A preliminary investigation on the seismic airgun reverberant field in a shallow water Arctic environment

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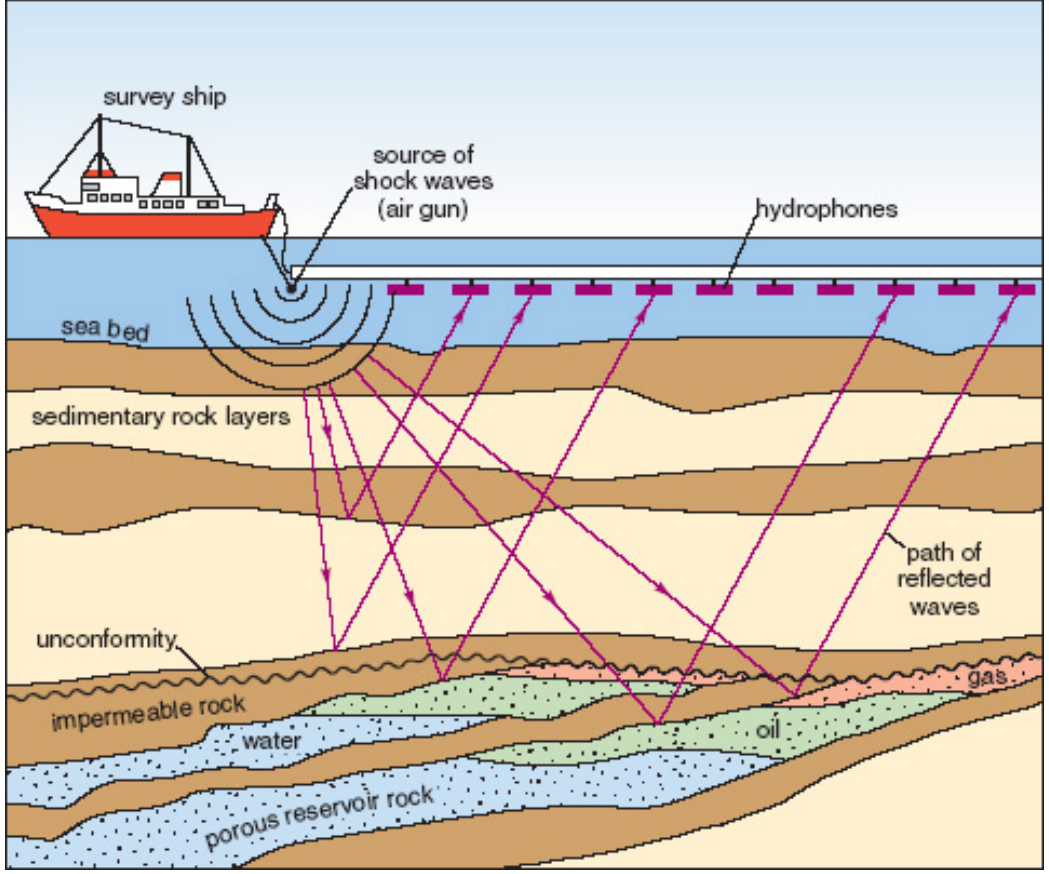
Introduction

- Seismic reflection profiling (seismic survey) is widely used by oil and gas industry for offshore oil and gas exploration.
- Airgun arrays used in seismic surveys produce high intensity pulses.
- Airgun array pressure output is proportional to number of airguns and the cube root of airgun volume

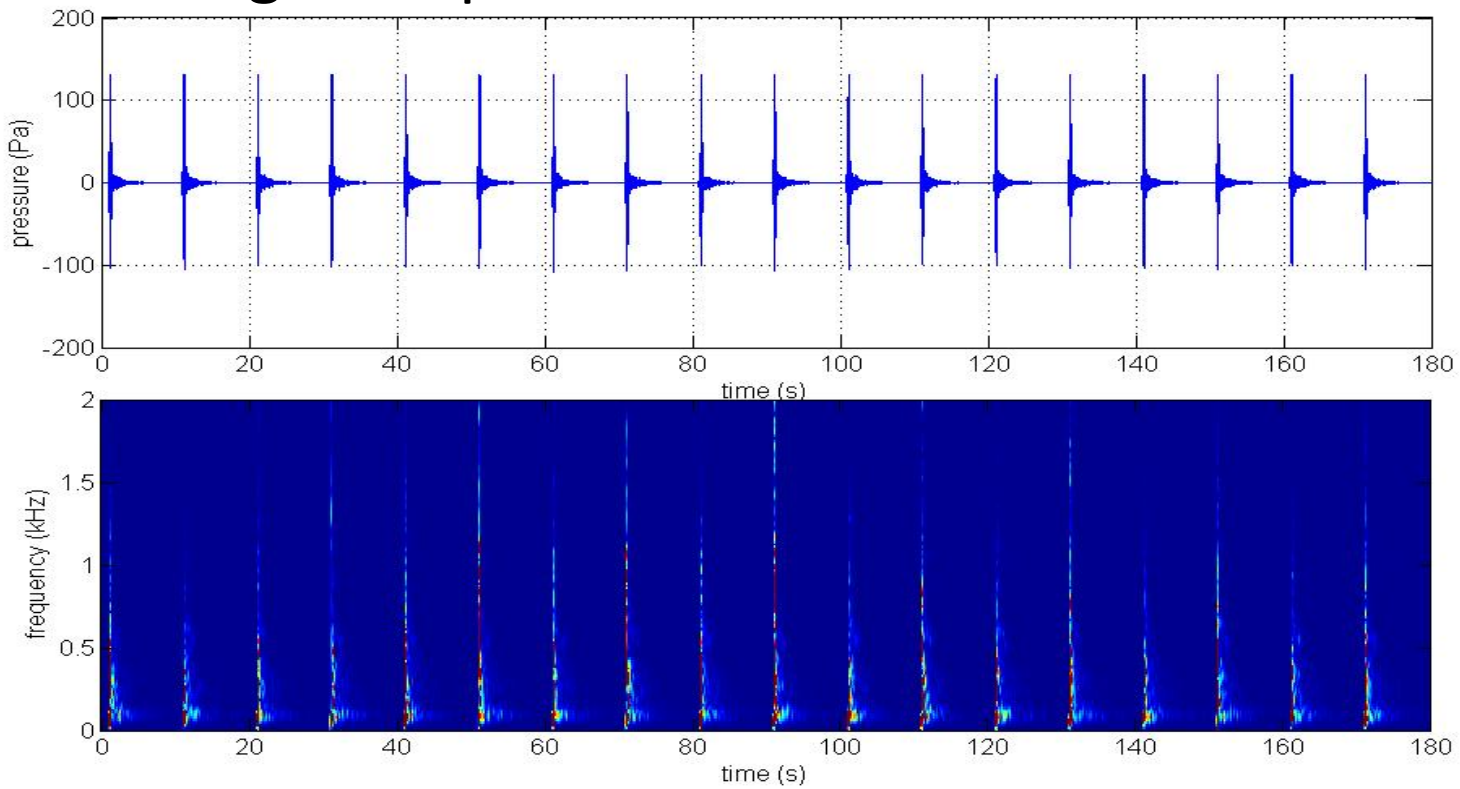


Courtesy of EPA

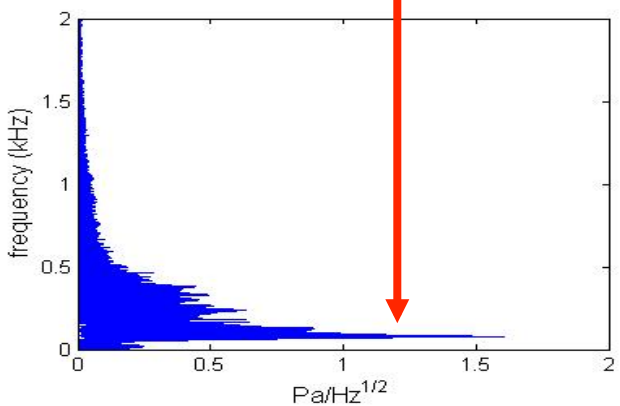
Photos by Shane Guan

Introduction

- Typically all airguns in an array fire in a synchronized fashion to produce coherent pulses every 10 – 20 s with the source vessel moving at a speed of 4 – 5 knots.

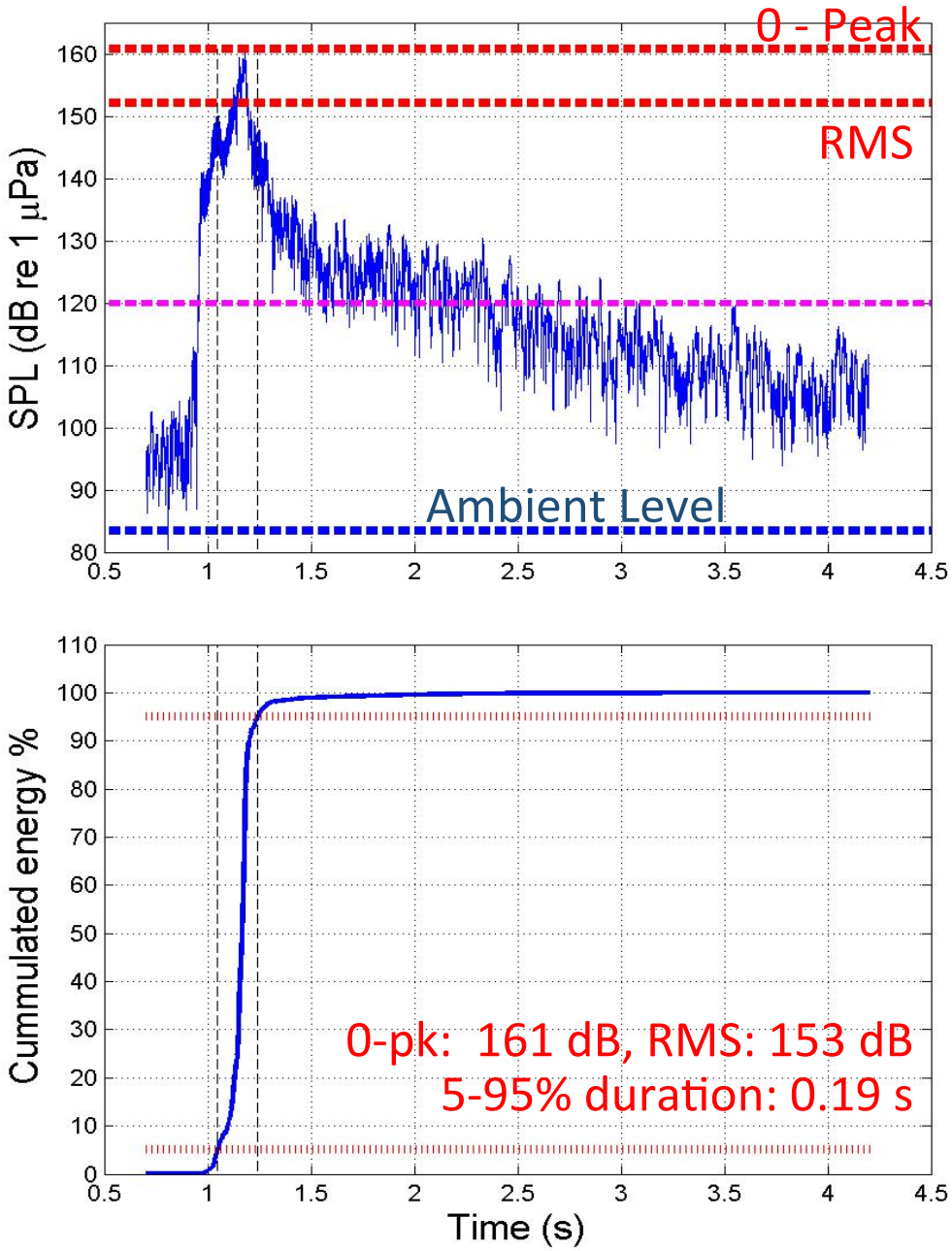


Majority of energy below 500 Hz



Introduction

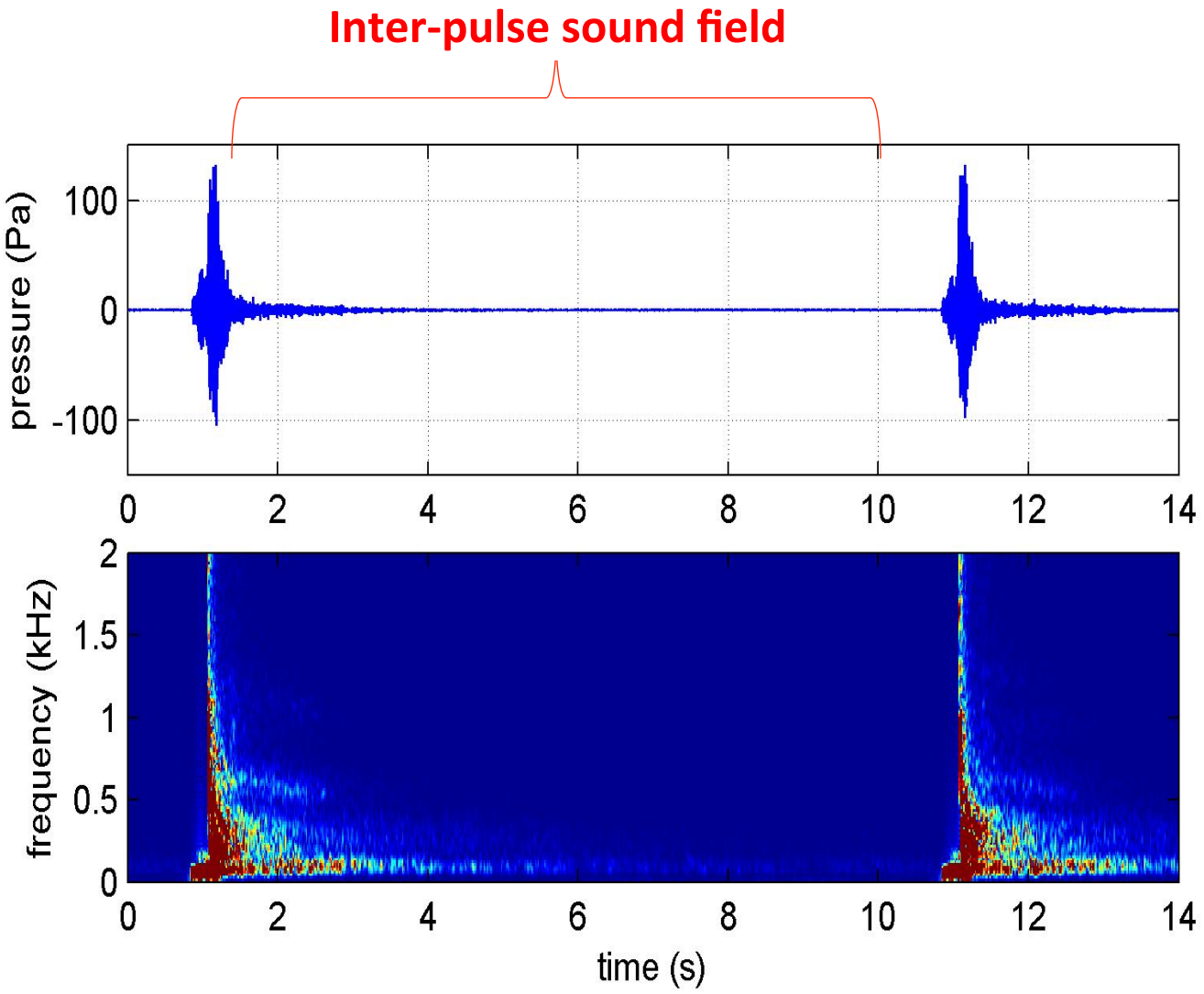
- Accepted metrics for describing airgun pressure output: 0-Peak level and RMS level
- Adverse effects to marine mammals have been shown to include hearing impairment (TTS, PTS) and behavioral disturbance.
- Few studies on inter-pulse noise levels, which may cause auditory masking (masking of biologically important signals), have been conducted.



Objectives

- Characterize the inter-pulse sound field during a marine seismic survey in a shallow water Arctic environment
- Compare the inter-pulse sound field with the ambient noise level when seismic airguns were off
- Inter-pulse sound field:

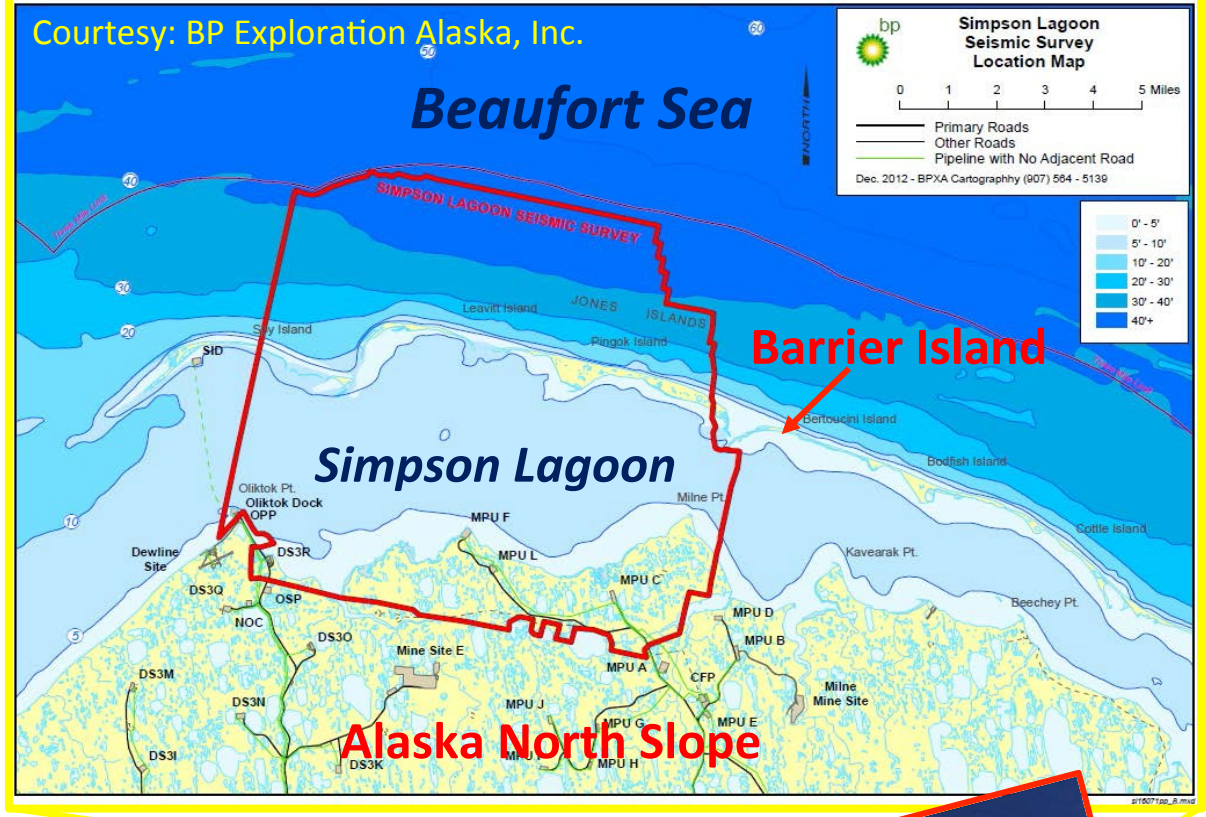
  Defined as a 9-s period 100-ms after the pulse peak

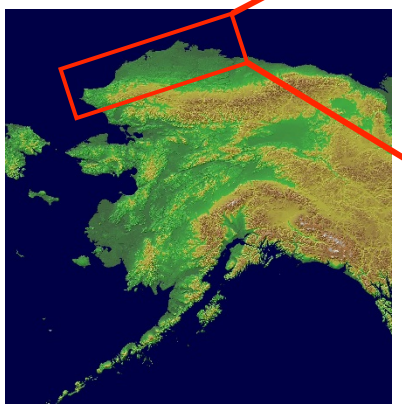


Material & Methods

- BP conducted a 3D ocean bottom cable seismic survey during 2012 Arctic open water season (Aug – Sep) in Simpson Lagoon of the Beaufort Sea
- The survey used 3 seismic vessels with relatively small airgun arrays.

Array Volume	640 in^3	320 in^3
No. Guns	16 40-in^3 guns	8 40-in^3 guns
0-peak	242 dB / 1 µPa-m	233 dB / 1 µPa-m
RMS Pressure	223 dB / 1 µPa-m	212 dB / 1 µPa-m

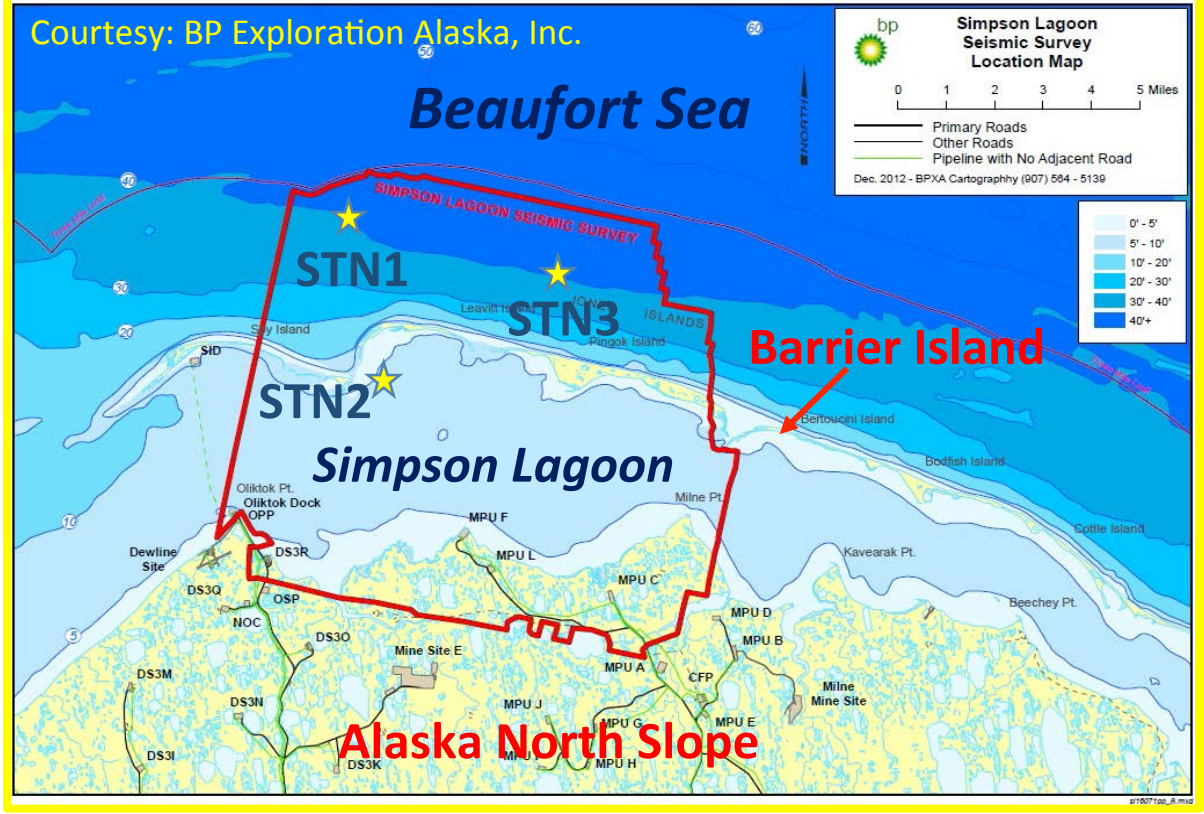




Material & Methods

- Continuous acoustic monitoring by 3 AMARs during seismic survey (27 July – 9 September)
- AMAR Specification:
  Sampling rate: 64,000 Hz
  24-bit dynamic range
  Noise floor: 20 dB re 1 $\mu Pa^2/Hz$
  Sensitivity: -165 ±3 dB re 1 V/µPa

AMAR	Location	Depth
STN1	70.5949°, -149.790°	12.2 m
STN2	70.5474°, -149.745°	2.8 m
STN3	70.5832°, -149.587°	12.4 m

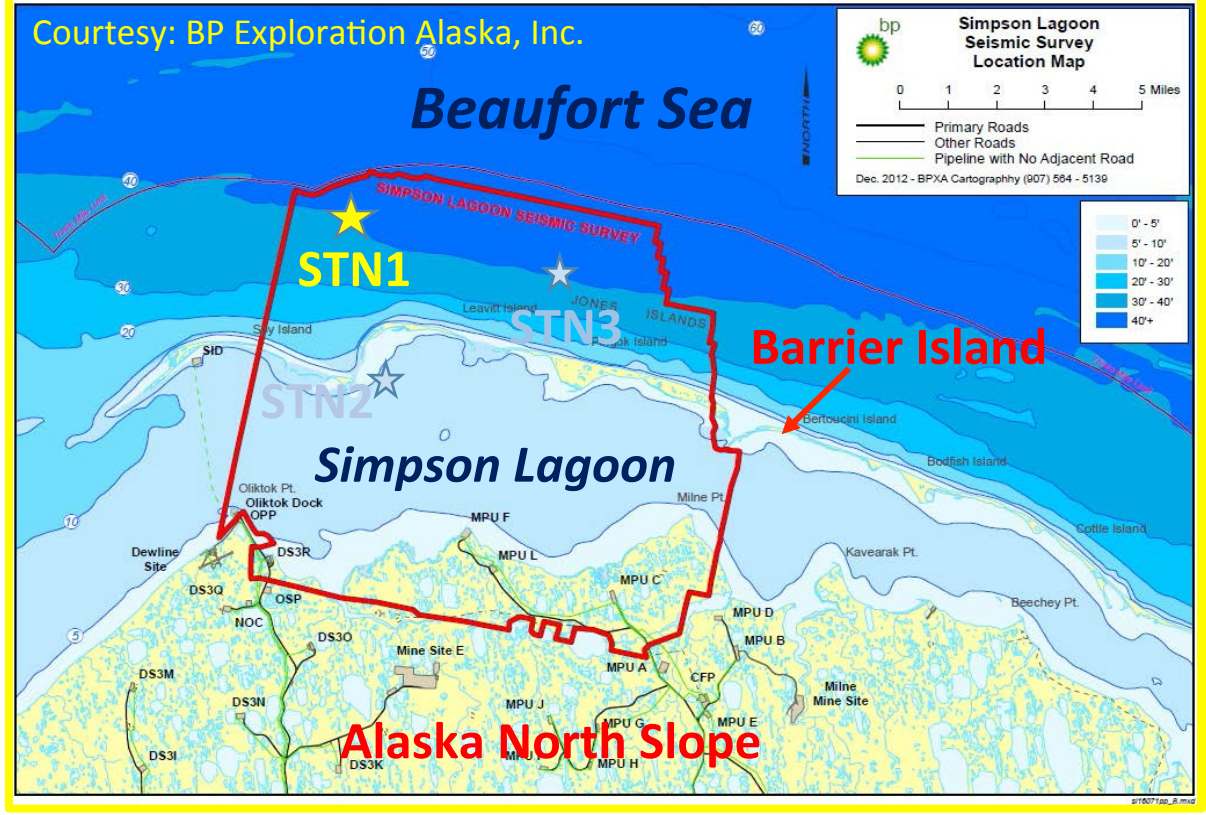


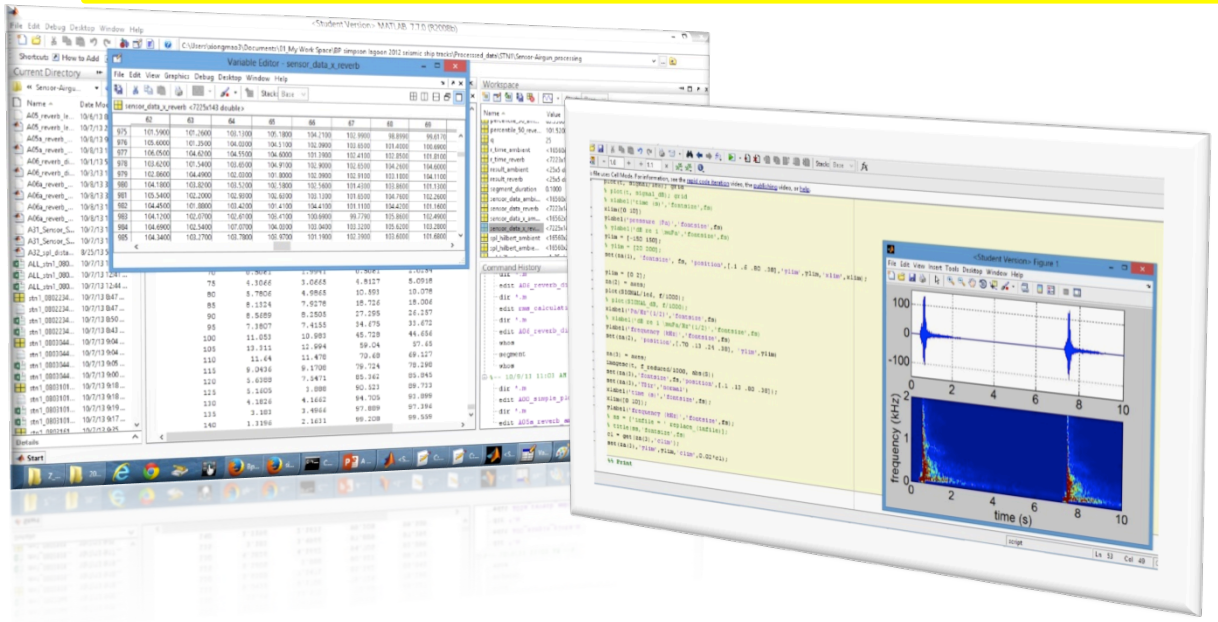
AMAR: Autonomous Multichannel Acoustic Recorder

Photo courtesy: JASCO Applied Sciences

Material & Methods

- A total of 3,300 hours recordings were collected, along with ship GPS tracks during airgun firing.
- In this preliminary study, we analyzed 86.5 hours of recordings from STN1, between August 3 and 6, 2012.
- All acoustic analyses were conducted using custom written MATLAB® codes

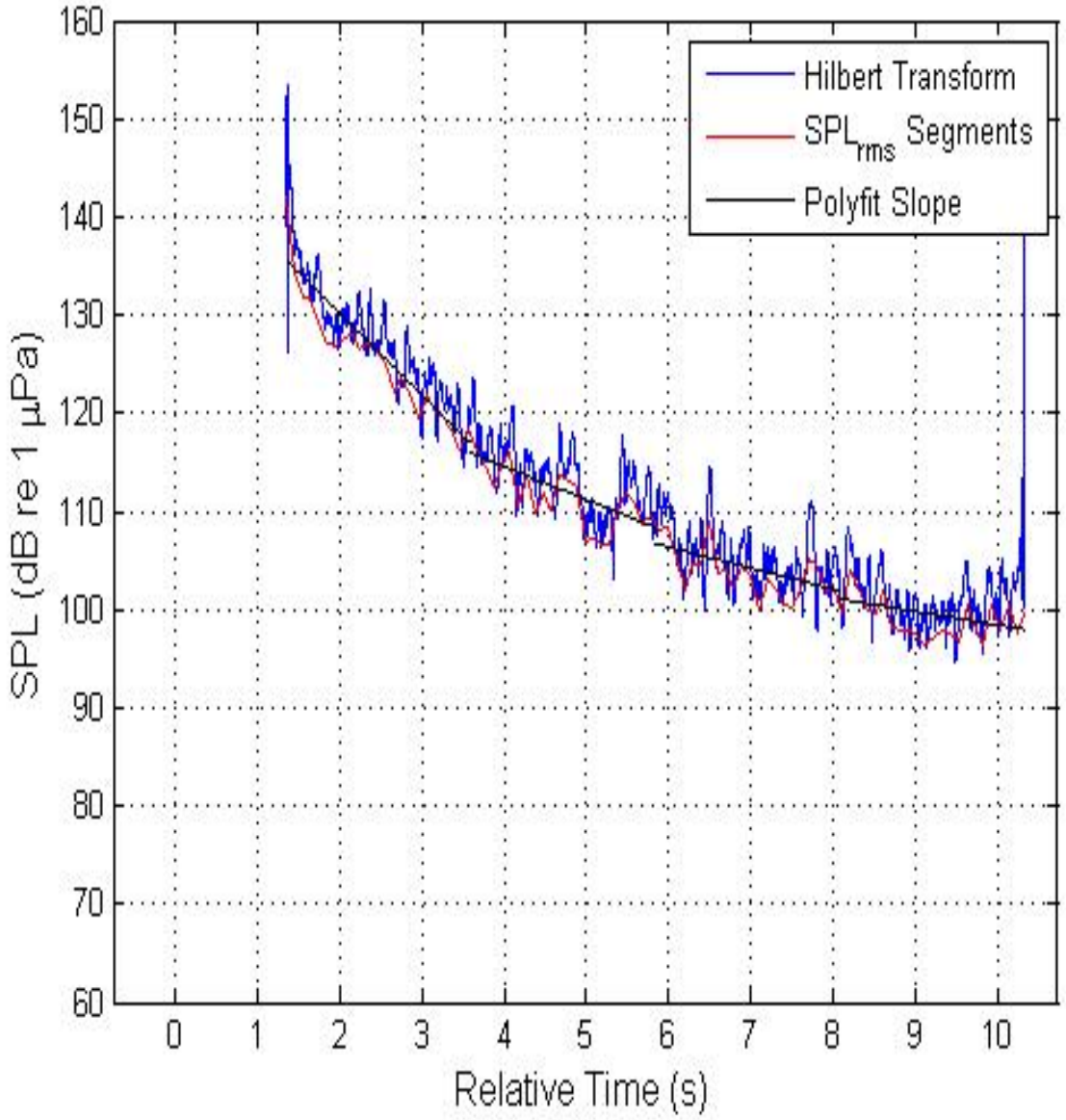




Material & Methods

Acoustic Analyses

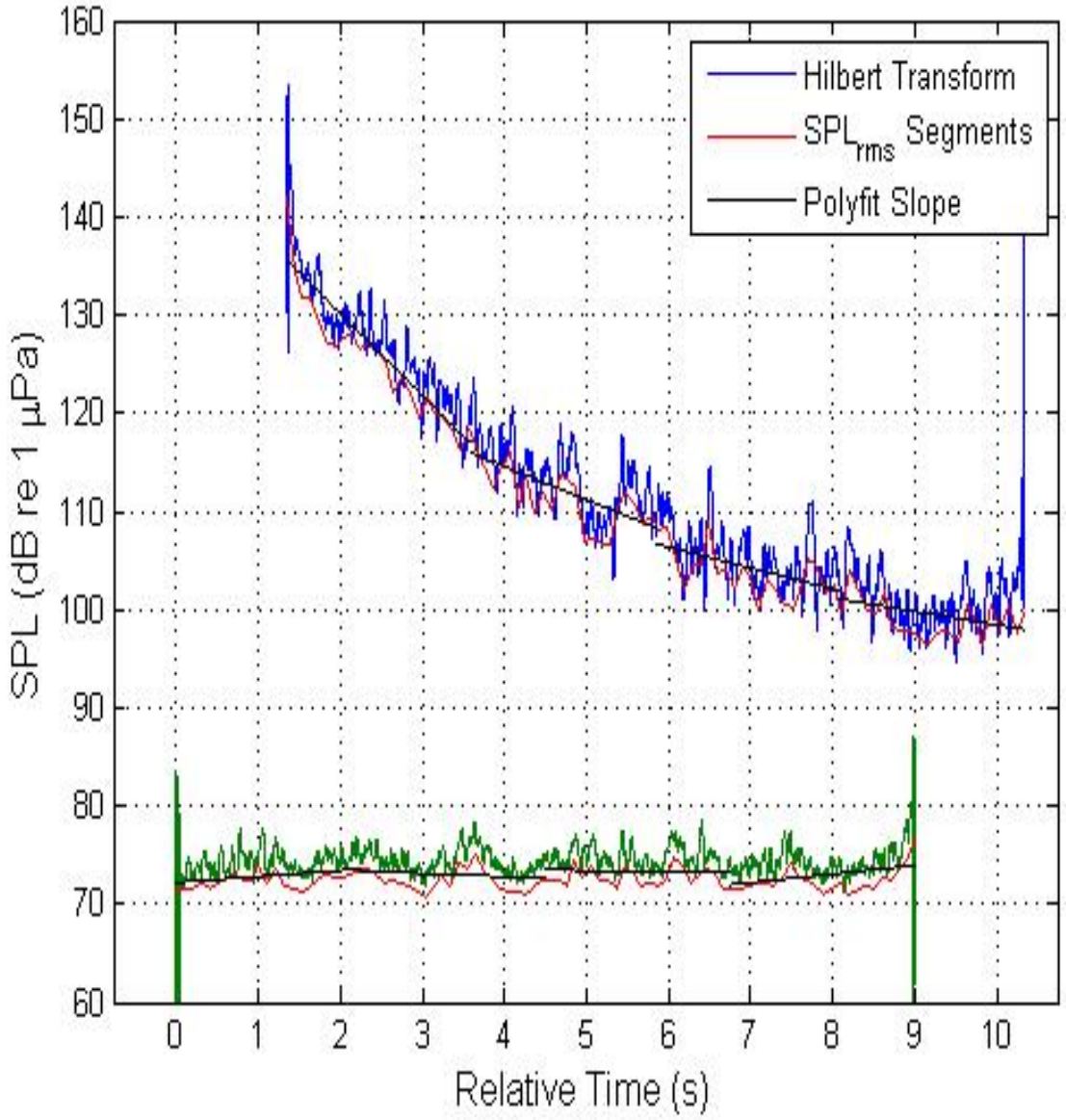
- Extracting transient signals with peak pressures > 0.08 Pa (98 dB re 1 µPa)
- 100-ms segments of SPL were calculated starting 100 ms after the peak of each pulse for the following 9 s.
- Hilbert transform were performed starting 100 ms after the peak of each pulse for the following 9 s.



Material & Methods

Acoustic Analyses

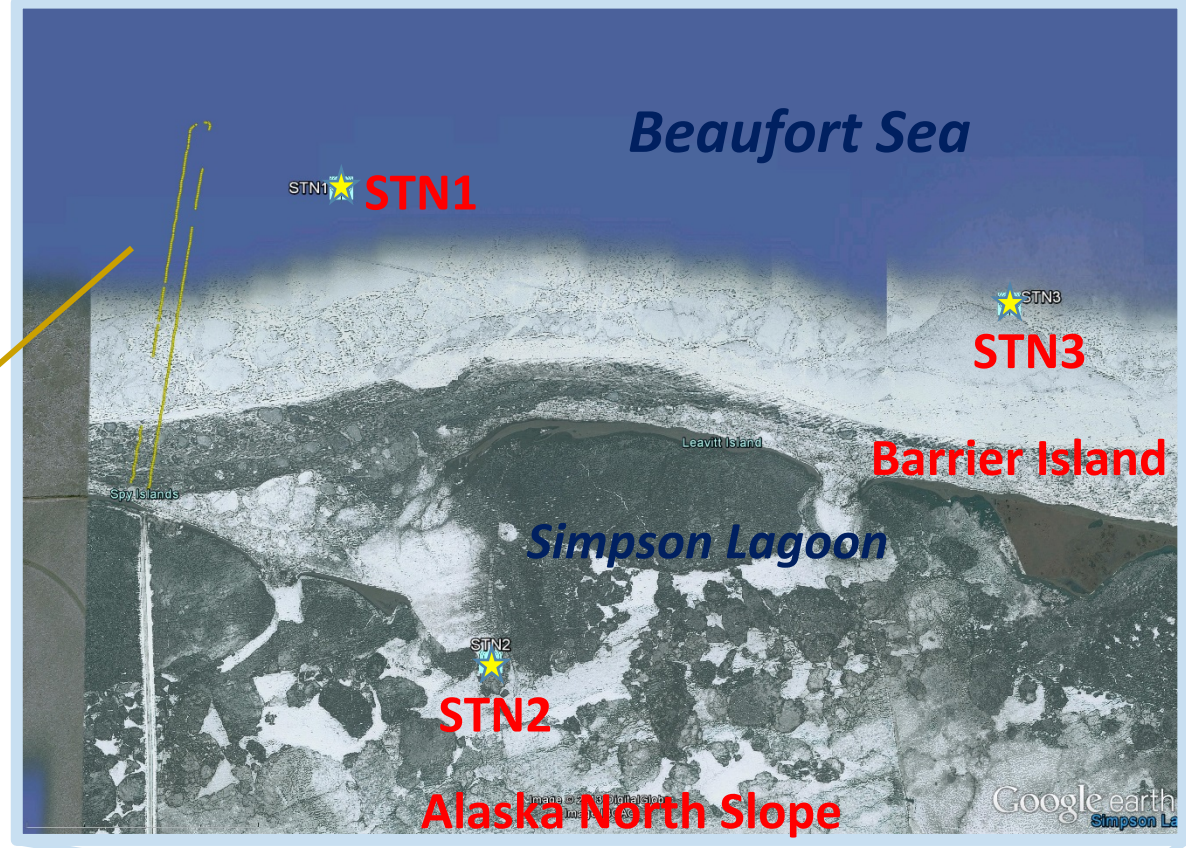
- For recordings do not contain seismic pulses, 10 s samples were taken for ambient noise analyses
- 100-ms segments of SPL were calculated each 10 s samples for the first 9 s.
- Hilbert transform were performed for each 10 s samples for the first 9 s.

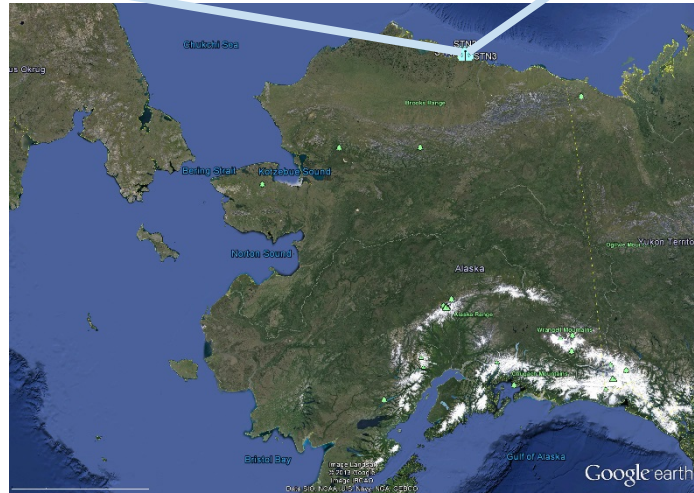


Material & Methods

Acoustic Analyses

- Pulses recorded by AMARs were matched with seismic vessels' airgun firing records along with GPS tracking.
- Amplitude distribution of inter-pulse and ambient levels were calculated to characterize the reverberant field.
- Characteristics of reverberant field in relation to ship's distances were investigated.



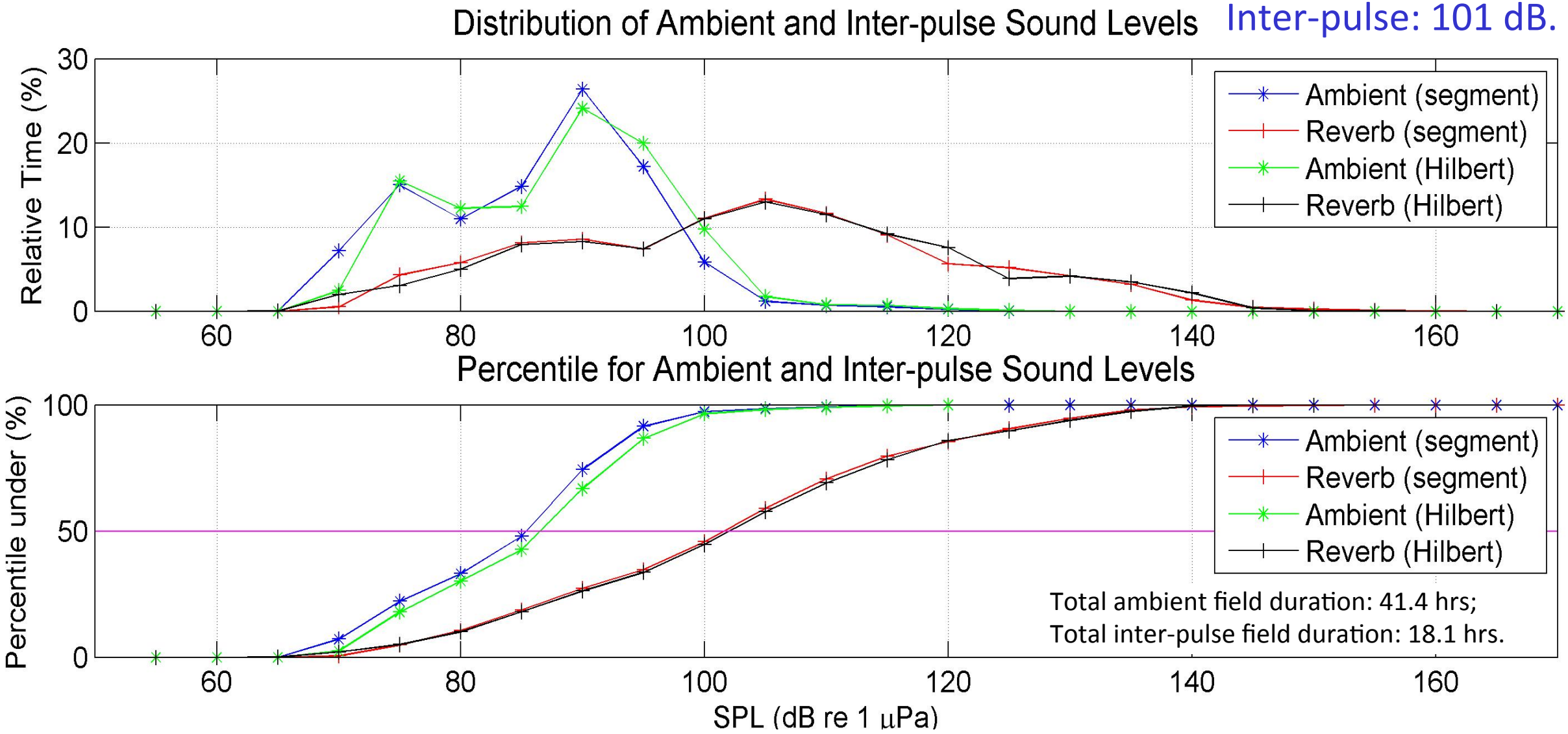


Results

50-percentile noise level:

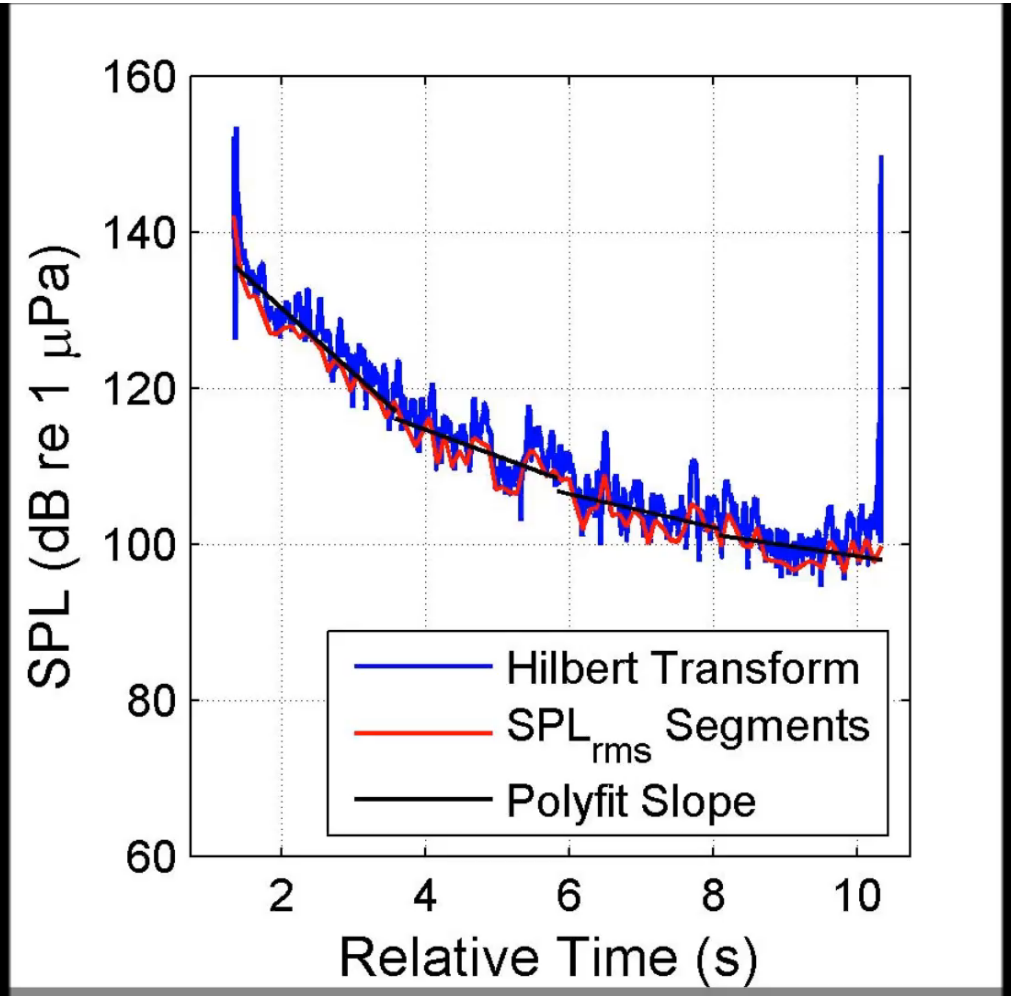
Ambient: 85 – 86 dB;

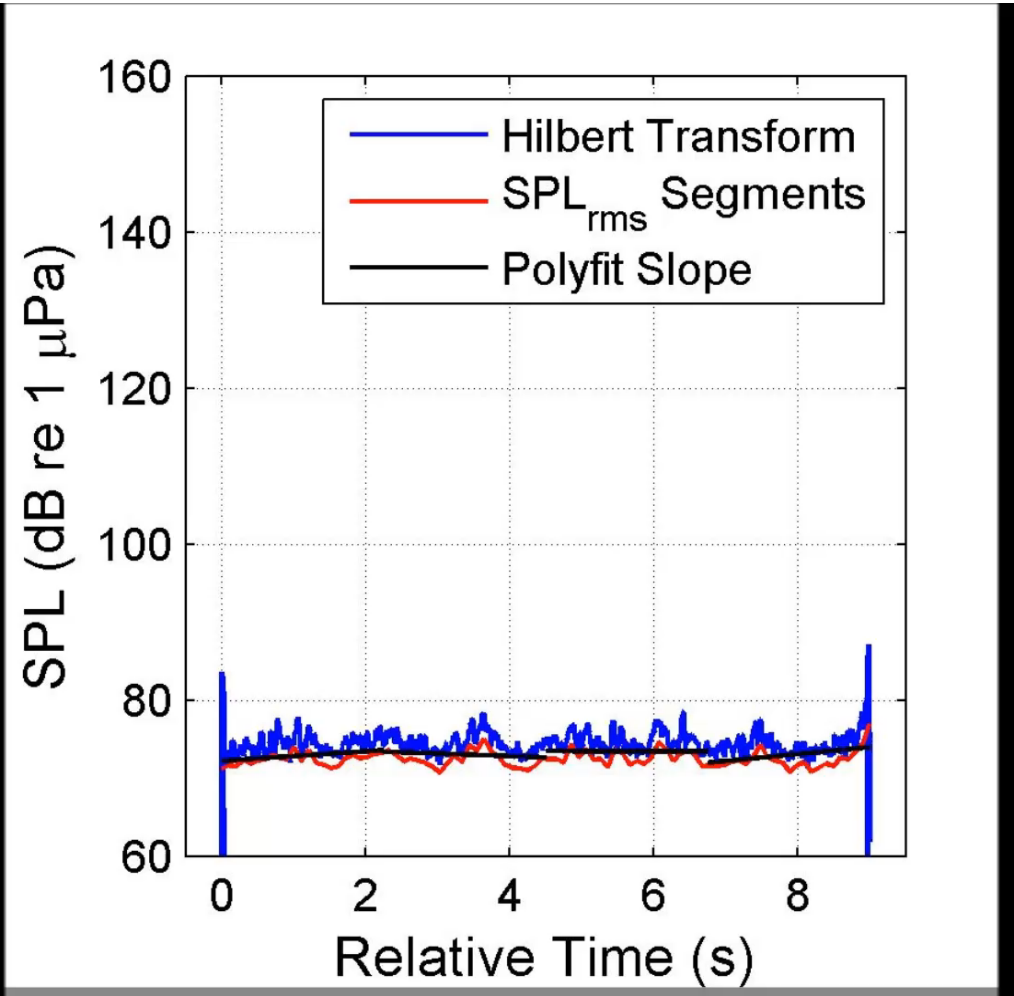
Inter-pulse: 101 dB.



Results

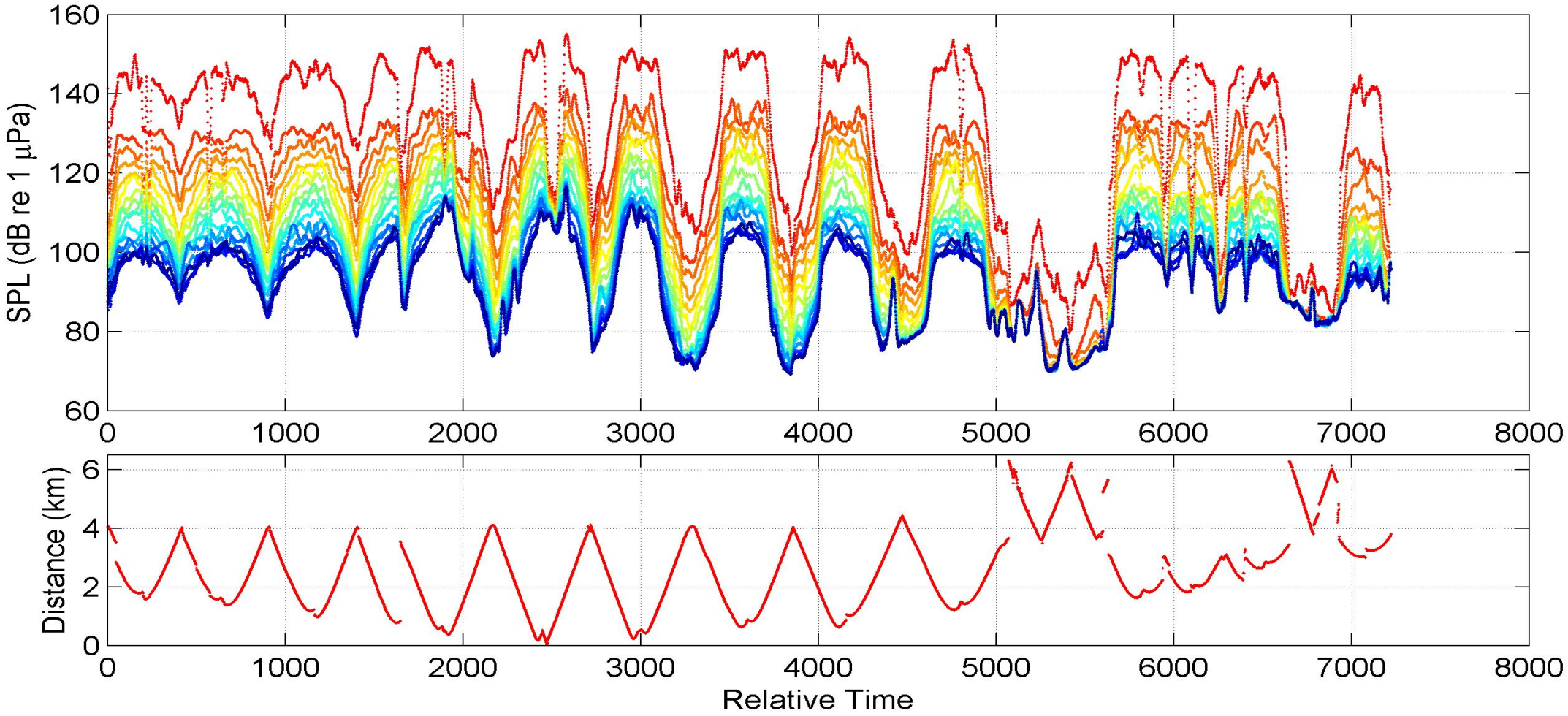
Inter-pulse Reverberant Level vs. Ambient Level without Pulses





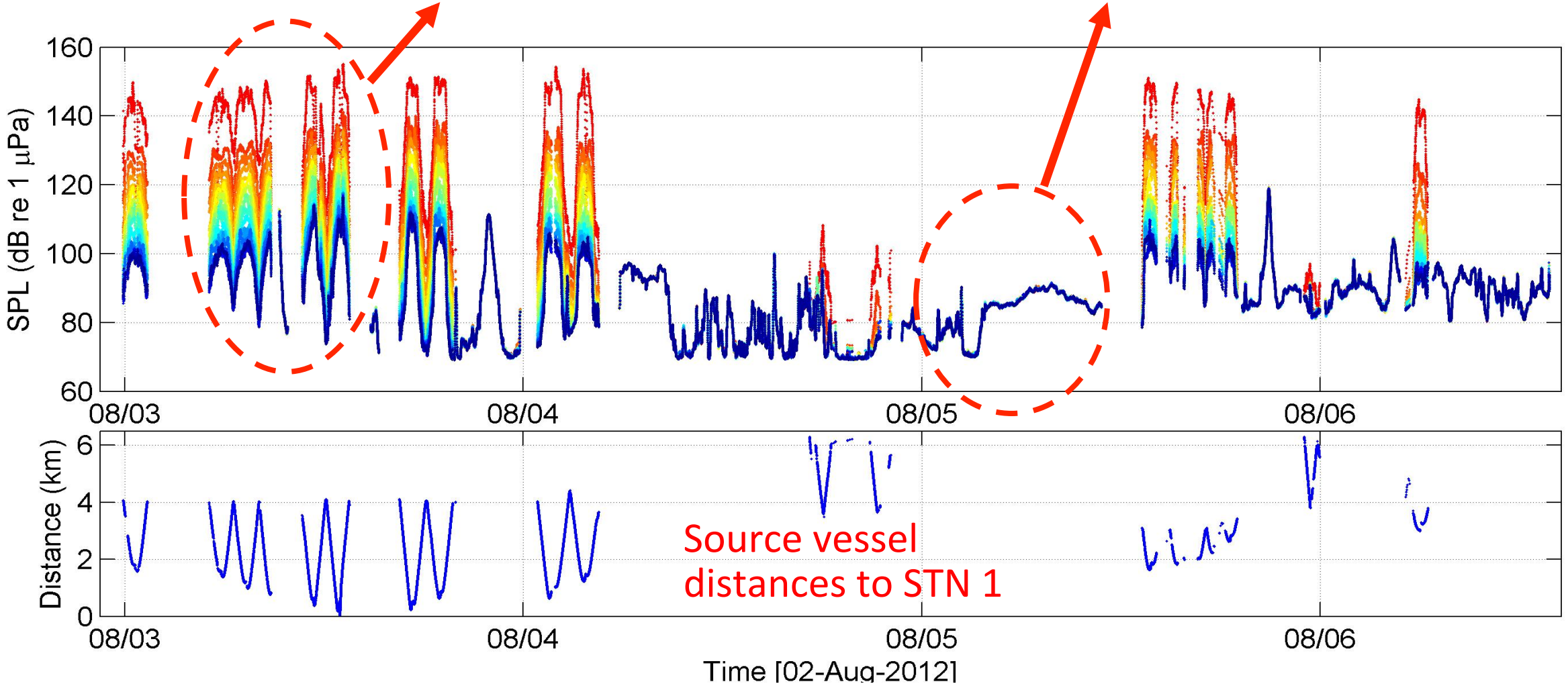
Results

Reverberant field noise level in relation with vessel distance



Results

Noise levels during airgun inter-pulse and with no airgun



Conclusion

- Marine seismic surveys could significantly elevate the noise levels by about 15 dB between pulses in shallow waters at ranges up to about 4 km due to reverberation and multi-path propagation.
- On average, inter-pulse sound field noise levels remained over 120 dB for approximately 1.4 seconds after an airgun pulse.
- Inter-pulse sound field noise levels were mostly (86% of the time) below 120 dB re 1 µPa, below the current noise exposure criteria by the National Marine Fisheries Service for Level B harassment by non-pulse noise.

Conclusion

- The amplitude distribution in the reverberant field has significant higher variance, as opposed to the ambient field without transient noise.
- Using 100-ms segment computation method calculation for inter-pulse noise levels and ambient noise levels (without airgun pulses) yielded essentially the same results as using Hilbert transform computation.

Acknowledgement

Data Source:

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- Mr. David Hannay (JASCO Applied Sciences)
- Mr. Bruce Martin (JASCO Applied Sciences)
- Mr. Alex MacGillivray (JASCO Applied Sciences)

Material & Methods

- BP conducted a 3D ocean bottom cable seismic survey during 2012 Arctic open water season in Simpson Lagoon of the U.S. Beaufort Sea
- The open-water marine surveys used three seismic vessels with relatively small airgun arrays.

Photo courtesy: JASAO Applied Sciences

Three source vessels used by BP's open water surveys in 2012: Resolution (top), Margarita (bottom left), and Storm Warning (bottom right).

Results

Noise levels during airgun inter-pulse and with no airgun