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Preliminary Acoustic Level Measurements of Airgun Sources from ConocoPhillips' 2006 Seismic Survey in Alaskan Chukchi Sea

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Overview

JASCO Research Ltd prepared a pre-season report [1] with estimates of airgun array sound level radii for use by ConocoPhillips for their 2006 seismic program in the Chukchi Sea. The pre-season report included range estimates for rms noise levels to 180 dB re µPa and 190 dB re µPa. JASCO has subsequently carried out *in situ* measurements to obtain high resolution calibrated recordings of the actual underwater noise signals from the airgun array on July 24–25, 2006. This report gives preliminary results of the analyses of the airgun recordings and provides endfire and broadside ranges to the 190–120 dB rms levels.

Introduction

ConocoPhillips is conducting a high-resolution seismic airgun survey program in the Chukchi Sea. The primary survey vessel for this program is the MV Patriot, operated by WesternGeco, which tows a pair of identical 3390 in^3 airgun arrays that are fired in alternation while surveying. On July 24–25, 2006, JASCO Research Ltd carried out underwater OBH measurements to provide *in situ* estimates of noise threshold level radii for the Patriot's airgun arrays and to compare with predictions from pre-season noise modelling. This preliminary report is intended to provide initial estimates of ranges to the 190–120 dB rms levels for ConocoPhillips' 2006 Chukchi Sea seismic survey program.

Field Recording Operations

JASCO Research performed acoustic measurements using three calibrated On-Bottom Hydrophone (OBH) recording systems. The OBH systems were deployed from the 39.2-foot support vessel M/S Torsvik, skippered by J. F. Johannesen. Ideally the recordings would have been carried out at the same location as used in the model, 71°15.1N 163°11.7W, but ice hazards prevented the survey vessel from operating in this area. The location, 69°56N 167°03W, which has similar bathymetry, was chosen as an alternate measurement location.

The OBH systems were deployed from the Torsvik and then Torsvik departed the survey area while Patriot followed the planned survey track. Digital acoustic recordings of approximately 21 hours of data were obtained from each OBH as the Patriot followed the survey line. Torsvik then returned to the survey area and recovered the three OBH's. Figure 1 shows the measurement plan, indicating the position of the three OBH systems in relation to the survey vessel track.

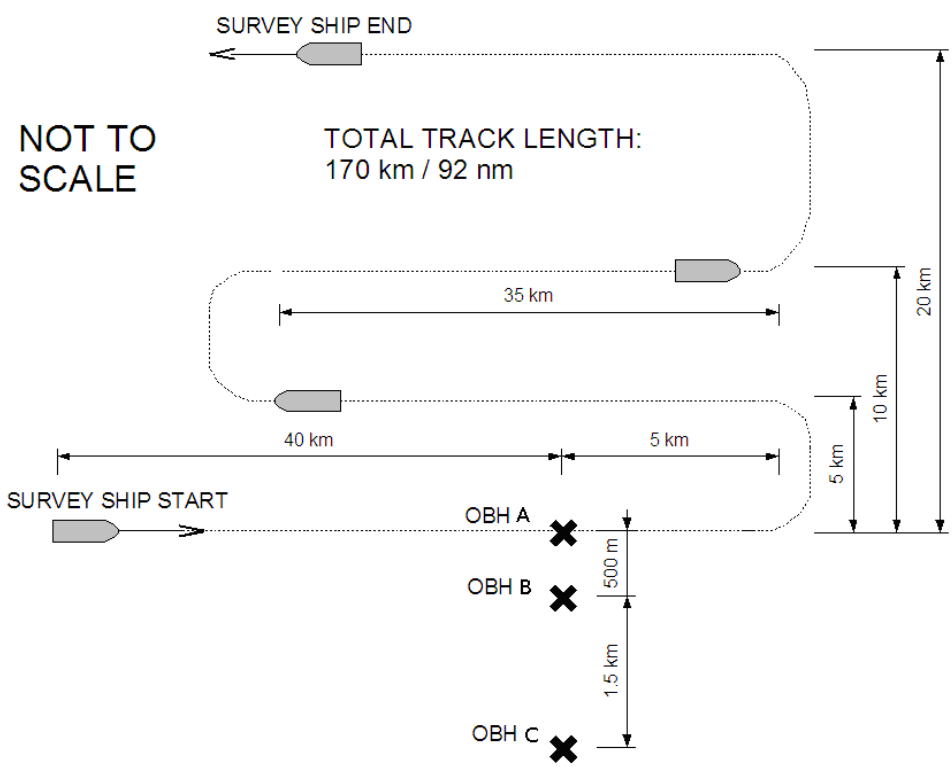

Figure 1: Survey vessel track line and OBH Locations for acoustic measurements.

Acoustic Recording Equipment

Each OBH system was mounted with two Reson calibrated reference hydrophones: TC4043 (nominal sensitivity -201 dB re V/uPa), and TC4032 (nominal sensitivity -170 dB re V/uPa). The less sensitive hydrophone (TC4043) was used for the close approach over the OBH where the more sensitive hydrophone (4032) would be saturated. Digital recordings were obtained with calibrated Sound Devices model 722 24-bit audio recorders set to a sampling rate of 32 kHz. After OBH retrieval, all data were backed up to two redundant 250 GB hard drives.

Data Analysis

Preliminary data analysis were carried out to determine rms sound pressure levels versus range from the airgun array sources. The data processing steps carried out were as follows:

1.) Delineate each pulse to determine start times.
2.) Apply hydrophone sensitivity and digital conversion gain to digital recording units to convert to microPascals (µPa).
3.) Determine the maximum sound pressure level for each pulse in dB//µPa.
4.) Compute cumulative square pressure functions through each pulse's duration.
5.) Determine times at which 5% and 95% of the cumulative square pressure for each pulse was received.
6.) For each pulse, compute the rms level by dividing the cumulative square pressure between the 5% and 95% times by the number of samples in this period, and taking the square root.

Patriot followed a slightly modified survey track as shown in Figure 2. The OBH located directly below the survey track is referred to as OBH A, the next as OBH B, and finally the last is OBH C. Patriot utilized the first of its arrays in full capacity and used the second array in varying states of reduced capacity. This preliminary report will only concern itself with the array in full capacity.

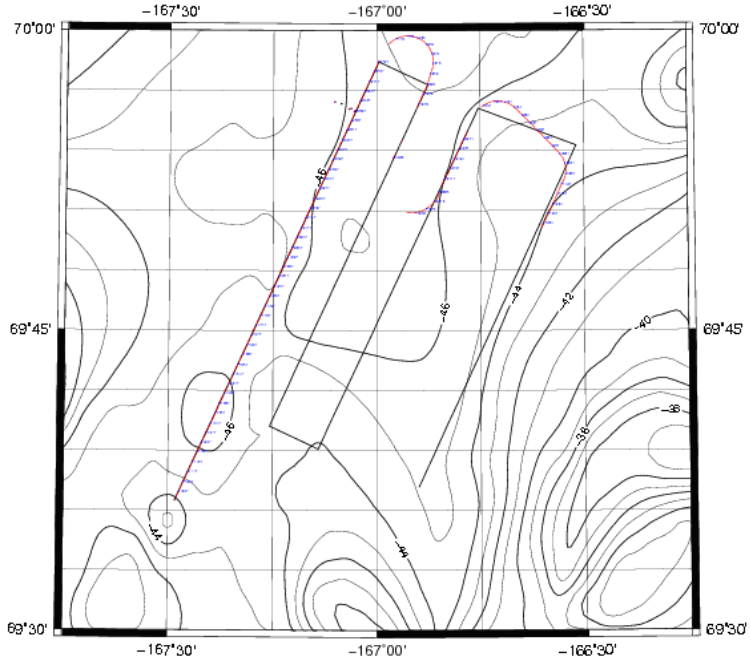

Figure 2: Patriot survey track.

Overall Results

Ranges from the airgun array to the OBH recording positions were computed for the times corresponding to each shot. Rms sound pressure level (SPL) for each shot was plotted against the corresponding source-receiver range. SPL vs. range plots were generated for all shots irrespective of endfire or broadside criteria and are shown in Figures 4, 5, and 6 for rms, peak, and SEL respectively. Endfire and broadside results were then isolated and plotted in Figures 7, 8, 9, 10, 11, and 12 for rms, peak, and SEL. Values were then estimated for 190-120 dB ranges, in 10 dB steps, for endfire and broadside.

The data presented in Figures 4, 5 and 6 are for both hydrophones on all three OBH systems. The excellent agreement of the data between the three different OBH systems indicates that the data are accurate and consistent.

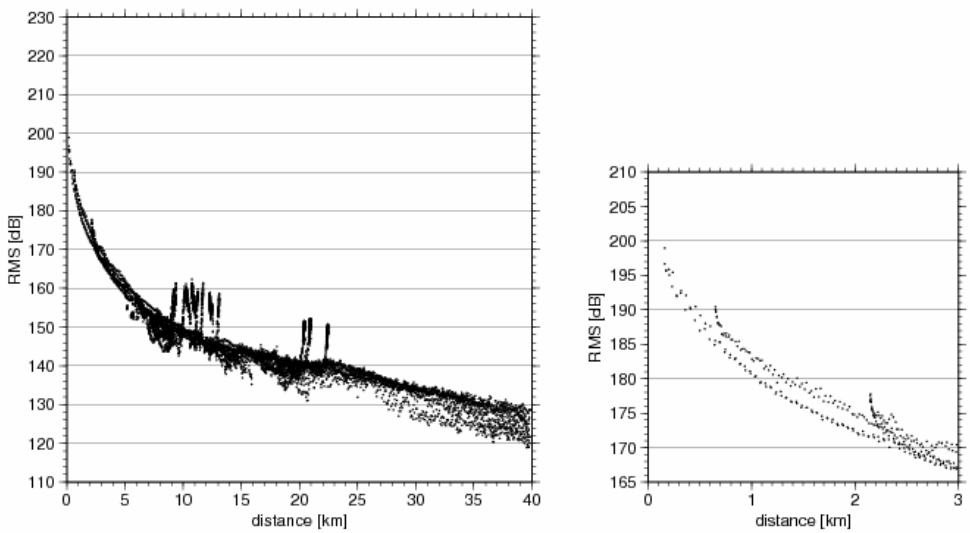

Figure 4: Combined RMS Results.

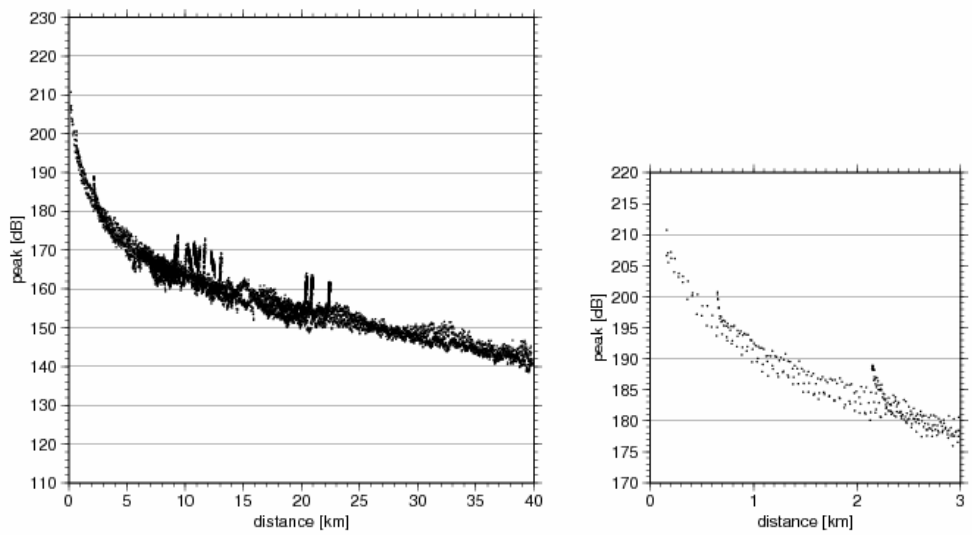

Figure 5: Combined Peak Results

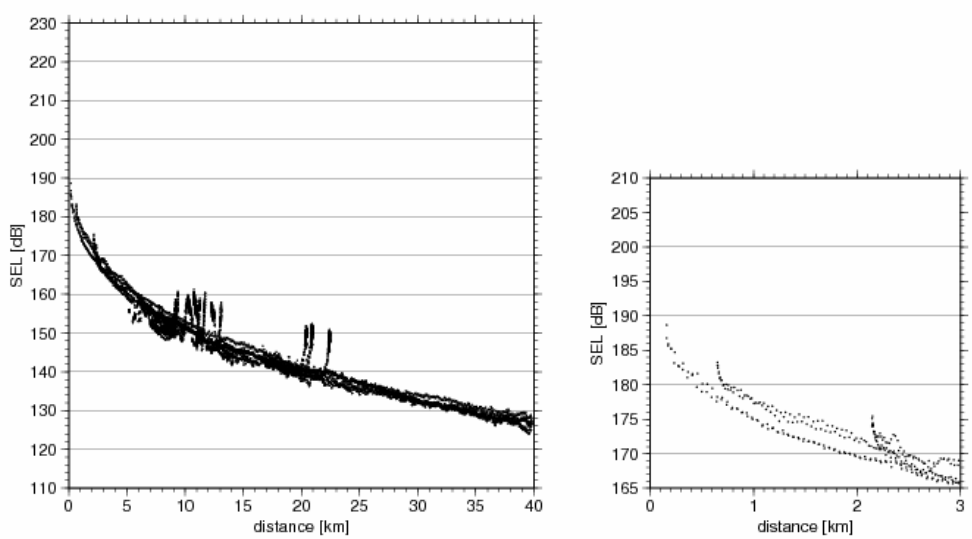

Figure 6: Combined SEL Results

Forward Endfire and Broadside Results

The majority of data points in Figures 4-6 are representative of endfire from the array. The spikes noted at approximately 150 m, 10 km, and 21 km correspond to broadside aspect of the array, which occurs when the array is in line OBHs. Referring to Figure 1 it can be seen that this should occur at 0 m, 5 km, 10 km and 20 km. Given the actual survey line that Patriot followed (Figure 2) and the fact that Patriot missed OBH A by 150 m, the broadside levels were observed at 150 m, 10 km, and 20 km. The approximately 10 dB increase in SPL at broadside clearly illustrates the inherent directionality of the airgun array.

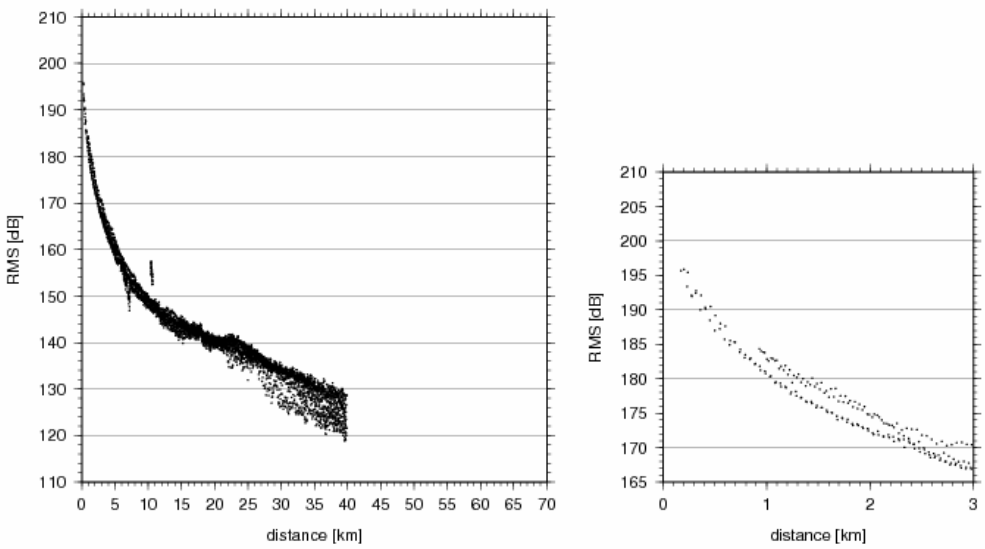

Figure 7: Endfire RMS Values

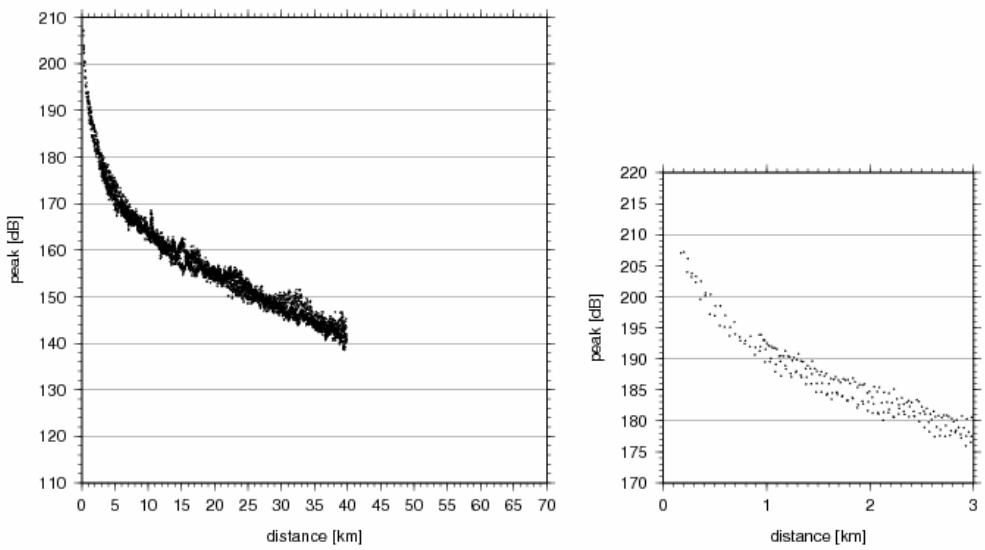

Figure 8: Endfire Peak Values

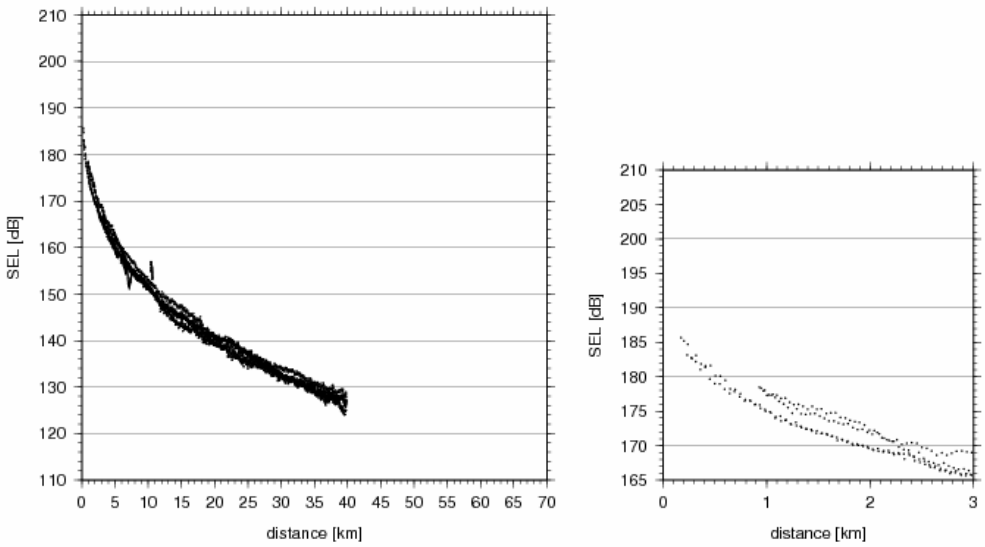

Figure 9: Endfire SEL Values

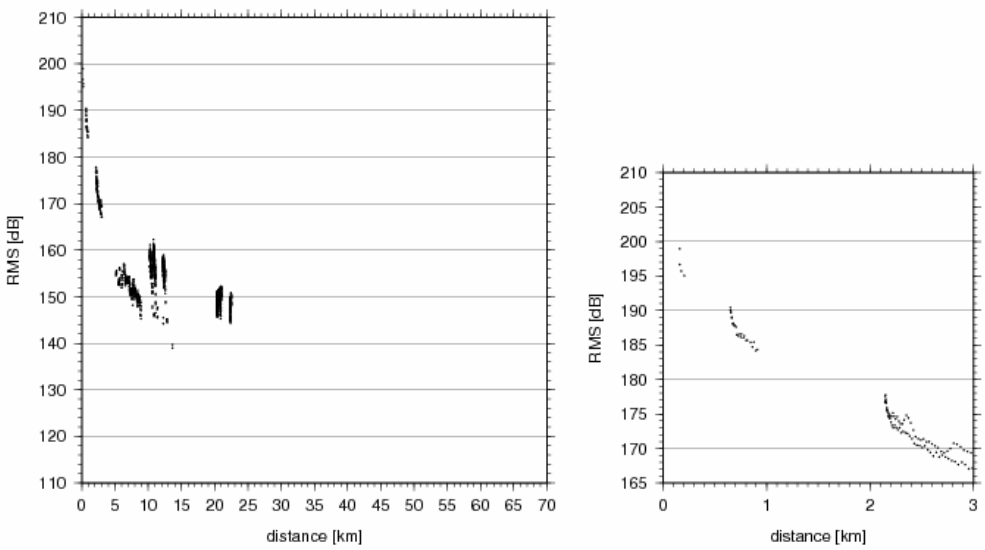

Figure 10: Broadside RMS Values

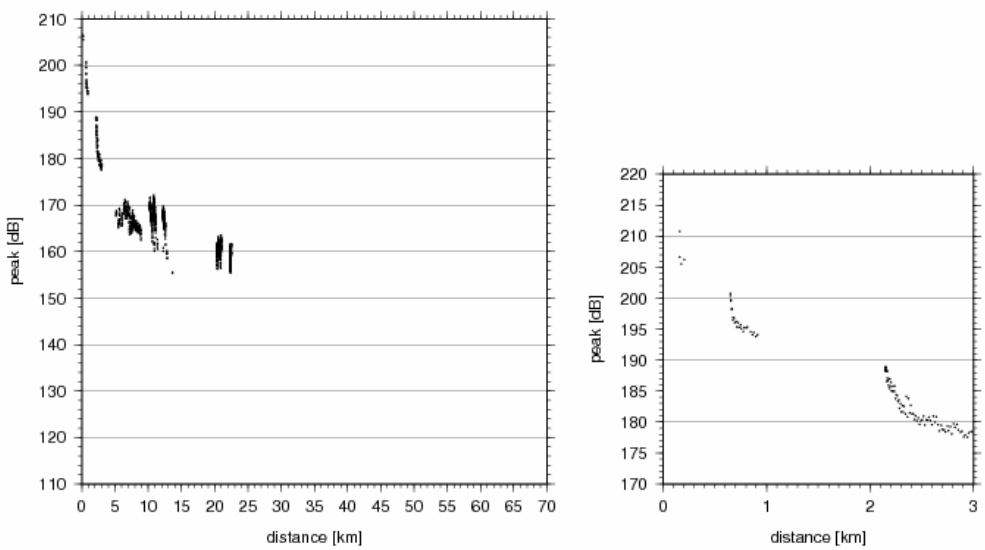

Figure 11: Broadside Peak Values

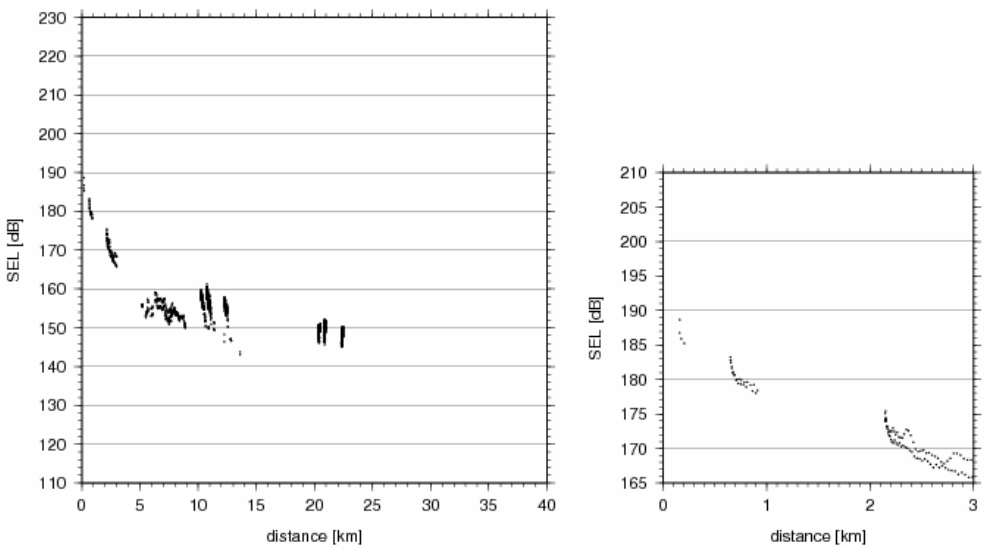

Figure 12: Broadside SEL Values

Threshold level ranges

Ranges from the airgun array to the 190–120 dB rms sound pressure level (SPL) thresholds were determined from acoustic data obtained on all three different OBH systems. These results are tabulated in Table 1 and Table 2. The broadside ranges are larger than the endfire ranges, however the angular zone ensonified by the broadside zone is narrow and is therefore small compared to area of the endfire zone. Note that the 120 dB radii were determined by extrapolating the trend in the rms data between 25 km and 40 km range. For the broadside case, the slope of the extrapolated endfire trend was offset by the average difference between endfire and broadside SPL values.

SPL	Forward Endfire Range (m)	Flat-weighted Range from Pre-season Estimate (m) [1]
120 dB rms	50000	23530
130 dB rms	35000	16260
140 dB rms	22000	10770
150 dB rms	9000	7480
160 dB rms	6000	4590
170 dB rms	2550	2050
180 dB rms	1100	850
190 dB rms	500	230

Table 1: Sound threshold level radii from 190 dB to 120 dB, in 10 dB increments, for airgun array endfire. Sound level radii from the pre-season acoustic modelling are also shown for comparison.

SPL	Broadside Range (m)
120 dB rms	65000
130 dB rms	51000
140 dB rms	36500
150 dB rms	22500
160 dB rms	12500
170 dB rms	6000
180 dB rms	1750
190 dB rms	700

Table 2: Sound threshold level radii from 190 dB to 120 dB, in 10 dB increments, for array broadside.

1. No endfire data existed for 190 dB, this value was extrapolated.

References

[1] Austin, M., Hannay, D., MacGillivray, A., Zykov, M., Characterization of Noise Emissions from ConocoPhillips' 2006 Seismic Survey in Alaskan Chukchi Sea. JASCO Reaseach Ltd. Report July 5, 2006