



University of
St Andrews

Sources of Anthropogenic Noise in the Ocean

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For SMM BRS Workshop Saturday 12th December 09.45-10.05

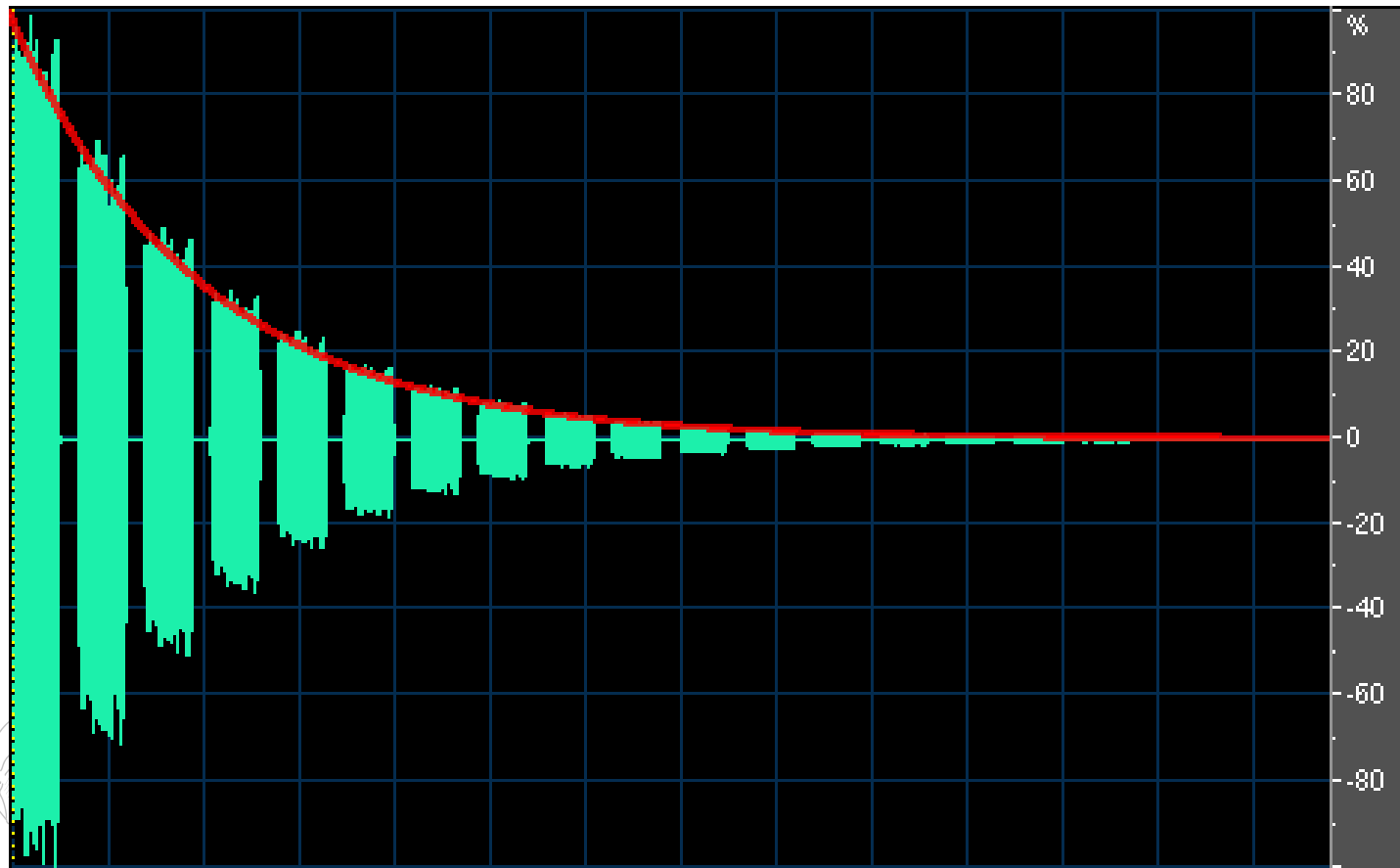


Sea Mammal
Research
Unit



The Decibel: Sound Intensity (dB) = $10 \log_{10} (I/I_{ref})$

Each successive sound is -3dB \approx halving of sound energy



$$\text{Sound Intensity (dB)} = 10 \log_{10}(I/I_{\text{ref}})$$

I/I_{ref}	Intensity in dB
0.001	-30
0.1	-10
1	0
10	10
100	20
1000	30



Sound Propagation

- Sound propagation is studied by isolating the following components:
- **Source Level:** the intensity of sound produced by a sound source (underwater loudspeaker or vocalizing animal) at a distance of 1 m
- **Transmission Loss:** the loss of energy as sound spreads from 1m out to a receiver and as it is absorbed in the sea
- **Received Level:** the level of sound measured in one location by a receiver (hydrophone)

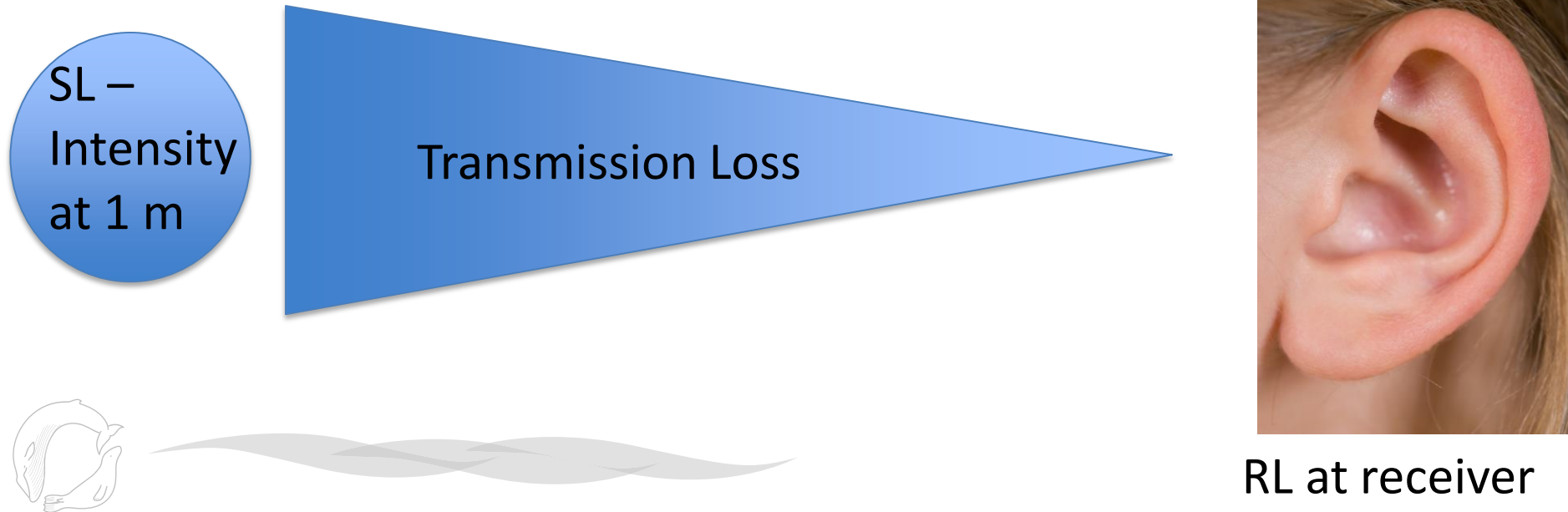


Passive Sonar Equation

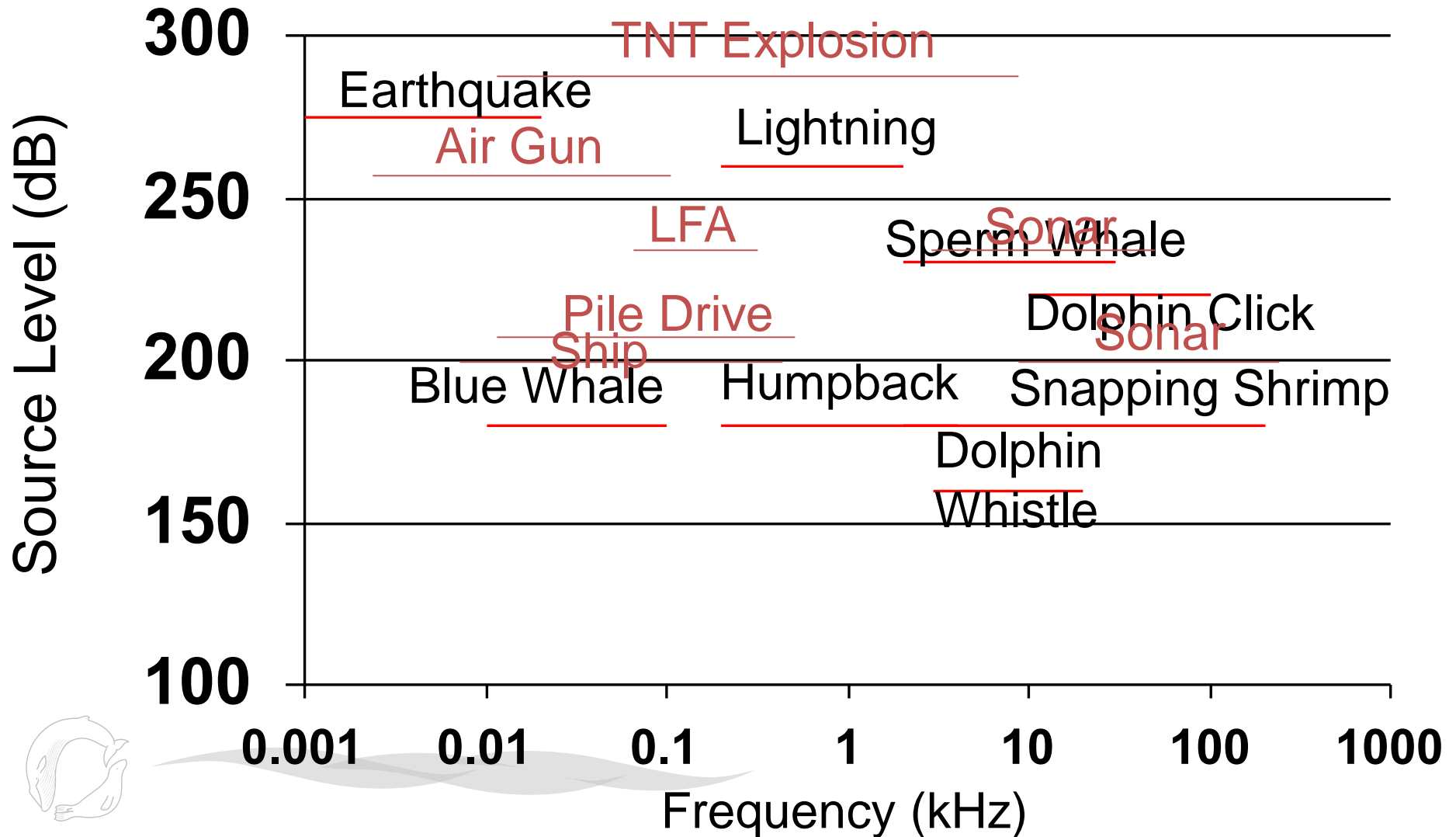
Source Level (SL) –

Transmission Loss (TL) =

Received Level (RL)



Over the past century, humans started producing sound in the ocean that may interfere with marine mammal use of sound



Sound Sources from the Human User Perspective

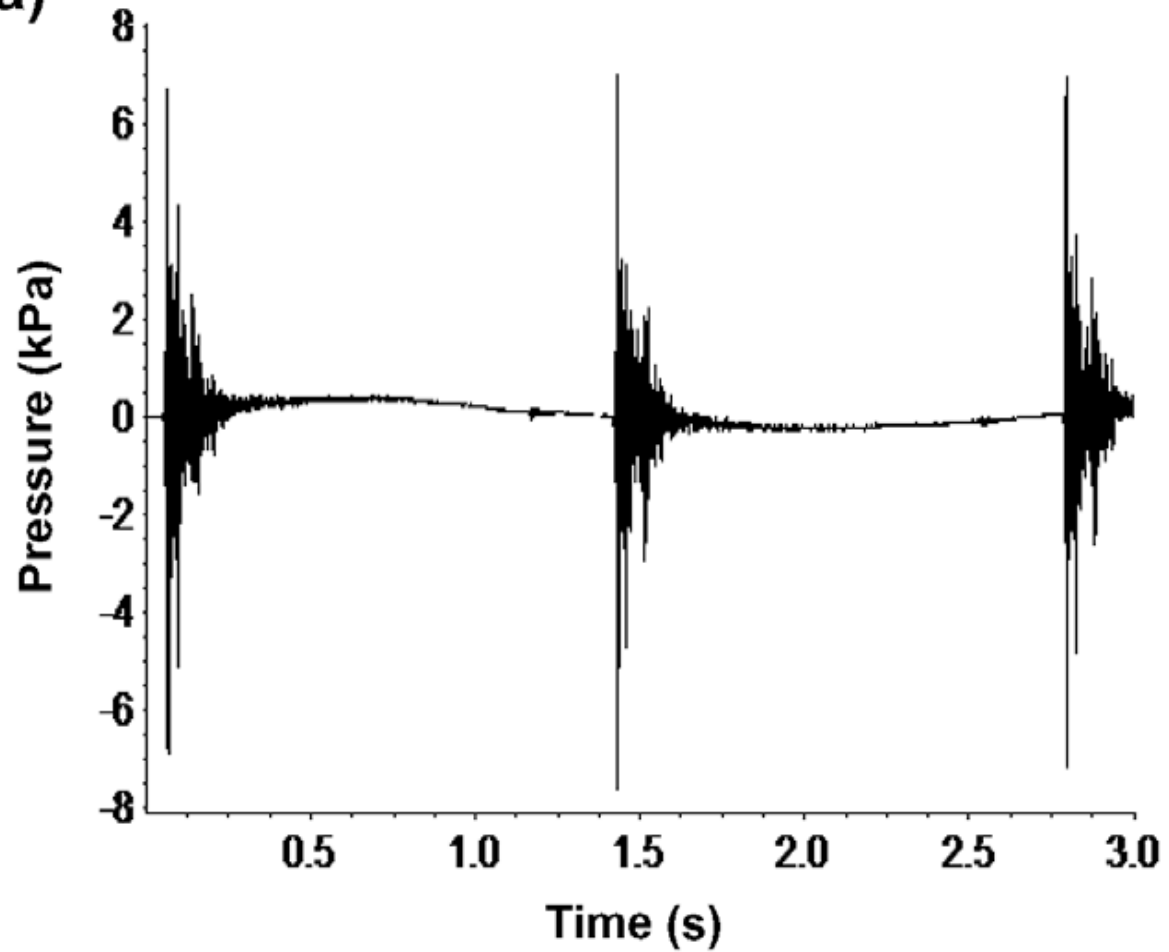
- Piling
- Ship propulsion noise
- Recreational boat traffic noise
- Acoustic Harassment Devices
- Sonar and underwater scientific active acoustics
- Airguns for Seismic Survey
- Explosions



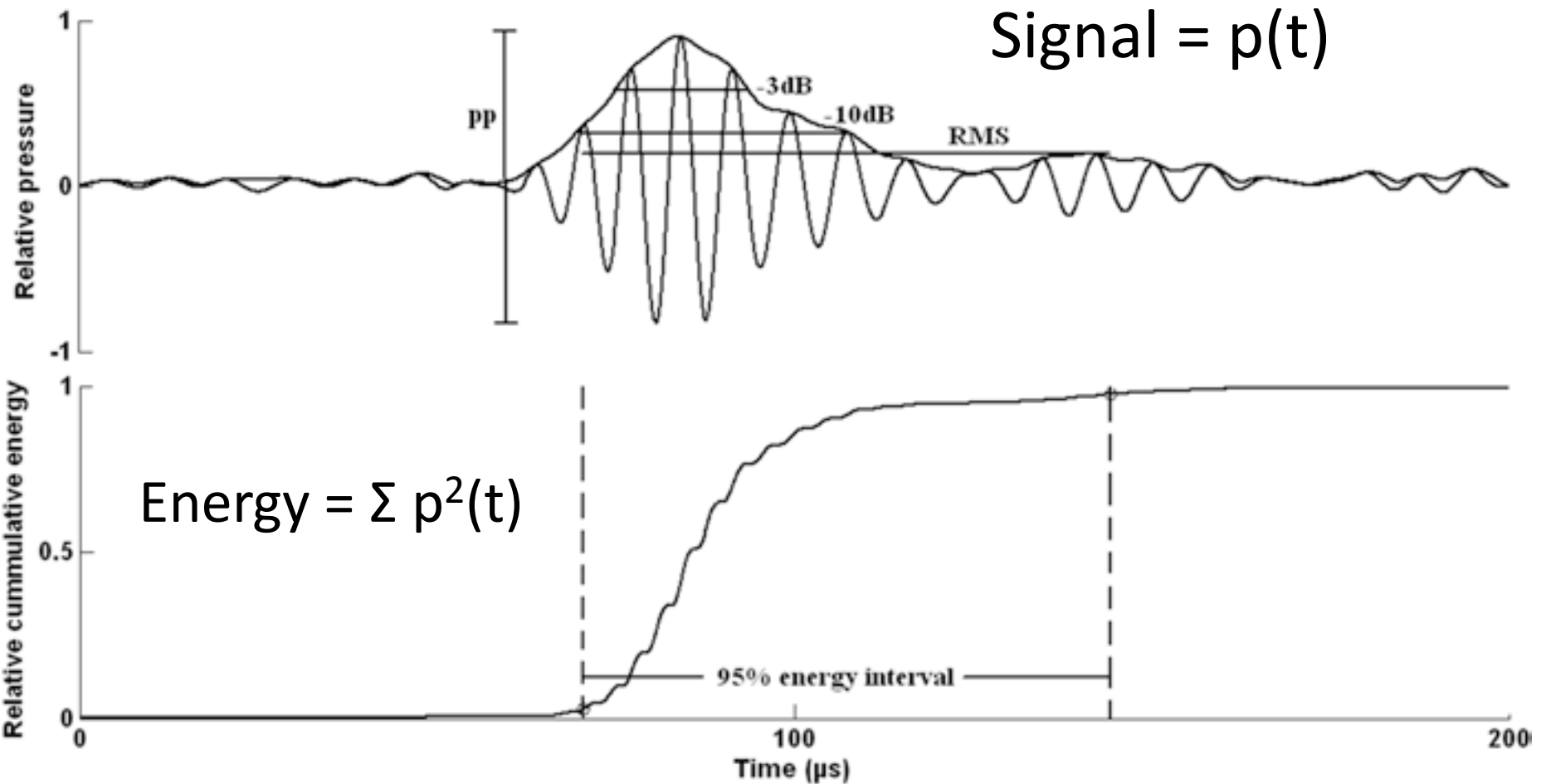
Pressure waveform of pile driving at 100m



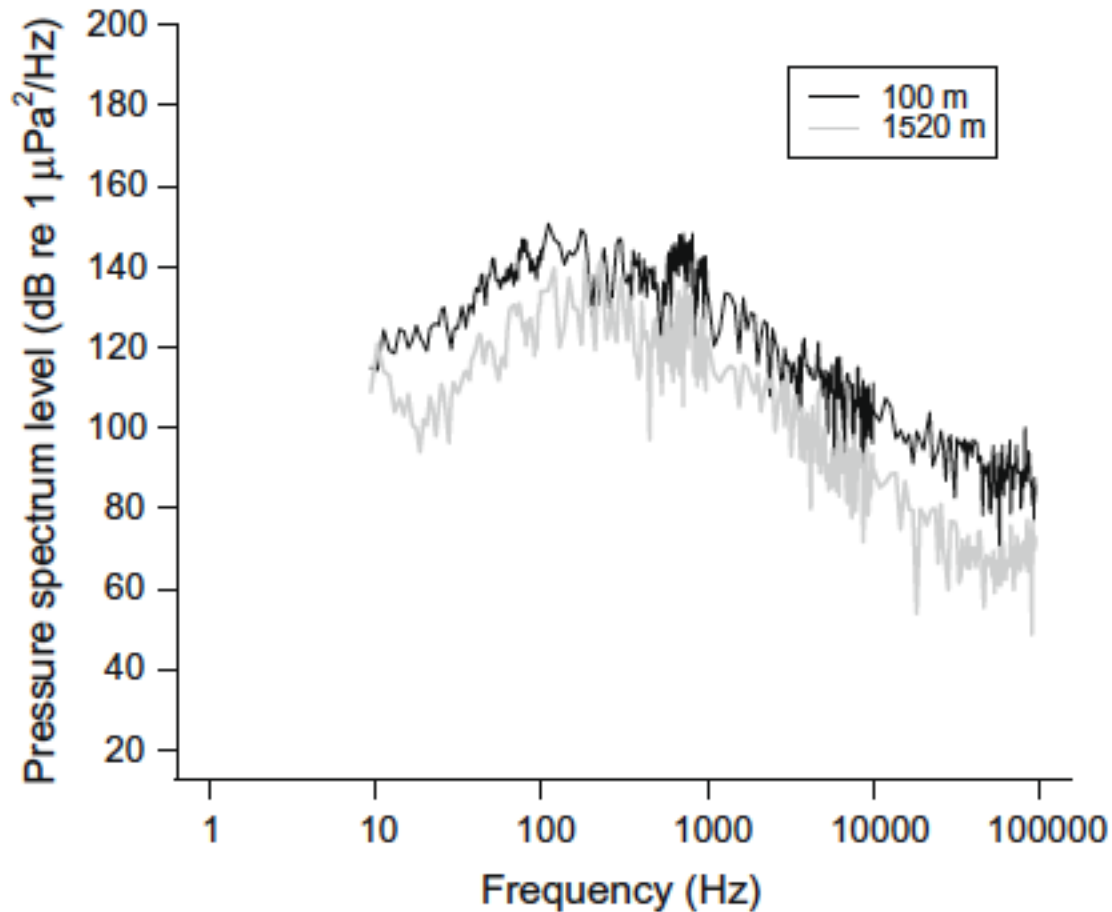
(a)



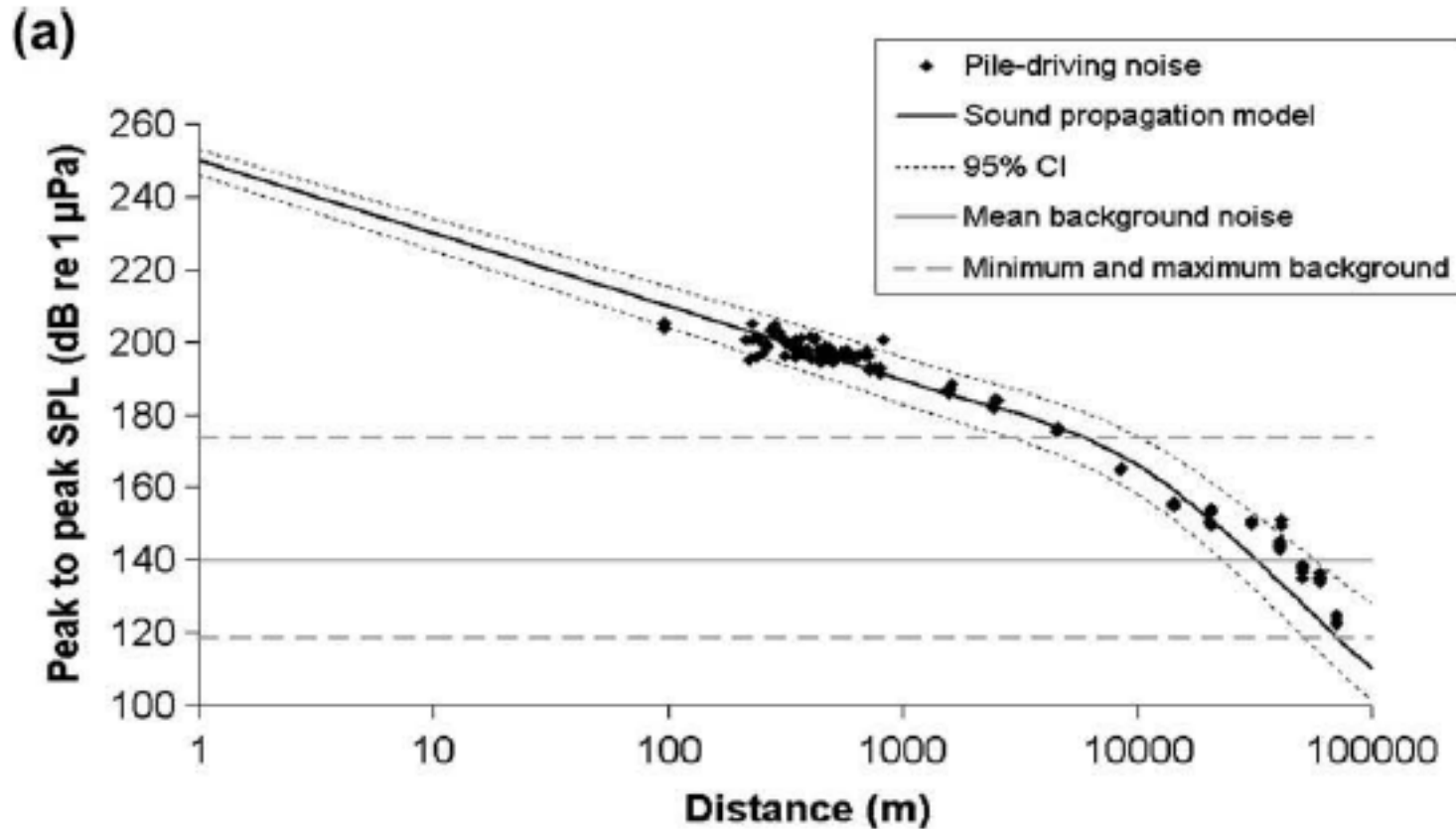
Measuring Energy in a Transient



Frequency Distribution (Spectrum) of Pile Driving Noise



Reduction in Sound Pressure Level with Range



How pile driving sounds at different ranges

What sounds different as you get farther away?



500m



2 km



8 km



20 km



40 km

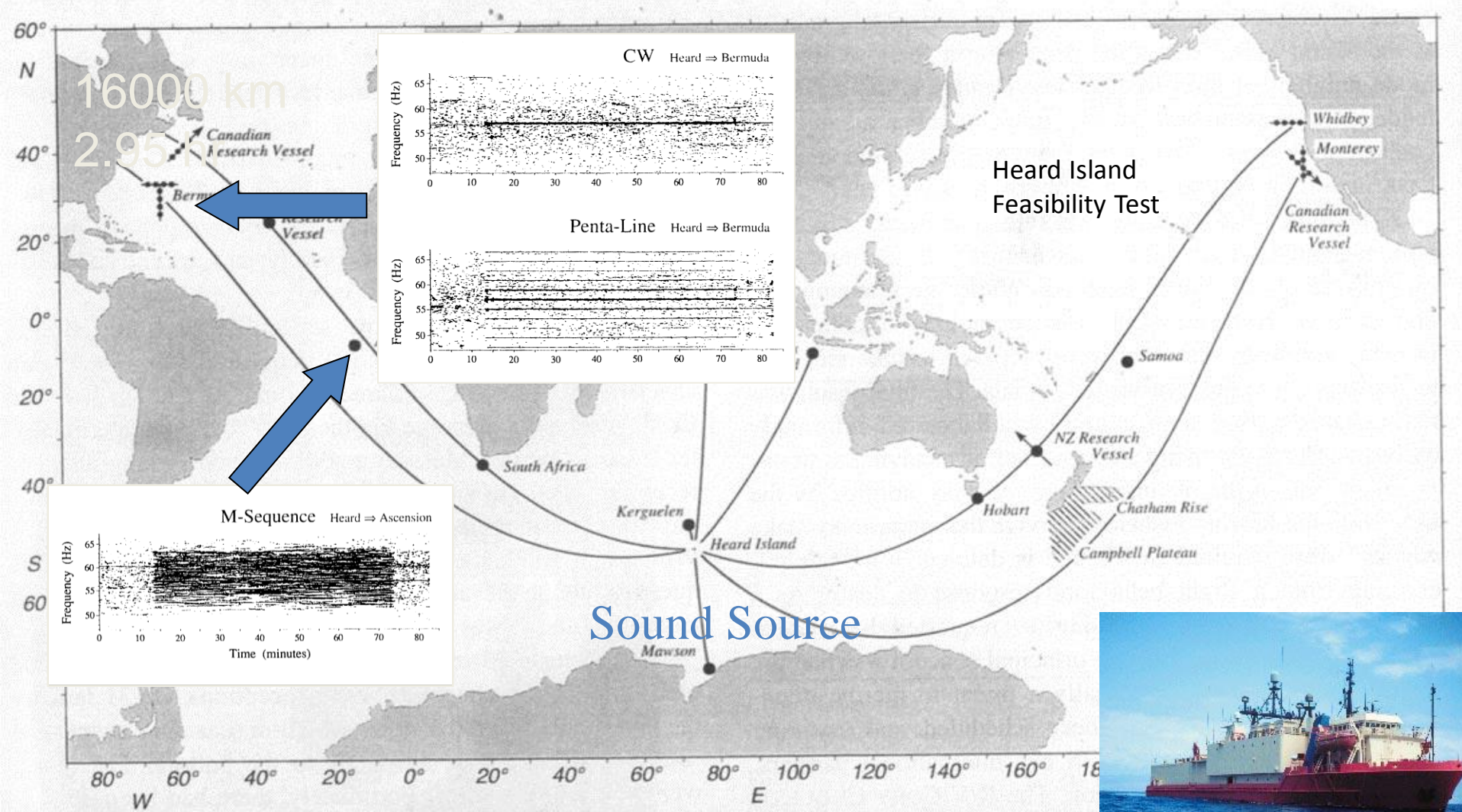




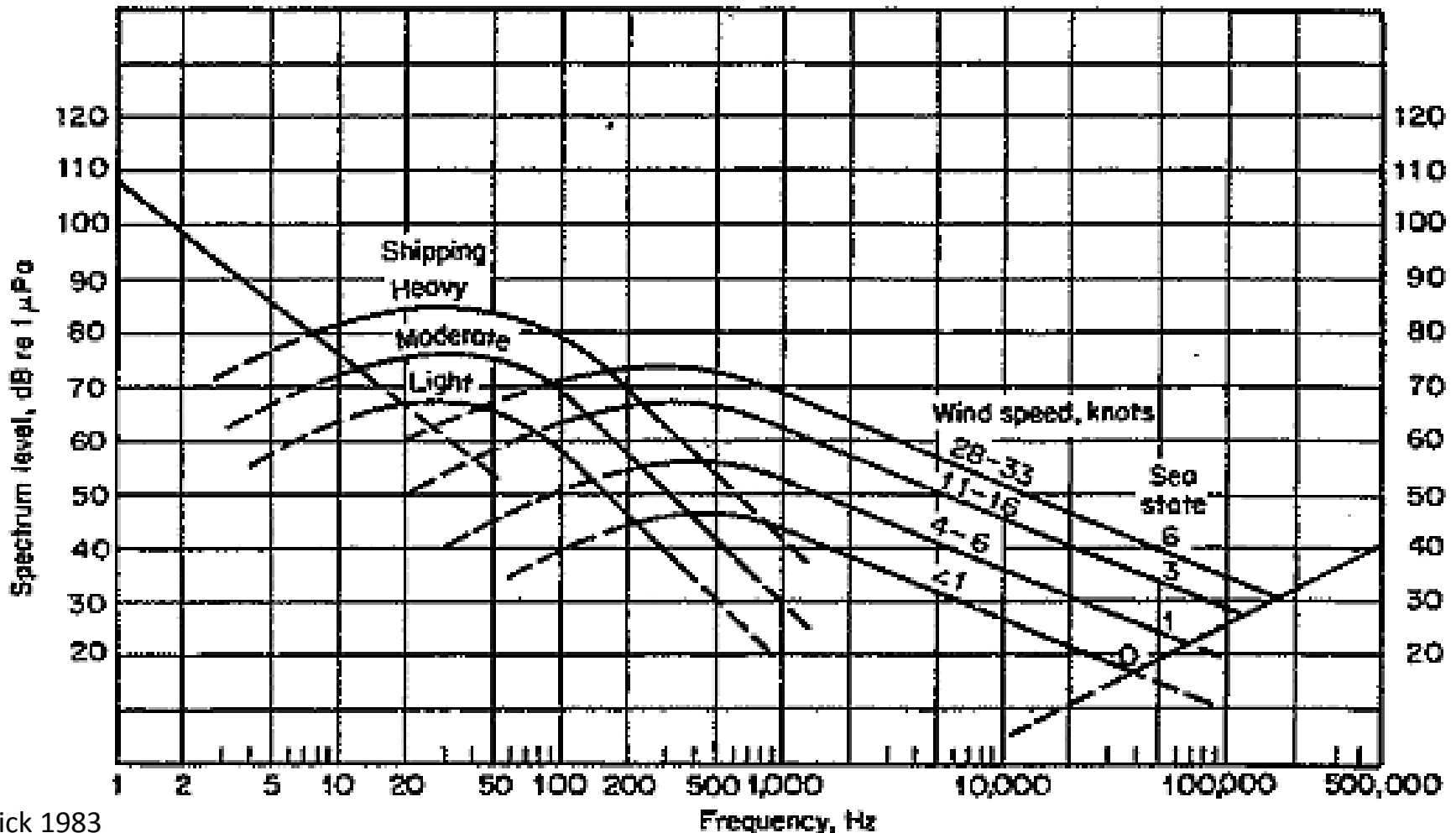
Propulsion noise from ship



Low frequency sound propagates great distance in the ocean

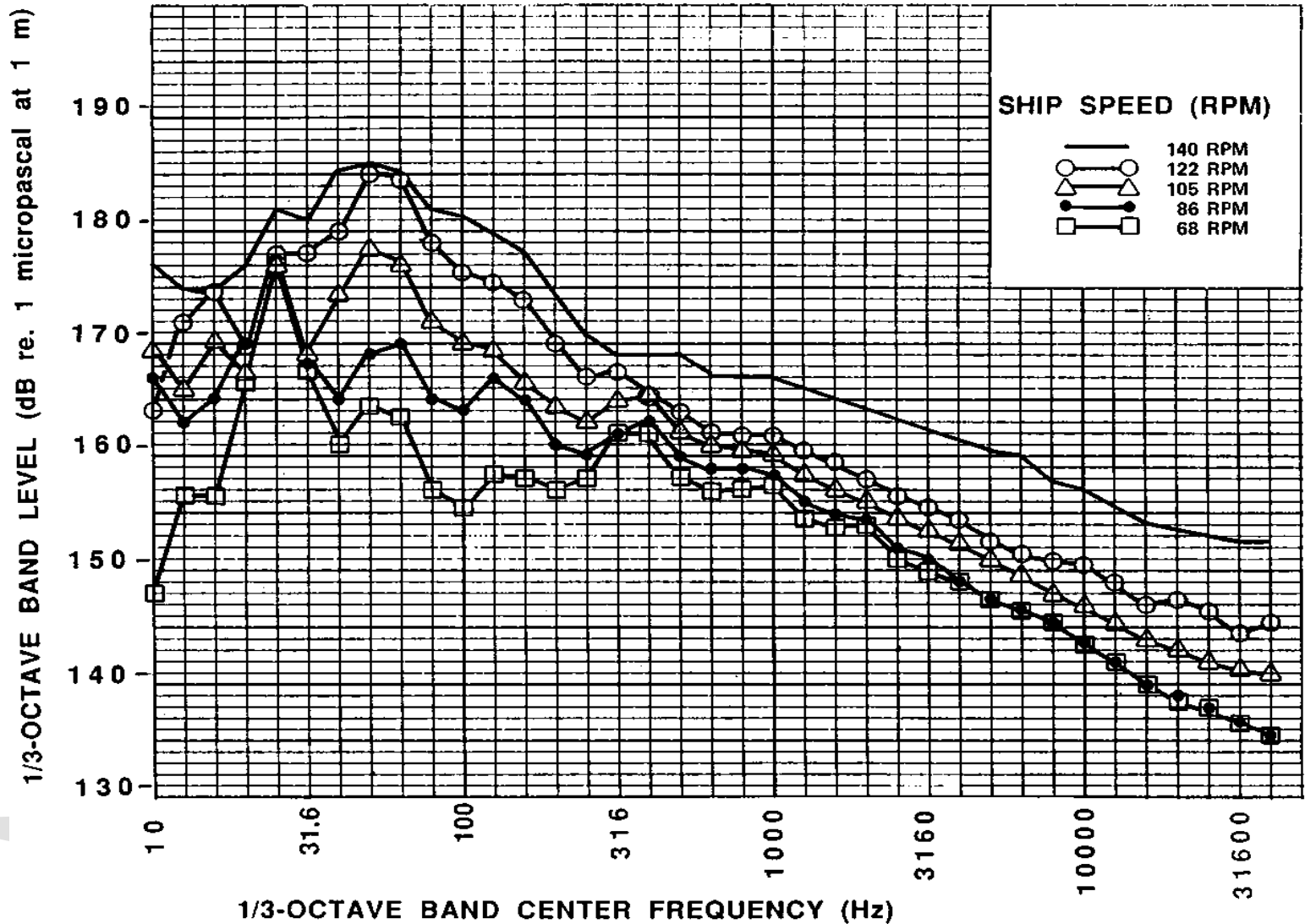


The aggregate sound of thousands of ships dominates average ambient ocean noise 10-200 Hz

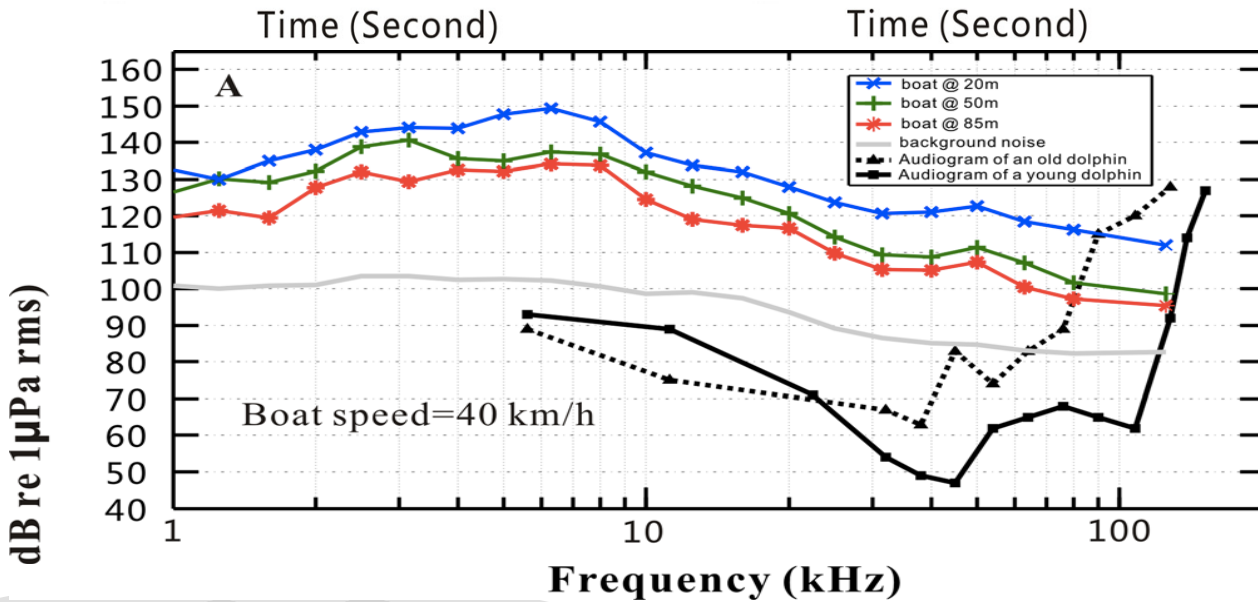
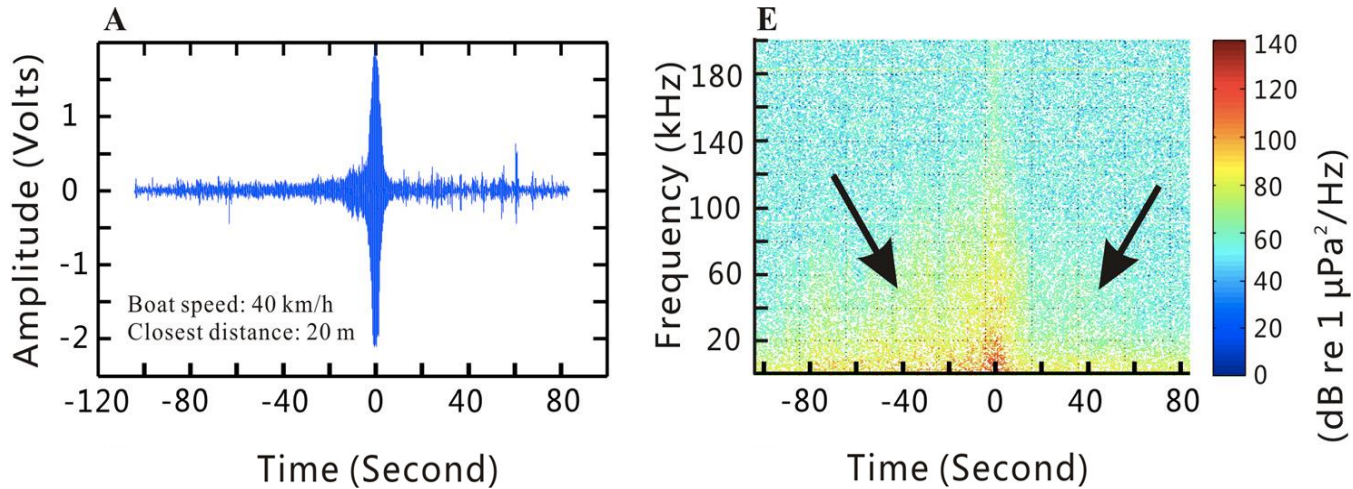


Cavitation of Ship's Propellers also creates higher frequency noise

Arveson and Vendittis (2000) jasa 107:118-129

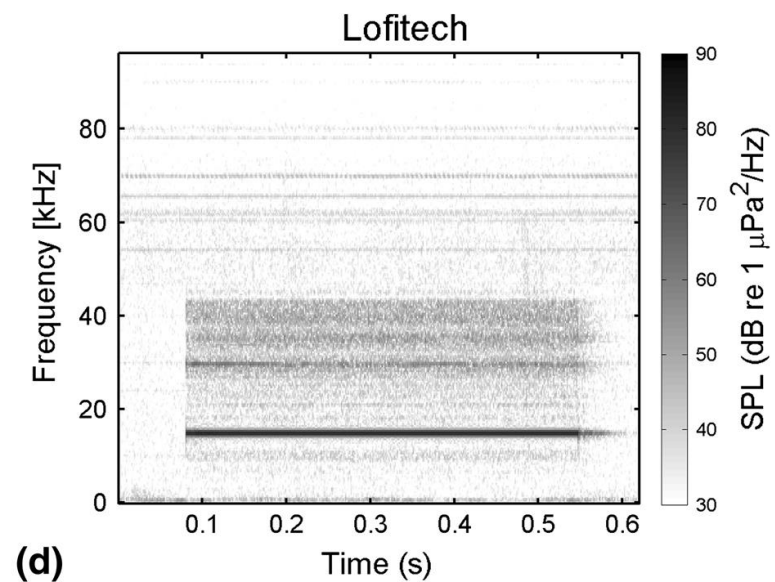
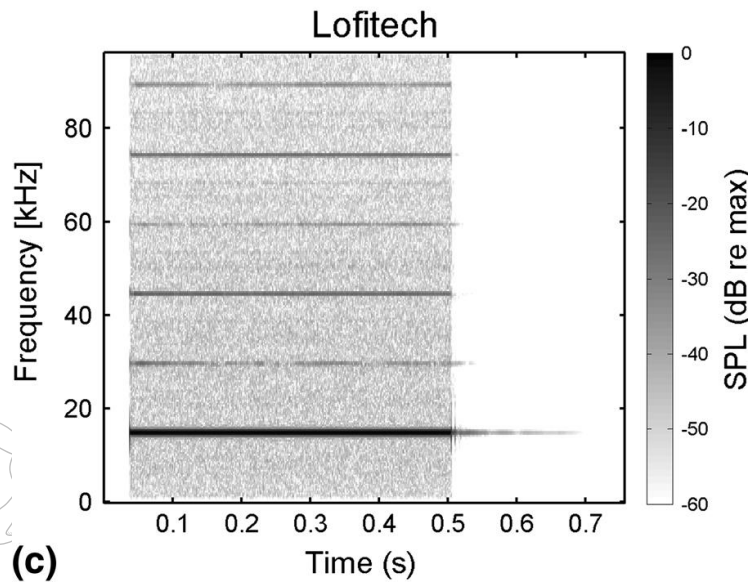
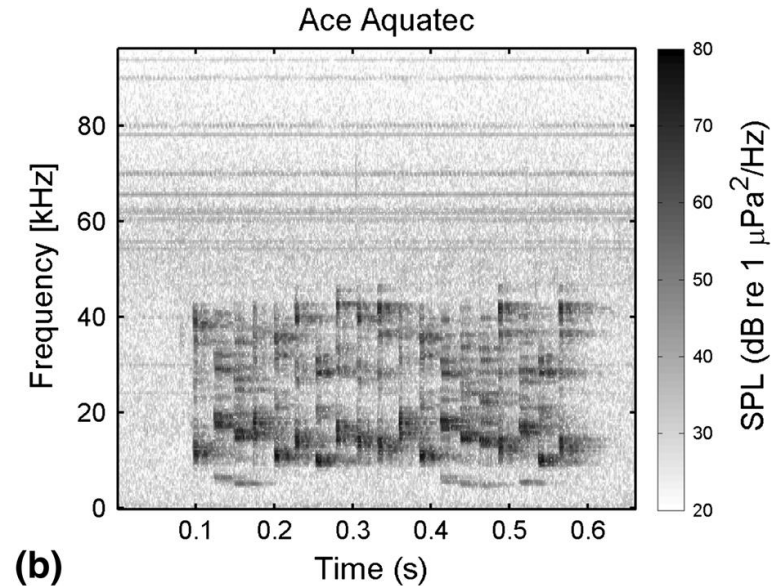
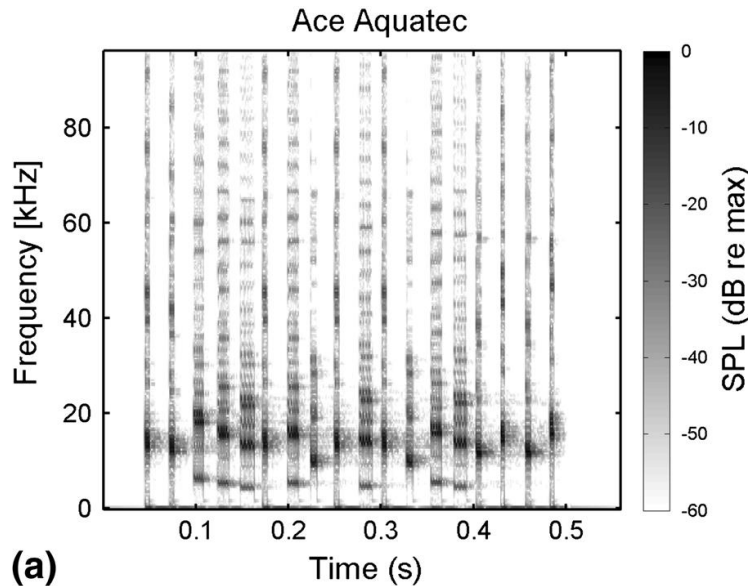


Noise from Passing Outboard



Acoustic Harassment Devices

SPL 186 – 193 dB re 1 μPa





Naval Sonar



Sonar Frequency Ranges Cover Nearly the full range of hearing of marine animals

- <1000 Hz for long range detection of large objects
- 1-10 kHz for medium range detection of naval targets
- >10 kHz for depth sounders
- >100 kHz for acoustic current profilers



Airgun used for Seismic Surveys

- <http://ocr.org/portfolio/seismic-airgun-surveys/>

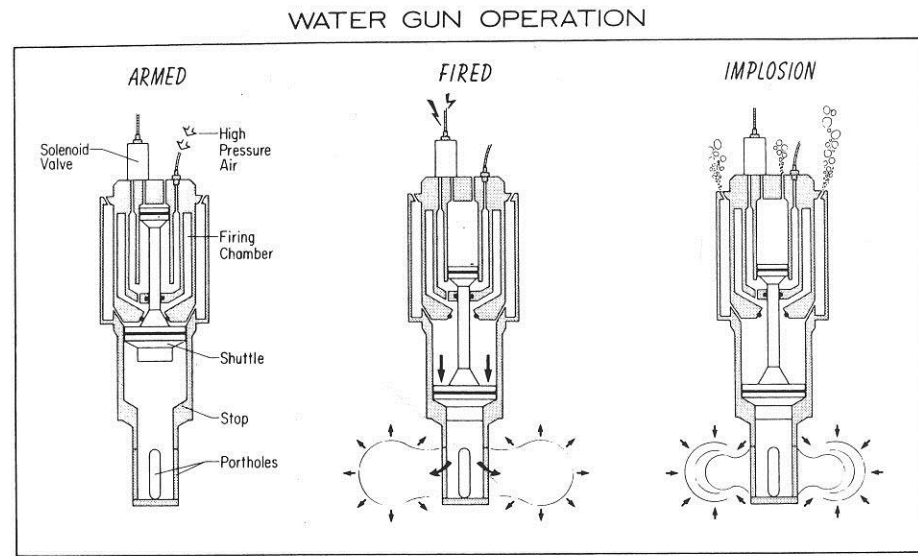
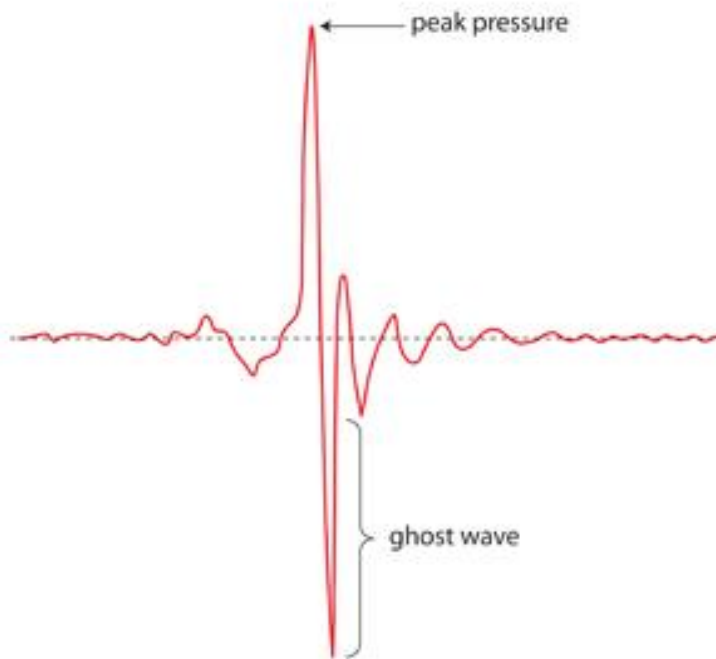
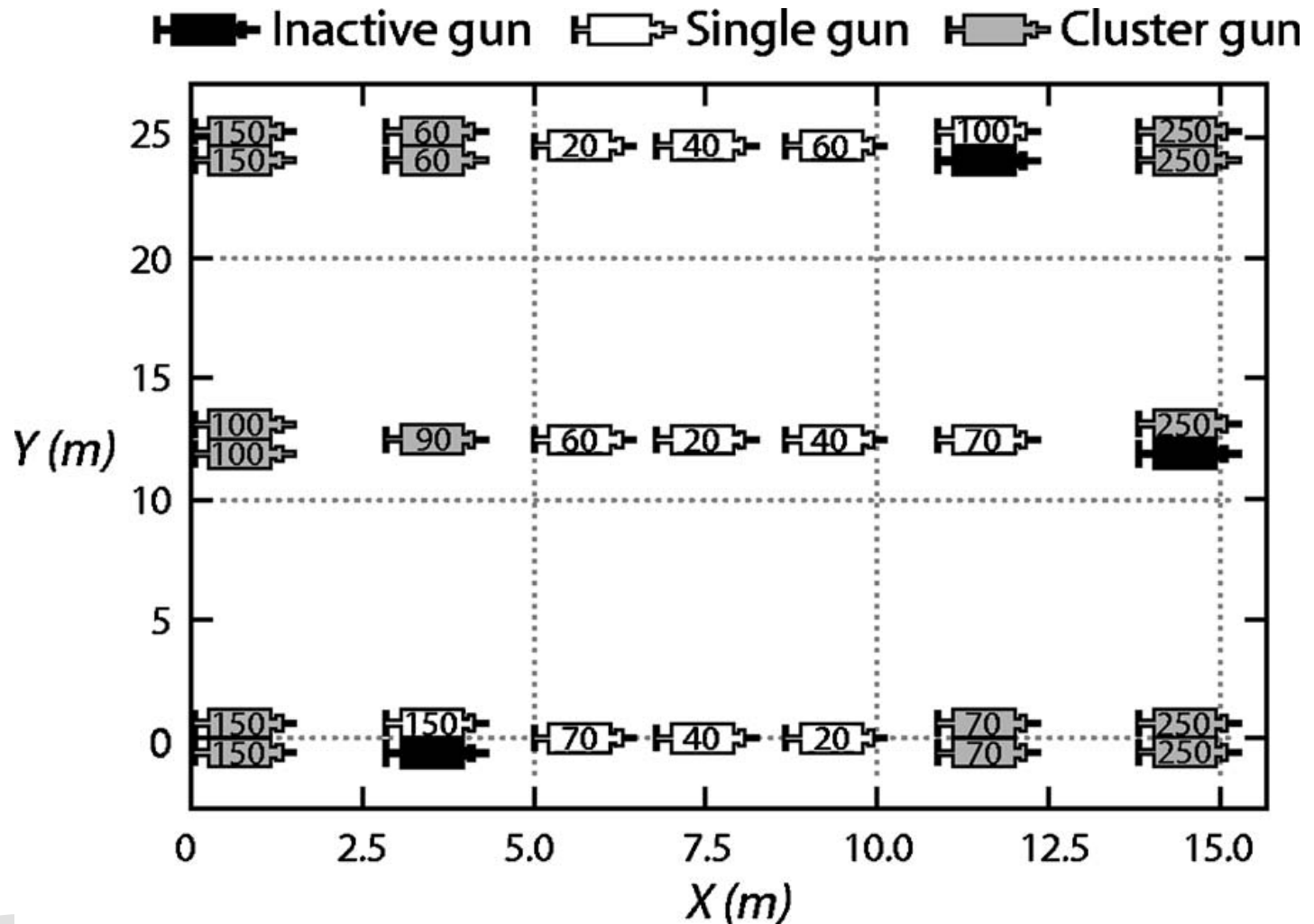
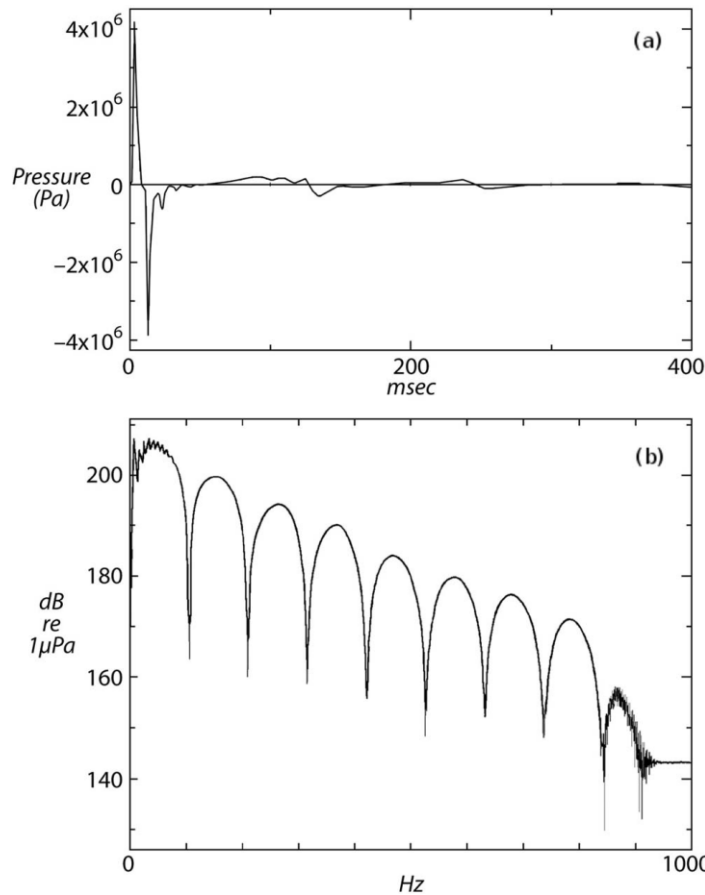


Figure 1. Graphic illustrating the various components of a water gun pulse. Graphic courtesy of Ebinger, Farokhkish and Wagner, USGS.

Airguns are deployed in arrays to direct sound downwards



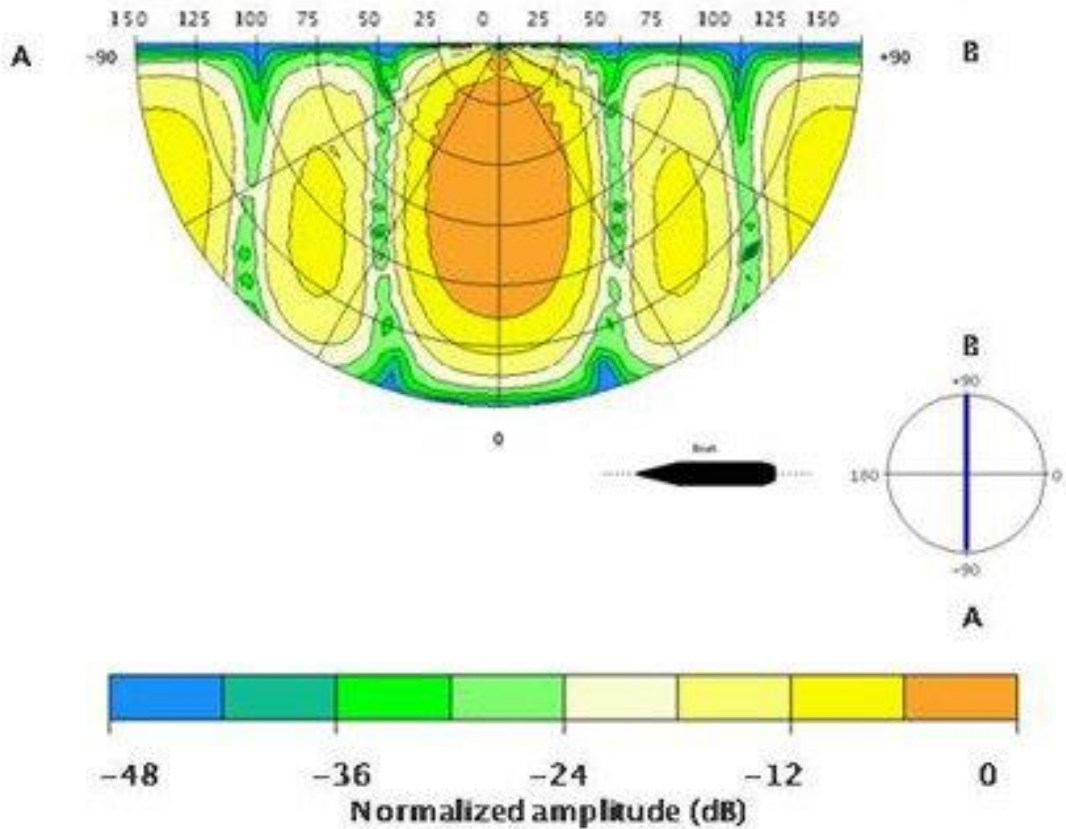
Waveform and Spectrum from Airgun Array



- Source Level 220-260 dB re $1 \mu\text{Pa}$ at 1 m
- Peak Frequency 10-200 Hz
- ~ 40 dB down at 1 kHz
- Energy is directed downwards



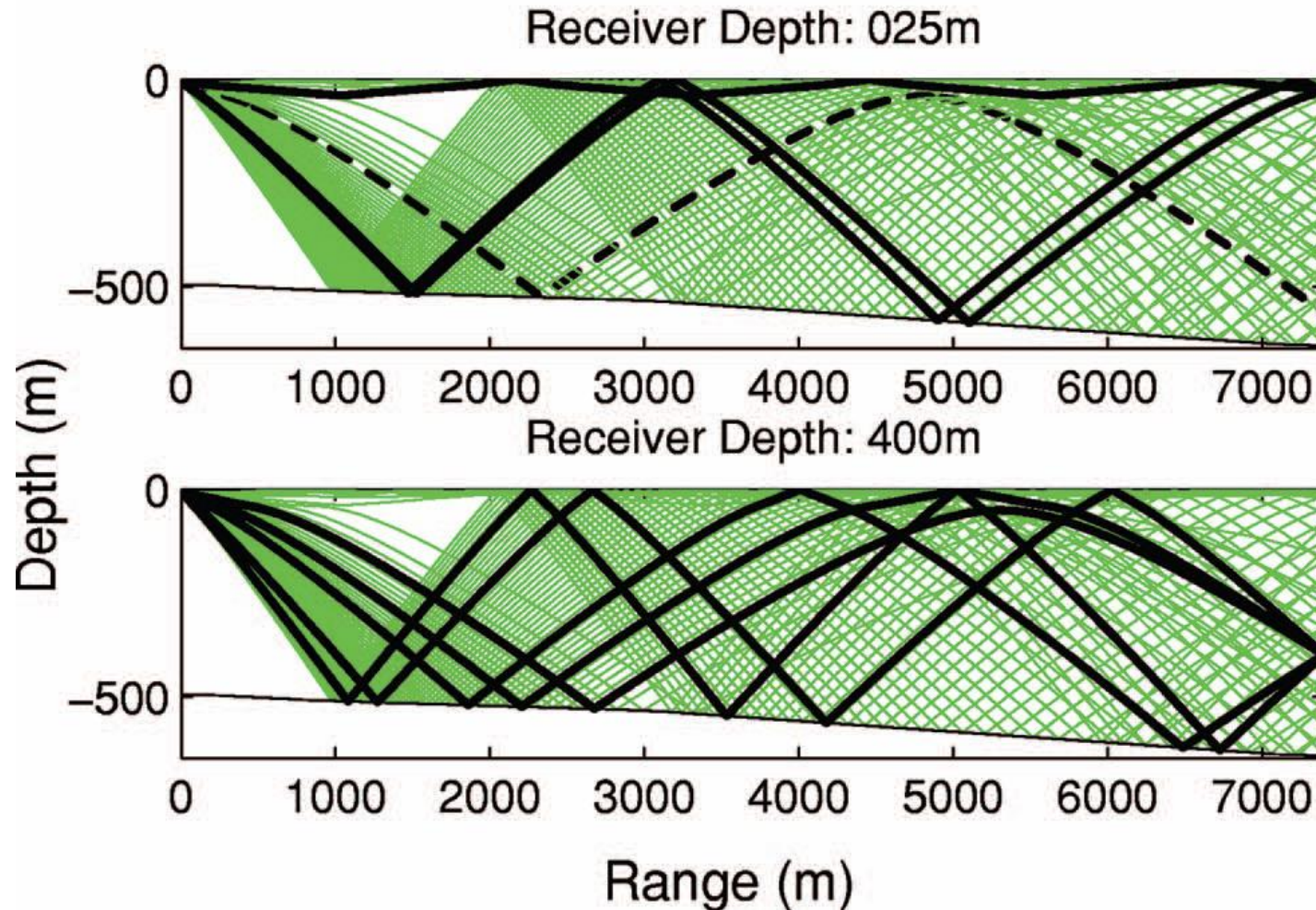
Beam Pattern of Air Gun Array for Seismic Survey



DOWN

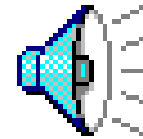
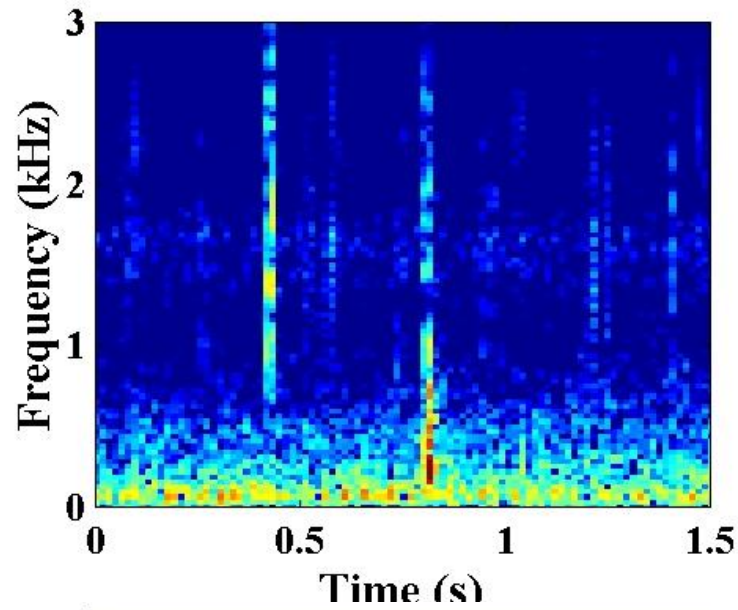


Multiple Paths for Airgun to Receiver Vary with Depth

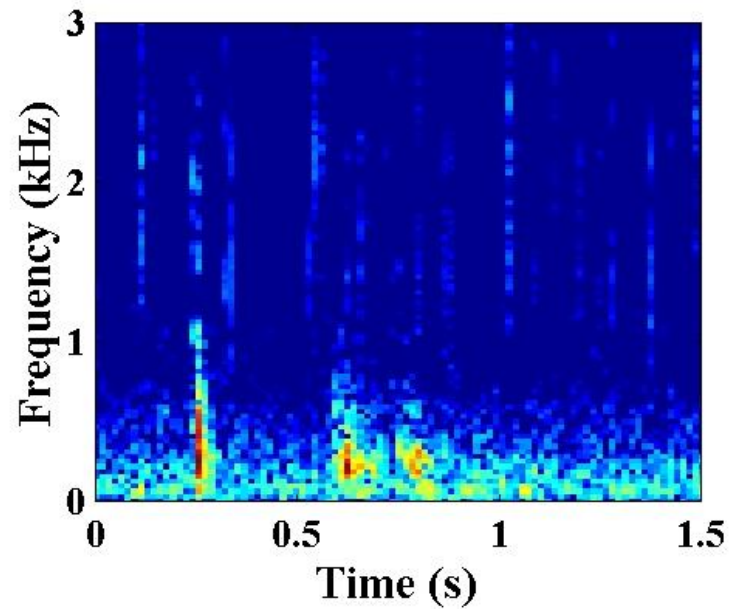


Variation in spectrum of airgun pulses with depth at 10 nm

20m



600m



Areas With Geophysical Exploration 1994-2005

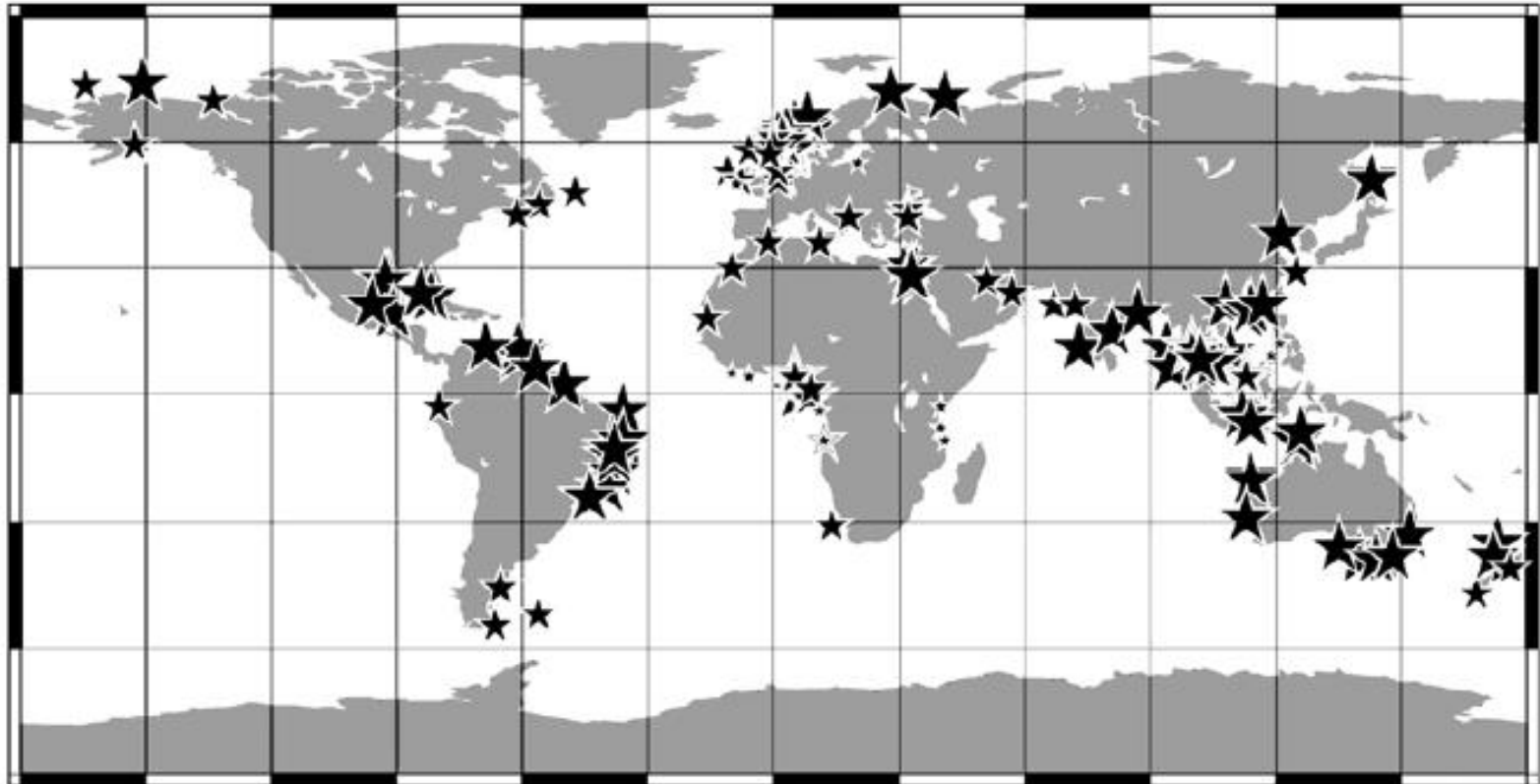


Fig. 5. Areas of offshore oil exploration from 1994 to 2005. Size of star denotes the relative level of activity. Data from the World Geophysical News



Underwater Explosions

- Airguns replaced explosions for seismic survey
- Source Level depends on charge

Type	Charge	Source Level dB re 1 μ Pa at 1m
Seal Bomb	2.3 g	205
Torpedo	45 kg	289
Ship Shock Test	4500 kg	304



Summary of Human Sources of Ocean Noise

Table 1. Typical sources of anthropogenic noise. Omni: omnidirectional; CW: continuous wave; V: vertical; H: horizontal; 10 000 lb = 4536 kg; 98 lb = 44 kg

Sound source	Source level (dB re 1 μ Pa @ 1 m)	Power (W)	Total energy per pulse (J)	Bandwidth $\Delta = 10$ dB (Hz)	Source direction	Pulse duration (s)
Ship shock trial (10000 lb explosive)	304	0.021×10^{15}	0.042×10^{15}	0.5–50	Omni	2
Torpedo MK-46 (98 lb explosive)	289	0.66×10^{12}	0.066×10^{12}	10–200	Omni	0.1
Air-gun array	260	0.21×10^9	6.2×10^6	5–300	$60 \times 180^\circ$ V	0.03
US Navy 53C ASW sonar	235	0.77×10^6	1.5×10^6	2000–8000	$40 \times 360^\circ$ H	2
SURTASS LFA sonar	235	0.59×10^6	0.029×10^9	100–500	$30 \times 360^\circ$ H	6–100
Pile-driving 1000 kJ hammer	237	0.46×10^6	0.023×10^6	100–1000	$15 \times 360^\circ$ H	0.05
Multibeam sonar deep-water EM 122	245	0.077×10^6	760	11 500–12 500	$1.0 \times 120^\circ$ V	0.01
Seal bombs (2.3 g charge)	205	2.6×10^3	79	15–100	Omni	0.03
Multibeam sonar shallow EM 710	232	2.2×10^3	4.5	70 000–100 000	$0.5 \times 140^\circ$ V	0.002
Sub-bottom profiler SBP 120	230	2.1×10^3	210	3000–7000	$3 \times 35^\circ$ V	0.1
Acoustic harassment device	205	1.3×10^3	330	8000–30 000	$90 \times 360^\circ$	0.15–0.5
Cargo vessel (173 m length, 16 knots)	192	66	–	40–100	$80 \times 180^\circ$	CW
Acoustic telemetry SIMRAD HTL 300	190	42	–	25 000–26 500	$90 \times 360^\circ$	CW
Small boat outboard engine (20 knots)	160	42×10^{-3}	–	1000–5000	$80 \times 180^\circ$	CW
Acoustic deterrent device	150	4.2×10^{-3}	1.4×10^{-3}	5000–160 000	$90 \times 360^\circ$	0.2–0.3
Operating windmill turbine	151	2.6×10^{-3}	–	60–300	$15 \times 360^\circ$ H	CW

