Multibeam Echosounders

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Multibeam echosounders: The high-resolution tool for mapping the seafloor

- Seafloor is not fully mapped
- Most bathymetry from satellite derived bathymetry
- Only 26.1% mapped to a high resolution

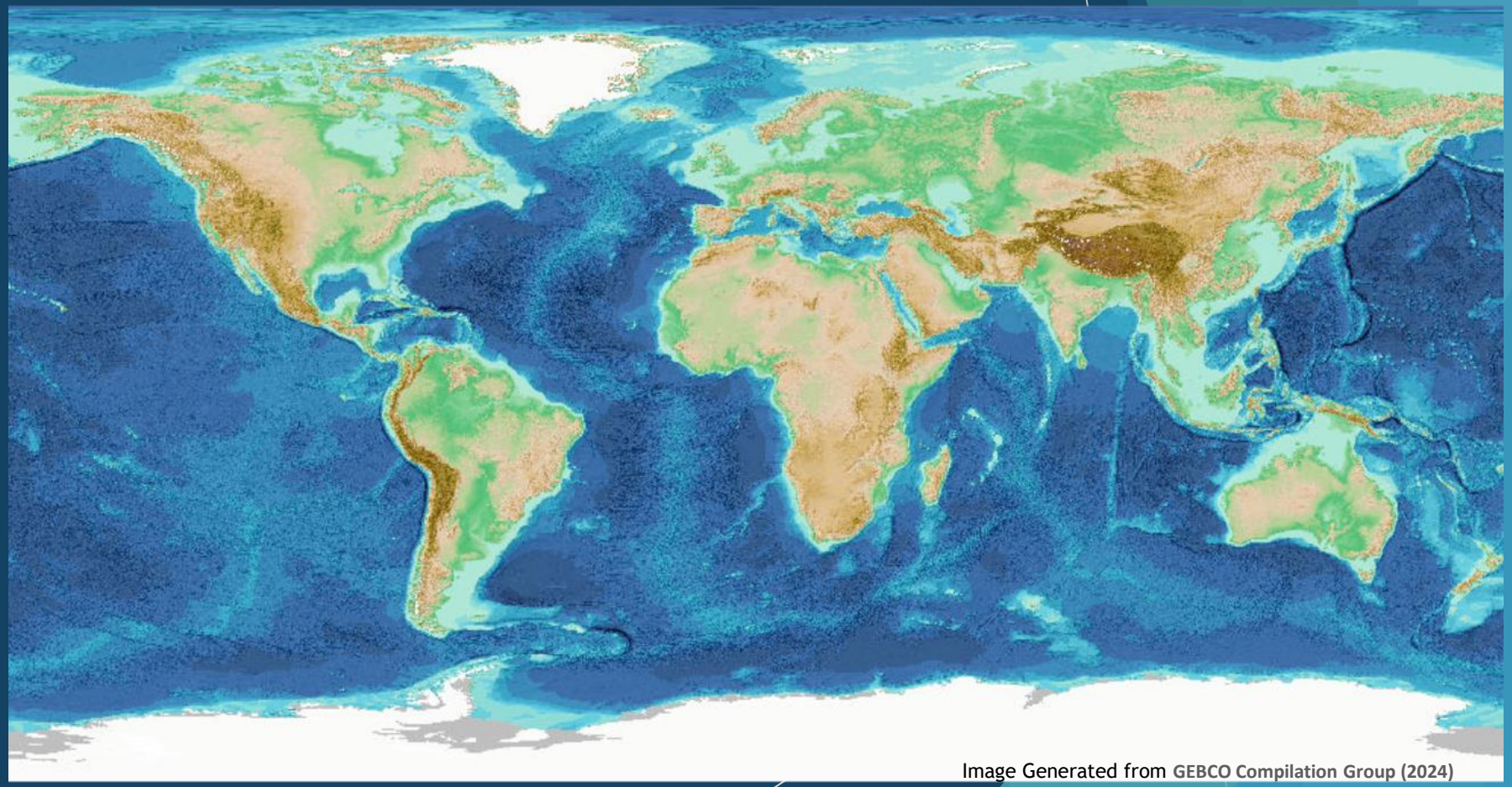


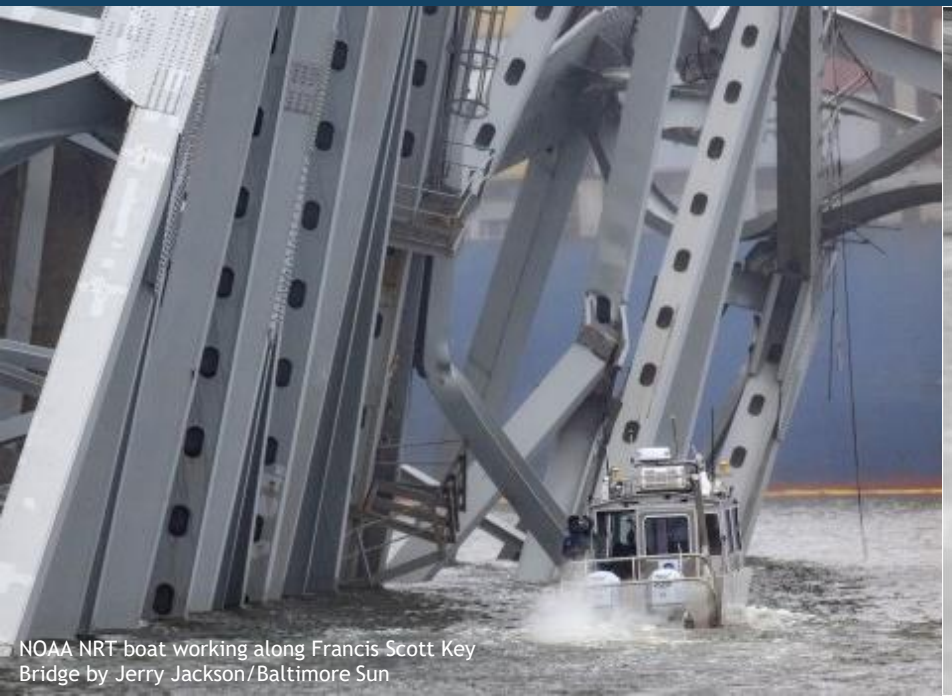
Image Generated from GEBCO Compilation Group (2024)

Multibeam echosounders:
The high-resolution tool for mapping the seafloor

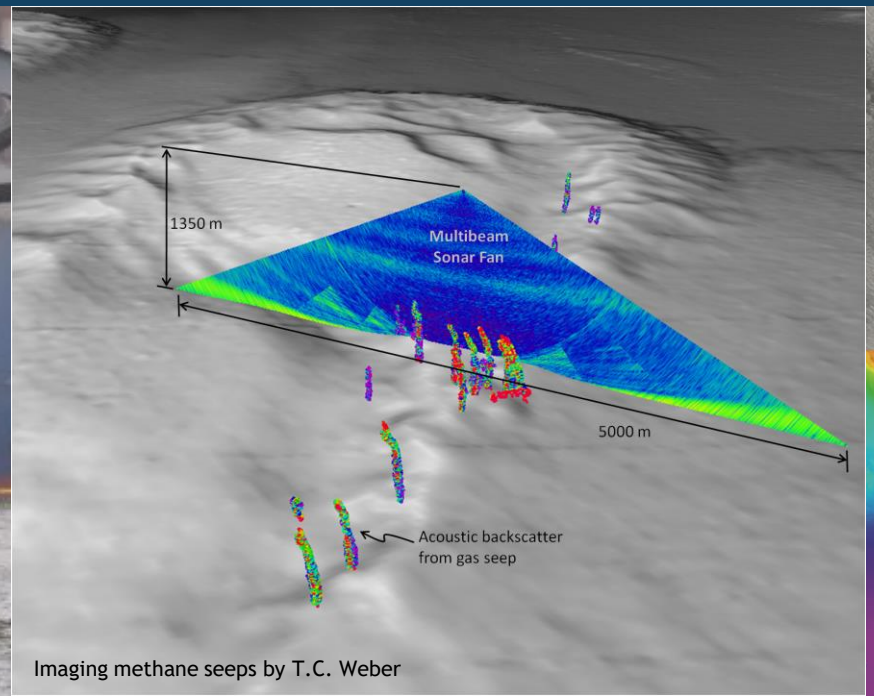
Not just for Exploration

Many products and uses from the same tool:

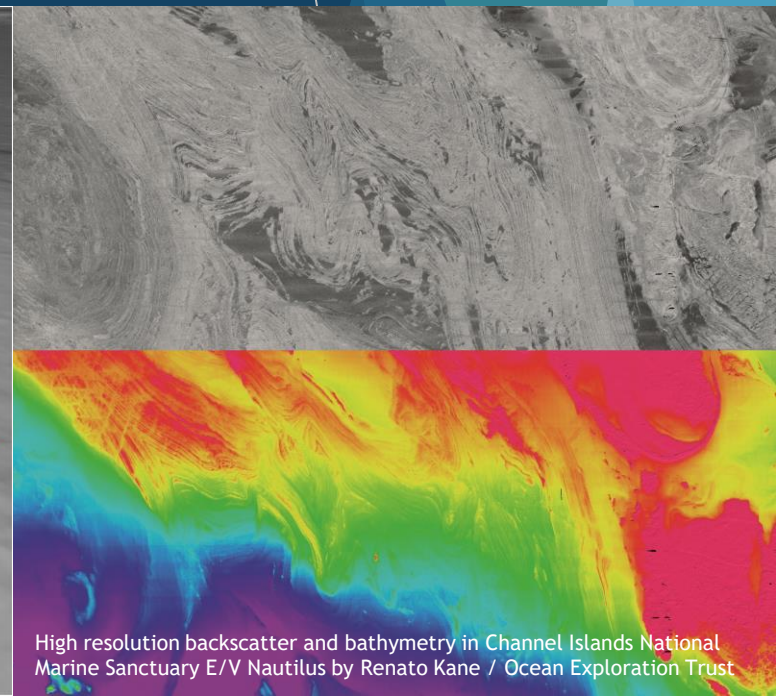
- Safety of navigation
- Geological research
- Fisheries science
- Offshore Engineering
- Marine archeology
- Habitat modeling
- Natural resource exploration
- Defense



NOAA NRT boat working along Francis Scott Key Bridge by Jerry Jackson/Baltimore Sun



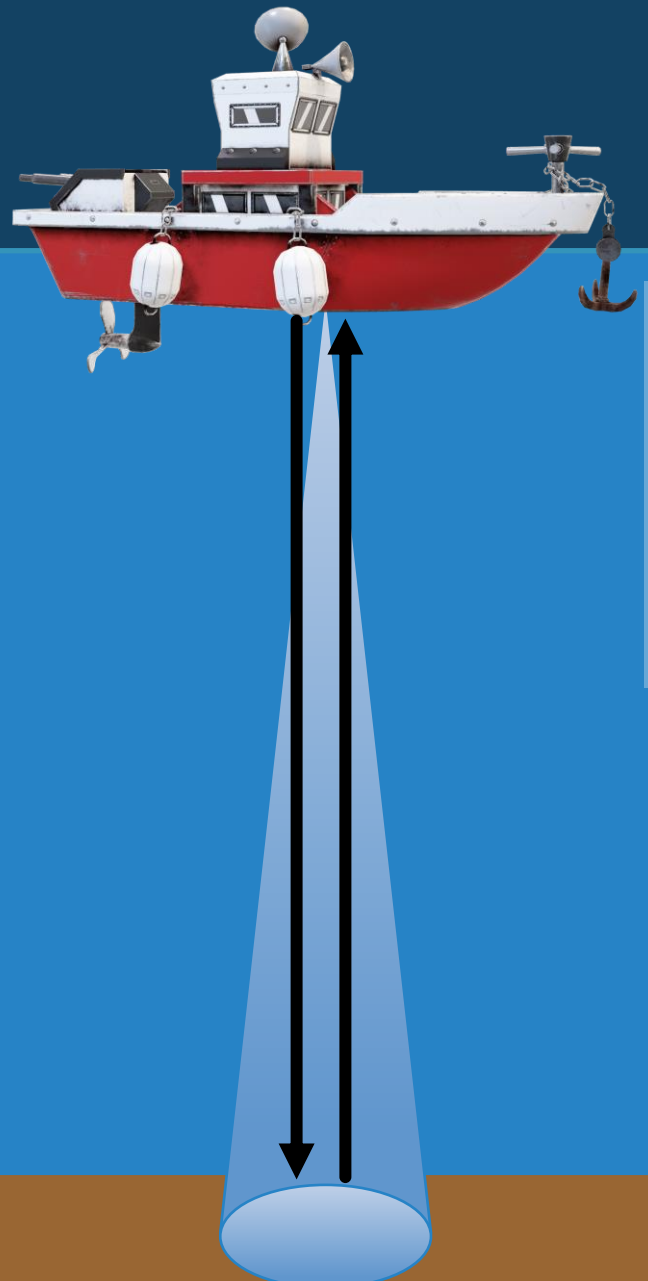
Imaging methane seeps by T.C. Weber



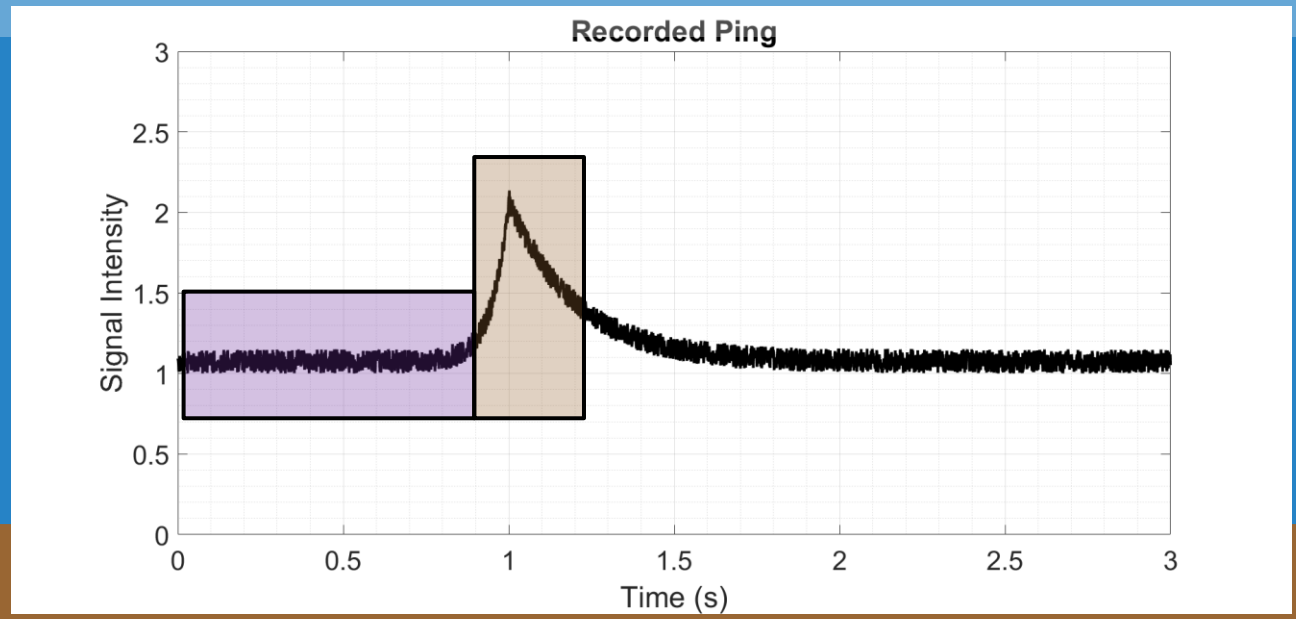
High resolution backscatter and bathymetry in Channel Islands National Marine Sanctuary E/V Nautilus by Renato Kane / Ocean Exploration Trust

Quick review slide on Single beam echosounders

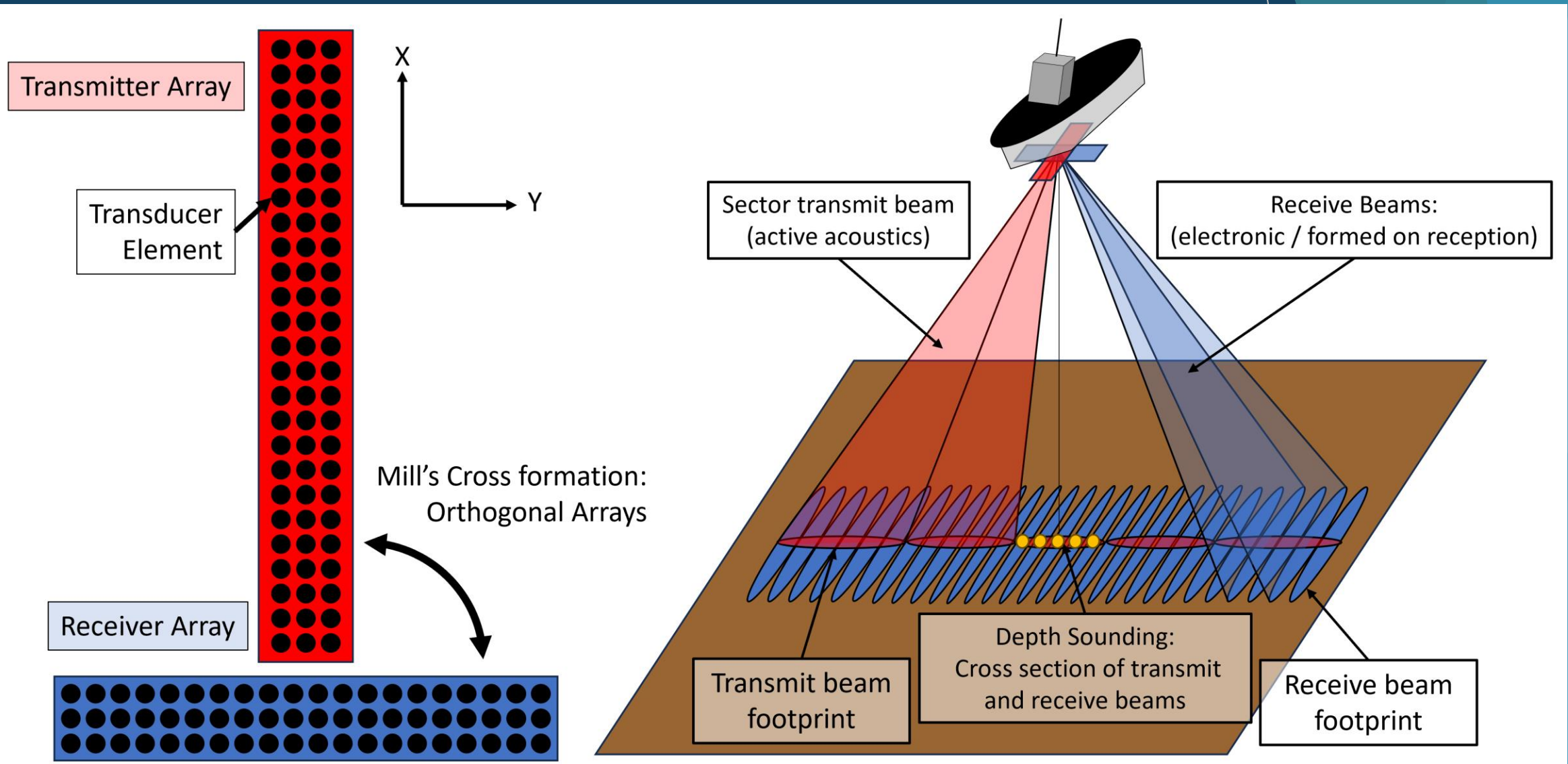
Quick review slide on single beam echosounders



- **Range : (Two-way travel time/2) * speed of sound in water**
- **Seafloor backscatter : Intensity level of return at seafloor**
- **Water column backscatter: Intensity level of return in the water.**



MBES Basics


Transmitter Array
Transducer Element
X
Y
Mill's Cross formation:
Orthogonal Arrays
Receiver Array
Sector transmit beam
(active acoustics)
Receive Beams:
(electronic / formed on reception)
Transmit beam footprint
Depth Sounding:
Cross section of transmit and receive beams
Receive beam footprint

An *array* of sizes: shallow-water system

Frequencies:
100-800kHz

Pulse lengths:
~0.010ms to ~5ms

Ping Rates:
1-50Hz

Source Levels:
200dB-220dB re 1μPA

Operational depths:
>1m to 600m

An *array* of sizes: deep-water systems

Frequencies:
10-70kHz

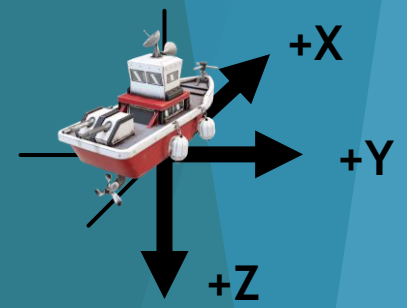
Pulse lengths:
~3ms to ~200ms

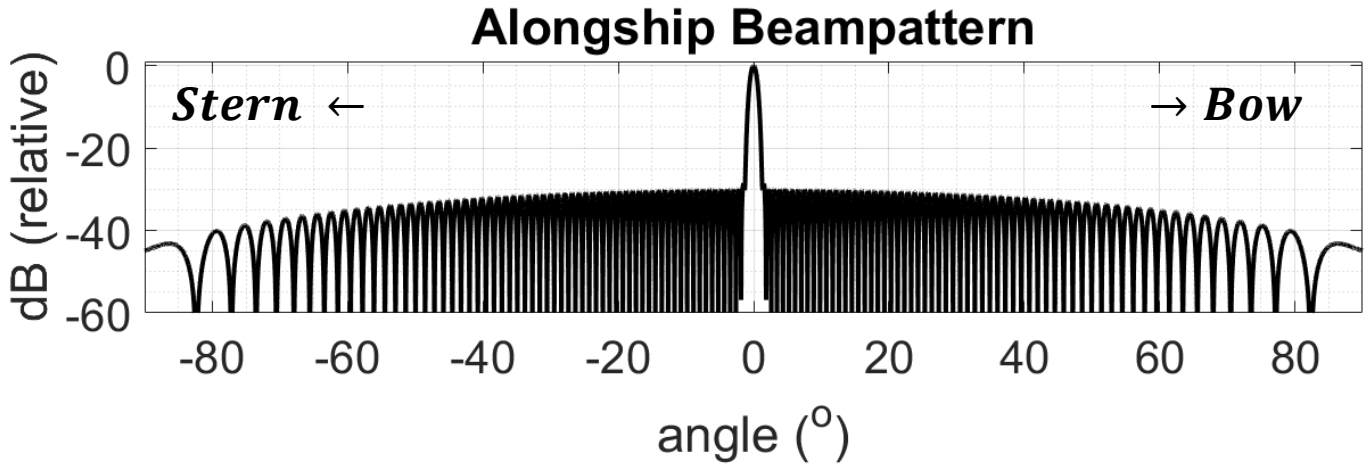
Ping Rates:
>1-12s

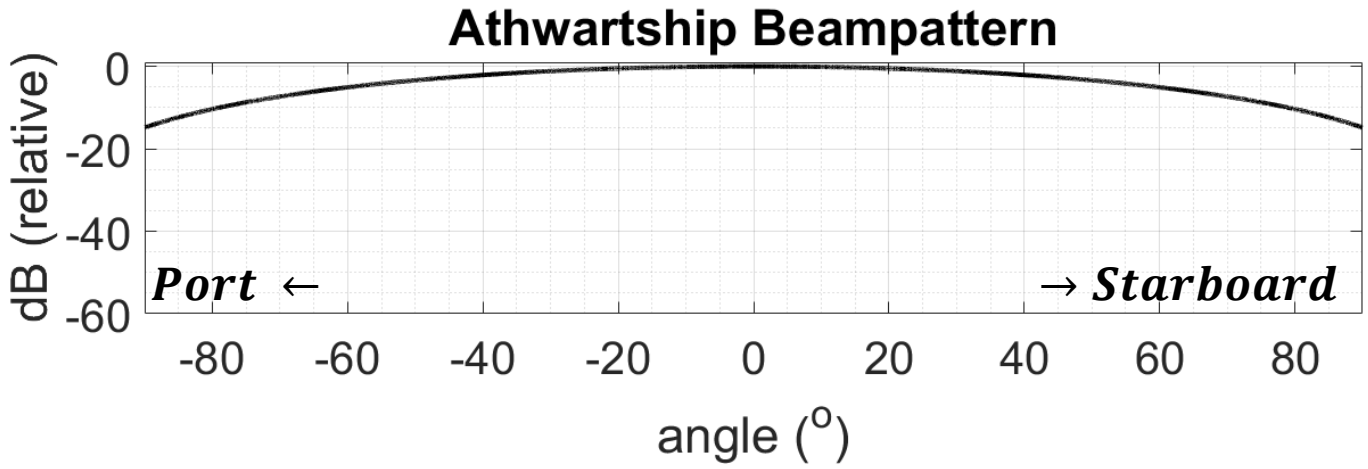
Source Levels:
220dB to 240dB re 1μPA

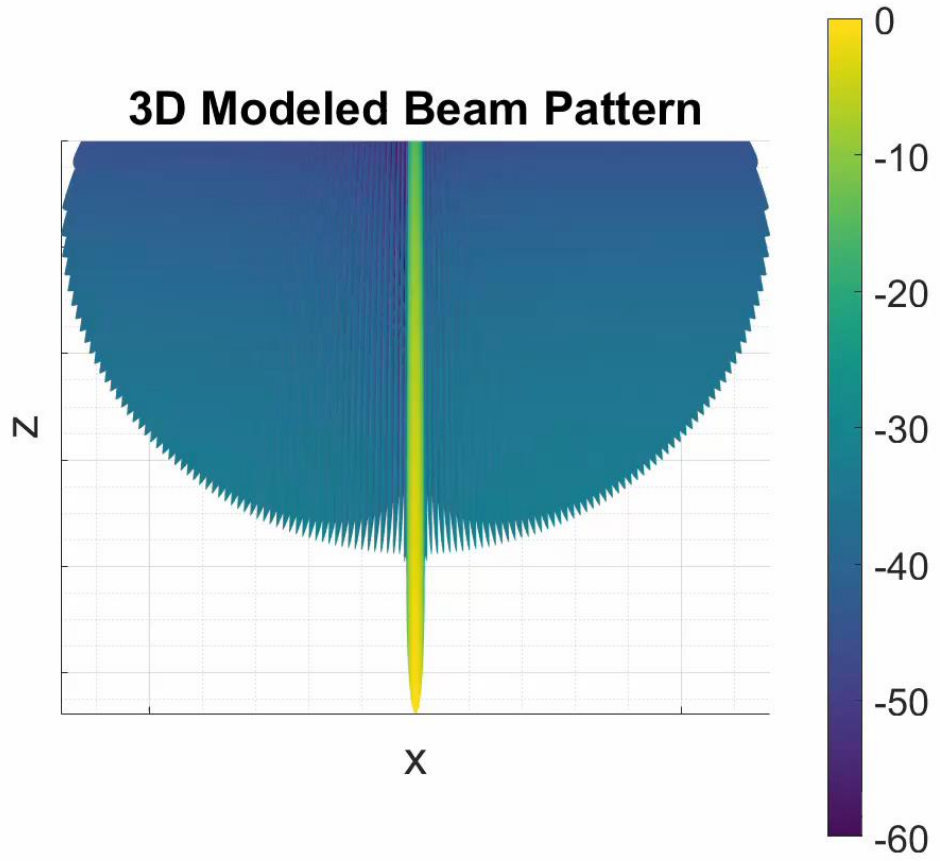
Operational depths:
~600m to 11,000m

A narrow swath of sound: Classical MBES radiation pattern



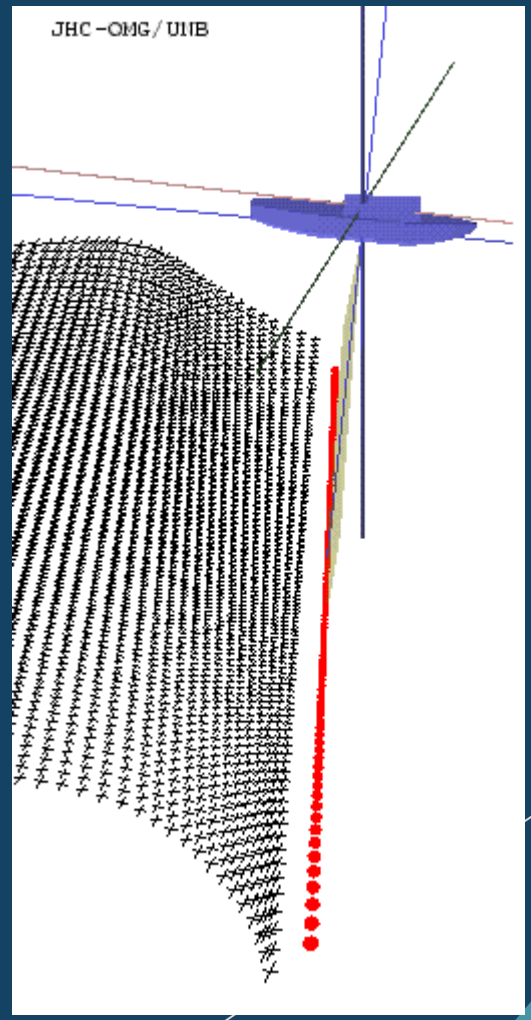


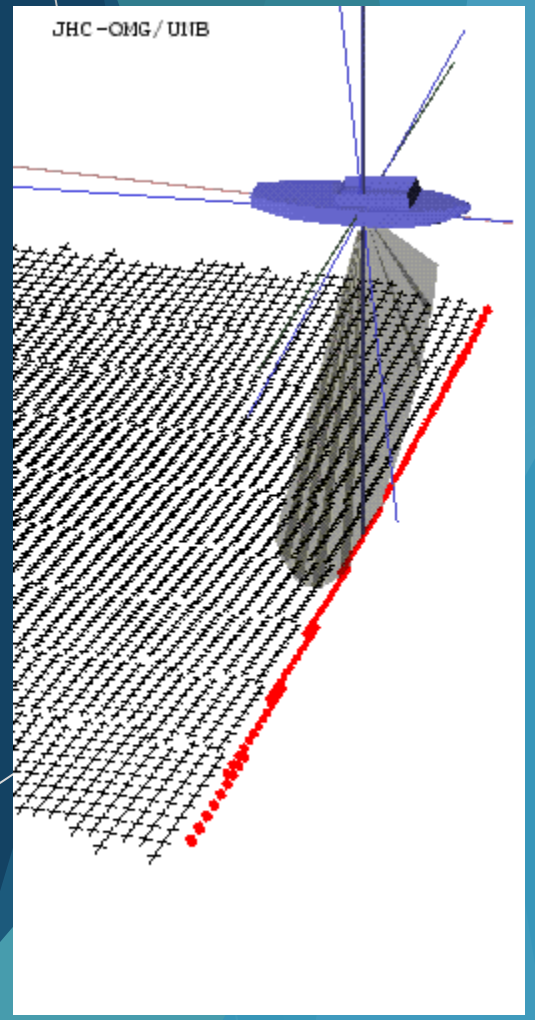




A narrow swath of sound: The radiation pattern

- Even sounding density of the seafloor is desired
- Vessel Motion bunches and spreads soundings
- *Multisector:* Uses advanced beamforming and active acoustics to improve across-track sounding distribution
- *Multiswath:* Improves along-track sounding density by using multiple swaths





A narrow swath of sound: The radiation pattern

- Multisector
  - Splits swath into smaller, independent sectors
  - Each sector is steered to compensate motion
  - Each sector is a *single pulse* in the *ping cycle*

- Multiswath:
  - Fires multiple pings in rapid succession
  - Swaths are angles slightly fore/aft
  - Can be one sector or multisector

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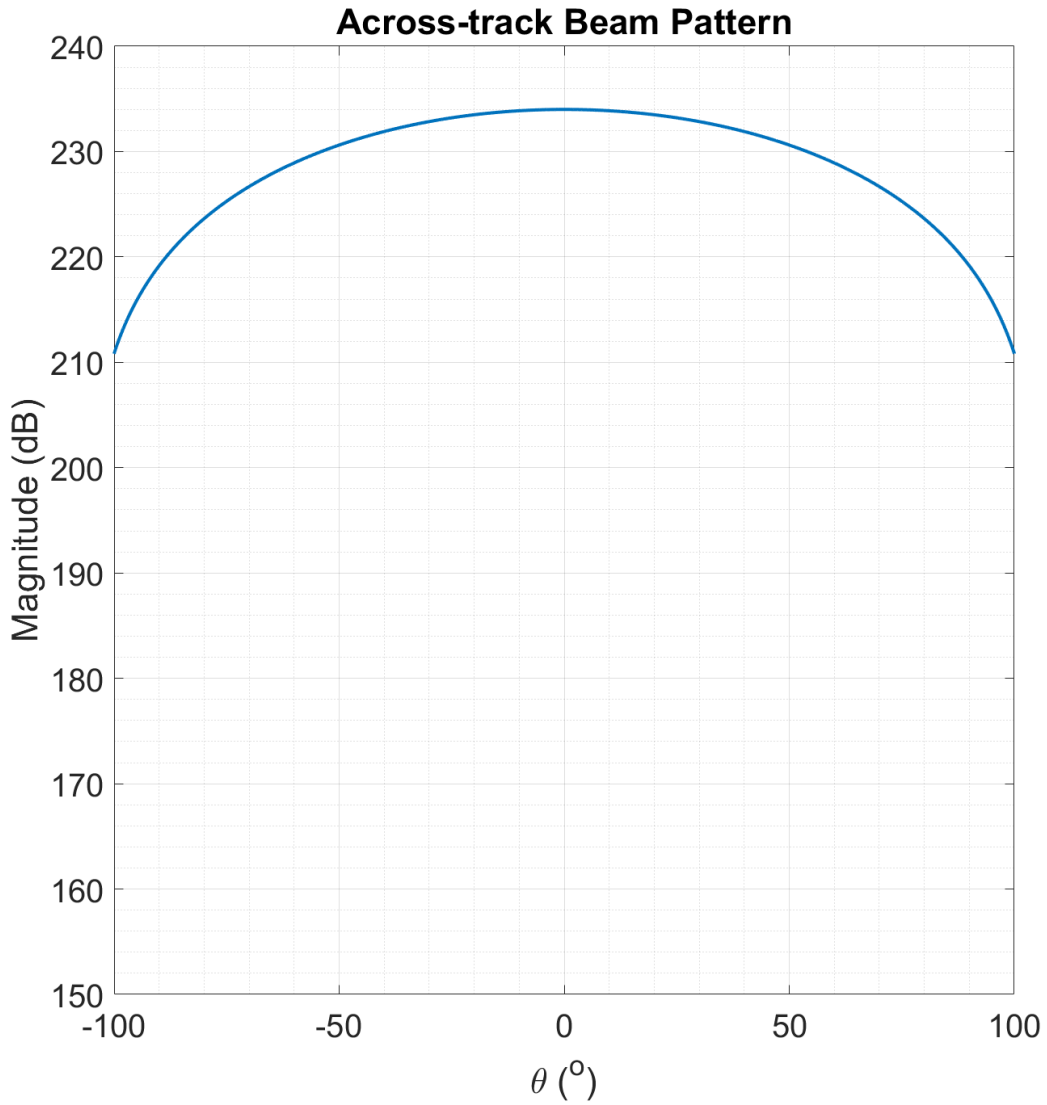
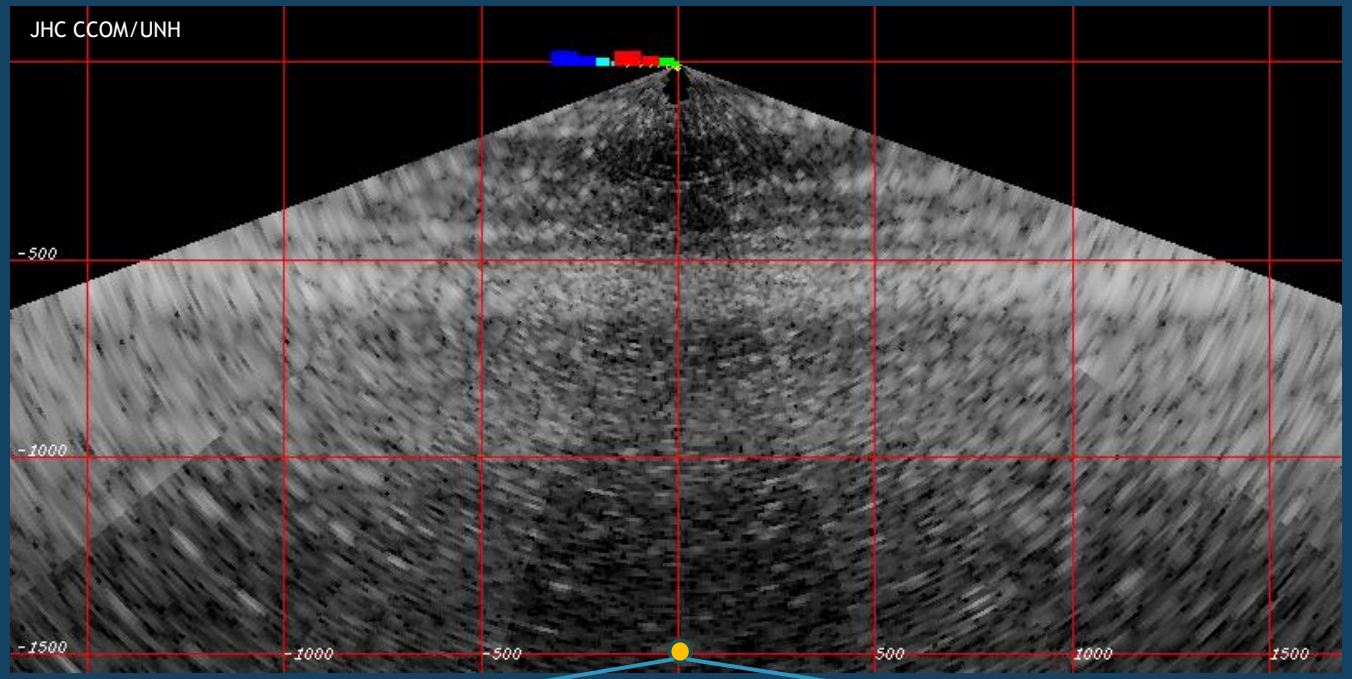
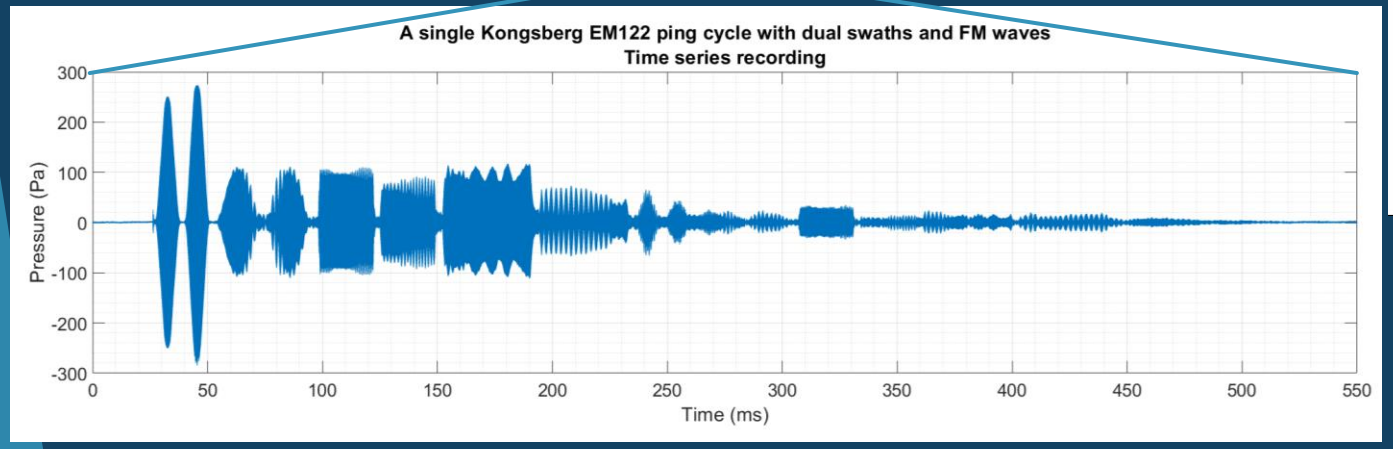
Deep-water 30kHz MBES example

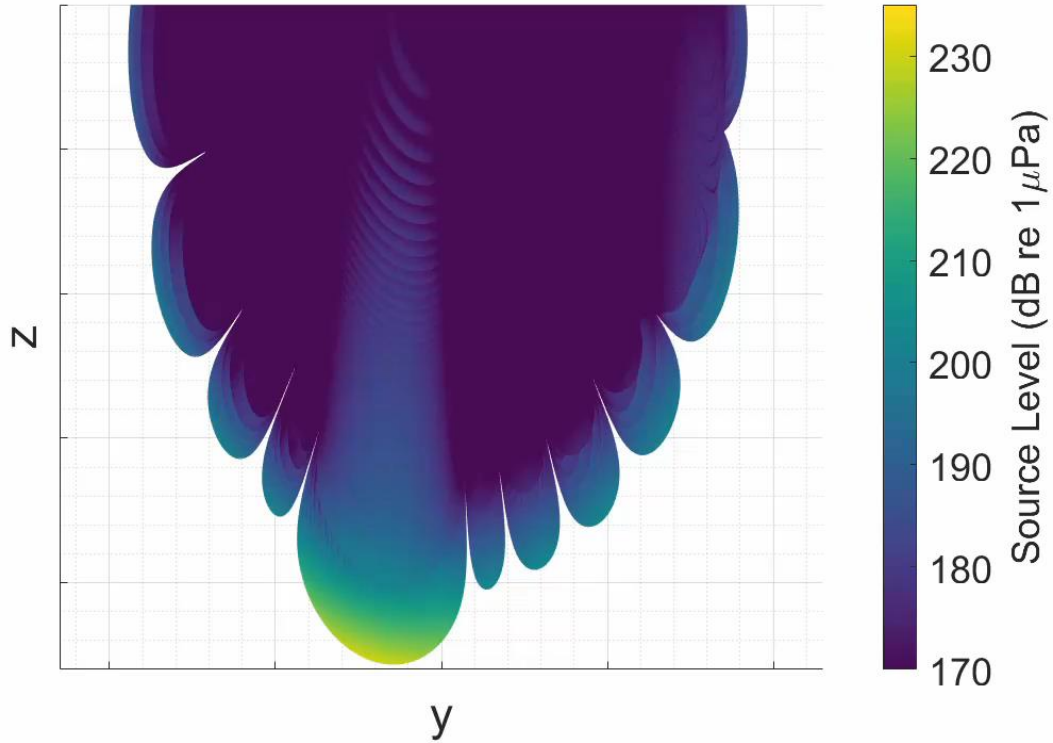


The ping cycle – Multisector/Multiswath

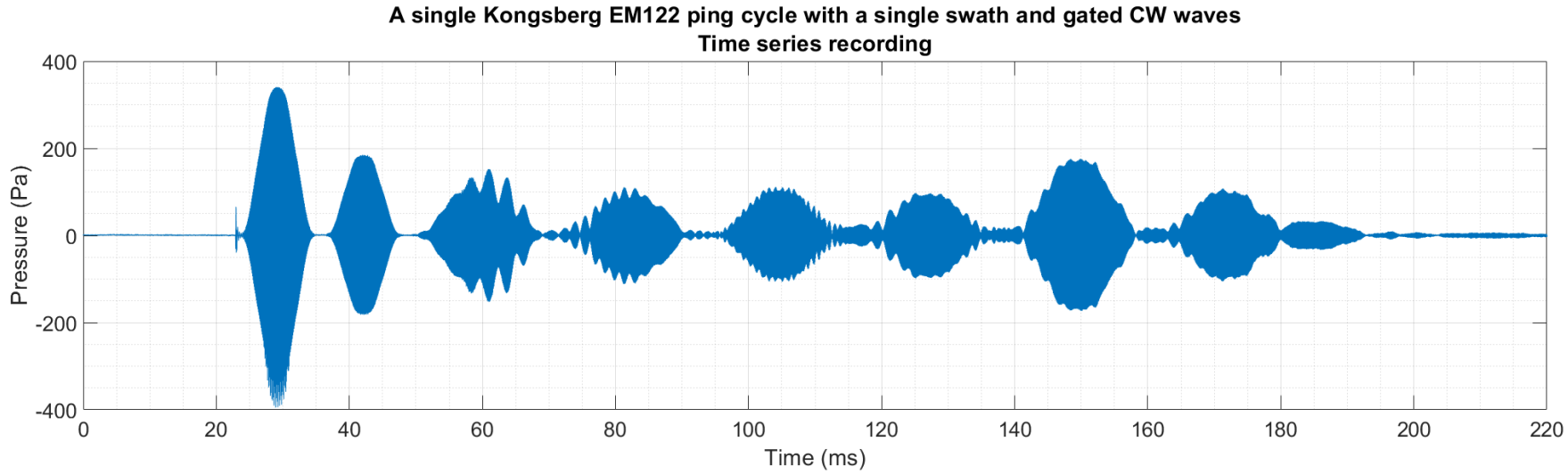


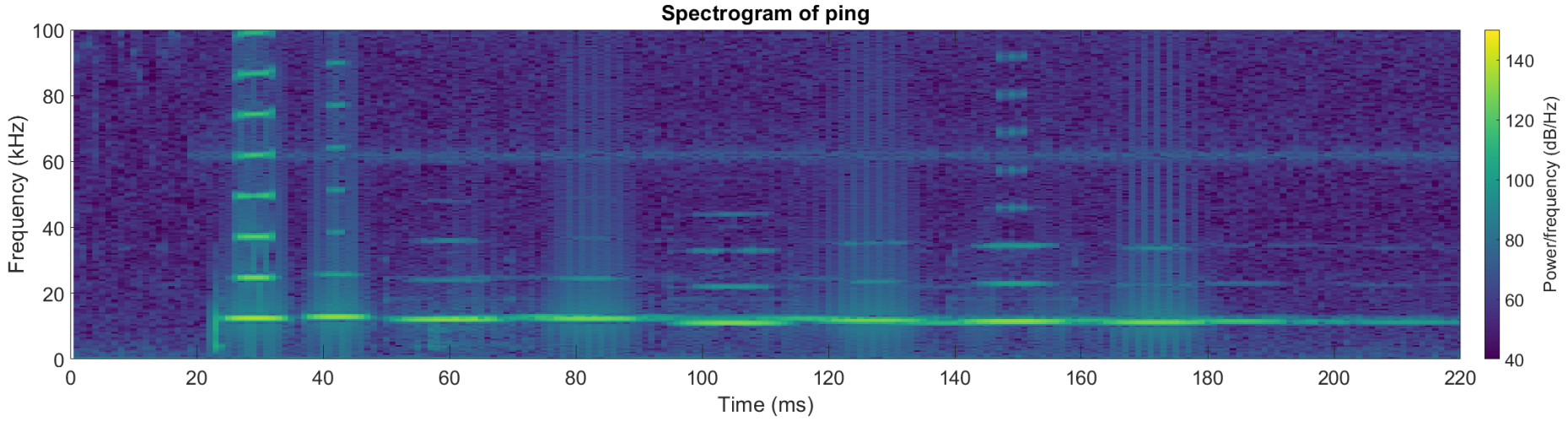


Modeled 12kHz Deep water multibeam echosounder radiation pattern



The ping - What does it sound / look like?





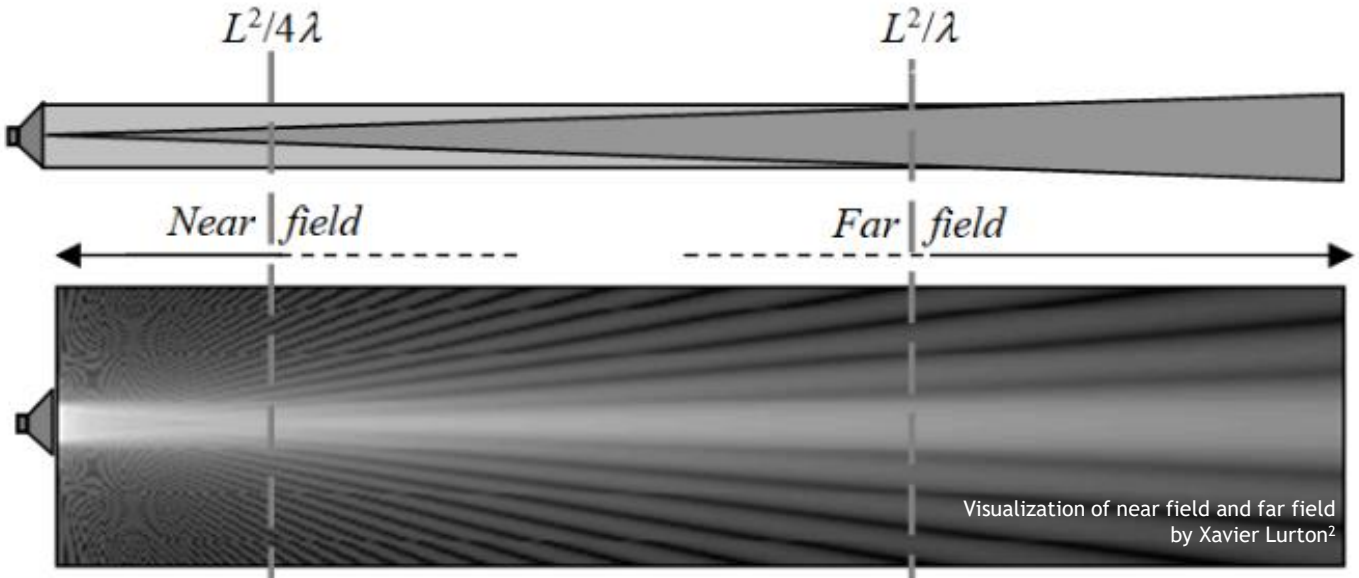
Source Level: Is 240dB really 240dB?

- Does the signal ever reach 240dB? – ***No***
  - Near field: a region of space close to the sonar where contributions from elements sum incoherently – Levels are lower than suggested by source level
  - *"Effective" source level: figure of merit used to estimate system performance in the far field*

<u>Near-field distance</u>

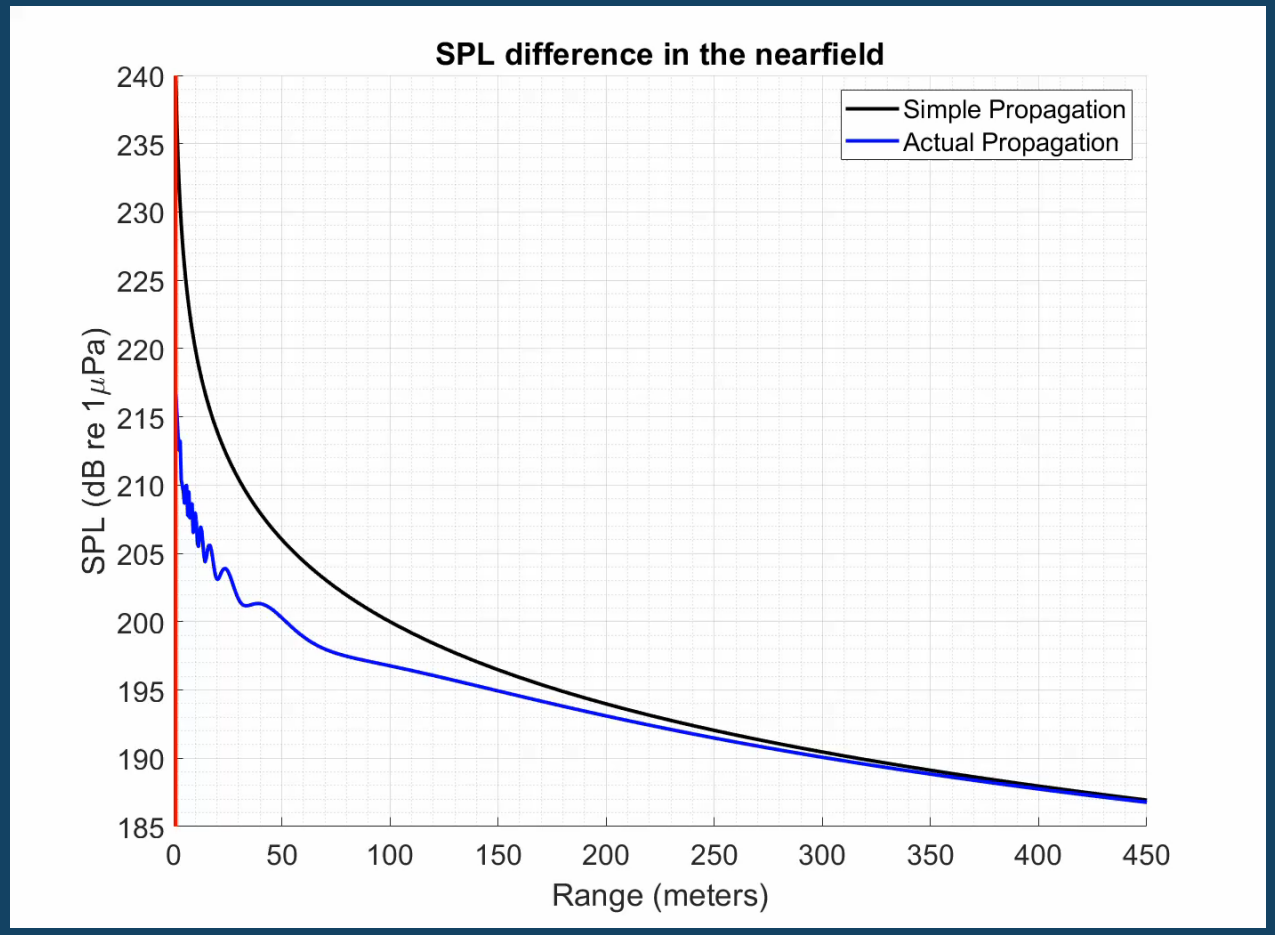
Shallow water system:
>1-5m

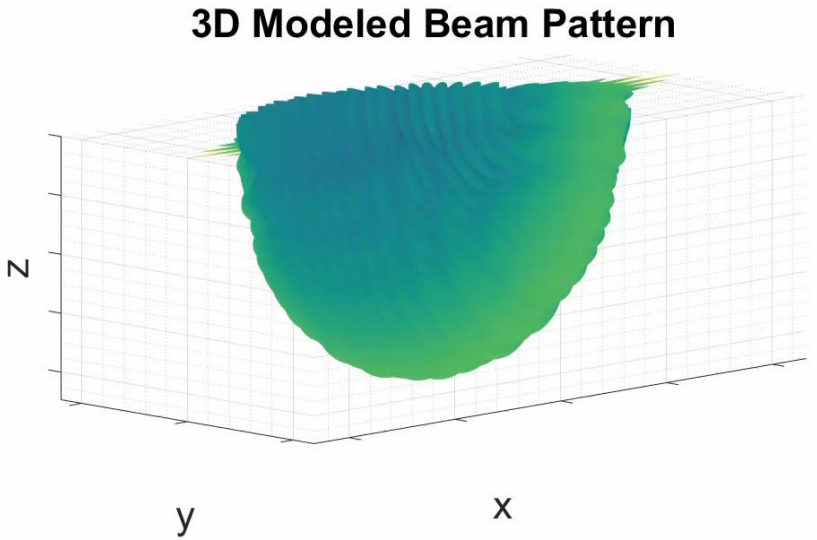
Deep water system:
~300-500m

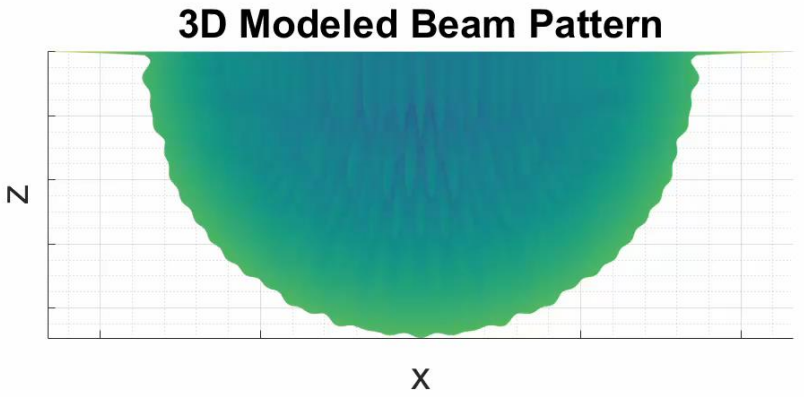


Visualization of near field and far field by Xavier Lurton[2]

Source Level:
Is 240dB really 240dB?







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Modeling MBES for acoustical impact and mitigation

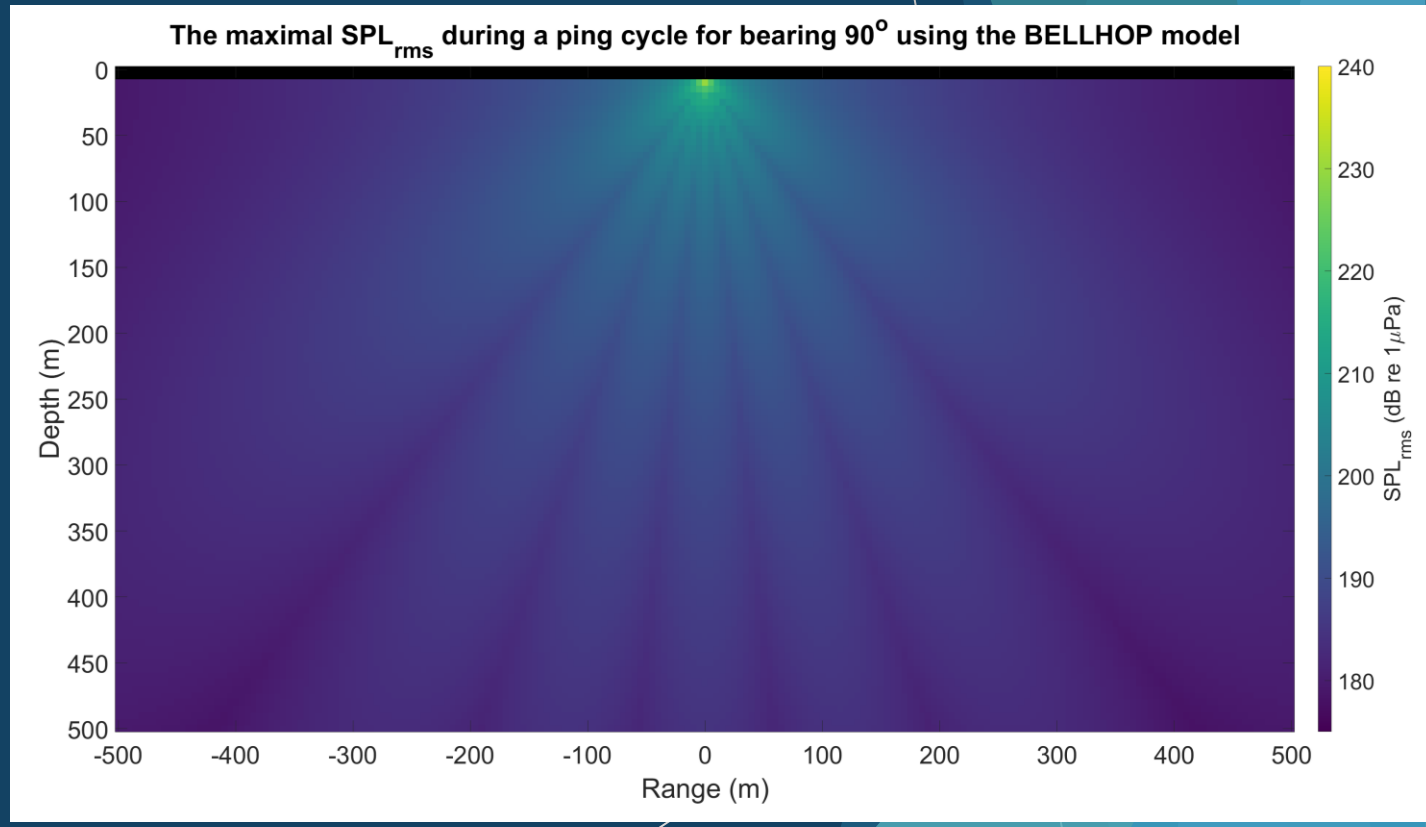
- Sound propagation modeling
  - Source model
  - Environment model
  - Thresholds
- Animal modeling
  - Species occurrence
  - Distribution
  - Behavior

Hearing Group	TTS Onset Acoustic Threshold ($SEL_{hg,24h}$)	PTS Onset Acoustic Threshold ($SEL_{hg,24h}$)
Low-Frequency (LF) Cetaceans	179	199
Mid-Frequency (MF) Cetaceans	178	198
High-Frequency (HF) Cetaceans	153	173
Underwater Phocid Pinnipeds (PW)	181	201
Underwater Otariid Pinnipeds (OW)	199	219

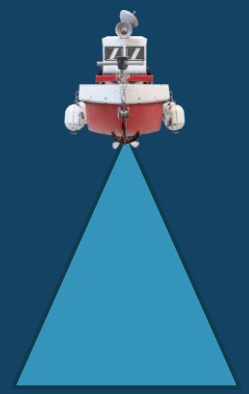
Source Type	Threshold (SPL_{rms})
Continuous	120
Non-Explosive Impulsive or intermittent	160

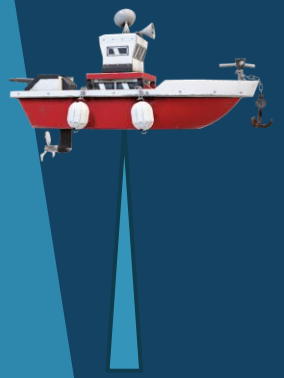
Modeling MBES for acoustical impact and mitigation

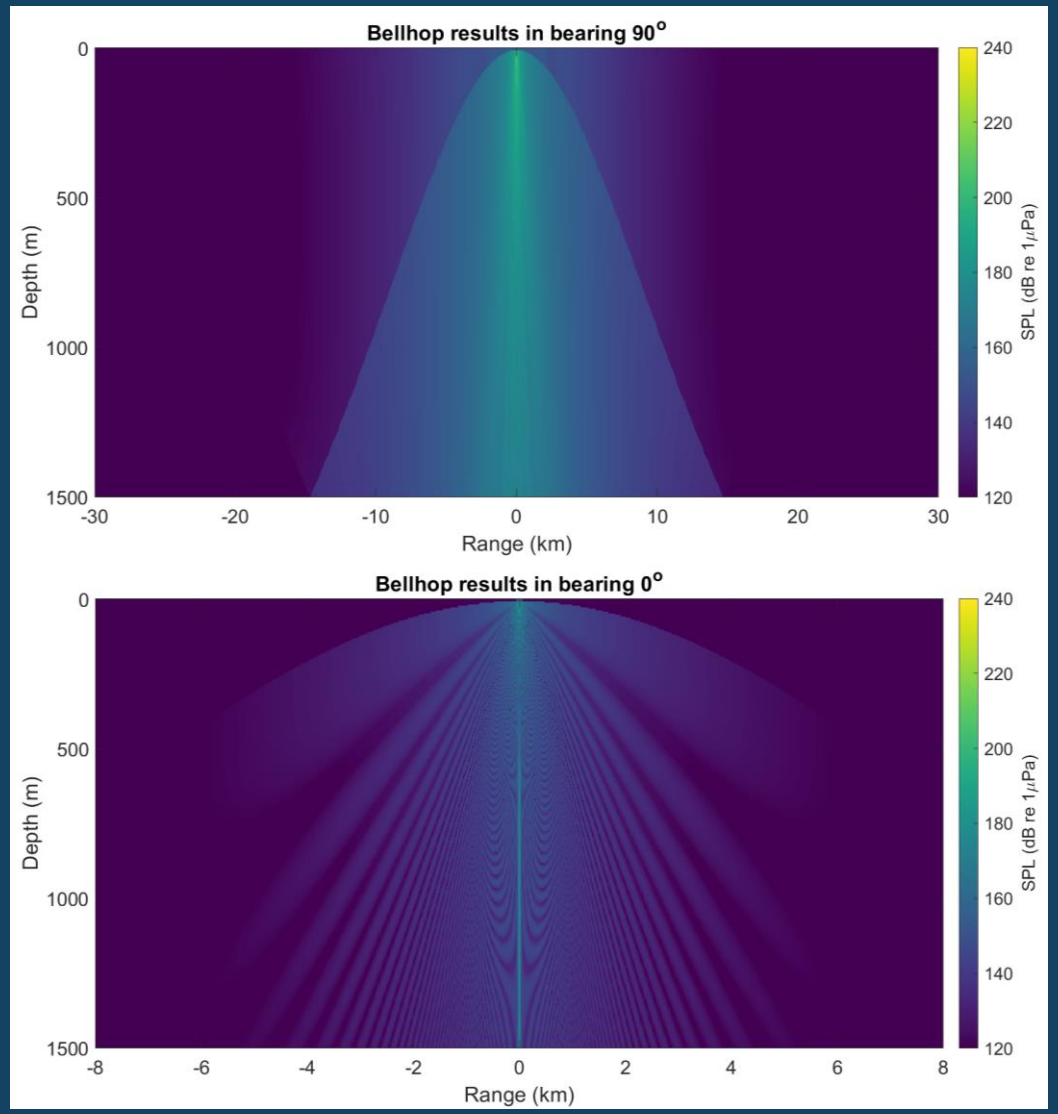
- Ray based propagation models well suited for MBES
- All sectors/swaths need to be considered
  - SPL_{rms} & SPL_{pk} ⇒ max value at field point
  - SEL ⇒ sum values at each field point
- Nearfield is not easy to couple into models

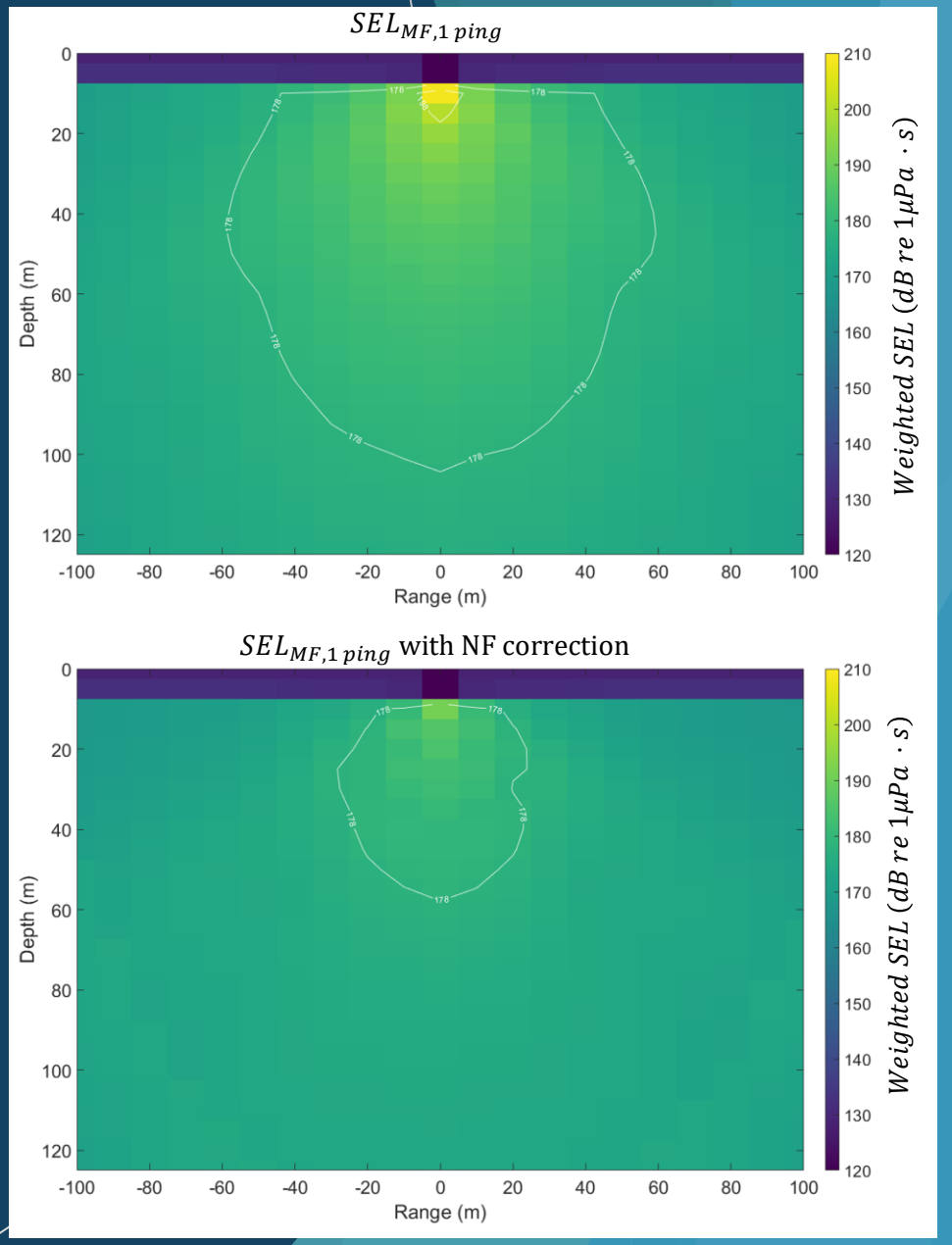


Modeling MBES for acoustical impact and mitigation









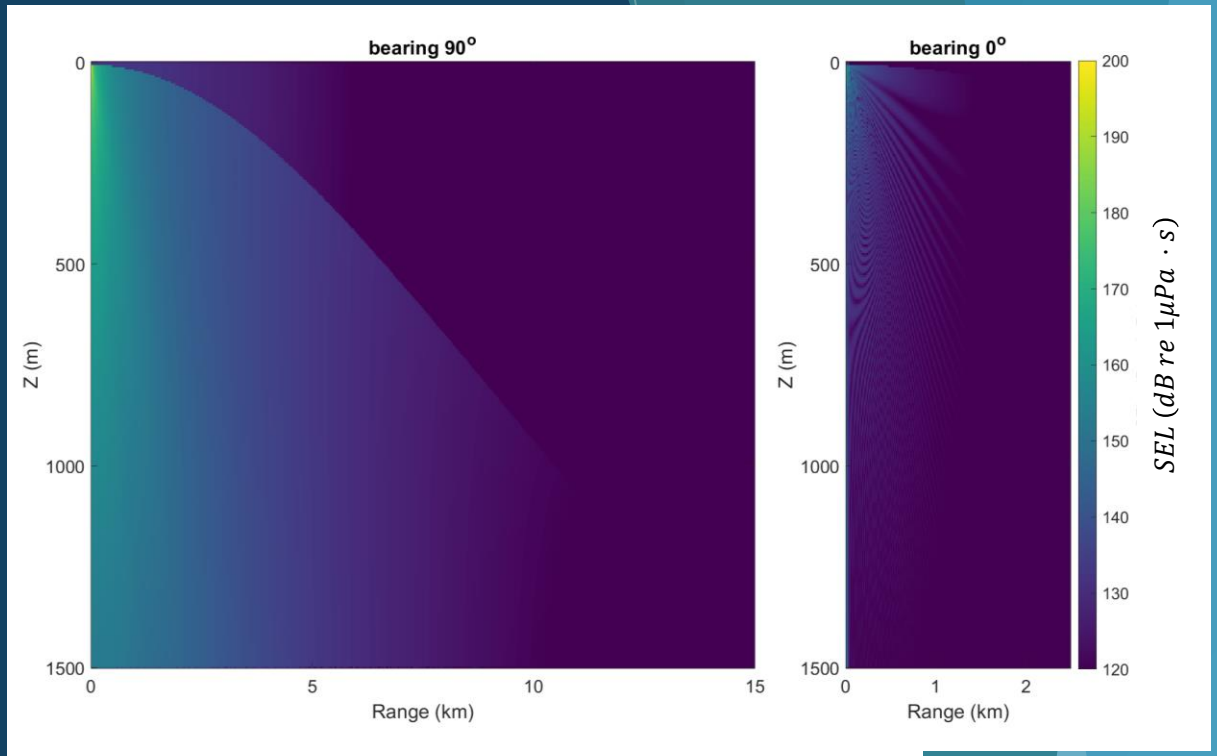
MBES regulation: Square peg round hole

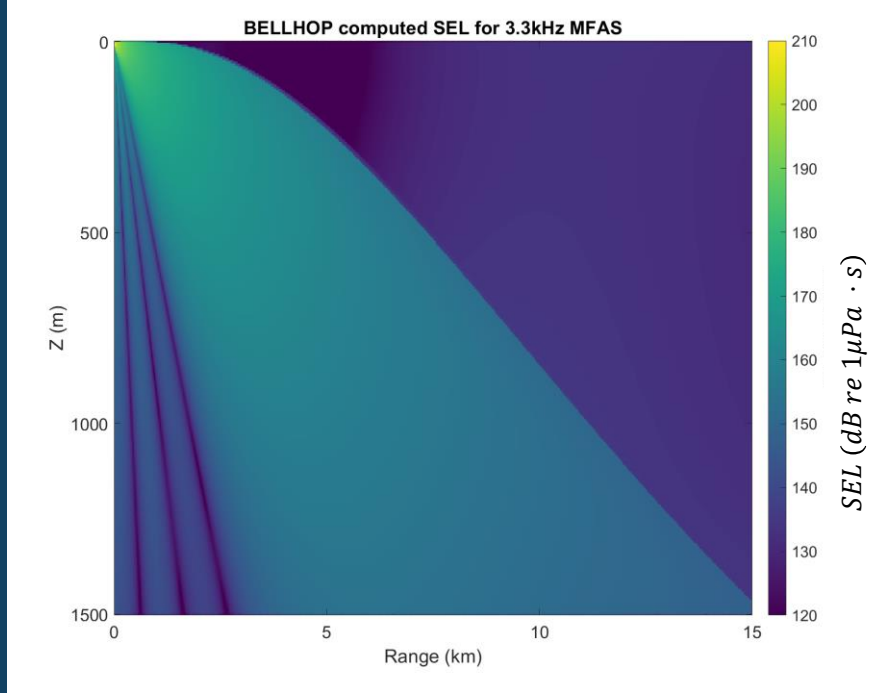
Multibeam Echosounder

- Most energy directed down in a narrow swath
- Very short pulse lengths with ping cycles from 6-12s

Naval Mid-Frequency Sonar

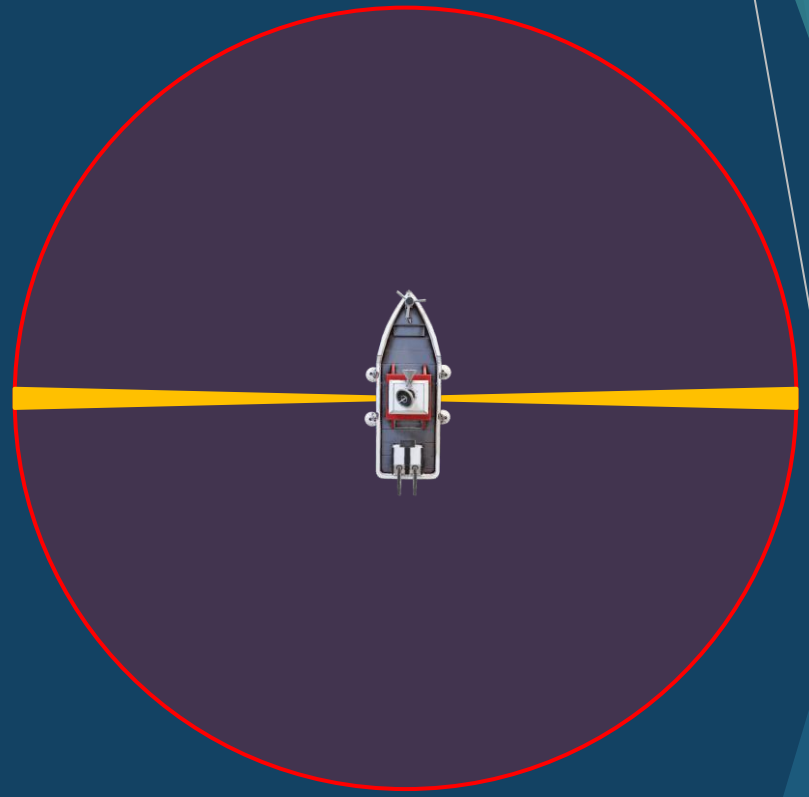
- Near omnidirectional horizontal radiation pattern to aid detection
- 1-3 second transmissions with ~30 ping cycles

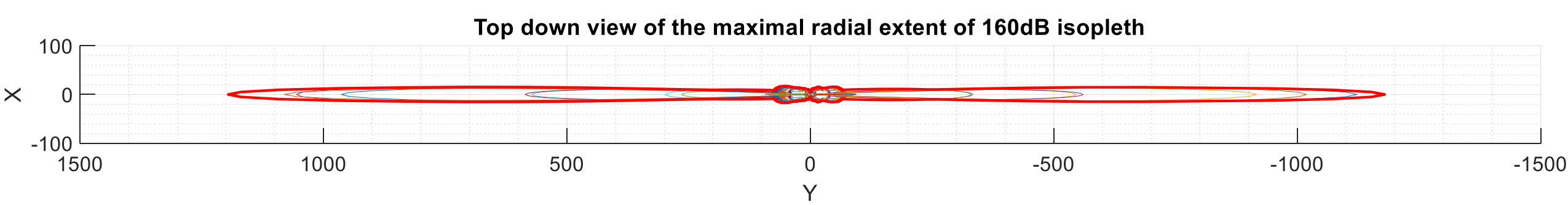




MBES regulation: Square peg round hole

- Safety radius is a common mitigation approach
  - Assumes omni-directional sound pattern
  - Defined by maximum extent of a chosen acoustic threshold
- For a 30kHz deep water system:
  - 160dB isopleth is 30m wide in the alongship direction and extends 1200m to either side
  - Statistically low probability of main beam exposure due to vessel movement and ping rate.





Thank you

- References and resources

  - Mayer, L., Jakobsson, M., Allen, G., Dorschel, B., Falconer, R., Ferrini, VS, Lamarche, G., Snaith, H., and Weatherall, P. (2018). The Nippon Foundation-GEBCO Seabed 2030 Project: The Quest to See the World's Oceans Completely Mapped by 2030. Geosciences 8(63). Doi: 10/3390/geosciences8020063
  - Michael Smith; Modelling approaches to multibeam echosounders for sound field characterization. J. Acoust. Soc. Am. 1 September 2024; 156 (3): 1552–1564. https://doi.org/10.1121/10.0028338
  - X. Lurton, An Introduction to Underwater Acoustics: Principles and Applications, 2nd ed., Springer Praxis Books, New York, 2010), pp. 53–84.
  - Joint interim report : Bahamas marine mammal stranding event of [15]-16 March 2000
