Sound levels from a 3D seismic survey in the Porcupine Basin: Development of a sound propagation model using observed data

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PIP Petroleum Infrastructure Programme

1. KEY QUESTION

Can a frequency-dependent sound propagation model be used to predict the sound levels observed at range from a broadband (estimated 10Hz to 200Hz) airgun signal?

Underwater acoustic monitoring is targeted as a research priority under the EU Marine Strategy Framework Directive. The aim of this project is to develop and calibrate, using observed data, a 2D model of acoustic propagation from seismic sources in Irish waters.

2. OBSERVING SOUND LEVELS

Research cruise CV14014

- Coincided with Polarcus 3D seismic surveying (**source**) (Fig. 1, 8).
- Collected acoustic data (**received**) (Fig. 1, 2, 3, 9).
- CTD casts for hydrographic data: input to model (Fig. 1).

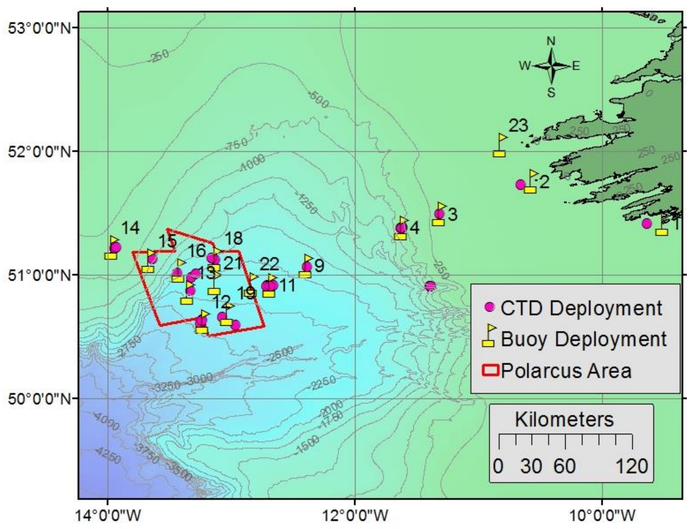

Figure 1: Cruise CV14014: July 12-22, 2014 in Porcupine Basin.

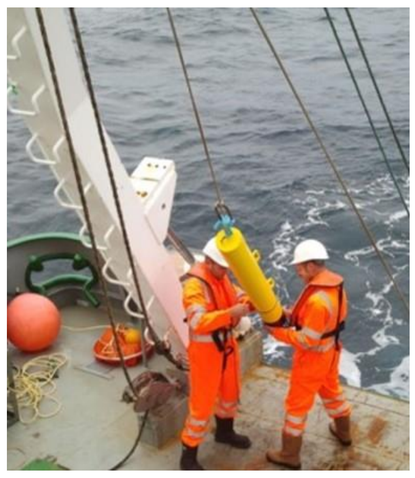

Figure 2: Acoustic recorder being deployed on CV14014.

3. MODELLING TRANSMISSION LOSS

RAMGeo

- **RAMGeo**: a Parabolic Equation technique used to **model sound propagation** at a single frequency.
- RAMGeo outputs transmission loss (TL) across range-dependent environment (Fig. 4, 5, 7).
- Source-to-Receiver pathways from CV14014 used to define model transects at **6 locations**: 11E, 12B, 12C, 18A, 22A, 22C (Fig. 3).

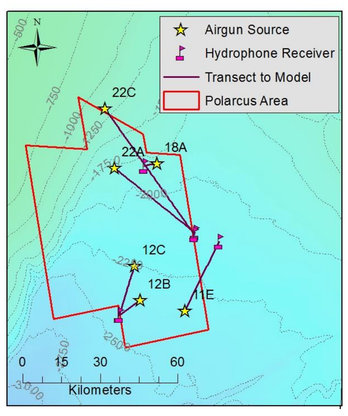

Figure 3: Observed source-to-receiver pathways used in modelling.

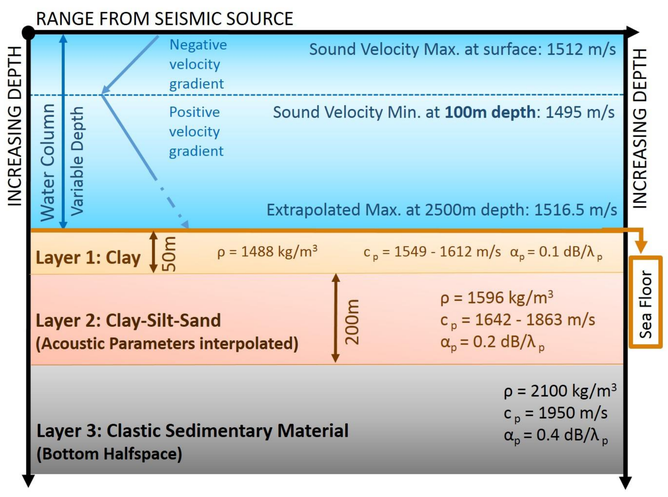

Figure 4: Schematic of Model E: geometric and acoustic environment defined for input to the RAMGeo model. Nominal acoustic values for seabed obtained from Hamilton (1980) and Jensen et al. (2011).

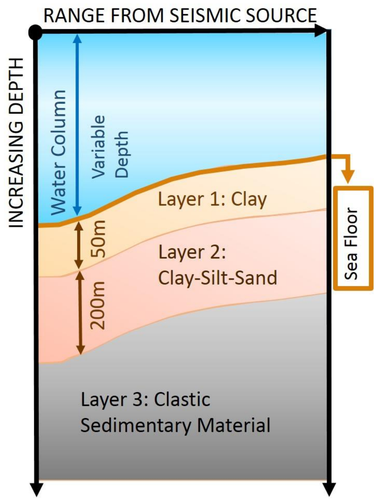

Figure 5: Schematic of seabed layers maintaining thickness and following bathymetric profile

RANGE AVERAGING TRANMISSION LOSS

- For TL to be representative of broadband signal, it must be **averaged across several frequencies** within the 1/3 octave bands.
- **Computationally intensive.**
- **Range-averaging** across a spatial interval equivalent to the 1/3 octave band is **much faster** (Fig. 6).

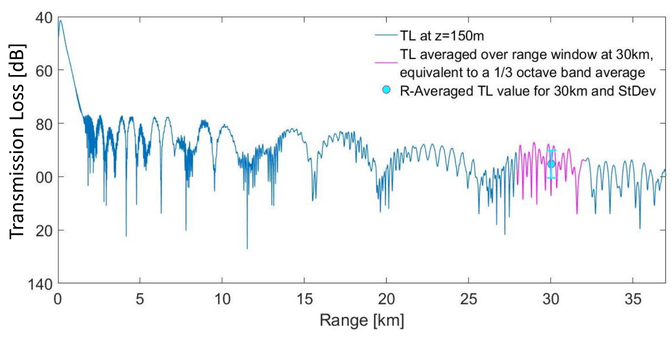

Figure 6: TL modelled at 150m depth at 100 Hz for 11E. Range-averaging (arithmetic average of TL) over window (magenta) gives average TL (cyan). Method based approximation of Harrison and Harrison's (1995).

5. RESULTS

Modelled and Observed Transmission Losses

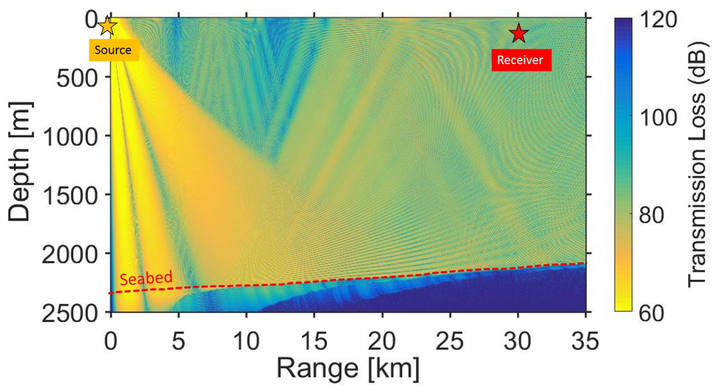

Figure 7: Transmission loss (TL) of 100Hz signal through water column and seafloor, modelled using RAMGeo across Location 11E's Source-Receiver pathway. Darker blues indicate less sound energy present (higher TL) while yellow indicates close to source levels. Source at z = 7m, R = 0m.

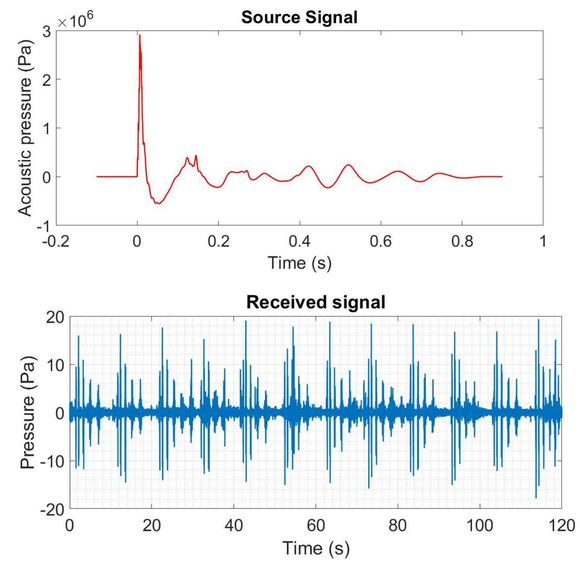

Figure 8 (Top): Source pressure-time signal corresponding to location 11E.
Figure 9 (Bottom): Received pressure-time signal observed at 11E; 12 seismic pulses and multiple arrivals for each visible over 120s extract.

- **Modelled TL values obtained at 1/3 octave bands**.
- Model TL range averaged at each centre frequency, f_c, (Fig.10.)

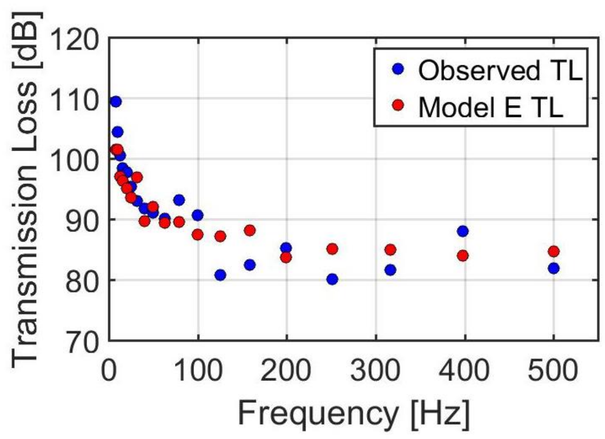

Figure 10: Comparison of modelled and observed transmission losses of source-to-received pulse energy at 1/3-octave band centre frequencies from 7.94 Hz to 501.19 Hz

- **PSD** computed **for received and source** signals using **Welch method** and integrated across 1/3 octave bands for power at each f_c.
- **Multiplied by duration** of signal at each f_c = SEL_{pulse}
- Observed TL computed using: **TL = SL - RL**

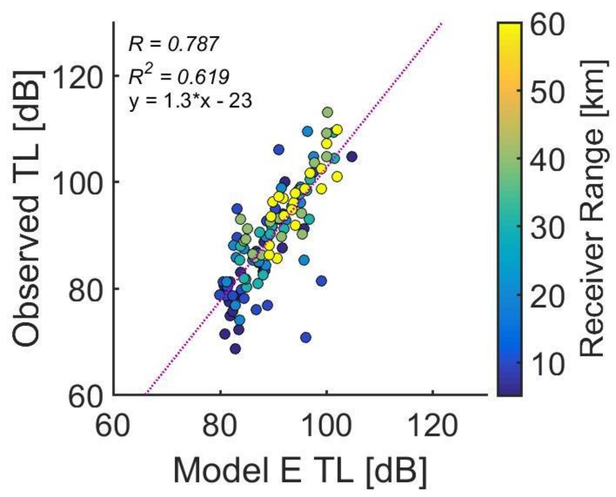

Figure 11: Distribution modelled-TL corresponding observed-TL pairs for Porcupine Basin Model 1 run in RAMGeo. Data for each 1/3 octave band from 6 locations at: 5km, 10km, 20km, 30km, 40km and 60km from source.

- **Modelled and corresponding observed TL** values obtained at each 1/3 octave band f_c from **6 locations** (Fig. 11).
- Modelled TL subtracted from SL at each band to predict SEL for a single pulse (SEL_{pulse}) at receiver
- 90% of f_c TLs within 10 dB of observed

- **Broadband SEL_{pulse}** values obtained by summing individual SEL_{pulse} levels across frequency spectrum at each location to represent **broadband signal** (Fig.12).

- **SEL_{pulse} predictions within 0.7 – 4.5 dB of observed at each location**

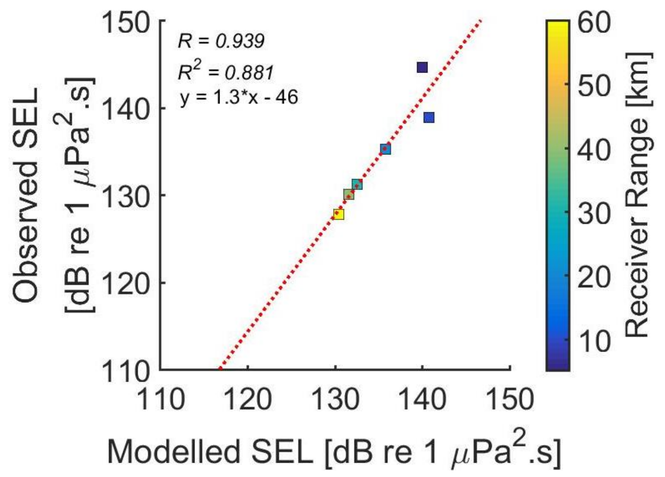

Figure 12: Broadband SEL_{pulse} for modelled and corresponding observed signal at each location illustrated by summed SEL at each location range: 5km, 10km, 20km, 30km, 40km and 60km from source.

6. DISCUSSION

- **Model E considered valid for the Porcupine Basin with strong agreement to the observed data** (broadband SEL_{pulse} predicted to within 5 dB at all six locations)
- **There is variation in the predictive power of model at individual centre frequencies.**

IMPROVING THE MODEL

- **Model E represents the fifth of six sets of model definitions tested.**
- Collection of higher resolution water column and seabed acoustic parameters for input to model would better define the model environment, as would inclusion of shear-wave propagation.

IMPLICATIONS

- **Noise from seismic surveys in Porcupine Basin region can be predicted using Model E in RAMGeo.**

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AcTUP V2.2l can be downloaded directly from the Centre for Marine Science and Technology, Curtin University website: https://cmst.curtin.edu.au/products/actoolbox.cfm

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ACKNOWLEDGEMENTS

We are grateful to RPS for the use of acoustic recorders, to the crew of the RV Celtic Voyager for assistance and support, to Polarcus for collaboration and sharing of data (such as real-time positional data and post-cruise logs) and to CMST, Curtin University, for making accessible the AcTUP V2.2l software, for generating source waveforms using their Air Gun Simulator and for their provision of processing codes, training and continued support in acoustic data analysis.

This project is funded by the Irish Shelf Petroleum Studies Group (ISPSG) of the Irish Petroleum Infrastructure Programme (PIP) Group 4. The ISPSG comprises: Atlantic Petroleum (Ireland) Ltd, Cairn Energy Plc, Chrysaor E&P Ireland Ltd, Chevron North Sea Limited, ENI Ireland BV, Europa Oil & Gas (Holdings) plc, ExxonMobil E&P Ireland (Offshore) Ltd., Kosmos Energy LLC, Maersk Oil North Sea UK Ltd, Petroleum Affairs Division of the Department of Communications, Energy and Natural Resources, Providence Resources plc, Repsol Exploración SA, San Leon Energy Plc, Serica Energy Plc, Shell E&PIreland Ltd, Sosina Exploration Ltd, Statoil (UK) Ltd, Tullow Oil Plc and Woodside Energy (Ireland) Pty Ltd.