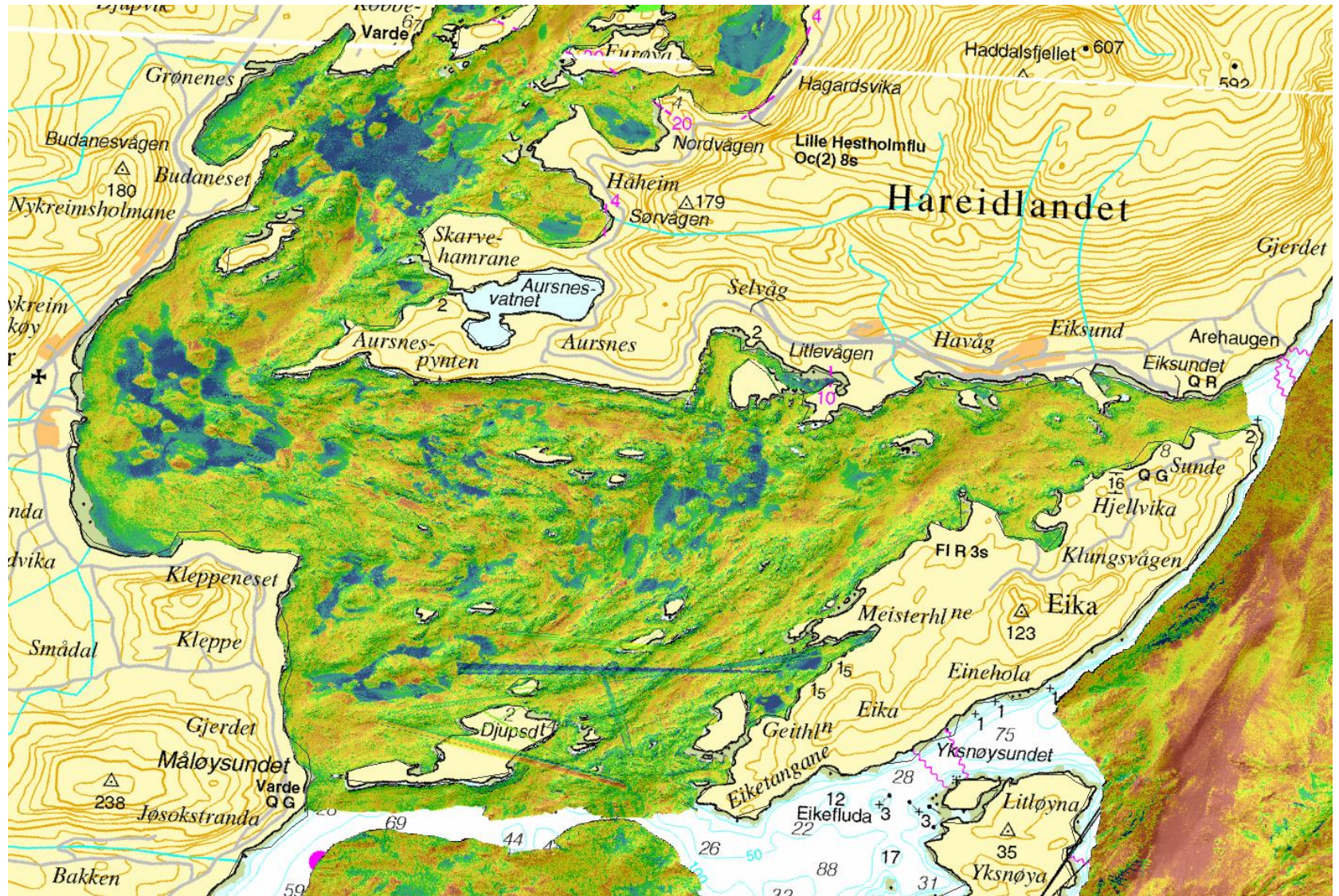


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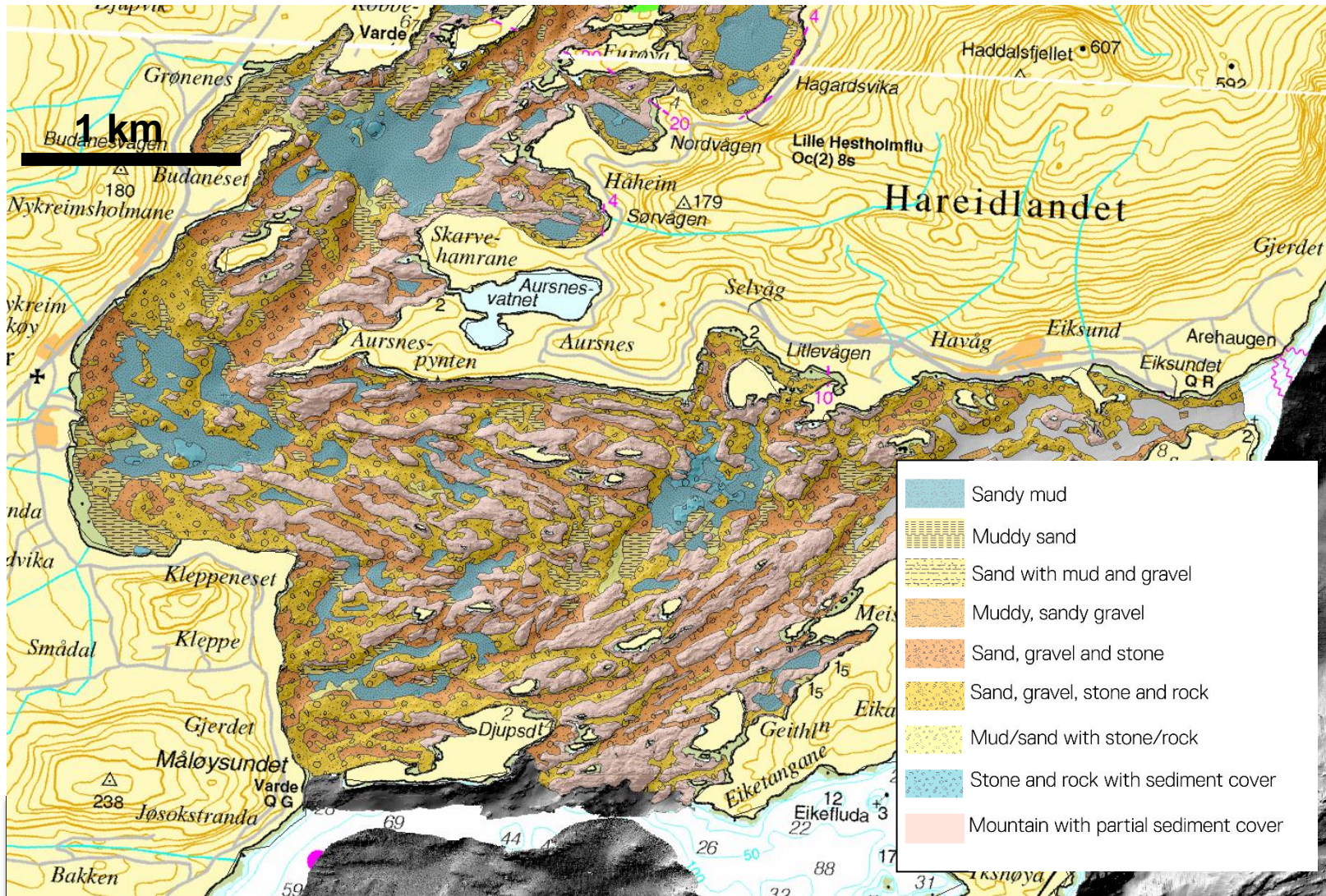
16 m TX frame array, 8 m RX frame array: $0.5^\circ \times 1.0^\circ$ @ 10 kHz

Backscatter



Courtesy Geological Survey of Norway

Backscatter interpretation

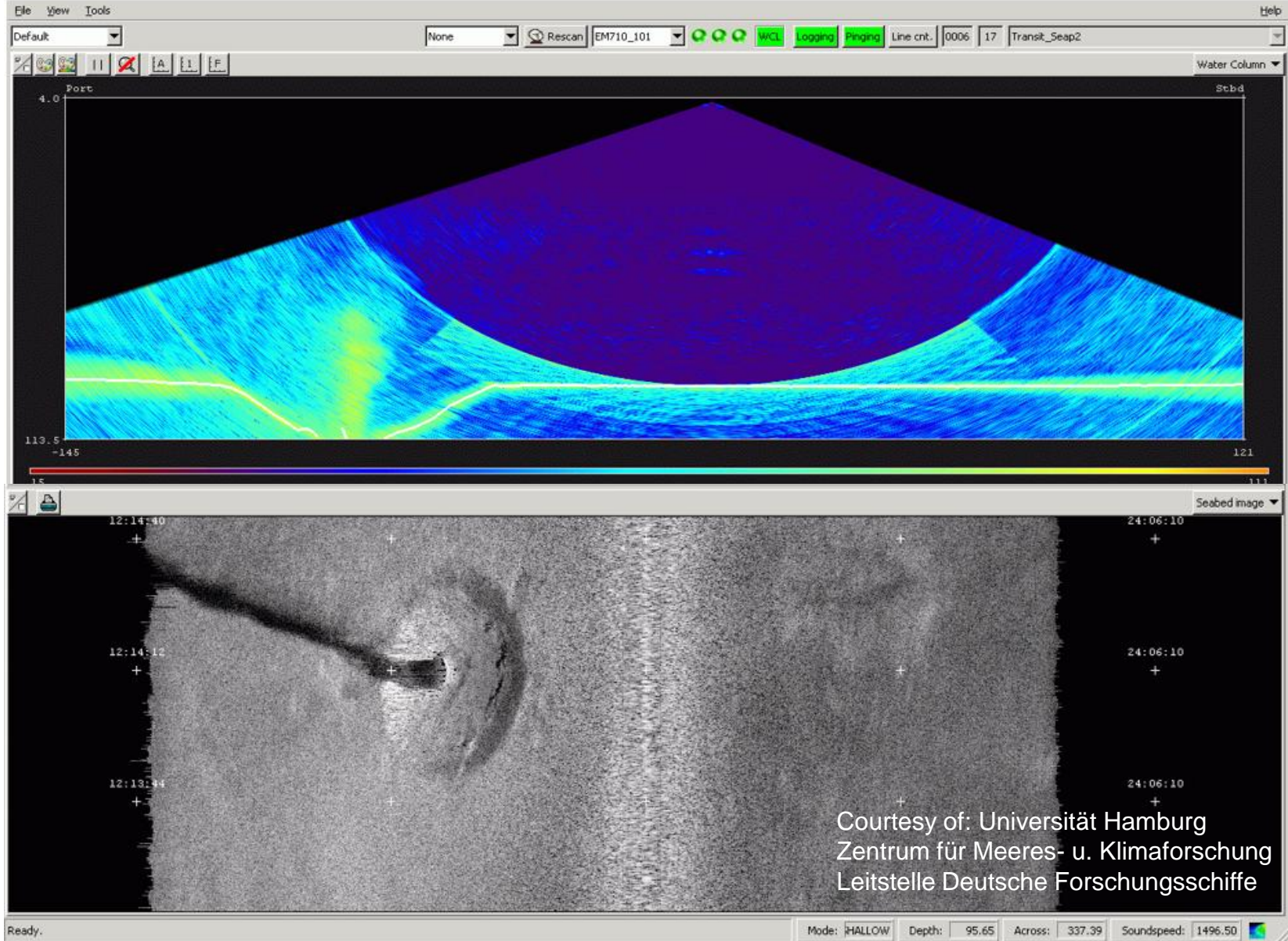


Courtesy Geological Survey of Norway

Water column data



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Courtesy of: Universität Hamburg
Zentrum für Meeres- u. Klimaforschung
Leitstelle Deutsche Forschungsschiffe



Water column data and multiple detections

GB Church, Sidney, B.C. Canada
Water Column Data – from a single pass



Courtesy of John Hughes Clarke – Ocean Mapping Group / University of New Brunswick

Trend: Research vessels, hydrographic vessels



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- Automation and Data Management
- Underwater Mapping
- Marine Robotics
- Marine Ecosystem Monitoring
- High Precision Acoustic Positioning
- Underwater Environmental Monitoring
- Camera and Light Systems
- Launch and Recovery Systems
- Position Reference Systems
- Dynamic Positioning
- Integrated Bridge Solutions and Navigation Systems
- Automation and Power Management
- Simulation Systems

Merging shallow and deep water data



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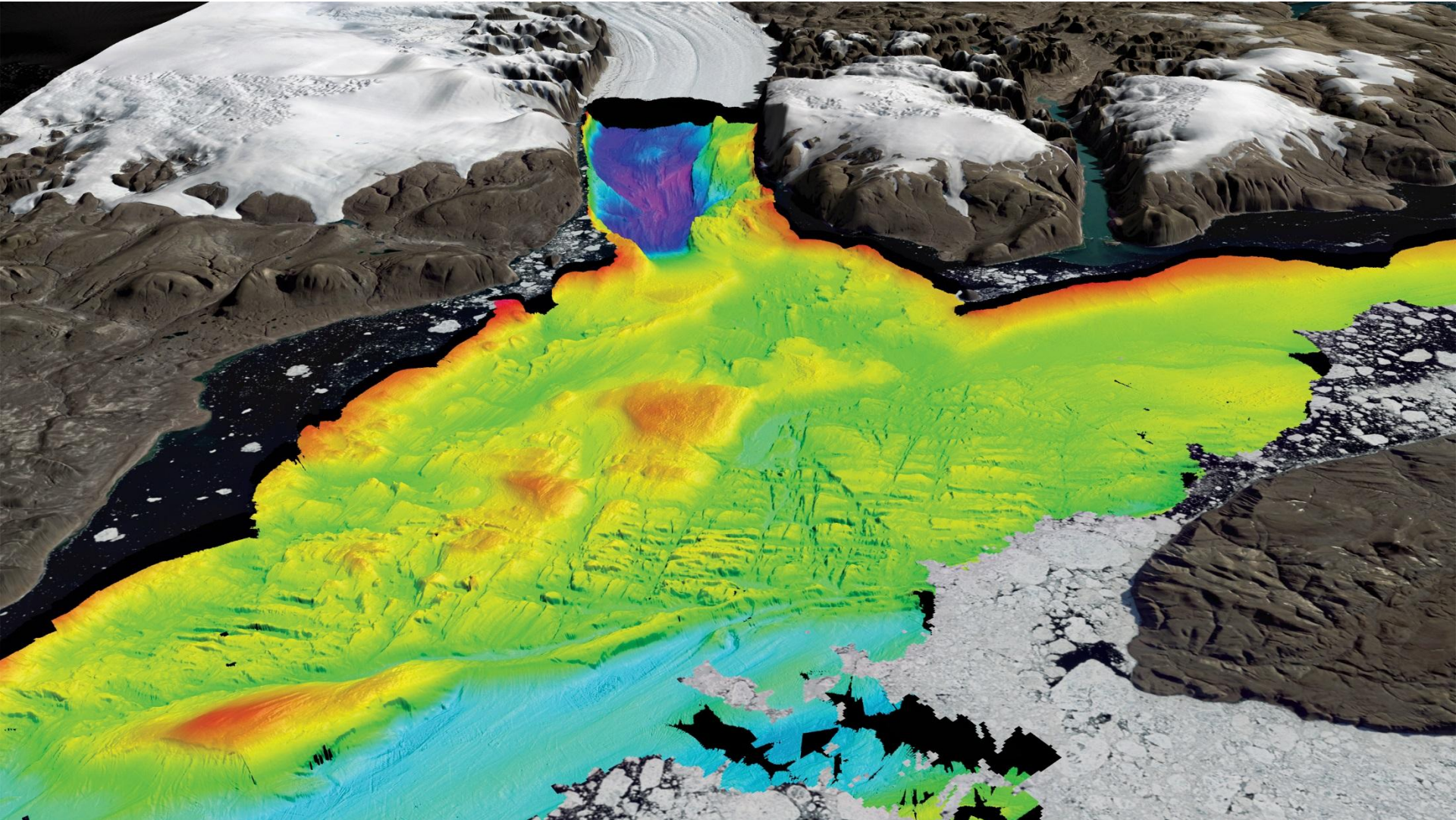
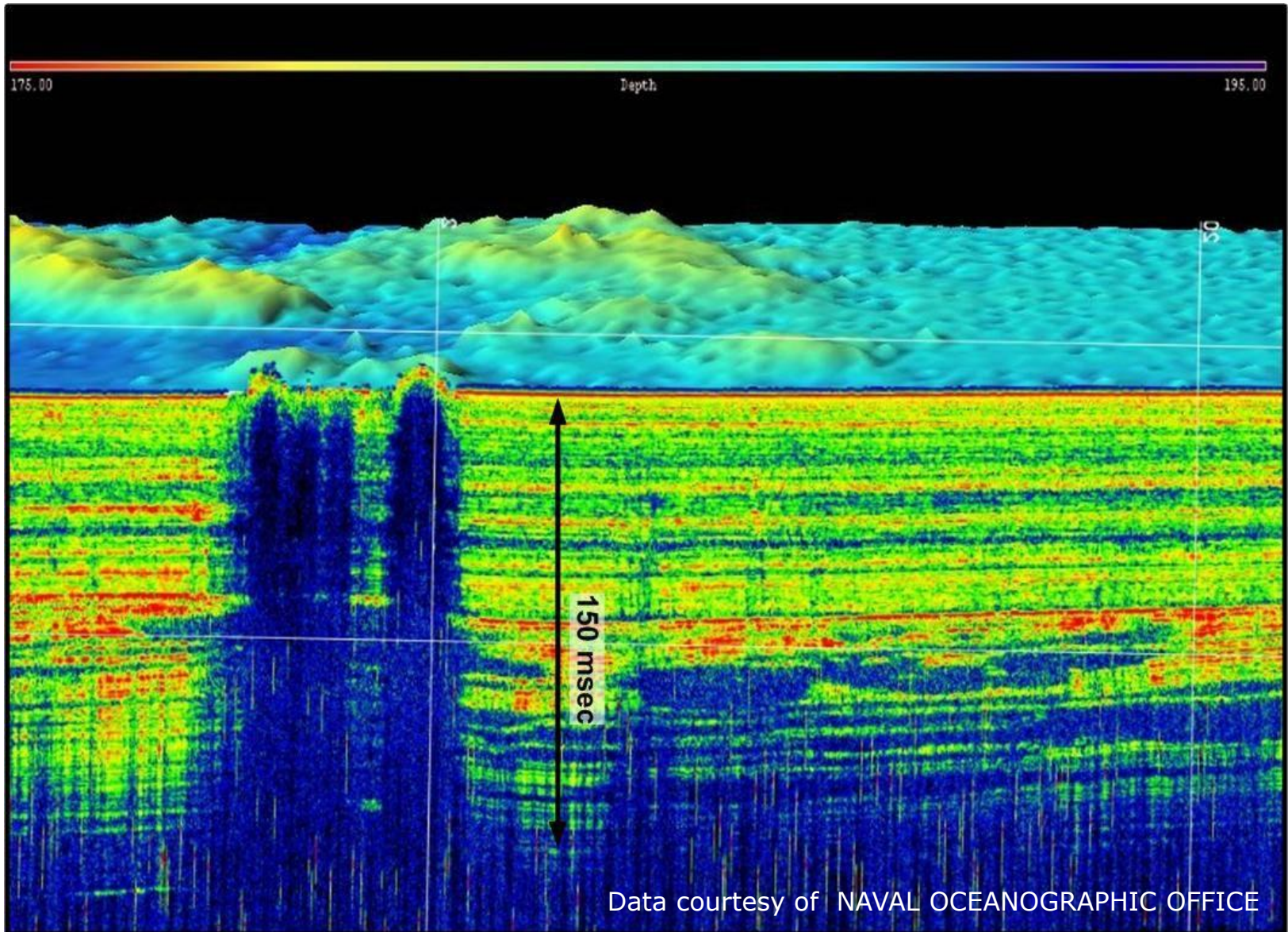


Image courtesy Stockholm University. EM 2040 and EM 122 data.



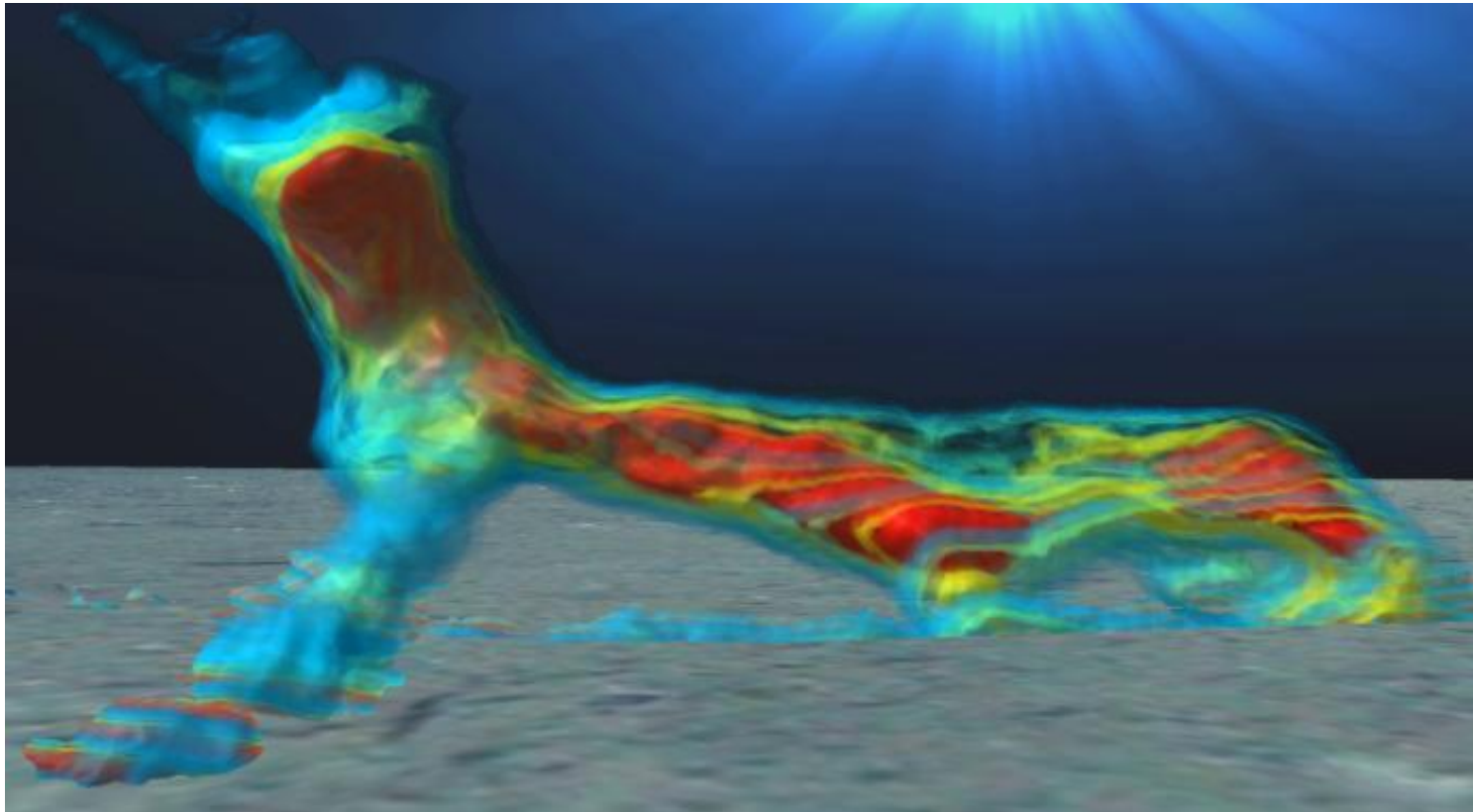
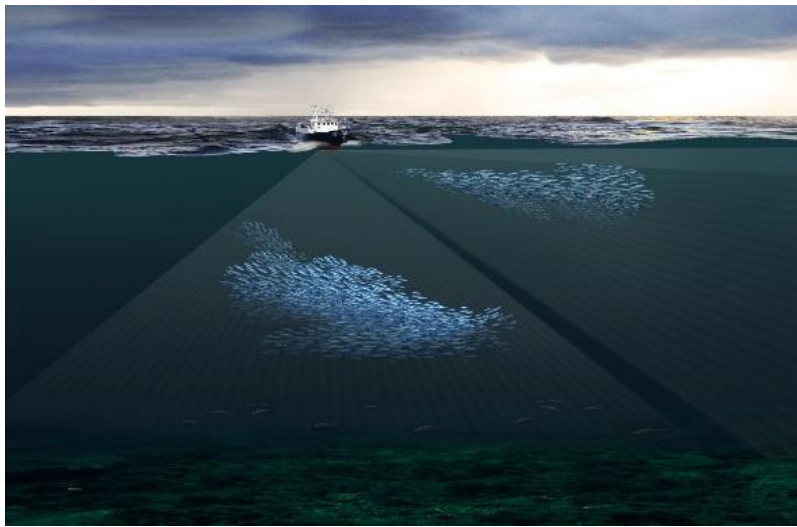
Sub-bottom profiler





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Fishery stock estimation



Schooling
Sand Eel
close to
bottom in
the North
Sea
mapped
with
Simrad
ME70
scientific
multibeam

Trend: portable systems for shallow water

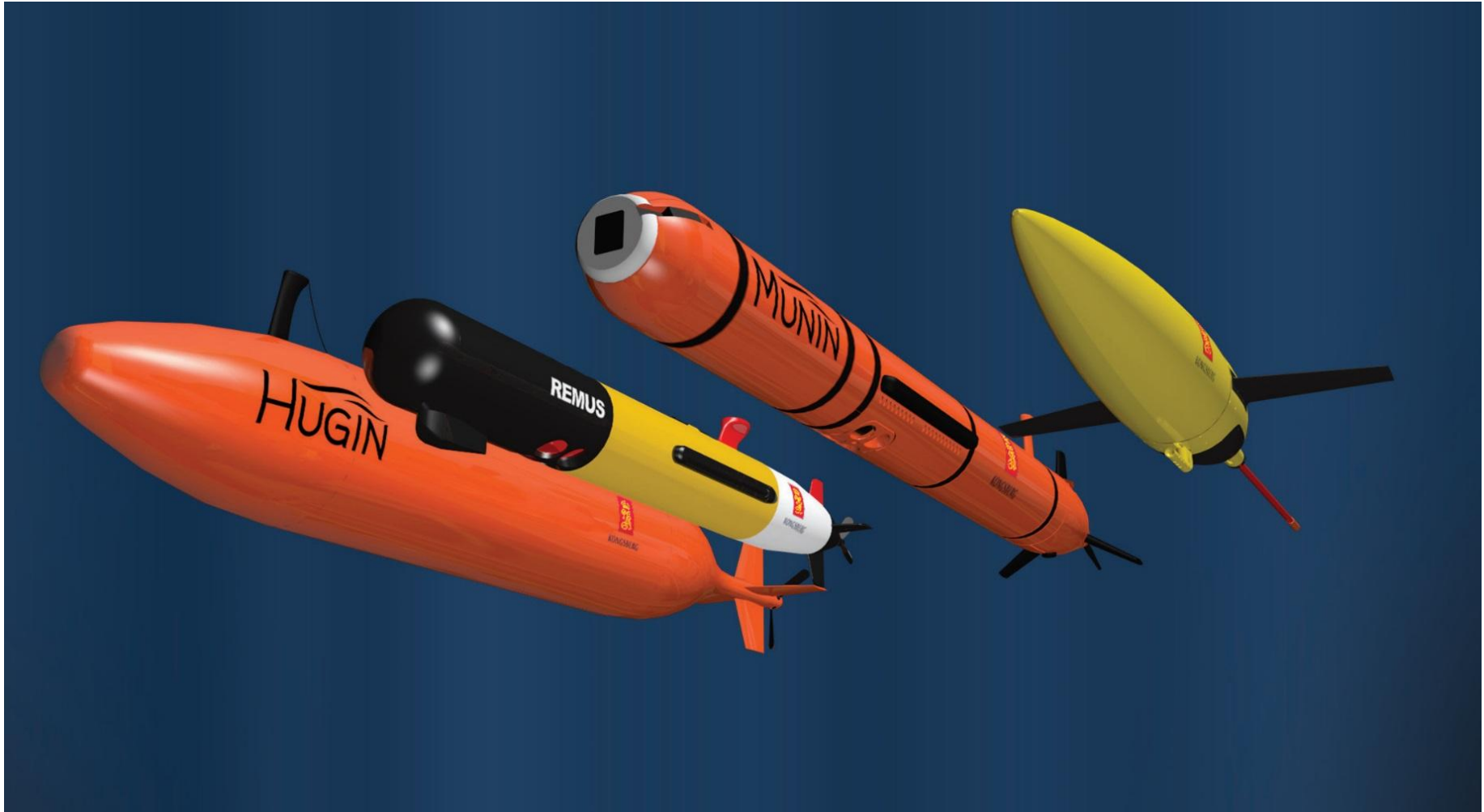


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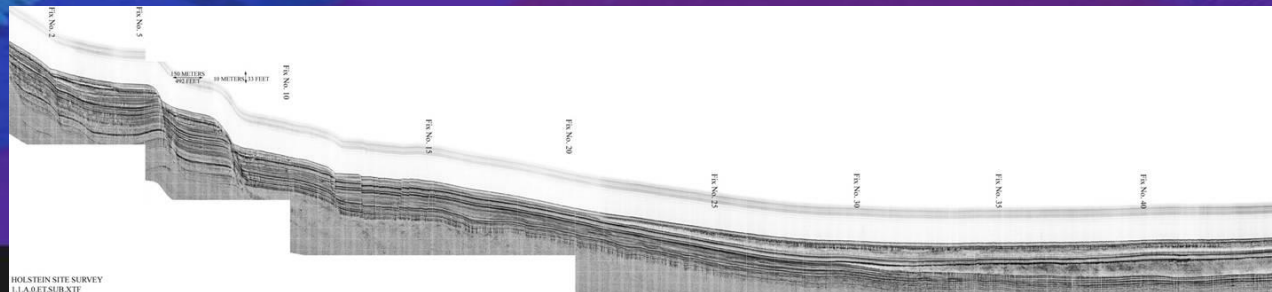
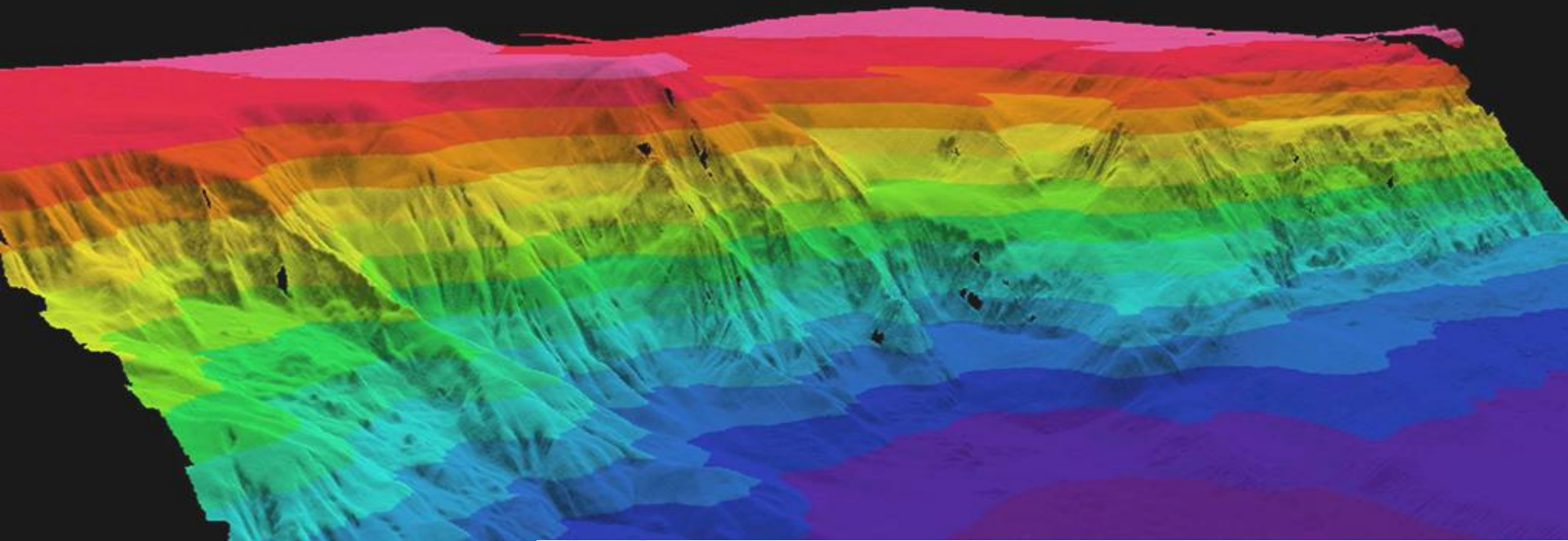




Trend: marine robotics



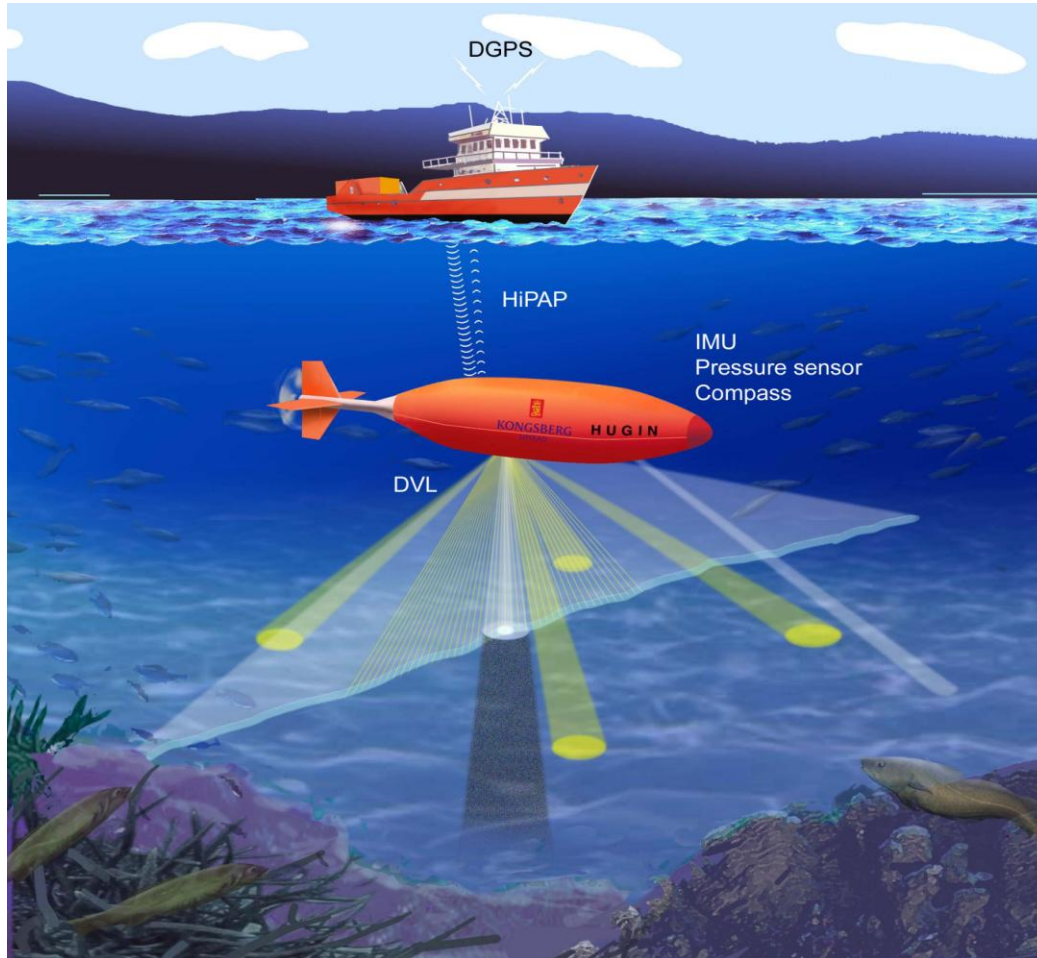
Gulf of Mexico commercial AUV survey 2000 - 2001



Courtesy C & C Technologies



GPS - USBL



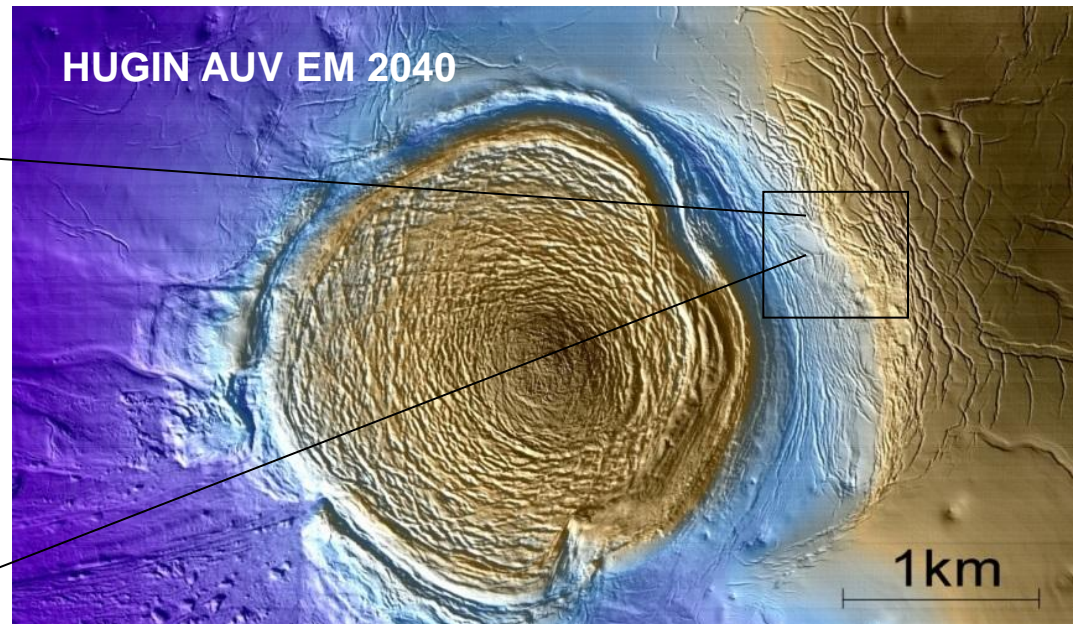
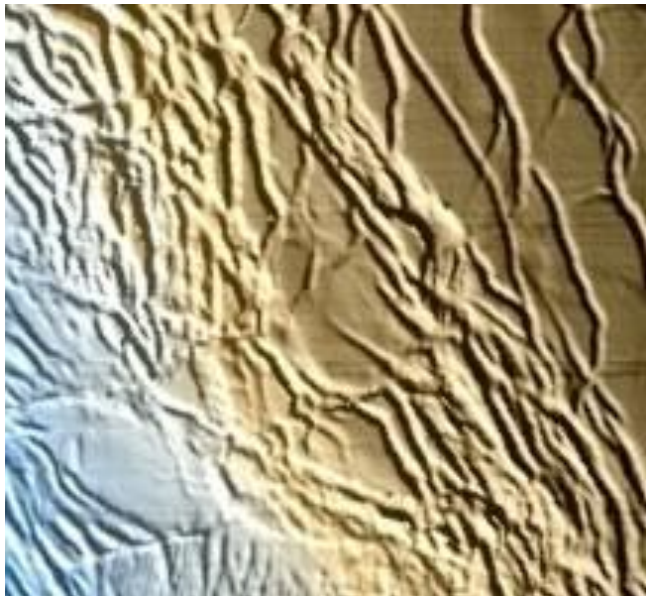
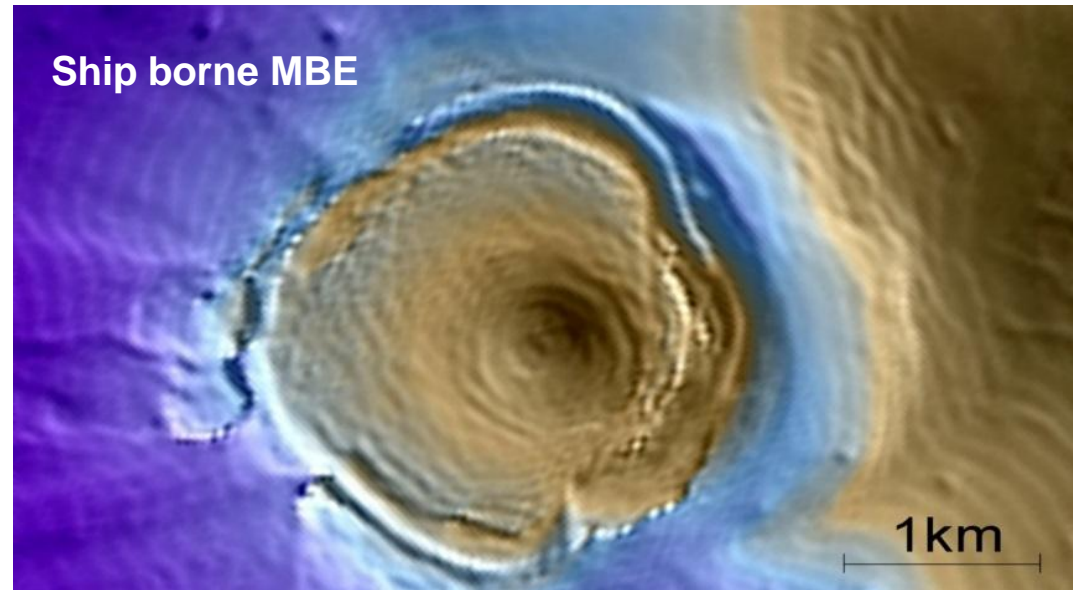
AUV survey position accuracies
Gulf of Mexico 2000 / 2001:

- 1300 m: 2 m (1σ)
- 2100 m: 4 m (1σ)

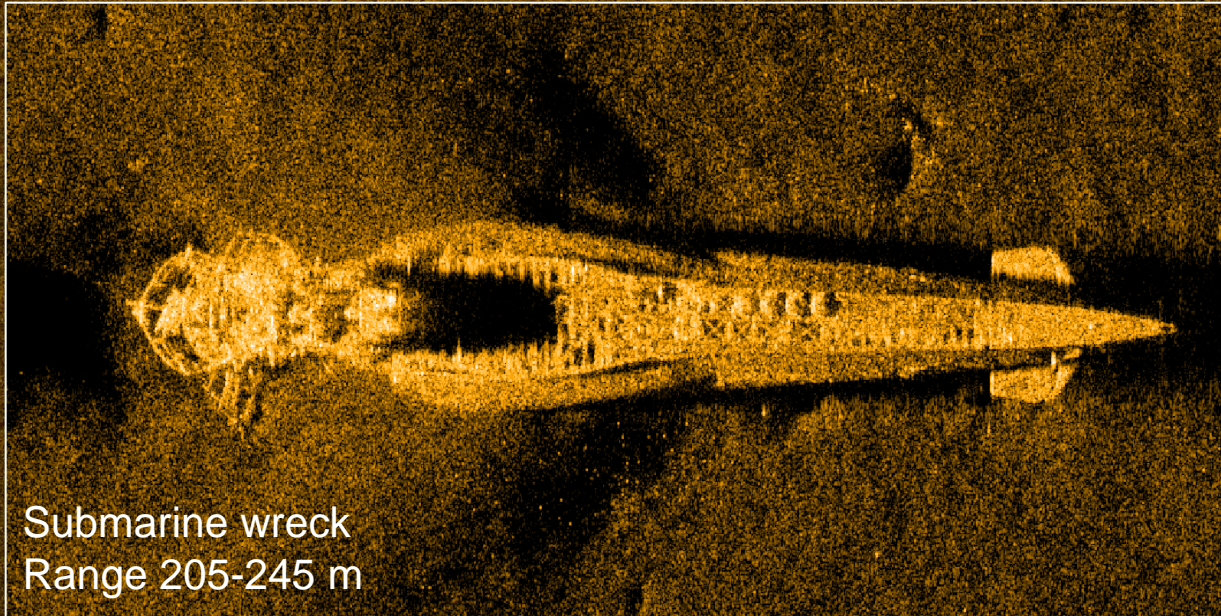


Detailed seabed mapping with AUV

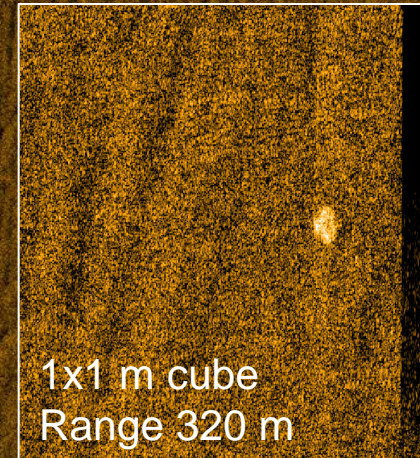
Data courtesy of Fugro



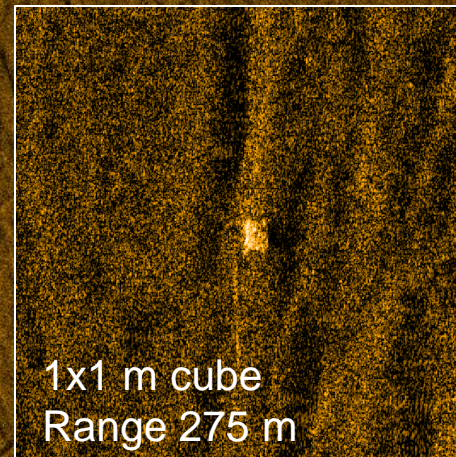
Synthetic aperture sonar long range example



Submarine wreck
Range 205-245 m



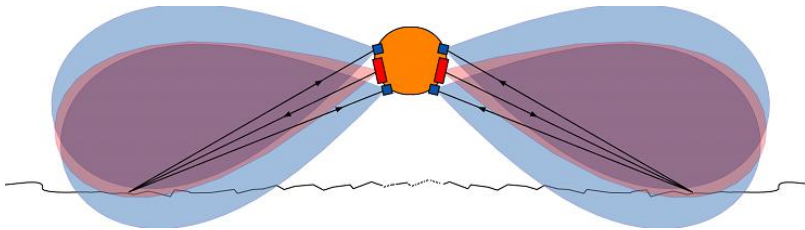
1x1 m cube
Range 320 m



1x1 m cube
Range 275 m

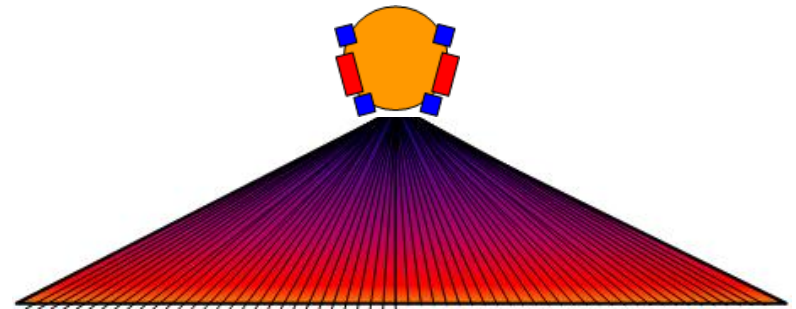
HISAS 1030 on HUGIN 1000-MR
Range 25-325 m
AUV altitude 40 m
Speed 2.3 knots

Interferometric SAS and MBE for hydrographic mapping



Interferometric SAS

- High area coverage rate, typically 2km²/hr.
- Blind zone directly below the vehicle (nadir gap)

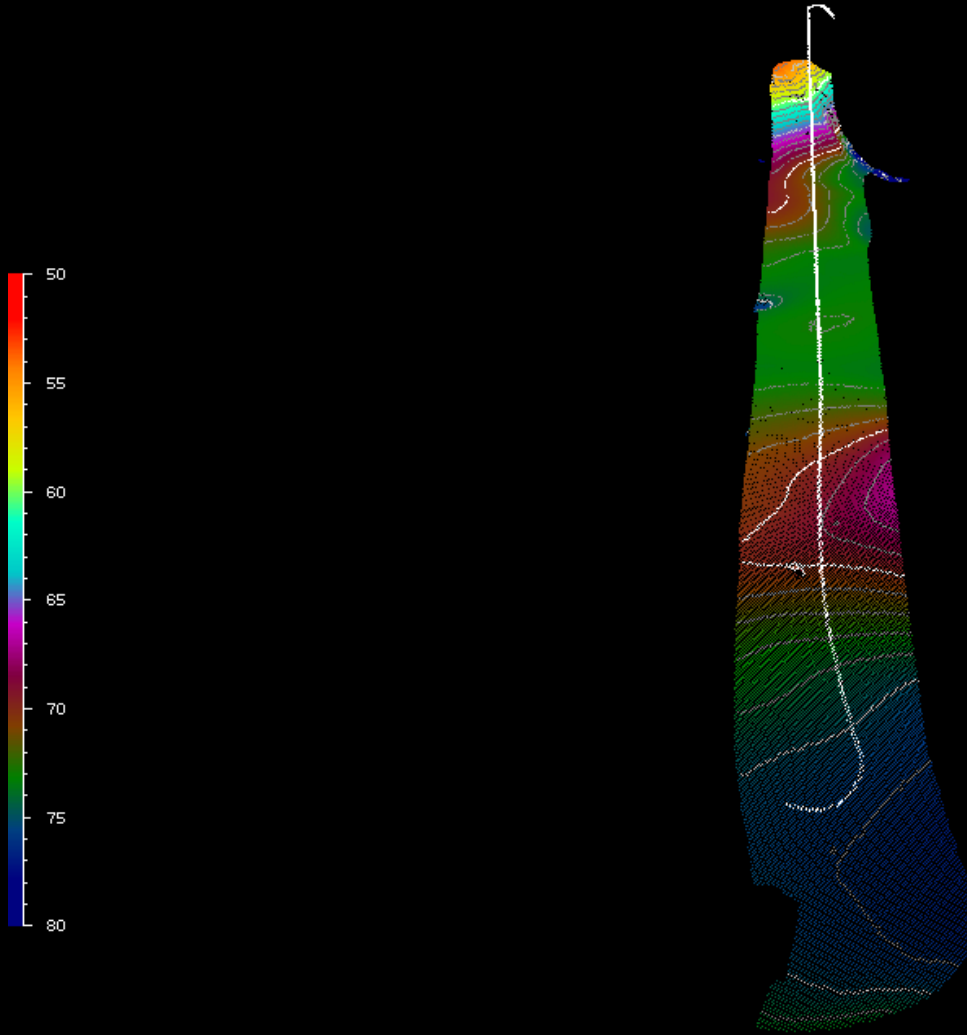


MBE

- Beamformers have advantage at nadir
- Less coverage than interferometric SAS



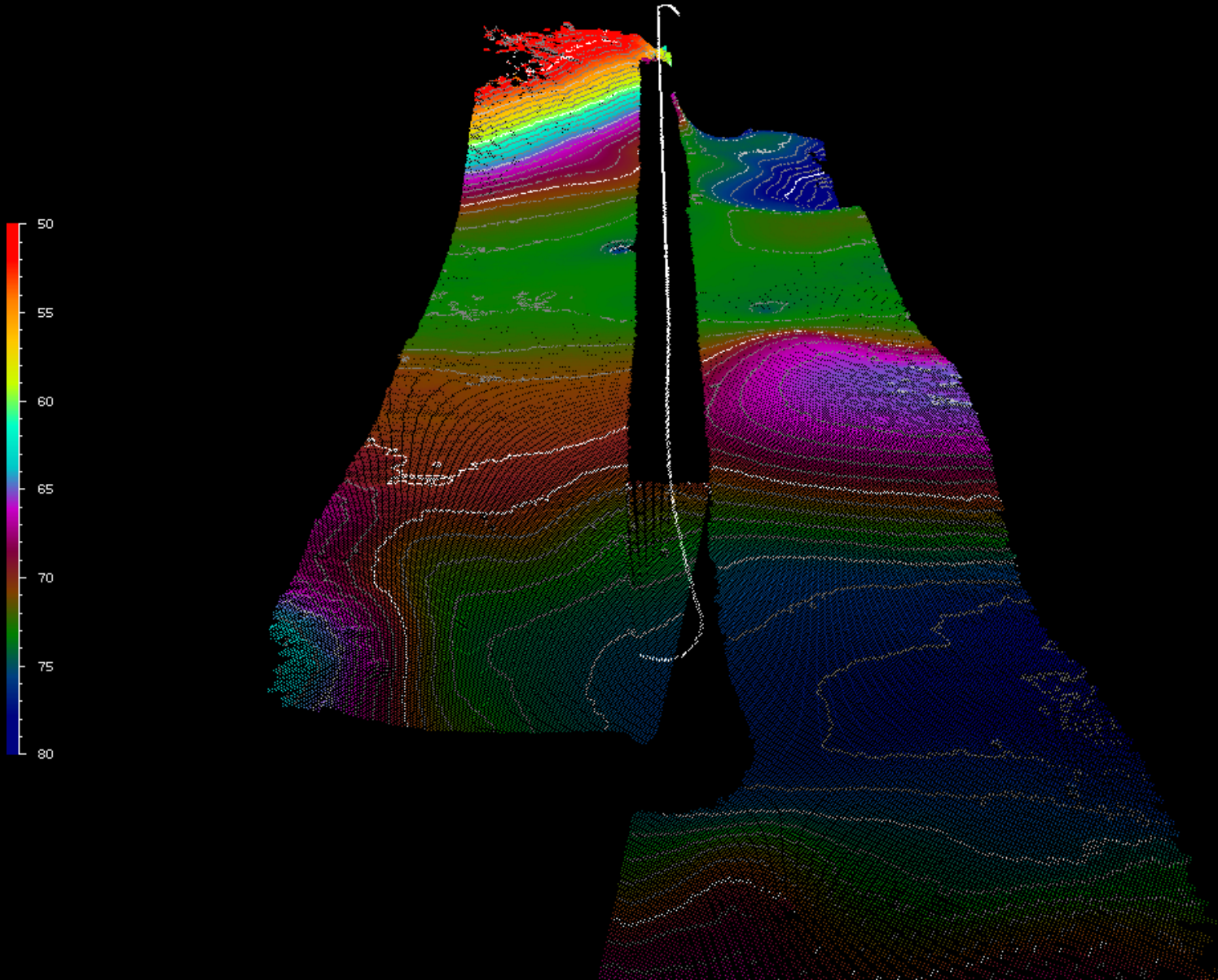
EM 2040 bathymetry (400 kHz)



HISAS sidescan bathymetry



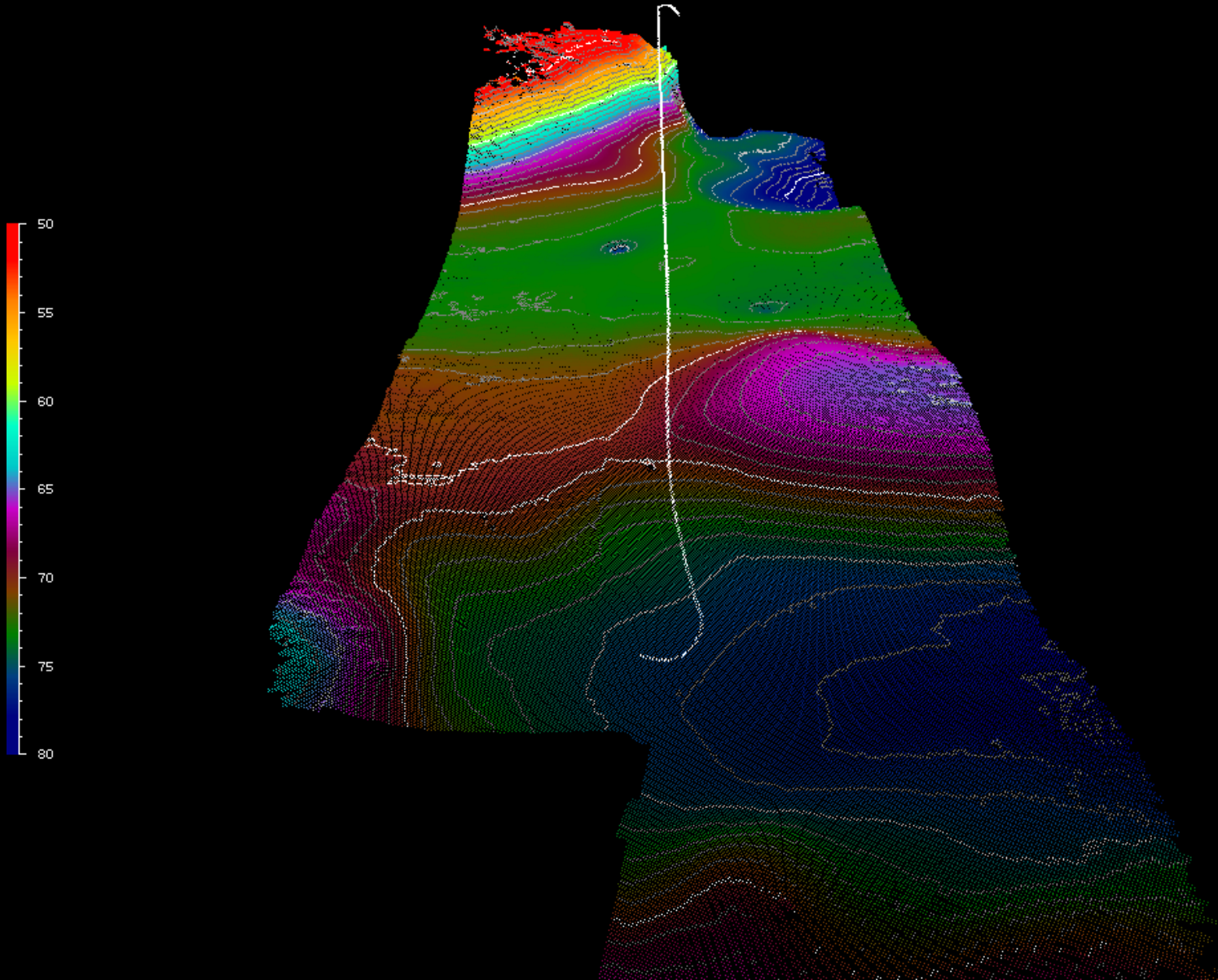
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Merged bathymetry



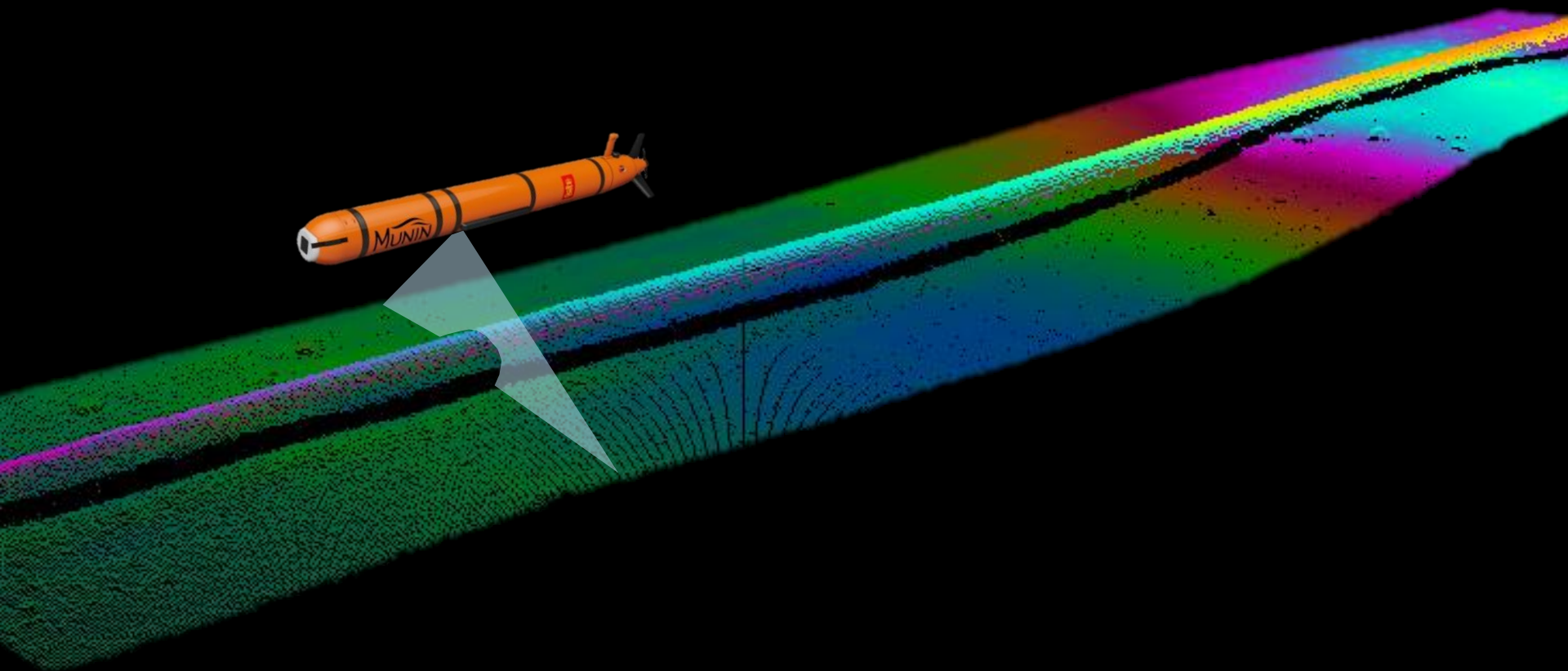
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Pipeline survey



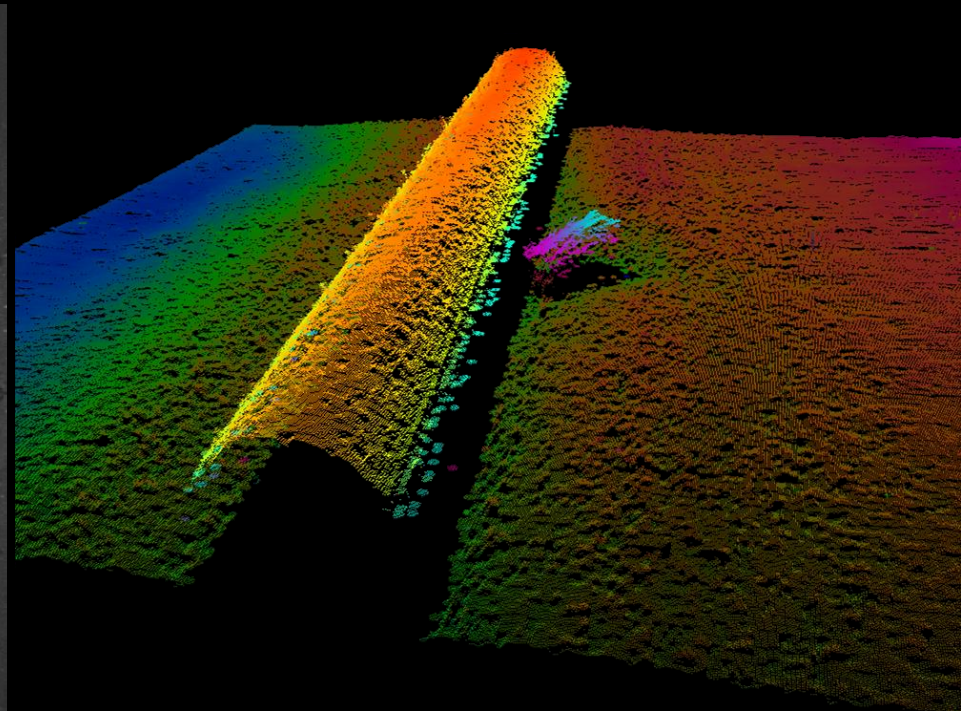
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Pipeline survey



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Trends in data processing



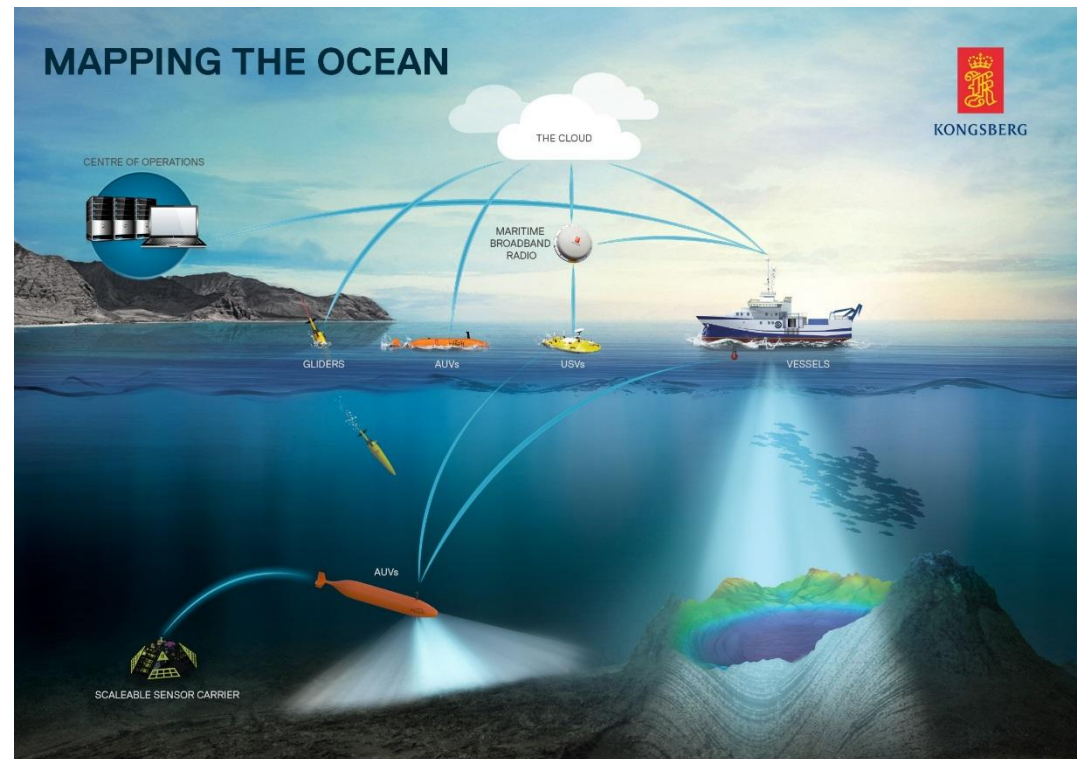
- Instruments produce cleaner data
- Higher data density, richer data sets – more processing and data handling
- More automated processing
- Ecosystem on open standards
- Value added services
- Land and ocean mapping meets

Courtesy Geological Survey of Norway



What holds the future?

- Cleaner data
- Improved accuracy
- Multifrequency seafloor classification
- Synthetic aperture sonar
- Continued robotization
- Extending from mapping to monitoring
- Connected operations
- Automated processing
- Open standards



MAPPING THE OCEAN



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CENTRE OF OPERATIONS



THE CLOUD

MARITIME
BROADBAND
RADIO



GLIDERS

AUVs

USVs

VESSELS

AUVs

SCALEABLE SENSOR CARRIER